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High Intensity Land Treatment (HILT) Practices

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HIGH INTENSITY LAND TREATMENT (HILT) PRACTICES

by

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ABSTRACT

Land treatment is categorized in the Resource Conservation and Recovery Act of 1976 (RCRA) as one of the land disposal options for managing hazardous wastes. Land treatment relies on detoxification of hazardous waste constituents within the defined treatment zone before such constituents can be transported to surface water, groundwater, or air. Under the authority of Subtitle C of RCRA, the U.S. Environmental Protection Agency has promulgated regulations governing the treatment and disposal of hazardous wastes in land treatment units (40 CFR, Part 264, Subpart M, July 26, 1982).

The objectives of this report were to identify land treatment facilities meeting the defined high intensity land treatment (HILT) criteria, and to describe the operation and management practices used at HILT facilities. A final objective was to compare operation and management practices used at HILT facilities with RCRA guidelines. The information needed to accomplish the objectives was obtained with data collection packets.

A total of twelve land treatment facilities completed the data collection packets. Six of these land treatment facilities qualified as HILT facilities under the defined criteria used in this report.

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SECTION 1
INTRODUCTION

The Resource Conservation and Recovery Act (RCRA) defines a land treatment facility as that part of a facility at which hazardous waste is incorporated into the soil surface. The objective of land treatment is the microbial degradation of the organic waste constituents and the immobilization of the inorganic waste constitutients. The only legitimate purpose of land treatment is to reduce the hazardous properties of an applied waste. To use the soil solely as a dilution or filtration medium is not considered land treatment. The owner or operator of a hazardous waste land treatment (HWLT) facility must demonstrate that reduction of hazardous properties is being accomplished.

For the purposes of this report a petroleum land treatment facility is characterized as a high intensity land treatment (HILT) facility when the minimum weight percentage of oil in the soil (oil/soil) equals a defined criterion based on temperature (climate). A criterion of 4.0 percent by weight oil/soil is defined for climatic regions where seasonal fluctuations cause the average minimum air temperature to fall below 9.9°C (50°F), here after referred to as 4.0 percent oil/soil. An 8.0 percent by weight oil/soil criterion is defined for climatic regions where the average minimum air temperature is greater than or equal to 9.9°C (50°F), here after referred to as 8.0 percent oil/soil. The value of 9.9°C (50°F) is chosen because biological degradation of petroleum is substantially reduced below this temperature.

The objectives of this report were to identify HILT facilities having the defined criteria and to describe the operation and management practices used at these facilities. A final objective was to compare operation and management practices used at HILT facilities with RCRA guidelines and criteria.

SECTION 2
SUMMARY OF RESULTS

Five land treatment facilities were identified that met the definition criteria for high intensity land treatment (HILT) of petroleum wastes. Four HILT facilities, 01[1] (Region V), 03 (Region VI), 04 (Region V), and 06 (Region X) are located in a climatic region where the HILT criterion is 4.0 weight percentage of oil in the soil (oil/soil). Two facilities, 02 (Region VI) and 05 (Region IX) are located in a climatic region having a HILT criterion of 8.0 percent oil/soil.[2] For comparative purposes Chicago, Illinois, temperature profile falls within the 4.0 percent oil/soil criterion climatic region and Houston, Texas, temperature profile falls within the climatic region having the 8.0 percent oil/soil criterion.

The average age of the HILT facilities is 9.0 years, with predicted site lives of 30 to 100 years. The 4.0 percent oil/soil facilities reported extreme air temperatures ranging from an average minimum of -25.3°C (-14°F) to an average maximum of 40.7°C (106°F). The average air temperatures ranged from minimum of -9.35°C (15°F) to a maximum of 25.3°C (78°F). The 8.0 percent oil/soil facilities reported minimum and maximum mean extreme and average air temperatures of -9.35°C (15°F) and 42.9°C (110°F), and 11°C (52°F) and 26.4°C (80°F) respectively. Average treatment area for the 4.0 percent oil/soil HILT facilities averaged 6.2 ha (15.4 acres). The two 8.0 percent oil/soil HILT facilities have treatment areas ranging from 4 ha (10 acres) (05) to 85 ha (210 acres) (02).

Petroleum wastes most frequently land treated by the HILT facilities identified are in decreasing order of frequency: API separator sludge, slop

[1]01 corresponds to HILT facility number 1, 02 corresponds to HILT facility number 2, etc.

[2]Facility 02, which does not meet the HILT criterion, is included as an additional example for southern climatic HILT operation/management practices.

values of approximately 3.1 percent and 2.9 percent after seven and six years, respectively, and the weight percentage of oil in the soil for facility 03 stabilized at 5.3 percent after six years. Facility 05 stabilized at 19 percent after eight years and facility 06 stabilized at 5.2 percent after eight years.

Calculations also were made to predict the total inorganic constituent loading for each facility in the soil over time. Based on a 30 year site life, calculations indicated that total inorganic constituent levels at all facilities were orders of magnitude lower than U.S. Environmental Protection Agency's guideline permissible limits.

The data received indicate that the six facilities meet RCRA operation/management requirements. All wastes that are applied to the soil are incorporated and mixed into the soil and tilled afterwards to ensure aerobic conditions in the soil-waste mixture. Four of the facilities add amendments including NPK and lime to the soil to increase biodegradation of the petroleum wastes. There were no indications that any of the facilities were using the soil as a filtration or dilution medium. Only one facility provided organic and inorganic soil sampling data (Table 31). The data indicated a 75 percent reduction in the weight percentage of oil in the soil compared with feed samples.

The six facilities reported that all run-on is diverted away from the treatment sites and that all run-off is collected and transported for further treatment.

Groundwater and unsaturated zone monitoring is conducted by all facilities on a quarterly or semi-annual basis. The information received primarily addressed frequency aspects of monitoring and not specific parameters monitored.

SECTION 4

REVIEW OF RCRA SUBPART "M" - LAND TREATMENT

Land treatment is categorized in the Resource Conservation and Recovery Act of 1976 (RCRA) as one of the land disposal options for managing hazardous wastes. In contrast to other land disposal options, land treatment relies on detoxification of waste hazardous constituents within the defined treatment zone before such constituents can be transported to surface water, groundwater, or air. Under the authority of Subtitle C of RCRA, the U.S. Environmental Protection Agency has promulgated regulations governing the treatment and disposal of hazardous wastes in land treatment units (40 CFR, Part 264, Subpart M, July 26, 1982). A brief review of these regulations is presented in this section.

PURPOSE OF TREATMENT

A land treatment unit is a hazardous waste management facility at which hazardous waste is applied and incorporated into the surface soil. The primary objective of land treatment is the degradation/transformation of organic waste constituents via soil treatment mechanisms and waste-soil interactions. The only legitimate purpose of land treatment is to reduce the hazardous properties of the applied waste. To use the soil solely as a dilution or filtration medium is not considered land treatment. The owner or operator must demonstrate that reduction of the waste's hazardous properties is being accomplished.

SURFACE WATER RUN-ON AND CONTAMINATED RUN-OFF

The control of run-on and contaminated run-off must meet the requirements in the General Standards Code of Federal Regulations 250.43(b) and (c). Land treatment facilities are subject to the same requirements that pertain to

FOOD-CHAIN CROPS

While the Agency does not yet have clear specifications on safe levels of contaminants in food-chain crops, the growth of food-chain crops for human consumption on land treatment facilities is discouraged.

CLOSURE

The owner or operator of a land treatment facility is required to develop and then implement a closure plan for the facility. The closure plan must specifically address the control/management of the following factors: the migration of the hazardous waste and hazardous constituents to groundwater; the release of any contaminated run-off to surface water; and the release of airborne particulate contaminants. The closure plan also must comply with the standards established for the growth of food-chain crops.

The owner or operator must also develop a post-closure care plan for the land treatment facility. This plan must provide for maintenance of the monitoring systems, restriction of access as appropriate for post-closure use, and control of the growth of food-chain crops to the same degree as required for active facilities. A final vegetative cover is required for closure and post-closure, and food-chain crops are not permitted as cover. Capping is not permitted as part of the closure and post-closure management of a land treatment facility.

SECTION 6

APPROACH USED FOR THE ASSESSMENT OF HILT FACILITIES

DEVELOPMENT OF THE DATA COLLECTION PACKET

The data collection packet format used in this report was based on the approach utilized for API's 1982 Refinery Solid Waste Report.(2) The questions asked in this report specifically addressed RCRA guidelines. The packet also was designed to obtain information with minimum effort required by facility personnel completing the packet.

The data collection packet for petroleum refineries characterized as high intensity was organized into five major sections. The sections included: (1) refinery processes and products; (2) petroleum waste stream identification and waste constituent identification; (3) facility site characterization; (4) management of the wastes; and (5) environmental implications.

Section 1, pertaining to the refinery, was designed to obtain information pertaining to the following items: refinery classification, production capacity, product distribution, and the processes utilized by the refinery. This information was used to relate process(es) to waste generation and characterization.

The second section dealt with the identification of the generated wastes, the average quantities produced, and the treatment methods used. Characterization of land treated wastes included organic and inorganic constituent identification and concentrations within particular waste streams. The identified physical form (% oil, water and solids) of the waste streams was also characterized.

The site characterization section was organized to obtain data pertaining to climate, facility size, waste incorporation depth, and flooding. Soil characterization information including soil permeability, erodibility, cation

SECTION 7

DESCRIPTION OF WASTE GENERATION/CHARACTERIZATION AT A PETROLEUM REFINERY

The basic function of a refinery is to obtain the desired products by separating the hydrocarbons into select fractions, converting other hydrocarbons into more desirable types, and removing impurities such as nitrogen and sulfur.

REVIEW OF TYPICAL REFINERY PROCESSES AND WASTES GENERATED

Refinery processes consist of three major categories of processes (3). These include: 1) separation, which isolates different classes of molecules from one another; 2) conversion, which changes less desirable hydrocarbons into more marketable types; and 3) treating, which eliminates elements such as sulfur, nitrogen, and other impurities from the hydrocarbon molecules.

A typical refinery processing flow diagram is depicted in Figure 1. The first process involves the removal of dissolved salts. This dissolved salt removal is necessary to prevent corrosion of the other unit processes. The desalted crude is then atmospherically distilled into the following fraction components: (a) gases, (b) natural gasoline, (c) naphtha, (d) light distillate oils, and (e) heavier gas-oil. Any remaining undistilled heavy material is then vacuum distilled into: (f) another gas-oil fraction, and (g) residum.

Separation

Inorganic salts and other suspended impurities must first be removed from the unprocessed crude in order to prevent pipe and machinery corrosion and to prevent interference with catalysts. To remove the inorganic salts, the crude oil is mixed with high temperature water in a desalter which emulsifies the oil and water. The water soluble salts are then dissolved by the suspended water globules. The water globules combine and separate from the crude under the influences of either an electrical field or a chemical solution. The resulting effluent water has a high concentration of dissolved solids, sulfides, phenols, oils, and ammonia. The effluent water is further processed in an oil-water separator for oil recovery. The crude oil is then drawn off for further processing.

There are three types of separation processes: fractionation, atmospheric distillation, and vacuum distillation. These separation processes are discussed separately in the following sections.

Fractionation--

The fractionation process separates various petroleum hydrocarbons from a heterogeneous mixture of the crude oil into distinct fractions. The mixture to be fractionated is first heated and sent to a fractionation tower for separation. While inside the fractionation tower, the heated hydrocarbon feed is separated into various fractions. The separated hydrocarbons are distributed according to the tower temperature gradient. The lighter fractions are condensed at cooler temperatures near the top while the heavier fractions condense toward the higher temperatures near the bottom of the tower. The hydrocarbon vapors, along with the steam used to heat the crude oil, collect in an overhead drum called an accumulator. The steam and hydrocarbon vapors cool and thus separate from each other. The wastewater is then discharged into a sewer system or a sour water stripper for treatment. The wastewater can contain oil, sulfides, phenols, and ammonia.

Atmospheric Distillation--

The first process the crude undergoes after desalting is atmospheric distillation. The crude oil is first heated to approximately 340°C (650°F) and then fed into a fractionation tower contained within an atmospheric distillation unit. This is the only time a fractionation tower receives a crude oil mixture. Generally feed to the fractionation tower is a product from another process. The heaviest molecules, those that do not vaporize, remain at the bottom of the tower. These molecules are then sent to a vacuum distillation tower or a thermal cracking process for further fractionation. Methane, ethane, propane, and butane, which are gases at room temperature and

There are three cracking methods used today. These are thermal cracking, catalytic cracking, and hydrocracking.

Thermal cracking--Thermal cracking (coking) subjects the heavy oils only to heat and pressure. Thermal cracking is used mostly for coking which prepares the feed for the catalytic and hydrocrackers.

Catalytic cracking--Catalytic cracking uses catalysts to promote the cracking reactions. Catalytic cracking accounts for the majority of the U.S. cracking capacity. There are two types of catalytic cracking, fluid catalytic cracking and thermofor catalytic cracking.

Fluid catalytic cracking (FCC) accounts for the majority of catalytic crackers. Fluid catalytic crackers are composed of a reactor and a generator. The catalysts used is a very fine silica-alumina powder. The feed, which is generally a gas-oil fraction, is mixed with hot catalyst and is vaporized prior to entering the FCC. These vapors are then cracked. FCCs converts 45 to 65 percent of the feed into gasoline. Fluid catalytic crackers are prime wastewater producers. Steam is used to strip the absorbed product from the catalyst as it leaves the reactor. Some steam is needed to keep the catalyst active. When the steam condenses wastewater results. This wastewater is highly polluted with sulfides, phenols, ammonia, and oils.

Thermofor catalytic cracking (TCC) is a less efficient process than fluid catalytic cracking. Thermofor catalytic cracking is mostly used by Mobil Corporation. TCCs have a smaller capacity than FCCs thus resulting in smaller quantities of wastewater, but with the same pollution problem as FCCs.

Hydrocracking--Hydrocracking is the newest cracking process. It is a highly versatile process which can shift the main product from gasoline to jet or diesel fuel as required. Hydrocracking can crack some oils which are resistant to other cracking processes. The oil feed is cracked and purified in a hydrogen atmosphere at pressures exceeding 6.9×10^6 Pa (1000 psi). The catalysts used in the hydrocracking process are silica-alumina and platinum.

Coking--

The coking process cracks heavy oils by using heat and pressure but without catalysts. Coking removes metals, such as nickel and vanadium, which would quickly inactivate the catalysts used in FCCs and TCCs. Coking produces gas-oil and some gasoline, but it also produces coke. The gas-oil produced by treated before disposal. The hydrofluoric acid catalyst process does not have the sludge and wash water problems that the sulfuric acid catalyst process does.

Polymerization--Polymerization combines small hydrocarbon molecules into higher octane gasoline molecules. Polymerization is not widely used since alkylation produces a higher octane product. The polymerization process results in small quantities of highly polluted water which is a result of pre-treating the hydrocarbon feed with a caustic solution.

Treating

Most crude fractions contain some impurities which must be removed in order to increase the number of products that can be made and to improve the quality of the products. Two processes are used for treating the feed: hydrotreating and drying and sweetening.

Hydrotreating--

Hydrotreating adds hydrogen to the hydrocarbon molecules, resulting in stabilization of the molecules and the displacement of impurities such as nitrogen and sulfur. The hydrotreating process is not a cracking process. Hydrotreating is generally used to treat naphthas, kerosene, diesel oil, and heating fuels. It is an effective means of producing low sulfur fuel oils (<0.5 percent S by weight) with low metal content feeds. The metal content of the feed is generally removed prior to use by thermal cracking.

Drying and Sweetening--

This process removes sulfur and sulfur compounds from gasoline, distillates, and lube oils. The sulfur compounds are called "sour" due to their foul odor, hence the term sweetening. The drying and sweetening process used depends upon the product to be treated. Hydrogen sulfide (H_2S) and some mercaptans, produced from light distillation are removed by a caustic soda wash. An organic solvent, if required, is added to dissolve any remaining mercaptans. Solvent removal from the feed is by gravity or by electrical separation. The solvent removed is regenerated by heating and steam stripping. The solvent wash can exert a high BOD loading in the wastewater. The spent caustic soda must first be neutralized and scrubbed before disposal or before phenols and sulfuric acid can be recovered from it. The caustic soda wash can also exert a high BOD and COD loading in the wastewater.

SECTION 8

DATA COLLECTION PACKET RESULTS

Five facilities have been defined as being within a category classified as high intensity. The assigned codes and the geographic location for the five facilities are: 01 (Region V), 03 (Region VI), 04 (Region V), 05 (Region IX), and 06 (Region X). A sixth facility (02, Region VI), a southern climatic region facility, did not meet the southern climatic HILT criterion of 8 percent oil/soil. Facility 02 was included in the report because it was the only facility to provide treatment soil sample analysis data, differences in operation/management practices with facility 05, and the maximum reported oil/soil value for facility 02 was within the oil/soil range for facility 05. Facility 02 was included only as an additional example of southern climatic land treatment operation/management practices. Table 1 lists these facilities and refinery processes used at each facility. Facility 02 is a private facility which land treats refinery wastes, therefore, process information is unavailable. Facility 04 did not supply process information.

The wastestream sources that are land treated for each facility are identified in Table 2. The most frequent waste streams that are land treated include: API separator sludge, slop oil emulsion solids, air flotation froth (DAF), and waste activated sludge (not an identified hazardous waste) in the order presented. Other waste streams that are land treated include induced air flotation sludge (IAF), clay fines, cooling tower sludge, leaded and nonleaded tank bottoms, lime sludges, heat exchanger bundle cleaning sludge, spent acid sludge, FCCU catalyst, polycatalyst, refinery scale, refinery oil wastes, and sodium cation exchange resin.

Waste sources have been characterized in terms of oil, water, and solids percentage. These data are presented in Tables 3, 4, 5, 6, and 7 for facilities 01, 03, 04, 05, and 06, respectively. Data for facility 02 were not given in the data packet. Table 8 summarizes these data. The physical properties of the wastes ranged from maximums of 91.8 percent water, 41

TABLE 2. HILT FACILITY WASTE STREAMS

Waste Source	Facility Code 01	02	03	04	05	06
Air Flotation Froth (DAF)	x	x		x	x	
Induced Air Flotation Sludge		x			x	
Slop Oil Emulsion Solids	x		x	x	x	x
Clay Fines						x
Cooling Tower Sludge				x		x
Primary Oil/Solids/Water Separation Sludge (Other than API)						
Tank Bottoms						x
Waste Activated Sludge	x	x		x		x
API Separator Sludge	x	x	x	x	x	x
Tank Bottoms (Other than Leaded)				x	x	
Lime Sludge				x		
Heat Exchanger Bundle Cleaning Sludge				x		
Spent Acid Sludge				x		
FCCU Catalyst						x
Polycatalyst						x
Refinery Scale						x
Refinery Oily Wastes						x
Sodium Cation Exchange Resin						x

TABLE 3. HAZARDOUS WASTE PHYSICAL COMPOSITION THAT IS LAND APPLIED AT FACILITY 01

Waste	Oil %	Water %	Solids %
Air Flotation Froth (DAF)	5	95	0
API Separator Sludge	12	78	10
Slop Oil Emulsion Solids	0.7	98.9	0.4
Waste Activated Sludge	0	95	5.0
Ave.	4.4	91.8	3.8

TABLE 4. HAZARDOUS WASTE PHYSICAL COMPOSITION THAT IS LAND APPLIED AT FACILITY 03

Waste	Oil %	Water %	Solids %
API Separator Sludge	8.6	65.4	26
Slop Oil Emulsion Solids	13.4	70.6	16
Ave.	11.0	68.0	21.0

TABLE 8. AVERAGE PHYSICAL FORM OF WASTES APPLIED TO HILT FACILITIES

Physical Form	% Composition Refinery Code						
	01	02	03	04	05	06	Ave.
Water	91.8	-	68.	50.5	67.5	29-42	62.7
Oil	4.4	-	11.	20	25	14-17	15.2
Solids	3.8	-	21	29.5	7.5	37-45	20.6

percent solids, and 25 percent oil to minimums of 36 percent water, 3.8 percent solids, and 4.4 percent oil. The mean physical properties of the wastes were 62.7 percent water, 20.6 percent solids, and 15.2 percent oil.

HAZARDOUS WASTE STREAM IDENTIFICATION-EPA LISTED

Five refinery waste streams have been classified as hazardous wastes by the U.S. Environmental Protection Agency. These waste streams are:

Dissolved Air Flotation (DAF) Float	K048
Slop Oil Emulsion Solids	K049
Heat Exchanger Bundle Cleaning Sludge	K050
API Separator Sludge	K051
Leaded Tank Bottoms	K052

The basis for listing these wastes as hazardous are: the DAF, slop oil emulsion solids, and API separator sludge contain both lead and chromium, the heat exchanger bundle cleaning sludge contains chromium, and leaded tank bottoms contain lead.

HAZARDOUS WASTE STREAM IDENTIFICATION-NOT EPA LISTED

All of the waste streams listed in Table 2 have either lead or chromium as a constituent. The API separator sludge, which is not a listed hazardous waste, from facility 04, contains the same quantity of chromium and 90 percent of the lead as the listed heat exchanger bundle cleaning sludge from the same facility. There are numerous other constituents identified as hazardous by U.S. Environmental Protection Agency contained in the waste streams (see Appendix D). Tables 9 through 14 list the reported inorganic waste constituents for the waste streams for facilities 01 through 06, respectively. Facilities 03, 05, and 06 were the only HILT facilities that reported organic

TABLE 11. INORGANIC HAZARDOUS CONSTITUENTS IN WASTE LAND APPLIED AT FACILITY 03

Hazardous Constituent	Waste Stream: Slop Oil Emulsion Solids mg/kg (dry wt.)	Waste Stream: API Separator Sludge mg/kg (dry wt.)
As	30.	32.
Ba	340.	340.
Be	0.24	0.24
Cd	2.4	2.4
Cr	480.	480.
Hg	6.0	7.0
Ni	55.	55.
Pb	43.	43.
Se	0.	1.0
H_2S	0.08	0.01
Sb	19.	16.

TABLE 12. INORGANIC HAZARDOUS CONSTITUENTS IN WASTE LAND APPLIED AT FACILITY 04

Hazardous Constituent	Waste Stream: DAF mg/kg	Slop Oil Emulsion mg/kg	Ht. Ex. Bndl Sludge mg/kg	API Separator Sludge mg/kg	Tank & Flare Sludges mg/kg
Cd	15.	16.	15.	16.	5.
Cr	76.	84.	120.	120.	100.
Fe	590.	1800.	10,000.	2,600.	330,000.
Ni	84.	100.	94.	94.	300.
Pb	84.	91.	80.	90.	80.
Zn	82.	180.	92.	92.	91.

TABLE 13. INORGANIC HAZARDOUS CONSTITUENTS IN WASTE LAND APPLIED AT FACILITY 05

Hazardous Constituent	Waste Stream: API* Separator Sludge mg/kg	Waste Stream: DAF* mg/kg
Ag	0.086	0.088
As	2.3	0.60
Ba	53.	50.
Be	0.07	0.07
Cd	1.6	0.24
Cr	34.	15.
Hg	2.4	0.2
Ni	16.	7.1
Pb	34.	14.
Sb	0.10	0.16
Se	1.8	1.3

*Average of two samples.

TABLE 14. CONTINUED.

Hazardous Constituents	Waste Stream					
	Filter Clay mg/kg	Poly-Catalyst mg/kg	Cooling Tower Sludge mg/kg	FCCU Catalyst mg/kg	Wastewater Treatment Sludge mg/kg	Sodium Cation Exchange Resin mg/kg
Sb	-	-	-	-	<3.8	-
As	<2.	10.	<0.3	<3.	<3.8-11.	-
Ba	100.	3000.	29.	200.	<5. -14.	-
Be	-	-	-	-	<1.	-
Cd	8.	<0.5-20.	64.	<2.	<2.	<0.5
Cr	170.	32.	2000.	50.	13.-740.	<15.
Pb	<2.	<1. -50.	40.	<2.-100.	<24.	<20.
Hg	2.	<0.2	0.09	3.	<0.008-0.022	<0.01
Ni	60.	30.	36.	1000.- 3000.	<10.-19.	-
Se	10.	<10.	0.7	<8.	<3.8	-
Ag	<2.	<2.	0.2	<2.	-	-

TABLE 15. ORGANIC HAZARDOUS CONSTITUENTS IN WASTE LAND APPLIED AT FACILITY 03

Hazardous Constituent	Waste Stream	
	Slop Oil Emulsion Solids mg/kg (dry wt.)	API Separator Sludge mg/kg (dry wt.)
Bis(2-ethylhexyl) phthalate	29.	0.
Chrysene	44.	0.
Cresols	9.3	53.
2,4 Dimethyl Phenol	3.3	3.2
Naphthalene	420.	0.
Phenol	8.9	91.
Toluene	3200.	1300.
Carbon Disulfide	0.51	0.16

TABLE 16. ORGANIC HAZARDOUS CONSTITUENTS IN WASTE LAND APPLIED AT FACILITY 05

Hazardous Constituent	Waste Stream			
	API Separator Sludge (mg/kg)		DAF (mg/kg)	
	Sample WC-1	Sample WC-2	Sample WC-7	Sample WC-8
Benzene	90.	69.	320.	330.
Ethylbenzene	88.	95.	300.	300.
Naphthalene	150.	88.	260.	300.
m,p,-nylenes	400.	400.	910	900.
o-nylenes	170.	160.	420.	430.
Toluene	260.	200.	1000.	1200.

TABLE 17. CONTINUED.

Hazardous Constituents	Waste Stream					
	Filter Clay mg/kg	Poly-Catalyst mg/kg	Cooling Tower Sludge mg/kg	FCCU Catalyst mg/kg	Wastewater Treatment Sludge mg/kg	Sodium Cation Exchange Resin mg/kg
Benzene	-	-	-	-	<7.	-
Benzo(a)-anthracene	-	-	-	-	-	-
Cresols	-	-	-	-	<4.	-
Carbon Di-sulfide	-	-	-	-	0.022-0.13	-
Hydrogen Sulfide	-	-	-	-	0.053-0.13	-
Naphthalene	-	-	-	-	<4.-7.	-
Methanethiol	-	-	-	-	0.005-0.06	-
Toluene	-	-	-	-	<7.	-
Methylethyl-ketone (MEK)	-	-	-	-	-	-
Chrysene	-	-	-	-	-	-

TABLE 19. SUMMATION OF HAZARDOUS ORGANIC CONSTITUENT WASTE CONCENTRATIONS FOR HILT FACILITIES

Waste Constituent	Facility Code 01 mg/kg	02 mg/kg	03 mg/kg (dry wt.)	04 mg/kg	05 mg/kg	06 mg/kg
Bis(2-ethylhexyl) Phthalate	-	-	29.	-	-	-
Chrysene	-	-	44.	-	-	150.
Cresols	-	-	62.3	-	-	60.
2,4 dimethyl phenol (xylenol)	-	-	6.5	-	-	-
Naphthalene	-	-	420.	-	399.	1777.
Phenol	-	-	99.9	-	-	-
Toluene	-	-	4,500.	-	1330.	4700.
Benzene	-	-	-	-	404.5	657.
Benzo(a)-anthracene	-	-	-	-	-	109.
Carbon Di-sulfide	-	-	0.66	-	-	0.42-0.578
Methanethiol	-	-	-	-	-	0.052-0.107
Methylethyl-ketone (MEK)	-	-	-	-	-	430.
Ethylbenzene	-	-	-	-	391.5	-
m,p,-nylene	-	-	-	-	1305.	-
o-nylene	-	-	-	-	590.	-

TABLE 20. CONTINUED

Parameter	Facility Code 01	02	03	04	05	06
Texture	Clay, silty mottled, gray/ brown, wet	Varies, silt, sandy silt, & silty sand	Very fine sand & silt	Sandy loam	Dune sand	Glacial till, silty clay
Cation Exchange Capacity (meq/100 g)	17.0-27.6	17.0-39.0	9.1	Not Given	Estimated low value	20.
pH	7.2- 7.8	8.0	6.4	7.6	7-8	6.
Subsurface Soil						
Permeability (m/hr)	1.73x10-6	3.81x10-4 - 3.81x10-6	7.21x10-4	3.6x10-2	0.9	3.6x10-4-3.6x10-3
Texture	Clay, silty with sand, brown/gray	Clays and sandy clay	Mostly silt and clay	Sandy loam glacial till	Moderately fine sand. Soil at 1-3 ft. below grade is approx. 95% compacted	Silty clay
Depth (m)	0-7.6	2.7-5.5	4.6	15.21	30.	9.
Physical Site Characteristics						
Location/distance (km) from refinery	4.8 km N.E.	32. km south	0.8 km N.E.	On site	Within refinery	Not given
Location/distance (km) of nearest weather station from HILT	Toledo Express Airport 48.3 km south	From GCWDA plant 8.0 km west	Wichita Fall, TX 129 km WSW	0.8 km west	L.A. International (LAX) Airport, 3.2 km north	Not given
Depth to bedrock (m)	36.6	Not given	Unknown	18.3	Unknown	30.
Depth to seasonally high water table (m)	36.6	0.9	Not Given	15.2	19.	2.4
Depth to usable aquifer	36.6	79.	152-183	76.2	No usable aquifer	9.
Previous land use, if any	None	Not known	Wooden, with no use	Inactive Refinery Property	Cultivated land-farm	None

oil/soil facilities was 0.75 m (29.6 inches) and 0.9 m (35.1 inches) for the 8.0 percent oil/soil facilities.

The surface soil permeability ranged from 4.32 x 10^{-7} m/hr (1.701 x 10^{-5} in/hr) (01) to 3.6 x 10^{-3} m/hr (0.14 in/hr) (06) for the 4.0 percent oil/soil facilities and from 3.81 x 10^{-4} - 3.81 x 10^{-2} m/hr (1.5 x 10^{-2} to 1.5 in/hr)(02) to 9.0 x 10^{-1} m/hr (34. in/hr) (05) for the 8.0 percent oil/soil facilities. The erodibility of the soil ranged from slight to moderate for both the 4.0 percent oil/soil and 8.0 percent oil/soil facilities.

The surface soil texture for the 4.0 percent oil/soil facilities ranged from glacial till, silty clay (01,06) to sandy loam (04) to very fine sand and silt (03). The surface soil texture for the 8.0 percent oil/soil facilities ranged from silt, sandy silt, and silty sand (02) to dune sand (05). The cation exchange capacity for the 4.0 percent oil/soil facilities ranged from 9.1 meq/100 g (03) to a maximum of 27.6 meq/100 g (01) with an average of 17 meq/100 g. The 8.0 percent oil/soil facilities had a cation exchange capacity range of estimated low value (04) to 8.0 meq/100 g (02). The pH for 4.0 percent oil/soil facilities ranged from 6.0 (06) to 7.8 (01) averaging 6.9. The pH for the 8.0 percent oil/soil facilities averaged 7.75, ranging from 7.5 (05) to 8.0 (02).

The subsurface soil texture is essentially the same as the surface soil texture for both the 4.0 percent oil/soil and 8.0 percent oil/soil facilities. The subsurface soil permeability for the 4.0 percent oil/soil facilities ranged from 1.73 x 10^{-6} (6.803 x 10^{-5} in/hr) (01) to 3.6 x 10^{-2} m/hr (1.42 in/hr) (04) averaging 9.65 x 10^{-3} m/hr (0.38 in/hr). The subsurface soil permeability ranged from 3.81 x 10^{-6} m/hr (1.5 x 10^{-4} in/hr) (02) to 9.0 x 10^{-1} m/hr (34 in/hr) (05).

Facilities 01, 03, 04, and 05 are all located within 4.8 km (3 miles) from the refineries that generated the wastes. Facility 02 was reported to be 32.2 km (20 miles) from the generated wastes. Facility 06 did not provide this information.

The four 4.0 percent oil/soil facilities (01, 03, 04, and 05) were not reported as wet land or as being adjacent to wet land. The 8.0 percent oil/soil facilities 02 and 05 were also not reported as wet land, however, facility 02 was adjacent to a wet land. The 4.0 percent oil/soil facilities

TABLE 21. EPA SUGGESTED INORGANIC CONSTITUENT LOADING LIMITS

Element	Total Loading
Sb	1,000 kg/ha - 30 cm*
As	1,100 kg/ha - 15 cm†
Ba	2,000 kg/ha - 30 cm*
Be	110 kg/ha - 15 cm†
Cd	7 kg/ha - 15 cm†
Cr	2,200 kg/ha - 15 cm†
Pb	2,200 kg/ha - 15 cm†
Hg	40 kg/ha - 30 cm*
Ni	220 kg/ha - 15 cm†
Se	7 kg/ha - 15 cm†
Ag	400 kg/ha - 30 cm*

*Reference 4.
†Reference 5.

through 06, respectively. These tables also present the quantity of constituent applied in 1 year. Based upon the concentration of each constituent in the waste and the waste application rate, the quantity of the constituent that would accumulate in the soil over a 30 year period has been calculated. This quantity is presented in the form of inorganic constituent weight per volume of incorporated zone soil weight for each facility. This value is then compared to the values presented in Table 21. The quantity of the constituents over the 30 year period for all the constituents for all facilities are orders of magnitude below the limits presented in Table 21. This would indicate that the quantities of the 11 hazardous constituents in Table 21 will not be the capacity limiting constituent (CLC) for these facilities.

Table 28 presents soil half-lives of several oily wastes as determined by various methods (6). Since all waste streams reported by the facilities are not included in Table 28, an average half-life of 304 days was calculated from the data presented in Table 28. Using this averaged half-life value and the frequency of waste application and the weight percentage of oil in the soil for each facility, calculations were then made to see how much oil would degrade between waste applications. The calculations were also done based on using the reported minimum half-life value of 125 days from Table 28. The results of the two sets of calculations are presented in Table 29.

Facility 01 applied its waste every 30 days for six to seven months per year using a yearly averaged application rate of 141 metric tons waste/ha/yr

TABLE 23. HAZARDOUS INORGANIC CONSTITUENT LOADING CALCULATIONS FOR FACILITY 02

Parameter	Effluent mg/l	Effluent* mg/kg	Waste Applied kg/yr	Effluent mg/yr	Effluent mg/30 yr	Effluent	EPA Limits
As	6.0	6.92	2.19×10^{7}	1.52×10^{8}	4.55×10^{9}	2.68×10^{-5} kg/ha-15 cm	1100 kg/ha-15 cm†
Ba	139.	160.3	2.19×10^{7}	3.51×10^{9}	1.05×10^{11}	3.09×10^{-4} kg/ha-30 cm	2000 kg/ha-30 cm§
Cd	2.	2.31	2.19×10^{7}	5.06×10^{7}	1.52×10^{9}	8.94×10^{-6} kg/ha-15 cm	7 kg/ha-15 cm†
Cr	708.	816.	2.19×10^{7}	1.79×10^{10}	5.37×10^{11}	3.16×10^{-3} kg/ha-15 cm	200 kg/ha-15 cm†
Ag	4.	4.61	2.19×10^{7}	1.01×10^{8}	3.03×10^{9}	8.91×10^{-6} kg/ha-30 cm	400 kg/ha-30 cm§
Ni	18.5	21.34	2.19×10^{7}	4.67×10^{8}	1.40×10^{10}	8.23×10^{-5} kg/ha-15 cm	220 kg/ha-15 cm†
Pb	141.	162.6	2.19×10^{7}	3.56×10^{9}	1.07×10^{11}	6.29×10^{-4} kg/ha-15 cm	2200 kg/ha-15 cm†
Se	12.	13.8	2.19×10^{7}	3.02×10^{8}	9.06×10^{9}	5.33×10^{-5} kg/ha-15 cm	7 kg/ha-15 cm†
Hg	0.4	0.46	2.19×10^{7}	1.01×10^{7}	3.03×10^{8}	8.91×10^{-7} kg/ha-30 cm	40 kg/ha-30 cm§

*Assumption: Density of waste = 0.867 kg/l.
†Reference 5.
§Reference 4.

TABLE 25. HAZARDOUS INORGANIC CONSTITUENT LOADING CALCULATIONS FOR FACILITY 04

Parameter	Effluent mg/kg	Waste Applied kg/yr	Effluent mg/yr	Effluent mg/30 yr	Effluent kg/ha-15 cm	EPA Limits*
Cd	67.	5824224	3.90×10^{8}	1.17×10^{10}	9.75×10^{-4}	7 kg/ha-15 cm
Cr	500.	5824224	2.91×10^{9}	8.74×10^{10}	7.28×10^{-3}	2200 kg/ha-15 cm
Ni	672.	5824224.	3.91×10^{9}	1.17×10^{11}	9.75×10^{-3}	200 kg/ha-15 cm
Pb	425.	5824224.	2.48×10^{9}	7.43×10^{10}	6.19×10^{-3}	2200 kg/ha-15 cm

*Reference 5.

TABLE 27. HAZARDOUS INORGANIC CONSTITUENT LOADING CALCULATIONS FOR FACILITY 06

Parameter	Effluent mg/kg	Waste Applied* kg/yr	Effluent mg/yr	Effluent mg/30 yr	Effluent kg/ha-15 cm	EPA Limits*
Sb	35.7	6.647×10^{6}	2.37×10^{8}	7.12×10^{9}	2.22×10^{-4} kg/ha-30 cm	1000 kg/ha-30 cm†
As	44.8	6.647×10^{6}	2.98×10^{8}	8.94×10^{9}	5.59×10^{-4} kg/ha-15 cm	1100 kg/ha-15 cm§
Ba	3737.	6.647×10^{6}	2.49×10^{10}	7.46×10^{11}	2.33×10^{-2} kg/ha-30 cm	2000 kg/ha-30 cm†
Be	0.9	6.647×10^{6}	5.98×10^{6}	1.79×10^{8}	1.12×10^{-5} kg/ha-15 cm	110 kg/ha-15 cm§
Cd	105.3	6.647×10^{6}	7.00×10^{8}	2.11×10^{10}	1.32×10^{-3} kg/ha-15 cm	7 kg/ha-15 cm§
Cr	5263.	6.647×10^{6}	3.49×10^{10}	1.05×10^{12}	6.56×10^{-2} kg/ha-15 cm	2200 kg/ha-15 cm§
Hg	16.21	6.647×10^{6}	1.08×10^{8}	3.23×10^{9}	1.01×10^{-9} kg/ha-30 cm	40 kg/ha-30 cm†
Ni	4875.	6.647×10^{6}	3.23×10^{10}	9.68×10^{11}	6.05×10^{-2} kg/ha-15 cm	220 kg/ha-30 cm§
Pb	1394.	6.647×10^{6}	9.26×10^{9}	2.77×10^{11}	1.73×10^{-2} kg/ha-15 cm	2200 kg/ha-15 cm§
Se	37.5	6.647×10^{6}	2.49×10^{8}	7.46×10^{9}	4.66×10^{-4} kg/ha-15 cm	7 kg/ha-15 cm§
Ag	8.28	6.647×10^{6}	5.50×10^{7}	1.65×10^{9}	5.16×10^{-5} kg/ha-30 cm	400 kg/ha-30 cm†

*Volumes shown represent maximum possible annual application.
†Reference 4.
§Reference 5.

TABLE 29. CALCULATED END-OF-YEAR OF OIL IN THE SOIL FOR DESIGNATED HILT FACILITIES

Year	Half-life of 60 days Facility Code						Half-life of 125 days Facility Code					
	01	02	03	04	05	06	01	02	03	04	05	06
0*	-	0.	-	-	0	-	0.	0.	0.	0.	0.	0
0†	-	4.4	-	-	0.2	-	0.4	4.4	8.0	0.6	0.2	0.3
1	-	0.07	-	-	3.4	-	0.6	0.5	0.9	2.7	5.9	1.6
2	-	0.07	-	-	3.6	-	0.8	0.6	1.0	3.2	7.2	1.9
3	-	-	-	-	3.6	-	0.8	0.6	1.0	3.4	7.6	2.0
4	-	-	-	-	-	-	-	-	-	3.4	7.6	2.0

Year	Half-life of 146 days Facility Code						Half-life of 304 days Facility Code					
	01	02	03	04	05	06	01	02	03	04	05	06
0*	0.	-	0.	0.	-	0.	0.	0.	0.	0.	0.	0.
0†	0.4	-	8.0	0.6	-	0.3	0.4	4.4	8.0	0.6	0.2	0.3
1	0.8	-	1.5	3.2	-	1.7	1.5	1.7	3.2	5.8	8.4	2.4
2	1.0	-	1.8	3.9	-	2.2	2.3	2.4	4.4	8.9	13.	3.7
3	1.0	-	1.8	4.1	-	2.3	2.7	2.7	5.0	10.	15.	4.4
4	-	-	-	4.1	-	2.3	2.9	2.8	5.2	11.	17.	4.8
5	-	-	-	-	-	2.4	3.0	2.9	5.3	12.	17.	5.0
6	-	-	-	-	-	2.4	3.1	2.9	5.3	12.	18.	5.1
7	-	-	-	-	-	-	3.1	-	-	-	19.	5.2
8	-	-	-	-	-	-	-	-	-	-	19.	5.2

*Assumed weight percentage of oil in the soil prior to use as a treatment facility.
†Weight percentage of oil in the soil just after initial waste application.

the soil stabilized to 5.2 percent after 16 years of continued use. Based upon calculations using 125 days for half-life, the weight percentage of oil in the soil stabilized at 2.0 percent after 7 years continued use.

Facility 01 reported a weight percentage of oil in the soil of 2.0 percent. This reported value falls within the calculated values presented in Table 29 for facility 01. The minimum calculated stabilized weight percentage of oil in the soil for facility 01 was 0.83 percent and the maximum calculated value was 3.2 percent.

Facility 02 also reported oil and grease concentrations in the soil. The minimum reported weight percentage of oil in the soil was 2.7 percent and the maximum reported value was 6.6 percent. The maximum calculated weight percentage of oil in the soil, based on a half-life of 304 days, was 2.9 percent (Table 29).

Facilities 01 (Region V), 03 (Region VI), 04 (Region V), and 06 (Region X) are located in a climatic region where the HILT criterion is 4.0 weight percentage of oil in the soil (oil/solil). Facility 02 (Region VI) and facility 05 (Region IX) are located in a climatic region having a HILT criterion of 8.0 percent oil/soil. Chicago, Illinois, temperature profile falls within the 4.0 percent oil/soil criterion climatic region and Houston, Texas, temperature profile falls within the climatic region having the 8.0 percent oil/soil criterion. For comparative purposes, two addition half-life values (60 days and 146 days) were calculated based on temperature profiles for Chicago and Houston.

OPERATION/MANAGEMENT OF HILT FACILITIES

Operational characteristics for the facilities meeting the definition of high intensity as per section 5 are presented in Table 30. The depth of waste incorporation for the 4.0 percent oil/soil facilities ranged from 0.15 m (6 inches) (03) to 0.66 m (26 inches) (04) and averaged 0.28 m (11 inches). The 8.0 percent oil/soil facilities had a depth of waste incorporation ranging from 0.28 m (11 inches) (05) to 0.46 m (18 inches) (02). The number of months the 4.0 percent oil/soil facilities were actively used per year ranged from 6-7 months (01) to 12 months (06), and averaged 8.25 months. The 8.0 percent oil/soil facilities were actively used 11 months (05) and 12 months (02) per year. The maximum waste application rates for the 4.0 percent oil/soil

TABLE 30. CONTINUED

Parameter	Facility Code					
	01	02	03	04	05	06
Reported weight percent of oil in soil (percent)	2.	4.6	Not given	Not given	§§	Not given
Calculated stabilized percent of oil in soil						
60 day $t_{1/2}$	-	0.07	-	-	3.6	-
125 day $t_{1/2}$	0.8	0.6	1.0	3.4	7.6	2.0
146 day $t_{1/2}$	1.0	-	1.8	4.1	-	2.4
304 day $t_{1/2}$	3.1	2.9	5.3	12.	19.	5.2

*Usually approx. 2 acres are injected in any one day. Frequency of waste application is reported frequency for reported maximum application rate.

†Per depth of incorporation.

§Based on maximum waste application rates reported.

#$kg/m^3/yr$.

**Based on reported waste application rates.

††Reported maximum target percentage of oil in the treatment soil.

§§Section will not be injected until the oil content is less than 10 percent.

waste is injected below the surface of the 0.254 m (10 inch) active zone using a 50 bbl vacuum truck adapted for this service. The waste is disked into the soil immediately after injection by a double row set of disks pulled behind the injection truck. The soil is also disked approximately twice a week without waste injection to aerate it. In addition, a rototiller is used to work the soil 1-2 times per week. A maximum of 10 percent oil in the soil has been established. Should any section exceed this amount, that section will not be injected until the oil content is less than 10 percent. The water content is maintained between 7 and 12 percent. When the water content falls below 8 percent, fresh water is applied. The waste application rate on a yearly average is approximately 29 metric tons/ha/week (13 tons/acre/week) (0.22 percent oil/soil). During the rainy season (November-March) wastes may not be applied for up to 12 weeks. During the summer months (June-September) application rates have been as high as 112 metric tons/ha/week (50 tons/acre/week) (0.86 percent oil/soil) for up to 6 weeks. The rate for summer application is limited by the 10 percent maximum oil content in the soil. The application rate is governed by the oil degradation rate, water content, availability of waste, and weather. If all these variables are acceptable, some part of the land treatment site could be injected each day, five days per week, throughout the year.

The waste at facility 06 is applied to the treatment site monthly by surface spreading 12 months per year. The wastes are applied as plant operations and maintenance necessitate waste removal. Most wastes are generated during the summer months. The waste application rate is adjusted to a maximum target of 5 percent oil/soil. The treatment site is tilled four to six times per year, and is limed and fertilized as needed.

Monitoring Practices

The U.S. Environmental Protection Agency requires land treatment facilities to monitor both groundwater (Part 264, 265, Subpart F) and the unsaturated zone (Part 264, 265, Subpart M). Groundwater monitoring is required according to the following schedule: quarterly for the first year and annually after the first year. Three sets of parameters are examined during monitoring of groundwater. The first parameter set reflects the aquifer's suitability as a drinking water supply. The second set of parameters is used for

TABLE 31. SOIL SAMPLE ANALYSIS FOR HAZARDOUS WASTE CONSTITUENTS APPLIED AT FACILITY 02

Parameter	Soil Sample			Ave.* Feed Sample mg/l§	Ave.† Feed Sample mg/kg	Soil Status (%)
	Site #1 mg/kg[1]	Site #2 mg/kg[1]	Ave. mg/kg[1]			
Oil & Grease	44067.	56500.	50284.	200258.	197454.	- 75.
Arsenic	3.	3.0	3.0	1.5	1.48	+103.
Barium	212.	206.	209.	42.1	41.5	+403.
Cadmium	0.98	1.10	1.04	0.5	0.5	+108.
Chromium	1278.	1556.	1417.	210.	207.	+584.
Lead	590.	1230.	910.	43.	42.4	+2046.
Mercury	2.1	2.5	2.3	0.10	0.10	+2200.
Selenium	6.0	6.0	6.0	3.0	2.96	+103.
Silver	1.0	1.0	1.0	1.0	0.99	+1.

*See calcul. sheet in Appendix B-3
†Based on 0.986 kg/l density
§Unless otherwise noted (dry wt.)

Groundwater, soil-pore water, and soil core sampling are analyzed twice a year for facility 03. Facility 04 reported that it performs its monitoring as required by RCRA parts 264 and 265 requirements.

Facility 05 monitors groundwater, soil moisture, and soil core ranging from bi-weekly for soil oil content, pH, soluble salts and bacteria count to annually for groundwater constituents. The individual monitoring programs are summarized in Tables 35 through 37 for groundwater soil moisture and soil core monitoring, respectively. The summation includes the type of sample taken, sample depth, frequency of sampling, and the constituents analyzed. Facility 06 monitors surface soil, soil cores, lysimeter water and groundwater.

Facilities 01 and 06 reported that waste related constituents were not found in the groundwater and surface water tested. Facility 05 observed no waste-related constituents in any of their soil core samples, but noted sample concentrations in selected lysimeter samples and are continuing to monitor this phenomenon. Facility 04 reported no statistically significant increase in values for groundwater parameters measured with time. The other facilities did not report groundwater or surface water monitoring data. The calculated half-life for the Chicago's climatic region is 146 days and for Houston's climatic region is 60 days. The half-life for Chicago's climatic region was based upon an oil reduction rate of 2.5 percent of soil weight and a single dose oil application of 2.0 percent oil in the soil. Houston's climatic half-life was based on an oil reduction rate of 6.2 percent soil weight per year and a single dose oil application of 2.0 percent oil in the soil (1). See Appendix B-3 for calculations.

Based upon the Chicago's climatic half-life value, the weight percentage of oil stabilized at 1.0 percent after three years, 1.8 percent after three years, 4.1 percent after four years, and 2.4 percent after eight years for facilities 01, 03, 04, and 06 respectively. Facilities 02 and 05, using Houston's climatic half-life value had a stabilized weight percentage of oil in the soil equal to 0.07 percent after two years and 3.6 percent after three years respectively. Figure 2 illustrates these results for the calculated half-lives for petroleum waste versus weight percentage of oil in the soil at the stabilization year for the HILT facilities.

The reported 2.0 percent oil/soil value for facility 01 is greater than the calculated 1.0 percent oil/soil value based on the half-life value

TABLE 36. CONSTITUENTS IN SOIL MOISTURE (LYSIMETER) MONITORING PROGRAM FOR FACILITY 05

Type of Sample	Depth (m)	Frequency	Constituents Analyzed
Lysimeter	4.6	Quarterly	pH, oil and grease, total organic halogen, total dissolved solids, chlorides, phenols (C_6H_5OH), total chromium, hexavalent chromium, iron, and lead
Lysimeter	0.46	Semi-annual	Cyanide, copper, nickel, arsenic, and mercury
Lysimeter	1.5	Semi-annual	Cyanide, copper, nickel, arsenic, and mercury
Lysimeter	3.05	Semi-annual	Cyanide, copper, nickel, arsenic, and mercury
Lysimeter	0.46	Quarterly	pH, oil and grease, total organic halogen, total dissolved solids, chlorides, phenols (C_6H_5OH), total chromium, hexavalent chromium, iron, and lead
Lysimeter	1.5	Quarterly	pH, oil and grease, total organic halogen, total dissolved solids, chlorides, phenols (C_6H_5OH), total chromium, hexavalent chromium, iron, and lead
Lysimeter	3.05	Quarterly	pH, oil and grease, total organic halogen, total dissolved solids, chlorides, phenols (C_6H_5OH), total chromium, hexavalent chromium, iron, and lead

TABLE 37. CONSTITUENTS IN SOIL MONITORING PROGRAM FOR FACILITY 05

Type of Sample	Depth (m)	Frequency	Constituents Analyzed
Soil	Top 0.254	Bi-Weekly	Oil content, pH, moisture, soluble salts, and bacteria count
Soil	Top 0.254	Monthly	Inorganic nitrogen, phosphorus and potassium
Soil	Top 0.254	Quarterly	pH, oil and grease, phenols (as C_6H_5OH), arsenic, total chromium, copper, cyanide, iron, lead, mercury, nickel, zinc
Soil	0.46-0.61	Semi-annual	pH, oil and grease, phenols (as C_6H_5OH), arsenic, total chromium, copper, cyanide, iron, lead, mercury, nickel, zinc
Soil	0.61-0.91	Semi-annual	pH, oil and grease, phenols (as C_6H_5OH), arsenic, total chromium, copper, cyanide, iron, lead, mercury, nickel, zinc
Soil	0.91-1.22	Semi-annual	pH, oil and grease, phenols (as C_6H_5OH), arsenic, total chromium, copper, cyanide, iron, lead, mercury, nickel, zinc

for the Chicago temperature profile. The calculated 1.8 percent oil/soil value based on the half-life value for the Houston temperature profile is less than the reported minimum 2.7 percent oil/soil value for facility 02.

HOW TREATMENT PRACTICES IN HILT FACILITIES MEET RCRA GUIDELINES

The data received indicate that the six HILT facilities are meeting the RCRA land operation/management requirements. All wastes that are applied to the soil are incorporated and mixed into the soil and tilled afterwards to insure aerobic conditions in the soil-waste mixture. Four of the facilities added amendments including NPK and lime to the soil to increase biodegradation of the petroleum wastes. There were no indications that any of the facilities were using the soil as a filtration or dilution medium. Only one facility (02) provided soil sample data. The data indicated a 75 percent reduction in the weight percentage of oil in the soil compared with the facility's feed samples. No time period was given with this information.

Each of the six facilities reported that all run-on is diverted away from the treatment sites and that all run-off is collected and routed for further treatment.

The subject of record keeping was not addressed directly by the data gathering packet. But in order for the facilities to provide the information requested, records had to be kept. Information pertaining to application rates, frequency of application, and quantities applied were supplied by the facilities.

Data pertaining to waste characterization was provided by all the HILT facilities. Twenty hazardous waste constituents were identified in the land treated wastes data, including constituent concentrations.

Very few data were provided pertaining to groundwater and unsaturated zone monitoring practices. The monitoring was performed quarterly or semi-annually as required in RCRA Parts 264 and 265. Unsaturated zone monitoring was performed twice per year, before and after the waste application season and according to RCRA requirements. There was no information given pertaining to monitoring plans. Soil, groundwater, and surface water background data were not provided.

The growth of food-chain crops was not addressed in the data gathering packet because vegetation is not used as a means of reducing petroleum wastes in the soil treatment medium.

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TABLE A-7. NON-HAZARDOUS ORGANIC WASTE CONSTITUENTS FOR FACILITY 03

Waste Constituent	Waste Stream: Slop Oil Emulsion Solids mg/kg (dry wt.)	Waste Stream: API Separator Sludge mg/kg (dry wt.)
Anthracene	38.	-
Naphthylamine	-	180.
Phenanthrene	360.	96.
Pyrene	110.	-

TABLE A-8. NON-HAZARDOUS ORGANIC WASTE CONSTITUENTS FOR FACILITY 05

Waste Constituent	Waste Stream			
	API Separator Sludge (mg/kg)		DAF (mg/kg)	
	Sample WC-1	Sample WC-2	Sample WC-7	Sample WC-8
C10 H22	340.*	330.*	550.*	660.*
C11 H24	370.*	310.*	480.*	560.*
C12 H26	110.*	-	-	-
Decahydro-2-methylnaphthalene	210.*	240.*	460.*	530.*
3,3-diethylpentane	-	-	620.*	640.*
3,3-dimethylpentane	-	240.*	-	-
Methylcyclohexane	190.*	260.*	910.*	820.*
3-methylhexane	-	190*	580.*	570.*
1-methyl-3-ethylbenzene	150.	-	560.	560.
1,2,4-trimethyl-benzene	290.	300.	690.	700.
1,3,5-trimethyl-benzene	-	-	160.	-
2,3,4-trimethyl-hexane	150.*	270.*	850.*	860.*
2,4,6-trimethyl-octane	320.*	340.*	780.*	870.*

*Tentative value based on the response of ethylbenzene standard.

TABLE A-10. NON-HAZARDOUS INORGANIC WASTE CONSTITUENTS FOR HILT FACILITIES

Waste Constituent	01 mg/kg	02* mg/kg	03 mg/kg dry	04 mg/kg	05 mg/kg	06 mg/kg
Co	9.3	-	37.	-	-	61.-84.
V	-	8.1	84.	-	11.25	73.-223.
Al	20,400.	4141.	-	-	-	-
Cu	950.	68.6	-	-	85.5	-
Fe	14,440.	3740.	-	244,990.	-	-
Mg	8,810	3829.	-	-	1415.	-
Mn	2,927	69.2	-	-	-	-
Zn	-	458.	-	537.	171.	-
Ca	21,220.	<2.3	-	-	6800.	-
Mo	62.6	-	-	-	-	-
Na	1,004.	-	-	-	3170.	-
P	260.	-	-	-	975.	-
K	-	-	-	-	74.5	-
B	-	-	-	-	20.15	-
Cl	-	-	-	-	3880.	-
F	-	-	-	-	3.35	-
S	-	-	-	-	1.405	-
SO_4	-	-	-	-	885.	-
NO_3-N	-	-	-	-	5.6	-
NH_3-N	-	-	-	-	152.	-
NCO_3	-	-	-	-	6650.	-

*Assumption: density of waste equals 0.867 kg/l.

TABLE A-11. CUMULATIVE* NON-HAZARDOUS ORGANIC WASTE CONSTITUENTS FOR HILT FACILITIES

Waste Constituent	01	02	03 mg/kg (dry/wt)	04	05 mg/kg	06 mg/kg
Anthracene	-	-	38.	-	-	2904.-2928.
Naphthylamine	-	-	180.	-	-	-
Phenanthrene	-	-	456.	-	-	1040.
Pyrene	-	-	110.	-	-	230.
C10 H22	-	-	-	-	940.	-
C11 H24	-	-	-	-	860.	-
C12 H26	-	-	-	-	110.	-
Decahydro-2-methylnaphthalene	-	-	-	-	720.	-

*Total non-hazardous organic waste constituents that are applied to the treatment site.

APPENDIX B
CALCULATIONS

APPENDIX B-1

Appendices B-1 and B-3 contain calculations used to determine if a facility meets the high intensity land treatment criterion discussed in Section 5. A facility can meet the criterion either by a single waste application or by a series of applications. The calculations in Appendix B-1 address the single waste application criteria using reported maximum waste application rates for each facility. Appendix B-3 addresses the series of application criteria.

<u>Facility 01</u>

- Reported Max. Application Rate = 250 yd^3 oil/acre
- Zone of incorporation is 0.833 ft.

  250 yd^3 oil/acre * 27 ft^3/yd^3 = 6750 ft^3 oil/acre

Density of Oil--

  315 lb oil/bbl oil * bbl/42 U.S. gal = 7.5 lb oil/U.S. gal

  7.5 lb oil/gal * gal/0.134 ft^3 = 55.97 lb oil/ft^3

Weight Percent Oil in the Soil Per Application--

  6750 ft^3 oil/acre * 55.97 lb oil/ft^3 = 377,798 lb oil/acre

  377,798 lb oil/acre * acre/43560 ft^2 * 1/0.833 ft * ft^3 soil/80 lb
  * 100% = 13%

  Weight percent oil in the soil = 13%

-HILT criteria is 4.0 weight percentage of oil in the soil.

<u>Facility 02</u>

- Reported application rate = 115 tons/acre/yr
- Zone of incorporation is 1 ft.

Facility 05

- Reported yearly average application rate = 13 tons waste/acre/week
- Zone of incorporation is 0.833 ft
- Average percentage of oil in wastes = 25%

Weight Percent Oil in the Soil Per Week--

$$13 \text{ tons/acre} * 2000 \text{ lb/ton} * 0.25 * \text{acre}/43560 \text{ ft}^2 * 11.833 \text{ ft}$$
$$* \text{ ft}^3 \text{ soil}/80 \text{ lb} * 100\% = 0.22\%$$

- HILT criterion is 8.0 weight percentage oil in soil

Facility 06

- Reported yearly waste application = 7327 wet wt tons
- Zone of waste incorporation is 1 ft
- Average percentage of oil in wastes = 15.5%
- Waste is applied monthly, therefore, waste application rate is 611 (wet wt) tons
- Total acreage is 20 acres, therefore, 30 wet wt ton/acre/month

Weight Percent Oil in the Soil Applied--

$$30 \text{ tons/acre} * 2000 \text{ lb/ton} * 0.155 * \text{acre}/43560 \text{ ft}^2 * 111 \text{ ft}$$
$$* \text{ ft}^3 \text{ soil}/80 \text{ lb} * 100\% = 0.27\%$$

- HILT criteria is 4.0 weight percentage oil in soil

APPENDIX B-2

Calculations for Tables 22 through 27. Inorganic constituent loading for the HILT facilities, in Section 8.

Facility 01 (Table 22)

Wastes Applied--

DAF	57,000 lbs/d
API Separator Sludge	31,000 lbs/d
Slop Oil Emulsion Solids	33,000 lbs/d
Total	121,000 lbs/d

$121{,}000 \text{ lbs/d} * 365 \text{ days} = 4.4165 \times 10^7 \text{ lbs/yr}$

$(4.4165 \times 10^7 \text{ lbs})/\text{yr} * 0.4536 \text{ kg/lb} = 20033244 \text{ kg/yr}$

Effluent (mg/yr) of Constituent--

Effluent (mg/kg) * wastes applied (kg/yr) = effluent (mg/yr)

Effluent (mg/yr) of Constituent--

Effluent (mg/l) * 1/density of waste (0.867 kg/l) = effluent (mg/kg)

Effluent (mg/kg) * waste applied (kg/yr) = effluent (mg/kg)

Constituent Applied (kg/ha-46 cm)--

210 acres * 0.4047 ha/acre = 85 ha

Note: Zone of incorporation for Facility 02 is 46 cm

Soil volume of 1.0 ha - 15 cm weighs 2×10^6 kg

1.0 ha - 30 cm weighs 4×10^6 kg

1.0 ha - 46 cm weighs 6.1×10^6/kg

$$\frac{\text{Constituent (mg)}}{\text{85 ha - 46 cm}} * \frac{10^{-6}\text{ kg}}{\text{mg}} * \frac{\text{85 ha - 46 cm}}{85 * 6.1 \times 10^6\text{ kg}}$$

= constituent (kg/weight of ha - 46 cm)

Constituent (kg/weight of ha - 46 cm) * [weight ratio of (incorporation zone soil volume/EPA limit soil volume)]

= constituent (kg/weight of constituent EPA limit soil volume)

Example--

Parameter	Effluent Conc. (mg/l)	Waste Applied (kg/yr)	Density of Waste (kg/l)
As	6.0	2.191×10^7	0.867

Effluent (mg/yr) for As--

(6.0 mg)/ℓ * ℓ/0.867 kg = 6.92 mg/kg

(6.92 mg)/kg * 2.191×10^7 kg/yr = 1.516×10^8 mg/yr

Effluent (mg) for 30 yr for As--

1.516×10^8 mg/yr * 30 yrs = 4.548×10^9 mg

As applied (kg/ha - 46 cm)--

$$\frac{4.548 \times 10^9\text{ mg}}{\text{85 ha - 46 cm}} * \frac{10^{-6}\text{ kg}}{\text{mg}} * \frac{\text{85 ha - 46 cm}}{85 * 6.1 \times 10^6\text{ kg}} = 8.77 \times 10^{-6}\text{ kg/ha - 46 cm}$$

As applied (kg/ha - 15 cm)--

$$8.77 \times 10^{-6}\text{ kg/ha - 46 cm} * \frac{6.1 \times 10^6\text{ kg}}{2 \times 10^6\text{ kg}} = 2.67 \times 10^{-5}\text{ kg/ha - 15 cm}$$

Facility 04 (Table 25)

Wastes Applied--

DAF	3033 ton/yr
API Separator Sludge	112 ton/yr
Heat Exchanger Bundle Cleaning Sludge	87 ton/yr
Slop Oil Emulsion Solids	2963 ton/yr
Tank Bottoms (other than leaded)	225 ton/yr
Total	6420 ton/yr

6420 ton/yr * 2000 lb/ton * 0.4536 kg/lb = 5824224 kg/yr

Effluent (mg/yr) of Constituent--

Effluent (mg/kg) * waste applied (kg/yr) = effluent (mg/yr)

Constituent Applied (kg/ha-66 cm)--

15 acres * 0.4047 ha/acre = 6 ha

Note: Zone of incorporation for Facility 04 is 66 cm

Soil volume of 1.0 ha - 15 cm weighs 2 x 10^6 kg

1.0 ha - 30 cm weighs 4 x 10^6 kg

1.0 ha - 66 cm weighs 8.8 x 10^6 kg

$$\frac{\text{Constituent (mg)}}{\text{6 ha - 66 cm}} * \frac{10^{-6}\text{ kg}}{\text{mg}} * \frac{\text{6 ha - 66 cm}}{6 \times 8.8 \times 10^{6}\text{ kg}}$$

= constituent (kg/weight of ha - 66 cm)

Constituent (kg/weight of ha - 66 cm) * [weight ratio of (incorporation zone soil volume/EPA limit soil volume)]

= constituent (kg/weight of constituent EPA limit soil volume)

Example--

Parameter	Effluent Conc. (mg/kg)	Waste Applied (kg/yr)
Cd	67.	5824224.

Constituent (kg/weight of ha - 25 cm) * [weight ratio of (incorporation zone soil volume/EPA limit soil volume)]

= constituent (kg/weight of constituent EPA limit soil volume)

Example--

Parameter	Effluent Conc. (mg/kg)	Waste Applied (kg/yr)
Sb	0.26	3.266×10^6

Effluent (mg/yr) for Sb--

$(0.26)/\text{kg} * (3.266 \times 10^6 \text{ kg})/\text{yr} = 8.5 \times 10^5 \text{ mg/yr}$

Sb applied (kg/ha - 25 cm)--

$$\frac{8.5 \times 10^5 \text{ mg/yr}}{4 \text{ ha - 25 cm}} * 30 \text{ years} * \frac{10^{-6} \text{ kg}}{\text{mg}} * \frac{4 \text{ ha - 25 cm}}{4 * 3.3 \times 10^6 \text{ kg}}$$

$$= 1.93 \times 10^{-6} \text{ kg/ha - 25 cm}$$

Sb applied (kg/ha - 30 cm)--

$$1.93 \times 10^{-6} \text{ kg/ha - 25 cm} * \frac{3.3 \times 10^6 \text{ kg}}{4 \times 10^6 \text{ kg}} = 1.59 \times 10^{-6} \text{ kg/ha - 30 cm}$$

Facility 06 (Table 27)

Wastes Applied--

Slop Oil Emulsion	385 tons/yr
API Sludge	333 tons/yr
Leaded Tank Bottoms	62 tons/yr
Refinery Scale (Hazardous)	176 tons/yr
Refinery Oily Wastes (Hazardous)	588 tons/yr
FCCU Catalyst	1000 tons/yr
Filter Clay	33 tons/yr
Poly Catalyst	72 tons/yr
Wastewater Treatment Sludge	2609 tons/yr
Refinery Scale (Nonhazardous)	1765 tons/yr
Refinery Oily Wastes (Nonhazardous)	12 tons/yr
Cooling Tower Sludge	286 tons/yr
Sodium Cation Exchange Resin	6 tons/yr
Total	7327 tons/yr

$7327 \text{ tons/yr} * 2000 \text{ lb/ton} * 0.4536 \text{ kg/lb} = 6.647 \times 10^6 \text{ kg/yr}$

for Facility 01, are those calculated in Appendix B-1. Facility 01 used two oil/soil values, one calculated in Appendix B-1 and the second calculated in Appendix B-3. The values used for Facility 01 in Table 29 were calculated using the second oil/soil value.

The equations used to obtain the values presented in Table 29 follow K. W. Brown's approach for zero order kinetics. The equations for half-life and degradation rate determination are presented below.

Half-Life Determination

$$t_{1/2} = \frac{0.50}{D_t} t$$

where t = time in days that waste was degraded

$t_{1/2}$ = half-life

D_t = fraction degraded in t days

Degradation Rate Determination

$$D_t = \frac{C_a - (C_r - C_s)}{C_a}$$

where D_t = fraction degraded

C_a = fraction applied

C_r = residual fraction in waste amended soil

C_s = amount of fraction present in unamended soil. Assumed $C_s = 0$.

$$D_t = \frac{C_a}{C_a} - \frac{(C_r)}{C_a}$$

$$D_t = 1 - \frac{Cr}{C_a}$$

$$D_t + \frac{C_r}{Ca} = 1$$

$$C_aD_t + C_r = C_a$$

$$C_a - C_aD_t = C_r$$

62.8 tons/acre * 2000 lb/ton * acre/43560 ft^2 * 11.833 ft * ft^3/80 lb-oil * 100% = 4.32% oil in soil

4.32% * 1/12 = 0.36%

Year 1--

Month

1) 0.36 * (-0.12) + 0.36 = 0.317
2) 0.317 + 0.36 = 0.677 * (-0.12) + 0.677 = 0.596
3) 0.596 + 0.36 = 0.956 * (-0.12) + 0.956 = 0.841
4) 0.841 + 0.36 = 1.201 * (-0.12) + 1.201 = 1.057
5) 1.057 + 0.36 = 1.417 * (-0.12) + 1.417 = 1.247
6) 1.247 + 0.36 = 1.607 * (-0.12) + 1.607 = 1.414
10) 1.414 + 0.36 = 1.774 * (-(125/125)*0.5) + 1.774 = 0.887
12) 0.887 * (-(57/125)*0.5) + 0.887 = 0.683

End of Year 2) 0.805
3) 0.827
4) 0.831
5) 0.832
6) 0.832

- HILT criteria is 4.0 weight percentage of oil in soil.

Facility 01

- Half-life of 146 days
- 30 days/146 days = 0.205 * 50% = 10.25%
- 0.36% oil/soil by weight applied each application

Year 1--

Month

1) 0.36 * (-0.1025) + 0.36 = 0.323
2) 0.323 + 0.36 = 0.683 * (-0.1025) + 0.683 = 0.613
3) 0.613 + 0.36 = 0.973 * (-0.1025) + 0.973 = 0.873

8) 3.144
9) 3.152
10) 3.156
11) 3.158
12) 3.159
13) 3.160
14) 3.160

- HILT criteria is 4.0 weight percentage oil in soil.

<u>Facility 01</u>

- Half-life of 125 days
- 30 days/125 days = 0.24 * 50% = 12% reduction
- 13% oil/soil by weight applied each application

Year 1--

Month
1) 13.0 * (-0.12) + 13.0 = 11.44
2) 11.44 + 13.0 = 24.44 * (-0.12) + 24.44 = 21.507
3) 21.507 + 13.0 = 34.507 * (-0.12) + 34.507 = 30.366
4) 30.366 + 13.0 = 43.366 * (-0.12) + 43.366 = 38.162
5) 38.162 + 13.0 = 51.162 * (-0.12) + 51.162 = 45.023
6) 45.023 + 13.0 = 58.023 * (-0.12) + 58.023 = 51.060
10) 51.060 + 13.0 = 64.060 * (-(125/125) * 0.5) + 64.060 = 32.03
12) 32.03 * (-(57/125) * 0.5) + 32.03 = 24.663

End of Year
2) 29.073
3) 29.861
4) 30.002
5) 30.027
6) 30.032
7) 30.033
8) 30.033

- HILT criteria is 4.0 weight percentage oil in soil.

Year 1--	Year 2--	Year 3--
Day	Day	Day
0) 4.36%	0) 0.501 + 4.36 = 4.86%	0) 0.56 + 4.36 = 4.92%
125) 2.18%	125) 2.43%	125) 2.46
250) 1.09%	250) 1.22%	250) 1.23
365) 0.501%	365) 0.56%	365) 0.57

- HILT criterion is 8.0 weight percentage oil in soil.

<u>Facility 02</u>

- Half life equals 304 days
- Waste applied once every year
- 365 days/304 days = 1.2 * 50% = 60% reduction
- 4.36% oil/soil by weight applied each year

Year--

1) 4.36 * (-0.6) + 4.36 = 1.744
2) 1.744 + 4.36 = 6.104 * (-0.6) + 6.104 = 2.440
3) 2.440 + 4.36 = 6.802 * (-0.6) + 6.802 = 2.721
4) 2.721 + 4.36 = 7.081 * (-0.6) + 7.081 = 2.832
5) 2.832 + 4.36 = 7.192 * (-0.6) + 7.192 = 2.877
6) 2.877 + 4.36 = 7.236 * (-0.6) + 7.236 = 2.894
7) 2.894 + 4.36 = 7.254 * (-0.6) + 7.254 = 2.902
8) 2.902 + 4.36 = 7.262 * (-0.6) + 7.262 = 2.904

- HILT criterion is 8.0 weight percentage oil in soil.

<u>Facility 03</u>

- Half life equals 125 days
- Waste applied once a year
- 7.95% oil/soil by weight percentage oil in soil

Year 1--	Year 2--
Day	Day
0) 7.95%	0) 0.91 + 7.95 = 8.86%
125) 3.98%	125) 4.43%

Year 5--

Day

0) 1.83 + 7.95 = 9.78%

146) 4.89%

292) 2.44%

365) 2.44 (-0.25) + 2.44 = 1.83%

- HILT criteria is 4.0 weight percentage oil in soil.

Facility 03

- Half life equals 304 days
- Waste applied once a year
- 365 days/304 days = 1.2 * 50% = 60% reduction
- 7.95% oil/soil by weight applied each year

Year--

1) 7.95 * (-0.6) + 7.95 = 3.18
2) 3.18 + 7.95 = 11.13 * (-0.6) + 11.13 = 4.452
3) 4.452 + 7.95 = 12.402 * (-0.6) + 12.402 = 4.96
4) 4.96 + 7.95 = 12.91 * (-0.6) + 12.91 = 5.164
5) 5.164 + 7.95 = 13.116 * (-0.6) + 13.116 = 5.246
6) 5.246 + 7.95 = 13.196 * (-0.6) + 13.196 = 5.278
7) 5.278 + 7.95 = 13.228 * (-0.6) + 13.228 = 5.291
8) 5.291 + 7.95 = 13.241 * (-0.6) + 13.241 = 5.296
9) 5.296 + 7.95 = 13.246 * (-0.6) + 13.246 = 5.298
10) 5.298 + 7.95 = 13.248 * (-0.6) + 13.248 = 5.299

- HILT criteria is 4.0 weight percentage oil in soil.

Facility 04

- Half-life of 125 days
- Waste applied every 14 days for maximum of eight months
- 14 days/125 days = 0.112 * 50% = 5.6% reduction
- 0.58% oil/soil by weight applied each application

Year 1--

Month

0.5) 0.58 * (-0.048) + 0.58 = 0.552
1.0) 0.552 + 0.58 = 1.132 * (-0.048) + 1.132 = 1.078
1.5) 1.078 + 0.58 = 1.658 * (-0.048) + 1.658 = 1.578
2.0) 1.578 + 0.58 = 2.158 * (-0.048) + 2.158 = 2.054
2.5) 2.054 + 0.58 = 2.634 * (-0.048) + 2.634 = 2.508
3.0) 2.508 + 0.58 = 3.088 * (-0.048) + 3.088 = 2.940
3.5) 2.940 + 0.58 = 3.520 * (-0.048) + 3.520 = 3.351
4.0) 3.351 + 0.58 = 3.931 * (-0.048) + 3.931 = 3.742
4.5) 3.742 + 0.58 = 4.322 * (-0.048) + 4.322 = 4.114
5.0) 4.114 + 0.58 = 4.694 * (-0.048) + 4.694 = 4.469
5.5) 4.469 + 0.58 = 5.099 * (-0.048) + 5.099 = 4.807
6.0) 4.807 + 0.58 = 5.387 * (-0.048) + 5.387 = 5.128
6.5) 5.128 + 0.58 = 5.708 * (-0.048) + 5.708 = 5.434
7.0) 5.434 + 0.58 = 6.014 * (-0.048) + 6.014 = 5.724
7.5) 5.724 + 0.58 = 6.305 * (-0.048) + 6.305 = 6.002
11.7) 6.002 + 0.58 = 6.582 * (-(146/146) * 0.5) + 6.582 = 3.291
12.0) 3.291 * (-(9/146) * 0.5) + 3.291 = 3.190

- End of Year 2) 3.928
3) 4.100
4) 4.139
5) 4.148
6) 4.150
7) 4.151
8) 4.151

- HILT criteria is 4.0 weight percentage oil in soil.

Facility 04

- Half-life of 304 days
- 14 days/304 days = 0.046 * 50% = 2.3% reduction
- 0.58% oil/soil by weight applied each application

Year 1--

Month

0.5) 0.58 * (-0.048) + 0.58 = 0.552

1.0) 0.552 + 0.58 = 1.132 * (-0.048) + 1.132 = 1.078

1.5) 1.078 + 0.58 = 1.658 * (-0.048) + 1.658 = 1.578

2.0) 1.578 + 0.58 = 2.158 * (-0.048) + 2.158 = 2.054

2.5) 2.054 + 0.58 = 2.634 * (-0.048) + 2.634 = 2.508

3.0) 2.508 + 0.58 = 3.088 * (-0.048) + 3.088 = 2.940

3.5) 2.940 + 0.58 = 3.520 * (-0.048) + 3.520 = 3.351

4.0) 3.351 + 0.58 = 3.931 * (-0.048) + 3.931 = 3.742

4.5) 3.742 + 0.58 = 4.322 * (-0.048) + 4.322 = 4.114

5.0) 4.114 + 0.58 = 4.694 * (-0.048) + 4.694 = 4.469

5.5) 4.469 + 0.58 = 5.099 * (-0.048) + 5.099 = 4.807

6.0) 4.807 + 0.58 = 5.387 * (-0.048) + 5.387 = 5.128

6.5) 5.128 + 0.58 = 5.708 * (-0.048) + 5.708 = 5.434

7.0) 5.434 + 0.58 = 6.014 * (-0.048) + 6.014 = 5.724

7.5) 5.724 + 0.58 = 6.305 * (-0.048) + 6.305 = 6.002

11.7) 6.002 + 0.58 = 6.582 * (-(146/146) * 0.5) + 6.582 = 3.291

12.0) 3.291 * (-(9/146) * 0.5) + 3.291 = 3.190

End of Year 2) 3.928

3) 4.100

4) 4.139

5) 4.148

6) 4.150

7) 4.151

8) 4.151

- HILT criteria is 4.0 weight percentage oil in soil.

Facility 04

- Half-life of 304 days
- 14 days/304 days = 0.046 * 50% = 2.3% reduction
- 0.58% oil/soil by weight applied each application

Facility 05

- Half-life of 60 days
- Average waste application is weekly for 12 months
- 7 days/60 days = 0.117 * 50% = 5.83% reduction
- 0.22% oil/soil by weight applied each week

Year 1--

Week 1

1) 0.22 * (-0.0583) + 0.22 = 0.207
2) 0.207 + 0.22 = 0.427 * (-0.0583) + 0.427 = 0.403
3) 0.403 + 0.22 = 0.623 * (-0.0583) + 0.623 = 0.586
4) 0.586 + 0.22 = 0.806 * (-0.0583) + 0.806 = 0.760
5) 0.760 + 0.22 = 0.980 * (-0.0583) + 0.980 = 0.923
6) 0.923 + 0.22 = 1.143 * (-0.0583) + 1.143 = 1.076

↓

52) 3.403 + 0.22 = 3.623 * (-0.0583) + 3.623 = 3.413

End of Year 2) 3.566

3) 3.573

4) 3.573

- HILT criterion is 8.0 weight percentage oil in the soil.

Facility 05

- Half-life of 125 days
- Average waste application is weekly for 12 months
- 7 days/125 days = 0.056 * 50% = 2.8% reduction
- 0.22% oil/soil by weight applied each week

Year 1--

Week

1) 0.22 * (-0.028) + 0.22 = 0.214
2) 0.214 + 0.22 = 0.434 * (-0.028) + 0.434 = 0.422
3) 0.422 + 0.22 = 0.642 * (-0.028) + 0.642 = 0.624
4) 0.624 + 0.22 = 0.844 * (-0.028) + 0.844 = 0.820

5) 17.976
6) 18.398
7) 18.630
8) 18.756
9) 18.826
10) 18.864
11) 18.885
12) 18.896
13) 18.903
14) 18.906
15) 18.908
16) 18.909
17) 18.910
18) 18.910

- HILT criterion is 8.0 weight percentage oil in soil.

Facility 06

- Half-life of 125 days
- Waste application is monthly for 12 months per year
- 30 days/125 days = 0.24 * 50% = 12% reduction
- 0.27% oil/soil by weight applied each month

Year 1--

Month

1) 0.27 * (-0.12) + 0.27 = 0.238
2) 0.238 + 0.27 = 0.508 * (-0.12) + 0.508 = 0.447
3) 0.447 + 0.27 = 0.717 * (-0.12) + 0.717 = 0.631
4) 0.631 + 0.27 = 0.901 * (-0.12) + 0.901 = 0.793
5) 0.793 + 0.27 = 1.063 * (-0.12) + 1.063 = 0.935
6) 0.935 + 0.27 = 1.205 * (-0.12) + 1.205 = 1.060
7) 1.060 + 0.27 = 1.330 * (-0.12) + 1.330 = 1.171
8) 1.171 + 0.27 = 1.441 * (-0.12) + 1.441 = 1.268
9) 1.268 + 0.27 = 1.538 * (-0.12) + 1.538 = 1.353
10) 1.353 + 0.27 = 1.623 * (-0.12) + 1.623 = 1.429

End of Year 2) 2.178
3) 2.304
4) 2.339
5) 2.348
6) 2.350
7) 2.351
8) 2.351

- HILT criterion is 4.0 weight percent oil in the soil.

Facility 06

- Half-life of 304 days
- Waste application is monthly for 12 months per year
- 30 days/304 days = 0.099 * 50% = 4.93% reduction
- 0.27% oil/soil by weight applied each month

Year 1--

Month
1) 0.27 * (-0.0493) + 0.27 = 0.257
2) 0.257 + 0.27 = 0.527 * (-0.0493) + 0.527 = 0.501
3) 0.501 + 0.27 = 0.771 * (-0.0493) + 0.771 = 0.733
4) 0.733 + 0.27 = 1.003 * (-0.0493) + 1.003 = 0.954
5) 0.954 + 0.27 = 1.224 * (-0.0493) + 1.224 = 1.164
6) 1.164 + 0.27 = 1.434 * (-0.0493) + 1.434 = 1.364
7) 1.364 + 0.27 = 1.634 * (-0.0493) + 1.634 = 1.554
8) 1.554 + 0.27 = 1.824 * (-0.0493) + 1.824 = 1.734
9) 1.734 + 0.27 = 2.004 * (-0.0493) + 2.004 = 1.906
10) 1.906 + 0.27 = 2.176 * (-0.0493) + 2.176 = 2.070
11) 2.070 + 0.27 = 2.340 * (-0.0493) + 2.340 = 2.225
12) 2.225 + 0.27 = 2.495 * (-0.0493) + 2.495 = 2.373

End of Year 2) 3.671
3) 4.382
4) 4.770

$-10{,}000 = 40{,}000 * (-R) + 40{,}000$

$-50{,}000 = -40{,}000\ R$

$R = t_f/t_{1/2} * 0.5$

where

t_f = frequency of application
$t_{1/2}$ = half-life
$1.25 = (365/t_{1/2}) * 0.5$
$t_{1/2} = 146$ days

2. Houston's climatic region

- oil reduction

$6.2\% * 2 \times 10^6$ lb = 124,000 lb

- oil applied

$2.0\% * 2 \times 10^6$ lb = 40,000 lb

$c = c_o * (-R) + c_o$

where

$c = 40{,}000 - 124{,}000 = -84{,}000$ lb
$c_o = 40{,}000$ lb
$-84{,}000 = 40{,}000 * (-R) + 40{,}000$
$-124{,}000 = -40{,}000\ R$
$R = 3.1$
$R = (t_f/t_{1/2}) * 0.5$
$3.1 = (365/t_{1/2}) * 0.5$
$t_{1/2} = 60$ days

Chromium

285.	mg/l (API Separator Sludge)	* 31.5%	=	89.8 mg/l
158.	mg/l (IAF Sludge)	* 33.45%	=	52.8 mg/l
245.	mg/l (DAF Sludge)	* 26.9%	=	65.9 mg/l
19.5	mg/l (WAS)	* 8.15%	=	1.6 mg/l
				210.1 mg/l

Lead

45.	mg/l (API Separator Sludge)	* 31.5%	=	14.2 mg/l
55.	mg/l (IAF Sludge)	* 33.45%	=	18.4 mg/l
37.5	mg/l (DAF Sludge)	* 26.9%	=	10.1 mg/l
3.5	mg/l (WAS)	* 8.15%	=	0.3 mg/l
				43.0 mg/l

For arsenic, cadmium, mercury, selenium, and silver the quantities of these constituents shown in the table were the same from each waste stream. See arsenic as an example.

APPENDIX B-5

Calculations to determine weight percentage of oil in the soil for facility 02's soil samples.

- Assumptions

  1. soil water holding field capacity
     sandy soil - 15% water
     clays - 40% water

  2. Assume soil at facility is 60% of field capacity.
     = 15% * 0.60 = 9% for sandy soils.

- Facility 2 consists of sandy soils.

APPENDIX C
DATA COLLECTION PACKET

Personnel at petroleum refineries and waste treatment facilities that land treat petroleum wastes were contacted by telephone. The telephone conversation included a description of the project and the criteria for high intensity. Refineries and facilities that either met the climatic region criterion or that were uncertain of their status were asked to complete the data collection packet.

For the purposes of this report a petroleum land treatment facility is characterized as a high intensity land treatment (HILT) facility when the minimum weight percentage of oil in the soil (oil/soil) equals a defined criterion based on temperature (climate). A criterion of 4.0 percent by weight oil/soil is defined for climatic regions where seasonal fluctuations cause the average minimum air temperature to fall below 9.9°C (50°F) here after referred to as 4.0 percent oil/soil. An 8.0 percent by weight oil/soil criterion is defined for climatic regions where the average minimum air temperature is greater than or equal to 9.9°C (50°F), here after referred to as 8.0 percent oil/soil. The value of 9.9°C (50°F) is chosen because biological degradation of petroleum is substantially reduced below this temperature.

ACKNOWLEDGMENT AND CONTACT SHEET

Confidential Information

Company Name ______________________

Refinery Address ______________________

____

____

____
Zip

Contact Name ______________________

Title ______________________

Telephone Number ______________________

Completion of this sheet acknowledges receipt of the data collection packet provides a company contact for any further correspondence in regards to the packet.

Please forward completed sheet to:

Dr. Ronald C. Sims
Utah Water Research Laboratory, UMC 82
Utah State University
Logan, UT 84322

(801)-750-3178

Refinery Code No. ______________
(To be assigned by USU)

INSTRUCTIONS

This data collection packet has been designed to be self-explanatory, however, a few clarification statements should be made. Questions 1 through 8 pertain to the refinery itself. Question 8 characterizes the wastes addressed in question 7 (Solid Waste). Question 8 is organized for characterization of one type of waste per sheet. One additional copy of question 8 is included.

Questions 9 through 15 pertain to treatment of the wastes and the land treatment sites. Questions 15 through 19 are also organized for characterization of only one land farm site.

Also included in this packet are General Purpose Continuation Sheets. If additional space is needed for any question, just note the question number and continue on the General Purpose Continuation Sheet.

For additional copies of any question and/or continuation sheets, attach a request note to the Acknowledgment and Contact Sheet and more copies will be sent to you.

FACILITY DATA COLLECTION PACKET

Facility Code__________

1. What is your refinery classification per 19 May 1974 Federal Register Petroleum Refining Point Source Category--Effluent Guidelines and Standards in accordance with NPDES permit?

   Topping__________
   Cracking__________
   Petrochemical__________
   Lube__________
   Integrated__________

2. What is the total crude capacity of this refinery?

   __________bbl/5 days.

3. Will refinery capacity increase in the next 5 years and by how much?

   ____
   ____

4. What percentages of crude, by sulfur content (% S wt) are processed?

   __________0.0-0.5%   __________1.1-1.5%
   __________0.51-1.0%   __________1.6-2.0%

5. What is the approximate percentage product distribution averaged over the year 1983?

LPG__________
Gasoline(motor)__________
Gasoline (aviation)__________
Napatha, Jet, Kerosene__________
Distillate__________
Diesel__________
Residual__________
Lube__________

Solid Waste

7. Please indicate how this refinery handles its solid wastes, including sludges from both acid processes and treatment facilities (at point of disposal):

Type	Volume Handled (lbs/d)	Method of Disposal*
Air Flotation Froth(DAF)		
API Separator Sludge		
Heat Exchanger Bundle Cleaning Sludge		
Induced Air Flotation Sludge(IAF)		
Leaded Tank Bottoms		
Slop Oil Emulsion Solids		
Clay Fines		
Cooling Tower Sludge		
Coker Blowndown Sludge		
HF Alkylation Sludge		
Primary Oil/Solids/water Separation Sludge (Other than API)		
Lime Sludge		
Spent Acid Sludge		
Spent Catalysis (Other Than FCC)		
Secondary Oil/Solids/ Water Separation Sludges (Other Than DAF/IAF)		
Tank Bottoms (Other Than Leaded)		
Waste Activated Sludge		
Waste FCC Catalyst		

*Note: Method of Disposal: Land disposal, land treatment, deep well injection, incineration, aerobic digestion, anaerobic digestion, sale, waste acceptance firms, decanting, thickening,chemical,centrifuging, filtration,etc.

*Definitions: Land disposal is equivalent to landfill(burial),land treatment is utilizing the upper soil zone for degrading and immobilizing the waste.

Site Characterization

9. Please provide the following information on climatology pertaining to waste disposal site(s).

   a) Distance and direction from refinery to land farm site(s).

   Site No.________ Site No.________ Site No.________
   ________(miles) ________(miles) ________(miles)
   ________(direction) ________(direction) ________(direction)

   b) Nearest weather station location.

   Site No.________ Site No.________ Site No.________
   ________ ________ ________
   ________ ________ ________
   ________ ________ ________

   c) Distance and direction of disposal site from the noted weather station.

   Site No.________ Site No.________ Site No.________
   ________(miles) ________(miles) ________(miles)
   ________(direction) ________(direction) ________(direction)

   d) Temperature: at a) disposal site or b) noted weather station (please circle a or b).

   Site No.________ Site No.________ Site No.________
   Average Min.________ Average Min.________ Average Min.________
   Average Max.________ Average Max.________ Average Max.________
   Extreme Min.________ Extreme Min.________ Extreme Min.________
   Extreme Max.________ Extreme Max.________ Extreme Max.________

   e) Relative Humidity: at a) disposal site or b) noted weather station (please circle a or b).

   Site No.________ Site No.________ Site No.________
   Average________ Average________ Average________
   Extreme________ Extreme________ Extreme________

   f) Precipitation (yearly average): at a) disposal site or b) noted weather station (please circle a or b).

   Site No.________ Site No.________ Site No.________
   Total________ Total________ Total________
   Snow________ Snow________ Snow________

   g) Rainfall intensity data: at a) disposal site or b) noted weather station (please circle a or b).

   Site No.________
   15 minute Max.________(in) Frequency________
   1 hour Max.________(in) Frequency________
   24 hour Max.________(in) Frequency________

   Site No.________
   15 minute Max.________(in) Frequency________
   1 hour Max.________(in) Frequency________
   24 hour Max.________(in) Frequency________

15. Please provide the following information on soil characteristics pertaining to the land treatment site:

Site No.____________

a) Surface soil permeability*:____________(cm/sec)

b) Surface soil erodibility: (check one)

Slight________Moderate________Severe________

c) Depth to bedrock____________(ft)

d) Depth to seasonally high water table________(ft)

e) Depth to usable aquifer____________

f) Surface soil texture____________

g) Surface soil cation exchange capacity____________

h) Surface soil pH____________

i) Subsurface soil**: Depth____________

Texture____________

Permeability____________

* Surface soil pertains to the zone of waste incorporation.

** Subsurface soil pertains to soil layer beneath zone of waste incorporation.

f) Waste application rate(s)** ____________________

g) Frequency of waste application ____________________

h) Are wastes mixed into a composite and then applied to the treatment site ? YES________ NO________

If NO are specific wastes designated to be applied to this site ?
YES________ NO________

If YES, please identify wastes applied to this site.
WASTES

i) Admendments added to soil to increase waste assimilation (NPK, lime, irrigation water, etc.) ____________________

j) Methods of waste application (surface spreading, spraying, subsurface injection, etc.) ____________________

k) Run-on and runoff controls. ____________________

l) Monitoring practices, including soil core and soil pore liquid and ground water. ____________________

m) How long do you intend to use this site ? (life of site) ____________________

n) What is your intended use for this site after closure ?

** How do rates vary with time of year; rational for selection a waste application rate, etc.

APPENDIX D

HAZARDOUS CONSTITUENTS REGULATED BY THE U.S. EPA[1]

Acetaldehyde
(Acetato)phenylmercury
Acetonitrile
3-(alpha-Acetonylbenzyl)-4-hydroxycoumarin and salts
2-Acetylaminofluorene
Acetyl chloride
1-Acetyl-2-thiourea
Acrolein
Acrylamide
Acrylonitrile
Aflatoxins
Aldrin
Allyl alcohol
Aluminum phosphide
4-Aminobiphenyl
6-Amino-1,1a,2,8,8a,8b-hexahydro-8-[hydroxymethyl]-8a-methoxy-5-methylcarbamate azirino[2',3':3,4]pyrrolo[1,2-a]indole-4,7-dione [ester] [Mitomycin C]
5-[Aminomethyl]-3-isoxazolol
4-Aminopyridine
Amitrole
Antimony and compounds, N.O.S.*
Aramite
Arsenic and compounds, N.O.S.
Arsenic acid
Arsenic pentoxide
Arsenic trioxide
Auramine
Azaserine
Barium and compounds, N.O.S.
Barium cyanide
Benz[c]acridine
Benz[a]anthracene
Benzene
Benzenearsonic acid
Benzenethiol
Benzidine
Benzo[a]anthracene
Benzo[b]fluoranthene
Benzo[j]fluoranthene
Benzo[a]pyrene
Benzotrichloride
Benzyl chloride
Beryllium and compounds, N.O.S.
Bis[2-chloroethoxy]methane
Bis[2-chloroethyl]ether
N,N-Bis[2-chloroethyl]-2-naphthylamine
Bis[2-chloroisopropyl] ether
Bis[chloromethyl] ether
Bis[2-ethylhexyl] phthalate
Bromoacetone
Bromomethane
4-Bromophenyl phenyl ether
Brucine
2-Butanone peroxide
Butyl benzyl phthalate
2-sec-Butyl-4,6-dinitrophenol [DNBP]
Cadmium and compounds, N.O.S.
Calcium chromate
Calcium cyanide
Carbon disulfide
Chlorambucil
Chlordane [alpha and gamma isomers]
Chlorinated benzenes, N.O.S.
Chlorinated ethane, N.O.S.
Chlorinated naphthalene, N.O.S.
Chlorinated phenol, N.O.S.
Chloroacetaldehyde
Chloroalkyl ethers
p-Chloroaniline
Chlorobenzene
Chlorobenzilate
1-[p-Chlorobenzoyl]-5-methoxy-2-methylindole-3-acetic acid
p-Chloro-m-cresol
1-Chloro-2,3-epoxybutane
2-Chloroethyl vinyl ether
Chloroform
Chloromethane
Chloromethyl methyl ether
2-Chloronaphthalene
2-Chlorophenol
1-[o-Chlorophenyl]thiourea
3-Chloropropionitrile
alpha-Chlorotoluene
Chlorotoluene, N.O.S.
Chromium and compounds, N.O.S.
Chrysene

[1] EPA. 1980. Identification and Listing of Hazardous waste. Part 261, Federal Register Vol. 45, No. 98., pp. 33132-33133. May 19, 1980.

Ethyleneimine
Ethylene oxide
Ethylenethiourea
Ethyl methanesulfonate
Fluoranthene
Fluorine
2-Fluoroacetamide
Fluoroacetic acid, sodium salt
Formaldehyde
Glycidylaldehyde
Halomethane, N.O.S.
Heptachlor
Heptachlor epoxide (alpha, beta, and gamma isomers)
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclohexane (all isomers)
Hexachlorocyclopentadiene
Hexachloroethane
1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-endo,endo-dimethanonaphthalene
Hexachlorophene
Hexachloropropene
Hexaethyl tetraphosphate
Hydrazine
Hydrocyanic acid
Hydrogen sulfide
Indeno(1,2,3-c,d)pyrene
Iodomethane
Isocyanic acid, methyl ester
Isosafrole
Kepone
Lasiocarpine
Lead and compounds, N.O.S.
Lead acetate
Lead phosphate
Lead subacetate
Maleic anhydride
Malononitrile
Melphalan
Mercury and compounds, N.O.S.
Methapyrilene
Methomyl
2-Methylaziridine
3-Methylcholanthrene
4,4'-Methylene-bis-(2-chloroaniline)
Methyl ethyl ketone (MEK)
Methyl hydrazine
2-Methyllactonitrile
Methyl methacrylate
Methyl methanesulfonate
2-Methyl-2-(methylthio)propionaldehyde-o-(methylcarbonyl) oxime
N-Methyl-N'-nitro-N-nitrosoguanidine
Methyl parathion
Methylthiouracil
Mustard gas
Naphthalene
1,4-Naphthoquinone
1-Naphthylamine
2-Naphthylamine
1-Naphthyl-2-thiourea
Nickel and compounds, N.O.S.
Nickel carbonyl
Nickel cyanide
Nicotine and salts
Nitric oxide
p-Nitroaniline
Nitrobenzene
Nitrogen dioxide
Nitrogen mustard and hydrochloride salt
Nitrogen mustard N-oxide and hydrochloride salt
Nitrogen peroxide
Nitrogen tetroxide
Nitroglycerine
4-Nitrophenol
4-Nitroquinoline-1-oxide
Nitrosamine, N.O.S.
N-Nitrosodi-N-butylamine
N-Nitrosodiethanolamine
N-Nitrosodiethylamine
N-Nitrosodimethylamine
N-Nitrosodiphenylamine
N-Nitrosodi-N-propylamine
N-Nitroso-N-ethylurea
N-Nitrosomethylethylamine
N-Nitroso-N-methylurea
N-Nitroso-N-methylurethane
N-Nitrosomethylvinylamine
N-Nitrosomorpholine
N-Nitrosonornicotine
N-Nitrosopiperidine
N-Nitrosopyrrolidine

Trypan blue
Uracil mustard
Urethane
Vanadic acid, ammonium salt
Vanadium pentoxide (dust)
Vinyl chloride
Vinylidene chloride
Zinc cyanide
Zinc phosphide

TABLE E-1. OPERATIONAL CHARACTERISTICS OF NON-HILT FACILITIES

Parameter	Facility Code 07	08	09	10	11	12
Region	VIII	V	VI	VI	X	VIII
Treatment area (ha)	5.7	5.7	6.1	20	2.8	4.8
Zone of incorporation (meter)	0.20	0.25	0.15	0.20	0.30	0.15
Reported waste application rates (maximum)	20815 kg waste/ha/application	76118 kg waste/ha/application	59.m^3 waste/ha/application	3.5 kg oil/m^3/application	772.kg/waste/ha/application	6725 kg oil/ha/application
Frequency of waste application	Every 3 months	2 to 3 times/week	Monthly	Monthly	Monthly	Monthly
Method of waste application	Surface spraying/spreading	Surface spreading	Surface spreading	Subsurface injection	Vacuum truck hose	Surface spreading
Number of months site actively used per year	8	6	10	12	12	10
Amendments added to soil	Lime and fertilizer	Lime and fertilizer	Lime and (NPK) fertilizer	-	Lime and fertilizer (once in 3 years)	Lime and (NPK) fertilizer