Topic: Land Treatment

1. Scope

Land treatment is a waste management practice in which waste materials are mixed with or applied to the soil surface. Land treatment is generally synonymous with the term landfarming or land application. In contrast to waste management methods that rely on mechanically engineered soils to enclose a high concentration of wastes (i.e. landfills, surface impoundments, etc.), land treatment utilizes the physical, chemical, and biological capabilities of the soil to adsorb, absorb, and decompose waste constituents. The primary objectives of land treatment design and management are to prevent the migration of waste constituents, to maximize the rate of biodegradation, to provide an environmentally sound fate for the waste, and to maintain the land's potential for future use.

Land treatment of organic, biodegradable industrial solid wastes is an environmentally sound waste management practice, if designed to minimize environmental impacts that could arise from the operation.

The rate that the soil-biological system can assimilate waste materials varies considerably. Successful operations require careful planning and management. This guideline is not intended to provide final site selection and design criteria, rather it is prepared as a design and management tool.

Hazardous waste land treatment facilities are subject to many additional requirements which are not addressed in this guideline (see Section 7). In addition, any placement of hazardous waste in a land treatment unit is considered land disposal under both state and federal regulations. Most hazardous wastes must be treated before they may be land disposed, and some hazardous wastes are prohibited from land disposal, unless the facility is specifically excluded by EPA from land disposal restrictions.

2. Wastes Not Suitable for Land Treatment

Land treatment generally is **not** recommended for:

2.1 Ignitable or reactive wastes (unless the resulting soil-waste mixture is non-ignitable or non-reactive);

2.2 Wastes containing radionuclides above natural background levels;

2.3 Wastes which are highly toxic and persistent in the soil (certain pesticides, polychlorinated biphenyls, and other highly toxic materials);

2.4 Wastes which readily leach from the soil; and

2.5 Highly volatile wastes which could result in a degradation of air quality.

3. Site Evaluation

Soil characteristics, climatic conditions, topography, surrounding land use, and hydrologic conditions are the principal factors which should be evaluated before a site is selected for the land application of wastes. Texas Commission on Environmental Quality (TCEQ) Technical Guideline No. 2, "Industrial Solid Waste Landfill Site Selection" should be consulted for additional site selection criteria, appropriate for all disposal sites. Some optimal site characteristics for land treatment units are listed below:

3.1 Land treatment units should be located on medium or fine textured soil with a natural or amended soil pH between 6.5 and 8.5. The soil should be at least 3 feet (1 m) deep with neither excessive nor very poor drainage. Suitable soil may be imported if existing soil is too thin. Up to 5 feet of suitable soil may be considered as the treatment zone, extending no more than 5 feet from the original soil surface. The thickness of the treatment zone may be variable across a unit, including only soil which supports effective waste treatment.

3.2 The depth from the bottom of the treatment zone to the seasonal high water table should be greater than 3 feet (1 m). A relatively impermeable layer (i.e., clay beds, shale, etc.) of at least 3 feet (1 m) thickness should retard contaminant migration in case of unexpected release from the overlying treatment zone.

3.3 The slope should be between 1% and 5% in order to minimize soil erosion and to allow surface drainage to occur.

3.4 Units should not be located in environmentally sensitive areas such as critical habitats of endangered species, wetlands, or recharge zones of sole-source aquifers.

3.5 Any land treatment unit located within the 100-year floodplain, should be protected by constructed dikes or levies of sufficient height and strength to prevent washout of waste materials by floodwater. .

3.6 Land treatment units should be isolated from the public. The separation distance is dependent upon site and waste characteristics, but 200 feet is considered a minimal separation from residential or commercial buildings.

3.7 Land treatment units should be designed so that storm water runoff from active portions of the treatment areas is collected and controlled by natural drainage features and/or by diversion structures and, if necessary, retained and treated prior to release. If units are to be located in areas where precipitation significantly exceeds evaporation, a wastewater treatment unit or plant may be a necessary part of the facility. The run-on and run-off control systems should be inspected at least weekly and after storm events for deterioration or malfunctions.

3.8 Any land application units that will require odor control measures or contain particulate matter which may be subject to wind dispersal must be managed to control wind dispersal and should be located so the prevailing winds are directed away from population centers.

3.9 In some circumstances, specific food chain crops can be grown in or on the treatment zone of a land application unit if the owner or operator can satisfy the conditions of 40 CFR 264.276.

30 TAC Section 335.204(b) includes site evaluation requirements for hazardous waste land treatment facilities.

4. Sampling

4.1 Waste Analysis

A preliminary analysis can be made from a single sample; however, more detailed sampling usually is necessary to determine suitable waste application rates since many wastes vary considerably in composition. Representative samples of each waste should be collected and analyzed over a period of time to obtain information on the variability of waste constituents. Sampling and sample storage procedures should follow EPA approved standard methods.

Some suggested parameters for waste analysis are listed in Table 4.1. Where it is appropriate, the analytical results should be expressed on a dry weight basis, due to the variability of moisture content in the wastes.

Table 4.1 Some Suggested Parameters and Methods* for Waste Analysis

Parameter	Suggested Method of Analysis
% Solids	Drying at 105°C for 16 hours
Total Organic Carbon	Method 9060 or other appropriate technique from SW-846
Total Kjeldahl Nitrogen	Kjeldahl and Steam Distillation
Nitrate (NO_3-N)	Colorimetry, Specific Ion Electrode
Ammonia (NH_3-N)	Colorimetry, Specific Ion Electrode
Total P	Strong Acid Digestion and Colorimetry
Na, K, Ca, Mg, Li	Strong Acid Digestion and Flame Photometry or Atomic Absorption
Anionic Constituents (B, Se, Br, F, CN, Cl, I)	Ion Chromatography or other appropriate technique from SW-846
Specific Conductance	Wheatstone Bridge or Equivalent
pH	Electrode
Total Alkalinity	Titration
Total Acidity	Titration
Trace Elements (Ag, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, V, Zn)	Strong Acid Digestion and Atomic Absorption or Appropriate Technique from SW-846
Oil and Grease	Soxhlet Extraction
Specific Organic Compounds (Phenols, Alcohols, Halogenated compounds, etc.)	Appropriate Technique from SW-846
Other Suspected Toxic Compounds	Appropriate Technique from SW-846

*USEPA. Test Methods for Evaluating Solid Waste, Office of Solid Waste and Emergency Response, Washington, D.C., SW-846, September 1994.

4.2 Soils

Suggested soil analyses are listed in Table 4.2. A soil test for fertilizer requirements would also be useful. Soil sampling procedures are described in *Hazardous Waste Land Treatment* (Brown, 1983). Samples should be taken of each soil series within the treatment area. It is useful to identify the facility's location on a soil survey map, which may be obtained from the USDA Soil Conservation Service (SCS). In addition, descriptions of general soil properties may be acquired from the SCS. Section 5.2 of this guideline, "Monitoring", contains additional information on soil testing and unsaturated zone monitoring.

Table 4.2 Suggested Analyses* for Soils

Parameter	Suggested Method of Analysis
pH	1:1 Soil Water Ratio
Moisture Content	Oven drying
Lime Requirement (to reach pH 6.5)	BaCl2 and TEA Method
Cation Exchange Capacity	Ammonium Saturation Method
Electrical Conductivity	Wheatstone Bridge or Equivalent
Soil Texture	Hydrometer
Organic Matter	Walkley-Black Method
Metals	Strong Acid Digestion

*Black, C.A., (ed.), 1965. Methods of Soil Analysis, Parts 1 & 2. Agronomy No. 9. American Society of Agronomy. Madison, Wisconsin.

5. Operation and Management

5.1 Waste Application Rates

The amount of waste that is applied per unit area of land, often called the waste application rate, is the critical factor of successful land application. In order to avoid problems associated with the overloading of soils, waste application rates should be carefully determined prior to initiating operations. Waste application rates should be specified in terms of the monthly application rate and the total cumulative application capacity over the expected lifetime of the facility. In determining waste application rates, the objective is to match waste applications with the capacity of the soil-biological system to assimilate the waste. Treatability studies which include laboratory and field studies are recommended for this determination.

Most wastes are complex mixtures that vary in composition. Thus, it is necessary to determine application rates based on individual constituents of the waste rather than on bulk waste characteristics. The waste constituents most often considered are nitrogen, salts, oil and grease, toxic organics, metals, water, and anionic toxicants. The quantity of each constituent in the waste must be determined from qualitative and quantitative chemical analyses.

Once the appropriate constituents of the waste have been identified, the soil's capacity for each constituent may be quantified. The pathways for assimilation include volatilization, degradation, plant uptake, accumulation of non-degradable constituents, and leaching of mobile constituents. The pathway for each waste constituent is governed by waste characteristics, soil properties, climate, site characteristics, and ground-water conditions. Although the mechanisms are complex, the assimilative capacity of the soil for individual waste constituents may be estimated on the basis of laboratory or pilot scale studies or, if available, existing information. Optimal results are obtained by testing specific waste-soil combinations.

Certain waste constituents, primarily metals, determine the total capacity of a soil for waste treatment. These constituents determine the life expectancy of the site and are termed "capacity limiting" constituents. Other constituents, such as oil and grease or water, limit the rate of application (i.e., how much and how often wastes may be applied) and are known as "rate limiting" constituents.

Waste application rates should be calculated so that no waste constituent exceeds the soil's assimilative capacity. Generally, just a few waste constituents will limit application rates due to the constituent's abundance in the waste or because the assimilative capacity for that constituent is very low. Once the main limiting constituents are identified, attention to other constituents may be reduced.

Waste which has not fully degraded should not be buried below the level where microbes lose access to oxygen. The waste application rate should be limited so that non-degradable solids in the waste do not raise the ground surface at a rate which buries deep waste too rapidly. In some parts of Texas where annual degradation rates are relatively low, non-degradable solids should be limited to two inches per year.

The operator should maintain records of the amount and frequency of waste applications, the waste analyses, and the location of waste placement. These records combined with the results of the monitoring systems are essential for evaluating and optimizing facility performance.

5.1.1 Treatability Studies

The functions of treatability studies are to determine whether a waste is suitable for land application and if so, to determine which design features and operating conditions will maximize the degradation and immobilization of waste constituents. A comprehensive testing program would include tests designed to determine (1) waste degradation rates, (2) the accumulation of non-degradable constituents, (3) acute and chronic toxicities, (4) the mobility of waste constituents in the soil profile, (5) plant uptake, and (6) the release of volatile compounds.

The studies should be conducted with site soils and the actual wastes to be land applied and conducted under conditions similar to the site conditions, i.e., temperature and moisture. Such programs commonly involve laboratory studies followed by field studies, as verification. Field studies offer additional insight into application procedures and information regarding runoff quality.

Immediate benefits of these studies include the ability to:

1. determine the actual land area required for waste application;

2. anticipate the quality of runoff generated and its proper management;

3. select appropriate equipment; and

4. avoid an initial "overloading" of the site.

Long-term benefits include anticipation of site closure requirements and minimization of ground-water or surface-water impacts. The TNRCC recommends that treatability studies be conducted on all Class I and Class II wastes to be land treated, unless adequate data is available from literature or from operating records.

5.1.2 Nitrogen

Raising harvestable crops may be necessary when treating wastes containing large amounts of nitrogen, in order to control leaching of nitrates and to prevent an accumulation of excess nitrogen in the soil. The annual waste application rate may provide slightly more nitrogen (NO_3 + NH_4 + Organic N) than the amount which will be utilized by the vegetative cover or harvestable crops. If wastes containing substantial amounts of nitrogen are surface applied, nitrogen may be added at a rate up to twice the crop's nitrogen requirement because of nitrogen losses through volatilization and denitrification. Waste materials treated on sites without vegetation should be limited to nitrogen additions of 125 lbs/ac/yr (140 kg/ha/yr) when nitrate leaching is a threat to ground-water resources.

5.1.3 Metals

In land treatment, some of the primary metals of concern are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn). These elements deserve special consideration because of their toxicity and their relative abundance in wastes. Numerous toxic elements such as mercury and molybdenum, are not discussed in this guideline because they are usually present in wastes in rather low amounts. However, no toxic element should be overlooked when determining waste application rates, as it may limit the amount of waste that can be safely applied to the site.

Under proper management, normal soils are capable of attenuating relatively large amounts of metals. Nevertheless, efforts should be made to limit the amount of metals entering waste streams destined for land application. The total amount of waste that may be applied is often limited by the waste's metal content because these elements are strongly bound by soil and remain there indefinitely.

The recommended maximum cumulative metal loadings for soils tabulated in Table 5.2, are based upon current U.S. EPA regulations and recommendations. These values take into consideration soil attenuation and leaching, as well as plant or animal toxicity. These recommendations, except as noted, apply only to soils with a natural or amended pH of 6.5 or greater and a cation exchange capacity greater than 5 meq/100 g. These loading rates are applicable for situations where the materials will be left in place and provided with a vegetative cover. Provided the metals remain immobilized, higher loading limits may be appropriate for other closure alternatives.

5.1.4 Soluble Salts

Salts will accumulate in soils if wastes containing substantial amounts of soluble salts are applied. The problems most commonly encountered are excessive total salts and high sodium levels. Both of these conditions can significantly lower the effectiveness of land application and may require remedial action. The basic principles of managing salinity on agricultural lands are well established and directly apply to managing soil salinity in a treatment situation. Generally, application rates should be designed to prevent an increase in specific conductivity of more than 4 mmhos/cm.

Table 5.2 Recommended Total Accumulation Limits for Metals

(adapted from U.S. EPA 1994 and Brown 1983)

Element	Acceptable Concentration in Soil (ppm)	Metal Accumulation in Surface 6 in. (15 cm) in lbs/ac (kg/ha)	Metal Accumulation in Surface 12 in. (30 cm) in lbs/ac (kg/ha)
As	500	980 (1100)	1964 (2200)
Cr	1000	1960 (2200)1	4020
Cu	250	500 (560)	980 (1100)
Ni	100	195 (220)	400 (450)
Pb	1000	1960 (2200)	4020 (4500)
Zn	500	980 (1100)	1960 (2200)

Element	Soil C.E.C.** (meq/100g)	Maximum Cumulative Application in lbs/ac (kg/ha) Background Soil pH <6.5	Background Soil pH >6.5
Cd	< 5	4.5 (5)	4.5 (5)
	5-15	4.5 (5)	8.9 (10)
	> 15	4.5 (5)	17.8 (20)

** Cation Exchange Capacity

* Annual addition of cadmium should be limited to 0.45 lb/ac (0.5 kg/ha). Specific regulations governing cadmium application rates are contained in Title 40 Code of Federal Regulations, Part 257.

5.1.5 Oil Grease, and Degradable Organic Materials

The soil-biological system provides an excellent medium for the biodegradation of oil, grease, and other degradable organic materials. When organic wastes are applied to the soil, populations of microbes utilize the waste as a substrate. Volatile fractions of the organic material may be lost to the atmosphere while the remaining fractions are subject to microbial degradation, leaching, plant uptake, or various chemical reactions. Certain constituents of organic materials may be resistant to degradation and remain relatively stable.

The rate at which organic materials are degraded and removed from the system is a function of temperature, moisture, the concentration of the waste in the soil, soil fertility, the rate that oxygen enters the soil, biological activity, photo degradation, and volatilization. In Texas, typical degradation rates for oil range from 0.2% to 0.6% of the soil weight per month. The rate may be increased with proper management, optimum climatic conditions, and the addition of supplemental nutrients. Degradation rates for oil and grease will generally increase with the amount of oil and grease in the soil up to about 7% of the soil weight, when nutrients are not a limiting factor. To maintain aerobic decomposition, the soil should be frequently cultivated and hydraulic loading carefully managed. Excessive applications of oil and grease to soils may prevent infiltration of air and water into the soil, decrease the rate of degradation, cause noxious odors, contaminate surface runoff or damage vegetation. Application rates for oil and grease should be based on the degradation and loss rate from the soil, the sensitivity of affected vegetation, and a consideration of soil properties.

The carbon to nitrogen ratio (C:N) of the waste may be useful for predicting the rate at which organic materials will degrade in the soil. A high nitrogen content (small C:N ratio) may result in nitrate leaching. A low nitrogen content (large C:N ratio) is usually associated with slow degradation because the lack of nitrogen will restrict microbial activity. Carbon to nitrogen ratios ranging from 10:1 to 50:1 are considered optimal for degradation. Organic materials containing less than 1.5% nitrogen (C:N > 66:1) may require supplemental nitrogen in the form of fertilizer to promote degradation. Fertilizer requirements from soil tests may be valuable for determining the amount of nitrogen and other nutrients which may need to be supplemented to enhance degradation.

5.1.6 Toxic Organic Compounds

Wastes may contain specific organic compounds which cause temporary or permanent damage when introduced into the environment. When land treatment is considered for wastes which contain toxic organics, special care must be taken in order to apply the waste at rates that will not threaten public health or the environment.

When an organic compound enters the soil system, it may be subject to volatilization, biological degradation, various chemical reactions, plant uptake, or leaching, depending upon the type of compound and environmental conditions. All of these factors must be considered when determining acceptable waste application rates for toxic organics. At this time, there is no general guideline for designing optimal application rates for specific organic compounds because of the complex mechanisms and pathways involved. Application rates should be based on a compound's degradation and loss rate from the soil, its mobility in the soil, and the toxicity of the compound. This information is usually gathered from laboratory tests, greenhouse tests, or pilot scale tests, and supplemented by information obtained from scientific literature.

Non-persistent organic compounds such as solvents, aldehydes and glycols, may temporarily sterilize the soil and damage vegetation when applied in excessive quantities. Special attention must be paid to the mobility of these compounds, especially those with low molecular weight, since they can migrate rapidly through soil and contaminate ground water.

The relatively persistent and non-volatile compounds such as phenols, biphenyls, and halogenated hydrocarbons can accumulate and suppress the capacity of the soil-biological system to assimilate wastes, and may cause permanent environmental damage. Attention should be paid to the toxicity and plant uptake of such compounds. Application rates for all organics should not exceed the capacity of the soil to provide an environmentally safe fate for the compounds under consideration.

5.1.7 Water (Hydraulic Loading)

Applications of aqueous waste or wastewater should be controlled and scheduled so that uncontrolled runoff or prolonged saturation of the soil does not occur. Excessive hydraulic loading may damage vegetation, limit access of disposal site traffic, restrict diffusion of oxygen into the soil, cause odors, and provide a driving force for contaminant migration.

The amount of water that can be assimilated by the soil system is dependent upon climate, vegetation, site characteristics, and soil properties. A mass balance equation, such as shown below, is useful for describing gains and losses of water from the system.

$$W + P - R = S + D + ET$$

where:

P = precipitation in inches (cm)
W = added water in inches (cm)
R = runoff in inches (cm)
S = storage in inches (cm)
D = internal drainage in inches (cm)
ET = evapotranspiration in inches (cm)

The equation may be used to estimate the amount of additional water that can be assimilated by substituting potential evapotranspiration (PET) for actual evapotranspiration (ET) and solving for W.

$$W = S + D + PET + R - P$$

When these equations are used, the runoff term (R) and the storage term (S) are usually neglected because runoff and storage are difficult to quantify and surface runoff at a landfarm often is minimized.

When determining waste application rates, the water balance should be performed on a weekly or monthly average basis due to seasonal variations in precipitation and evapotranspiration.

5.1.8 Toxic Anions

Wastes may contain several toxic constituents that exist as anions in the soil. These are primarily boron, bromide, cyanide, iodide, fluoride, and selenium. The soil mechanisms that attenuate anions are weak, thus anions tend to be relatively mobile in the soil. These anions are also toxic to plants and animals. Boron, cyanide, iodide, and selenium are toxic at levels of a few parts per million. Therefore, waste application rates must be carefully designed to avoid leaching these constituents to ground water.

5.2 Monitoring

Land treatment facilities should be monitored in order to detect the migration of contaminants and to assess the environmental impacts associated with land application of wastes. Furthermore, monitoring yields valuable information about the performance of the facility. A minimal monitoring program should include quarterly or semi-annual sampling and analysis of soil, soil-pore water, and ground water. Sampling lysimeters placed immediately beneath the treatment zone serve both to demonstrate that waste and leachate are being degraded and to provide warning before ground water is affected if the land treatment unit is not functioning adequately. A system for record keeping should supplement a monitoring program in order to keep track of waste applications and waste analyses.

Samples of the waste routinely should be analyzed for the constituents which have been determined to limit waste application. The waste should be sampled at least annually or whenever waste characteristics change. The waste should be analyzed for parameters such as those listed in Table 4.1. If waste characteristics change, waste application rates may require modification.

TCEQ Technical Guideline No. 6, "Ground Water Monitoring" should be consulted for general information concerning ground-water and unsaturated zone monitoring at land application sites. The first samples collected for establishing background conditions should be analyzed quantitatively for all constituents of concern in the waste. Subsequent routine samples should be analyzed for general indicators, such as pH, TOC, TDS, and chlorides, in addition to the primary application rate limiting constituents.

Periodic soil monitoring should be used to measure the accumulation, vertical migration, and degradation of waste constituents. Soil cores should be collected to a depth below the treatment zone. The sample portion from below the treatment zone should be analyzed separately in order to determine whether migration of waste constituents beneath the treatment zone has occurred. Soil sample locations should be chosen on a random basis. The number of background samples obtained should be sufficient to ensure that the Type I and Type II error rates characterizing the subsequent statistical analysis are appropriate and protective of human health and the environment. The samples collected for establishing background conditions should be analyzed for all of the limiting constituents in the waste. Routine soil samples should be analyzed for the rate limiting and capacity limiting constituents.

5.3 Runoff and Surface-Water Protection

Land application facilities should be designed and operated to prevent uncontrolled surface run-off of waste materials. This may be achieved by proper scheduling of waste applications, by not making excessive applications, by incorporating waste into the soil, and by halting waste applications during saturated or near-saturated conditions.

Stormwater run-off from land application facilities, if not properly managed, may contaminate surface water resources. The volume of contaminated stormwater runoff can be minimized by controlling soil erosion, by preventing run-on from surrounding areas, constructing run-off collection and containment systems and by using vegetated buffer zones.

All runoff from active portions of a land treatment facility should be contained, unless the operator of the facility can demonstrate that the run-off is of acceptable quality. Land treatment facilities should be designed to contain at least all storm water run-off resulting from a 100-year, 24-hour rainfall event. Impounded stormwater runoff may be suitable for irrigation of the land treatment area, but must not be discharged without appropriate state and/or federal authorization. Contaminated storm water from the treatment area may require treatment before discharge.

5.4 Crops

In some operations, harvestable plants may be used to assimilate nitrogen and to recover other plant nutrients which may be present in the waste. Vegetation may benefit the treatment process through improved soil structure, increased soil aeration, increased infiltration rates, reduced runoff and soil erosion, and by providing added stability for disposal site traffic.

Growing edible crops on land treatment areas that have received toxic wastes generally is not recommended because of possible hazards to public health. Prior to harvest and utilization, food chain crops should be subjected to detailed analyses to determine their suitability for consumption by animals. Analyses are necessary because crops may be physically contaminated with waste, and excessive plant uptake of metals or toxic organics may occur.

5.5 Management Methods

Operators should be able to demonstrate their ability to properly manage the disposal area, including safe handling of waste materials and proper management of soils, vegetation, and monitoring programs.

Operations can be limited by severe weather conditions. Waste applications to frozen or saturated soils generally are not recommended. If wastes cannot be applied continuously, it may be necessary to provide on-site storage facilities for the waste. Storage facilities may serve to buffer the waste generation process, equalize waste concentrations, lower the cost of shut-down and start-up procedures, and provide an alternative when waste applications are restricted.

Soil moisture should be kept between the wilting point (about 15 bars moisture tension) and field capacity (1/3 bar moisture tension) of the soil. Especially in arid areas, water may need to be added. If soil gets too wet or too dry, the rate of waste degradation will drop, and microbe populations will take some time to recover, even after proper moisture is restored. Dry soils containing oily wastes may be difficult to rewet.

There are many systems available for applying wastes to the land surface. Selection of the most effective system should be based on waste characteristics, site characteristics, and the relative benefits of each system. One of the prime considerations in selecting an application system is ensuring the uniformity of waste application rate and distribution. Surface application methods may include sprinkler irrigation, flood irrigation, furrow irrigation, and surface spreading from various hauling vehicles. Waste solids may be applied from spreading vehicles, such as a conventional manure spreader. Discing or plowing soon after waste application is effective in controlling odors, minimizing the contamination of runoff, and promoting rapid degradation of organic wastes.

Some successful land treatment units have included liners and leachate collection systems below the treatment zone.

6. Final Closure

Land treatment units should begin closure when the unit is no longer being used or the cumulative application limits are reached. In the first phase of closure, although no new waste is applied, tilling, addition of fertilizer, maintenance of moisture levels, run-on control, run-off control and other management methods which promote waste degradation should continue until the waste in the unit has been substantially degraded. The required degree of degradation will depend on the final closure plans. The owner/operator of the unit should take all necessary actions to ensure that the closed land treatment unit does not endanger public health or the environment and that no threat to ground or surface waters exists. Specific procedures will vary depending on site characteristics, management methods, and waste characteristics. However, several general procedures are applicable to final closure of land treatment units.

1) Soil, vegetation, and ground-water samples should be collected and analyzed for contaminants. The results of these analyses should be interpreted to determine what corrective actions, if any, are necessary.

2) The soil should be treated as necessary to maintain a soil pH greater than

6.5.

3) Soil conservation measures, such as a vegetative cover, should be established.

4) All soil that will not support vegetation or otherwise cannot safely be left in place should be removed and disposed of properly.

5) Storm water control structures should not be removed until the quality of runoff from the site meets acceptable limits for non-permitted discharges.

6) A permanent record of disposal activities should be entered in the county deed records.

7. Regulatory Requirements in Texas

The Texas Commission on Environmental Quality (TCEQ) is the agency responsible for the regulation of industrial solid waste in Texas. The agency's authority is based upon the Texas Solid Waste Disposal Act (Health and Safety Code, Chapter 361). The TCEQ has assembled a set of technical guidelines to promote the proper management of industrial solid wastes. Although these documents contain basic recommendations, they should be considered as guidance, and not as regulations or requirements. Many industrial solid wastes; e.g., hazardous wastes, have specific regulatory requirements governing their management. Specific requirements for industrial hazardous waste land treatment units can be found at 30 Texas Administrative Code (TAC) Chapter 335, Subchapter F.

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