TD367
.R37
1982y
Vol.3

c.2

000D82003

DRAFT

c.2

RCRA GUIDANCE DOCUMENT

LAND TREATMENT

RECEIVED
ENVIRONMENTAL PROTECTION AGENCY
LIBRARY, REGION V

[to be used with Subpart M, Part 264
of the RCRA Regulations]

U.S. Environmental Protection Agency
Region 5, Library (PL-12J)
77 West Jackson Boulevard, 12th Floor
Chicago, IL 60604-3590

TABLE OF CONTENTS

Page

A. Purpose and Use 1

B. "Treatment" Demonstration [§264.272].....3

1. The Regulations

2. Guidance

3. Discussion

C. Design and Operating Requirements [§264.273].....9

I. Maximization of Treatment.....9

1. The Regulations

2. Guidance

3. Discussion

II. Minimization of Run-off.....18

1. The Regulations

2. Guidance

3. Discussion

III. Management of Collected Run-on/Run-off.....23

1. The Regulations

2. Guidance

3. Discussion

IV. Wind Dispersal Control.....27

1. The Regulations

2. Guidance

3. Discussion

U.S. Environmental Protection Agency

Page

D. Unsaturated Zone Monitoring [§264.278].....32

I. Selection of "Principal Hazardous Constituents".....32

1. The Regulations

2. Guidance

3. Discussion

II. Monitoring Procedure.....35

1. The Regulations

2. Guidance

3. Discussion

III. Evaluation and Response.....48

1. The Regulations

2. Guidance

3. Discussion

E. Closure and Post-Closure Care [§264.280].....51

1. The Regulations

2. Guidance

3. Discussion

References.....60

Appendix I

A. Purpose and Use

Under the authority of Subtitle C of the Resource Conservation and Recovery Act (RCRA), EPA has promulgated interim-final regulations for the treatment and disposal of hazardous waste in land treatment units (40 CFR Part 264). This guidance document presents land treatment unit design and operating specifications which the Agency believes comply with the Treatment-Demonstration Requirements (§264.272), the Design and Operating Requirements (§264.273), the Unsaturated Zone Monitoring Requirements (§264.278) and the Closure and Post-Closure Requirements (§264.280) contained in these regulations.

Section 264.272 requires the owner or operator to demonstrate that hazardous constituents in the applied wastes can be completely degraded, transformed, or immobilized in the treatment zone. The data used for the treatment demonstration must be generated under conditions similar to those present in the treatment zone of the facility.

Section 264.273 provides the design and many of the operating requirements necessary at land treatment units. It focuses particularly on requirements which are designed to maximize treatment of hazardous constituents within the treatment zone and minimize the escape of these constituents to ground water, surface water, and air. Section 264.278 contains the unsaturated zone monitoring requirements which are aimed at evaluating the performance of the unit, while Section 264.280 delineates the closure and post-closure care provisions.

The requirements in all of the Sections mentioned above consist of performance-oriented statements and rules, and, as a result, are also general in nature. This provides maximum flexibility to the owner or operator in locating, designing, operating, and closing his unity. However, while this approach provides flexibility, it lacks certainty because the permitting official must render a value judgment on the acceptability of the particular design, operation, and closure specifications proposed for each given unit. As a result, there will be considerable negotiation during permitting when this approach is used.

To provide additional certainty to this permitting process, this document identifies specific designs and operational procedures which the Agency believes accomplish the performance requirements in Sections 264.272, 264.273, 264.278, and 264.280. Permit applicants who design, construct, operate, and close their units in accordance with the specifications contained herein will be considered in compliance with these Sections.

The Agency wishes to emphasize that the specifications in this document are guidance, not regulations. EPA is not requiring, and does not intend, that all land treatment units be designed and operated in this way. On the contrary, the Agency believes there are other designs and operating procedures which may be acceptably used, depending on unit-specific factors. Detailed discussions of various land treatment design and operational approaches, including those recommended in this document, are provided in the EPA technical resource document

entitled Hazardous Waste Land Treatment (1). Owners or operators who wish to utilize a very different design or operation than those recommended herein may do so by providing sufficient data to the permitting official which demonstrates compliance with the various performance requirements.

This document is arranged according to the section of the regulation to which it corresponds. EPA is particularly interested in information and suggestions concerning the usefulness of this document, expansion of it, and the effectiveness of the guidance in ensuring compliance with the performance requirements in the regulations. Those wishing to send technical information or suggestions concerning this document should address them to: Rod Jenkins, Chief, Land Disposal Branch, Office of Solid Waste (WH-565E), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460.

B. "Treatment" Demonstration [§264.272]

1. The Regulations

Section 264.272 states that the owner or operator must demonstrate with literature, experimental and/or operating data, that hazardous constituents in the applied wastes can be completely degraded, transformed, or immobilized in the treatment zone of the unit. The demnstration must be based on conditions similar to those in the treatment zone. "Treatment zone" is defined as the portion of the unsaturated zone below and including the land surface in which the owner or operator intends to maintain the conditions necessary for effective degradation, transformation,

immobilization. [The dimensions of this zone will be specified in the permit. Section 264.271 specifies that the maximum depth of the treatment zone must be (a) no more than 1.5 meters (5 feet) from the initial soil surface, and (b) more than one meter (3 feet) above the seasonal high water table.]

2. Guidance

a. Comprehensive waste analysis data should be used to identify hazardous constituents present in the waste in significant concentrations.

b. A thorough literature search should be conducted on each hazardous constituent present in the waste. Available information on (and factors affecting) the degradation, transformation, immobilization, and toxicity of each hazardous constituent, under conditions similar to those present in the treatment zone of the facility, should be gathered.

c. If sufficient data to support the demonstration of treatment is unavailable in the literature, the owner or operator should conduct laboratory studies to examine the fate and effects of hazardous constituents in the soil system and to determine the impacts of various environmental factors or treatment processes. Laboratory studies should include, at a minimum, studies addressing degradation, transformation, mobility, and toxicity of hazardous constituents. The environmental factors that should be examined include at least soil pH, temperature, and moisture.

d. Field pilot studies should be conducted to verify certain laboratory results, discover any unforeseen potential environmental

problems, and investigate interactions which cannot be adequately assessed in the laboratory.

e. The owner or operators of existing (interim status) units should consider the use of actual monitoring data, in lieu of laboratory and field studies, to make the treatment demonstration. Such monitoring data should include results from comprehensive soil core (including treatment zone) soil pore-liquid, ground water, run-off, and air monitoring generated over an extended period (i.e., several years) of unit operation. This data should clearly demonstrate treatment with no unacceptable release of hazardous constituents or hazardous degradation products from the treatment zone.

f. All data used directly to support the treatment demonstration should be generated under conditions which simulate at least the following characteristics of the unit:

(i) characteristics of the land-treated waste;

(ii) characteristics of the treatment zone including the soil texture, pH, cation exchange capacity, organic matter content, moisture content, and depth of soil to the seasonal high water table;

(iii) topography of the treatment zone including slope;

(iv) climate of the area including temperature, precipitation, evaporation, and wind patterns; and

(v) operating practices including waste application method and rate, tilling depth and frequency, and soil conditioning practices (e.g., pH adjustment, fertilization, etc.).

3. Discussion

The treatment demonstration required under §264.272 can be accomplished using information derived from published literature, laboratory studies, field studies and/or actual land treatment unit operation experience (i.e., monitoring results). Successful demonstrations will most often involve data obtained from several of the above sources.

A literature search on each hazardous constituent in the particular waste in question should first be conducted. Information in the published literature may assist in the design of laboratory or field experiments, or significantly reduce or eliminate the need for additional experimentation. However, to completely eliminate the need for additional testing, comprehensive literature data on the degradation, transformation, mobility, and toxicity of hazardous constituents under conditions similar to the treatment zone must be clearly documented. Such literature data must also have been subjected to a thorough peer review. However, the Agency believes that for most land treated hazardous wastes, an inadequate data base is available in the literature to conclusively predict the fate of particular hazardous constituents under particular site-specific conditions.

Therefore, a combination of laboratory and field studies often will be necessary to provide the required treatability data. Laboratory studies may be used as rapid screening techniques for examining, within a reasonable time frame, the treatment of hazardous constituents in a soil system, and the effects of

various environmental factors on this treatment. These studies should include tests directly addressing the degradation, transformation, and mobility of the hazardous constituents in the waste. The Agency suggests the use of soil respirometry tests and/or organic constituent analysis and characterization studies conducted over time to examine hazardous constituent degradation and transformation. Soil thin-layer chromatography tests or column leaching studies (using undisturbed soils collected from the field) may be used to examine constituent mobility. Discussion of the advantages and disadvantages of each of these tests, and specific procedures for completing them are provided in Hazardous Waste Land Treatment (1).

In addition, laboratory studies (and field studies) should evaluate the potential toxicity of hazardous constituents in the waste to microbes and plants. Prevention of microbial toxicity is important to ensure successful biodegradation of degradable waste constituents, while phytotoxicity must be limited in order that an effective vegetative cover may be established. Suggested procedures for completing these studies are also provided by EPA's technical resource document on land treatment (1).

While laboratory tests provide valuable data, the extrapolation of this data to field conditions is often difficult because of the complex interactions that occur in the field. Therefore, the Agency believes that field studies usually will be necessary to verify certain lab-generated results. The extent of verification required will depend on a number of factors

including the variability in the laboratory test results, and specific waste and land treatment unit characteristics. The Regional Administrator will determine the extent of field verification necessary.

Field pilot studies should be kept as small as possible. Generally, plots should be no greater than 500 m^2, unless specialized equipment requires additional room for waste application or incorporation. In general, waste application rates and treatment zone conditions (e.g., pH maintenance) must be selected based on the best available information obtained from the literature, laboratory studies, and previous experience.

It may be possible to demonstrate the treatment of hazardous constituents in a particular waste based solely on previous land treatment unit monitoring data. This monitoring data, however, must be comprehensive and clearly demonstrate degradation or transformation of hazardous organic constituents within the treatment zone and no unacceptable migration of any hazardous constituents to below the treatment zone.

Finally, any data, regardless of the source, which is used to support the demonstration of treatment must be generated under conditions similar to those present in the land treatment unit. Specific unit characteristics the owner or operator should consider are outlined in the guidance section above. The Regional Administrator may require the owner or operator to consider additional characteristics which may be very important at a specific unit. With regard to treatment zone characteristics,

the Agency believes that the series classification will usually adequately define the necessary similarities of soils; the soil phase should also be considered in evaluating similarities in surface soils.

C. Design and Operating Requirements [§264.273]

I. Maximization of Treatment [§264.273(a)]

1. The Regulations

The performance standard delineated in §264.273(a) requires owners and operators to design, construct, operate, and maintain the land treatment unit such that the treatment of hazardous constituents by degradation, transformation, or immobilization, is maximized within the treatment zone.

2. Guidance

a) A land treatment unit should be located, designed, and constructed so that the treatment zone contains soils having one or more of the following textures (USDA Classification): loam, silt loam, sandy clay loam, sandy loam, silty clay loam, or clay loam.

b) A land treatment unit should be designed and located so that the treatment zone does not contain karst formations or irregular terrain such as fissures, faults or bedrock outcrops.

c) The owner or operator should carefully determine the proper waste application rate based on data on the properties of the land treated waste and on the characteristics of the treatment zone. The selected waste application rate must not exceed the capacity of the treatment zone to degrade, transform, or immobilize hazardous constituents.

d) The pH of all portions of the treatment zone should be maintained at greater than or equal to 6.0 and less than or equal to 8.0.

e) Measures that affect microbial and chemical reactions (e.g., fertilization, tilling, moisture control) should be carefully evaluated and optimized to enhance the effectiveness of treatment processes.

f) All design and operating recommendations specified in other sections of this document should be followed.

3. Discussion

To meet the performance standard of Section 264.273(a), each owner or operator should (a) properly locate, design, and construct the land treatment unit such that the treatment zone contains soils suitable for land treatment, and (b) then operate the unit so that treatment occurs within the defined (in the facility permit) boundaries of this zone.

Particular attention should be directed toward ensuring that the treatment medium is adequate for the degradation, transformation, or immobilization of the hazardous constituents of the waste. The Agency recognizes that different soil characteristics and depths will be acceptable under different unit-specific conditions. Several general recommendations relating to soil type, however, can be derived from experiences with currently successful land treatment operations.

Each particular type of soil has certain advantages and disadvantages with regard to use in a land treatment system.

Coarse textured soils (e.g., sand) will remain aerated while fine soils (e.g., clay) may often become reduced due to wetness. The aeration state of the soil will play an important role in determining how quickly, by what pathway, and in what form various waste constituents will be degraded. In general, most waste constituents are more rapidly degraded under aerobic conditions. While the aeration conditions of fine textured soils may be less desirable, the generally higher sorptive capacity of these soils may be very effective in immobilizing various ions. The advantages and disadvantages of various soil textures, as defined in the 1975 USDA soil classification system (2), are given in Table 1. A more detailed discussion of each of the parameters in the table is contained in Hazardous Waste Land Treatment (1). In general, hazardous waste land treatment units should not be established on extremely deep sandy soils having hydraulic connection to underlying aquifers, due to the great potential for hazardous constituents leaching to ground water. Similarly, silty soils which have a severe problem with crusting should not be selected due to the extreme potential for erosive transport of hazardous constituents. Loam, silt loam, sandy clay loam, sandy loam, silty clay loam, and clay loam soils generally provide the most suitable medium for land treatment of hazardous wastes. However, in all cases, soils having these textures will have to be properly managed (e.g., maintenance of pH and fertility) to maintain their treatment capabilities.

TABLE 1 SUITABILITY OF VARIOUS SOIL TEXTURES FOR LAND TREATMENT OF HAZARDOUS INDUSTRIAL WASTES

Texture	Advantages	Disadvantages
sand	very rapid infiltration usually oxidized and dry low run-off potential	very low CEC very high hydraulic conductivity rate low available water little soil structure
loamy sand	high infiltration low to medium run-off	low CEC moderate to high hydraulic conductivity rate low to medium available water
loam	moderate infiltration fair oxidation moderate run-off potential generally accessible good CEC	fair structure
silt loam	moderate infiltration fair oxidation moderate run-off potential generally accessible good CEC	some crusting
silt	low infiltration fair to poor oxidation good CEC good available water	high crusting potential poor structure high run-off
silty clay loam	medium-low percolation fair structure high CEC	moderate run-off often wet fair oxidation
clay loam	medium-low percolation good structure med-poor aeration high CEC high available water	med-low infiltration med-high run-off often wet

TABLE 1 (con't)

Texture	Advantages	Disadvantages
clay	low percolation high CEC high available water	low infiltration often massive structu high run-off sometimes low aeratio
sandy clay	med-low percolation med-high CEC	fair structure moderate-high run-off
sandy clay loam	med-high available water good aeration	medium infiltration

From: K.W. Brown and Assoc., Inc. Hazardous Waste Land Treatment, U.S.EPA publication SW-874, Contract No. 68-03-2940, September, 1980 (1).

In addition, special consideration in siting and designing a land treatment unit should be given to avoiding karst formations and broken or irregular terrain, such as bedrock outcrops, fissures, and faults. Such formations often provide direct passages to ground water.

Successful operation of a land treatment unit in compliance with the §264.273(a) performance standard also depends upon properly designing, operating, and constructing the unit such that the treatment zone provides sufficient soil depth for treatment of hazardous constituents sufficiently above the seasonal high water table in order to minimize environmental impacts and optimize treatment processes. As mentioned earlier in this document, Section 264.271 of the regulations specifies that the boundaries of the unit's treatment zone will be defined in the facility permit. Treatment of hazardous constituents within these defined treatment zone boundaries (i.e., the vertical and horizontal dimensions) will then be the required goal of that unit. Section 264.271 requires that the maximum depth of the treatment zone must be 1.5 meters from the initial soil surface, or 1 meter above the seasonal high water table, whichever depth is less. The Agency believes this maximum limit provides adequate soil medium for acceptable treatment. The second part of this requirement ensures a minimum buffer between the bottom of the treatment zone and the seasonal high water table. Additional rationale for this standard is provided in the preamble to the regulation.

Many operational controls are also very important in ensuring maximization of treatment within the treatment zone. Waste application rate is one of the most important factors determining the success of a land treatment unit. Overloading the system can result in significant environmental impacts resulting from hazardous constituent volatilization, run-off, or leaching to ground water. The waste application rate should be carefully determined so that the capacity of the soil to degrade, transform, or immobilize hazardous constituents is not exceeded. In determining the proper application rate, the owner or operator should consider the characteristics of the waste and of the unit, particularly soil properties, hydrogeology, climate and type of vegetative cover, if any. Generally, one or only a few waste constituents will limit application rates because of the constituent's concentratic in the waste, or because the soil's assimilative capacity for the constituent is very low. Further discussion on determining the application rate limiting constituents is provided in the EPA technical resource document entitled Hazardous Waste Land Treatment (1).

Furthermore, because land treated wastes are often complex mixtures of both inorganic and organic hazardous constituents, the owner or operator should determine the application rate so that adequate consideration is given not only to degradation and transformation processes, but also to immobilization processes. For instance, the application rate must not inhibit the physical, chemical, and biological processes essential to the degradation

of organic constituents. In addition, to attain treatment of inorganics and persistent organics, the application rate must not exceed the capacity of the treatment zone to immobilize these constituents. In assessing the treatment zone's immobilization capacity, particular attention should be given to the cation exchange capacity, pH, and organic matter content of the soil. Laboratory and pilot scale studies, as well as existing information in the literature, which reflect the conditions present in the land treatment unit should be used in determining the assimilative (degradation, transformation, and immobilization) capacity of the treatment zone. Some of this information should have been generated in the treatment demonstration explained in Section B of this document. Additional information on specific waste constituents can be found in the literature (1, 3).

Maintenance of a soil pH in the treatment zone in the range of 6-8 generally provides optimum soil pH conditions for degradation, transformation, and immobilization processes. Data has shown that the optimum soil pH for microorganisms lies in the range of 6-8 (4,5,6); hence, waste biodegradation is greatest in this pH range. In addition, most heavy metals are much less mobile in soil and less available to plants at pH levels greater than 6.0 (7,8,9). At pH levels greater than 8.0, however, the mobility of certain metals increases, and the availability of certain plant and microbial nutrients (e.g., phosphorus, iron) decreases (4). This condition leads to leaching hazards and less than optimum biological treatment of wastes. Maintenance

of a neutral soil pH is a widely recommended practice for hazardous and nonhazardous waste land treatment (6,10,11,12).

While the Agency generally recommends a soil pH in the range of 6-8, it recognizes that there are a few exceptions to this general rule. For instance, there are a limited number of hazardous constituents (e.g., selenium) which are more available to plants in neutral pH soils than in acid soils. Each owner or operator should evaluate data on the mobility of the hazardous constituents of the waste under various soil pH regimes prior to land treating the waste.

In an effort to maximize treatment, the owner and operator should also carefully manage any other additional operational measures, such as method of waste application, fertilization, tilling method and frequency, and moisture control, which influence the effectiveness of treatment processes.

Finally, to ensure compliance with the Section 264.273(a) performance standard, the owner or operator should follow the additional guidance related to unit design, construction, operation, and closure provided in other sections of this document. Important sections include those pertaining to design and operating conditions for minimizing run-off, wind dispersal control, unsaturated zone monitoring, and closure and post-closure care procedures. Run-on and run-off management systems must also be developed and implemented, as required in Sections 264.273(c) and 264.273(d) of the regulations, respectively.

II. Minimization of Run-off [§264.273(b)]

1. The Regulations

Section 264.273(b) requires the owner or operator to design, construct, operate, and maintain the treatment zone to minimize run-off of hazardous constituents during the active life of the land treatment unit. [The regulations also contain requirements pertaining to the control of run-off and run-on. Section 264.273(c) specifies that the owner or operator must design, construct, operate and maintain a run-on control system to control flow onto or into the treatment zone during peak discharge from at least a 25-year storm. Under Section 264.273(d) the owner or operator must design, construct, operate and maintain a run-off management system to collect and control at least the water volume resulting from a 24-hour, 25-year storm. Guidance related to run-on and run-off control systems is provided in Hazardous Waste Land Treatment (1).]

2. Guidance

a) The treatment zone of the unit should not contain soils (or soil-waste mixtures) having very low infiltration rates.

b) The surface slope of the active portion of a land treatment unit should be greater than 0.2 - 0.5 percent and less than five percent.

c) Waste should not be applied to the treatment zone when the surface of the zone is frozen (less than or equal to 0°C).

d) Waste should not be applied during rainy weather or when the treatment zone is saturated.

e. A vegetative cover should be established on the treatment zone whenever practicable.

3. Discussion

Run-off of hazardous constituents from land treatment units may result in significant environmental contamination. Therefore, the Agency believes that the goal of all land treatment units should be to minimize the generation of run-off. This can be achieved through proper unit siting, design, and construction, particularly with regard to soil characteristics and slope, as well as through proper management of unit operation, including the scheduling, method and rate of waste application.

Proper design of the treatment zone can greatly minimize run-off potential. The treatment zone should not be composed of soils or soil-waste mixtures which have very low infiltration rates. (Infiltration is the entry of water into the soil, normally measured as a rate having units of cm per sec. or cm per hour.) In addition, soils subject to crusting should be avoided. Soil types recommended in Section C of this document generally provide favorable infiltration properties.

The slope of the treatment zone is one of the most important factors influencing the degree and rate of hazardous constituent run-off. To minimize run-off, the surface slope of the active portion should be less than 5 percent. However, a minimum slope of 0.2-0.5 percent is recommended to provide adequate surface drainage and to minimize water and waste ponding.

Land treatment units may be equipped with terraces and grass waterways to control the run-off of liquid and hazardous constituents. This is particularly essential when significant areas are rendered barren for one or several seasons by repeated waste applications, as might occur for a sludge-type waste. Proper conservation terracing is also important if the waste is applied to a continuously vegetated surface. Terraces will slow the flow of intensive storm water off the unit, allowing optimal infiltration and putting less strain on retention basins. Furthermore, by decreasing the slope length, less sediment will erode from the slopes, and much less sediment will accumulate in the retention structures. The run-off quality will also be improved prior to the run-off entering retention structures. Information on the design of terraces is provided in Hazardous Waste Land Treatment (1).

Proper management of unit operation also contributes significantly to run-off control. Particular attention should be given to the timing of waste applications. The Agency recommends that waste applications be curtailed during periods when the surface of the treatment zone is frozen, during rainy weather and when the treatment zone is saturated. These conditions not only significantly increase the potential for run-off, but also generally inhibit treatment processes, which are essential to the success of a land treatment unit.

The Agency believes that, in most cases, successful operation of land treatment units will be limited to periods when

surface soils are unfrozen. The incorporation of wastes into frozen soils usually cannot be effectively accomplished. Kincannon (12) found that at low temperatures (approximately 4.5°C), congealing and solidification of oily waste sludges was a severe problem. Inadequate waste incorporation results in increased risk of run-off, volatilization, or wind erosion, as well as reduced waste exposure to biological and chemical treatment mechanisms.

In addition, research data indicates that treatment processes within a land treatment unit will be severely limited by low temperatures. Powell (14) found that potential waste decomposition in Arctic regions may be less than 15% of that in the southern U.S.. According to Harris (15), microbial activity slows during the cool seasons and practically ceases when soils are frozen. Studies by Dibble and Bartha (5) found negligible microbial activity at 5°C, while Raymond et al (16) reported that results from studies of two field locations showed little evidence of degradation during the winter months. As a result of poor mixing and negligible degradation at low temperatures, waste applied during the winter may cause significant run-off contamination problems during the spring thaw. Because of these problems, existing land treatment units often discontinue or significantly reduce waste application during the winter months (16, 17).

EPA also recommends that the application of wastes be curtailed during heavy, rainy weather and when the treatment zone is saturated with water. Rainy weather will obviously increase the potential for contaminated run-off problems.

Saturated soil conditions favor increased run-off, as well as accelerated migration of waste constituents through the treatment zone due to dissolution or physical removal, or as a result of anaerobic conditions (18). Dissolution of waste constituents will be a severe problem if the waste contains significant amounts of water soluble substances such as the anions of carbonic, sulfuric, hydrochloric, and nitric acids, and certain pesticides such as carbaryl (18). Anaerobic conditions adversely affect major (aerobic) degradation and immobilization processes, and increase the potential for odor problems (19, 20). Aerobic biodegradation of simple or complex organic material in soil is commonly greatest at 50-70% of the soil water holding capacity (5). Inhibition is observed at lower values due to inadequate water, and at higher values due to the reduction in oxygen levels. The solubility of most heavy metals is also increased under more reducing conditions.

Saturated soil conditions also usually cause practical operational problems. Plowing or tilling under these conditions is usually very difficult. Attempts at manipulating saturated soil, or even wet soil, usually aggravate problems because plowing with heavy equipment often compacts soil and adversely affects soil structure and porosity. Loss of pore space subsequently enhances anaerobic conditions because pore spaces provide channels through which oxygen diffuses into and through soils.

Finally, vegetative cover should be established in the treatment zone whenever practicable. Vegetation will assist in

minimizing run-off of hazardous constituents. Additional guidance on vegetative covers is provided in Section C IV of this document.

III. Management of Collected Run-on/Run-off [§264.273(e)]

1. The Regulations

Section §264.273(e) specifies that collection and holding facilities (e.g., tanks or basins) associated with run-on/run-off control systems must be emptied or otherwise managed expeditiously to maintain the capacity of the system. If the collected run-on/run-off is a hazardous waste as defined in Part 261, it must be handled as such.

Section 264.273(c) requires a run-on control system to prevent flow onto the treatment zone during a peak discharge from at least a 25-year storm, while Section 264.273(d) requires a run-off management system to both control and collect run-off from at least a 24-hour, 25-year storm. Collection of run-on is not specifically required by the regulations. However, if a collection facility is associated with the run-on control system, it must be managed such that the capacity of the system is maintained. Collection facilities will usually be associated only with run-off management facilities.

2. Guidance

a) A comprehensive analysis of the collected run-on/ run-off should be conducted to determine if it is "hazardous".

b) The following options should be evaluated for the disposal or treatment of hazardous and non-hazardous run-on/ run-off liquid:

(i) Reapplication to the hazardous waste land treatment unit to enhance treatment processes, promote growth of vegetation, or provide control of wind dispersal of hazardous constituents;

(ii) Solar evaporation; and

(iii) Disposal or treatment in a hazardous waste disposal or treatment unit, other than a land treatment unit.

c) The following additional options should be evaluated for the disposal or treatment of nonhazardous run-on/run-off liquid:

(i) Treatment and disposal via a wastewater treatment plant; and

(ii) Direct discharge under a NPDES (National Pollutant Discharge Elimination System) permit.

3. Discussion

There are several available alternatives for managing collected run-on and run-off liquid. The first step in evaluating these treatment or disposal alternatives is to determine the characteristics of the collected liquid. If such liquid is "hazardous", it must be treated or disposed of in a permitted hazardous waste management unit. If it is non-hazardous, other alternatives are available. Thus, a complete analysis of the collected liquid must be conducted.

Hazardous (or nonhazardous) collected liquid may be disposed of through (a) reapplication to the hazardous waste land treatment unit, (b) solar evaporation, or (3) treatment or disposal in a permitted hazardous waste management unit (other than a land treatment unit).

Reapplication of the collected liquid to the land treatment unit may be the most practicable means of run-on/run-off liquid treatment and disposal. This reapplied liquid may be used to enhance microbial degradation of waste constituents, or as an irrigation water source to promote vegetative crop growth. In addition, the collected liquid may be used for surface wetting in the control of wind dispersal of hazardous constituents.

If reapplication systems are used, care must be taken not to saturate the treatment zone and thus, inhibit treatment processes. When sprinkler irrigation systems are used, the systems should be designed to apply water at a rate lower than the infiltration rate to minimize run-off. The system should also be designed to provide proper pressure at the nozzles to help spread the water as uniformly as possible. Also, if the run-on/run-off liquid contains hazardous constituents, irrigation systems should be run only during periods of low wind velocity to minimize wind dispersal problems. If the liquid contains significant levels of nutrients, salts, or hazardous constituents, it will be necessary to keep a record of water applications to monitor constituent accumulations.

The land area needed for reapplication of collected run-on/ run-off will depend on the annual application rate and the annual volume of collected run-on/run-off. The annual application rate will be determined either by some limiting constituent in the run-off or by the hydraulic loading of the land. The land area needed is equal to the annual collected run-on/run-off volume divided by the annual application rate. If the application rate is set on the

basis of hydraulic loading, care must be taken to allow for chronic wet periods which will increase the volume and reduce the application rate when compared to the average annual values. Hydraulic loading and run-off models have been developed which utilize long-term weather information. Information regarding these models can usually be obtained from local Soil Conservation Service engineers or consulting firms. The spatial requirements for systems of this type often include preapplication holding ponds that are used to empty run-off retention structures and hold the liquid for future application to the land, to avoid application on soil that is already saturated, frozen, or covered with snow.

Areas in the Western United States, where the moisture deficit (evaporation minus precipitation) is greater than ten inches, have a high potential for using evaporation for ultimate disposal of collected liquid. The area needed for evaporation ponds is a function of the annual run-off volumes held in the pond plus the moisture that falls on the pond divided by the evaporation rate in inches per acre for the climatic area under consideration. The liquid may be sprayed in the air above the pond to enhance evaporation if no volatile or aerosol hazard will result. The use of nozzles that form large droplets is encouraged to help minimize spray drift and any aerosol effects.

Another option for treatment or disposal of hazardous collected liquid is disposal in a permitted hazardous waste management unit. This option, however, is likely to be less economical than the other alternatives suggested above.

Collected liquid which is found to be nonhazardous may be treated or disposed of by two additional methods. If the plant or company owns and operates a wastewater treatment plant, the run-on/run-off water can be pumped to the plant, treated, and disposed via the wastewater treatment facility permit. Care must be taken to ensure that this added volume of water does not overwhelm the treatment plant. New facilities should have this capacity designed into them. Where the option of using an existing wastewater treatment facility is not a viable alternative, an NPDES (National Pollutant Discharge Elimination System) permit may be applied for. This would allow direct discharge of the run-off liquid after collection if it meets the water quality standards specified in the NPDES permit.

IV. Wind Dispersal Control [§264.273(f)]

1. The Regulations

Section 264.273(f) states that if the treatment zone contains particulate matter which may be subject to wind dispersal, the owner or operator must manage the unit to control the wind dispersal.

2. Guidance

a) Waste applications should be planned to correspond with periods of low wind velocity and atmospheric stability.

b) The surface soil of the treatment zone should be stabilized through surface wetting with water or use of chemical soil stabilizing agents.

c) A vegetative cover should be established on the treatment zone.

d) The effectiveness of natural or man-made wind barriers for wind dispesal control should be evaluated in unit design.

3. Discussion

Because large tracts of waste-treated land are often exposed to wind erosion, wind dispersal of hazardous waste is one of the most important environmental concerns at hazardous waste land treatment units. The wind dispersal of hazardous waste will be influenced by a number of factors including the velocity and turbulence of the wind, the characteristics of the surface soil-waste mixture (e.g., moisture content, texture), and the nature and orientation of cover vegetation.

While wind velocity has a major influence, wind turbulence probably has an even more significant impact. This results from wind-carried particles exerting a large impact on particles not yet disengaged.

Moisture content and texture of soils also significantly influence the susceptibility of soil-waste particles to wind erosion. The greater the moisture content, the greater the wind velocity needed to induce particle movement. In addition, moderately coarse particles (e.g., silt size) are more susceptible to wind erosion than fine, less detachable particles (e.g., clay) or coarse, heavier, and less transportable particles (e.g., sand). Soils having a higher organic matter content will also provide greater potential for particle aggregation.

As a first step toward minimizing wind dispersal problems, the Agency recommends that all waste applications be carefully timed to avoid periods of excessive wind and atmospheric instability. Waste application activities provide, in many cases, the most significant opportunity for wind dispersal of hazardous constituents.

Second, the surface soil of the treatment zone should be stabilized through surface wetting with water or use of chemical soil stabilizing agents. Surface wetting with water is an effective and economical means of increasing the resistance of the soil-waste mixture to wind erosion by increasing the cohesiveness of soil particles. Numerous types of surface irrigation systems, commonly used in agricultural operations, are available for water application. In certain cases, the waste itself may provide the necessary moisture for limited periods of time. Additional water application, however, may be necessary between waste applications. Care should be taken to prevent saturation of the treatment zone and inhibition of treatment processes.

Chemical soil stabilizing compounds may be used in lieu of, or in combination with, surface wetting with water. Many chemical soil stabilizers, including organic polymers and other resin emulsions, are currently available. These compounds vary in their effectiveness and cost. Information on several chemical soil stabilizers can be found in a recent report (21). In evaluating these compounds, special attention should be given not only to the compound's effectiveness and cost, but also to its effect on

plant emergence and growth, and waste treatment. As in the case of soil moisture, the waste itself may act as a stabilizer against erosion.

Third, a vegetative cover should be established on the treatment zone between waste applications, whenever practicable. However, the vegetative cover crop should not be planted until sufficient tilling and cultivation (when necessary) has allowed adequate stabilization of the waste. An effective vegetative cover may eliminate the need for continuation of surface soil stabilization via water or chemical agents. In addition to controlling wind dispersal of particulates, vegetation can minimize run-off and water borne erosion by maximizing evapotranspiration and infiltration, and can absorb excess nutrients such as nitrogen. In situations where liquid hazardous wastes are surface spread by irrigation, or where wastes are subsurface injected, it may be possible to maintain a continuous vegetative cover. In instances where solid hazardous wastes are surface spread only during the warm season, a management schedule should be developed which will allow enough time for the establishment of at least a temporary cover crop after applications are complete. In situations where waste is treated year round, the active portion of the unit should be subdivided into plots or rows, so that the annual application can be made within one or two short periods to given plots or rows, followed by incorporation, surface contouring or terracing as needed, and vegetation establishment on those plots or rows. To maximize wind dispersal control, the rows of vegetation

(between nonvegetated rows) should run perpendicular to the prevailing wind direction.

Vegetation should be selected which is easily established and maintained, and relatively tolerant of potentially phytotoxic waste constituents, including organics, salts, metals, and excess water where that is a factor. Disease and insect resistance should also be considered. Information on the potential phytotoxicity of various waste constituents has been reviewed by several authors (1,3,7,22,23).

Grasses are often a good choice for vegetation because they are relatively tolerant of many toxic waste constituents, and can usually easily be established from seed. Perennial sod crops native to the area are often the most desirable surface cover, since they provide more protection against erosion, and a longer period of active ground cover than annual grasses or small grains. The most suitable or desirable plant species for a vegetative cover, however, will vary depending upon the season and the region of the country. Agronomists from the State Agricultural Extension Service, USDA, or local university should be consulted to provide information on varieties and cultural practices best suited to the given region. Additional information on the selection of vegetative covers for land treatment units is available from several sources (1,3,24).

Regardless of the plant species selected, vegetation establishment may require lime, fertilizer, the use of a mulch and watering to ensure success. Information on the specific

cultural practices required for successful establishment in a particular region can also be obtained from the area agronomists mentioned above.

Finally, each owner or operator should also evaluate the use of natural (e.g., tree lines) or man-made (e.g., fences) wind barriers in minimizing dispersal of hazardous waste. Since such barriers will only temporarily redirect the wind, they will often not be very effective at units having large fields. There may be instances, however, particularly with small units, when such measures may be effective and economically feasible.

Land treatment units having wind dispersal control measures which include waste application timing, and a combination of surface soil stabilization with water chemical agents, and/or vegetative cover will be considered in compliance with Section 264.273(f) of the RCRA regulations. Wind barriers may also fulfill part or all of the wind dispersal control requirements depending on unit-specific considerations. The acceptability of wind barriers will be evaluated on a case-by-case basis.

D. Unsaturated Zone Monitoring [§264.278]

I. Selection of "Principal Hazardous Constituents"

1. The Regulations

Section 264.278(a) specifies that "principal hazardous constituents" (PHCs) may be designated for unsaturated zone monitoring purposes in lieu of monitoring for all hazardous constituents. "Principal hazardous constituents" are the most mobile hazardous constituents which are also

relatively persistent and present in significant concentrations in the waste. "Principal hazardous constituents" may be specified in the permit by the Regional Administrator only after a review of data from waste analyses, literature reviews, laboratory tests, and field studies submitted by the owner or operator.

2. Guidance

a. The owner or operator should submit comprehensive waste analysis data which identifies the hazardous constituents present in the waste and their concentrations.

b. The owner or operator should gather and submit available data in the literature pertaining to the relative mobility and persistence of the various hazardous constituents in the waste. This data should adequately address the conditions present in the land treatment unit.

c. The owner or operator should evaluate the data generated in performing the treatment demonstration (see Section B of this document) and extract any pertinent information related to the relative mobility and persistence of the hazardous constituents.

d. Data gleaned from the literature and treatment demonstration should, if necessary, be supplemented with additional laboratory or field tests.

3. Discussion

A hazardous constituent, to be designated as a "principal hazardous constituent" (PHC), must be one of the most mobile hazardous constituents present in the waste. In addition, consideration will also be given to the concentration and persistence of the

constituent; a highly mobile hazardous constituent which is present in insignificant concentrations, or which is quickly degraded, would be an unacceptable PHC. The Regional Administrator will usually elect to designate at least two PHCs because it is likely, based on mobility, concentration, and persistence, that no single hazardous constituent will clearly represent the "best" principal hazardous constituent.

The use of PHCs allows the owner or operator to significantly reduce the analytical burden associated with monitoring. Thus, the owner or operator should work closely with the Regional Administrator in providing the necessary data to determine acceptable PHCs. It is important that the data meet quality assurance criteria and allow a clear understanding of the relative mobility and persistence of the various hazardous constituents in the waste under conditions similar to those present in the unit. In evaluating literature data and designing experimental tests, the owner or operater should consider the facility characteristics outlined in the Treatment Demonstration (Section B).

Because the selection of a principal hazardous constituent will be very waste- and facility-specific, the Agency cannot define a precise selection and testing protocol. The Regional Administrator will determine the exact type and extent of data needed to support the selection of one or more principal hazardous constituents for a particular waste at a specific unit.

II. Monitoring Procedure

1. The Regulations

Section 264.278 requires that all land treatment units have an unsaturated zone monitoring program that is capable of determining whether hazardous constituents have migrated below the treatment zone. The monitoring program must include momh soil-core and soil-pore liquid monitoring. Monitoring for hazardous constituents must be performed on a background plot (until background levels are established) and immediately below the treatment zone (active portion). The number, location, and depth of soil-core and soil-pore liquid samples taken must allow an accurate indication of the quality of soil-pore liquid and soil below the treatment zone and in the background area. The frequency and timing of soil-core and soil-pore liquid sampling must be based on the frequency, time and rate of waste application, proximity of the treatment zone to ground water, soil permeability, and amount of precipitation. The Regional Administrator will specify in the facility permit the sampling and analytical procedures to be used. The owner or operator must also determine if statistical increases in hazardous constituents (or PHCs) have occurred below the treatment zone.

[Ground-water monitoring is also required at hazardous waste land treatment units. Requirements pertaining to ground-water monitoring are provided under Subpart F of Part 264. Run-off or air emission monitoring is not specifically required at land treatment units under the Part 264 regulations.]

2. Guidance

a) Soil-core monitoring - Background

Background concentrations of principal hazardous constituents should be established using the following procedure.

(i) Take at least eight randomly selected soil cores for each soil series present in the treatment zone from similar soils where waste has not been applied. The cores should penetrate to a depth below the treatment zone but no greater than 15 centimeters (6 inches) below the treatment zone.

(ii) After taking each soil core, backfill the core hole with soil.

(iii) Obtain one sample from each soil-core portion taken below the treatment zone.

(iv) Composite the soil-core samples from each soil series to form a minimum of four composite samples for each soil series (i.e., randomly composite two soil-core samples to form a composite sample; since eight core samples per soil series were taken, a total of four composite samples will be formed).

(v) Preserve and ship the composite samples according to procedures specified in Test Methods for Evaluating Solid Waste. (25).

(vi) Analyze each composite sample for the principal hazardous constituents according to the methods included in Test Methods for Evaluating Solid Waste (25).

(vii) For each soil series, a background arithmetic mean and variance for each principal hazardous constituent should be determined by pooling all composite sample measurements.

b) Soil core monitoring - Active Portion

(i) The owner or operator should take at least six randomly selected soil cores per uniform area, semi-annually. However, if a uniform area is greater than 5 hectares (12 acres), at least two randomly selected soil cores per 1.5 hectares (4 acres) should be taken semi-annually. The cores should penetrate to a depth below the treatment zone but no greater than 15 centimeter (6 inches) below the treatment zone.

(ii) After taking each soil core, backfill each core hole with native soil or other material that will prevent direct passage of waste constituents to below the treatment zone.

(iii) The pH of the treatment zone in each uniform area should be determined using the following procedure:

(A) Obtain one representative sample from each soil-core portion taken within the treatment zone.

(B) Composite the soil-core samples from each uniform area to form a minimum of three composite samples for each uniform area. However, if a uniform area is greater than 5 hectares (12 acres), a minimum of one composite sample per 1.5 hectares (4 acres) should be formed.

(C) Preserve and ship the composite samples according to procedures provided in Test Methods for Evaluating Solid Waste (25).

(D) Determine the pH of each composite sample according to the method included in Test Methods for Evaluating Solid Waste (25).

(iv) The concentrations of principle hazardous constituents below the treatment zone in each uniform area should be determined using the following procedure:

(A) Obtain one sample from each soil-core portion taken below the treatment zone.

(B) Composite the soil-core samples from each uniform area to form a minimum of three composite samples for each uniform area. However, if a uniform area is greater than 5 hectares (12 acres), a minimum of one composite sample per 1.5 hectares (4 acres) should be formed.

(C) Preserve and ship each composite sample according to procedures provided in Test Methods for Evaluating Solid Waste (25).

(D) Analyze each composite sample for the principal hazardous constituents according to the methods included in Test Methods for Evaluating Solid Waste (25).

(E) For each uniform area, an arithmetic mean and variance for each principal hazardous constituent should be determined by pooling all composite measurements.

c) Soil-pore liquid monitoring - Background

Background concentrations of principal hazardous constituents should be established using the following procedure.

(i) For each soil series present in the treatment zone, install two soil-pore liquid monitoring devices at randomly selected locations (see Appendix I) in similar soils where waste has not been applied. The sample collecting portions of the

monitoring devices should be placed at a depth no greater than 30 centimeters (12 inches) below the actual treatment zone used at the unit.

(ii) Collect and analyze samples from each of the soil-pore liquid monitoring devices on at least a quarterly basis for at least one year. If liquid is not present at a regularly scheduled sampling event, a sample should be collected as soon as liquid is present.

(iii) Sample preservation and shipment should be done in accordance with the procedures provided in Test Methods for Evaluating Solid Waste (25).

(iv) Samples should be analyzed for the principal hazardous constituents according to the methods included in Test Methods for Evaluating Solid Waste (25).

(v) For each soil series, a background arithmetic mean and variance for each principal hazardous constituent should be determined by pooling all measurements.

d) Soil Pore-liquid Monitoring - Active Portion

(i) The owner or operator should install three soil-pore liquid monitoring devices at randomly selected locations (see Appendix I) per uniform area, but no less than one device per 1.5 hectares (4 acres). The sample collecting portion of the monitoring device should be placed at a depth no greater than 30 centimeters (12 inches) below the treatment zone.

(ii) Samples from each of the soil-pore liquid monitoring devices should be collected and analyzed at least quarterly unless

the wastes are applied very infrequently. If liquid is not present at a regularly scheduled sampling event, the monitoring device should be checked within 24 hours of each following significant waste application or rainfall event, and a sample drawn when sufficient liquid is present.

(iii) Samples should be preserved and shipped according to procedures provided in Test Methods for Evaluating Solid Waste (25).

(iv) Samples should be analyzed for the principal hazardous constituents according to methods included in Test Methods for Evaluating Solid Waste (25).

(v) For each uniform area, an arithmetic mean and variance for each principal hazardous constituent should be determined by pooling all measurements.

3. Discussion

The above guidance provides specific procedural protocols for soil-core and soil-pore liquid monitoring in both background plots and in the active portion of the unit. Guidance on the installation of and equipment needs for these monitoring systems is provided elsewhere (1, 26, 27). Guidance on ground-water monitoring at hazardous waste disposal facilities is currently being developed.

Although the regulations specify that the number of samples, and the frequency and timing of unsaturated zone sampling must be based upon a number of unit-specific factors, the guidance delineated above provides the minimum elements of what the Agency considers acceptable unsaturated zone monitoring protocols. EPA

has attempted to develop soil-core and soil-pore liquid monitoring protocols which would not only minimize sampling and analytical costs, but also assure statistically reliable results. To accomplish this, the Agency incorporated, in both monitoring protocols, the essential elements of random sampling in given "uniform areas" and sample compositing.

Soil characteristics, waste type, and waste application rate are all important factors in determining the environmental impact of a particular land treatment unit or part of a unit on the environment. Therefore, areas of the land treatment unit within which these characteristics are similar (i.e., uniform areas) should be sampled as a single monitoring unit. As used in the recommended protocols, a uniform area is an area of the active portion of a land treatment unit which is composed of soils of the same soil series (as defined in the 1975 USDA soil classification system: Reference 24) and to which similar wastes or waste mixtures are applied at similar application rates. If, however, the texture of the surface soil differs significantly among soils of the same series classification, the phase classificatic of the soil should be considered in defining "uniform areas". A certified professional soil scientist should be consulted in designating uniform areas.

In addition, EPA recommends that the location of soil-core sampling or soil-pore liquid monitoring devices within a given uniform area be randomly selected. Random selection of samples ensures a more accurate representation of conditions within a

given uniform area. Procedures for randomly selecting sampling locations are provided in Appendix I of this document.

Finally, the protocols specify that within a given uniform area, samples should be composited to form a minimum number of composite samples for analysis. The Agency believes that compositing is an effective mechanism to increase statistical reliability and to reduce analysis costs.

The soil-core and soil-pore liquid monitoring protocols for both the active portion of the unit and a background area [i.e., some other area where waste has not been applied and which has soil characteristics similar to those present in the active portion; for the purposes of this guidance, similar soil characteristics means soils of the same soil series (and similar surface soil texture)] are provided. Active portion samples must be collected from uniform areas which are selected based upon the soil series, waste type and application rate. The appropriate background area is an untreated area having soil of the same soil series. The determination of the appropriate background area is based solely on soil series; waste type and application rates are irrelevant in background area selection. It is important that uniform areas and associated background areas be selected under the supervision of a certified professional soil scientist.

The Agency realizes that the owners or operators of certain units will have background data on hazardous constituents (in soil and soil-pore liquid) generated during the interim status

period. This information may be submitted to the Regional Administrator to fulfill some or all of the Part 264 requirements related to the establishment of background values. This background information should have been obtained using procedures which at least generally conform with the guidance provided in this document. The Regional Administrator will determine the validity of the background data generated during the interim status period, and the extent to which this data will fulfill the final Part 264 requirements.

The background soil-core monitoring protocol recommends a minimum of eight soil cores from each background area. Background soil cores should penetrate to the same depth as the cores taken from the active portion. (Soil cores from the active portion should be taken at a depth below the depth of the treatment zone but no deeper than 15 centimeters (6 inches) below the treatment zone depth.) The limit on the depth of the soil cores enables a valid and accurate comparison of the levels of principal hazardous constituents immediately below the treatment zone (active portion) to background levels at the same depth. One sample should be taken from each soil core portion taken below the depth of the treatment zone. These samples should then be composited to form at least four composite samples for analysis of principal hazardous constituents. The Agency believes that four samples are the minimum number of samples necessary to ensure the establishment of accurate background data. The arithmetic mean and variance for each principal hazardous constituent should then

be determined by pooling all composite sample measurements from each background area representing a specific soil series.

The soil-core monitoring protocol for the active portion of a land treatment unit is similar to the background protocol with the following exceptions: (a) soil cores are collected from uniform areas; (b) a minimum of six soil cores per sampling area (uniform area) is recommended; and (c) sampling within the treatment zone is recommended for the determination of soil pH, and (d) monitoring frequency is semi-annual, rather than a one-time event. Sampling from uniform areas is included for the active portion to allow the selection of sampling areas to be based not only on soil series, but also on waste type and application rates. The active portion protocol also specifies that if a given uniform area is greater than 5 hectares (12 acres), at least two randomly selected soil cores per 1.5 hectares (4 acres) should be taken semi-annually. This provision is included to ensure that an adequate number of cores are taken from very large uniform areas.

A minimum of six cores (which are composited to form three samples for analysis) per sampling area is suggested for the active portion, rather than eight (as in background), in order to minimize the burden of the active portion sampling and analysis. Active portion monitoring must be carried out throughout the unit operating life, closure, and post-closure, whereas background monitorng is a one-time event.

Finally, it is recommended in the soil-core monitoring protocol for the active portion that the pH of the treatment zone in each uniform

area be determined by taking a representative sample from each soil-core portion within the treatment zone. A "representative sample" of soil within the treatment zone may be obtained by collecting subsamples from each 30 cm (12 inch) depth interval (within the treatment zone), and then compositing and mixing these subsamples to form a composite sample.

The regulations only require analysis for principal hazardous constituents be conducted on soil-core samples taken below the treatment zone. However, analysis for these constituents of samples taken within the treatment zone may provide important information on the success of degradation and transformation, if such mechanisms are used to attain treatment. All analyses should be conducted according to the methods provided in Test Methods for Evaluating Solid Waste (25).

A specific protocol for soil-pore liquid monitoring (background and active portion) is also provided in this guidance. Background areas are selected according to the same criteria (i.e., soil series) as specified for soil-core monitoring. In order to minimize costs and to adequately account for changes in soil-pore liquid quality over time, the Agency is recommending that background levels be established using quarterly monitoring of two soil-pore monitoring devices per soil series over a period of one year. The sample collection portions of the background soil-pore liquid monitoring devices should be placed at the depth corresponding to the depth of active portion devices (i.e., no greater than 30 cm below treatment zone).

Although the elements of the protocol for soil-pore liquid monitoring on the active portion of the unit are generally similar to those for soil-core monitoring on the active portion, there are several notable differences. First, only one half as many soil-pore liquid monitoring devices are specified per unit of area in order to limit the costs associated with installation of numerous monitoring devices. Second, compositing of soil-pore liquid samples is not recommended because only the minimum number of samples are specified in the protocol to minimize the cost of lysimeter installation and management. If the number of samples is significantly increased, compositing of samples may be considered. Third, the maximum depth for sampling below the treatment zone is somewhat greater than that provided for soil core samples (30 centimeters instead of 15 centimeters). This provides flexibility to the owner or operator for site-specific variations in the installation of soil-pore liquid monitoring devices.

Finally, the frequency for the sampling and analysis of soil-pore liquid is greater than that for soil cores (i.e., quarterly versus semi-annually). This is because information on fast-moving principal hazardous constituents is needed on a more frequent basis. The Agency believes that at least quarterly sampling and analysis is necessary for soil-pore liquid monitoring at units at which waste is applied on a relatively frequent basis (i.e., at least 3 times per year). More frequent sampling may be necessary, for example, at units located in areas

with highly permeable soils or high rainfall, or at which wastes are applied very frequently. The timing of sampling should be geared to the waste application schedule as much as possible.

At land treatment units at which wastes are applied infrequently (i.e., only once or twice a year), quarterly sampling and analysis of soil-pore liquid may be unnecessary. Because soil-pore liquid is instituted primarily to detect fast-moving principal hazardous constituents, monitoring for these constituents many months after waste application would be useless. The Agency believes that if fast-moving principal hazardous constituents are to migrate out of the treatment zone, they will migrate at least within 90 days following waste application (assuming normal climatic conditions). Therefore, owners or operators of land treatment units at which wastes are applied infrequently may monitor soil-pore liquid less frequently (semi-annually or annually). The Regional Administrator will determine the frequency of sampling and analysis necessary based on the frequency and rate of waste application, and on the characteristics of the waste and unit treatment zone.

If sufficient liquid is not present in the soil-pore liquid monitoring devices during a scheduled sampling, the owner or operator should obtain a sample immediately after liquid is present. Following an unsuccessful sampling, the owner or operator should check the monitoring devices for liquid within 24 hours following any significant rainfall or waste application event.

Existing land treatment units covered under the interim status regulations, promulgated on May 19, 1980, were required to

have implemented unsaturated zone monitoring systems, including soil-pore liquid monitoring devices. EPA realizes that many of these devices were not installed according to the exact specifications (e.g., located randomly in "uniform" areas) provided in this guidance. The Regional Administrator will evaluate the design and location of these existing systems and determine the extent of system modification necessary. In many cases, the Agency believes no relocation or modification will be necessary; in certain cases, however, additional devices will have to be installed.

Finally, although the Part 264 regulations do not require run-off or air emission monitoring, the Agency believes that such monitoring is good management practice at all hazardous waste land treatment units. At least periodic monitoring of run-off quality will be necessary during the active life to determine the management and ultimate disposal of collected run-off. For example, if the collected run-off is a hazardous waste, it must be treated or disposed of in a permitted hazardous waste management unit. (See Section C III of this document for a discussion of management of collected run-off.) In addition, periodic air monitoring should be conducted to evaluate the success of controls geared toward minimizing wind dispersal and volatilization of hazardous constituents.

III. Evaluation and Response

1. The Regulations

Under Section 264.278(f), the owner or operator must compare the results for each hazardous constituent (or PHC)

obtained in soil-core and soil-pore liquid monitoring, to its respective background value to determine if statistically significant increases have occurred. Section 264.278(g) specifies that if statistically significant increases are observed, the owner or operator must notify the Regional Administrator of this finding within 7 days. The owner or operator must then, within 90 days, submit to the Regional Administrator a request for permit modification to incorporate modifications to unit operations which will maximize treatment of hazardous constituents within the treatment zone.

Under Section 264.278(h), however, the owner or operator may demonstrate that a source other than the regulated unit caused the increase or that the increase resulted from error in sampling, analysis or evaluation. In making this demonstration, the owner or operator must (1) within 7 days notify the Regional Administrator in writing that he intends to make a demonstration, (2) within 90 days, submit a report to the Regional Administrator demonstrating that a source other than the regulated land treatment unit caused the increase or that the increase resulted from error in sampling analysis or evaluation, (3) within 90 days, submit to the Regional Administrator an application for a permit modification to make any appropriate changes to the unsaturated zone monitoring program at the unit, and (4) continue to monitor in accordance with the established unsaturated zone monitoring program.

2. Guidance

a) If statistically significant increases in

hazardous constituents (or PHCs) are observed, the following modifications to unit operations should be considered to maximize treatment within the treatment zone:

(i) modifications of waste characteristics;

(ii) reduction of waste application rate;

(iii) modification in method or timing of waste application;

(iv) cessation of the application of one or more particular wastes at the unit;

(v) modifications to treatment zone cultivation or management practices; and

(vi) modification of characteristics of the treatment zone, particularly soil pH or organic matter.

3. Discussion

Hazardous constituent movement to below the treatment zone may result from improper unit design, operation, or location. Problems related to unit design and operation can often be corrected, while serious problems resulting from poor unit siting are more difficult to rectify. Certain locational "imperfections" may be compensated for through careful unit design, construction, and operation.

If statistically significant increases of hazardous constituents are detected below the treatment zone via unsaturated zone monitoring, the owner or operator should closely evaluate the unit's operation, design and location to determine the source of the problem. The characteristics of the waste should be evaluated for possible effects on treatment effectiveness.

The rate, method, and timing of waste application should be examined. Management of the treatment zone including maintenance of physical, chemical and biological characteristics necessary for effective treatment, should also be reevaluated. Soil pH and organic matter content of the treatment zone are two important parameters which should be assessed. Finally, the owner or operator should determine if the design or location of the unit is causing failure of the system. Topographic, hydrogeologic, pedalogic and climatic factors all play a role in determining the success of the land treatment system. In certain cases, the necessary unit modifications will be very minor, while in other cases they will be major. Numerous unit-specific factors must be considered to make this determination. The Regional Administrator will make the final determination of the modifications necessary based on the seriousness of the problem.

In order to make the demonstration provided for under §264.278(h), the owner or operator should carefully investigate activities occurring near the unit to confirm the source of the contamination, and also closely examine the procedures used in completing unsaturated zone monitoring. Resampling of the unit may be required to determine errors in sampling, analysis, or evaluation. The exact elements of the demonstration will be determined on a case-by-case basis.

E. Closure and Post-Closure Care [§264.280]

1. The Regulations

The regulations specify that, during the closure period, the

owner or operator must continue all operations necessary to maximize degradation, transformation, or immobilization of hazardous constituents within the treatment zone except to the extent that such operations are inconsistent with the vegetative cover requirement specified in Section 264.280(a)(8). These operations are simply extensions of those required under §264.273(a). The closure requirements also specifically require (a) minimization of run-off, (b) maintenance of run-on control and run-off management systems, (c) control of wind dispersal of hazardous waste, (d) food-chain crop growth restrictions, (e) continuation of unsaturated zone monitoring, and (f) establishment of vegetative cover at such time that the cover will not substantially impede degradation, transformation, or immobilization of hazardous constituents within the treatment zone. Soil-pore liquid monitoring may be terminated 90 days after the last waste application.

The post-closure care requirements state that the owner or operator must (a) continue all operations necessary to enhance degradation and transformation, and sustain immobilization of hazardous constituents, (b) maintain the vegetative cover, (c) maintain run-on control and run-off management systems, (d) control wind dispersal of hazardous waste,(e) assure that the growth of food chain crops complies with §264.276, and (f) continue unsaturated zone monitoring (except soil-pore liquid monitoring which may be terminated 90 days after last waste application).

An owner or operator may be exempted from the vegetative cover requirement under closure, and all of the post-closure care

requirements if he demonstrates to the Regional Administrator that the entire treatment zone contains no statistically significant increases in hazardous constituents over background. In addition, Subpart F of the regulations states that if the above successful demonstration is made and if the unsaturated zone monitoring (§264.278) has not shown statistically significant increases of hazardous constituents (or PHCs) over background below the treatment zone at any time during the active life of the unit, then the the owner or operator is exempt from ground-water monitoring during the post-closure period.

Owners or operators of land treatment faciities must also comply with the general closure requirements provided under Subpart G. These requirements address the closure performance standard (§264.111), the closure plan (§264.112), time allowed for closure (§264.113), disposal or decontamination of equipment (§264.114), certification of closure (§264.115), post-closure care period (§264.117), post-closure plan (§264.118), and notices (§264.119 and §264.120).

2. Guidance

(a) To meet the above closure and post-closure care requirements under §264.280 the owner or operator should follow the applicable recommendations provided in Section C of this document.

(b) Unsaturated zone monitoring during the closure care period should be carried out in accordance with the protocol outlined in Section D of this document.

(c) In enhancing degradation and transformation, and in sustaining the immobilization of hazardous constituents during the post-closure care period, the owner or operator should, at a minimum, consider the effects of soil pH, soil moisture content, nutrient levels, and physical, chemical, or biological disturbances of the treatment zone.

(d) Unsaturated zone monitoring during the post-closure care period should be carried out in accordance with the protocol outlined in Section D of this document except that the minimum frequency of sampling should follow a geometrically progressive schedule (i.e., 1/2, 1, 2, 4, 8, 16 and 30 years after the post-closure care period begins). If not already terminated during the closure period, soil-pore liquid monitoring may be terminated 90 days after the last waste application.

(e) To demonstrate that the entire treatment zone contains no statistically significant increases in hazardous constituents over background, the owner or operator should use the following procedure:

i. Background

A. Take at least eight randomly selected (see Appendix I) soil cores for each soil series present in the treatment zone from similar soils where waste has not been applied. The soil cores must penetrate to a depth equal to the depth of the treatment zone.

B. From each soil core, obtain one sample of every 30 centimeter (12 inch) depth increment so that the sample increments correspond for all soil cores within a soil series.

C. Composite all soil-core samples for each depth increment of a soil series, to form at least four composite samples (for each depth increment of a soil series) for analysis. Analyze each composite sample for the hazardous constituents of the waste according to methods provided in Test Methods for Evaluating Solid Waste (25).

(D) For each depth increment in each soil series, a background arithmetic mean and variance for each hazardous constituent should be determined by pooling all measurements.

ii. Active Portion

(A) Take at least six randomly selected soil cores per uniform area. However, if a uniform area is greater than (12 acres) at least two randomly selected soil cores per 1.5 hectares (4 acres) should be taken. The soil cores must penetrate to the bottom of the treatment zone.

(B) From each soil core, obtain one sample of every 30 centimeter (12 inch) depth increment, so that the sample increments correspond for all soil cores within a uniform area.

(C) Composite all soil-core samples for each depth increment of a uniform area to form a minimum of three composite samples (for each depth increment of a uniform area). However, if a uniform area is greater than 5 hectares (12 acres), the minimum for each depth increment is one composite sample per 1.5 hectares (4 acres).

(D) Analyze each composite sample for the hazardous constituents of the waste according to methods provided in Test Methods for Evaluating Solid Waste (25).

(E) For each depth increment in each uniform area, an arithmetic mean and variance for each hazardous constituent should be determined by pooling all measurements.

iii. Comparison

Compare the arithmetic mean results for each hazardous constituent determined in paragraph (e)(ii)(E) of this Section to its respective background arithmetic mean determined in paragraph (e)(i)(D) of this Section, using the statistical test or procedure specified in the facility permit to determine statistically significant changes.

3. Discussion

"Closure" of a land treatment unit begins after the last load of waste is accepted for treatment. The initial phases of closure include management practices which are simply extensions of those carried out during active unit operation. All practices designed to maximize the degradation, transformation, and immobilization of hazardous constituents must be continued throughout the closure period, except those practices that will prevent the establishment of a vegetative cover (after sufficient treatment has occurred). Such activities (e.g., tilling of soil) must be terminated when the establishment of the vegetative cover commences according to the provisions specified in Section 264.280(a)(8).

In addition, unsaturated zone monitoring should be continued as specified in Section D of this document. Soil pore liquid monitoring may be terminated 90 days after the last waste application.

During the closure period, the owner or operator must also establish a vegetative cover over the closed portion of the unit. This vegetative cover must not be established until sufficient treatment has occurred so that the termination of certain management practices (e.g., tilling) and the establishment of a vegetative cover will not substantially impede treatment processes. This vegetative cover must be capable of sustaining growth without requiring extensive maintenance (e.g., frequent fertilization, liming, watering). Specific guidance on potential vegetative covers is contained in Hazardous Waste Land Treatment (1).

The Agency recognizes that degradation and transformation processes at land treatment units are, in many cases, long term processes. Complete degradation and transformation of certain degradable waste constituents may take several years. The accomplishment of sufficient treatment (after which certain active treatment management activities may be reduced and a vegetative cover established), however, usually may be possible within a shorter time frame. Therefore, during the closure period, the Agency requires the completion of certain active practices (e.g., tilling) which promote sufficient treatment and allow establishment of a vegetative cover. The Agency does believe that, in general, sufficient treatment will have been achieved when it is determined that certain active treatment management activities (e.g., tilling) are no longer necessary to maintain continued degradation of residual organic constituents, and continued effective immobilization of inorganic constituents.

Also, the vegetative cover must not be established until it is determined that the cover will not substantially inhibit degradation, transformation, or immobilization of hazardous constituents. Results from unsaturated zone monitoring, treatment zone analyses, and data on run-off liquid quality, should be used in judging the degree of treatment achieved.

The Agency believes that, in many cases, the closure activities at land treatment units (i.e., sufficient treatment (via tilling, etc.) and establishment of vegetative cover) may be accomplished within 180 days (as specified in Subpart G), assuming the last waste applications occur at the early stages of closure. Additional time, however, may be required by a number of other land treatment units due to one or more factors.

The post-closure care requirements include activities for enhancing and sustaining treatment, and precautions for managing and monitoring for unacceptable releases (e.g., run-on/run-off controls, unsaturated zone monitoring). Therefore, treatment may be completed during the post-closure care period without increased environmental risk. Soil pH, soil moisture content, nutrient levels, and significant physical, chemical, or biological disturbances of the treatment zone may all play a major role in enhancing sustaining the degradation, transformation and immobilization of hazardous constituents. These factors should be carefully examined and corrected periodically, if necessary, throughout the post-closure care period to ensure maintenance of treatment processes.

Soil-core monitoring during the post-closure care period should continue as recommended in Section H of this document, except that the frequency of monitoring may follow a progressive geometric schedule of 1/2, 1, 2, 4, 8, 16, and 30 years after post-closure care begins. The reduced frequency of this monitoring is suggested because EPA believes that the risk of hazardous constituent migration will be reduced over time in closed land treatment units where waste applications have ceased and treatment is nearing completion.

Soil-pore liquid monitoring during the closure and post-closure care periods will only have to continue for 90 days after the last waste application. Thus, depending on when wastes are applied during the closure period, soil-pore liquid monitoring may or may not have to be conducted during the post-closure care period. At least two sampling events should occur during that 90 days following the last waste application.

Finally, the Agency has provided a sampling protocol for use in demonstrating that the entire treatment zone contains no statistically significant increases in hazardous constituents over background. This soil-core monitoring protocol differs from the one provided in Section D of this document in that samples are taken of various depth increments within the treatment zone, rather than just below the treatment zone. Samples from respective depths within each uniform area may be composited to form a minimum of four samples for analysis. Background and active-portion samples at each depth should then be compared using an appropriate statistical procedure.

If a successful demonstration is made under §264.280(d), the owner or operator is not required to establish a vegetative cover or comply with the post-closure care requirements. However, the Agency still believes that it is good management practice to establish a vegetative cover, even if hazardous constituents are not present, in order to minimize soil erosion.

References

1. Brown, K.W. and Assoc., Inc., Hazardous Waste Land Treatment, U.S. EPA publication, SW-874, Contract No. 68-03-2940 (9/80).

2. Soil Survey Staff, Soil Conservation Service, USDA, Soil Taxonomy; A Basic System of Soil Classification for Making and Interpreting Soil Surveys, Agriculture Handbook No. 436, U.S. Government Printing Office, Washington, DC, 12/75.

3. Overcash, M.R. and D. Pal, Design of Land Treatment Systems for Industrial Wastes - Theory and Practices. Ann Arbor Science, Ann Arbor, Michigan, 1978.

4. Brady, N.C., The Nature and Properties of Soils - 8th Ed. McMillan Publ. Co., N.Y., 1974.

5. Dibble, J.T. and R. Bartha, "Effect of Environmental Parameters on Biodegradation of Oil Sludge," App. Env. Microbiology 37: 729-38, 1979.

6. SCS Engineers, Land Cultivation of Industrial Wastes and Municipal Solid Wastes: State of the Art Study. Volume I. Contract No. 68-01-2435, U.S. Environmental Protection Agency, August, 1978.

7. Page, A.L., Fate and Effects of Trace Elements in Sewage Sludge When Applied to Agricultural Lands. A Literature Review Study. EPA-670/2-74-005, U.S. Environmental Protection Agency, January 1974.

8. Dowdy, R.H., and W.E. Larson. "The Availability of Sludge-born Metals to Various Vegetable Crops." J. of Env.Quality 4: 278-282, 1975.

9. Chaney, R.L., P.T. Hundemann, W.T. Palmer, R.J. Small, M.C.White and A.M. Decker, "Plant Accumulation of Heavy Metals and Phytotoxicity Resulting from Utilization of Sewage Sludge and Sludge Composts on Cropland," pp 86-97. In Proc. Nat'l Conf, Composting Municipal Residues and Sludges. Information Transfer Inc., Rockville, Md., 1978.

10. Huddleston, R.L., "Treatment of Oily Wastes by Land Farming," Presented at the RSMA Meeting, "Disposal of Industrial and Oily Sludges by Land Cultivaton," Houston, Texas, January 18-19, 1978.

11. CONCAWE, Sludge Farming: A Technique for the Disposal of Oily Refinery Wastes, Report No. 3/80, 1980.

12. U.S. Environmental Protection Agency, "Principles and Design Criteria for Sewage Sludge Application on Agricultural Land.", Chapter 9 in Sludge Treatment and Disposal - Vol. 2., 1978.

13. Kincannon, C.B., Oily Waste Disposal by Soil Cultivation Process., EPA - R2-72-100, U.S. EPA, 12/72.

14. Rowell, Michael J., "Land Cultivation in Cold Regions" In: Disposal of Industrial and Oily Sludges by Land Cultivation, Resource Systems & Mgmt Assoc., 1980.

15. Harris, J.O., "Petroleum Wastes in Soil" In: Land Application of Waste Materials, Soil Conservation Society of America, Akeny, Iowa, 1976.

16. Raymond, R.L., J.O. Hudson, and J.W. Jamison, "Oil Degradation in Soil." Applied and Environmental Microbiology, 31:4 522-535, 1976.

17. Lewis, R.S., Sludge Farming of Refinery Wastes as Practiced at Exxon's Bayway Refinery and Chemical Plant. Presented at the National Conference on Disposal of Residues on Land, St. Louis, Missouri, Sept. 13-16, 1976.

18. Fuller, W.H., Movement of Selected Metals, Asbestos, and Cyanide in Soil: Applications to Waste Disposal. EPA - 600/2-77-020, U.S. EPA, April, 1977.

19. Lytle, Paul E., Site Visit: Gulf Coast Waste Disposal Authority, Houston, Texas; Trip report. U.S. EPA, Office of Solid Waste, Wash., D.C., Jan. 1, 1978.

20. Lennon, James V., Site Visit: IT Corporations, Martines, Calif., Trip Report, U.S. EPA, Office of Solid Waste, Washington, D.C., Oct. 24, 197. Slide Presentation.

21. Versar, Inc. Technical Assistance in the Coal BAT Review-II; Special Report: Revegetation of Coal Strip Mines, U.S.EPA Contract No. 68-01-5149, November 26, 1979.

22. Allaway, W.H. Agronomic Control over Environmental Cycling of Trace Elements. Adv. Agron. 20:235-274, 1968.

23. Chaney, R.L. and P.M. Giordano. Microelements as related to plant deficiencies at toxicities. pp 234-279. In: L.F. Elliott and R.J. Stevenson (ed.) Soils for Management of Organic Wastes and Waste Waters. American Socity of Agronomy, Madison, WI., 1977.

24. Lutton, R.J. Evaluating Cover Systems for Solid and Hazardous Waste. U.S. EPA publication no. SW-867. EPA-IAG-D7-01097, 9/80.

25. U.S. Environmental Protection Agency, Test Methods for Evaluating Solid Waste, Publication No. SW-846, 1982.

26. Wilson, L.G., Monitoring in the Vadose Zone: A Review of Technical Element and Methods, EPA-600/7-80-134, Contract No. V-0591-NALX, 6/80.

27. Fenn, D., E. Cocozza, O. Braids, B. Yare, and P. Roux, Manual for Ground Water Monitoring at Solid Waste Disposal Facilities, EPA publication SW-611, Contract. No. 68-01-3210, 12/80.

Appendix I

Random Sampling

If n units are to be selected from the population, a simple random sample is defined as a sample obtained in such a manner that each possible combination of n units has an equal chance of being selected (1). In practice, each unit is selected separately, randomly, and independently of any units previously drawn. For unsaturated zone monitoring, each unit to be included in the "sample" is either a volume of soil (soil core) or a volume of liquid (soil-pore liquid).

It is convenient to spot the field location for soil-coring and soil-pore liquid devices by selecting random distances on a coordinate system and using the intersection of the two random distances as the location at which a soil core should be taken or a soil-pore liquid monitoring device installed. This system works well for fields of both regular and irregular shape, since the points outside the area of interest are merely discarded, and only the points inside the area are used in the sample.

The location, within a given uniform area of a land treatment unit (i.e., active portion monitoring), at which a soil core should be taken or a soil-pore liquid monitoring device installed should be determined using the following procedure:

(1) Divide the land treatment unit into uniform areas, as defined in Section H of this document. A certified professional soil scientist should be consulted in completing this step;

(2) Map each uniform area by establishing two base lines at right angles to each other which intersect at an arbitrarily selected origin, for example, the southwest corner. Each baseline should extend to the boundary of the uniform area.

(3) Establish a scale interval along each base line. The units of this scale may be feet, yards, miles, or other units depending on the size of the uniform area. Both base lines must have the same scale.

(4) Draw two random numbers from a random numbers table (usually available in any basic statistics book). Use these numbers to locate one point along each of the base lines.

(5) Locate the intersection of two lines drawn perpendicular to these two base line points. This intersection represents one randomly selected location for collection of one soil core, or for installation of one soil-pore liquid device. If this location at the intersection is outside the uniform area, disregard and repeat the above procedure.

(6) For soil-core monitoring, repeat the above procedure as many times as necessary to obtain six soil coring locations within each uniform area of the land treatment unit. If a uniform area is greater than twelve acres, repeat the above procedure as necessary to provide at least two soil coring locations per four acres. [If the same location is selected twice, disregard the second selection and repeat as necessary to obtain different locations] This procedure for randomly selecting soil coring locations must be repeated at each sampling event (i.e., semi-annually).

U.S. Environmental Protection Agency
Region 5, Library (PL-12J)
77 West Jackson Boulevard, 12th Floor
Chicago, IL 60604-3590

DATE DUE

(7) For soil-pore liquid monitoring, repeat the above procedure as many times as necessary to obtain three locations for installation of soil-pore liquid monitoring devices within each uniform area. In addition, there should be no less than one soil-pore liquid monitoring device (location) per four acres of uniform area. Monitoring at these same randomly selected locations will continue throughout land treatment unit life (i.e., devices do not have to be relocated at every sampling event).

One point should be made regarding randomly locating soil-pore liquid monitoring devices according to the procedure specified above. In many cases, this procedure will result in the selection of a sampling location situated in the middle of the active portion. In order to prevent operational inconvenience and sampling bias, the monitoring system should be designed and installed so that the above-ground portion of the device is located at least 10 meters from the sampling location. If the above-ground portion of the device is located immediately above the sampling device, the sampling location will often be avoided because of operational difficulties. Thus, samples collected at this location will be biased and not representative of the treated area.

Locations for monitoring on background areas should be randomly determined using the following procedure:

(1) Consult a certified professional soil scientist in determining an acceptable background area. The background area must have characteristics (i.e., at least soil series classification)

similar to those present in the uniform area of the land treatment unit it is representing.

(2) Map an arbitrarily selected portion of the background area by establishing two base lines at right angles to each other which intersect at an arbitrarily selected origin.

(3) Complete steps 3, 4, and 5 as defined above.

(4) For soil-core monitoring, repeat this procedure as necessary to obtain eight soil coring locations within each background area.

(5) For soil-pore liquid monitoring, repeat the above procedure as necessary to obtain two locations for soil-pore liquid monitoring devices within each background area.

Referencees

(1) Petersen, R.G., and L.D. Calvin. Sampling. In Methods of Soil Analysis, Part 1, Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling. C.A. Black, ed. American Society of Agronomy, Inc., 1965. p. 57-59.

(2) N.C-118. Sampling and Analysis of Soils, Plants, Waste Waters and Sludges: Suggested Standardization and Methodology. N.C. Regional Publication 230. Kansas State University Agricultural Experiment Station, 1975.