CHAPTER TWELVE

LAND TREATMENT MONITORING

12.1 BACKGROUND

A monitoring program is an essential component at any land treatment unit and should be planned to provide assurance of appropriate facility design, to act as a feedback loop to furnish guidance on improving unit management, and to indicate the rate at which the treatment capacity is being approached. Because many assumptions must be made in the design of a land treatment unit, monitoring can be used to verify whether the initial data and assumptions were correct or if design or operational changes are needed. Monitoring cannot be substituted for careful design based on the fullest reasonable understanding of the effects of applying hazardous waste to the soil; however, for existing Hazardous Waste Land Treatment (HWLT) units (which must retrofit to comply with regulations), monitoring can provide much of the data base needed for demonstrating treatment.

Figure 12-1 shows the topics to be considered when developing a monitoring program. The program must be developed to provide the following assurances:

1. that the waste being applied does not deviate significantly from the waste for which the unit was designed;

2. that waste constituents are not leaching from the land treatment area in unacceptable concentrations;

3. that ground water is not being adversely affected by the migration of hazardous constituents of the waste(s); and

4. that waste constituents will not create a food-chain hazard if crops are harvested.

12.2 TREATMENT ZONE

As is depicted in Figure 12-2, the entire land treatment operation and monitoring program revolve about a central component, the <u>treatment zone</u>. Concentrating on the treatment zone is a useful approach to describing and monitoring a land treatment system. The treatment zone is the soil to which wastes are applied or incorporated; HWLT units are designed so that degradation, transformation, and immobilization of hazardous constituents and their metabolites occur within this zone.

In practice, setting a boundary to the treatment zone is difficult. In choosing the boundaries of the treatment zone, soil-forming processes and the associated decrease in biological activity with depth should be considered.

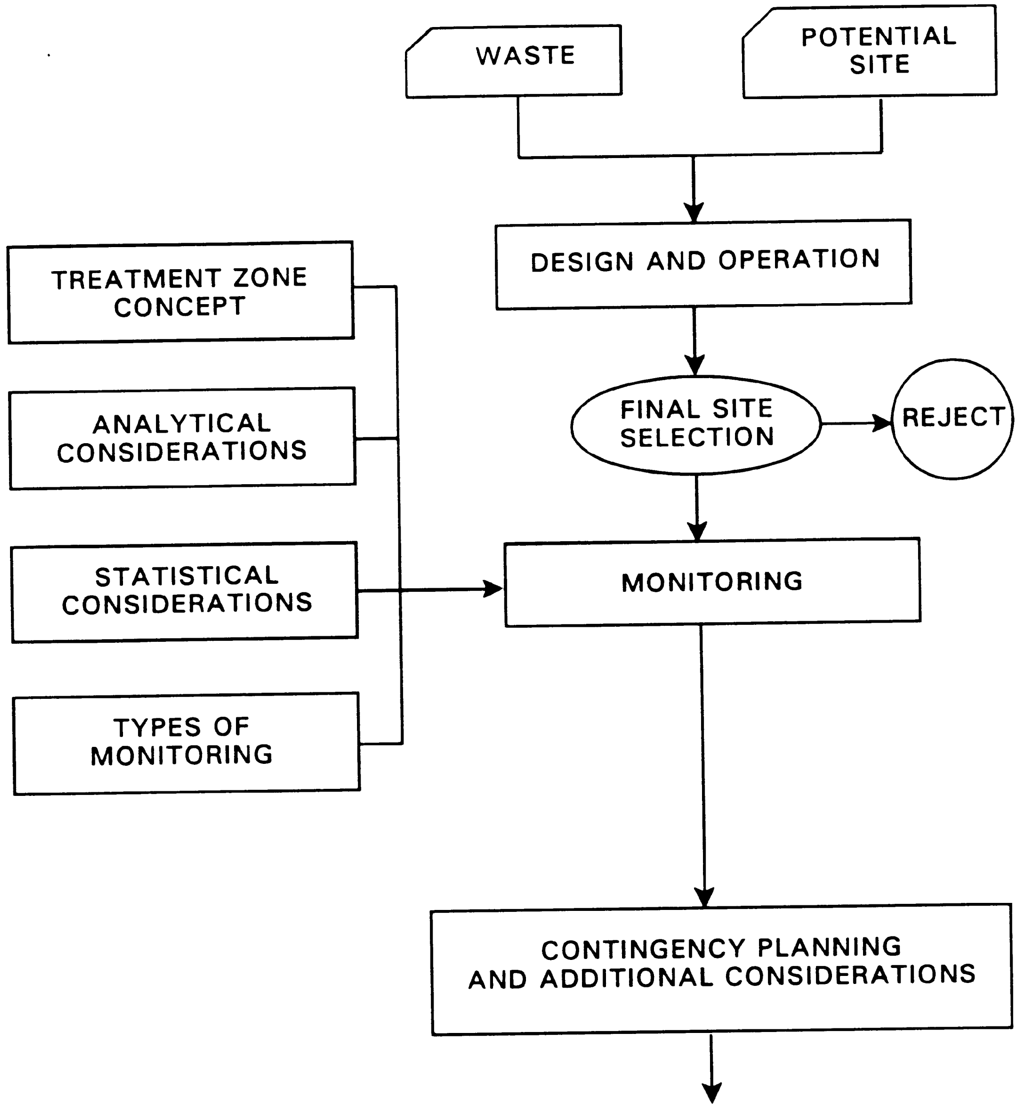

Figure 12-1. Topics to be considered in developing a monitoring program for an HWLT unit.

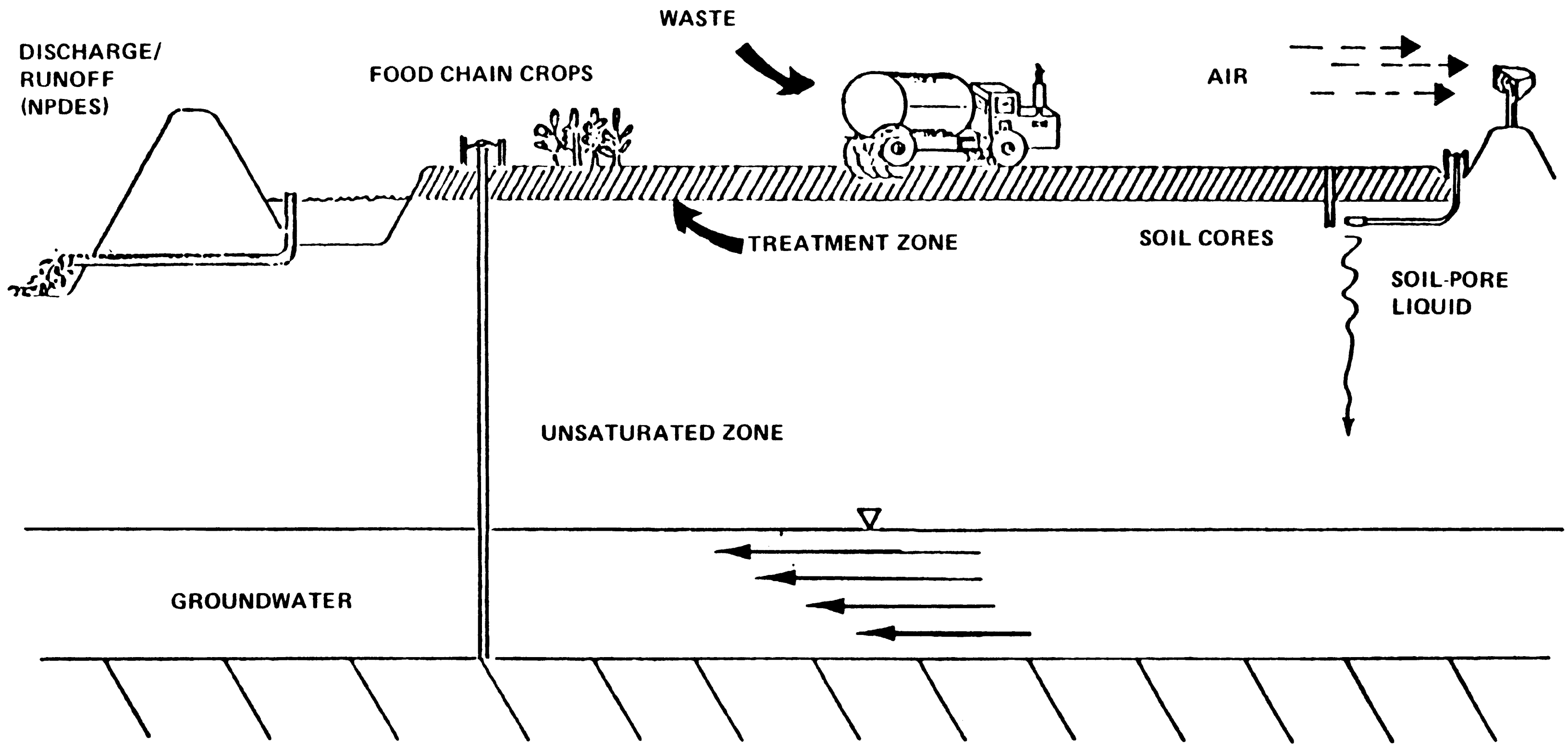

Figure 12-2. Various types of monitoring for land treatment units.

12.3 REGULATORY DEFINITION

The current regulations (U.S. EPA, 1982a) require the following types of monitoring:

1. Ground water detection monitoring to determine if a leachate plume has reached the edge of the waste management area (40 CFR 264.98).

2. Ground water compliance monitoring to determine if the facility is complying with ground water protection standards for hazardous constituents (40 CFR 264.99).

3. Monitoring of soil pH and concentration of cadmium in the waste when certain food-chain crops are grown on HWLT units where cadmium is disposed of (40 CFR 264.276).

4. Unsaturated zone monitoring, including soil cores and soil-pore liquid monitoring, to determine if hazardous constituents are migrating out of the treatment zone (40 CFR 246.278).

5. Waste analysis of all types of waste to be disposed at the HWLT unit (40 CFR 264.13).

12.4 MONITORING AND SAMPLING STRATEGY

As discussed earlier, the monitoring program centers around the treatment zone.

The frequency of sampling and the parameters to be analyzed depend on the characteristics of the waste being disposed, the physical layout of the unit, and the surface and subsurface characteristics of the site. Table 12-1 provides guidance for developing an operational monitoring program. Each of the types of monitoring is discussed below.

12.4.1 Waste Monitoring and Sampling Strategy

Waste streams need to be routinely sampled and tested to check for changes in composition. A detailed description of appropriate waste sampling techniques, tools, procedures, etc., is provided in Chapter Nine of this manual (in Part III, Sampling). These procedures should be followed during all waste sampling events. Waste analysis methods are provided in this manual. The analyst should choose the appropriate method, based on each waste and specific constituents to be tested for.

The frequency with which a waste needs to be sampled and the parameters to be analyzed depend greatly on the variables that influence the quantity and quality of the waste. When waste is generated in a batch, as would be expected from an annual or biannual cleanout of a lagoon or tank, the waste should be fully characterized prior to each application. When the waste is

TABLE 12-1 GUIDANCE FOR AN OPERATIONAL MONITORING PROGRAM AT HWLT UNITS

Media to be Monitored	Purpose	Sampling Frequency	Number of Samples	Parameters to be Analyzed
Waste	Quality Change.	Quarterly composites if continuous stream; each batch if intermittent generation.	One	At least rate and capacity limiting constituents, plus those within 25% of being limiting, principal hazardous constituents, pH and EC.
Soil cores (unsaturated zone)	Determine slow movement of hazardous constituents.	Quarterly	One composited from two per 1.5 ha (4 ac); minimum of 3 composited from 6 per uniform area.	All hazardous constituents in the waste or the principal hazardous constituents, metabolites of hazardous constituents, and nonhazardous constituents of concern.
Soil-pore liquid (unsaturated zone)	Determine highly mobile constituents.	Quarterly, preferably following leachate generating precipitation snowmelt.	One composited from two samplers per 1.5 ha (4 ac); minimum of 3 composited from 6 per uniform area.	All hazardous constituents in the waste or the principal hazardous constituents, mobile metabolites of hazardous constituents, and important mobile nonhazardous constituents.
Groundwater	Determine mobile constituents.	Semiannually	Minimum of four suggested--one upgradient, three downgradient.	Hazardous constituents and metabolites or select indicators.
Vegetation (if grown for food chain use)	Phytotoxic and hazardous transmitted constituents (food chain hazards).	Annually or at harvests.	One per 1.5 ha (4 ac) or three of processed crop before sale.	Hazardous metals and organics and their metabolites.
Runoff water	Soluble or suspended constituents.	As required for NPDES permit.	As permit requires, or one.	Discharge permit and background parameters plus hazardous organics.
Soil in the treatment zone	Determine degradation, pH, nutrients, and rate and capacity limiting constituents.	Quarterly	7-10 composited to one per 1.5 ha (4 ac).	
Air	Personnel and population health hazards.	Quarterly	Five	Particulates (adsorbed hazardous constituents) and hazardous volatiles.

generated more nearly continuously, samples should be collected and composited based on a statistical design over a period of time to ensure that the waste is of a uniform quality. For example, wastes that are generated continuously could be sampled weekly or daily on a flow-proportional basis and composited and analyzed quarterly or monthly. When no changes have been made in the operation of the plant or the treatment of the waste which could significantly alter concentration of waste constituents, the waste should, at a minimum, be analyzed for (1) the constituents that restrict the annual application rates (RLC) and the allowable cumulative applications (CLC), (2) the constituents that are within 25% of the level at which they would be limiting, and (3) all other hazardous constituents that have been shown to be present in the waste in the initial waste characterization. Because synergism and antagonism as well as unlisted waste metabolites can create hazards that cannot be described by chemical analysis alone, routine multigenicity testing may be performed if the treatment demonstration has indicated a possible problem. In addition, waste should be analyzed as soon as possible after a change in operations that could affect the waste characteristics.

12.4.2 Ground Water Monitoring and Sampling Strategy

To ensure that irreparable ground water damage does not occur as a result of HWLT, it is necessary that the ground water quality be monitored. Ground water monitoring supplements the unsaturated zone monitoring system but does not replace it. A contamination problem first detected in the leachate water may indicate the need to alter the management program, and ground water can then be observed for the same problem. It is through the successful combination of these two systems that accurate monitoring of vertically moving constituents can be achieved. Ground water monitoring requirements are discussed in Chapter Eleven of this manual.

12.4.3 Vegetation Monitoring and Sampling Strategy

Where food-chain crops are to be grown, analysis of the vegetation at the HWLT unit will aid in ensuring that harmful quantities of metals or other waste constituents are not being accumulated by, or adhering to surfaces of, the plants. Although a safety demonstration before planting is required (U.S. EPA, 1982a), operational monitoring is recommended to verify that crop contamination has not occurred. Vegetation monitoring is an important measurement during the post-closure period where the area may possibly be used for food or forage production. Sampling should be done annually or at each harvest. The concentrations of metals and other constituents in the vegetation will change with moisture content, stage of growth, and the part of the plant sampled, and thus results must be carefully interpreted. The number of samples to analyze is again based on a sliding scale similar to that used for sampling soils. Forage samples should include all aerial plant parts, and the edible parts of grain, fruit, or vegetation crops should be sampled separately.

12.4.4 Runoff Water Monitoring and Sampling Strategy

If runoff water analyses are needed to satisfy NPDES permit conditions (National Pollution Discharge Elimination System, U.S. EPA, 1981), a monitoring program should be instituted. This program would not be covered under RCRA hazardous waste land disposal requirements, but it would be an integral part of facility design. The sampling and monitoring approach will vary, depending on whether the water is released as a continuous discharge or as a batch discharge following treatment to reduce the hazardous nature of the water. Constituents to be analyzed should be specified in the NPDES permit.

When a relatively continuous flow is anticipated, sampling must be flow proportional. A means of flow measurement and an automated sampling device are a reasonable combination for this type of monitoring. Flow can be measured using a weir or flume (U.S.D.A., 1979) for overload flow-water pretreatment systems and packaged water treatment plants, and in-line flow measurement may be an additional option on the packaged treatment systems. The sampling device should be set up to obtain periodic grab samples as the water passes through the flow-rate measuring device. A number of programmable, automated samplers that can take discrete or composite samples are on the market.

For batch treatment, such as mere gravity separation or mechanically aerated systems, flow is not so important as is the hazardous constituent content of each batch. Sampling before discharge would, in this case, involve manual pond sampling, using multiple grab samples. The samples would preferably represent the entire water column to be discharged in each batch rather than a single depth increment. Statistical procedures should again be used for either treatment and discharge approach.

12.4.5 Unsaturated Zone Monitoring and Sampling Strategy

The unsaturated zone is described as the layer of soil or parent material separating the bottom of the treatment zone and the seasonal high-water table or ground water table and is usually found to have a moisture content less than saturation. In this zone, the movement of moisture may often be relatively slow in response to soil properties and prevailing climatic conditions; however, in some locations, soils and waste management practices may lead to periods of heavy hydraulic loading that could cause rapid downward flux of moisture.

An unsaturated zone monitoring plan should be developed for two purposes: (1) to detect any significant movement of hazardous constituents out of the system, and (2) to furnish information for management decisions. In light of the variability in soil-water flux and the mobility of hazardous waste constituents, the unsaturated zone monitoring plan should include sampling the soil to evaluate relatively slow-moving waste constituents (soil core monitoring) and sampling the soil-pore liquid to evaluate fast-moving waste constituents. Monitoring for hazardous constituents should be performed on a representative background plot(s) 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-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 data from this program must be sufficient to determine if statistically significant increases in hazardous constituents (or selected indicator constituents) have occurred below the treatment zone. Location and depth of soil core and soil-pore liquid samples follow the same reasoning, but the number, frequency, and timing of soil core sampling differs somewhat from that required for soil-pore liquid sampling. Thus, the unique aspects of these topics will be considered together with discussions of techniques for obtaining the two types of samples.

12.4.5.1 Location of Samples

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 for which these characteristics are similar (i.e., uniform areas) should be sampled as a single monitoring unit. A uniform area is defined as an area of the active portion of a land treatment unit which is composed of soils of the same soil series (U.S.D.A., 1975) 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 classification of the soil should be considered in defining "uniform areas." A certified professional soil scientist should be consulted in designating uniform areas.

Based on that definition, it is recommended 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. It is convenient to spot the field location for soil core 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 because 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 under the direction of a certified professional soil scientist.

2. Set up coordinates for 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 far enough for all of the uniform area to fall within the quadrant.

3. Establish a scale interval along each base line. The units of this scale may be feet, yards, meters, or other units, depending on the size of the uniform area, but both base lines should have the same units.

4. Draw two random numbers from a random-number table (available in most basic statistics books). Use these numbers to locate one point along each of the base lines.

5. Locate the intersection of two lines drawn perpendicular to the base lines through these 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 the desired number of locations within each uniform area of the land treatment unit. This procedure for randomly selecting locations must be repeated for each soil core sampling event but will be needed only once in locating soil-pore liquid monitoring devices.

Locations for monitoring on background areas should also be randomly determined. Again, consult a certified professional soil scientist in determining an acceptable background area. The background area must have characteristics (including soil series classification) similar to those present in the uniform area of the land treatment unit it is representing, but it should be free from possible contamination from past or present activities that could have contributed to the concentrations of the hazardous constituents of concern. Establish coordinates for an arbitrarily selected portion of the background area and use the above procedure for randomly choosing sampling locations.

12.4.5.2 Depth of Samples

Because unsaturated zone monitoring is intended to detect pollutant migration from the treatment zone, samples should logically be obtained from immediately below this zone. Care should be taken to ensure that samples from active areas of the land treatment unit and background samples are monitoring similar horizons or layers of parent material. Because soils seldom consist of smooth, horizontal layers, but are often undulating, sloped, and sometimes discontinuous, it would be unwise to specify a single depth below the land surface to be used for comparative sampling. A convenient method for choosing sampling depths is to define the bottom of the treatment zone as the bottom of a chosen diagnostic solid horizon and not as a rigid depth. Sampling depth would then be easily defined with respect to the bottom of the treatment zone. At a minimum, soil core and soil-pore liquid sampling should monitor within 30 cm (12 in.) of the bottom of the treatment zone. Additional sampling depths may be desirable, for instance, if analytical results are inconclusive or questionable. Core samples should include only the 0- to 15-cm increment below the treatment zone, whereas soil-pore liquid samplers should be placed so that they collect liquid from anywhere within this 30-cm zone.

12.4.5.3 Soil Core Sampling Techniques

Soil Cores

Waste constituents may move slowly through the soil profile for a number of reasons, such as the lack of sufficient soil moisture to leach through the system, a natural or artificially occurring layer or horizon of low hydraulic conductivity, or waste constituents that exhibit only a low to moderate mobility relative to water in soil. Any one or a combination of these effects can be observed by soil core monitoring. Based on the treatment zone concept, only the portions of soil cores collected below the treatment zone need to be analyzed. The intent is to demonstrate whether there are significantly higher concentrations of hazardous constituents in material below the treatment zone than in background soils or parent material.

Soil core sampling should proceed according to a definite plan with regard to number, frequency, and technique. Previous discussions of statistical considerations should provide guidance in choosing the number of samples required. Background values for soil core monitoring should be established by collecting at least eight randomly selected soil cores for each soil series present in the treatment zone. These samples can be composited in pairs (from immediately adjacent locations) to form four samples for analysis. For each soil series, a background arithmetic mean and variance should be calculated for each hazardous constituent. For monitoring the active portion of the land treatment facility, a minimum of six randomly selected soil cores should be obtained per uniform area and composited, as before, to yield three samples for analysis. If, however, a uniform area is >5 ha (12 ac), at least two randomly selected soil cores should be taken per 1.5 ha (4 ac) and composited in pairs based on location. Data from the samples in a given uniform area should be averaged and statistically compared. If analyses reveal a large variance from samples within a given uniform area, more samples may be necessary. Soil coring should be done at least semiannually, except for background sampling, which, after background values are established, may be performed as needed to determine if background levels are changing over time.

It is important to keep an accurate record of the locations from which soil core samples have been taken. Even when areas have been judged to be uniform, the best attempts at homogeneous waste application and management cannot achieve perfect uniformity. It is probable in many systems that small problem areas, or "hot spots," may occur, causing localized real or apparent pollutant migration. Examples of "apparent" migration might include small areas where waste was applied too heavily or where the machinery on-site mixed waste too deeply. The sampling procedure itself is subject to error and so may indicate apparent pollutant migration. Therefore, anomalous data points can and should be resampled at the suspect location(s) to determine if a problem exists, even if the uniform area as a whole shows no statistically significant pollutant migration.

The methods used for soil sampling are variable and depend partially on the size and depth of the sample needed and the number and frequency of samples to be taken. Of the available equipment, oil field augers are useful if small samples need to be taken by hand, and bucket augers give larger samples. Powered coring or drilling equipment, if available, is the preferable choice because it can rapidly sample to the desired depths and provide a clean, minimally disturbed sample for analysis. Due to the time involved in coring to 1.5 m, and sometimes farther, powered equipment can often be less costly than hand sampling. In any case, extreme care must be taken to prevent cross contamination of samples. Loose soil or waste should be scraped away from the surface to prevent it from contaminating samples collected from lower layers. The material removed from the treatment zone portion of the borehole can be analyzed, if desired, to evaluate conditions in the treatment zone. It is advisable to record field observations of the treatment zone even if no analysis is done. Finally, boreholes absolutely must be backfilled carefully to prevent hazardous constituents from channeling down the hole. Native soil compacted to about field bulk density, clay slurry, or other suitable plug material may be used.

Sample handling, preservation, and shipment should follow a chain-of-custody procedure and a defined preservation method such as is found in Chapter Nine of this manual or in the analytical section of EPA document SW-874, Hazardous Waste Land Treatment (U.S. EPA, 1983). If more sample is collected than is needed for analysis, the volume should be reduced by either the quartering or riffle technique. (A riffle is a sample-splitting device designed for use with dried ground samples.)

The analysis of soil cores must include all hazardous constituents that are reasonably expected to leach or the principal hazardous constituents (PHCs) that generally indicate hazardous constituent movement (U.S. EPA, 1982a).

Soil-Pore Liquid

Percolating water added to the soil by precipitation, irrigation, or waste applications may pass through the treatment zone and may rapidly transport some mobile waste constituents or degradation products through the unsaturated zone to the ground water. Soil-pore liquid monitoring is intended to detect these rapid pulses of contaminants (often immediately after heavy precipitation events) that are not likely to be observed through the regularly scheduled analysis of soil cores. Therefore, the timing of soil-pore liquid sampling is a key to the usefulness of this technique. Seasonability is the rule with soil-pore liquid sample timing (i.e., scheduled sampling cannot be on a preset date, but must be geared to precipitation events). Given that sampling is done soon after leachate-generating precipitation or snowmelt, the frequency also varies depending on site conditions. As a starting point, sampling should be done quarterly. More frequent sampling may be necessary 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 where wastes are applied infrequently (i.e., only once or twice a year) or where leachate-generating precipitation is highly seasonal, quarterly sampling and analysis of soil-pore liquid may be unnecessary. Because soil-pore liquid sampling is instituted primarily to detect fast-moving hazardous constituents, monitoring for these constituents many months after waste application may be useless. If fast-moving hazardous constituents are to migrate out of the treatment zone, they will usually migrate within at least 90 days following waste application, unless little precipitation or snowmelt has occurred. Therefore, where wastes are applied infrequently or leachate generation is seasonal, soil-pore liquid may be monitored less frequently (semiannually or annually). A final note about timing is that samples should be obtained as soon as liquid is present. The owner or operator should check the monitoring devices for liquid within 24 hr of any significant rainfall, snowmelt, or waste application.

The background concentrations of hazardous constituents in the soil-pore liquid should be established by installing two monitoring devices at random locations for each soil series present in the treatment zone. Samples should be taken on at least a quarterly basis for at least one year and can be composited to give one sample per quarter. Analysis of these samples should be used to calculate an arithmetic mean and variance for each hazardous constituent. After background values are established, additional soil-pore liquid samples should occasionally be taken to determine if the background values are changing over time.

The number of soil-pore liquid samplers needed is a function of site factors that influence the variability of leachate quality. Active, uniform areas should receive, in the beginning, a minimum of six samplers per uniform area. For uniform areas >5 ha, at least two samplers per 1.5 ha (4 ac) should be installed. Samples may be composited in pairs based on location to give three samples for analysis. The number of devices may have to be adjusted up (or down) as a function of the variability of results.

To date, most leachate collection has been conducted by scientists and researchers, and there is not an abundance of available field equipment and techniques. The U.S. EPA (1977) and Wilson (1980) have prepared reviews of <u>pressure vacuum lysimeters</u> and <u>trench lysimeters</u>. The pressure vacuum lysimeters are much better adapted to field use and have been used to monitor pollution from various sources (Manbeck, 1975; Nassau-Suffolk Research Task Group, 1969; The Resources Agency of California, 1963; James, 1974). These pressure vacuum samplers are readily available commercially and are the most widely used, both for agricultural and waste monitoring uses. A third type of leachate sampler is the vacuum extractor as used in the field by Smith et al. (1977). A comparison of in situ extractors was presented by Levin and Jackson (1977).

These soil-pore liquid sampling devices are described in Chapter Nine of this manual (in Part III, Sampling).

12.4.6 Treatment Zone Monitoring and Sampling Strategy

Treatment zone monitoring of land treatment units is needed for two purposes. One main purpose is to monitor the degradation rate of the organic fraction of the waste material and parameters significantly affecting waste treatment. Samples are needed at periodic intervals after application to be analyzed for residual waste or waste constituents. Such measurements need to be taken routinely, as specified by a soil scientist. These intervals may vary from weekly to semiannual, depending on the nature of the waste, climatic conditions, and application scheduling. The second major function of treatment zone sampling is to measure the rate of accumulation of conserved waste constituents to provide some indication of the facility's life.

The sampling schedule and number of samples to be collected may depend on management factors, but a schedule may be conveniently chosen to coincide with unsaturated zone soil core sampling. For systems that will be loaded heavily in a short period, more (and more frequent) samples may be needed to ensure that the waste is being applied uniformly and that the system is not being overloaded. About seven to ten samples from each selected 1.5-ha (4-ac) area should be taken to represent the treatment zone, and these should be composited to obtain a single sample for analysis. In addition, if there are evidently anomalous "hot spots," these should be sampled and analyzed separately.

12.4.7 Air Monitoring and Sampling Strategy

The need for air monitoring at a land treatment unit is not necessarily dictated only by the chemical characteristics of the waste. Wind dispersal of particulates can mobilize even the most immobile, nonvolatile hazardous constituents. Therefore, it is suggested that land treatment air emissions be monitored at frequent intervals to ensure the health and safety of workers and adjacent residents. This effort may be relaxed if the air emissions are positively identified as innocuous compounds or too low in concentration to have any effect. Although air monitoring is not currently required, it is strongly recommended because wind dispersal is a likely pathway for pollutant losses from a land treatment unit.

Sampling generally involves drawing air over a known surface area at a known flow rate for a specified time interval. Low-molecular-weight volatiles may be trapped by solid sorbents, such as Tenax-GC. The high-molecular-weight compounds may be sampled by Florisil, glass-fiber filters, or polyurethane foam.

12.5 ANALYSIS

12.5.1 Analytical Considerations

Parameters to be measured include pH, soil fertility, residual concentrations of degradable rate-limiting constituents (RLC), and the concentrations of residuals that limit the life of the disposal site (CLC), plus those that, if increased in concentration by 25%, would become limiting. Hazardous constituents of concern should also be monitored. Based on the data obtained, the facility management or design can be adjusted or actions taken, as needed, to maintain treatment efficiency. Projections regarding facility life can also be made and compared with original design projections. Because the treatment zone acts as an integrator of all effects, the data can be invaluable to the unit operator.

The analyst should use specific methods in this manual for determining hazardous waste constituents.

12.5.2 Response to Detection of Pollutant Migration

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

1. Alter the waste characteristics.

2. Reduce waste application rate.

3. Alter the method or timing of waste applications.

4. Cease application of one or more particular wastes at the unit.

5. Revise cultivation or management practices.

6. Alter the characteristics of the treatment zone, particularly soil pH or organic matter content.

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