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ABSTRACT

This lesson is an introduction to disposal of sludge by landfill. A brief explanation of the complete process is provided, including discussions of sludge suitability, site selection, method selection and operation, site closure, and ultimate reuse. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, sanitary landfill text material (presented in sections titled: introduction to landfill, method selection, landfill operations, and site closure), references, and worksheet. (JN)

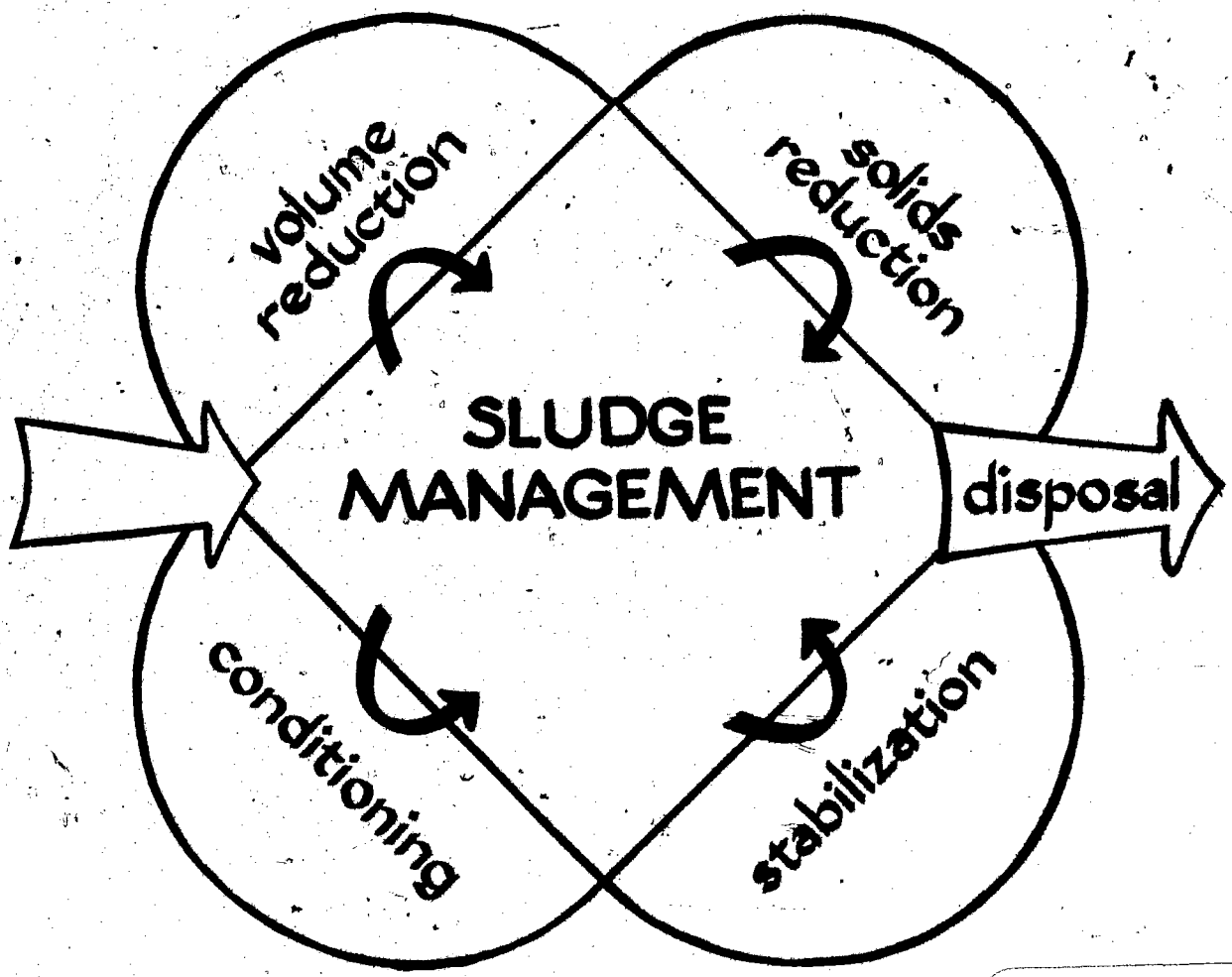
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SANITARY LANDFILL



INSTRUCTOR'S GUIDE

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

LANDFILL

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Developed Under:
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LANDFILL

CONTENTS

LANDFILL

Lesson Description

This lesson is an introduction to disposal of sludge by landfill. Most value would be gained by exposure to this lesson after Unit Processes, but this module is not dependent on any other solids handling preprocessing steps.

This lesson covers a brief explanation of the complete process of disposal of sludge by landfill including sludge suitability, site selection, method selection and operation, site closure and ultimate reuse.

Estimated Time

Student Preview of Objectives	5 - 10 minutes
Presentation of Material	30 - 45 minutes
Worksheet	10 minutes
Correct Worksheet and Discussion	10 minutes

Instructional Materials List

1. Student text, "Landfill".
2. Slide/tape set, "Landfill".
3. Slide projector, 35mm.
4. Tape player with synchronization to slide projector.
5. Screen
6. Samples of sludge with different levels of % solids content.
7. Information on landfill operations in local area.

Suggested Sequence of Presentation

1. Assign text to read before class session.
2. Have students review objectives in class.
3. Show slide/tape program or lecture using the slide series.
4. Assign worksheet.
5. Correct worksheet and discussion on questions that arise.

Required Reading

Student text, "Landfill".

Objectives

Upon completion of this lesson, the student should be able to do the following:

1. Define the process of disposal by landfill.
2. List three other materials removed during the wastewater treatment process that are disposed of in the same manner as sludge.
3. Explain the effect of solids concentration on the method selection and operation of sludge disposal by landfill.
4. Explain why only stabilized sludges are recommended for landfill disposal.
5. Give four examples of landfill site characteristics that will have an influence on the type of landfill method selected.
6. Give three examples of materials used for membrane liners.
7. Explain why liners or imported clays are used.
8. Explain why sludge landfilling sites are limited to slopes of greater than 1% and less than 20%.
9. Describe the disposal of sludge by the sludge only, trench method.
10. Describe the disposal of sludge by the sludge/soil, area fill method.
11. Describe the disposal of sludge by the codisposal with refuse method.
12. Give two examples of variations in normal disposal methods which could be used for applications of low solids content and unstabilized sludges.
13. Describe two equipment operation problems that can result from low solids content sludges.
14. List four physical conditions that effect disposal site selection.
15. Explain why sludge characteristics would have an influence on the site selection process.
16. Explain the importance of leachate control.
17. Explain how methane is produced and why it creates a problem.
18. Describe the process of site closure.
19. List four possible uses of a completed landfill site.
20. Explain why a good plan for final use of the completed landfill is a step toward acceptance of a proposed site.

LANDFILL - LESSON OUTLINE

I. PROCESS OF LANDFILL

A. Definition - Disposal by Landfill

Disposal by landfill can be defined as the planned burial of wastewater solids at a designated site.

B. General - solids are placed in a prepared site or excavated trench and covered with a layer of soil.

C. Complete Process

1. Site selection

2. Landfill operation

3. Site closure and reuse

II. LANDFILL METHOD (SELECTION)

A. Sludge Suitability

1. Stabilized

2. Solids content > 20%

B. Landfill Site Characteristics

1. Types of soils

2. Geology of the area

3. Location of ground and surface water

4. Local topography

a) Slope with minimum slopes of 1%

b) Slope with maximum slopes of 20%

C. Methods of Disposal

1. Sludge only, trench

a) Narrow trench

b) Wide trench

2. Sludge/soil area fill

a) Area-fill mound

b) Area-fill layer

c) Diked containment

3. Codisposal

a) Sludge/refuse mixture

b) Sludge/soil mixture

D. Physical Conditions - Site Selection

1. Site life and size

2. Site access

3. Soils, geology, and topography

4. Ground and surface water

E. Other Conditions - Site Selection

1. Environmentally sensitive areas

2. Archeological and historical significance

3. Types of vegetation

4. Land use and cost

III. OPERATION - MONITORING

A. Leachate

1. Cause

a) Excess moisture in sludge

b) Rainfall

2. Control

a) Storm runoff channels

b) Imported soils and liners

3. Treatment

a) Recycle through landfill

b) Evaporation ponds

c) On-site treatment

d) Discharge with domestic wastewater

B. Methane

1. Produced by decomposition of organic matter

2. 5 - 15% concentration in air - explosive

3. Gas control facilities, vent to atmosphere

C. Worker Safety

1. Caution when transporting, handling, and covering sludge.

2. Washing facilities for

a) Personnel

b) Equipment

D. Continual Monitoring

1. Bacterial quality

2. pH

3. Chlorides, nitrates

4. Total dissolved solids

5. Heavy metals

IV. SITE CLOSURE

A. Final Step in the Overall Process of Landfilling.

B. Final Cover

1. Predetermined plan

2. No exposed sludge

3. Final grading 3 - 5 years after closure.

C. Vegetation

1. Enhance attenuative properties of the soil.
2. Erosion control.
3. Infiltration
4. Visual enhancement

D. Final Use or Reuse

1. Parks
2. Playgrounds
3. Golf courses
4. Parking areas
5. Landing fields
6. Industrial and commercial

E. Continued Monitoring

1. Gas production
2. Leachate
3. Ground stability

Narrative

Slide #

1. This module discusses Landfill Planning and Operations.

2. It was written by Ronald M. Sharman. The instructional development was done by Priscilla Hardin. Paul H. Klopping served as Project Director. Technical review was provided by Envirotech Operating Services.

3. Sludge disposal by landfill represents a popular alternative as the last step in the treatment process.

4. Disposal by landfill can be defined as the planned burial of wastewater solids, including processed sludge, screenings, grit, and ash, at a designated site.

5. In general, the solids are placed in a prepared site or excavated trench and covered with a layer of soil.

6. The complete procedure of disposal by landfill includes an extensive process of site selection, landfill operation, along with plans for site closure and reuse.

7. The sludge landfill operation is concerned with the suitability of the material to be landfilled, the cost of hauling and movement of of the materials, and monitoring for pollutants of the landfill runoff, referred to as leachate, and off gas production.

8. Choice of landfill method is directly related to the suitability of the sludge to be landfilled, and characteristics of the proposed site.

9. Solids content or concentration is related to the nature of the wastewater treatment process and any conditioning or dewatering preprocessing steps.

10. Generally speaking, only dewatered sludges with solids concentrations of greater than 15% are suitable for disposal by landfilling. Sludges with solids contents of less than 15% create handling problems and will not support cover material or machinery.

11. Characteristics of the landfill site that have a bearing on method selection include: 1. Types of soils, 2. Geology of the area, 3. Location of ground and surface water, and 4. Local topography.

12. Soil permeability is the ability of soils to pass or transmit liquid. Desirable landfill sites have deep and fine textured soils. The finer the soil, the greater the protection of nearby ground water quality. Sites operating on clay and clay loams, for instance, have operated successfully with as little as 2 - 5 feet of soil separating sludge deposits from the highest ground water levels.

13. Both bedrock and water table levels influence the choice of landfill method. All efforts must be made to halt possible contamination of the ground water. Geologic examination is required to locate any irregular formations such as faults and fractures that could lead to ground water contamination.

14. Membrane liners are sometimes used when soil permeabilities or soil depths are not adequate to protect ground water quality. The most common being asphaltic materials or synthetic membranes. Imported clays or polymeric materials can also be used to lower soil permeabilities.

15. Sludge landfilling is limited to sites with minimum slopes of 1% and maximum slopes of 20%.

16. Flat terrain tends to cause ponding, whereas steep slopes promote erosion.

17. The methods of disposal of sludge by landfill are divided into three categories: 1. Sludge only, trench; 2. Sludge/soil, area fill; 3. Codisposal, with refuse.

18. The sludge only, trench, method takes two forms: narrow and wide trench. Both forms involve the excavation of trenches so that the dewatered sludge is entirely buried below the original ground surface. Normal operation allows for the sludge to be deposited directly into the trench from a haul vehicle. Daily cover of the newly deposited sludge reduces odors and controls vecotrs.

19. Narrow trenches have widths of less than 10 feet. They allow for applications of low solids content and unstabilized sludges.

20. Excavation and covering equipment operate from the surface areas adjacent to the trench. This method requires surface soil cover thickness of 4 feet.

21. Wide trenches usually receive sludges with solids contents of 20% or more. Excavation is accomplished by equipment which enters the trench itself. In daily operation, equipment travels out on the sludge spreading a layer of cover soil before it.

22. Wide trench, technically classified as greater than 10 feet, may in reality occupy acres of land.

23. In comparison, a narrow trench operation can accept lower solids content sludges, whereas a wide trench operation permits more intensive land use.

24. In a sludge/soil, area-fill operation, sludge is usually placed entirely above the original ground surface.

25. The sludge received is usually mixed with soil in increase its effective solids content and stability. This allows for disposal in areas of shallow ground water or prominent bedrock.

26. Sludge that is received at the landfill is usually mixed with a bulking agent which absorbs excess moisture from the sludge and increases its workability. The amount of soil required to serve as a bulking agent depends upon the original solids content of the sludge.

27. Area-fill mound operations require a solids content of 20% or more. The sludge/soil mixtures are stacked into mounds approximately 6 feet high. Cover soil is applied atop each lift of mounds in a 3 foot thickness.

28. The area-fill layer method lends intself to lower solids contents of around 15%. The sludge/soil mixtures are spread evenly in layers ½ - 3 feet thick. Interim cover between layers is about 1 foot of soil, with a final cover of 3 - 5 feet. Level ground is preferred for this operation but mildly sloping terrain can be used.

29. Aboveground diked containments receive sludge of 20% or more solids content. Haul vehicles dump their sludge directly form the top of the dikes, building layers up to 10 feet thick with a cover layer of 3 - 5 feet. In this application, sludge may or may not be mixed with soil.

30. Sludge area-fill methods allow for good land utilization in areas of shallow water tables or bedrock. These methods may require imported soils as a bulking agent, greater machine operation time, and a greater need for runoff or leachate control.

31. Codisposal is defined as the receipt of sludge at a conventional municipal before landfill site. Two methods of codisposal have been identified. 1. Sludge/refuse mixture, 2. Sludge/soil mixture.

32. In a sludge refuse landfill, stabilized or unstabilized sludge with a solids content of 3% or more can be mixed with refuse. This sludge mixture is then spread at the working face of the landfill. The sludge and refuse are thoroughly mixed, compacted and covered with a soil layer of 2 feet.

33. When problems occur at codisposal landfills, the difficulties are often due to the liquid nature of sludge. Sludge of low solids content is difficult to confine and may cause equipment slippage.

34. A modification of sludge-refuse condisposal is sometimes used in which sludge is mixed with soil and applied as cover over a completed refuse fill area. Although this, technically, is not sludge land filling, it is a viable alternative which is particularly useful in promoting vegetative growth in completed fill areas and reducing siltation or erosion.

35. Using existing refuse landfills for condisposal offers several advantages: 1. Easy site approval, 2. Less public opposition, 3. Lower cost.

36. The method of landfill operation is an integral part of the site selection process.

37. Other factors involved in selecting a sludge landfill site span many disciplines: land use planning, economics, engineering, along with social and political concerns.

38. Some of the physical conditions that affect disposal site selection require a closer look. These include: 1. Site life and size, 2. Site acess, 3. Soil, geology, and topography, 4. Ground and surface water.

39. Site life and size is directly related to sludge quantity and method of landfill. Since the entire area cannot be used as fill area, concessions must be made for buffer areas, access roads, and on-site structures.

40. The haul routes to the prospective site should utilize major highways to the maximum extent possible. The most favorable haul conditions combine level terrain, miniumu distance, and low numbers of schools, residences, parks, and traffic congestion.

41. The Clean Water Ace of 1973 requires that all point source discharges of pollutants must comply with NPDES Permits issued for the facility. Water quality must be protected, whether it be existing surface water on the site or the ground water table, including its recharge zone.

42. Many of the problems resulting from poor choice of topography and soil types can be prevented by careful site selection. Ponding, erosion, and contamination of water supplies.

43. Other factors that will influence the site selection process include: 1. A concern for environmentally sensitive areas, 2. The archeological and historical significance of the site, 3. The types of vegetation, and 4. Land use and cost.

44. Environmentally sensitive areas such as wetlands, floodplains, permafrost areas, critical habitats of endangered species, and recharge zones of sole source aquifers should be avoided when selecting a landfill site.

45. The determination of the archaeological or historical status of a potential site is usually addressed in an environmental impact report. Any finds of significance in relation to the archaeology or history of the site must be accommodated before the site can be approved.

46. The type and quantity of vegetation in the area of the proposed site should be considered during evaluation. Vegation can serve as a natural buffer, reducing visual impact, odor, and other nuisances. At the same time, clearing a site of timber can add significantly to the initial project costs.

47. Early in the site selection process, cost-effectiveness, both in capital costs and estimated operational costs must be evaluated. Zoning restrictions, including the assessment of current and future development, should also be considered.

48. Consideration must also be given to local, state, and federal regulations governing the degree of sludge stabilization, the loading rates, the frequency and depth of cover, monitoring, and reporting.

49. The acceptability of a given combination of the landfilling method and site are contingent on the characterisitics of the sludge received. A thorough investigation of sludge characteristics should be performed before site and method selection are finalized.

50. The evaluation of sludge characteristics performed during site selection represents the beginning of a long-term monitoring responsibility covering site operation, closure, and restoration. This usually addresses ground water and/or surface water quality along with the possibility of gas production.

51. Measurements of volatility indicate possible levels of odor production. Measurements of solids content dictates the handleability of the sludge. Both sludge characteristics influence landfill operations.

52. The presence of heavy metals, such as lead, zinc, and cadmium, along with nitrates, chlorides, and other toxic material should be identified. These substances move easily through the soil and represent a potential pollution source.

53. Excess moisture in landfill sludge runs off as leachate. Rainfall can increase the problem. A properly designed fill will allow storm water runoff to be diverted around the landfill.

54. Surface water, leachate, and ground water should be tested on a continual basis.

55. Bacterial quality, pH, and total dissolved solids are the major constitutents included in this type of analysis.

56. Leachate may enter into the water system by either percolation, through the soil, or runoff into surface waters. Careful site selection and attention to design considerations can prevent or minimize leachate contamination.

57. The control of leachate may be accomplished by natural conditions such as deep and less permeable soils. Where permeable soils exist, imported soils or liners are used to contain collected leachate.

58. Collected leachate may be treated by recycle through the landfill, evaporation from shallow collection ponds, or by installing a small on-site treatment plant. Depending on the leachate characteristics, it may by possible to discharge to an existing wastewater system for subsequent treatment with domestic wastewater.

59. Gas is produced by the decomposition of organic matter in sludge. The primary gases of decomposition are methane and carbon dioxide. When methane is present in air at between 5 - 15% concentration and is confirmed in an enclosed area, it may be explosive.

60. The methane produced at a sludge landfill can move through the soil by diffusion to the atmosphere where it dissipates or it can seep into nearby buildings which can create hazardous conditions.

61. Installation of gas control equipment may be necessary when inhabitated structures or buildings are located near the landfill. Migration can be controlled by installing barriers to gas flow and/or by collecting and venting the gas.

62. As with any construction activity, safety methods must be implemented in accordance with OSHA guidelines. Work areas and access roads must be well marked to avoid on-site vehicle mishaps. Personnel should use caution when transporting, handling, and covering sludge. Washing facilities should be located on or near the disposal site for use in case of bodily or equipment contact with sludge.

63. Planning for site closure and ultimate use of the fill site represents the final step in the overall process of sludge landfilling.

64. When each section of the landfill is completed, the final cover should be graded according to a predetermined plan. It is imperative that no sludge remain or become exposed after the grading has been completed.

65. Final grading of the site is to be performed after sufficient time has elapsed to allow for initial settlement. Settlement due to the volume reduction of sludge creates cracks or fissures in the cover material. Experience has shown that additional grading may take place 3 - 5 years after closure. It is important that all sludge be completely covered to the specified depth with cover material.

66. Leachate and gas from sludge landfills will continue to be produced long after the fill is completed. An ongoing monitoring and control program must be maintained and continued after site closure.

67. In most instances, a completed site will require some vegetation. Through careful selection, plants can enhance the attenuative properties of the soil as well as perform the traditional functions of erosion control, infiltration management, and visual enhancement.

68. Lands reclaimed by landfill disposal operations can be valuable assets as parks, playgrounds, golf courses, parking areas, landing fields, light industrial and commercial building sites.

69. It is important to understand that construction on a completed landfill can be hazardous. Problems can arise from non-stable ground, continuing gas production, odors, and leachate.

70. Land reclaimed by landfill disposal operations can be a valuable asset to a city. Final land use can be compatible with and complementary to existing natural conditions and activities and help meet the future needs of the community.

71. The selection and design of final land uses should be the result of a comprehensive land planning study that considers all aspects of site selection, proposed filling operations, as well as closure and final uses.

LANDFILL - WORKSHEET

1. Disposal by landfill can be defined as:

   _____ a. The utilization of screenings, grit, and ash as a bulking agent.

   _____ b. The bacterial stabilization of septic sludge.

   __X__ c. The planned burial of wastewater solids at a designated site.

   _____ d. The compression of solids to reduce overall volume.

2. The complete procedure of disposal by landfill includes:

   __X__ a. Site selection

   _____ b. Suitability selection

   __X__ c. Landfill operation

   __X__ d. Site closure and reuse

3. The major cost involved with landfill operation is:

   _____ a. Equipment maintenance

   _____ b. Chemical purchase

   _____ c. Road repair

   __X__ d. Sludge hauling

4. Soil permeability is the ability of soils to:

   __X__ a. Pass or transport liquid

   _____ b. Contaminate ground water

   _____ c. Support equipment

   _____ d. Create erosion

5. The existence of any irregular formations such as faults or fractures could lead to:

   _____ a. Archeological finds

   _____ b. A slow up in operation

   __X__ c. Ground water contamination

   _____ d. Fast site selection

6. Materials that make up membrane liners include:

   X a. Asphaltic compositions

   X b. Portland cement

   X c. Liquid rubbers

   X d. Synthetic polymer membranes

7. Which method of disposal of sludge by landfill involves excavation below the original ground surface?

   ____ a. Sludge/soil, area fill

   X b. Sludge only, trench

   ____ c. Codisposal with refuse

8. Which method involves the receipt of sludge at a conventional municipal landfill?

   ____ a. Sludge only, trench

   ____ b. Sludge/soil, area fill

   X c. Codisposal with refuse

9. Which method involves the placement of sludge above the original ground surface?

   ____ a. Sludge only, trench

   X b. Sludge/soil, area fill

   ____ c. Codisposal with refuse

10. Which two variations on normal disposal methods could be used for applications of low solids content or unstabilized sludges?

   X a. Sludge only, narrow trench

   ____ b. Sludge only, wide trench

   ____ c. Sludge/soil, area fill layer

   ____ d. Sludge/soil, area fill mound

   ____ e. Sludge/soil, diked containment

   X f. Codisposal, sludge/refuse mix

   ____ g. Codisposal, sludge/soil mix

11. Sludge of low solids content is difficult to confine and also:

    X a. Will not support equipment.

    ____ b. Causes direct ground water contamination.

    ____ c. Slows the process of site closure.

    X d. May cause equipment slippage.

12. Factors involved in selecting a sludge landfill site span many disciplines. Some of these include:

    X a. Land use planning

    X b. Economics

    X c. Engineering

    X d. Social and political fields

13. The acceptability of a given combination of landfill methods and sites is contingent on the characteristics of the sludge received. Some of these sludge characteristics include:

    X a. Volatility

    X b. Heavy metals

    ____ c. Color

    ____ d. Taste

    X e. Moisture

14. Excess moisture at the landfill site is referred to as:

    ____ a. Permeate

    ____ b. Potassium contaminate

    X c. Leachate

    ____ d. Solids concentration

15. Excess moisture or runoff can be controlled by:

    ____ a. Deep well injection

    X b. Deep and less permeable soils

    X c. Imported soils or liners

    ____ d. Sun drying

16. Methane is produced by the decomposition of organic matter in sludge. At what concentration, methane in air, is it explosive?

    _____ a. 0 - 5%
    X b. 5 - 15%
    _____ c. 15 - 30%
    _____ d. 30 - 40%

17. Experience has shown that additional grading may take place _____ years after site closure.

    _____ a. 1 - 3 years
    X b. 3 - 5 years
    _____ c. 5 - 9 years
    _____ d. 13 years

18. A good plan for final use of the completed landfill is a step toward _____ of a proposed site.

    _____ a. abandonment
    _____ b. reclamation
    X c. acceptance
    _____ d. solicitation

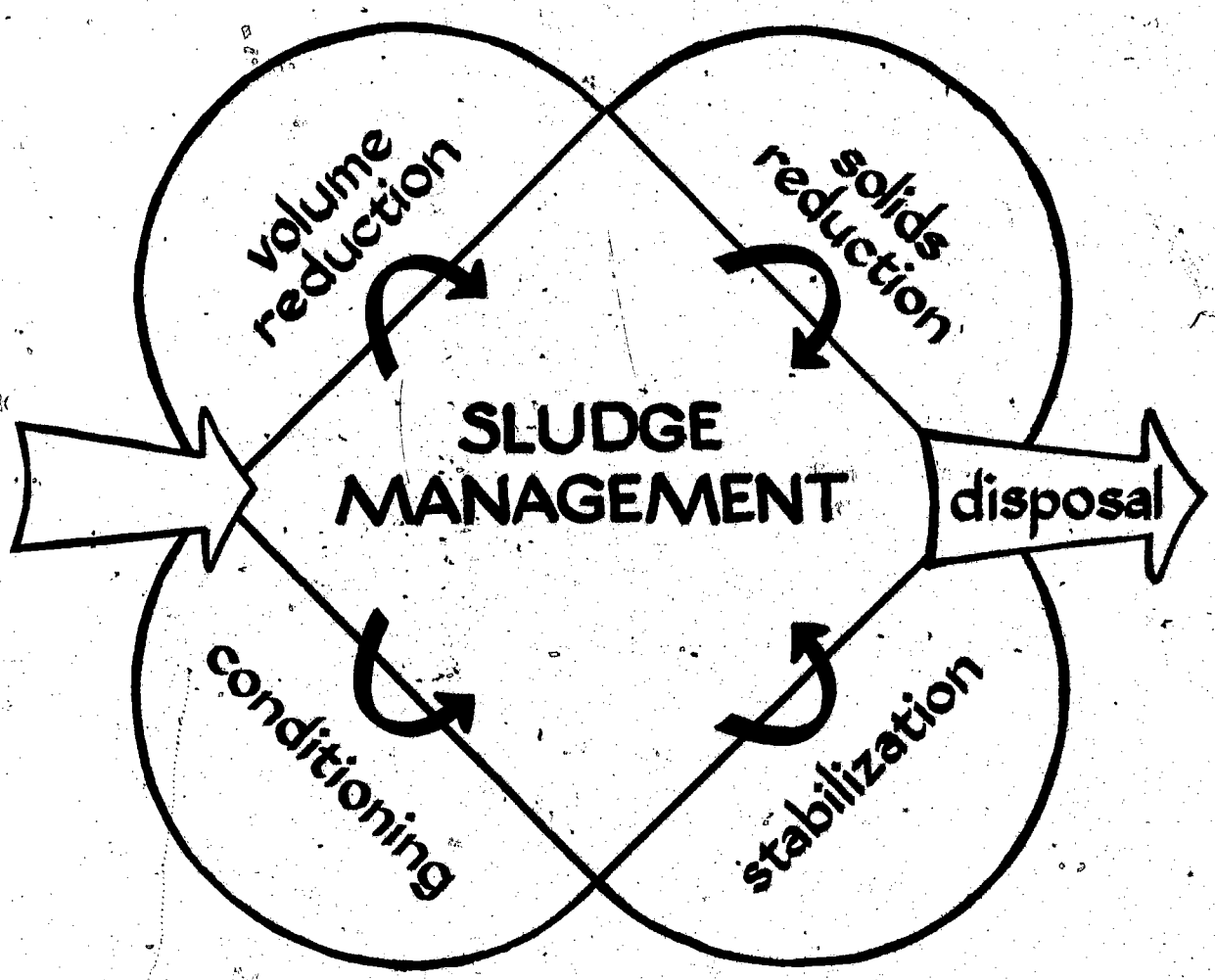
SLUDGE TREATMENT

and

DISPOSAL

COURSE # 166

SANITARY LANDFILL



STUDENT WORKBOOK

Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

LANDFILL

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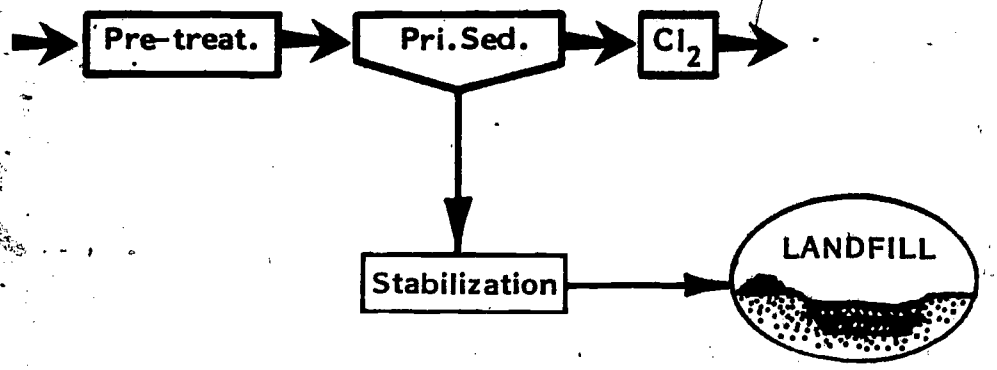
LANDFILL

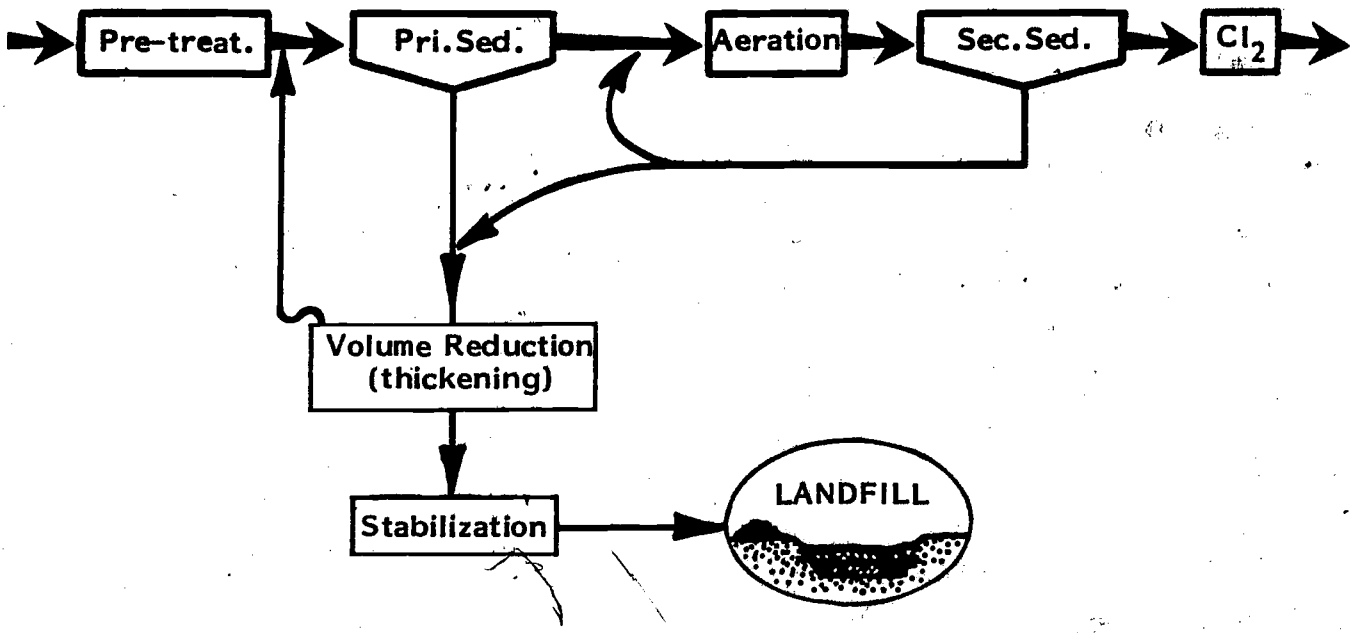
CONTENTS

PLANT FLOW DIAGRAMS

PRIMARY PLANT



SECONDARY PLANT



Objectives

Upon completion of this lesson, the student should be able to do the following:

1. Define the process of disposal by landfill.
2. List three other materials removed during the wastewater treatment process that are disposed of in the same manner as sludge.
3. Explain the effect of solids concentration on the method selection and operation of sludge disposal by landfill.
4. Explain why only stabilized sludges are recommended for landfill disposal.
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LANDFILL

GLOSSARY

Archaeology -- The scientific study of material remains (as fossils, relics, artifacts, monuments) of past human life.

Bulking Agent - Materials used to absorb excess moisture from sludge to increase solids concentration and handleability. Soil, wood chips, and sometimes refuse, are commonly used.

Codisposal - Landfill method where sludge is received at a conventional municipal refuse landfill.

Dewater - To drain or remove water from sludge with the purpose of reducing overall volume and to increase handleability.

Leachate - Excess moisture in the sludge or rainfall runoff which could cause contamination to ground water by percolation through the soil.

Membrane Liners - Asphalt, cement, rubber, or synthetic polymer membranes used as protection against ground water contamination.

Methane - Gas by-product of the decomposition of organic matter. When methane is present in air at concentrations between 5 - 15%, it is potentially explosive.

Permeability - (1) The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.
(2) The capacity of a rock or rock-material to transmit a fluid.

Recharge Zone - Zone from which precipitation flows into underground water sources.

Rock Fault - A fracture in the earth's crust accompanied by the displacement of one side of the fracture with respect to the other and in a direction parallel to the fracture. This results in a channel where the flow of water or other substances can take place.

Sludge Only, Trench - Landfill method which involves the excavation of trenches so that dewatered sludge is entirely buried below the ground surface.

LANDFILL - GLOSSARY

Sludge/Soil, Area Fill - Landfill method where dewatered sludge is placed above the original ground surface.

Solids Concentration - The amount or percentage of solids in a unit volume of water.

Stabilized Sludge - A sludge that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would not cause a nuisance or odors.

Volatile Solids - The quantity of solids in water, sewage or sludge, lost on ignition of the dry solids at 600° C.

Water Table - The average depth or elevation of the ground water over a selected area.

LANDFILL PLANNING & OPERATIONS

This module discusses Landfill Planning and Operations.

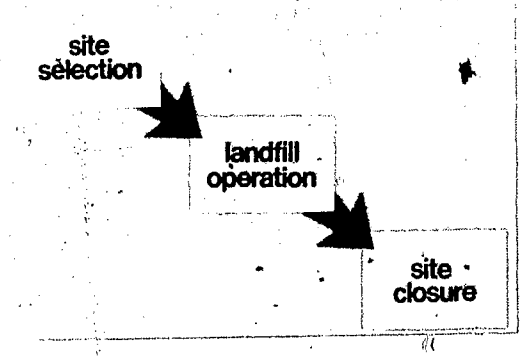
It was written by Ronald M. Sharman. The instructional development was done by Priscilla Hardin. Paul H. Klopping served as Project Director. Technical review was provided by Envirotech Operating Services.

Ultimate Disposal Method

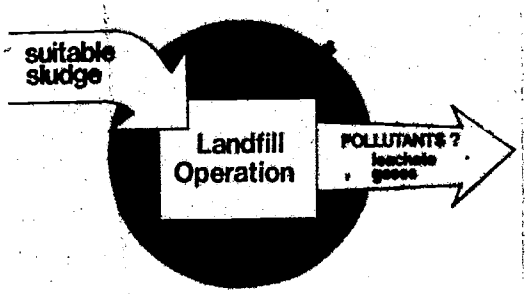
Sludge disposal by landfill represents a popular alternative as the last step in the treatment process.

Disposal by landfill can be defined as the planned burial of wastewater solids, including processed sludge, screenings, grit, and ash, at a designated site.

In general, the solids are placed in a prepared site or excavated trench and covered with a layer of soil.



The complete procedure of disposal by landfill includes an extensive process of site selection, landfill operation, along with plans for site closure and reuse.



The sludge landfill operation is concerned with the suitability of the material to be landfilled, the cost of hauling and movement of the materials, and monitoring for pollutants of the landfill runoff, referred to as leachate, and off gas production.

Choice of landfill method is directly related to the suitability of the sludge to be landfilled and characteristics of the proposed site.

STABILIZATION? To offset potential odor and vector problems only stabilized sludges should be used. Solids content or concentration is related to the nature of the wastewater treatment process and and conditioning or dewatering preprocessing steps.

15% solids or more! Generally speaking, only dewatered sludges with solids concentrations of greater than 15% are suitable for disposal by landfilling. Sludges with solids contents of less than 15% create handling problems and will not support cover material or machinery.

LANDFILL CHARACTERISTICS Characteristics of the landfill site that have a bearing on method selection include:

1. Types of soils.
2. Geology of the area.
3. Location of ground and surface water.
4. Local topography.

PERMEABILITY Soil permeability is the ability of soils to pass or transmit liquid. Desirable landfill sites have deep and fine textured soils. The finer the soil, the greater the protection of nearby ground water quality. Sites operating on clay and clay loams, for instance, have operated successfully with as little as 2 - 5 feet of soil separating sludge deposits from the highest ground water elevations.

BEDROCK Both bedrock and water table levels influence the choice of landfill method. All efforts must be made to halt possible contamination of the ground water. Geologic examination is required to locate any irregular formations such as faults and fractures that could lead to ground water contamination.

WATER TABLE

PROTECT THE GROUND WATER

Membrane liners are sometimes used when soil premeabilities or soil depths are not adequate to protect ground water quality. The most common types are asphaltic materials or synthetic membranes. Imported clays or polymeric materials can also be used to lower soil permeabilities.

SLOPE - - 1% - 20%

Sludge landfilling is limited to sites with minimum slopes of 1% and maximum slopes of 20%.

Flat terrain tends to cause ponding, whereas steep slopes promote errosion.

The methods of disposal of sludge by landfill are divided into three categories:

1. Sludge only, trench.
2. Sludge/soil, area fill.
3. Codisposal, with refuse.

TRENCHES - SLUDGE ONLY

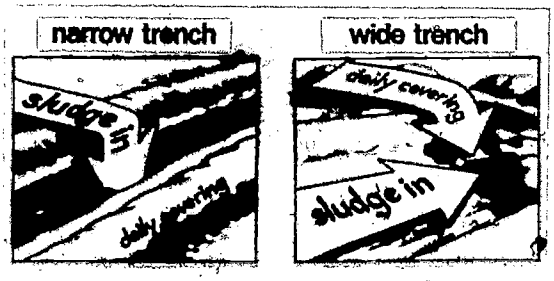
***Narrow**

***Wide**

The sludge only, trench method takes two forms: narrow and wide trench. Both forms involve the excavation of trenches so that the dewatered sludge is entirely buried below the original ground surface. Normal operation allows for the sludge to be deposited directly into the trench from a haul vehicle. Daily cover of the newly deposited sludge reduces odors and controls vectors.

NARROW TRENCH

Narrow trenches have widths of less than 10 feet. They allow for applications of low solids content and unstabilized sludges.



accepts low solids sludges

permits more intensive land use

Excavation and covering equipment operate from the surface areas adjacent to the trench. This method requires surface soil cover thickness of 4 feet.

Wide trenches usually receive sludges with solids contents of 20% or more. Excavation is accomplished by equipment which enters the trench itself. In daily operation, equipment travels out on the sludge spreading a layer of cover soil before it.

Wide trench, technically classified as greater than 10 feet, may in reality occupy acres of land.

In comparison, a narrow trench operation can accept lower solids content sludges, whereas a wide trench operation permits more intensive land use.

SLUDGE/SOIL - AREA FILL In a sludge/soil, area-fill operation, sludge is usually placed entirely above the original ground surface.

The sludge received is usually mixed with a soil as a bulking agent to increase its effective solids content and stability. This allows for land surface application in areas of shallow ground water or prominent bedrock.

BULKING AGENT Sludge that is received at the landfill is usually mixed with a bulking agent which absorbs excess moisture from the sludge and increases its workability. The amount of soil required to serve as a bulking agent depends upon the original solids content of the sludge.

AREA-FILL OPERATIONS

Area-fill mound operations require a solids content of 20% or more. The sludge/soil mixtures are stacked into mounds approximately 6 feet high. Cover soil is applied atop each lift of mounds in a 3 foot thickness.

AREA-FILL LAYER METHOD

The area-fill layer method lends itself to lower solids contents of around 15%. The sludge/soil mixtures are spread evenly in layers 0.5 - 3 feet thick. Interim cover between layers is about 1 foot of soil, with a final cover of 3 - 5 feet. Level ground is preferred for this operation but mildly sloping terrain can be used.

DIKED CONTAINMENTS

Aboveground diked containments receive sludge of 20% or more solids content. Haul vehicles dump their sludge directly from the top of the dikes, building layers up to 10 feet thick with a cover layer of 3 - 5 feet. In this application, sludge may or may not be mixed with soil.

AREA-FILL

*shallow water table
*bedrock
*require bulking agent
*machinery
*leachage control

Sludge area-fill methods allow for good land utilization in areas of shallow water tables or bedrock. These methods may require imported soils as a bulking agent, greater machine operation time, and a greater need for runoff or leachate control.

CODISPOSAL

*Sludge/refuse

*Sludge/soil

*3% sludge minimum conc

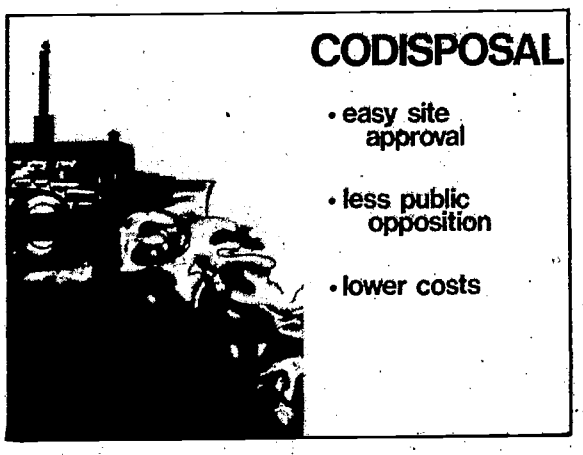
Codisposal is defined as the receipt of sludge at a conventional municipal refuse landfill site. Two methods of codisposal have been identified.

1. Sludge/refuse mixture.
2. Sludge/soil mixture.

In a sludge refuse landfill, stabilized or unstabilized sludge with a solids content of 3% or more can be mixed with refuse. This sludge mixture is then spread at the working face of the landfill. The sludge and refuse are thoroughly mixed, compacted and covered with a soil layer of 2 feet.

When problems occur at codisposal landfills, the difficulties are often due to the liquid nature of sludge. Sludge of low solids content is difficult to confine and may cause equipment slippage.

A modification of sludge-refuse codisposal is sometimes used in which sludge is mixed with soil and applied as cover over a completed refuse fill area. Although this, technically, is not sludge land filling, it is a viable alternative which is particularly useful in promoting vegetative growth in completed fill areas and reducing siltation or erosion.



Using existing refuse landfills for codisposal offers several advantages:

1. Easy site approval.
2. Less public opposition.
3. Lower cost.

The method of landfill operation is an integral part of the site selection process.

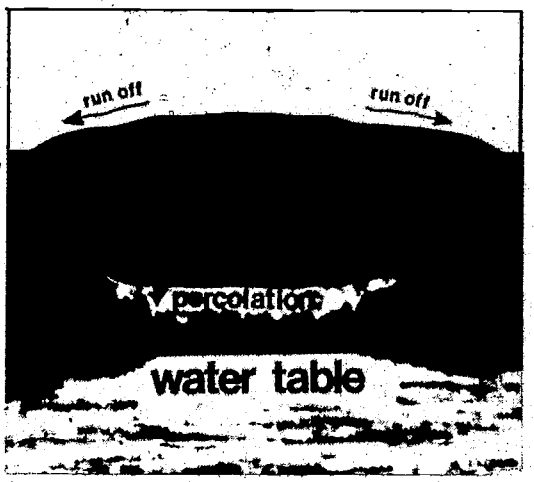
Other factors involved in selecting a sludge landfill site span many disciplines: land use planning, economics, engineering, along with social and political concerns.

Some of the physical conditions that affect disposal site selection require a closer look. These include:

1. Site life and size.
2. Site access.
3. Soils, geology, and topography.
4. Ground and surface water.

Site life and size is directly related to sludge quantity and method of landfill. Since the entire area cannot be used as fill area, concessions must be made for buffer areas, access roads, and on-site structures.

The haul routes to the prospective site should utilize major highways to the maximum extent possible. The most favorable haul conditions combine level terrain, minimum distance, and low numbers of schools, residences, parks, and traffic congestion.

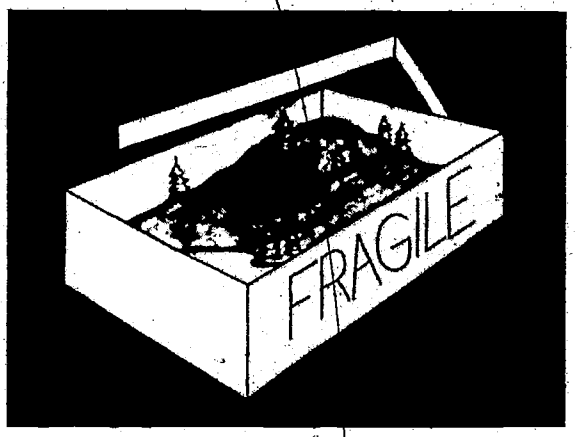


The Clean Water Act of 1973 requires that all point source discharges of pollutants must comply with NPDES Permits issued for the facility. Water quality must be protected, whether it be existing surface water on the site or the ground water table and its recharge zone.

Ponding, erosion, and contamination of water supplies can be prevented by careful selection of topography and soil types.

Other factors that will influence the site selection process include:

1. A concern for environmentally sensitive areas.

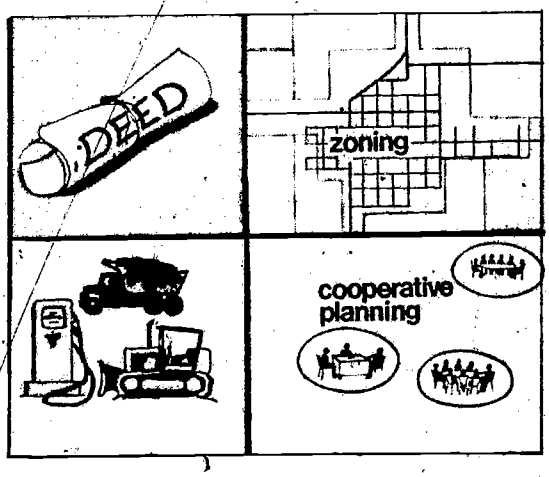


2. Archeological and historical significance.
3. Types of vegetation.
4. Land use and cost.

Environmentally sensitive areas such as wetlands, floodplains, permafrost areas, critical habitats of endangered species, and recharge zones of sole source aquifers should be avoided when selecting a landfill site.

The determination of the archaeological or historical status of a potential site is usually addressed in an environmental impact report. Any finds of significance in relation to the archaeology or history of the site must be accommodated before the site can be approved.

The type and quantity of vegetation in the area of the proposed site should be considered during evaluation. Vegetation can serve as a natural buffer, reducing visual impact, odor, and other nuisances. At the same time, clearing a site of timber can add significantly to the initial project costs.



Early in the site selection process, cost-effectiveness, both in capital costs and estimated operational costs must be evaluated. Zoning restrictions, including the assessment of current and future development, should also be considered.

Consideration must also be given to local, state, and federal regulations governing the degree of sludge stabilization, the loading rates, the frequency and depth of cover, monitoring, and reporting.

SLUDGE CHARACTERISTICS? The acceptability of a given combination of the landfilling method and site are contingent on the characteristics of the sludge received. A thorough investigation of sludge characteristics should be performed before site and method selection are finalized.

The evaluation of sludge characteristics performed during site selection represents the beginning of a long-term monitoring responsibility covering site operation, closure, and restoration. This usually addresses ground water and/or surface water quality along with the possibility of gas production.

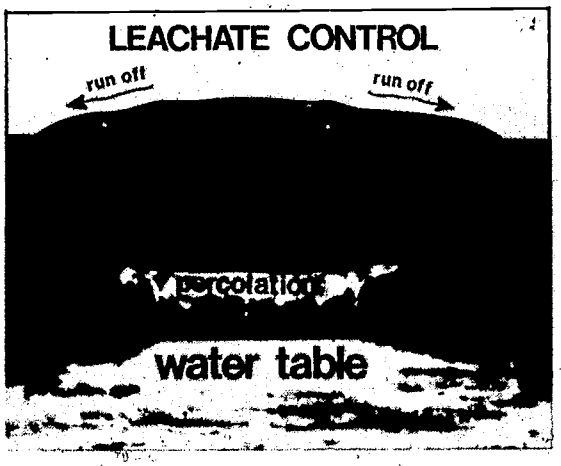
VOLATILITY Measurements of volatility indicate possible levels of odor production. Measurements of solids content dictates the handleability of the sludge. Both sludge characteristics influence landfill operations.

HEAVY METALS The presence of heavy metals, such as lead, zinc, and cadmium, along with nitrates, chlorides, and other toxic material should be identified. These substances move easily through the soil and represent a potential pollution source.

MOISTURE Excess moisture in landfill sludge runs off as leachate. Rainfall can increase the problem. A properly designed fill will allow storm water runoff to be diverted around the landfill.

Surface water, leachate, and ground water should be tested on a continual basis.

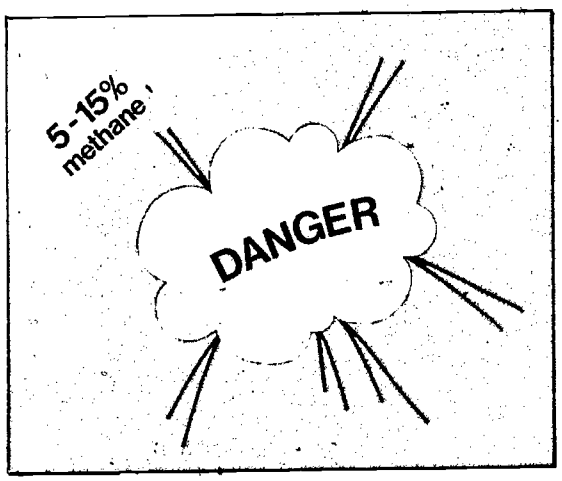
Bacterial quality, pH, and total dissolved solids are the major parameters or constituents included in this type of analysis.



Leachate may enter into the water system by either percolation, through the soil, or runoff into surface waters. Careful site selection and attention to design considerations can prevent or minimize leachate contamination.

The control of leachate may be accomplished by natural conditions such as deep and less permeable soils. Where permeable soils exist, imported soils or liners are used to contain collected leachate.

Collected leachate may be treated by recycle through the landfill, evaporation from shallow collection ponds, or by installing a small on-site treatment plant. Depending on the leachate characteristics, it may be possible to discharge to an existing wastewater system for subsequent treatment with domestic wastewater.



Gas is produced by the decomposition of organic matter in sludge. The primary gases of decomposition are methane and carbon dioxide. When methane is present in air at between 5 - 15% concentration and is confined in an enclosed area, it may be explosive.

The methane produced at a sludge landfill can move through the soil by diffusion to the atmosphere where it dissipates or it can seep into nearby buildings which can create hazardous conditions.

Installation of gas control equipment may be necessary when inhabited structures or buildings are located near the landfill. Migration can be controlled by installing barriers to gas flow and/or by collecting and venting the gas.

As with any construction activity, safety methods must be implemented in accordance with OSHA guidelines. Work areas and access roads must be well marked to avoid on-site vehicle mishaps. Personnel should use caution when transporting, handling, and covering sludge. Washing facilities should be located on or near the disposal site for use in case of bodily or equipment contact with sludge.

SITE CLOSURE

Planning for site closure and ultimate use of the fill site represents the final step in the overall process of sludge landfilling.

When each section of the landfill is completed, the final cover should be graded according to a predetermined plan. It is imperative that no sludge remain or become exposed after the grading has been completed.

Final grading of the site is to be performed after sufficient time has elapsed to allow for initial settlement. Settlement due to the volume reduction of sludge creates cracks or fissures in the cover material. Experience

has shown that additional grading may take place 3-5 years after closure. It is important that all sludge be completely covered to the specified depth with cover material.

Leachate and gas from sludge landfills will continue to be produced long after the fill is completed. An ongoing monitoring and control program must be maintained and continued after site closure.

LAND RECLAMATION

In most instances, a completed site will require some vegetation. Through careful selection, plants can enhance the attenuative properties of the soil as well as perform the traditional functions of erosion control, infiltration management, and visual enhancement.

Lands reclaimed by landfill disposal operations can be valuable assets as parks, playgrounds, golfcourses, parking areas, landing fields, light industrial and commercial building sites.

It is important to understand that construction on a completed landfill can be hazardous. Problems can arise from non-stable ground, continuing gas production, odors, and leachate.

Land reclaimed be landfill disposal operations can be a valuable asset to a city. Final land use can be compatible with and complementary to existing natural conditions and activities and help meet the future needs of the community.

COMPREHENSIVE PLANNING The selection and design of final land uses should be the result of a comprehensive land planning study that considers all aspects of site selection, proposed filling operations, as well as closure and final uses.

DESIGN CRITERIA

Method	Sludge solids content	Trench width	Bulking required	Bulking agent	Bulking ratio[a]	Cover Thickness Interim	Cover Thickness Final	Imported soil required	Sludge application rate (in actual fill areas)	Equipment
Narrow trench	15-20% 20-28%	2-3 ft. 3-10 ft.	No[c] No[c]	--- ---	---	------ ------	2-3 ft. 3-4 ft.	No	1,200-5,600 yd^3/acre	Backhoe with loader, excavator, trenching machine
Wide trench	20-28% ≥28%	10 ft. 10 ft.	No[c] No[d]	--- ---	---	------	3-4 ft. 4-5 ft.	No	3,200-14,500 yd^3/acre	Track loader, dragline, scraper, track dozer
Area fill mound	≥20%	---	Yes[d]	Soil	0.5-1 soil 1 sludge	3 ft.	3-5 ft.	Yes	3,000-14,000 yd^3/acre	Track loader, backhoe with loader, track dozer
Area fill layer	≥15%	---	Yes[d]	Soil	0.25-1 soil: sludge	0.5-1 ft.	2-4 ft.	Yes	2,000-9,000 yd^3/acre	Track dozer, grader, track loader
Diked containment	20-28% ≥28%	--- ---	No[b,c] No[b,d]	Soil Soil	0.25-0.5 soil: 1 sludge	1-2 ft.	3-4 ft.	Yes	4,800-15,000 yd^3/acre	Dragline, track dozer, scraper
Sludge/refuse mixture	≥3%	---	Yes[d]	Refuse	4-7 tons refuse: 1 wet ton sludge	0.5-1 ft.	2 ft.	No	500-4,200 yd^3/acre	Dragline, track loader
Sludge/soil mixture	≥20%	---	Yes	Soil	1 soil: 1 sludge	0.5-1 ft.	2 ft.	No	1,600 yd^3/acre	Tractor with disc, grader, track loader

[a] Volume basis unless otherwise noted.
[b] But sometimes used.
[c] Land-based equipment
[d] Sludge-based equipment

1 ft = 0.305 m
1 yd^3 = 0.765 m^3
1 acre = 0.405 ha

References

1. Process Design Manual for Sludge Treatment and Disposal, U.S.E.P.A., EPA 430/9-78-011, Cincinnati, 1979.

2. Process Design Manual for Municipal Sludge Landfills, U.S.E.P.A., EPA-625/1-78-010, Cincinnati, October, 1978.

3. Process Design Manual for Sludge Treatment and Disposal, U.S.E.P.A., EPA-625/1-79-011, September, 1979.

LANDFILL - WORKSHEET

1. Disposal by landfill can be defined as:

   _____ a. The utilization of screenings, grit, and ash as a bulking agent.

   _____ b. The bacterial stabilization of septic sludge.

   _____ c. The planned burial of wastewater solids at a designated site.

   _____ d. The compression of solids to reduce overall volume.

2. The complete procedure of disposal by landfill includes:

   _____ a. Site selection

   _____ b. Suitability selection

   _____ c. Landfill operation

   _____ d. Site closure and reuse

3. The major cost involved with landfill operation is:

   _____ a. Equipment maintenance

   _____ b. Chemical purchase

   _____ c. Road repair

   _____ d. Sludge hauling

4. Soil permeability is the ability of soils to:

   _____ a. Pass or transport liquid

   _____ b. Contaminate ground water

   _____ c. Support equipment

   _____ d. Create erosion

5. The existence of any irregular formations such as faults or fractures could lead to:

   _____ a. Archeological finds

   _____ b. A slow up in operation

   _____ c. Ground water contamination

   _____ d. Fast site selection

11. Sludge of low solids content is difficult to confine and also:

_____ a. Will not support equipment.

_____ b. Causes direct ground water contamination.

_____ c. Slows the process of site closure.

_____ d. May cause equipment slippage.

12. Factors involved in selecting a sludge landfill site span many disciplines. Some of these include:

_____ a. Land use planning

_____ b. Economics

_____ c. Engineering

_____ d. Social and political fields

13. The acceptability of a given combination of landfill methods and sites is contingent on the characteristics of the sludge received. Some of these sludge characteristics include:

_____ a. Volatility

_____ b. Heavy metals

_____ c. Color

_____ d. Taste

_____ e. Moisture

14. Excess moisture at the landfill site is referred to as:

_____ a. Permeate

_____ b. Potassium contaminate

_____ c. Leachate

_____ d. Solids concentration

15. Excess moisture or runoff can be controlled by:

_____ a. Deep well injection

_____ b. Deep and less permeable soils

_____ c. Imported soils or liners

_____ d. Sun drying

6. Materials that make up landfill liners include:

_____ a. Asphaltic compositions

_____ b. Portland cement

_____ c. Liquid rubbers

_____ d. Synthetic polymer membranes

7. Which method of disposal of sludge by landfill involves excavation below the original ground surface?

_____ a. Sludge/soil, area fill

_____ b. Sludge only, trench

_____ c. Sludge mounding

8. Which method involves the receipt of sludge at a conventional municipal landfill?

_____ a. Sludge only, trench

_____ b. Sludge/soil, area fill

_____ c. Codisposal with refuse

9. Which method involves the placement of sludge above the original ground surface?

_____ a. Sludge only, trench

_____ b. Sludge/soil, area fill

_____ c. Codisposal with refuse

10. Which two variations on normal disposal methods could be used for applications of low solids content or unstabilized sludges?

_____ a. Sludge only, narrow trench

_____ b. Sludge only, wide trench

_____ c. Sludge/soil, area fill layer

_____ d. Sludge/soil, area fill mound

_____ e. Sludge/soil, diked containment

_____ f. Codisposal, sludge/refuse mix

_____ g. Codisposal, sludge/soil mix

16. Methane is produced by the decomposition of organic matter in sludge. At what concentration is airborne methane explosive?

_____ a. 0 - 5%

_____ b. 5 - 15%

_____ c. 15 - 30%

_____ d. 30 - 40%

17. Experience has shown that additional grading may take place _____ years after site closure.

_____ a. 1 - 3 years

_____ b. 3 - 5 years

_____ c. 5 - 9 years

_____ d. 13 years

18. A good plan for final use of the completed landfill is a step toward _____ of a proposed site.

_____ a. abandonment

_____ b. reclamation

_____ c. acceptance

_____ d. solicitation