NC Operator Certification Program

Land Application of Residuals

Study Guide

Water Pollution Control System Operators Certification Commission
North Carolina Department of Environmental Quality
Division of Water Resources

deq.nc.gov/opcert

Feb 2024

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Purpose

The purpose of this training manual is to provide operators with the basic knowledge required to operate and manage land application and distribution of residuals systems in North Carolina. It is also intended to assist operators in preparing for the NC Land Application of Residuals certification exam. Finally, we hope that this manual will serve as a resource for land application of residuals operators after certification.

Disclaimer

This manual has been written based on current North Carolina laws, regulations, and permits available at the time. These will change and evolve over time. You should keep yourself aware of these changes. The organizations and government agencies that are involved in the land application or distribution of residuals will make efforts to inform the regulated community as changes occur. However, you are ultimately responsible for ensuring that you are operating in compliance with current laws, regulations, and permits.

Further, we make no guarantee that the manual is completely free of errors or omissions. It is not intended to be a comprehensive technical reference. Rather, the primary goal is to provide operators information on relevant NC laws, regulations, and permit conditions. Another goal of this manual is to provide context for restrictions and requirements imposed on land application and distribution of residuals by NC laws, regulations, and permit conditions.

You should also be aware that some residuals generators, preparers, and land appliers are separately required to comply with federal regulations: Title 40, Code of Federal Regulation, Part 503, Standards for the Use or Disposal of Sewage Sludge.

North Carolina regulations specifically incorporate and require compliance with the federal regulations. In most cases, compliance with the state regulations results in compliance with federal regulations as well. However, the state and federal regulatory programs operate independently, and the regulated community must comply with both. This manual discusses some requirements of Part 503 but is by no means a complete guide. Any questions concerning compliance with Part 503 should be directed to EPA Region 4 in Atlanta, GA.

About This Manual

The NC Land Application of Residuals Operator Certification program began in 1994. A committee of experts in the wastewater, regulatory, soils, agronomy, engineering, and associated fields developed a list of topics that the committee felt each operator of a land application of residuals system should be familiar with. This list of objectives is called the “Needs-to-Know”. The original manual was developed based on these Needs-To-Know items.

Since then, the manual has been updated almost every year to reflect changes in regulations, permit conditions, and technical guidance. In 2020, a significant review of the Needs-To-Know items was completed and the manual was accordingly updated and reorganized. With a few exceptions, the manual now follows the sections and conditions of the current permit layout and discusses virtually every permit condition. The hope is that operators will find this reorganization more relevant to their day to day responsibilities and will assist them in achieving and maintaining compliance.

Acknowledgements

This manual is a combination of the guidance materials gathered from various sources in conjunction with the local insights and expertise of the Residuals Management and Groundwater Committee of the North Carolina Water Pollution Control Association, the staff of the Division of Water Resources, Dr. A.R. Rubin of the Biological and Agricultural Engineering Department of North Carolina State University, and the North Carolina Department of Agriculture under the guidance of the Water Pollution Control System Operators Certification Commission.

We would especially like to thank Art Dunn, Clarence Manke and Steve Stark of the Operations/Training Unit of the Division of Water Quality of the Minnesota Pollution Control Agency for their permission to use many portions of their manual as well as the South Carolina Department of Health and Environmental Control, the Oregon State University Extension Service, the University of Sacramento, and S&ME, Inc. for their contributions to this manual.

Over the years, the NC Division of Water Resources has partnered with a long list of individuals and organizations, all of whom have contributed greatly to the success of the program:

- North Carolina State University Department of Crop and Soil Sciences
- North Carolina Rural Water Association
- North Carolina Department of Agriculture & Consumer Services
- AWWA Residuals Management and Groundwater Committee
- City of Raleigh
- City of Durham
- Town of Cary
- City of Charlotte
- EMA Resources, Inc
- Branch Residuals and Soils, LLC
- Willcox & Mabe Soil Solutions, PLLC
- Synagro Technologies, Inc
- Agri-Waste Technology, Inc
- TWW Consulting
- WithersRavenal
- Terra Renewal

Needs-To-Know
Land Application of Residuals
North Carolina WPCSOCC

Chapter 1. What Are Residuals?

1-1. Describe each of these materials:
   a. Wastewater treatment residuals
      i. Domestic
      ii. Industrial
   b. Water treatment residuals

1-2. Understand the difference between biological residuals and non-biological residuals.

1-3. Describe the following properties and characteristics of residuals:
   a. Total solids
      i. Organic solids
      ii. Inorganic solids
   b. Pathogens
   c. Nutrients
   d. Metals
   e. Synthetic organic chemicals
   f. Soluble salts

1-4. Be familiar with the pH scale and understand the concepts of acidity and alkalinity.

1-5. List the options for use or disposal of residuals.

1-6. Explain why the US Environmental Protection Agency (EPA) and the NC Division of Water Resources (DWR) consider land application and distribution of residuals "beneficial reuse".

1-7. List the concerns associated with land application and distribution of residuals.

Chapter 2. How are Residuals Regulated and Permitted?

2-1. Identify the federal regulations governing the use of residuals and the significance of the rules being self-implementing.

2-2. List the materials that are regulated under 40 CFR Part 503.

2-3. List the materials that are not regulated under 40 CFR Part 503.

2-4. Identify the state regulations that govern land application and distribution of residuals permits.

2-5. Identify the materials that are regulated under 15A NCAC 2T.

2-6. Identify the materials that are not regulated under 15A NCAC 2T.

2-7. Describe the following materials and understand the difference between them: “residuals”, “sludge”, “sewage sludge”, and “biosolids”.

2-8. Identify the regulations that govern the certification of land application of residuals operators.

2-9. Identify the commission that oversees the operator certification program.

2-10. Identify the department and division of state government that administers the operator certification program.

2-11. List the requirements for renewing an operator certification and know how often it must be renewed.

2-12. Identify the department and division of state government that issue land application and distribution of residuals permits.

2-13. List the different types of residuals permits.

2-14. Explain the importance of reading and understanding the permit.

2-15. Explain the difference between “bagged” and “bulk” residuals.

2-16. Understand the importance of a soil scientist to the permitting process for Class B residuals.

2-17. Define the terms “dedicated site” and “non-dedicated site” and explain the operational differences.

2-18. Explain when groundwater sampling may be required as part of the permitting requirements for residuals.

2-19. Be familiar with the standard parts of a land application or distribution of residuals permit.

2-20. Know the standard period for which permits are issued and the timeframe required for permit renewal.

2-21. Explain how a "non-discharge system" must be operated and maintained.

Chapter 3. Residuals Quality – Can We Apply?

3-1. Know the pollutants (metals) in residuals that have been identified by EPA and DWR as being of significant concern.

3-2. Explain the three types of pollutant (metals) limits found in NCAC 15A 2T:

  a. Ceiling Concentration Limits

  b. Monthly Average Concentration Limits

  c. Cumulative Pollutant Loading Rate

3-3. Know which pollutant (metals) limits above apply to Class A or Class B residuals.

3-4. Explain the importance of municipal pretreatment programs in relation to pollutants (metals) and how they affect the quality of residuals.

3-5. Explain why pathogen reduction is required prior to land application or distribution of biological residuals.

3-6. Explain the difference between Class A and Class B pathogen reduction requirements.

3-7. Define "vector attraction" as it relates to biological residuals.

3-8. Be familiar with the in-plant vector attraction reduction options.

3-9. Know the details of the vector attraction reduction alternatives that can be met in the field.

3-10. List the three standards of quality that residuals must meet to be considered Class B residuals.

3-11. List the three standards of quality that residuals must meet to be considered Class A residuals.

Chapter 4. Residuals (Sludge) Generation and Processing

4-1. Explain why residuals must be processed before they are land applied or distributed.

4-2. Explain the difference between primary and secondary sludge.

4-3. Identify methods used to thicken residuals prior to land application or distribution.

4-4. Be familiar with the following stabilization methods and know which level(s) of pathogen reduction each can achieve:
   a. aerobic digestion
   b. anaerobic digestion
   c. composting
   d. lime stabilization
   e. heat drying

4-5. Explain the difference between raw and stabilized residuals.

4-6. Know the typical pH value of residuals coming from a municipal facility after aerobic or anaerobic digestion.

4-7. Explain how lime stabilization affects the pH of the processed residuals.

4-8. Explain the difference between thickening and dewatering.

4-9. Identify the commonly used methods of residuals dewatering.

4-10. Identify the range of percent solids for liquid, dewatered (cake), and dried residuals.

4-11. Understand how processing methods can affect the end-product characteristics of residuals.

4-12. Explain why residuals storage may be necessary.

Chapter 5. Residuals Quality Calculations

5-1. Know how to find and use data from a residuals analysis.

5-2. Know how to convert from a wet weight concentration (mg/L) to a dry weight concentration (mg/kg).

5-3. Know how to convert from a dry weight concentration (mg/kg) to a wet weight concentration (mg/L).

5-4. Know how to convert dry weight concentrations (mg/kg) to pounds per dry ton (lbs/dry ton).

5-5. Know how to convert gallons to dry tons based on the percent solids of the residuals.

5-6. Know how to convert dry tons to gallons based on the percent solids of the residuals.

5-7. Know how to calculate dry tons per acre.

5-8. Know how to calculate annual and cumulative pollutant loading rates.

5-9. Know how to calculate field acreage.

5-10. Know how to calculate the geometric mean for seven residuals samples.

Chapter 6. Application Rates – How Much Can We Apply?

6-1. Define agronomic rate.

6-2. Define Realistic Yield Expectation (RYE) and know how to obtain it.

6-3. List the primary and secondary macronutrients and three micronutrients.

6-4. Understand the difference between macronutrients and micronutrients.

6-5. Explain why agronomic rates are usually based on nitrogen.

6-6. Identify the forms of nitrogen found in residuals.

6-7. Explain the process of mineralization.

6-8. List the forms of nitrogen that are plant available and describe how they behave in the soil.

6-9. Know the steps involved in calculating application rates based on nitrogen.

6-10. Explain why harvesting and removal of the crop is important.

6-11. Explain why application rates must sometimes be based on the liming potential of the residuals.

6-12. Define Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP) and explain their importance.

6-13. Explain why it is often necessary to apply the agronomic rate in split applications.

6-14. Describe the difficulties associated with application of wet residuals.

Chapter 7. Application Rate Calculations

7-1. Calculate the concentration (mg/kg) of Plant Available Nitrogen (PAN) in residuals from a residuals analysis.

7-2. Calculate the pounds per dry ton (lbs/dry ton) of PAN in the residuals.

7-3. Calculate the application rate in dry tons per acre (dry tons/ac).

7-4. Given the application rate, calculate the number of acres required to land apply residuals produced annually.

7-5. Knowing the application rate (dry tons/ac) and the amount of PAN in residuals (lbs PAN/dry ton), calculate pounds of PAN per acre (lbs PAN/ac).

7-6. Using soil test recommendations, calculate application rates based on Agricultural Lime Equivalent (ALE) and Calcium Carbonate Equivalent (CCE).

7-7. Calculate Sodium Adsorption Ratio (SAR) using data from a residuals analysis.

7-8. Using soil test data, calculate Exchangeable Sodium Percentage (ESP).

Chapter 8. The Land Treatment System

8-1. Define “setback” and identify features requiring setbacks.

8-2. Be familiar with the following soil and site properties and how they relate to the suitability of a site for land application of residuals.

  a. soil texture
  b. soil structure
  c. infiltration
  d. percolation and permeability
  e. soil depth and restrictive horizons
  f. seasonal high water table
  g. topography (slope and landscape position)
  h. soil pH

8-3. Explain how a seasonal high water table affects residuals operations.

8-4. Know the restrictions that limit where you can land apply Class B and bulk Class A residuals.

8-5. Explain the importance of maintaining proper soil pH and describe how to maintain it.

8-6. Explain how applying high pH residuals can affect treatment processes in the soil.

8-7. Describe the role of vegetation in the land treatment system.

8-8. List factors that influence crop selection/suitability and management.

8-9. List common annual crops and perennial crops and list advantages and disadvantages of each in the operation of land application systems.

8-10. Be familiar with the grazing and harvesting restrictions that must be imposed when Class B residuals are land applied.

8-11. Describe the difficulties associated with application of residuals containing high nitrate levels to forage crops.

8-12. Describe issues to consider when planning a haul route.

8-13. Describe the factors that influence application scheduling for agricultural crops.

8-14. Explain the relationship between the scheduling of residuals application and the quality of the crop.

8-15. List considerations of application events with the landowner/farmer.

8-16. Know the restrictions that limit when and under what conditions you can land apply Class B and bulk Class A residuals.

8-17. Describe the effect of the weather (especially rainfall and frozen soils) on land application activities.

8-18. Describe strategies for managing odors at the land application site.

8-19. Describe practices to prevent runoff and erosion.

8-20. Be familiar with the physical, chemical, and biological treatment processes that occur at the land treatment system.

8-21. Identify where an operator can obtain advice and useful information regarding agricultural operations.

Chapter 9. Transport and Application Equipment and Methods

9-1. Describe the type of transport and application equipment associated with the handling of dewatered and liquid residuals.

9-2. List the two methods of land application of residuals: surface and subsurface.

9-3. Explain the difference between incorporation and injection.

9-4. Identify the circumstances under which residuals would be surface applied to a site.

9-5. Identify the circumstances under which the residuals should be incorporated into the soil.

9-6. Identify circumstances under which residuals would be applied using a high floatation self-propelled applicator and list advantages and disadvantages of this application method.

9-7. Identify circumstances under which residuals would be applied using spray irrigation and list advantages and disadvantages of this application method.

9-8. Explain the importance of calibrating land application equipment.

9-9. Be familiar with calibration methods and procedures.

Chapter 10. More O&M, Inspections, General Conditions, & Operator Designation

10-1. Understand the importance of an Operation and Maintenance Plan and identify the components it must contain.

10-2. Understand the need to have a copy of the permit on site during application.

10-3. Know the steps that must be included in a spill response plan, and where written copies of the plan should be kept.

10-4. Understand the importance of reporting emergencies, spills, and failures. Know the corrective measures that should be taken to minimize impacts on public health and the environment.

10-5. Explain the importance of completing the landowner agreement form.

10-6. List the responsibilities of the landowner and explain why it is important to communicate these responsibilities.

10-7. Describe the inspection that the Permittee or designee is required to conduct prior to a land application event.

10-8. Understand the authority of Division of Water Resources representatives to inspect any land application sites or facilities covered by the permit.

10-9. Describe the responsibilities of the Permittee with regards to designating an ORC and Back-up ORC(s) and updating designations for a land application of residuals permit.

10-10. Define the terms Operator in Responsible Charge (ORC) and Back-up Operator in Responsible Charge (Back-up ORC) and list their responsibilities.

Chapter 11. Health and Safety

11-1. Understand the responsibilities of the employer, the site supervisor, and the employee regarding safety in the workplace.

11-2. Know the types of hazards and injuries associated with a land application site.

11-3. List the types of personal protective equipment needed on and around a land application site.

11-4. Define the term "confined space" and describe the procedures for entering a confined space.

11-5. List the possible confined spaces at a land application operation.

11-6. Describe the personal hygiene practices that should be used.

11-7. Describe the proper procedure for lifting and carrying heavy objects.

11-8. Describe the importance of lockout/tagout procedures.

11-9. Explain the safety precautions required around land application vehicles, both on the road and off the road.

11-10. Identify the importance of adhering to all traffic laws, speed limits, and weight limits in a land application operation.

11-11. Describe the hazards related to the following types of equipment and know the safety procedures that must be used around them:

  a. Tractors
  b. Power take off equipment
  c. Vacuum/pressure equipment
  d. Hydraulic equipment

Chapter 12. Public Involvement

12-1. Explain the importance of public relations when managing a land application project.

12-2. Understand the importance of handling complaints in a timely and professional manner.

Chapter 13. Monitoring and Reporting

13-1. Explain the value of records as a tool in operating and planning the land application of residuals.

13-2. Know the monitoring and reporting requirements contained in a land application permit.

13-3. Identify the records and forms that must be kept and know the time-period for which they must be maintained.

13-4. Describe the reports that must be submitted to NC DWR and EPA and know the deadline(s) for submission.

13-5. Know the units of measurement that must be used on required reports.

13-6. Describe the requirements for non-compliance notification.

Chapter 14. Sampling Procedures

14-1. Define the following types of residuals samples:

   a. composite sample
   b. grab sample
   c. representative sample

14-2. Know the proper procedures when sampling residuals for:
   a. Nutrients / metals
   b. Pathogens
   c. Vector attraction reduction
   d. TCLP

14-3. Explain the correct procedure for collecting residuals samples from tanks, lagoons, compost piles, or stockpiles.

14-4. Describe the proper procedure for preserving and shipping residuals samples.

14-5. Describe the correct sampling procedures for soils.

Chapter 15. Consequences of Violating the Permit

15-1. Understand that the Environmental Management Commission (EMC) delegates its enforcement authority, established in the NC General Statutes, to the Division of Water Resources.

15-2. Be familiar with the types of enforcement actions that the Division of Water Resources can take against a Permittee for violation of the permit.

15-3. Know the grounds for which the Water Pollution Control System Operators Certification (WPCSOCC) may take disciplinary action against a certified operator.

15-4. List the possible types of disciplinary actions the WPCSOCC can take.

15-5. Understand that Permittees and certified operators can face criminal prosecution and penalties for willful and knowing violations and actions.

15-6. Explain the concept of professional ethics and the importance of professional ethics in the environmental field.

Formulas for Land Application of Residuals

Dry weight concentration $$\text{mg/kg} = \frac{\text{mg/L}}{\text{\% solids}}$$

Wet weight concentration $$\text{mg/L} = \text{mg/kg} \times \text{\% solids}$$

Pounds per dry ton $$\text{lbs/dry ton} = \text{mg/kg} \times 0.002$$

$$\text{Dry tons} = \frac{\text{gallons} \times 8.34\ \text{lbs/gal} \times \text{\% solids}}{2000\ \text{lbs/ton}}$$

$$\text{Gallons} = \frac{\text{dry tons} \times 2000\ \text{lbs/ton}}{8.34\ \text{lbs/gal} \times \text{\% solids}}$$

Pounds per year (lbs/year) = mg/L x MGY (annual effluent application) x 8.34 lb/gal

Dry tons per acre $$\text{dry tons/ac} = \frac{\text{\# dry tons}}{\text{\# acres}}$$

Pounds per acre $$\text{lbs/ac} = \text{lbs/dry ton} \times \text{dry tons/ac}$$

Dry tons per acre $$\text{dry tons/ac} = \text{wet tons/ac} \times \text{\% solids}$$

Plant Available Nitrogen (PAN), mg/kg

For *Surface* Application: $[MR \times (TKN - NH_4^+)] + (0.5 \times NH_4^+) + NO_3^- + NO_2^-$

For *Subsurface* Application: $[MR \times (TKN - NH_4^+)] + NH_4^+ + NO_3^- + NO_2^-$

$$\text{Application Rate (dry tons/ac)} = \frac{\text{PAN residuals need to supply (lb/ac)}}{\text{PAN in residuals (lb/dry ton)}}$$

Wet tons per acre $$\text{wet tons/ac} = \frac{\text{dry tons/ac}}{\text{\% solids}}$$

Formulas for Land Application of Residuals

Gallons per cubic yard $\text{gal/yd}^3 = \dfrac{201.974 \text{ gal}}{\text{yd}^3}$

Cubic yards to dry tons $= \text{yd}^3 \times \% \text{ solids} \times 201.974 \text{ gal/yd}^3 \times 8.34 \text{ lbs/gal} \times 1 \text{ dry tons/2000 lbs} = \text{dry ton}$

Dry tons to cubic yards $= \dfrac{\text{dry tons} \times 2000 \text{ lbs/dry ton}}{\% \text{ solids} \times 201.974 \text{ gal/yd}^3 \times 8.34 \text{ lbs/gal}} = \text{yd}^3$

Acres needed $= \dfrac{\text{dry tons produced}}{\text{application rate (dry tons/ac)}}$

Pounds per acre = lbs/dry ton x dry tons/acre

Lime Based Agronomic Loading Rate (dry tons/ac) $= \dfrac{\text{Recommended tons lime/ac}}{\% \text{ CCE of residuals}}$

Lime Based Application Rate (dry tons/ac) = ALE of residuals/1 ton ag-lime x Recommended tons ag-lime/acre

Sodium Adsorption Ratio (SAR) $= \dfrac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$ **Units are milliequivalents/liter (meq/L)

**Milliequivalents/liter (meq/L) $= \dfrac{\text{concentration (mg/L)}}{\text{equivalent weight}}$

Exchangeable Sodium Percentage (ESP) $= \dfrac{\text{Na meq/100g}}{\text{CEC meq/100g}} \times 100$

1 acre = 43560 square feet

Formulas for Land Application of Residuals

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$$\text{Cubic yards to dry tons} = \text{yd}^3 \times \%\ \text{solids} \times 201.974\ \text{gal/yd}^3 \times 8.34\ \text{lbs/gal} \times 1\ \text{dry tons/2000 lbs} = \text{dry ton}$$

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**Units are milliequivalents/liter (meq/L)

$$\text{**Milliequivalents/liter (meq/L)} = \frac{\text{concentration (mg/L)}}{\text{equivalent weight}}$$

$$\text{Exchangeable Sodium Percentage (ESP)} = \frac{\text{Na meq/100g}}{\text{CEC meq/100g}} \times 100$$

1 acre = 43560 square feet

Chapter 1

What are Residuals?

Residuals are the solid, semi-solid, or liquid materials generated during the treatment of wastewater or drinking water. They are unavoidable by-products of making water cleaner. Managing these by-products is one of the biggest challenges associated with the ongoing operation and maintenance of wastewater and water treatment facilities.

Wastewater Residuals

Wastewater residuals are generated during the treatment of domestic and/or industrial wastewater. ***Domestic wastewater*** comes from toilets, tubs and showers, restroom, and kitchen sinks, washing machines and other activities of daily living. Sources of domestic wastewater include homes, non-industrial businesses, and institutions such as schools. Domestic wastewater is usually dilute and fairly uniform in composition – in fact, it is often 99.9% water and only 0.1% solids.

In many cases, domestic wastewater is collected and transported, by a series of pipes known as sewer or collection systems, to centralized domestic wastewater treatment plants. Often referred to as municipal wastewater treatment plants, they are designed to treat mainly domestic wastewater.

However, municipal wastewater treatment plants also accept industrial wastewater, providing it will not disrupt treatment processes. ***Industrial wastewater*** is water used in processes of manufacture, industry, mining, etc. Sources of industrial wastewater include paper and fiber plants, steel mills, refining and petrochemical operations, chemical and fertilizer plants, meat packers, and poultry processors.

The composition of industrial wastewater is usually more varied and concentrated than domestic wastewater. Before sending it to a municipal treatment plant, some industries must pretreat their wastewater to remove or reduce high strength or toxic wastes to acceptable levels.

Municipal wastewater treatment plants rely almost exclusively on biological treatment processes (using microorganisms under controlled conditions) to reduce solids and pollutants so that the ***effluent*** (treated liquid) can be safely returned to the environment. The solid, semi-solid, and liquid residues generated during the biological treatment of domestic wastewater or a combination of domestic and industrial wastewater are referred to as ***domestic wastewater residuals*** or ***sewage sludge*** (Figure 1-1). These residuals are ***biological residuals***.

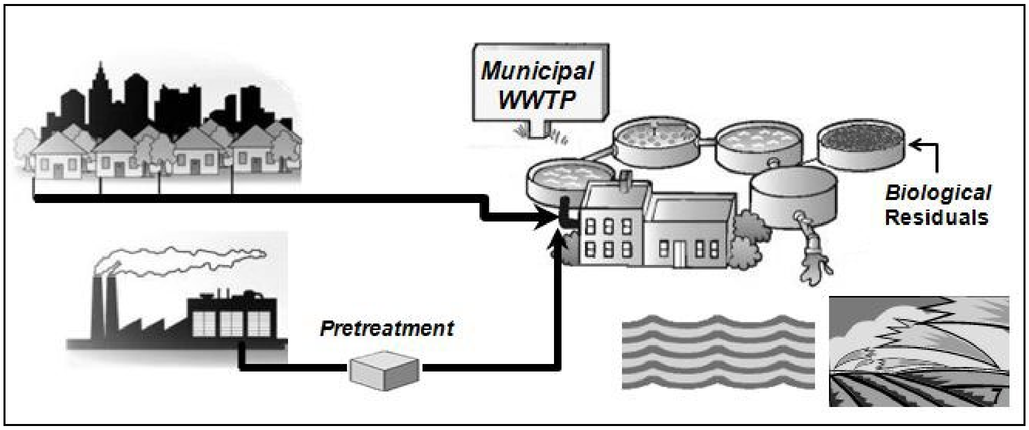


Figure 1-1. Generation of domestic/municipal residuals.

Some industries treat their wastewater onsite at the industry instead of sending their wastewater to municipal wastewater treatment plants. The volume and composition of some industrial wastewater is such that it must be treated separately from domestic wastewater.

The goal of an industrial wastewater treatment plant is the same as a municipal wastewater treatment plant: to reduce/remove solids and pollutants from the wastewater so that the effluent can be safely returned to the environment. The solid, semi-solid, and liquid residues generated during the treatment of industrial wastewater are ***industrial wastewater residuals*** or ***industrial sludge*** (Figure 1-2)***.***

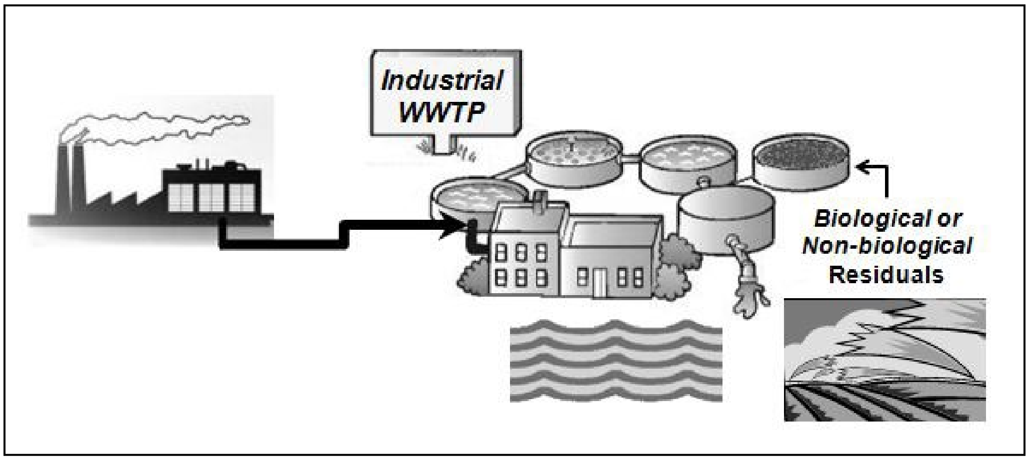


Figure 1-2. Generation of industrial residuals.

Some industrial plants use biological treatment processes just like municipal wastewater treatment plants. These are industries that deal with biodegradable materials, such as food processes, breweries, and even paper, plastics, and petrochemicals. The residuals generated from these plants are considered ***biological*** residuals.

However, some industrial wastewater contains chemicals or pollutants require non-biological mechanisms. In some cases, these types of chemicals or pollutants could kill the microorganisms. Industries often use physical/chemical processes (chemical precipitation, ion exchange, filtration, carbon adsorption, and dissolved air floatation) to treat the wastewater. Residuals generated from these plants are considered ***non-biological*** residuals.

Water Treatment Plant Residuals

Water treatment residuals are generated when raw water from rivers, lakes, and reservoirs is treated in water supply treatment plants. Water treatment plants purify the water using non-biological processes (coagulation, flocculation, sedimentation, and filtration).

They often mix non-toxic aluminum-based and iron-based chemicals into the water as part of the water cleaning process. These chemicals, called coagulants, bind with small particles, and cause them to stick to other small particles, forming large clumps. Flocculation is gentle stirring or agitation to encourage clumps to form into masses large enough to settle or be filtered from the water.

The purified drinking water is sent to homes and businesses for activities of daily living, commerce, and industry. The solid, semi-solid, and liquid residues generated during the treatment of drinking water are ***water plant residuals*** (Figure 1-3), often to referred as ***alum or ferric sludge*** (if alum or iron-based chemicals are used during the treatment process).

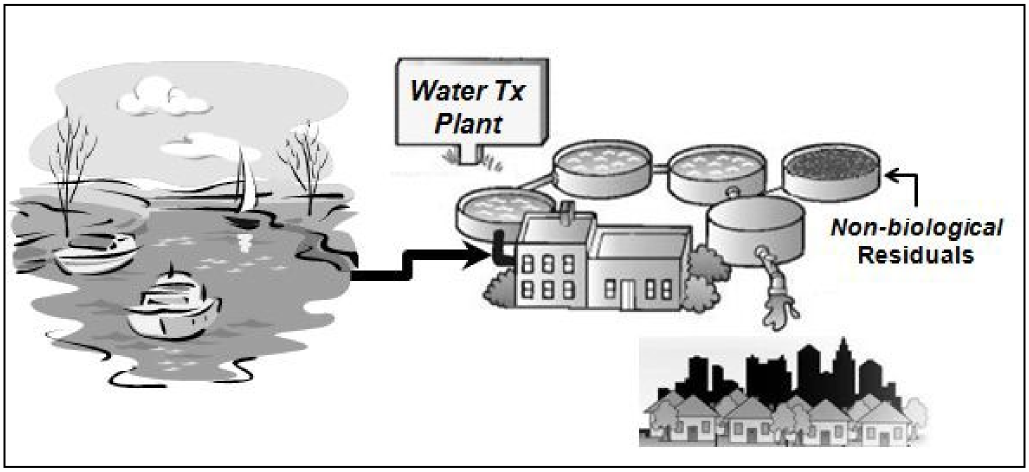


Figure 1-3. Generation of water treatment residuals.

Review

You will see the terms introduced in this section (domestic, industrial, residuals, sludge, sewage sludge, biological, non-biological) repeatedly as you proceed through this manual. The definitions will become a little more detailed and complex, but if you understand the following concepts and the information presented in Figure 1-4 and, you'll be off to a good start.

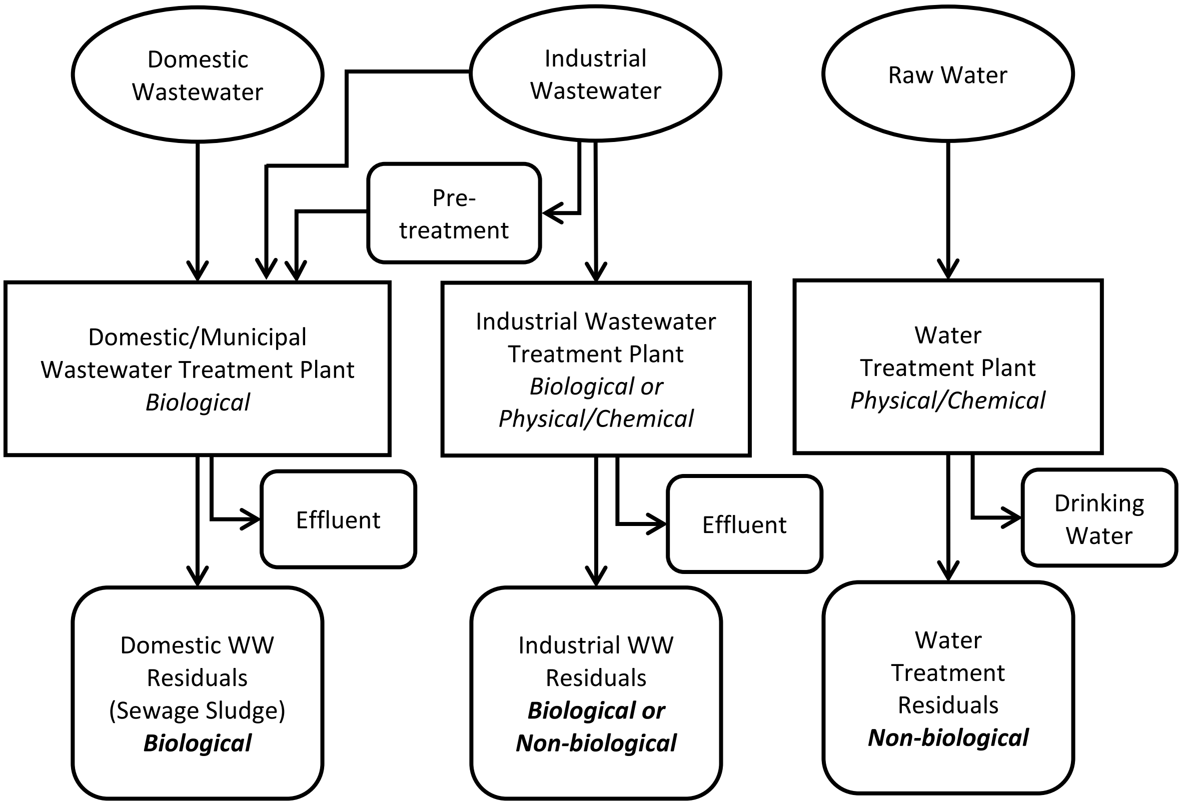


Figure 1-4. Sources and types of residuals.

The term *sewage sludge* refers only to residuals generated during the biological treatment of domestic wastewater and/or a combination of domestic and industrial wastewater in a domestic wastewater treatment plant. Residuals generated in this way are always considered *biological residuals*.

Industrial wastewater residuals can be referred to as sludge, but they do not meet the definition of *sewage sludge*. These residuals can be *biological or non-biological*, depending on the treatment processes used to treat the wastewater from which they were generated.

Water treatment plant residuals can be referred to as sludge, *alum* sludge, or *ferric* sludge, but they also do not meet the definition of *sewage sludge*. These residuals are always considered *non-biological*.

What's in Residuals?

The composition of residuals may vary greatly between treatment plants and, to a lesser extent, over time at a single plant. Proper operation and maintenance of a land application system requires a basic understanding of the physical, biological, and chemical characteristics of residuals. How much water and solid material do they contain? What kind of materials and how much of each are present? Are these materials beneficial or toxic? Are the residuals suitable for land application?

Solids

The water content of untreated residuals can be as high as 99.5%, which means they contain only 0.5% solids. Knowing the exact *amount* of solids in residuals is critical to all aspects of land application (Figure 1-5).

- ❑ ***Total solids (TS)***, as the term implies, includes all the solid material in residuals. Total solids content is the concentration of solid materials in a volume of residuals, expressed as a percentage. Often referred to as "percent solids", total solids content impacts all aspects of residuals management, including type and amount of storage, mode of transportation, and application methods and equipment.

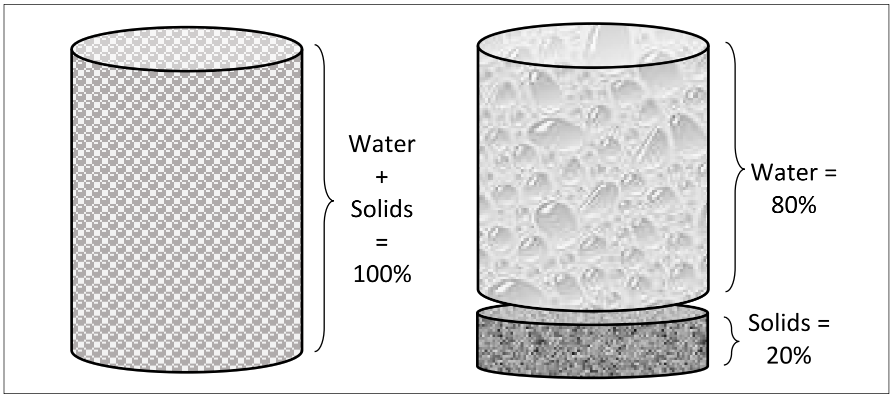


Figure 1-5. An example of total solids content in a volume of residuals, expressed as a percentage.

Knowing the *type* of solids present is just as important. Based on their chemical composition, there are two categories of residuals solids: organic and inorganic (Figure 1-6).

- ***Organic solids*** are naturally occurring plant and animal-based materials that contain carbon. They are present in residuals in the form of proteins, carbohydrates, fats, and other cellular materials. They are readily decomposed by bacteria and other organisms. Organic solids are roughly equivalent to ***volatile solids***, which are solids that volatilize (burn off) during combustion.

  Volatile solids content provides a rough estimate of the readily decomposable organic solids in residuals and is an important indicator of potential odor problems. Odor generated by decomposing organic solids is one of the major problems associated with land application of residuals. One of the major goals of residuals processing is the reduction of organic/volatile solid content.

- ***Inorganic solids*** are materials of non-biological origin, like sand and silt. These materials are inert and resist decomposition. They are not combustible and are roughly equivalent to "fixed" or non-volatile solids. Common inorganic solids are metals and dissolved salts.

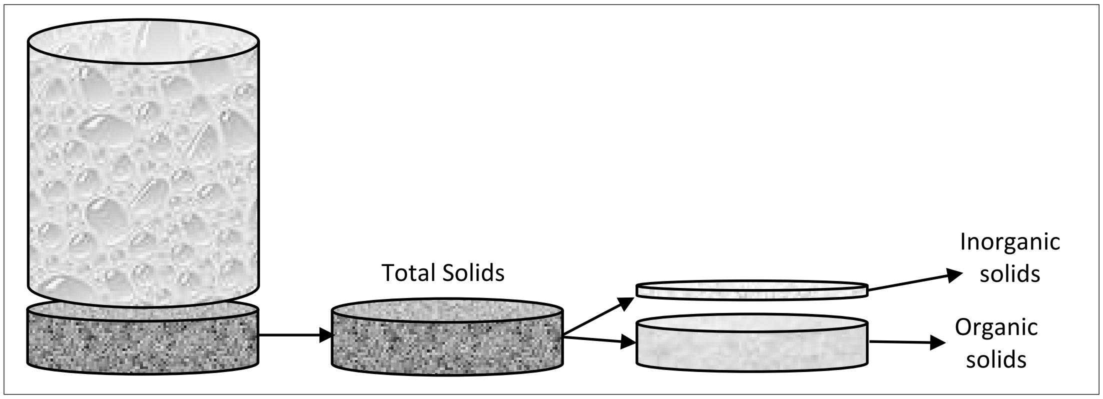


Figure 1-6. Total solids is made up of organic and inorganic solids.

Pathogens

Untreated domestic wastewater contains millions of microorganisms per gallon. Most of these organisms are not harmful to humans. Some of them are essential to biological wastewater treatment. Others, however, can cause serious diseases such as typhoid, cholera, shigellosis, dysentery, polio, and hepatitis.

Disease-causing microorganisms are called ***pathogens*** and include bacteria, viruses, protozoa, and helminths (Figure 1-7). Humans with diseases discharge these harmful organisms with their bodily wastes. Many serious outbreaks of contagious diseases have been traced to contamination of drinking water or food supplies by the wastes from a human disease carrier.

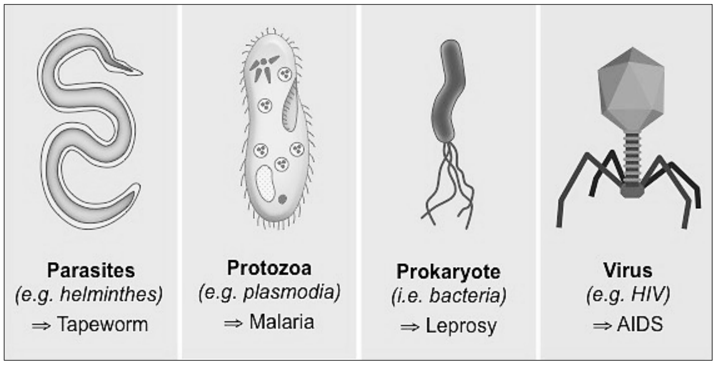


Figure 1-7. Types of pathogens.

During the biological treatment of domestic wastewater, pathogens in the wastewater are concentrated in the residuals that are generated. These pathogens present a public health hazard if they are: transferred to food crops grown on land to which residuals are applied; contained in runoff to surface waters from land application sites; or transported away from the site by pests such as insects, rodents, and birds (***vectors***).

Nutrients

We've mentioned nutrients already. ***Nutrients*** are chemical elements that all plants and animals require for growth. When land applied, residuals can provide crops with essential nutrients, such as nitrogen and phosphorus. In excess, however, nutrients are contaminants that can pollute both surface and groundwater and reduce crop yields. Nitrogen and phosphorus are the two nutrients of major concern.

Too much nitrogen and phosphorus in surface waters cause large growths of algae called algal blooms. Algal blooms can severely reduce or eliminate oxygen in the water, leading to the death of large numbers of fish (Figure 1-8). Nitrogen pollution in groundwater -- which millions of people in the United States use as their drinking water source -- can be harmful, even at low levels. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water.

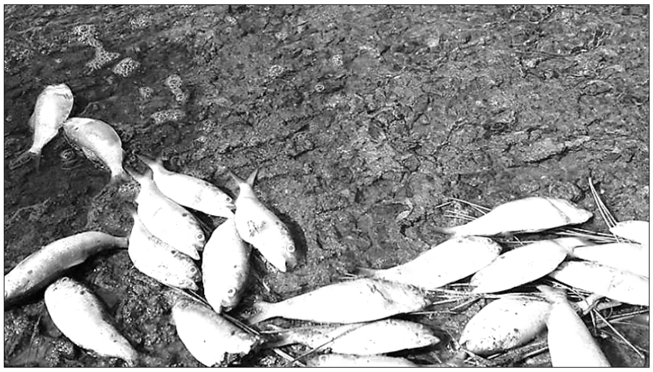


Figure 1-8. Thousands of dead fish found in Pamlico River resulting from an algal bloom.

Metals

Metals are inorganic chemical elements like copper and zinc. Although some are essential nutrients, most of them can be toxic to all forms of life at relatively low concentrations. Unlike organic pollutants, metals are not biodegradable. They persist indefinitely and over time can accumulate in the soil and enter the food chain at levels that are toxic to plants, humans, and other animals (Figure 1-9).

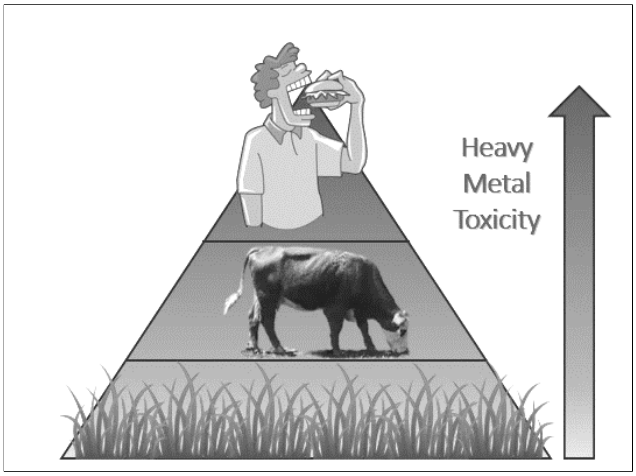


Figure 1-9. Metals accumulate in the food chain and become increasingly toxic.

Synthetic Organic Chemicals

Synthetic organic chemicals are complex, man-made compounds that contain carbon. They are found in pesticides, herbicides, solvents, and household chemicals such as cleansers, medical products, and paint and are very different from the naturally occurring organic solids we discussed earlier.

Like metals, synthetic organic chemicals are not biodegradable and can persist in the soil for many years. Also, like metals, they accumulate in the food chain and can be toxic to plants, animals, and humans. Fortunately, these compounds are rarely detected in residuals. When detected, they are present in such low concentrations (near the lowest detectable limits) that studies have found risks to be extremely low.

Soluble Salts

Soluble salts are compounds that readily dissolve in water. They contain positive and negative atoms or molecules called ***ions***. Ions are held together by the strong force of attraction between particles with opposite charges. When one of these compounds dissolves in water, the ions that form the solid are released into solution. An example is common table salt (NaCl) which exists as solid crystals until placed in water, where the crystals dissolve releasing positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-) (Figure 1-10).

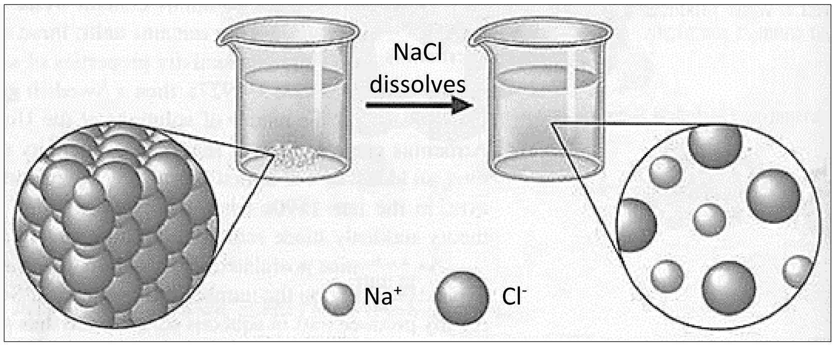


Figure 1-10. When solid NaCl dissolves, the Na^+ and Cl^- ions are randomly dispersed in the water.

Other soluble salts present in wastewater include sulfates, potassium, calcium, and manganese. They are removed during wastewater treatment and are present in residuals. Other salts such as ferric chloride, alum, and lime are added to aid in water or wastewater treatment. When land applied, residuals with high levels of soluble salts can negatively impact soil and crops.

pH

pH is an indication of the acidity of a substance. In technical terms, it is the measure of the log of the concentration of the hydrogen ions (H^+) in a solution. pH does not have a unit; it is expressed as a number ranging from 1 to 14 (Figure 1-11). When the pH of a solution equals 7, the solution is neutral. When the pH is higher than 7, the solution is basic (or alkaline). When the pH is less than 7, the solution is acidic.

pH is a logarithmic factor, which means that when pH decreases by one unit the solution is ten times more acidic. When the pH falls by 2 units, the solution is 100 times more acidic. For example, a solution with a pH of 5 is ten times more acidic than a solution with a pH of 6, whereas a solution with a pH of 4 is 100 times more acidic than a solution with a pH of 6.

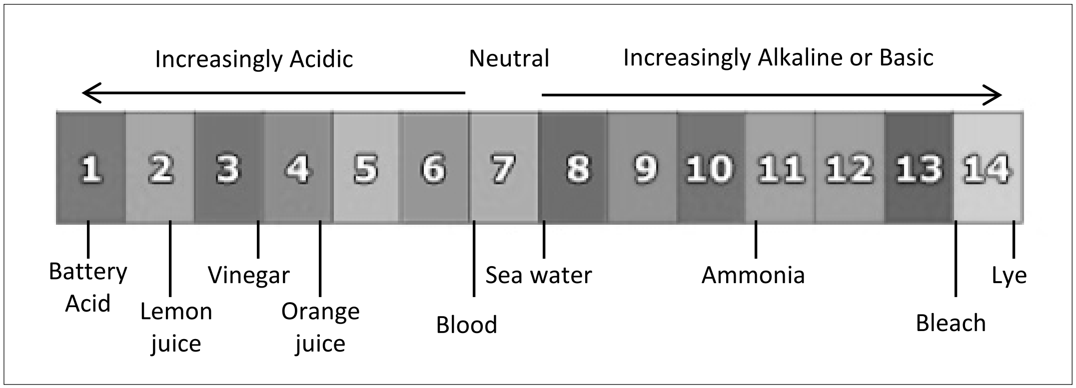


Figure 1-11. The pH scale.

The pH of residuals can affect crop production at land application sites by altering the pH of the soil and influencing the uptake of metals by soil and plants. Depending on the processing method, the pH of treated residuals can range from around 7 to 12 or higher.

What Are the Final Use or Disposal Options?

- ☐ ***Incineration.*** Incineration involves burning residuals at very high temperatures, turning them into ash. This reduces the volume of the residuals by as much as 95 percent and significantly decreases the material handling aspects of residuals management. Incineration facilities, however, produce significant amounts of air pollutants.

- ☐ ***Landfill Disposal.*** Residuals can be disposed of in a permitted landfill where they are mixed with municipal solid waste and buried.

- ☐ ***Surface Disposal.*** Residuals can be placed in a surface disposal unit, which is land used for final disposal and not treatment or storage. These include monofills, lagoons, and trenches, and does not include land on which residuals are either treated or stored.

- ☐ ***Land Application and Distribution.*** Land application is the spraying or spreading of residuals onto the land surface; the injection of residuals below the land surface; or the incorporation of residuals into the soil so that the residuals can condition the soil or fertilize crops or vegetation grown in the soil. Distribution is the sale, giveaway, or transfer of residuals for eventual land application. Before residuals are land-applied, they must meet strict standards of quality.

Land Application – The Option of Choice

Residuals have many characteristics that are beneficial to soil and plants. Biological residuals are rich in organic solids which, when added to soil, increase the soil's ability to absorb and store moisture. They provide important nutrients for plant growth, as well as food and energy for beneficial soil microorganisms.

Consequently, agricultural use of residuals can significantly improve crop growth and yield, while reducing fertilizer costs for farmers. Non-biological residuals normally contain fewer organic solids and nutrients but can often be used as a liming agent to raise soil pH (Figure 1-12).

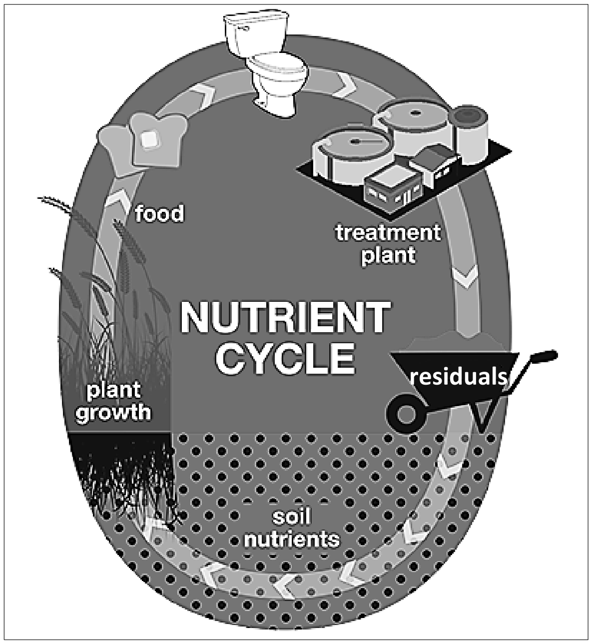


Figure 1-12. EPA and DWR consider land application of residuals "beneficial reuse".

Land application takes advantage of the beneficial qualities of residuals, whereas incineration and landfill disposal do not. It also frees up much needed space in landfills for materials that have no other disposal options. For these reasons, the US Environmental Protection Agency (EPA) and the NC Division of Water Resources (DWR) consider land application ***"beneficial use"*** of residuals and encourage the practice.

Obviously, there are certain public health, environmental, and nuisance risks associated with the land application of residuals, including:

- transmission of disease
- exposure to toxic chemicals
- surface water, groundwater, and soil contamination
- nuisances: odors, truck traffic, dust, noise

When conducted in accordance with federal and state regulations, however, it presents negligible risk to public health and the environment. Regulatory requirements include:

- analyzing residuals quality and composition
- processing to meet standards for safe use
- site investigation and permitting
- nutrient management
- setbacks and public access restrictions
- grazing and harvesting restrictions
- monitoring, recordkeeping, and reporting
- certified operator requirements

Code of Federal Regulations Title 40 Part 503

https://www.ecfr.gov/current/title-40/chapter-I/subchapter-O/part-503

Chapter 2

How Are Residuals Regulated and Permitted?

Federal and state regulations provide strict quality control standards for the generation, use, or disposal of residuals. These standards were specifically developed to protect human health and the environment, including the health of animals, crops, soils, wildlife, and aquatic life.

Federal Regulations

The Clean Water Act (CWA) is the primary federal law governing water pollution. Congress passed the CWA in 1972 and required the United States Environmental Protection Agency (EPA) to develop federal regulations for the safe use and disposal of residuals. These regulations are found in Title 40 Code of Federal Regulations (40 CFR) Parts 503 and 257.

40 CRF Part 503, *"Standards for the Use and Disposal of Sewage Sludge"*, applies to:

- sewage sludge generated during the biological treatment of domestic wastewater or a combination of domestic and industrial wastewater in a domestic wastewater treatment plant *and*
- residential ***septage*** (liquid or solid material removed from a septic tank)

Part 503 does not regulate and specifically excludes these materials:

- hazardous waste
- grit and screenings
- incinerator ash
- residuals that are co-fired
- residuals generated at an industrial facility
- residuals generated at a drinking water treatment facility

Apart from hazardous waste, 40 CFR Part 257 regulates the final use and disposal of materials excluded from Part 503.

The following persons must comply with the requirements of Part 503:

- ***Generator:*** the owner (Permittee) of a treatment works that produces residuals. Often the generator is also the preparer and land applier.
- ***Preparer:*** the generator or a person who receives sewage sludge from the generator and changes the quality (provides additional processing) prior to land application.

- ***Land applier:*** the person who applies sewage sludge to land to condition soil and/or fertilize crops. This could be a municipality, a private contractor, or a farmer.
- Owners/operators of sewage sludge surface disposal sites.
- Owners/operators of sewage sludge incinerators.

Part 503 defines a “person” as an individual, association, partnership, corporation, municipality, State or Federal agency.

Part 503 regulates the final use or disposal of sewage sludge when it is incinerated, land applied or distributed, or placed on a surface disposal site. It establishes minimum national standards for these activities, including:

- General Requirements
- Pollutant Limits
- Pathogen & Vector Attraction Reduction Requirements
- Management Practices
- Monitoring Frequency
- Recordkeeping & Reporting

Part 503 and 257 establish minimum national standards for the use and disposal of residuals. EPA requires individual states to adopt regulations at least as stringent as the federal regulations but allows states to adopt more restrictive regulations and to administer them differently.

The federal regulations are “self-implementing”. This means that generators/preparers, land appliers, and owner/operators of surface disposal sites and incinerators must comply with the federal regulations even if EPA does not require them to obtain a federal permit. Types of compliance include monitoring, reporting, and record keeping. EPA can take enforcement action directly against persons who violate the federal requirements.

State Regulations

North Carolina General Statute 143-213 gives the Environmental Management Commission (EMC) and the Department of Environmental Quality (DEQ) the authority to develop and enforce state regulations and issue permits for the use and disposal of residuals. The state regulations that you must be familiar with include:

- ***15A NCAC 02T*** - *Waste Not Discharged to Surface Waters*
- ***15A NCAC 2L*** - *Classifications and Water Quality Standards Applicable to the Groundwaters of NC*
- ***15A NCAC 8G*** - *Water Pollution Control System Operator Rules*

15A NCAC 02T

Within DEQ, the Division of Water Resources (DWR) administers the state's residuals management programs in accordance with 15A NCAC 02T. These regulations apply to ***non-discharge systems***, i.e., systems that do not discharge waste to surface waters of the state. ***Surface waters*** mean any stream, river, brook, swamp, lake, sound, tidal estuary, bay, creek, reservoir, waterway, or other body or accumulation of water.

The requirements relating to residuals management are found in Section .1100 of the 02T regulations. 02T .1100 defines residuals as any solid, semi solid, or liquid waste generated by:

- a domestic wastewater treatment facility
- an industrial wastewater treatment facility
- a drinking water supply treatment facility
- an air pollution control facility (There are no residuals permitted from this type of facility in NC. This type of residuals will not be discussed further)

02T .1100 regulates the use of residuals when they are:

- land applied or distributed
- placed in a surface disposal unit

02T .1100 *does not* regulate residuals when they are:

- sent to a landfill (covered under Division of Waste Management Rules)
- incinerated (covered under Division of Air Quality Rules)

02T .1100 *does not* apply to these materials:

- residuals that meet the definition of a hazardous waste
- oil, grease, grit, and screenings from wastewater treatment facilities
- coal ash that is regulated under 02T .1200
- animal waste that is regulated under 02T .1300 and .1400
- residuals that are transported out of state for treatment, storage, use, or disposal
- septage (permitted by NC Division of Waste Management)

Part 503 vs 02T .1100

The 02T regulations specifically incorporate and require compliance with the federal regulations. In most cases, compliance with the state regulations results in compliance with federal regulations as well. However, the state and federal regulatory programs are operated independently, and the regulated community must comply with both. This manual discusses some requirements of Part 503 but is not intended as a complete guide.

Table 2-1 compares the applicability of Part 503 to 02T.

Table 2-1. 40 CFR Part 503 (federal regulation) applies to sewage sludge only (domestic/municipal wastewater residuals and residential septage). 15A NCAC 02T (state regulation) applies to domestic/municipal wastewater residuals, industrial wastewater residuals, and water treatment residuals.

	40 CFR Part 503 (Federal)	**15A NCAC 02T (State)**
Materials covered	• Domestic wastewater residuals • Septage	• Domestic wastewater residuals • Industrial wastewater residuals • Drinking water residuals
Materials excluded	• Hazardous waste • Grit and screenings • Incinerator ash • Residuals that are co-fired • Industrial wastewater residuals • Drinking water residuals	• Hazardous waste • Grit, screenings, oil, and grease • Septage • Coal ash • Animal waste • Out of state use
Use or Disposal Practice	• Land application/distribution • Surface disposal • Incineration	• Land application/distribution • Surface disposal

EPA has adopted the term ***biosolids*** which it defines as sewage sludge that has been treated and is appropriate for land application. Since industrial wastewater residuals and water treatment residuals do not meet EPA's definition of sewage sludge, they also do not meet EPA's definition of biosolids. They are, however, often referred to as biosolids, even by regulators.

The 02T regulations do not use the term biosolids and refer only to residuals. To be consistent with these regulations, this manual primarily uses the term "residuals". Residuals is a general term used to refer to solids generated during wastewater treatment (domestic or industrial) and drinking water treatment.

15A NCAC 2L

The 2L regulations, "*Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina"*, are intended to protect the quality of groundwater, which serves as the primary drinking water supply to approximately one-half of North Carolina's population. These regulations include the Groundwater Quality Standards, 15A NCAC 02L .0202, which are based upon state and federal drinking water standards.

Groundwater quality standards are the maximum concentrations of contaminants in groundwater that can be tolerated without creating a threat to human health or that would otherwise make groundwater unsuitable as a drinking water source. The goal of these standards is to maintain existing high-quality groundwater and to protect existing and future beneficial uses.

The standards affect all activities that can potentially impact groundwater quality, including land application of residuals. Land application and distribution programs must be effectively operated and maintained so that groundwater quality is not impaired.

Some residuals management programs are required to monitor groundwater quality. Monitoring activities include installation of monitoring wells, sample collection, and analysis of groundwater, and reporting analytical data to DWR.

The compliance boundary is a boundary around the disposal system at and beyond which groundwater quality standards may not be exceeded. For sites permitted before December 30, 1983, the compliance boundary is established in accordance with 15A NCAC 02L .0107(a) at either 500 feet from the residual land application area, or at the property boundary, whichever is closest to the residual land application area.

For sites permitted on or after December 30, 1983, the compliance boundary is established in accordance with 15A NCAC 02L .0107(b) either 250 feet from the residual land application area, or 50 feet within the property boundary, whichever is closest to the residual land application area.

The review boundary is midway between the compliance boundary and the land application area. If groundwater monitoring is required, a network of wells must be installed at the review boundary. A single monitoring well is also required in the up-gradient direction of the groundwater flow that serves as a background quality well.

Groundwater monitoring at the review boundary serves as a warning of the possible spread of contamination to the compliance boundary. When Groundwater Quality Standards are exceeded at the review boundary, the Permittee must implement a plan that will prevent a violation of standards at the compliance boundary. This plan must include installation of monitoring wells at the compliance boundary.

An exceedance of groundwater standards at or beyond the compliance boundary is subject to remediation action according to 15A NCAC 02L .0106(d)(2) as well as enforcement actions in accordance with North Carolina General Statute 143-215.6A through 143-215.6C.

Other State Regulations and Local Ordinances

Other state regulations may impact land application activities. Of particular concern to DWR are:

- Applicable river buffer rules in 15A NCAC 02B .0200.
- Erosion and sedimentation control requirements in 15A NCAC Chapter 4 and under the Division's General Permit NCG010000.
- Any requirements pertaining to wetlands under 15A NCAC 02B .0200 and 02H .0500.
- Documentation of compliance with Article 21 Part 6 of Chapter 143 of the General Statutes.

In addition to state and federal regulations, there may be local regulations or ordinances that apply to land application programs. Local regulations usually deal with the zoning or location of land application systems rather than the actual operation of these facilities. Local ordinances can specify how property in certain areas can be used.

It is beyond the scope of this manual to review all regulations, ordinances, and other legal issues potentially relevant to land application of residuals. Owners and operators of land application programs should research additional regulations and local ordinances, if any, to ensure compliance with them.

15A NCAC 8G

15A NCAC 8G, the "*Water Pollution Control System Operator Rules*", are certification rules that establish minimum professional standards for the operation and maintenance of water pollution control systems. The body responsible for overseeing these rules is the ***Water Pollution Control System Operators Certification Commission (WPCSOCC)***.

The WPCSOCC consists of eleven members, nine which represent some facet of the wastewater industry and two which represent the animal agricultural industry. The North Carolina General Assembly has given the WPCSOCC the authority to adopt, revise, interpret, and implement the rules by which certified operators must abide.

The purpose of the WPCSOCC and 8G is to assure protection of public health and the environment, as well to:

- establish the procedures for the examination and certification of operators of water pollution control systems,
- provide for the classification of water pollution control systems, and
- establish procedures for review and determine appropriate action when complaints of operator misconduct or incompetence are received.

Currently, 15A NCAC 8G provides for the certification of these types of operators:

- land application of residuals
- biological wastewater
- physical/chemical wastewater
- collections
- surface irrigation
- subsurface

Obtaining Certification

To become certified, operators must meet the following general eligibility requirements:

- be at 18 years old
- have a high school degree or GED
- attend and successfully complete an approved training school
- be able to perform calculations
- be able to read and understand regulations

In addition, an applicant for certification as a Land Application of Residuals Operator must meet ***one*** of the following:

- have one year of actual experience in the land application of residuals *or*
- be a graduate of a two or four year college or university and have taken and passed a minimum of six courses in the basic sciences *or*
- hold a valid grade 2 or higher biological water pollution control system operator certification

If an applicant is unable to meet the actual experience requirement meets the other prerequisite education and certification requirements, the applicant may apply for a Land Application of Residuals System ***Operator-In-Training (OIT)*** certificate. Upon sitting for the examination and achieving a passing score, the applicant will be issued a Land Application of Residuals System OIT certificate. When the required operational experience has been accrued, the OIT certificate holder can apply for conversion to full certification by submitting an application documenting the experience, along with a conversion fee.

Once certified, 8G requires that certified operators must:

- abide by all statutes and rules regarding the operation of water pollution control systems
- notify the WPCSOCC, *in writing*, within 30 calendar days of address changes
- maintain active certificates by renewing them every year

Maintaining Certification

To renew a certificate, an operator must obtain at least six hours of approved continuing education every year (following the year of initial certification) and pay an annual renewal fee. Certificates become invalid if they are not renewed by midnight, December 31.

Operators can renew certificates that have been invalid for less than two years by completing all outstanding continuing education requirements and paying all outstanding renewal and late fees. Certificates that have been invalid for two or more consecutive years cannot be renewed. Operators must attend the initial training school again, and re-take and pass the exam within twelve months of completing the school.

We will discuss operator responsibilities and other requirements of 15A NCAC 8G in much more detail in later chapters.

Implementing Regulations – Residuals Permitting Programs

The Division of Water Resources implements and enforces 02T .1100 through its residuals permitting programs. Anyone that land applies, distributes, or places residuals in a surface disposal unit must first receive a permit from DWR. Assisted by staff from seven regional offices located around the state, DWR's Non-Discharge Permitting Branch issues permits for a variety of non-discharge systems, including residuals permits (Figure 2-1).

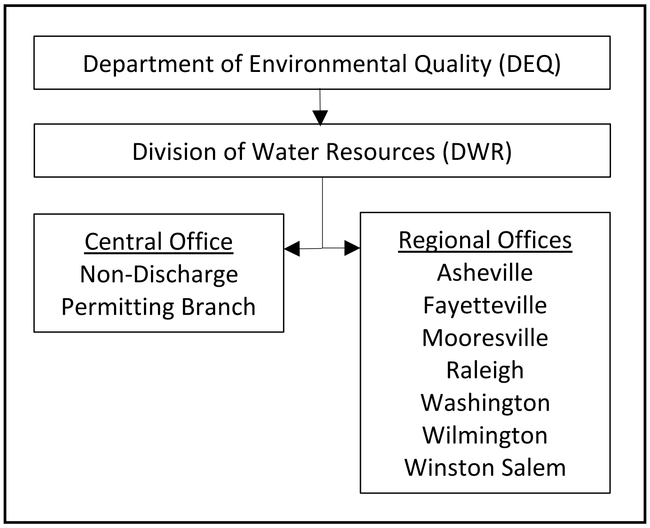


Figure 2-1. Simplified organizational chart showing the relationship between DWR's central and regional offices.

What is a Permit?

A permit is a binding agreement between DWR and the Permittee. It is a legal document that is enforceable by law. It incorporates the regulatory requirements of 02T .1100 and explains the responsibilities of the Permittee. The Permittee is responsible for understanding and complying with the permit and all related environmental regulations and laws. If any part of the permit is unclear, the Permittee should contact the appropriate DWR regional office for assistance.

Who is the Permittee?

In most cases, DWR issues the residuals permit to the generator/preparer, who is the Permittee. An example is DWR issues a permit to the town manager of a municipality for land application of the residuals generated during wastewater treatment at the wastewater treatment plant.

The Permittee may enter into contractual agreements with other entities (private contractors or residuals management companies) to transport and/or land apply the residuals. However, the municipality is still responsible for any activities covered by the residuals permit.

In some cases, DWR issues the residuals permit to a private contractor or company for management of residuals generated by one or more sources. In this situation, the contractor or company is the Permittee and is the responsible party for management of the residuals. There is, however, the concept of “cradle to grave” which means that the generator/preparer is never completely free of responsibility for its residuals, from generation to ultimate use or disposal.

It is wise for the generator/preparer to provide guidance and oversee the activities of the contractor, even if the contractor is the Permittee. If the contractor does not follow good management practices, the preparer may lose the trust of the farmer and the community.

Types of Residuals Permits

DWR issues the following types of residuals permits:

- Distribution of Class A Residuals
- Land Application of Class B Residuals
    - Non-Dedicated Sites
    - Dedicated Sites
- Surface Disposal of Residuals

Distribution of Class A Residuals Permits

Class A residuals meet the highest standards of treatment and quality. They are safe for use on lawns, gardens, or areas accessible by the public. Class A residuals can be sold or given away in bags or other small containers or can be distributed in bulk quantities to be land applied over large areas.

Bag and other container means a bag, bucket, bin, box, carton, vehicle, trailer, tanker, or an open or closed receptacle with a load capacity of 1.102 short tons or one metric ton or less. Class A residuals distributed in this manner are used by the small-scale user, such as a home gardener or landscaper.

Class A residuals are usually permitted for distribution rather than land application since the end user that applies the residuals is not always under the direct control of the generator. Class A Distribution permits are not site-specific. Because Class A residuals are of such high quality, DWR does not evaluate and approve specific fields or land where they can be applied.

The land onto which Class A residuals are applied is deemed permitted under 15A NCAC 02T .1103. ***Deemed permitted*** means that an application site is permitted by regulation and that residuals can be applied to it if it meets the requirements of federal and state regulations and does not violate permit conditions. It is the responsibility of the land applier or end user to determine if a site meets the requirements.

Class A residuals that are distributed in bags or other small containers pose little threat for over-application, runoff, or causing environmental concerns or nuisance conditions. Consequently, they have few restrictions on their use. The characteristics of bagged Class A residuals are often like those of other fertilizers and soil amendments available for retail, and the residuals are often marketed as such.

Bulk residuals mean residuals that are not sold or given away in a bag or other container but are transported in large amounts for application to the land. Bulk Class A residuals are used by commercial or municipal appliers for agriculture, tree and turf farms, golf courses, and parks. Because there is a greater likelihood of over-application, runoff, or nuisance conditions with application of bulk Class A residuals, there are more restrictions on their use.

Land Application of Class B Residuals Permits

Class B residuals meet lower (but still considerable) standards of treatment and quality. Consequently, permits for land application of Class B residuals are more restrictive than distribution permits. Site restrictions and operational requirements allow for final treatment to occur through natural processes at the application site.

Class B residuals cannot be sold or given away in bags or distributed for application to home gardens, golf courses, and parks. They can only be land applied on sites that a soil scientist has evaluated and that DWR has approved. There are two types of Class B residuals permits.

○ *Non-Dedicated Sites*

Most Class B permits are issued for land application to ***non-dedicated*** sites: agricultural land where crops are planted and removed on an agricultural schedule. Residuals must be applied at agronomic rates. The ***agronomic rate*** is the amount of residuals that will meet but not exceed the nutrient needs of the crop. We will discuss agronomic rates in detail in a later chapter.

- ### *Dedicated Sites*

  Permits for land application of Class B residuals to ***dedicated sites*** involve at least one of the following:

  ☐ bulk residuals are applied at greater than agronomic rates

  ☐ bulk residuals are applied through fixed irrigation facilities or irrigation facilities fed through a fixed supply system

  ☐ the primary use of the application fields is for the disposal of residuals and crop production is of secondary importance

  These permits allow bulk application of residuals on the same land repeatedly and over a long period of time. Sites are not managed agronomically. Because of the likelihood of over-application of residuals, requirements are more rigorous than those for non-dedicated permits. On-site groundwater monitoring wells are usually required.

Surface Disposal Permits

Surface disposal describes a permitted site on which residuals are placed for final disposal, not for conditioning the soil or fertilizing crops. Surface disposal sites are not tied to agronomic rates. Examples of surface disposal units are monofills, lagoons, or trenches.

Permit Layout

Residuals permits are comprehensive documents that address all aspects of operation. Although each permit is unique to an operation, they all follow similar formats. The standard parts of the permit are:

- Cover letter
- Description
- Section I: Schedules
- Section II: Performance Standards
- Section III: Operation and Maintenance Requirements
- Section IV: Monitoring and Reporting Requirements
- Section V: Inspections
- Section VI: General Conditions
- Attachments
  - Attachment A (sources – Class A and Class B)
  - Attachment B (sites – Class B only)
  - Attachment C (monitoring wells – Dedicated permits only)

The permit conditions covered in this manual are based on the standard conditions currently used in residuals permits. Permit conditions (and regulations) evolve. If your permit has not been renewed or modified for several years, it may have some conditions that are different from those in newly issued or recently renewed permits. Until it is modified or renewed, you must abide by the conditions and requirements of ***your*** permit.

Your permit is unique. *Read it!*

Cover Letter

The Cover Letter is addressed to the Permittee and contains the permit number, facility name, a statement authorizing the residuals management program, and a primary DWR contact. If it accompanies a permit renewal, the letter highlights changes in permit conditions from the previous version.

Program Description

The description is a summary of the permitted activities and establishes the effective and expiration date of the permit.

Section I: Schedules

The Schedules section of the residuals permit is where you will find one-time compliance events, such as permit renewal requirements (a renewal application must be submitted no later than six months prior to the expiration of the current version of the permit). Be sure to read the entire permit for *on-going* monitoring and reporting requirements.

Section II: Performance Standards

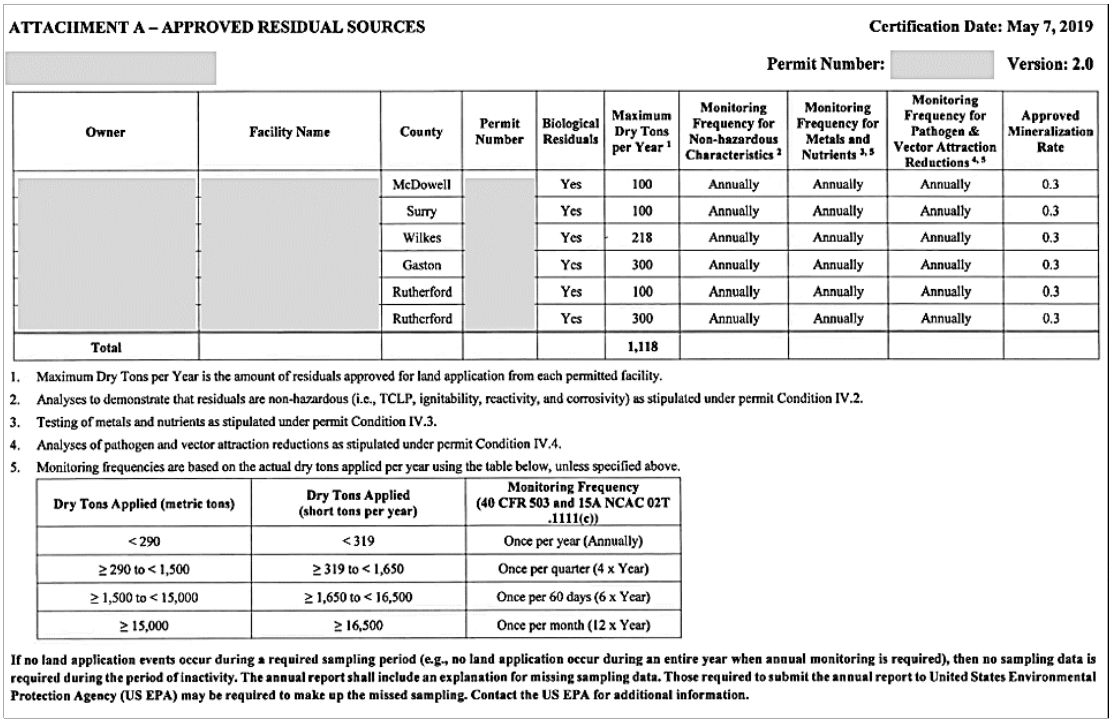
The Performance Standards section of the permit describes how the residuals program must function. It must be operated and maintained as a ***non-discharge system*** so that there is no discharge to surface waters and no violation of groundwater or surface water standards. The creation of ***nuisance conditions*** (odors, dust, noise, traffic, etc.) due to improper operation and maintenance is also prohibited.

Operation as a non-discharge system means that there must be no runoff of residuals from the application site or leaching of inadequately treated contaminants through the soil. ***Runoff*** is water from precipitation or from residuals that flows over the surface of the soil toward a stream or lake without being absorbed into the soil. ***Leaching*** is the downward movement of a dissolved substance through the soil.

The permit only allows land application or distribution of residuals generated by sources listed in Attachment A. Both Class A and Class B permits contain an Attachment A. It may list one source or multiple sources (Figure 2-2).

Class B permits allow land application only to the sites listed in Attachment B (Figure 2-3). For each field/site, Attachment B lists the field/site number, the owner, the lessee (if there is one), county, latitude, longitude, net acreage, and dominant soil series. It also lists the total acreage of all approved fields/sites combined. Since DWR does not approve the specific sites upon which Class A residuals are applied, Class A permits do not have an attachment B.

Attachment C, if there is one, lists the groundwater monitoring wells located at the site and contains requirements for groundwater monitoring. Only a very few residuals permits (those for Land Application to Dedicated Sites) contain an Attachment C.



ATTACHMENT A – APPROVED RESIDUAL SOURCES **Certification Date: May 7, 2019**

[redacted] **Permit Number:** [redacted] **Version: 2.0**

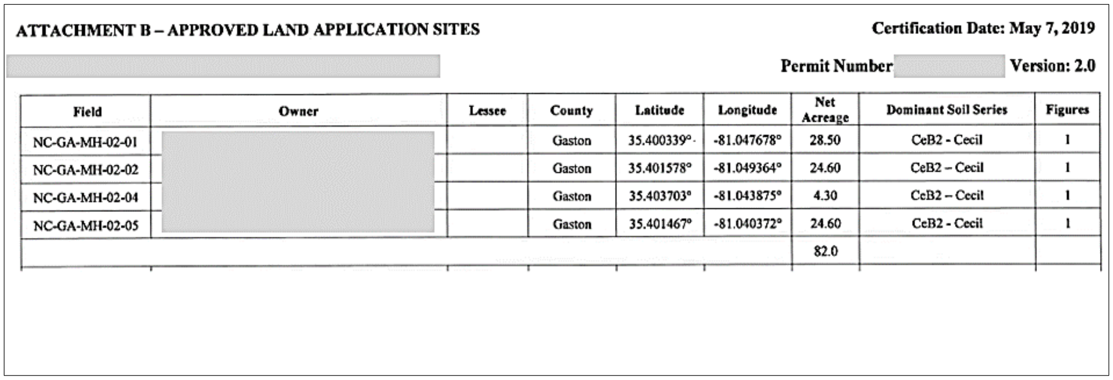
Owner	Facility Name	County	Permit Number	Biological Residuals	Maximum Dry Tons per Year[1]	Monitoring Frequency for Non-hazardous Characteristics[2]	Monitoring Frequency for Metals and Nutrients[3,5]	Monitoring Frequency for Pathogen & Vector Attraction Reductions[4,5]	Approved Mineralization Rate
[redacted]	[redacted]	McDowell	[redacted]	Yes	100	Annually	Annually	Annually	0.3
		Surry		Yes	100	Annually	Annually	Annually	0.3
		Wilkes		Yes	218	Annually	Annually	Annually	0.3
		Gaston		Yes	300	Annually	Annually	Annually	0.3
		Rutherford		Yes	100	Annually	Annually	Annually	0.3
		Rutherford		Yes	300	Annually	Annually	Annually	0.3
Total					**1,118**				

1. Maximum Dry Tons per Year is the amount of residuals approved for land application from each permitted facility.
2. Analyses to demonstrate that residuals are non-hazardous (i.e., TCLP, ignitability, reactivity, and corrosivity) as stipulated under permit Condition IV.2.
3. Testing of metals and nutrients as stipulated under permit Condition IV.3.
4. Analyses of pathogen and vector attraction reductions as stipulated under permit Condition IV.4.
5. Monitoring frequencies are based on the actual dry tons applied per year using the table below, unless specified above.

Dry Tons Applied (metric tons)	Dry Tons Applied (short tons per year)	Monitoring Frequency (40 CFR 503 and 15A NCAC 02T .1111(c))
< 290	< 319	Once per year (Annually)
≥ 290 to < 1,500	≥ 319 to < 1,650	Once per quarter (4 x Year)
≥ 1,500 to < 15,000	≥ 1,650 to < 16,500	Once per 60 days (6 x Year)
≥ 15,000	≥ 16,500	Once per month (12 x Year)

If no land application events occur during a required sampling period (e.g., no land application occur during an entire year when annual monitoring is required), then no sampling data is required during the period of inactivity. The annual report shall include an explanation for missing sampling data. Those required to submit the annual report to United States Environmental Protection Agency (US EPA) may be required to make up the missed sampling. Contact the US EPA for additional information.

Figure 2-2. Both Class A and B permits contain an Attachment A.



ATTACHMENT B – APPROVED LAND APPLICATION SITES **Certification Date: May 7, 2019**

[redacted] **Permit Number** [redacted] **Version: 2.0**

Field	Owner	Lessee	County	Latitude	Longitude	Net Acreage	Dominant Soil Series	Figures
NC-GA-MH-02-01	[redacted]		Gaston	35.400339°	-81.047678°	28.50	CeB2 - Cecil	1
NC-GA-MH-02-02			Gaston	35.401578°	-81.049364°	24.60	CeB2 – Cecil	1
NC-GA-MH-02-04			Gaston	35.403703°	-81.043875°	4.30	CeB2 – Cecil	1
NC-GA-MH-02-05			Gaston	35.401467°	-81.040372°	24.60	CeB2 - Cecil	1
						82.0		

Figure 2-3. Class B permits contain an Attachment B. Class A permits do not.

The next chapter covers more of the Performance Standards, specifically those relating to residuals quality:

- concentration of metals
- degree of pathogen reduction
- reduced attractiveness to vectors (organisms such as rodents, insects, or birds that can spread disease by carrying and transferring pathogens)

Chapter 3

Residuals Quality – Can You Apply?

Before residuals can be land applied or distributed, they must first be determined to be non-hazardous by performing a Toxicity Characteristic Leaching Procedure (TCLP). This requirement will be discussed when we get to the Monitoring and Reporting section of the permit.

Once they are determined to be non-hazardous, residuals must meet the standards of quality contained in the Performance Standards section of the permit before they can be land applied or distributed:

- pollutant (metal) concentrations must be below specified limits (all residuals)
- pathogen levels must be greatly reduced (biological residuals)
- attractiveness to vectors (rodents, insects, birds, etc.) must be greatly reduced (biological residuals)

Distribution of Class A Residuals permits require that residuals meet very high standards of quality:

- Class A pollutant limits
- Class A pathogen reduction requirements
- One vector attraction reduction alternative

Land Application of Class B Residuals permits require that residuals meet lesser, but considerable, standards of quality:

- Class B pollutant limits
- Class B pathogen reduction requirements
- One vector attraction reduction alternative

Pollutant (Metals) Limits

In general conversation, the word “pollutant” can mean any substance that contaminates air, soil, or water. However, when federal and state regulations use the term ***pollutant*** in relation to residuals, they are referring to metals. In this context, the terms “pollutants” and “metals” are used interchangeably.

Federal and state regulations have identified nine metals of concern and set limits on the amount of these pollutants (metals) allowed in residuals that are land applied:

- Arsenic (As)
- Cadmium (Cd)
- Copper (Cu)
- Lead (Pb)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Selenium (Se)
- Zinc (Zn)

There are three types of pollutant concentration limits:

- Ceiling Concentration Limits
- Monthly Average Concentration Limits
- Cumulative Pollutant Loading Rates

☐ ***Ceiling Concentration Limits.*** Ceiling Concentration Limits are the maximum amounts of the nine regulated metals allowed in residuals that are land applied or distributed. Both Class A and Class B permits prohibit the land application or distribution of residuals that exceed any one of Ceiling Concentration Limits.

Ceiling Concentration Limits are *instantaneous* with respect to compliance, which means they are based on the lab results of an individual sample collected from one location at one point in time. Residuals that exceed the Ceiling Concentration Limit for even one of the regulated metals cannot be land applied. We will discuss alternatives later in the chapter.

☐ ***Monthly Average Concentration Limits.*** In addition to meeting the Ceiling Concentration Limits, Class A residuals must also meet the more stringent Monthly Average Concentration Limits. Monthly average means the arithmetic mean of all measurements taken during the month.

For example, the Monthly Average Concentration Limit for Arsenic is 41 mg/kg. If three samples are taken in one month, the concentration of Arsenic in one of the samples can be greater than 41 mg/kg. However, the average concentration of Arsenic in the samples must be at or below 41 mg/kg.

☐ ***Cumulative Pollutant Loading Rates.*** Cumulative Pollutant Loading Rates (CPLRs) apply to Class B residuals only. These limits are the maximum quantities of the regulated metals that can be added to an area of land over its lifetime.

Class A Pollutant Limits

Class A residuals cannot exceed either the Ceiling Concentration Limits or the Monthly Average Concentration Limits. Tracking Cumulative Pollutant Loading Rates is not required. Class A permits contain a table like Table 3-1.

Table 3-1. Class A Pollutant Limits

Parameter	Ceiling Concentration *(mg/kg)*	Monthly Average Concentration *(mg/kg)*
Arsenic	75	41
Cadmium	85	39
Copper	4,300	1,500
Lead	840	300
Mercury	57	17
Molybdenum	75	n/a
Nickel	420	420
Selenium	100	100
Zinc	7,500	2,800

Class B Pollutant Limits

Class B residuals cannot exceed either the Ceiling Concentration Limits or the Cumulative Pollutant Loading Rates. They can exceed the Monthly Average Concentration Limits. Class B permits contain a table like Table 3-2.

Each time you apply Class B residuals, you must record the amount of each metal you applied to a field. You must track annual and total loadings of each metal to each field. When the Cumulative Pollutant Loading Rate is reached for any one of the nine metals, no additional bulk residuals can be applied to that field.

Table 3-2. Class B Pollutant Limits.

Parameter	Ceiling Concentration *(mg/kg)*	CPLR *(lbs/acre)*
Arsenic	75	36
Cadmium	85	34
Copper	4,300	1,338
Lead	840	267
Mercury	57	15
Molybdenum	75	n/a
Nickel	420	374
Selenium	100	89
Zinc	7,500	2,498

Class B permits require that you determine compliance with the CPLRs using one of the following methods:

- By calculating the existing cumulative level of pollutants using actual analytical data from all historical land application events of residuals; or
- For land where residuals application has not occurred or for which the required data is incomplete, by determining background concentrations through representative soil sampling.

Reducing Metals – The National Pretreatment Program

Industries are the major source of metals in wastewater. Municipal wastewater treatment plants are not designed to treat this kind of industrial waste, which can have negative effects on effluent quality and ultimately residuals quality.

To reduce or eliminate the discharge of industrial contaminants to municipal treatment plants, EPA established the National Pretreatment Program in the 1980's. Industries are now required to use treatment techniques and management practices to reduce or eliminate metals and other contaminants and dispose of them safely before sending their wastewater to municipal plants or discharging it to the environment.

As a result, the quality of residuals with regards to industrial contaminants has improved significantly over the last forty years. The concentrations of metals in residuals generated by most municipal wastewater treatment plants are sufficiently low that Ceiling Concentration Limits are rarely exceeded. Treatments plants, however, must rigorously monitor the residuals they generate to ensure that this is the case.

Pathogen Reduction Requirements

The second criteria used to evaluate residuals quality is pathogen reduction. Because biological wastewater treatment plants (municipal and industrial) use bacteria and other microorganisms to break down waste, biological residuals are likely to contain high concentrations of pathogens. Before biological residuals can be land applied, they must be processed to greatly reduce pathogen concentrations.

Non-biological residuals are exempt from meeting the pathogen reduction requirements, provided they are not mixed with residuals that have been generated during the treatment of domestic wastewater, the treatment of animal processing wastewater, or the biological treatment of industrial wastewater.

At a minimum, all residuals that are land applied must meet Class B pathogen reduction requirements. Residuals that do not achieve at least Class B pathogen reduction cannot be land applied.

Residuals permits do not specify the process by which pathogens must be reduced. Instead, the permit refers to 02T .1106 which describes the processes that preparers can use. These processes are very specific for treatment plant operating conditions and residuals characteristics. Preparers must document that they have met the operational and technical standards for whichever option they select.

Class A Pathogen Reduction Requirements

The goal of Class A pathogen reduction is to reduce pathogens to a level that does not pose a risk of disease transmission through casual contact or ingestion. Residuals that meet Class A pathogen reduction undergo such rigorous treatment that pathogens are virtually eliminated. These residuals are safe for use on lawns, gardens, or areas accessible by the public with no waiting periods and fewer site restrictions than Class B residuals.

To achieve Class A pathogen reduction, residuals must meet *both* requirements specified in 02T .1106(b):

1. they must be tested for pathogen density ***and***
2. they must be treated by a process known to reduce pathogens and prevent re-growth

Table 3-3 lists the alternatives for meeting these requirements. Treatment alternatives 2(E) through 2(K) are known as Processes to Further Reduce Pathogens (PFRPs). Table 3-5 describes Class A treatment alternatives in some, but not full, detail. For specific details, refer to 02T .1106.

Table 3-3. Class A Pathogen Reduction Requirements

1) Demonstrate Pathogen Density
    - A. Fecal coliform: <1,000 MPN/gram TS

      or
    - B. Salmonella: <3 MPN/4 gram TS

and

2) Meet One Treatment Alternative
    - A. Time/Temperature
    - B. Alkaline Treatment
    - C. Prior Testing for Enteric Virus/Helminth Ova
    - D. No Prior Testing for Enteric Virus/Helminth Ova
    - E. PFRP: Composting
    - F. PFRP: Heat Drying
    - G. PFRP: Heat Treatment
    - H. PFRP: Thermophilic Aerobic Digestion
    - I. PFRP: Beta Ray Irradiation
    - J. PFRP: Gamma Ray Irradiation
    - K. PFRP: Pasteurization

Class B Pathogen Reduction Requirements

When Class B requirements are met, pathogen levels are significantly reduced, but they are still present. Final pathogen removal occurs through natural processes at the application site. The goal of Class B pathogen reduction is to reduce pathogens to a level where the residuals are safe to use with additional site management and access restrictions. When these requirements are met, Class B residuals are as safe as Class A residuals.

To achieve Class B pathogen reduction, residuals must meet *one* of the requirements these requirements:

1. they must be tested for pathogen density ***or***
2. they must be treated in a Process to Significantly Reduce Pathogens (PSRP)

Table 3-4 lists the alternatives for meeting pathogen reduction alternatives for Class B biological residuals. Table 3-6 describes Class B pathogen reduction requirements in some, but not full, detail. For specific details, refer to 02T .1106.

Table 3-4. Class B Pathogen Reduction Requirements

1) Demonstrate Fecal Coliform Density
   < 2,000,000 MPN or CFU/gram TS

or

2) Meet One Treatment Alternative (PSRP)
   A. Aerobic Digestion
   B. Air Drying
   C. Anaerobic Digestion
   D. Composting
   E. Lime Stabilization

Demonstrating Pathogen Density

One of the commonly used alternatives for demonstrating that Class B pathogen reduction requirements have been met is the density of fecal coliform bacteria. Almost all Class A residuals are tested for fecal coliform density (very few preparers test for salmonella). So, it’s important to know what fecal coliform are and understand their role in demonstrating pathogen reduction.

Residuals contain numerous species of pathogens and testing for each species is impractical. Many pathogens are difficult to isolate and can be dangerous in concentrations that are too small to easily measure. Instead, the presence of pathogens is determined indirectly by testing for indicator organisms. ***Indicator organisms*** respond to treatment processes and environmental conditions in a manner like pathogens but are not themselves pathogenic.

Fecal coliform bacteria are often used as indicator organisms because they are very abundant in human wastes and are much easier to locate and identify than viruses and other pathogens. Although most fecal coliform bacteria are not pathogenic, they can be used demonstrate the potential presence or absence of pathogens.

Fecal coliform test results for residuals are reported as either Most Probable Number (MPN) or Colony Forming Units (CFU) of fecal coliform bacteria per gram of total solids. Both are methods of estimating the number of living bacterial cells in a sample rather than a direct count using a microscope, which includes both dead and living cells.

Class A residuals must be monitored for the density of fecal coliform or Salmonella sp. bacteria at the time that the residuals are used or disposed, or at the time they are prepared for sale or giving away in a bag or other container, rather than immediately following treatment.

Table 3-5. Treatment Alternatives for Class A Pathogen Reduction.

Alternative A:	***Time/Temperature*** ~ Residuals are subjected to one of four time/temperature regimes.
Alternative B:	***Alkaline Treatment*** ~ The pH of the residuals must be raised to above 12 and remains above 12 for 72 consecutive hours. During this period, the temperature of the residuals must be above 52ºC for 12 hours or longer. At the end of the 72-hour period during which the pH is above 12, the residuals must be air dried to achieve a total solids >50%.
Alternative C:	***Prior Testing for Enteric Viruses/Viable Helminth Ova*** ~ Residuals are analyzed before and after pathogen reduction treatment for enteric viruses or viable helminth ova. If specified densities are demonstrated, the residuals are Class A if the operating parameters for the pathogen reduction treatment are met and documented to the satisfaction of the Division.
Alternative D:	***No Prior Testing for Enteric Viruses/Viable Helminth Ova*** ~ The density of enteric or viable helminth ova in the residuals is below specified levels at the time that the residuals are used or disposed or is prepared for sale or giving away in a bag or other contained for application to the land.
Alternative E:	***Process to Further Reduce Pathogens: Composting*** ~ Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the residuals is maintained at 55ºC for 3 consecutive days or longer. Alternately, using the windrow composting method, the temperature of the residuals is maintained at 55ºC for 15 consecutive days or longer. During the period when the residuals are maintained at 55ºC, the windrow is turned a minimum of 5 times.
Alternative F:	***Process to Further Reduce Pathogens: Heat Drying*** ~ Residuals are dried by direct or indirect contact with hot gases to reduce the moisture content of the residuals to 10 percent or lower. Either the temperature of the residuals particles exceeds 80ºC or the wet bulb temperature of the gas in contact with the residuals as they leave the dryer exceeds 80ºC.
Alternative G:	***Process to Further Reduce Pathogens: Heat Treatment*** ~ Residuals are heated to a temperature of 180ºC or higher for 30 minutes. This process is only available to residuals that are in a liquid state.
Alternative H:	***Process to Further Reduce Pathogens: Thermophilic Aerobic Digestion*** ~ Residuals are agitated with air or oxygen to maintain aerobic conditions, and the mean cell residence time of the residuals is 10 days at 55ºC to 60ºC. This process is only available to residuals that are in a liquid state.
Alternative I:	***Process to Further Reduce Pathogens: Beta Ray Irradiation*** ~ Residuals are irradiated with beta rays from an accelerator at dosages of at least 1.0 megarad at room temperature (approximately 20ºC).
Alternative J:	***Process to Further Reduce Pathogens: Gamma Ray Irradiation*** ~ Residuals are irradiated with gamma rays from certain isotopes, such as Cobalt 60 and Cesium 137, at room temperature (approximately 20ºC).
Alternative K:	***Process to Further Reduce Pathogens: Pasteurization*** ~ The temperature of the residuals is maintained at 70ºC or higher for 30 minutes or longer.

Table 3-6. Alternatives for Meeting Class B Pathogen Reduction Requirements.

Alternative 1:	***Fecal Coliform Density Demonstration*** ~ Seven samples of the biological residuals are collected at the time the residuals are used or disposed, and the geometric mean of the density of fecal coliform in the samples collected is less than either 2,000,000 Most Probable Number per gram of total solids (i.e., dry weight) or 2,000,000 Colony Forming Units per gram of total solids (i.e., dry weight basis).
Alternative 2:	***Process to Significantly Reduce Pathogens*** ~ The biological residuals processed in a process to significantly reduce pathogens. The processes to significantly reduce pathogens are as follows: A. ***Aerobic Digestion*** ~ Biological residuals are agitated with air or oxygen to maintain aerobic conditions for a specific mean cell time at a specific temperature. Values for the mean cell residence time and temperature are between 40 days at 20 degrees Celsius and 60 days at 15 degrees Celsius B. ***Air Drying*** ~ Biological residuals are dried on sand beds or on paved or unpaved basins for a minimum of three months. During two of the three months, the ambient average daily temperature is above zero degrees Celsius. C. ***Anaerobic Digestion*** ~ Biological residuals are treated in the absence of air for a specific mean cell residence time at a specific temperature. Values for the mean cell residence time and temperature are between 15 days at 35 to 55 degrees Celsius and 60 days at 20 degrees Celsius. D. ***Composting*** ~ Using either the within-vessel, static aerated pile, or windrow composting methods, the temperature of the biological residuals is raised to 40 degrees Celsius or higher and remains at 40 degrees Celsius or higher for five days. For four hours during the five days, the temperature in the compost pile exceeds 55 degrees Celsius. Natural decay of the biological residuals under uncontrolled conditions is not sufficient to meet this process. E. ***Lime Stabilization*** ~ Sufficient lime is added to the biological residuals to raise the pH to 12 after two hours of contact.

Vector Attraction Reduction

The third component of residuals quality is vector attraction reduction. Vector attraction refers to those characteristics of biological residuals that attract vectors such as birds, rodents, and insects. Vectors looking for food are attracted to the organic solids in biological residuals and can transport pathogens away from land application sites, potentially posing a health concern to the public.

Biological residuals that are land applied must meet vector attraction reduction requirements. Unlike pollutant concentrations and pathogen reduction, there is only one level of vector attraction reduction. Both Class A and Class B biological residuals must meet one of the alternatives listed in Table 3-5. As with pathogen reduction, residuals permits do not specify the method by which vector attraction must be reduced. Instead, permits refer to 02T .1107 which describes processes that can be used.

Table 3-7. Vector Attraction Reduction Alternatives and Location Where They Must Be Met

1. 38-Percent Volatile Solids Reduction	WWTP
2. 40-Day Bench Scale Test	
3. 30-Day Bench Scale Test	
4. Specific Oxygen Uptake Rate (SOUR) Test	
5. 14-Day Aerobic Process	
6. Alkaline Stabilization	
7. Drying of Stabilized Residuals	
8. Drying of Unstabilized Residuals	
9. Injection	Field
10. Incorporation	

Alternatives 1 to 8 reduce vector attraction through biological, chemical, or physical processes at the treatment plant. Some alternatives reduce vector attraction by destroying volatile organic solids (solids that burn off during combustion). Others reduce vector attraction by creating environmental conditions (high pH or dryness) unfavorable to vectors.

All these processes are very specific for various treatment plant operating conditions and residuals characteristics. Preparers must document that they have met the operational and technical standards for whichever option they select and provide documentation to the land applier.

Alternatives 9 and 10 reduce vector attraction by creating a barrier between the residuals and potential vectors. These alternatives involve incorporating (tilling) or injecting residuals into the soil at the land application site. They can be used for residuals that do not meet Alternatives 1 through 8. These alternatives require the land applier to certify that vector attraction reduction is done properly.

Non-biological residuals are exempt from meeting the vector attraction reduction requirements, provided they are not mixed with residuals that have been generated during the treatment of domestic wastewater, the treatment of animal processing wastewater, or the biological treatment of industrial wastewater.

Pathogen Reduction and Vector Attraction Reduction

Compliance with pathogen reduction and vector attraction reduction requirements must be demonstrated separately. Demonstrating that vector attraction reduction requirements have been met does not mean that pathogen reduction requirements have also been met, and vice versa. They are, however, often related steps of a process. Some vector attraction reduction alternatives are suitable only for residuals that have been processed by certain methods, such as by aerobic or anaerobic digestion or composting (Table 3-8).

Residuals Quality Summary

To qualify as Class A, residuals must meet:

- Class A pollutant concentration limits
- Class A pathogen reduction requirements (if biological)
- One vector attraction reduction alternative (if biological)

Residuals that are land applied must, at a minimum, meet Class B requirements:

- Class B pollutant concentration limits
- Class B pathogen reduction requirements (if biological)
- One vector attraction reduction alternative (if biological)

The next chapter describes commonly used treatment and processing methods. Contingency plans for residuals that fail to meet minimum requirements for land application are also discussed.

Table 3-8. Vector Attraction Reduction Alternative and the Pathogen Reduction Alternatives for which they are appropriate.

	Vector Attraction Reduction Alternatives	*Pathogen Reduction Alternatives*
1.	***Reduction in Volatile Solids (38-Percent Volatile Solids Reduction)*** The mass of volatile solids must be reduced by a minimum of 38% between the time the biological residuals enter the digestion process and the time they are land applied.	Aerobically or anaerobically digested residuals.
2.	***Additional Digestion of Anaerobically Digested Residuals (40-Day Bench Scale Test*)** When the 38% volatile solids reduction requirement cannot be met for anaerobically digested residuals, vector attraction reduction can be demonstrated by digesting a portion of the previously digested residuals anaerobically in the laboratory in a bench-scale unit for forty additional days at a temperature between 30 and 37°C (86 and 98.6°F). After the forty-day period, the vector attraction reduction requirement is met if the volatile solids in the residuals at the beginning of that period are reduced by less than 17%.	Only for anaerobically digested residuals that cannot meet the requirements of Alternative 1.
3.	***Additional Digestion of Aerobically Digested Residuals (30-Day Bench Scale Test)*** When the 38% volatile solids reduction requirement in this subsection cannot be met for aerobically digested residuals, vector attraction reduction can be demonstrated by digesting a portion of the previously digested residuals that has a percent solids of 2% or less aerobically in the laboratory in a bench-scale unit for thirty additional days at 20°C (68°F). After the thirty-day period, the vector attraction reduction requirement is met if the volatile solids in the residuals at the beginning of that period are reduced by less than 15% percent.	Only for aerobically digested liquid residuals with 2% or less solids that cannot meet the requirements of Alternative 1 - e.g., residuals treated in extended aeration plants. Sludges with 2% solids must be diluted.
4.	***Specific Oxygen Uptake Rate (SOUR) Test*** The specific oxygen uptake rate (SOUR) for residuals treated in an aerobic process must be less than or equal to 1.5 milligrams of oxygen per hour per gram of total solids (dry weight basis) at a temperature of 20°C (68°F).	Liquid residuals from aerobic processes run at temperatures between 10 to 30°C. (should not be used for composted residuals).
5.	***14-Day Aerobic Processes*** Use aerobic processes at greater than 40ºC (average temperatures 45ºC) for 14 days or longer (e.g., during composting). The residuals must be treated in an aerobic process for fourteen days or longer. During that time, the temperature of the residuals must be higher than 40°C (104°F) and the average temperature of the residuals must be higher than 45°C (113°F).	Composted residuals (Alternatives 3 and 4 are likely to be easier to meet for residuals from other aerobic processes).

6.	***pH Adjustment (Alkaline Stabilization)*** The pH of the residuals must be raised to twelve or higher by alkali addition and, without the addition of more alkali, must remain at twelve or higher for two hours and then at 11.5 or higher for an additional twenty-two hours.	Alkali-treated residuals (alkaline materials include lime, fly ash, kiln dust, and wood ash)
7.	***Drying of Stabilized Residuals*** Reduce moisture content of residuals that do not contain unstabilized solids from other than primary treatment to at least 75% solids. Residuals cannot be mixed with other materials when using this alternative.	Residuals treated by an aerobic or anaerobic process (i.e., residuals that do not contain unstabilized solids generated in primary wastewater treatment)
8.	***Drying of Unstabilized Residuals*** Reduce moisture content of residuals with unstabilized solids from a primary wastewater treatment process to at least 90% solids. Residuals cannot be mixed with other materials when using this alternative.	Residuals that contain unstabilized solids generated in primary wastewater treatment (e.g., heat dried residuals)
9.	***Injection*** Inject residuals beneath the soil surface: a. so that no significant amount of residuals is present on the land surface within one hour of injection; and b. within eight hours after being discharged from the pathogen treatment process if Class A for pathogens.	Residuals applied to the land
10.	***Incorporation*** Incorporate residuals applied to or placed on the land surface: a. within six hours after application to the land if Class B for pathogens; or b. within eight hours after being discharged from the pathogen treatment process if Class A for pathogens.	Residuals applied to the land

Chapter 4

Residuals (Sludge) Generation and Processing

This section describes the generation and processing of biological residuals at a municipal wastewater treatment plant. Although the focus here in on municipal wastewater treatment plants, biological treatment of industrial wastewater and subsequent generation of biological residuals at an industrial treatment plant are much the same as at a municipal plant.

As a land application operator, you may never work in a water or wastewater treatment plant. You may not be involved in residuals processing and may only see the end-product that you will land apply or distribute. However, the methods and degrees of processing affect the characteristics of the product(s) you will be working with.

Biological Residuals Generation

Once wastewater reaches the plant, it goes through physical, chemical, and biological treatment processes that remove contaminants and generate residuals (Figure 4-1).

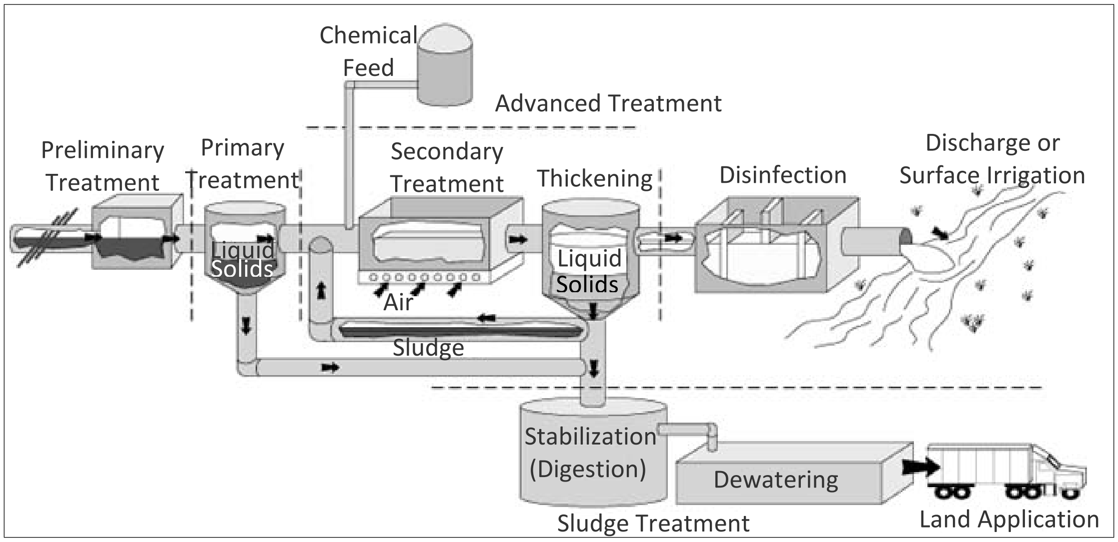


Figure 4-1. A typical domestic wastewater treatment plant.

- ☐ ***Preliminary Treatment.*** Preliminary treatment is the first step in wastewater treatment and involves removing grit and screenings. Grit is sand, gravel, cinders, or other heavy inorganic material. Screenings are rags and other large materials. Grit and screenings are not considered residuals and are not suitable for land application. These materials must be disposed of in a landfill.

☐ ***Primary Treatment.*** Primary treatment is the separation of the larger, heavier solids from wastewater. Wastewater is held in a sedimentation tank or clarifier to allow the solids to settle to the bottom. These solids are drawn off the bottom of the tank or clarifier and are called ***primary sludge.***

Because many of the inorganic solids are removed during preliminary treatment, primary sludge has a high organic content and ranges from 60 to 80% volatile organic solids. This material is coarse, fibrous, and odorous. The solids content ranges from 3 to 5%. Usually, the water content of this sludge can be easily reduced by thickening or dewatering.

☐ ***Secondary Treatment.*** From the primary clarifier, wastewater travels to an aeration tank or other treatment unit, where it is exposed to high concentrations of microorganisms. The microorganisms consume the suspended and dissolved organic solids in the wastewater, producing new microorganisms, carbon dioxide, and other by-products.

The wastewater travels to a secondary clarifier, where the older microorganisms settle to the bottom as a concentrated suspension called ***secondary sludge***. It has an inoffensive odor when fresh, but it turns septic rapidly because of biological activity. Secondary sludge is lighter and less fibrous than primary sludge. The total solids content is between 0.5 and 1.0%, and volatile organics are around 75%. It is more difficult to thicken and dewater than primary sludge.

At this stage, the unprocessed primary and secondary sludges are ***raw or unstabilized***. They cannot be land applied without processing. Sludge addresses three important factors:

1. pathogen levels
2. attractiveness to vectors
3. water content

Because primary and secondary sludges have different properties, they may be processed separately up to a point. The two sludges, however, are almost always combined prior to the end of the treatment.

Biological Sludge/Residuals Processing

Sludge or residuals processing refers to the methods used to alter properties and reduce the volume of residuals prior to land application. These methods include:

- ○ thickening (optional)
- ○ stabilization (mandatory for biological residuals)
- ○ dewatering (optional)

Reducing pathogens and vector attraction is mandatory for biological residuals. Reducing the water content is optional, but improves the efficiency of subsequent treatment processes, reduces storage volume, and decreases transportation costs.

Thickening

Although not required, sludge is often thickened before undergoing further processing. By removing some of the excess water, thickening increases the solids content and reduces the volume of the sludge. Thickening also promotes more efficient stabilization and reduces costs for subsequent storage, transfer, and end use. The total solids of thickened sludge is less than 15%. It still behaves as a liquid and can be pumped. Some thickening methods require that sludge be chemically conditioned (pretreated) to increase the efficiency of the method. Chemicals used include ferric chloride, lime, alum, and organic polymers.

- ☐ ***Gravity Thickening.*** Gravity thickening is most effective on heavy primary sludge or a mixture of primary and secondary sludge. It is often done in a circular tank where the sludge settles to the bottom of the tank (Figure 4-2). The supernatant (clear wastewater) is returned to the beginning of the plant for treatment. The thickened sludge is removed from the bottom of the tank for further processing. This form of thickening produces sludge with 0.5 to 3% total solids.

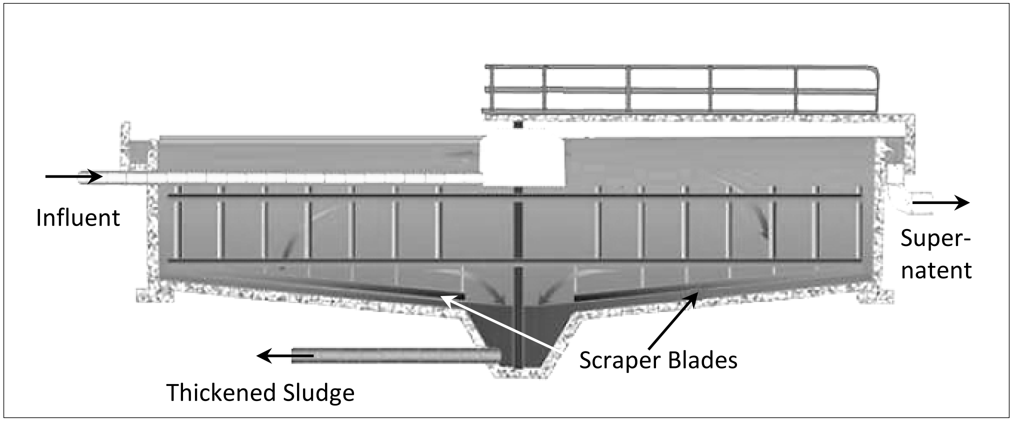


Figure 4-2. Cross sectional view of a gravity thickening tank.

Sludge can also be thickened using a gravity belt thickener. This type of thickener consists of a wide porous belt rotating between two top rollers. The sludge is mixed with polymer and then fed onto the top of the belt. Polymers are chemicals used to coagulate (thicken) suspended solids and produce large clumps of solid materials (floc). Multiple rows of plows slow the flow of sludge and provide additional time for drainage. The thickened sludge falls off the belt as it goes over the end roller (Figure 4-3). Gravity belt thickening requires more operator attention and pre-conditioning using a polymer. Total solids contents of between 5 to 7% can be achieved.

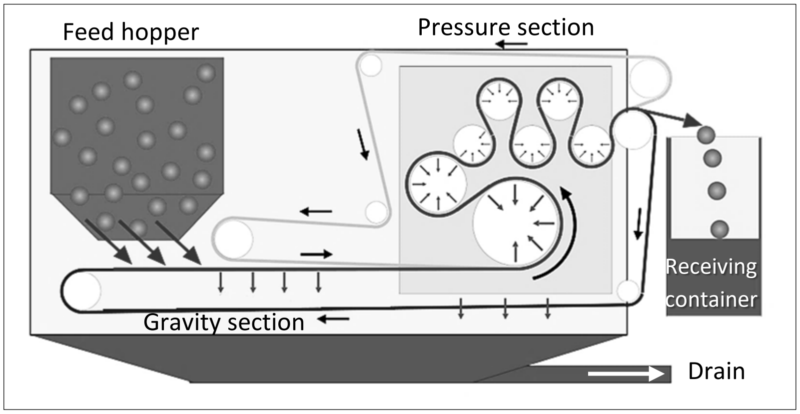


Figure 4-3. Gravity belt thickener.

- ☐ ***Dissolved Air Flotation Thickening.*** In dissolved air flotation (DAF), pressurized air is injected into the sludge. The bubbles attach themselves to the solid particles and float them to the surface. The solids form a floating blanket, which is skimmed off (Figure 4-4). This method can be very effective with secondary sludge. Solid contents of between 2 and 8% can be achieved. Polymers are added to increase efficiency.

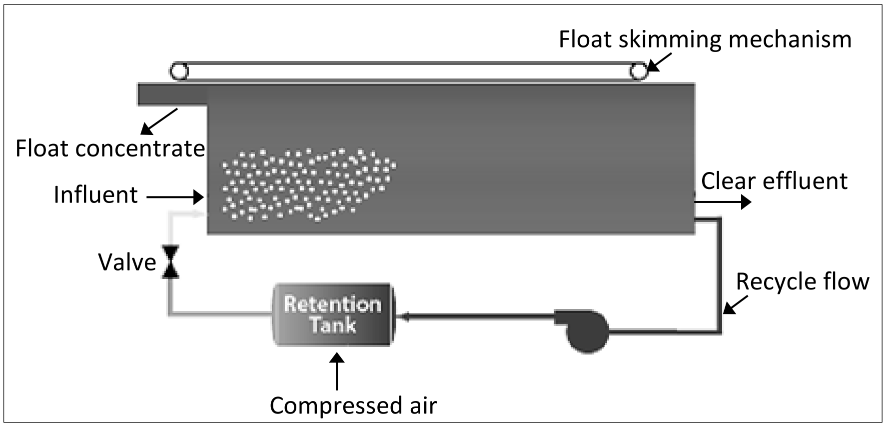


Figure 4-4. Dissolved air flotation.

- ☐ ***Centrifuges.*** Centrifugal thickening uses centrifugal force instead of gravity to separate wastewater solids from liquid. This force is created in a cylindrical bowl that rotates at high speed (Figure 4-5). This thickening method is only used with secondary sludge. Centrifuge thickening can achieve up to around 8% total solids.

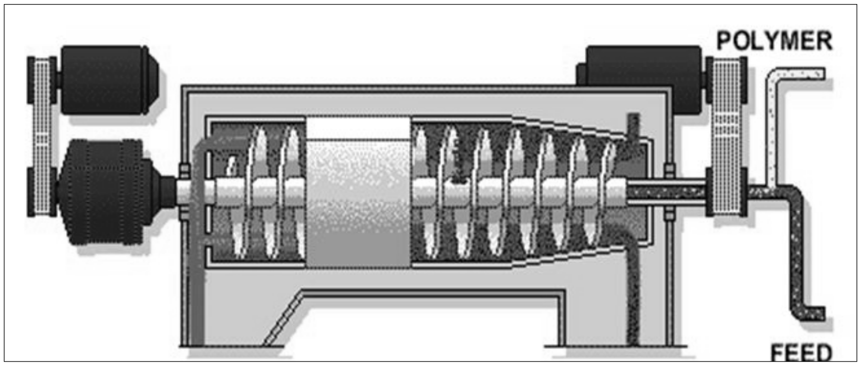


Figure 4-5. Centrifuge thickening.

Stabilization

Residuals that are land applied must be treated by a stabilization process that reduces pathogens, reduces volatile solids, or inhibits their decomposition, and reduces odors. Reducing odors reduces vector attraction. Time and temperature are essential components of stabilization processes. Some commonly used stabilization processes are aerobic and anaerobic digestion, composting, lime and alkaline stabilization, and heat drying.

- ☐ ***Aerobic Digestion.*** Aerobic means with oxygen. This type of digestion is a biological process used to treat secondary sludge. Raw sludge is placed in an unheated tank and mixed with air (aerated) for days depending on type of residuals and temperature. Bacteria rapidly consume the organic matter in the solids and convert it into carbon dioxide. Once the organic matter decreases and becomes limited, the bacteria die or become food for other bacteria. The total volume of sludge is reduced.

  This method of aerobic digestion (called mesophilic aerobic digestion) is a Process to Significantly Reduce Pathogens (PSRP) and, under proper operating conditions, produces residuals that are Class B for pathogen reduction. Aerobic digestion produces a humus-like, biologically stable product that can generate odors. These residuals have fair dewatering characteristics and a pH of around 7.0.

Thermophilic Aerobic Digestion is an aerobic digestion process that takes place at higher temperatures. "Thermophilic" simply means high heat. It is a Process to Further Reduce Pathogens (PFRP) and is capable of producing residuals that are Class A for pathogens. This pathogen reduction alternative is only appropriate for liquid residuals.

- ☐ ***Anaerobic Digestion.*** Anaerobic digestion is a biological process that takes place in an oxygen-free (anaerobic) enclosed tank that may or may not be heated for a period of days depending on temperature. It is a two-step process that involves two different anaerobic bacteria. In the first step, acid-forming bacteria convert organic solids in the residuals to organic acids. In the second step, methane-forming bacteria consume the organic acids, producing carbon dioxide, methane, and water.

  Anaerobic digestion can produce residuals that are Class B for pathogens. Anaerobically digested residuals are well-stabilized and are more easily dewatered than aerobically digested residuals, but they can be more odorous. The pH of anaerobically digested residuals is usually around 7.0. The methane (biogas) produced by this method can be used to meet some of the energy requirements of the wastewater treatment plant.

  Thermophilic Anaerobic Digestion operates at higher temperatures. When one of the time/temperature regimes allowed by pathogen reduction Alternative A, thermophilic anaerobic digestion produces residuals that are Class A for pathogens.

- ☐ ***Composting.*** Composting is another biological decomposition process in which microorganisms break down the organic material in residuals and produce carbon dioxide, water, and heat. Raw or digested sludge can be composted. Bulking agents such as wood chips, bark, sawdust, straw, or even finished compost are added to the residuals to absorb moisture, increase porosity, and add a source of carbon.

  The intense decomposition generates heat, with temperatures reaching 55 to 60°C (131-140°F) within the mixture. Aeration and/or frequent mixing or turning are required to supply oxygen and remove excess heat. The material is moved into curing piles after active composting.

  There are three methods of composting: windrow, forced air static pile, and in-vessel.

  - ☐ ***Windrow method***. Residuals are mixed with bulking agent and piled in long rows. Because there is no piping to supply air to the piles, they must be mechanically turned to supply oxygen and keep the piles aerobic. During mixing, the material on the outside is moved inward so it is subjected to the higher temperature deeper inside the pile.

Mixing is accomplished by either (1) drums and belts powered by agricultural equipment and pushed or pulled through the windrow pile; or (2) self-propelled mixing equipment that straddles the pile (Figure 4-6).

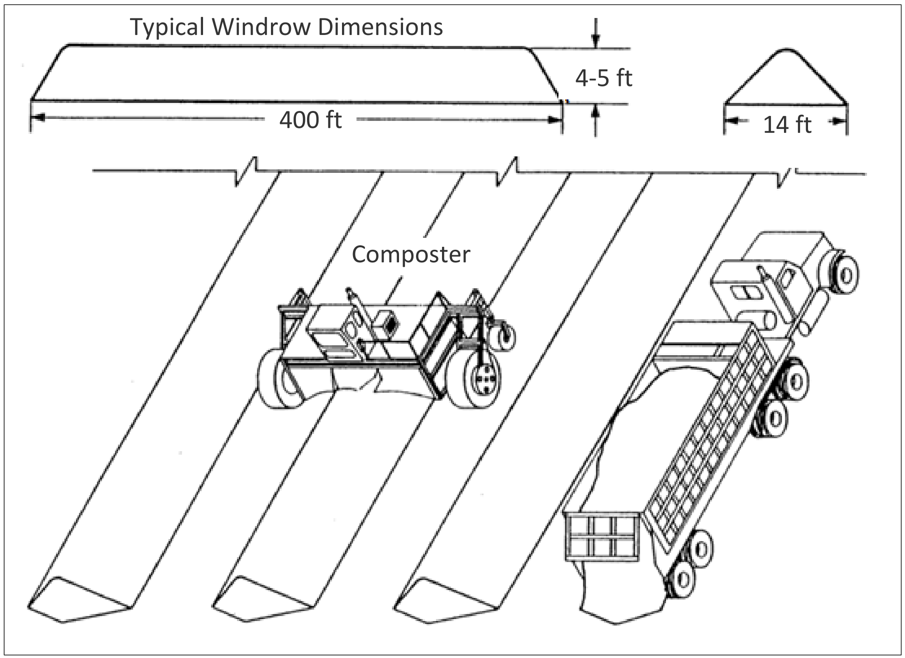


Figure 4-6. Windrow method of composting.

□ ***Forced air static pile method*****.** Raw or digested residuals are mechanically mixed with a bulking agent and stacked into long piles over a bed of perforated pipes through which air is blown into the compost piles to maintain aerobic conditions (Figure 4-7).

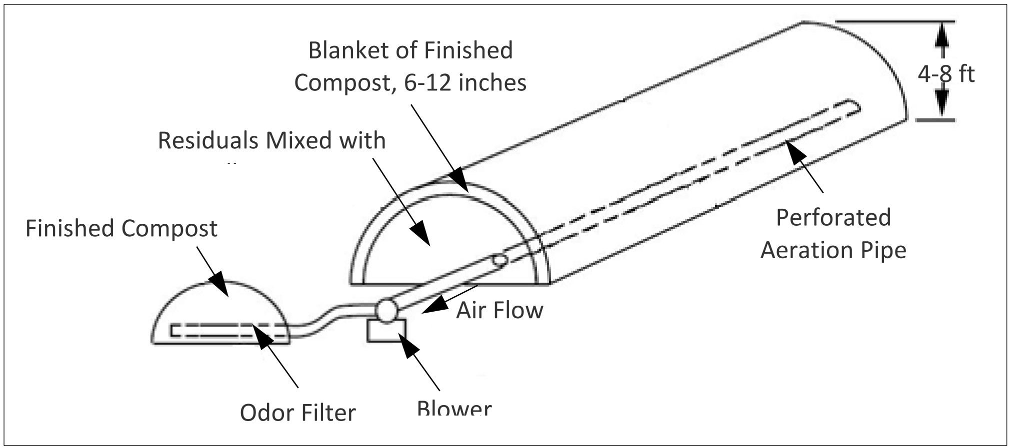


Figure 4-7. Composting with force air.

- ***In-vessel method***. In-vessel composting is similar to forced air static pile composting but takes place in a tank or vessel. Raw or digested residuals are mechanically mixed and fed into a silo, tunnel, channel, or vessel. Augers, conveyors, rams, or other devices are used to aerate, mix, and move the material through the vessel to the discharge point. Air is blown into or drawn out of the vessel while the moisture content is maintained, and the temperature is closely monitored (Figure 4-8).

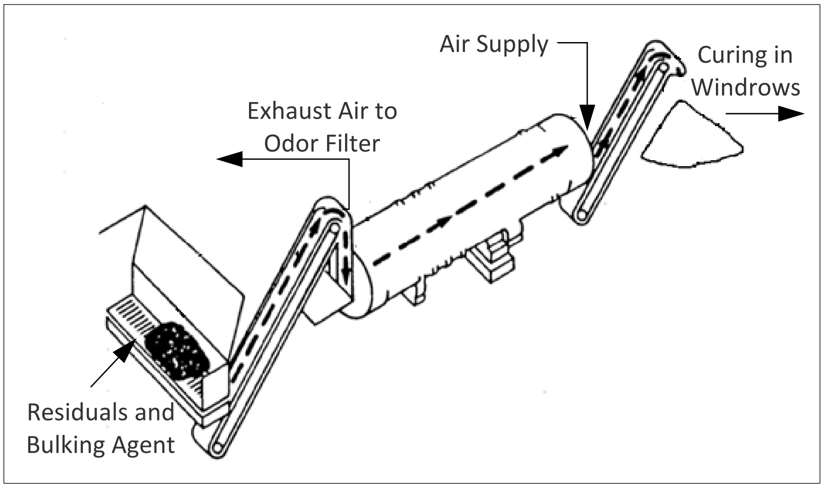


Figure 4-8. In-vessel composting.

Depending on the time and temperature variables involved in the operation, composting can yield residuals that are either Class A or Class B for pathogen reduction (Table 4-1). The production of a Class B product, however, is not always economically justified since the residuals cannot be used without restrictions. The additional expense to reach Class A requirements is marginal.

Table 4-1. Class A and Class B Pathogen Reduction Requirements for Composting

Class A	*Windrow:* residuals are maintained at 55° C or higher for at least 15 consecutive days and are turned 5 times.
	Aerated static pile or in-vessel: residuals are maintained at 55° C or higher for at least 3 consecutive days
Class B	*Windrow, aerated static pile, or in-vessel:* residuals are maintained at 40° C for 5 days during which temperature exceeds 55° C for at least 4 hours.

Composting produces a humus-like material that is easy to handle and use. Composted residuals have the characteristics of a good organic fertilizer, providing large quantities of organic matter and nutrients to the soil. However, because of the intense biological activity during the composting process, they may contain lower levels of nitrogen than residuals stabilized by another method. They can be stored indefinitely and generate minimal odors even if rewetted.

- ☐ ***Lime Stabilization.*** Lime stabilization is a chemical stabilization process in which residuals are mixed with a liming material. Instead of reducing volatile solids, it raises the pH of the residuals to a level that creates conditions unfavorable for the growth of organisms, slowing the decomposition of organic solids and reducing odors. Unlike some other stabilization methods, lime stabilization *increases* the volume of residuals because of the addition of lime.

  A lime slurry can be added to liquid residuals or dry lime can be added to dewatered residuals. Mixing occurs by diffused air or mechanical mixers (Figure 4-9) and must be sufficient to ensure that the entire mass of residuals contacts the lime and undergoes the increase in pH. Liming material *must* be in the form of lime: either hydrated lime ($Ca(OH)_2$) or quicklime (CaO). The pH of the mixture must reach and be maintained at 12 or higher for a minimum of two hours.

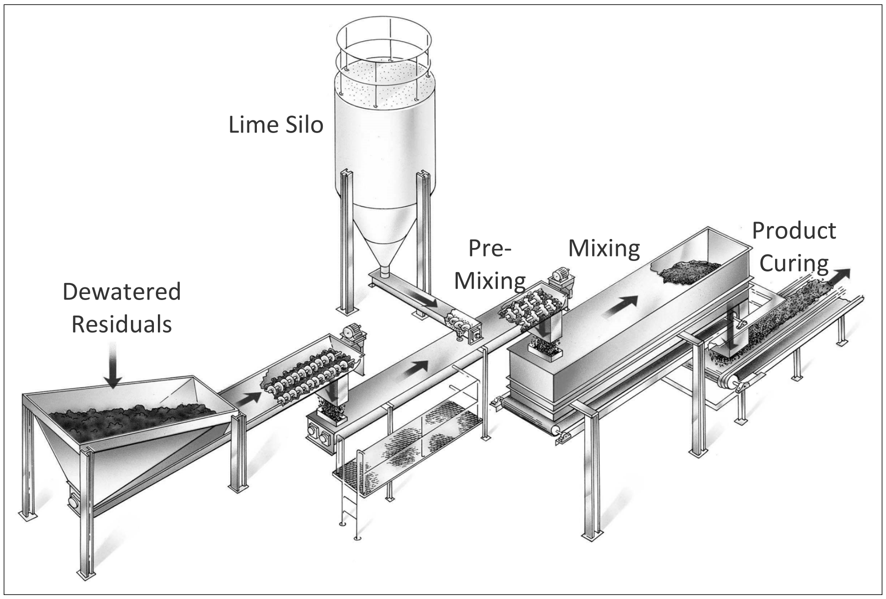


Figure 4-9. Lime stabilization process.

Lime stabilization is a PSRP and can produce residuals that meet Class B pathogen reduction requirements. Lime stabilization can reduce bacterial and viral pathogens by 99% or more but isn’t as effective on hardy species of helminth ova.

Lime stabilized residuals can become unstable if the pH drops below 10.5 after processing. This method reduces pathogens and vector attraction by reducing or stopping biological activity. However, this reduction in biological activity is not permanent. When the pH drops, surviving bacteria become biologically active, leading to a regrowth of bacteria and odors that can potentially attract vectors.

Consequently, it is recommended that lime stabilized residuals be applied as possible after vector attraction reduction is completed and while pH remains elevated. If this is not possible and odor problems develop before the residuals have left the wastewater treatment plant, additional lime may need to be added to maintain the elevated pH. Further treatment by drying or composting may be needed. In the field, lime stabilized residuals may need to be injected or incorporated or a top dressing of additional lime may need to be applied.

Because lime stabilization is a simple process and can be started and stopped relatively quickly and easily, it is sometimes used as a secondary or backup stabilization method when other methods fail to meet pathogen reduction and vector attraction reduction requirements.

Alkaline Stabilization. Alkaline stabilization is a PFRP and can produce residuals that meet Class A pathogen reduction requirements. Unlike lime stabilization, other types of alkaline material can be used instead or in addition to lime. Fly ash, lime kiln dust, and cement kiln dust are often used in alkaline stabilization because of their availability and relatively low cost. Another difference is that higher doses of alkaline material produce heat during treatment.

Alkaline stabilized residuals are drier than lime stabilized residuals and resemble topsoil. They tend to have fewer odors. Otherwise, their characteristics are similar to lime stabilized residuals.

☐ ***Heat Drying.*** Heat drying is a PFRP and, when conducted according to requirements, produces residuals that are Class A for pathogens. This process involves heating residuals in a dryer to evaporate most of the water. It results in a very dry product, often in the shape of small pellets, with a solids content of 90% or higher (Figure 4-10). By removing most of the water, heat drying significantly reduces both volume and weight of the residuals.

While a slight odor may be noticeable from the dry product, odor tends to increase after the material is gets wet, especially if the residuals were not digested prior to drying. Therefore, these residuals should be stored and maintained under dry conditions and land while the solids content remains high. The best way to reduce odors in the finished product is to digest the residuals prior to dewatering and drying.

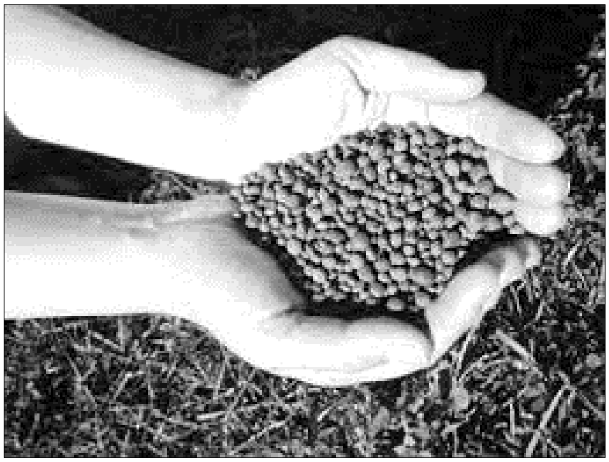


Figure 4-10. Heat drying produces Class A residuals in the form of pellets.

Table 4-2 summarizes common stabilization methods and level of pathogen reduction that each can achieve.

Table 4-2. Common stabilization methods and level of pathogen reduction that each can achieve.

Stabilization Method	Level of Pathogen Reduction
Aerobic Digestion	Class B
Thermophilic Aerobic Digestion	Class A
Anaerobic Digestion	Class B
Thermophilic Anaerobic Digestion	Class A
Composting	Class A or B
Lime Stabilization	Class B
Alkaline Stabilization	Class A
Heat Drying	Class A

Dewatering

Like thickening, dewatering increases the solids content and reduces the volume of residuals. Dewatering processes, however, concentrate residuals to >15% to around 40% total solids. Dewatered residuals usually behave as a solid and are referred to as “cake”. Dewatering reduces both volume and weight of the residuals, increasing economic value by reducing transportation or storage costs. Methods of dewatering include drying beds, centrifuges, filter presses, vacuum filters, and rotary presses.

☐ ***Drying Bed Dewatering.*** Drying beds are a low-tech means of dewatering. Residuals are placed on a sand bed where liquid drains from the residuals through the sand, to a series of subsurface drains (Figure 4-11). The liquid is returned to the head of the plant for treatment. Liquid remaining in the residuals is further reduced by evaporation. Drying beds are used for dewatering well-digested, stabilized residuals. Trying to air-dry raw, unstabilized residuals results in significant odors.

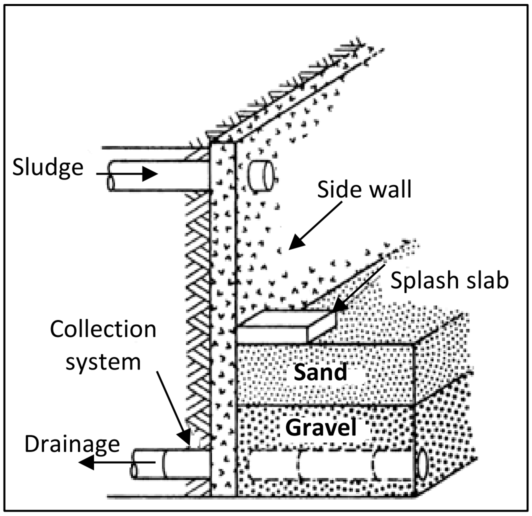


Figure 4-11. Typical sand drying bed construction.

A total solids content up to 40% can be achieved using drying beds. However, this can require extended drying times. Wet weather decreases efficiency. Although capital costs are low, drying beds require a large amount of land which may not be available. Removing the dewatered residuals is labor intensive, as it is accomplished by manual shoveling into wheelbarrows or trucks or mechanically by scrapper or front-end loader.

☐ ***Filter Press Dewatering.*** A filter press is a series of vertical plates, belts, or frames. The devices are pressed together as residuals are introduced under pressure (Figure 4-12). Water passes through the plates, belts, or frames and is returned to the treatment plant.

Solids are retained between the plates or belts and are then dropped onto a conveyer or into a large hopper.

- ☐ ***Centrifuge Dewatering.*** Centrifuges are used for dewatering as well as thickening. The solid/liquid separation process is achieved by rotating liquid residuals at high speed. Centrifugal action spins the water away from the solids, which are sent out the middle of the centrifuge. The excess water is returned to the beginning of the treatment plant. Solid concentrations of well-digested residuals can be increased from 2 or 3% to as much as 20 or 25% with polymer added.

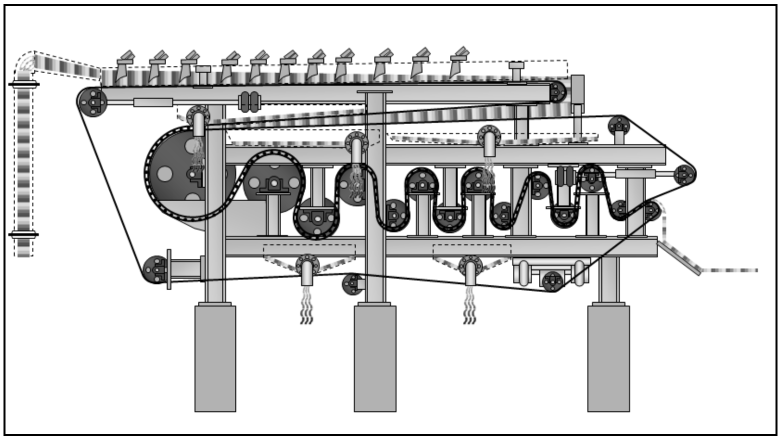


Figure 4-12. Belt filter press.

- ☐ ***Vacuum Filter Dewatering.*** A rotating drum covered by a filter cloth is passed through a vat of residuals that have been conditioned with polymer. As a vacuum is applied between the drum surface and the filter, water is drawn inward, and a layer of residuals is left attached to the drum surface. When the vacuum is released, the dewatered residuals are removed by a scraper (Figure 4-13). Solids contents of 15 to 30% can be obtained.

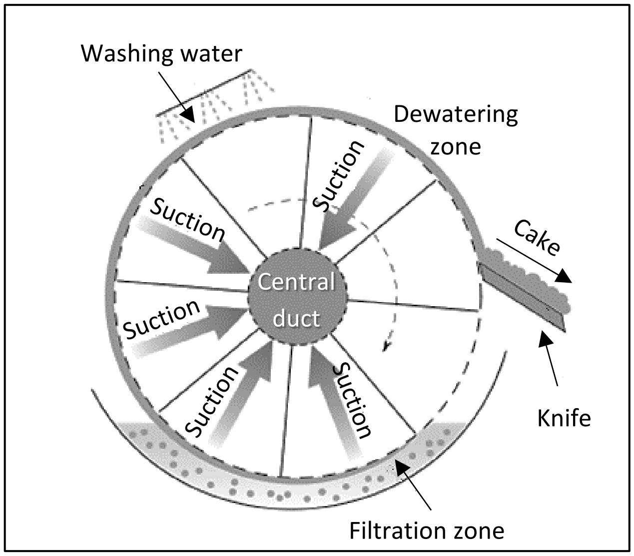


Figure 4-13. Vacuum filter.

- **Rotary Press.** The rotary press dewaters by filtration and squeezing through rotating screens (Figure 4-14). The residuals are dosed with polymer and fed into a channel formed by the rotating screens. Free water passes through the screens, which move in continuous but slow, concentric motion. The motion of the screens creates a "gripping" effect towards the end of the channel, where cake accumulates against the outlet gate, and the motion of the screens squeezes out additional water. The cake is continuously released through the pressure-controlled outlet.

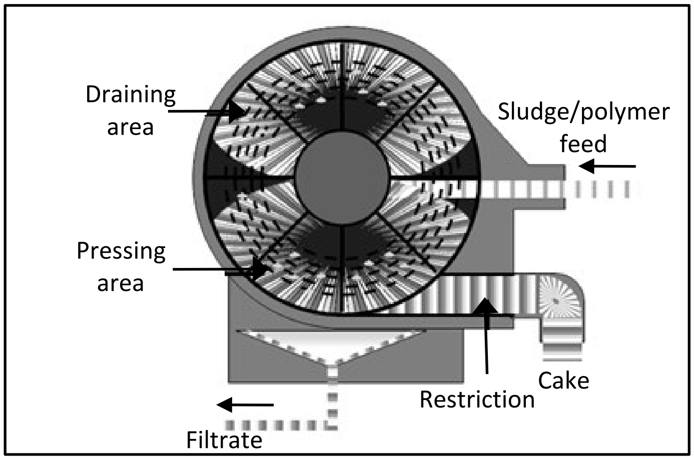


Figure 4-14. Rotary press.

End-Product Characteristics

The following is a summary of how the method and degree of processing can affect residuals that will be land applied.

- ☐ ***Quality.*** Residuals quality (Class B or Class A) impacts all facets of a land application or distribution program. While it is usually the preparer's responsibility to certify that the residuals have met pathogen reduction and vector attraction reduction requirements (except for VAR alternatives 9 and 10), having some knowledge of processing methods will help you feel confident that the residuals you are land applying meet state and federal requirements.

- ☐ ***Total Solids.*** The type and degree of processing determines the solids content of residuals. Knowing whether they have been thickened or dewatered and, if so, by what method tells you what type of material you will be land applying (Table 4-3).

Table 4-3. Solids content of liquid, cake, and dried residuals.

Type of Residuals	Solids Content
Liquid	≤ 15%
Cake	>15 to ≈ 40% *
Dried	≥90%

* Unless otherwise noted in Attachment A of the permit, DWR defines "cake" residuals as those that have greater than 15% solids by weight and can be stacked without flowing, as well as can be handled, transported, and spread as a solid (e.g., using a backhoe, front end loader, slinger spreader, broadcast spreader or other equipment designed for handling solid materials) without leaving any significant liquid fraction behind.

- ☐ ***pH.*** Stabilization method determines the pH of residuals, which can range from around 7.0 (digested residuals) to > 12 (lime stabilized residuals). When land applied, the pH of the residuals impacts soil pH which in turn impacts the efficiency of treatment mechanisms in the soil and crop health. Managing the pH of your application fields is critical part of your job as an operator.

☐ ***Odor.*** Odor is the single most important cause of public dissatisfaction with land application of residuals. Odor potential affects how, where, and when you land apply. Odor potential varies by the type of residuals processed, the degree of processing, and to some extent, the method of processing.

Primary sludge is more odorous than secondary sludge. Anaerobically digested material is more odorous than aerobically digested material. Lime stabilized residuals become odorous if the pH drops. Heat dried residuals can develop odors if they are re-wetted. Well stabilized residuals are much less prone to odors than those that are not adequately stabilized.

☐ ***Nitrogen Availability.*** We haven't discussed this yet, but stabilization method affects the rate at which some nutrients, particularly nitrogen, becomes available to plants and microorganisms. Freshly digested residuals contain more available nitrogen than do residuals produced with more intensive stabilization processes like composting. Consequently, stabilization method must be considered when you calculate application rates.

Residuals Storage

Treatment plants generate residuals daily. However, immediate land application of the generated residuals is often not possible. Class B residuals cannot be stored at any application site unless written approval has been requested and received from DWR. Consequently, residuals must often be stored at the treatment plant. Storage options include any combination of drying beds, lagoons, separate tanks, and pad areas to store liquid, dewatered or dried sludge.

Storage is necessary during inclement weather when land application sites are not accessible or when application is prohibited. Storage may also be needed to accommodate seasonal restrictions on land availability due to cropping practices or equipment availability. For small generators, storage allows accumulation of enough material to efficiently complete land application in a single spreading operation.

Even though it is necessary, there are some problems associated with storage of residuals, including:

☐ ***Regrowth of Bacteria.*** There is some concern that pathogen regrowth can occur during storage. Regrowth is more likely in Class A residuals, which are so highly treated that virtually all pathogens and non-pathogenic bacteria are killed. Under the right environmental conditions, however, there is the possibility that the very few pathogenic bacteria remaining could re-establish themselves with no non-pathogenic bacteria to suppress them.

This is why regulations require that Class A pathogen reduction must take place before or at the same time as vector attraction reduction when certain vector attraction reduction alternatives are used. Regulations also require that Class A residuals must be monitored for the density of fecal coliform or Salmonella bacteria at the time that the residuals are distributed.

Recent Water Environment Research Foundation (WERF) research has found that regrowth of fecal coliform sometimes occurs after anaerobic digestion processes, both Class B and Class A, followed by dewatering with centrifuges. Research to determine the cause continues.

☐ ***Odor.*** We just discussed the odor potential of some residuals. This potential only increases with storage. Reasons why stored residuals may generate odors include:

  ○ pH drop in lime stabilized residuals
  ○ low oxygen concentrations (anaerobic conditions) within the residuals
  ○ re-wetting of dried residuals
  ○ prolonged storage of inadequately stabilized residuals
  ○ poor housekeeping

☐ ***Vegetation.*** Weeds can establish themselves in stored residuals that are exposed to the elements (drying beds, pads, lagoons, etc.). The weeds can then be transported along with the residuals and applied to a farmer’s field. If the farmer ends up with a field of weeds competing with his crop, he may decide to opt out of your program.

Contingency Plans

We have already learned that residuals must pass the TCLP test *and* must at least meet Class B quality standards (metals, pathogens, and vector attraction) or they cannot be land applied. Preparers and land appliers should develop contingency plans for residuals that do not meet the requirements for land application. The options are limited to:

- Retesting the residuals to make the results were not caused by a lab error or problem with sampling procedures.
- Mixing or blending them with residuals that *do* meet the requirements in the hopes that the quality of the combined residuals improves. Essentially, you are trying to “dilute” the residuals.
- If residuals fail to meet pathogen reduction or vector attraction reduction requirements, try an alternative stabilization method, such as lime stabilization or composting.
- If residuals fail to meet vector attraction reduction requirements at the treatment plant, meet them in the field by incorporating or injecting the residuals.
- Incinerate the residuals or take them to a landfill.

Chapter 5

Evaluating Residuals Quality

To ensure that residuals meet the required quality for land application, all residuals permits require the permit holder to submit samples to an approved laboratory. After testing the samples for specific chemical, physical, and biological ***parameters*** (characteristics or properties), the lab sends the test results to the permittee. Reviewing the lab results is the focus of this section. We will discuss monitoring and reporting requirements and sampling procedures in later chapters.

Reviewing the Residuals Analysis

When you review a laboratory report, the first thing you need to determine is whether the test results are reported on a wet weight basis or on a dry weight basis. ***Wet weight basis*** means the reported test results are based on the weight of a sample in its "as-received" or "as-is" condition. The residuals contain water as well as solids. The units for wet weight concentrations are milligrams per liter (mg/L).

We know that the liquid content of residuals can be quite high and can vary greatly with the method/amount of processing and handling. In turn, wet weight concentrations of the parameters in residuals vary based on the liquid content of the residuals. Consequently, the weight of the dry solids must used to compare residuals with different amounts of water.

Dry weight basis means that there is no water in the sample. Concentrations are independent of the liquid content of the residuals. You can think of dry weight concentrations as having been "corrected" for moisture content. Dry weight results allow you to compare the concentrations of parameters in your residuals to regulatory limits, regardless of the liquid content.

For these reasons, almost all residuals analysis results are reported as or must be converted to a dry weight basis. There are two exceptions when wet weight concentrations must be used. These will be discussed in later chapters.

To determine dry weight concentrations, you have to know how the amount of liquid versus the amount of solids in the sample. The lab weighs the sample in its "as-is" condition. The lab then dries the sample until all the water evaporates and weighs the dry material that is left. The weight of the dry material is the total solids (TS) content of the sample. It is reported as a percentage and is often referred to as "percent solids" (Figure 5-1). Remember the figure below from Chapter 1?

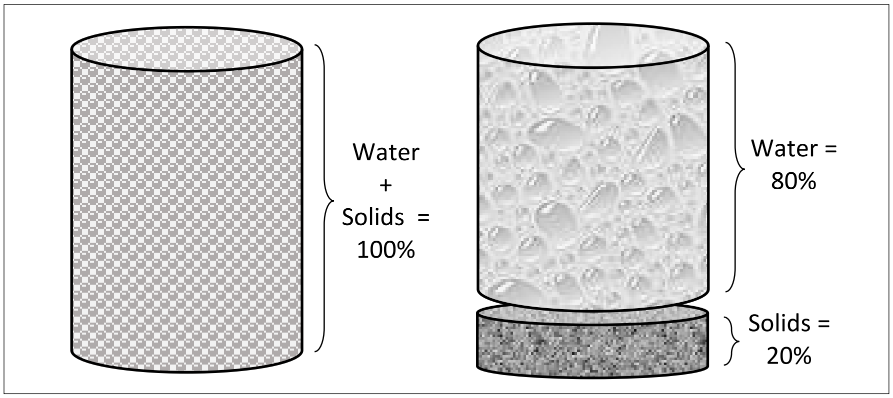


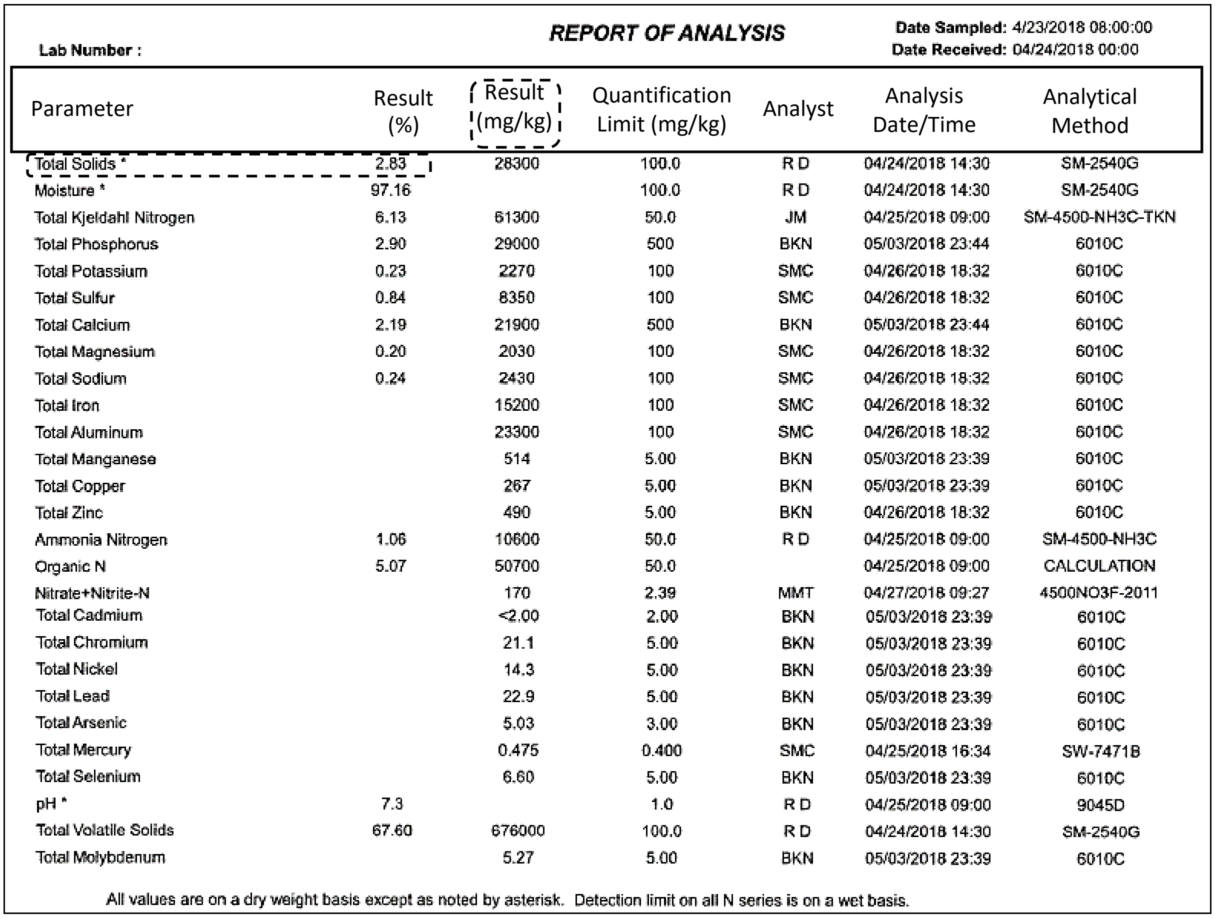
Figure 5-1. Total solids content is the weight of the solid material, minus the weight of the water, in a volume of residuals expressed as a percentage.

You should request that your lab report the results on a dry weight basis, which means that the lab converts the concentrations from wet to dry. The units for dry weight concentrations are milligrams of parameter per kilogram of dry residuals (mg/kg). Dry weight concentrations are sometimes reported as parts per million (ppm). These two measurement units are the same: 1 mg/kg = 1 ppm.

If your test results are reported on a wet weight basis (mg/L), you must convert almost all results to dry weight concentrations so you can compare them to regulatory limits and for recordkeeping/reporting purposes. To convert the results, you must use the total solids content of the sample which should be included in the residuals analysis. We will learn how to make these conversions later in this chapter.

Figure 5-2 shows an example of a residuals analysis that has a total solids content of 2.83%. The results are reported on a dry weight basis (mg/kg). Other information included on report:

- ○ quantification limit
- ○ initials of person conducting the analysis
- ○ date and time analysis was conducted
- ○ analytical method used (discussed in a later chapter)



Lab Number :

REPORT OF ANALYSIS

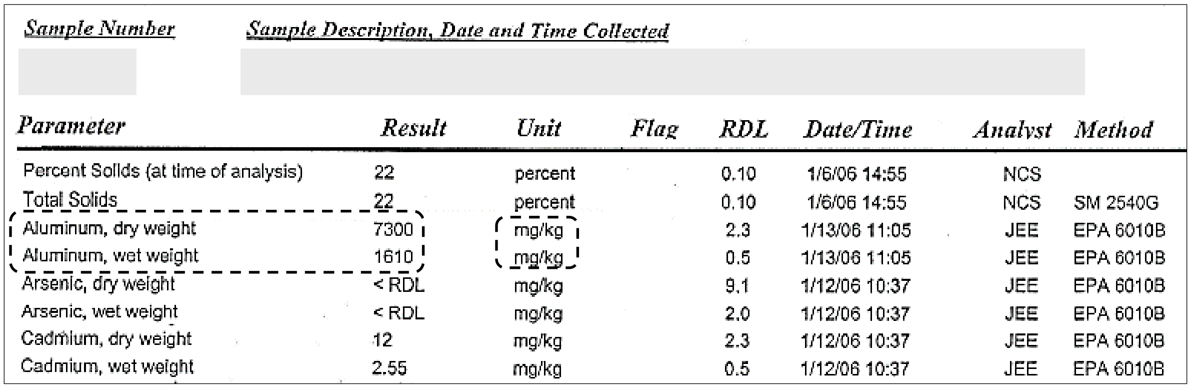
Date Sampled: 4/23/2018 08:00:00
Date Received: 04/24/2018 00:00

Parameter	Result (%)	Result (mg/kg)	Quantification Limit (mg/kg)	Analyst	Analysis Date/Time	Analytical Method
Total Solids *	2.83	28300	100.0	R D	04/24/2018 14:30	SM-2540G
Moisture *	97.16		100.0	R D	04/24/2018 14:30	SM-2540G
Total Kjeldahl Nitrogen	6.13	61300	50.0	JM	04/25/2018 09:00	SM-4500-NH3C-TKN
Total Phosphorus	2.90	29000	500	BKN	05/03/2018 23:44	6010C
Total Potassium	0.23	2270	100	SMC	04/26/2018 18:32	6010C
Total Sulfur	0.84	8350	100	SMC	04/26/2018 18:32	6010C
Total Calcium	2.19	21900	500	BKN	05/03/2018 23:44	6010C
Total Magnesium	0.20	2030	100	SMC	04/26/2018 18:32	6010C
Total Sodium	0.24	2430	100	SMC	04/26/2018 18:32	6010C
Total Iron		15200	100	SMC	04/26/2018 18:32	6010C
Total Aluminum		23300	100	SMC	04/26/2018 18:32	6010C
Total Manganese		514	5.00	BKN	05/03/2018 23:39	6010C
Total Copper		267	5.00	BKN	05/03/2018 23:39	6010C
Total Zinc		490	5.00	BKN	04/26/2018 18:32	6010C
Ammonia Nitrogen	1.06	10600	50.0	R D	04/25/2018 09:00	SM-4500-NH3C
Organic N	5.07	50700	50.0		04/25/2018 09:00	CALCULATION
Nitrate+Nitrite-N		170	2.39	MMT	04/27/2018 09:27	4500NO3F-2011
Total Cadmium		<2.00	2.00	BKN	05/03/2018 23:39	6010C
Total Chromium		21.1	5.00	BKN	05/03/2018 23:39	6010C
Total Nickel		14.3	5.00	BKN	05/03/2018 23:39	6010C
Total Lead		22.9	5.00	BKN	05/03/2018 23:39	6010C
Total Arsenic		5.03	3.00	BKN	05/03/2018 23:39	6010C
Total Mercury		0.475	0.400	SMC	04/25/2018 16:34	SW-7471B
Total Selenium		6.60	5.00	BKN	05/03/2018 23:39	6010C
pH *	7.3		1.0	R D	04/25/2018 09:00	9045D
Total Volatile Solids	67.60	676000	100.0	R D	04/24/2018 14:30	SM-2540G
Total Molybdenum		5.27	5.00	BKN	05/03/2018 23:39	6010C

All values are on a dry weight basis except as noted by asterisk. Detection limit on all N series is on a wet basis.

Figure 5-2. Example of a residuals analysis that reports results in dry-weight concentrations (mg/kg).

The conversion to dry weight can make a huge difference in the numbers (a factor of fifty for a two-percent solids sample). Figure 5-3 is a residuals analysis that has reported concentrations in both wet weight and dry weight. Notice the difference between the two. Also notice that the lab listed dry weight units (mg/kg) for both concentrations. Occasionally a lab converts the results and reports dry weight concentrations, but fails to change the units from mg/L to mg/kg. If you have any questions about how the data is reported, you should contact the lab.



Sample Number [redacted]

Sample Description, Date and Time Collected [redacted]

Parameter	*Result*	*Unit*	*Flag*	*RDL*	*Date/Time*	*Analyst*	*Method*
Percent Solids (at time of analysis)	22	percent		0.10	1/6/06 14:55	NCS	
Total Solids	22	percent		0.10	1/6/06 14:55	NCS	SM 2540G
Aluminum, dry weight	7300	mg/kg		2.3	1/13/06 11:05	JEE	EPA 6010B
Aluminum, wet weight	1610	mg/kg		0.5	1/13/06 11:05	JEE	EPA 6010B
Arsenic, dry weight	< RDL	mg/kg		9.1	1/12/06 10:37	JEE	EPA 6010B
Arsenic, wet weight	< RDL	mg/kg		2.0	1/12/06 10:37	JEE	EPA 6010B
Cadmium, dry weight	12	mg/kg		2.3	1/12/06 10:37	JEE	EPA 6010B
Cadmium, wet weight	2.55	mg/kg		0.5	1/12/06 10:37	JEE	EPA 6010B

Figure 5-3. Example of a residuals analysis that reports both weight and dry weight concentrations, but lists the units as mg/kg for both.

Laboratory Quantification or Reporting Limits

If you receive a report with a parameter value listed as non-detect (ND) or that is qualified by a less than symbol (<), it means the chemical is not present at a high enough level for the laboratory equipment to detect. It may be present, but cannot be "seen" by the instrument. When a chemical is not detected, the result is usually shown as less than (<) the reporting limit, which is the lowest concentration that the lab can reliably detect.

For example, if you go back to Figure 5-2, the residuals analysis in reports that the concentration of Cadmium is <2.00 mg/kg, which is the lab’s reporting limit. Since the Ceiling Concentration Limit for Cadmium is 85 mg/kg, the data is acceptable. The results demonstrate compliance with the permit and regulatory limit for Cadmium.

However, if the Ceiling Concentration Limit for Cadmium was 1.00 mg/kg, the data would not be acceptable because, while we know that the concentration is below 2.00 mg/kg, the lab results do not demonstrate that the concentration is below 1.00 mg/kg. When using lab results to demonstrate compliance with state or federal regulations, samples must be analyzed using detection limits that are lower than the concentration limits specified in the permit and regulations.

Residuals Quality Calculations

The first thing we will do is practice converting the wet weight pollutant (metals) concentrations in our residuals to dry weight concentrations. This will allow us to determine if any pollutant limits have been exceeded.

Converting Wet Weight Concentrations to Dry Weight Concentrations

Convert test results to dry weight concentrations by dividing the wet weight concentration by the percent total solids, expressed as a decimal (the decimal equivalent is the percentage divided by 100). When going from a wet weight concentration to a dry weight concentration, the dry weight concentration will always be higher (because you are taking away the water).

$$\boxed{\text{mg/kg} = \frac{\text{mg/L}}{\text{\% solids}}}$$

Example 1:

The wet weight concentration of zinc in the residuals you are going to land apply is 198 mg/L. The residuals have a total solids content of 22%. What is the dry weight concentration of zinc?

First, always convert % to decimal equivalent (divide % solids by 100) : $\frac{22}{100} = 0.22$

$$\text{mg/kg} = \frac{198 \text{ mg/L}}{0.22} = 900 \text{ mg/kg zinc}$$

The Ceiling Concentration Limit for zinc is 7,500 mg/kg and the Monthly Average Concentration Limit is 2,800 mg/kg zinc. The residuals do not exceed either, so the residuals meet the Class A pollutant limits for zinc (they would still have to meet the limits for the eight other regulated metals).

Example 2:

Your residuals have a percent solids of 15%. The concentration of copper (Cu) in the residuals is 500 mg/L. What is the dry weight concentration of copper?

$$\text{mg/kg} = \frac{500 \text{ mg/L}}{0.15} = 3{,}333.3 \text{ mg/kg copper}$$

The residuals are below the Ceiling Concentration Limit of 4,300 mg/kg copper, but are above than the Monthly Average Concentration Limit of 1,500 mg/kg copper. So the residuals do not meet the Class A pollutant limits. They do meet the Class B pollutant requirements, but would require tracking of Cumulative Pollutant Loading Rates (CPLR).

Converting Dry Weight Concentrations to Wet Weight Concentrations

Since residuals are applied in their “as-in” condition, you will also need to convert dry weight concentrations back to wet weight concentrations. When going from a dry weight concentration to a wet weight concentration, the concentration will always be lower (think of this as dilution).

$$\boxed{\text{mg/L} = \text{mg/kg} \times \% \text{ solids}}$$

Example 1:

We just calculated that the dry weight concentration of copper in the residuals is 3,333.3 mg/kg. We know that the solids content is 15.0%. What is the wet weight concentration of copper? Remember, always convert % to the decimal equivalent.

mg/L = 3,333.3 mg/kg x 0.15 = 500.0 mg/L copper

Example 2:

The dry weight concentration of nickel in the residuals is 38.2 mg/kg. The solids content is 22.0%. What is the wet weight concentration of nickel?

mg/L = 38.2 mg/kg x 0.22 = 8.4 mg/L nickel

Converting Dry Weight Concentrations to Pounds per Dry Ton

Eventually, you need to know concentrations of metals and nutrients in units such as pounds per dry ton (lbs/dry ton) or pounds per gallon (lbs/gal) because you will be making your residuals applications on a tons or gallons basis.

To convert mg/kg to lbs/dry ton, you multiply by a conversion factor of 0.002. A conversion factor is the number or formula you need to convert a measurement in one set of units to the same measurement in another set of units.

lbs/dry ton = mg/kg x 0.002

Example 1:

Your residuals have a dry weight concentration of 900 mg/kg zinc. How many pounds of zinc is in a dry ton of the residuals?

lbs/dry ton = 900 mg/kg x 0.002 = 1.8 lbs zinc/dry ton

Example 2:

Your residuals have a dry weight copper concentration of 1,162.2 mg/kg. How many pounds of copper is in a dry ton of the residuals?

lbs/dry ton = 1,162.2 mg/kg x 0.002 = 2.32 lbs copper/dry ton

Converting Gallons to Dry Tons

Convert gallons to dry tons using the formula below. The formula contains two conversion factors:

- one gallon of water weighs 8.34 pounds
- one ton equals 2000 pounds

$$\text{dry tons} = \frac{\text{gallons} \times 8.34\ \text{lbs/gal} \times \%\ \text{solids}}{2000\ \text{lbs/ton}}$$

Example 1:

A WWTP produces 6,500,000 gallons of residuals a year at 4.5% solids. How many dry tons of residuals are produced yearly?

$$\text{dry tons} = \frac{6{,}500{,}000 \times 8.34\ \text{lbs/gal} \times 0.045}{2000\ \text{lbs/ton}} = \frac{2{,}439{,}450.0\ \text{lbs}}{2000\ \text{lbs/ton}} = 1{,}219.73\ \text{dry tons}$$

Example 2:

A WWTP produces 2,000,000 gallons of residuals a year at 3.2% solids. How many dry tons of residuals are produced yearly?

$$\text{dry tons} = \frac{2{,}000{,}000 \times 8.34\ \text{lbs/gal} \times 0.032}{2000\ \text{lbs/ton}} = \frac{533{,}760.0\ \text{lbs}}{2000\ \text{lbs/ton}} = 266.88\ \text{dry tons}$$

Converting Dry Tons to Gallons

To convert dry tons to gallons, rearrange the formula above so that is looks like this:

$$\boxed{\text{gallons} \quad = \quad \frac{\text{dry tons x 2000 lbs/ton}}{\text{8.34 lbs/gal x \% solids}}}$$

<u>Example 1:</u>

A WWTP produces 1,219.7 dry tons of residuals a year at 4.5% solids. How many gallons of residuals are produced yearly?

$$\text{gallons} - \quad \frac{\text{1,219.7 dry tons x 2000 lbs/ton}}{\text{8.34 lbs/gal x 0.045}} = \frac{\text{2,439,400.0 lbs}}{\text{0.3753 lbs/gal}} = \text{6,499,866.70 gallons}$$

<u>Example 2:</u>

A WWTP produces 800 dry tons of residuals a year at 5.3% solids. How many gallons of residuals are produced yearly?

$$\text{gallons} - \quad \frac{\text{800 dry tons x 2000 lbs/ton}}{\text{8.34 lbs/gal x 0.053}} = \frac{\text{1,600,000.0 lbs}}{\text{0.44202 lbs/gal}} = \text{3,619,745.70 gallons}$$

Calculating Dry Tons per Acre

To calculate Annual Pollutant Field Loadings, you need to know how many dry tons you applied per acre over the year. To get dry tons/acre, you just divide the number of dry tons applied by the number of acres.

$$\text{dry tons/acre} = \frac{\text{\# dry tons applied}}{\text{\# acres}}$$

Example 1:

You applied 14 dry tons to a field that is 17.5 acres. How many dry tons/acre were applied?

$$\text{dry tons/acre} = \frac{\text{14 dry tons}}{\text{17.5 acres}} = \text{0.8 dry tons/acre}$$

Example 2:

You applied 300.2 dry tons of residuals to a field that is 41.4 acres. How many dry tons of residuals did you apply per acre?

$$\text{dry tons/acre} - \frac{\text{300.2 dry tons}}{\text{41.4 acres}} = \text{7.25 dry tons/acre}$$

Calculating Annual Pollutant (Metal) Field Loadings

When land applying Class B residuals, you must calculate and report annual pollutant loadings for each regulated pollutant to each field (lbs/acre). The annual pollutant loading is determined by the concentration of metals in the residuals and the annual loading rate in gallons or tons per acre.

Example 1:

Residuals are applied at a rate of 5.0 dry tons per acre per year. The residuals contain the concentrations listed below. What is the annual pollutant loading for each of these constituents?

Arsenic = 5.0 mg/kg
Copper = 1,000 mg/kg
Zinc = 2,000 mg/kg

1. Convert each dry weight concentration to lbs/ton using the 0.002 conversion factor.

   lbs Arsenic/dry ton = 5.0 mg/kg x 0.002 = 0.01 lbs/dry ton
   lbs Copper/dry ton = 1,000 mg/kg x 0.002 = 2.0 lbs/dry ton
   lbs Zinc/dry ton = 2,000 mg/kg x 0.002 = 4.0 lbs/dry ton

2. Using the application rate of 5 dry tons/acre, calculate the annual pollutant loading rate (lbs/acre).

   0.01 lbs Arsenic/dry ton x 5 tons/acre/year = 0.05 lbs Arsenic /acre
   2.0 lbs Copper/dry ton x 5 tons/acre/year = 10 lbs Copper /acre
   4.0 lbs Zinc/dry ton x 5 tons/acre/year = 20 lbs Zinc/acre

Example 2:

For the year, you applied 136,400.00 gallons of residuals to a field that was 9.40 acres. The residuals had a total solids content of 2.53%. The wet weight concentration of arsenic in the residuals was 0.130 mg/L. What was the Annual Pollutant Field Loading (lbs/acre) for arsenic?

1. Convert the wet weight of arsenic (mg/L) to dry weight (mg/kg).

$$\frac{0.130\text{ mg/L}}{0.0253} = 5.138\text{ mg/kg arsenic}$$

2. Convert dry weight of arsenic to pounds of arsenic /dry ton.

$$5.138\text{ mg/kg} \quad \text{X} \;\; 0.002 = 0.0103\text{ lbs arsenic/dry ton}$$

3. Calculate the dry tons of residuals you applied (convert gallons to dry tons).

$$\frac{136{,}400.0\text{ gal} \times 8.34\text{ lbs/gal} \times 0.0253}{2000\text{ lbs/ton}} = \frac{28{,}780.67\text{ lbs}}{2000\text{ lbs/ton}} = 14.390\text{ dry tons}$$

4. How many dry tons were applied to each acre?

$$\frac{14.390\text{ dry tons}}{9.40\text{ acres}} = 1.531\text{ dry tons/acre}$$

5. What was the Annual Pollutant Field Loading (APFL) for arsenic (how many lbs of arsenic were applied per acre over the year)? We know that there were 0.0103 lbs of arsenic in each dry ton of residuals and that 1.5315 dry tons were applied per acre.

$$\text{APFL} = 0.0103\text{ lbs arsenic/dry ton} \times 1.531\text{ dry tons/acre} = 0.0158\text{ lbs arsenic/acre}$$

Calculating Cumulative Pollutant (Metals) Loading Rates (CPLRs)

When applying Class B residuals, you must track Cumulative Pollutant Loading Rates (CPLRs). Once the maximum CPLRs of one of regulated metals is reached, no more Class B residuals can be added to that field over its lifetime. If you are confident that you are nowhere near the CPLR for a specific metal, you can add the Annual Pollutant Field Loading for the year that just ended to the sum of all the previous Annual Pollutant Field Loadings for that metal.

However, to be safe (especially if you are getting anywhere near the CPLR for a metal), you should track the loadings of each pollutant to each field for each application event and add it to the running total of all previous applications to that field.

Example 1:

The Annual Pollutant Field Loading of copper to a particular field for the last 3 years was: 150.5 lbs/acre, 130.3 lbs/acre, and 200.5 lbs/acre. The Field Loading of copper for the year that just ended was 102.4 lbs copper/acre. What is the current CPLR for copper for that field and how many more lbs/copper can be applied to that field? The lifetime limit for copper is 1,338 lbs/acre.

Current CPLR = 150.5 + 130.3 + 200.5 + 102.4 = 583.7 lbs copper/acre

Remaining Allowable Copper = 1,338 lbs/acre - 583.7 lbs/acre = 754.3 lbs copper/acre

Example 2:

Your residuals have a dry weight arsenic concentration of 5.03 mg/kg. You applied 320.0 dry tons to a field that is 28.3 acres. Prior to this last application, the Cumulative Pollutant Loading Rate for this field was 5.31 lbs arsenic/acre. What is the Cumulative Pollutant Loading Rate for arsenic after this last application?

1. How many pounds of arsenic was in a dry ton of the residuals?

   lbs/dry ton = 5.03 mg/kg x 0.002 = 0.0101 lbs arsenic /dry ton

2. How many dry tons/acre were applied?

   $$\text{dry tons/acre} = \frac{\text{320.0 dry tons}}{\text{28.3 acres}} = \text{11.31 dry tons/acre}$$

3. How many lbs of arsenic did you apply to each acre during that application event?

   lbs/acre = 0.0101 lbs arsenic/dry ton x 11.31 dry tons/acre = 0.114 lbs arsenic/acre

4. What is the Cumulative Pollutant Loading Rate of arsenic for that field, including the arsenic applied during the last application event?

   Current CPLR = 5.31 lbs arsenic/acre + 0.114 lbs arsenic/acre = 5.42 lbs arsenic/acre

Calculating Acreage

For record keeping and reporting purposes, you must know how to calculate acreage. There are 43,560 ft^2 in one acre.

Example 1:

Residuals are applied on a field that is 1,389 feet long and 860 feet wide. Calculate the acreage.

1. Calculate area (ft^2).

   1,389 feet x 860 feet = 1,194,540.0 ft^2

2. Convert ft^2 to acres.

   Since there are 43,560 ft^2/acre, then: $\frac{1{,}194540.0\ ft^2}{43{,}560\ ft^2/acre} = 27.42$ acres

Example 2:

A tank truck has an average application width of 28 feet. If 30 loads are applied and the truck empties each load over a 600-foot run, how many total acres have been covered?

1. Calculate area (ft^2) covered by one load and multiply by 30 loads.

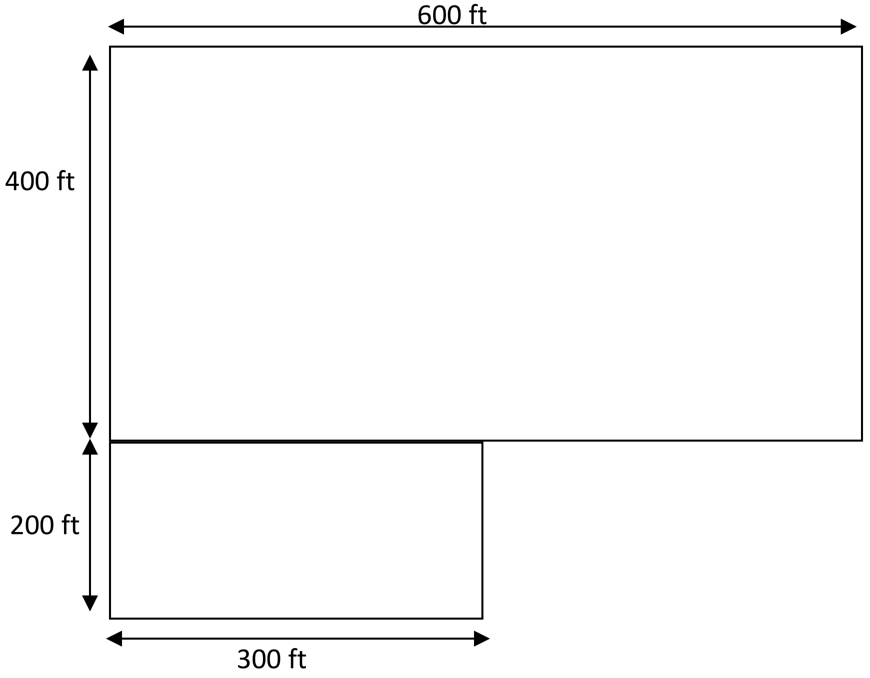
   28 feet x 600 feet/load x 30 loads = 504,000.0 ft^2

2. Convert ft^2 to acres.

$$\frac{504{,}000.0\ ft^2}{43{,}560\ ft^2/acre} = 11.57 \text{ acres}$$

Example 3:

Residuals are applied on the following field. Calculate the acreage.



Divide the field into 2 sections:

One section is: 400 feet x 600 feet = 240,000 ft^2
The other section is: 200 feet x 300 feet = $\underline{60,000\ ft^2}$
The total area is: 300,000 ft^2

Convert ft^2 to acres:

$$\frac{300,000\ ft^2}{43,560\ ft^2/acre} = 6.89\ acres$$

Calculating Geometric Mean

One of the most common ways to verify that Class B residuals have met pathogen reduction requirements is by demonstrating that the fecal coliform density of the residuals is < 2,000,000 MPN or CFU/gram total solids (dry weight basis). This alternative requires collecting seven grab samples over a two week period immediately prior to the time of use or disposal and then calculating the geometric mean of the samples.

Although the regulations do not specify the total number of samples for Class A residuals, it is recommended that a sampling event extend over two weeks, and that at least seven samples be tested to confirm that the mean bacterial density of the samples is below 1,000 MPN/gram of total solids (dry weight basis). The analysis of seven samples increases the method precision by reducing the standard error caused by variations in residuals quality.

Geometric mean is a type of average used when comparing results that may be scattered by a factor of one or two orders of magnitude. Under the right conditions, fecal coliform can grow at an exponential rate very quickly and results can vary widely from sample to sample. Using the geometric mean reduces the possibility that an unusually high or low number will seriously skew the average.

First take the log of the seven sample readings. Add these 7 numbers up, divide the total by 7, then take the anti-log of that number.

Example 1: Lab results show the following for fecal coliform MPN/gram of dry solids:

Sample 1	1,000,000 MPN/gram dry solids	Log = 6.000
Sample 2	2,600,000 MPN/gram dry solids	Log = 6.415
Sample 3	5,200,000 MPN/gram dry solids	Log = 6.716
Sample 4	650,000 MPN/gram dry solids	Log = 5.813
Sample 5	1,250,000 MPN/gram dry solids	Log = 6.100
Sample 6	3,780,000 MPN/gram dry solids	Log = 6.577
Sample 7	7,800,000 MPN/gram dry solids	Log = 6.892
	Sum of logs	= 44.513
	Average of logs	= 6.359
	Antilog of the average	**= 2,285,598.8 MPN/gram dry solids**

These residuals ***do not*** meet the Class B pathogen reduction requirements.

Example 2: Lab results show the following for fecal coliform MPN/gram of dry solids:

Sample 1	1,000,000 MPN/gram dry solids	Log =	6.000
Sample 2	2,600,000 MPN/gram dry solids	Log =	6.415
Sample 3	5,200,000 MPN/gram dry solids	Log =	6.716
Sample 4	650,000 MPN/gram dry solids	Log =	5.813
Sample 5	1,250,000 MPN/gram dry solids	Log =	6.100
Sample 6	3,780,000 MPN/gram dry solids	Log =	6.577
Sample 7	2,900,000 MPN/gram dry solids	Log =	6.462
	Sum of logs	=	44.083
	Average of logs	=	6.298
	Antilog of the average	=	**1,984,135.97 MPN/gram dry solids**

These residuals ***do*** meet the Class B pathogen reduction requirements.

Chapter 6

Application Rates - How Much Can You Apply?

If your residuals meet either Class A or Class B requirements and are suitable for land application, we now need to figure out how much you can apply. To determine application rates, we must look at the nutrient content of the residuals.

When applied on non-dedicated fields, the permit requires that residuals must be applied at or below agronomic rates. The a***gronomic rate*** is the rate that provides the nutrient needs of a crop but does not overload the soil with nutrients or other constituents that may eventually reach and contaminate surface or groundwater, limit crop growth or yield, or adversely impact soil quality. In North Carolina, the agronomic rate must be based on ***realistic yield expectation (RYE)***, which is the estimated yield for a specific plant or crop grown on a specific type of soil.

Before we learn to how to calculate application rates, we need a basic understanding of plant nutrients.

Plant Nutrients

Plants need at least 16 essential nutrients to grow and complete their life cycle. Three of these nutrients (carbon, hydrogen, and oxygen) are non-mineral nutrients that are supplied by air or water. The other 13 are mineral nutrients that come from the soil or from amendments added to the soil (fertilizers, manure, or residuals).

Nutrients that plants use in large amounts are called ***macronutrients*** (Table 6-1). Macronutrients can be broken into two groups: primary and secondary. The ***primary macronutrients*** are nitrogen (N), phosphorus (P), and potassium (K). These nutrients usually are lacking from the soil first and are the ones most frequently supplied to plants by fertilizers.

The ***secondary macronutrients*** are calcium (Ca), magnesium (Mg), and sulfur (S). Plants also use large amounts of these nutrients, but they are more abundant in soils and don't need to be replenished as often.

The ***micronutrients*** are boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Z). These elements are required by plants and are present in soils in very small amounts, but their role in plant growth is equally as important as the macronutrients.

Table 6-1. Essential plant nutrients that come from the soil or from amendments added to the soil.

Nutrient	Chemical Symbol	Macro/Micro
Nitrogen	N	Macronutrient (Primary)
Phosphorus	P	Macronutrient (Primary)
Potassium	K	Macronutrient (Primary)
Calcium	Ca	Macronutrient (Secondary)
Magnesium	Mg	Macronutrient (Secondary)
Sulfur	S	Macronutrient (Secondary)
Iron	Fe	Micronutrient
Manganese	Mn	Micronutrient
Boron	B	Micronutrient
Molybdenum *	Mo	Micronutrient
Copper *	Cu	Micronutrient
Zinc *	Zn	Micronutrient
Chlorine	Cl	Micronutrient

*metals

Nutrients in Residuals

Most residuals contain significant amounts of nitrogen and phosphorus and some amount of all other essential plant nutrients. Applying residuals to crops can reduce commercial fertilizer requirements and save farmers money. However, residuals cannot be substituted for commercial fertilizer on a pound-for-pound basis.

Unlike commercial fertilizers that can be blended to match the exact nutrient requirements of a specific crop, residuals are not a balanced fertilizer. The primary nutrients – nitrogen, phosphorus, and potassium – are not present in ratios that match crop needs.

Application rates must be based on a single targeted nutrient. This is called the “limiting” or “priority” nutrient. When residuals are applied at agronomic rates for the priority nutrient, the remaining nutrients will either be over- or under-applied.

Nitrogen is currently the limiting or priority nutrient for land application programs in North Carolina. This means that residuals application rates are based on supplying adequate nitrogen for crop needs. There are several reasons why application rates are based on nitrogen:

1. Nitrogen is required by crops in greater amounts than any other nutrient; consequently, the crop requirements for most other nutrients are usually met when application rates are based on nitrogen.
2. Nitrogen is the nutrient most likely to be lost to surface and groundwater if applied at greater than agronomic rates.
3. Excess nitrogen can have negative effects on plant growth and crop quality.

Forms and Availability of Nitrogen

To accurately calculate application rates, you must be familiar with the different forms of nitrogen and their availability to plants. The nitrogen in residuals exists in both ***organic*** and ***inorganic*** forms. At the time they are applied, 80 to 90% of the nitrogen in most residuals is bound up with organic material in the form of proteins, amino acids, and other cellular material. Only a small amount, 10 to 20%, is in inorganic form (Figure 6-1).

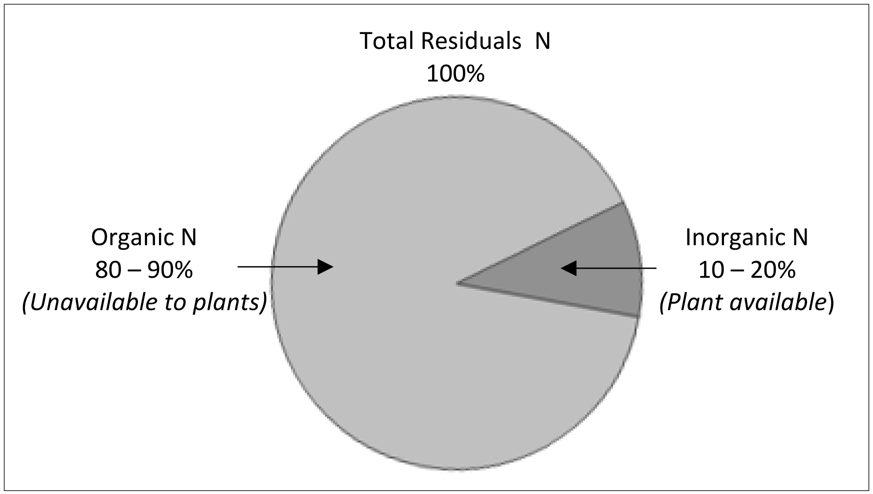


Figure 6-1. Forms of nitrogen in most residuals at time of land application.

The inorganic nitrogen is immediately available for plants to use. Plants cannot use the organic nitrogen (Org–N) in the residuals until microorganisms convert it to inorganic forms during a process called ***mineralization***. As microorganisms decompose (***mineralize***) the Org–N, more inorganic nitrogen is released and becomes available to plants. The result is a slow release fertilizer that makes nitrogen available throughout a crop's growing cycle.

Mineralization is a two-step process (Figure 6-2). In the first step, microorganisms convert Org–N to ammonium (NH_4^+). Ammonium can be taken up by plant roots or it can be converted, first to nitrite (NO_2^-), then rapidly to nitrate (NO_3^-). The conversion of ammonium to nitrate is called ***nitrification***. Both NH_4^+ and NO_3^- are inorganic forms of nitrogen that are plant available.

Ammonium and nitrate, however, behave very differently in the soil. Ammonium is a cation (has a positive charge) and sticks to soil particles that have a net negative charge. Therefore, it is not very mobile in the soil. It may also ***volatilize*** (turn into a gas) and escape to the atmosphere as ammonia gas (NH_3).

Nitrate is an anion (has a negative charge) and is repelled by negatively charged soil particles. It is highly mobile. Nitrate that is not taken up by plants has a high potential to leach (move downward) to groundwater.

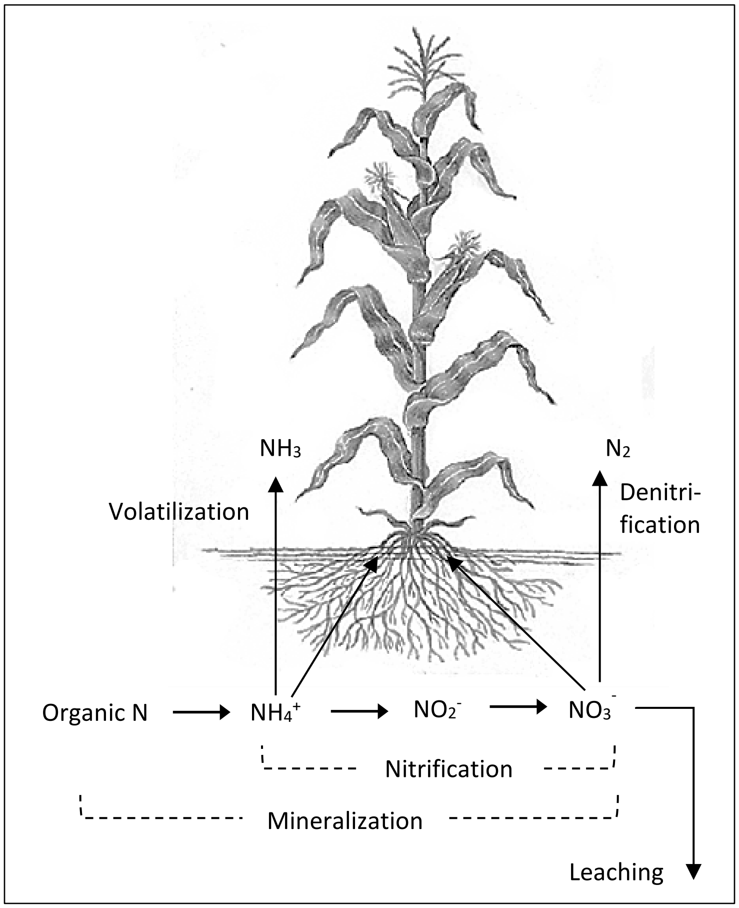


Figure 6-2. Simplified nitrogen cycle.

Review

At non-dedicated sites (where crops are planted and removed on an agricultural schedule), permits require that residuals and other sources of nutrients be applied at or below the agronomic rate. The agronomic rate is based on one priority nutrient. In North Carolina, the priority nutrient is nitrogen. Therefore, the agronomic rate is the rate that provides, but doesn't exceed, the nitrogen needs of the crop. Plants can only use nitrogen when it is in plant available forms.

Determining Residuals Application Rates Based on Nitrogen

Calculating application rates based on nitrogen involves the following steps:

1. Determine the Plant Available Nitrogen (PAN) needs of the crop, based on the Realistic Yield Expectation (RYE).
2. Determine PAN provided by other sources.
3. Determine PAN needed from residuals.
4. Calculate the amount of PAN in the residuals to be applied.
5. Calculate the residuals application rate on a dry ton per acre basis.
6. Convert the residuals application rate to “as delivered” basis.

Step 1: Determine the Agronomic Rate based on RYE

The agronomic rate (PAN requirements of crop) is based on the Realistic Yield Expectation (RYE), which is the estimated yield for a specific crop grown on a specific soil. The RYE must be determined by one of the following methods:

1. Using the Division of Water Resources’ pre-approved site specific historical data for specific crop or soil types by calculating the mean of the best three yields of the last five consecutive crop harvests for each field; or

2. Using recommended application rates for specific crop and soil types provided by North Carolina State University Department of Soil Science. NCSU manages a website for convenient access to recommended application rates: (**https://realisticyields.ces.ncsu.edu/**). When using this method, the printout page must be kept on file and reprinted every five years.

If the RYE cannot be determined using one of these methods, the Permittee may use the RYE and appropriate nutrient application rates reported in one of the following:

1. Crop Management Plan as outlined by the local Cooperative Extension Office, the North Carolina Department of Agriculture and Consumer Services, the Natural Resource Conservation Service, or other agronomist.

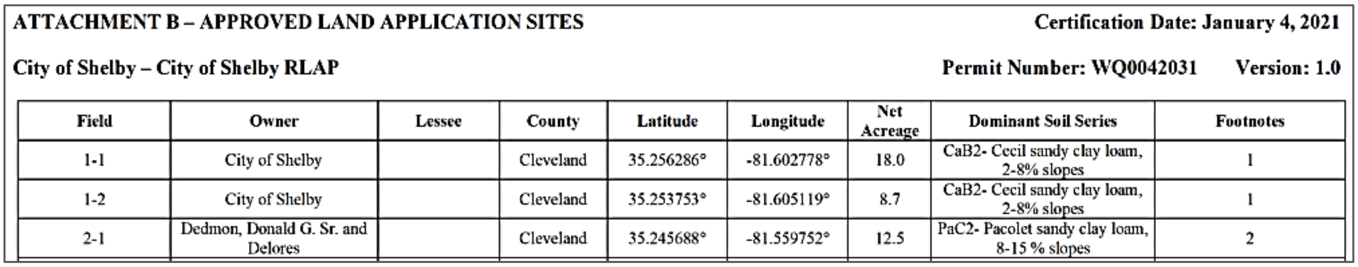
2. Waste Utilization Plan as outlined by the Senate Bill 1217 Interagency Group - Guidance Document: Chapter 1 (http://www.enr.state.nc.us/DSWC/pages/guidance_docs.html).

3. Certified Nutrient Management Plan as outlined by the Natural Resources Conservation Services (NRCS). These plans must meet the USDA-NRCS 590 Nutrient Management Standards (ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/590.pdf).

If the RYE and appropriate nutrient application rates cannot be determined by any of these methods, the Permittee must contact DWR for guidance.

Using NCSU's Realistic Yield Database

To use NCSU's RYE database, you need to know the crop to be grown and the dominant soil type for a particular field. Most permits list the dominant soil type for each permitted field in Attachment B. For example, the dominant soil series for the first field listed in Attachment B below, Field 1-1, is Cecil sandy clay loam (Figure 6-3). A soil series is type of soil that is defined by its properties and characteristics. We will discuss soil series further in a later chapter.



ATTACHMENT B – APPROVED LAND APPLICATION SITES **Certification Date: January 4, 2021**

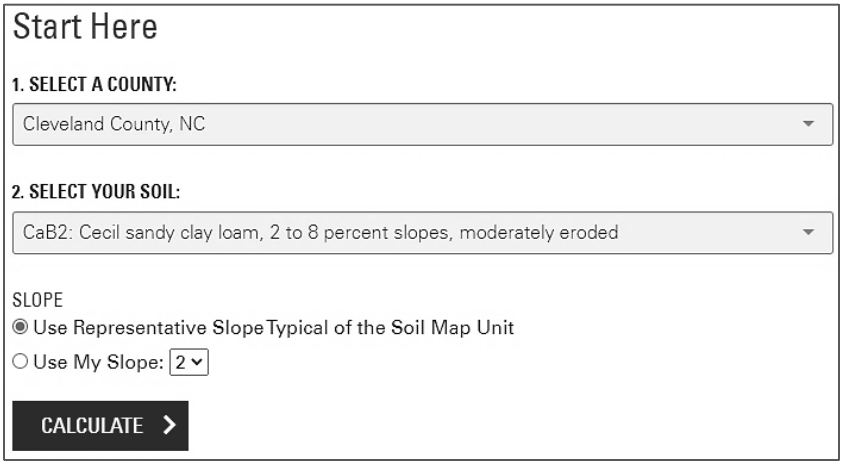
City of Shelby – City of Shelby RLAP **Permit Number: WQ0042031** **Version: 1.0**

Field	Owner	Lessee	County	Latitude	Longitude	Net Acreage	Dominant Soil Series	Footnotes
1-1	City of Shelby		Cleveland	35.256286°	-81.602778°	18.0	CaB2- Cecil sandy clay loam, 2-8% slopes	1
1-2	City of Shelby		Cleveland	35.253753°	-81.605119°	8.7	CaB2- Cecil sandy clay loam, 2-8% slopes	1
2-1	Dedmon, Donald G. Sr. and Delores		Cleveland	35.245688°	-81.559752°	12.5	PaC2- Pacolet sandy clay loam, 8-15 % slopes	2

Figure 6-3. Example of Attachment B from a Class B Land Application Permit showing county and dominant soil series.

Go the NCSU's webpage. Select your county and the soil type for a particular field. The soil types listed on the webpage are often more detailed than the descriptions listed in your permit. There may be several choices for one soil type, based on surface texture and slope. Pick the one that most closely matches your field.

Then correct for slope by clicking the button "Use Representative Slope Typical of the Soil Mapunit" or click "Use my slope" and enter the slope of your field. Click calculate (Figure 6-4). In this example, we need to search for the realistic yield expectations for crops grown on a field located in Cleveland County, whose dominant soil series is Cecil sandy clay loam.



Start Here

1. SELECT A COUNTY:

Cleveland County, NC

2. SELECT YOUR SOIL:

CaB2: Cecil sandy clay loam, 2 to 8 percent slopes, moderately eroded

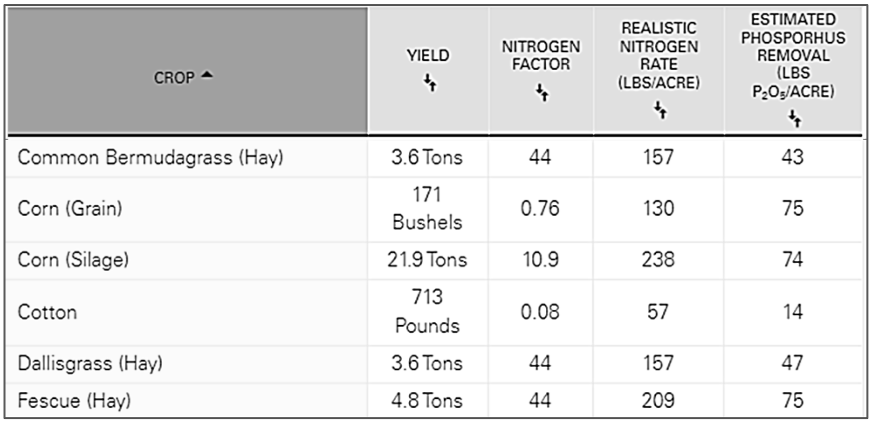
SLOPE

● Use Representative Slope Typical of the Soil Map Unit

○ Use My Slope: 2

Figure 6-4. NCSU’s realistic yield database.

The database returns realistic yield expectations and realistic nitrogen rates (and estimated phosphorus removal) for a variety of crops. If the crop to be grown on that field is corn for grain, then the realistic yield expectation is 171 bushels, and the realistic nitrogen rate is 130 lbs PAN/acre/year (Figure 6-5). If the crop to be grown on that field is fescue, the RYE would be 4.8 tons and the realistic nitrogen rate would be 209 lbs PAN/acre/year.



CROP	YIELD	NITROGEN FACTOR	REALISTIC NITROGEN RATE (LBS/ACRE)	ESTIMATED PHOSPORHUS REMOVAL (LBS P_2O_5/ACRE)
Common Bermudagrass (Hay)	3.6 Tons	44	157	43
Corn (Grain)	171 Bushels	0.76	130	75
Corn (Silage)	21.9 Tons	10.9	238	74
Cotton	713 Pounds	0.08	57	14
Dallisgrass (Hay)	3.6 Tons	44	157	47
Fescue (Hay)	4.8 Tons	44	209	75

Figure 6-5. NCSU’s realistic yield database.

Step 2: Determine PAN provided by other sources.

The farmer/landowner must provide you with information on any additional nutrient sources applied or intended to be applied.

- **PAN Contributions from Conventional Fertilizers.** Nitrogen contributed by conventional inorganic chemical fertilizers is an important component in the overall nitrogen budget available to growing crops. It must be accounted for in the application rate calculation.

Our goal is to apply residuals at rates that will supply crops with adequate nitrogen. Some crops need a starter fertilizer (nitrogen applied at seeding) for best growth. Starters applied at rates that supply 10 to 30 lb. nitrogen per acre. Sometimes supplemental nitrogen is applied during the growing season as a “side dress”. Side dressing is the application of fertilizer between the rows of growing crops.

Table 6-2 provides a summary of conventional N fertilizers in terms that are helpful in discussions with farmers.

Table 6-2. Conventional nitrogen fertilizers.

Fertilizer	Chemical Formulation	Nutrient Content ($N-P_2O_5-K_2O$)
Ammonium nitrate	NH_4NO_3	33-0-0
Ammonium sulfate	$(NH_4)_2SO_4$	21-0-0
Anhydrous ammonia	NH_3	82-0-0
Calcium nitrate	$Ca(NO_3)_2$	15.5-0-0
Diammonium phosphate	$(NH_4)_2HPO_4$	18-46-0
Potassium nitrate	KNO_3	13-0-44
Urea	$CO(NH_2)_2$	45-0-0

Note that the nutrient content of conventional fertilizers is expressed as a series of three numbers that are the percentage content of:

1. nitrogen (N)
2. available phosphate (P_2O_5)
3. soluble potash (K_2O)

Fertilizer nutrients are expressed in terms of pounds of elemental N, but P and K are expressed as pounds of P_20_5 and pounds of K_2O. For example, 100 lbs of fertilizer labeled 11-52-0 contains 11 lbs of N, 52 lbs of P_2O_5, and no K_2O. Converting the P and K in residuals to P_2O_5 and K_2O is discussed in a later chapter.

☐ **PAN Contributions from animal waste.** If the farmer has or will apply animal waste to the fields where residuals will be applied, you must also include the amount of PAN contained in the manure. The farmer is required to provide this information to you. Plant available nitrogen from animal waste applications is calculated in a similar manner to residuals PAN.

Step 3: Determine PAN needed from residuals.

The next step is to calculate the amount of PAN needed from the residuals, which is the difference between the total PAN needed to produce the yield goal and PAN from other sources.

Step 4: Calculate the amount of PAN in the residuals to be applied.

The PAN in residuals is the amount of nitrogen available to crops during the first year following application (lbs/dry ton). This includes the inorganic nitrogen in the residuals at the time of application plus the amount of the organic nitrogen that will mineralize and become available to plants over the year.

Calculating PAN in your residuals requires three pieces of information:

a. concentrations of different forms of N present in the residuals
b. stabilization method and mineralization rate
c. method of application: surface or subsurface (incorporation or injection)

a. **Concentrations of different forms of N present at application in residuals.**

Total N (TN) = Organic N + inorganic N (NH_4^+ + NO_3^- + NO_2^-)

We can obtain the concentrations of the different forms of inorganic N from our laboratory report which can be reported in several ways:

NH_4^+ = Ammonium Nitrogen; sometimes reported as NH_3 (Ammonia Nitrogen)
NO_3^- = Nitrate Nitrogen
NO_2^- = Nitrite Nitrogen

Sometimes reported together as NO_3^- + NO_2^-

You may see the different forms of inorganic nitrogen reported or expressed in this manner:

NH_3–N
NH_4–N
NO_3–N
NO_2–N

The "–N" ending does not mean "minus N" in this context. It just means nitrogen in the form of ammonia, ammonium, nitrate, or nitrite, etc.

However, the organic nitrogen contained in residuals cannot be measured directly. Nitrogen can be bound in so many different organic compounds that there is not a single lab test that can measure organic N.

The lab report should report another measurement called Total Kjeldahl Nitrogen (TKN). ***Total Kjeldahl Nitrogen*** measures organic N plus NH_4^+.

$$\boxed{\text{TKN} = \text{Org–N} + NH_4^+}$$

The amount of Org–N in the sample is calculated by rearranging this formula and subtracting NH_4^+ from TKN. If your lab reports values for both TKN and Org–N, they have made the calculation for you. If your lab reports TKN only, you must do the calculation yourself.

$$\boxed{\text{Org–N} = \text{TKN} - NH_4^+}$$

b. Stabilization method and mineralization rate.

To calculate how much Org–N will mineralize during the year of application (how much nitrogen will become plant available), you need to know the mineralization rate for your residuals. The mineralization rate should be listed in Attachment A of your permit. If not, you can get it from Table 6-3.

Mineralization rates depend on soil temperatures and other factors, but mainly depend on the stabilization process used at the treatment plant. The higher the degree of stabilization, the slower the mineralization rate and the lower the amount of Org–N released for plant uptake. Composting and anaerobic digestion are more intensive methods of stabilization than aerobic digestion or lime stabilization, and therefore have a lower mineralization rate.

Table 6-3. Percent of Org–N in residuals that will mineralize and become plant available during year following application.

Residuals Processing Method	Mineralization Rate
Unstabilized Primary and Secondary Residuals	40%
Aerobically Digested and Lime Stabilized Residuals	30%
Anaerobically Digested Residuals	20%
Composted Residuals	10%

c. Method of application: surface or subsurface (incorporation or injection).

- ☐ ***Surface application.*** Residuals are sprayed or spread on the soil surface and left on the surface with no further action.

- ☐ ***Subsurface application.*** Residuals are either 1) incorporated into the soil after being surface applied; or 2) injected directly below the soil surface with specialized equipment.

The amount of PAN is also affected by application method. When residuals are applied on the soil surface and are not quickly incorporated, about half of the NH_4^+ is lost to the air as ammonia gas (NH_3) in a process is called ***volatilization***. For calculations, we assume that 50% of the ammonium present in the residuals at the time of application is lost if the residuals are surface applied.

Ammonium loss occurs only with surface application. Injecting or incorporating residuals eliminates volatilization because the residuals are not exposed to the air. When residuals are injected or incorporated soon after application, all the ammonium in the residuals is plant available.

Step 5: Calculate the residuals application rate on a dry ton/acre basis.

Now we need to calculate the amount of residuals (dry tons/acre) that will supply the crop with the PAN it needs. From Step 3, we know the amount of PAN the residuals need to supply. From Step 4, we know the amount of PAN in the residuals we are going to land apply. To calculate the application rate, we divide the amount of PAN the residuals need to supply(lbs/acre) by the PAN in our residuals (lbs/dry ton).

Step 6. Convert the application rate to "as-delivered" basis.

Since the residuals will be delivered and applied as a liquid, wet cake material, or dried pellets, we need to convert the application rate in dry tons/acre to "as-delivered" units. For dewatered residuals, convert dry tons/acre to wet tons/acre or cubic yards/acre. For liquid residuals, convert dry tons/acre to gallons/ acre.

Reductions/Additions to the Application Rate Based on Nitrogen

Class B permits contain two conditions related to the application rate and crop removal:

- ☐ When residuals are land applied to grazed pasture, the agronomic rate must be reduced by 25% in accordance with the USDA-NRCS 590 Nutrient Management Standards. This reduction is necessary because the cattle will return some nutrients to the soil as manure.

- ☐ If land application sites are over-seeded or double-cropped and *both* crops receive residuals, then the second crop can receive an application of PAN at a rate not to exceed 50 pounds per acre per year. This practice is allowed only if the second crop is harvested or grazed. If the second crop is planted for erosion control only and is tilled into the soil, then no additional PAN can be applied.

Over-seeding is the practice of planting another crop or grass on top of the existing crop. ***Double-cropping*** is when a second crop is planted after the first has been harvested. For example, a warm season crop like bermudagrass grown in the summer can be followed by a cool season grass like rye in the winter.

Crop Removal – Part of Applying at Agronomic Rates

Crop removal (e.g., harvesting, grazing) is an essential part of applying nutrients at agronomic rates. Nutrients from residuals and other sources are taken up by the crop and incorporated into plant tissue. If the crop and its stored nutrients are not removed, the nutrients are returned to the soil as the crop residues decompose. Consequently, it is important that the crop and its nutrients be removed through harvesting or grazing.

For example, forage crops are often mowed and baled and then left in the field to rot. The nutrients are not removed and will eventually return to the soil. Failure to remove the crop can lead to excessive nutrient levels in the soil, potential plant toxicity, and surface water or groundwater contamination.

Determining Residuals Application Rates Based on Liming Potential

Although not technically a nutrient, lime is sometimes used as the basis for determining the application rate. Lime and alkaline stabilized residuals can have a significant liming potential because of their high pH. Most soils in North Carolina are naturally acidic and need liming periodically, so applying high pH residuals can save farmers money.

However, continued application of high pH residuals at agronomic nitrogen rates can raise the soil pH to 8 or higher, which is not desirable for most crops. High soil pH reduces the availability of some micronutrients and the activity of microorganisms. Consequently, the application rate for high pH residuals may need to be based on their liming potential and the lime requirement of the soil. Determining the application rate based on the liming potential of the residuals requires a corresponding soil test report.

Residuals that may have a liming effect on the soil should be tested to see what their liming potential is. There are two ways liming equivalence can be reported by the lab:

- ○ Agricultural Lime Equivalent (ALE) and
- ○ Calcium Carbonate Equivalent (CCE)

❑ Agricultural Lime Equivalent

If your permit specifies that the application rate must be based on the liming potential of the residuals, or if you think their liming potential is high, ask your lab to determine the ***agricultural lime equivalent (ALE)*** of the residuals. The ALE is the amount of residuals that will provide a liming effect equal to one ton of agricultural grade limestone (ag-lime), which is the standard material referenced by soil tests.

The lime recommendation on a soil test report is always based on the amount of commercial strength ag-lime (tons/acre) required to raise soil pH to the desired level. The ALE of the residuals is reported on the residuals analyses as a number, 5.0 for example. This means that 5.0 tons of residuals equals 1 ton of ag-lime. If the soil test report recommends 1 ton of ag-lime per acre, then applying 5.0 tons of residuals will have the liming effect of one ton of ag-lime. The lower the ALE value, the stronger the material is as a liming source.

☐ Calcium Carbonate Equivalent (CCE)

Some labs report the ***Calcium Carbonate Equivalent (CCE)*** of the residuals instead of ALE. The concept is the same as ALE, but the application rate based on CCE is calculated a little differently. The CCE is the neutralizing value of a liming material compared to ag-lime, expressed as a percentage. A material with a CCE of 100% would be just as effective as ag-lime in liming value. A material with a CCE of 40% would be only 40% as effective.

The importance of maintaining proper soil pH and its impact on land application activities is discussed in detail in Chapter 8.

Limitations on the Residuals Application Rate

While your goal is to apply residuals at rates based on nitrogen or liming potential, there are several factors that can limit the application rate:

- maximum Cumulative Pollutant Loading Rates for Class B residuals
- sodium content of the residuals
- risk of runoff and/or crop damage
- soil phosphorus levels (a future possibility)

Cumulative Pollutant Loading Rates

We have already learned that Class B residuals have limits on the amount of the nine regulated metals that can be added to a field over its lifetime. Once the limit for one of the metals has been reached, no more residuals can be applied to that field. Because metal concentrations are so low in most residuals, it is unlikely that any of those limits would be reached for years. But you must track metals application and be aware of the possibility.

Sodium

Residuals application is sometimes limited by the sodium (Na) content of the residuals. Sodium is a soluble salt and residuals high in sodium can result in serious soil and crop related problems. All residuals permits require that residuals are monitored for potential sodium hazard using the sodium adsorption ratio. The ***sodium adsorption ratio*** (SAR) is the relative proportion of sodium ions (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions.

Before land applying Class B residuals or distributing Class A residuals with a SAR value of 10 or higher, the permit holder must obtain and implement recommendations from at least one of the following:

- the local Cooperative Extension Office
- the NC Department of Agriculture and Consumer Services
- the Natural Resource Conservation Service
- a NC Licensed Soil Scientist
- an agronomist

The recommendations must the address the sodium application rate, soil amendments (e.g., gypsum, etc.), or a mechanism for maintaining site integrity and conditions conducive to crop growth. The permit holder must maintain written records of these recommendations and details of their implementation.

Class A permits also require the permit holder to notify third-party entities of the effects of a high SAR content residuals on their receiving sites.

Class B permits require that all fields be tested for sodium levels. The ***exchangeable sodium percentage*** (ESP) is the ratio of sodium to total amount of cations in the soil and is calculated from soil test data. The permit does not set a specific limit that cannot be exceeded, but an ESP of 15% or higher signifies excessive sodium in the soil. Review your soil test data and seek help if ESP is high.

Risk of Runoff and Crop Damage

Remember, the application rate is the maximum amount of residuals you can apply per acre per year. This doesn’t mean that you can or should apply the calculated rate during one application event.

The volume of liquid residuals that you can apply at one time is limited by the soil’s capacity to absorb the water in the residuals (the ***hydraulic loading rate***). Exceeding this capacity can result in ponding or runoff of the material. The volume of liquid and cake residuals you can apply at one time can also be limited by potential physical damage (smothering) of the crop.

Consequently, applying the application rate often involves more than one application, and maybe several, each at a relatively low rate. This conservative approach helps protect water quality, maintains good relations with the farmer and community, and helps ensure compliance with the permit without affecting the total amount of residuals that you can apply per acre over the year.

Phosphorus

Currently, North Carolina regulations and permits do not require that you limit application rates based on the phosphorous content of residuals or on the phosphorus levels in the soil. However, increasing attention is being paid to the amount of phosphorus being added to the soil by residuals application. Many states now regulate, or are considering regulations, that will reduce the application of residuals based on phosphorus content.

When residuals application rates are based on nitrogen, phosphorus is usually over-applied. The reason is that most crops require only one-fifth to one-half as much phosphorus as nitrogen. Soils have a great capacity to retain phosphorus. For years, people believed that controlling erosion and soil loss from agricultural fields prevented phosphorus from being transported to adjacent water bodies. Since most phosphorus is adsorbed to soil particles, the thinking was that there would be little transport of phosphorus if erosion was controlled.

However, recent developments have shown that a significant portion of phosphorus loss can occur in dissolved form. As excess phosphorus accumulates in the soil, the potential for phosphorus to exist in soluble form increases. Dissolved phosphorus that is transported from fields to lakes, rivers, and streams can lead to excessive aquatic plant growth, resulting in eutrophication.

Phosphorus-based regulations and guidelines can potentially impact the feasibility of land application of residuals. When residuals are applied at rates that meet but not exceed the phosphorus needs of the crop, significantly fewer residuals can be applied per acre. Two to four times as much land will be required to apply the same amount of residuals as when rates are based on nitrogen needs.

It is in the interest of residuals permit holders and operators to monitor soil test reports for soil phosphorus levels and to track if and how fast the levels are increasing. If soil test phosphorus is already rated very high or excessive, additional phosphorus loading from residuals may not be appropriate. Strategies and best management practices to manage soil phosphorus levels are needed to maintain sustainable land application programs in the future.

For more information, see the Water Environment Federation's article, *Phosphorus in Biosolids: How to Protect Water Quality While Advancing Biosolids Use*, at http://www.wrrfdata.org/PhosphorusFS/WEF-PhosphorusFactSheet2014.html.

Chapter 7

Application Rate Calculations

Calculating Residuals Application Rates Based on Nitrogen

Example 1:

Given the information below, calculate the residuals application rate (dry tons/acre). Then convert dry tons/acre to "as-delivered" units (gallons, wet tons, or cubic yards).

1. Determine the PAN needs of the crop based on RYE.

   Using the example from the last chapter, the dominant soil series for the field we will apply Class B residuals to is Cid-Lignum complex (from Attachment B of the permit). We plan to grow corn for grain. From NCSU's Realistic Yield Database, we find that the nitrogen (or PAN) requirement for a corn grain crop grown on the soil type of our field is 130 lbs PAN/acre/year.

2. Determine PAN provided by other sources.

   The farmer tells you that no manure will be applied to the field. He does plan to apply a side-dressing of nitrogen fertilizer when the corn plants are a few inches high. The side-dressing will contribute 50 lbs N per acre.

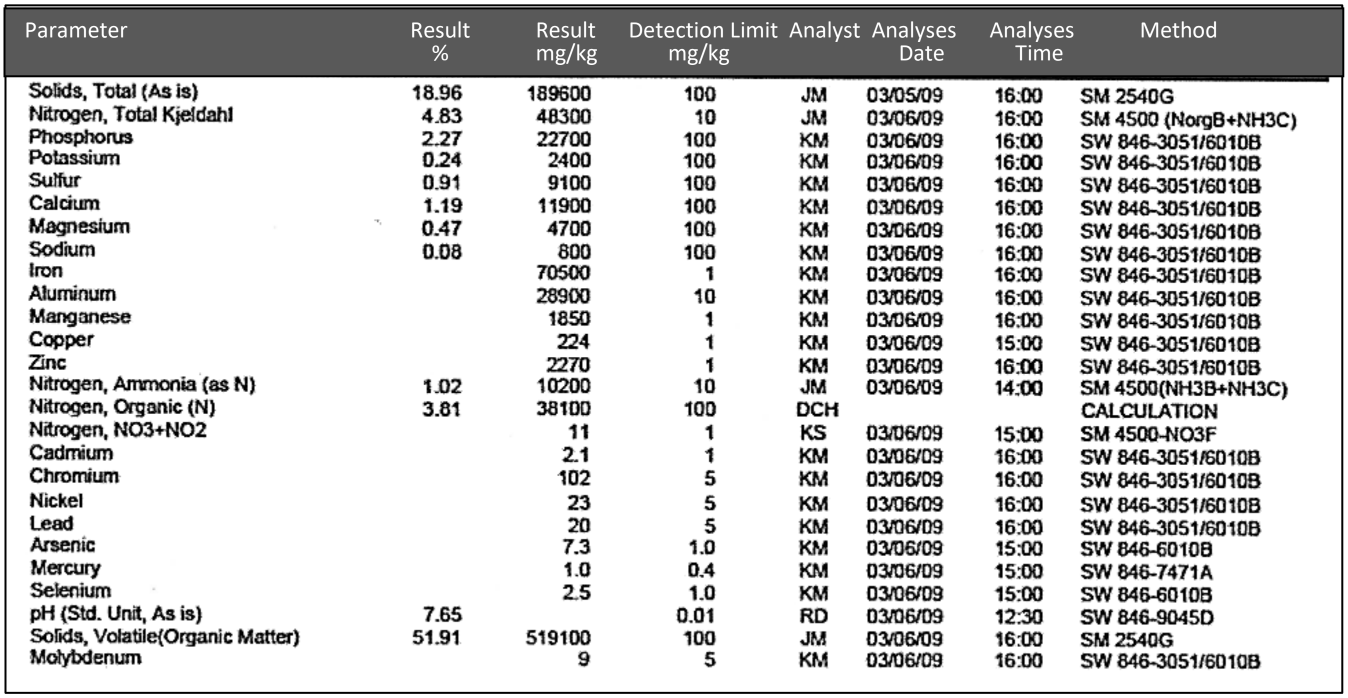
3. Calculate the amount of PAN needed from residuals.

   Subtract the additional source of PAN (from the side-dressing) from the total amount of PAN needed by the crop.

   PAN needed from residuals = 130 lbs/acre – 50 lbs/acre = 80 lbs PAN/acre

4. Calculate the amount of PAN in the residuals to be applied (the amount of N that will become available in the first year following application).

   a. First, we need to know the concentrations of the different forms of N in the residuals. We get these from our residuals lab report (Figure 7-1). We can see that our results are reported as dry weight, so we don't have to convert the concentrations from wet weight.



Parameter	Result %	Result mg/kg	Detection Limit mg/kg	Analyst	Analyses Date	Analyses Time	Method
Solids, Total (As is)	18.96	189600	100	JM	03/05/09	16:00	SM 2540G
Nitrogen, Total Kjeldahl	4.83	48300	10	JM	03/06/09	16:00	SM 4500 (NorgB+NH3C)
Phosphorus	2.27	22700	100	KM	03/06/09	16:00	SW 846-3051/6010B
Potassium	0.24	2400	100	KM	03/06/09	16:00	SW 846-3051/6010B
Sulfur	0.91	9100	100	KM	03/06/09	16:00	SW 846-3051/6010B
Calcium	1.19	11900	100	KM	03/06/09	16:00	SW 846-3051/6010B
Magnesium	0.47	4700	100	KM	03/06/09	16:00	SW 846-3051/6010B
Sodium	0.08	800	100	KM	03/06/09	16:00	SW 846-3051/6010B
Iron		70500	1	KM	03/06/09	16:00	SW 846-3051/6010B
Aluminum		28900	10	KM	03/06/09	16:00	SW 846-3051/6010B
Manganese		1850	1	KM	03/06/09	16:00	SW 846-3051/6010B
Copper		224	1	KM	03/06/09	15:00	SW 846-3051/6010B
Zinc		2270	1	KM	03/06/09	16:00	SW 846-3051/6010B
Nitrogen, Ammonia (as N)	1.02	10200	10	JM	03/06/09	14:00	SM 4500(NH3B+NH3C)
Nitrogen, Organic (N)	3.81	38100	100	DCH			CALCULATION
Nitrogen, NO3+NO2		11	1	KS	03/06/09	15:00	SM 4500-NO3F
Cadmium		2.1	1	KM	03/06/09	16:00	SW 846-3051/6010B
Chromium		102	5	KM	03/06/09	16:00	SW 846-3051/6010B
Nickel		23	5	KM	03/06/09	16:00	SW 846-3051/6010B
Lead		20	5	KM	03/06/09	16:00	SW 846-3051/6010B
Arsenic		7.3	1.0	KM	03/06/09	15:00	SW 846-6010B
Mercury		1.0	0.4	KM	03/06/09	15:00	SW 846-7471A
Selenium		2.5	1.0	KM	03/06/09	15:00	SW 846-6010B
pH (Std. Unit, As is)	7.65		0.01	RD	03/06/09	12:30	SW 846-9045D
Solids, Volatile(Organic Matter)	51.91	519100	100	JM	03/06/09	16:00	SM 2540G
Molybdenum		9	5	KM	03/06/09	16:00	SW 846-3051/6010B

Figure 7-1. Residuals analysis.

Residuals data needed:

- ○ Total Kjeldahl Nitrogen (TKN) = 48,300 mg/kg
- ○ Ammonia (NH_4^+) = 10,200 mg/kg
- ○ Nitrate + nitrite (NO_3^- + NO_2^-) = 11 mg/kg

b. Next, we need to know the residuals stabilization method in order to use the correct mineralization rate. Let's say our residuals were anaerobically digested.

From Table 7-1, we see that the mineralization rate for anaerobic digestion is 20%.

Table 7-1. Mineralization rate based on stabilization method.

Residuals Processing Method	Mineralization Rate
Unstabilized Primary and Secondary Residuals	40%
Aerobically Digested Residuals, Lime Stabilized	30%
Anaerobically Digested Residuals	20%
Composted Residuals	10%

c. The last piece of information we need to know is the method of residuals application (surface application vs subsurface incorporation or injection). For this example, we will say the residuals will be surface applied.

   Summary of data needed to calculate PAN in the residuals:

   - Total Kjeldahl Nitrogen (TKN) = 48,300 mg/kg
   - Ammonium (NH_4^+) = 10,200 mg/kg
   - Nitrate + nitrite ($NO_3^- + NO_2^-$) = 11 mg/kg
   - Mineralization Rate (MR) = 20%
   - Application Method = Surface application

d. Now we can calculate the amount of plant available nitrogen in the residuals using the PAN formula for surface application.

$$\boxed{\text{PAN (mg/kg)} = [\text{MR} \times (\text{TKN} - NH_4^+)] + (0.5 \times NH_4^+) + NO_3^- + NO_2^-}$$

$$\text{PAN (mg/kg)} = [0.2 \times (48{,}300 - 10{,}200)] + (0.5 \times 10{,}200) + 11$$

$$\text{PAN (mg/kg)} = [0.2 \times (38{,}100)] + 5{,}100 + 11$$

$$\text{PAN (mg/kg)} = 7{,}620 + 5{,}100 + 11$$

PAN (mg/kg) = 12,731 mg/kg PAN in residuals

Convert mg/kg to lbs/dry ton. Remember this formula?

$$\boxed{\text{lbs PAN/dry ton} = \text{mg/kg} \times 0.002}$$

lbs PAN/dry ton = 12,731 mg/kg x 0.002 = 25.46 lbs PAN/dry tons of residuals

(Since the lab reported the concentration of Organic N (38,100 mg/kg) we could have skipped part of the first where we subtracted NH_4^+ from TKN to get Org-N.)

5. **Calculate the residuals application rate on a dry ton/acre basis.**

From Step 3, we know the amount of PAN the residuals need to supply (80.0 lbs PAN/acre). From Step 4, we know the amount of PAN in the residuals we are going to land apply (25.46 lbs PAN/dry ton). Now we need to calculate the volume of residuals in dry tons/acre needed to supply the required nitrogen using this formula:

$$\boxed{\text{Application Rate (dry tons/ac)} \quad = \quad \frac{\text{PAN residuals need to supply (lb/ac)}}{\text{PAN in residuals (lb/dry ton)}}}$$

$$\text{Application Rate (dry tons/ac)} = \frac{\text{80.0 lbs PAN/ac}}{\text{25.46 lbs PAN /dry ton)}} = \text{3.14 dry tons/ac}$$

6. **Convert the application rate in dry tons/acre to "as-delivered" basis.**

From the lab results we see that the percent solids of the residuals is 18.96% or 0.1896 in decimal form. Since the total solids is greater than 15%, we the know the residuals are probably dewatered, so we can convert dry tons/acre to wet tons/acre or cubic yards/acre.

- ☐ Convert dry tons/acre to wet tons/acre

$$\boxed{\text{Wet tons/ac} \quad = \quad \frac{\text{dry tons/ac}}{\text{\% solids}}}$$

$$\text{Wet tons/acre} = \frac{\text{dry tons/ac}}{\text{\% solids}} = \frac{\text{3.14 dry tons/ac}}{0.1896} = \text{16.57 wet tons/ac}$$

- ☐ Convert dry tons/ac to cubic yards/ac

Converting dry tons/ac to cubic yards/ac requires the use of a conversion factor that we haven't seen yet: 1 yd^3 = 201.974 gallons

$$\text{Dry tons to cubic yards} = \frac{\text{dry tons/ac x 2000 lbs/dry tons}}{0.1896 \text{ x } 201.974 \text{ gal/yd}^3 \text{ x } 8.34 \text{ lbs/gal}} = yd^3$$

$$yd^3/ac = \frac{\text{3.14 dry tons/ac x 2000 lbs/dry tons}}{0.1896 \text{ x } 201.974 \text{ gal/yd}^3 \text{ x } 8.34 \text{ lbs/gal}} = 103.77\ yd^3/ac$$

Example 2:

Given the information below, calculate the residuals application rate (dry tons/acre). Then convert dry tons/acre to "as-delivered" units.

1. **Determine the PAN needs of the crop based on RYE.**

   The dominant soil series for the field we will apply to is Badin-Tarrus complex. We again plan to grow corn for grain. From NCSU's Realistic Yield Database, we find that the realistic nitrogen (or PAN) requirement for a corn grain crop grown on the soil type of our field is 121 lbs PAN/acre/year.

2. **Determine PAN provided by other sources.**

   The farmer tells you that no manure will be applied to the field. He does plan to apply 10 lbs/acre nitrogen as starter fertilizer.

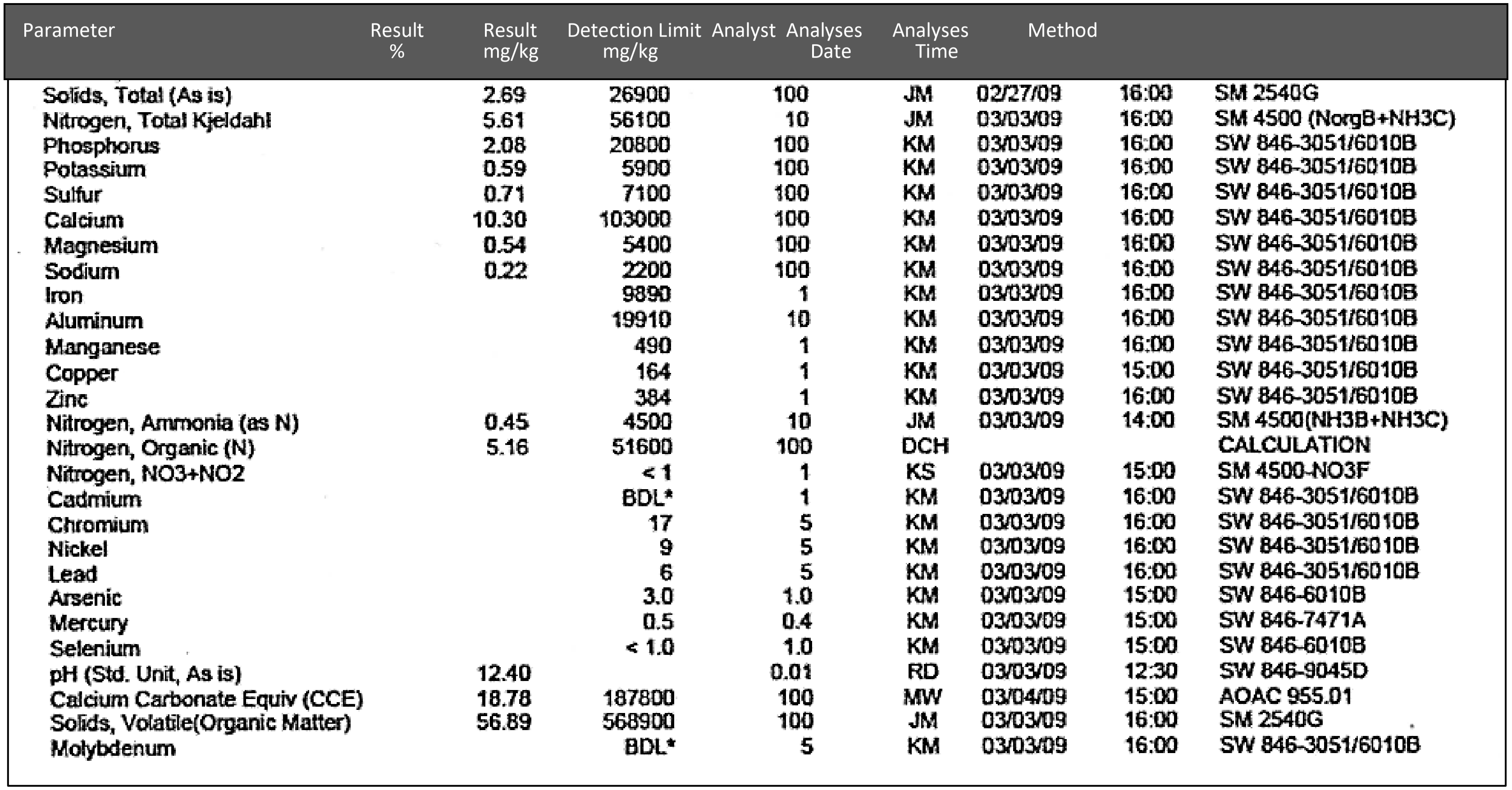
3. **Calculate the amount of PAN the residuals needed from residuals.**

   Subtract the additional source of PAN (from the side-dressing) from the total amount of PAN needed by the crop.

   PAN needed from residuals = 121.0 lbs/acre – 10.0 lbs/acre = 111.0 lbs PAN/acre

4. **Calculate the amount of PAN in the residuals to be applied (the amount of N that will become plant available during the first year following application).**

   a. First, we need to know the concentrations of the different forms of N in the residuals. We get these from our residuals lab report (Figure 7-2). We can see that our results are reported as dry weight, so we don't have to convert the concentrations from wet weight.



Parameter	Result %	Result mg/kg	Detection Limit mg/kg	Analyst	Analyses Date	Analyses Time	Method
Solids, Total (As is)	2.69	26900	100	JM	02/27/09	16:00	SM 2540G
Nitrogen, Total Kjeldahl	5.61	56100	10	JM	03/03/09	16:00	SM 4500 (NorgB+NH3C)
Phosphorus	2.08	20800	100	KM	03/03/09	16:00	SW 846-3051/6010B
Potassium	0.59	5900	100	KM	03/03/09	16:00	SW 846-3051/6010B
Sulfur	0.71	7100	100	KM	03/03/09	16:00	SW 846-3051/6010B
Calcium	10.30	103000	100	KM	03/03/09	16:00	SW 846-3051/6010B
Magnesium	0.54	5400	100	KM	03/03/09	16:00	SW 846-3051/6010B
Sodium	0.22	2200	100	KM	03/03/09	16:00	SW 846-3051/6010B
Iron		9890	1	KM	03/03/09	16:00	SW 846-3051/6010B
Aluminum		19910	10	KM	03/03/09	16:00	SW 846-3051/6010B
Manganese		490	1	KM	03/03/09	16:00	SW 846-3051/6010B
Copper		164	1	KM	03/03/09	15:00	SW 846-3051/6010B
Zinc		384	1	KM	03/03/09	16:00	SW 846-3051/6010B
Nitrogen, Ammonia (as N)	0.45	4500	10	JM	03/03/09	14:00	SM 4500(NH3B+NH3C)
Nitrogen, Organic (N)	5.16	51600	100	DCH			CALCULATION
Nitrogen, NO3+NO2		< 1	1	KS	03/03/09	15:00	SM 4500-NO3F
Cadmium		BDL*	1	KM	03/03/09	16:00	SW 846-3051/6010B
Chromium		17	5	KM	03/03/09	16:00	SW 846-3051/6010B
Nickel		9	5	KM	03/03/09	16:00	SW 846-3051/6010B
Lead		6	5	KM	03/03/09	16:00	SW 846-3051/6010B
Arsenic		3.0	1.0	KM	03/03/09	15:00	SW 846-6010B
Mercury		0.5	0.4	KM	03/03/09	15:00	SW 846-7471A
Selenium		< 1.0	1.0	KM	03/03/09	15:00	SW 846-6010B
pH (Std. Unit, As is)	12.40		0.01	RD	03/03/09	12:30	SW 846-9045D
Calcium Carbonate Equiv (CCE)	18.78	187800	100	MW	03/04/09	15:00	AOAC 955.01
Solids, Volatile(Organic Matter)	56.89	568900	100	JM	03/03/09	16:00	SM 2540G
Molybdenum		BDL*	5	KM	03/03/09	16:00	SW 846-3051/6010B

Figure 7-2. Residuals analysis.

Residuals data needed:

- Total Kjeldahl Nitrogen (TKN) = 56,100 mg/kg
- Ammonia (NH_4^+) = 4,500 mg/kg
- Nitrate + nitrite (NO_3^- + NO_2^-) = <1 mg/kg

b. Next, we need to know the residuals stabilization method in order to use the correct mineralization rate. Let's say our residuals were lime-stabilized this time. From the table we saw in last chapter, we see that the mineralization rate for lime stabilized residuals is 30%.

Mineralization rate based on stabilization method.

Residuals Processing Method	Mineralization Rate
Unstabilized Primary and Secondary Residuals	40%
Aerobically Digested Residuals, Lime Stabilized	30%
Anaerobically Digested Residuals	20%
Composted Residuals	10%

c. The last piece of information we need to know is the method of residuals application (surface application vs subsurface incorporation or injection). For this example, we will say the residuals will be injected.

Summary of data needed to calculate PAN in the residuals:

- Total Kjeldahl Nitrogen (TKN) = 56,100 mg/kg
- Ammonia (NH_4^+) = 4,500 mg/kg
- Nitrate + nitrite (NO_3^- + NO_2^-) = <1 mg/kg
- Mineralization Rate (MR) = 30% or 0.30
- Application Method = Injection

d. Now we can calculate the amount of plant available nitrogen in the residuals using the PAN formula for subsurface application.

$$\boxed{\text{PAN (mg/kg)} = [\text{MR} \times (\text{TKN} - NH_4^+)] + NH_4^+ + NO_3^- + NO_2^-}$$

PAN (mg/kg) = [0.3 x (56,100 – 4,500)] + 4,500 + 1

PAN (mg/kg) = [0.3 x 51,600] + 4500 + 1

PAN (mg/kg) = 15,480 + 4500 + 1

PAN (mg/kg) = 19,981 mg/kg PAN in residuals

Convert mg/kg to lbs/dry ton.

$$\boxed{\text{lbs/dry ton} = \text{mg/kg} \times 0.002}$$

lbs PAN/dry ton = 19,981 mg/kg x 0.002 = 40.0 lbs PAN/dry tons of residuals

(Since the lab reported the concentration of Organic N (51,600 mg/kg) we could have skipped part of the first where we subtracted NH_4^+ from TKN to get Org–N.)

5. Calculate the residuals application rate on a dry ton/acre basis.

From Step 3, we know the amount of PAN the residuals need to supply. From Step 4, we know the amount of PAN in the residuals we are going to land apply. Now we need to calculate the volume of residuals in dry tons/acre needed to supply the required nitrogen using this formula:

$$\boxed{\text{Application rate (dry tons/ac)} = \frac{\text{PAN residuals need to supply (lb PAN/acre)}}{\text{PAN in residuals (lb PAN/dry ton)}}}$$

$$\text{Application rate (dry tons/ac)} = \frac{\text{111.0 lbs PAN/ac}}{\text{40.0 lbs PAN /dry ton}} = \text{2.78 dry tons/ac}$$

6. Convert the application rate in dry tons/acre to “as-delivered” basis.

From the lab results we see that the percent solids of the residuals is 2.69% or 0.0269 in decimal form. Since the % solids is 2.69, we the know the residuals are in liquid form, so we should convert dry tons per acre to gallons per acre.

$$\boxed{\text{gal/ac} = \frac{\text{dry tons/ac} \times \text{2000 lbs/ton}}{\text{8.34 lbs/gal} \times \text{\% solids}}}$$

$$\text{gal/ac} = \frac{\text{2.78 dry tons/ac} \times \text{2000 lbs/dry ton}}{\text{8.34 lbs/gal} \times 0.0269} = \frac{\text{5,560 gal/ac}}{0.2243} = \text{24,788.23 gal/ac}$$

Calculating Pounds of PAN Per Acre

Example 1:

If the residuals application rate is 16.5 dry tons/acre and your residuals contain 4.67 lbs PAN/dry ton, calculate lbs PAN/acre.

We can use the same formula we used when calculating metals loadings per acre:

lbs/acre = lbs/dry ton x dry tons/acre

lbs PAN/acre = 4.67 lbs PAN/dry ton x 16.5 dry tons/acre = 77.06 lbs PAN/acre

Example 2:

If the target application rate is 2.78 dry tons of residuals and the residuals contain 40.0 lbs PAN/dry ton, calculate lbs PAN/acre.

lbs PAN/acre = 40.0 lbs PAN/dry ton x 2.78 dry tons/acre = 111.09 lbs PAN/acre

Calculating Application Rates Based on Liming Potential

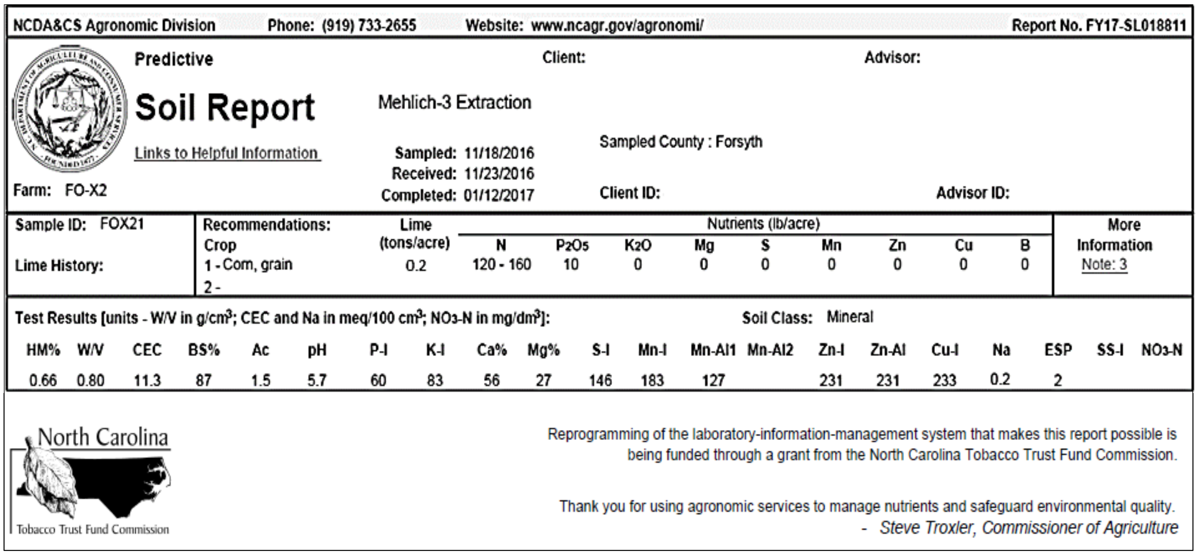
Example 1:

If your permit specifies that the application rate must be based on the liming potential of your residuals, or if you think their liming potential is high, ask your lab to determine the ***Calcium Carbonate Equivalent (CCE)*** or the ***agricultural lime equivalent (ALE)*** of the residuals.

Remember from Chapter 6 that the CCE is the neutralizing value of a liming material compared to ag-lime, expressed as a percentage. A material with a CCE of 100% would be just as effective as ag-lime in liming value. A material with a CCE of 40% would be only 40% as effective.

Let's look at the residuals analysis on Page 6 (Figure 7-2). Did you notice that the pH of the residuals was 12.40? Even if your application rates are based on nitrogen, this is a situation where you would want to calculate the application rate based on liming potential and compare to the application rate based on nitrogen.

How many dry tons of residuals should be applied per acre if the CCE is 18.78% and the soil test calls for 0.2 tons/acre of lime (Figure 7-3)? What is the "as-delivered" application rate? The % solids of the residuals is 2.69%.



NCDA&CS Agronomic Division **Phone: (919) 733-2655** **Website: www.ncagr.gov/agronomi/** **Report No. FY17-SL018811**

Predictive

Soil Report

Links to Helpful Information

Mehlich-3 Extraction

Client:

Advisor:

Sampled: 11/18/2016
Received: 11/23/2016
Completed: 01/12/2017

Sampled County : Forsyth

Farm: FO-X2

Client ID:

Advisor ID:

Sample ID: FOX21

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
		Nutrients (lb/acre)									
1 - Com, grain	0.2	120 - 160	10	0	0	0	0	0	0	0	Note: 3
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: **Soil Class:** Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.66	0.80	11.3	87	1.5	5.7	60	83	56	27	146	183	127		231	231	233	0.2	2		

North Carolina
Tobacco Trust Fund Commission

Reprogramming of the laboratory-information-management system that makes this report possible is being funded through a grant from the North Carolina Tobacco Trust Fund Commission.

Thank you for using agronomic services to manage nutrients and safeguard environmental quality.
- *Steve Troxler, Commissioner of Agriculture*

Figure 7-3. Soil test report.

$$\boxed{\text{Lime-Based Application Rate (dry tons/acre)} = \frac{\text{Recommended tons lime/acre}}{\text{\% CCE of residuals}}}$$

$$\text{Lime-Based Application Rate (dry tons/acre)} = \frac{\text{0.2 tons lime/acre}}{0.1878} = \text{1.06 dry tons/acre}$$

The application rate based on nitrogen was 2.78 dry tons/acre, compared to 1.06 dry tons/acre when based on the liming potential of the residuals. Let's see what the difference is when we convert the rate to an "as-delivered basis".

☐ Convert dry tons/acre to gallons/acre

$$\boxed{\text{gal/ac} = \frac{\text{dry tons/ac} \times \text{2000 lbs/ton}}{\text{8.34 lbs/gal} \times \text{\% solids}}}$$

$$\text{gal/ac} = \frac{\text{1.06 dry tons/ac} \times \text{2000 lbs/dry ton}}{\text{8.34 lbs/gal} \times 0.0269} = \frac{\text{2,120.0 gal/ac}}{0.2243} = \text{9,451.6 gal/ac}$$

"As-delivered" Nitrogen-Based Application Rate (gal/acre) = 24,788.23 gal/acre

"As-delivered" Lime-Based Application Rate (gal/acre) = 9,451.6 gal/acre

The most prudent agronomic recommendation is to not exceed the soil's lime requirement. Special cases may need a soil or crop consultant for additional advice. Raising soil pH to too high a level can be injurious to crops and cause micronutrient deficiencies.

Example 2:

The agricultural lime equivalent (ALE) is the amount of residuals that will provide a liming effect equal to one ton of agricultural grade limestone (ag-lime), which is the standard material referenced by soil tests.

The lime recommendation on a soil test report is always based on the amount of commercial strength ag-lime (tons/acre) required to raise soil pH to the desired level. The ALE of the residuals is reported on the residuals analyses as a number, 5.0 for example. This means that 5.0 tons of residuals equals 1 ton of ag-lime. If the soil test report recommends 1 ton of ag-lime per acre, then applying 5.0 tons of residuals will have the liming effect of one ton of ag-lime. The lower the ALE value, the stronger the material is as a liming source.

What is the lime-based application rate if the ALE is 6.5 and the soil test calls for 0.4 tons/acre of lime? What is the "as-delivered" rate? The % solids of the residuals is 17.8%. Since it takes 6.5 tons of residuals to equal one time of ag-lime, and 0.4 tons/acre of ag-lime are needed, then the residuals application rate is:

Lime-Based Application Rate (dry tons/acre) = ALE of residuals/1 ton ag-lime x Recommended tons ag-lime/acre

Lime-Based Application Rate (dry tons/acre) = 6.5 tons residuals/1 ton ag-lime x 0.4 tons ag-lime/ac = 2.6 dry tons/ac

Then, convert the application rate in dry tons/acre to “as-delivered” basis. We know that the residuals are probably dewatered because the solids content is 17.8%. So we should calculate the “as-delivered” amount in wet tons/acre or cubic yards/acre.

□ Convert dry tons/ac to wet tons/acre

$$\boxed{\text{Wet tons/acre} = \frac{\text{dry tons/acre}}{\text{\% solids}}}$$

$$\text{Wet tons/acre} = \frac{2.6 \text{ dry tons/acre}}{0.178} = 14.6 \text{ wet tons/acre}$$

□ Convert dry tons/acre to cubic yards/acre

$$\boxed{\text{yd}^3\text{/acre} = \frac{\text{dry tons/ac} \times 2000 \text{ lbs/dry ton}}{\text{\% solids} \times 201.974 \text{ gal/yd}^3 \times 8.34 \text{ lbs/gal}} = \text{yd}^3\text{/ac}}$$

$$\text{yd}^3\text{/acre} = \frac{2.6 \text{ dry tons/acre} \times 2000 \text{ lbs/dry ton}}{.0269 \times 201.974 \text{ gal/yd}^3 \times 8.34 \text{ lbs/gal}} = \frac{5{,}200 \text{ lbs/ac}}{45.30 \text{ lbs/yd}^3} = 114.79 \text{ yd}^3\text{/ac}$$

Calculating the Sodium Adsorption Ration (SAR)

Your lab may calculate and report the SAR value. If not, you must calculate it yourself. Even if the lab does report it, there have been instances where labs have calculated and reported SAR incorrectly. Calculate the SAR of your residuals using the formula below. You will need to use the square root function on your calculator.

$$\text{Sodium Adsorption Ratio (SAR)} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Units are milliequivalents/liter (meq/L)

Before you can use this formula, the concentrations of Na^{+}, Ca^{2+}, and Mg^{2+} must be in milliequivalents/liter. A ***milliequivalent/liter (meq/L)*** is the weight wet concentration of the element (mg/L) divided by the equivalent weight of the element. The equivalent weight of an element is constant and never changes. The equivalent weights of Na^{+}, Ca^{2+}, and Mg^{2+} are 23, 20, and 12, respectively.

$$\text{Milliequivalents/liter (meq/L)} = \frac{\text{concentration (mg/L)}}{\text{equivalent weight}}$$

SAR is calculated using the ***wet weight concentrations*** (mg/L) of sodium, calcium, and magnesium. If the concentrations were reported on a wet weight basis, ***do not convert them to a dry weight basis***. If the concentrations of Na^{+}, Ca^{2+}, and Mg^{2+} were reported on a dry weight basis, then you have to convert them to wet weight concentrations before you can calculate milliequivalents/liter. Remember this formula? mg/L = mg/kg x % solids

Example 1:

What is the SAR of residuals that have a total solids content of 5.28% and the following concentrations Na^+, Ca^{2+}, and Mg^{2+}:

$$\left.\begin{array}{l}\text{Sodium } (Na^+) = 174.24 \text{ mg/L} \\ \text{Calcium } (Ca^{2+}) = 427.68 \text{ mg/L} \\ \text{Magnesium } (Mg^{2+}) = 142.56 \text{ mg/L}\end{array}\right\}$$

These concentrations are already in mg/L (weight wet) so they are in the correct units to convert to meq/L.

First, convert mg/L to meq/L using the formula:

$$\boxed{\text{Milliequivalents/liter (meq/L)} \quad = \quad \frac{\text{concentration (mg/L)}}{\text{equivalent weight}}}$$

The equivalent weights are: $Na^+ = 23$, $Ca^{2+} = 20$, $Mg^{2+} = 12$ (these never change)

$$\text{meq/L} = \frac{174.24 \text{ mg/L } Na^+}{23} = 7.58 \text{ meq/L } Na^+$$

$$\text{meq/L} = \frac{427.68 \text{ mg/L } Ca^{2+}}{20} = 21.38 \text{ meq/L } Ca^{2+}$$

$$\text{meq/L} = \frac{142.56 \text{ mg/L } Mg^{2+}}{12} = 11.88 \text{ meq/L } Mg^{2+}$$

Now, calculate SAR using the formula:

$$\text{Sodium Adsorption Ration (SAR)} = \frac{Na^+}{\sqrt{½\,(Ca^{2+} + Mg^{2+})}}$$

$$\text{SAR} = \frac{7.58}{\sqrt{½\,(21.38 + 11.88)}} = \frac{7.58}{\sqrt{½\,(33.26)}} = \frac{7.58}{\sqrt{16.63}} = \frac{7.58}{4.08} = 1.86$$

Is there cause for concern if the SAR for your residuals is 1.86?

Example 2:

What is the SAR of residuals with a total solids content of 8.3% and the concentrations below. The equivalent weights of Na^+, Ca^{2+}, and Mg^{2+} are 23, 20, and 12, respectively.

Sodium (Na^+) = 996.0 mg/L

Calcium (Ca^{2+}) = 439.9 mg/L

Magnesium (Mg^{2+}) = 149.4 mg/L

First, convert mg/L to meq/L using the formula: $\text{meq/L} = \frac{\text{concentration mg/L}}{\text{equivalent weight}}$

$$\frac{996.0 \text{ mg/L } Na^+}{23} = 43.3 \text{ meq/L } Na^+$$

$$\frac{439.9 \text{ mg/L } Ca^{2+}}{20} = 22.0 \text{ meq/L } Ca^{2+}$$

$$\frac{149.4 \text{ mg/L } Mg^{2+}}{12} = 12.45 \text{ meq/L } Mg^{2+}$$

Now, calculate SAR using the formula: $\text{SAR} = \sqrt{\frac{Na^+}{0.5\,(Ca^{2+} + Mg^{2+})}}$

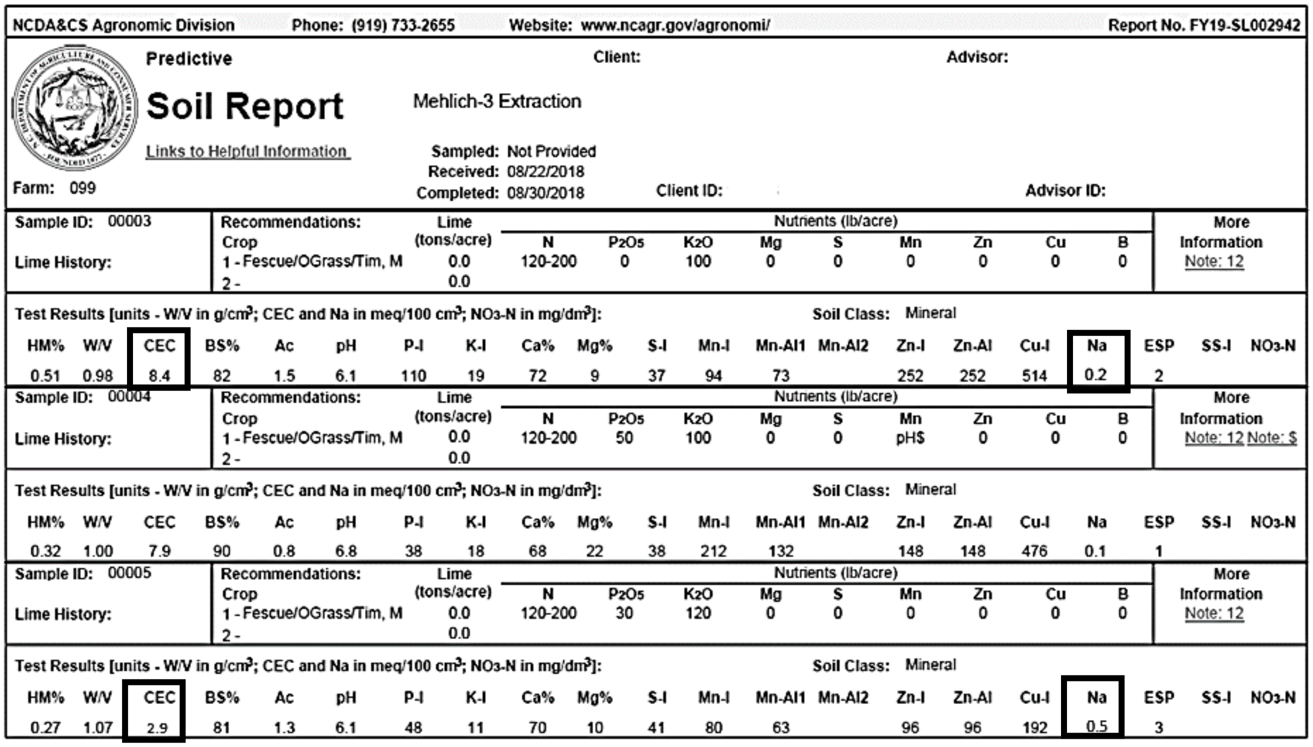
$$\text{SAR} = \frac{43.3}{\sqrt{0.5\,(22.0 + 12.45)}} = \frac{43.3}{\sqrt{0.5\,(34.45)}} = \frac{43.3}{\sqrt{17.23}} = \frac{43.3}{4.15} = 10.43$$

Is there cause for concern if the SAR for your residuals is 10.43?

Exchangeable Sodium Percentage (ESP)

Exchangeable Sodium Percentage (ESP) is a calculation using data from the soil test report (Figure 7-4). It is the ratio of sodium ions to the cation exchange capacity (CEC), which is the sum of all the cations a soil is capable of holding. (CEC will be discussed in more detail in a later section). The units for both Na and CEC are milliequivalents per 100 grams of soil (meq/100g). Use this formula to calculate ESP:

$$\text{ESP} = \frac{\text{Na meq/100g}}{\text{CEC meq/100g}} \times 100$$



NCDA&CS Agronomic Division Phone: (919) 733-2655 Website: www.ncagr.gov/agronomi/ Report No. FY19-SL002942

Predictive

Soil Report

Mehlich-3 Extraction

Client:

Advisor:

Links to Helpful Information

Sampled: Not Provided
Received: 08/22/2018
Completed: 08/30/2018

Farm: 099

Client ID:

Advisor ID:

Sample ID: 00003

Lime History:

Recommendations:

Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B
1 - Fescue/OGrass/Tim, M	0.0	120-200	0	100	0	0	0	0	0	0
2 -	0.0									

More Information: Note: 12

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.51	0.98	8.4	82	1.5	6.1	110	19	72	9	37	94	73		252	252	514	0.2	2		

Sample ID: 00004

Lime History:

Recommendations:

Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B
1 - Fescue/OGrass/Tim, M	0.0	120-200	50	100	0	0	pH$	0	0	0
2 -	0.0									

More Information: Note: 12 Note: $

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.32	1.00	7.9	90	0.8	6.8	38	18	68	22	38	212	132		148	148	476	0.1	1		

Sample ID: 00005

Lime History:

Recommendations:

Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B
1 - Fescue/OGrass/Tim, M	0.0	120-200	30	120	0	0	0	0	0	0
2 -	0.0									

More Information: Note: 12

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.27	1.07	2.9	81	1.3	6.1	48	11	70	10	41	80	63		96	96	192	0.5	3		

Figure 7-4. Soil test report.

Example 1:

What is the ESP for Field 00003? Is there cause for concern about the ESP of this field?

$$ESP = \frac{0.2\ meq/100g}{8.4\ meq/100g} \times 100 = 2.3\%$$

Example 2:

What is the ESP for a Field 00005? Is there cause for concern about the ESP of this field?

$$ESP = \frac{0.5\ meq/100g}{2.9\ meq/100g} \times 100 = 17.2\%$$

Supplemental Information *(Not on Exam)*

Calculating the Fertilizer P and K Value of Residuals

Residuals data reported by the lab are the elemental concentrations of P and K. Commercial fertilizer values for P and K, however, are expressed as P_2O_5 and K_2O. To accurately assess the nutrient value of residuals, the elemental concentrations of P and K reported by the lab must be converted to P_2O_5 and K_2O.

To convert P to P_2O_5, multiply by 2.27 $\boxed{P_2O_5 \ = \ P \text{ x } 2.27}$

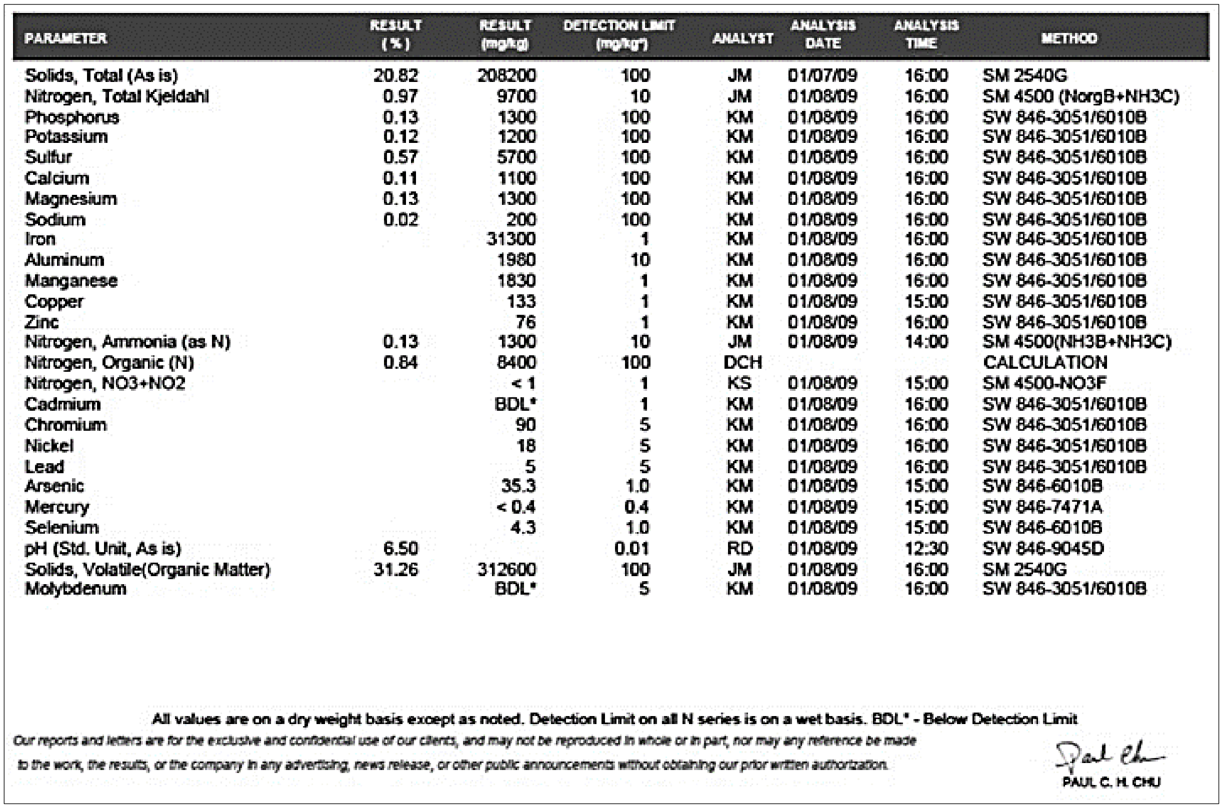
To convert P_2O_5 to P, multiply by 0.44 $\boxed{P \ = \ P_2O_5 \text{ x } 0.44}$

To convert K to K_20, multiply by 1.20 $\boxed{K_20 \ = \ K \text{ x } 1.20}$

To convert K_20 to K, multiply by 0.83 $\boxed{K \ = \ K_20 \text{ x } 0.83}$

Example 1:

From our lab analysis (Figure 7.5), we know that the residuals contain 1,300 mg/kg phosphorus and 1,200 mg/kg potassium. How many lbs/dry ton of each do the residuals contain?



PARAMETER	RESULT (%)	RESULT (mg/kg)	DETECTION LIMIT (mg/kg*)	ANALYST	ANALYSIS DATE	ANALYSIS TIME	METHOD
Solids, Total (As is)	20.82	208200	100	JM	01/07/09	16:00	SM 2540G
Nitrogen, Total Kjeldahl	0.97	9700	10	JM	01/08/09	16:00	SM 4500 (NorgB+NH3C)
Phosphorus	0.13	1300	100	KM	01/08/09	16:00	SW 846-3051/6010B
Potassium	0.12	1200	100	KM	01/08/09	16:00	SW 846-3051/6010B
Sulfur	0.57	5700	100	KM	01/08/09	16:00	SW 846-3051/6010B
Calcium	0.11	1100	100	KM	01/08/09	16:00	SW 846-3051/6010B
Magnesium	0.13	1300	100	KM	01/08/09	16:00	SW 846-3051/6010B
Sodium	0.02	200	100	KM	01/08/09	16:00	SW 846-3051/6010B
Iron		31300	1	KM	01/08/09	16:00	SW 846-3051/6010B
Aluminum		1980	10	KM	01/08/09	16:00	SW 846-3051/6010B
Manganese		1830	1	KM	01/08/09	16:00	SW 846-3051/6010B
Copper		133	1	KM	01/08/09	15:00	SW 846-3051/6010B
Zinc		76	1	KM	01/08/09	16:00	SW 846-3051/6010B
Nitrogen, Ammonia (as N)	0.13	1300	10	JM	01/08/09	14:00	SM 4500(NH3B+NH3C)
Nitrogen, Organic (N)	0.84	8400	100	DCH			CALCULATION
Nitrogen, NO3+NO2		< 1	1	KS	01/08/09	15:00	SM 4500-NO3F
Cadmium		BDL*	1	KM	01/08/09	16:00	SW 846-3051/6010B
Chromium		90	5	KM	01/08/09	16:00	SW 846-3051/6010B
Nickel		18	5	KM	01/08/09	16:00	SW 846-3051/6010B
Lead		5	5	KM	01/08/09	16:00	SW 846-3051/6010B
Arsenic		35.3	1.0	KM	01/08/09	15:00	SW 846-6010B
Mercury		< 0.4	0.4	KM	01/08/09	15:00	SW 846-7471A
Selenium		4.3	1.0	KM	01/08/09	15:00	SW 846-6010B
pH (Std. Unit, As is)	6.50		0.01	RD	01/08/09	12:30	SW 846-9045D
Solids, Volatile(Organic Matter)	31.26	312600	100	JM	01/08/09	16:00	SM 2540G
Molybdenum		BDL*	5	KM	01/08/09	16:00	SW 846-3051/6010B

All values are on a dry weight basis except as noted. Detection Limit on all N series is on a wet basis. BDL* - Below Detection Limit

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Paul Chu
PAUL C. H. CHU

Figure 7-5. Residuals analysis.

a. Convert mg/kg P and K to lbs/dry ton.

lbs/dry ton = mg/kg x 0.002

1,300 mg/kg P x 0.002 = 2.6 lbs P/dry ton

1,200 mg/kg K x 0.002 = 2.4 lbs K/dry ton

b. Calculate the lbs/acre of P and K that would be applied annually based on the application rate of 16.5 dry tons/acre.

lbs P/acre = lb P/dry ton x ALR (dry tons/acre)

2.6 lbs P/dry ton x 16.5 dry tons/acre = 42.9 lbs P/acre

lbs K/acre = lb K/dry ton x ALR (dry tons/acre)

2.4 lbs K/dry ton x 16.5 dry tons/acre = 39.6 lbs K/acre

c. Convert elemental P and K to P_2O_5 and K_20 .

$$\boxed{P_2O_5 = P \times 2.27}$$

42.9 lb P x 2.27 = 97.4 lbs P_2O_5/acre

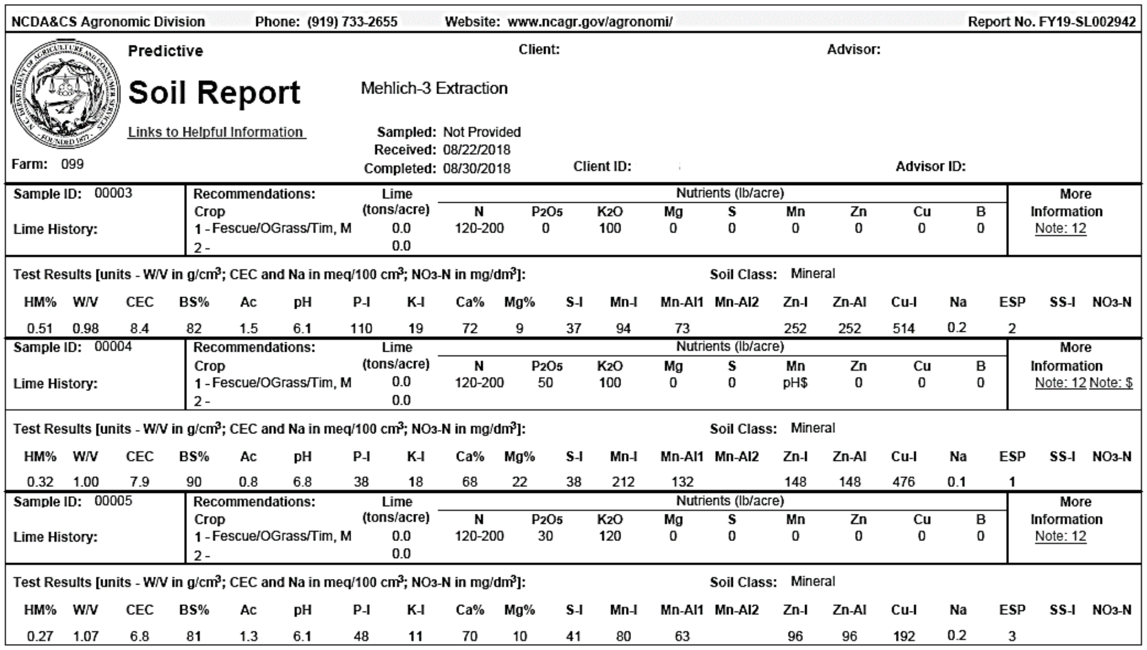
$$\boxed{K_20 = K \times 1.20}$$

39.6 lb K x 1.20 = 47.5 lbs K_20 /acre

d. Compare P and K delivered in residuals to fertilizer recommendations from soil test report (Figure 7-6).

For Field 00003, the recommendation is to add no supplemental P_2O_5. If we apply the application rate based on nitrogen to this field, we will over-apply phosphorus by approximately 100 lbs/acre. The recommendation for K_2O is to add 100 lbs/acre. Since the residuals will only supply 47.5 lbs K_2O/acre, supplemental fertilizer will be needed to supply the 100 lbs K_2O/acre recommended.

For Field 00004, the recommendation is 50 lbs P_2O_5/acre. If we apply the application rate based on nitrogen to this field, we will over-apply phosphorus by approximately 50 lbs/acre instead of 100 lbs/acre. The recommendation for K_2O is to add 120 lbs/acre. As with the first field, supplemental fertilizer will be needed to supply the lbs K_2O/acre recommended.



NCDA&CS Agronomic Division **Phone: (919) 733-2655** **Website: www.ncagr.gov/agronomi/** **Report No. FY19-SL002942**

Predictive
Soil Report
Links to Helpful Information

Mehlich-3 Extraction

Client:
Advisor:

Sampled: Not Provided
Received: 08/22/2018
Completed: 08/30/2018

Farm: 099
Client ID:
Advisor ID:

Sample ID: 00003
Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Fescue/OGrass/Tim, M	0.0	120-200	0	100	0	0	0	0	0	0	Note: 12
2 -	0.0										

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: **Soil Class:** Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.51	0.98	8.4	82	1.5	6.1	110	19	72	9	37	94	73		252	252	514	0.2	2		

Sample ID: 00004
Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Fescue/OGrass/Tim, M	0.0	120-200	50	100	0	0	pH$	0	0	0	Note: 12 Note: $
2 -	0.0										

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: **Soil Class:** Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.32	1.00	7.9	90	0.8	6.8	38	18	68	22	38	212	132		148	148	476	0.1	1		

Sample ID: 00005
Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Fescue/OGrass/Tim, M	0.0	120-200	30	120	0	0	0	0	0	0	Note: 12
2 -	0.0										

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: **Soil Class:** Mineral

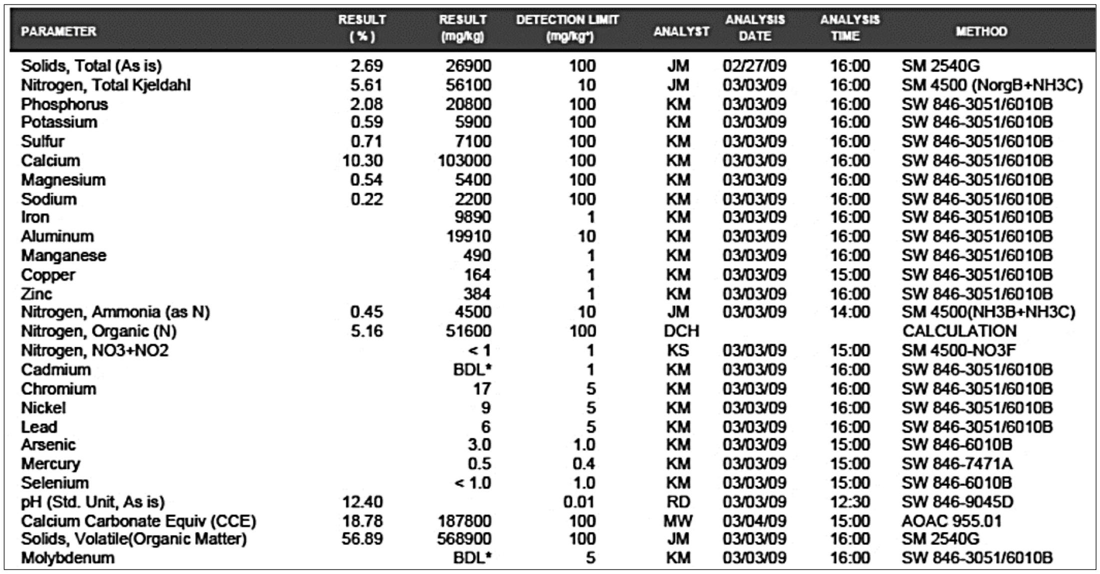
HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.27	1.07	6.8	81	1.3	6.1	48	11	70	10	41	80	63		96	96	192	0.2	3		

Figure 7-6. Soil test report.

The phosphorus index (P-I) for Field 00003 is very high. This is why no additional phosphorus is recommended. The phosphorus indexes for Fields 00004 and 00005 are in the medium range, so these fields are not as concerning as Field 00003. It would be a good management practice to suspend application on this field for a year or two and carefully monitor phosphorus levels in all three fields to see how the levels are increasing or decreasing.

Example 2:

From our lab analysis (Figure 7-7), we know that the residuals contain 20,800 mg/kg phosphorus and 7,100 mg/kg potassium. How many lbs/dry ton of each do the residuals contain?



PARAMETER	RESULT (%)	RESULT (mg/kg)	DETECTION LIMIT (mg/kg*)	ANALYST	ANALYSIS DATE	ANALYSIS TIME	METHOD
Solids, Total (As is)	2.69	26900	100	JM	02/27/09	16:00	SM 2540G
Nitrogen, Total Kjeldahl	5.61	56100	10	JM	03/03/09	16:00	SM 4500 (NorgB+NH3C)
Phosphorus	2.08	20800	100	KM	03/03/09	16:00	SW 846-3051/6010B
Potassium	0.59	5900	100	KM	03/03/09	16:00	SW 846-3051/6010B
Sulfur	0.71	7100	100	KM	03/03/09	16:00	SW 846-3051/6010B
Calcium	10.30	103000	100	KM	03/03/09	16:00	SW 846-3051/6010B
Magnesium	0.54	5400	100	KM	03/03/09	16:00	SW 846-3051/6010B
Sodium	0.22	2200	100	KM	03/03/09	16:00	SW 846-3051/6010B
Iron		9890	1	KM	03/03/09	16:00	SW 846-3051/6010B
Aluminum		19910	10	KM	03/03/09	16:00	SW 846-3051/6010B
Manganese		490	1	KM	03/03/09	16:00	SW 846-3051/6010B
Copper		164	1	KM	03/03/09	15:00	SW 846-3051/6010B
Zinc		384	1	KM	03/03/09	16:00	SW 846-3051/6010B
Nitrogen, Ammonia (as N)	0.45	4500	10	JM	03/03/09	14:00	SM 4500(NH3B+NH3C)
Nitrogen, Organic (N)	5.16	51600	100	DCH			CALCULATION
Nitrogen, NO3+NO2		< 1	1	KS	03/03/09	15:00	SM 4500-NO3F
Cadmium		BDL*	1	KM	03/03/09	16:00	SW 846-3051/6010B
Chromium		17	5	KM	03/03/09	16:00	SW 846-3051/6010B
Nickel		9	5	KM	03/03/09	16:00	SW 846-3051/6010B
Lead		6	5	KM	03/03/09	16:00	SW 846-3051/6010B
Arsenic		3.0	1.0	KM	03/03/09	15:00	SW 846-6010B
Mercury		0.5	0.4	KM	03/03/09	15:00	SW 846-7471A
Selenium		< 1.0	1.0	KM	03/03/09	15:00	SW 846-6010B
pH (Std. Unit, As is)	12.40		0.01	RD	03/03/09	12:30	SW 846-9045D
Calcium Carbonate Equiv (CCE)	18.78	187800	100	MW	03/04/09	15:00	AOAC 955.01
Solids, Volatile(Organic Matter)	56.89	568900	100	JM	03/03/09	16:00	SM 2540G
Molybdenum		BDL*	5	KM	03/03/09	16:00	SW 846-3051/6010B

Figure 7-7. Residuals analysis.

a. Convert mg/kg P and K to lbs/dry ton.

$$\boxed{\text{lbs/dry ton} = \text{mg/kg} \times 0.002}$$

lbs P/dry ton = 20,800 mg/kg P x 0.002 = 41.6 lbs P/dry ton

lbs K/dry ton = 7,100 mg/kg K x 0.002 = 14.2 lbs K/dry ton

b. Calculate the lbs/acre of P and K that would be applied annually based on the application rate of 2.8 dry tons/acre.

lbs P/acre = lb P/dry ton x ALR (dry tons/acre)

lbs P/acre = 41.6 lbs P/dry ton x 2.8 dry tons/acre = 116.5 lbs P/acre

lbs K/acre = lb K/dry ton x ALR (dry tons/acre)

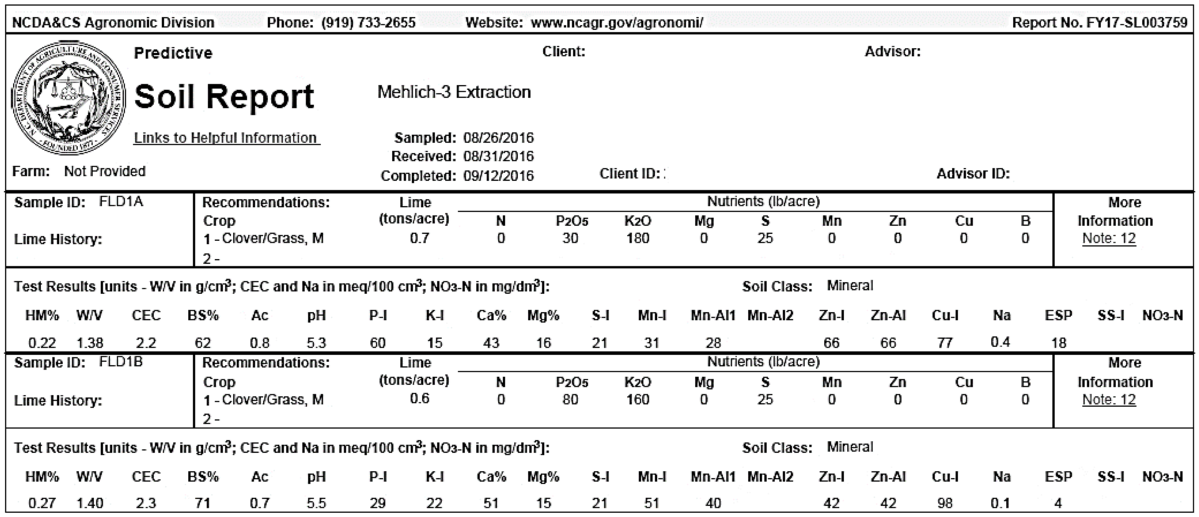
lbs K/acre = 14.2 lbs K/dry ton x 2.8 dry tons/acre = 39.8 lbs K/acre

c. Convert elemental P and K to P_2O_5 and K_20 .

$\boxed{P_2O_5 = P \times 2.27}$ 116.5 lb P x 2.27 = 264.5 lbs P_2O_5/acre

$\boxed{K_20 = K \times 1.20}$ 39.8 lb K x 1.20 = 47.8 lbs K_20 /acre

d. Compare P and K delivered in residuals to fertilizer recommendations from soil test report (Figure 7-8).



NCDA&CS Agronomic Division **Phone:** (919) 733-2655 **Website:** www.ncagr.gov/agronomi/ **Report No. FY17-SL003759**

Predictive

Soil Report

Mehlich-3 Extraction

Client:

Advisor:

Links to Helpful Information

Sampled: 08/26/2016
Received: 08/31/2016
Completed: 09/12/2016

Farm: Not Provided

Client ID:

Advisor ID:

Sample ID: FLD1A

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Clover/Grass, M	0.7	0	30	180	0	25	0	0	0	0	Note: 12
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: **Soil Class:** Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.22	1.38	2.2	62	0.8	5.3	60	15	43	16	21	31	28		66	66	77	0.4	18		

Sample ID: FLD1B

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Clover/Grass, M	0.6	0	80	160	0	25	0	0	0	0	Note: 12
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: **Soil Class:** Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.27	1.40	2.3	71	0.7	5.5	29	22	51	15	21	51	40		42	42	98	0.1	4		

Figure 7-8. Soil test report.

The recommendation is to add 30 lbs P_2O_5/acre Field to FLD1A and 80 lbs P_2O_5/acre to field FLD1B. As is usually the case, we will over-apply phosphorus if we apply the application rate based on nitrogen to these fields. The phosphorus indexes are high (FLD1A) and medium (FLD1B), so are not quite as concerning as the field in the previous example.

The recommendation for K_2O is to add 180 lbs/acre Field to FLD1A and 160 lbs/acre to field FLD1B. Since the residuals will only supply 47.8 lbs K_2O/acre, supplemental fertilizer will be needed to supply the lbs K_2O/acre recommended.

For Sample 00004, the recommendation is 50 lbs P_2O_5/acre. If we apply the application rate based on nitrogen to this field, we will over-apply phosphorus by approximately 50 lbs/acre instead of 100 lbs/acre. The recommendation for K_2O is to add 120 lbs/acre. As with the first field, supplemental fertilizer will be needed to supply the lbs K_2O/acre recommended.

Chapter 8

The Land Treatment System

We have finally arrived at the land application site. This is where final treatment and beneficial use of residuals occurs. The soils and crops at the site function as a natural treatment system to break down organic matter, recycle nutrients, reduce pathogens, and transform and/or trap metals and organic contaminants. But not all site, conditions, or crops are suitable for land application of Class B or even bulk Class A residuals.

8.1 Site Suitability – Where Can You Apply?

We have mentioned several times already that Class B permits are site-specific. A soil scientist evaluates and approves the fields listed in Attachment B of the permit. This provides you, as the operator, with some assurance that the fields are suitable for the growth of crops and final treatment of residuals. However, Class B permits still contain many restrictions on where you can land apply.

Even though Class A permits are not site-specific, they contain many of the same restrictions on where and when you can apply bulk Class A residuals. Consequently, land appliers of bulk Class A residuals must be just as familiar with the restrictions in their permits as land appliers of Class B residuals.

To properly manage your site and to comply with your permit, you must be familiar with these restrictions and understand why they are necessary.

Setbacks

Before we get to Section III of the permit (Operation and Maintenance Requirements) there is one last condition from the Performance Standards section that we need to discuss: setback requirements. When applying bulk Class A or Class B residuals, you must maintain the setbacks (non-application areas) listed in your permit. Only Class A residuals that are sold or given away in bags or other small containers have no setback requirements.

Setback means the minimum separation in linear feet, measured on a horizontal plane, required between residuals application areas and sensitive physical features such as buildings, roads, property lines, public or private wells, and water bodies. These setback requirements provide an extra layer of protection to prevent environmental impacts and reduce potential nuisances.

Setbacks are intended do the following:

- keep residuals on the site
- control runoff or leaching from the application area
- protect surface and groundwater
- reduce off-site odors and other nuisance conditions

Standard setback distances are established in the 02T regulations. Specific setbacks may vary from permit to permit, so you must read the permit to verify the setbacks for your application site.

For special situations, setback distances may need to be greater than those required by your permit. As a good management practice, the greater the distance you put your application area and surface water bodies and drinking water wells, the lower the possibility for surface or groundwater contamination. You can increase setback distances at your discretion, but you can never reduce them.

Residuals permits do not specify how large fields must be, but from a practical standpoint, the area of application should be large enough to justify hauling residuals to the site. The removal of application areas to accommodate setback distances can result in less acreage at the site than is acceptable. Setback requirements may cause you to decide a field or even an entire site is unsuitable for your program.

> Remember, your permit describes “cake” residuals as those that have greater than 15% solids by weight and can be stacked without flowing, as well as can be handled, transported, and spread as a solid.

☐ *Setbacks for Class B Land Application Areas*

Setbacks for Class B residuals vary by application method (Table 8-2). Residuals that are injected or incorporated are less likely to runoff or generate odors than residuals that are surface applied. Surface application by irrigation produces small droplets that may drift off the site. The small droplets also increase odor. Consequently, some setbacks for surface application by irrigation are greater than those for surface application by vehicle.

Setbacks to property lines are not applicable when the Permittee, or the entity from which the Permittee is leasing, owns both parcels separated by the property line.

Setbacks distances from land where Class B residuals are applied to property lines or habitable residences can be reduced or waived if the landowner agrees. Setback waiver forms must be completed, notarized, signed by all parties involved, and recorded with the county Register of Deeds. Waivers are terminated upon change of ownership of any of the parties involved.

Table 8-2. Standard setback distances for land application of Class B residuals.

Setback Description	Surface Application by Vehicle (ft)	Surface Application by Irrigation (ft)	Injection / Incorporation (ft)
Each habitable residence or place of assembly under separate ownership or not to be maintained as part of the project site	400	400	200
Each habitable residence or place of assembly owned by the Permittee, the owner of the land, or the lessee or operator of the land to be maintained as part of the project site	0	200	0
Each property line	50	150	50
Public right of way	50	50	50
Each private or public water supply source	100	100	100
Surface waters such as intermittent and perennial streams, perennial waterbodies, and wetlands	32.8	32.8	32.8
Surface water diversions such as ephemeral streams, waterways, and ditches	25	25	25
Groundwater lowering ditches where the bottom of the ditch intersects the SHWT (seasonal high water table)	25	100	25
Subsurface groundwater lowering drainage systems	0	100	0
Each wells with exception of monitoring well	100	100	100
Bedrock outcrops	25	25	25
Top of slope of embankments or cuts of two feet or more in vertical height	15	15	15
Each building foundation or basement	0	15	0
Each water line	0	10	0
Nitrification field	0	20	0

Flagging Fields

Setback distances should be accurately measured and not estimated. Class B permits require that land application areas must be clearly marked on each site prior to and during a land application event. Non-application areas and boundaries are usually marked using brightly colored flags. These flags are placed in the field to show equipment operators which areas of the field should or should not receive residuals. Mark the areas on a site map and make sure the equipment operator can read and understand the map.

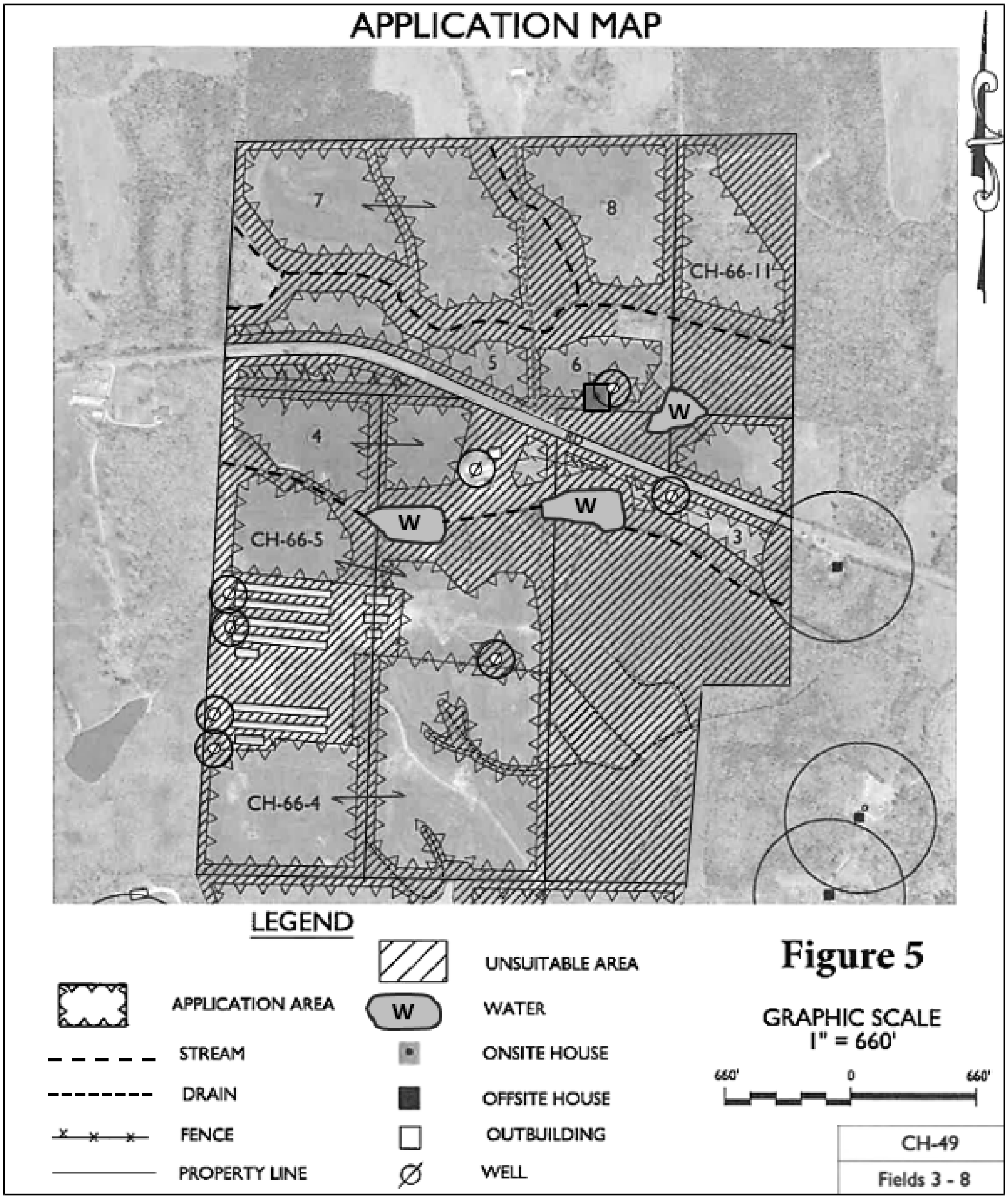


Figure 8-1. Example of a site map from a Class B residuals permit.

☐ *Setbacks for Bulk Class A Land Application Areas*

Setbacks for bulk Class A residuals depend on the solids content (Table 8-1). Cake residuals are more likely to stay where applied. The risk of runoff is greater with liquid residuals, so some of the minimum setback distances for this material are greater than for cake material.

Table 8-1. Standard setback distances for land application of bulk Class A residuals.

Setback Description	Liquid Residuals (ft)	Cake Residuals (ft)
Each private or public water supply source	100	100
Surface waters such as intermittent and perennial streams, perennial waterbodies, and wetlands	100	25
Surface water diversions such as ephemeral streams, waterways, and ditches	25	0
Groundwater lowering ditches where the bottom of the ditch intersects the SHWT (seasonal high water table)	25	0
Each well with exception of monitoring wells	100	100
Bedrock outcrops	25	0

Soil – Half of the Land Treatment System

We have now reached Section III of the permit, Operation and Maintenance Requirements. This section may seem tedious and theoretical. But whether you are applying Class B or bulk Class A residuals, a basic understanding of soil and site properties will help you understand the terms and concepts in your permit, communicate with regulators and landowners, and make sound management decisions.

The roles soil plays in the land treatment system include:

- provides a medium for plant growth
- provides a habitat for microorganisms
- stores and supply water and nutrients to plants
- filters, stores, and breaks down contaminants

Soil forms over hundreds of years from rocks and decaying plants and animals. It is made up of solid material and the space between the solid material. The solid material consists of mineral particles and organic matter. The spaces between the solid material, called ***pore space***, is filled with either air or water. An “ideal” soil contains around 45 to 48% mineral particles, 2 to 5% organic matter, 25% air, and 25% water (Figure 8-2).

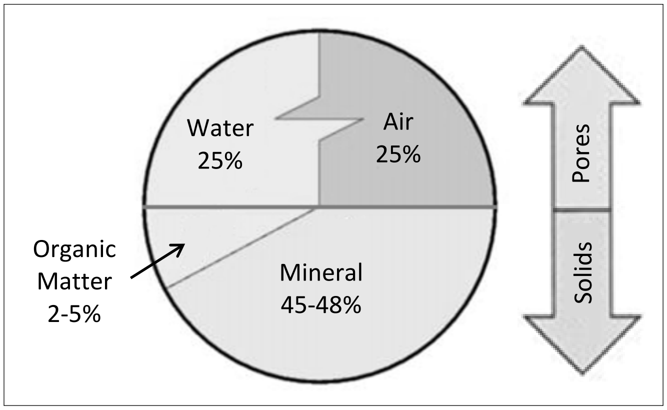


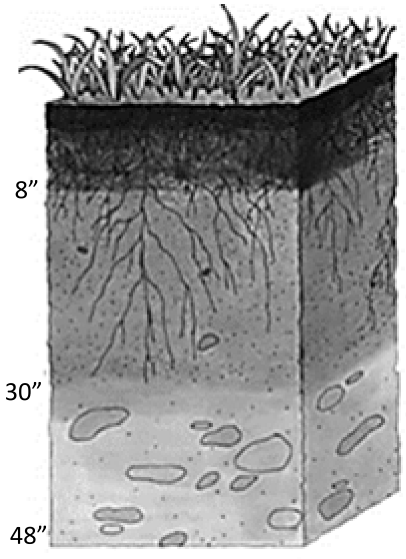
Figure 8-2: Composition of an “ideal” soil.

What is a Soil Profile, a Soil Horizon, and a Soil Series?

To understand how one soil differs from another, soil scientists “classify” and name soils by evaluating their physical, biological, and chemical properties. Soil is classified based on a three-dimensional volume or unit of soil called a soil profile. A ***soil profile*** is a vertical section of soil from the ground surface to the parent material (the original material the soil formed from). Each profile consists of a series of layers, called ***soil horizons***, whose properties differ from the layers above and beneath.

Soils have at least one, and usually three or four, horizons. Additional horizons are often present, depending upon soil forming factors and soil age. Under disturbed conditions (heavy agriculture, building sites, or severe erosion) some horizons may be partially or completely lost. Most of the soils in North Carolina that are suitable for land application have profiles with, at a minimum, the horizons shown in Figure 8-3. For our purposes, we are mainly concerned with the A and B horizons.

We talked about soil series earlier when we learned how to calculate the agronomic rate. Soils that have very similar profiles are classified as the same ***soil series***, which is simply a kind or type of soil. Except for variations in texture in the surface layer, the soils of one series have major horizons that are similar in thickness, arrangement, and other properties. Soils in the same series should not only look alike but should behave alike.



A horizon	Surface horizon or “topsoil”. It is usually darker than lower layers, loose, and crumbly with varying amounts of organic matter mixed with mineral particles. Zone of maximum ***biological*** activity in a soil.
B horizon	“Subsoil”. Usually contains more clay and less organic matter than the A horizon. Zone of maximum ***chemical*** activity in a soil.
C horizon	Consists of slightly broken-up bedrock. Very little organic material and plant roots do not penetrate this layer.

Figure 8-3. A simplified soil profile.

Soils can vary greatly over short distances. A land application site or field may contain several different soil series, each with unique properties. Some of these properties are ***inherent*** – they are permanent and do not change. Other properties are ***dynamic*** and change depending on how you manage the site.

Understanding the limitations imposed by inherent soil properties and the challenges posed by dynamic soil properties will help you manage your site in a manner that maintains, and possibly improves, it’s treatment capacity.

Soil Properties and Landscape Features

Soil properties and landscape features that impact the land application of residuals include:

- soil texture
- soil structure
- infiltration
- percolation and permeability
- soil depth and restrictive horizons
- seasonal high water table
- topography (slope and landscape position)
- soil pH

Soil Texture

Soil texture has to do with the mineral particles in a soil. These particles are divided into three groups based on size: sand-sized particles are the largest, silt-sized particles are medium-sized, and clay-sized particles are the smallest. Every soil contains some of each particle size, but not every soil contains the same amounts. The percentage of each size in a given soil determines it's texture.

The major soil textural classes take their names from the three particle size categories (sand, silt, and clay) and from a fourth category called loam. ***Loam*** is not another particle size, but is a balanced mix of sand, silt, and clay-sized particles (Figure 8-4).

Texture influences soil suitability for residuals application in many ways. Texture determines the size and shape of soil pores, which affects water movement into and through the soil. Texture influences the balance between water-filled pores and air-filled pores, creating different soil environments for root growth and microorganism activity.

There are a total of 12 soil textural classes that can be lumped into three general categories: coarsely-textured (sandy soils), medium-textured (loamy soils), and finely-textured (clay soils) (Table 8-3). Coarsely-textured soils have large spaces (***macropores***) between their soil particles. Water and air pass through these macropores rapidly. Consequently, coarsely-textured soils are usually well-aerated and well-drained.

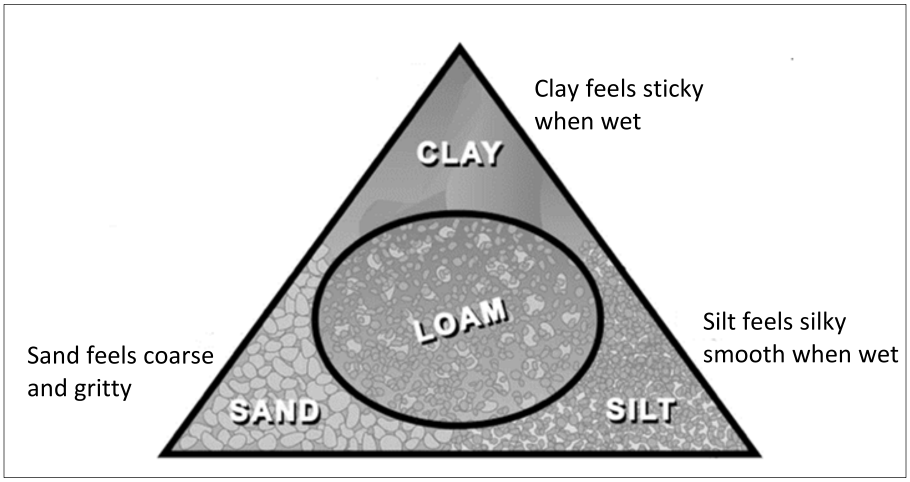


Figure 8-4. The 4th major textural class: loam is a balanced mixture of sand, silt, and clay sized particles.

However, water often passes through these soils too quickly for significant treatment to occur. In addition, these soils may not hold enough water and nutrients to support healthy vegetation. A poor vegetative cover results in reduced uptake of water, nutrients, and pollutants and an increased potential for soil erosion.

Clayey soils have smaller spaces (***micropores***) between soil particles. Due to cohesive and adhesive forces, micropores hold water, nutrients, and pollutants more tightly than macropores. Consequently, water tends to move into and through finely-textured soils more slowly.

Table 8-3. General categories of soil texture.

General Terms	Textural Class
Sandy Soils (coarsely-textured)	Sand Loamy sand
Loamy Soils (medium-textured)	Sandy loam Loam Silt loam Silt Clay loam Sandy clay loam Silty clay loam
Clayey Soils (finely-textured)	Sandy clay Silty clay Clay

Loamy or medium-textured soils have a range of pore sizes. Water can flow through the smaller pores while air can move through the larger pores. Medium-textured soils provide favorable environments for root growth, store large amounts of water for plant use, and have good nutrient-supplying power.

Because texture is the relative proportion of sand-, silt-, and clay-sized particles, it can be modified only through the addition of one of these particle sizes. This may be feasible when working in greenhouses or small garden plots but changing soil texture on a large scale is not practical, so soil texture is considered an inherent property.

Soil Structure

Soil structure is the arrangement of individual sand, silt, and clay particles into clusters of particles called soil aggregates. Aggregates occur in different shapes and patterns, resulting in different kinds of soil structure. These include granular, blocky, platy, prismatic, structureless-single grained (sand), and structureless-massive (Figure 8-5).

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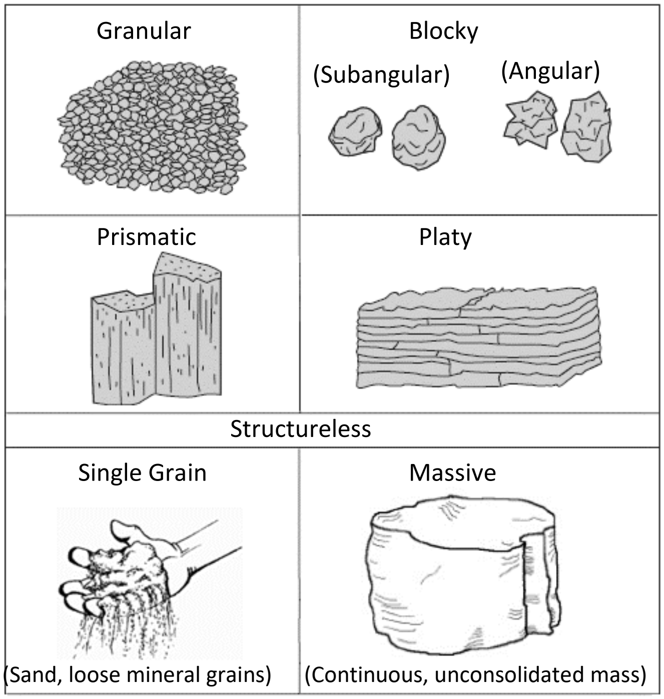


Figure 8-5. Types of soil structure.

Soil structure is important because it modifies some of the undesirable effects of certain textures on water and air movement. Structure creates relatively large pores between the aggregates, which are much larger than those between individual soil particles. Water, air, and plant roots move more readily through the macropores between aggregates than through the micropores inside the aggregates. Good structure means good aeration and a favorable balance between air and water containing pores.

The ideal structures for agriculture and land application of residuals is granular structure in the topsoil (A horizon) and blocky structure in the subsoil (B horizon). Water movement in soils with platy, prismatic, or massive structure is slow and restricted

Unlike texture, structure is easily altered by management practices. Maintaining strong, stable aggregates is important in any good soil management strategy. Residuals are a valuable soil amendment because they add organic matter which encourages the formation and maintenance of good soil structure. In addition, residuals application stimulates root growth which tends to bind particles together.

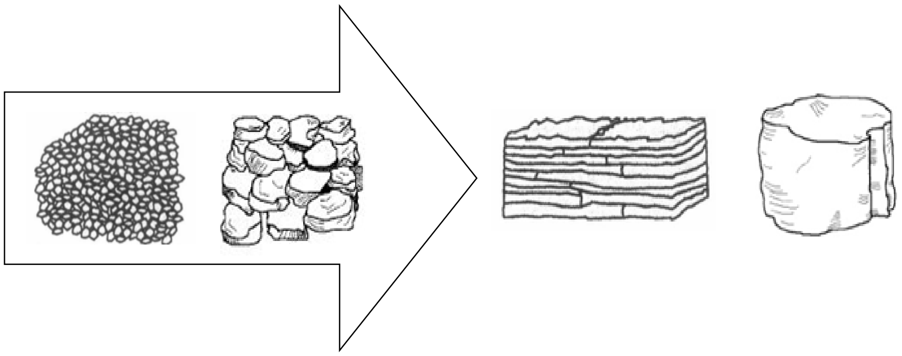


Figure 8-6. Granular and blocky structure can be changed into platy or massive structure due to compaction.

On the other hand, driving heavy equipment on wet soil (especially clayey soil) breaks down soil aggregates. The breakdown of soil aggregates is called ***soil compaction***. Soil particles are pressed closely together and macropores disappear. Compaction can change granular or blocky structure into platy or massive structure (Figure 8-6). Subsurface compaction (traffic pans and plow pans) are compacted layers that can develop beneath the topsoil because of driving heavy equipment or tilling soil when wet.

Compaction of topsoil can also occur. ***Surface crusting*** is a form of compaction that happens when the impact from water falling on or flowing over bare soil breaks down soil aggregates. Individual soil particles become suspended in water, flow together, and then dry into a hard crust (Figure 8-7).

Soil compaction impairs water and air movement into and through the soil, seedling germination and emergence, root penetration, and nutrient and water uptake by crops. Whenever possible soil compaction should be avoided. Limiting operations on wet soils, reducing load weight when possible, and controlling traffic will go a long way toward limiting compaction and maintaining soil productivity.

Compaction can be reduced by subsoiling, a process of deep tilling with a disk chisel, subsoiler (disk ripper), or ripper. This method of soil management penetrates soil below normal tillage depths (usually 12-18” deep) and breaks up soil to allow increased water movement, better aeration of roots and access to minerals and nutrients needed for plant growth. Low-disturbance subsoiling equipment can break up deep soil while leaving the surface virtually untouched.

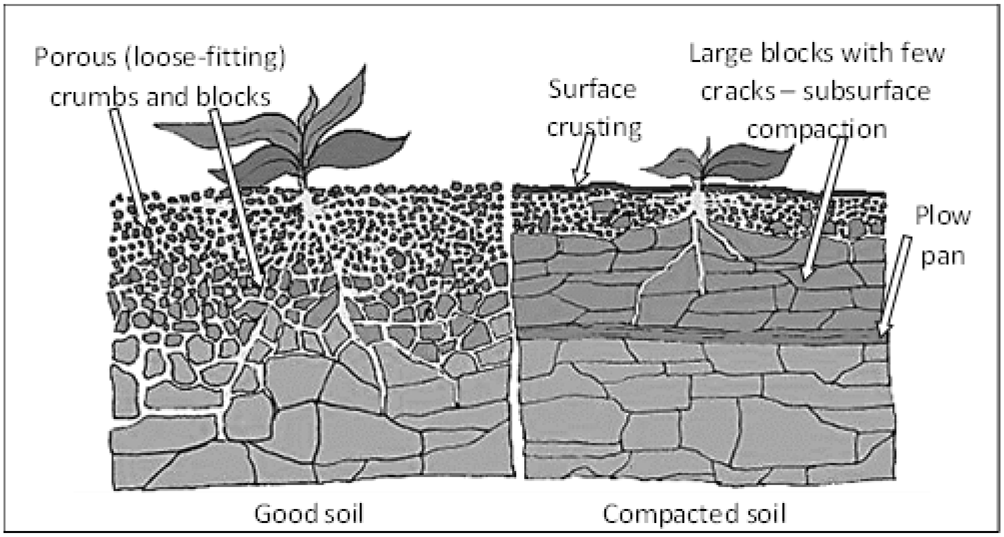


Figure 8-7. Soil with good structure and soil with surface crusting and subsurface compaction.

Infiltration

Infiltration is the movement of water *into* the soil. ***Infiltration rate*** (expressed in inches per hour) is the maximum rate at which water enters the soil. A moderate to rapid infiltration rate is desirable for plant growth and the environment. Infiltration rate is a function of surface texture and structure, vegetative cover, slope, and soil moisture.

- ☐ **Surface texture and structure.** We have already discussed the effects of texture and structure on water movement. A surface soil with medium to course texture and good structure will have a rapid infiltration rate. Infiltration rates can be near zero for very clayey and compacted surface soil.

- ☐ **Vegetation.** A healthy vegetative cover or crop protects soil structure and increases infiltration rates. Without the protective benefits of vegetative cover, water falling on or flowing over the soil destroys the soil's surface structure and results in surface crusting.

- ☐ **Slope.** On flat or gently sloping land, water has more time to soak into the soil surface. On steeper slopes, water moves over the surface more rapidly and the amount of time for infiltration is reduced. Soils tend to be thinner on steep slopes, limiting storage of water. Where bedrock is exposed, little infiltration can occur, except through large cracks which is unacceptable. We will discuss slope in more detail later in this section.

- ☐ **Soil moisture. I**nfiltration rates are higher when the soil is dry than when it is wet. As the soil becomes wet, the infiltration rate decreases. If all soil pores are filled with water the soil is said to be ***saturated***. Water must move downward through the soil profile before more water can enter at the surface. When the surface soil is completely saturated, the infiltration rate will be quite low.

When the surface soil is temporarily saturated and more water is added through rainfall or residuals application, the water must go somewhere. It either ponds on the soil surface or moves downslope as runoff. In most cases, the surface soil does not stay saturated for long periods. Water that infiltrates the soil surface and isn't taken up by plants or lost through evaporation moves downward through the larger pores.

Table 8-4 shows the influence of texture, slope, vegetation, and surface conditions on infiltration rates. A dry sandy soil on a gentle slope with a good vegetative cover will have a much higher infiltration rate than a wet finely-textured surface soil on a sparsely covered steep slope.

Table 8-4. Influence of texture, slope, vegetation, and surface conditions on infiltration rates.

	Slope		
	0 to 3%	3% to 9%	>9%
	Inches per hour		
Sand	>1.00	>0.70	>0.50
Loamy sand	0.70 to 1.00	0.50 to 1.00	0.40 to 0.70
Sandy loam and fine sandy loam	0.50 to 1.00	0.40 to 0.70	0.30 to 0.50
Loam and silt loam	0.30 to 0.70	0.20 to 0.50	0.15 to 0.30
Sandy clay loam and silty clay Loam	0.20 to 0.40	0.15 to 0.25	0.10 to 0.15
Clay, sandy clay, and silty clay	0.10 to 0.20	0.10 to 0.15	<0.10

For poor vegetative cover or surface soil conditions, actual rates may be as much as 50% less than shown.

Source: Sprinkler Irrigation Association Journal

Percolation and Permeability

The movement of water *through* the soil once it infiltrates the soil surface is called ***percolation***. ***Permeability*** is the rate (inches per hour) at which water percolates through the soil. Permeability is largely determined by soil texture and structure. Sandy soils have very rapid permeability, and clayey soils have very slow permeability. But, as we have discussed, this property also depends on soil structure. Good soil structure enhances permeability by providing stable aggregates that have small pores within aggregates and large pores between them.

Soils that are well suited for land application of residuals have moderate or moderately slow permeability. If water moves through the soil too slowly, soil will become waterlogged and saturated. If water moves through the soil too rapidly, nutrients and contaminants can leach to groundwater before they are adequately treated.

Soil Depth and Restrictive Horizons

Soil depth is the distance from the soil surface to bedrock or other restrictive horizons. A ***restrictive horizon*** is a layer in a soil profile that roots, water, and air cannot penetrate. Examples of restrictive horizons include:

- bedrock
- densely compacted material (traffic pan or plow pan)
- natural hardpans (soil cemented by iron, lime, gypsum, silica, etc.)
- seasonal high water table (discussed below)

Soil depth determines how much water can infiltrate and be held by the soil and how much space plant roots can occupy. Deep soils hold more plant nutrients and water than shallow soils and provide more treatment opportunities for contaminants.

Shallow soils limit the volume of soil available for treatment of contaminants and increase the risk of groundwater contamination. Areas where bedrock is close to the soil surface make particularly poor land application sites. Fractures or cracks in bedrock can act as direct conduits for contamination of groundwater. Shallow soils also limit the types of crops that can be grown and the yield of those crops.

For these reasons, residuals permits do not allow application of Class B or bulk Class A residuals where the vertical separation between bedrock and the *depth of residuals* (not the soil surface) is less than one foot. If residuals are to be incorporated or injected, there must be at least one foot between bedrock and the depth of residuals. For example, if residuals are incorporated to a depth of 4 inches, the depth to bedrock must be at least 16 inches.

Seasonal High Water Table

The seasonal high water table (SHWT) is one of the restrictive horizons we just mentioned. Before we define and discuss the seasonal high water table, we need to first define and discuss some other terms, some of which have been mentioned earlier.

Some of the water that infiltrates the soil is used by plants or evaporates. The remaining water percolates downward through the unsaturated portion of the soil until it reaches the ***saturated zone***, where all the pores in the soil or bedrock are filled with water. The surface or uppermost level of the saturated zone is called the ***water table***. When water percolates through the soil and reaches the water table, it becomes ***groundwater***. Groundwater is any water contained in interconnected pores located below the water table.

Water table depths are determined by the restrictive layers present below the soil surface. These layers have little to no permeability, and therefore restrict water movement. These layers may be very deep and cover a large area. A water table that results from such a confining layer is called an ***apparent or permanent water table*** (Figure 8-8).

A water table may also be caused by a shallow restrictive horizon in the soil that creates saturated conditions above it, while unsaturated conditions exist below it. This type of water table is called a ***perched water table***. Perched water tables usually occurs over a small area and are of shorter duration than a permanent water table.

The depth of the permanent water table varies from place to place, mainly due to changes in landscape position. At the top of slope, soils are usually (but not always) well-drained, with the water table at some depth. Soils at the bottom of a slope, where water accumulates, are often poorly drained, with the water table near or at the soil surface.

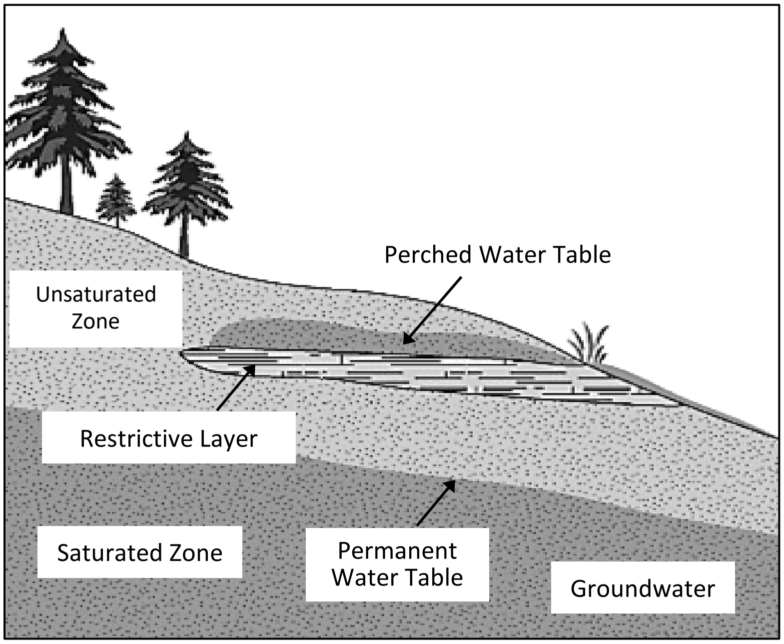


Figure 8-8. Perched and permanent water tables.

The depth of the water table at a particular location also varies over time, moving up and down in response to weather conditions (Figure 8-9). The fluctuation of the water table occurs seasonally, rising in rainy seasons and dropping during dry periods.

The ***seasonal high water table*** (SHWT) is the highest average depth of free water during the wettest season. How high the water table rises in the soil and how long the soil remains saturated determines a soil's drainage class.

Soils that have a water table depth of 60 inches or more during much of the year are considered well-drained and are the most suitable for land application. Poorly drained soils have a water table at or within 12 inches of the soil surface for most of the year. The use of poorly drained and very poorly drained soils for land application is limited, either seasonally or year-round, because wet soils:

- Do not provide adequate treatment capacity and waste contaminants may move directly to groundwater.
- May limit the type of plants that can be grown on the site and can impact the quality of the vegetative cover.
- Are subject to compaction by equipment traffic that destroys soil structure and reduces the infiltrative capacity of a site.

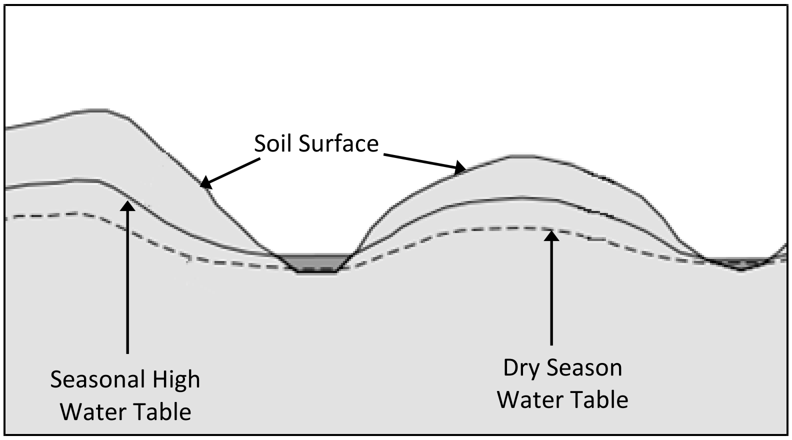


Figure 8-9. Changes in water table from location to location and from wet to dry season.

For these reasons, residuals permits do not allow application of Class B or bulk Class A residuals where the vertical separation between the seasonal high water table and the *depth of residuals* (not the soil surface) is less than one foot.

If residuals are to be incorporated or injected, there must be at least one foot between the seasonal high water table and the depth of residuals. If the residuals are incorporated to a depth of 4 inches, the depth to the seasonal high water table must be at least 16 inches.

Topography

Topography refers to the shape or contour of the land surface. You can think of it as the “lay of the land”. The topography of a site influences the types of soils that are present, the depth of those soils, and the water movement characteristics of the site. The two components of topography are slope and landscape position.

- ☐ ***Slope.*** Slope is the vertical rise or fall over a given horizontal distance (Figure 8-10). The steeper the slope the less suitable the site. Low infiltration rates on steep slopes encourage runoff and soil erosion. The steeper the slope, the faster the runoff flow and the more soil particles it carries away. Soils on steep slopes are thinner, provide less treatment, and are less productive.

  There is less potential for runoff and erosion on gently sloping or level land. Soils are deeper and more developed, which makes maintaining a cover crop easier and fields are more accessible to equipment.

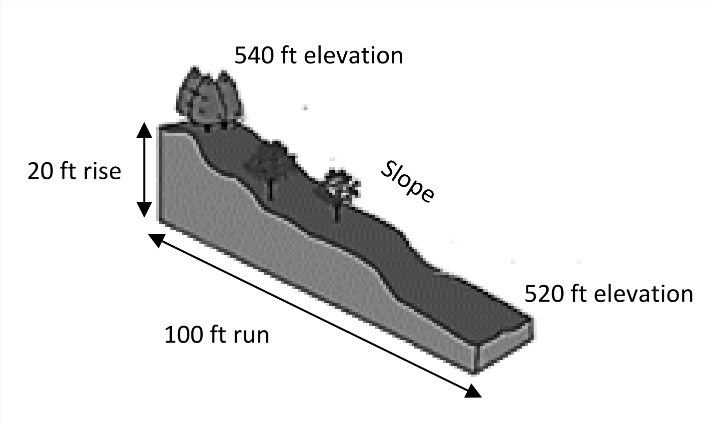


Figure 8-10. Slope is the vertical rise or fall over a given horizontal distance.

You can calculate percent slope with the aid of a detailed topographic map and using the equation below:

$$\% \text{ Slope} = \frac{\text{Vertical change (rise)}}{\text{Horizontal change (run)}} \times 100$$

For example, a 20-foot change in elevation per 100 horizontal feet is a 20% slope.

$$\% \text{ Slope} = \frac{20 \text{ ft (rise)}}{100 \text{ ft (run)}} \times 100 = 20\%$$

However, it's much easier to measure slope using instruments designed for this purpose. Two inexpensive instruments that are easy to operate are the "inclinometer/clinometer" and the "Abney hand level". Both instruments are used by observing an object at eye level at some point up or down slope and reading the percent slope on a scale.

☐ ***Landscape Position.*** In addition to the steepness of a slope, the *shape* of a slope is also important. A convex slope curves outward like the outside surface of a ball, a concave slope curves inward like the inside surface of a saucer, and a linear slope is like a tilted flat surface. The shape of a slope depends on its position on the landscape.

Figure 8-11 shows the following landscape positions that may be present at a land application site:

○ *Summit* – a broad, nearly level or gently sloping convex surface (also called ridgetop or upland); the highest point in a given area.

○ *Shoulder slope* — the convex upper portion of the slope.

○ *Side slope* — the mid-portion of the slope.

○ *Foot slope* — the gently sloping, slightly concave slope at the base of the side slope where the slope starts to flatten.

○ *Toe slope* — the lowest part of the slope where it almost completely flattens.

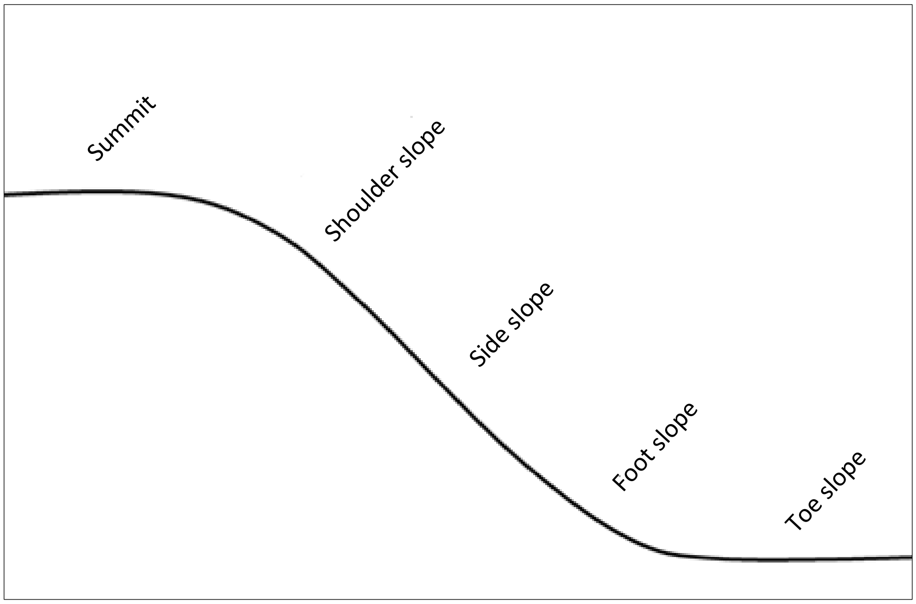


Figure 8-11. Cross-sectional view of the different landscape positions.

Figure 8-12 shows the possible slope contours or shapes, including:

- *Nose slope* – the projecting end of a hillside; a convex area that sheds water.
- *Head slope* – the concave surface at the head of a drainage way.

The summit, shoulder slope, and nose slope are the most suitable for land application. These positions shed water in a divergent manner, so that flow is not concentrated. This results in more infiltration and less runoff.

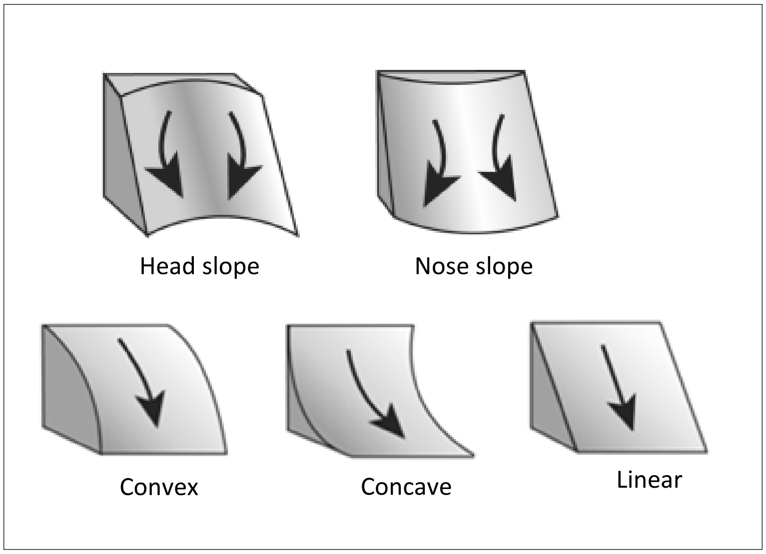


Figure 8-12. Possible slope contours or shapes.

The summit, shoulder slope, and nose slope are the most suitable for land application. These positions shed water in a divergent manner, so that flow is not concentrated. This results in more infiltration and less runoff.

In foot slope and head slope positions, surface water converges. Since these positions accumulate water, they are often saturated, with the water table at or near the soil surface. Additional water from land applied residuals will compound the problems in these areas. These areas may not be suitable for land application or may need reduced loading rates.

On a small scale, microtopography refers to minor variations across a landscape. A localized circumstance such as a rock outcropping or wet depressional area may require setbacks, but often are not large enough to rule out the usefulness of an entire site.

Another topographic category to consider is the floodplain. A ***floodplain*** is the relatively flat, low area that borders a stream or river, usually dry but subject to flooding. The standard for floodplain management used by most federal and state agencies is the 100-year flood. The term "100-year flood" is misleading. It is not the flood that will occur once every 100 years. Rather, it is the flood elevation that has a 1% chance of being equaled or exceeded in any given year.

Residuals permits prohibit the application of Class B or bulk Class A residuals within the 100-year flood plain, unless the residuals are injected or incorporated within a 24-hour period following a residuals land application event.

Soil pH

Managing soil pH is one of the most important components of maintaining soil fertility and a healthy crop. Remember, the pH scale runs from 0 to 14. Lower numbers indicate more acidic soils and higher numbers indicate more alkaline or basic soils.

Soil pH levels that are too high or too low lead to deficiencies of many nutrients, a decline in microbial activity, decreases in crop yield, and deterioration of soil health.

When soil pH is maintained between 6.5 and 7.0:

- nutrients are the most soluble and available to plants
- metals are more insoluble and unavailable
- microorganisms are most active
- soil fertility increases

☐ ***Nutrient/Metal Availability.*** Before a nutrient can be used by plants it must be dissolved in the soil solution. Most nutrients are soluble and available when soil pH is in the range 6.0 to 7.0. This is an ideal range for most crops. At a soil pH greater than 6.5, most metals are insoluble and immobile and pose no threat to health or the environment (Figure 8-13).

When soil pH is too low, primary and secondary macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) are tied up in the soil and are unavailable to plants. On the other hand, low soil pH *increase*s the solubility and mobility of most metals. Except for molybdenum, the lower the soil pH, the more soluble metals become and the more available they are for uptake by plants.

To avoid metal availability to plants, the soil pH should be maintained at 6.5 or above. This soil pH level promotes the formation of insoluble metal compounds that are immobile and unavailable to plants. *Proper management of soil pH is extremely important in controlling the movement of metals in the soil.*

Low pH soils (pH < 5.5) also *increase* the solubility of manganese, iron, and aluminum (a non-nutrient mineral). Aluminum and manganese are toxic to plants at relatively low concentrations, resulting in stunted plants and poor yields. In soils with proper pH, they are non-toxic.

When the soil pH is too high, phosphorus, manganese, and some of the micronutrients becomes insoluble and deficiencies may result.

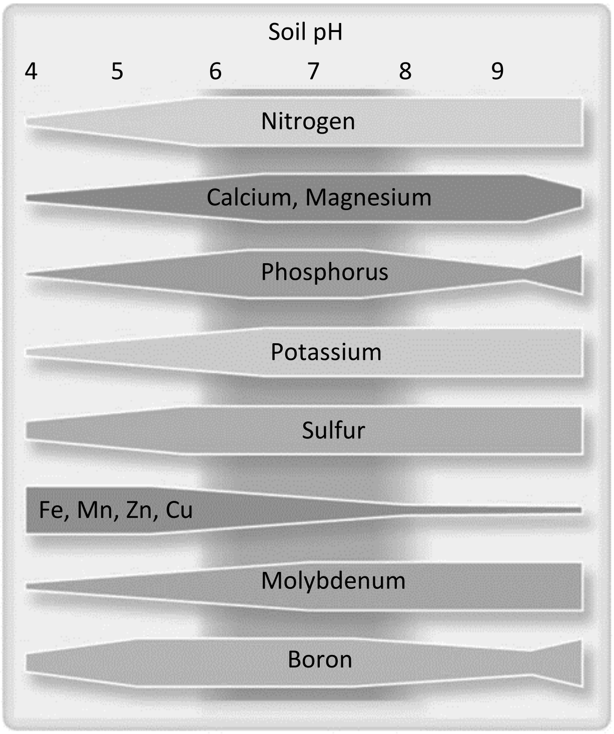


Figure 8-13. Influence of soil pH on nutrient availability. The wider the bar the more available the nutrient. The skinny portions doesn’t mean that the nutrient is not there; it means that it is not available to plants.

- ❑ ***Soil microorganism activity.*** Like crops, most microorganisms prefer a pH between 6.0 and 7.0 for best performance. Soil pH that is either too high or too low *decreases* the activity of the beneficial soil microorganisms that decompose organic matter and contaminants. Proper soil pH increases microorganism activity, which improves soil structure, drainage, and aeration. This in turn allows for better use of nutrients, increased root development, and drought tolerance.

- ☐ ***Soil fertility.*** In addition to influencing the availability of nutrients, soil pH can also influence the total amount of nutrients present in a soil. Clay and organic soil particles have negatively charged sites on their surfaces which attract and hold positively charged ions (cations) against the downward movement of water through the soil profile.

  This process is called ***adsorption*** (not to be confused with ***ab*sorption**, which is the process by which ions are taken into plant roots). These adsorbed cations are also called exchangeable cations because they are replaced or exchanged with other cations in the soil solution. (Figure 8-14). The number of cations a soil is capable of holding is the soil's ***cation-exchange capacity (CEC)***. The higher the CEC of a soil, the larger the supply of plant nutrient cations and the more fertile the soil.

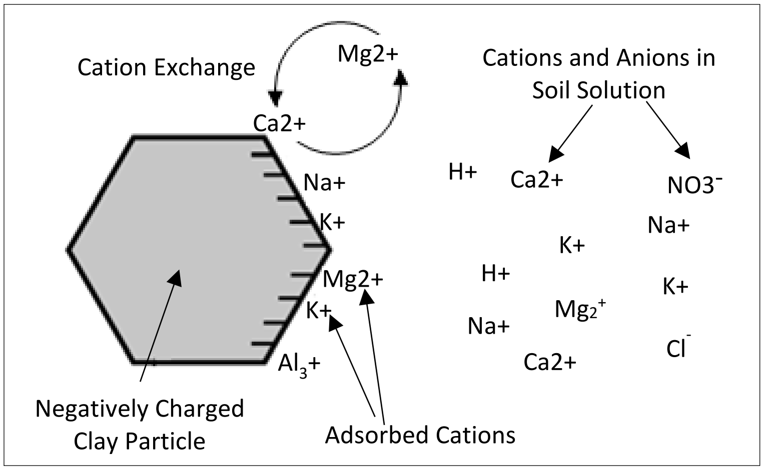


Figure 8-14. Cation exchange capacity increases when soil pH is 6.0 or higher.

  A soil's CEC is determined by the amount of clay and organic matter it contains but is influenced to some extent by soil pH. When the soil pH is below 6.0, the CEC of clay particles is relatively constant. When the soil pH is 6.0 or higher, the CEC of organic matter and some clay particles increases. Maintaining proper soil pH helps maintain the supply of exchangeable nutrient cations.

  Table 8-5 summarizes the effect of soil pH on the availability of nutrients, metals, and other cations, as well as microbial activity and treatment mechanisms.

Nearly all North Carolina soils are naturally acidic. Fortunately, soil pH can be increased relatively easily by adding lime. Liming materials are relatively inexpensive, comparatively mild to handle, and leave no objectionable residues in the soil.

Some older permits may have a permit condition prohibits application of Class B and bulk Class A residuals to fields if the soil pH is not maintained at 6.0 or greater, unless enough lime is applied to achieve a final soil pH of at least 6.0. ***Newly issued or renewed permits probably do not contain this permit condition.*** Regardless, maintaining a proper soil pH is a critical part of managing your site.

There are two types of liming materials:

1. ***Calcitic limes*** contain only calcium carbonate ($CaCO_3$), calcium hydroxide [$Ca(OH)_2$], or calcium oxide (CaO).
2. ***Dolomitic lime*** contains significant amounts of magnesium carbonate ($MgCO_3$). North Carolina law requires that dolomitic lime contain at least 6% magnesium in the carbonate form by weight.

Table 8-5. Summary of the effect of soil pH on the availability of nutrients, metals, etc.

Strongly Acid pH < 5.5	Slightly Acid to Neutral or Slightly Alkaline 6.0 – 7.0	Alkaline to Strongly Alkaline > 7.5
• Calcium, magnesium, nitrogen, phosphorus, boron, and molybdenum are unavailable • Heavy metals (except for Molybdenum) become more soluble and available • Aluminum, iron, and manganese become more available and can be toxic to plants • Negative sites on soil particles and adsorbed cations decrease, decreasing overall fertility • Bacterial populations and activity decline	• Metals are insoluble and unavailable (pH $\geq$ 6.5) • Essential nutrients are more soluble and available, ideal for plant growth • Biological activity increases • Negative sites on soil particles and adsorbed cations increase (CEC), increasing fertility • Al, Fe, and Mn are insoluble, unavailable, and non-toxic	• Phosphorus, iron, copper, zinc, boron, and manganese are unavailable • Molybdenum (a metal) becomes more available • Bacterial populations and activity decline • Mineralization slows down or stops

If a soil is low in magnesium, dolomitic lime should be used; otherwise calcitic lime can be used. Some piedmont soils are naturally high in magnesium, whereas most sandy soils in the coastal plain have little magnesium. A magnesium fertilizer could be used instead of dolomitic lime, but the cost of this treatment is almost always considerably higher. Your soil test report will indicate which lime should be used.

Lime is either applied and left on the soil surface or incorporated. Because liming materials are relatively immobile in the soil, surface application increases soil pH only in the top two to three inches. Incorporation increases the effectiveness of all liming materials by mixing them throughout the rooting zone. For fields with row crops, lime can be applied and incorporated before planting or after harvest.

However, incorporation is not feasible for permanent pasture or wooded sites. If any fields are to be refurbished or planted to a new crop, this is the ideal time to adjust soil pH to the proper depth for good mixing potential. Otherwise, surface liming is the best option.

Fall liming has many advantages. Lime has more time to react with the soil before the period of most rapid growth begins in the spring. In addition, soils are usually drier and more accessible in the fall than in the spring.

Remember, if you are applying high pH residuals (such as alkaline stabilized), no additional agricultural lime may be needed. Instead, you must monitor soil pH to make sure that it is not too high.

Other Site Restrictions

☐ *Public Access (Class B only)*

Class B permits require that public access must be restricted for 365 days after land application of Class B residuals to public contact sites. ***Public contact sites*** are those that are used frequently by the public or where the potential for public exposure is high. These include public parks, ball fields, cemeteries, plant nurseries, golf courses, etc. Controlling access to these types of sites is impractical.

When Class B residuals are applied to ***non-public contact sites***, such as farmland in rural areas or fenced areas, public access must be restricted for 30 days (Table 8-6). Controlling access to non-public contact sites for 30 days is much easier than controlling access to public contact sites for 365 days. Consequently, non-public contact sites are much more suitable for application of Class B residuals.

Public access to land associated with a dedicated land application site must be restricted continuously while the land is permitted for active use, and for one calendar year after the final land application of residuals.

Some older Class B permits may require that public access controls include posting signs in a clearly visible and conspicuous manner at the entrance to each land application site during a land application event, and for as long as the public access restrictions apply. ***Newly issued or renewed permits probably do not contain this permit condition.***

Table 8-6. Public access restrictions for Class B land application sites. There are no public access restrictions on land where Class A residuals are applied.

Public access to public contact sites shall be restricted for one calendar year after a residuals land application event
Public access to non-public contact sites shall be restricted for 30 days after a residuals land application event
Public access to land associated with a dedicated land application site shall be restricted continuously while the land is permitted for active use, and for one calendar year after the final land application of residuals

☐ *Water Supply Watersheds*

Permits do not allow application of Class B or bulk Class A residuals to new land application sites that are located within any of the following:

- ○ a WS-I watershed
- ○ the Critical Area of a WS-II watershed
- ○ the Critical Area of a WS-III or WS-IV watershed

A watershed is an area of land that drains all its water to a specific lake or river. All land is located within a watershed of one kind or another, but land that is classified as being within a water supply watershed most likely has protection rules that affect land use and other activities. Check with your local government to see if the watershed rules are in effect in your area.

☐ *Threatened or Endangered Species*

Permits prohibit land application of Class B or bulk Class A residuals where the activity is likely to adversely affect a threatened or endangered species or its designated critical habitat. An adverse effect includes any direct or indirect action that reduces the likelihood that a threatened or endangered species will survive or recover from an impact. The critical habitat is any location where a threatened or endangered species may live or grow during any stage of its life cycle.

Even if a threatened or endangered species or its designated critical habitat is located on a proposed application site, land application may still be possible. When conducted in accordance with permit conditions, it is unlikely that the land application activity will cause any adverse effect to threatened or endangered species.

If there is some specific reason to believe otherwise, a land applier should evaluate whether any threatened or endangered species or habitats at the site could potentially suffer a negative impact. A listing of threatened or endangered species for North Carolina can be found on U.S. Fish and Wildlife Service's web site: http://www.fws.gov/endangered/.

☐ *On-Site Storage*

Class B permits prohibit storing or staging of residuals at any land application site without prior written approval from DWR. If approval is granted, Class B residuals must be stored or staged in a manner to prevent runoff of leachate and other wastewaters generated.

Newer Class A permits allow residuals to be stored or staged at the land application site for up to 30 days for biological residuals and 60 days for non-biological residuals. When Class A residuals are stored on-site the setback distances above must be maintained. They must also be stored or staged in a manner to prevent runoff of leachate and other wastewaters generated.

Summary of Restrictions on Where You Can Apply

The public access restrictions for Class B residuals are listed in Table 8-6. The restrictions on where you can land apply or distribute Class B and bulk Class A residuals are summarized in Table 8-7.

8.2 Crops – The Other Half of the Land Treatment System

Crops play such a vital role in the land treatment system that residuals permits prohibit application of Class B or bulk Class A residuals if the site does not have an established vegetative cover crop, unless:

- the residuals are injected or incorporated within a 24-hour period following the application of residuals, or
- the site is a Division-approved no-till site (no-till is a way of growing crops or pasture from year to year without disturbing the soil through tillage or plowing).

The critical functions that crops perform include:

- removing nutrients and water from the soil
- preventing soil erosion and runoff
- maintaining and improving soil structure
- enhancing habitat for microorganisms

Table 8-7. Soil and site conditions where Class B or Bulk Class A residuals ***cannot*** be land applied.

If the slope of the land is greater than 10% when liquid residuals are surface applied, or if the slope of the land is greater than 18% when liquid residuals are injected or incorporated;
If the vertical separation of the seasonal high water table and the depth of residuals application is less than one foot;
If the vertical separation of the depth to bedrock and the depth of residuals application is less than one foot;
Within the 100-year flood elevation, unless the residuals are injected or incorporated within a 24-hour period following a residuals land application event;
If the land fails to assimilate the bulk residuals or the application causes the contravention of surface water or groundwater standards;
To a non-dedicated site if the application exceeds agronomic rates;
If the residuals are likely to adversely affect a threatened or endangered species listed under section 4 of the Endangered Species Act or its designated critical habitat;
If the land application sites are located within a WS-I watershed pursuant to 15A NCAC 02B .0212 or within the Critical Area of a WS-II pursuant to Sub-Item (4)(g) of Rule 15A NCAC 02B .0212, or within the Critical Area of a WS-III or WS-IV watershed pursuant to Sub-Item (4)(h) of Rules 15A NCAC 02B .0215, and .0216.

You may not have much input into the crops that will be grown at your site(s). You will most likely be working with crops the farmer has already selected and management practices the farmer already follows. Neither the regulations nor the permit prohibit applying residuals to any specific crop. However, some crops are more suitable than other for residuals application. Considerations include the type of crop, the nitrogen needs of the crop, and the end use of the crop.

Type of Crop

There are three broad types or categories of crops that are suitable for application of residuals: row crops, forage crops, and trees. They each have their own advantages and management issues.

- ☐ ***Row Crops.*** A row crop is a crop that can be planted in rows wide enough to allow it to be tilled or otherwise cultivated by agricultural machinery early in the season. Row crops are ***annuals***, which means they live for just one season and must be planted every year. Examples are corn, soybeans, and small grains (wheat, barley, and oats).

  Row crops can result in long periods of time when the soil is without cover vegetation, long periods when application equipment can't access field, and may have restrictions on end use.

- ☐ ***Forage Crops.*** Forage is the edible parts of plants, other than separated grain, that provides feed for grazing animals or that can be harvested for feeding later as hay. Forage crops grown in North Carolina range from cool-season to warm-season grasses and legumes. Some forage crops are annuals, and some are ***perennials*** (live for multiple seasons).

  The primary forage crops in North Carolina are tall fescue and coastal bermuda. Forages such as annual ryegrass, many species of clover, and others are also grown across the state. Although small grains and soybeans are considered row crops when grown for their grain or seeds, they can also be grown as forage for grazing or hay production.

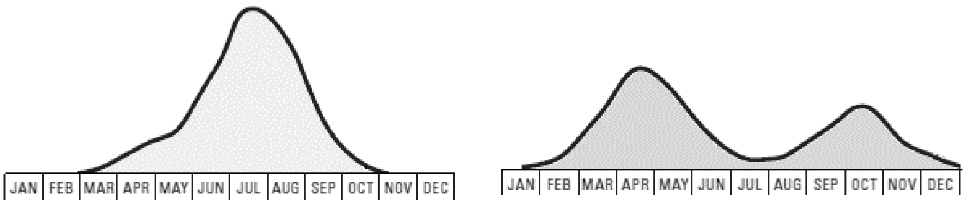
  Forage crops offer more flexibility than row crops for land application operations, especially when farmers grow a combination of both warm and cool season forages. During our discussion of application rates, we learned that ***overseeding*** is the practice of planting another crop or grass on top of the existing crop.

  Overseeding can extend application opportunities. Year-round application is often possible by using seasonal overseeds. For example, a warm season grass like coastal bermudagrass can be grown in the summer followed by fescue or another cool season grass to help with nutrient uptake during the periods when the coastal bermuda is dormant (Figure 8-15).

  Some forage species are not tolerant of this arrangement, and an overseeded species may seriously damage the main crop. Examples of grasses, forages, or grains that should be avoided as an overseed include gamagrass, switchgrass, or bluestems.

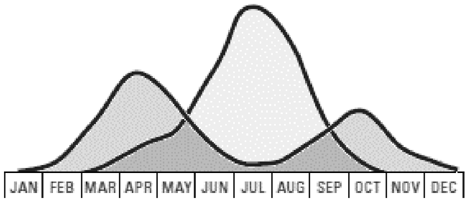
When using a winter overseed, you must be careful to protect the warm-season grass. Controlled grazing or harvesting may be necessary to keep the winter overseed from becoming overly aggressive over the warm-season grass.

Although forage crops may provide more flexibility for land application, when they are grown for hay they require mowing, drying, raking, and baling, which must be done during dry periods. They can also be costly and time-consuming to establish.



Warm Season Bermudagrass

Cool Season Fescue



Bermudagrass Overseeded with Fescue

Figure 8-15. Year-round application may be possible using seasonal overseeds.

- ☐ ***Trees.*** Applying residuals to trees is another option for beneficial reuse of residuals. There is the added benefit of producing marketable products such as timber, fiber, and Christmas trees. Trees are perennials and can remain in place for years. They have extensive root systems and use large quantities of water. Harvesting can range from every 7 to 25 years, depending on the goal. Undergrowth must be managed.

  Hardwood plantations have advantages over both natural forests and other crops for residuals application. Species can be matched to specific sites to ensure rapid growth. Under short rotations, trees can be whole-tree harvested, removing the nutrients from the site in a non-food chain product. Under medium to longer rotations, high value solid-wood products such as lumber or veneer can be grown.

Nutrient Requirements of Crop

The nutrient requirements of a crop impact its suitability, in terms of both expense and time. We know that residuals are not a balanced nutrient source. When applied at agronomic rates, some nutrients will be under-supplied, and some will be over-supplied. Some crops are less tolerant of nutrient imbalances than others.

If a crop is commercially marketable, then the time and expense of providing supplemental fertilizer to increase yield is economically justified. If the primary purpose of the crop is to receive residuals, however, then a more tolerant crop with minimal requirements may be satisfactory.

Since most application rates are based on nitrogen, crops that have high nitrogen requirements, such as corn, small grains, and forages, may be better choices for land application of residuals than crops with lower nitrogen requirements. Growing high nitrogen crops can reduce the amount of land needed as well as the costs associated with transportation and application.

On the other hand, applying higher amounts of nitrogen to forage grown for hay requires more cuttings, and more cuttings require more management. Applying high nitrogen residuals can also increase the potential for burning or yellowing of leaves, reducing forage quality.

End Use of Crop

The intended end use of a crop affects its suitability for receiving Class B residuals. There are three end use categories:

- *food crops* – crops produced for consumption by humans (vegetables, fruits, grains)
- *feed crops* – crops produced for consumption by animals (forages and grains)
- *fiber crops* – crops grown for fiber production (cotton and flax)

Because many food crops have significant waiting periods before they can be harvested if grown on fields that have received Class B residuals, feed and fiber crops are more suitable for these sites. There are no restrictions or waiting periods for crops receiving Class A residuals, either bagged or in bulk.

Food crops whose harvested parts touch or grow below the soil/residuals mixture cannot be harvested for time periods ranging from 14 to 38 months (Table 8-8). Consequently, root crops and low-growing fruits and vegetables are the least suitable and the least practical crops for Class B residuals application. Farmers must be aware of and agree to these significant waiting periods when considering whether to grow these types of crops.

In contrast, feed, fiber, and food crops whose harvested parts do not touch the soil surface only have a 30 day waiting period before they can be harvested or grazed. Crops grown for fiber or for animal feed (e.g., field corn grown for grain or silage, forage crops, and cotton) are much better choices for residuals application than many food crops.

Animals cannot be allowed to graze on land that receives Class B residuals for 30 days after application. Sites used for grazing must have fencing to prevent access after each land application event. Make sure that the farmer can and will restrict grazing for 30 days as required. The farmer must either have additional acreage that does not receive residuals or have sufficient hay or other feed to maintain the cattle until the waiting period has passed.

Table 8-8. Harvesting and grazing restrictions for Class B residuals.

Crop Description	Waiting Period
Food crops with harvested parts that touch the residual/soil mixture and are totally above ground (e.g., melons, cucumbers, squash, etc.).	14 months
Food crops with harvested parts below the land surface (e.g., root crops such as potatoes, carrots, radishes, etc.) where residuals remain on the land surface for 4 months or longer prior to incorporation into the soil.	20 months
Food crops with harvested parts below the land surface (e.g., root crops such as potatoes, carrots, radishes, etc.) where residuals remain on the land surface for less than 4 months prior to incorporation.	38 months
Turf grown on land where residuals have been applied.	12 months
Food crops, feed crops, and fiber crops, whose edible parts do not touch the surface of the soil.	30 days
Animals shall not be allowed to graze during land application or during the restricted period. Sites that are to be used for grazing shall have fencing to prevent access after each land application event.	30 days

Nitrate Toxicity

Another important consideration when applying residuals to feed crops is ***nitrate toxicity***. Some feed crops accumulate more nitrates in their tissue than other crops. Consumption of forages containing excessive concentrations of nitrates can cause nitrate toxicity or poisoning in cattle. Cattle become sick and often die as a result. When harvested and stored, forages continue to be toxic and can cause death months after harvest.

Plants with the highest potential for nitrate accumulation include sudangrass, sorghum, Johnsongrass, pearl millet, and many more. Corn and small grains that are highly fertilized can also accumulate toxic levels. Some weeds such as pigweed take up and accumulate nitrates at a greater rate than most forages. If they are grazed or baled in hay, they can cause problems. These forages and weeds are especially prone to accumulating toxic levels of nitrates during drought, long periods of cloudy weather, or when soil nitrogen levels are excessive.

The first step in managing high nitrate forages is to have a good testing program. The NCDA&CS Forage Testing Lab will, upon request, analyze forage for nitrates will notify producers immediately when it finds high nitrate levels. A link to their website is listed at the end of this chapter.

You may also consider planting forages with a relative lower risk of nitrate accumulation. New forage species, particularly forage winter wheat and spring barley varieties, have been found to have lower nitrate levels than their counterparts when grown in similar environments.

Healthy animals are less likely to be adversely affected than animals in poor health. Cattle can become conditioned to eat larger amounts of feed with a high nitrate content if the increase is gradual. Table 8-9 shows feeding precautions for forages with various levels of nitrate.

Table 8-9. Feeding precautions for forages with various levels of nitrates.

Nitrate Ion % In Forage	Unadapted Animals	Adapted Animals
0.0 – 0.25	Safe: Generally considered safe for all animals	Safe
0.25 – 0.50	Slight Risk: Should not make up more than 50% of total intake for pregnant animals	Safe
0.50 – 1.00	Moderate Risk: Do no feed to pregnant animals. Limit to less than 50% total intake for all other animals.	Slight Risk
1.00 – 1.50	High Risk: Exercise extreme caution when feeing. Limit to 33% of the ration.	Moderate Risk
1.50 – 2.00	Severe Risk. Do not feed to any animals free choice. If using in a mixed ration, limit to 25% of the ration.	High Risk
2.00 – 2.50	Extreme Risk: Do not feed at all.	Severe Risk
2.50 and up	Extreme Risk: do not feed at all.	Extreme Risk

Source: Nitrate Management in Beef Cattle. Poore et al.

Crop Management

Establishing and maintaining a healthy crop or vegetative cover is one of your highest priorities of a land application operator. Maintain proper soil pH. Apply lime and supplemental nutrients as advised by your soil test report. Control pests, weeds, and diseases. Watch out for compaction.

Inspect your crop(s) regularly. If symptoms are observed early and are correctly diagnosed, there is a chance you can correct them during the growing season. Unless you are an experienced farmer or an agronomist, you will likely need help from experts to diagnose the problem.

You almost certainly will need to take plant tissue samples for analysis (discussed in a later chapter). Similar symptoms often have several causes, making it difficult to correctly diagnose the problem from visual observation alone. For example, disease or insect damage frequently resembles certain micronutrient deficiencies.

Once plants begin to show stress, the problem is often well-established and may require significant time and effort to correct. Maintaining a healthy crop is critical to the success of a land application program. In addition to the many restrictions on when and where you can or can’t land apply, the O&M section of the permit also requires that you take adequate measures to prevent runoff and erosion from bulk Class A and Class B land application sites.

We have already learned that runoff is water from precipitation or liquid from residuals that flows over the soil surface towards surface waters without infiltrating the soil. We've also learned that runoff can transport nutrients and other contaminants to surface waters. Runoff can also carry soil particles with it, resulting in soil erosion.

Soil erosion is the transport of a field's topsoil from one place to another, either by runoff or by wind. This loss of topsoil reduces levels of soil organic matter, contributes to the breakdown of soil structure, decreases biological activity, and the amount of water, air, and nutrients available to the crop. In short, erosion creates a less favorable environment for crop growth and ultimately reduces crop yield and treatment capacity of the soil.

Runoff and erosion also have negative off-site impacts. Eroded topsoil transported by wind or water can end up in surface waters -- clogging streams, filling lakes, and reducing storage in reservoirs. Accumulated sediment in water bodies smother aquatic life and shade out desirable aquatic vegetation. Soil particles also transport nutrients, pesticides, and other contaminants that degrade water bodies as sources of drinking water and recreational use.

Therefore, minimizing the impact of water or wind forces is the main objective for erosion control. The most effective way to control erosion is to maintain a healthy crop on the soil surface for as much of the year as possible. Water and wind erosion occur almost exclusively when the soil is exposed. The protective canopy formed by healthy vegetation reduces the impact of rain and wind, decreasing runoff and loss of topsoil.

Planting a cover crop after harvesting row crops or overseeding a warm season forage with a cool season forage ensures that fields are not bare through the fall and winter. A cover crop not only reduces runoff and erosion, but increases soil organic matter, improving soil structure, increasing infiltration, and providing nutrient uptake. Cover crops can be grown during winter and early spring when the soil is especially susceptible to erosion.

Tillage and cropping practices that reduce soil organic matter or result in subsurface compaction also contribute to erosion and runoff. In addition to planting cover crops, best management practices (BMPs) that reduce runoff and erosion and improve soil conservation include conservation tillage, crop rotations, contour farming, grassed waterways, and many others.

Application Scheduling - When Can You Apply?

Scheduling land application events is quite complex and requires careful planning and management. Scheduling depends primarily on the stage of crop growth, growing season and cropping schedules, weather and field conditions, and nuisance issues.

Stage of Crop Growth

Ideally, residuals application should be scheduled to coincide with periods of maximum nutrient uptake by the crop, especially for nitrogen. Crop nutrient needs are not constant. Nutrient demand can be very high during some stages of growth and minimal during others. Each crop is different.

Providing nutrients either too early or too late in the growing season can reduce crop yield and result in nutrient loss. Timing residuals application to coincide with plant growth requirements increases the farmer's crop yields and reduces the amount of nutrients that escape to the environment through runoff or leaching.

Corn, for example, requires relatively little nitrogen early in its growth. As it begins to elongate, its nitrogen requirements increases significantly, and then decreases. Figure 8-16 shows nitrogen uptake by corn as a function of weeks after planting. It also shows the availability of nitrogen from commercial fertilizer and from residuals. Notice that the nitrogen from residuals coincides much more closely with corn's nitrogen uptake than does the commercial fertilizer.

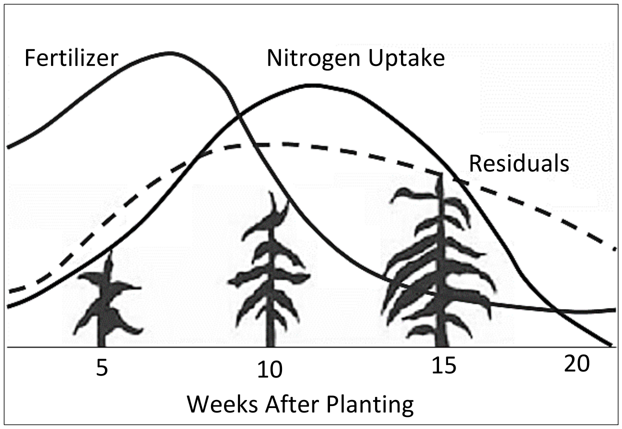


Figure 8-16. Nitrogen uptake by corn compared to PAN availability from commercial fertilizer and from residuals.

Stage of growth also affects nitrate accumulation in plant tissues. Nitrate levels are higher in young, immature plants and decrease as plants mature. If you are concerned about nitrate levels in a forage crop, plan grazing and mowing schedules accordingly if possible. If grazing or harvesting can be delayed until the plants are more mature, nitrate levels will be lower. Under conditions of stress or high levels of soil nitrate, however, plant nitrate concentrations can remain high at maturity.

Growing Seasons and Cropping Schedules

Although the best time to apply residuals is near the time when the crop needs the nutrients, it may be difficult to coordinate this with your farmers’ schedules. The application of residuals to agricultural fields requires that you work closely with your farmers. You must apply residuals at times that are convenient for the farmer and that do not interfere with tilling, planting, and harvesting of crops.

Coordinate application events with farmer. Discuss cropping schedules and identify potential application periods early in the year. Questions to ask: Which fields will be available in the upcoming season? When will the fields be available? What crops will be grown on those fields?

☐ ***Row Crops.*** Row crops limit the time of year during which residuals can be applied. Most farmers will not allow application equipment on row crops during the growing season (Figure 8-17). Consequently, residuals must be applied in the spring before planting or in the fall after harvesting. At these times, you can drive equipment over the soil, apply residuals in any form, and inject or incorporate them.

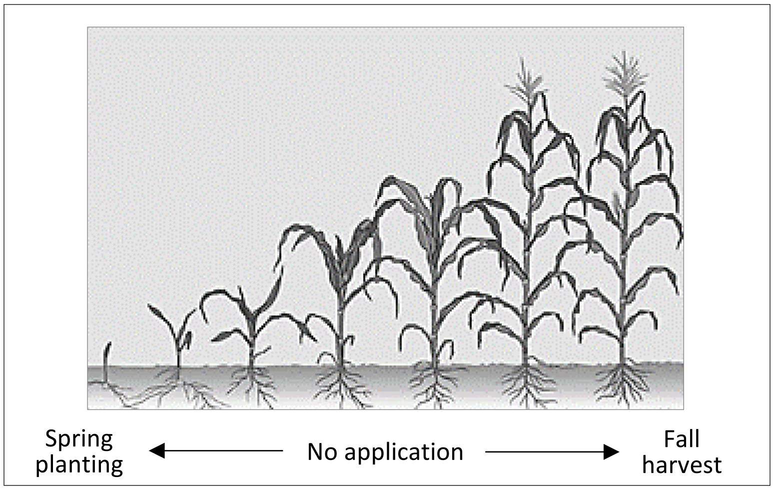


Figure 8-17. When applying to fields where row crops are grown, residuals are applied prior to planting and/or after harvest. Dates vary across the state.

For spring applications, residuals should be applied close to the time of planting, but far enough in advance of the planting dates to allow for reaction with the soil. If seeds are planted immediately after residuals application, high levels of ammonia or salts can inhibit germination and reduce seedling growth. When residuals are applied in the fall after row crops have been harvested, a cover crop should be planted to retain the nutrients over the winter months.

☐ ***Forage crops.*** Forage crops offer more flexibility than row crops for land application operations, especially when farmers grow a combination of both warm and cool season forages, as discussed earlier.

The best time to apply residuals to perennial forage crops is when they are in early stages of growth or right after they have been grazed or cut to a height of four to six inches. Apply residuals as soon as possible after cutting or grazing to reduce potential injury to the regrowth. Applying residuals, especially liquid residuals, to forage that has not been cut or grazed can cause matting, laying down, and smothering. Also, applying residuals at advanced stages of growth can result in burning or yellowing of the leaves, which reduces forage quality.

☐ ***Trees.*** Because forests are perennial, the scheduling of residuals applications is not as complex as it may be for agricultural land application programs. Residuals application to forest soils can be made either annually or once every several years. Timing is less critical in forest applications when nutrients can be incorporated into the soil throughout the growing period.

Having sites/fields with both row crops and forage crops will provide greater flexibility in scheduling and allow you to expand windows of opportunity for year-round land application.

Weather and Field Conditions

Even when the timing is right based on the farmer’s schedule and the crop’s growing season, weather and field conditions can interfere with application. To reduce the potential for surface and groundwater contamination, residuals permits prohibit application of Class B and bulk Class A residuals under the following conditions:

- When the land is flooded, frozen, or snow-covered, or is otherwise in a condition such that runoff of the residuals would occur.
- During precipitation events or within 24 hours following a rainfall event of 0.5 inches or greater in a 24-hour period.
- If the land fails to assimilate (absorb) the bulk residuals or the application causes the contravention of surface water or groundwater standards

Also, driving heavy equipment on fields under these conditions increases the potential for soil compaction and rutting, which reduces crop yields and makes the farmer unhappy. It is more difficult and dangerous to operate application equipment on wet or muddy fields.

In addition, mud from the field may be carried out onto roadways, creating nuisance conditions, and making neighbors unhappy. It is often a good idea to let the farmer make the final decision about when soil conditions are suitable for applying residuals.

Drought increases the potential for nitrate accumulation in plants. If possible, residuals should not be applied during very dry weather, especially if residuals or other forms of nitrogen were applied earlier in the season. Wait several weeks after soil moisture is adequate before cutting forage for hay following a drought.

Nuisance Issues

Nuisance issues and concerns from neighbors and the community often arise when residuals are applied. Farmers may have to deal with complaints about odors and increased truck traffic, as well as concerns about pollutants and pathogens in the residuals. As an operator, you must be sensitive to these issues and carefully manage the operation to minimize problems.

Bulk residuals cannot be applied if the application causes nuisance conditions. When scheduling land application activities, consider the impact increased traffic, noise, odor, and dust may have on neighbors and the surrounding community. Identify sites with close neighbors and use common sense and courtesy when scheduling application events. Arrange delivery schedules to disrupt neighbors’ schedules as little as possible. Avoid applying when neighbors are most likely to be outside: before and after work and on weekends and holidays.

Odors are the number one complaint. Methods to reduce odors at land application sites include:

- Apply well-stabilized material.
- Minimize storage time prior to application.
- When possible, select more isolated sites and fields away from neighbors.
- Clean equipment daily.
- Inject or incorporate residuals when possible.
- Avoid application when wind conditions may carry odors off-site.
- In summer, apply as early in the day as possible.
- Consider sending batches of particularly odorous residuals to a landfill.

Summary of Restrictions on When You Can Apply

Table 8-10. Site conditions when Class B or bulk Class A residuals ***cannot*** be land applied.

When the land does not have an established vegetative cover crop unless the land is a Division-approved no-till site, or the residuals are injected, or incorporated within a 24-hour period following the application of residuals.
When the land is flooded, frozen, or snow-covered, or is otherwise in a condition such that runoff of the residuals would occur.
During precipitation events, or within 24 hours following a rainfall event of 0.5 inches or greater in a 24-hour period.
If the land fails to assimilate (absorb) the bulk residuals or the application causes the contravention (violation) of surface water or groundwater standards.
When the application causes nuisance conditions.

Review of Land Treatment Processes

In this chapter, we have discussed the two components of the land treatment system -- soil and crops -- and the roles they play in the beneficial use of residuals through land application. The following section summarizes the processes that remove, transform, and recycle nutrients and contaminants. We have already discussed many of these in earlier chapters but bringing them together in one section may help you better understand the concepts.

Physical Treatment

- ☐ ***Sedimentation and filtration*** are primary removal mechanisms for large particles in the water entering the soil surface. These include total suspended solids (sediment), nutrients attached to soil particles such as phosphorus, and pathogens.

  Sedimentation occurs because water slows down, allowing suspended solids to settle out. As water passes through the vegetation and soil particles, some contaminants are filtered or retained and remain close to the soil surface where other treatment processes can occur.

- ☐ ***Natural die-off*** of pathogens occurs because they cannot survive exposure to sunlight or warm, dry conditions. Even in moist soil, aerobic conditions lead to rapid die-off. The only chance for pathogens to move through the soil to groundwater is if soil remains saturated and anaerobic for long periods of time.

Biological Treatment

The land treatment system contains numerous living organisms such as fungi and bacteria that decompose or transform material placed on or in the soil. It is estimated that there may be as many as 8,000 pounds of microorganisms per acre in the first six inches of soil. Microorganisms transform or destroy nutrients and contaminants through the following biological processes:

- ☐ ***Decomposition*** is the breakdown of complex organic molecules into simpler organic and inorganic molecules by soil organisms.

- ☐ ***Mineralization*** is a form of decomposition in which organic substances are converted to inorganic substances by soil microorganisms. In nitrogen mineralization, organic nitrogen is converted to ammonium (NH_4^+) and (NO_3^-).

- ☐ ***Elimination and predation*** is when a microorganism kills another microorganism. Some pathogens are killed by antibiotics naturally produced by fungi. Others are killed by other organisms and eaten.

- ☐ ***Denitrification*** is the transformation of the nitrate and nitrite forms of nitrogen to gaseous nitrogen, which can escape to the atmosphere. This process is not harmful to human health or the environment but the fact that it only occurs under anaerobic conditions could mean that beneficial treatment processes are not taking place.

Chemical Treatment

The land treatment system also acts as a chemical filter. Finely-textured soils with a pH around 6.5 provide the most effective chemical treatment. The following chemical processes can alter nutrients and contaminants such as inorganic chemicals, persistent organic compounds, and pathogens:

- ☐ ***Adsorption*** *(not absorption)* is the process by which negative charges on the surfaces of clay particles and organic matter attract and hold positively charged particles, removing them temporarily from soil solution.

- ☐ ***Ion exchange*** is the replacement or transfer of ions adsorbed on soil particles and organic matter with similarly charged ions in the soil solution. This exchange allows ions to move back and forth between the soil solution and exchange sites, becoming available for uptake by plants and microorganisms as needed.

- ○ **Cation exchange** is the adsorption and exchange of non-metal and metal cations to negatively charged sites on soil particles and soil organic materials. Cation-exchange capacity (CEC) is the measure of a soil's potential to exchange cations and is related to pH and organic matter content.

- ○ **Anion exchange** is the exchange and replacement of negatively charged ions to positively charged sites on soil particles. Anion exchange capacity is relatively low in most soils and plays a minor role in supplying plants with anions when compared to cation exchange. Anions such as nitrate (NO_3^-) are repelled by the negative charge on soil particles. They remain mobile in the soil solution and are susceptible to leaching.

☐ ***Precipitation*** is a reaction in which an insoluble solid is formed from two or more soluble ions or compounds. Precipitation reactions in soils reduce the toxicity and mobility of metals and other harmful trace elements that may be present in the soil system.

☐ ***Volatilization*** is the chemical transformation of a substance from a liquid or solid to a gas. In terms of nitrogen, volatilization is the conversion of ammonium (NH_4^+) to ammonia gas (NH_3), which is released to the atmosphere.

The Ideal Site

As we've seen throughout this chapter, residuals permits contain many restrictions on *where* and *when* you can land apply or distribute residuals. Does the ideal site exist? If so, where? A successful land application program requires careful planning and a flexible land base. In addition to federal, state, and local restrictions, there are economic and logistical factors to consider when building and maintaining your land application program.

☐ ***Hauling Distances and Accessibility.*** A site should be within an economical hauling distance from the treatment plant. What is the travel time per trip? The number of round trips each vehicle must make in one workday limits how many miles can be traveled. Are the roads congested? Delays due to traffic decreases the number of trips that can be made to a site in a day.

Consider possible routes to the site, facilities along your route (schools, churches, residential communities, shopping centers, etc.), and road conditions and limitations. Are there road or bridge weight restrictions or bridge height restrictions that can keep vehicles from getting to a site? Are there any local limits on heavy vehicle traffic in certain residential or business districts that may limit options for getting to a site?

Once at the site, you must be able to access it with heavy farm equipment and over-the-road transport equipment. The best fields in the world are of no value if vehicles and equipment can't get to them. Does the farm have a safe and accessible entrance? Are turning angles adequate for vehicles? Are there blind turns or hidden entrances that may create a safety hazard to vehicle drivers and other motorists? Will warning signs or flagmen be necessary?

☐ ***Distance to Neighbors.*** The further away from residential developments, recreational areas, and other public access areas the better. The more isolated an application site is the fewer citizen complaints you will receive. Even people who are not opposed to land application programs may be sensitive to odors and truck traffic in the area. Discuss the level of public acceptance in the neighborhood and community with the landowner/farmer. Public relations and education are discussed in Chapter 13.

☐ ***Landowner Attitude.*** If the land is not owned by the Permittee, the attitude of the landowner is an important component of site suitability. The landowner must be willing to comply with all permit requirements and restrictions and to provide the Permittee with information required by the Landowner Agreement (discussed in the next chapter). Is the owner a good manager and environmental steward?

☐ ***More Than One Landowner.*** Have more than one landowner in your program. Over the life of a land application program, a multitude of things can happen that cause a landowner deciding to withdraw from the program or sell their property to someone who may not want to participate. Having multiple landowners involved in the program increases the chances that your land application program will not be interrupted.

☐ ***Minimum Field/Site Size.*** As we discussed earlier, there is no established minimum for field or site size. However, sufficient acreage should be available to justify hauling residuals there. Decide what the minimum acceptable size will be. Consider such factors as hauling distance, setback requirements (you make lose 20 percent or more of your site to setbacks), adjacent properties (residences, schools, shopping centers, etc.), area required for staging and operation of equipment, and the availability of other sites.

☐ ***Total Permitted Acreage.*** Ensure an adequate permitted land base for continuous operation of the program. Having more land available than you need for one year of operations allows for greater flexibility in scheduling application events with participating landowners. Only one-third to one-half of the land in your program may be available each year for residuals application.

Consequently, it is a good idea to estimate two to three times the number of acres required, based on the dry tons per year allowed by the permit. Be careful not to permit too much acreage, however, as farmers may become dissatisfied with the program if they are not provided residuals as promised.

Maintaining Your Land Treatment System

To maintain a healthy crop and productive soil at your site, you will most likely need to seek advice and information at times from experts in agricultural operations. Some sources of technical assistance you can call on for help are listed below.

- ☐ ***NC Cooperative Extension.*** The NC Cooperative Extension has educational centers located in every county. Each center has a staff with technical and programmatic responsibilities to serve the needs of their clients. Extension staff has expertise in crop and forage planting, harvesting, pest management, soil and plant science, animal and livestock husbandry, and some areas have regional water quality specialists.

- ☐ ***NCDA&CS Agronomic Division.*** The mission of the NCDA&CS Agronomic Division is to provide all North Carolina residents with diagnostic and advisory services that increase agricultural productivity, promote responsible land management, and safeguard environmental quality. The Division's regional agronomists provide on-site consulting services to help troubleshoot nutrient and nematode problems, establish appropriate agronomic sampling programs, and implement management recommendations in a cost-effective and environmentally sound manner.

- ☐ ***Natural Resources Conservation Service (NRCS).*** The Natural Resources Conservation Service (NRCS) is a branch of the U.S. Department of Agriculture. It provides technical assistance for the conservation of natural resources to all citizens who request such assistance. In the area of surface irrigation of wastewater, NRCS provides technical assistance with soil maps and soil interpretations, crop yield estimates, and erosion control and other best management practices.

- ☐ ***North Carolina Division of Soil and Water Conservation (DSWC).*** The Division of Soil and Water Conservation (DSWC) and the 96 soil and water conservation districts that serve North Carolina are dedicated to helping landowners reduce soil erosion and improve water quality through proper management of their natural resources. The Division of Soil and Water works very closely with NRCS in the design and implementation of conservation measures, as well as policy decisions concerning the most effective means of natural resource conservation and use of available funds to meet conservation goals.

- ☐ ***Private consultants or residuals management companies.*** Depending on the kind of assistance you are looking for, you may need to hire a private consultant or residuals management company. These individuals or companies may specialize in certain areas such as soil and crops. Or they may have expertise in all aspects of residuals management from site acquisition, permitting, sampling, transport and application, distribution and marketing, and completing annual reports.

Planting Guide for Forage Crops in North Carolina
https://content.ces.ncsu.edu/planting-guide-for-forage-crops-in-north-carolina

Forages for North Carolina: General Guidelines and Concepts
https://content.ces.ncsu.edu/forages-for-north-carolina-general-guidelines-and-concepts

NCDA&CS Hay Alert – Forage Testing
https://www.ncagr.gov/hayalert/TestingForage.htm

Chapter 9

Equipment & Methods

Residuals permits do not stipulate what type of equipment you must use to transport or apply residuals. This is largely determined by the liquid content of the residuals you are applying (Table 9-1). We have already talked in general terms about application methods (surface and subsurface) and have discussed several permit requirements related to application method. In this chapter, we will discuss the following topics in some detail:

- transport equipment
- application methods
- application equipment
- equipment calibration

Table 9-1. Solids content and handling systems.

Type of Residuals	Solids Content	Handling Systems
Liquid	1 to 15%	Tankers, Pumper Trucks Pumps/Pipelines Tractor-Pulled Tank Wagons High Flotation, Self-Propelled Vehicles Hose-Drag Systems Spray Irrigation Systems
Cake (Dewatered)	>15 to ≈ 40% *	Dump Trucks/Trailers (Rear and Side Dump) Ram Eject Trailers Manure Spreaders High Flotation, Self-Propelled Spreaders
Dried	≥90%	Dump Trucks/Trailers (Rear and Side Dump) Ram Eject Trailers Manure Spreaders, Lime/Litter Spreaders High Flotation, Self-Propelled Spreaders

* Unless otherwise noted in the permit, "***cake***" residuals are those that have greater than 15% solids by weight and can be stacked without flowing, and can be handled, transported, and spread as a solid without leaving any significant liquid fraction behind.

Transporting Dewatered Residuals

Dewatered residuals are transported in dump trucks or tractor-trailer trucks. They are loaded at the treatment plant using conveyor belts or storage hoppers, or with front-end loaders for stockpiled material at the application site. To reduce odors and spills, trucks and trailers should be equipped with covers (hard top or tarped). Other necessary features include leak-proof tailgates with seals, turnbuckle latches (welded to gate and back end of truck), and wide anti-splash shields.

- ☐ ***End dump trucks and trailers.*** A standard dump truck has an open-box bed that is mounted to the chassis frame and is hinged at the rear. A hydraulic ram mounted between the cab and the truck body raises the front of the bed, allowing the material in the bed to be deposited (dumped) on the ground behind the truck. The tailgate can be configured to swing up on top hinges (and sometimes also to fold down on lower hinges) or to be lifted above the bed by pneumatic rams (Figure 9-1).

  An end dump tractor-trailer combination works similarly, except the trailer itself contains the hydraulic hoist. They have large capacities and unload rapidly but can be very unstable when raised in dumping position.

Figure 9-1. End dump truck and trailers.

- ☐ ***Side dump trucks and trailers.*** Side dump trucks and trailers work the same way as end dump trucks except that the hydraulic rams force the bed to tip sideways, dumping the material to the right or left of the truck (Figure 9-2). Side dump trucks/trailers have large capacities and unload rapidly. In addition, their low center of gravity increases stability and decreases the risk of tipping over while dumping.

Figure 9-2. Side dump truck.

☐ ***Ram eject or push out tractor-trailers.*** Unlike end or side dump trucks or trailers, ram-eject trailers don't rely on gravity to unload the residuals. A hydraulic ram blade extends the full width and height of the truck or trailer body. This blade moves from front to rear, wiping the sides and bottom cleanly, ejecting the load evenly from a rear ramp (Figure 9-3). Load hang ups (sticking or bridging), common with gravity-dependent dump trucks, rarely happen.

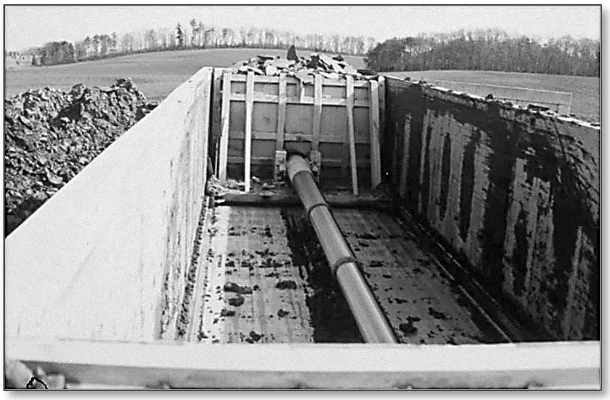


Figure 9-3. Ram eject trailer.

Like side dump trucks/trailers, the vertical center of gravity doesn't change when dumping, so the risk of tipping over is low. Because ram-eject units can empty the load up hill, residuals can be stacked or stockpiled temporarily.

Transporting Liquid Residuals

Any sealed tank-type vehicle can be used for hauling liquid residuals. Liquid residuals are loaded into transport vehicles with pumps and hoses. Standard pumps capable of handling solids can transfer the residuals, or tankers may contain built-in vacuum-pressure pumps.

☐ ***Tankers.*** A tanker (also called tank truck or tank trailer) can refer to both a straight truck and a semi that hauls tanks. Semi-trailer type tankers holding 6,000 to 7,000 gallons are most common (Figure 9-4). They can be made of stainless steel or aluminum and should be equipped with internal baffles to minimize the movement of liquids inside the tanks. They can be top or bottom loading.

Figure 9-4. Tanker for hauling liquid residuals.

☐ ***Pumper trucks.*** Smaller vehicles (3,500 to 4,500 gallons) are good for on-site transport or for sites close by the treatment plant. They can also be used for sites that large tankers can't access (Figure 9-5).

Figure 9-5. Pumper truck.

☐ ***Pipeline systems.*** Liquid residuals can also be pumped from the treatment plant directly to the land application site through an above or below ground pipeline system. The residuals are then transferred from the pipeline to an application vehicle or spray irrigation system. Pipeline transport is not feasible if there are multiple, widely separated land application sites.

Application Methods

You've hauled your residuals to the land application site and you're now ready to apply them. Before we discuss application equipment, we will discuss the two categories of application: surface application and subsurface application.

☐ ***Surface application.*** Residuals are sprayed or spread on the soil surface and left on the surface with no further action. Liquid, dewatered, and dried residuals can be surface applied. This method can be used on row crops prior to planting, forage and pastures, and trees. Residuals can be surface applied only if Vector Attraction Reduction (VAR) requirements were met at the treatment plant.

Surface application requires the least amount of energy and time and is the most widely used application method in North Carolina. However, residuals that are surface applied are more prone to odors, loss of nitrogen to the atmosphere by volatilization, and surface runoff.

☐ ***Subsurface application.*** Residuals are either 1) incorporated into the soil after being surface applied or 2) injected directly below the soil surface with specialized equipment.

  ○ ***Incorporation*** means the mixing of residuals with topsoil to a minimum depth of four inches by methods such as disking, plowing, and rototilling. Liquid, dewatered, or dried residuals can be incorporated.

  ○ ***Injection*** means the subsurface application of liquid residuals to a depth of four to 12 inches. Residuals are placed directly into the soil, in the same field operation as application.

Subsurface application -- either incorporation or injection -- helps to reduce odors, nitrogen loss due to volatilization, and the risk of surface runoff. Injection and incorporation also can be used to meet Vector Attraction Reducation (VAR) requirements in the field if they were not met at the wastewater treatment plant.

Injection and incorporation are usually not options when applying residuals to hay and forage crops, as crop damage may occur. Incorporation usually requires a second trip across the field with tillage equipment which increases the amount of time required and soil compaction.

Injection is more costly than surface application due to the higher horsepower requirements, additional equipment needed (injection tool bars), and higher maintenance costs. Injection works well in Coastal Plain soils but is not well suited to areas of the state with shallow, rocky soils.

Meeting Vector Attraction Reduction (VAR) in the Field -- A Review

Injection - VAR Option 9: Biological residuals must be injected into soil so that no significant amount of residuals is present on the land surface 1 hour after injection, except Class A residuals which must be injected within 8 hours after being discharged from the pathogen reduction process.

Incorporation - VAR Option 10: Class B biological residuals must be incorporated into the soil within 6 hours after application to the land. Class A biological residuals must be applied to the land within 8 hours after being discharged from the pathogen treatment process.

Applying Dewatered Residuals

Different types of application equipment offer advantages and disadvantages over other types of equipment. While you may not have the luxury of being able to select among several types of equipment, you need to be aware of the limitations your equipment may have on your system.

After delivery to the site, dewatered residuals are transferred to application vehicles by front-end loaders or similar equipment. They can be land applied using a farm-type manure spreader pulled by a tractor or by application vehicles developed specifically for applying residuals.

☐ ***Box-type, rear-discharge manure spreader.*** Box-type spreaders range in size from under three tons (100 cubic ft.) to 20 tons (725 cubic ft.). A front-end loader or other device delivers residuals to the bed of the spreader. A discharge mechanism at the rear of the spreader distributes the residuals over the field (Figure 9-6).

Figure 9-6. Rear-discharge manure spreader.

Rear-delivery technologies include single or double horizontal beaters (Figure 9-7a), double vertical beaters, and spinners. Horizontal beaters spread residuals only as wide as the wheel tracks. Double vertical beaters have a greater discharge capacity and spread residuals wider, thinner, and more uniformly compared with horizontal beaters (Figure 9-7b). Spinner units rely on centrifugal force to project material from the rear of the spreader (Figure 9-7c). They work best on drier residuals (pellets).

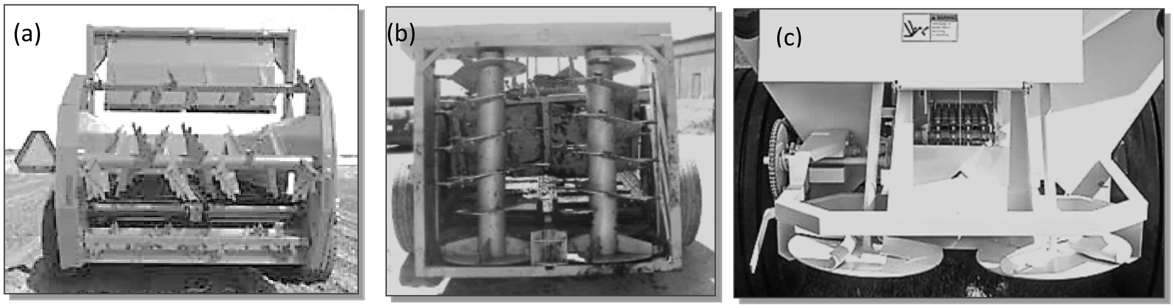


Figure 9-7. (a) Single horizontal beater. (b) Double vertical beaters. (c) Spinner unit.

☐ ***Side-discharge manure spreader.*** This type of spreader has a V-shaped hopper (to prevent material hanging up) and augers to move residuals toward the discharge port. A rotating paddle or set of spinning hammers slings the material out of the discharge port (Figure 9-8).

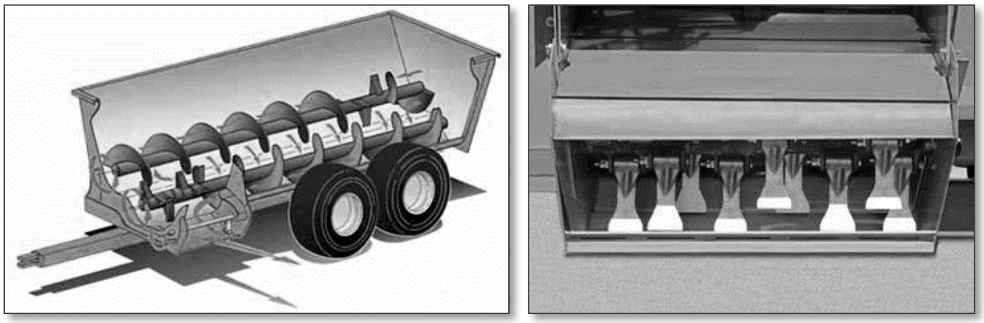


Figure 9-8. Side-discharge manure spreader augers and hammer expeller discharge port.

Side-discharge spreaders are capable of throwing long distances (Figure 9-9). Throw distance is dependent on the moisture content of the residuals, with wetter (15-20% solids) residuals having a greater throw distance than drier materials such as composts or pellets.

Figure 9-9. Side-discharge manure spreader.

- ☐ ***Specialized application vehicles.*** These self-propelled, off-road vehicles are equipped with over-sized, high-flotation tires that distribute the weight of the vehicle for a surface pressure of only 15 lb./in^2, minimizing soil compaction. Residuals are spread from the rear of the hopper (Figure 9-10).

Figure 9-10. Self-propelled application vehicle with high-flotation tires.

Dewatered residuals can be left on the surface or incorporated into the soil using standard agricultural disks or other tillage equipment pulled by a tractor or bulldozer. Dewatered residuals are usually not incorporated when applied to forages or minimum- or no-tilled land.

Applying Liquid Residuals

Equipment used to apply liquid residuals includes:

- ○ Application vehicles
  - □ Pumper/tank trucks
  - □ Tractor-pulled tank wagons
  - □ Self-propelled, high flotation vehicles
  - □ Umbilical hose systems
- ○ Spray irrigation systems

Application Vehicles

❑ ***Tractor-pulled tank wagons.*** **T**ractor-pulled tank wagons ("honey wagons") provide flexibility since they are two separate units (Figure 9-11). The tank wagons range in capacity from 1,000 to 8,000 gallons, but the larger ones may be too heavy for fields. Older tank wagons may rely on gravity to empty the load, but many are now pressurized.

Figure 9-11. Tractor-pulled tank wagon.

☐ ***Pumper trucks/tank trucks.*** Vehicles used to transport liquid residuals to the application site, like pumper trucks and tankers, can also be used to land apply the residuals. When transported in large tankers, however, it is more efficient and cost-effective to transfer residuals to other application vehicles which can return to the tankers to be refilled several times (Figure 9-12). When used in this capacity, tankers are called “nurse” trucks.

☐ ***Self-propelled, high flotation vehicles.*** These vehicles are similar to the self-propelled, high flotation vehicles used to apply dewatered residuals except they have a tank instead of a hopper Figure 9-13).

Figure 9-12. Residuals being transferred from “nurse” truck to application vehicle.

Figure 9-13. Self-propelled, high flotation vehicle with tank for liquid residuals.

☐ ***Umbilical hose systems (also called hose-drag systems).*** Residuals are pumped from a nurse tank or other source through a hose that continuously supplies a distribution device mounted to the back of a tractor or track/dozer. The tractor drags the umbilical hose across the field as the residuals are discharged (Figure 9-14).

Hose-drag applicators are expensive and are practical only when applying residuals at sites with large, flat fields. However, they reduce the time required for application since they don't have to leave the field to fill up. And because there are no tanks, hose-drag applicators place less weight on the soil, reducing soil compaction.

Figure 9-14. Umbilical or hose drag applicator.

Distribution Devices

Application vehicles can be equipped with a variety of distribution devices that allow them to surface apply, incorporate, or inject liquid residuals.

☐ ***Conventional splash plates.*** A splash plate is a metal plate mounted on the back of a tank at an angle. When residuals hit the splash plate they are thrown upwards in a broad fan-shaped plume (Figure 9-15). Although simple and economical, this method of spreading liquid residuals results in high rates of nitrogen loss due to volatilization of NH_4^+ and odors.

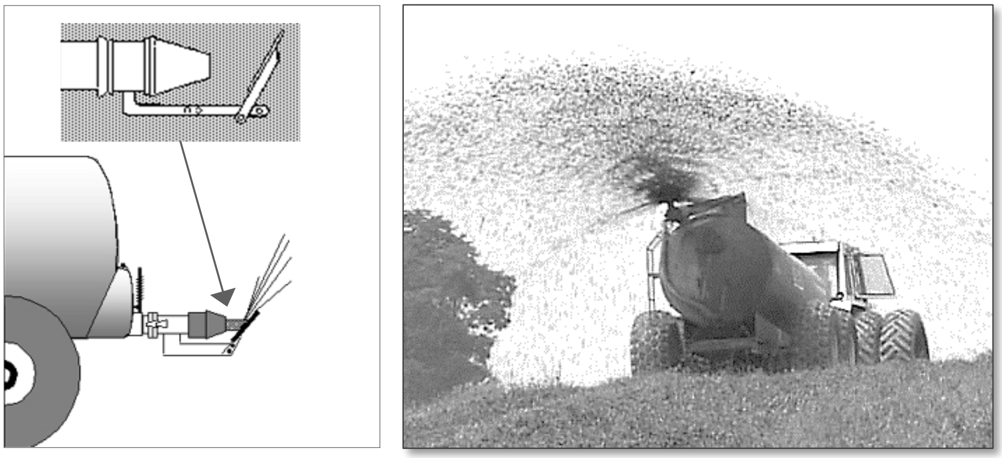


Figure 9-16. Conventional splash plates throw residuals upward.

Improvements on the conventional splash plate reduce the distance that residuals are exposed to air, reducing NH_4^+ volatilization and odors (Figure 9-16a - e).

☐ ***Low level or profile splash plates*** set much closer to the soil surface than conventional splash plates.

☐ ***Downward trajectory splash plates*** that deflect residuals toward the ground.

☐ ***Toolbars with multiple discharge points.*** A toolbar is a frame that can be mounted on or pulled behind a tank or tractor. A manifold (distribution box) with flexible tubing sends residuals to the individual discharge units.

  ○ ***Multiple splash plates.*** Residuals discharge against individual splash plates to form a thin curtain of residuals.

  ○ ***Drop tubes or hoses.*** A tool bar with hoses or tubes that run along the ground and delivers residuals directly to the soil surface.

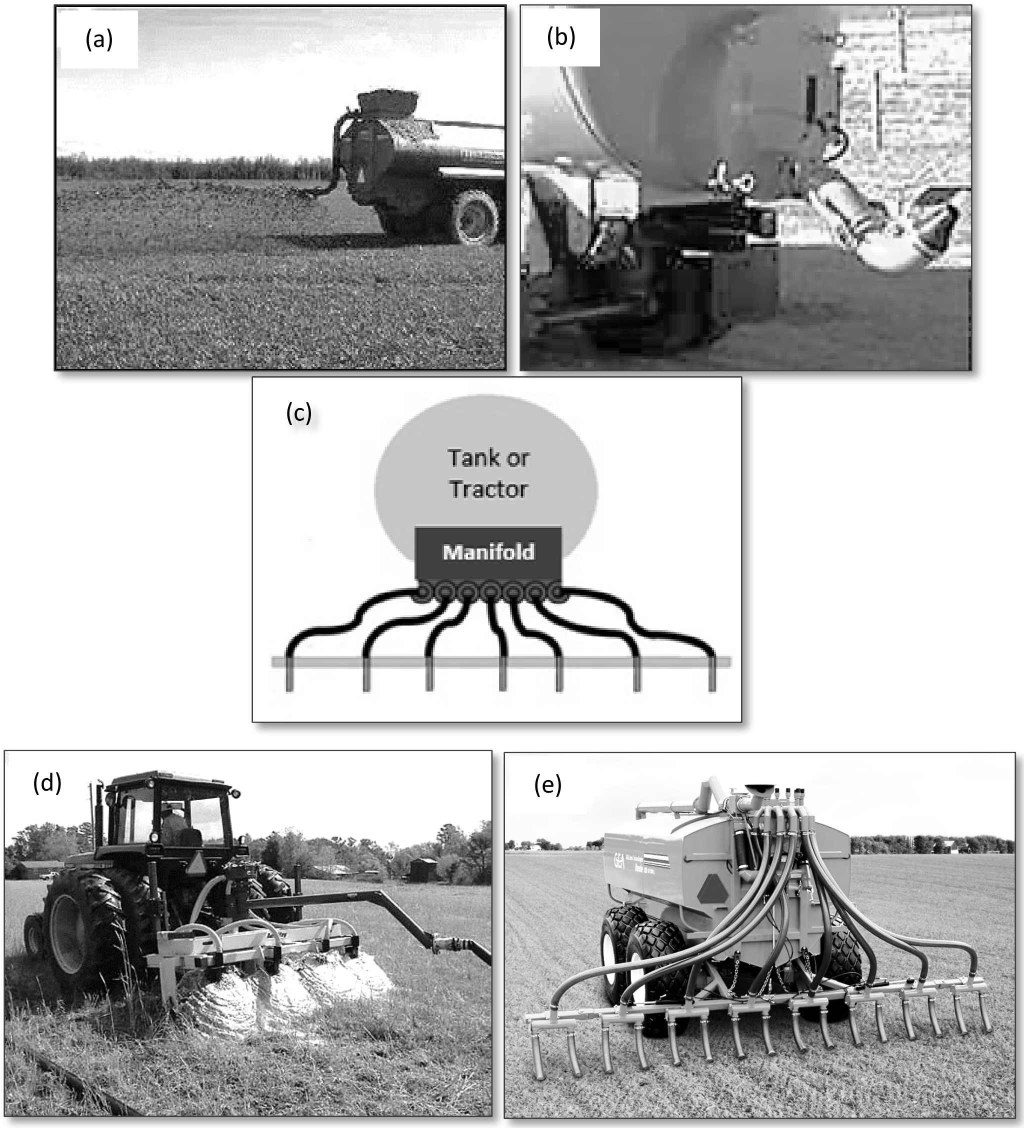


Figure 9-16. (a) Low profile splash plate. (b) Downward trajectory splash plate. (c) Toolbar multiple discharge points. (d) Toolbar with multiple splash plates. (e) Toolbar with multiple tubes.

Like dewatered residuals, liquid residuals can be incorporated after surface application. This is usually accomplished as a second step, using standard agricultural disks or other tillage equipment pulled by a tractor or bulldozer. However, liquid application vehicles can be equipped with implements that incorporate residuals into the soil at the time of application.

☐ ***Incorporating-type applicators*** immediately mix the residuals into the soil using cultivators or concave disks (Figure 9-17). Speed of application, lower power requirements, and uniform mixing of soil and residuals are advantages of this approach.

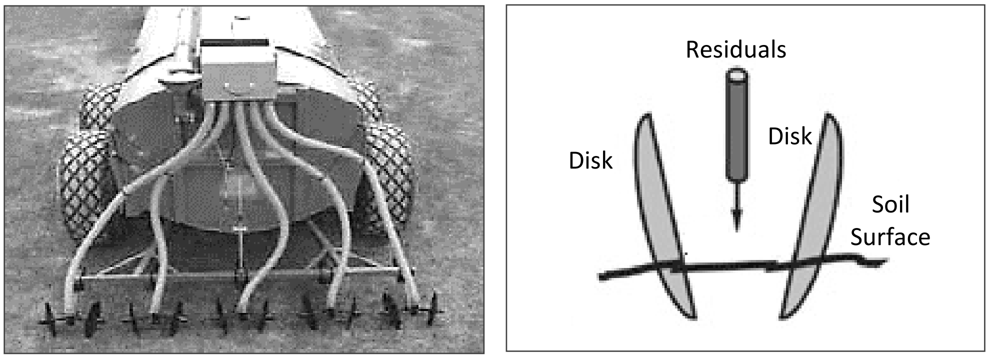


Figure 9-17. Incorporating-type applicator.

As we've discussed, injection of liquid residuals involves placing residuals directly below the soil surface. This requires the use of ground openers.

☐ ***Injecting devices*** are ground openers, such as knives or sweeps, that are mounted on a toolbar anywhere from 18 to 30 inches apart. The openers slice through the soil, creating a cavity into which residuals are directed, usually just behind the openers.

Knife injectors (often called shanks) are vertical knife-like blades, resembling a chisel plow, that cut 8- to 14-inch deep grooves in the soil and inject residuals in concentrated, vertical bands (Figure 9-18). Limited mixing of the soil and residuals and high power requirements are commonly reported concerns. Knife injectors may have an advantage in heavy soils if subsoiling is needed to break up a clay pan.

Sweep injectors create larger and more shallow channels than knives. They spread residuals in horizontal patterns (up to 18 inches wide) under the soil surface, resulting in a more uniform application. Placement of the residuals higher in the soil profile reduces fuel costs, power requirements, and risk of leaching in sandy soils. Residuals can be injected at higher rates with sweeps than with knife injectors.

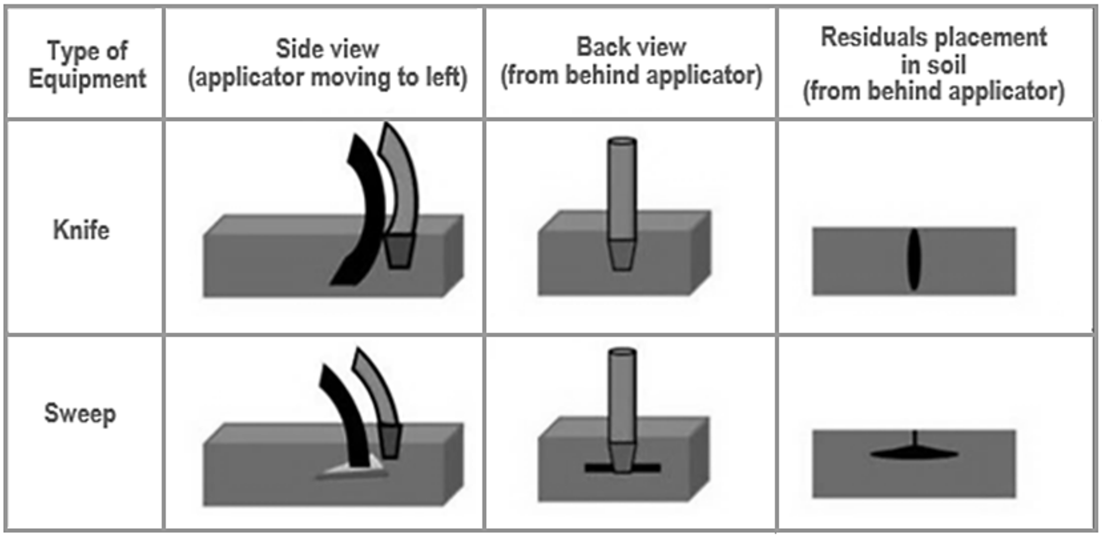


Figure 9-18. Injection patterns of knife and sweep injectors.

Spray Irrigation Systems

A few systems in North Carolina are permitted to apply liquid residuals by spray irrigation. The residuals must have a very low solids content, usually no greater than 5% (although there are cases where residuals with a higher percent solids have been successfully irrigated). Spray irrigation is most practical for large fields of 50 acres or more that are reasonably flat with a uniform shape.

- ☐ ***Big Gun/Reel Systems (also called a hard-hose travelers).*** A hard-hose traveler consists of a portable hose reel or drum mounted on a trailer or wagon, a medium-density polyethylene hose (“hard hose”), and a big gun sprinkler mounted on a gun cart (Figure 9-19).

Figure 9-19. Hard-hose traveler: big gun, gun cart, and hose reel.

The hose is wound around the reel with the end attached to the gun cart. The gun cart (with the hose attached) is pulled out some distance from the reel. Residuals are pumped through the hose to the sprinkler. The hose reel slowly "reels in" the gun cart as the sprinkler operates.

- ☐ ***Center Pivot System.*** A center pivot is a self-propelled system that rotates around a central pivot point. Residuals are supplied at the anchored end and distributed from sprinkler heads, spray nozzles, and small guns mounted to the distribution pipe (Figure 9-20). The unit is driven by an electrical motor mounted at the fixed end. The application rate of each gun increases with its distance from the fixed center, so that there is uniform application of residuals as the pivot moves in a circular motion.

Figure 9-20. Center pivot irrigation system.

Equipment and Application Method Pros and Cons

Tables 9-2 and 9-3 summarize the advantages and disadvantages of some of the equipment and the application methods just discussed.

Table 9-2. Equipment advantages and disadvantages

Type of Equipment	Advantages	Disadvantages
High Flotation Equipment	• Reduced soil compaction • Productivity • Professional image	• High capital • High operating expenses • Field size limited
Umbilical Hose Systems	• Save time because they don't have to leave field to fill up • Place less weight on soil, less compaction	• Expensive • Only practical at sites with large, flat fields
Spray Irrigation Systems	• Some are lower maintenance • Low labor costs • Reduced soil compaction	• Aerosols / odor • Increased setbacks • Crop and soil limitations

Table 9-3. Application method advantages and disadvantages

Application Method	Advantages	Disadvantages
Surface Application	• Requires the least amount of energy and time • Can be used on forage crops, tree stands, or on cleared land before planting row crops	• More prone to odors • Higher loss of nitrogen to the atmosphere • Greater risk of surface runoff
Subsurface Application (Incorporation or Injection)	• Reduces odor problems • Good for high profile areas • Maximizes Plant Available Nitrogen • Aerates soil, can reduce compaction • Vector Attraction Reduction	• Can't use on hay, pasture, or no-till fields • Requires more energy, higher maintenance cost • Must inject/incorporate before planting • Doesn't work well in clayey, rocky soil (injection)

Equipment Calibration (covered in the field)

To achieve the desired or target rate in the field, you must learn how to calibrate each piece of application equipment. Periodic equipment calibration runs are the only way to know that you are applying residuals at an appropriate rate.

Information presented in manufacturer's charts are based on average operating conditions for relatively new equipment. Discharge rates and application rates change over time as equipment gets older and components wear. Application rates and patterns may vary depending on forward travel and/or PTO speed, gear box settings, gate openings, operating pressures, spread widths, and overlaps.

Equipment should be calibrated on a regular basis to ensure proper application rates and uniformity. Calibration is a simple procedure involving collecting and measuring the material being applied at several locations in the application area. Calibration helps ensure that nutrients from residuals are applied efficiently and at proper rates.

There are two components of equipment calibration:

1. Determining spreader uniformity
2. Verifying actual application rates

1. Uniformity

Application equipment must be maintained and operated so it applies a given application rate as evenly as possible across a field. Areas of over-application due to uncalibrated equipment can result in increased runoff or ponding, accumulation of nutrients or metals, crop damage, or nitrate leaching to groundwater. Areas of low application can result in low crop yield, leaving unused nutrients that can be lost to the environment.

Some spreaders do not spread much beyond their physical width. The spread width is simply the width of the spreader. If the application rate across the spread width is fairly uniform, the spreader is normally run "edge to edge" in adjacent passes.

Other spreaders deposit material for some distance on each side of the spreader as well as directly behind the spreader. The spread width is wider than the spreader. The application rate of these spreaders is greatest directly behind the spreader and decreases with distance from the spreader path (Figure 9-21).

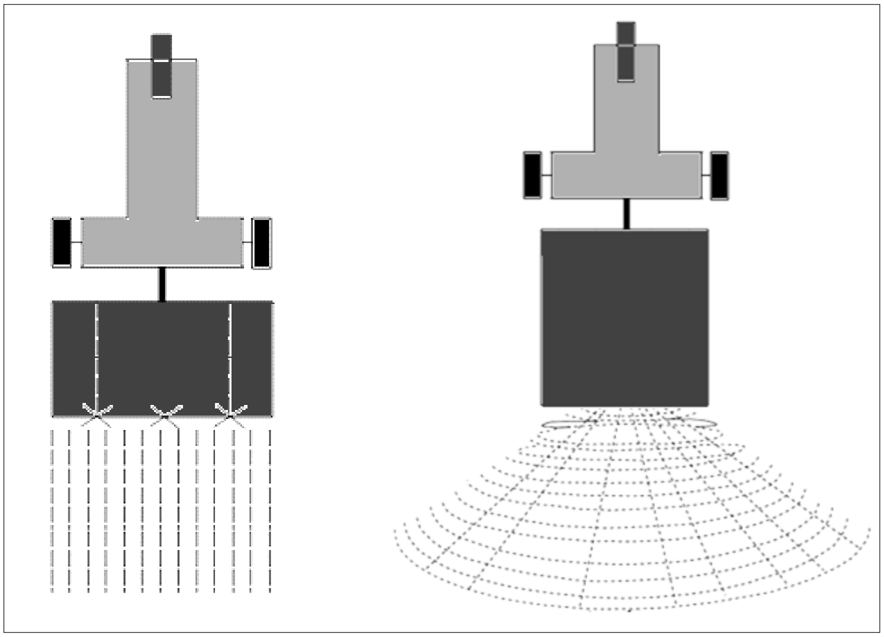


Figure 9-21. Examples of spread patterns.

Uneven distribution of residuals across a spreader swath can be reduced by adjusting the distance between adjacent spreader paths so that there is some overlap of the outside edges of the spreader width. The additive effect in the overlap areas tends to even out the uneven distribution. The outer fringes of the coverage area beyond these points should be overlapped on each subsequent path (Figure 9-22 a and b).

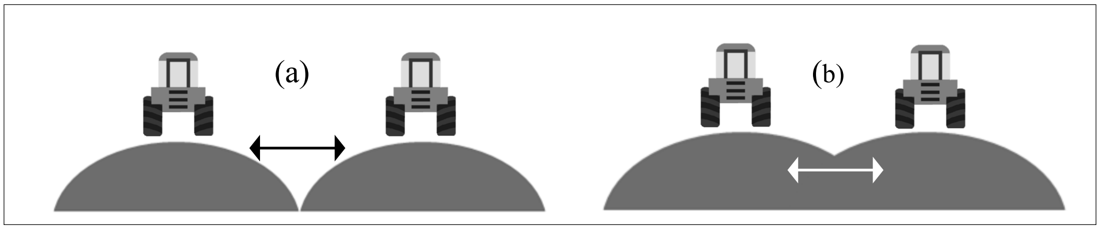


Figure 9-22. (a) No overlap: poor uniformity. (b) Overlap: improved uniformity.

To determine the amount of overlap that results in the most uniform application across the entire field, you must determine the effective spread or swath width of the spreader. The ***effective swath width*** is the strip of residuals behind or to the side of the spreader that is relatively uniform. The edge of the effective swath width occurs at the point where the application rate is approximately one-half the maximum rate.

The effective swath width can be determined by a simple uniformity test. Place a line of trays or pans of known weight evenly across the spreader path, 2 to 4 feet apart. The pans should be a minimum of 12 inches by 12 inches or 15 inches in diameter, no more than 24 inches square, and 2 inches to 4 inches deep.

Uniformity Test for Rear-Discharge Spreader

For rear-discharge spreaders, make one spreader pass directly over the center pan, if possible. Center pans may need to be shifted out of wheel tracks. Locate the point on either side of the center of the path where the amount of residuals caught in the containers is half of the amount collected in the center (Figure 9-23). The distance between these containers is the ***effective swath width***.

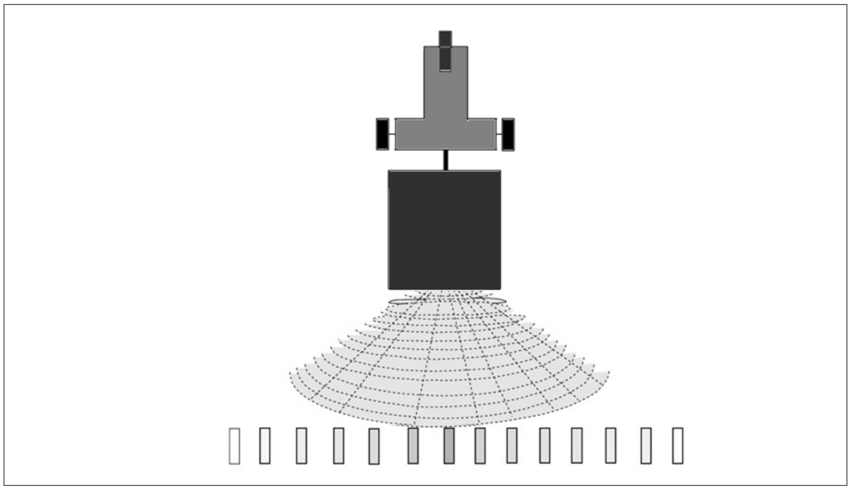


Figure 9-23. Set up for uniformity test for rear-discharge spreader.

You can think of effective swath width as the distance between the center point of one pass of a spreader and the center point of the next pass. An application pass one ‘effective spreader width’ from the last should provide an overlap that results in a relatively uniform application. In most cases, operators use visual observation of the adjacent spreader wheel tracks to achieve parallel swath widths in the field.

Uniformity Test for Side-Discharge Spreader

For side-discharge spreaders, make one pass alongside the pans. Record tractor and spreader settings. Locate point where amount of residuals caught in the pans is 1/2 the amount collected in the pan closest to the edge of the spreader pass (Figure 9-24). The distance between these containers is the effective swath width.

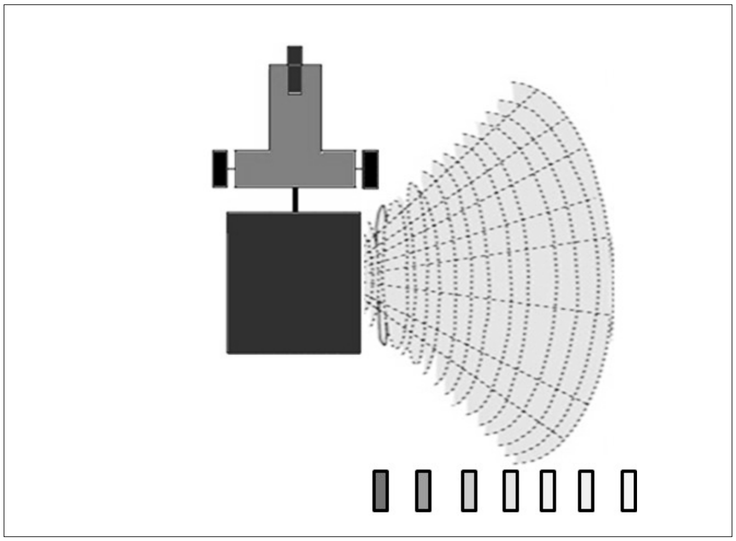


Figure 9-24. Set up for uniformity test for side-discharge spreader.

Example of Effective Swath Width Determination for Rear-Discharge Spreader

The spread width is 40 feet (Figure 9-25). The point where the amount of residuals caught in the containers is one-half of the amount collected in the center occurs at 17 feet on either side of the middle pan. The e*ffective swath width* is 34 feet (distance between containers). You can also think of it as the distance between the center point of one spreader pass and the center point of the next pass.

It may be difficult to obtain good uniformity with some spreaders Some spreaders may spread residuals at a greater rate along the outside edges of the spreading swath than in or near the spreader path. In these cases, overlap will make uniformity worse, and the best uniformity is attained with no overlap — run the spreader “edge to edge” in adjacent passes.

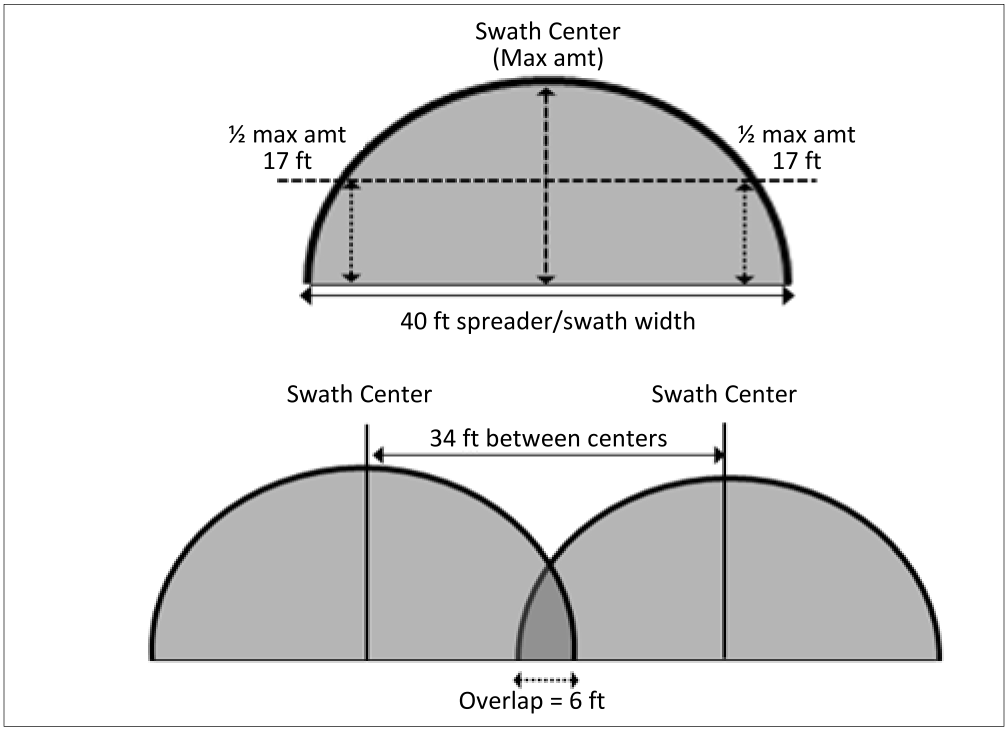


Figure 9-25. Example of effective spread width determination for rear-discharge spreader.

2. Verifying Actual Application Rates

The objective is to determine the actual application rate in terms of pounds of PAN applied per acre. Knowing the application rate in gallons or tons per acre is not enough. If the amount of PAN applied per acre exceeds agronomic rate, the spreader must be recalibrated to provide lower rate, and vice versa.

Calibration is not an exact process. It may take several spreader runs and experimentation with different ground speeds, discharge settings, and overlap (if any) before a suitable rate is achieved. It is a process of figuring out the combination of travel speed, equipment settings, and overlap needed to apply residuals at the desired rate. Expect variations of ± 10%.

We will cover two methods of calibration: the Load-Area Method and the Weight-Area Method. Work sheets for conducting these calibration methods are included at the end of this chapter.

Load-Area Calibration Method for Tank Wagons and Spreaders

The Load-Area Calibration Method can be used for tank wagons and manure spreaders. For simplicity, the description of the Load-Area Method below is for a liquid tank spreader. When using it to calibrate dewatered residuals, some of the calculations are a bit different.

To complete the calibration, you will need these pieces of information:

- Percent solids of the residuals
- Amount of PAN in the residuals (lbs PAN/dry ton)
- Target application rate (lbs PAN/acre)
- Spreader volume (in gallons or cubic feet)

1. While maintaining constant speed, spread one full load of residuals in a rectangular pattern with appropriate overlap, if any. Record details of the operating conditions (e.g., tractor gear, throttle setting, PTO speed, tractor speed, etc.).
2. Using a measuring wheel, measure and record the length and width of coverage in feet. Do not include the outer fringe areas where the coverage is much lighter than the overlapped areas.
3. Calculate the size of the coverage area. Multiply the length (ft) by the width (ft) and divide by 43,560 ft^2/acre. Record the coverage area in acres.

$$\boxed{\text{Coverage area (acres)} = \frac{\text{length (ft)} \times \text{width (ft)}}{43{,}560\ \text{ft}^2\ /\ \text{acre}}}$$

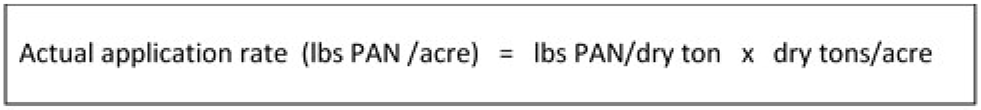
4. Divide the volume of the spreader load by the acres covered. Record the actual application rate in gallons per acre.

$$\boxed{\text{Actual application rate (gal /acre)} = \frac{\text{spreader load volume (gal)}}{\text{coverage area (acres)}}}$$

Then convert gallons/acre to dry tons/acre. Remember this equation?

$$\boxed{\text{Actual application rate (dry tons/acre)} = \frac{\text{gallons} \times 8.34\ \text{lbs/gallon} \times \%\ \text{solids}}{2000\ \text{lbs/dry ton}}}$$

5. Calculate the actual application rate in pounds PAN/acre. You will need the lbs PAN/dry ton of surface applied residuals you calculated from your residuals analysis.



Actual application rate (lbs PAN /acre) = lbs PAN/dry ton x dry tons/acre

6. Compare the actual application rate to your target application rate. If it unacceptable, repeat the process at different spreader settings, speeds, and/or overlap until the target application rate is achieved. When the target application rate is obtained, record operational settings, speed, and overlap for future reference.

Weight-Area Calibration Method for Solid and Semi-Solid Spreaders

The Weight-Area Calibration Method is for calibrating equipment used to spread dewatered or dried residuals. This method involves measuring the spreader discharge over a small area. The application rate is determined by dividing the collected material (weight) by the collection area.

To complete the calibration, you will need these pieces of information:

- Percent solids of the residuals.
- Amount of PAN in the residuals (lbs PAN/dry ton).
- Target application rate – the amount of PAN needed from residuals (lbs PAN/acre).

1. Obtain a large bucket and a tarp or plastic sheet about 100 square feet (9 x 12, 10 x 10, 10 x 12, etc.). Weigh the bucket and tarp using a set of spring-tension or platform scales. Record weight.

2. Spread the tarp and pin on the field surface at each corner with a tent stake or long nail through the eyelets. Measure tarp for exact surface area (length x width) and record.

3. For rear-discharge spreaders, start applying residuals downrange of tarp and spread directly across the center of it. For side-discharge spreader, make a pass alongside the tarp. in a manner similar to the regular spreading patterns and settings of the applicator (speed, spreader settings, overlap).

4. Remove pins or stakes and fold the tarp being careful not to spill any collected material. Put in the bucket and weigh the tarp, bucket, and residuals (gross weight).

5. Calculate the actual application rate in dry tons per acre:

   a. Calculate the application rate in pounds per ft^2 by dividing the weight of residuals collected (lbs) by the tarp area (ft^2).

$$\text{Actual application rate (lbs/ft}^2\text{)} = \frac{\text{weight of residuals (lbs)}}{\text{area of tarp (ft}^2\text{)}}$$

   b. Calculate the actual application rate in wet tons per acre by multiplying lbs/ft^2 by 43,560 ft^2/ac divided by 2,000 lbs/ton to get wet tons per acre.

$$\text{Actual application rate (wet tons/acre)} = \frac{\text{lbs/ft}^2 \times 43{,}560\ \text{ft}^2\text{/ac}}{2000\ \text{lbs/ton}}$$

   c. Calculate the application rate in dry tons per acre by multiplying wet tons per acre by percent solids.

$$\text{Actual application rate (dry tons/acre)} = \text{wet tons/acre} \times \%\ \text{solids}$$

6. Calculate the actual application rate in pounds PAN per acre.

$$\text{Actual application rate (lbs PAN/acre)} = \text{lbs PAN/dry ton} \times \text{dry tons/acre}$$

7. Compare actual application rate to target application rate. If the application rate is not acceptable, repeat the procedure at different spreader settings, speed, overlap, or a combination until the desired application rate is achieved. When the desired application rate is obtained, record the tractor and spreader settings for future reference.

Equipment Calibration Summary

If the actual spreader application rate is lower or higher than the target rate, it can be altered using a combination of the following suggestions:

1. Change field driving speed. Reducing speed increases the application rate proportionately. Increasing travel speed reduces the application rate.
2. Change amount of overlap. Reducing overlap decreases the rate proportionally. Increasing overlap increases the application rate.
3. Change spreader settings. For semi-solid or solid manure spreaders change the speed of the bed conveyor chain or change gate openings for side discharge spreaders.
4. Make changes and repeat the calibration procedure until the desired application rate is achieved. Record the tractor and spreader settings for future reference.

Load-Area Method for Calibrating Liquid Applicators Work Sheet

1. Gather information before performing calibration:

    a. Capacity of spreader/applicator (from manufacturer info) ____________ gallons

    b. Percent solids of residuals (from residuals analysis) ____________ %

    c. Pounds of PAN/dry ton of residuals (calculated earlier) ___________ lbs PAN/dry ton

    d. PAN needed from residuals (determined earlier) _______________ lbs PAN/ac

4. While maintaining constant speed, spread one full load using the regular spreading patterns of the applicator. Record details of the operating conditions (e.g., tractor gear, throttle setting, PTO speed, tractor speed, etc.). Record final equipment speeds and settings for future use.

    e. Record forward speed, gear, or throttle setting ___________________________.

    f. Record the tank pressure or PTO speed or setting _________________________.

3. Measure the width of coverage where it is fairly uniform (the effective swath width). Do not include the outer fringe areas where the coverage is much lighter. Measure the length of coverage.

    g. Effective swath width _____________ ft

    h. Spread area length ____________ ft

    i. Spread area = (g x h) = ________________ ft^2

    j. Spread area in acres = (i ÷ 43,560 ft^2/ac) = __________________ ac

5. Compute the application rate.

    k. Gallons spread ÷ spread area = (a ÷ j) = ____________________ gallons/ac

    l. Dry tons applied per acre = (k x 8.34 x b ÷ 2000) = _________________ dry tons/ac

6. Compute actual PAN applied per acre.

    m. Actual lbs PAN applied per acre = (c x l) = ________________ lb PAN/ac

7. Compare actual application rate (m) to your target application rate (d). If the application rate is not acceptable, repeat the procedure at different spreader settings, speed, and/or overlap until the desired application rate is achieved. Record final equipment speeds and settings for future use.

Weight-Area Method for Calibrating Solid and Semi-solid Spreaders Work Sheet

1. Gather information before performing calibration:
   a. Percent solids of residuals (from residuals analysis) ___________ %
   b. Pounds of PAN/dry ton of residuals (calculated earlier) __________ lbs PAN/dry ton
   c. PAN needed from residuals (determined earlier) ______________ lbs PAN/ac

2. Obtain a large bucket and a tarp or plastic sheet at least 100 ft^2 (9 x 12, 10 x 10, 10 x 12, etc). Weigh the bucket and tarp using an accurate set of spring-tension or platform scales. Record weight.

   d. Weight of tarp plus bucket: ___________ lbs

3. Spread the tarp and pin it on the field surface at each corner with a tent stake or long nail through the eyelets. Measure tarp for exact surface area (length x width) and record.

   e. Area of tarp: width __________ ft x length __________ ft = __________ ft^2

4. For rear-discharge spreaders, start applying residuals downrange of tarp and spread directly across the center of it. For side-discharge spreader, make a pass alongside the tarp in a manner similar to the regular spreading patterns and settings of the applicator (speed, spreader settings, overlap). Record the settings for future use.
   f. Record forward speed, gear, or throttle setting _________________________
   g. Record PTO speed or setting ____
   h. Record spreader gate setting ____

5. Remove pins or stakes and fold the tarp, being careful not to spill any collected residuals. Place in the bucket and weigh the tarp, bucket, and residuals (gross weight). Calculate net weight of residuals.
   i. Gross weight of bucket, tarp, and residuals = ___________ lbs
   j. Net weight of residuals = (i – d) = ____________ lbs

6. Compute the actual application rate (dry tons/acre):

   k. Actual application rate (lbs/ft^2) = (j ÷ e) = _______________ lbs/ft^2
   l. Actual application rate (wet tons/ac) = [(k x 43,560 ft^2/ac) ÷ 2000 lbs/ton] = _________ wet tons/ac
   m. Actual application rate (dry tons/ac) = (a x l) = ______________ dry ton/ac

7. Compute actual lbs PAN applied per acre.
   n. Actual lbs PAN applied per acre = (b x m) = ___________ lb PAN/ac

8. Compare the actual application rate (n) to your target application rate (c). If the actual application rate is not acceptable, repeat the procedure at different spreader settings, speed, or both, until the desired application rate is achieved. Record final equipment speeds and settings for future use.

Chapter 10

More O&M Requirements, Inspections, General Conditions, and Operator Designation

This chapter covers the remaining requirements contained in the Operation and Maintenance (O&M) section of the permit, including:

- notifying DWR of land application activities
- maintaining an Operation and Maintenance Plan
- maintaining copies of the permit and O&M plan onsite
- maintaining spill control provisions and plan in trucks
- transfering information between the Permittee and landowner or user
- designating certified operators

Section V of the permit, Inspections and General Conditions, is also covered. We have temporarily skipped Section IV, Monitoring and Reporting, which is covered in Chapter 13.

Notification

Class B permits require that you notify the appropriate DWQ Regional Office and local government official (i.e., county manager, city manager, or health director) ***at least 48 hours prior to the initial application of Class B residuals to any new land application site***. This notification must be made to the DWQ regional supervisor between 8:00 a.m. until 5:00 p.m. on Monday through Friday, excluding State Holidays.

Class B permits also require that the appropriate DWR regional office must be notified by email or telephone ***at least 24 hours prior to conducting <u>any</u> land application activity***. The notification must include, at a minimum, the anticipated application times, field ID numbers, and location of land application activities. If it becomes necessary to apply to additional fields due to unforeseen events, the Regional Office must be notified prior to commencing the application to those fields.

Class A permits do not require notification prior to application/distribution of Class A residuals.

Operation and Maintenance Plan

All residuals permits (Class A and Class B) require the Permittee to maintain an Operation and Maintenance Plan (O&M Plan) that has been approved by DWR (Figure 10-1). An O&M Plan is a written document that explains how the land application program is to be operated on a day-to-day basis to ensure public health, safety, and compliance with applicable regulations.

The O&M plan is an important guide for new staff and should be prepared in such a way that it can explain to an operator how to run the program and keep it in compliance. The plan should be tailored to an individual program and should be updated as needed. ***Note: any changes or revisions to an O&M Plan must be approved by DWR prior to using the revised plan.***

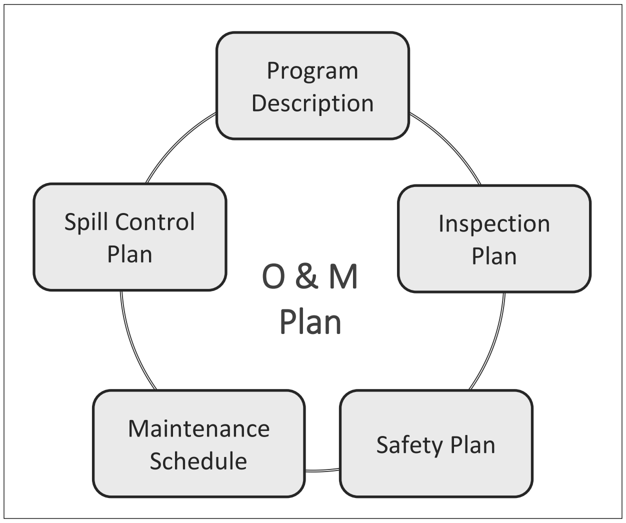


Figure 10-1. Components of the O&M Plan.

The O&M Plan, at the minimum, must include:

- ○ Description of the program, and associated facilities and equipment, in sufficient detail to show what operations are necessary for the program to function and by whom the functions are to be conducted
- ○ Description of anticipated maintenance of facilities and equipment associated with the program
- ○ Include provisions for safety measures, including restriction of access to sites and equipment
- ○ Spill control provisions:
    - □ Response to upsets and bypasses including control, containment, and remediation
    - □ Contact information for plant personnel, emergency responders, and regulatory agencies

- Detailed inspection procedures:
    - Names or titles of personnel responsible for conducting inspections
    - Frequency and location of inspections, and procedures to assure that the selected locations and inspection frequency are representative of the residuals management program
    - Description of record keeping and actions to be taken by the inspector in the event that noncompliance is observed
- Detailed sampling and monitoring procedures:
    - Names or titles of personnel responsible for conducting sampling and monitoring
    - Description of monitoring procedures including parameters to be monitored
    - Sampling frequency and procedures to assure that representative samples are collected. Fluctuation in temperature, flow, and other operating conditions can affect the quality of the residuals gathered during a particular sampling event. The sampling plan shall account for any foreseen fluctuations in residuals quality and indicate the most limiting times for residuals to meet pathogen and vector attraction reduction requirements

Copies of Permit, O&M Plan, and Spill Control Provisions & Plan

When Class B or bulk Class A residuals are applied, copies of the permit and the O&M Plan must be maintained at the land application site during land application activities. Spill control provisions and plan must also be maintained in all residuals transport and application vehicles when transporting or applying bulk residuals. Figure 10-2 contains an example of a spill control plan.

Spill control provisions may include:

- Broom
- Shovel
- Tarp
- Absorbents
- Flares, triangles, cones
- First aid kit
- PPE (coveralls, Tyvex suit, Tyvex or rubber booties, latex gloves, leather work gloves, eye protection, steel-toe boots, dust mask/respirator, other PPE as appropriate)

Example Spill Control Plan

In the event of a spill, the following action shall be taken *immediately*.

1. ***Management of Spill Clean-up Activities:*** The person in charge at the spill site will take immediate charge and initiate clean-up activities. If necessary, additional assistance will be requested from the Permittee, the NC Department of Transportation, or private contractors.
2. ***Halt the Source of the Spill:*** Such as a ruptured container, overturned truck, or leaking valve.
3. ***Contain the Spill:*** Use straw bales, an earthen barrier, sandbags, absorbents, or other blocking material to form a dike to contain the spill. The person in charge at the spill site will advise the clean-up personnel where to get the straw, lime, and other items necessary to complete the clean-up operation, i.e., local farmers, farm supply centers, nurseries.
4. ***Initial Clean-Up:*** Employ front-end loaders, vacuum equipment, sludge application vehicles, and/or a local septic tank service to remove as much of the spilled material as possible. Straw and/or sand will be scattered in the spill area to soak up the remaining material. The straw and sand soaked material will be collected and removed to a disposal area approved by representatives of DWR.
5. ***Final Clean-Up:*** Employ rotary brush sweeper if needed and apply lime to the spill area upon the approval of the clean-up efforts by DWR. If the event occurs on private property, the clean-up will be completed to the satisfactory of the property owner and DWR. The goal is to restore the spill area to its original condition if possible.
6. ***Notification:*** As soon as safely possible after the spill occurs, the person in charge at the spill site or a designee will notify the Permittee and, if applicable, the contractor's main office. The Permittee, contractor, or other designee will notify the appropriate DWR regional office by telephone (xxx) xxx-xxxx as soon as possible, but not more than 24 hours after, or on the next working day following the occurrence. For afterhours reporting, the DWR's emergency number (800-662-7956) will be called to report all incidences.
7. ***Reporting:*** The Permittee will provide a written report to the appropriate DWR regional office within 5 days of the occurrence. The report must detail how the spill occurred and all action that was taken.

Figure 10-2. Example of a spill control plan.

Transfer of Information

When residuals are applied on land owned by someone other than the Permittee, residuals permits require that a certain amount of information be transferred between the Permittee and landowner or person receiving the residuals.

❑ Class B Permits – Land Owner Agreements

Class B residuals cannot be applied on sites not owned by the Permittee unless a Land Owner Agreement (LOA) between the Permittee and landowner is in effect. The LOA expires with the expiration of the permit and must be renewed during the permit renewal process.

The LOA is a binding, enforceable contract between the Permittee and landowner. As the operator and representative of the Permittee that will have direct contact with the landowner, you must know the details of the LOA for each landowner in your land application program.

The Permittee and the landowner each have responsibilities. The landowner must provide the Permittee with a statement detailing the volume of other nutrient sources (i.e., commercial fertilizers, manures, or other animal waste products) that have been or will be applied to the site, and a copy of the most recent Nutrient Management Plan (NMP) if a NMP is required by the US Department of Agriculture, National Resources Conservation Service (NRCS), or other state agencies.

The Permittee must calculate application rates based on the provided information and use appropriate reductions. The Permittee must provide the landowner with information and data including:

- residuals and soil sample results
- application methods
- schedules for typical cropping patterns
- description of the equipment used
- a copy of the permit

The Permittee and the landowner must agree on residuals application rates and schedules based on cropping patterns, results of soil samples, and the permitted application limits. The landowner must inform the Permittee of any revisions or modifications to the intended use and cropping patterns prior to each planting season. This allows the Permittee to amend the LOA and schedule application events at appropriate times.

Site restrictions regarding public access, crop harvest, and grazing animals must be implemented by either the Permittee or the landowner. If they agree that the Permittee will implement site restrictions, the Permittee must certify that they have been met and maintain this certification for five years. If they agree that the landowner will implement the appropriate restrictions, the Permittee must provide the landowner with a list of the restrictions and certify that the landowner was appropriately informed.

❑ Class A Permits

Transfer of information requirements in Class A permits depend on whether the residuals are distributed in bags or in bulk.

Bagged Residuals

When Class A residuals are sold or given away in bags or other containers, a label or an information sheet must be provided to the person who receives Class A residuals. At a minimum, the label or information sheet must contain the following:

- The name and address of the person who prepared the residuals.
- A statement that residual land application is prohibited except in accordance with the instructions on the label or information sheet.
- A statement that the residuals must be applied at agronomic rates and recommended rates for its intended use.

Bulk Residuals

Class A permits require that the Permittee notify all third-party entities receiving bulk Class A residuals that land application activities occurring on the third-party's property must meet the setback requirements and the management practices and restrictions that were covered in Chapter 8.

Class A permits prohibit the Permittee from distributing bulk Class A residuals to any person or entity known to be applying residuals contrary to the conditions of the permit. The Permittee must report to the appropriate regional office any person or entity known to be applying residuals contrary to the conditions of the permit.

Inspections

Section V of the permit requires the permit holder to provide adequate inspection and maintenance to ensure proper operation of the residuals program. It also requires that the Permittee allow regulatory inspections.

Inspections by Permittee or Designee

Before each residuals land application event (Class B and bulk Class A), the Permittee or someone the Permittee designates (usually the ORC) must inspect the residuals processing, storage, transport, and application facilities to identify malfunctions, facility deterioration, and operator errors that could result in discharges to the environment, a threat to human health, or a public nuisance. Inspection and maintenance must be conducted in accordance with the approved O&M Plan.

The permit holder must maintain an inspection log that includes, at a minimum:

- date and time of inspection
- observations made
- any maintenance, repairs, or corrective actions taken

The Permittee must maintain this log for five years from the date of inspection and make the log available to DWR upon request. Remember that one of the responsibilities of the ORC is to document the operation, maintenance, and all visitation of the system in a log that is maintained at the site. These requirements can be met by maintaining a single log if it is clear who is making each entry.

Remember that the WPCSOCC Rules (15A NCAC 8G) require the ORC of a classified land application system to visit each application field/site during or within 48 hours of land application unless alternate ORC visitation is specified in the Inspection Plan as part of an approved O&M Plan.

Regulatory Inspections

Residuals permits state that any authorized DWR representative may, upon presentation of credentials, enter and inspect any property, premises, or place on or related to the land application sites or facilities covered by the permit at any reasonable time for the purpose of determining compliance with the permit. They may also inspect or copy any records required to be maintained under the terms and conditions of the permit and collect groundwater, surface water, or leachate samples.

Regional office staff conduct several types of inspections, including:

- site or field evaluation when a permit application or modification is received
- routine compliance inspections to evaluate compliance with permit conditions and applicable regulations
- investigation of complaints or incidents such as spills or other emergencies
- follow-up inspections to ensure deficiencies have been addressed or corrective actions have been taken
- technical assistance visits to offer advice to solve problems and/or improve operations when requested by the Permittee or operator

The most common type of inspection is a routine compliance inspection. These inspections are usually conducted annually, and inspectors normally schedule them in advance with the permit holder and/or ORC. Inspection areas can include the residuals generating/preparing and storage facilities, sampling procedures, transportation, land application site(s), and monitoring and recordkeeping.

At the conclusion of an inspection, the inspector should discuss their findings with the ORC and/or permit holder. If violations are found, the inspector will follow up with some form of written notice outlining the corrective actions that must be taken. Depending on the nature and severity of the violation(s), additional consequences may follow. The types of enforcement actions available to DWR are discussed later in this chapter.

General Conditions

We have finally arrived at the last section of the permit. The conditions in this section are administrative in nature and relate to the management of the permit itself:

- Violation of the permit can result in enforcement action.
- Name or ownership changes require a permit modification.
- The permit does not exempt the Permittee from any other laws, rules, ordinances.
- The permit can be revoked or modified by the Division.

The Division can take enforcement action if the permit holder fails to comply with its conditions and limitations. The Division can void the permit if land application or distribution events are not carried out according to the conditions of the permit. The permit is effective only with respect to the nature and volume of residuals described in the permit application and other supporting documentation.

In the event the residuals program changes ownership or the Permittee changes his or her name, a formal permit modification request must be submitted to the Division. This request must be made on official Division forms and must include appropriate documentation from the parties involved and other supporting documentation as necessary. The Permittee of record remains fully responsible for maintaining and operating the residuals program until a permit is issued to the new owner.

The permit does not exempt the permit holder from complying with all statutes, rules, regulations, or ordinances, which may be imposed by other jurisdictional government agencies (e.g., local, state, and federal).

The Division will not renew the permit if the annual renewal fee has not been paid and can revoke or modify the permit if the permit holder does any of the following:

- violates the permit or the 2T regulations
- obtains the permit by misrepresentation or failing to disclose all relevant facts
- refuses to allow Department employees to inspect (as described earlier)
- fails to pay the annual permit fee

Certified Operator Requirements

Upon classification by the DWR Operator Certification Program, the O&M section of the permit requires that the Permittee designate certified operators. The Permittee must designate one Operator in Responsible Charge (ORC), and one or more Back-up ORCs in accordance with NCAC 15A 8G (Water Pollution Control System Operator Rules). The permit further requires that the ORC or Back-up ORC must visit the system in accordance with 15A NCAC 08G .0204 and must comply with all other requirements in 8G .0204.

"Operator in Responsible Charge (ORC)" means the individual designated by the Permittee as the operator of record for the land application system and who has primary responsibility for the operation of the system. ***"Back-up ORC"*** means Back-up Operator in Responsible Charge and refers to the operator(s) designated to fill in or substitute for the ORC when the ORC is not available.

“Classification” in this context means that DWR Operator Certification Program evaluates a permitted system and decides if certified operators are required. When a system is classified, the Permittee is notified in writing how the system is classified, what type of certified operators it requires, and when these operators must be designated. The Permittee must then employ or contract with appropriately certified operators to supervise and manage the operation of the system.

Although both Class A and Class B permits contain this condition, Class A distribution programs are not currently classified and consequently not required to designate certified operators. These programs could be classified in the future and required to designate operators, but currently there are no plans to do so.

Class B land application programs *are* classified by DWR and, therefore, are required to designate certified operators who have active Land Application of Residuals certificates. To designate these operators, the Permittee must submit a completed Water Pollution Control System Operator Designation Form to the DWR Operator Certification Program. The designation form must be signed by the Permittee and countersigned by all the designated operators.

Deadlines for submission of designation forms:

- For new systems
    - 60 days prior to the first land application event.
- For existing systems
    - Within 120 days of receiving notification of a change in the classification of the system requiring the designation of a new Operator in Responsible Charge (ORC) and Back-up Operator in Responsible Charge (Back-up ORC) of the proper type; <u>*or*</u>
    - Within 120 days of a vacancy in the position of Operator in Responsible Charge (ORC) or Back-up Operator in Responsible Charge (Back-up ORC); <u>*or*</u>
    - ***Within seven days*** of vacancies in both ORC and Back-up ORC positions, replacing or designating at least one of the responsibilities.

Responsibilities of an ORC

In Chapter 2, we discussed the basic responsibilities that come with operator certification. When designated as an ORC, a certified operator takes on these additional responsibilities, which are contained in 8G .0204:

- Possess a valid certificate of the appropriate type for the system.
- Visit the land application of residuals system as often as is necessary to ensure its proper operation, but in no case less frequently than during application or within 48 hours after application of residuals, unless otherwise specified in the permit.
- Operate and maintain the system efficiently and attempt to ensure compliance with the permit and all applicable local, state, and federal requirements.
- Certify, by signature, the validity of all monitoring and reporting information performed on the system as required by the permit and provide the owner a copy.
- Document the operation, maintenance, and all visitation of the system in a daily log that must be maintained at the system.

- Notify the owner of the system within 24 hours, and in writing within five calendar days of first knowledge, of any:
    - Overflows from the system or any treatment process unit.
    - Bypasses of the system or any treatment process unit.
    - Violations of any limits or conditions of the permit.
- Notify the owner, in writing, of the need for any system repairs and modifications that may be necessary to ensure the compliance of the system.
- Be available on an on-call basis for in-person interactions:
    - For consultations with the system owner and regulatory officials.
    - To handle emergency situations.
    - To provide access to the facility by regulatory agencies.
- Upon vacating an ORC position, notify the DWR Operator Certification Unit and the appropriate regional office of the vacancy, in writing within 14 days.

The ORC requirement to visit a site during application or within 48 hours after land application can be a little tricky for some programs. Large municipalities often land apply at numerous sites almost every day throughout the year. Smaller generators may only land apply once or twice a year. Establishing a visitation requirement that fits all programs is difficult.

8G does allow alternate ORC visitation to be established in the permit. This is accomplished by proposing alternate visitation in the Inspection Plan. If approved by DWR, the alternate visitation supersedes the requirement in 8G.

Responsibilities of a Back-up Operator in Responsible Charge

The Back-up ORC(s) may act as surrogate for the ORC for a period:

- not to exceed 40% of the required visitation per calendar year; or
- not to exceed 120 consecutive calendar days when the ORC is absent due to:
    - the vacancy of the ORC position; or
    - personal or familial illness.

When acting as a surrogate for the ORC, the Back-up ORC must fulfill all the responsibilities of the ORC described above.

We will discuss the consequences for certified operators who fail to fulfill their responsibilities in a later chapter.

Chapter 11

Health and Safety

Accidents and injuries don't just happen, they are caused. Behind every accident is a chain of events which lead up to an unsafe act, unsafe conditions, or a combination of both. Safety in the workplace should be everyone's concern. Communication between employers, supervisors, and employees generates ideas and safety awareness that leads to accident prevention. Safety programs, safety manuals and safety meetings are essential in providing the lines of communication that lead to a safe, accident-free workplace.

This chapter does not attempt to provide complete guidance on all occupational safety and health hazards you may encounter as a land application operator. There are a number of intensive safety programs, “stand-alone” programs (for example, Hazard Communication, Confined Space, and Lockout/Tagout) that you may be required or allowed to attend. First and foremost, become familiar with you company’s health and safety program. If you want or require more in-depth knowledge of any health and safety topics, the NC Occupational Health and Safety’s website is a helpful resource.

Regulatory Overview

A variety of federal and state laws and regulations exist to protect workers in both the private and public sectors. At the federal level, the regulatory agency that oversees worker safety is the U.S. Occupational Safety and Health Administration (OSHA). In North Carolina, the Division of Occupational Safety and Health (OSH) has adopted federal OSHA standards, making them more restrictive in some cases. Areas covered by NC OSH:

- General Industry (29 CFR 1910)
- Construction (29 CFR 1926)
- Maritime Operations (29 CFR 1915, 1918)
- Agricultural Operations (29 CFR 1928)

❑ Employer Responsibilities

1) Each employer shall furnish to each of his employees a place of employment free from recognized hazards that are causing, or likely to cause, serious injury or death to his employees.
2) Every employer shall furnish and use safety devices and safeguards, and shall adopt and use practices, means, methods, operations, and processes that are reasonably adequate

to render such employment and place of employment safe. Every employer shall do every other thing reasonably necessary to protect the life and safety of employees.

3) No employer shall require any employee to go or be in any employment or place of employment that is not safe.

4) No employer shall fail or neglect the following: to provide and use safety devices and safeguards; to adopt and use methods and processes that are reasonably adequate to render the employment and place of employment safe; to do every other thing reasonably necessary to protect the life and safety of the employees.

☐ Responsibilities of the Site Supervisor

The responsibilities of the Site Supervisor are to:

1) Establish and supervise an accident prevention program and a training program that is designed to improve the skills and competency of all employees in the field of occupational safety and health.
2) Conduct preliminary investigations to determine the cause of any accident that results in injury. The results of this investigation should be documented for reference.
3) Establish and maintain a system for maintaining records of occupational injuries and illnesses.
4) Provide new employees with a safety orientation on the special hazards and precautions of any new job.
5) Conduct job briefings with employees before starting any job to acquaint employees with any unfamiliar procedures.
6) Issue any needed safety equipment and manuals conduct periodic group safety meetings.
7) Conduct periodic group safety meetings.

☐ Employee Responsibilities

The following items are the responsibility of the employee:

1. Comply with OSHA standards and rules that are applicable to his or her own actions and conduct.
2. Keep informed of current safe work practices and procedures.
3. Be responsible for his or her own safety.
4. Request instruction from the site supervisor if there is a question as to the safe

performance of work assigned.

5. Use appropriate safety devices and wear suitable clothing and appropriate personal protective equipment (PPE).
6. Report to the site supervisor any unsafe conditions, practices, or procedures.

Health and Safety Program

As mentioned above, it is the site supervisor's responsibility to develop a Health and Safety Program. This program should include:

- procedures for reporting incidents, injuries, and unsafe conditions, or practices
- instructions on identification and safe use of hazardous gases, chemicals and materials and emergency procedures following exposure
- use and care of personal protective equipment

☐ Incident Reporting

As part of the Health and Safety Program, all facilities should develop a formal incident reporting and investigation program. All incidents, including injuries, accidents and near misses should be reported to the site supervisor immediately. These incidents should be investigated as soon as possible to determine their root cause.

The information gained from an investigation should then be used to change work practices and to eliminate hazardous activities. Injuries requiring treatment other than first aid treatment must be reported on OSHA 200 form (Log and Summary of Injuries and Illnesses).

☐ Hazard Communication Standard

The Hazard Communication Standard, mandated by OSHA, is another important component of any Health and Safety Plan. The goal of the Hazard Communication Standard is to reduce injuries and illnesses resulting from improper use, storage, etc., of chemicals in the workplace. Employers must inform or instruct employees about the following regarding chemicals that are used in the workplace:

- safety and health standards for the safe use of those chemicals
- known health hazards of the chemicals used in the workplace
- methods of hazard control
- proper labeling of containers
- maintaining current material safety data sheets (MSDS) on all chemicals

    - chemical inventory
    - procedures to use in normal use or a foreseeable emergency
    - training in recognizing, evaluating, and controlling hazards

Health and Safety Hazards

As a land application of residuals operator, you will be exposed to numerous common hazards:

- physical injuries
- infections and infectious diseases
- oxygen deficiency
- toxic or suffocating gases or vapors
- dust, fumes, and mists
- chemical contamination
- explosive gas mixtures
- fire
- electrical shock
- noise-induced hearing loss
- heat exhaustion and heat stroke

☐ General Site Safety

The land application site should be restricted to authorized personnel. This is necessary to prevent mishaps involving the public and to help ensure that the site and all equipment are protected from vandalism and theft. Maintaining the land application site promotes a safe, well-kept working environment. Site maintenance includes the following:

- Keep walks, aisles and access ways clear of tools and materials. Also, it is important to maintain clear access to electrical panels, control valves and fire extinguishers.
- Clean up puddles of oil, sludge, wastewater, or fuel promptly and thoroughly. Use absorbent material if necessary.
- Dispose of dirty and oily rags, used absorbent materials, trash and other waste materials in approved containers. The waste should be removed from the site and disposed of properly.
- Provide scrap containers or scrap collection area where needed.
- Keep the sanitary facilities clean.
- Keep the supply area organized and free of hazards.

☐ Personal Protective Equipment (PPE)

Employers must provide personal protective equipment to their workers and ensure its proper use. Employers are also required to train each worker required to use personal protective equipment:

- when it is necessary
- what kind is necessary
- how to properly put it on, adjust, wear, and take it off
- the limitations of the equipment
- proper care, maintenance, useful life, and disposal of equipment

Employees should use the personal protective equipment, or protective devices, provided for their work. Before starting work, these items should be inspected by the employee to ensure that they are in safe operating condition. These items include, but are not limited to:

- gloves
- safety glasses and shoes
- earplugs or muffs
- hard hats
- respirators
- coveralls, vests, and full body suits

☐ Medical Safety

There should be present, or available always, a person (or persons) with first aid training. This training should include but not be limited to:

- bleeding control and bandaging
- artificial respiration, including mouth-to-mouth resuscitation
- poisons
- shock, unconsciousness, stroke
- burns
- sunstroke, heat exhaustion
- frostbite, hypothermia
- strains, sprains, hernias
- fractures and dislocations
- bites and stings
- transportation of the injured
- specific health hazards likely to be encountered by co-workers

There should be adequate first aid kits and supplies on site and readily available. A list of all employees with first aid qualifications should be posted, along with a list of emergency telephone numbers.

Where the eyes or body of any person may be exposed to injurious chemicals and/or materials, suitable facilities for quick drenching or flushing of the eyes and body should be provided, within the work area, for immediate use.

☐ Immunization

Each facility may want to consult a physician or the local health department to determine the need for immunizations for the employees working at the land application site. Adult tetanus and diphtheria should be given routinely every ten years, or at shorter intervals, when injury occurs.

☐ Personal Hygiene

Wastewater is disinfected to reduce pathogens but still contains trace amounts of living microorganisms. Hence, good personal hygiene is very important!

- ○ Keep your hands away from your nose, mouth, eyes, and ears to avoid ingestion of the wastewater and residuals.
- ○ Non-permeable gloves should be worn when handling any equipment covered with wastewater or residuals.
- ○ Special care should be taken to keep any area of broken skin covered to avoid possible infection (e.g., protective, waterproof dressing). If a worker suffers an injury which results in an open wound or laceration, they should be given a tetanus booster.
- ○ Wash hands thoroughly with soap before smoking, eating, drinking, or after work.
- ○ Work clothing should be changed and washed daily.
- ○ If contact with wastewater or residuals does occur, wash the area thoroughly with water and soap. Sponge any cuts with an antiseptic solution and cover with a clean, dry gauze dressing and waterproof adhesive.

☐ Lifting and Carrying

Individuals should observe the following guidelines to avoid possible injury when lifting and carrying objects:

- ☐ set your feet far enough apart to provide good balance and stability (approximately the width of your shoulders
- ☐ get as close to the load as practical, bending your legs at the knees, and bending at the hips to keep your back as straight as possible
- ☐ straighten your legs to lift the object, and at the same time, bring your back to a vertical position
- ☐ when lifting an object with another person, be sure that both individuals lift at the same time and let the load down together

❑ Heat Exhaustion/Heat Stroke

Heat exhaustion is a condition whose symptoms may include heavy sweating and a rapid pulse, a result of your body overheating. It's one of three heat-related syndromes, with heat cramps being the mildest and heatstroke being the most severe.

Causes of heat exhaustion include exposure to high temperatures, particularly when combined with high humidity, and strenuous physical activity. Without prompt treatment, heat exhaustion can lead to heatstroke, a life-threatening condition. Fortunately, heat exhaustion is preventable.

If you think you're experiencing heat exhaustion:

- Stop all activity and rest
- Move to a cooler place
- Drink cool water or sports drinks

Contact your doctor if your signs or symptoms worsen or if they don't improve within one hour. If you are with someone showing signs of heat exhaustion, seek immediate medical attention if he or she becomes confused or agitated, loses consciousness, or is unable to drink. You will need immediate cooling and urgent medical attention if your core body temperature (measured by a rectal thermometer) reaches 104 F (40 C) or higher.

Heatstroke is a condition caused by your body overheating, usually as a result of prolonged exposure to or physical exertion in high temperatures. This most serious form of heat injury, heatstroke, can occur if your body temperature rises to 104 F (40 C) or higher. The condition is most common in the summer months.

Heatstroke requires emergency treatment. Untreated heatstroke can quickly damage your brain, heart, kidneys, and muscles. The damage worsens the longer treatment is delayed, increasing your risk of serious complications or death.

❑ Confined Space Safety

There are two types of confined spaces. The first, a confined space, is defined as a space that has limited means of access (entry) and egress (exit), has an adequate size and configuration for employee entry and is not designed for continuous worker occupancy. The second type, a permit-required confined space, requires a permit for entry.

A permit-required confined space is a confined space that may have a potentially hazardous atmosphere, may have an engulfment hazard, may have an entrapment hazard, or it may contain any other recognized hazard.

If a facility has permit-required confined spaces, a written confined space entry program must be developed and followed to be in compliance with OSHA regulations. Enclosed facilities that are used to handle wastewater or wastewater solids, such as the tanks and/or tanker trucks, would fall under the permit-required confined space regulations. **Do not enter a permit-required confined space without proper training, equipment, and support personnel.** (The confined space regulations can be found in the Code of Federal Register 29 CFR 1910.147.)

The atmosphere of a confined space may be extremely hazardous because of the lack of natural ventilation. This can result in the following dangerous situations:

- oxygen-deficient atmospheres
- flammable atmospheres
- toxic atmospheres

An oxygen-deficient atmosphere has less than 19.5% available oxygen (Figure 11-1). Any atmosphere with less than 19.5% oxygen should not be entered without an approved self-contained breathing apparatus (SCBA). Oxygen-deficient atmospheres may be found in sewers, manholes, septic tanks, and pump tanks.

When working in a confined space that does not require a permit, several safety actions must be taken.

- Use a ladder, hoist or other device when accessing these work areas.
- Verify that the confined space is clean and well ventilated. Test the atmosphere of the space, from the top of the workspace to the bottom, for flammable/toxic gases and oxygen deficiencies PRIOR to entering the workspace and repeat testing during the work period.
- Use lifelines and always assign a standby person to remain on the outside of the confined space. It is the standby person's responsibility to be in constant contact (visually and/or verbally) with the workers inside the confined space when anyone is in the space.
- Wear ear protection, as needed. Noise within a confined space can be amplified because of the design and acoustic properties of the space.
- Be mindful of the possibility of falling objects when working in confined spaces.
- SCBA should be used in confined spaces where there is insufficient oxygen.

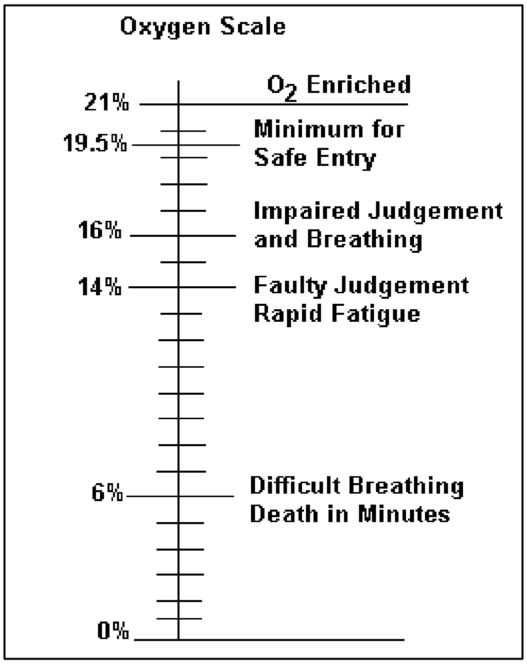


Figure 11-1.Oxygen scale (from Confined Spaces, 1988).

☐ Lockout/Tagout Policy

A lockout is a padlock placed on a power source to block the release of hazardous energy that could set a machine in motion or otherwise endanger an employee working on the machine. Locks are usually used with a lockout device that holds an energy control point, such as a switch lever or valve handle in the “off” position and prevents machines or equipment from being operated while the machine is being worked on.

A tagout is a written warning that tells other workers not to operate a switch or valve that could release hazardous energy or set a machine in motion. Lockout is preferred because it is a more secure method of controlling and isolating hazardous energy sources. Although lockout/tagout policies most commonly refer to electrical energy, the following types should also be covered:

- mechanical
- hydraulic
- pneumatic
- stored
- chemical
- thermal

A written lockout/tagout program should be developed that specifies how individual machines or equipment will be taken out of and returned to service. Once the program has been developed, all employees who use or perform maintenance on any of the affected equipment must be properly trained.

☐ Electrical Safety

Treat all electricity and electric power equipment with caution. Ordinary 120 V electricity can be fatal. Most wastewater treatment systems operate from 120 V to 4000 V or more. In case of electrocution, turn off power to the electrical source or use an insulated implement, such as a piece of wood to separate the person from the source. Do not attempt to pull a victim away from the electrical source with your bare hands.

The following is a list of general electrical safety practices (from Operation of Municipal Wastewater Treatment Plants, WEF):

- Allow only qualified and authorized personnel to work on electrical equipment and wiring or to perform electrical maintenance.
- Provide and use lockout devices and tags at all locations.
- Always assume electrical equipment and lines to be energized unless they are positively proven to be de-energized and properly grounded. If it is not grounded, it is not dead.

- Prohibit use of metal ladders or metal tape measures around electrical equipment.
- Ensure that two people always work as a team on energized equipment.
- Use approved rubber gloves on voltages more than 300 V.
- Do not open an energized electrical control panel.
- Before work is done on a line or bus that operates at 440 V or higher, be sure it is de-energized, locked out, and grounded in an approved manner.
- Do not test a circuit with any part of the body.
- Prevent grounding by avoiding body contact with water, pipes, drains, or metal objects while working on electrical equipment or wiring.
- Do not bypass or render inoperative any electrical safety devices.

When working in close quarters, cover all energized circuits with approved insulating blankets.

- Use only tools that have insulated handles.
- Never use metal-cased flashlights.
- Do not wear jewelry when working with or near electric circuitry.
- Ground or double-insulate all electrical tools.
- Use rubber mats at control centers and electrical panels.
- Always keep electric motors, switches, and control boxes clean.

☐ Fire Protection and Prevention

It is important to be fire conscious in the outdoor environment. Employees should be knowledgeable of the fire conditions at the site and operate accordingly. Poor site maintenance, worn or defective electrical systems, and welding and cutting may contribute to dangerous situations. The following precautions should be observed:

- Do not smoke in equipment or near fuel trailers. No open flame should be allowed near wastewater and residuals storage tanks. Combustible gases accumulate in these tanks and are vented to the surrounding area.
- Wastepaper, rags, and other combustible materials should not be allowed to accumulate.
- Do not tamper with or remove fire-fighting equipment from designated locations for purposes other than fire-fighting or rescue operations. Access to fire equipment should not be hindered. If fire extinguishers are used they should be promptly recharged.
- Inspect fire extinguishers monthly to be sure they are in good operating condition.
- Do not carry loads over people. Do not hoist, lower, or move any person with a crane by allowing them to stand on the headache ball or hook, or by any unapproved method.
- Do not stand under a suspended load or boom unless the nature of the work requires it.

There are four different types of fire extinguishers:

1. Class A - ordinary combustibles such as paper or wood
2. Class B - flammable liquids such as fires in fuel oil, gasoline, paint, grease, solvents, etc.
3. Class C - electrical equipment such as fires in wiring, overheated fuse boxes, conductors, and other electrical sources
4. Class D - metals such as magnesium and sodium require special dry powders extinguishers labeled D

Vehicle, Field Operations, and Heavy Equipment Safety

Agriculture ranks among the most hazardous industries. As a land application operator, you will likely be exposed to additional hazards and safety concerns related to agriculture and heavy farm machinery.

☐ Vehicle Safety

Only employees with a current N.C. driver's license can drive vehicles on public roads. Inspect the vehicle prior to operating it and follow all safety guidelines while operating it, including:

- Operate all vehicles within the legal speed limit or at slower speeds where conditions warrant.
- Do not transport unauthorized personnel.
- Keep vehicle windshields and windows clear of obstructions.
- Always provide ample room for stopping.
- Always remain alert.
- Remember that the risk of accident is much greater in an intersection.

Only operate specialized vehicles if you have specifically been trained to do so. Again, inspect the vehicle prior to operating and follow all safety guidelines while operating it, including:

- Be familiar with the capacity, required clearances, and all bridge weight limitations for safe use of the vehicle.
- Before loading or unloading, take the key out of the vehicle and set the parking brake.
- Carefully inspect trucks or trailers before moving to ensure that material and equipment are properly loaded and secure.

- Unless the vehicle is designed for more than one person, do not allow anyone else on the vehicle.
- Do not start the vehicle until everyone is clear. Slight steering movement can occur as the engine starts, causing machine movement.
- Make sure that the air system (if present) has reached operating pressure before driving away.
- For slow moving vehicles (SMV), be sure that the SMV symbol is prominently displayed can be easily seen.
- For slow moving vehicles, your vehicle should be equipped with proper rearview mirrors that can see behind and around your vehicle or the machine in tow. One of the most common road accidents that occur with these vehicles is when you make a left-hand turn and cannot see a vehicle attempting to pass.
- Drive at a safe, legal speed to ensure safety and complete control of the vehicle.
- Yield the right-of-way to local trucks and local road maintenance machinery.
- Use chock blocks by the tractor and trailer when the driver leaves the vehicle.
- Maintain all Department of Transportation requirements.

☐ General Farm and Heavy Equipment Safety

Several specific types of equipment are discussed below. However, there are general recommendations you should follow when working with any farm or heavy equipment, including:

- Read and follow O&M manuals for each type of equipment.
- Operate machinery only if you have been trained and authorized to use it.
- Wear the appropriate PPE equipment.
- Don’t wear jewelry, long loose hair, or loose clothing on the job. While gloves are recommended for many tasks, don’t wear them in situations where they could pull you into a machine.
- Use seat belt where fitted.
- Don’t try to adjust or reposition material while a machine is running.
- Always operate machinery with the safeguards in place. Report missing or damaged safeguards to the site supervisor.
- Keep equipment in good working order.
- When servicing, turn pumps off and depressurize all equipment.

- Never start an engine in a closed building.
- Never leave equipment with engine running.
- Never refuel equipment while engine is running or hot.
- Drive to the conditions and your level of ability.
- Scan ahead for obstacles/hazards.
- Do not exceed manufacturer's specifications (i.e., load and towing limits).
- Ensure that loads are well secured and not able to move.
- Remove keys after use to prevent unauthorized access
- Discuss safety hazards and emergency procedures with coworkers to make sure you are all on the same page.

○ Machine Guarding

Machines can cause a variety of injuries ranging from minor abrasions, burns, or cuts to severe injuries such as fractures, lacerations, crushing injuries, or even amputation. Machine guards are your first line of defense against injuries caused by machine operation.

Any machine part, function, or process, which may cause injury must be equipped with adequate safeguards in these locations:

- at the point of operation, where the machine contacts the material and performs operations such as cutting, punching, grinding, boring, forming or assembling.
- near power transmission components such as pulleys, belts, connecting rods, cams, chains, sprockets, cranks, and gears; and
- at other parts of the machine that move (rotation, reciprocating movement, transverse movement) while the machine is working.

Three of these locations and the types of injuries they can cause are discussed below:

- ***Pinch Point:*** two parts move together and there is a possibility that a body part could be caught between them. Body parts that get caught can be cut or crushed; loose clothing that gets caught can pull body parts into the mechanism. Stay away from moving objects. Keep shields in place (Figure 11-2).

- ***Crush Point:*** two objects moving toward each other, or one moving object hits a stationary object. Body parts can be crushed by the moving part or dropped item. The most common example of a crush-point hazard is the attachment to the drawbar of tractor**.** Other examples of crush point hazards include three-point hitches and components moved by hydraulic cylinders.

- ***Wrap Point:*** rotating components, such as a Power Take Off (PTO) shaft. Clothing caught by the spinning shaft can pull a person into the mechanism. Keep shields in place and shut off power before approaching the mechanism (Figure 11-2).

Make sure that all machine guards are in place and working properly. Put them back on if you remove them. Replace them if lost or damaged. Stay clear of parts that can't be shielded/guarded.

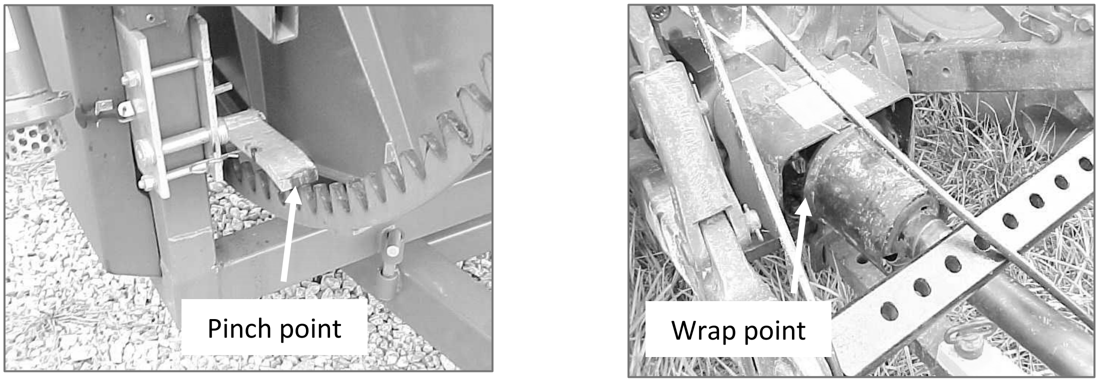


Figure 11-2. Unguarded pinch and wrap points.

Tractor Safety

Tractor rollovers are the leading cause of fatalities in the agriculture industry. These incidents take place when these farm vehicles turn on their side or tip over backward. Rollovers come about very quickly, often in seconds, which leaves the driver little or no chance to get clear as the tractor tips or rolls.

Side rollovers usually take place when the tractor is being used on sloped surfaces. As the slope increases, the chance of a side rollover is greater. The center of gravity is altered toward the downward slope. The chance of a side overturn also increases if you are driving on rough surfaces or if you hit obstacles and potholes. Side mounted implements also increase the chance of side rollovers.

Rear rollovers sometimes happen when implements are improperly hitched behind the tractor. If a chain or rope is hitched too high on the tractor when pulling something out of the ground, the tractor can be pulled over backwards. This can also happen if there is not enough weight on the front of the tractor. Rear rollovers can also take place when driving up a steep slope. If brakes are applied to decrease the speed of the tractor, the tractor can pivot on the back axle causing the front end to rise.

Never operate a tractor that isn't equipped with ***Roll Over Protective Structures (ROPS)***, which are cabs or frames designed to prevent tractor rollover injuries. New tractors come equipped with factory installed ROPS. Older tractors can be retrofitted with ROPS obtained from tractor manufacturer. All ROPs must be OSHA-approved. Almost all tractor roll overs without ROPS result in fatalities. ROPs and proper seat belt use can eliminate nearly all fatalities.

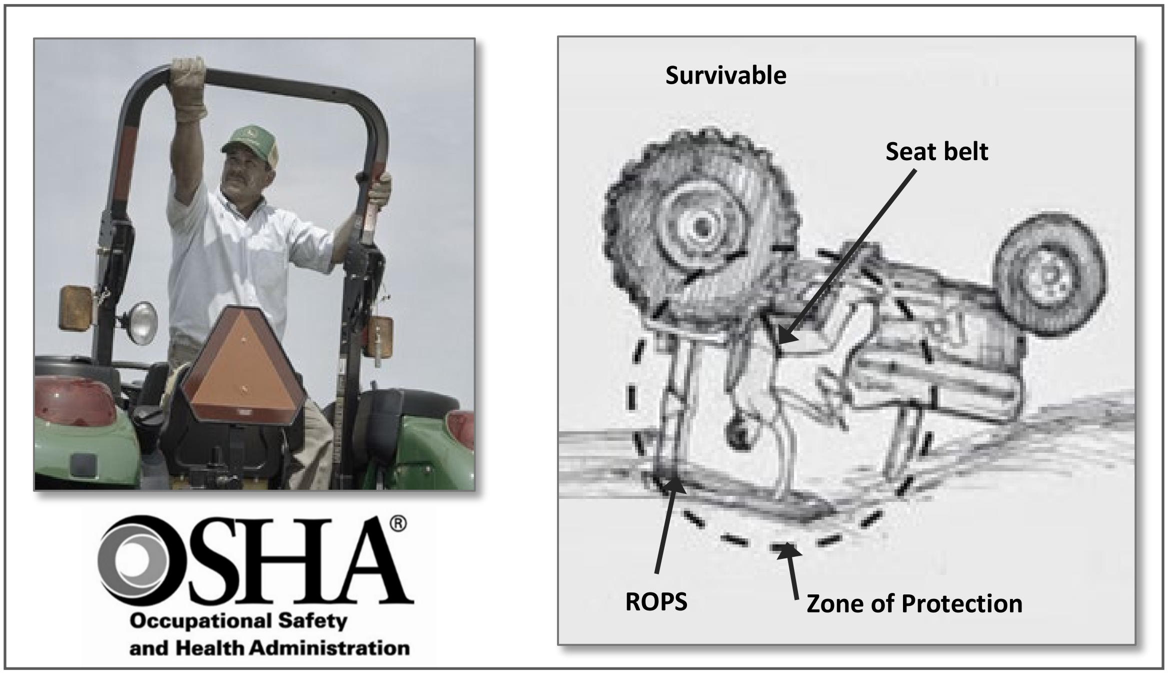


Figure 11-3. Tractor with ROPS and zone of protection.

When properly operated, maintained, and equipped, tractors are generally safe. Practice all safety guidelines, including the ones below.

- Always wear a seat belt when operating machinery with ROPS, even with an enclosed cab. Seat belts keep operators within the zone of protection.
- Never use seat belts on a tractor _without_ ROPS.
- Keep side mounted implements on the uphill side of the tractor to increase stability.

- Stay as far away from the edge embankments or ditches as possible. The weight of the tractor can cause the ground to give way.
- Avoid turning on a slope, if possible, or turn the tractor toward the downward slope, if you must. A sudden uphill turn is more likely to cause tipping.

❑ Power Take Off (PTO) Safety

Power Take-Off (PTO) is a device used to transfer power from a tractor to an implement that does not have its own engine or motor. A drive shaft connects the implement to the PTO stub at the rear of the tractor Figure 11-4). When engaged, the PTO stub and drive shaft spin at speeds of 9 - 16 rotations per second. This spinning motion creates a wrapping hazard that we mentioned before.

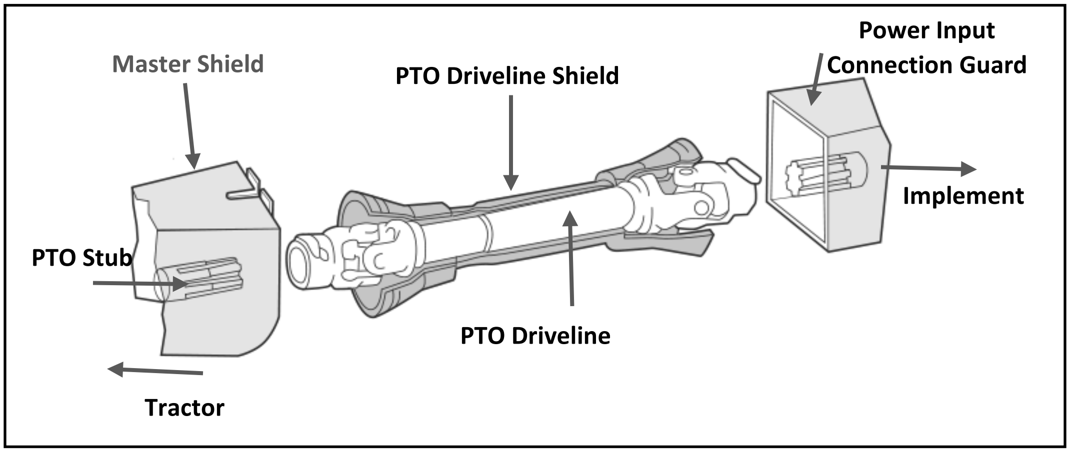


Figure 11-4. PTO drive shaft connecting tractor to implement, with appropriate guards and shields.

These safety practices offer protection from the most common types of PTO entanglements.

- Keep all components of PTO systems shielded and guarded.
- Never wear jewelry, long hair, or loose clothing when operating (Figure 11-5).
- Regularly test driveline guards by spinning or rotating them to ensure that they have not become stuck to the shaft.
- Always walk around tractors and machinery instead of stepping over a rotating shaft. NEVER step over the PTO shaft.
- Never grip a PTO guard while the shaft is turning
- Always use the driveline recommended for your machine. Never switch drivelines among different machines.

- Be sure PTO driveline is securely locked onto the tractor PTO stub shaft.
- Always disengage the PTO and shut off the tractor before dismounting to clean, repair, service, or adjust machinery.

❑ Pressure/Vacuum Equipment

Pumping air out of a tank or truck creates a vacuum inside. Opening the primary and secondary shutoff valves on suction hoses forces the tank to try to equalize the pressure inside, letting the truck suck up liquids and sludges. The power of the vacuum inside the truck or tank creates a potential hazard for anyone working with or around vacuum/pressure equipment.

Figure 11-5. Mock demonstration of a wrapping injury caused by a PTO device.

A vacuum hose under suction can produce an air velocity of up to 624 mph. If a body part comes in contact with a hose end, you will not be able to pull yourself free. Concentrated vacuum on the body can result in serious injury (rupture, suffocation, crushing, cutting) or death. If such an incident occurs, stop the vacuum, and seek medical attention immediately – do not delay! Some protective actions include:

- Keep vacuum tools and hoses away from face and body.
- Never attach hose, pipe, or accessories with vacuum on.
- Use an inline vacuum relief valve when operating near the end of the hose or pipe.

Residuals often produce combustible gases. The accumulation of gases within a confined space offers the potential for the vessel to explode or relieve the pressure at a weak point. The proper venting of tanks is imperative. The tank should be vented at the end of each day's operation. Pressure relief valves must be kept in good working condition.

In addition, the following venting procedures should be used when operating equipment:

- Vent tank (so there is no pressure or vacuum) by opening hatches or manholes.
- Always stay to the side of all covers when opening. Never stand with your head or body over the cover when opening.
- Do not go on top of a tank when it is under pressure, as the pressure relief valve can operate at any time.
- Relieve pressure before opening any door or hatch or disconnecting any hose or tube (to avoid possible injury from unrestrained action of the hose).
- When opening a pressurized tank's manhole cover after the pressure has been relieved, always open the clamping devices next to the hinge first. Open the clamp with the safety catch last.
- Do not restrict or block off safety valves or blowdown lines.

☐ Hydraulic Systems

Hydraulic systems are popular on many types of agricultural equipment because they reduce the need for complex mechanical linkages and allow remote control of numerous operations. Tractors and other heavy equipment use pressurized hydraulic fluids to lift or change position of implements, to operate remote hydraulic motors, and to assist with steering and braking.

To do their work, hydraulic systems must store fluid under high pressure, typically 2,000 pounds or more per square inch. The fluid, under tremendous pressure, is also hot. When working with hydraulic equipment, you are subject to three types of hazards:

1. Burns from the hot, high-pressure spray of fluid
2. Bruises, cuts, or abrasions from flailing hydraulic lines
3. Hydraulic fluid injection deep under skin

The third type of injury is probably the most common and results from a pinhole leak in a hose. A tiny hole or break can release fluid in an almost invisible stream at over 3,000 psi. It might not hurt that much or look that bad at first, but within hours it results in excruciating pain that requires immediate attention and specialized surgery. Delayed treatment increases the risk of losing fingers, a whole hand, or even death. Administer first aid and contact a physician when anyone is injured from hydraulic fluid.

Follow all rules for safe hydraulics operation, including:

- Inspect hydraulic equipment regularly for leaks.
- Never use hands/fingers even if wearing gloves when checking for leaks. Run a piece of wood or cardboard along hose instead.
- Incorporate pressure relief valves into the hydraulic system to avoid pressure buildups during use. Keep these valves clean and test them periodically to ensure correct operation.
- Make sure all pressure is relieved and fluid is cool before loosening fittings or removing lines.
- Never assume a hydraulic system is depressurized even if it's turned off. Lines or accumulators can hold residual pressure for weeks or even months.
- Consult O&M manual for depressurization procedure.
- Always lower the hydraulic working units to the ground before leaving the machine. Secure the working units when you must work on the system while raised; do not rely on the hydraulic lift.
- Never service the hydraulic system while the machine engine is running unless absolutely necessary (for example, when you are bleeding the system).
- Do not remove cylinders until the working units are resting on the ground or securely on safety stands or blocks; shut off the engine.

Figure 11-6. Hydraulic fluid injection injury.

Safety First!

You are responsible for the safety of your own actions while on the job. Conduct yourself professionally, with your mind always on your own safety and the safety of others; the workplace is no place for horseplay or lack of attention. Serve as a good role model to co-workers for safe work practices and behavior. Immediately warn co-workers and notify your supervisor of any malfunctioning equipment, hazardous conditions, and unsafe behavior in the workplace – someone's life may depend on it.

Chapter 12

Public Involvement and Education

Land application of residuals is a “beneficial reuse” of materials but some stakeholders may oppose the practice. This opposition may stem from a valid concern about potential impacts to human and animal health and the environment. Some of the strongest opposition arises from concerns about quality of life issues: odor, dust, noise, traffic, and property values.

Misinformation abounds on the topic and that does not help anyone. A search of the internet for “sludge” or “biosolids” or “residuals” shows the extent of negative information people are exposed to. For many, this negative and sometimes unscientific information may be their first introduction to land application of residuals. First impressions can be difficult to overcome.

Whether or not, public perceptions are accurate, they can’t be ignored. Overcoming public resistance and gaining public support is a critical component and of a successful land application program. The most effective way to gain support is through an active outreach and education program based on accurate information, transparency, and communication.

A public outreach and education program puts a “face” on your project and allows you to get accurate information to the community. It provides an opportunity for you to meet and get to know key players who can help you defend your project. Communication is always better than a lack of communication. Engaging in open honest dialogue discourages gossip and fear while building trust and support.

Steps to achieving trust and support include:

- ☐ Identifying stakeholders
- ☐ Developing and implementing a communication plan
- ☐ Being consistent in your messaging
- ☐ Handling complaints in a timely manner
- ☐ Planning for crisis
- ☐ Planning for pushback

Identify Stakeholders

One of the first steps in developing a successful public outreach and education program is identifying “stakeholders”. These are individuals or groups who are interested in or may be affected by your land application program. Stakeholders often include:

- ☐ Farmers, neighbors, and the nearby community
- ☐ Elected and appointed officials)
- ☐ Local government staff (planning, zoning, etc.)

- ☐ Agricultural organizations (Cooperative Extension, Farm Bureau, Soil and Water Conservation Districts)
- ☐ Residuals consultants and contractors
- ☐ Local colleges and universities
- ☐ Regulatory agencies (DEQ, local health departments)
- ☐ Your co-workers and managers

Develop a Communication Plan

When permitting a new land application site, begin communicating with stakeholders early, in the initial planning phase if possible. Seeking early input from local officials and citizens is the best way to gain support. Involving the people who will be affected by the project and listening to their concerns builds trust and helps ensures that the project fits successfully into the community.

Some helpful strategies are listed below.

- ☐ At the beginning of the project, visit and brief local officials and staff on your plans. Also, visit Cooperative Extension and Soil and Water Conservation District staff. Ask for their input on suitable sites and potential local concerns.
- ☐ Conduct farmer meetings. Provide them with information about your program: residuals characteristics, agronomic and economic value of your residuals; and operational procedures. Ask farmers for input regarding:
    - ○ their interest in participating in the program,
    - ○ potential concerns of the community, and
    - ○ help with building strategic relationships.
- ☐ Inform adjacent property owners and the local community through formal notices, meetings or hearings associated with state or local permitting requirements as well as informal channels, and one-on-one contacts. Distribute door hangers or brochures for neighbors of potential sites. Develop fact sheets and displays for use at public meetings, libraries, and agricultural meetings. Ask local governments and organizations to include information in listservs, publications, newsletters, and social media.
- ☐ Provide staff who can communicate effectively.
- ☐ Relay information in terms the public can understand.
- ☐ Talk with stakeholders, not at them.
- ☐ Listen to stakeholder concerns; don't just give information to them.
- ☐ Respond to concerns with specific, concrete answers.
- ☐ Seek ways to adapt your project to accommodate local concerns.
- ☐ Provide accurate, credible information, including websites where they can find more information.
- ☐ Keep a library of useful, credible information: research from universities, Cooperative Extension, and other impartial and reputable organizations.

- ☐ If available, have information about your program readily available: recent analysis, soil data, historical application information, and documentation from the State and EPA (annual reports).

Develop an on-going communications strategy to help maintain public trust and support. Provide regularly scheduled opportunities for open discussion with stakeholders. Methods of communication include:

- ☐ Attend and participate in local agricultural functions (Cattleman's Association meetings, Farm City celebrations).
- ☐ Maintain contact with agricultural organizations.
- ☐ Schedule tours of treatment plants and hold field demonstrations at land application sites. Invite a variety of stakeholders. Keep them informal and encourage discussion. These types of interactions can provide the public with information and can provide residuals managers with feedback on their programs.
- ☐ Schedule tours of treatment plants for school groups, which has the added benefits of educating the next generation and introducing career options to students.
- ☐ Share information about your program so that the public can understand issues and make informed decisions. These can include:
    - ○ Presentations to local organizations
    - ○ Newsletters and news releases of the past year's successes and upcoming plans
    - ○ An educational website
    - ○ Social media
- ☐ Consider a plan to inform and involve stakeholders in discussions regarding changes to the program.

Be Consistent in Your Messaging

Everyone in your organization, from managers and technical staff to field operators, must understand, support, and be able to communicate the benefits of land application. Keep your message simple and consistent. Develop key points about the source of residuals and the benefits of land applying them:

- ☐ Residuals are one of the byproducts of treating wastewater and drinking water – activities that protect human health and the environment.
- ☐ Land application is reuse and recycling of nutrients, keeping residuals out of landfills.
- ☐ Land application of residuals is good for soil and crops.
- ☐ Land application of residuals is safe.

Be familiar with the product you are applying and its specific characteristics. If you are applying biological residuals, be ready to explain they:

- ☐ Provide nutrients (nitrogen, phosphorus, micro-nutrients), reducing the need for commercial fertilizers and saving farmers money.
- ☐ Provide organic matter which creates topsoil and increases the soil’s ability to hold water and nutrients, which reduces soil erosion and increases crop yields.
- ☐ Promote natural soil communities and nutrient cycles.

Although non-biological residuals may not provide nutrients and organic material, they often have a high pH (alkaline) and can be used instead of lime to raise soil pH to levels beneficial to crops and soil microorganisms.

Land application of treated residuals is safe. Be ready to explain that residuals are strictly regulated by state and federal government which require they are:

- ☐ The product of specific treatment processes that are closely monitored to demonstrate pathogen and vector attraction reduction.
- ☐ Sampled for toxic chemicals, pollutants, and nutrients.
- ☐ Applied at agronomic rates, maintaining required setback distances from wells, property lines, etc.
- ☐ Applied under the supervision of state-certified operators.

Handle Complaints in a Timely Manner

Develop a plan to handle complaints swiftly. To the person or group complaining, the issue is very important. Don’t let their concerns fester. By taking prompt action, you show you are taking the concerns seriously and have nothing to hide.

Attempt to meet with the person or group in a controlled environment to avoid confrontation. Be prepared with talking points about your program, but realize that when people are emotionally upset, they may have difficulty receiving facts. If available, send them information right away, before you meet, so they have time to review and digest the material. With a well-developed communication strategy, this information will be readily available for you to share.

Plan for the Crisis

Despite your best efforts to prevent them, CRISES AND EMERGENCIES will happen. Truck spills are one of the most common emergency situations encountered when applying residuals. Luckily, you have a road map to follow in these situations: your Spill Control Plan that is required as part of your

Operation and Maintenance Plan. A copy of this plan as well as a written description of the product being transported needs to be in every vehicle that hauls residuals.

Regardless of the type of situation that arises, to maintain the trust and support of the community, you need to handle things in an appropriate manner. Failure to address and contain a crisis can have lasting consequences. Once you lose public confidence, it is hard to regain it. This is why you need a crisis communication plan in place before any issues arise.

A crisis communication plan is a written document that outlines the coordination and flow of information during a crisis. With a plan in place, your organization is more likely to respond to a crisis quickly, accurately, and confidently. How your organization responds to a crisis will help determine how the public perceives your organization.

The plan needs to designate one individual as the primary spokesperson to represent the organization, make official statements, and answer media questions throughout the crisis. This person's role is to provide facts and deliver a consistent message. The message needs to convey that the organization is taking responsibility and correcting the problem.

Your crisis communication plan needs to address all the possible scenarios you can foresee and provide appropriate responses. Be prepared. Update the plan regularly and work through your scenarios ahead of time. Make sure all employees are trained and know how to respond when the crisis happens.

What to Do When the Media Calls?

Dealing with the media is stressful, whether during a crisis or during normal operations. We have already discussed that part of a crisis communication plan is identifying one person who will deal with the media during the crisis. The media may also contact your organization at times when there is no crisis.

Some organizations are large enough to have a public information officer who will handle media inquiries. Many organizations, however, do not and you may find yourself being asked for an interview. Here are some tips to help you in such a situation.

- ☐ Be prepared. Decide on two or three key points you always feel comfortable making. Write your key points and supporting facts down to help you prepare. Always know what you want to achieve through an interview.
- ☐ Find out who will be conducting the interview and for which media outlet they work. Find out how the reporter will conduct the interview – face-to-face, by telephone, or by email. Is it for

print, website, radio, or television? Ask the reporter what the story will be about and what they expect and hope to gain from the interview.

☐ Lead with the key points that you have prepared. Repeat them multiple times. Answer the question asked but also repeat your point so it is not missed or misinterpreted.

☐ Keep your answers (and your talking points) short and simple. Avoid jargon and technical terms. Explain unfamiliar terms, including acronyms. Don't overwhelm a reporter with a lot of information and assume he/she will know what to emphasize.

☐ Make your points and stop talking. Don't ramble. Don't comment if you are not fully prepared. Don't volunteer information unless it is a point the company wants to make, and the question hasn't been asked.

☐ Listen to each question carefully before responding. If you don't understand it, ask the reporter to repeat it. If you don't know the answer to a question or need time to collect data or your thoughts, tell the reporter you will get back with them later with an answer.

☐ Resist the temptation, or pressure, to reply instantly. Don't be afraid of pauses. Take your time when answering questions. You are the one being interviewed. You have the correct information. You can take a moment to collect your thoughts and answer succinctly.

☐ Correct any misinformation in a question before answering it. You may need to rephrase the question as part of your answer. You can also rephrase the question to make it a more positive or at least neutral questions.

☐ Don't let a reporter put words in your mouth. If the reporter's summary of your remarks is not consistent with what you said, immediately correct any misinformation. You can do this politely, but don't let the reporter take advantage of you.

☐ If a reporter interrupts you, ask that the reporter allow you to finish your point/answer.

☐ Assume the reporter will print or broadcast anything you say. **Nothing is ever off the record.** Any conversation or exchange with a reporter is an interview. Assume that a microphone or camera is always on.

☐ **Always tell the truth.** Release only the information you know is accurate. Avoid rumors, gossip, and lying. Stick to the facts. Don't speculate.

☐ A reporter may hammer you with difficult questions, they may befriend you hoping you will drop your guard, they may be very genuine, or a wonderful person, or very antagonistic; none of those things matter. It is not your job to trust or distrust a reporter. Your job is to get the information out to the public that you wish to share.

☐ Think before you speak.

☐ Stay calm. Remain positive. Don't be impatient, defensive, or annoyed with a reporter. If an unplanned communication with a reporter catches you off guard and you feel unprepared, politely thank them for their time and interest, decline the interview, and ask if you can reschedule at time that works for both of you.

Plan for Pushback

Despite your best efforts to gain public acceptance for your land application program, there may be opposition groups that are not interested in common ground. Try to identify active and potential groups like this. Become familiar with tactics they might use and develop strategies to effectively neutralize those tactics. Always remain professional in all your dealings with anyone.

Planning for worst case scenarios needs to be a part of your crisis communication plan. It is a form of risk assessment. Sometimes members of these groups will cross the line. Prepare yourself and your staff on how to handle aggressive, confrontational people. Do not to engage with them if possible. Call 911 if they create an unsafe situation or you feel physically threatened.

Post ‘No Trespassing’ signs at all entrances to land application sites. Improve security at the facilities where the residuals are generated. Be aware and make drivers aware that these people like to follow trucks. Encourage the farmer to call 911 if anyone trespasses. If you can do so without escalating the situation, take photos of anyone confronting you in a threatening way or trespassing.

While vocal and disruptive, these groups are usually a small percentage of your community and may not even be from within your community. They may be part of an organized regional or national group. Keep them on your radar, but don’t obsess about them. Continue to build and maintain support among people that are willing to listen and engage in constructive dialogue.

Resources and References

See the online manual section at: deq.nc.gov/opcert.

Chapter 13

Monitoring and Reporting Requirements

Section IV of the permit tells you exactly what to monitor and how often. It also specifies when and how you must report the results.

Monitoring

All residuals permits require residuals monitoring. Land application of Class B residuals also require soil sampling. A few permits (dedicated sites) require groundwater monitoring. All residuals permits state that DWR can require any monitoring (including groundwater, plant tissue, and surface water analyses) whenever necessary to ensure groundwater and surface water protection.

Self-monitoring and reporting is the foundation of NC's residuals permitting programs. Failure to comply with all monitoring and reporting requirements is a violation of the permit and may result in enforcement action. Monitoring results must be maintained for a minimum of five years.

Residuals Monitoring

Residuals from each approved source listed in Attachment A must be monitored. For each source, Attachment A lists the owner, facility name, county, permit number, whether the residuals are biological, the maximum dry tons per year produced per year, monitoring frequencies, and approved mineralization rate (Figure 13-1). Unless otherwise specified, monitoring frequency is based on the actual dry tons applied per year using Table 13-1.

Hazardous Waste Determination

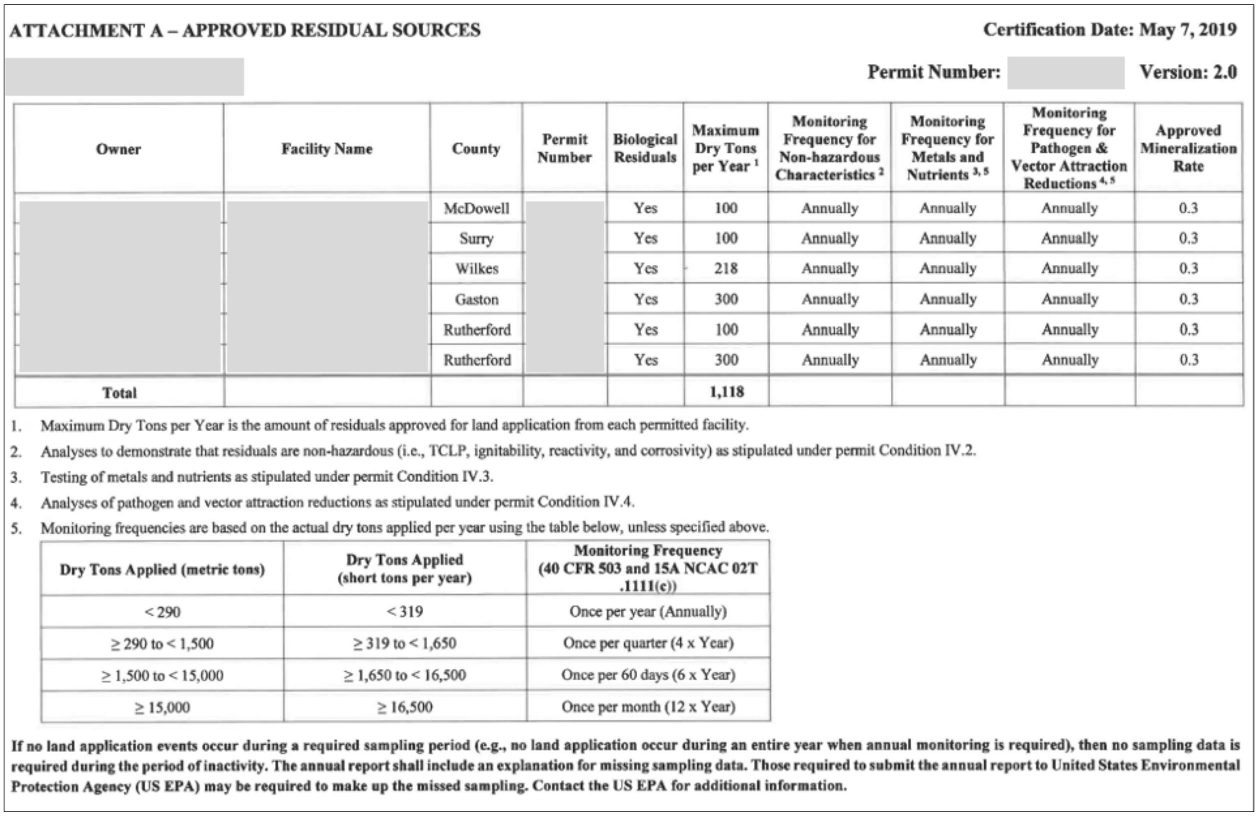
All residuals must be analyzed to demonstrate that they are non-hazardous. A hazardous waste is a material with a chemical composition or other properties that make it capable of causing illness, death, or some other harm to humans and other life forms when mismanaged or released into the environment. The analyses must include:

- ☐ ignitability (waste that can readily catch fire and sustain combustion)
- ☐ corrosivity (waste that is acidic or alkaline which can readily corrode or dissolve flesh, metal, or other materials)
- ☐ reactivity (waste that readily explodes or undergoes violent reactions)
- ☐ toxicity (waste that exceeds the regulatory limits for contaminants)

Toxicity is determined by the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP measures the concentration of over 40 organic and inorganic contaminants. Your permit contains a table that lists the maximum concentration of these contaminants allowed in residuals that are land-applied or distributed. Residuals that fail the test for one or more of these compounds can be blended and retested. If they never pass the TCLP, they are considered hazardous or toxic waste and must be disposed of in a hazardous waste landfill.

The TCLP results are reported in mg/L (wet weight). Since the table of maximum allowed concentrations in your permit is also in mg/L, this is another instance (in addition to the SAR calculation) when you do not need to convert mg/L to mg/kg (dry weight). If your results were reported on a wet weight basis, you can compare your results directly to the table.

Once the residuals have been monitored for two years at the frequency specified in Attachment A, the permit holder may submit a permit modification request to reduce the frequency of this monitoring requirement. The minimum monitoring frequency is at least once per permit cycle (five years).



ATTACHMENT A – APPROVED RESIDUAL SOURCES **Certification Date: May 7, 2019**

[redacted] **Permit Number:** [redacted] **Version: 2.0**

Owner	Facility Name	County	Permit Number	Biological Residuals	Maximum Dry Tons per Year[1]	Monitoring Frequency for Non-hazardous Characteristics[2]	Monitoring Frequency for Metals and Nutrients[3, 5]	Monitoring Frequency for Pathogen & Vector Attraction Reductions[4, 5]	Approved Mineralization Rate
[redacted]	[redacted]	McDowell	[redacted]	Yes	100	Annually	Annually	Annually	0.3
		Surry		Yes	100	Annually	Annually	Annually	0.3
		Wilkes		Yes	218	Annually	Annually	Annually	0.3
		Gaston		Yes	300	Annually	Annually	Annually	0.3
		Rutherford		Yes	100	Annually	Annually	Annually	0.3
		Rutherford		Yes	300	Annually	Annually	Annually	0.3
Total					**1,118**				

1. Maximum Dry Tons per Year is the amount of residuals approved for land application from each permitted facility.
2. Analyses to demonstrate that residuals are non-hazardous (i.e., TCLP, ignitability, reactivity, and corrosivity) as stipulated under permit Condition IV.2.
3. Testing of metals and nutrients as stipulated under permit Condition IV.3.
4. Analyses of pathogen and vector attraction reductions as stipulated under permit Condition IV.4.
5. Monitoring frequencies are based on the actual dry tons applied per year using the table below, unless specified above.

Dry Tons Applied (metric tons)	Dry Tons Applied (short tons per year)	Monitoring Frequency (40 CFR 503 and 15A NCAC 02T .1111(c))
< 290	< 319	Once per year (Annually)
≥ 290 to < 1,500	≥ 319 to < 1,650	Once per quarter (4 x Year)
≥ 1,500 to < 15,000	≥ 1,650 to < 16,500	Once per 60 days (6 x Year)
≥ 15,000	≥ 16,500	Once per month (12 x Year)

If no land application events occur during a required sampling period (e.g., no land application occur during an entire year when annual monitoring is required), then no sampling data is required during the period of inactivity. The annual report shall include an explanation for missing sampling data. Those required to submit the annual report to United States Environmental Protection Agency (US EPA) may be required to make up the missed sampling. Contact the US EPA for additional information.

Figure 13-1. Attachment A.

Table 13-1. Monitoring frequencies from Attachment A of the permit.

Dry Tons Applied (metric tons)	Dry Tons Applied *(short tons per year)*	Monitoring Frequency
< 290	< 319	Once per year (Annually)
≥ 290 to < 1,500	≥ 319 to < 1,650	Once per quarter (4 x Year)
≥ 1,500 to < 15,000	≥ 1,650 to < 16,500	Once per 60 days (6 x Year)
≥ 15,000	≥ 16,500	Once per month (12 x Year)

Pathogen and Vector Attraction Reduction Requirements

Biological residuals must be monitored for compliance with pathogen and vector attraction reduction requirements. The permit doesn't specify which alternatives must be used, but the required data must be specific to the stabilization process used, and sufficient to demonstrate compliance with the Class A or Class B pathogen reduction requirements and one vector attraction reduction requirement. Analyses must be performed on the residuals as they are distributed, or land applied.

Note: Any exceptions from pathogen or vector attraction reduction requirements are specified in Attachment A.

Other Parameters

All residuals must be analyzed for metals, nutrients, and other parameters listed in your permit. At a minimum, these include the parameters listed in Table 13-2.

The TCLP results are reported in mg/L (wet weight). Since the table of maximum allowed concentrations in your permit is also in mg/L, this is another instance (in addition to the SAR calculation) when you do not need to convert mg/L to mg/kg (dry weight). If your results were reported on a wet weight basis, you can compare your results directly to the table.

Once the residuals have been monitored for two years at the frequency specified in Attachment A, the permit holder may submit a permit modification request to reduce the frequency of this monitoring requirement. The minimum monitoring frequency is at least once per permit cycle (five years).

Table 13-2. Other required residuals analyses (nutrients, metals, total solids, etc.).

Aluminum	Mercury	Potassium
Ammonia-Nitrogen	Molybdenum	Selenium
Arsenic	Nickel	Sodium
Cadmium	Nitrate-Nitrite Nitrogen	Sodium Adsorption Ratio (SAR)
Calcium	Percent Total Solids	TKN
Copper	pH	Zinc
Lead	Phosphorus	
Magnesium	Plant Available Nitrogen (by calculation)	

Soil Monitoring (Usually Class B Only)

All Class B permits (dedicated and non-dedicated) require routine soil sampling (Table 13-3). An annual representative soils analysis (i.e., Standard Soil Fertility Analysis) must be conducted on each land application site listed in Attachment B that received residuals during the calendar year.

This analysis shall be in accordance with the soil sampling guidance located in the Sampling Instructions section of the NC Department of Agriculture & Consumer Services' website (http://www.ncagr.gov/agronomi/pubs.htm). The Permittee shall maintain these results for a period of no less than five years, and these results shall be made available to the Division upon request. Each Standard Soil Fertility Analysis shall include the parameters in Table 13-3.

Table 13-3. Parameters that Standard Soil Fertility Analysis must include.

Acidity	Exchangeable Sodium Percentage	Phosphorus
Base Saturation (by calculation)	Magnesium	Potassium
Calcium	Manganese	Sodium
Cation Exchange Capacity	Percent Humic Matter	Zinc
Copper	pH	

Groundwater Monitoring

Land application of Class B residuals to dedicated sites usually require groundwater monitoring. If required, monitoring wells must be sampled at the frequencies and for the parameters specified in Attachment C. In addition to parameters and frequencies, Attachment C also lists the type of sample to collect, daily maximum allowable concentrations, and footnotes. The footnotes contain instructions specific to the individual permit.

Two copies of the monitoring well sampling and analysis results must be submitted on a Compliance Monitoring Form (GW-59), along with attached copies of laboratory analyses, on or before the last working day of the month following the sampling month. The Compliance Monitoring Form (GW-59) must include the permit number, the appropriate well identification number, and one GW-59a certification form must be submitted with each set of sampling results. All information must be submitted to the following address: Division of Water Resources, Information Processing Unit, 1617 Mail Service Center, Raleigh, North Carolina 27699-1617.

Recordkeeping and Reporting Requirements

When applying Class B and bulk Class A residuals, you must keep the following records for all land application events:

a. Source of residuals (as listed in Attachment A)
b. Date of land application
c. Location of land application (field name listed in Attachment B)
d. Approximate acreage applied
e. Method of application
f. Weather conditions
g. Dominant soil series
h. Soil conditions
i. Proposed crop
j. Nitrogen Application Rate based on RYEs
k. Volume of residuals land applied per acre in gallons, cubic yards, dry tons, or wet tons
l. Volume of animal waste or other nutrient source applied per acre in gallons, cubic yards, dry tons, or wet tons
m. Volume of soil amendments applied per acre in gallons, cubic yards, dry tons, or wet tons
n. Annual and cumulative totals applied to each field for the following:
    i. Class A and Class B residuals (dry tons per acre)
    ii. Animal waste and other sources of nutrients (dry tons per acre)
    iii. Heavy metals as specified in Condition II.6. (pounds per acre)
    iv. Plant available nitrogen (pounds per acre)
    v. Phosphorus (pounds per acre)

Recently issued or renewed Class A permits require that you keep the following records for all bulk Class A residual distribution events:

a. Residuals source (as listed in Attachment A)
b. Date of distribution
c. Name and address of residuals recipient
d. Volume of residuals distributed to each recipient
e. Intended use of residuals

Older Class A permits may require that you keep more detailed records of distribution events.

Reporting to DWR

All residuals permits require two kinds of reporting:

1. ***Non-compliance notification*** requires permit holders to contact DWR when permit violations occur.
2. ***An annual report*** that is a detailed summary of the land application activities that occurred during the calendar year (Jan. 1 – Dec. 31).

Noncompliance Notification

Residuals permits require the Permittee to report permit violations to the appropriate DWR Regional Office within 24 hours of first knowledge. Such violations include:

- Any process unit failure (e. g., mechanical, electrical, etc.) rendering the facility incapable of adequate residual treatment
- Any failure resulting in a discharge to surface waters
- Any time self-monitoring indicates the program has gone out of compliance with its permit limitations
- Land application or distribution of residuals abnormal in quantity or characteristic
- Any discharge from a vehicle or piping system transporting residuals

Outside normal business hours the Permittee should call the Division's Emergency Response personnel at telephone number (800) 662- 7956, (800) 858- 0368, or (919) 733- 3300. All noncompliance notifications must be followed by a written report to the Regional Office within five days of first knowledge of the occurrence. The report must outline the actions proposed or taken to ensure the problem does not recur.

The Annual Report

All residuals permits require that an annual report be submitted to ***DWR on or before March 1st***. The purpose of the report is to provide monitoring results and records of land application or distribution activities that occurred from January 1 through December 31 of the previous year.

DWR reviews the annual report to ensure that the requirements of the permit and regulations have been satisfied.

The annual report must meet the requirements described in the *Instructions for Residuals Application Annual Reporting Forms*. Instructions for reporting and annual report forms are available at https://deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/non-discharge-permitting, or can be obtained by contacting the Non-Discharge Permitting Unit directly.

These forms are the only approved forms that you may use when submitting the Annual Report. Any other forms must be approved by DWR before they are submitted as part of the report, or the report may be returned as incomplete. Contact the Non-Discharge Permitting Unit for more information on adapting existing forms.

*Please note: The Non-Discharge Branch has transitioned to electronic permitting and reporting. Permit applications, annual reports, certifications, etc. should be submitted electronically using the **Electronic Application/Document Upload** form. Please do not submit paper copies.

Be aware when completing forms electronically, some of the information is automatically calculated and entered into the spreadsheets. All forms are password protected to help ensure that changes are not inadvertently made to the form. If you wish to manually enter data into protected cells, call the Non-Discharge Permitting Unit for assistance.
The forms must be signed appropriately in accordance as follows:

- in the case of corporations, by a principal executive officer of at least the level of vice-president, or his authorized representative
- in the case of a partnership or a limited partnership, by a general partner
- in the case of a sole proprietorship, by the proprietor
- in the case of a municipal, state, or other public entity by either an executive officer, elected official in the highest level of elected office, or another authorized employee

An alternate person may be designated as the signing official, provided that a delegation letter is provided from a person who meets the referenced criteria.

Annual Report for Class B Permits

The forms required for Class B Annual Reports are listed in Table 13-4.

Table 13-4. Forms and supplemental documentation required in the Annual Report for Class B permits. Submit in the order shown.

Cover letter

Annual Land Application Certification Form	Form ACF
Annual Residual Sampling Form – Standard Parameters	Form RSSF
Annual Residual Sampling Form - Blank	Form RSSF - B
Annual Metals Field Loading Summary Form	Form MFLSF
Annual Land Application Field Summary Form	Form FSF
Annual Land Application Field Summary Form – Supplemental	Form FSF (Supp)
Lab Sheets	
Annual Pathogen and Vector Attraction Reduction Form	Form PVFR 2T
Field Soils Test Results	

☐ *Cover Letter*

Submit a cover letter, which lists all items and attachments included in the annual report as well as a brief description of the previous year's operation. The Cover Letter should include:

- contact information for the Permittee as well as the preparer of the forms in the event that additional information is required for completion of the annual report.
- a narrative description of any event of non-compliance that occurred the previous year, as required in FORM ACF and PVRF.
- a written explanation of any other irregular event as required as part of any of the Annual Report Forms.

☐ *Annual Land Application Certification Form (ACF)*

The Annual Land Application Certification Form (FORM ACF) provides information on the total amounts of residual applied, how the permitted acreage was utilized, and certifies that the permitted program was compliant with all permit condition over the previous calendar year. If the program was not compliant for the entire year, a written description of the following items must be included in the Cover Letter:

- date and time span of non-compliance
- explanation of action (or lack of action) that caused non-compliance
- corrective action taken
- action taken by DWR to date (if any)

The Permittee (or a properly delegated authority), the Preparer, and the Land Applier (if different from the Permittee or Preparer), must sign this form.

☐ *Annual Residual Sampling Summary Form (RSSF)*

The Annual Residuals Sampling Summary Form provides yearly sampling results of standard pollutants of concern associated with most residuals permits for each permitted residuals generating source.

- A separate form must be submitted for each permitted residuals generating source.
- All sampling results (lab sheets) gathered over the previous year must be submitted and included in the LAB SHEETS section of the annual report (see below).
- TCLP results do not need to be entered into either Form RSSF or Form RSSF – B.
- If parameters not included on the form are included in the Facility's permit, or have been sampled by the Permittee, FORM RSSF – B must be completed and submitted with these sampling results.
- A list of all laboratories used to analyze the samples must be provided.
- The Preparer (or a properly delegated authority) must sign this form.

☐ *Form RSSR - B*

This form provides additional space to track sampling results of additional pollutants of concern not included in Form RSSF.

☐ *Annual Metals Field Loading Summary Form (MFLSF)*

The Annual Metals Field Loading Summary Form provides analytical results for residuals applied to a specific field, as well as the annual metals loading to that field. The person responsible for land application to this field must sign this form.

- This spreadsheet contains automatic formulas in the light-green shaded cells that will calculate the annual dry tons applied and the annual metals loading once the permit number, residual data, and the total dry tons per acre per event are entered into the spreadsheet.
- This spreadsheet is linked to FORM FSF. Be sure to verify the results on this spreadsheet, and that the data is correctly being transferred to FORM FSF.

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☐ *Annual Land Application Field Summary Form (FSF)*

The Annual Land Application Field Summary Form provides information on the amounts of Plant Available Nitrogen (PAN), and annual and cumulative metals applied to the field. FORM FSF must be completed and submitted for every permitted field receiving residuals. **If a permitted field does not receive residuals for an entire calendar year please note this in the narrative of the cover letter**.

This spreadsheet contains formulas in the light-green shaded cells that will automatically calculate the following information once the permit number, gallons or cubic yards applied per event, percent solids, forms of nitrogen, and all other information is entered into the spreadsheet.

- Volume applied per acre (dry tons/acre)
- Annual dry tons applied
- PAN Applied (lbs/acre): once the name of the crop type is entered for either Crop 1 or Crop 2 column (only one should be entered) the corresponding PAN Applied column will be calculated.
- Total Volume of residuals applied
- Total PAN applied to each crop type.
- Current Cumulative Loading of metals
- The dry tons of residuals applied per acre is calculated assuming that there are 206.96 gallons of residuals per cubic yard. If site-specific data exists indicating a different volume conversion is required contact the Division for approval and instructions for updating the spreadsheet.
- When entering the "Volume Applied" to the field the Preparer must enter **either** the volume in cubic yards or in gallons in the corresponding column. If both values are entered the spreadsheet will use the cubic yard value to calculate the dry tons per acre applied.
- This spreadsheet is linked to FORM MFLSF. Verify the results on this spreadsheet, and that the Annual Lbs/acre for each metal is correctly being transferred from FORM MFLSF.
- This spreadsheet is linked to FORM FSF (SUP). Verify the results on this spreadsheet, and that the Annual Lbs/acre of PAN for each crop type is correctly being transferred from FORM FSF (SUP).
- All field soils tests gathered over the previous year must be submitted and included in the FIELD SOILS TEST section of the annual report (see below).
- The person responsible for land application to this field must sign this form.

☐ *Annual Land Application Field Summary Form Supplementary (FSF-Sup)*

This form provides additional space to track land application events and nitrogen PAN loading for a field.

☐ *Laboratory Sheets*

All sampling results (lab sheets) gathered over the previous year must be submitted.

- Make sure that lab sheets clearly identify which residual source they are associated with.

- Organize all lab sheets associated with FORM RSSF by residual source in the same order that FORMS RSSF are organized.
- Sampling results for TCLP sampling must be included.

☐ *Pathogen & Vector Attraction Reduction Form (PVRF 02T)*

The Annual Pathogen and Vector Attraction Reduction Form (FORM PVRF) provides certifications that appropriate actions were taken to properly reduce pathogens and vector attraction potential.

- Pathogen reduction and vector attraction reduction alternative and options listed in this form as part of 15A NCAC 02T .1106 and .1107, match the alternatives and options listed in 40 CFR 503.32 and .33 respectively. The Preparer should verify which regulations are identified in their permit and certify the corresponding form.
- The preparer of the form must check one of the two boxes supplied indicating whether the requirements have been met or not. If the requirements have not been met, the Permittee must include an explanation of the following in the narrative of the submitted Cover Letter.
  - date and time span of non-compliance
  - description of alternative or option attempted and explanation of action (or lack of action) that caused non-compliance.
  - corrective action taken.
  - action taken by DWR to date (if any).
- The copy of the analytical results or supporting documentation (e.g., time/temperature records) must be submitted verifying that the pathogen and vector attraction reduction requirements have been met by the indicated method.
- The person responsible for land application to this field and the preparer (if different from the Applier) must sign this form.

☐ *Field Soil Test Results*

All field soils test sampling results gathered over the previous year must be submitted.

- Make sure that soils test sheets clearly identify which field(s) they are associated with, and that the field numbers on the test sheets are consistent with the field names used in the permit.
- Organize all field soils sheets associated with FORM FSF by field name in the same order that FORMS FSF are organized.

☐ *Additional Documentation*

- Operation logs
- Maintenance logs
- Cropping and field activity logs

- Any information to show compliance

Annual Report for Class A Permits

Class A Annual Reports use some of the same forms Class B Annual Reports do (Table 13-5). The instructions and guidance are the same as those used to complete Class B Annual Reports.

Table 13-5. Forms and supplemental documentation required in the Annual Report for Class A permits. Submit in the order shown.

Cover letter	
Annual D&M/Surface Disposal Certification and Summary Form	Form DMSDF
Annual D&M/Surface Disposal Certification and Summary Form - Supplemental	Form DMSDF(supp)
Annual Residual Sampling Form – Standard Parameters	Form RSSF
Annual Residual Sampling Form - Blank	Form RSSF - B
Lab Sheets	
Annual Pathogen and Vector Attraction Reduction Form	Form PVFR 2T

Submitting the Annual Report

Remember, all residuals permits require that an annual report be submitted to ***DWR on or before March 1st*.** The Non-Discharge Branch has transitioned to electronic permitting and reporting. Permit applications, annual reports, certifications, etc. should be submitted electronically using **the Electronic Application/Document Upload** form. Please do not submit paper copies.

Follow these instructions when completing the report:

- Submit the Annual Report in the order shown in the table.
- The cover letter should always be first, followed by the standard forms.
- All sampling results (lab sheets) required by permit and gathered over the previous year must be submitted.
- Make sure that lab sheets clearly identify which field or residual source they are associated with.
- All supplemental information and lab sheets should be clearly organized and placed after the standard forms.
- Include the WQ permit number and facility name on all forms.
- The facility name must match the facility name on the WQ Permit.
- If necessary for clarity, include attachments to the forms.
- Attachments will be considered part of the Annual Report and should be numbered to correspond to the section to which they refer.

DWR will not accept an Annual Report unless all the instructions are followed. Failure to submit all the required information is a violation of permit conditions.

Reporting to EPA

Some facilities must also submit an annual report to ***EPA on or before February 19*** each year. These requirements apply to facilities if:

- ○ the design flow rate is equal to or greater than one million gallons per day,
- ○ they serve 10,000 or more people,
- ○ they are required to have an approved pretreatment program (Class I Sludge Management Facility), or
- ○ they are otherwise required to report.

EPA's Biosolids Center of Excellence (Region 7, Lenexa, KS) receives and reviews these annual reports (see Compliance and Annual Biosolids Reporting). EPA started to electronically collect reports in 2017. For more information on authorization and electronic reporting, visit the links:
Submit a Biosolids Annual Program Report on EPA's Central Data Exchange
Biosolids Annual Program Report FAQ Pages
General Information on NPDES Electronic Reporting
NPDES State Program Authorization Information

Note: If no land application events occur during a required sampling period (e.g., no land application occur during an entire year when annual monitoring is required), then DWR requires no sampling data during the period of inactivity. The annual report must include an explanation for the missing sampling data. ***Those required to submit the annual report to EPA may be required to make up the missed sampling.*** Contact the EPA for additional information and clarification.

Common Monitoring/Reporting Problems

Some common monitoring and reporting problems include:

- ○ Incomplete annual reports
    - □ Parts of reports not submitted (forms, lab sheets)
    - □ Forms missing permit number, facility name, signatures
    - □ Forms and documents in wrong order
- ○ Residuals not sampled before application
    - □ Ceiling concentrations of metals exceeded
    - □ Residuals failed TCLP
- ○ Samples not representative of residuals applied (sampled at wrong time or place)

- Sampling not conducted at proper frequency
- Over-application of PAN
- No soil test or field numbers do not match permit
- Problems with laboratory reporting limits or non-detects
- Pathogen and Vector Attraction Reduction (Form PVRF-2T)
    - No data submitted showing requirements were met
    - Data submitted but requirements weren't met

Why Keep Good Records?

There are several reasons why maintaining good records is a good management practice, including:

- Required by your permit
- Necessary to prove compliance to regulators and increase public acceptance
- Use as a management tool for planning, troubleshooting, and decision making
    - Should a field with high soil pH receive high pH residuals?
- Can help you if there's a complaint or problem
    - Did residuals kill crop or was it over-application of herbicide by farmer?
    - Did high nitrate hay kill cattle or was it poor animal management?

Chapter 14

Residuals and Soil Sampling

The Monitoring and Reporting section of the permit tells you exactly what to monitor and how often. It also specifies when and how you must report the results. It doesn't, however, tell you much about how to collect the samples that need to be analyzed. This chapter discusses residuals and soil sampling procedures.

Residuals Sampling

As a land application operator, your job duties may include collecting and submitting residuals samples to a laboratory for testing. Sampling is often the responsibility of treatment plant staff or contractors. Regardless of who samples, sample collectors must be trained in proper sampling procedures. These procedures must be followed carefully to obtain accurate information about residuals quality.

Ideally, the sampling plan discussed earlier will contain enough specific information to ensure compliance with regulatory requirements. The plan needs to provide sample collectors with the necessary information to consistently collect and handle samples in a manner that is appropriate for the tests to be run and representative of the material being tested. The more detailed the sampling plan, the less opportunity for error or misunderstanding during sampling, analysis, and data interpretation.

This chapter provides general information on residuals sampling. Persons responsible for sampling must be familiar with the permit's sampling plan and seek additional guidance when needed. A list of resources on the collection and analysis of residuals samples is included at the end of this section.

Representative Samples

Residuals samples must be representative of the final product you are going to land apply. The term "***representative sample***" means that a sample has the same properties and composition as the entire volume of residuals being sampled.

For a sample to be representative, you must collect it from an appropriate sampling location or point. As a land application operator, the sampling location you are most interested in is after the last treatment process prior to the residuals leaving the treatment plant. This is where the sample is the most representative of the residuals that will be transported for land application. We will discuss sampling locations a little later in this chapter.

Sample Types

There are two types of residuals samples: grab samples and composite samples.

- ☐ A ***grab sample*** is an individual sample collected at one location and at one point in time. It represents the quality of the residuals at the time and place it was collected. Grab samples are collected for parameters that are unstable, hard to preserve, or have strict time limits between sample collection and arrival at the laboratory. When sampling residuals, always collect grab samples for:
    - pathogens (fecals)
    - volatile and semi-volatile organics
    - pH

- ☐ A ***composite sample*** is made up of multiple grab samples that are mixed together to form a single sample. The individual grab samples should be as uniform in volume or weight as possible. In most cases, a composite sample is more representative of the characteristics of the entire amount of residuals being sampled than a grab sample. Composite samples are appropriate for:

    - total solids
    - metals
    - nutrients
    - TCLP

There are other types of samples that are part of a Quality Assurance/Quality Control (QA/QC) system to limit error and evaluate the quality of sample collection procedures.

- ☐ ***Temperature blanks*** are sample bottles filled with distilled water that are placed in each cooler prior to shipment. Upon arrival at the laboratory the temperature of the sample bottle is measured to evaluate if samples were adequately cooled during sample shipment.

- ☐ ***Equipment blanks*** are used to evaluate the effectiveness of equipment cleaning procedures and should be collected when non-disposable sampling equipment is used. They are prepared in the field by pouring de-ionized water through/over the sampling equipment and collecting it in the same type of sample containers as the residuals samples.
- ☐ ***Trip blanks*** are only used when sampling for volatile organics. They are prepared prior to the sampling event and stored in the same cooler with the actual samples. At no time after they

are prepared should trip blanks be opened before they reach the laboratory. Their purpose is to evaluate contamination introduced during shipping and field handling procedures.

☐ ***Field blanks*** are samples of analyte-free water (water that is free of any of the substances that will be tested for in the actual samples) that is poured into sample containers in the field, preserved, and shipped to the laboratory with the residuals samples. They are used to evaluate contamination from field conditions during sampling.

☐ ***Field duplicates*** are independent samples that are collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently. Duplicate samples demonstrate the precision of the sampling system, from initial sample collection through analysis at the laboratory.

Sampling Equipment

Appropriate sampling equipment depends on the specific tests that will be run and on the solids content of the residuals. Sampling equipment must be made of material that will not contaminate the samples. Do not use galvanized or zinc- or chrome-coated implements. The best choices are Teflon, glass, and stainless steel because they are relatively inert (they don’t react with the sample). However, glass is fragile, and Teflon is expensive.

Important restrictions and requirements for sampling equipment:

- ***pathogens (fecals):*** you can use plastic, glass, or stainless steel but all equipment must be ***sterile***
- ***total solids, metals, and nutrients:*** you can use plastic, stainless steel, or glass
- ***volatile and semi-volatile organics (for TCLP):*** you can use glass or stainless steel - you ***cannot*** use plastic

Pre-sterilized, disposable scoops, and other sampling devices can be purchased, eliminating the need to sterilize sampling equipment. Non-disposable equipment should be thoroughly cleaned after sampling and put away until the next sampling event. Cleaning procedures differ slightly, depending on the type of sampling equipment and what tests will be conducted. Equipment should be dedicated to sampling and not used for other activities.

☐ *Sampling Equipment -- Liquid Residuals*

Liquid residuals samples can be collected using the following equipment:

- ○ ***Buckets and pitchers*** can be used to sample liquid residuals from taps.
- ○ ***Composite liquid sludge samplers or "coliwasas"*** are useful when collecting liquid sludge from a lagoon, tank, or other containment areas. The coliwasa is a long glass, plastic, or stainless steel tube equipped with an end closure that can be opened and closed when lowered into the residuals. You can collect a "core" or sample the entire depth of the residuals with this device. Most coliwasas are about 5 feet long, but longer ones are available (Figure 14-1).

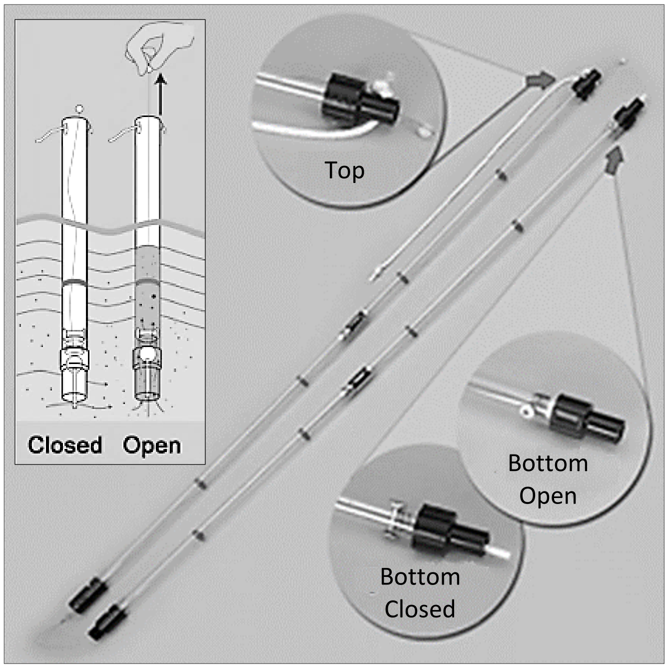


Figure 14-1. Composite liquid sludge sampler.

❑ *Sampling Equipment -- Dewatered or Dried Residuals*

You can collect samples of dewatered or dried residuals using the following types of equipment:

- ○ ***Trowels, scoops, or a gloved hand*** can be used when collecting samples from conveyor belts, shallow bins, and drying beds.
- ○ ***Thief samplers*** are useful when sampling drier residuals such as compost or pellets. A thief sampler consists of two slotted tubes, one of which fits inside the other. The outer tube has a pointed tip that allows the sampler to penetrate the residuals being sampled. Rotating the inner tube opens and closes the sampler. Thief samplers are usually made of stainless steel or brass (Figure 14-2).
- ○ ***Triers*** can be used for sampling dewatered residuals. The trier is a single long tube cut in half lengthwise almost the entire length of the tube. The end and edges of the tube

are sharpened so the trier can be more easily pushed into the residuals and rotated to collect a core.

- ***Augers*** are useful in a variety of situations, especially when you can't push a thief or trier into hard or compacted residuals. Made of stainless steel, an auger consists of a handle and extension that ends in corkscrew-like blades. Twisting the auger allows you to penetrate hard material. You can collect a grab sample from a specific dept, or you can collect a composite sample throughout the entire depth of the residuals, emptying the residuals into a bucket and returning to the drilled hole until you reach the bottom. Additional extensions are available.

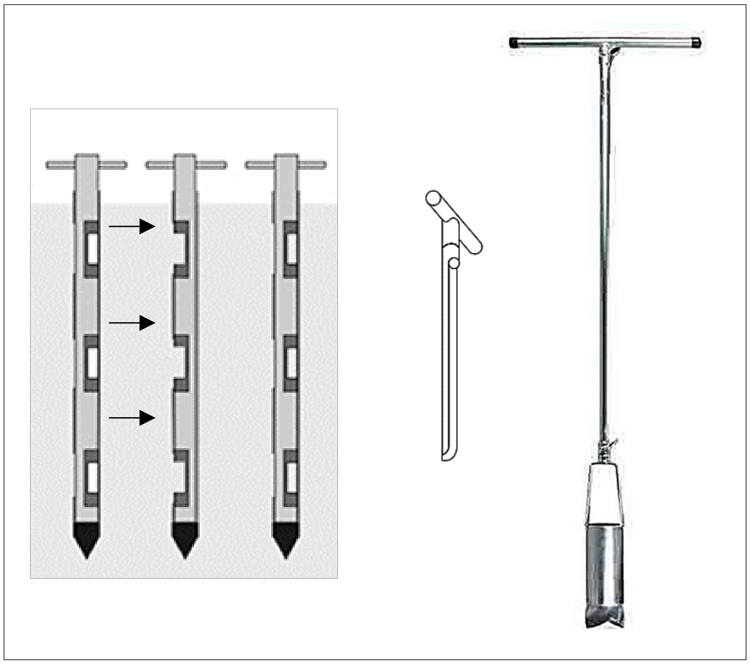


Figure 14-2. Thief, trier, and soil auger (equipment not to scale).

❑ *Sample Containers*

As with sampling equipment, sample containers must be made of material that will not react with and contaminate the samples. Do not use galvanized or zinc- or chrome-coated containers. Containers must be clean and contaminant free. Ideally, your laboratory can provide certified pre-cleaned, laboratory-grade containers, eliminating the need for you or other staff to clean them.

Important requirements for sample containers:

- ***pathogens (fecals):*** you can use plastic or glass, but all containers must be ***sterile*** - pre-sterilized plastic bags are widely available
- ***total solids, metals, and nutrients:*** containers can be either plastic or glass
- ***volatile & semi-volatile organics (for TCLP):*** containers *must* be glass with Teflon-lined lids

Sample Collection Points or Locations

Because there are so many different types and combinations of processing methods, appropriate sampling points differ from facility to facility. Liquid residuals can be sampled at the treatment plant from digesters, storage tanks, pipelines, or lagoons. Dewatered residuals can be sampled from conveyor belts, bins, drying beds, piles, front-end loaders, or during truck loading or unloading. Table 14-1 lists typical sampling locations.

Depending on the reason for sampling, it may be appropriate to sample and analyze for certain parameters in different places and at different times. For example, let's say liquid residuals will be dewatered following digestion. Treatment plant personnel need to sample the residuals before they leave the digester to determine if vector attraction reduction requirements have been met.

However, it would not be appropriate to sample the liquid digested sludge for other parameters. The appropriate place for you, as a land application operator, to sample the residuals is after dewatering. This is the location where samples collected are most representative of the residuals that you will land apply.

Above all, sampling locations must be easily accessible and safe. Safety should always be your first concern during sampling.

Sample Collection Methods

Collection methods depend, in part, on the parameters you are sampling for.

- ***Total solids, metals, nutrients, and TCLP (all residuals).*** Sample for these parameters at the frequency specified in the permit. Take the number of grab samples required by your sampling plan and mix together to form a composite sample.

- ***Pathogens (biological residuals).*** When sampling for pathogens, collect a grab sample directly into a sterile container. Do not transfer them. Nothing but the sample itself should touch the inside of the bag.
- ***Volatile and semi-volatile organic compounds (biological residuals).*** When sampling for volatile and semi-volatile organics, collect a grab sample directly into a glass container, leaving no headspace. Cap with a Teflon-lined lid.

Table 14-1. Typical residuals sampling locations.

Residuals Type	Sampling Location

Anaerobically Digested	Taps on the discharge side of positive displacement pumps
Aerobically Digested	1. Taps on discharge lines from pumps 2. If batch digestion, sample directly from digester. Two cautions: • If aerated during sampling, air entrains in the sample and VOCs may purge with escaping air. • When aeration is shut off, solids separate rapidly in well digested residuals.
Thickened Residuals	Taps on the discharge side of positive displacement pumps
Lagoons/Tanks	Use a coliwasa to collect samples from a randomized grid-like pattern, then composite the collected samples.
Dewatered Residuals	
1. Belt Filter Press, Centrifuge, Vacuum Filter Press	1. Discharge chutes or conveyors.
2. Plate and Frame Press	2. Random locations from the press or random locations from the storage container.
3. Bins or Drying Beds	3. Random locations from grid system established over the bins/beds. For composite samples, each grab sample should include the entire depth of the sludge.
Compost Piles	Collect samples from a randomized grid-like pattern within the piles of finished compost ready for sale/distribution. For composite samples, each grab sample should include the entire depth of the sludge.
Stockpiles	Collect samples from a randomized grid-like pattern within the stockpile or collect samples when residuals are being loaded onto trucks for transport. For composite samples, each grab sample should include the entire depth of the sludge.

Sample Collection Methods

Collection methods depend, in part, on the parameters you are sampling for.

○ ***Total solids, metals, nutrients, and TCLP (all residuals).*** Sample for these parameters at the frequency specified in the permit. Take the number of grab samples required by your sampling plan and mix together to form a composite sample.

○ ***Pathogens (biological residuals).*** When sampling for pathogens, collect a grab sample directly into a sterile container. Do not transfer them. Nothing but the sample itself should touch the inside of the bag.

○ ***Volatile and semi-volatile organic compounds (biological residuals).*** When sampling for volatile and semi-volatile organics, collect a grab sample directly into a glass container, leaving no headspace. Cap with a Teflon-lined lid.

Sample collection methods also depend on whether the residuals are flowing through pipes, moving on a conveyor belt, or stored in a lagoon, drying bed, bin, or pile. The best place to sample is usually where the residuals are flowing or moving because they are more likely to be well-mixed and representative.

It is more difficult to collect a representative sample when the residuals are stationary. When collecting composite samples from a lagoon or tank, bin, drying bed, compost pile, or stockpile, you need to collect samples from different locations and depths to make a representative sample.

☐ *Sampling Liquid Residuals from a Digester*

If liquid residuals are not going to be dewatered after digestion, the best time and place to sample them is from the digester while they are being discharged to holding tanks or during transfers. Most facilities have a sample tap on the discharge line.
Before you collect the samples, allow the residuals to flow from the tap for several seconds to flush out stagnant residuals accumulated in the tap. This ensures that the samples collected are representative of the residuals that will leave the plant.

To collect a composite sample from the digester, collect a series of grab samples throughout the entire time the residuals are being discharged. For example, if residuals are discharged over a six-hour period, take six grab samples at one hour intervals. Record the time that you collected each sample. Pour each grab sample into a clean bucket and keep the bucket on ice throughout the sampling period (Figure 14-3).

When you are finished collecting the grab samples, thoroughly mix them in the bucket and quickly fill the sample container. If the residuals solids are settling rapidly, mix the residuals vigorously and remove grab samples with a ladle. When filling the sample container, leave a half-inch of headspace at the top of the container to provide room for expansion.

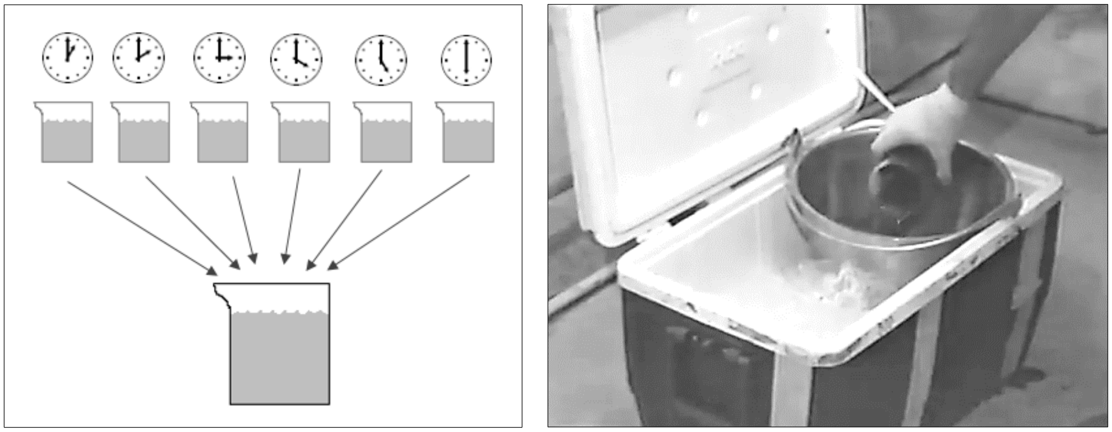


Figure 14-3. Multiple grab samples taken at regular intervals at the same location combine to form a composite sample.

Collect a grab sample for pathogens using a sterile sample bag or appropriate container. Place the sterile bag directly under the residuals stream. To prevent contamination, nothing but the sample itself should touch the inside of the bag. Leave a half-inch of headspace at the top of the bag to provide room for expansion. Liquid residuals, especially anaerobically digested residuals, are prone to gas production which can cause containers to burst.

If you need to collect a grab sample for volatile and semi-volatile organics, carefully pour the liquid residuals into the sample container to avoid entrapping air within the sample. You want to prevent any volatilization of the sample, so fill the container to overflowing and cap with a Teflon-lined lid. Check for air bubbles by turning the container upside down and tapping the lid. If air bubbles rise, open the container and fill with additional sample and recap.

❑ *Sampling Liquid Residuals from a Lagoon or Tank*

When sampling liquid residuals from a lagoon or tank, you must include floating, suspended, and sediment layers in the sample. To collect this type of sample, use a composite liquid waste sampler or coliwasa. Make sure it is open at both ends and slowly lower it into the residuals, allowing the level of liquid inside and outside the sampler to stay the same.

When the tip of the sampler reaches the bottom of the lagoon or tank, close the stopper, and lock it in place. Slowly withdraw the sampler. The sample collected should represent an accurate cross-section of the entire depth of sampled residuals.

For a composite sample, collect a cross-section of the entire depth as described above and pour contents into a clean bucket. Repeat at random locations around the lagoon or tank until an adequate number of grab samples has been collected. Mix the contents of the bucket thoroughly and transfer to a sample container.

For pathogens, collect grab samples (cross-section of the entire depth) from random locations around the lagoon and transfer directly into sterile containers.

❑ *Sampling Dewatered Residuals from a Moving Conveyor Belt*

Collect dewatered residuals as they are discharged onto a conveyor belt or as they are dropping into a hopper (Figure 14-4). Collect a composite sample by taking a series of grab samples at regular intervals over the entire discharge period. Keep the samples on ice in a clean bucket until you are ready to fill the containers.

Mix the residuals thoroughly, mixing and folding for several minutes before filling the container. Gas formation is less likely with dewatered or dried residuals, so leaving room for expansion within the sample container is less critical than with liquid samples.

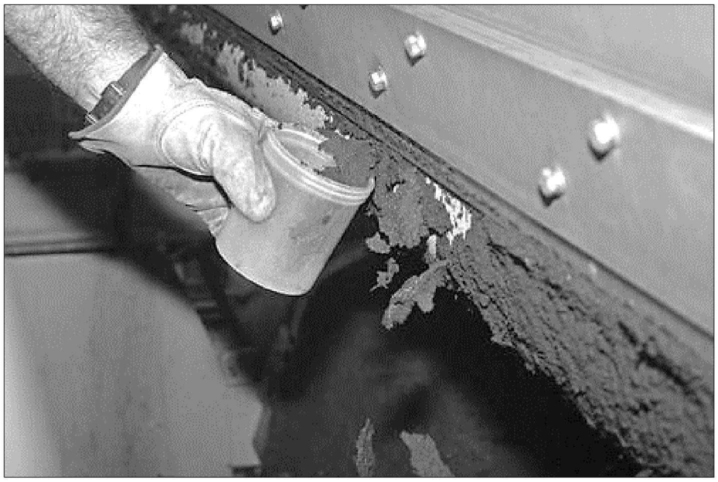


Figure 14-4. Sampling dewatered residuals as they are dropping into belt press hopper.

Collect a grab sample for pathogens using a sterile scoop to collect residuals off the conveyor or as they fall into the hopper. Pack the residuals directly into a sterile sample container. Volatile and semi-volatile organic samples (for TCLP) must be collected to minimize volatilization. Fill the sample container completely, packing the residuals into the glass container so there are no air spaces. Fill to overflowing and screw on a Teflon-lined lid.

❑ *Sampling Residuals from Bins or Drying Beds*

To collect a composite sample, diagram the bin or drying bed, divide the diagram into four sections, and mark the sample collection points. Collect equal sample volumes from the center of each of the sections, using a scoop if the bin or drying bed is shallow.

If the residuals are deeper, use a coring device (like an auger) to collect a single core sample through the entire depth of the residuals. Position the coring device, press, and twist down into the residuals, twist again and remove. Empty the collected residuals into a bucket. Repeat this process until you reach the bottom of the bin or drying bed. If you are sampling a drying bed, try not to get too much sand in the sample.

Combine the samples and mix thoroughly to make sure the composite sample is representative of the entire contents of the bin or drying bed. If the combined sample is too large to mix in a bucket, mix it on a plastic sheet. Layer the residuals, folding them onto themselves and mixing. Repeat this two-step process five or six times before filling the sample container.

To collect a sample for pathogens, use sterile gloves or a sterile scoop. Take a grab sample and put it directly into a sterile sample container. Collect another grab sample for volatile and semi-volatile organics, filling container completely so there are no air spaces.

☐ *Sampling Residuals from Compost Pile or Stockpile*

When collecting samples from a compost pile, the compost must be fully cured and ready to be land applied. To collect a composite sample, diagram the pile and note the sample collection points before you start.

Collect full cores the entire depth of the residuals at randomly selected points along the length of the pile. Collect multiple cores and mix. To collect a sample for pathogens, use sterile gloves or a sterile scoop. Dig deep into the pile. Take a grab sample and put it directly into a sterile sample container.

You can collect samples from a stockpile the same way. However, it is often more difficult to get representative samples from a stockpile. Its shape is less uniform, so gauging how many grab samples to take from each section can be difficult. The size of a stockpile can make it difficult to get grab samples from all depths.

Mixing Techniques for Composite Samples

The cone and quarter method is technique you can use to mix and reduce a large volume of residuals to the volume needed to send to the lab. Pour grab samples on the center of a clean plastic sheet forming a cone-shaped pile. Flatten and divide the pile into quarters. Randomly discard two of the quarters. Reshape the remaining two quarters into a cone-shaped pile, flatten, and divide into quarters. Randomly discard two of the quarters. Repeat until the sample volume is roughly the amount needed to fill the sample container (Figure 14-5).

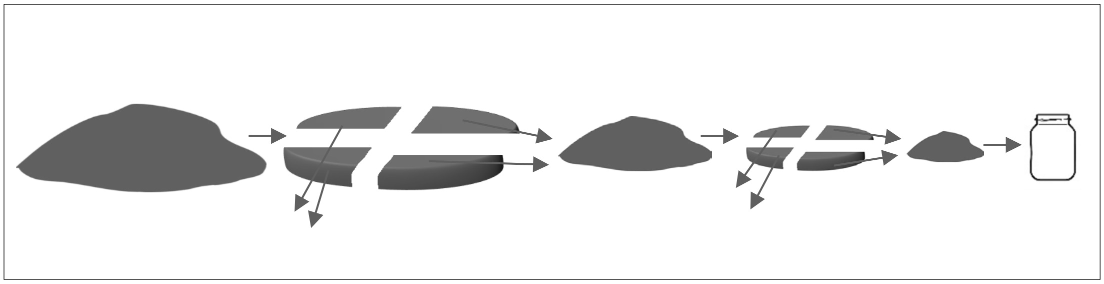


Figure 14-5. Cone and quarter method of reducing volume of a sample.

Another mixing technique involves taking subsamples. After collecting the grab samples, mix them all together on a clean tarp, breaking any large clumps. Using a flat-bottomed scoop or spatula, divide the pile randomly into smaller piles. Then, use one of the smaller piles to fill the sample container. It is very important to use a flat-bottomed instrument because a curved bottom instrument will favor certain particle sizes and will bias the final sample.

Sample Size

Depending on the specific method used to analyze the sample, the lab will need a minimum amount of sample for accurate results. Sample volumes usually range from 250 milliliters (mL) to one liter (L) or more. If your sampling plan does not specify the minimum volume to collect, check with your lab in advance of any sampling activities to make sure you collect more than enough for analysis.

Timing of Sampling

Sampling and analysis should take place as close as possible to the time that land application is to occur. However, you should allow enough time to receive the results before you land apply or distribute the residuals. If residuals are land applied before sample results are available, and the results subsequently show that a regulatory limit was exceeded, the permit holder will be in violation of the permit. You also need sample results to calculate application rates.

Number of Samples

When using pathogen density to verify that Class B residuals have met pathogen reduction requirements, regulations require that you collect and analyze seven grab samples over a two-week period.

When using pathogen density to verify that Class A residuals have met pathogen reduction requirements, regulations do not specify the number of grab samples that must be collected and analyzed. It is recommended, however, that at least seven grab samples be collected and tested over a two-week period for Class A residuals also. Collecting seven samples increases the likelihood that the results will be representative of the residuals.

For other parameters, your sampling plan should specify the number of samples to take. In general, the more samples you take, the greater the chance that the results will be representative of the residuals that are land applied. The larger the volume of residuals a facility generates and land applies, the greater the number of samples needed to obtain representative results. The same applies if the characteristics of residuals generated by a facility vary significantly over time.

Sample Labeling and Packing

As you collect your samples, prepare a label for each sample container that provides information uniquely identifying and describing the sample. Labels and ink should be waterproof. Fix labels to containers with clear waterproof tape.

Sign and date a custody or tamper proof seal and place the seal across the container lid so that it would break if the container were opened. This may require several seals. Instead of using custody seals, you may place sample containers into a tamper-evident bag. Wrap glass containers in bubble wrap to protect them from leaking or breaking.

Sample Preservation

Once you have labeled and wrapped your samples, you must preserve them to maintain the chemical and physical properties they had at the time you collected them. For residuals samples, cooling them to $\leq$6˚C (*without freezing them*) is usually the most appropriate preservation method. Keep the samples at this temperature by putting them on ice in a cooler until the analyses are performed. Depending on the analytical method the lab will use, liquid residuals samples may need to be preserved with the combination of a chemical preservative and chilling to $\leq$ 6 ˚C.

For method-specific details concerning all facets of sample preparation and preservation, consult the references cited in Table II 40 CFR Part 136, *"Guidelines for Establishing Test Procedures for the Analysis of Pollutants"*.

Analytical Methods

EPA has established test procedures and methods that laboratories must use when analyzing residuals. An appropriate method is one that has been evaluated and determined to produce acceptable data in terms of accuracy and precision. Analyses that are performed to show compliance with permit requirements must be conducted using specified methods. The permit holder, not the lab, is responsible for choosing appropriate analytical methods. Your sampling plan should specify appropriate analytical methods for any parameters monitored for compliance purposes.

Sample Holding Time

Sample holding time is the maximum amount of time that can pass between sample collection and completion of analysis in the lab. When the holding time for a sample is exceeded, the results may be inaccurate and are considered invalid or inconclusive. Consequently, it is essential that analyses are conducted in a timely manner within the specified holding times.

Holding times vary from eight hours (fecal coliform samples) to several months or longer (most metals). The holding time for a grab sample starts at the moment of collection. The holding time for a composite sample begins at the time the last grab sample in the set was collected. Table 14-2 summarizes holding times and other requirements for different parameters.

Note that the footnote for the table extends the holding time for biosolids to 24 hours for the following sample types using either EPA Method 1680 (LTB-EC or 1581: Class A composted, Class B aerobically digested, and Class B anaerobically digested.

Chain of Custody Forms

A Chain of Custody form must accompany each sample or group of samples sent to the lab for analyses. The sample collector is responsible for completing and signing the form. If multiple coolers are required to contain all samples from one sampling location, the sample collector must prepare a separate form for each cooler.

Table 14-2. Summary of sample requirements.

Parameter	Container	Type	Preservative	Holding Time
pH	Glass or plastic	Grab	None	None – perform immediately

Pathogens (Fecal Coliform)	Pre-sterilized glass or plastic	Grab	Cool to ≤ 6°C	8 hours [1]
Organics, Volatile & Semi-volatile	Glass with Teflon-lined lids	Grab	Cool to ≤ 6°C	14 days
Metals (except Mercury)	Glass or plastic	Composite	Cool to ≤ 6°C	180 days
Mercury	Glass or plastic	Composite	Cool to ≤ 6°C	28 days
%TS	Glass or plastic	Composite	Cool to ≤ 6°C	7 days
Total Kjeldahl Nitrogen	Glass or plastic	Composite	Cool to ≤ 6°C	28 days
Ammonia	Glass or plastic	Composite	Cool to ≤ 6°C	28 days
Nitrate-Nitrite	Glass or plastic	Composite	Cool to ≤ 6°C	28 days
Nitrate	Glass or plastic	Composite	Cool to ≤ 6°C	48 hours
Nitrite	Glass or plastic	Composite	Cool to ≤ 6°C	48 hours
Nitrate-Nitrite	Glass or plastic	Composite	Cool to ≤ 6°C	28 days
Total Phosphorus	Glass or plastic	Composite	Cool to ≤ 6°C	28 days

[1] For fecal coliform samples for sewage sludge only (biosolids), the holding time is extended to 24 hours for the following sample types using either EPA Method 1680 (LTB-EC or 1581: Class A composted, Class B aerobically digested, and Class B anaerobically digested.

Chain of Custody forms are legal documents. All relevant fields must be completed accurately. Required information includes:

- permit holder’s name and information
- unique sample ID number
- date, time, and location of sample collection
- sample type (grab, composite)
- preservation method(s)
- parameters to be analyzed
- analytical methods to be used
- special conditions or remarks
- sample collector’s name and signature

Each time the custody of a sample or group of samples is transferred, a signature, date, and time must be entered onto the Chain of Custody form. This provides documentation of each person having possession of the sample and helps to protect its integrity by ensuring that only authorized people have custody of it.

Field Logbook

All sampling activities must be documented in a bound logbook. All information required for the Chain of Custody form and all relevant observations regarding sampling conditions should be recorded in the logbook. The goal is to record sufficient information so that anyone can reconstruct the sampling event without relying on your memory. These details are useful if the lab results are unusual or suspicious and can help show that proper sampling techniques were used.

Groundwater Sampling

Because there are only a handful of residuals permits in NC that require groundwater monitoring, we will not go into sampling protocol in this manual. As with all sampling, groundwater data is only as good as the samples that are analyzed. The best laboratory cannot compensate for improper or poorly executed sampling procedures or for physical and chemical alteration of a sample due to inappropriate sample collection, transport, or storage. Permit holders and/or operators needing to sample groundwater monitoring wells should seek the help and advice of a professional laboratory or consultant.

Soil Sampling

The NCDA&CS' Agronomic Services Division analyzes soil samples, plant, solution and irrigation water samples, and animal, municipal and industrial wastes. Recommendations made by these services are designed to improve production efficiency and protect natural resources. Thirteen agronomists provide on-site consultations across the state to help farmers and operators solve field problems and implement recommendations.
Class B permits require that an annual representative soils analysis (i.e., Standard Soil Fertility Analysis) be conducted on each land application field listed in Attachment B that received residuals during the calendar year. Class B permits require that soil samples be conducted in accordance with publications available on the NC Department of Agriculture & Consumer Services (NCDA&CS) website (http://www.ncagr.gov/agronomi/pubs.htm).

Soil testing is a critical component of a successful land application of residuals program. A soil test chemically extracts and measures most of the elements essential to plant nutrition. Soil test results and subsequent fertilizer recommendations for the crop to be grown are the only reliable way to provide crop nutrient requirement. It also measures soil acidity and pH. These factors are indicators of lime requirement, nutrient availability, and the potential of the soil to produce crops. This information enables you to apply nutrients with environmental stewardship in mind.

The NCDA&CS Agronomic Division conducts two types of soil tests: predictive and diagnostic. The predictive is the standard soil test that provides the lime and fertilizer recommendations necessary to optimize yields. In contrast, the diagnostic soil test is used when samples are collected because of an observed problem situation. The purpose of a diagnostic test is to identify specific nutrient deficiencies or excesses that may be preventing optimal plant growth.

Collecting Routine Soil Samples

When sampling a large area, the goal is to collect a sample is representative of the entire area. Before sampling, it is a good idea to make a detailed map. Copies of aerial photographs from soil surveys may be helpful. Divide the map into individual sample areas of 15 to 20 acres or less. Each area should ideally have similar soil type, planting history, and management history.

Always use clean, stainless-steel sampling equipment and a clean, plastic bucket. Brass, bronze, or galvanized tools are likely to contaminate the sample with copper and/or zinc. If the sample-mixing bucket has been used for fertilizer or other chemicals, wash it thoroughly before use.

A soil probe is best for collecting cores, but a shovel will work. Walking in a zigzag pattern, collect 15 to 20 cores and place each soil core into a clean plastic bucket. (Figure 14-6A). Collect samples from similar areas or management zones based on soil type, tillage methods, cropping history, waste application history, etc.

After sampling an area, thoroughly mix the sample breaking up clumps and removing any large particles of trash. Do not group together cores from areas that you know have received different treatments (Figure 14-6B).

Avoid small areas that differ markedly from the rest of the field—wet spots, severely eroded areas, old building sites, fence rows, spoil banks, burn row areas, old woodpile or fire sites and fertilizer application bands. Such samples can bias evaluations of a field’s nutrient-supplying

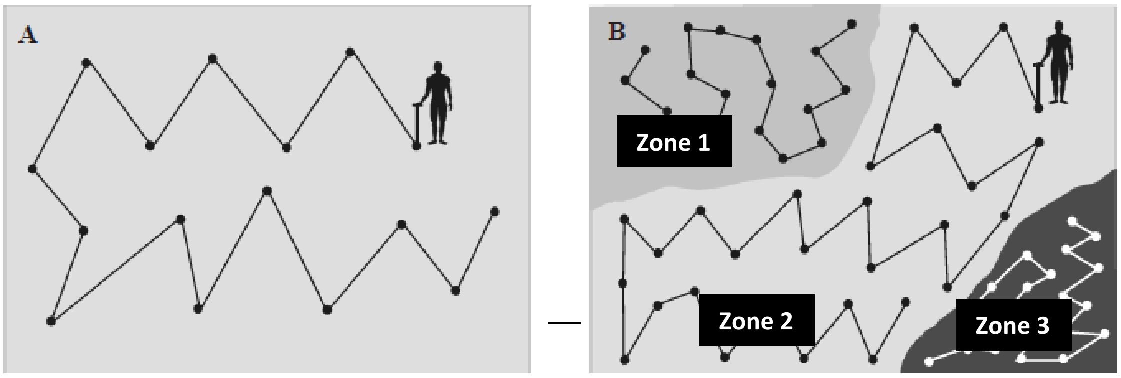


Figure 14-6. Sampling strategies. a) Use a zigzag pattern to collect cores randomly from a field with uniform soil. b) Subdivide fields that have distinct zones (soil type, cropping history, etc.) if it is feasible to lime and fertilize each area separately.

The sampling depth for agricultural land where conventional tillage is practiced is 6 to 8 inches. Where an existing sod is already established, such as pasture or hay, sampling depth is 4 inches. Where conservation or no-till is established, sampling depth is 4 inches (Figure 14-7).

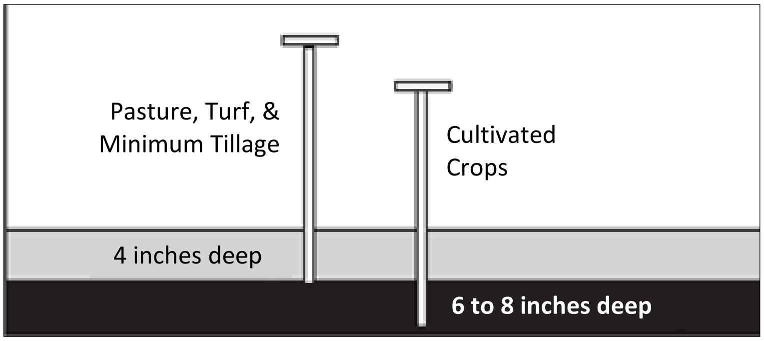


Figure 14-7. Proper sampling depth depends on tillage practices for the area sampled.

When to Sample

Whenever possible, sample three to six months before planting. For field crops, submitting soil samples right after harvest provides plenty of time to plan a liming and fertilization program before the busy growing season. Sample the soil from perennial or sod-crop areas three to four months before establishing the crop or applying lime or fertilizer.

In September and October, the laboratory workload is relatively light, and results can be returned within about two weeks. The laboratory has its greatest workload from November through March due to the thousands of agricultural samples received during this time. Turn-around time can be six weeks or more. Anyone who can schedule their sampling at another time of year is urged to do so.

Do not collect samples when the soil is too wet to till. Wet soils are difficult to mix thoroughly and may affect the quality of the subsample taken. It is best to wait for dryer conditions. On the other hand, if the soil is too dry it can be very difficult to collect the cores.

Boxing Soil Samples

Use NCDA&CS soil sample boxes, which are available at the Agronomic Lab and County Extension Offices and can be delivered by a regional agronomist upon request. Label them completely and fill with soil to the red line. Soil can be moist, but not wet enough to degrade the box. Do not use plastic bags. Do not use tape.

Complete the appropriate sample information form (Figure 14-8) using permanent ink or pencil. You must list a crop or crop code to get lime and fertilizer recommendations. Forms are available from NCDA&CS regional agronomists, Cooperative Extension offices, the Agronomic Division office in Raleigh and online at www.ncagr.gov/agronomi/forms.htm.

Packaging and Shipping Samples

If sending several sample boxes through the mail, pack them carefully in a sturdy cardboard box. Fill any voids with newspaper. Place samples in the same order as the info sheet (front left to back right). Place the sample info sheet in a zip lock bag if samples are moist and place on top of samples. Drop off or ship samples to the Agronomic Lab.

Some of the most common packaging problems are that boxes are not packaged tightly, boxes are crumbled, and soil samples get mixed together. Sometimes the lab can salvage situations like this; sometimes they cannot.

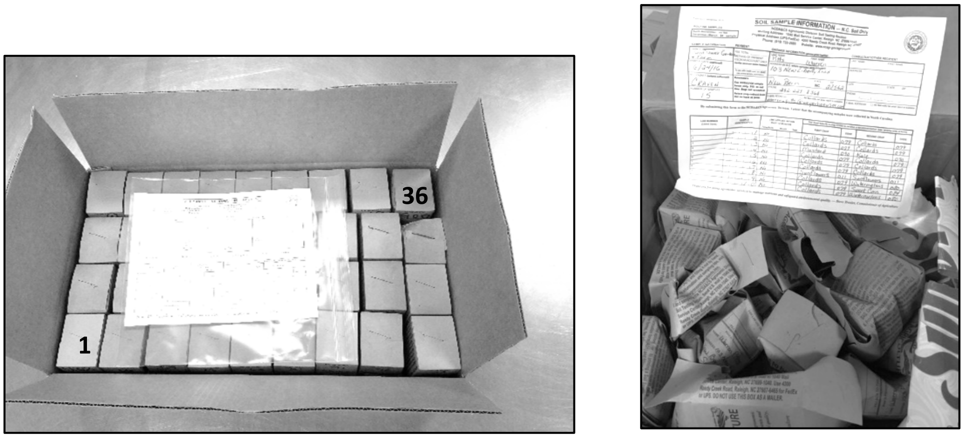


Figure 14-8. Properly and improperly packed soil samples.

Soil Sample Information Sheet (Routine)

Directions for filling out the sample information sheet and crop codes are printed on the back of the form (Figure 14-9). To get the most value from your soil test, take the time to fill in the blanks completely and be sure to list the crop or crops to be grown. Also check to make sure that the code you put on the form corresponds to the code on the sample box.

Use permanent ink or pencil. If the sheet gets wet, regular ink can bleed. The lab must be able to read your writing so take some care in completing the form. As directed earlier, mail the completed form with the sample box, keeping a copy for your future reference.

It is helpful to include your PALS/Customer number on the information sheet to ensure the correct account is used. PALS is the Public Access Laboratory-information-management System that the Agronomic Lab uses to allow you to access your recent test results. The Agronomic Lab has detailed instructions online to help you use this program.

What Does My Soil Test Report Tell Me?

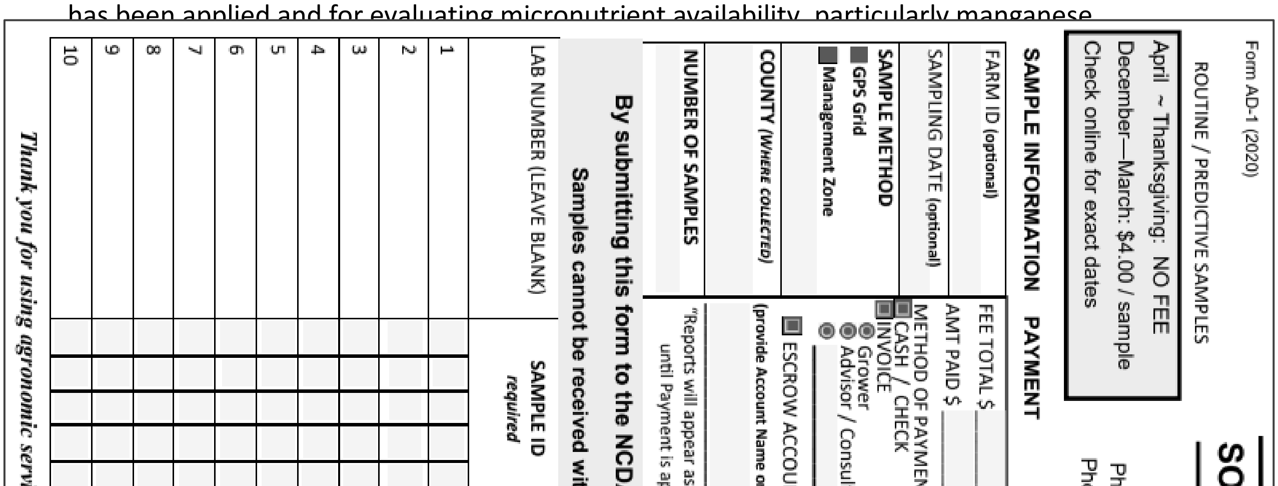
Your soil test report gives you crop specific recommendations for lime rate and nutrient rates. Test results include pH, P-Index, K-Index, Zn-Index, Cu-Index. Agronomist comments are also included on diagnostic and heavy metal reports (Figure 14-10).

The NCDA&CS Agronomic Division tries to present soil test results and recommendations in a way that is easy to understand. Reports contain explanatory information, hyperlinks to relevant publications and, often, specific comments from an agronomist. If additional guidance is required, regional agronomists and county Cooperative Extension personnel are available to help clients interpret results and implement recommendations.

Soil pH and Lime

If the test finds that the soil pH is too low for your soil type and crop, the amount of lime required to achieve the target pH is recommended. These recommendations are based on soil pH, exchangeable acidity (Ac), target pH, and residual lime credit. The residual lime credit is determined by the information you provided about the lime history of the sample.

Lime rates for crops grown on a large scale are expressed in units of tons/acre. based on the information The lowest recommended rates are 0.3 ton/acre. If the lime recommendation is 0, no lime should be applied. The pH determination is also useful for indicating when too much lime has been applied and for evaluating micronutrient availability, particularly manganese.



Form AD-1 (2020)

SO

ROUTINE / PREDICTIVE SAMPLES

Ph

Ph

April ~ Thanksgiving: NO FEE
December—March: $4.00 / sample
Check online for exact dates

SAMPLE INFORMATION

FARM ID (optional)

SAMPLING DATE (optional)

SAMPLE METHOD
■ **GPS Grid**
■ **Management Zone**

COUNTY (WHERE COLLECTED)

NUMBER OF SAMPLES

PAYMENT

FEE TOTAL $

AMT PAID $

METHOD OF PAYMEN
☐ CASH / CHECK
☐ INVOICE
○ Grower
○ Advisor / Consul
○

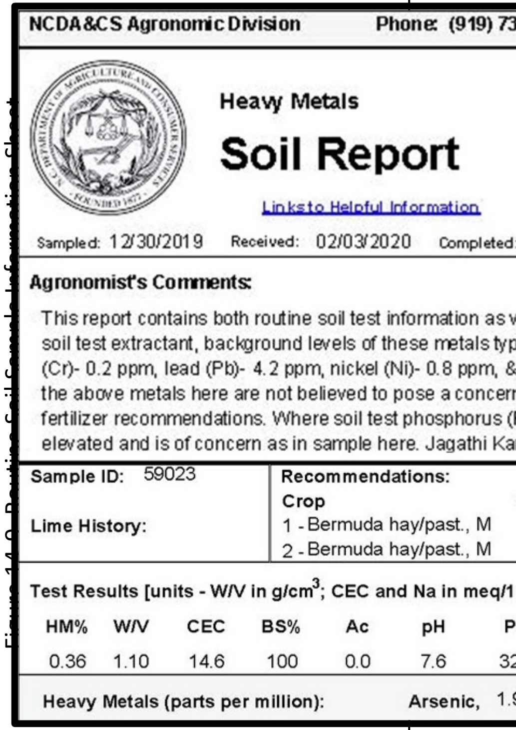
☐ ESCROW ACCOU
(provide Account Name o

"Reports will appear as
until Payment is a

By submitting this form to the NCD
Samples cannot be received wi

LAB NUMBER (LEAVE BLANK)	**SAMPLE ID** *required*
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Thank you for using agronomic serv



NCDA&CS Agronomic Division Phone: (919) 73

Heavy Metals

Soil Report

Links to Helpful Information

Sampled: 12/30/2019 Received: 02/03/2020 Completed

Agronomist's Comments:

This report contains both routine soil test information as w
soil test extractant, background levels of these metals typ
(Cr)- 0.2 ppm, lead (Pb)- 4.2 ppm, nickel (Ni)- 0.8 ppm, &
the above metals here are not believed to pose a concern
fertilizer recommendations. Where soil test phosphorus (
elevated and is of concern as in sample here. Jagathi Ka

Sample ID: 59023

Lime History:

Recommendations:

Crop

1 - Bermuda hay/past., M

2 - Bermuda hay/past., M

Test Results [units - W/V in g/cm^3; CEC and Na in meq/1

HM%	W/V	CEC	BS%	Ac	pH	P
0.36	1.10	14.6	100	0.0	7.6	32

Heavy Metals (parts per million): Arsenic, 1.

Figure 14-9. Routine Soil Sample Information Sheet

Figure 14-10. Soil Test Report.

Nutrient Index Values

Many of the nutrients are reported as index values, which provide a relative scale of actual soil-test nutrient levels. Table 14-3 relates these index values to general nutrient availability and indicates the likelihood of crop yield increase to fertilization.

In most cases, soil tests do not measure nitrogen because it does not persist long in soil. Recommendations for N (and sometimes for B) are based on research/field studies for the crop being grown, not on soil test results. Phosphorus and potassium values are based on test results and a crop response to nutrient additions is not expected when the index value is above 50. If they are below 50, follow the fertilizer recommendations given.

Table 14 –3. Relationship between soil test index and yield

Index Range	Nutrient	Crop Yield in Response to Nutrient Application					
		Status	**P+**	**K+**	**Mn**	**Zn**	**Cu**
1-10	Very Low	high	high	high	high	high	high
11-25	Low	high	high	high	high	high	high
26-50	Medium	med/low	med/low	none	none	none	none
51-100	High	none	low/none	none	none	none	none
100+	Very High	none	none	none	none	none	none

+ Crop response to phosphate (P_2O_5) and potash (K_2O) decreases as the soil index approaches 50.

Micronutrients are required in much lower amounts, so crop responses are not expected when index values are above 25. When soil test index values are less than these critical levels, the soil test report will indicate the amount of nutrient to apply for optimum plant growth in the Recommendations Section of the report.

You should pay special attention to micronutrient levels. If $, pH$, $pH, C or Z notations appear on the soil report, refer to NCDA&CS publication*: $ NOTE: Secondary Nutrients & Micronutrients.* Soil test index values above 100 indicate excessive amounts are present in the soil.

Sodium (Na) is evaluated for all samples. Values less than 0.4 meq/100 cm3 are inconsequential to plant nutrition. However, on sandy soils, values of 0.4 to 0.5 meq/100 cm3 or greater may indicate that sodium accounts for 15 to 20% of the CEC as calculated by the exchangeable sodium percentage. Such levels could interfere with plant uptake of calcium, magnesium and potassium and also adversely affect soil structure. When Na is excessive, soluble salt levels may be high enough to cause root injury.

Plant Tissue Sampling and Analysis

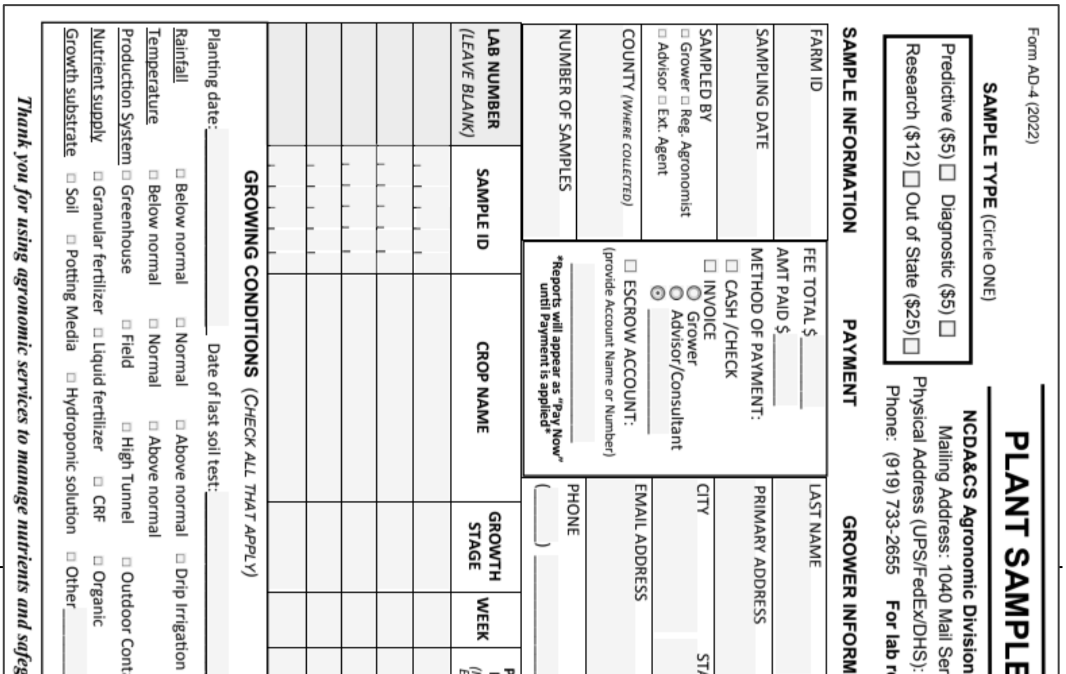
Residuals permits do not routinely require plant tissue analysis. Plant tissue analysis, or tissue testing, is a chemical measurement of essential plant nutrients within a sample of plant tissue. It can be used to routinely monitor the nutrient status of a crop. More importantly, however, you can use to identify nutrient deficiencies and toxicities before they reach a critical stage.

Tissue sampling methods depend on the crop and the purpose of the sample. The plant part to select depends on the crop and sometimes on the stage of growth as well. Guidelines for sample collection may differ based on whether you are trying to diagnose a problem or just monitor nutrient status. In all cases, it is important to collect enough material to represent the entire area of interest. To receive good interpretations, you must submit a good sample.

When sampling plant tissue, you must submit the correct plant part(s) to receive valid interpretations and recommendations on a Plant Analysis Report. Collecting samples incorrectly can result in misleading findings and inappropriate nutrient management decisions. See the NCDA&CS *Plant Tissue Analysis Guide* for detailed information on appropriate plant parts to sample.

When monitoring the status of seemingly healthy crops or plants, take samples from a uniform area. If the entire field is uniform, one composite sample can represent a number of acres. If there are variations in soil type, topography, or crop history, take multiple samples so that each unique area is represented by its own sample.
You can pick up sample containers at any county Cooperative Extension Office or at the Agronomic Division Office in Raleigh (they are not available by mail). You can also submit tissue samples in *paper bags* along with a completed Plant Sample Information Form (Figure 14-11). ***Do not*** use plastic bags.

When trying to diagnose problems with a crop, take samples from both "good" and "bad" areas. Comparison between the groups of samples helps pinpoint the limiting element. Comparative sampling also helps factor out the influence of drought stress, disease, or injury.
Again, consult the NCDA&CS *Plant Tissue Analysis Guide* to determine the appropriate part of the plants to sample.



Form AD-4 (2022)

PLANT SAMPLE

SAMPLE TYPE (Circle ONE)
Predictive ($5) ☐ Diagnostic ($5) ☐
Research ($12) ☐ Out of State ($25) ☐

NCDA&CS Agronomic Division
Mailing Address: 1040 Mail Ser
Physical Address (UPS/FedEx/DHS):
Phone: (919) 733-2655 **For lab r**

SAMPLE INFORMATION
FARM ID
SAMPLING DATE
SAMPLED BY
☐ Grower ☐ Reg. Agronomist
☐ Advisor ☐ Ext. Agent
COUNTY (*WHERE COLLECTED*)
NUMBER OF SAMPLES

PAYMENT
FEE TOTAL $
AMT PAID $
METHOD OF PAYMENT:
☐ CASH /CHECK
☐ INVOICE
○ Grower
○ Advisor/Consultant
○
☐ ESCROW ACCOUNT:
(provide Account Name or Number)
Reports will appear as "Pay Now" until Payment is applied

GROWER INFORM
LAST NAME
PRIMARY ADDRESS
CITY
ST
EMAIL ADDRESS
PHONE
(   )

LAB NUMBER (*LEAVE BLANK*)	**SAMPLE ID**	**CROP NAME**	**GROWTH STAGE**	**WEEK**

GROWING CONDITIONS (*CHECK ALL THAT APPLY*)
Planting date: ___ Date of last soil test: ___
Rainfall ☐ Below normal ☐ Normal ☐ Above normal ☐ Drip Irrigation
Temperature ☐ Below normal ☐ Normal ☐ Above normal
Production System ☐ Greenhouse ☐ Field ☐ High Tunnel ☐ Outdoor Cont
Nutrient supply ☐ Granular fertilizer ☐ Liquid fertilizer ☐ CRF ☐ Organic
Growth substrate ☐ Soil ☐ Potting Media ☐ Hydroponic solution ☐ Other

Thank you for using agronomic services to manage nutrients and safeg

Figure 14-11. Plant Sample Information Sheet.

It can be very helpful to collect and submit “matching” soil samples from the root zones of both “good” and “bad” plants for the most complete evaluation. An evaluation of the soil in the affected area can be made along with an evaluation of the plant tissue. Sampling healthy and unhealthy plants, and their respective soil, is very effective in problem solving. The diagnostic soil test is used when samples are collected because of an observed problem situation. The purpose of a diagnostic test is to identify specific nutrient deficiencies or excesses that may be preventing optimal plant growth.

Diagnostic soil samples are collected like routine ones except you submit a Diagnostic Soil Sample Information Sheet (Figure 4-12). Diagnostic interpretations require more details than predictive. When sending matching soil samples indicate the matching sample ID in the designated areas on the information sheet. Be sure the grower name and address are exactly the same on all matching information sheets. Consult NCDA&CS’s *Submitting a Diagnostic Soil Sample with a Problem Plant Sample* for more information.

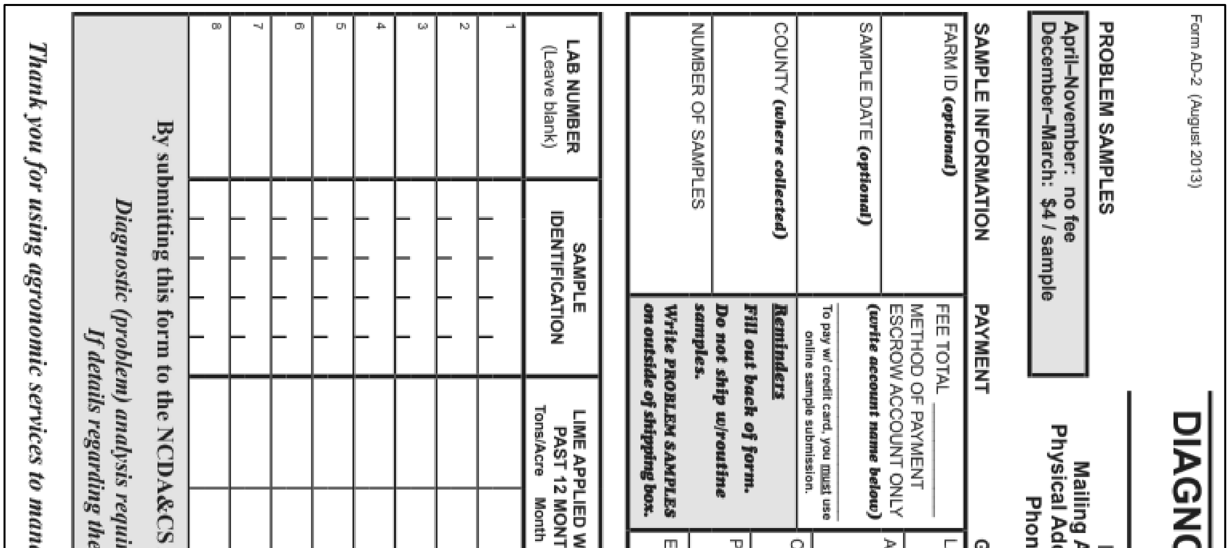
What Does My Plant Tissue Report Tell Me?

The plant analysis report has three sections: laboratory results, interpretation and recommendations. Results include concentrations of 11+ essential plant nutrients and sodium, on a dry-weight basis. Ratios of important elements, including N:K, N:S and Fe:Mn, are also provided (Figure 14-13).

Interpretation is based on sufficiency ranges established for each crop. Nutrient concentrations are converted to a standard index scale of 0–124. The scale is divided into zones that indicate whether nutrient levels are deficient, low, sufficient, high or in excess. An index value of 50–75 is desirable, in most cases.

When appropriate, the report contains fertilizer recommendations and supporting information. Diagnostic reports may also provide site specific suggestions for corrective action. The inclusion of these suggestions will depend on how completely you filled out the sample information form.

A plant analysis may indicate that a nutrient deficiency or toxicity does not exist. Therefore, a factor other than nutrition may be responsible for poor plant growth or visual symptoms.



Form AD-2 (August 2013)

DIAGNO

Mailing A
Physical Add
Phon

PROBLEM SAMPLES

April–November: no fee
December–March: $4 / sample

SAMPLE INFORMATION

FARM ID ***(optional)***

SAMPLE DATE ***(optional)***

COUNTY ***(where collected)***

NUMBER OF SAMPLES

PAYMENT

FEE TOTAL ________

METHOD OF PAYMENT
ESCROW ACCOUNT ONLY
(write account name below)

To pay w/ credit card, you must use online sample submission.

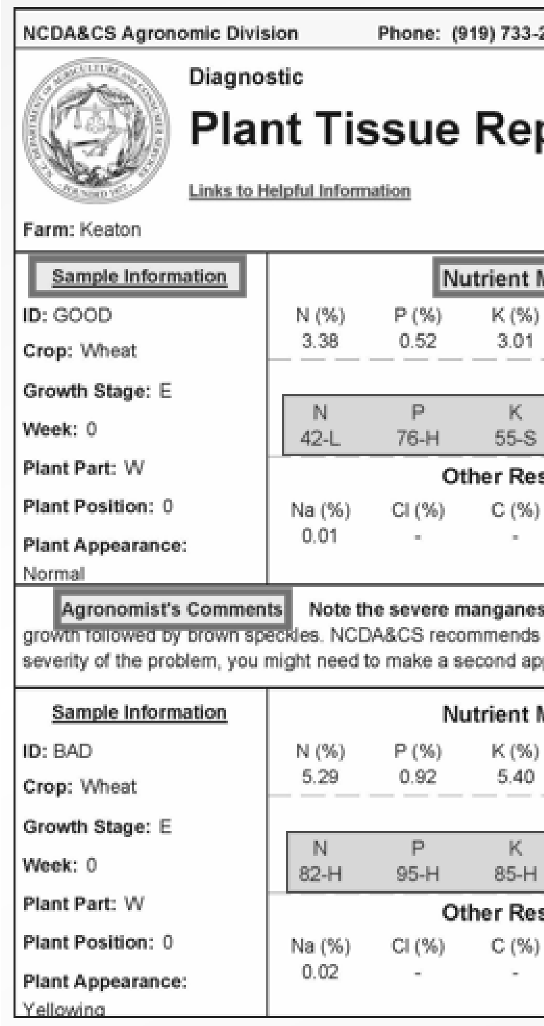
Reminders
Fill out back of form.
Do not ship w/routine samples.
Write PROBLEM SAMPLES on outside of shipping box.

LAB NUMBER (Leave blank)	SAMPLE IDENTIFICATION	LIME APPLIED W PAST 12 MONT Tons/Acre	Month
1			
2			
3			
4			
5			
6			
7			
8			

By submitting this form to the NCDA&CS
Diagnostic (problem) analysis requi
If details regarding the

Thank you for using agronomic services to man

Figure 14-12. Diagnostic Soil Sample Information Sheet.



NCDA&CS Agronomic Division **Phone: (919) 733-**

Diagnostic

Plant Tissue Rep

Links to Helpful Information

Farm: Keaton

Sample Information

ID: GOOD
Crop: Wheat
Growth Stage: E
Week: 0
Plant Part: W
Plant Position: 0
Plant Appearance:
Normal

Nutrient M

N (%)	P (%)	K (%)
3.38	0.52	3.01

N	P	K
42-L	76-H	55-S

Other Res

Na (%)	Cl (%)	C (%)
0.01	-	-

Agronomist's Comments **Note the severe manganes**
growth followed by brown speckles. NCDA&CS recommends
severity of the problem, you might need to make a second ap

Sample Information

ID: BAD
Crop: Wheat
Growth Stage: E
Week: 0
Plant Part: W
Plant Position: 0
Plant Appearance:
Yellowing

Nutrient M

N (%)	P (%)	K (%)
5.29	0.92	5.40

N	P	K
82-H	95-H	85-H

Other Res

Na (%)	Cl (%)	C (%)
0.02	-	-

Figure 14-13. Plant Tissue Report.

Plant analysis reports also provide valuable data for making fertilizer management decisions as well as an excellent record of crop nutrient use and needs from year to year under different environmental conditions. Combined with yield data, they can also document nutrient use on fields where residuals are land applied. In this way, plant analysis reports can serve as valuable evidence of responsible crop management and environmental stewardship.

Forage Analysis

Plant tissue analysis does not include analysis of forage plants for use as animal feed. Forage analysis is a test to determine if there are potential problems with using a crop for animal feed. It is provided through the NCDA&CS Food & Drug Protection Division, not through the Agronomic Division. Forage analysis is not required by the permit, but it the best way to determine the nutrient content of a forage and the potential for nitrate toxicity.

References

References, as well as manuals, appendices and formula sheets are available on the WPCSOCC website:

deq.nc.gov/opcert

Look for Wastewater / manuals downloads appendices references

Chapter 15

Consequences of Violating the Permit

All conditions in a land application of residuals permit are important. Ignorance of permit conditions or failure to adhere to them usually results in non-compliance and the possible enforcement actions against the Permittee.

The Environmental Management Commission (EMC) has the authority to require and issue permits for land application of residuals systems. The EMC also has the authority to ensure that all permitted land application of residuals systems are properly operated and maintained in accordance with their permit conditions.

The enforcement powers of the EMC are outlined in General Statute 143-215.6, which describes the types of actions and establishes the protocols upon which enforcement procedures and policies are based. As with permit issuance, the EMC delegates its enforcement authority to the Director of the Division of Water Resources.

Consequences for the Permittee – Enforcement Action

Enforcement actions are usually initiated by regional office inspectors when they find permit violations during a compliance inspection, complaint investigation, or annual report review. There are several types of enforcement actions that DWR can use to prompt or compel a permit holder to comply with their permit.

☐ ***Notice of Deficiency.*** A Notice of Deficiency (NOD) is a letter sent to the Permittee for minor violations that cause no harm to the environment or public health. The NOD may require corrective action and/or a response.

☐ ***Notice of Violation.*** A Notice of Violation (NOV) is a letter sent to the Permittee giving notice of non-compliance with the permit and/or environmental law(s). The letter notifies the Permittee of the specific violation and associated regulation. In addition, the NOV describes the requirements that the Permittee must take to correct the violation or must take as a result of the violation. The NOV usually indicates that the Permittee must complete the corrective actions and notify the regulatory agency within a certain period of time.

Examples of possible violations are:

- Failing to pay annual renewal fee.
- Failing to submit the annual report or submitting it late.

- ○ Applying residuals that do not meet pathogen reduction or vector attraction reduction requirements.
- ○ Applying residuals that exceed one or more pollutant (metal) limits.
- ○ Failing to notify regional office prior to an application event.
- ○ Applying residuals within a setback area.
- ○ Accepting and applying residuals from a generator/preparer that is not listed on Attachment A as an approved source.
- ○ Allowing runoff of residuals from the application area.

☐ ***Civil Penalty.*** Civil penalties are monetary fines assessed against a Permittee for violation(s) of the permit and environmental regulations. The assessment of a penalty is based on the specifics of each civil penalty case. The law requires consideration of specific assessment factors by the assessor for each case. General Statute 143-215.6A allows the assessment of civil penalties of up to $25,000 per day per violation. Each day that a violation occurs may be considered as a separate violation.

☐ ***Permit Revocation.*** The Division can revoke a permit for any of the following:

- ○ Violating any terms or conditions of the permit.
- ○ Obtaining a permit by misrepresentation or failure to disclose fully all relevant facts.
- ○ Refusing to allow authorized employees of the Department to inspect the system, review records, or to take samples.
- ○ Failing to pay the annual fee within 30 days after being billed.

☐ ***Special Order of Consent.*** A Special Order by Consent (SOC) is an agreement that a permit holder enters into with the Environmental Management Commission in order to achieve some stipulated actions designed to reduce, eliminate, or prevent water quality degradation. Limits set for particular parameters under a Non-Discharge permit may be relaxed in an SOC, but only for a time determined to be reasonable for making necessary improvements to the program.

☐ ***Injunctive Relief.*** Injunctive relief is a court order to discontinue or prevent an existing or potential violation. DWR can request the N.C. Attorney General to issue a court order to restrain violation or threatened violation and for other further relief as the court deems proper. This option may be used if a Permittee demonstrates consistent non-compliance with regulations or if an imminent danger exists to health or the environment.

☐ ***Criminal Penalty.*** DWR refers environmental crimes to the State Bureau of Investigation (SBI). An environmental crime is a willful and knowing violation of permit conditions and environmental regulations. These types of violations are deliberate acts that are not the product of an accident or mistake. If convicted of an environmental crime, a violator can face fines up to $250,000 per day, a prison sentence of up to 10 years, or both.

In addition, a violator can also be investigated by the Federal Bureau of Investigation (FBI) and prosecuted by the EPA for violations of the Clean Water Act. If convicted, the violator can face additional fines and additional prison time.

Consequences for the Operator – Disciplinary Actions

The enforcement actions described above are actions that DWR can take against the permit holder. It is the Permittee's responsibility to ensure that the system is properly operated, properly maintained, and is in compliance with permit conditions. Ultimately, it is the Permittee who is responsible for any violation of a permit condition, regardless of who is actually operating the system.

However, this doesn't mean that certified operators aren't accountable for their actions. When it appears that operator misconduct or negligence have contributed to noncompliance, an inspector can request that the operator attend an informal "show cause" meeting at the DWR regional office. During this fact-finding meeting, the inspector presents the operator with the observed or perceived problems. The operator then has an opportunity to answer or explain the allegations.

If the regional office staff is satisfied with the outcome of the meeting, there may be no further action. However, if staff remain concerned about the operator's conduct, they may refer the matter to the WPCSOCC with a recommendation for disciplinary action.

☐ ***Disciplinary Action by the WPCSOCC.*** The WPCSOCC can take disciplinary action against a certified operator based on one or more of the following grounds:

- ○ Failure to use reasonable care or judgment in the performance of duties.
- ○ Failure to apply their knowledge or ability in the performance of duties.
- ○ Incompetence or the inability to perform duties.
- ○ Practicing fraud or deception.

When presented with a case of alleged operator negligence, incompetence, or deceit, a disciplinary committee is convened. The committee is made up of several WPCSOCC members and a certified operator who holds the same type of certificate as the operator involved in the case. After hearing from both the regional office staff and the operator, the committee must determine if disciplinary action is warranted. It can take one of three actions:

- ○ Issue a letter of reprimand to the operator.
- ○ Suspend the operator's certificate(s).
- ○ Permanently revoke the operator's certificate(s).

If a certification is revoked, an operator must wait two years after revocation before petitioning the Commission for any new certification. The WPCSOCC will only consider certification if there is substantial evidence that the conditions leading to the revocation have been corrected.

If the WPCSOCC determines the operator is eligible for a new certification, the operator will be required to take and pass another examination for certification. All examination eligibility requirements must be met. Operational experience accrued prior to the revocation of any previously held certification(s) cannot be used to meet examination eligibility requirements.

Taking disciplinary action against a certified operator is an unpleasant task. Members of the WPCSOCC consider each case seriously, thoroughly, and fairly. They know what it takes to get certified and understand that an operator's livelihood often depends on staying certified. It is their sincere hope that all certified operators view their certificates with a sense of pride and professional ethics. However, their primary duty is to prevent harm to human health and the environment.

☐ ***Criminal Penalties.*** DWR can refer certified operators as well as Permittees to the State and/or Federal Bureau of Investigations (SBI / FBI) if they are suspected of environmental crimes. Remember, environmental crimes are willful and knowing violations. They are deliberate acts that are not the product of an accident or mistake. Like Permittees, operators can be prosecuted by the state or federal government and be fined and/or sentenced to probation or prison.

Permit Holder Responsibilities Versus Operator Responsibilities

Where do the responsibilities of a permit holder and a certified operator begin and end? The bottom line is:

- The owner must provide the resources necessary for the operator to do his or her job and must allow the operator to do that job as required by 15A NCAC 8G (Operator Rules).

- The operator must make reasonable efforts to secure the resources needed to properly operate and maintain the system and must attempt ensure compliance with the owner's permit.

As an operator, you can't force a permit holder to spend money on maintenance or repairs. You can't force a permit holder to hire enough staff to properly operate and maintain the system. But, as it says above, you must make reasonable efforts to get what you need to do your job and comply with the permit and regulations as best you can under the circumstances.

This is one of several reasons why documentation and good record keeping are essential. Your logbook is your friend. Accurate, detailed, and timely entries can demonstrate to an inspector that you are doing your best to maintain a high level of operations. Keep copies of emails, memos, or other communication with the owner. Written communication is necessary to show that you have reported to the owner any actions needed to prevent or eliminate a violation as well as any conditions that may cause or are causing a violation.

Consider the Risks

You may find yourself being pressured by an employer or Permittee not to keep such thorough records, to falsify them, or in some other way to jeopardize your certificate(s). Even with no outside pressure, you may find yourself tempted to take questionable shortcuts or unethical actions to save yourself from a difficult situation. The penalties for misconduct or environmental crimes can be harsh, loss of employment, loss of career, and in some cases personal legal liability.

The WPCSOCC wants you to be a proud front-line environmental professional, playing a key role in protecting and preserving the public health and environment of North Carolina. By managing residuals responsibly and conscientiously, you will advance the practice of beneficial reuse and contribute to its economic sustainability and to your continued livelihood.