GEI Consultants

Nitrogen Mineralization Rate Studies

March 19, 2024

PRESENTATION OBJECTIVES

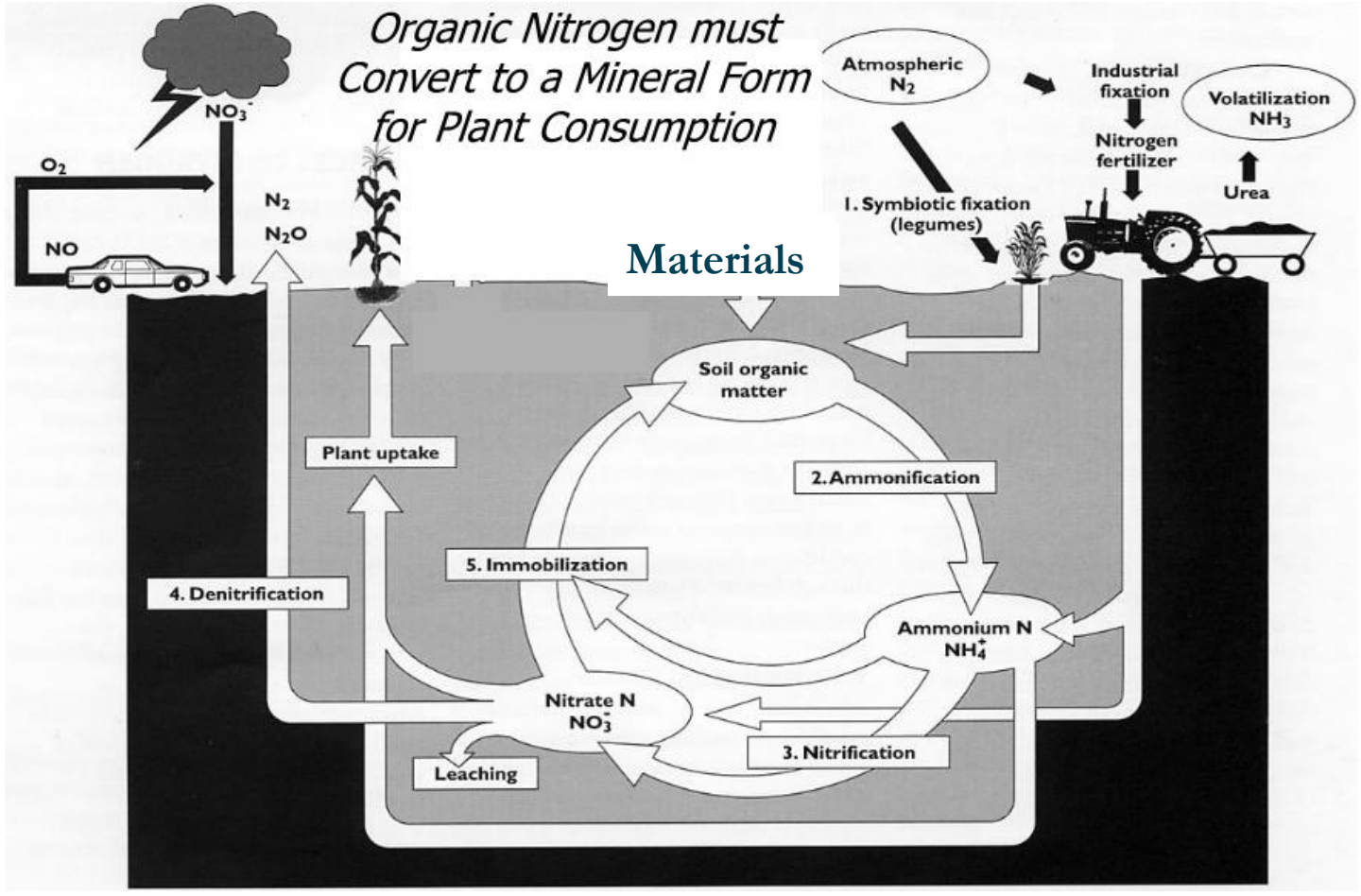
1. Land Application Nitrogen Management Primer
2. What is a nitrogen mineralization rate study?
3. Biosolids mineralization rates
4. How do rates for biosolids compare to other organic-based byproducts?
5. Example: Paper Mill Residuals

Land Application Nitrogen Management Primer

Land Application Benefits

- Improves soil structure
  - Increases infiltration
  - Reduces runoff
  - Improves transfer of oxygen
- Increases water holding capacity
  - Reduces potential to become flowable
  - Lessens opportunity to leach soluble constituents
- Provides energy for microbes
- Enhances nutrient holding capacity and ability to retain contaminants
- Sequesters soil carbon
  - Landfill gas avoidance
  - Increase soil carbon
- Reduces need for commercial fertilizer
- Diverts materials from being landfilled when properly managed
- **IMPROVES SOIL HEALTH AND IMPROVES SUSTAINABILITY**

Introduction to Nitrogen Cycle

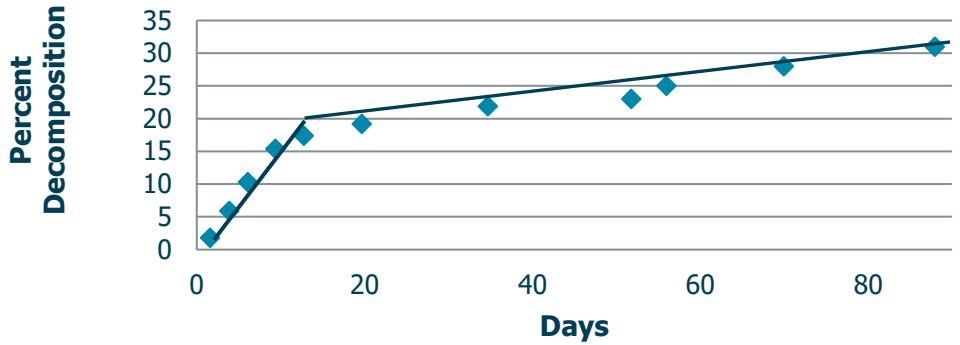


What is a Nitrogen Mineralization Study?

Purpose of Nitrogen Mineralization Study

- Results used as a tool to aid contractors, regulators, and plant operators quantify and manage the nitrogen content of land-applied biosolids or any other organic based by-product over time.

Nitrogen Mineralization Studies



Example Decomposition Curve

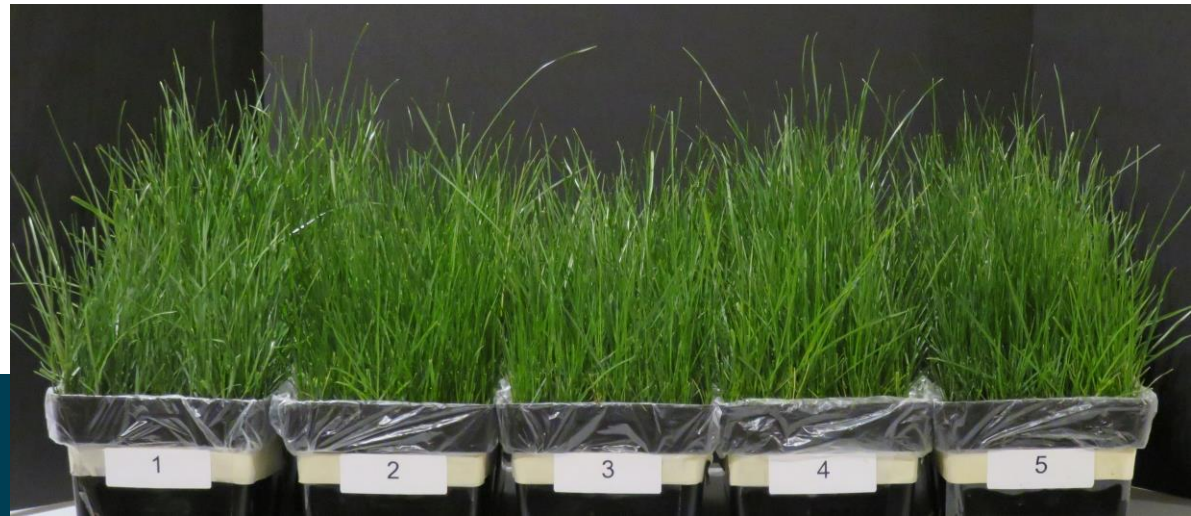
- Highly controlled laboratory study
- Soil microbes release C as CO2 during decomposition.
- Decomposition kinetics determined in the lab.
- Organic carbon decomposition predicted over 4 years with proprietary model.
- Lab procedures and model developed by John Gilmour, PhD, former Dean of the University of Arkansas Department of Agriculture which have been corroborated with long-term field studies

Other Means to Assist in Nitrogen Management

- Greenhouse Studies
- Field Plots and Program Observations

Greenhouse Studies

- Typically Comparative Studies
- Evaluate Byproduct Performance by Quantifying
  - Nutrients available to plants
  - Nutrient immobilization (e.g. high carbon byproducts) and how to mitigate
  - Influence of a byproduct on soil pH
  - Potential salinity issues
  - Potential toxicity
- Confirm N-mineralization study results
- Provide Visual Demonstration



Field Plots and Program Observations

- Field plots are a substitute for greenhouse studies and provide field demonstrations, but can be influenced by climate and other factors
- Program observation invaluable in identifying long-term benefits or trends in material performance

Biosolids Mineralization Rates

Regulatory Requirements

- NR 204.07(8)(b) “Standard” nitrogen mineralization rate for sewage sludge
  - “Unless specific mineralization rates are determined by the permittee, the following mineralization rates are to be used in calculating the available organic nitrogen from initial sludge application and from carryover of previous years' application: 25%-12%-6% in years 1 through 3.”
  - NOTE: these were developed primarily form UW field plot studies across the State
- Language taken from WPDES permits for most industrial by-products:
  - The total number of pounds of nitrogen that may be landspread per acre per year shall not exceed the nitrogen needs of the cover minus any other nitrogen added to the landspreading site, including fertilizer or manure. Nitrogen applied can be calculated on the basis of plant available nitrogen, as long as the release of nitrogen from the organic material is credited to future years. This permit requires that the Total Kjeldahl Nitrogen application amount in any calendar year shall not exceed 165 pounds per acre per year on any site, except when alternate numerical nitrogen loading limits are approved in writing via the department’s landspreading management plan approval.

Best Practices

- N min and nitrification activity in soil are sensitive to the following (per Rigby et al. [2016]):
  - Biosolids application rate
  - Climatic regions for similar biosolids types (more biological activity in warmer climates)
  - Differences in upstream wastewater treatment processes that affect the balance of primary and secondary
  - Soil type
  - Sludge handling
    - Cake vs. Slurry
    - Drying method (mechanical vs. thermal)
- Consequently, greater inputs of supplementary mineral fertilizer N may be supplied than are required for crop production, leading to an increased risk of fertilizer N runoff and higher application costs than is necessary.
- **Bottom Line: Economic and environmental benefits are possible by conducting a nitrogen mineralization study.**

National Perspective

- Gilmour et al. (2000) studied biosolids in Arkansas, Michigan, Virginia, and Washington state using both long-term field studies completed by major universities and his predictive modeling.
  - Quantified mineralization rates of biosolids to determine the amount of plant available nitrogen (PAN) released when biosolids are land-applied to agricultural crops. The biosolids studies had ‘typical’ carbon and nitrogen contents.
  - General Biosolids Findings:
    - Biosolids decomposition was not related to biosolids treatment process
    - Biosolids percent decomposition and creation of PAN from biosolids organic nitrogen followed similar patterns supporting the use of decomposition rates to estimate PAN
    - Biosolids decomposition varied among biosolids and across locations and years for the same biosolids. However, the use of an average biosolids decomposability rate in the estimation of PAN may suffice in the case of fresh biosolids. A much smaller decomposability was observed for biosolids that had been composted or stored in a lagoon for an extended time period.

National Perspective (Con't)

- Comparative Study Findings:
  - Good relationships between crop nitrogen content, crop nitrogen uptake, or crop yield and inorganic nitrogen fertilizer (PAN) were obtained for all locations and years. These relationships were used to determine PAN in all biosolids under field conditions.
  - Ammonia volatilization varied from 10% to 85%, with an average of 37%
- Predictive Model Findings:
  - The computer model provided good predictions of biosolids PAN created during the growing season under field conditions.
  - Biosolids PAN created during the growing season under field conditions was related to biosolids total nitrogen content through the predictive model and biosolids-specific parameters.
  - Estimates of PAN from the computer model using actual biosolids decomposability and actual field weather required actual analytical data to estimate PAN.

How do rates for biosolids compare to other organic-based byproducts?

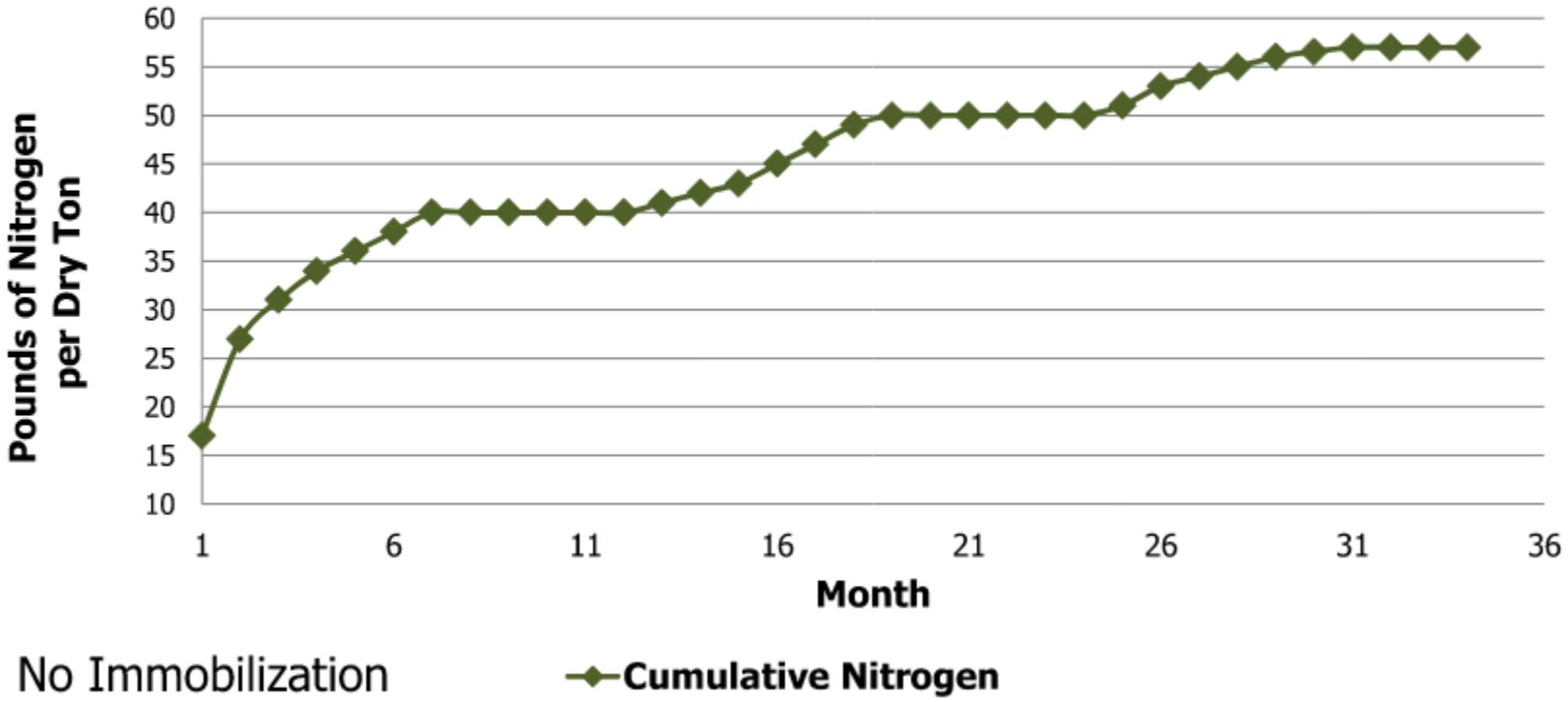
Example Mineralization Rates

- Application of biosolids and other organic based by-products impact soil nitrogen and its availability to plants
- Understanding the decomposition kinetics of carbon and the relationship of carbon to nitrogen (C:N) allows us to successfully manage biosolids and other organic based by-products

	Example rapid decomposition rates (kr, daily %)	Example C:N values
Tomato waste	0.110	28:1
Alfalfa	0.118	9:1
Dairy manure	0.018	18:1
Municipal biosolids	0.021	7:1
Combined papermill solids	0.050	28:1
Primary papermill solids	0.005	140:1

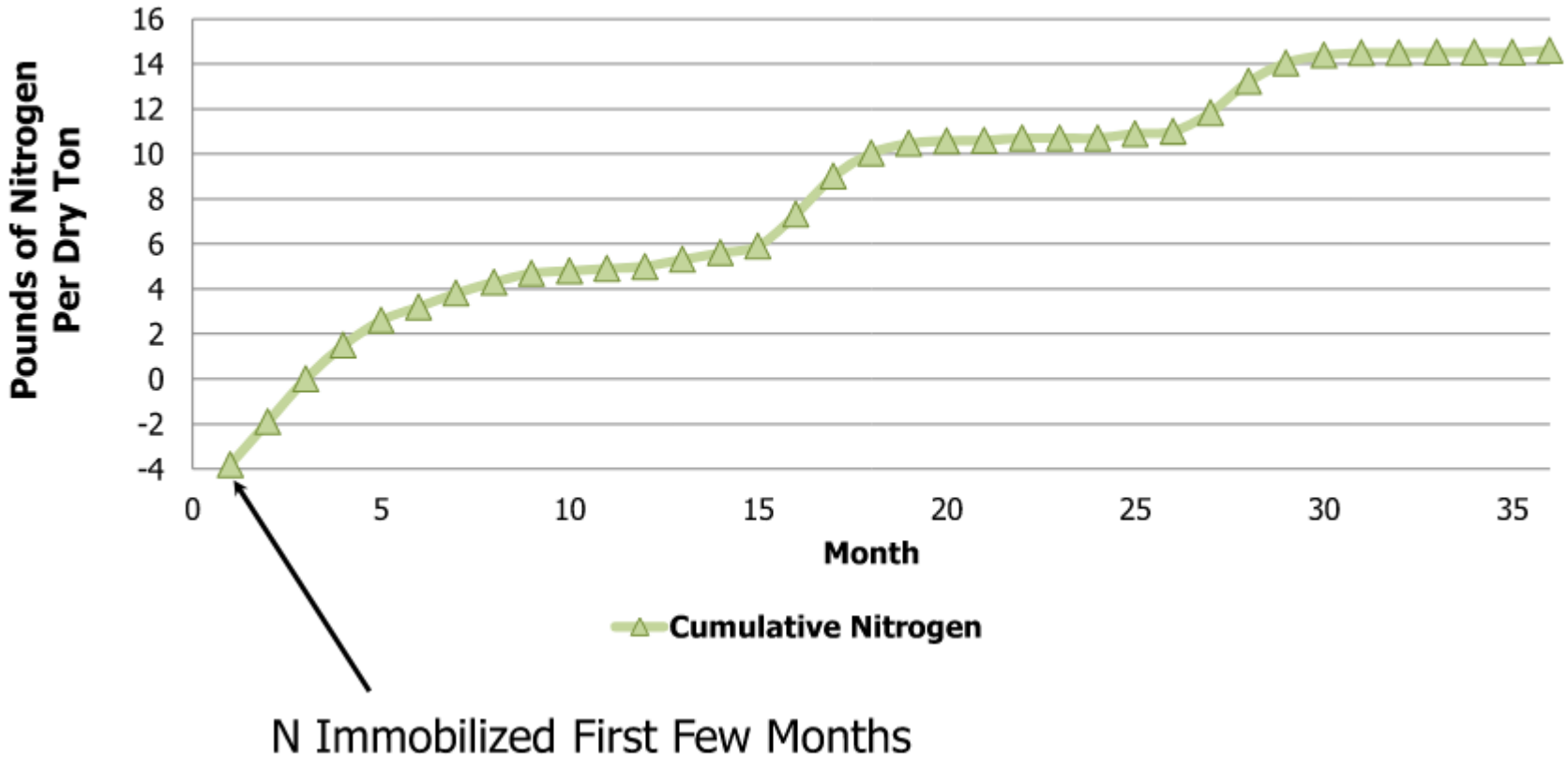
Nitrogen Mineralization (Low C:N)

C:N = 8:1

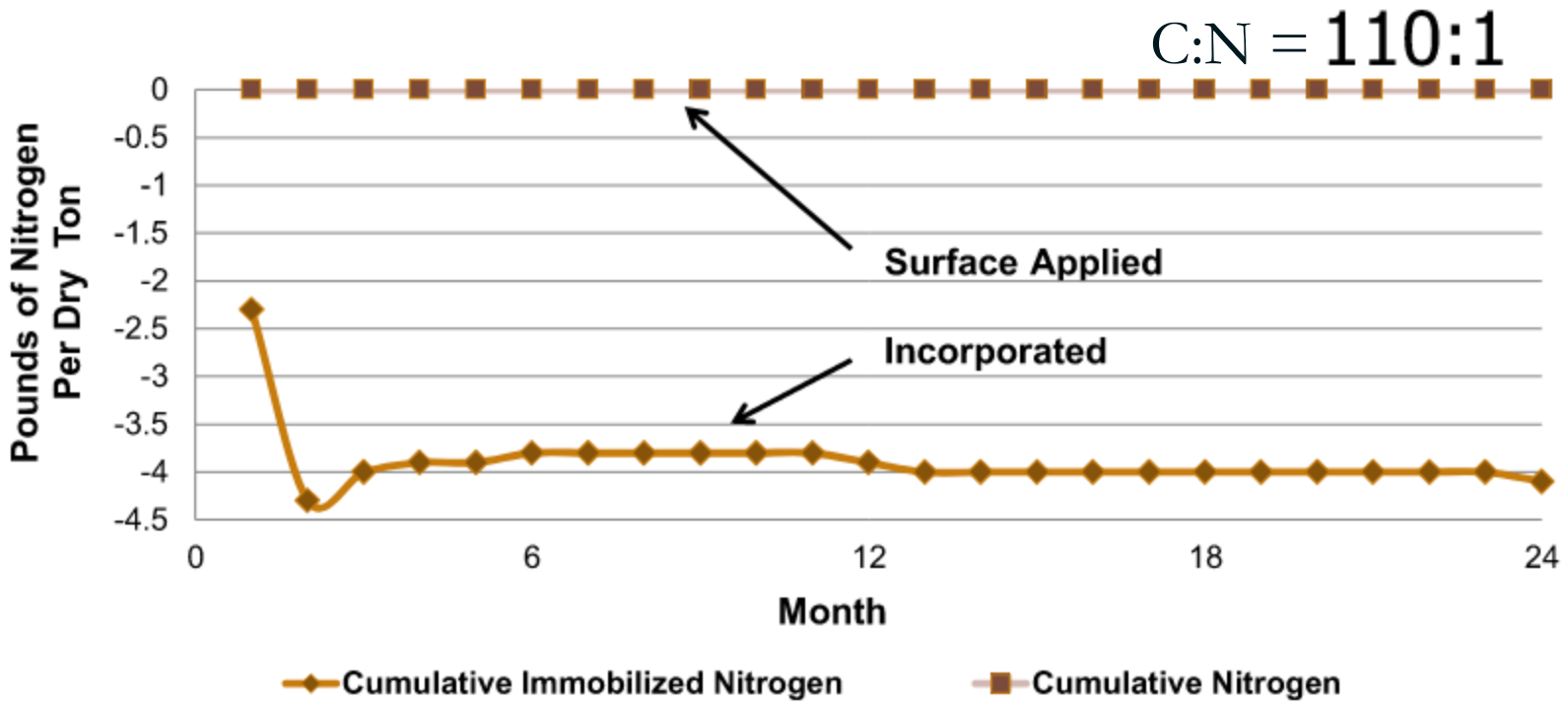


Nitrogen Mineralization (Medium C:N)

C:N = 21:1



Nitrogen Mineralization (High C:N)



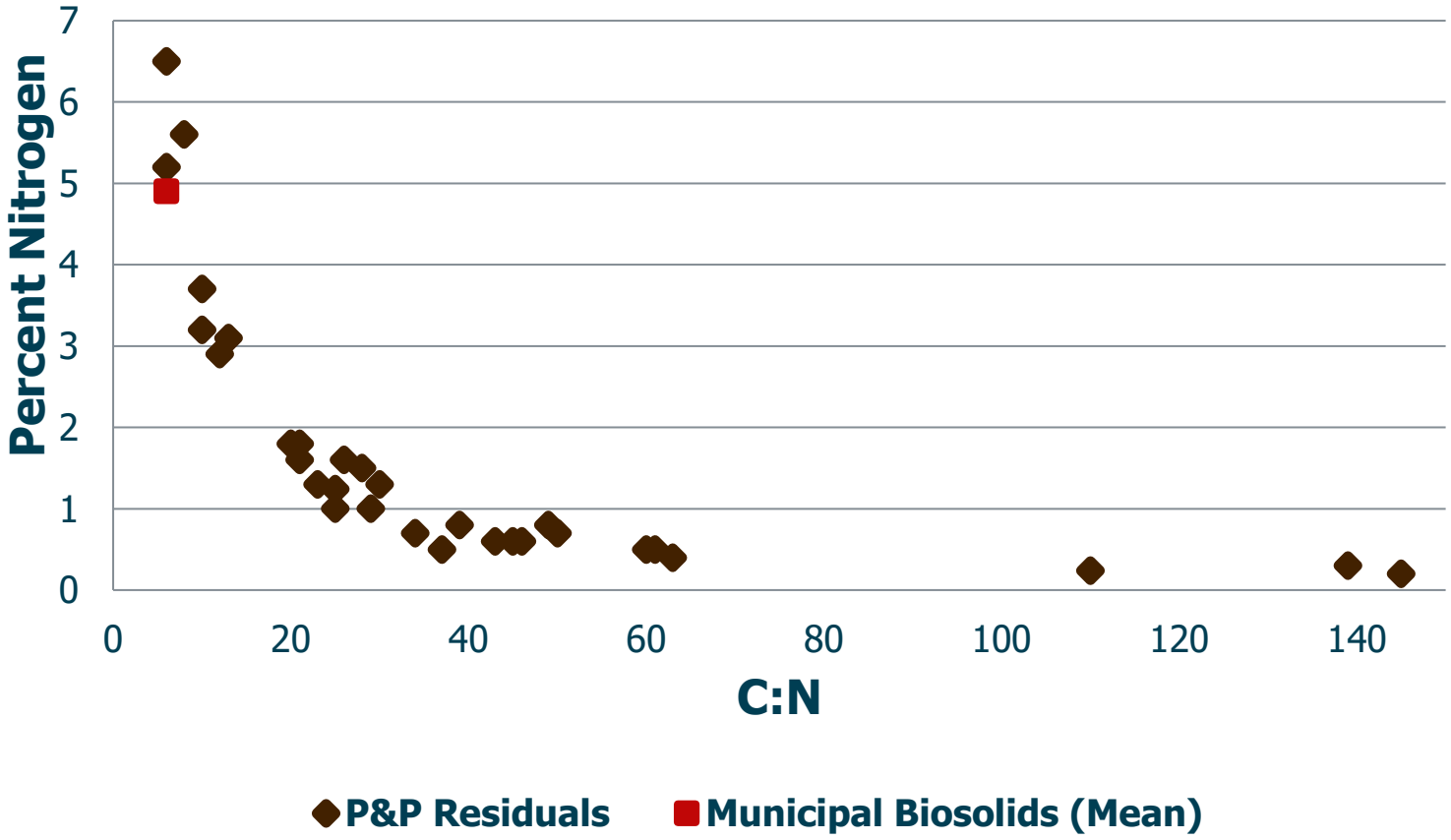
Example: Paper Mill Residuals

Performance of Papermill Residuals differs from Biosolids due to Carbon Source and Treatment System

- Primary Solids
  - High carbon (primarily wood based)
  - Potentially high calcium
  - Low phosphorus
- Secondary Solids (Biomass)
  - High carbon
  - High nitrogen
  - Moderate phosphorus

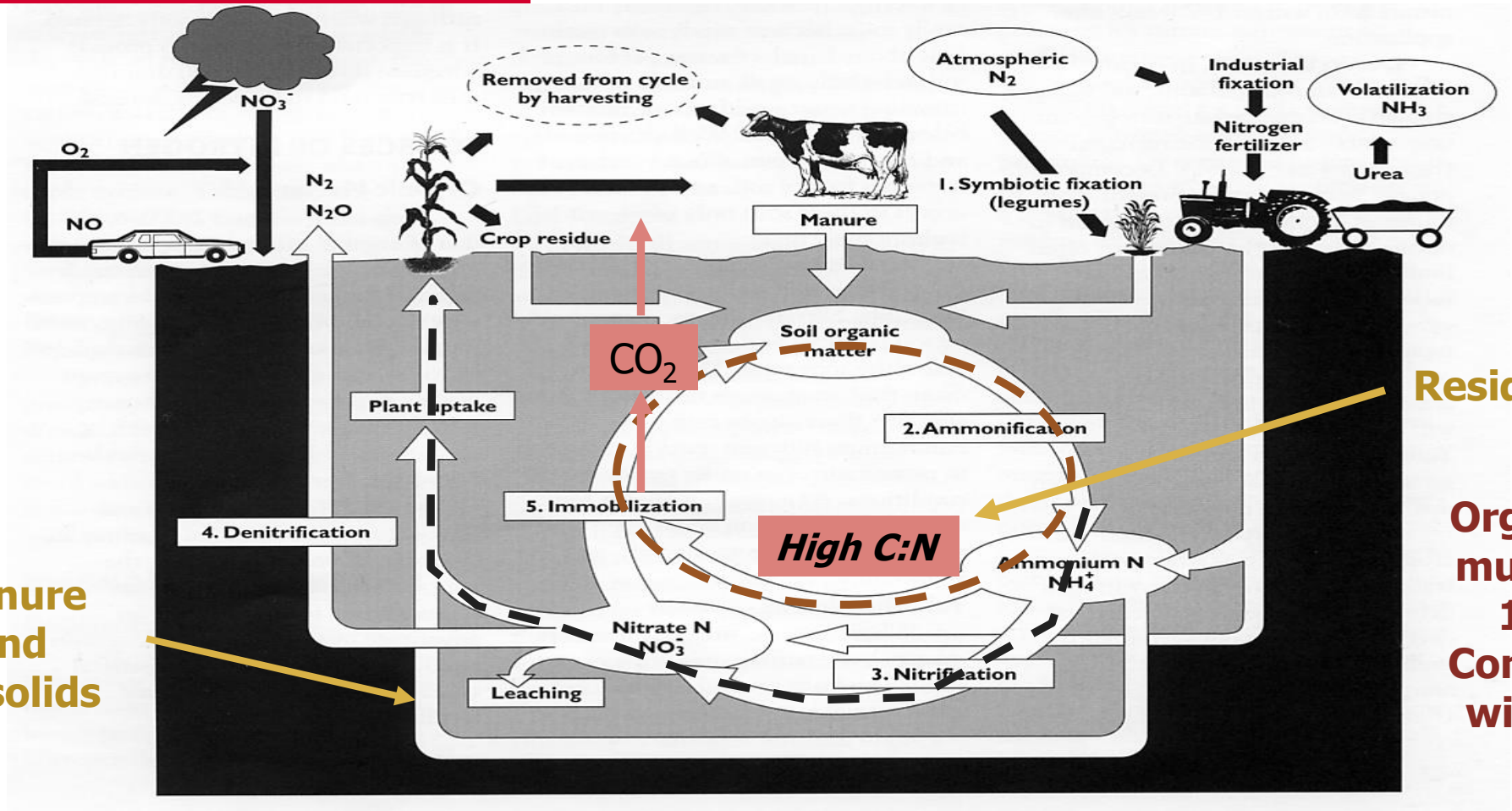
Percentage of Secondary Solids Governs Nutrient Content and C:N

Biosolids vs. Residuals



PAN = plant-available nitrogen <u>when incorporated</u>.
Total PAN is nitrogen released over a period of 2 to 4 years.

Nitrogen Cycle



Residuals

Organic C:N must fall to 15:1 to Continue on with Cycle

Manure and Biosolids

Carbon to Nitrogen Ratio (C:N) Affect on Plant Growth

- Low C:N less than 15:1
  - Nitrogen readily available to decomposing microbes and crops
  - Organic nitrogen converted to mineral, or plant-available nitrogen (PAN)
  - Mineral nitrogen, especially nitrates is leachable
- Moderate C:N of 15:1 to ~30:1
  - Nitrogen of soil temporarily immobilized (tied up) to support decomposition
  - Limits PAN early in the growing season
- High C:N, which can exceed 100:1
  - Decomposing microbes will immobilize mineral nitrogen in soil up to 2 or more growing seasons
  - Net PAN may be ‘0’

Questions

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