Wastewater Treatment in Soils

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Model Decentralized Wastewater Practitioner Curriculum

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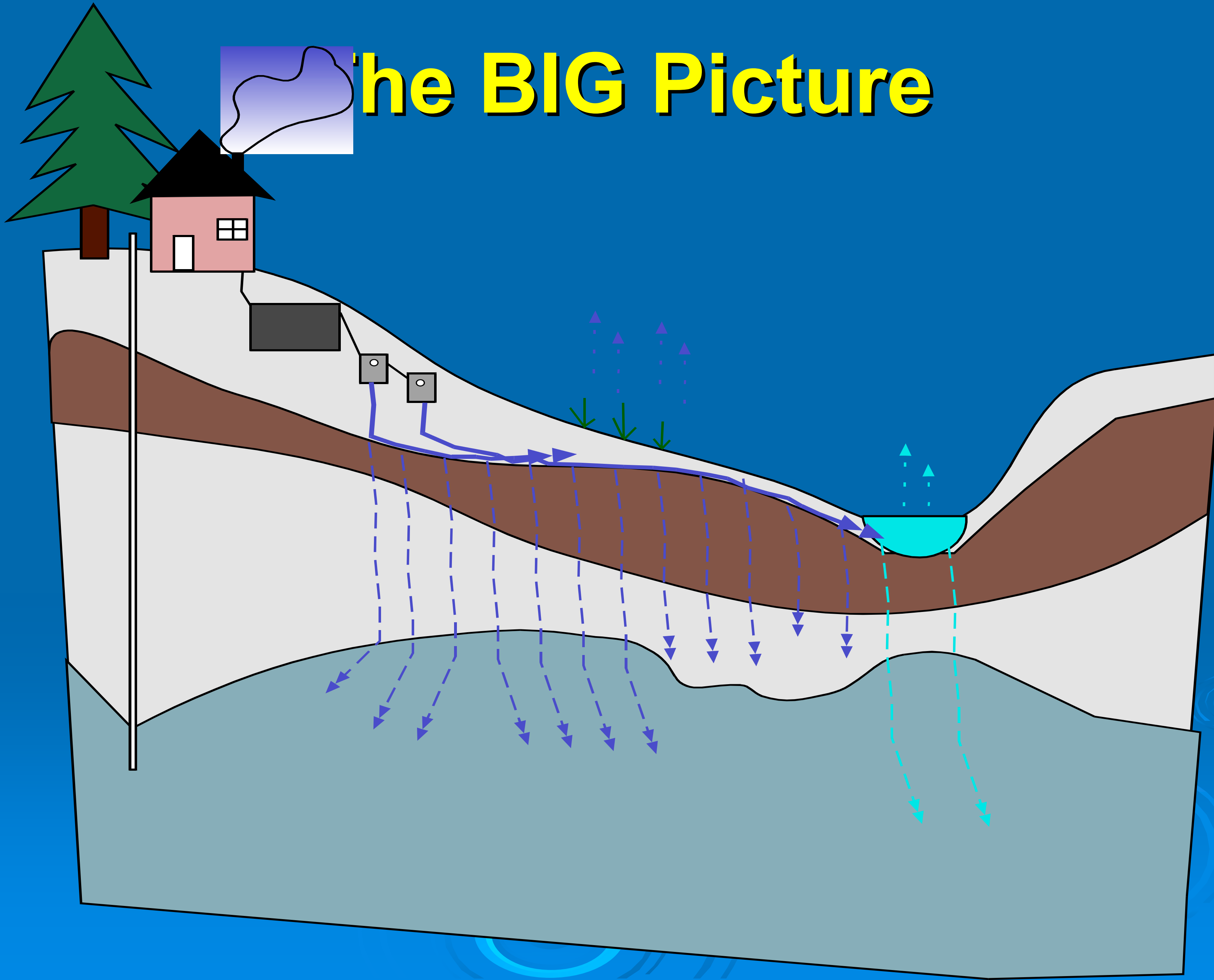
Overview

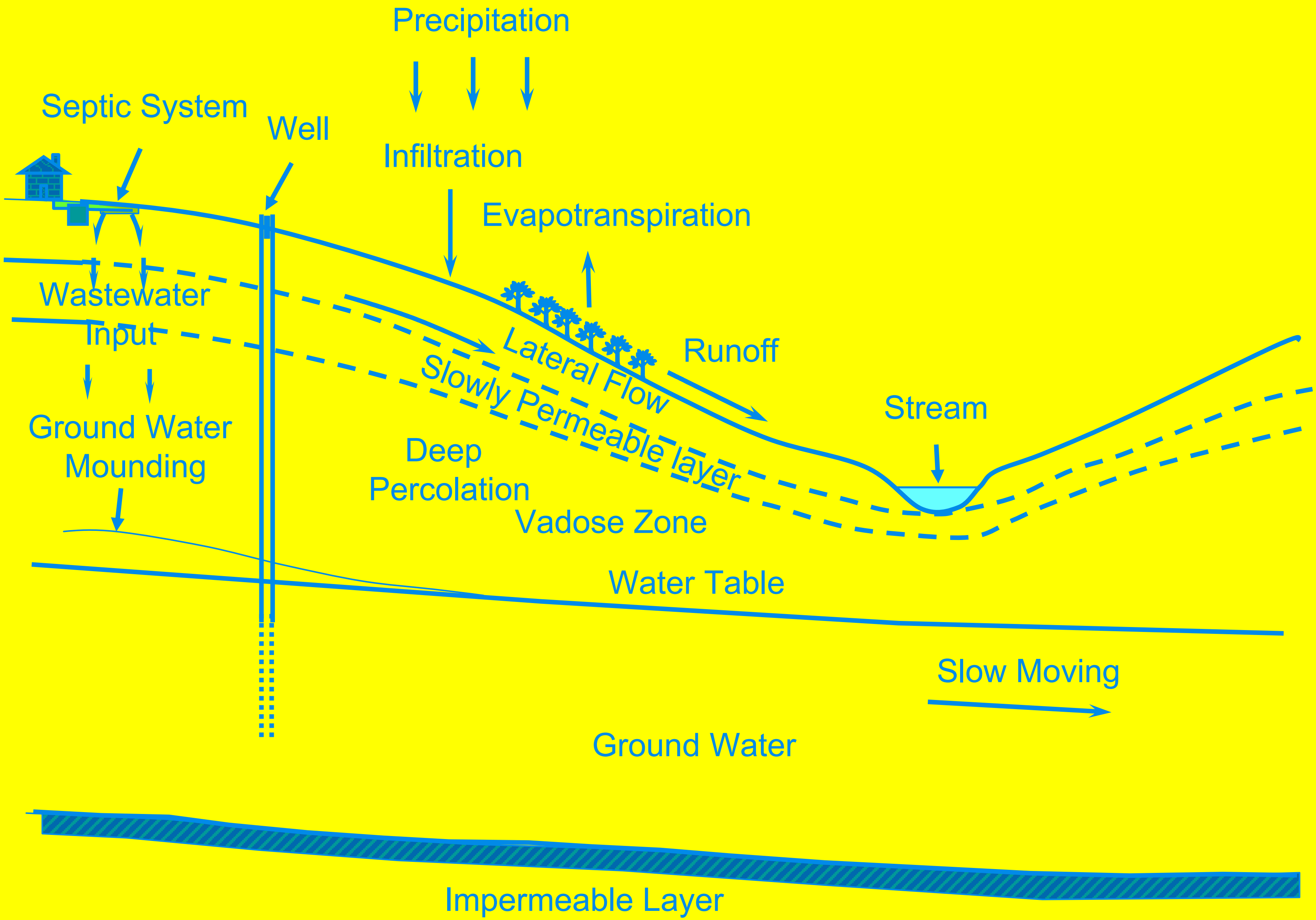
- What is Sewage?
- What kinds of Systems?
- What is Soil?
- How do Soils & Sewage interact?
  - Biomat and the treatment environment
- Concerns

Sewage

- What is it?
  - Water
  - Bacteria food
    - BOD
    - Nutrients
  - TSS
    - Solids
  - Pathogens
  - Solutes
  - Others

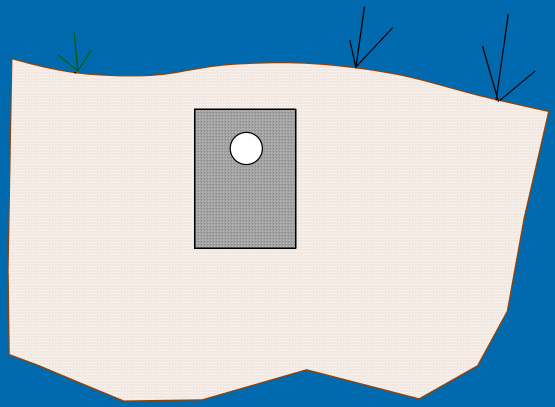
The BIG Picture

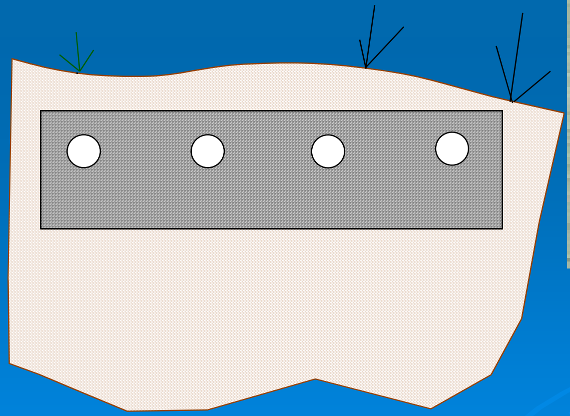


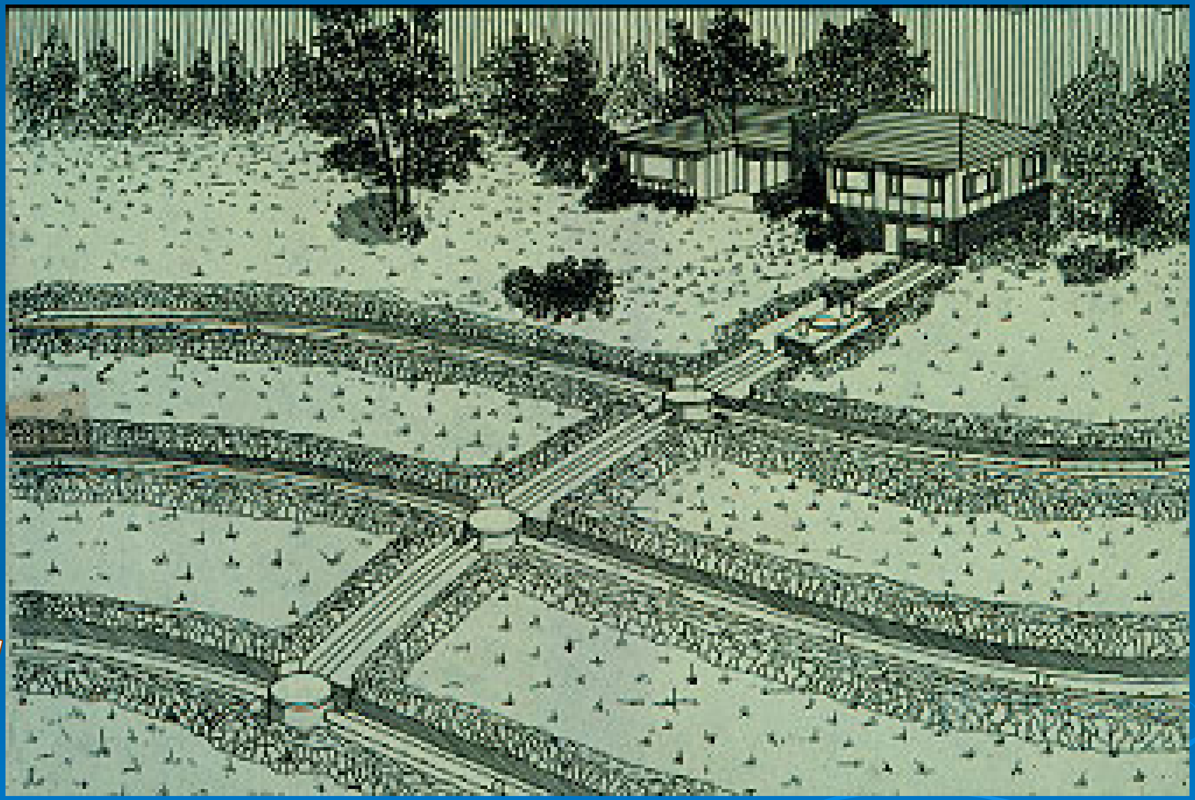


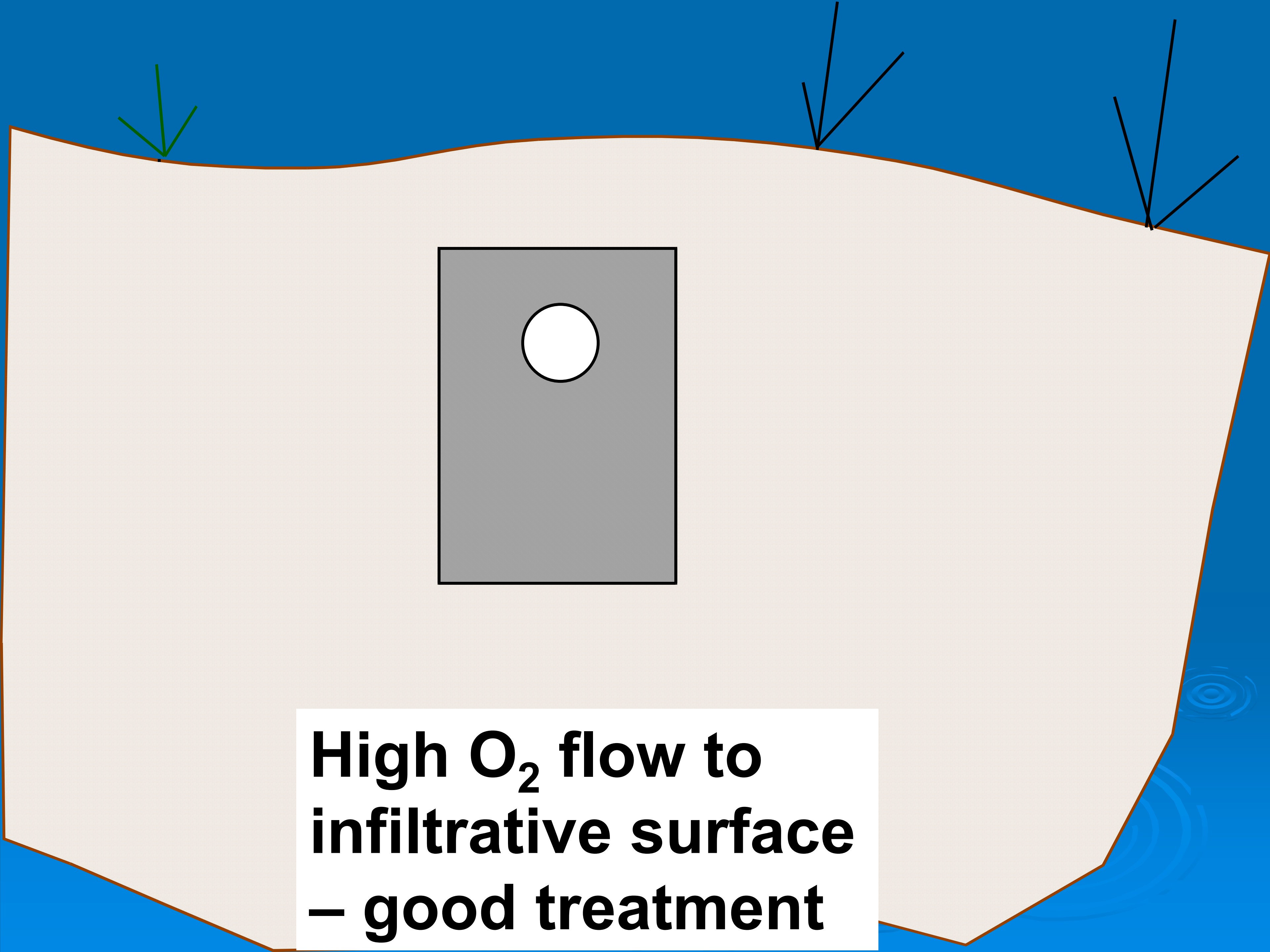
Precipitation
Septic System
Well
Infiltration
Evapotranspiration
Wastewater
Input
Lateral Flow
Runoff
Slowly Permeable layer
Stream
Ground Water
Mounding
Deep
Percolation
Vadose Zone
Water Table
Slow Moving
Ground Water
Impermeable Layer

Systems

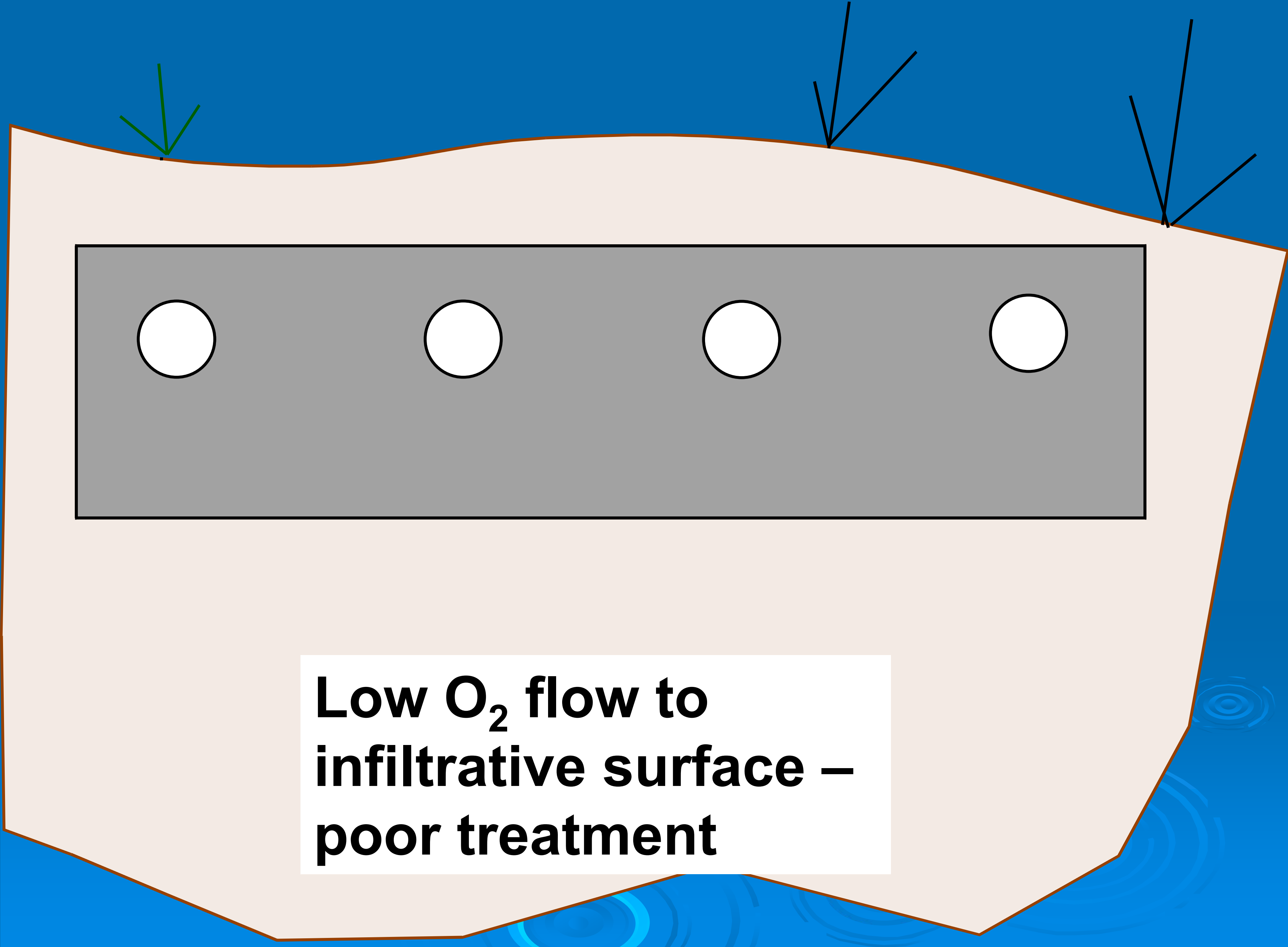








High O_2 flow to infiltrative surface – good treatment



Low O_2 flow to infiltrative surface – poor treatment

Protection methods

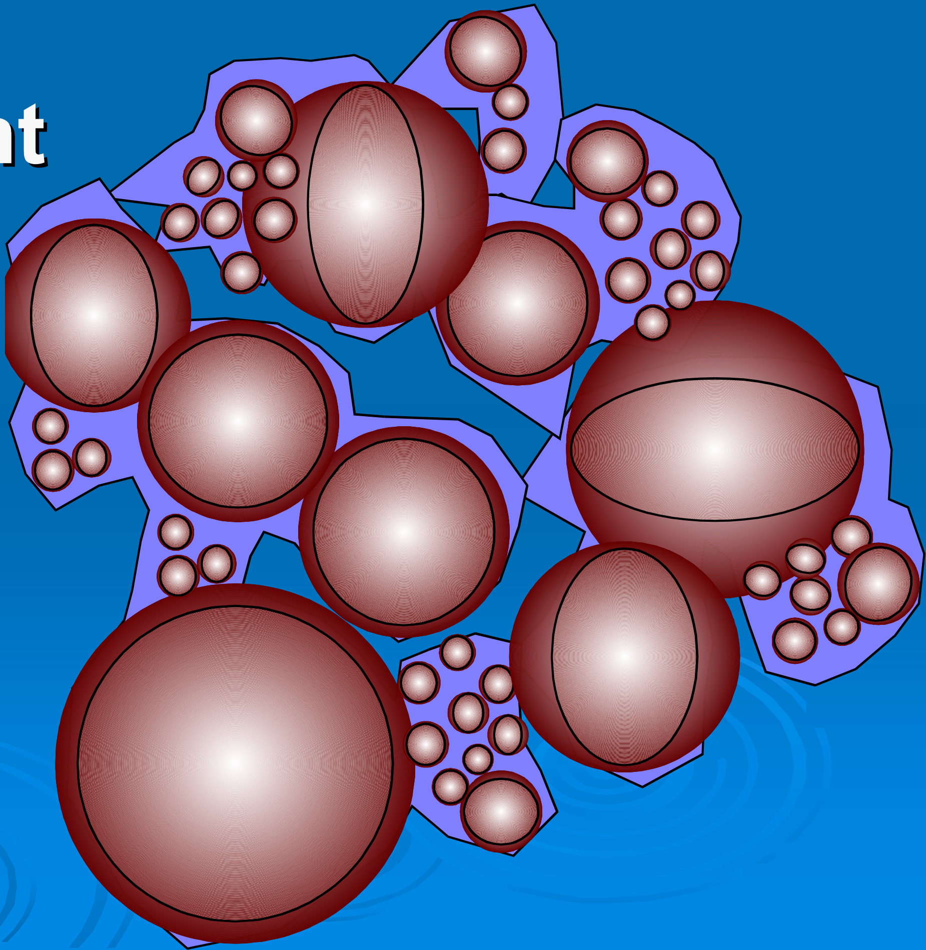
- Separation
  - Vertical
  - Covered
- Setbacks

What is Soil?

- Particles – Texture
  - % Sand - % Silt - % Clay
  - Structure
- Minerals & Nutrients
  - Organic matter
- Pores: Air & Water
- Surface Area
- Soil Organisms

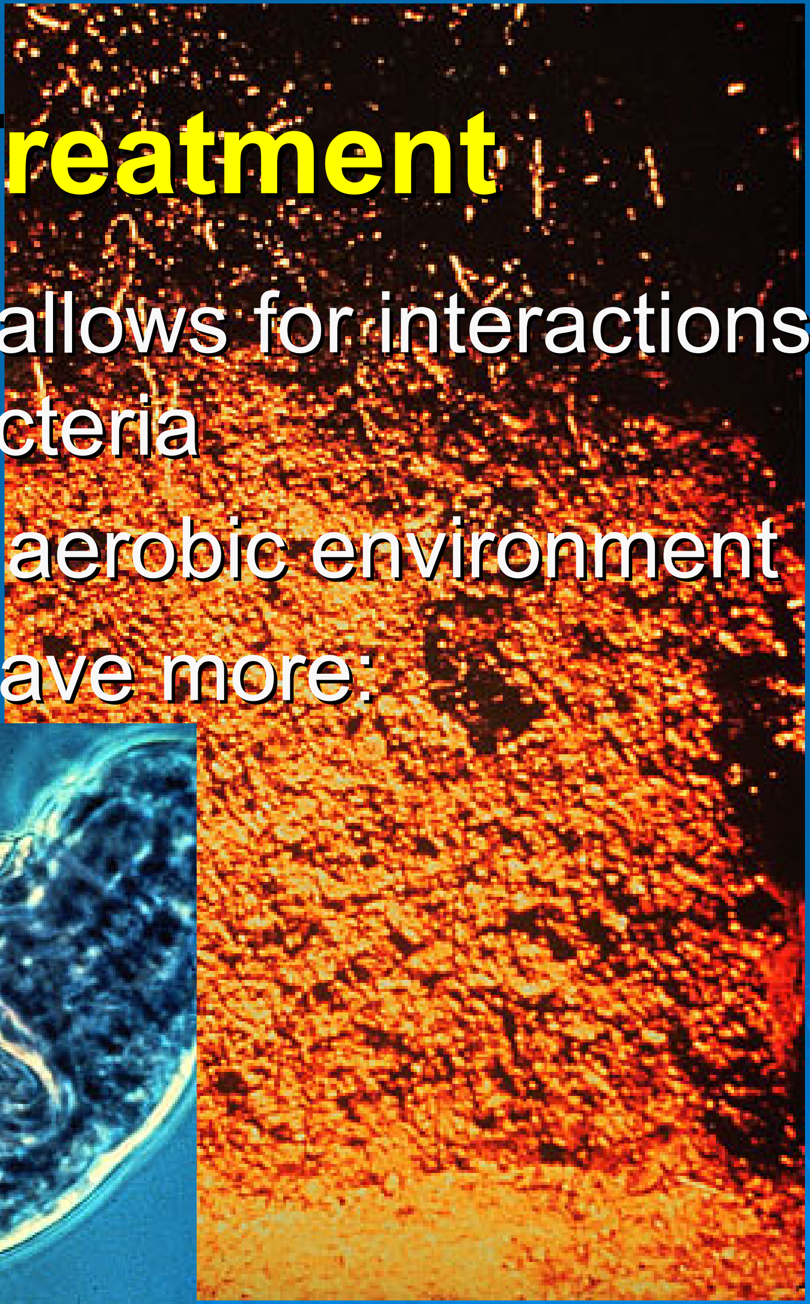
How wastewater is treated?

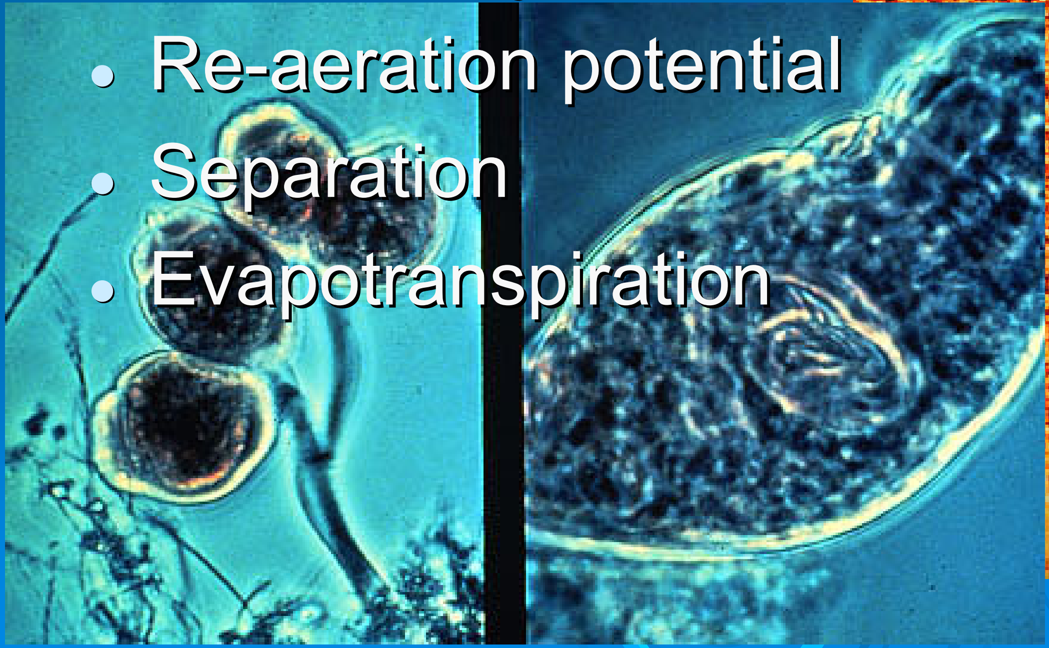
- Inside the trench the conditions are Anaerobic
- Aerobic environment
- Bacteria
- Unsaturated
  Flow



Depth & Treatment

- Separation distance allows for interactions with particles and bacteria
- Oxygen is critical for aerobic environment
- Shallower systems have more:
  - Re-aeration potential
  - Separation
  - Evapotranspiration





Soil Development

- Parent Material
  - Soil profile
- Environmental Changes
- Landscape Position

Parent Material

- Till
- Outwash
- Loess
- Lacustrine
- Bedrock
  - Weather bedrock
- Organic

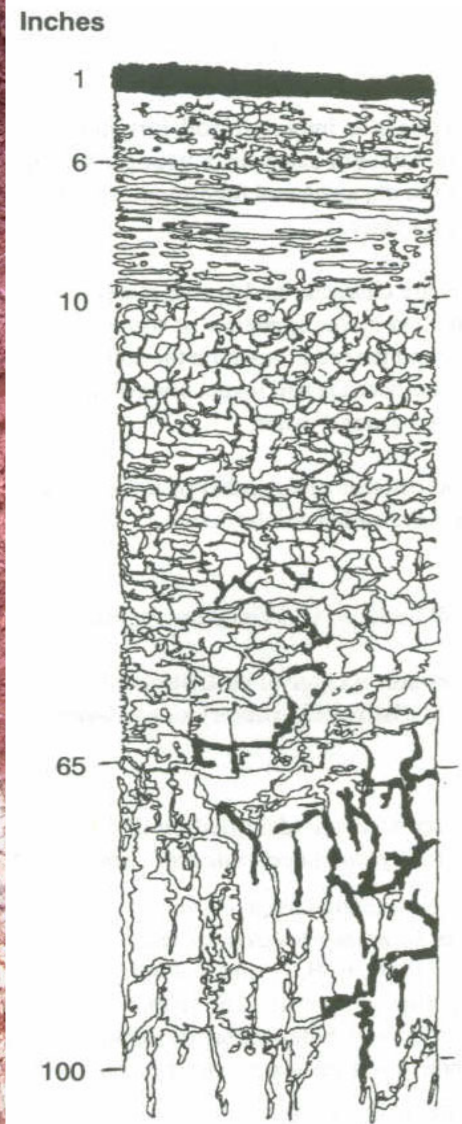
Environmental Changes

- Compaction
- Temperature
- Water
- Wind
- Vegetation

Landscape Position

- Erosion
- Transfer
- Wetness

Soil Profile and Horizons



Horizons

O— Layers dominated by organic material.

A— Mineral horizons forming at the surface or below the O horizon.

E— Mineral horizon where there has been a loss of silicate clay, iron or aluminum, leaving a concentration of sand and silt particles.

B— Horizons forming below A, E, or O horizon. These horizons are changed from their original rock structure.

C— Horizons or layers that are little affected by soil weathering but are not rock.

R— Rock that takes more than hand-digging with a spade to dislodge.

Understanding these ideas will help in create a better system design

Unsaturated Soil

- Soil color is important in identifying the Aerobic state of the soil
- Bright colors are well aerated or drained
- Grays (redox features) are wet

Color & Saturation

Well Drained

Moderately Well Drained

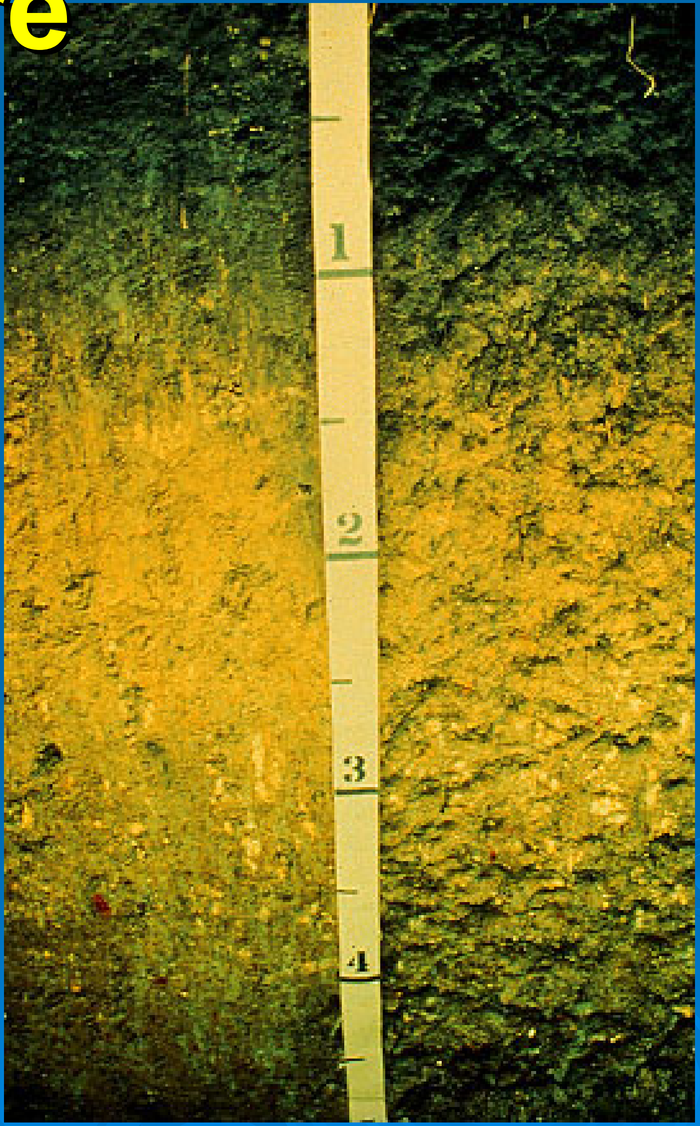
Poorly Drained

Munsell Colorbook

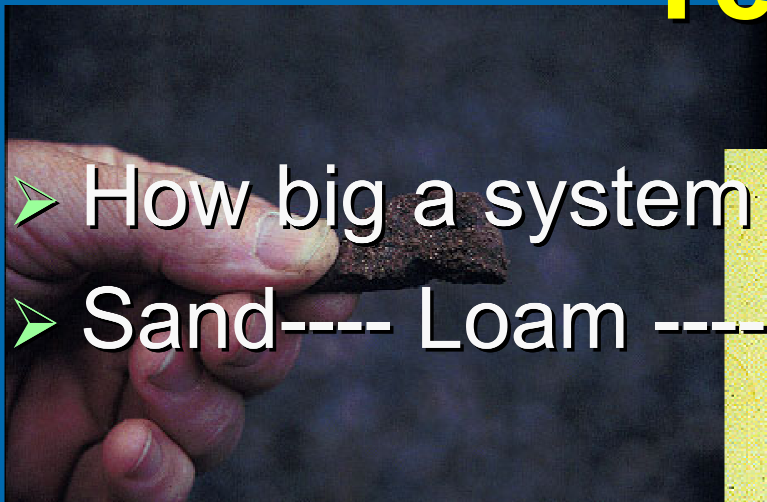
Other visual keys determination to saturated conditions

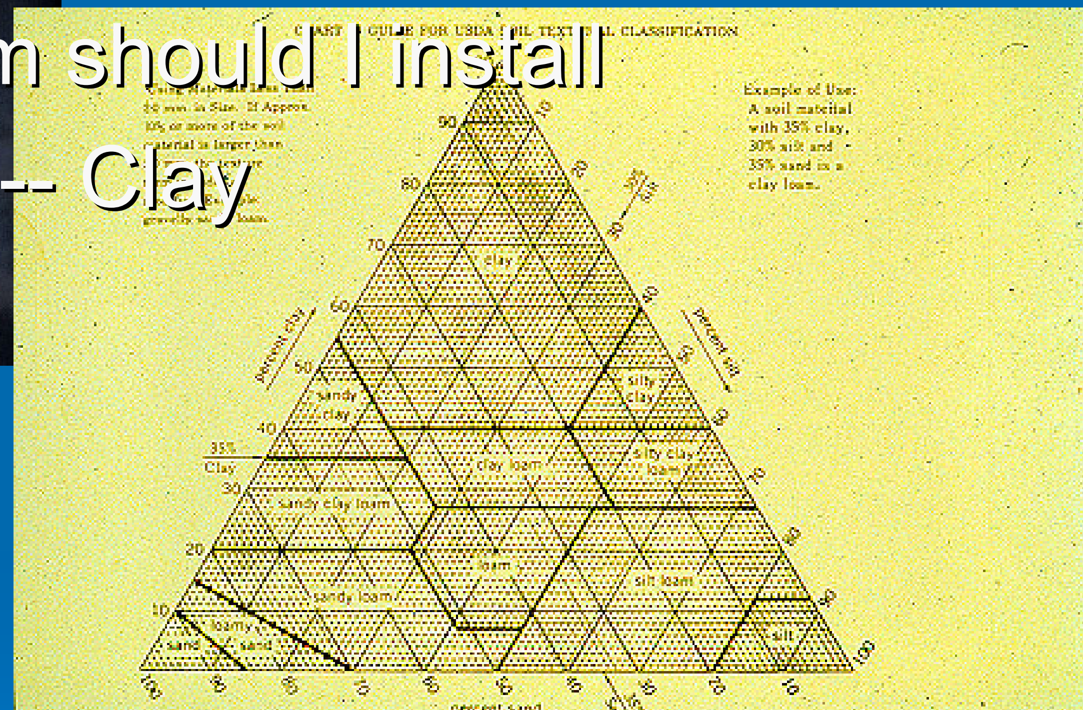
Texture

- Coarser soils:
  - Faster movement
  - Less surface area
  - Less removal sites
- Finer soils:
  - Slower movement
  - More surface area
  - More removal sites



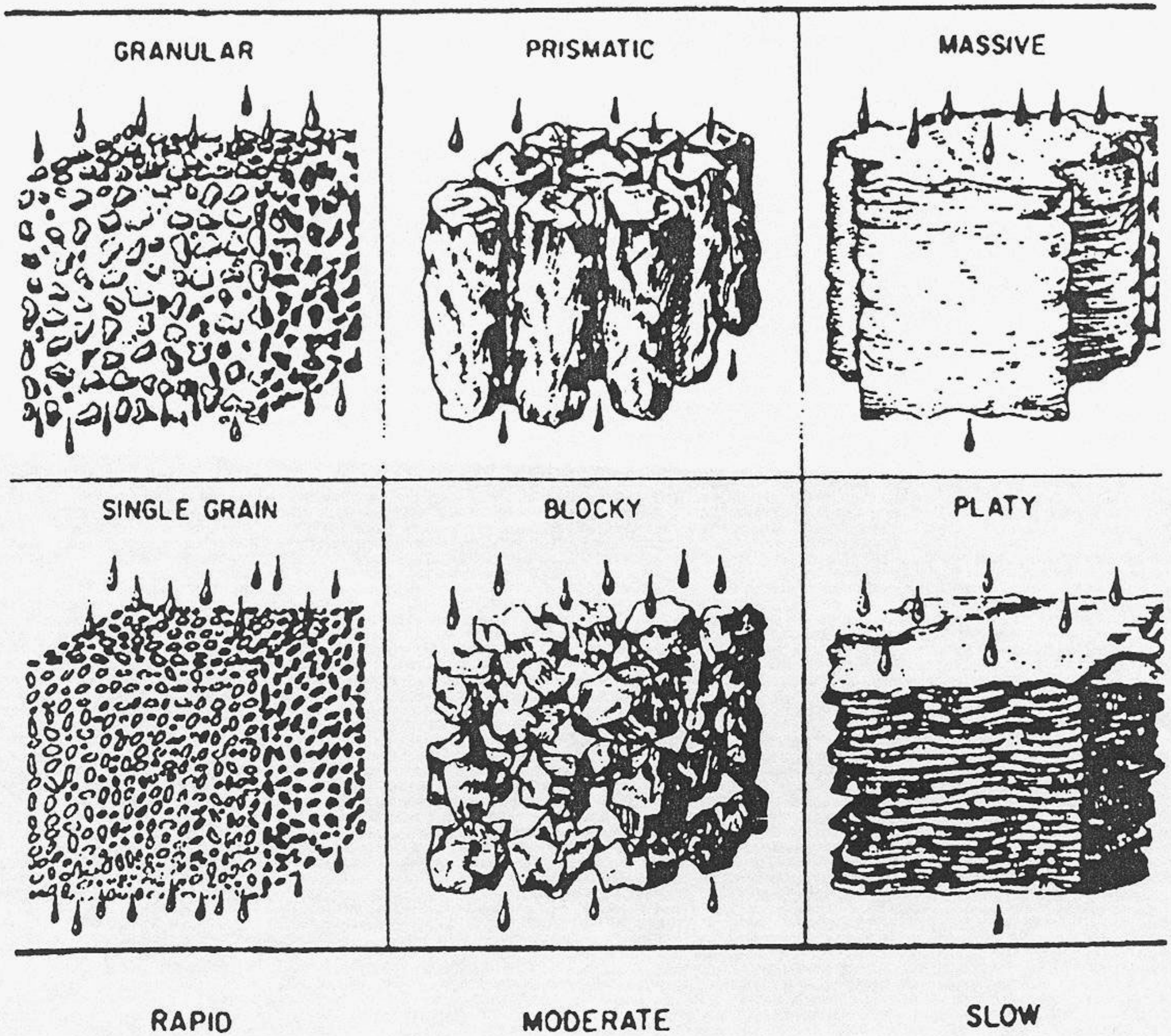
Texture





- How big a system should I install
- Sand---- Loam ---- Clay

Structure



ʼig. 3–6 Soil structure influences the infiltration rate of water, as shown. (*Source:* Irrigatic
ɔn Western Farms, U.S. Dept. of Interior and USDA, Agr. Inf. Bul. No. 199, 1959.)

Soil Structure impacts

Major Types	# Pores	Water Movement
Granular	Many	High
Prismatic	↓	↓
Blocky		
Platy		
Massive	Few	Low

Granular Soil Structure

Columnar Soil Structure

Photos by G. Loomis

Sandy Textured Structureless – Single Grain Soil

High potential for poor wastewater treatment

Soil Structure

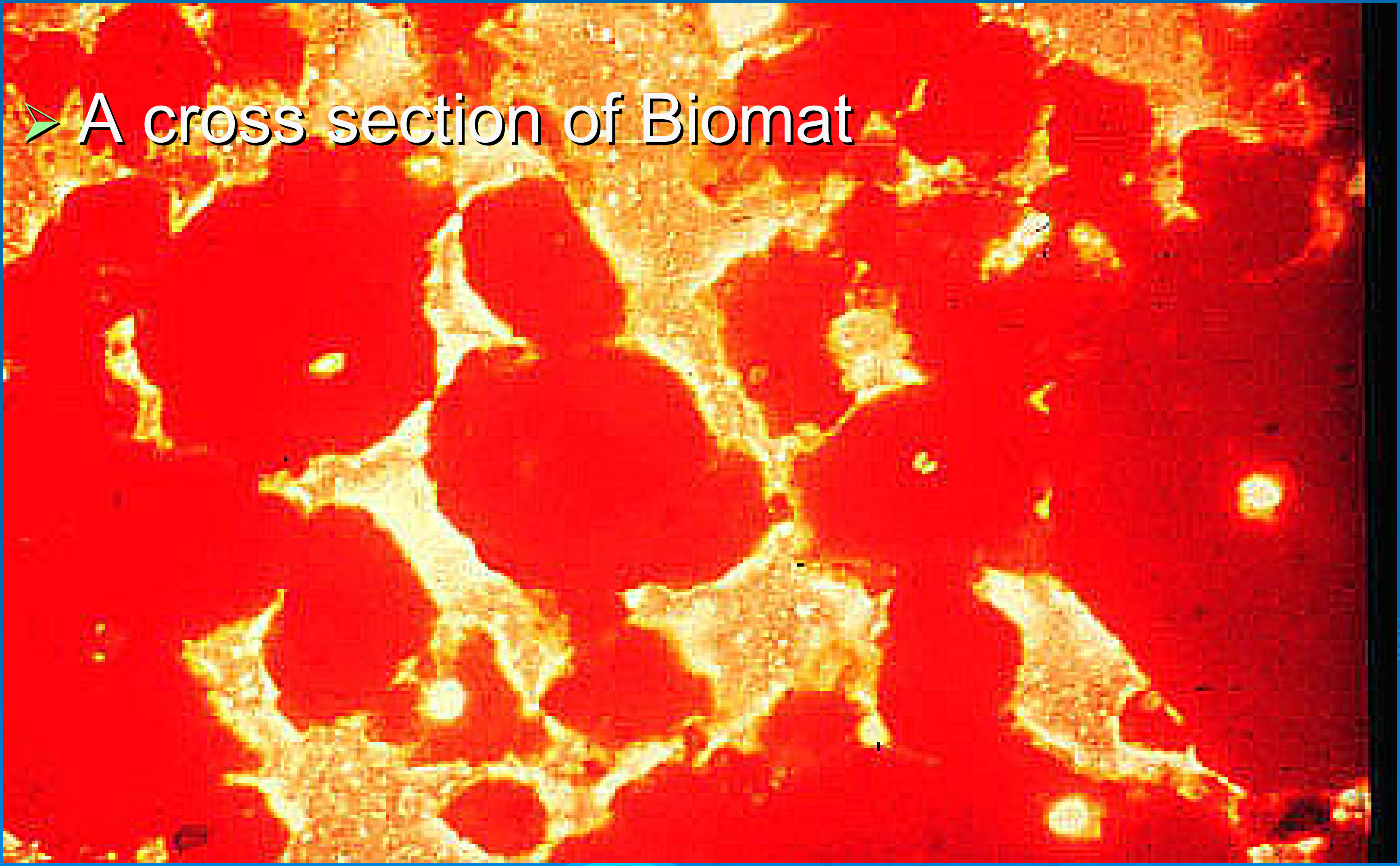
- Easily altered or destroyed
- Dynamic, changed by:
  - Moisture content
  - Chemistry of soil water
  - Biological activity
  - Construction/ management practices
  - Clay mineralogy

What happens when you put wastewater in the soil?

- Biomat forms
- Creating unsaturated flow

- This means:
  - More contact with the soil particles
  - Aerobic organisms treat the wastewater

Biomat



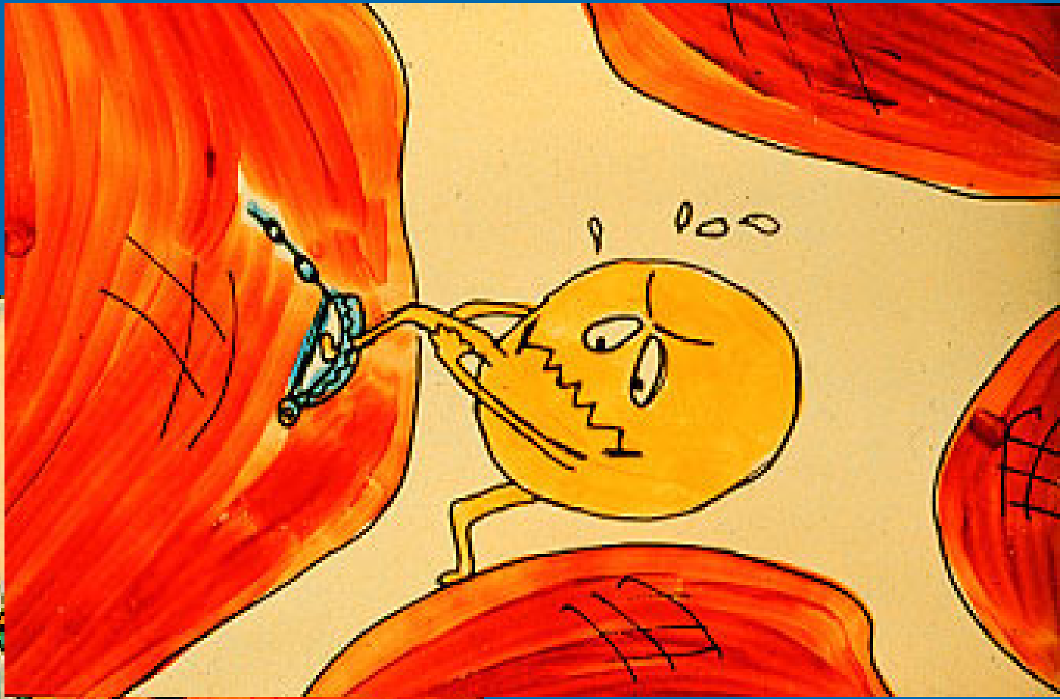
- A cross section of Biomat

How do pathogens get treated?

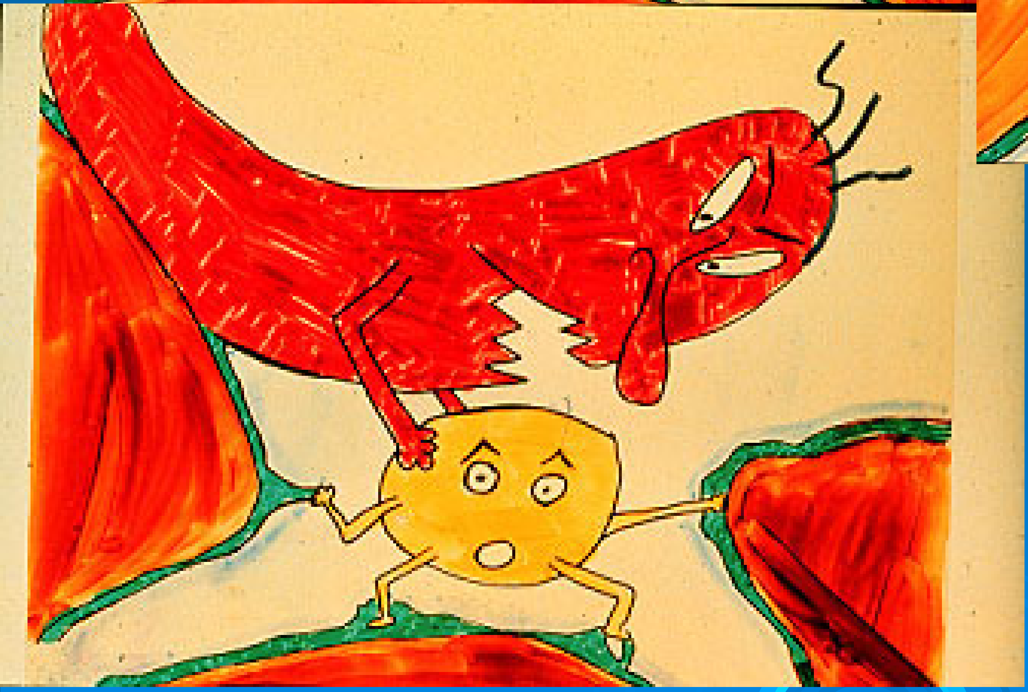
- They are physically filtered
- They are attached to the soil particles
- They die due to environmental conditions
- They are attacked by soil organisms

- Given time the soil is a very effective treatment medium

Pathogen retention



Pathogen removal



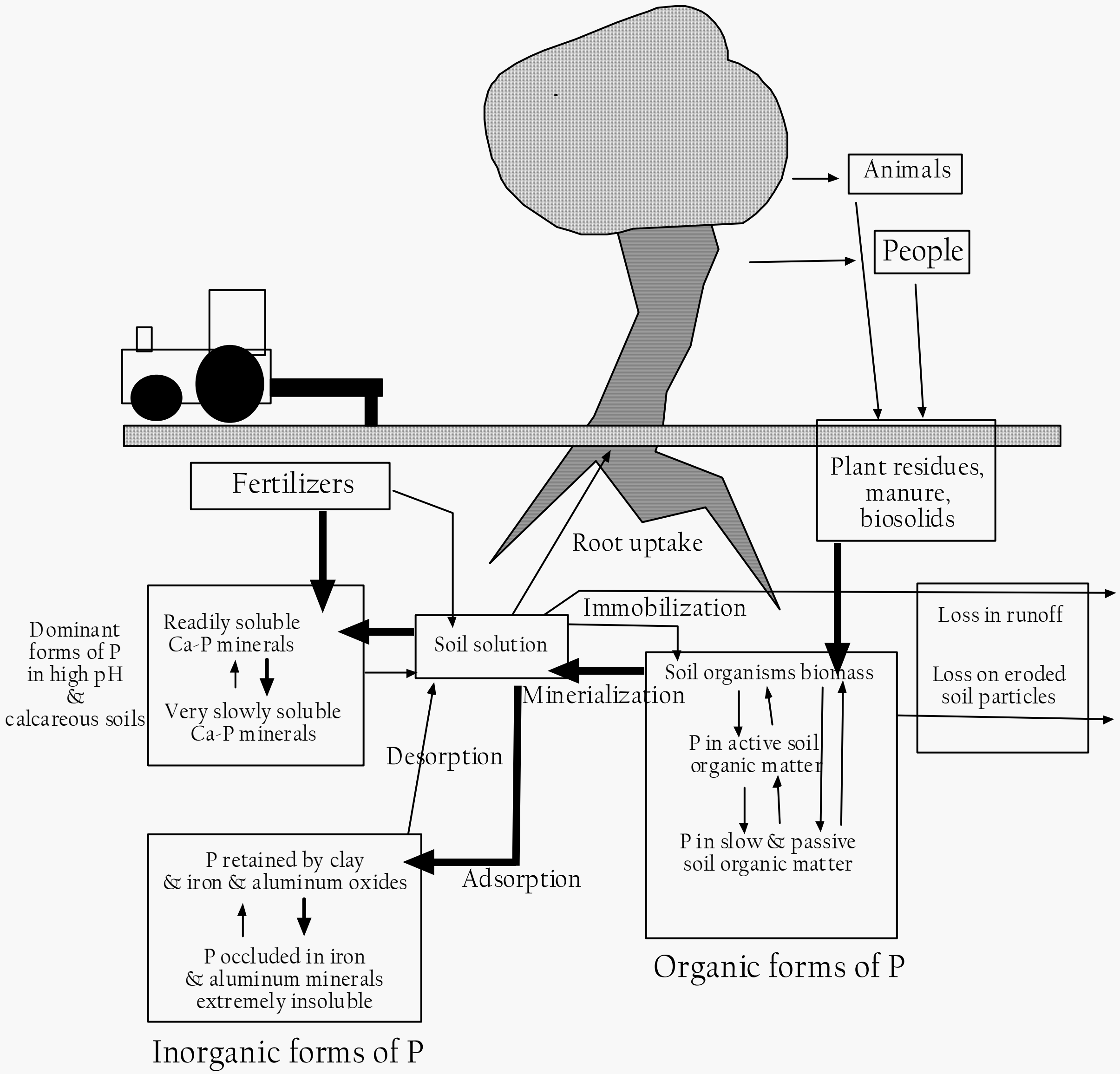
What Nutrients?

- Nutrients of concern
  Nitrogen & Phosphorus
- N - groundwater trouble
- P - Surface water trouble

Points of impact

Phosphorus

- P complexes with other minerals in the soil
- The complexes are insoluble
- P will move if the soil moves (erosion)
- Some of the P is used by the vegetation
- Soils have finite capacities to sorbs Phosphorus



Animals
People
Fertilizers
Plant residues, manure, biosolids
Root uptake
Immobilization
Dominant forms of P in high pH & calcareous soils
Readily soluble Ca-P minerals
Very slowly soluble Ca-P minerals
Soil solution
Soil organisms biomass
Loss in runoff
Loss on eroded soil particles
Mineralization
P in active soil organic matter
Desorption
P in slow & passive soil organic matter
P retained by clay & iron & aluminum oxides
Adsorption
P occluded in iron & aluminum minerals extremely insoluble
Organic forms of P
Inorganic forms of P

Phosphorus Removal in Conventional Septic Systems

- Phosphorus adsorbed to iron, aluminum, calcium, and magnesium in soils
- P removal depends on soil surface area
- Sands have less surface area than finer soil particles
- Wet soils have potentially less iron in them, so less P removal potential

Nitrogen Removal in Conventional Septic System

- Less than 15 percent removal in septic tank

  Septic tank effluent composed of organic-N and ammonium-N

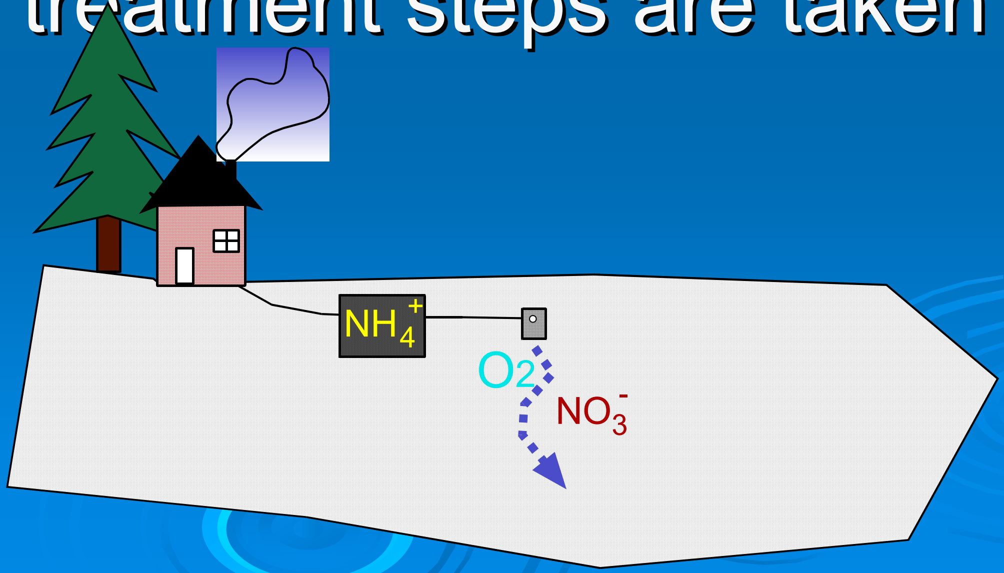
  Conversion to nitrate-N in drainfield

  Nitrate-N very mobile

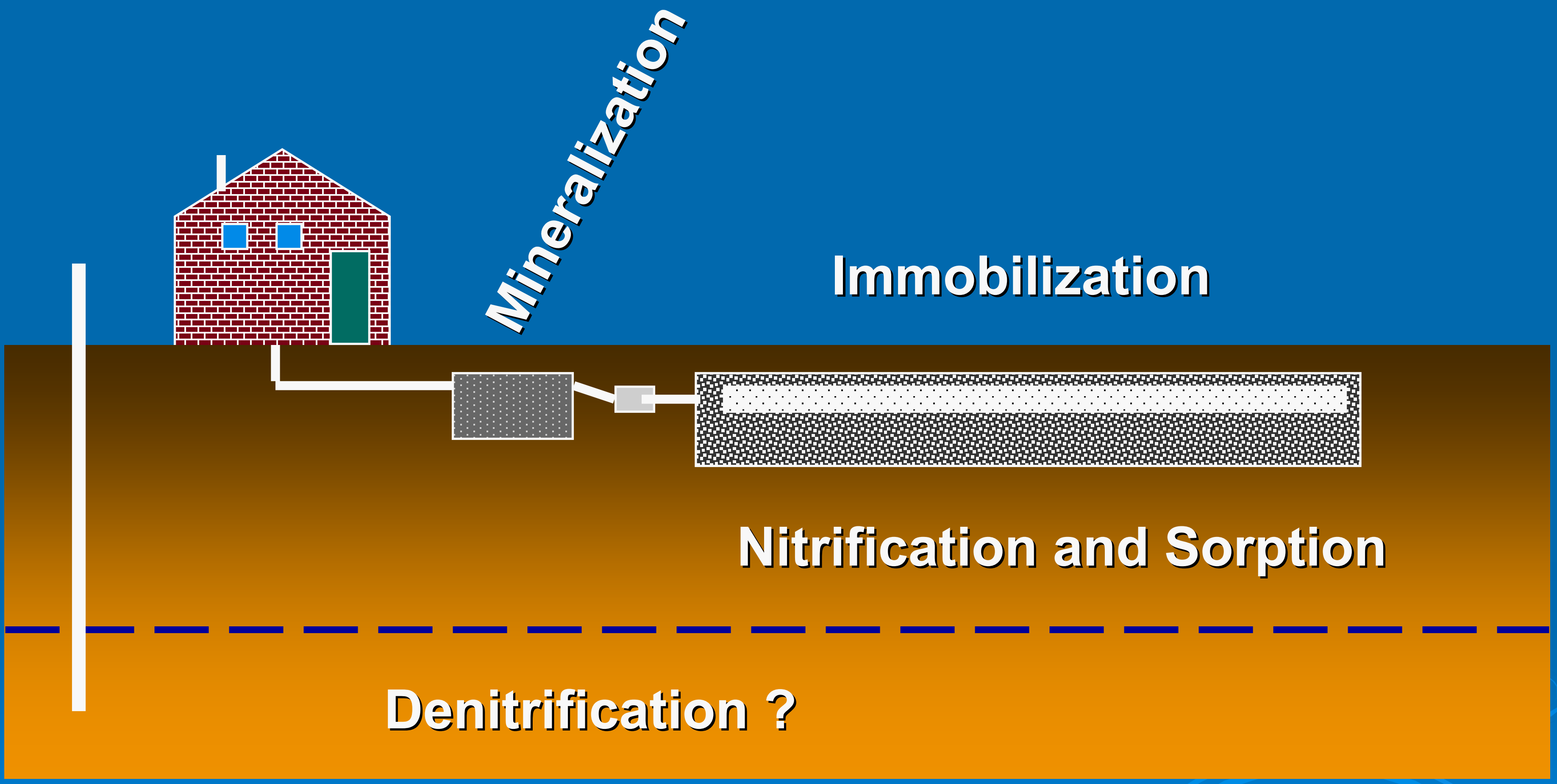
  10 ppm EPA nitrate-N drinking water standard

Nitrogen

- N starts as Ammonia
- In an aerobic environment it is transformed to Nitrate
- Nitrate moves with the water unless additional treatment steps are taken



N Cycle in Septic Systems



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VOC and HCs

- Source
  - cleaning fluids, solvents
- Variable amounts

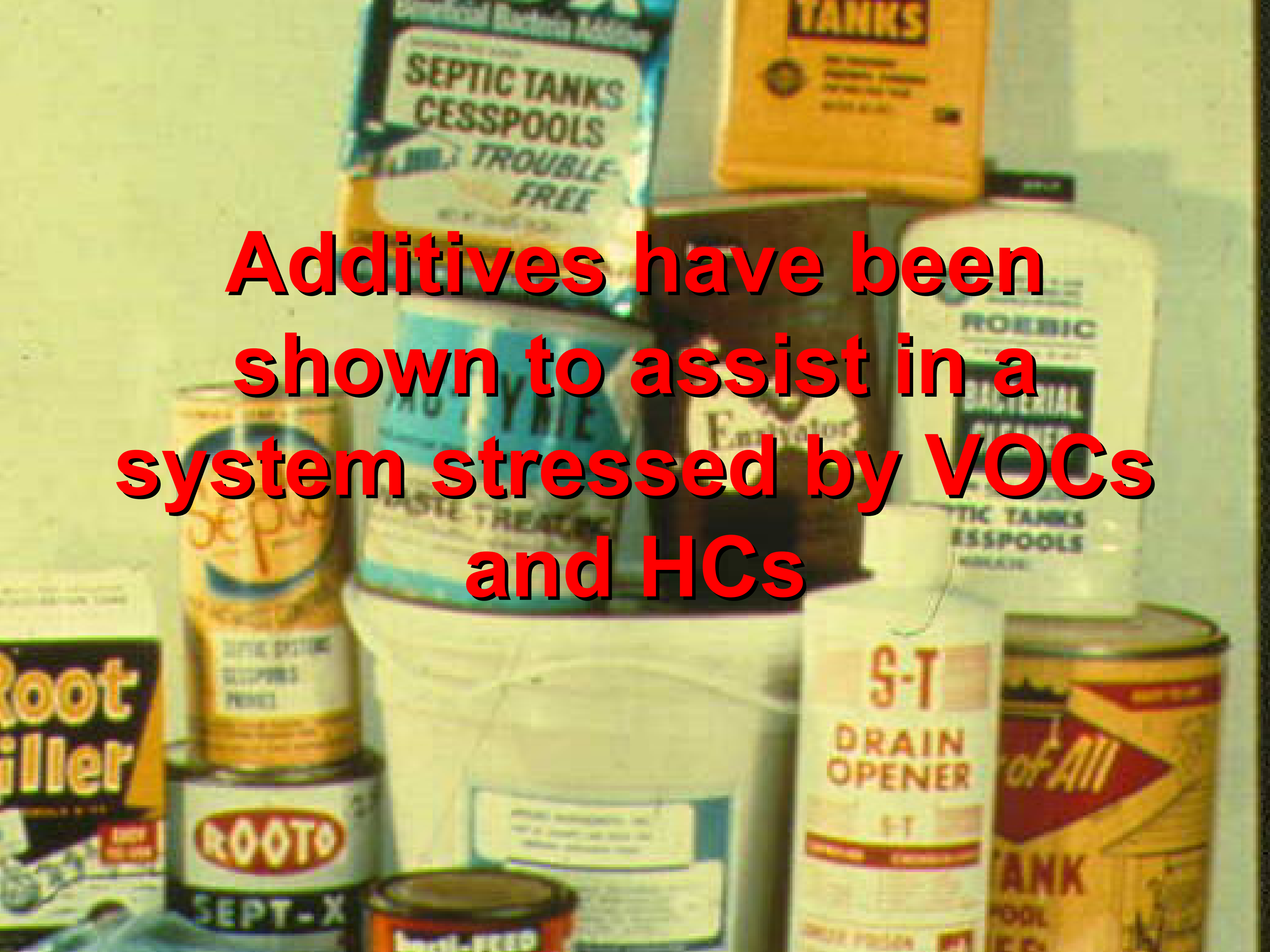
VOC and HCs: Concerns

- Carcinogens
- Toxins

VOC and HCs: Reactions

- Sorption
- Microbial transformation
- Volatilization

Additives have been shown to assist in a system stressed by VOCs and HCs



Pollutant attenuation potential

Pollutant	Aerobic Soils	Wet Soils	Sandy Soils	Non- Sandy Soils
Phosphorus	+	-	-	+
Nitrogen	-	+	-	+
Pathogens	+	-	-	+

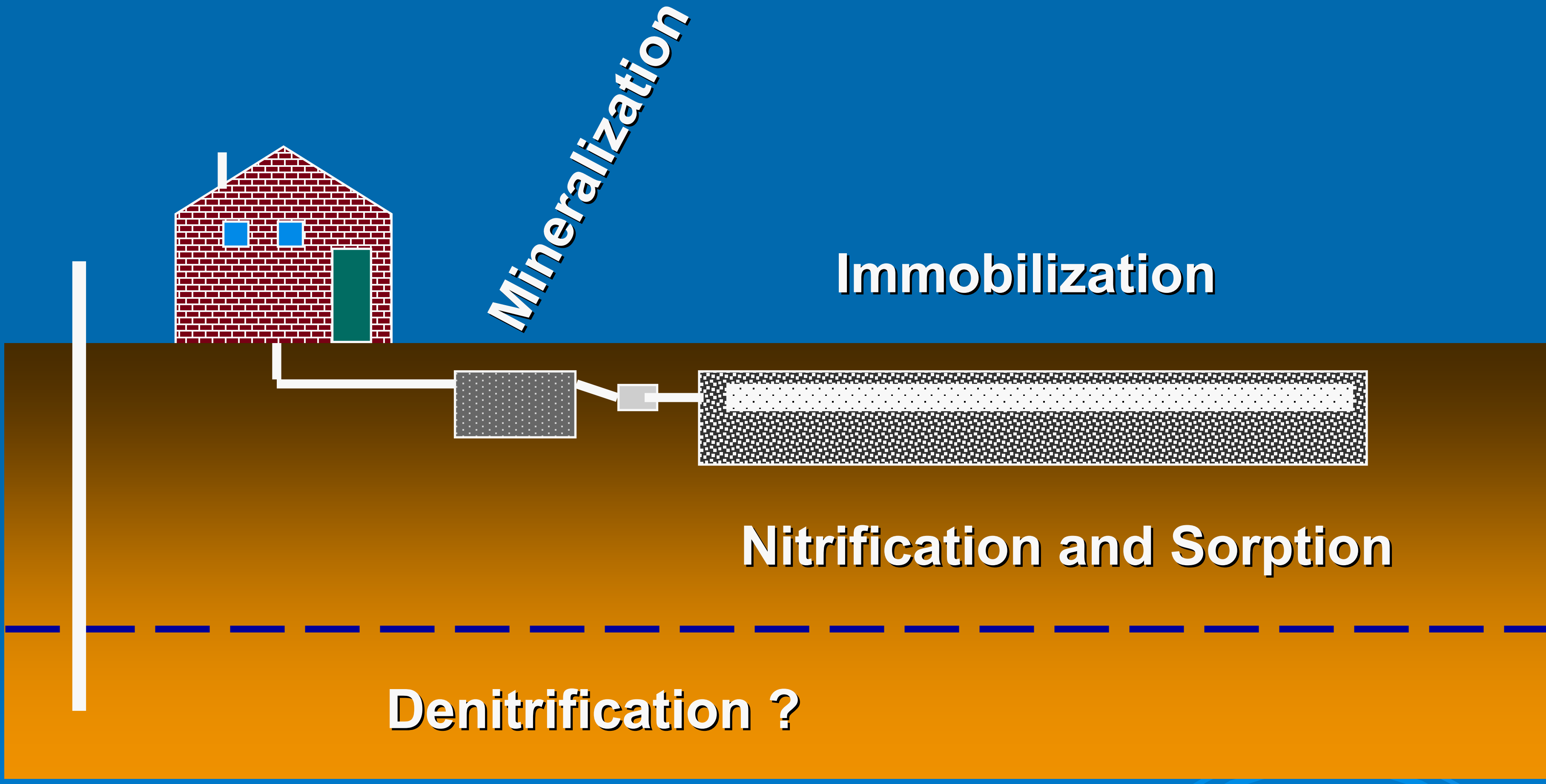
+ = promotes attenuation

- = discourages attenuation

Treatment Challenges

- Shallow bedrock
- Karst bedrock
- Saturated soils
- Slowly permeable soils
- Rapidly permeable soils
- Fill soils
- Seasonally used systems

N Cycle in Septic Systems



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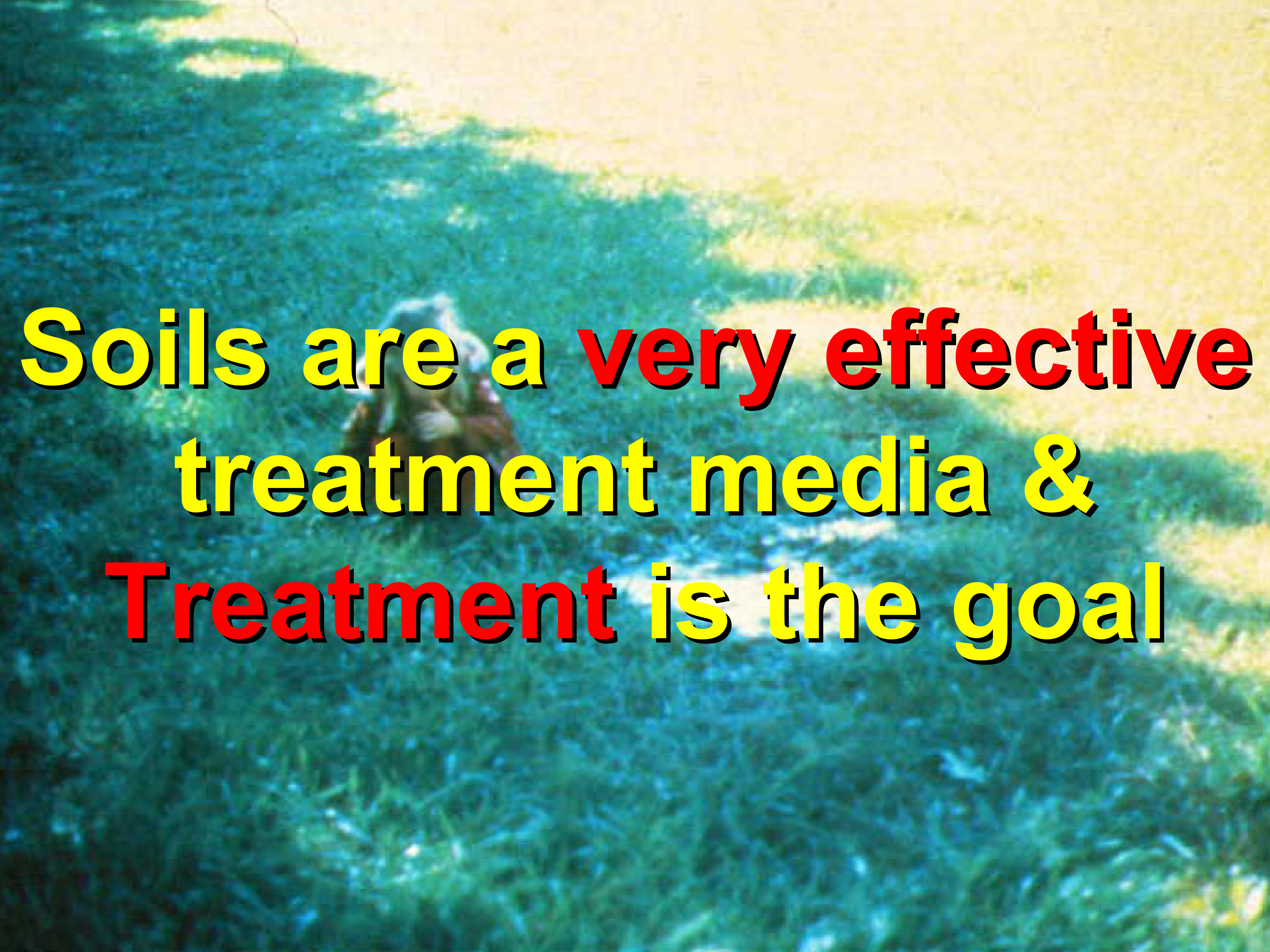
Soils are a very effective treatment media &
Treatment is the goal