OKLAHOMA COOPERATIVE EXTENSION

Subsurface Fates of Contaminants from Onsite Septic Systems

Sergio M. Abit Jr., PhD
Associate Professor of Soil Science
State Specialist on Onsite Wastewater Treatment Systems

Today's Target

Better understanding of the processes involved in the treatment of key contaminants from OWTS.

Improved appreciation of what we do.

NOWRA

To strengthen and promote the onsite and decentralized wastewater industry.

Subsurface Fates of Contaminants from Onsite Septic Systems

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Subsurface Fates of Contaminants from Onsite Septic Systems

1. Nitrogen
2. Phosphorus
3. Pathogenic Bacteria

1. Transformations
2. Transport
3. Sorption (Attachment)
4. Survival

Why worry about excess nitrogen and phosphorus?

They are environmental and health hazards

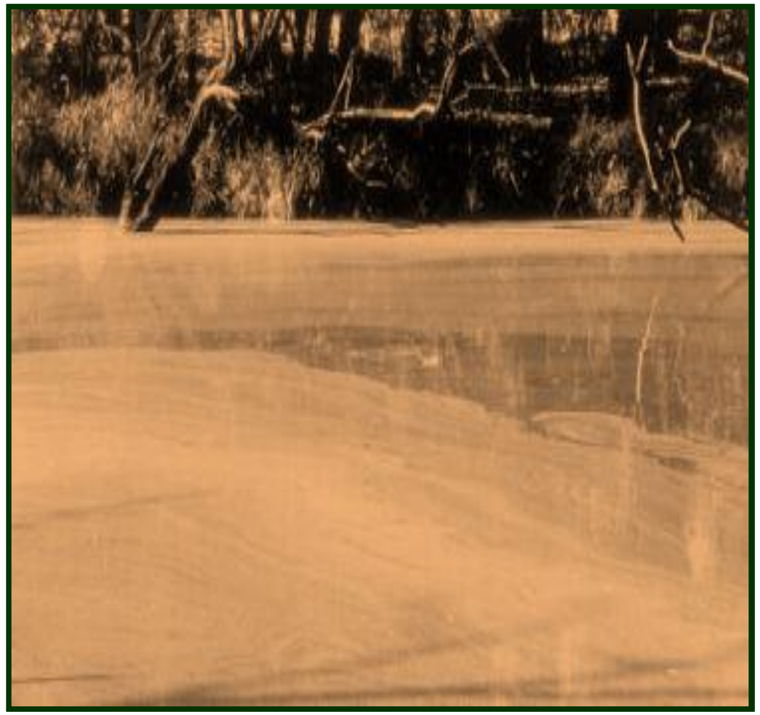
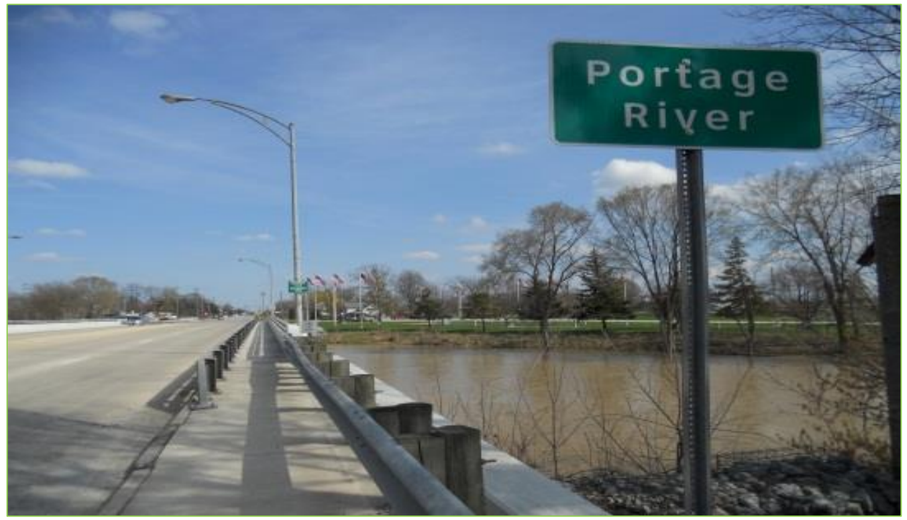


Photo: www.hobbyfarms.com

Why worry about pathogenic bacteria?

Tarnishes the reputation of the OWTS Industry



Portage River Basin, OH

Examiner, April 12, 2010

Failed septic systems a major cause of bacteria in Portage River basin

Pathogenic Bacteria in Onsite Wastewater

Bacteria
Escherichia coli (pathogenic)
Legionella pneumophila
Leptospira spp.
Salmonella typhii
Salmonella
Shigella
Vibrio cholerae
Yersinia enterocolitica

Source: FDOH (2011) and Lowe et al. (2007).

Pathogenic Bacteria in Onsite Wastewater

Bacteria	Disease caused
Escherichia coli (pathogenic)	Gastroenteritis
Legionella pneumophila	Legionellosis (Legionnaires' disease)
Leptospira spp.	Leptospirosis (Weil's disease)
Salmonella typhii	Typhoid fever
Salmonella	Salmonellosis
Shigella	Shigellosis (Bacillary dysentery)
Vibrio cholerae	Cholera
Yersinia enterocolitica	Gastroenteritis

Source: FDOH (2011) and Lowe et al. (2007).

Pathogenic Bacteria in Onsite Wastewater

Bacteria	Disease caused	Symptoms
Escherichia coli (pathogenic)	Gastroenteritis	Diarrhea
Legionella pneumophila	Legionellosis (Legionnaires' disease)	Malaise, acute respiratory illness
Leptospira spp.	Leptospirosis (Weil's disease)	Jaundice, fever
Salmonella typhii	Typhoid fever	High fever, diarrhea
Salmonella	Salmonellosis	Vomiting, abdominal pain, diarrhea
Shigella	Shigellosis (Bacillary dysentery)	Dysentery
Vibrio cholerae	Cholera	Diarrhea, dehydration
Yersinia enterocolitica	Gastroenteritis	Diarrhea

Source: FDOH (2011) and Lowe et al. (2007).

What happens to excess N, P and pathogenic bacteria at the Soil Treatment Area (STA)?

Excess Nitrogen

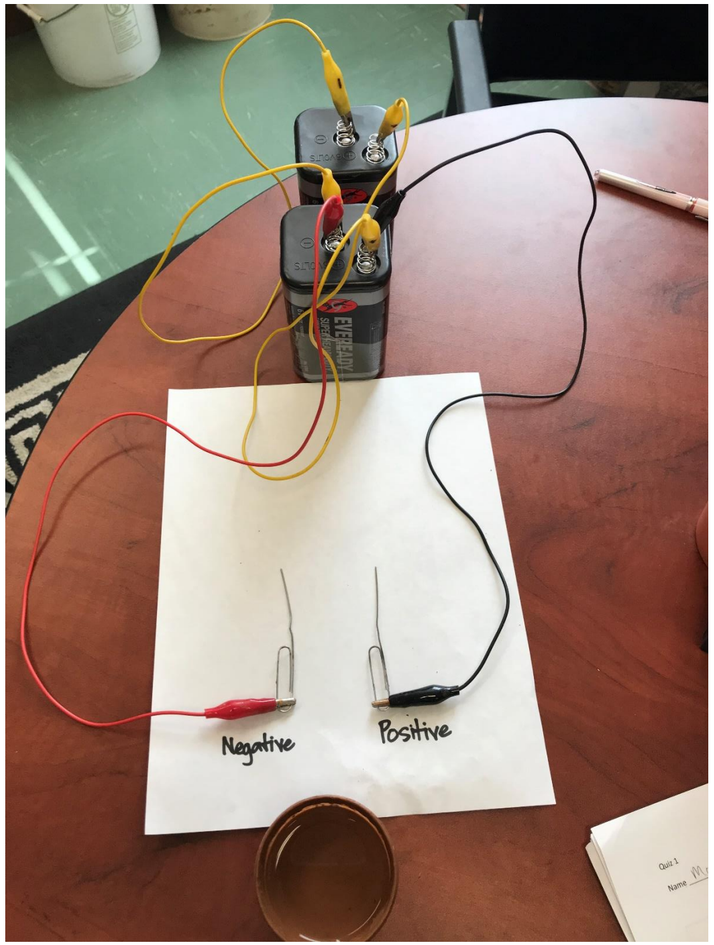
Two dissolved forms of nitrogen:

1. Nitrate (NO_3^-)
2. Ammonium (NH_4^+)

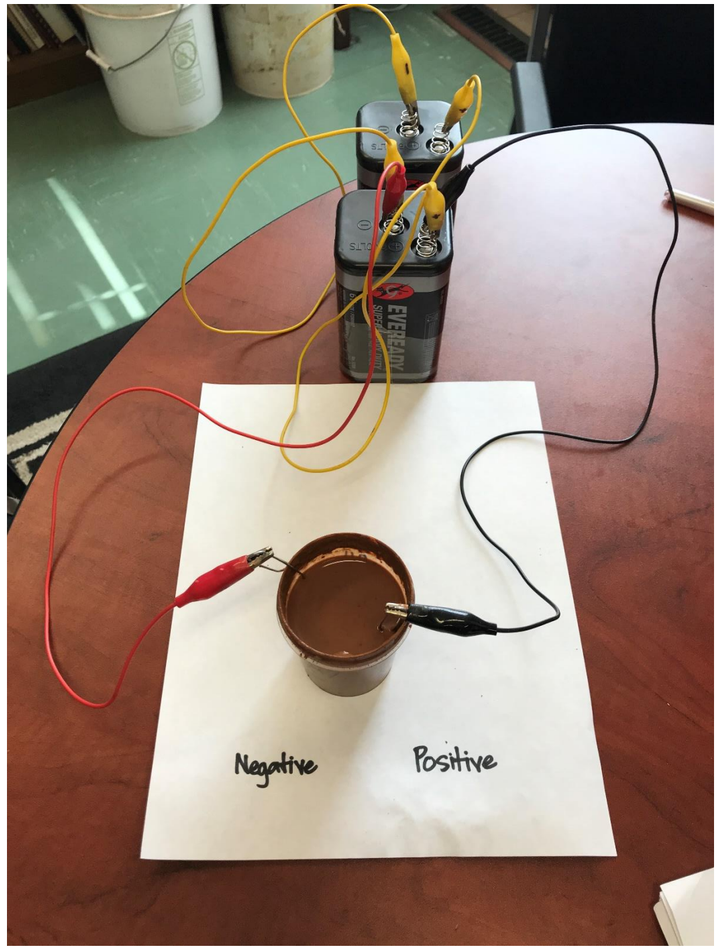
Main form of nitrogen in wastewater in the septic tank

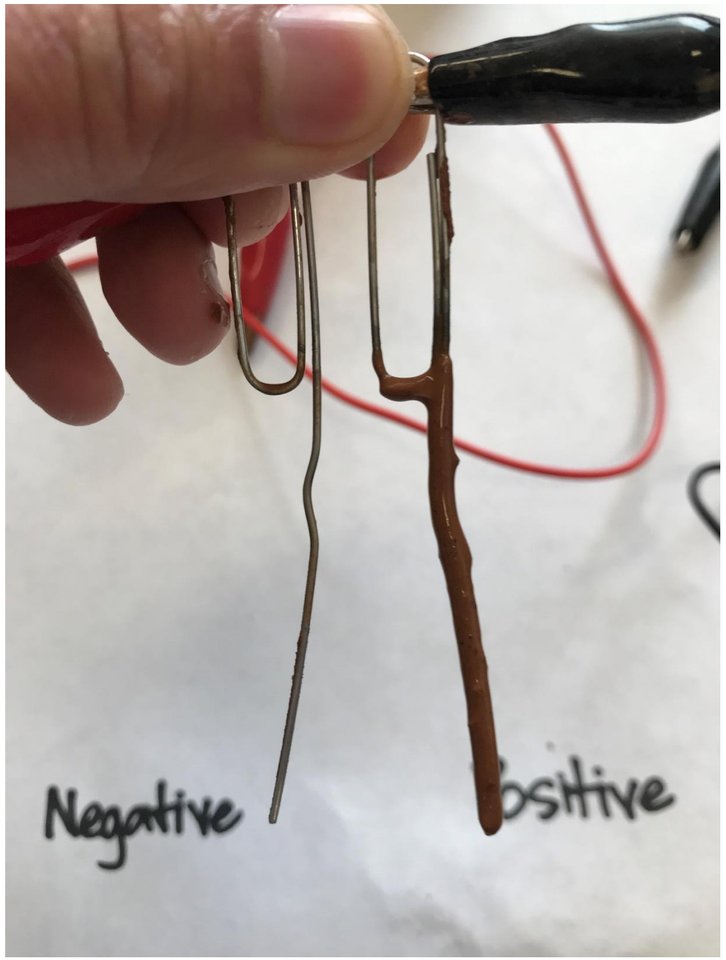
Before we discuss nitrogen…

Guess What… Soil has a charge!

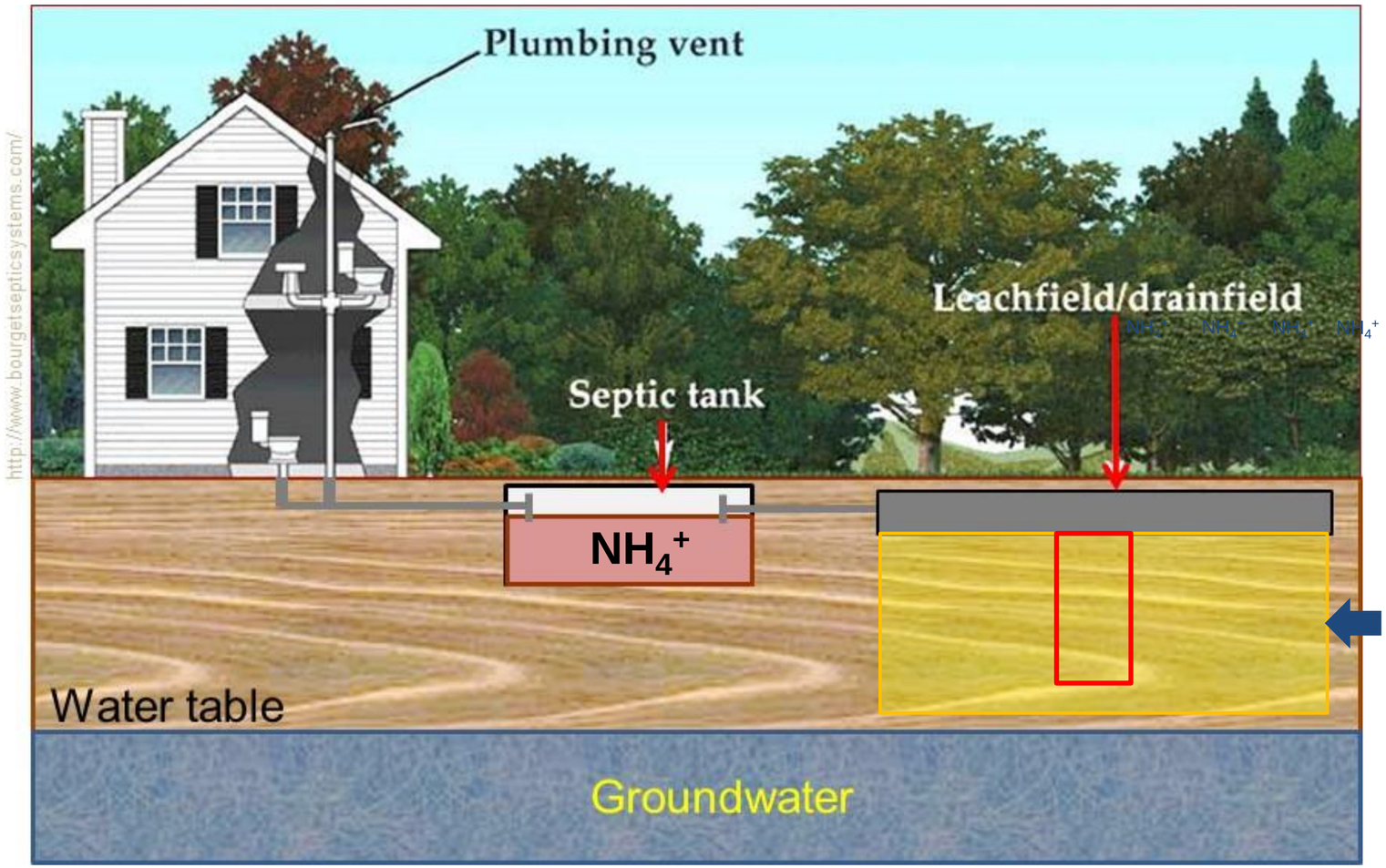


Soil pH : 7



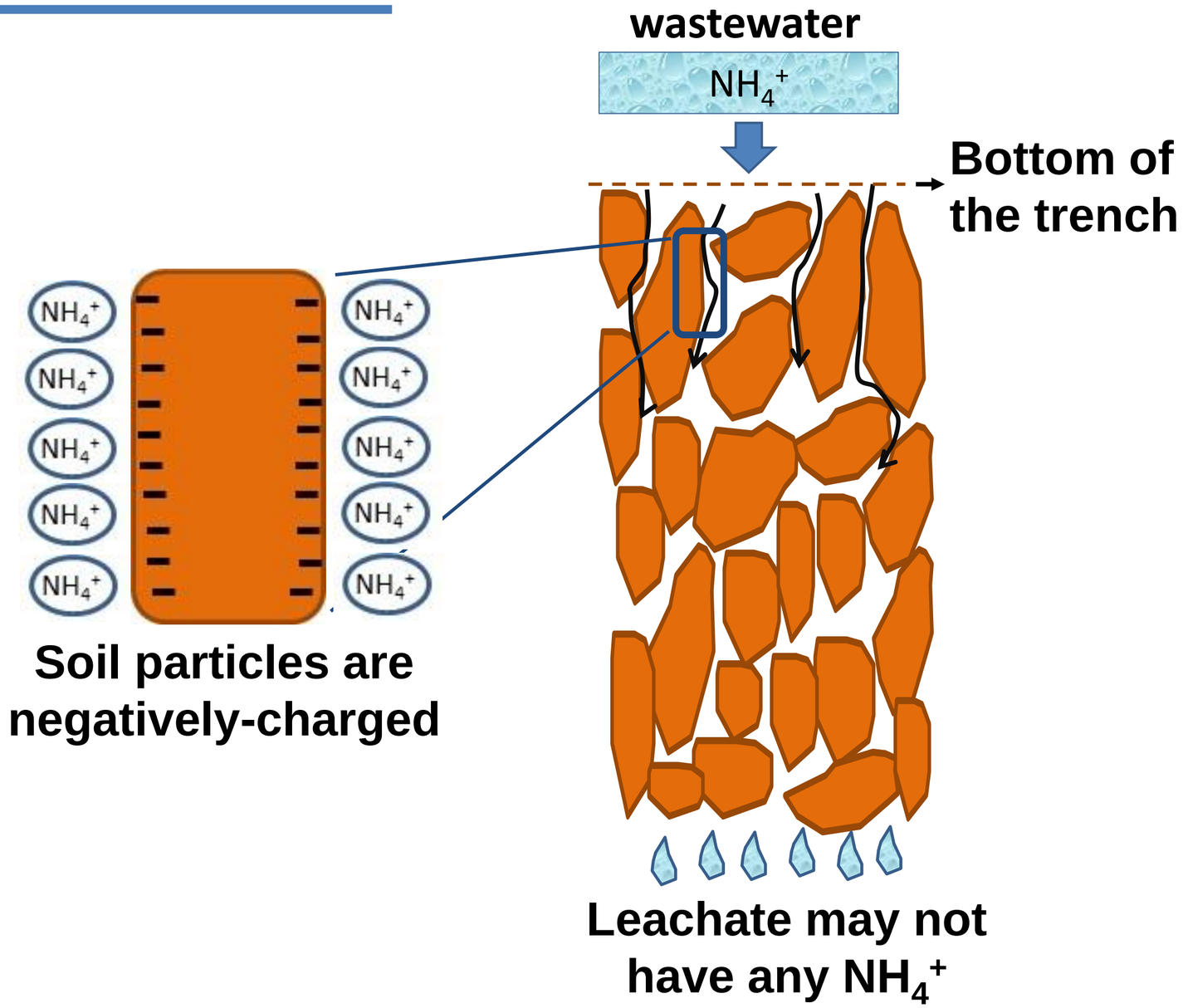


Forms of Nitrogen



Soil Treatment Area (STA)

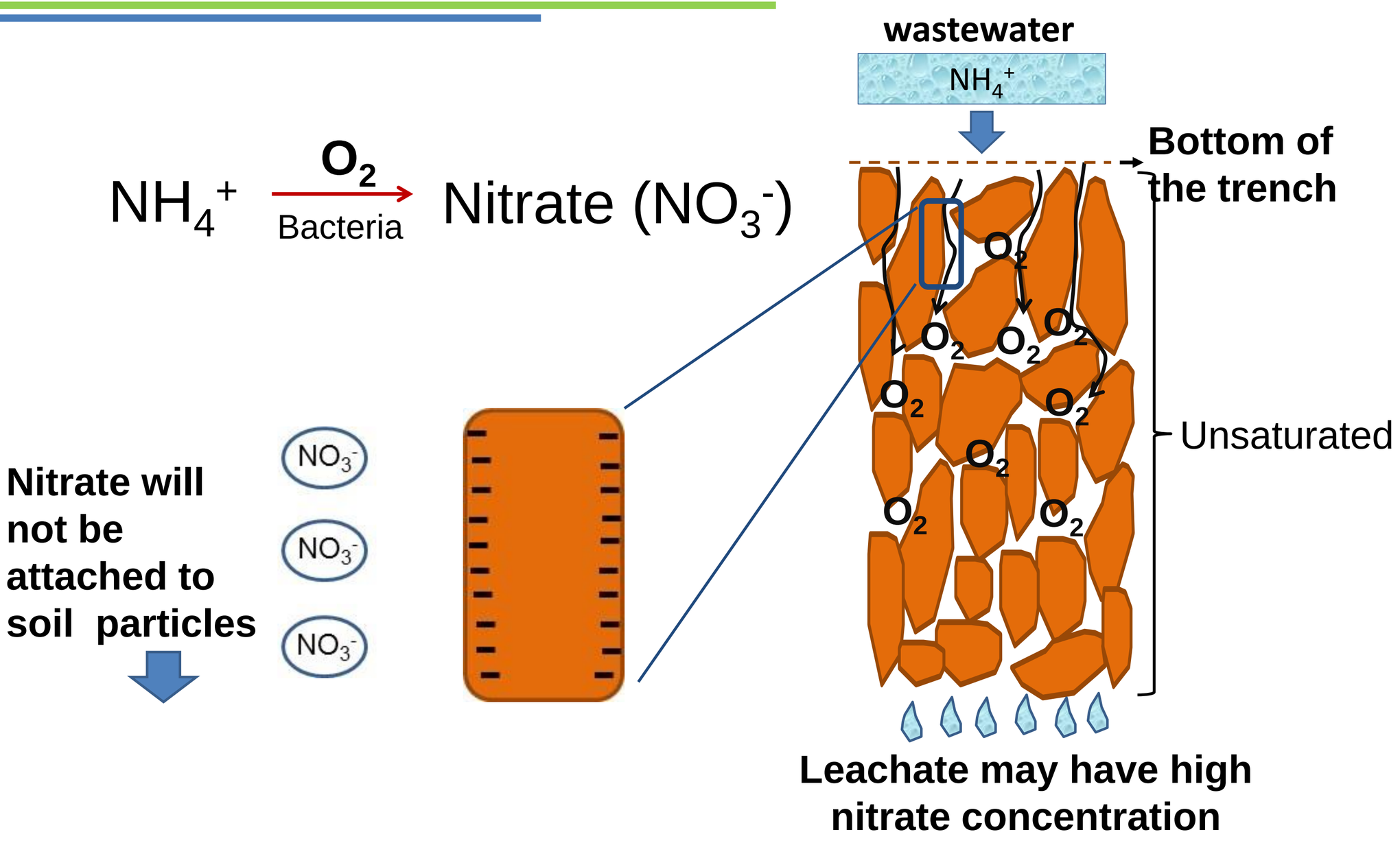
Forms of Nitrogen



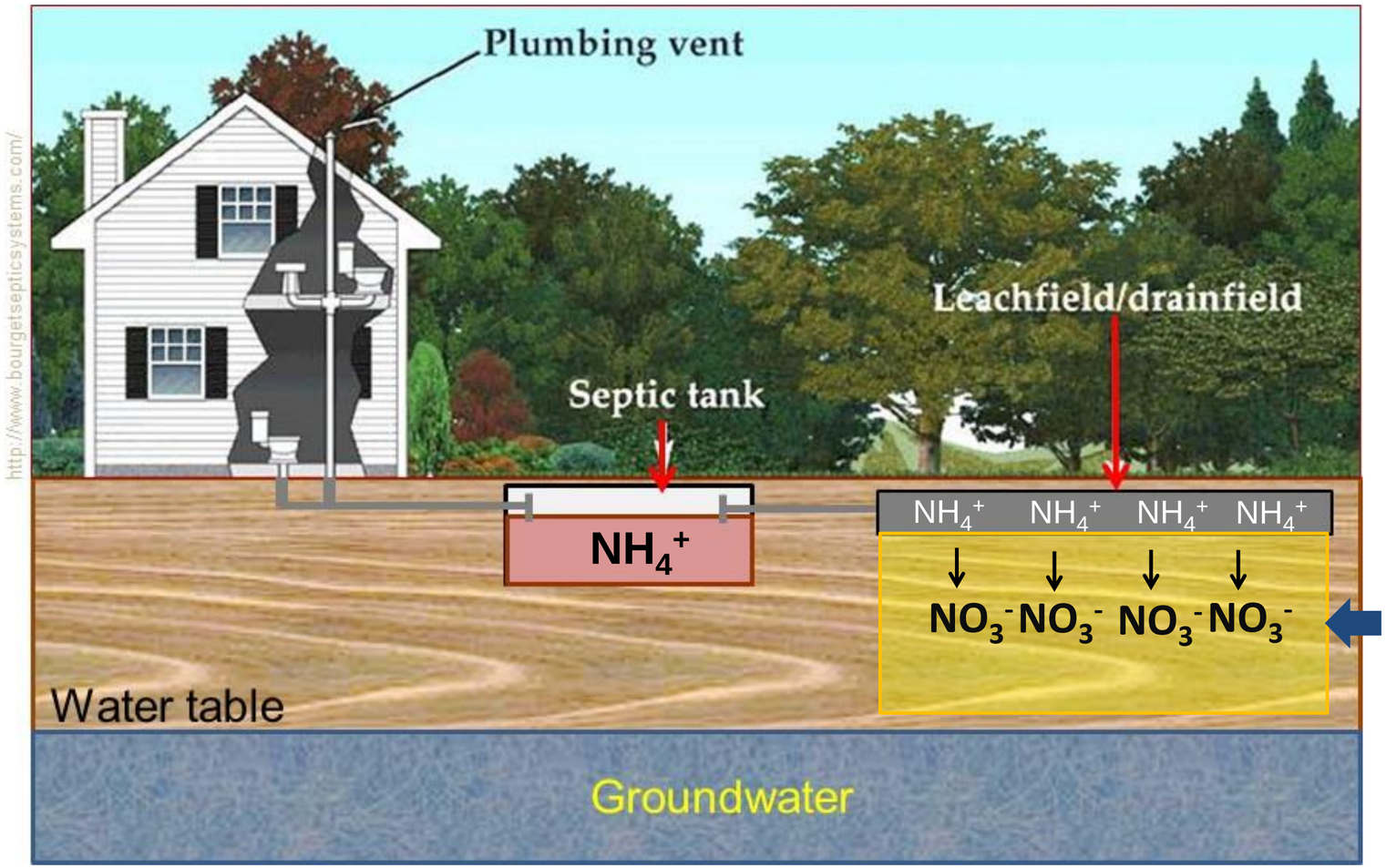
What about nitrate (NO_3^-)?

Forms of Nitrogen

$NH_4^+ \xrightarrow[\text{Bacteria}]{O_2}$ Nitrate (NO_3^-)



Forms of Nitrogen



Soil Treatment Area (STA)

What is going to happen to nitrate?

Fates of Nitrogen in the STA

1. Leached by moving water- **may pollute groundwater**
2. Taken-up by plant roots and utilized by soil microorganisms
3. Undergo **denitrification**

Denitrification?

NO_3^- ⟶ N_2↑

- Active bacteria
- Organic matter
- Saturated conditions
- Anaerobic conditions

Nitrate (NO_3^-)

What type of soil/site to look for to increase likelihood of treating nitrate?

1. Medium textured soils or finer

- Higher chance that nitrate is removed from the wastewater before it reaches the groundwater

2. Deep water table

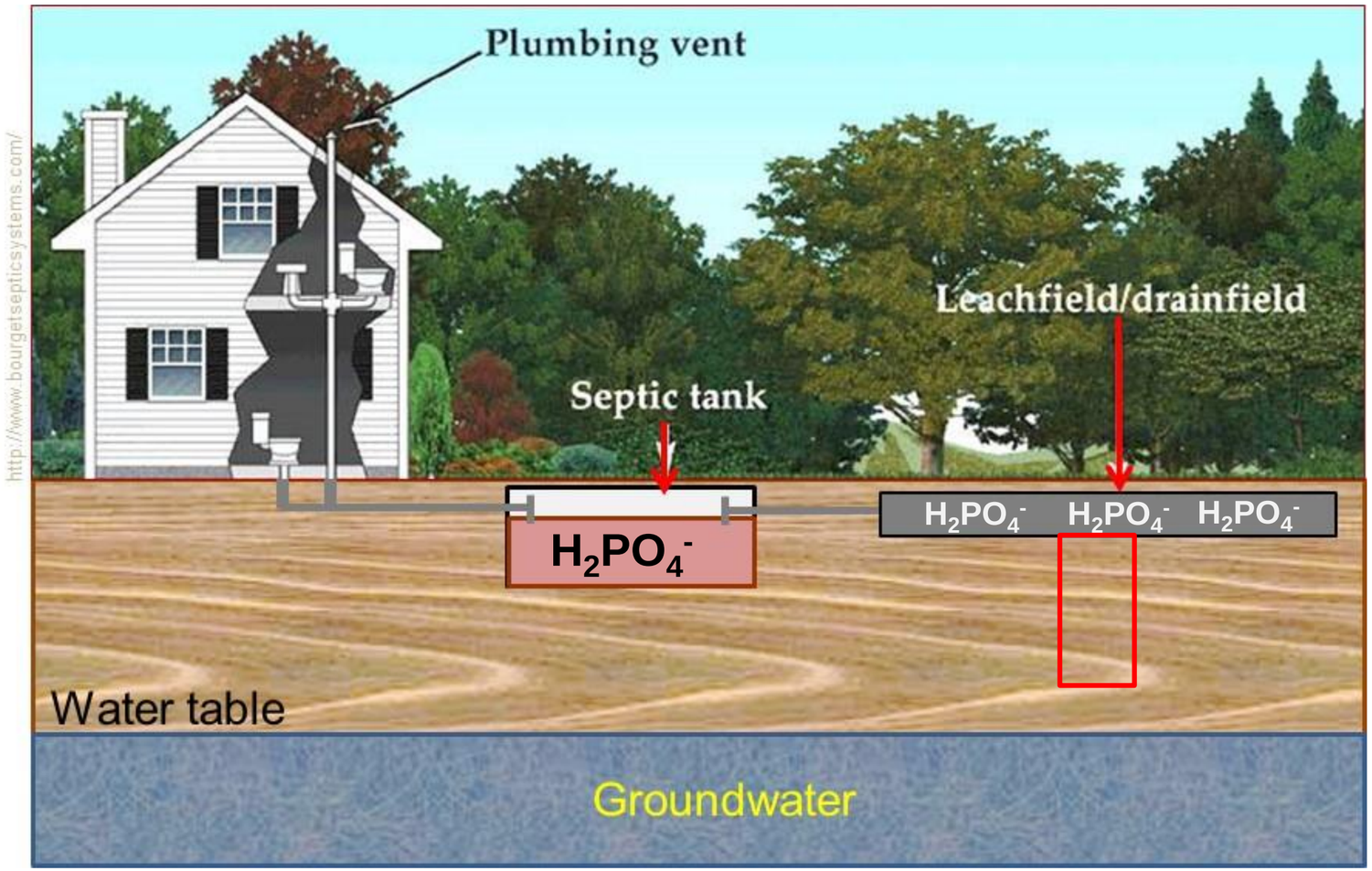
Phosphorus

Soluble forms of P in Septic Tank

1. $H_2PO_4^-$
2. HPO_4^{2-}

Negatively charged but are effectively attached to soil particles by forming chemical bonds with other substances

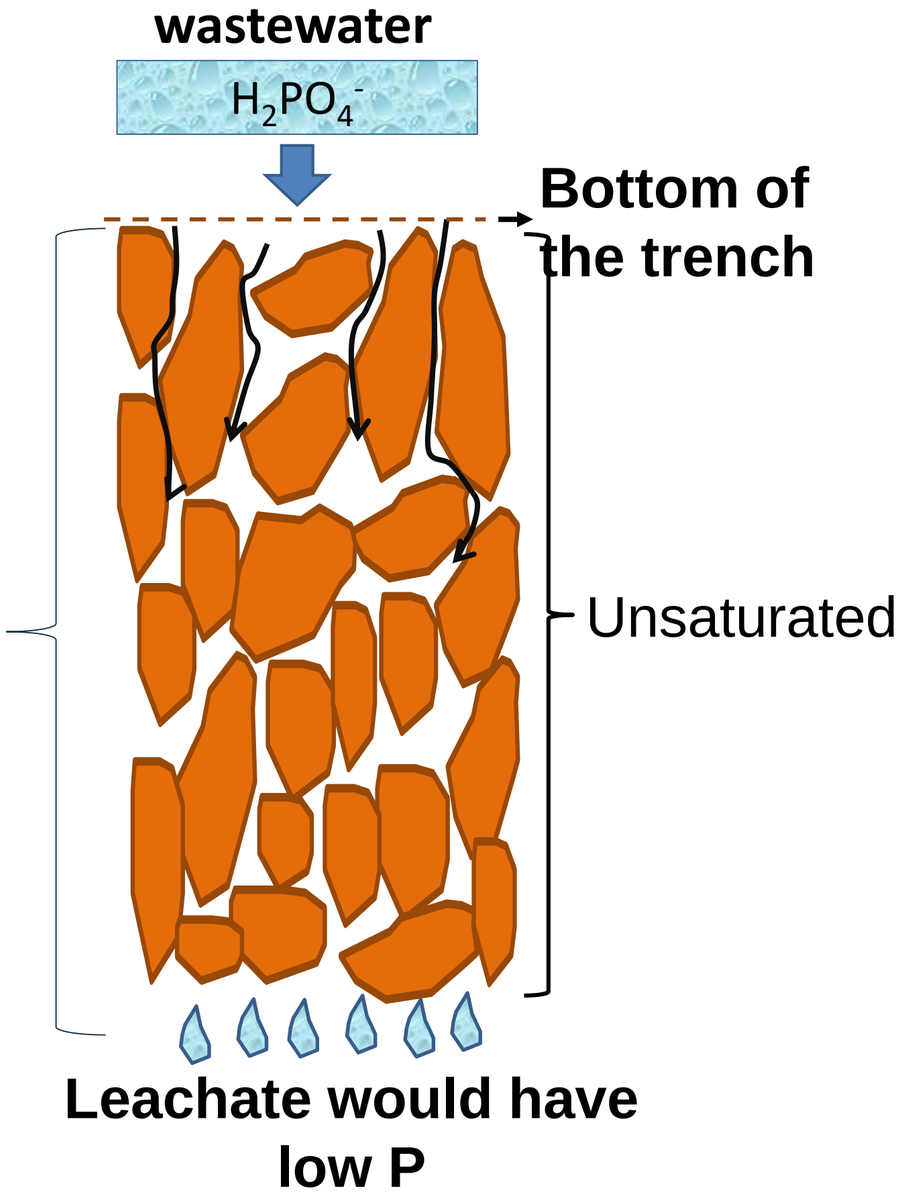
Phosphorus



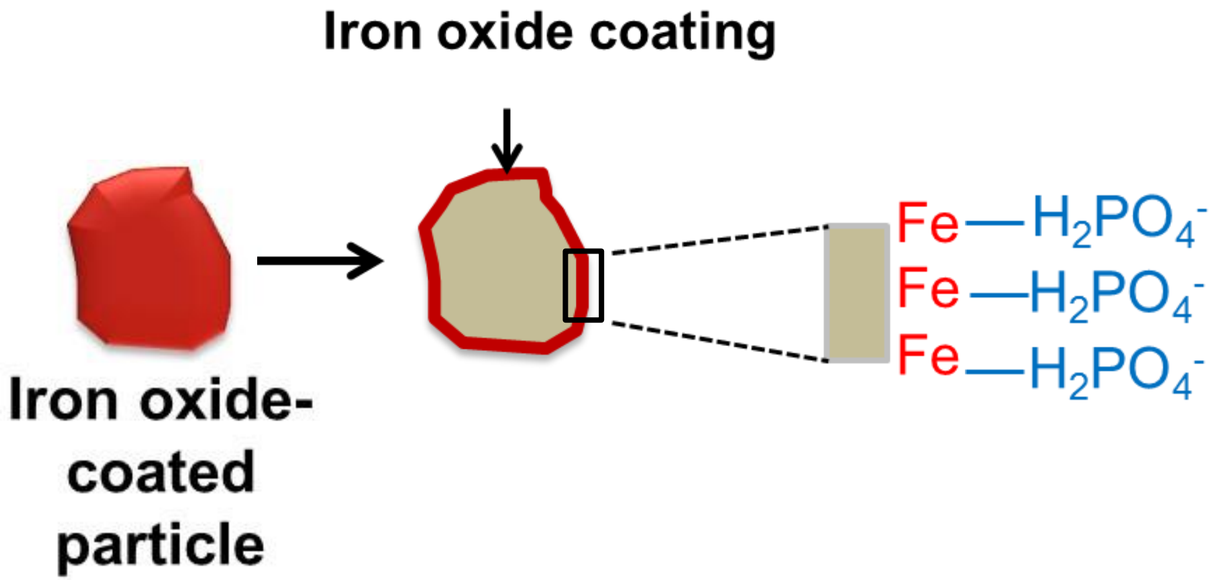
What is going to happen to phosphate?

Phosphorus

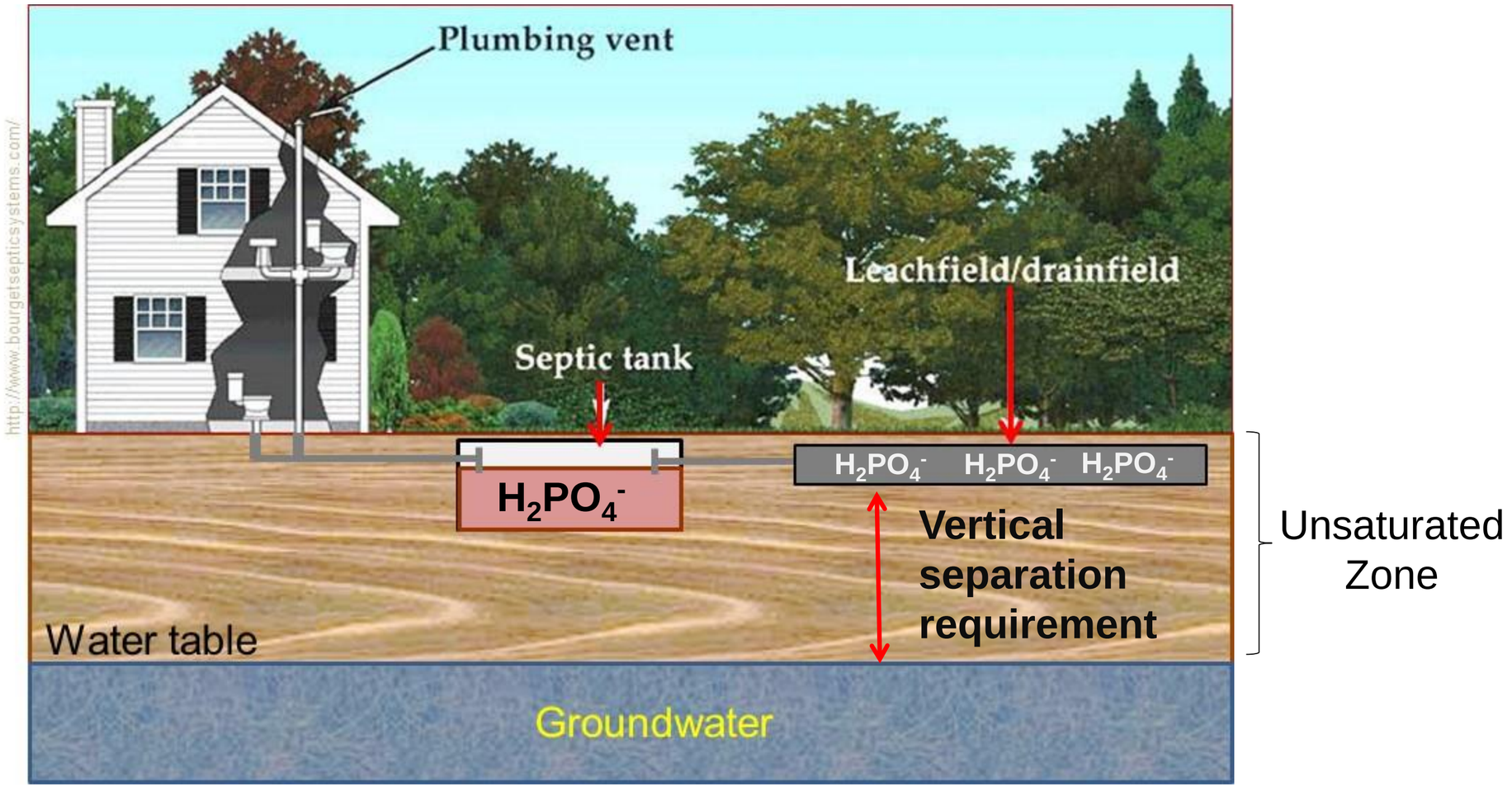
- form insoluble complexes with Fe, Al or Mg or Ca in soil
- Attach to soil coatings



Phosphorus

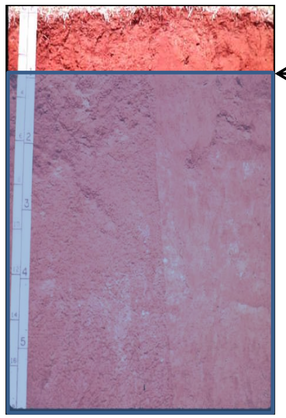

Iron oxide coating
Iron oxide-coated particle
Fe—$H_2PO_4^-$
Fe—$H_2PO_4^-$
Fe—$H_2PO_4^-$

Phosphorus



What is going to happen if the water table comes close to the bottom of the trenches?

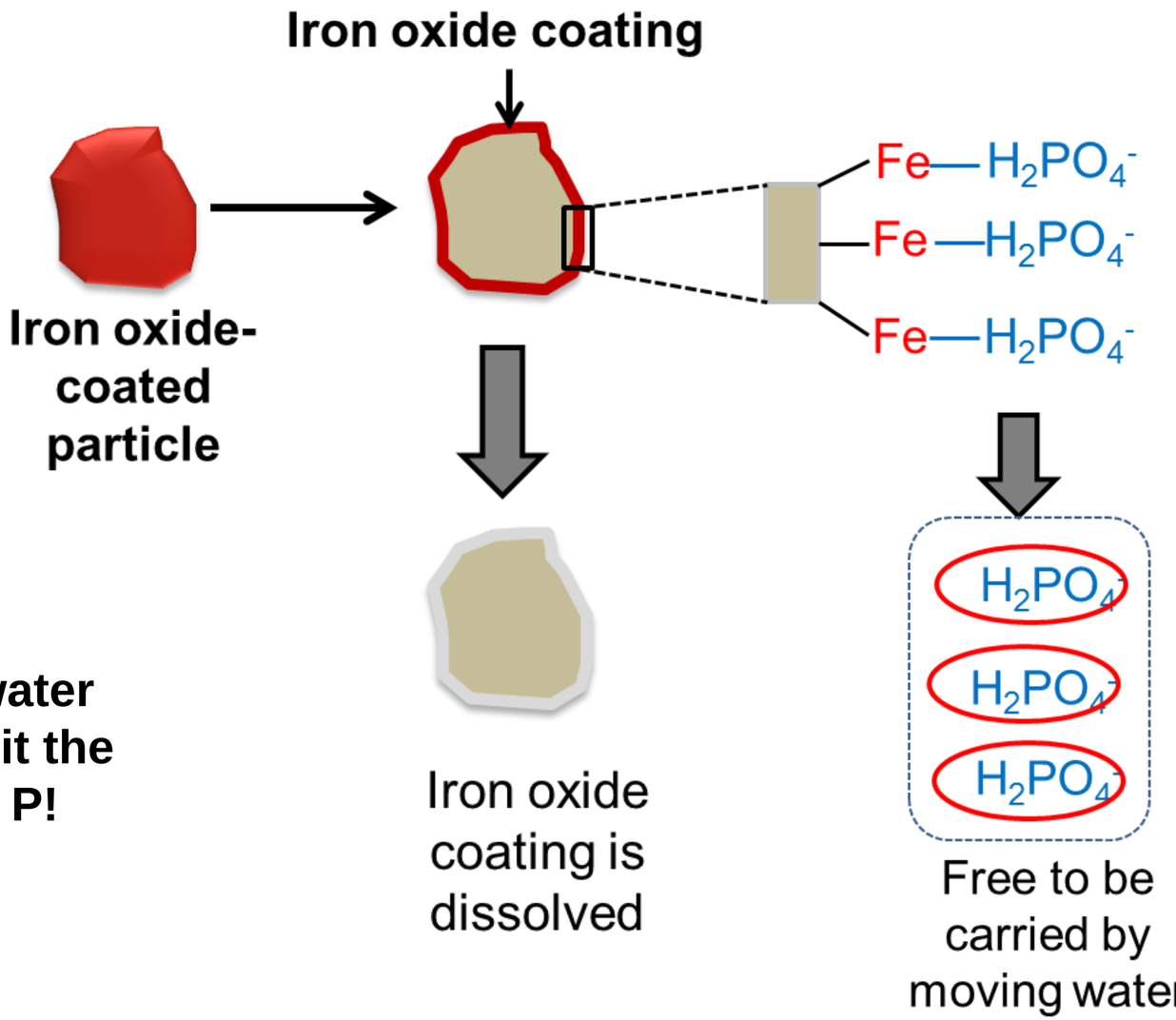
Phosphorus



Water Table

Receding water carries with it the dissolved P!

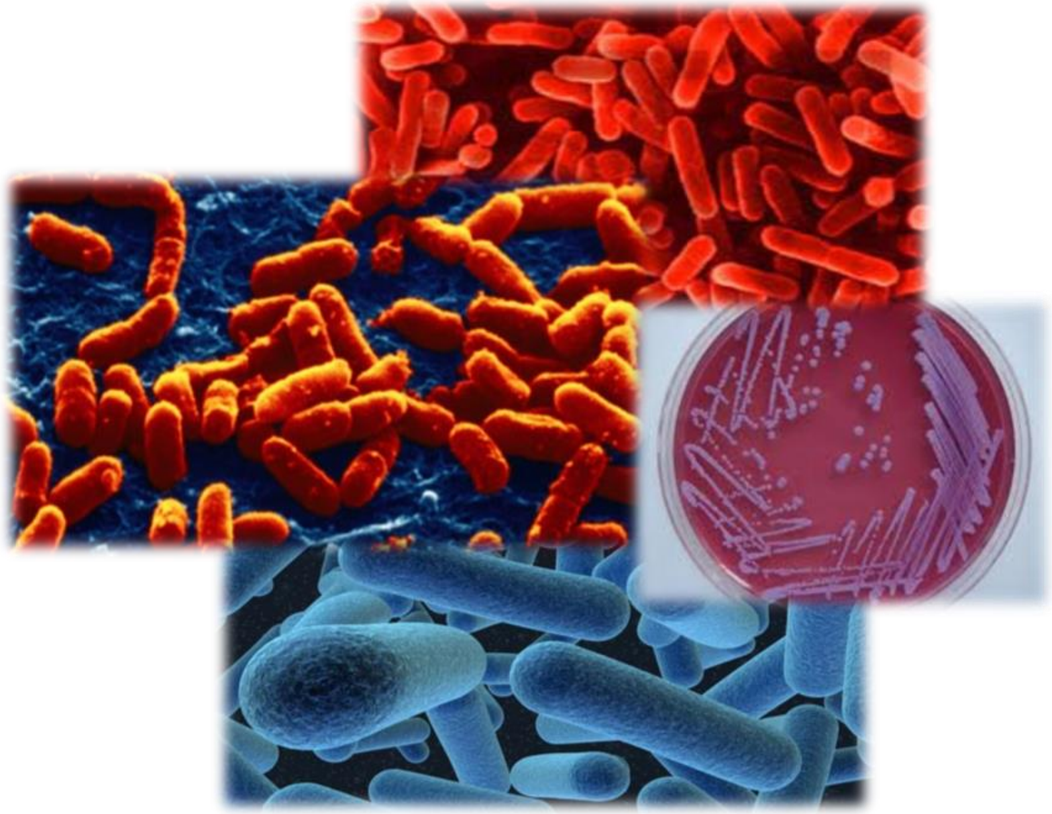
Water Table



Phosphorus

What type of soil/site to look for to increase likelihood of treating phosphorus?

1. **High clay content** **(that effectively allows water flow)** – high P sorption or attachment potential
2. **Red Soils** – high iron content
3. **Deep water table**



Bacteria

Images:

homoartificialis.wordpress.com

blogs.discovermagazine.com

popsci.com

guardian.co.uk

Bacteria

Characteristics:

1. Some are pathogenic
2. Some are motile
3. Have varied surface charge properties (different degrees of negativity)
4. Survival depends on:
   - **Moisture Condition**
   - **Adequate Carbon**
   - **Soil pH (6-8)**
   - **Aeration**
   - **Ability to compete with other bacteria**

Bacteria

Fates in the soil:

1. Could be attached to or filtered by the soil
2. Multiply under favorable growing conditions
3. Not survive if out-competed by native soil organisms

Bacteria

Soil properties to look for to increase likelihood of treating bacteria in onsite wastewater:

1. **The finer the soil texture, the better** (fine but still allows effective water movement)**.**

More effective **Filtration** and
Surface Attachment

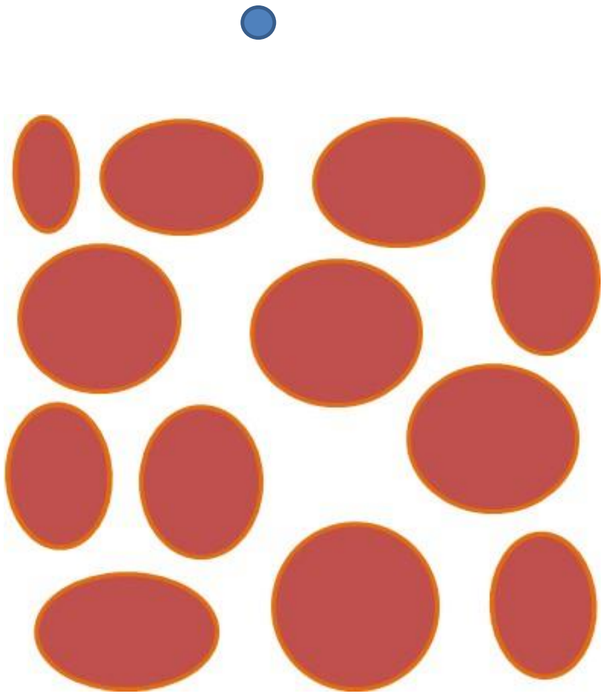
Bacteria

Soil properties to look for to increase likelihood of treating bacteria in onsite wastewater:

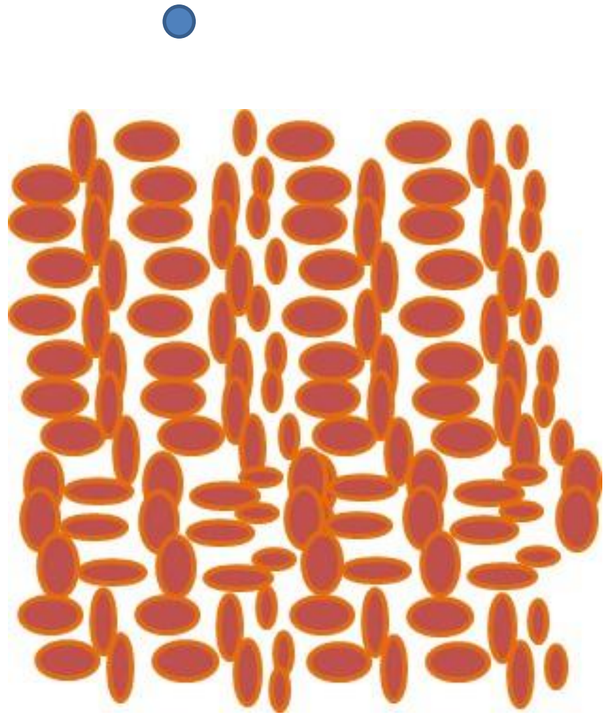
1. **The finer the soil texture, the better** (fine but still allows effective water movement).

More effective **Filtration** and **Surface Attachment**

Bacteria - Filtration



Coarse-Textured Soils



Fine/Medium-Textured Soils

Bacteria - Filtration

Influence of Soil Texture

Fine Textures

↓

Small Pores

↓

Entrapment more likely

↓

Retention by filtration is more-likely

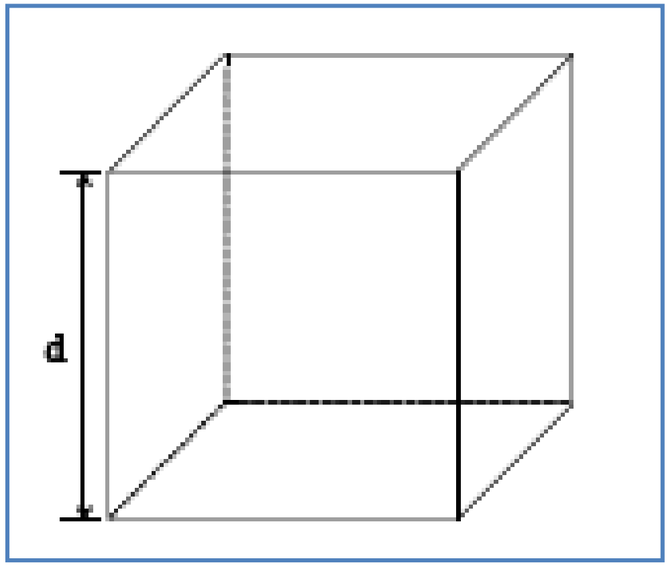
Bacteria – Sorption (surface attachment)

Surface attachment; dependent on particle surface area

Largely influenced by particle size

How is surface area related to particle size?

Particle Size and Surface Area

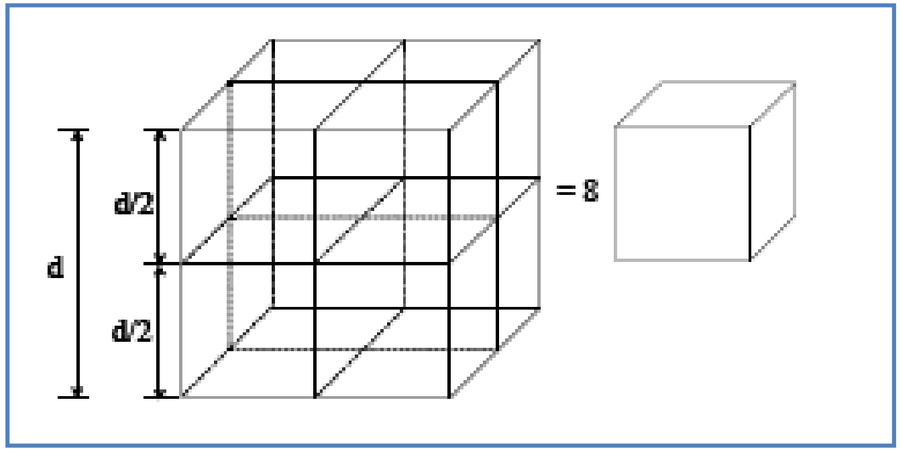


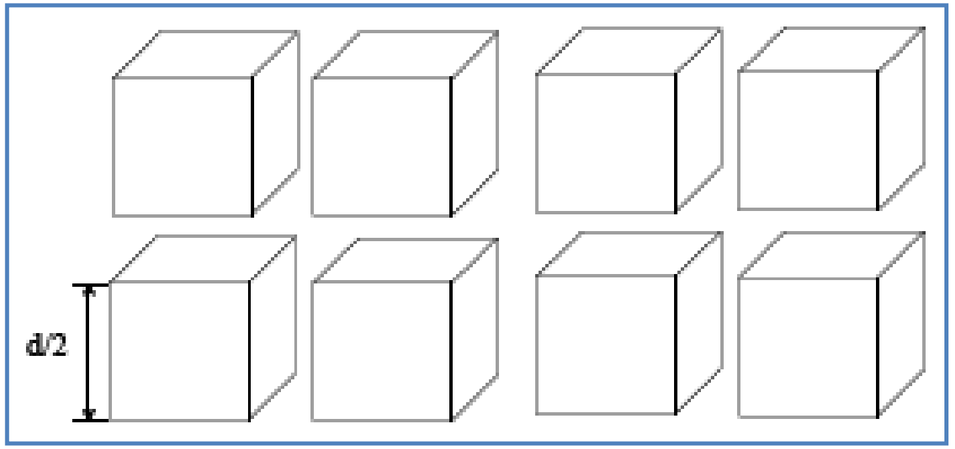
Volume d^3

Surface Area $6d^2$

Surface Area/ Volume $6d^2/d^3 = 6/d$

Particle Size and Surface Area



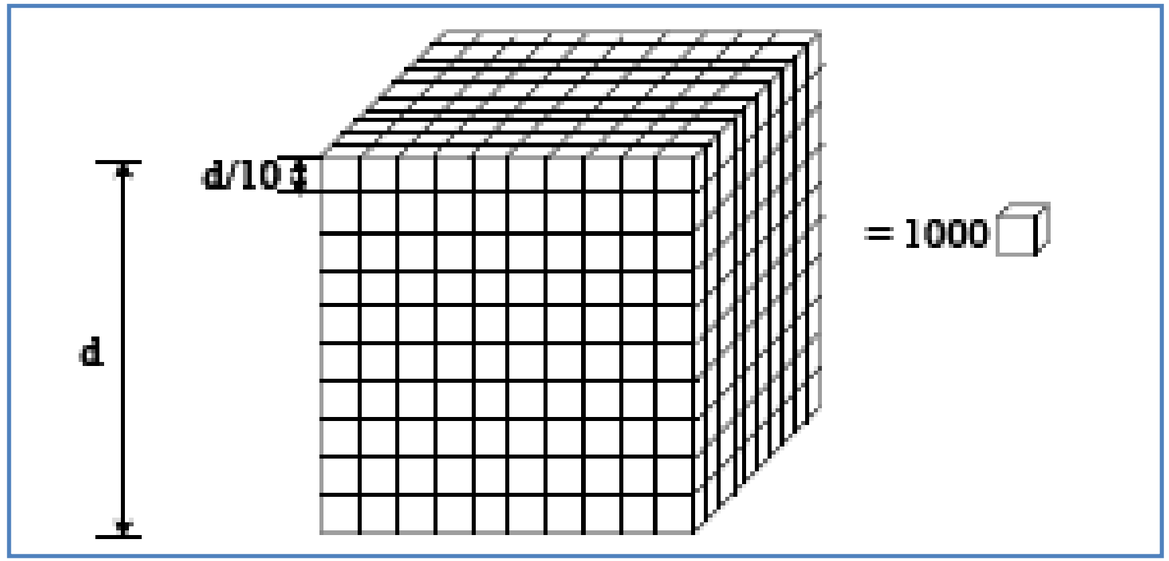


Volume $8(d/2)^3 = d^3$

Surface Area $8x6(d/2)^2 = 48d^2/4$

Surface Area/ Volume $12d^2/d^3 =$ 12/d

Particle Size and Surface Area

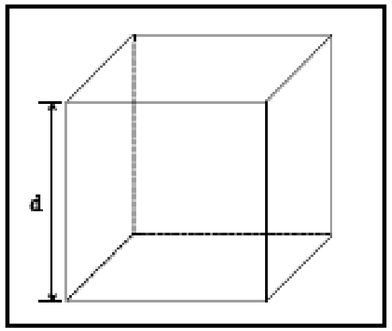


Volume $1000(d/10)^3 = d^3$

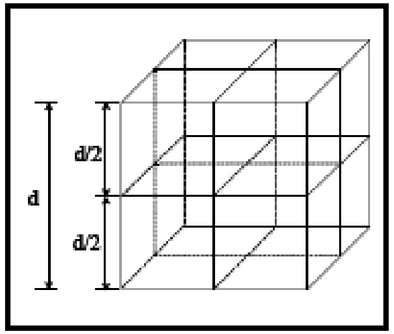
Surface Area $1000x6(d/10)^2 = 6000d^2/100$

Surface Area/ Volume $60d^2/d^3 =$ 60/d

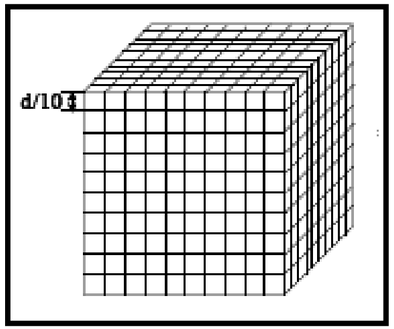
Particle Size and Surface Area



Surface Area/ Volume = 6/d



Surface Area/ Volume = 12/d



Surface Area/ Volume = 60/d

Particle Size and Surface Area

Particle	Effective Diameter (cm)	Surface Area (cm^2)	Specific Surface Area (cm^2/g)
Sand	5×10^{-3}	7.9×10^{-5}	445

Roth

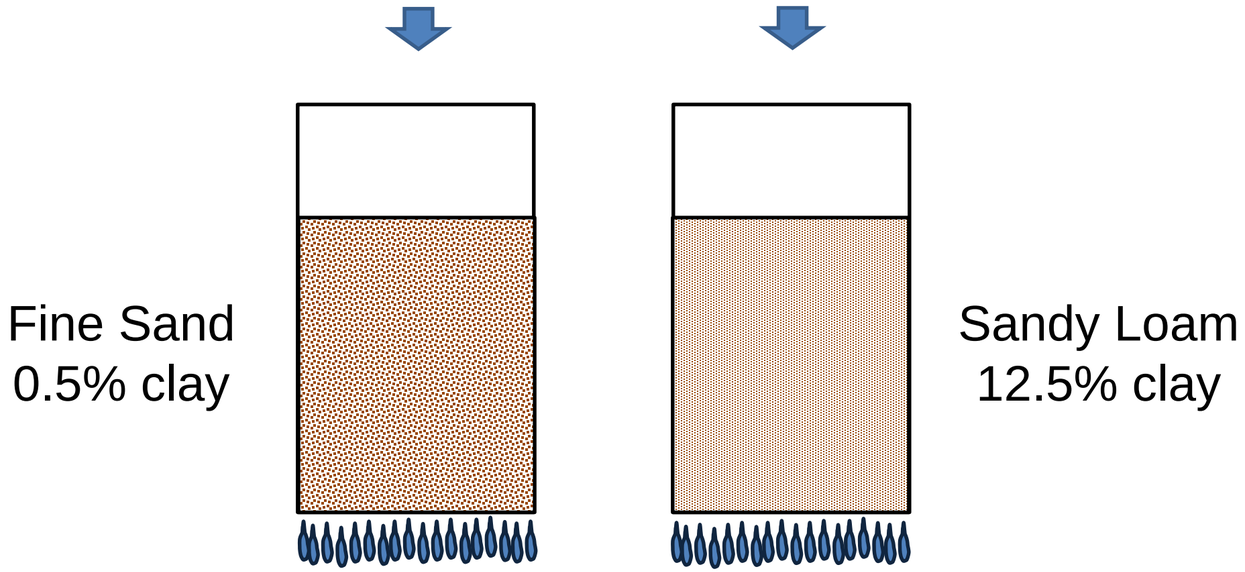
Particle Size and Surface Area

Particle	Effective Diameter (cm)	Surface Area (cm^2)	Specific Surface Area (cm^2/g)
Sand	5×10^{-3}	7.9×10^{-5}	445
Clay	2×10^{-4}	6.3×10^{-8}	7.4×10^{6}

Roth

Bacterial Retention –Effect of Texture

Applied suspension with known concentrations of *E. coli* and *Salmonella*



Abit, et al., 2014

Bacterial Retention –Effect of Texture

Result from a bacterial transport experiment using soil columns involving *E.coli and Salmonella*

	Clay (%)	**Fractional Recovery (%)**	
		E. coli	*S. typhimurium*
Fine Sand	0.50	87	78

Abit, et al., 2014

Bacterial Retention –Effect of Texture

Result from a bacterial transport experiment using soil columns involving *E.coli and Salmonella*

	Clay (%)	**Fractional Recovery (%)**	
		E. coli	*S. typhimurium*
Fine Sand	0.50	87	78
Sandy Loam	12.5	0.04	0.04

Abit, et al., 2014

Bacteria

Soil properties to look for to increase likelihood of treating bacteria in onsite wastewater:

1. **Medium- and Fine-textured soils are better**

Bacteria

Soil properties to look for to increase likelihood of treating bacteria in onsite wastewater:

1. Medium- and Fine-textured soils are better
2. **Red soils are better**
   - **Coated with Iron Oxides**

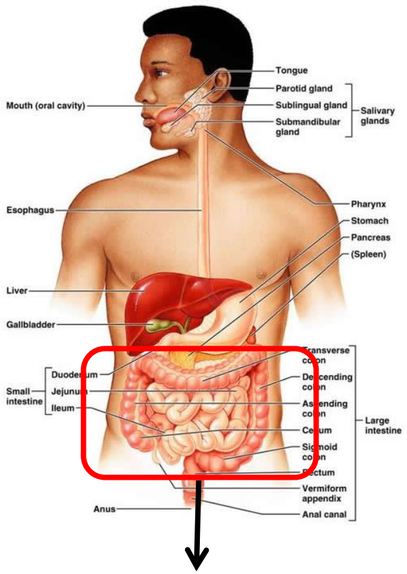
Bacteria

Soil properties to look for to increase likelihood of treating bacteria in onsite wastewater:

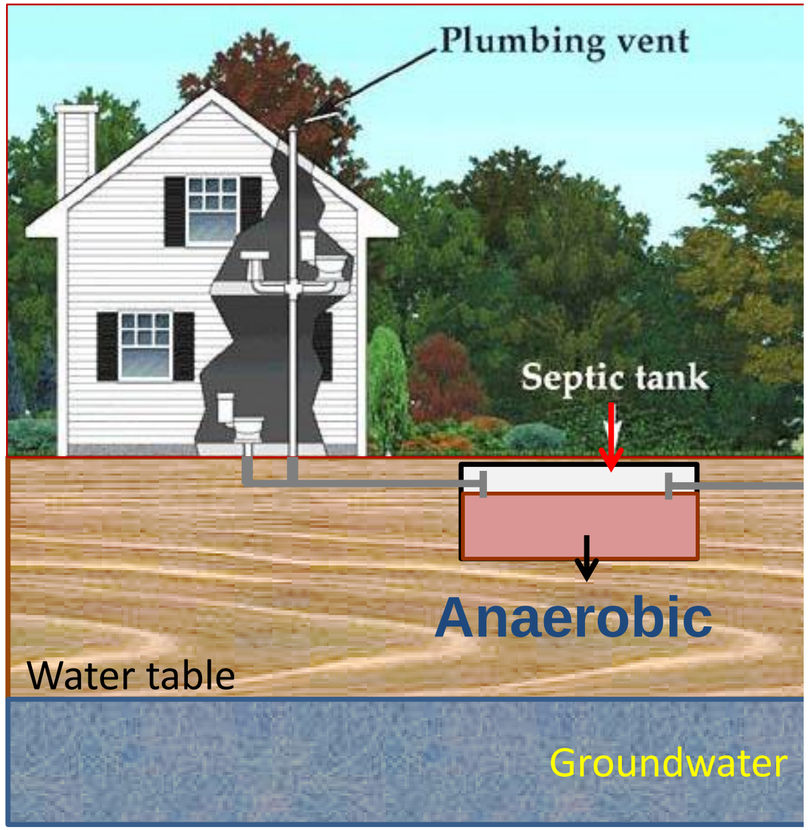
1. Medium- and Fine-textured soils are better
2. Red soils are better
3. **Well-drained soils**
   - **Deep Water Table**
   - **Thick unsaturated zone**

Bacteria

Well-drained Soils

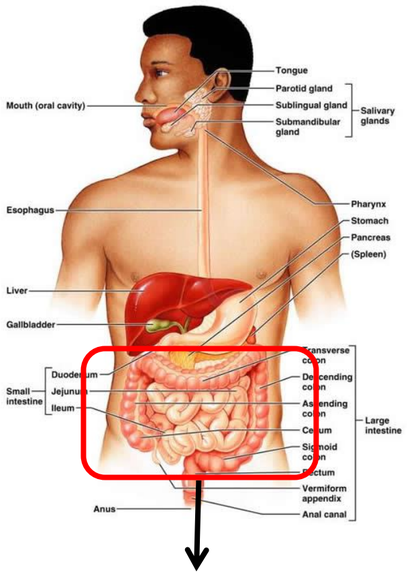


Anaerobic

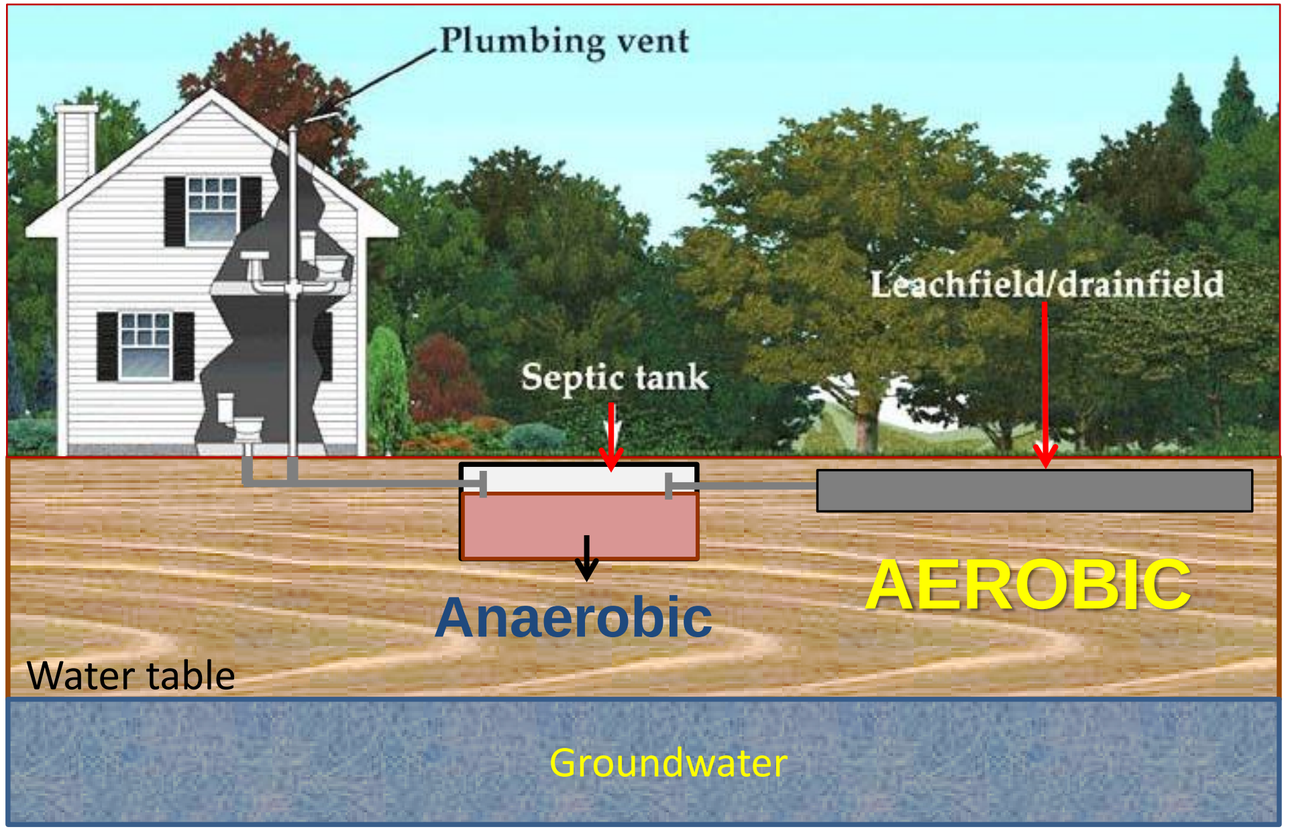


Bacteria

Well-drained Soils



Anaerobic



Bacteria

What happens to bacteria in an unsaturated or aerobic STA?

1. Anaerobic bacteria will weaker.
2. Anaerobic bacteria will be out-competed by native aerobic bacteria in the soil.
3. Attachment is more effective.

Bacteria

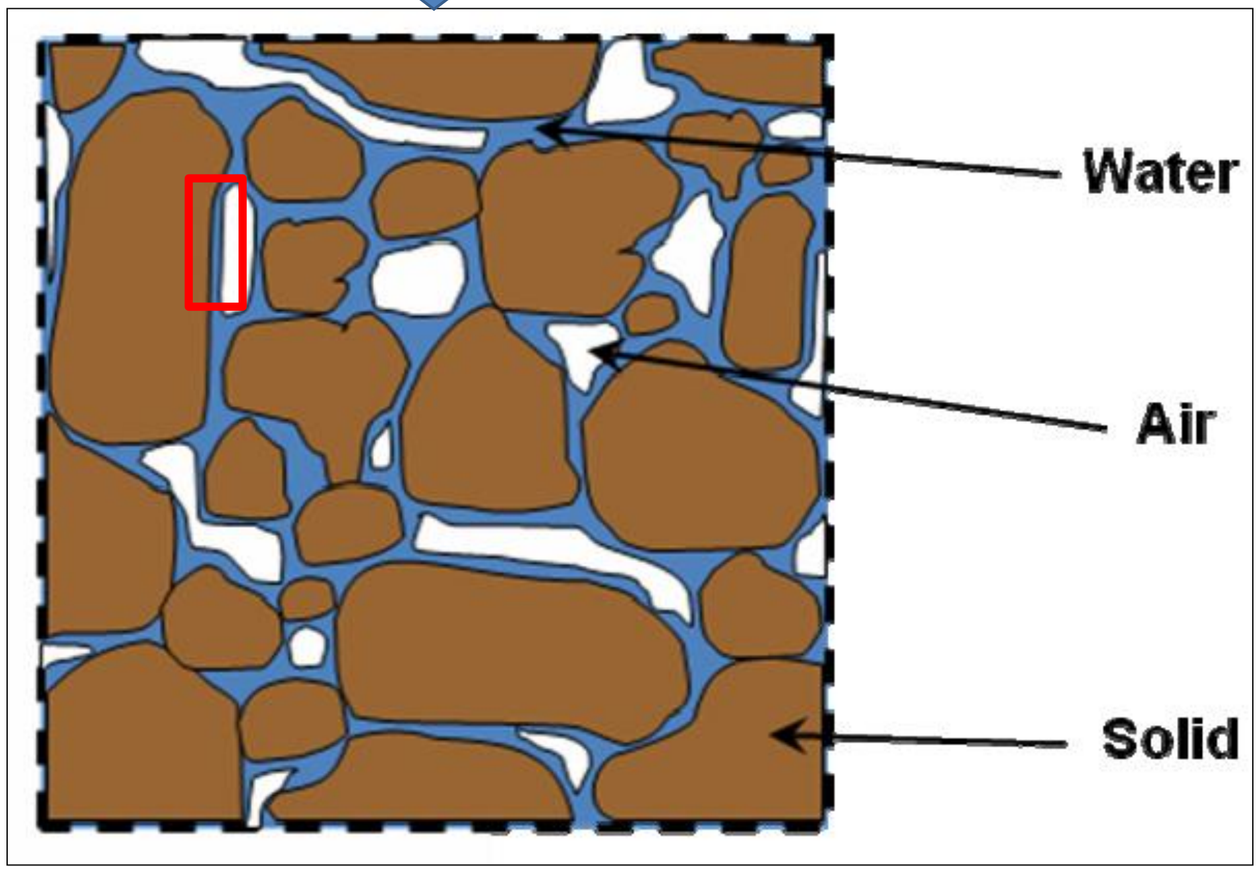
What happens to bacteria in an unsaturated or aerobic STA?

1. Anaerobic bacteria will weaker.
2. Anaerobic bacteria will be out-competed by native aerobic bacteria in the soil.
3. **Attachment is more effective.**

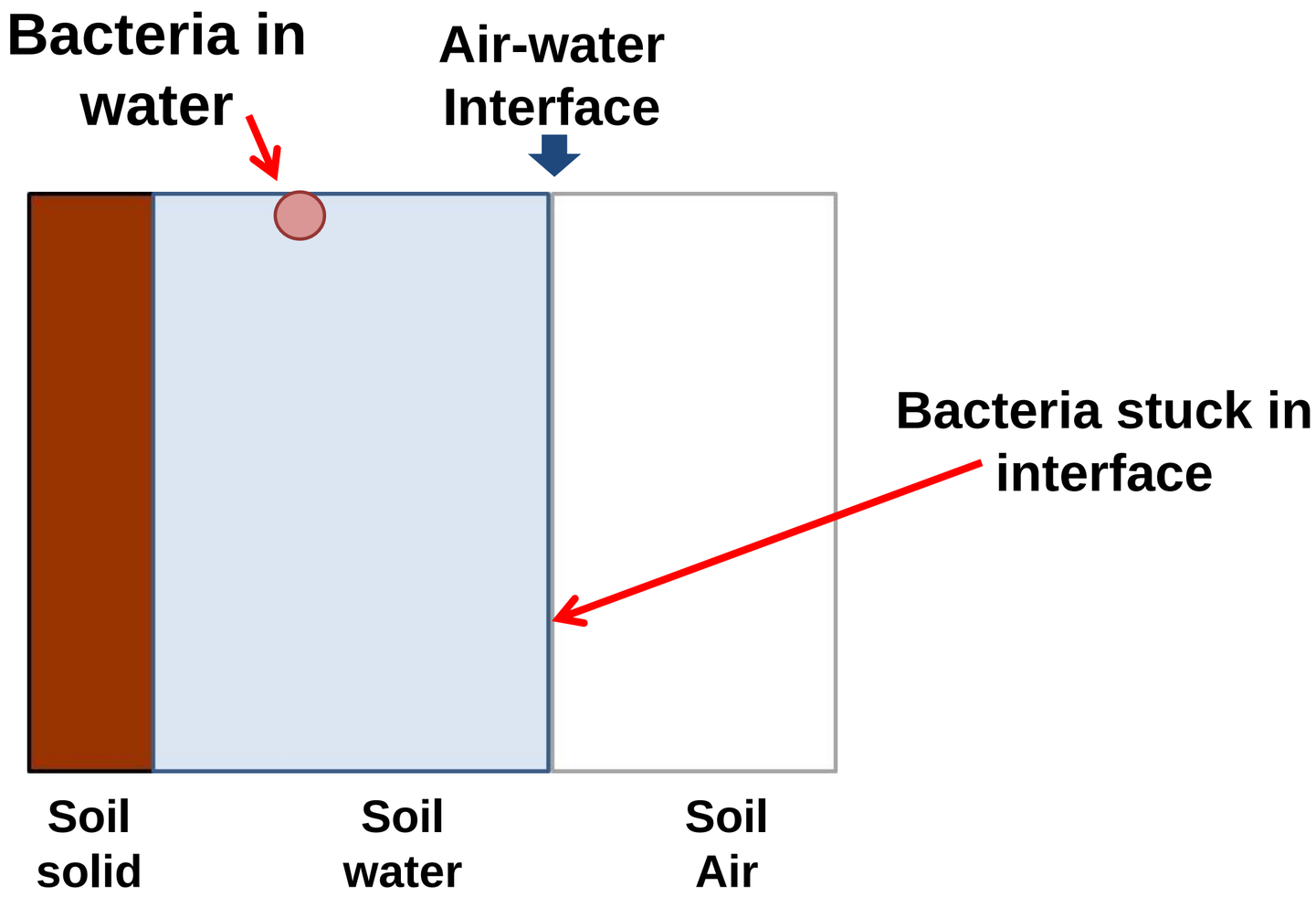
Bacterial Sorption in Unsaturated Soil

wastewater

bacteria



Bacterial Sorption in Unsaturated Soil



Bacterial Sorption in Unsaturated Soil

Result from an *E. coli* transport experiment using soil columns with fine sand

	Percent Retained in Soil
Saturated Soil	19

Abit, et al., 2012

Bacterial Sorption in Unsaturated Soil

Result from an *E. coli* transport experiment using soil columns with fine sand

	Percent Retained in Soil
Saturated Soil	19
Unsaturated Soil	**42**

Abit, et al., 2012

Take-home Points: Nitrogen

1. Ammonium (NH_4^+) is the main form of N in septic tanks.
2. In aerobic STAs, NH_4^+ is converted to nitrate (NO_3^-).
3. Because soil surfaces are negatively charged, the negatively-charged nitrate is effectively carried by the water downward.
4. Enough vertical separation should be provided so that nitrate may be removed by:
    a) Root uptake
    b) Utilization by soil microorganisms
    c) Denitrification

Take-home Points: Phosphorus

1. In septic tanks, dissolved P are in anionic forms ($H_2PO_4^-$, HPO_4^{2-}).
2. Dissolved P are effectively attached to: Fe and Al oxides or Ca and Mg
3. To increase the likelihood of treatment of P-enriched onsite wastewater, the STA has to have:
   a) Soils with high clay content
   b) Red Soils
   c) Well-drained soil (deep water table)

Take-home Points: Bacteria

1. Some bacteria in septic waste water are pathogenic.
2. To increase the likelihood of treatment of bacteria in onsite wastewater, the STA has to have:
   a) Soils with high clay content
   b) Red Soils
   c) Well-drained soil (deep water table)

Plug.

Second Talk @ 4 PM

Microbiology in Advanced Treatment Systems

How do we end?

Better understanding of the processes involved in the treatment of key contaminants from OWTS.

Improved appreciation of what we do.

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OKLAHOMA COOPERATIVE EXTENSION

Thank you!