OKLAHOMA COOPERATIVE EXTENSION

Microbiology in Advanced Treatment Systems

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Presentation Outline

1. Microorganisms in Onsite Wastewater – why do we care?
2. Why/When do we need advanced systems?
3. What affects microbial growth and survival?
4. Common methods of treatment in Advanced Systems:
    - Addition of more surfaces
    - Aeration
    - Materials that influence microbial activity
    - Increasing microbe-wastewater contact
5. Take-home Points

Why do we care about microbes in OWTS?

Microorganisms accomplish the treatment of various substances in onsite wastewater.

1. Partial decomposition of solids
2. Degradation of dissolved harmful compounds
3. Transformation of contaminants (*e.g.* N)
4. Outcompete/Predate on harmful microorganisms

Many microorganisms in onsite wastewater are pathogens.

Make us sick!

Why do we care about microbes in OWTS?

Microorganisms accomplish the treatment of various substances in onsite wastewater.

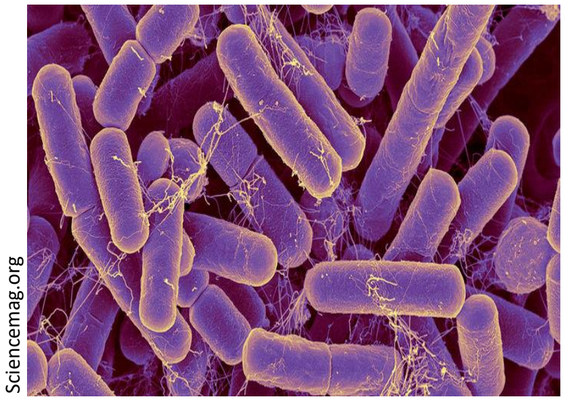
1. Partial decomposition of solids
2. Degradation of dissolved harmful compounds (pharmaceuticals, hormones, etc.)
3. Biochemical transformation of chemical contaminants (*e.g.* N)
4. Outcompete/Predate on harmful microorganisms

Many microorganisms in onsite wastewater are pathogens.

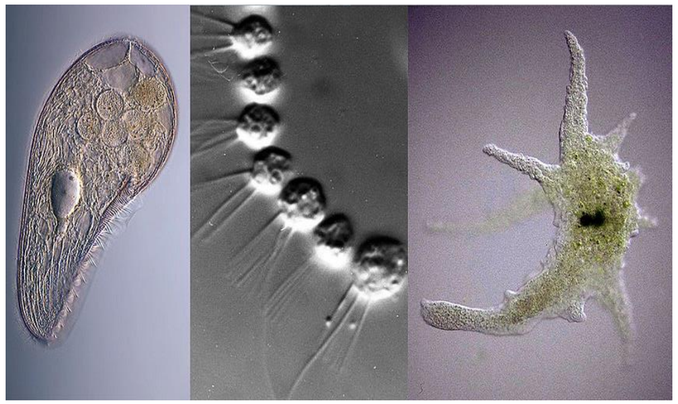
Make us sick!

What pathogenic microbes are we up against?

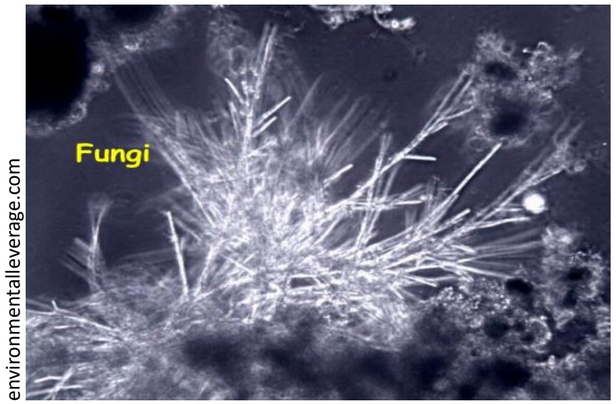
Microorganisms in Onsite Wastewater


Sciencemag.org

Bacteria

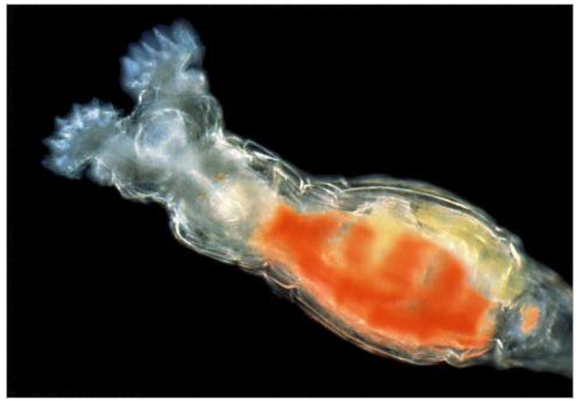

Wikipedia

Protozoa

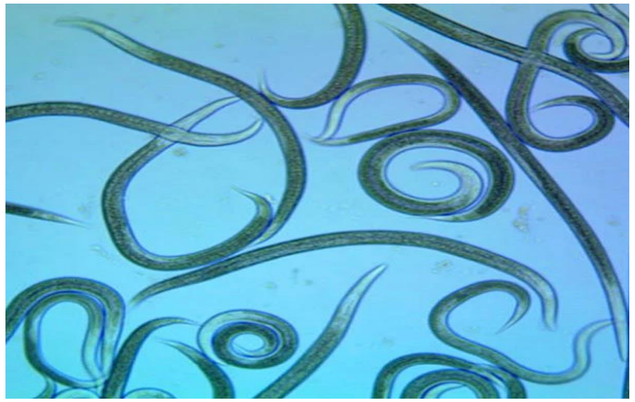


environmentalleverage.com

Fungi


Micrographia.com

Rotifers


planetnatural.com

Nematodes

What pathogenic microbes are we up against?

Bacteria Isolated from 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).

What pathogenic microbes are we up against?

Bacteria Isolated from 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).

What pathogenic microbes are we up against?

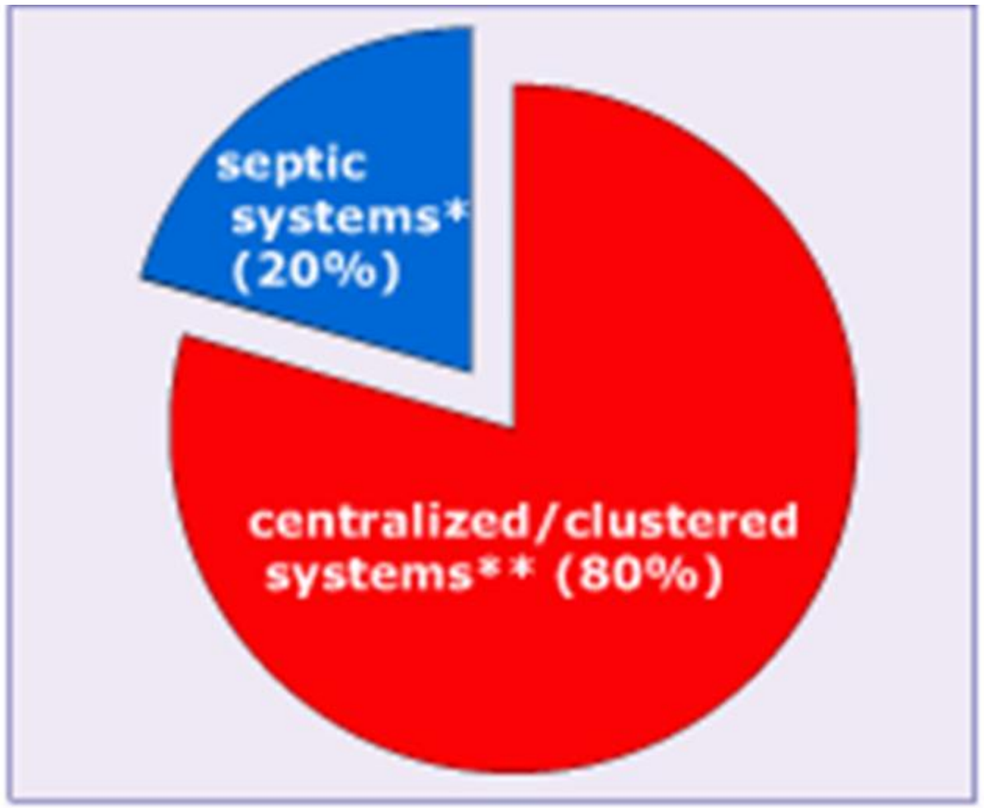
Bacteria Isolated from Onsite Wastewater

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).

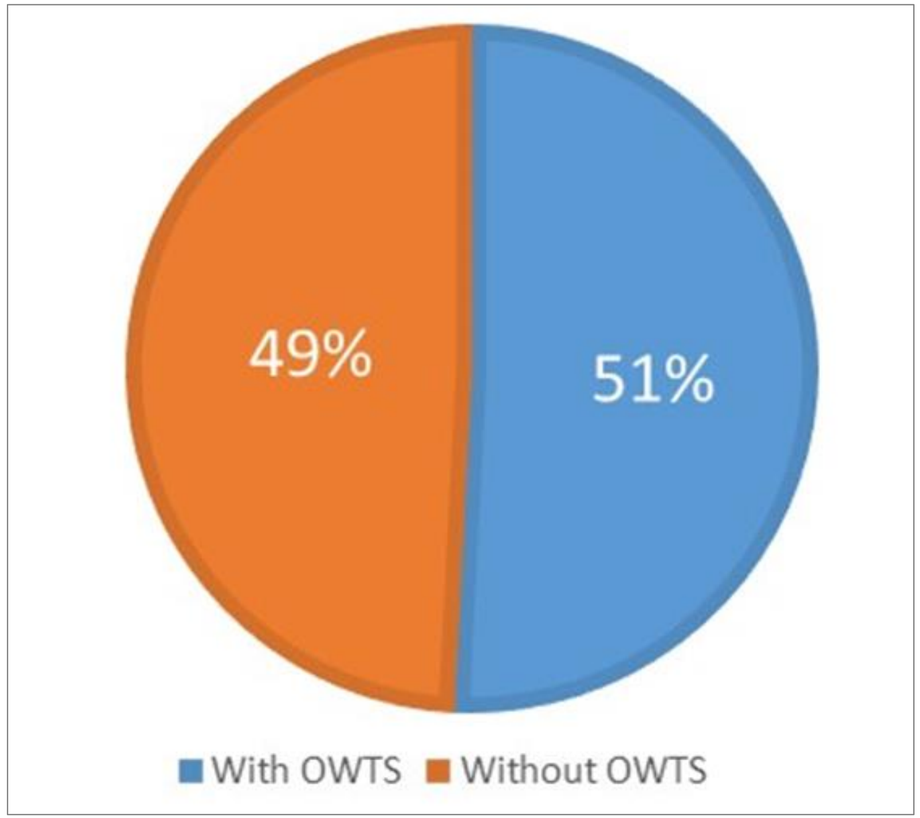
This matters because…

Percentage of housing units served by septic systems and by centralized treatment systems



EPA

Nationwide



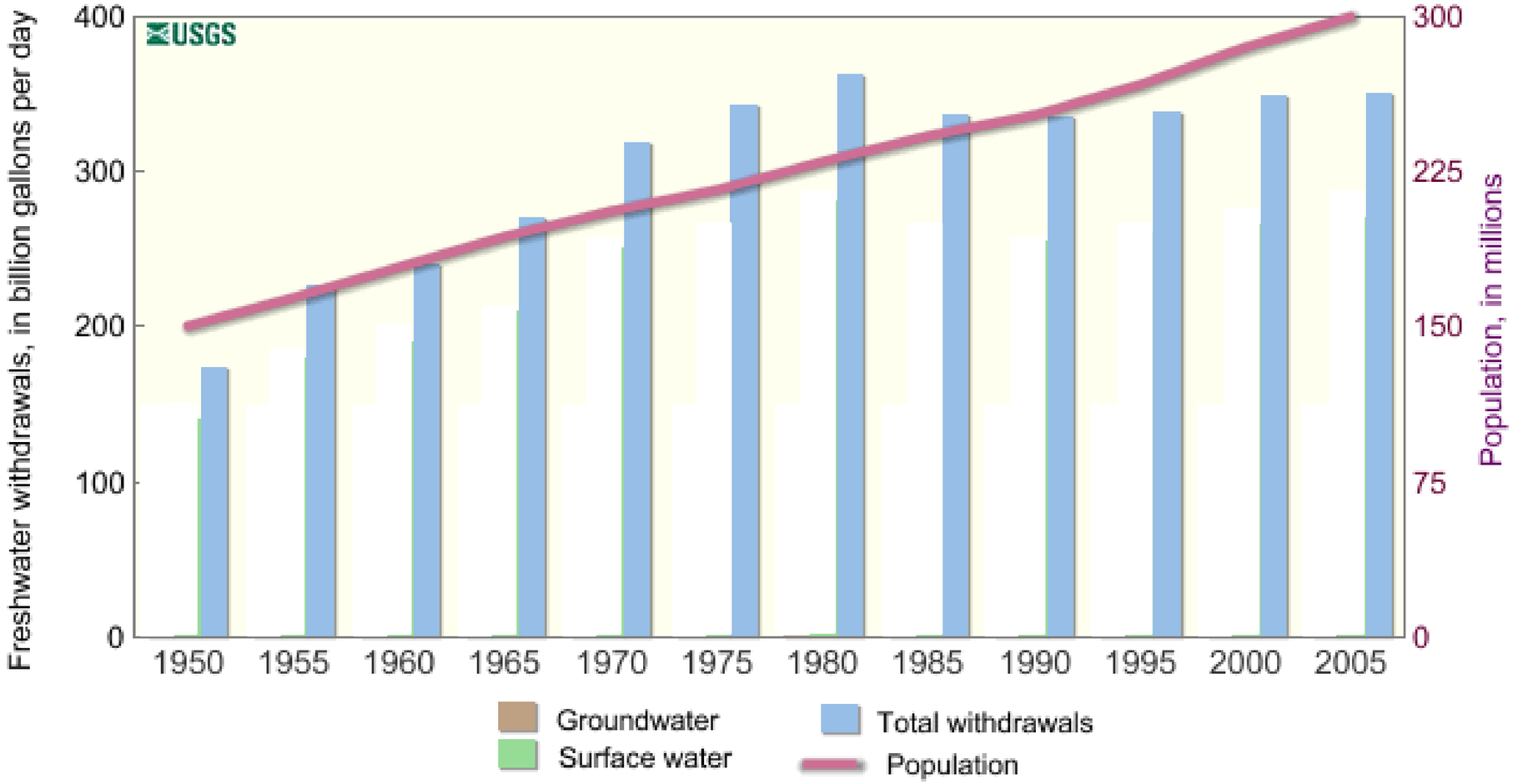
Abit

Oklahoma

(2002 to 2017)

This matters because…

Our sources of water for various human uses are in close proximity to where we disperse onsite wastewater



Microbiology in septic systems do matter!!

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Microbiology in Advanced Treatment Systems

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When do we need advanced systems?

Advanced Treatment Systems

When all is good… we go conventional!

What happens here?

Treatment at the Soil Treatment Area

Pathogenic Bacteria:

- Weakened, Out-competed, Die

Pharmaceuticals and other Emerging Contaminants:

- Sorbed on soil surfaces and/or degraded by microbes

Phosphorus:

- Form insoluble complexes with Fe, Al, Mg and/or Ca

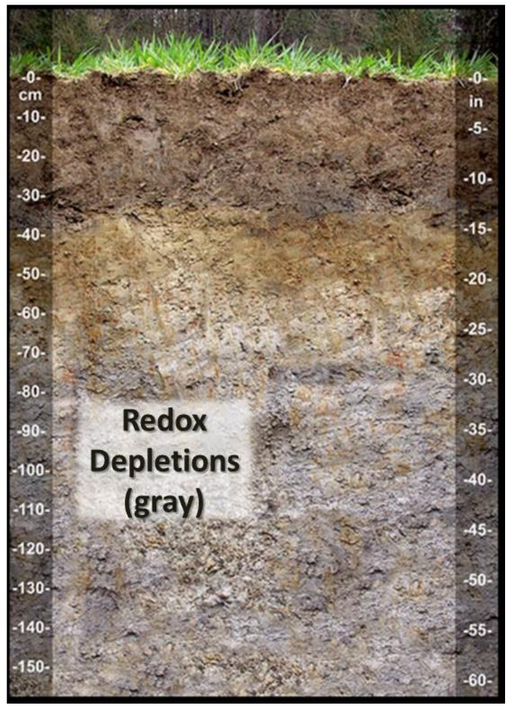
Nitrogen:

- Taken-up by plants, utilized my soil microbes, denitrified

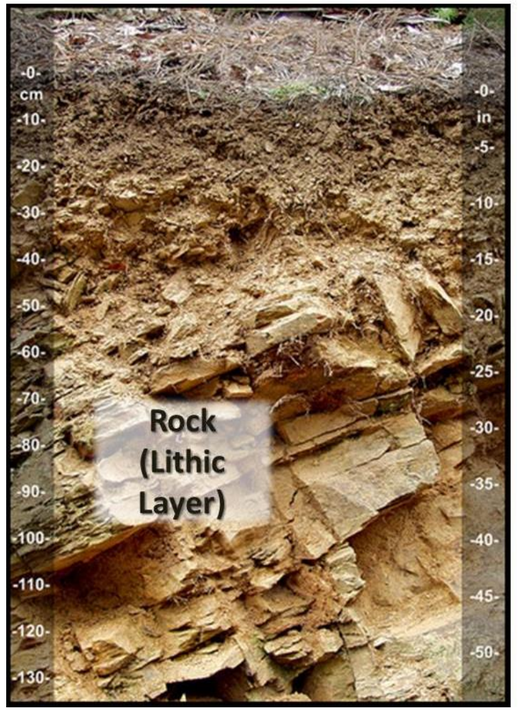
What if all is NOT good?

- Land area too small
- There are limiting layers

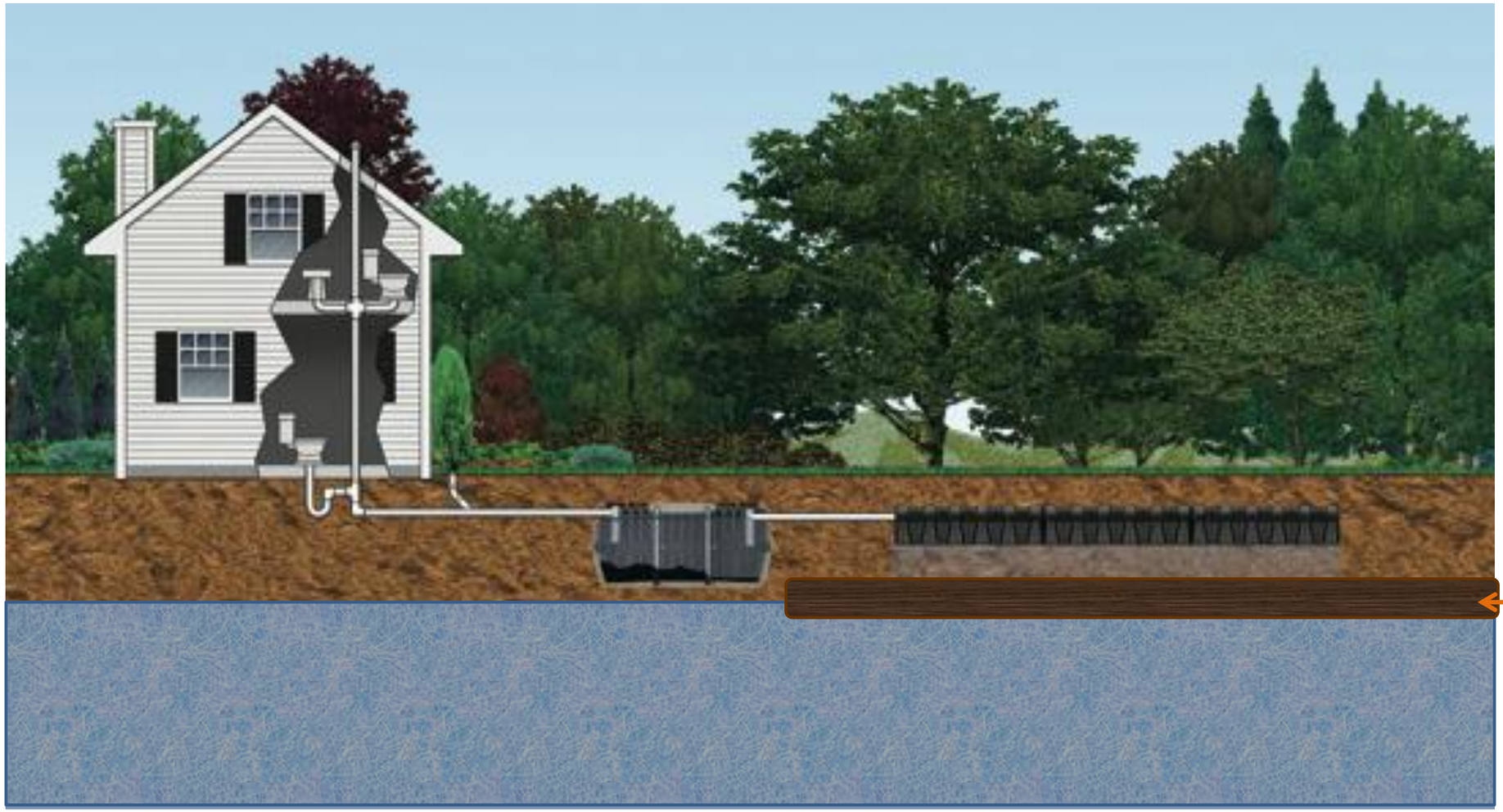
Water-saturated layer



Impervious to boring



What if all is NOT good?



Then what to we do?

Enhance Pre-treatment prior to Disposal

We have to help the soil!

We have to improve pre-treatment of the wastewater prior to releasing it to the environment!

Advanced Treatment Systems

The Process…

Different advanced systems uses proprietary designs and technologies.

All *(those that I know)*

Involve **microorganisms**, principally bacteria, to degrade organic contaminants (solid and dissolved) and/or change the speciation of chemicals

Manipulate conditions (growth factors) to favor some microbes or kill others

Factors Affecting Microbial Activity/Survival

1. Carbon and Energy Sources

- Abundant in wastewater –not a limiting factor

2. Aeration

- **Aerobes** –require O_2; adversely affected by absence of O_2
- **Anaerobes** – does not require O_2, not favored by presence of O_2
- **Facultative** – both aerobic and anaerobic metabolism

Factors Affecting Microbial Activity/Survival

3. pH/Chemical properties of wastewater

- Bacteria – mostly require near-neutral pH; some are adapted to acidic conditions
- Fungus – can survive a wide range of pH (from 4 all the way to 10)

4. Mobility/Access

- Affects ability to access food
- Affects likelihood of being “eaten” a predator

Factors Affecting Microbial Activity/Survival

1. Carbon and Energy Sources
2. **Aeration**
3. **pH/Chemical Properties of Wastewater**
4. **Mobility/Access**

Usual Enhancements in Advanced Systems

ALL influences (+/-) microbial activity

- Increase Contact w/ Surfaces
- Modify Aeration Status
- Add Substrate/ Material
- Increase water-microbe contact

SOME or a COMBINATION of these!!

Usual Enhancements in Advanced Systems

Increase Contact w/ Surfaces

Affects Sorption

Affects Filtration

Modify Aeration Status

Make it Aerobic

Make it Anaerobic

Add Substrate/ Material

Material that affects chemical conditions and microbial processes

Increase water-microbe contact

Recirculation

Turbulence

Moving surfaces

Usual Enhancements in Advanced Systems

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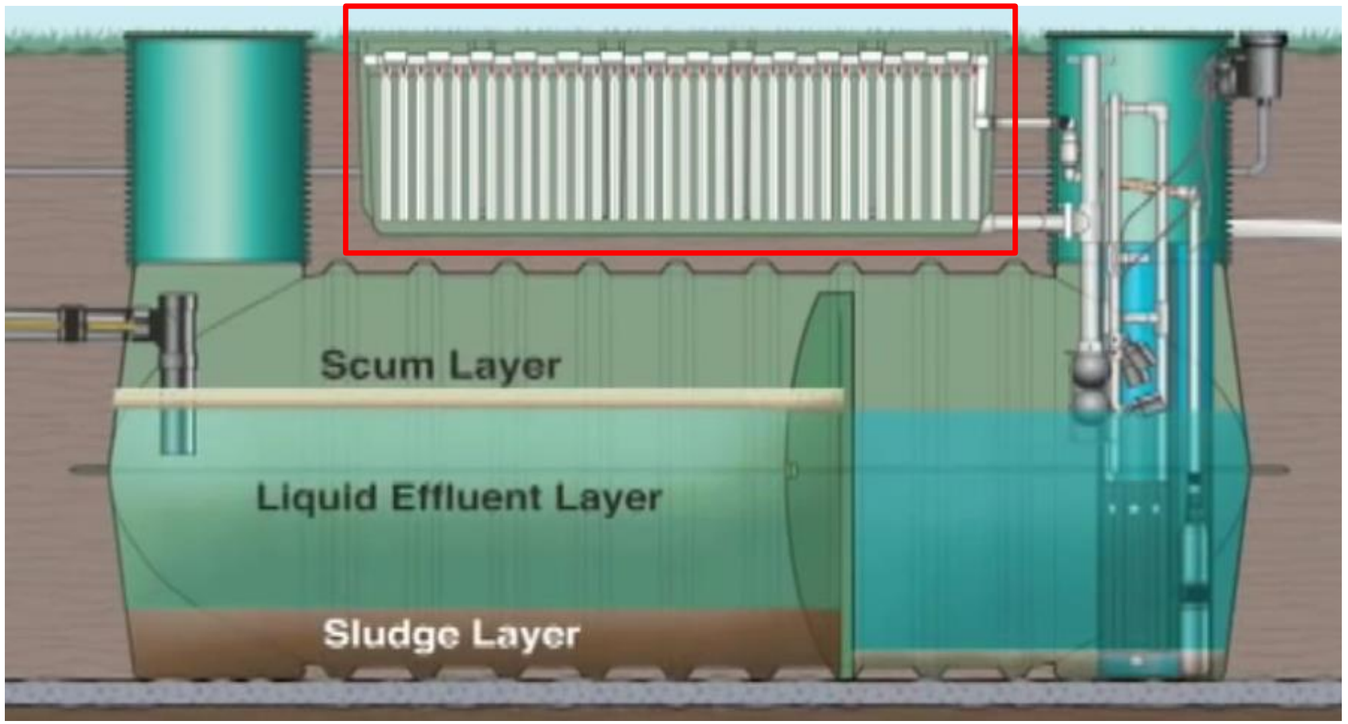
Adding Surfaces (in advanced systems)

A chamber that has a material (*e.g.* fabric) that:

- can physically filter suspended solids
- can physically filter organisms
- microbes can lodge and treat the effluent as it passes through

Adding Surfaces - *Example*

Textile in Filter Pod



Orenco Systems

- Fine suspended particulates/colloids filtered by fabric
- Wastewater passes through surface where microbes that helps with the treatment are lodged

Adding Surfaces - *Examples*

>99% disinfection of Fecal Coliforms
(Patterson, 1999)

Organic Material
(Peat)

Treated by **Sorption?**
Filtration?

Pore diameter of peat: 100–4,600 µm
(Rezanezhad et al., 2016)

Microbial Group	Example	Size (µm)
Bacteria	*Pseudomonas*	0.5 x 1.5
Actinomycetes	*Streptomyces*	0.5 -2.0
Fungi	*Mucor*	8.0
Algae	*Chlorella*	5 x 13
Protozoa	*Euglena*	15 x 50
Nematodes	*Pratylenchus*	1,000

Sylvia et al.

Adding Surfaces - *Examples*

>99% disinfection of Fecal Coliforms
(Patterson, 1999)

Organic Material
(Peat)

Treated by **Sorption?**
Filtration?

Particle size of peat (µm)	Surface Area, m^2/g		
	Methylene Blue	Telon Blue	Nitrogen Adsorption
150-250	122.2	11.8	27.3
355-500	104.0	7.8	26.6
710-1000	77.5	6.2	26.5

Poots and McKay, 1979

Compare to sand: $0.04 m^2/g$

Important Note: Surfaces of peat material are charged and exhibit some degree of hydrophobicity

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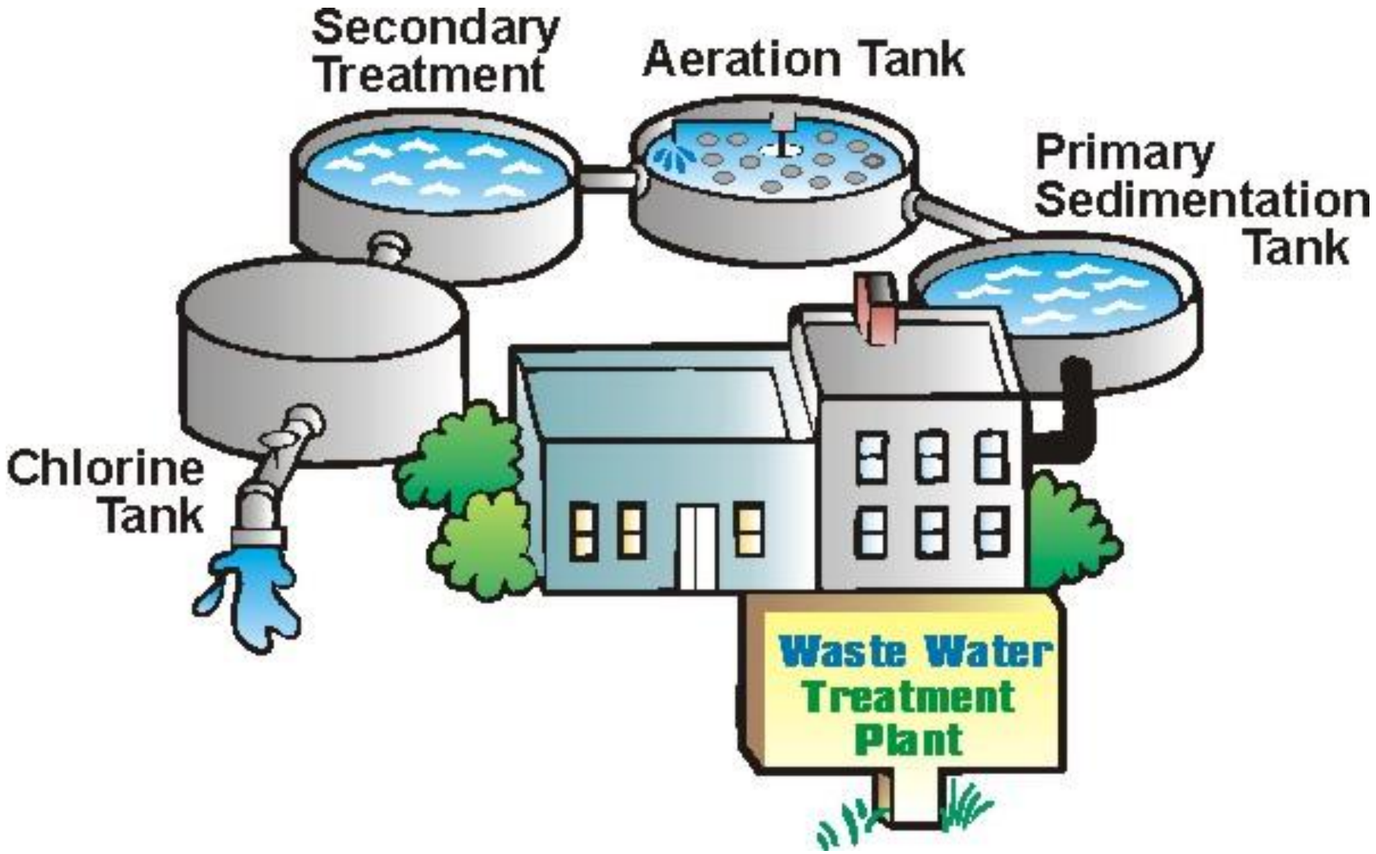
Aeration –Example: Aerobic Treatment Units (ATUs)

ATUs are miniaturized wastewater treatment plants



www.dep.state.pa.us

Aeration –Example: Aerobic Treatment Units (ATUs)

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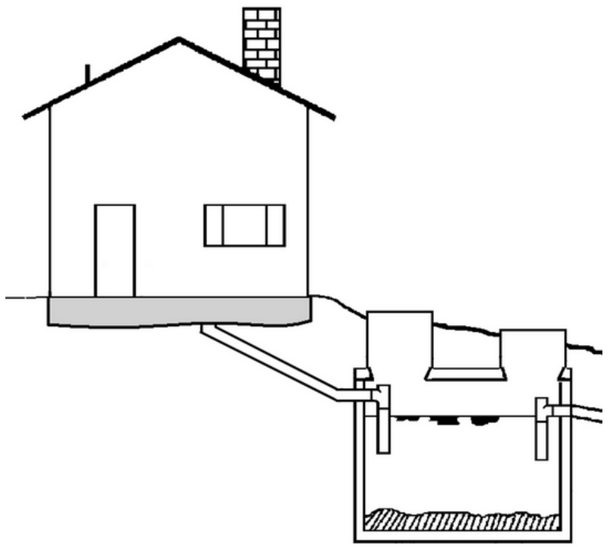
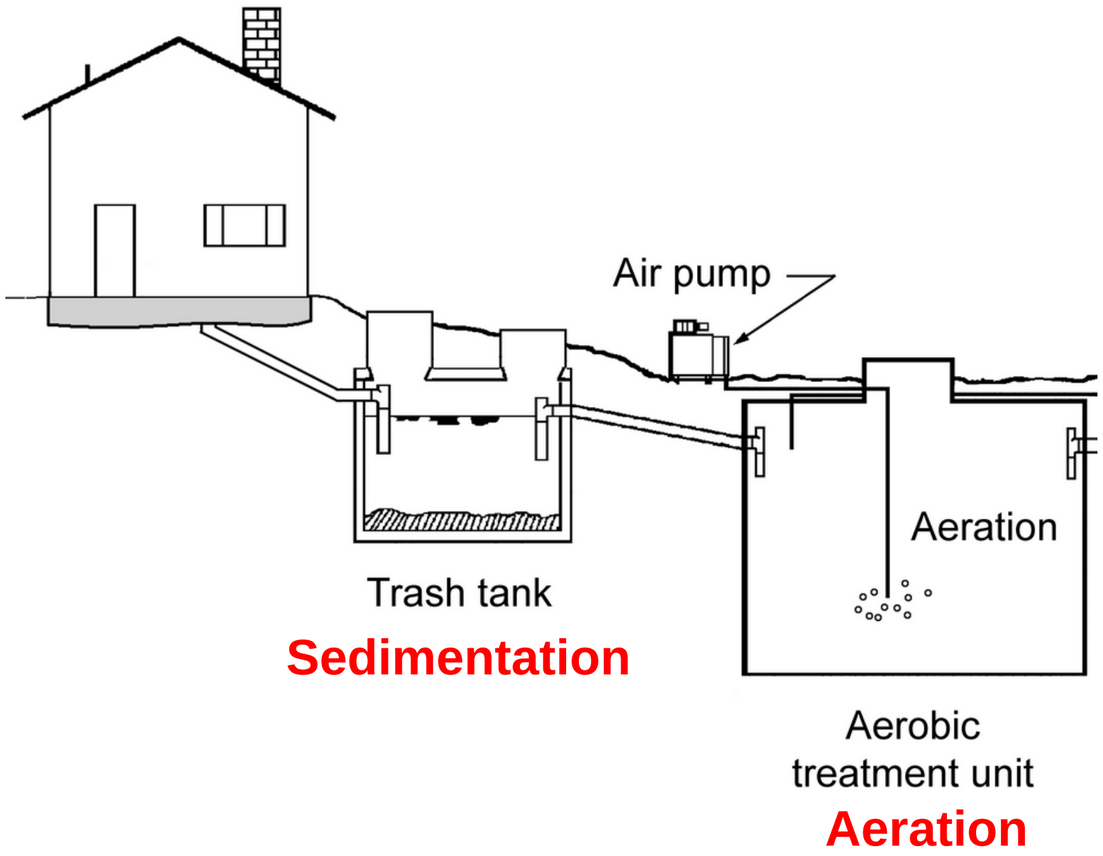


Trash tank

Sedimentation

Aeration –Example: Aerobic Treatment Units (ATUs)

ATUs are miniaturized wastewater treatment plants



Aeration –Example: Aerobic Treatment Units (ATUs)

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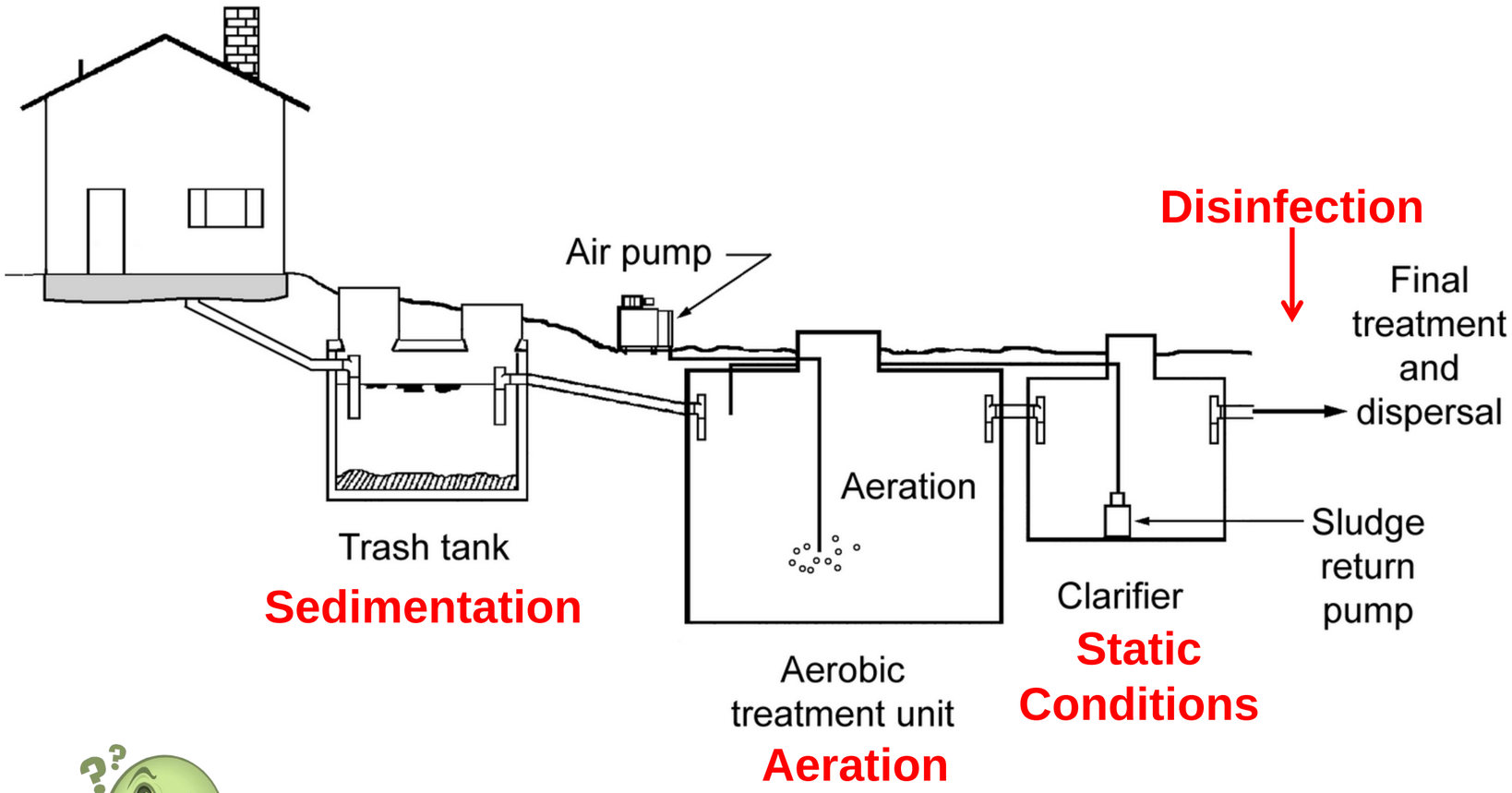
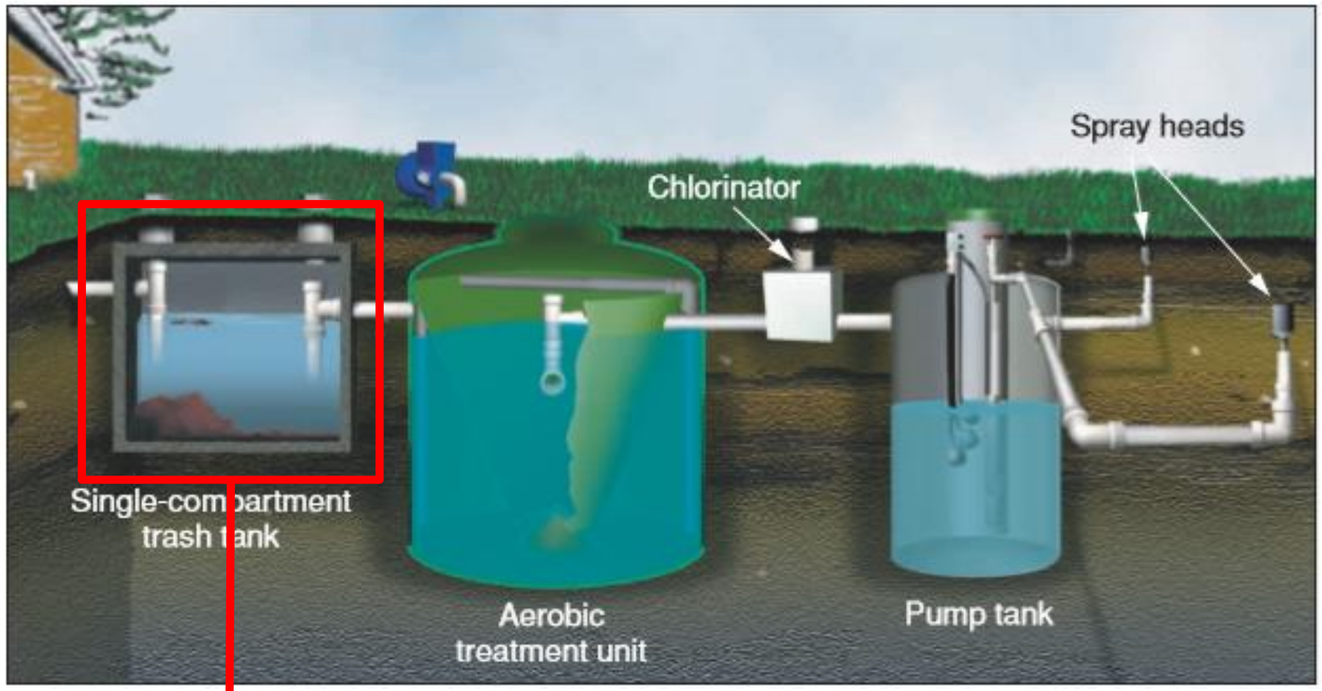


How does aeration help with wastewater treatment?

Aeration –Example: Aerobic Treatment Units (ATUs)

1. Aeration **increases decomposition** of organic compounds



https://agrilifeextension.tamu.edu

Conditions are anaerobic (no air introduced)

In the absence of oxygen

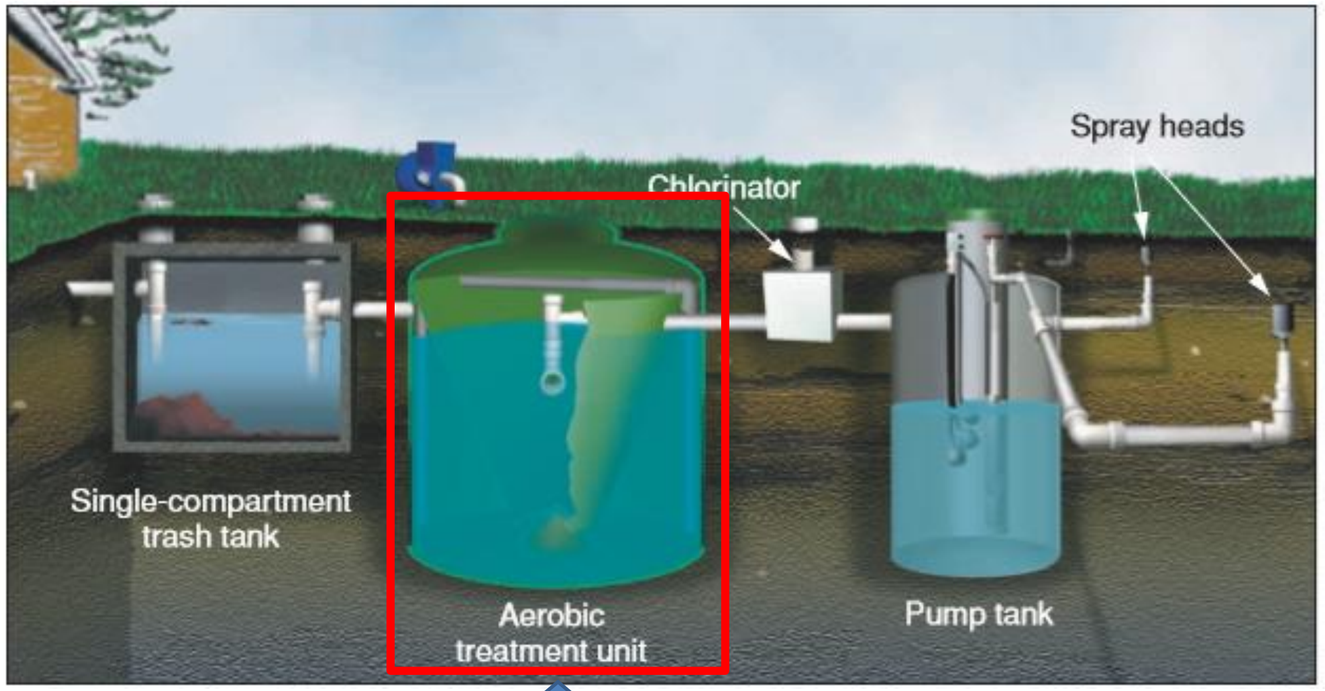
$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH + 2ATP$$

Microbial activity is relatively slow

Decomposition of organic compounds is SLOW

Aeration –Example: Aerobic Treatment Units (ATUs)

1. Aeration **increases decomposition** of organic compounds



What happens here?

- Atmospheric air (21% O_2) is pumped into the tank (bubbled in the septic effluent).

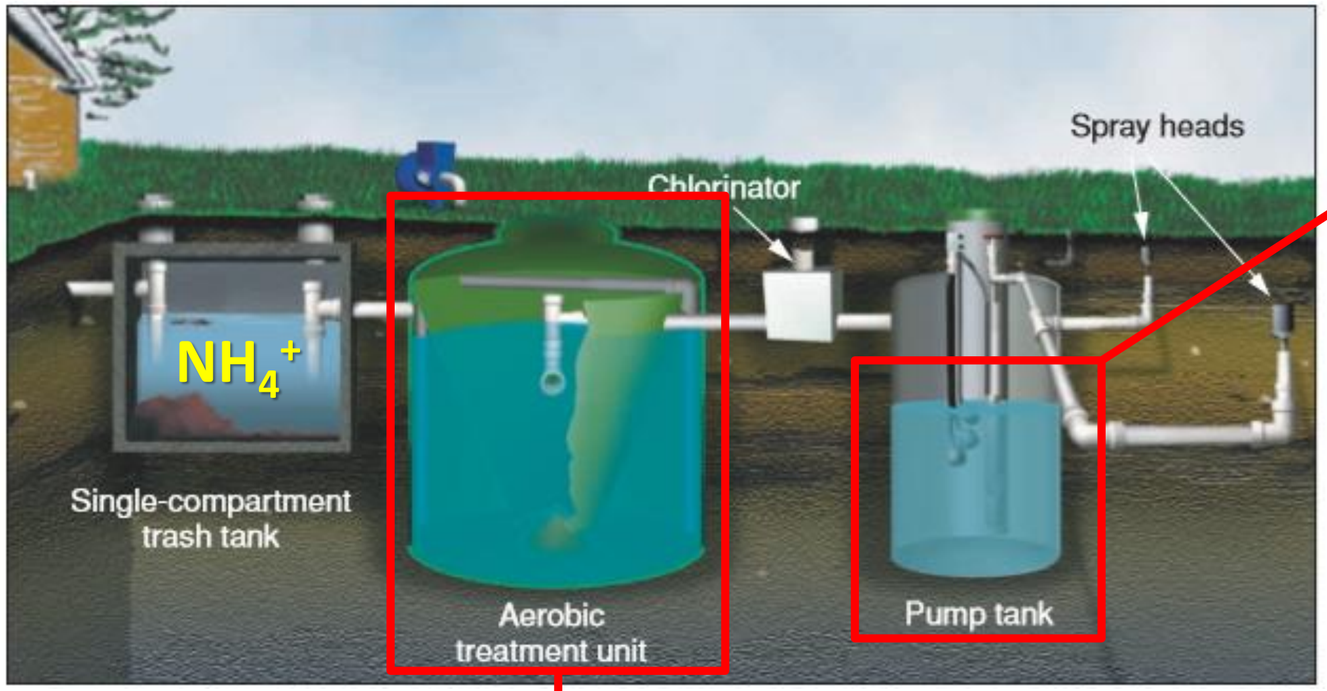
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36ATP$$

Active microbial community

More effective decomposition of organic compounds

Aeration –Example: Aerobic Treatment Units (ATUs)

2. Aeration **changes speciation** of chemical contaminants



Static Conditions

Close to bottom potentially could have reducing conditions

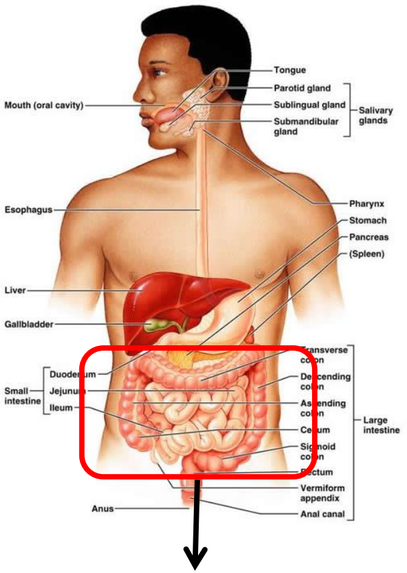
May provide opportunities for **denitrification** to occur

$NO_3^- \longrightarrow N_2\uparrow_{gas}$

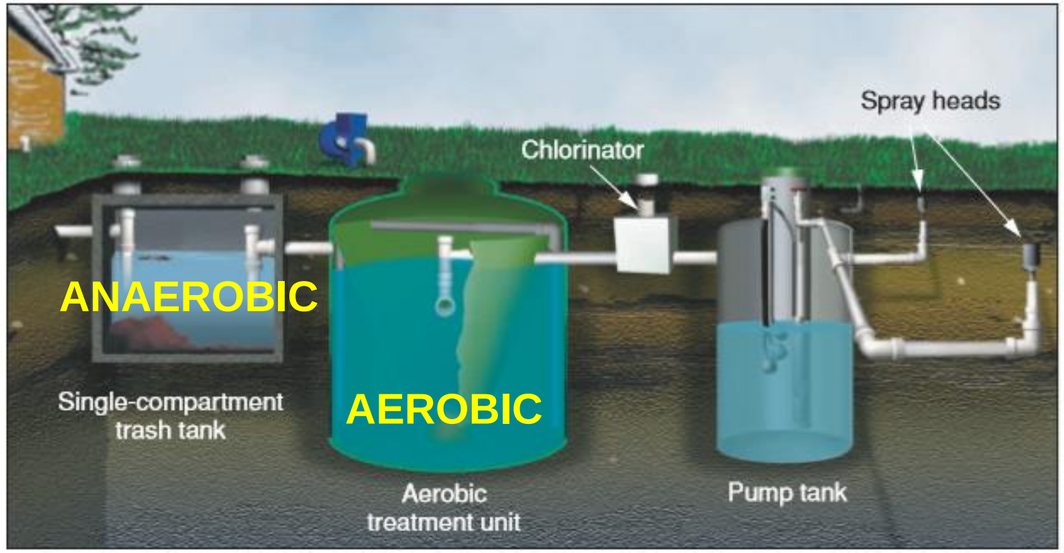
$$NH_4^+ \xrightarrow[\text{Bacteria}]{O_2} \text{Nitrate } (NO_3^-)$$

Aeration –Example: Aerobic Treatment Units (ATUs)

3. Aeration **adversely affect** **activity and survival of** pathogens



Anaerobic



What happens to anaerobes in the aeration tank?

1. Anaerobic bacteria will weaker.
2. Anaerobic bacteria will be out-competed by native aerobic bacteria in the aeration tank.

Aeration –Example: Aerobic Treatment Units (ATUs)

1. Aeration **increases decomposition** of organic compounds

2. Aeration **changes speciation** of chemical contaminants

3. Aeration **adversely affect activity and survival** of pathogens

Usual Enhancements in Advanced Systems

Increase Contact w/ Surfaces

Affects Sorption

Affects Filtration

Modify Aeration Status

Make it Aerobic

Make it Anaerobic

Add Substrate/ Material

Material that affects chemical conditions and microbial processes

Increase water-microbe contact

Recirculation

Turbulence

Moving surfaces

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Substrate that aids microbial processes

Example: Peat Biofilter System

Treats in a variety of ways:

1. Physical (filtration)
2. Adsorption

Talked about this earlier

3. Biological

- Enhances microbial diversity
- Affects water chemistry leading to treatment of pathogens
- Quasi-stable temperature

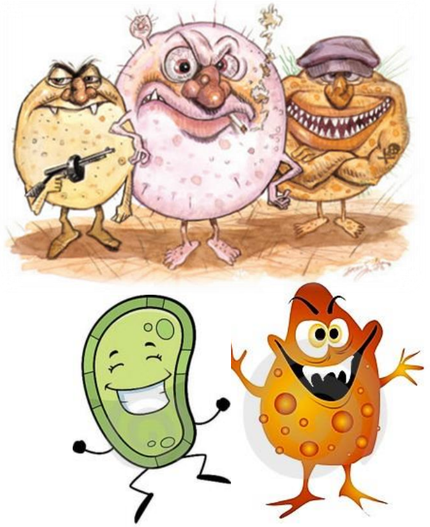
Substrate that aids microbial processes

Example: Peat Biofilter System – diversity of microbes/functions

- Porous material
- Peat fiber are not uniform in size.

→ Wide range in pore size distribution → Leads to functionally redundant, diverse microbial population

ANUA



Microbial Population Tend to be **Stable** and **Resilient**

Stable: can perform a function even in the face of variation in environmental conditions

Resilient: can “bounce back” to functional health after a severe disturbance

Substrate that aids microbial processes

Example: Peat Biofilter System – diversity of microbes/functions

- Porous material
- Peat fiber are not uniform in size.

ANUA

Wide range in pore size distribution → Wide range in aeration status

Lots of Large Pores

↓

Drain Quickly

↓

Aerobic Packets

↓

Supports activity of aerobes

Recall:

- Aerobes are more efficient at degrading organic compounds
- Aerobes can outcompete pathogenic microbes (usually anaerobes)

Substrate that aids microbial processes

Example: Peat Biofilter System – diversity of microbes/functions

- Porous material
- Peat fiber are not uniform in size.

→ Wide range in pore size distribution → Wide range in aeration status

ANUA

Small Pores

↓

Retain Water Longer

↓

Anaerobic Packets

↓

Sites for reducing reactions

← Favors the action of denitrifiers. Upto 97% reduction in nitrate concentration has been recorded (Patterson, 1999)

Substrate that aids microbial processes

Example: Peat Biofilter System – water chemistry and pathogens

- Conditions are normally acidic (decomposition of the peat produced organic acids; pH 4)

→ Fungi and bacteria tolerant to acidic conditions would dominate

ANUA

Most pathogenic bacteria are not acid-tolerant and undergo significant die-off in acidic conditions

Those that survive are not as active – can't compete with the acid-tolerant species; easy targets for predators an

Substrate that aids microbial processes

Example: Peat Biofilter System – fairly stable temperatures

- Effectively holds moisture → Water has a very high heat capacity

ANUA

Require high amounts of heat energy to change the temperature

Temperature does not change drastically even when outside air temperatures changes

Favors activity and survival of microorganisms involved in treatment

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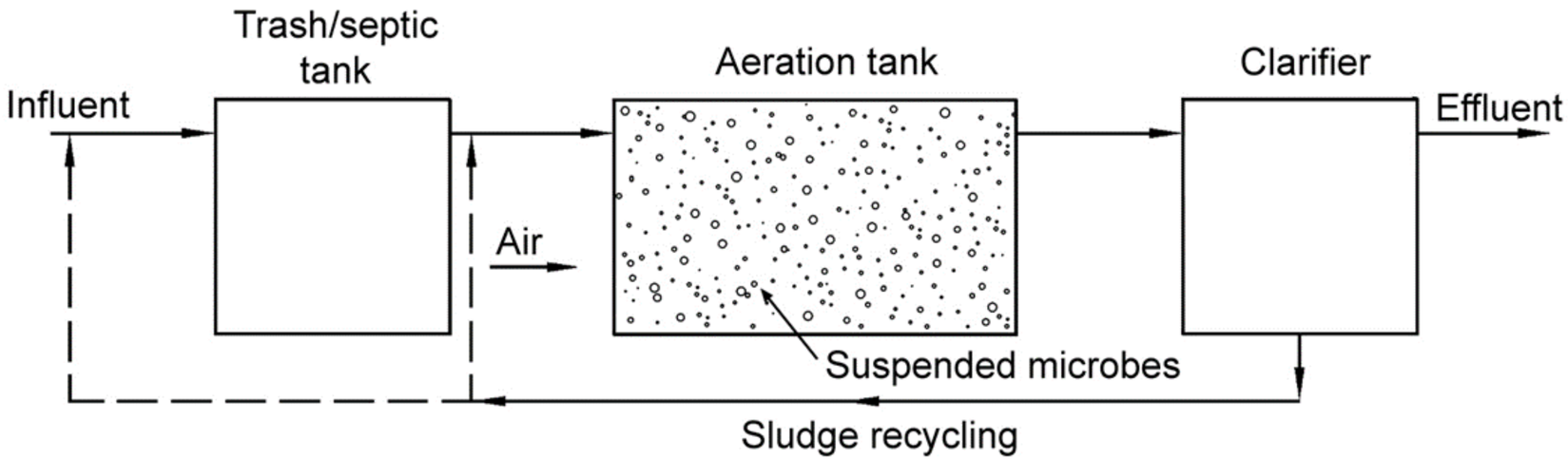
Increase Water-Microbe Contact

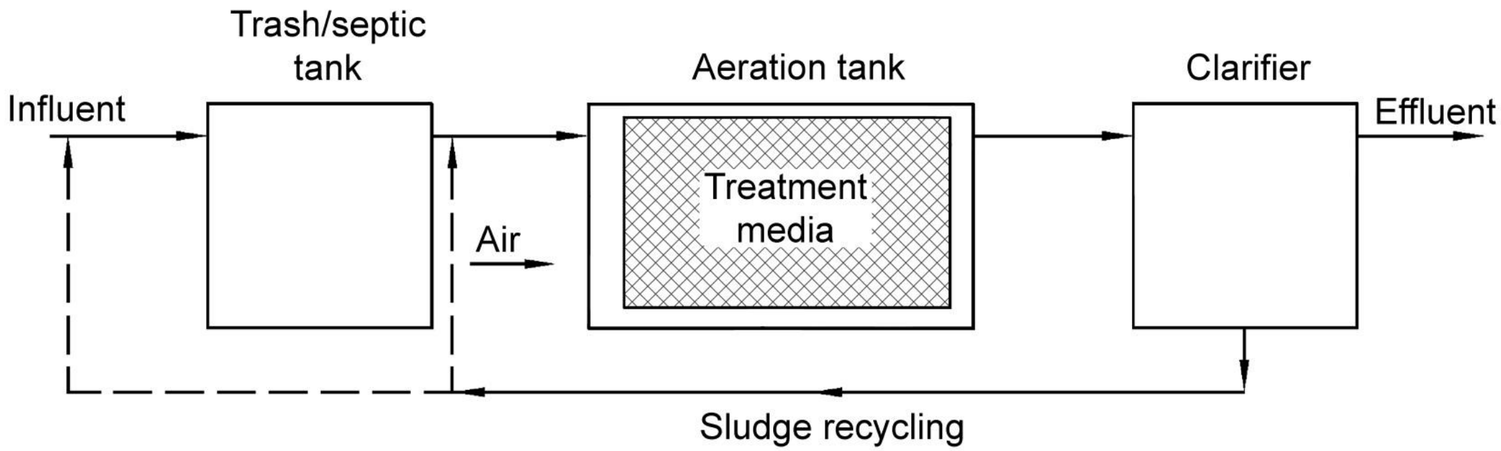
Suspended growth bioreactor



- Water is stirred when bubbled with atmospheric air
- As water moves, it increases the likelihood/frequency of contact between the bacteria (flocs) and particulates/soluble organic compounds

Increase Water-Microbe Contact

Attached growth bioreactor

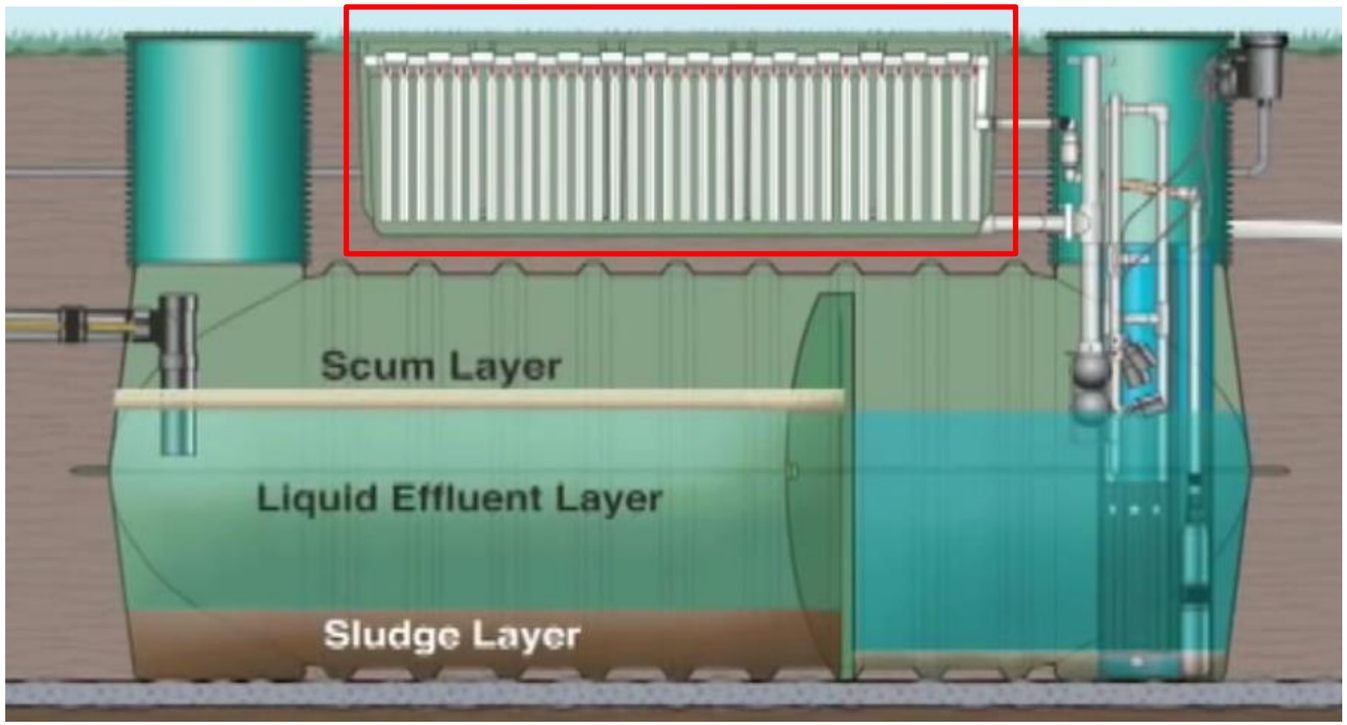


Wastewater and dissolved oxygen are brought in contact with the attached microorganisms by either pumping the liquid past the media or by moving the media through the liquid.

Increase Water-Microbe Contact

Recirculation

Textile in Filter Pod



Orenco Systems

Water is recirculated through the Filter Pod multiple times before the effluent is passed on for dispersal

Increases the likelihood of:

- Sorption of bacteria (removal of bacterial)
- Immobilization of dissolved contaminants by bacteria sorbed on textile

Usual Enhancements in Advanced Systems

ALL influences (+/-) microbial activity

Increase Contact w/ Surfaces	Modify Aeration Status	Add Substrate/ Material	Increase water-microbe contact
Affects Sorption	Make it Aerobic	Material that affects chemical conditions and microbial processes	Recirculation
Affects Filtration	Make it Anaerobic		Turbulence
			Moving surfaces

Disinfection (if surface applied)

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Affects Filtration	Make it Anaerobic		Turbulence
			Moving surfaces

Disinfection (if surface applied)

Usual Enhancements in Advanced Systems

Disinfection

- Lime
- Ozone
- Chlorine Compounds
- Ultraviolet Irradiation

Why is this still needed?

Take-home Points

1. Microbes in septic systems are good and bad

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2. Advanced systems are needed if there are soil and site limitations that prevents effective treatment.

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3. Advanced systems usually involve components that: a) change aeration, b) change chemical conditions, and/or c) change mobility/access of microbes

Take-home Points

1. Microbes in septic systems are good and bad
2. Advanced systems are needed if there are soil and site limitations that prevents effective treatment.
3. Advanced systems usually involve components that a) changes aeration, b) changes chemical conditions, and/or c) changes mobility/access of microbes
4. Common methods of treatment in Advanced Systems:
    - Addition of more surfaces
    - Aeration
    - Materials that enhance microbial activity
    - Increasing microbe-wastewater contact

Thank You!

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