Wastewater Treatment As a Function of SOIL CONDITION

Some **elements of a soil condition** that are important for wastewater treatment:

- **Particle size distribution**
- **Bulk density**
- **Pore size distribution**
- **Oxidation potential**
- **Organic matter content**
- **Clay mineralogy**
- **Temperature regime**

Soil properties that we describe in a profile description (texture, structure, consistence, color, root abundance, *etc.*) are indicators of these elements.

The soil **condition** of a loam-textured "A" horizon will be much different than the soil **condition** of a loam-textured "C" horizon.

Wastewater treatment in soil is accomplished by:

BIOLOGICAL (dominant) **and PHYSICAL Attenuation Processes**

The effectiveness of these processes depends on:

- **particle surface area**
- **retention time**
- **oxidation potential**

Soils with a higher specific SURFACE AREA (surface area/unit mass) provide more attachment sites for microbes and expose microbes to more oxygen molecules per unit of oxygen concentration.

Which burns faster?

- **a solid cubic-foot of wood = 6 sq-ft of surface area**
- **a cubic-foot of wood cut into one-inch cubes = 72 sq-ft of surface area**

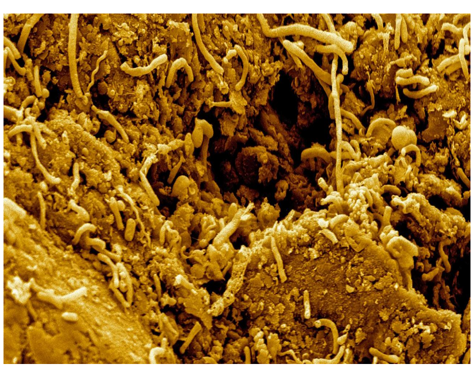
WHY?

Surface Area of 1 g of SiL = ~1 tennis court

Surface Area of 1 g of S = ~1 m^2

MICROBES ON SOIL PARTICLES

more surface area = more microbes = more treatment



In a handful of fertile soil:

- more individual organisms than the total number of humans that have ever lived

10^{12} bacteria 10^4 protozoa

10^4 nematodes 25 km of fungi (mycorrhizae)

- fraction of soil surface area covered by soil microbes = 10^{-6} %

(same as % of land area on Earth covered by humans)

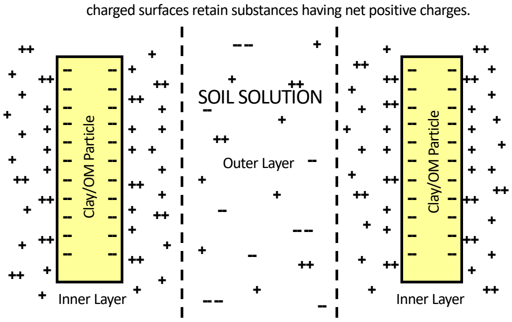
Young, I.M. & J.W. Crawford. Interactions and Self-Organization in the Soil-Microbe Complex.. Science 304, 1634 (2004).

Where in a soil profile do most organisms live?

Why?

In addition …………..

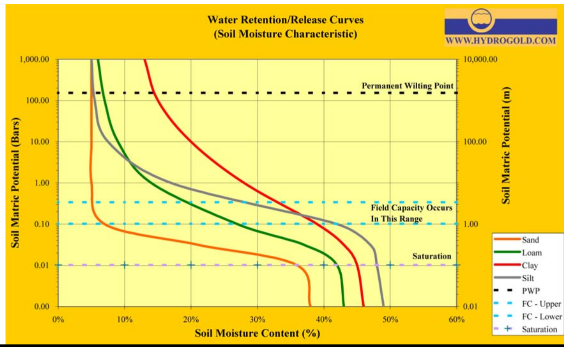
Clay and OM particles have "active" surface area due to negative charges associated with their surfaces (exchange complex). These negatively charged surfaces retain substances having net positive charges.



QUESTION: **Where in a soil profile does one encounter the most clay and OM?**

RETENTION TIME is proportional to soil water holding capacity. Greater soil water holding capacity results in longer retention time.

more time exposed to microbes = more treatment



RETENTION TIME is also indirectly proportional to water flow rate in soil.

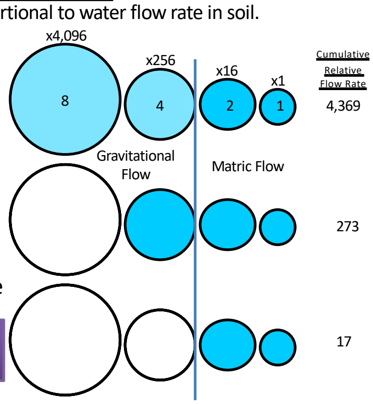
WATER FLOW RATE as a function of PORE SIZE DISTRIBUTION

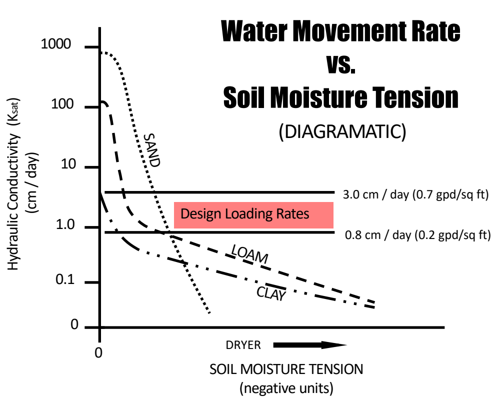
Poiselle's Equation

$$Q = \frac{r^4 \Delta P}{8 v L}$$

r = radius of tube

Water moves exponentially slower through small pores than through large pores.





Finally ………….

OXIDATION POTENTIAL

- **Sufficient free oxygen is required for BOD oxidation.**
- **Free oxygen is toxic to many pathogens.**

Fick's Law of Diffusion

Where, $F = - \Theta_a D_e (\Delta C_a / \Delta h)$

F = mass flux of O_2 (lbs ft^{-2} day^{-1})

D_e = effective O_2 diffusion coefficient (ft^2 day^{-1})
(influenced by pore size and other factors) → **Oxygen diffuses at a faster rate through large pores than through small pores.**

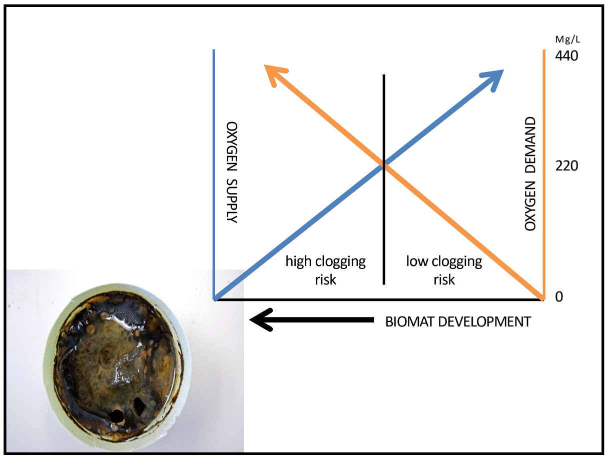
(ΔC_a / **Δh**) = O_2 concentration (lbs ft^{-3}) as a function of depth (ft)
(concentration gradient) → **Oxygen diffusion rates decrease with depth.**

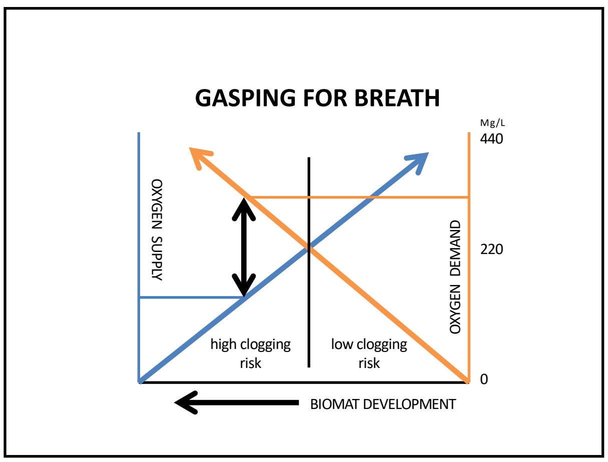
Θ_a = air-filled porosity (ft^3 ft^{-3}) → **Oxygen diffuses more slowly through wet soil.**

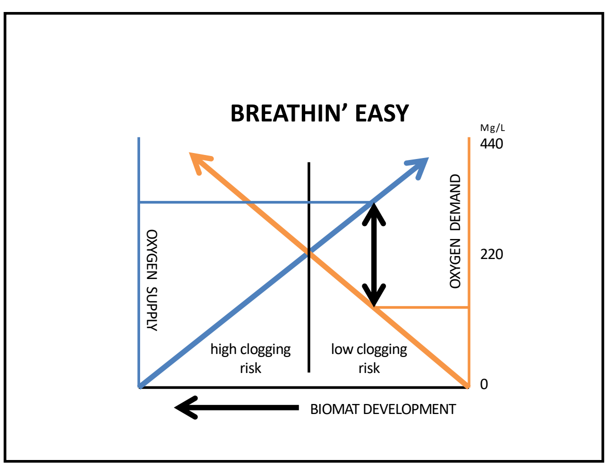
QUESTIONS:

Where are the largest pores typically located in a soil profile? Why?

Where is the moisture content typically lowest in a soil profile? Why?


Mg/L
440
220
0
OXYGEN SUPPLY
OXYGEN DEMAND
high clogging risk
low clogging risk
BIOMAT DEVELOPMENT


GASPING FOR BREATH
Mg/L
440
220
0
OXYGEN SUPPLY
OXYGEN DEMAND
high clogging risk
low clogging risk
BIOMAT DEVELOPMENT


BREATHIN' EASY
Mg/L
440
220
0
OXYGEN SUPPLY
OXYGEN DEMAND
high clogging risk
low clogging risk
BIOMAT DEVELOPMENT

Determining ORGANIC LOAD Per Day

1. Obtain septic tank **EFFLUENT** sample(s).
2. Perform **BOD_5** concentration analysis (Mg/L).
3. Calculate total **ORGANIC LOAD** per day.

ORGANIC LOAD = (**Lbs/Day**)

Design Flow (**Gal/Day**) x

(BOD Concentration (**Mg/L**) x 0.000008347) **Lbs/Gal**

ORGANIC LOADING RATE (Lbs/Day/Ft^2)

= Organic Load (Lbs/Day) ÷ Drainfield Area (Ft^2)

OR

DRAINFIELD AREA (Ft^2)

= Organic Load (Lbs/Day) ÷ Organic Loading Rate (Lbs/Day/Ft^2)

Conclusion 6) - WAS Dept of Health Report, 2004

6) Field studies have shown the majority of the sand-based treatment systems and soil dispersal components operate with minimal clogging problems when an organic loading rate of around $5.0x10^{-4}$ lb/BOD_5/ft^2/day is applied. EPA recommends a maximum design organic loading rate of 1.0×10^{-3} lb BOD_5/ft^2/day for septic tank effluent applied to soil. This loading rate has an implicit factor of safety found in the design hydraulic loading rate of 0.8 gpd/ft^2, and assumes a BOD_5 concentration of 150 mg/L. A number of field studies have found when the organic loading rate is greater than 1.2×10^{-3} lb BOD_5/ft^2/day on a continuous basis there is increased likelihood of biological clogging and ponding of the soil or sand media, particularly if problems with oxygen transfer exist in the system.

Conclusion 6) published in :
Rule Development Committee Issue Research Report – Septic Tank Effluent,
WAS Dept. of Health – Wastewater Management Program, February 1, 2004

Table 3. **Soil Organic Loading Rates (lbs. BOD_5/ ft^2/day)**

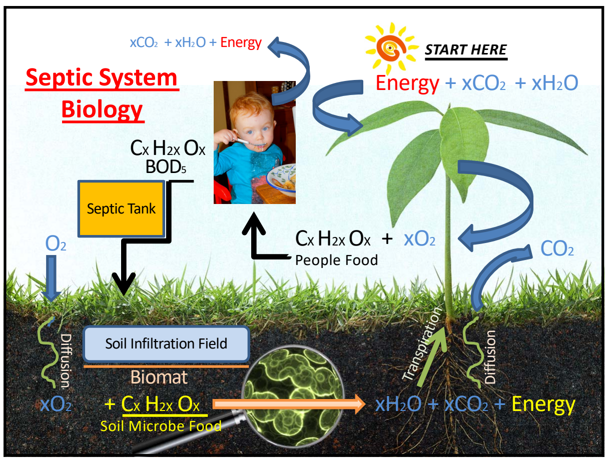
From Various BOD_5 Concentrations of Residential Strength Septic Tank Effluent

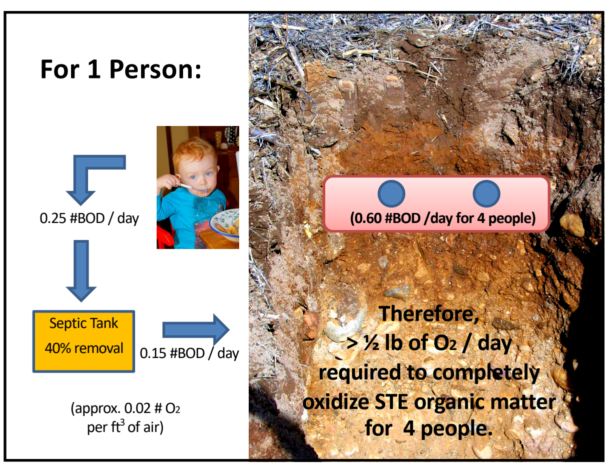
Hydraulic Loading Rate[1] (gpd/ ft^2)	Soil Organic Loading Rate[2] BOD = 150 mg/L	Soil Organic Loading Rate BOD = 200 mg/L	Soil Organic Loading Rate BOD = 250 mg/L	Soil Organic Loading Rate BOD = 300 mg/L
0.2	.00025	.0003	.0004	.0005
0.4	.0005	.0006	.0008	.001
0.6	.00075	.001	.0012	.0015
0.8	.001	.0013	.0017	.002
1.0	.0012	.0017	.002	.0025

[1] Proposed WA State hydraulic loading rates for various soil types in rule

[2] EPA Recommended Soil Organic Loading Rates using BOD_5 = 150 mg/L

Table 3. published in :
Rule Development Committee Issue Research Report – Septic Tank Effluent,
WAS Dept. of Health – Wastewater Management Program, February 1, 2004





Organic Loading Calculations

BOD is reported as a concentration: **ppm** or **mg/L**

1,000,000 mg H_2O = 1 L

Converting **mg/L** to **lbs/gal**:

mg/L x **0.000008345** = **lbs/gal**

Design Flow gal/d x **BOD concentration** lbs/gal = **Total BOD Load** lbs/d

Total BOD Load lbs ÷ **Total Area** ft^2 = **Organic Loading Rate** $lbs/ft^2/d$

Recommended **OLR** values:
0.0006 $lbs/ft^2/d$ (fine textured soil) to
0.001 $lbs/ft^2/d$ (coarse textured soil)

COMPARE

1. SILTY CLAY LOAM - moderate blocky structure

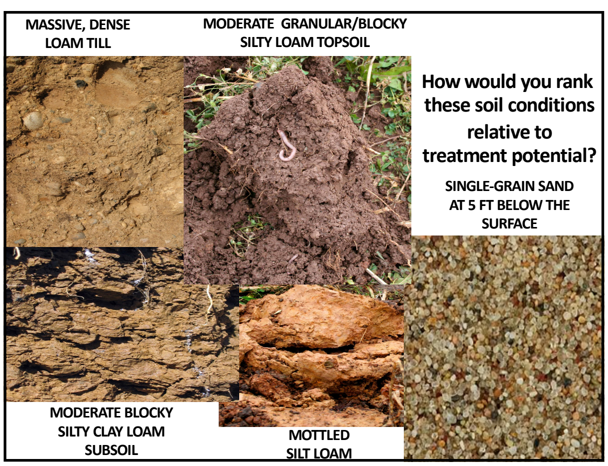
450 Gal/Day x [180 Mg/L x 0.000008347] Lbs/Gal = 0.68 Lbs/Day

0.68 Lbs/Day ÷ 1,125 Ft^2 = **0.0006 Lbs/Ft^2/Day**

2. SAND - single grain

450 Gal/Day x [180 Mg/L x 0.000008347] Lbs/Gal = 0.68 Lbs/Day

0.68 Lbs/Day ÷ 643 Ft^2 = **0.0011 Lbs/Ft^2/Day**

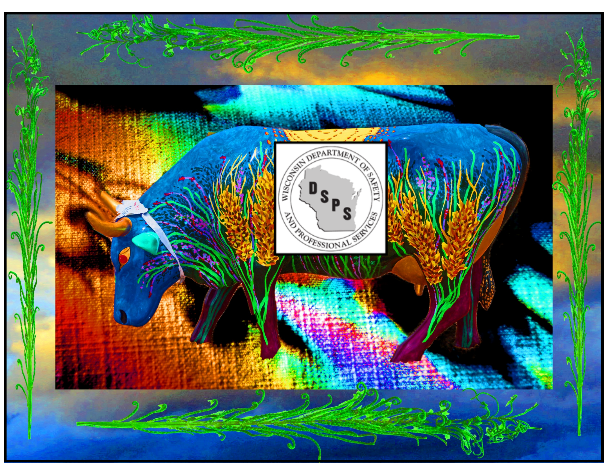


TAKE-HOME THOUGHT

Dispersal area longevity and treatment potential is fundamentally about supplying sufficient oxygen to the infiltration surface. Water dispersal will not be a problem in most soil conditions as long as sufficient oxygen is available to mitigate infiltration-restrictive biomat development.

A soil dispersal area placed in an effective soil condition and sized using an appropriate organic loading rate will function with negligible risk for hydraulic failure.

KEEP 'EM SHALLOW



To ponder …….

What is the organic loading rate for a 3 bedroom home with a 30-day average STE-BOD_5 concentration of 220 mg/L applied to medium sand soil?

OLR $lbs/d/ft^2$ = (**Design Flow** gal/d x **BOD_5 Concentration** lbs/gal) ÷ **Total Area** ft^2

= (**450** gal/d x **0.00184** lbs/gal) ÷ **643** ft^2 (450 ÷ 0.7 gpd/ft^2)

= **0.0013** $lbs/ft^2/d$

What is the organic loading rate for a 3 bedroom home with a 30-day average STE-BOD_5 concentration of 220 mg/L applied to a SiCL soil with moderate structure?

OLR lbs/d/ft = **450** gal/d x **0.00184** lbs/gal) ÷ **1,125** ft^2

= 0.0007 $lbs/ft^2/d$ (450 ÷ 0.4 gpd/ft^2)

WHICH SOIL WOULD YOU CHOOSE FOR YOUR DRAINFIELD?