Wastewater Basics 101

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Wastewater Basics 101

- Target audience
  - policy makers, leaders, and planners
  - People who have a water quality agenda

- This presentation discusses the fundamentals of converting wastewater back to water
  - How do we (humans) interact with the hydrologic cycle

Wastewater Basics 101

- Major Focus
  - What ***is*** in wastewater and how do we get ***it*** out
  - Organic matter, nitrogen, & phosphorus
- Minor Focus
  - Individual and small community wastewater treatment systems
    - Wastewater basics are universal
    - Independent of scale

Wastewater

- By definition (for today's purpose)
  - Water that has constituents of human and/or animal metabolic wastes
  - Water that has the residuals from cooking, cleaning and/or bathing
- Thus,
  - Domestic wastewater
    - Our focus is wastewater that comes from a home

Wastes and Water

- The more water you have,
  - The more wastewater you generate
  - Romans knew that water carried away the smell

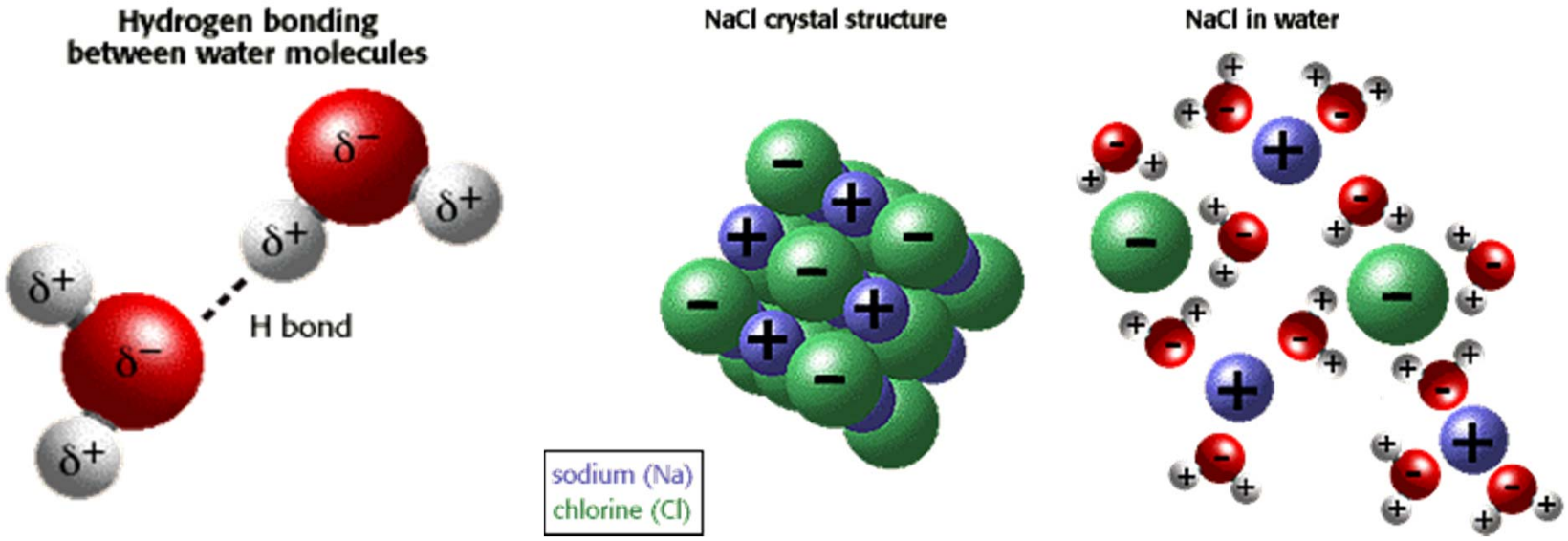
Wastes and Water

- If water is not available
  - Then wastewater is not generated
  - The original low-flush toilet

Carriage Water

- There is no other substance that can transport wastes like water can
  - it cleans the inside of our body
  - it cleans the outside of our body
  - it carries away our metabolic wastes
- In high population densities
  - water is the best means to collect and transport waste away

Water is the Universal Solvent



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Water is Dense and has Viscosity

- Water is heavy
  - provides for buoyancy
  - provides for inertia forces
- Water is viscous
  - can suspend items
  - can erode surfaces

So, our Chore is to Get Wastes out of Water

- Is it difficult to get waste out of water?
  - Yes, but we have a lot of help available to us
  - Our team includes
    - Gravity → *Drivers of the hydrologic Cycle*
    - The sun → *Drivers of the hydrologic Cycle*
    - Billions of microorganisms → *Ultimate Decomposers*
    - And, the soil → *The basis for all wastewater treatment*

Wastewater

- By weight
  - Is 99.9% water
  - It is the 0.1% that we have to remove
- That 0.1% contains
  - Organic matter
  - Microorganisms (a few of which are pathogenic)
  - Inorganics compounds

Major Measures of What's in Water

- Oxygen Demand
  - Biochemical oxygen demand
  - Chemical oxygen demand
- Indicator organisms
  - Fecal coliform
  - Escherichia coli ***(E Coli 0157:H7 is the really bad boy)***
- Solids content
  - Total suspended solids
  - Total dissolved solids

Other Measures of What's in Water

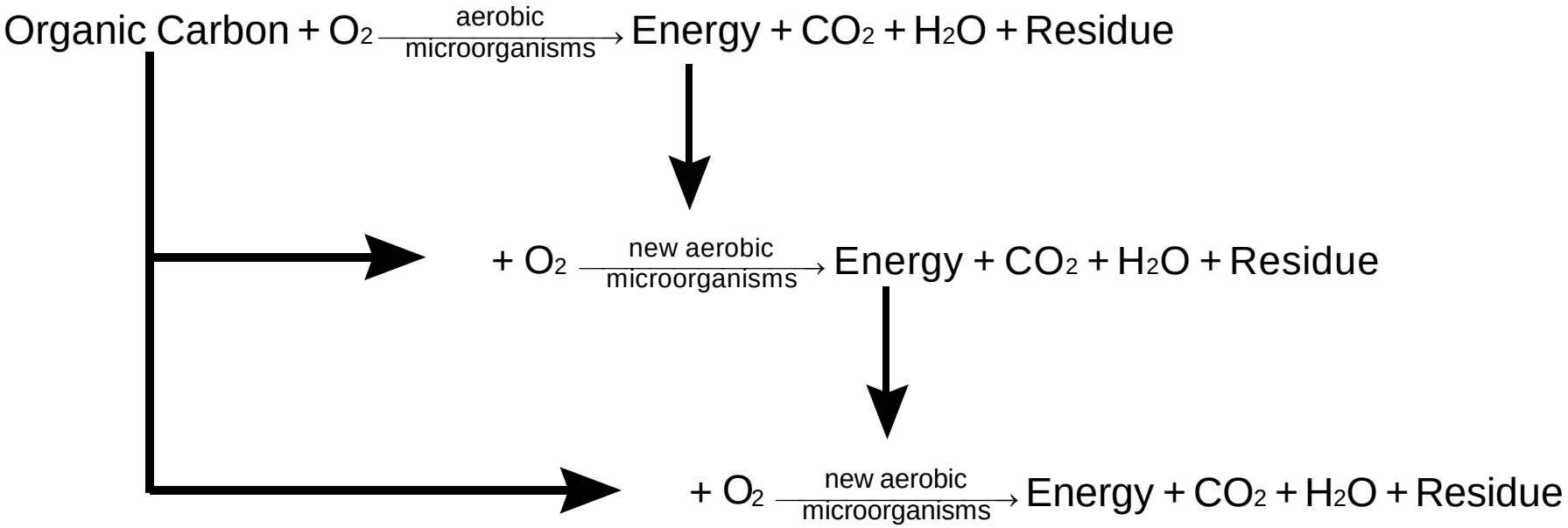
- Chemical analyses
  - Ammonia & nitrate
  - Total & reactive phosphorus
  - pH
  - Alkalinity
- Volatile compounds
  - Dissolved gases
  - Odors

Oxygen Demand

- Indictor of mass of dissolved oxygen needed by microorganisms to degrade organic and some inorganic compounds
  - High BOD/COD is indirect indicator of the organic content
  - Ammonia is inorganic and creates an oxygen demand
    - As it is converted to nitrate

Aerobic Biotransformation

- Dissolved oxygen is consumed in the process of convert organic matter into inorganic matter



Organic Matter

- Contains more than
  - Carbon, hydrogen, and oxygen
- Can also contains
  - Nitrogen
  - Phosphorus
  - Sulfur
  - Many other compounds

Degradation of Organic Matter

- Releases these other compounds
  - Typically in an inorganic form
- For example
  - Nitrogen becomes ammonia/ammonium
    - Creates an additional oxygen demand
  - Phosphorus becomes ortho-phosphate

Nitrogen Cycle

- Nitrogen is a component of protein
  - As proteins are degraded, nitrogen is released
  - Nitrogen converts to ammonia/ammonium
  - Process of ammonification

Organic-N + Microorganisms $\rightarrow$ NH_3/ NH_4^+

Biological Nitrification

- Ammonia/ammonium is then converted to nitrite and nitrate
  - Nitrification
  - Oxygen demand
- Nitrification is a two-step autotrophic process
  - the conversion from ammonium to nitrate

Nitrosomonas

Step 1: $NH_4^+ + 3/2O_2 \rightarrow NO_2^{2-} + 2H^+ + H_2O$

Nitrobacter

Step 2: $NO^{2-} + 1/2O_2 \rightarrow NO^{3-}$

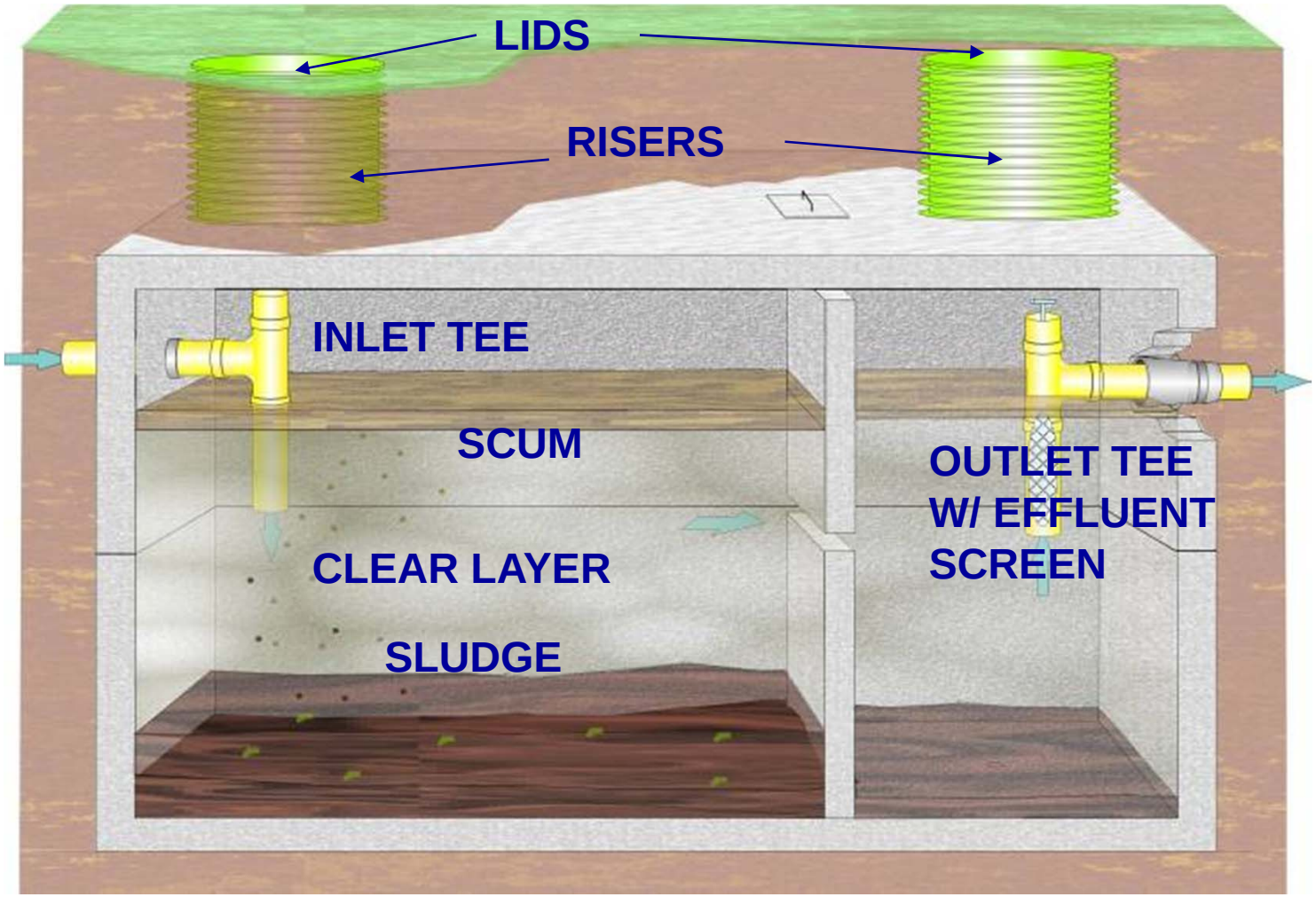
Okay, Let's go Back to the Bigger Picture

- We focused on oxygen demand
  - We have wastewater with organic matter
  - And other stuff
- However, the first treatment step
  - Is liquid/solid separation
  - Very inexpensive energy source
  - Very large return on investment
    - In terms of treatment

Preliminary/Primary Treatment

- Gravity as a treatment method
- Floaters and Sinkers *(go ahead and giggle)*
  - Based on buoyancy
    - Water is very dense – many waste products float
      - Paper products
      - Fats, oils, grease
    - Some organic solids are more dense than water and sink
      - Bacterial cells
      - Food wastes

Small System Primary Treatment



Basic Assumptions

- 50% reduction in oxygen demand
  - Because organic solids remain in tank
  - Creates an accumulation in the tank
    - That is either very slow to degrade
    - Or will not degrade
- Tremendous reduction in suspended solids
- Minimal biotransformation
  - Anaerobic environment

Now, Let's Remove the Remainder of the Oxygen Demand

- Secondary treatment
  - the second major process
  - Provide dissolved oxygen to aerobic microorganism to finish the job
- Two questions
  - How much land is available?
  - How much energy are you willing to purchase?

Providing Dissolved Oxygen

- Air is only 21% (+/-) oxygen
  - Have to move a lot of air through water to transfer the oxygen
  - Oxygen readily dissolves into water
- Passive – large footprint, low energy
  - Moving air over water allows for transfer
- Mechanical – small footprint, much energy
  - Moving air through water for enhanced transfer

Secondary Treatment Devices

- The soil
  - Attached growth
  - Passive aeration
  - Low loading rate
  - Excessive growth of biosolids is problematic
- Trickling filters
  - Attached growth
  - Passive aeration
  - biosolids can slougth
- Activate sludge
  - Suspended growth
  - High loading rate
  - Activated sludge is the biosolids
  - Mechanical aeration

Okay, Inventory Time

- After secondary treatment and clarification
  - We have reduced oxygen demand
    - Oxidized the organic carbon
    - Converted organic nitrogen to nitrate
  - Clarified the effluent
  - Put a hurt on the microbial population
- If nutrients are not an issue
  - We can now disinfect if surface discharged

If Nutrients are an Issue

- Tertiary treatment – the third major process
  - Nutrient removal
  - Some references include disinfection
- Nitrate and phosphate
  - Required nutrients for plant growth
  - Excessive plant growth
    - Creates an oxygen demand
    - Crowds out other aquatic organisms

Denitrification

- NO_3^- can be reduced,
  - under anoxic conditions, to N_2 gas through heterotrophic biological denitrification
  - Two issues
    - Anoxic conditions
    - Heterotrophic bacteria

Anoxic Conditions

- Classical definition
  - Very low concentration of dissolved molecular oxygen (i.e., anaerobic)
    - Forces the use of chemically-bound oxygen
  - Dissolved organic carbon is available
    - Heterotrophic bacterial use organic carbon as food source

Biological Denitrification

- Totally cool process
  - Nitrate has oxygen
  - Through reduction/oxidation processes
    - Oxygen is pulled from nitrate ion
    - Nitrogen evolves as a gas form

Heterotrophic Bacteria

$$NO_3^- + \text{Organic Matter} \rightarrow N_2 + CO_2 + OH^- + H_2O$$

Operational Issues

- Here is the rub
  - we consumed the organic carbon in the previous step
  - Under aerobic conditions
- Thus, our process must
  - Remove dissolved oxygen
  - Add organic carbon back into solution

Recirculation

- Recirculate a fraction of the
  - Secondary treated water back through primary treatment
- Assumptions
  - Nitrates are formed during secondary treatment
  - Organic carbon is available in primary treatment
  - Raw wastewater is anaerobic

Phosphorus Removal

- Chemical treatment
  - Phosphate is an anion: PO_4^{3-}
  - Cations can be added to bind with phosphate
    - Ca^{2+}
    - Al^{3+}
    - Fe^{3+}
  - Naturally occurs in soil systems
    - Except sandy soils
  - Each form an insoluble precipitant

Phosphorus Removal

- Biological Methods
  - Encourage the luxurious uptake of phosphorus within microbial cells
  - Harvest the cells before the excess phosphorus is released
  - Requires very controlled conditions

Future Wastewater Treatment

- Pharmaceuticals and Personal Care Products
  - what other “stuff” goes down the drain with our wastes
  - medicines, hormones, antibacterial soaps
  - many of these products are not removed with traditional means.
- Will we call this “quaternary treatment”?

So, the Ultimate Question…..

- At what point does wastewater become water?
  - are you willing to consume recycled water?
    - you are consuming recycled water
    - it's called the hydrologic cycle
  - but, the cycle is getting smaller
    - civilization will have to adapt to the notion of their being a direct connection between the wastewater treatment plant and the water treatment plant

Questions?

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