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Detoxifying Oxidized Contaminants

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Detoxifying Oxidized Contaminants

- Contaminants: harmful water pollutants.
- Oxidized: can receive electrons.
- The common characteristic of all oxidized contaminants is that they are bacterial electron acceptors. Opposite of biological instability, e.g., BOM or NH_4^+.
- Reduction yields a harmless solute or an easily removed solid → detoxified. No brine or residue that is a disposal challenge and cost.

Examples of Oxidized Contaminants

- Nitrate – agriculture and wastewater – reduced to N_2
- Perchlorate – rocket fuel – reduced to Cl^- and H_2O
- Selenate – coal-fired power plants, irrigation drainage, industry – reduced to solid Se°
- Chromium(VI) – mining areas and metals industries – reduced to $Cr(OH)_{3(s)}$
- Chlorinated solvents, like TCE – everywhere – semi-conductors, metals working, dry cleaners, etc. – reduced to ethene and Cl^-
- Bromate – from ozone use in water treatment, bromine industry – reduced to Br^-
- Radionuclides, including Pu, U, and Np – Nuclear-weapons sites, mines, and mills – reduced to, e.g., $UO_{2(s)}$

What are the necessary conditions?

- Anoxia, or dissolved oxygen removed
- Excellent biomass retention as a biofilm
- Satisfactory pH, usually near neutral
- Availability of nutrients, particularly P
- Supply sufficient electron donor
  - Organic compound (for heterotrophs)
  - Hydrogen gas (H_2) or S (for autotrophs)

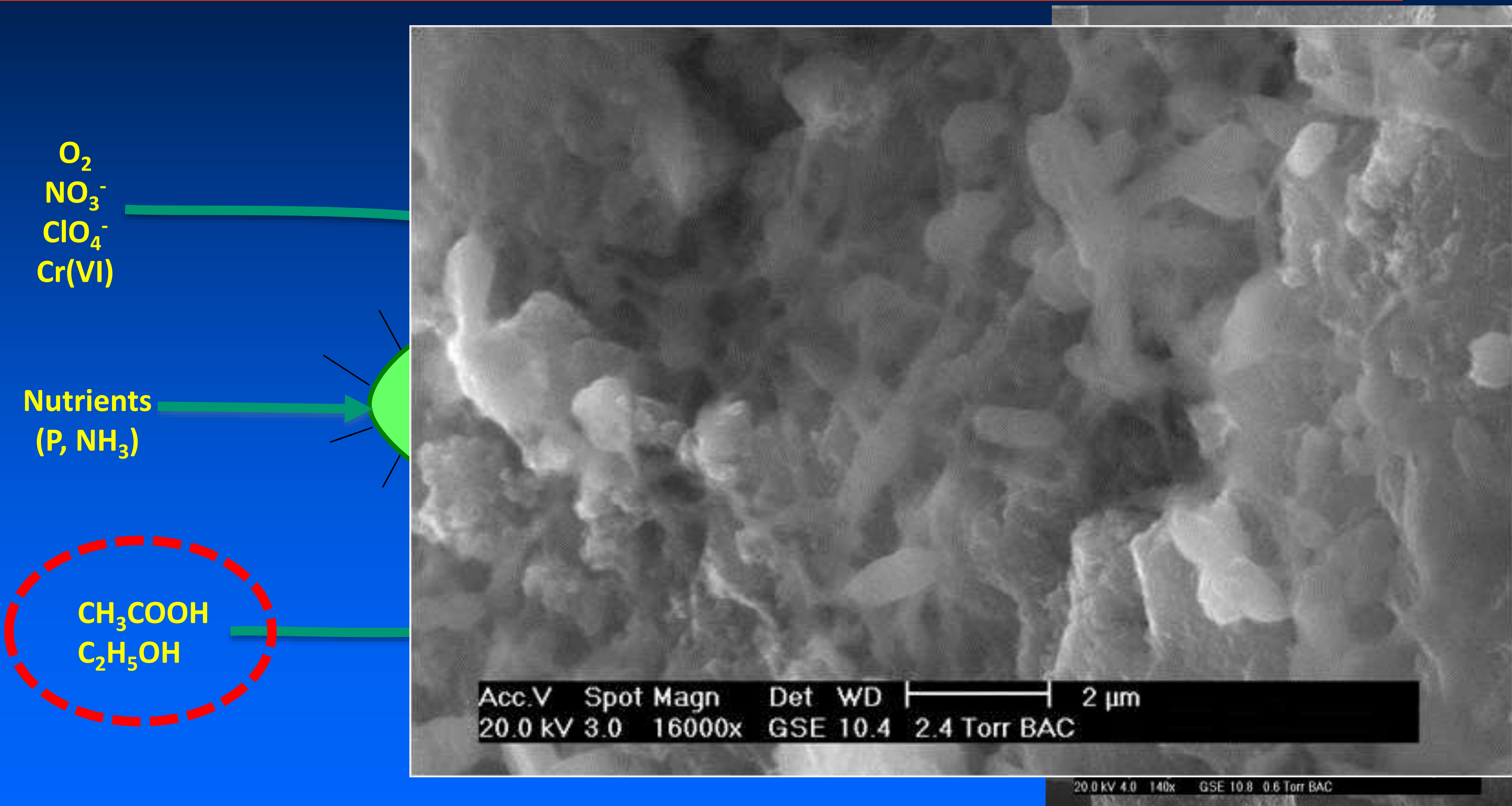
Heterotrophic vs Autotrophic

- Heterotrophic processes use an ORGANIC C source
- Autotrophic processes use an INORGANIC C source (e.g., CO_2 or HCO_3^-)
- Typically,
  - a microorganism that uses an organic donor also uses it an the C source
  - A microorganism that uses an inorganic donor also uses an inorganic C source

What should you know?

- What is the status of heterotrophic and autotrophic biofilm process available for reducing oxidized contaminants?
- What are the pros and cons of each approach?

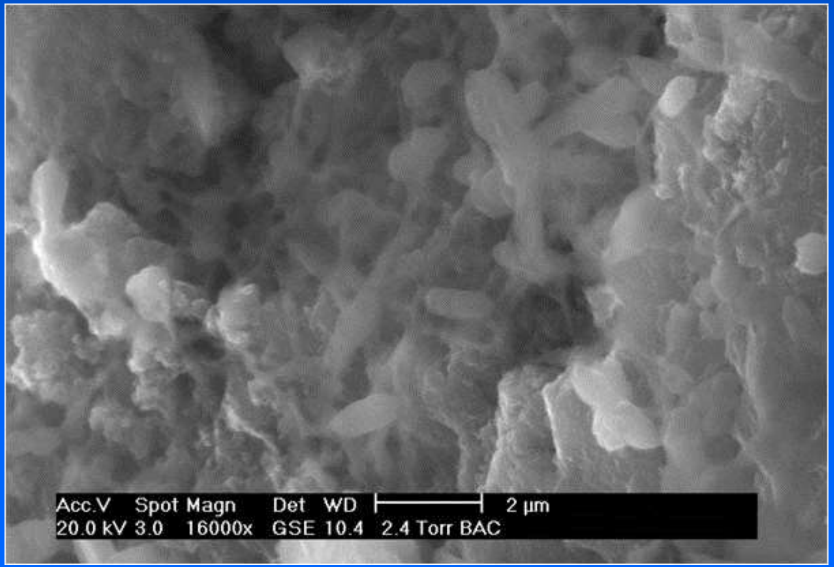
Heterotrophic Processes



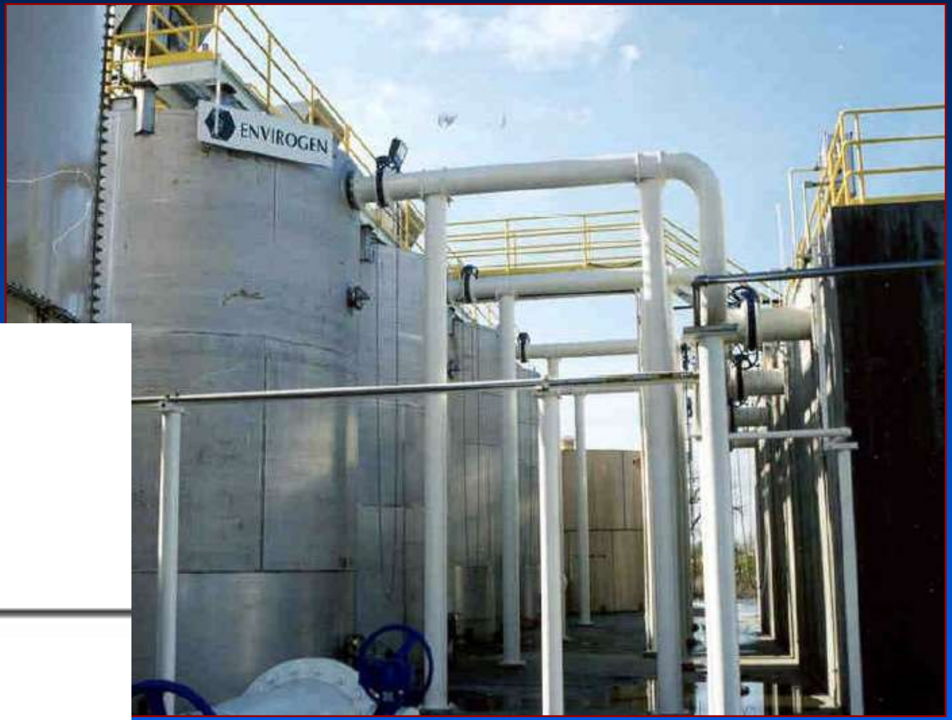
Media: GAC, anthracite, sand, expanded clay

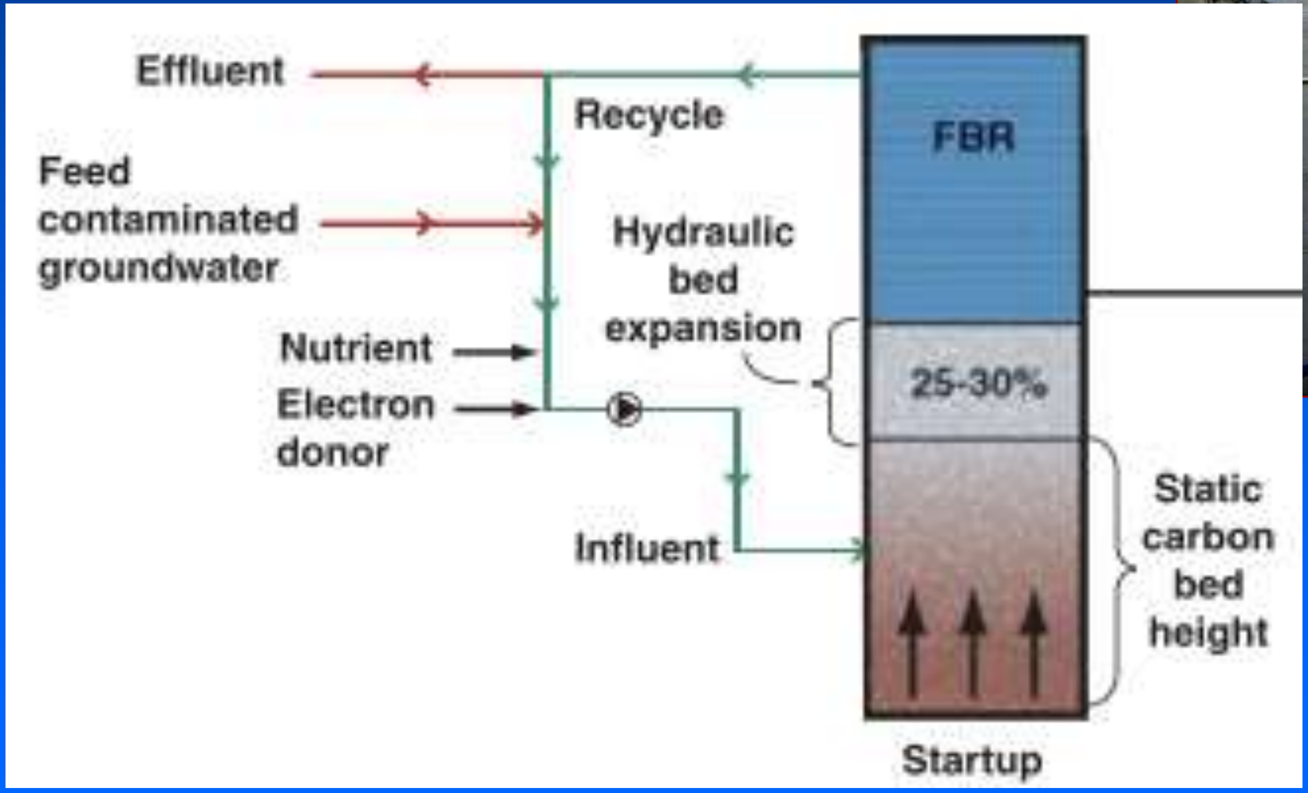
General organic carbon considerations

- High biomass growth / fast kinetics
- Expensive/limited certified suppliers
- Disinfection by-product precursor
- May need specialized storage

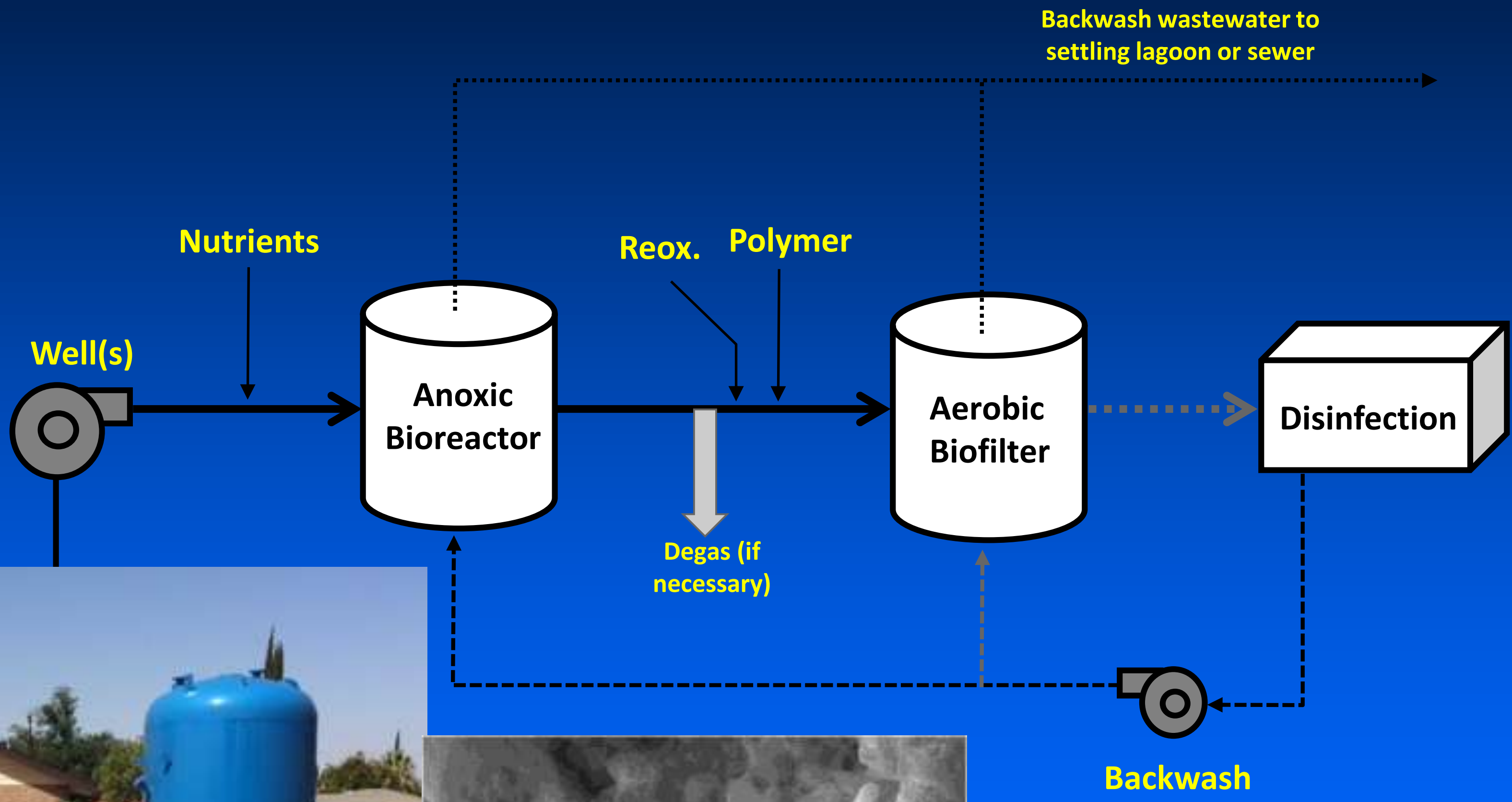


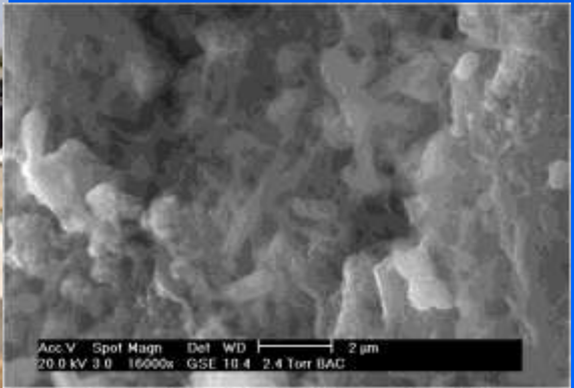
Envirogen fluidized-bed bioreactor





Two-Stage Fixed Bed





Autotrophic Processes

- Autotrophic processes use an INORGANIC C source
- Typically, *inorganic donors* use *inorganic C sources*

Examples of Inorganic Donors

- Hydrogen gas (H_2)
- Reduced sulfur (S^o, H_2S, $S_2O_3^{2-}$)
- Reduced iron (Fe^{2+})

Advantages and Disadvantages of Autotrophy

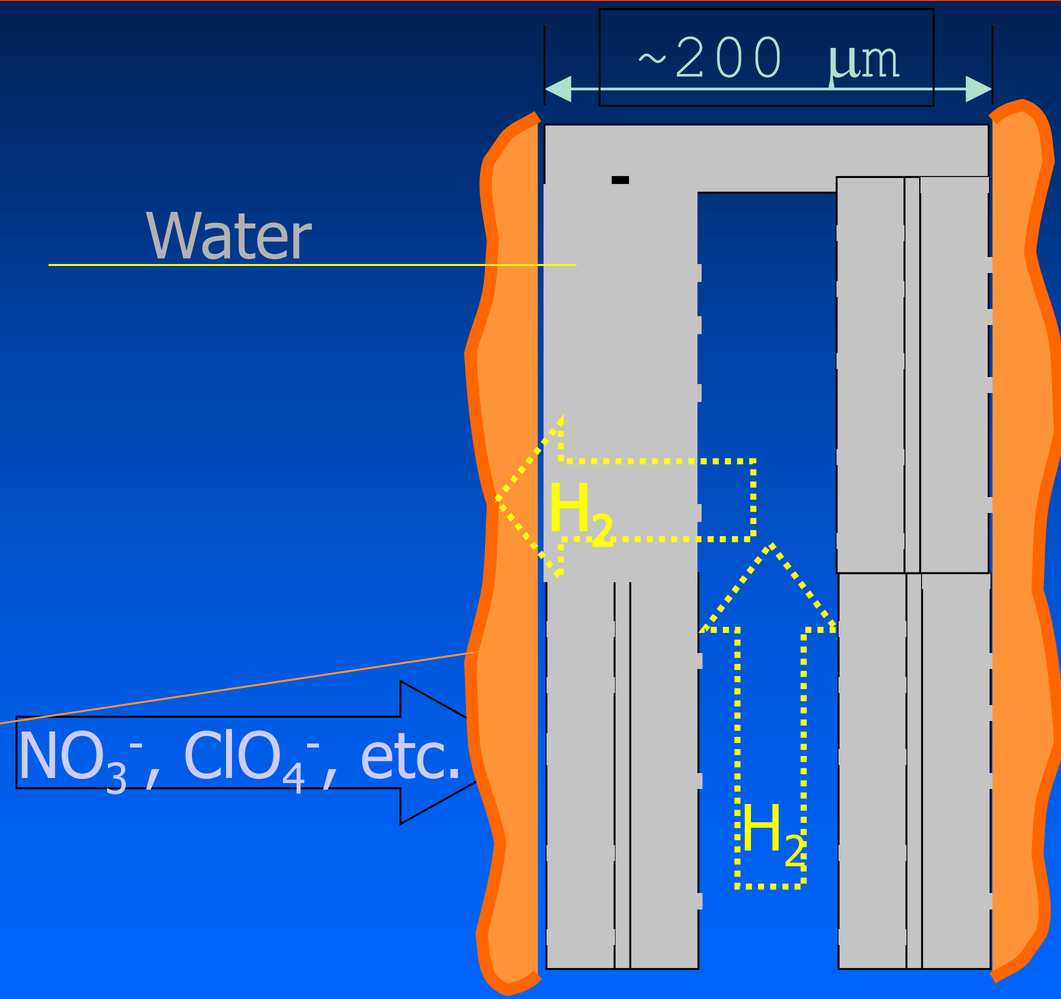
- Lower biomass yields, but slower growth rates
- Often sparsely soluble – no residual, but need special delivery strategy
- Typically have no or low toxicity, but may have special handling needs

H_2 as an autotrophic donor

- Low cost
- High electron density per unit mass
- Can be produced on site
- Can reduce the wide range of oxidized contaminants (“universal electron donor”)

The Membrane Biofilm Reactor (MBfR) for delivering H_2 to the biofilm

POLYPROPYLENE MEMBRANE!

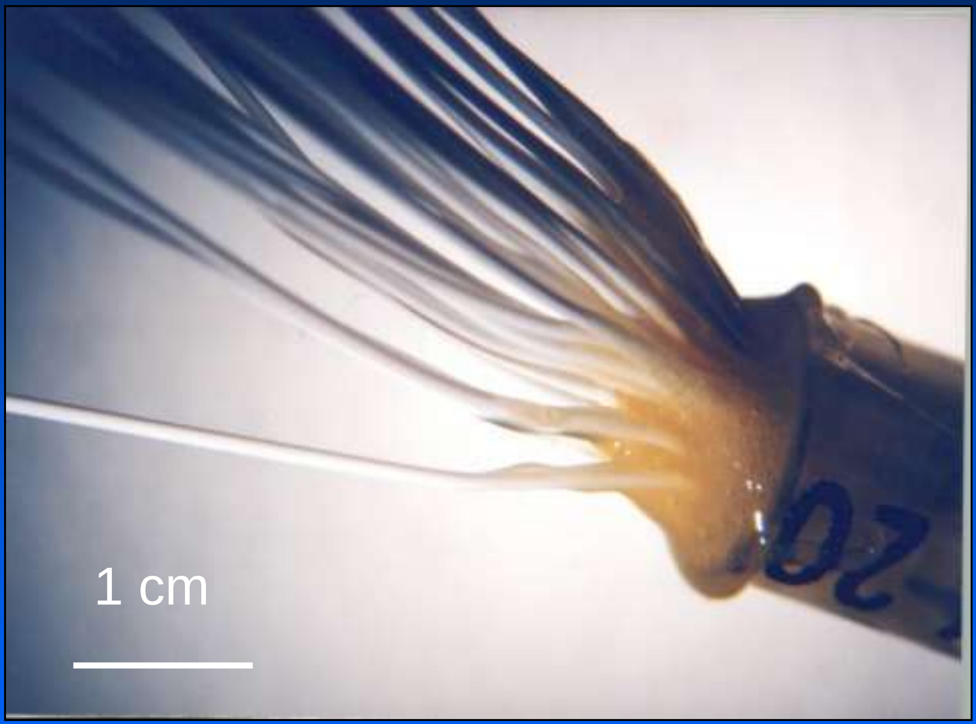


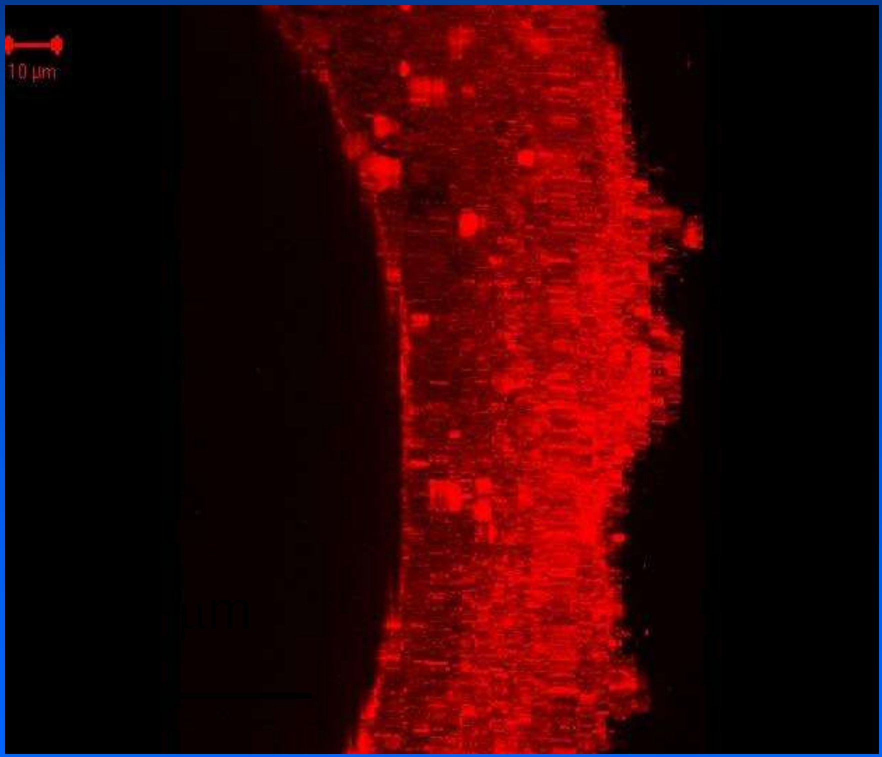
Biofilm "reactive barrier"

"Supply on demand"

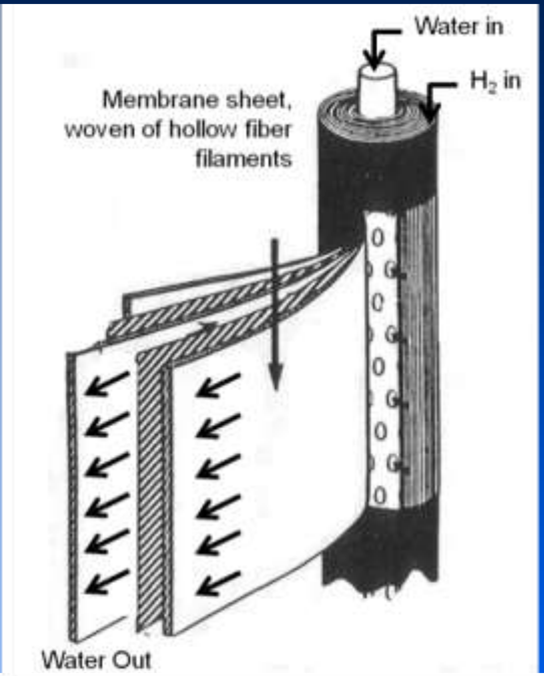
H_2-use efficiency nearly 100%

What do the hollow-fibers and biofilms look like?





Pilot- and Commercial-scale MBfR – ARoNITE by APTwater



Spiral wound sheets of polypropylene fibers

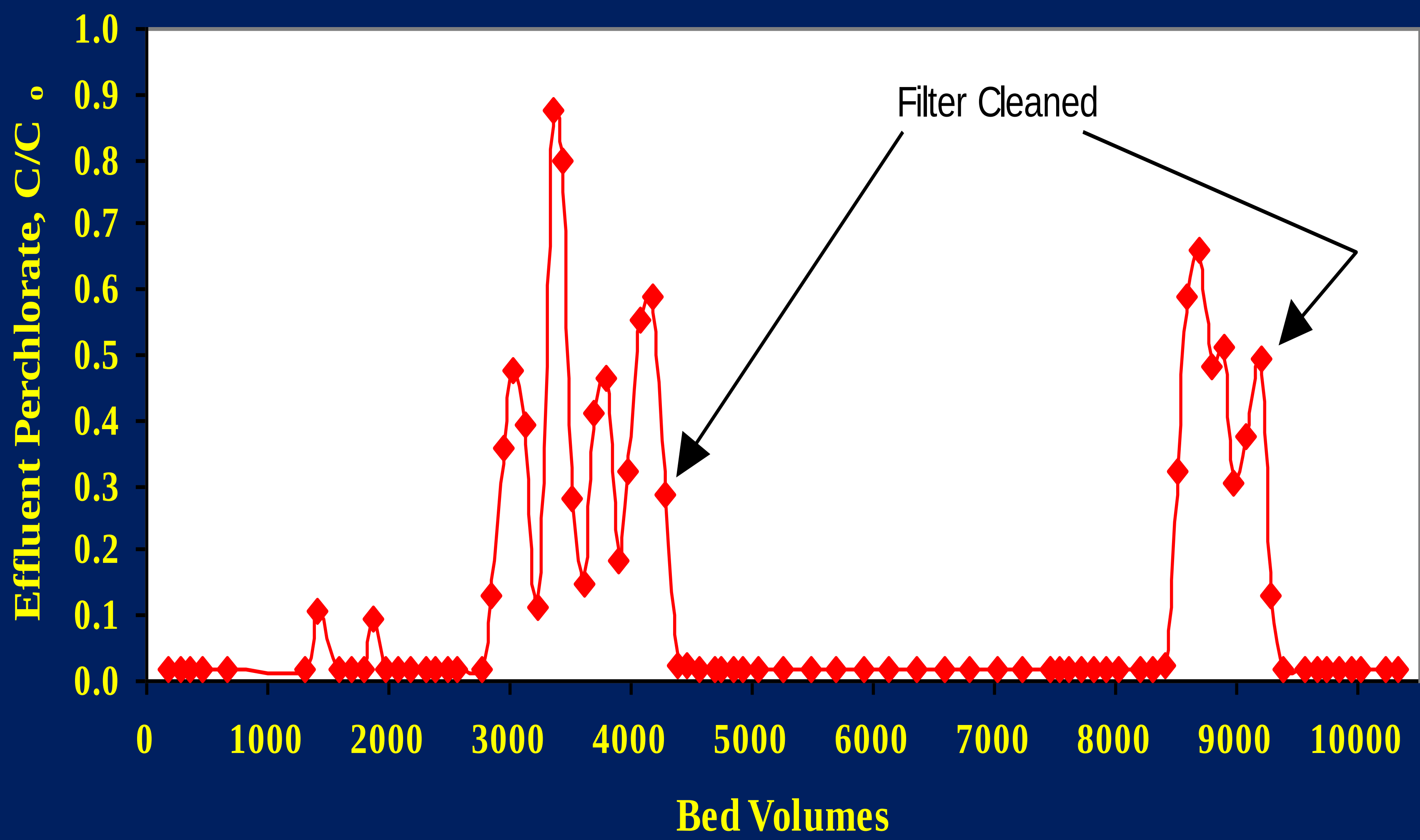
Inside the tank of modules for one stage of a pilot

Full-scale multi-stage ARoNITE in Calliforina

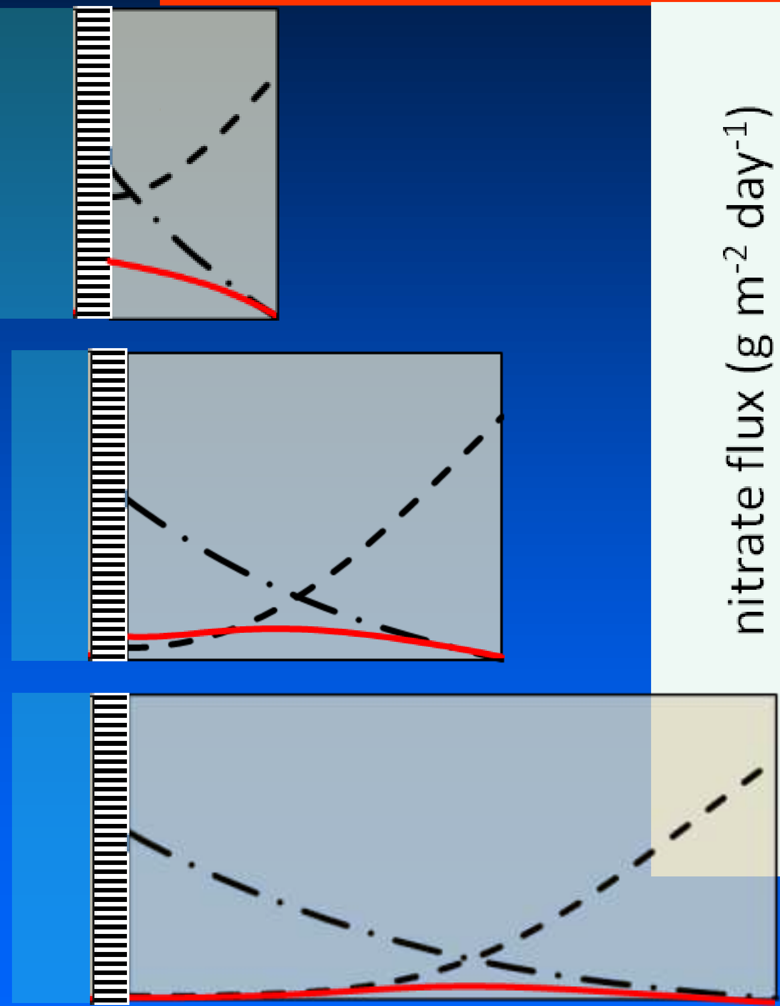
Take-Home Lessons and Pressing Issues

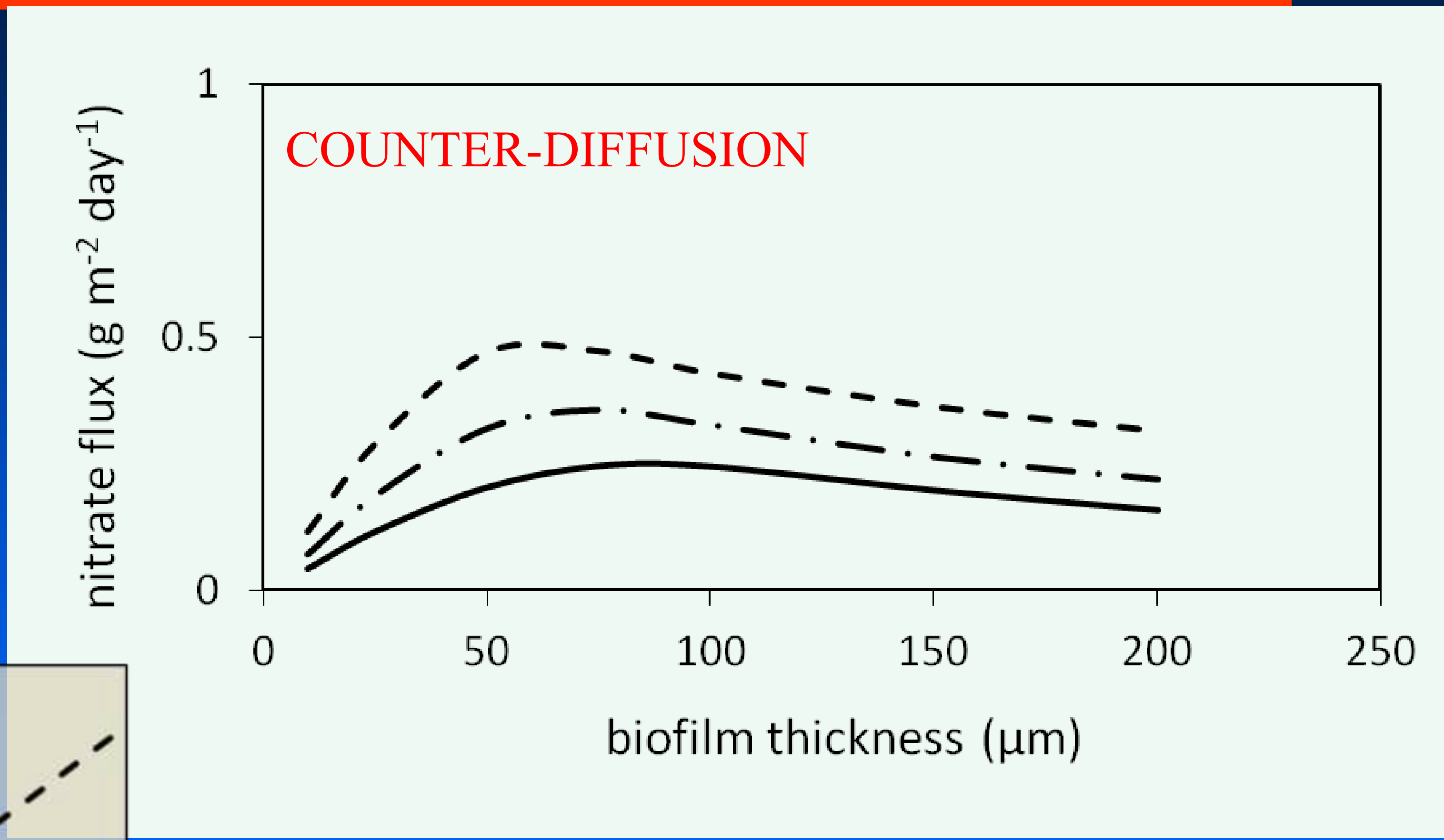
1) Biomass management is critical
   a) To prevent excessive biofilm accumulation and head loss
   b) “Backwashing” methods are well developed

Heterotroph Fixed-Bed Example



Can have too much autotrophic biofilm



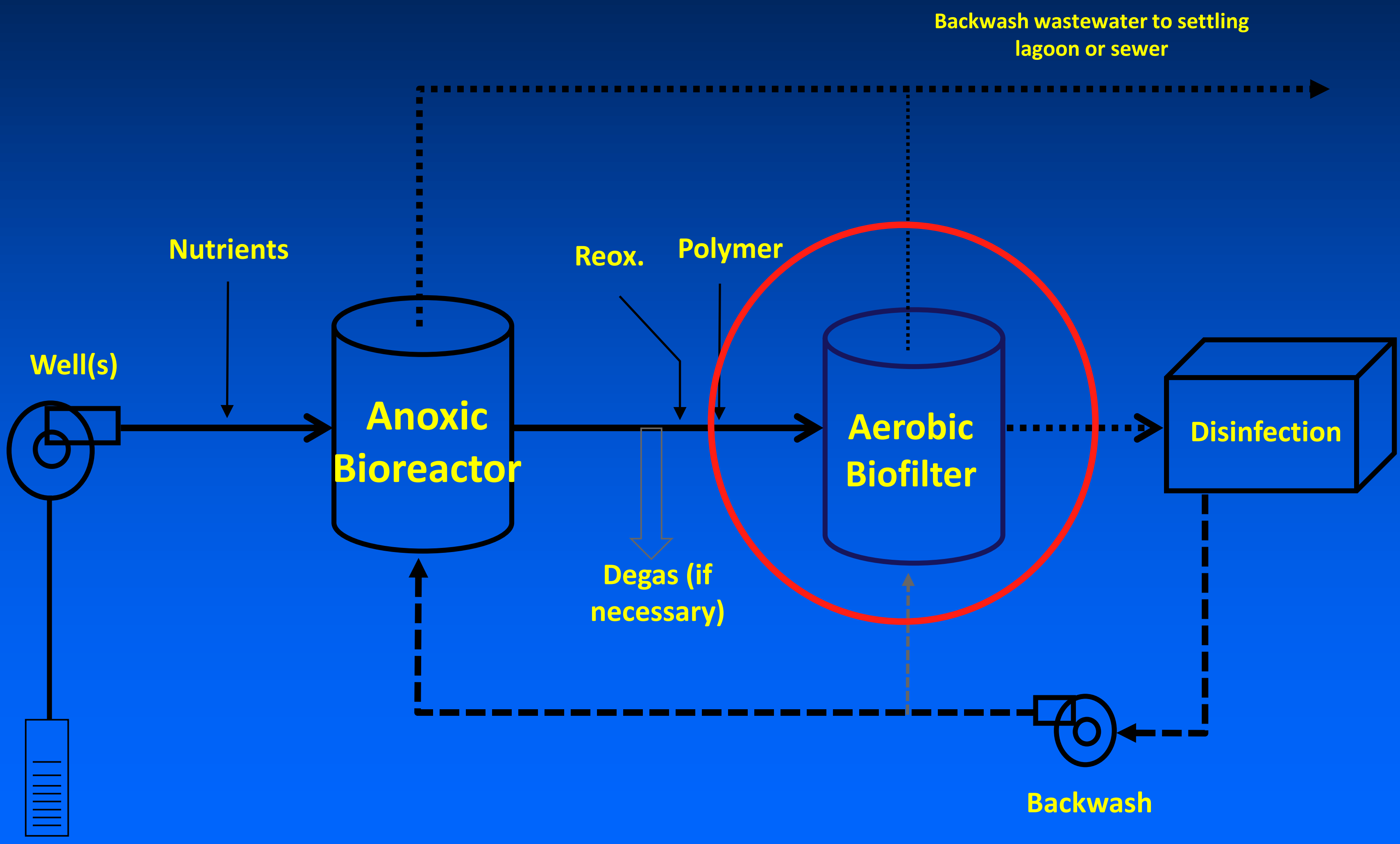


Modeling results from Rob Nerenberg. Lack of donor and acceptor overlap with a too-thick biofilm

Take-Home Lessons and Pressing Issues

1) Biomass management is critical
   a) To prevent excessive biofilm accumulation and head loss
   b) "Backwashing" methods are well developed
2) Accurate delivery of the donor is essential
   a) Avoid over- or under-dosing for organic donors
   b) Ensure enough delivery capacity for H_2

Aerobic Post-treatment with Heterotrophic Processes



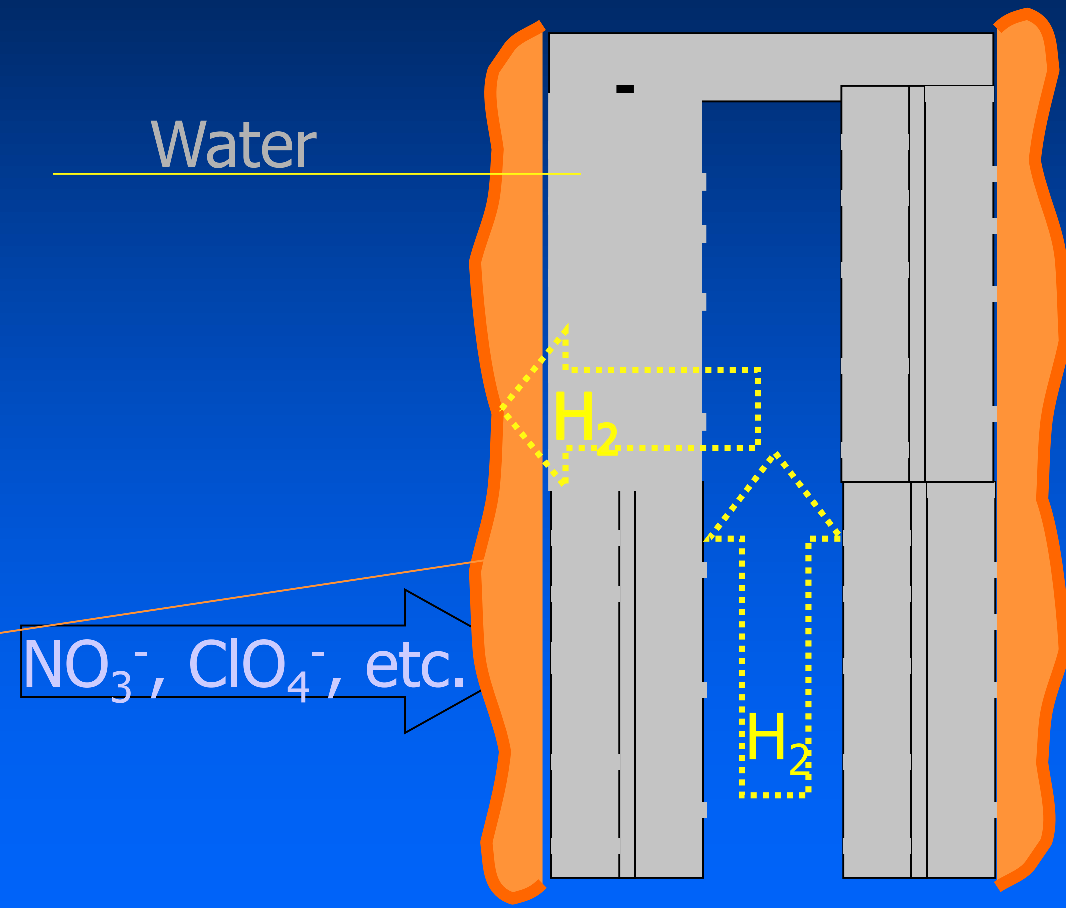
H_2-Based On-demand Delivery

POLYPROPYLENE MEMBRANE!

Biofilm “reactive barrier”

“Supply on demand”

H_2-use efficiency nearly 100%



Take-Home Lessons and Pressing Issues

1) Biomass management is critical
   a) To prevent excessive biofilm accumulation and head loss
   b) "Backwashing" methods are well developed
2) Accurate delivery of the donor is essential
   a) Avoid over- or under-dosing for organic donors
   b) Ensure enough delivery capacity for H_2
3) pH control needed due to base release.
4) Automated operation and on-line monitoring are needed and being implemented
5) Removing multiple oxidized contaminants is a major advantage and challenge

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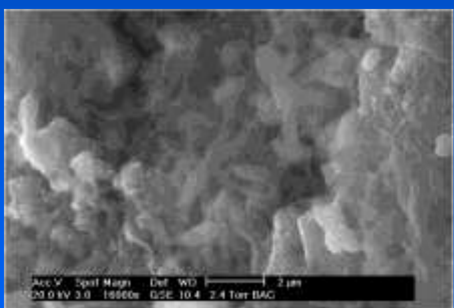

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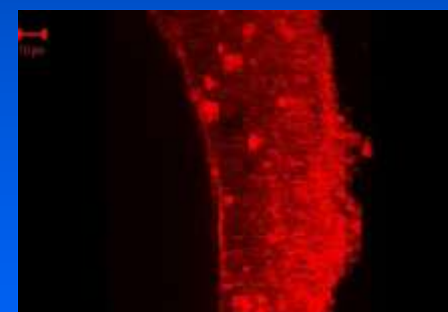

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