Resource and energy recovery from wastewater

Resource & energy recovery

Wastewater =

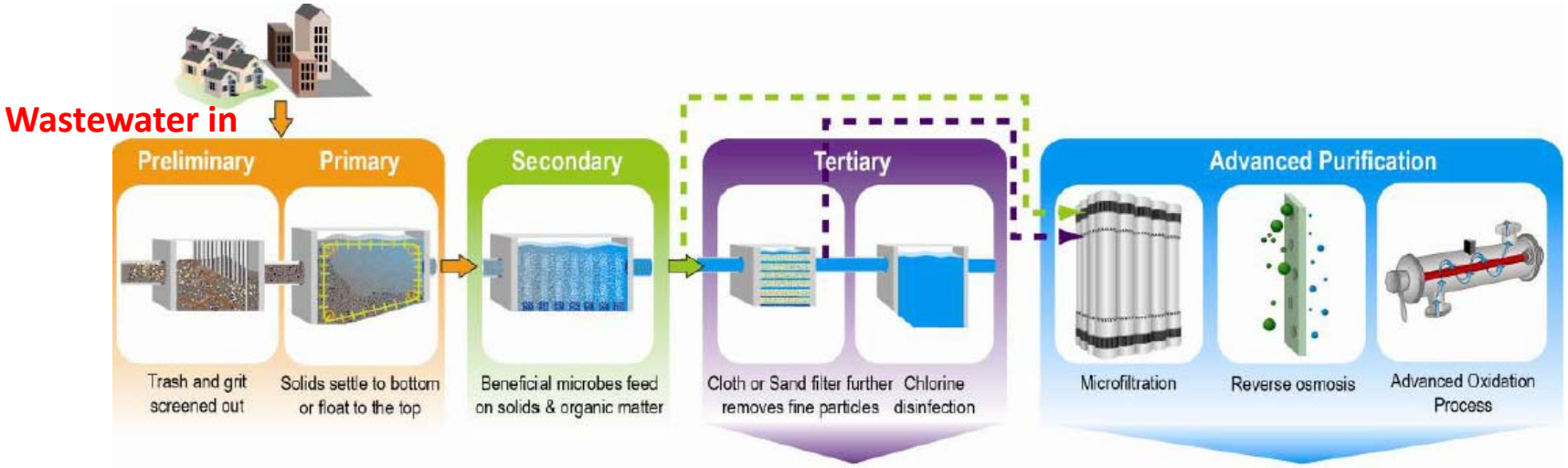
Water

+ Nutrients (N & P)

+ Organic matter

(= reduced carbon = chemical energy)

Wastewater reuse



Recycled water out
applications: lakes and ocean non-potable reuse

***Purified* recycled water out**
applications: potable/non-potable reuse, groundwater replenishment

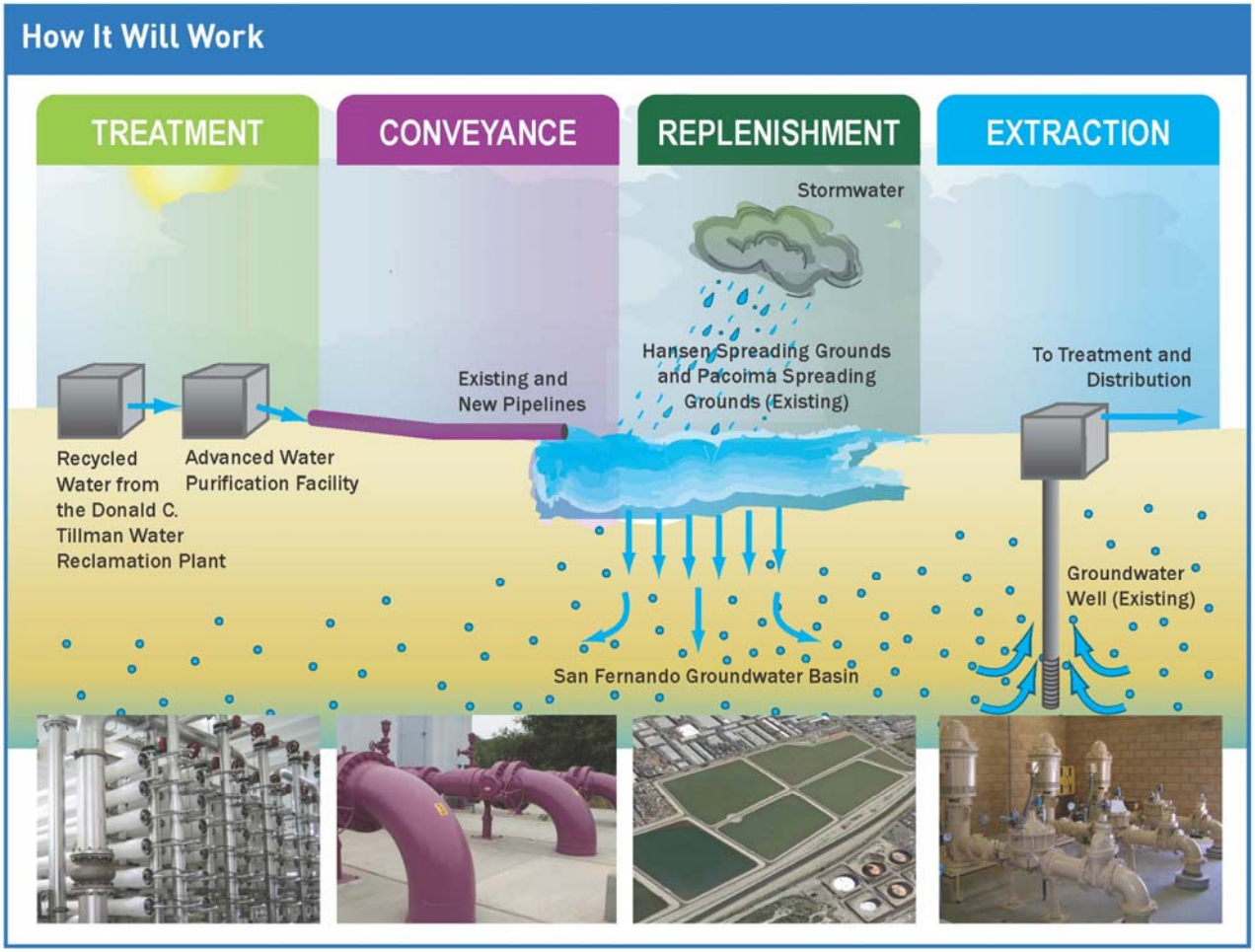
Wastewater reuse

- Non-potable commercial, industrial, or agricultural use
- Recreational use
- Irrigation
- Seawater intrusion barrier
- Potable use
  - Indirect potable use
  - Direct potable use (not yet common)

"Purple pipe" system in the U.S.

Example use: Japanese Garden, LA, USA

Example use: LA District, USA



Wastewater reuse: adv. & disadv.

- **Advantages**
  - Reliability (in quantity): produced year round
  - High quality: good for industrial use
  - Cost
    - Generally cheaper capital & operation costs than desalination cost
    - Cost getting comparable to drinking water supply in some dry regions of the world
  - In many cases in dry regions, use less energy than importing water

- **Disadvantages**
  - Safety/reliability (in quality) concerns
  - Cost for distribution
    - Need to install separate distribution system
  - The “ick” factor: public opposition

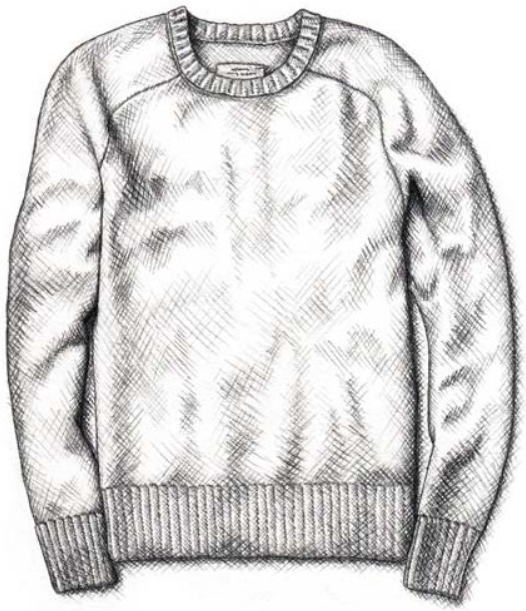
Thought experiment - 1

Thought experiment - 2

Thought experiment - 3

Thought experiment – 3 (2)

Photo © Mary Ellen Mark



Nutrient recovery & resource production

- Recovering nutrients
  - By composting / sludge application
    - As soil amendment / fertilizer
    - Potential health threats: pathogens, toxic & recalcitrant pollutants, etc.
  - By chemical precipitation

    ex) struvite; $MgNH_4PO_4 \cdot 6H_2O$

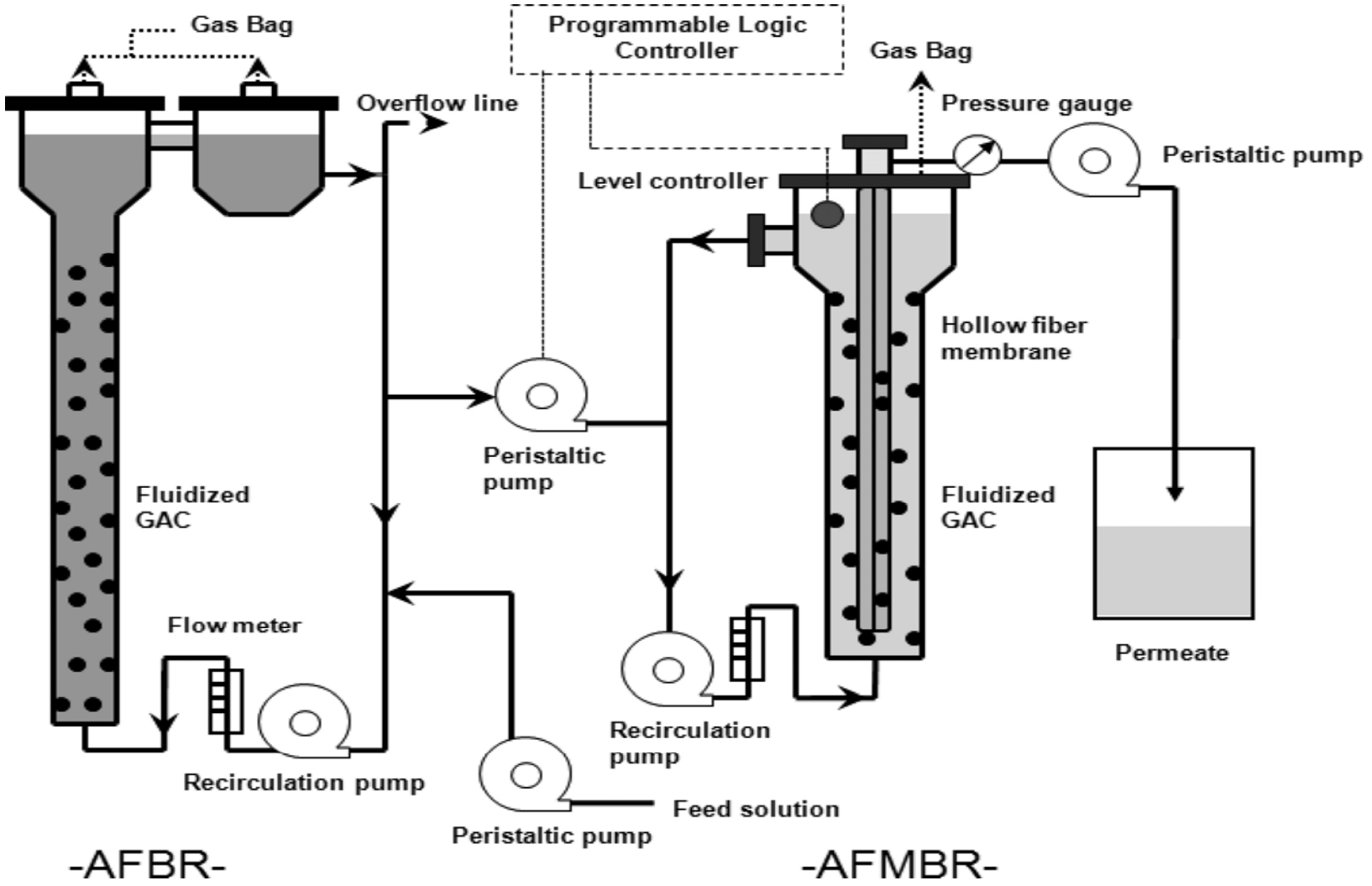
- Producing valuable materials

  ex) Bioplastics: PHB (polyhydroxybutyrate)
  - Can be made to high quality plastic products
  - Some microorganisms produce PHB in nutrient-deficient conditions

Energy recovery

- Shoot for energy positive wastewater treatment
- Anaerobic processes (CH_4 production)
  - Either from sludge or directly from wastewater
- Production of bio-oil, bio-ethanol, etc.
- Microbial fuel cells (MFCs)
  - Generate electricity directly from wastes & wastewater

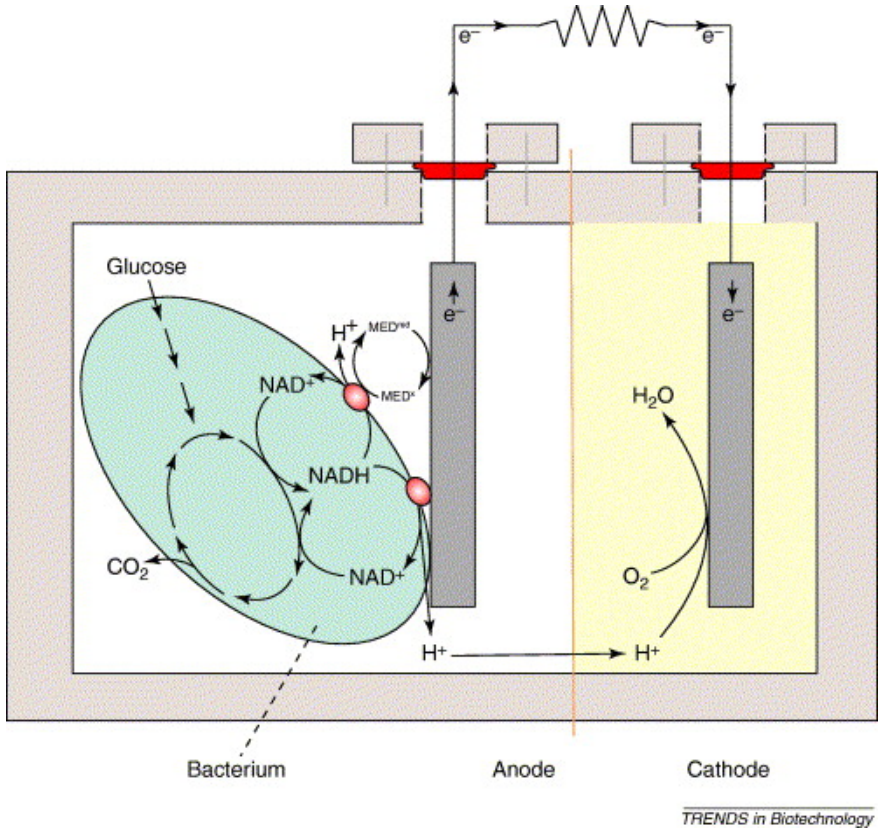
Anaerobic Fluidized Bed Membrane Bioreactor



J. Kim, …, **P. L. McCarty** and **J. Bae**, *ES&T*, 2011.

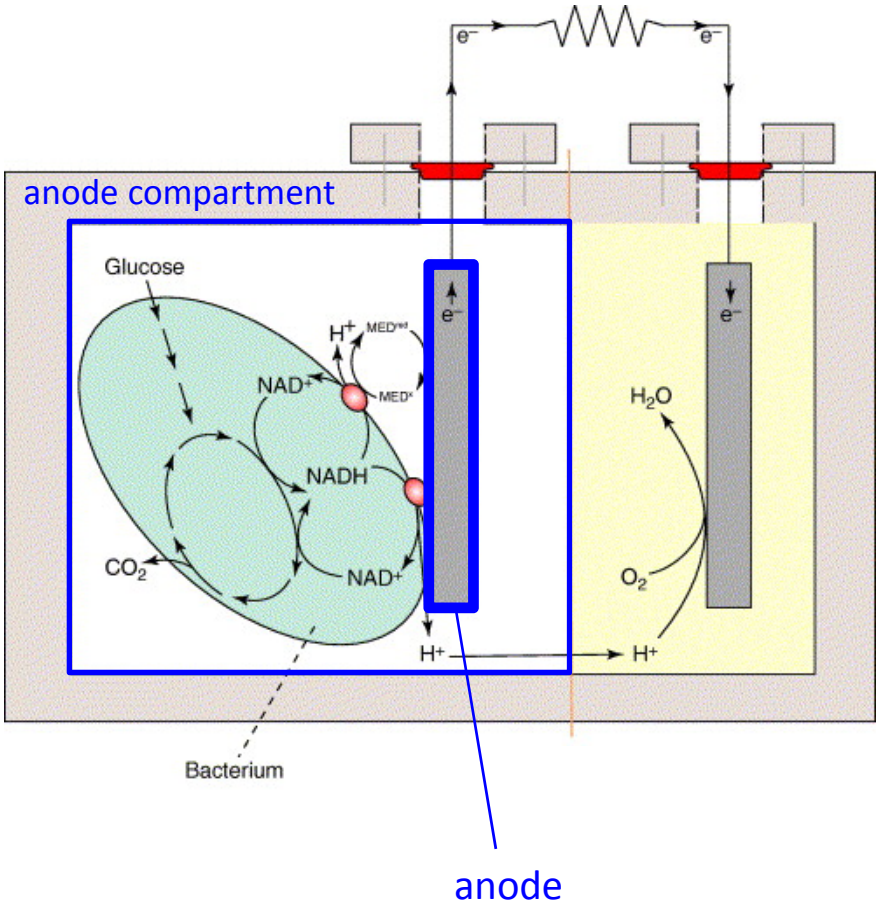
Microbial Fuel Cell (MFC)

- A device that converts the chemical energy to electrical energy by the action of microorganisms
- The redox reaction is catalyzed by microorganisms



MFC – Anode compartment

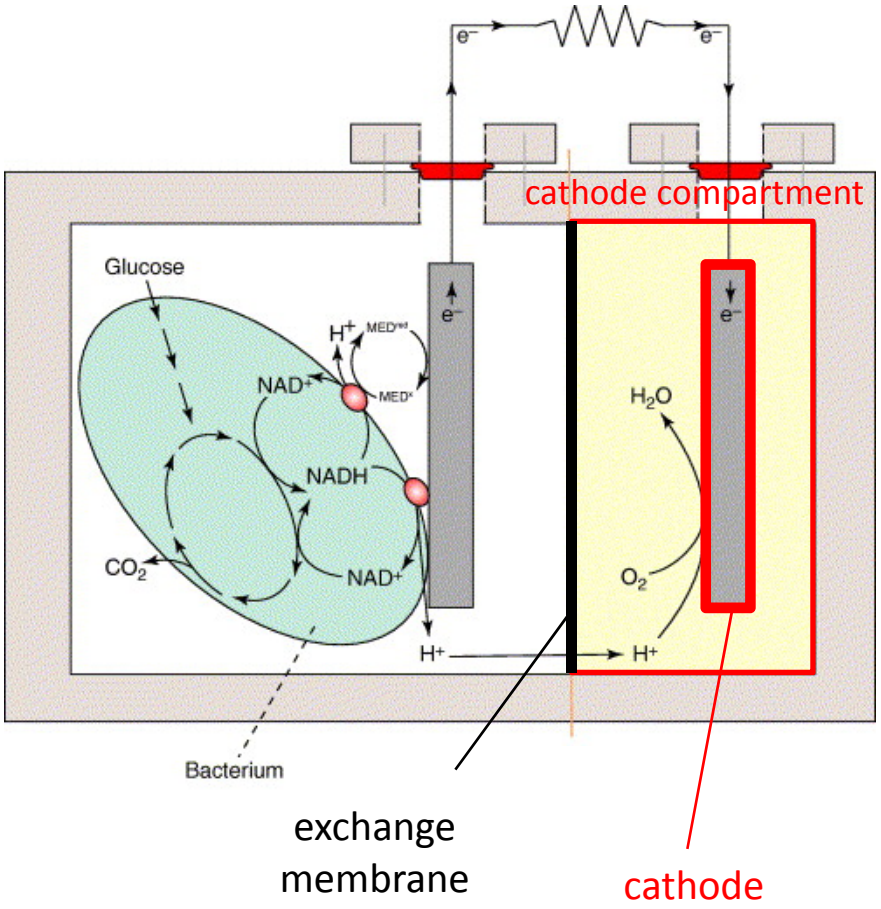
- Anode
  - Should be conductive, bio-compatible, chemically stable with substrate
  - Stainless steel mesh, graphite plates or rods
- Bacteria live in the anode compartment and oxidize the substrate provided
- Anode compartment should be kept low in DO
- Substrates: usually organics – carbohydrates, protein, VFAs, cellulose, and wastewater



MFC – Cathode compartment / EM

- Cathode compartment
  - Usually oxygen is used as an oxidizing agent
  - Catalysts used for the oxygen reduction reaction: Pt most common

- Exchange membrane
  - Allows proton (H^+) to flow from the anode compartment to cathode compartment



MFC – pros & cons

- Advantages
  - Generation of energy out of bio-waste / organic matter
  - Direct conversion of substrate energy to electricity
  - No gas treatment required
  - Aeration may not be needed (the cathode may be passively aerated)

- Disadvantages
  - Low power density: losses of electric potential significant
  - High initial cost