Membrane Bioreactors (MBRs) in wastewater treatment and reclamation

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Membrane Bioreactors (MBRs)

- Suspended growth activated sludge treatment system using membranes for liquids/solids separation.
- No need for clarifiers.
- Different module configurations:
  - Immersed hollow fiber (vacuum)
  - Immersed flat-sheet (vacuum)
  - External tubular, hollow fiber, capillary (positive pressure)
- Cross-flow or dead-end filtration.
- Low-pressure membrane filtration, either MF or UF is used to separate the solids.

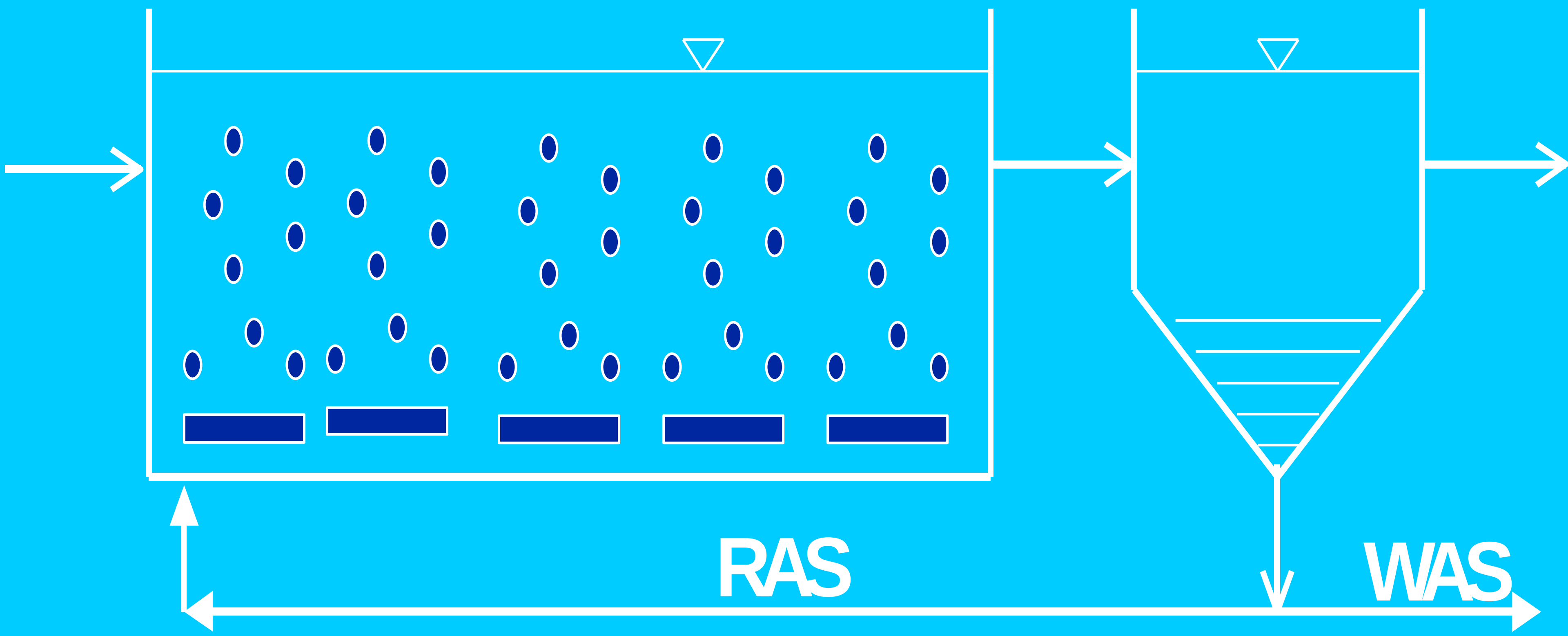
Membrane Bioreactors (MBRs)

- In immersed systems, the module is <u>suspended</u> in the process tank and <u>submerged</u> in the liquid to be treated.
  - 3-9 psig vacuum on the fibers.
  - Permeate is drawn through the membrane material to the inside of the fibers and withdrawn from the system.
  - To minimize solids buildup on the outside of the fibers, course bubbles are introduced directly beneath the fibers.
  - Since the fibers are loose, the action of the coarse bubbles cleans the fibers and causes additional mechanical cleaning as the fibers move against each other.

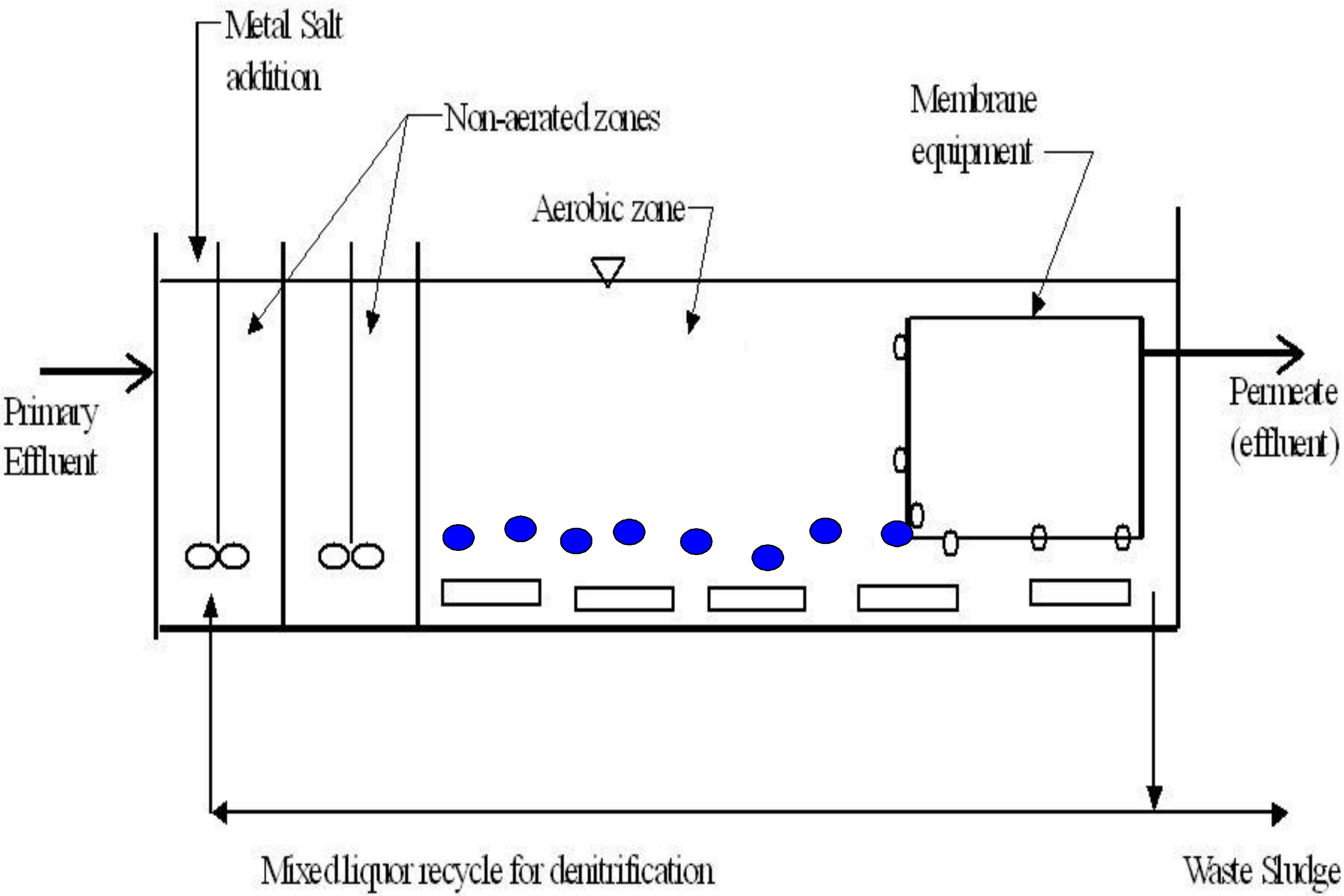
Increasing Use of MBRs

- With advances in polymer industry and decreasing membrane costs, MBRs have been globally employed exponentially for wastewater reclamation and reuse.
- The increased need for reclaimed water in arid environments has encouraged the development of new wastewater reclamation technologies. MBR is one of these.
- A perfect technology for draught areas (i.e., Middle-east), where reclaimed wastewater should be reused for various purposes to preserve water sources.
- Industrial wastewater=>reuse (textile, mining, etc)

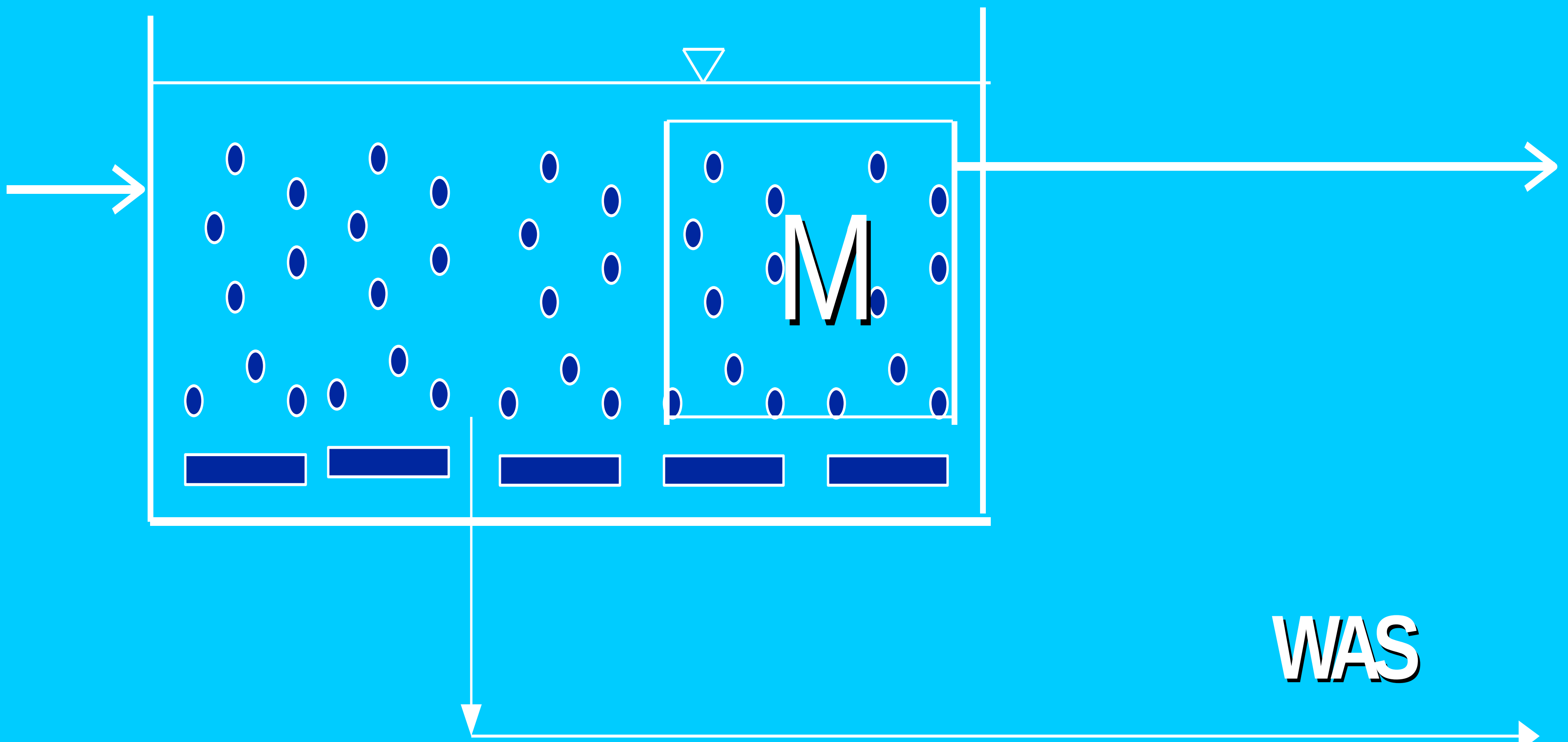
Conventional Activated Sludge



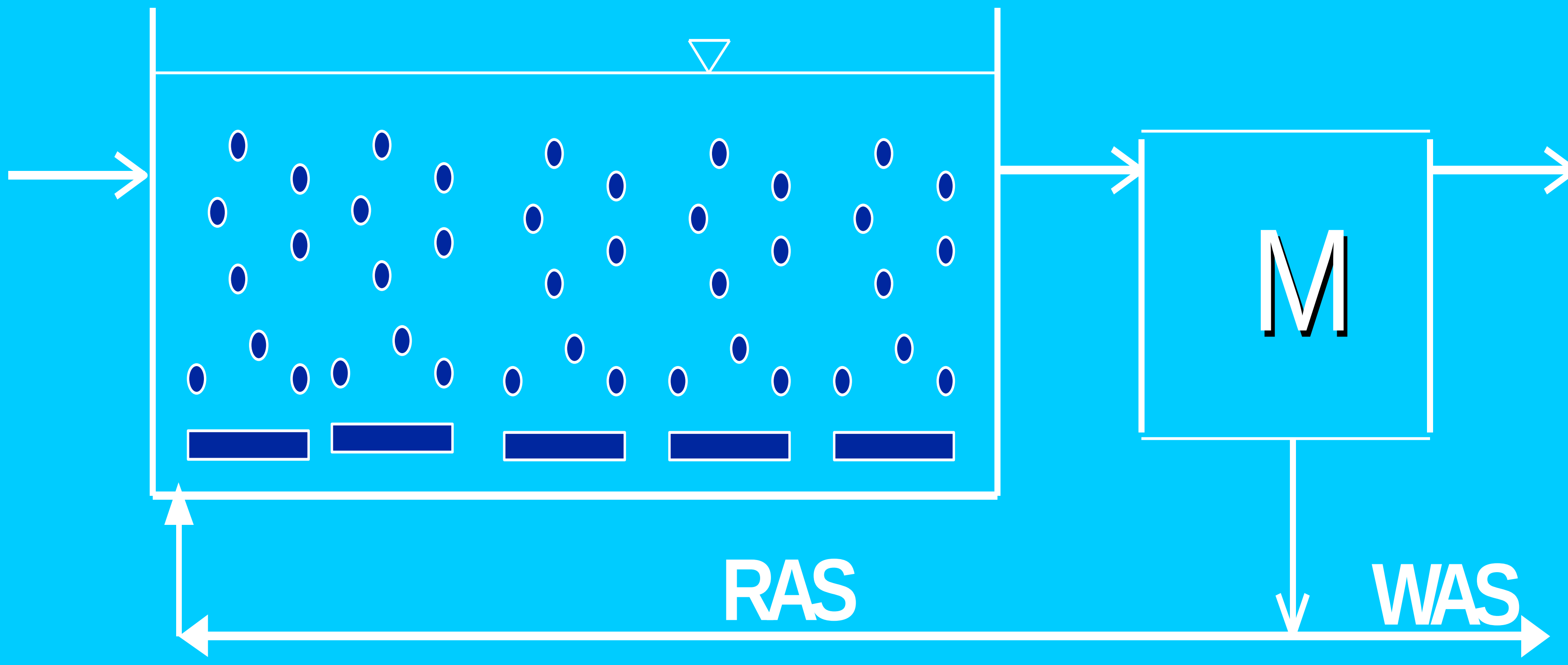
Flow Schematic for MBR System



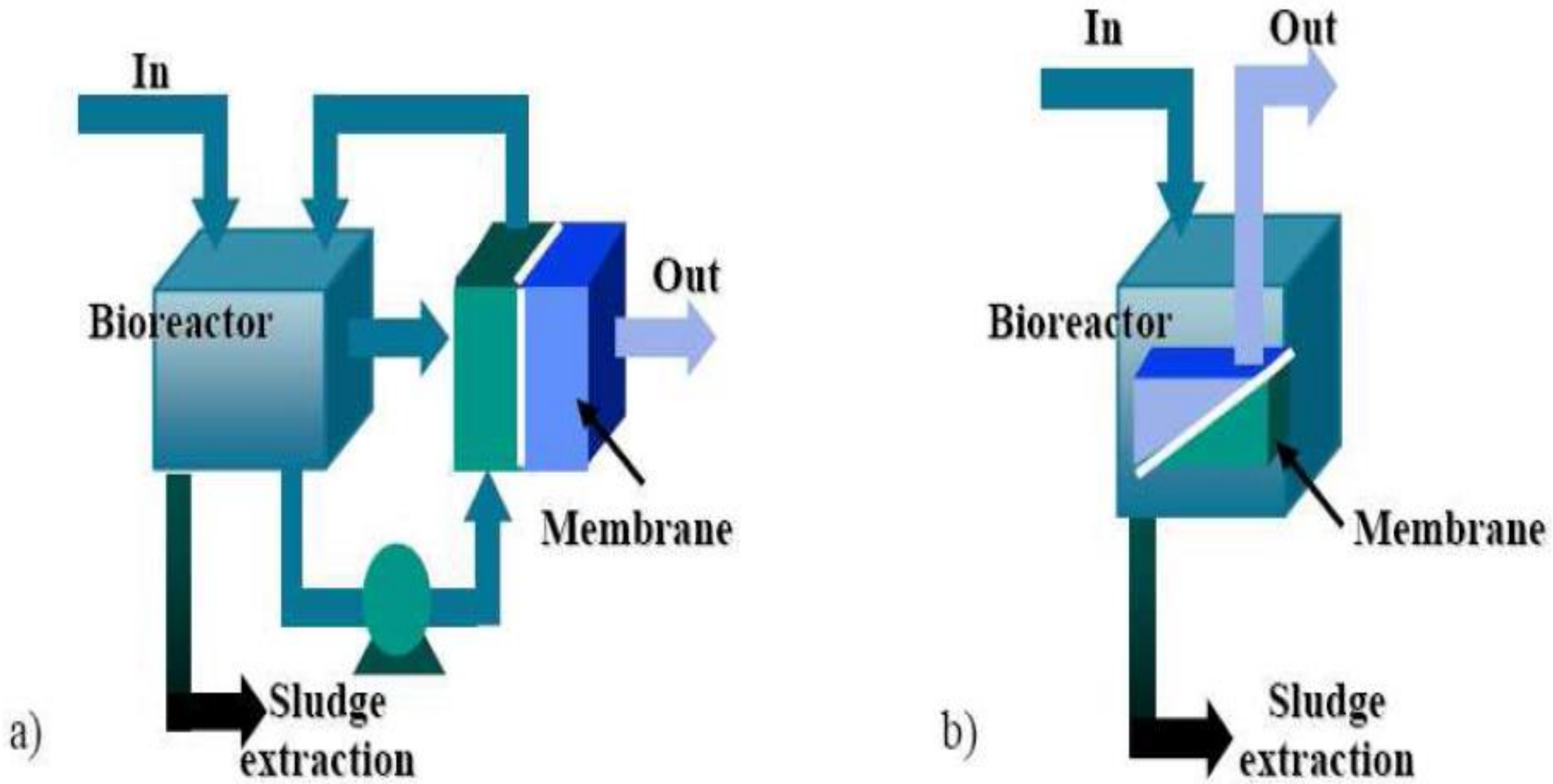
Internal MBR



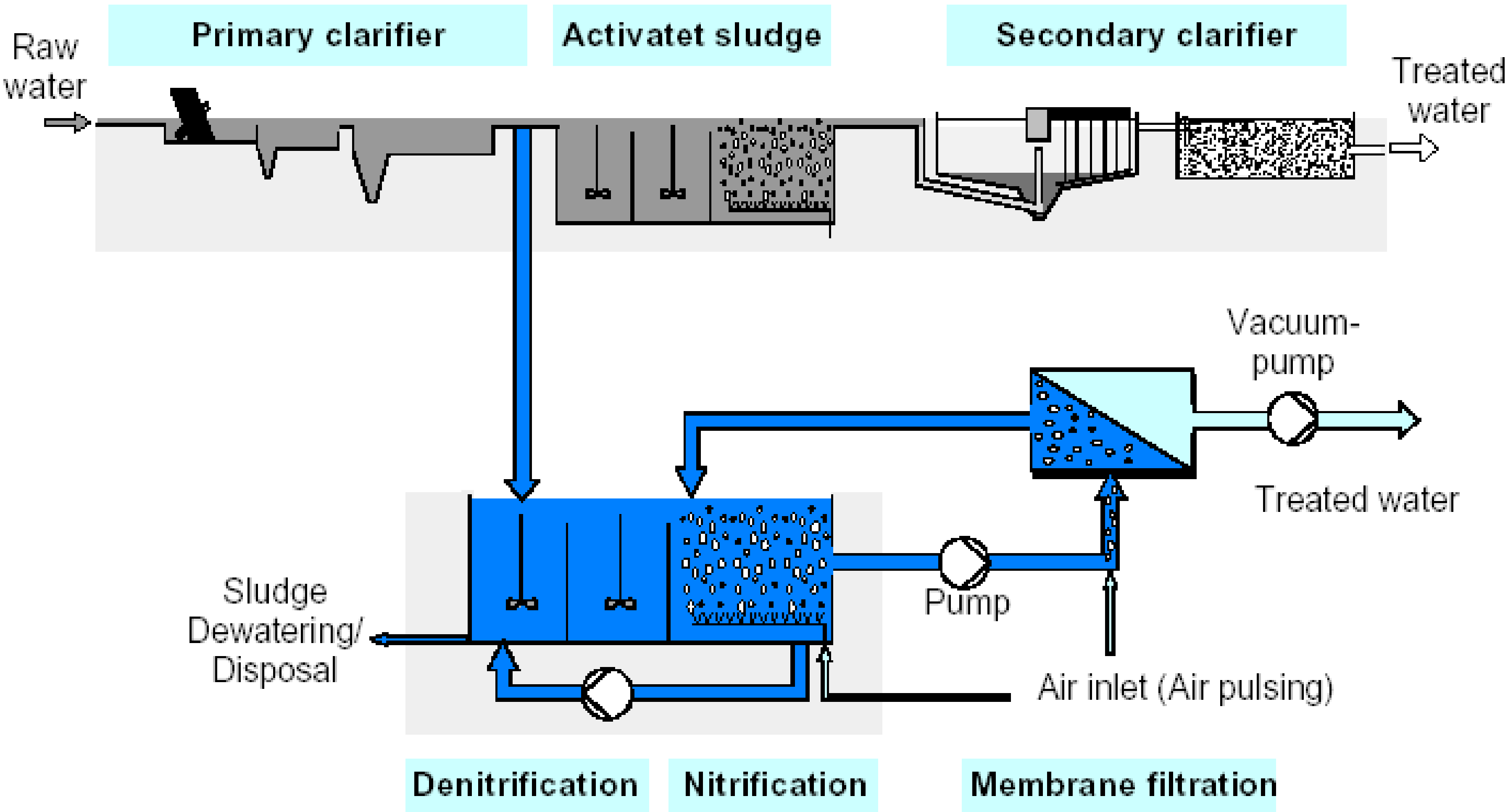
External MBR



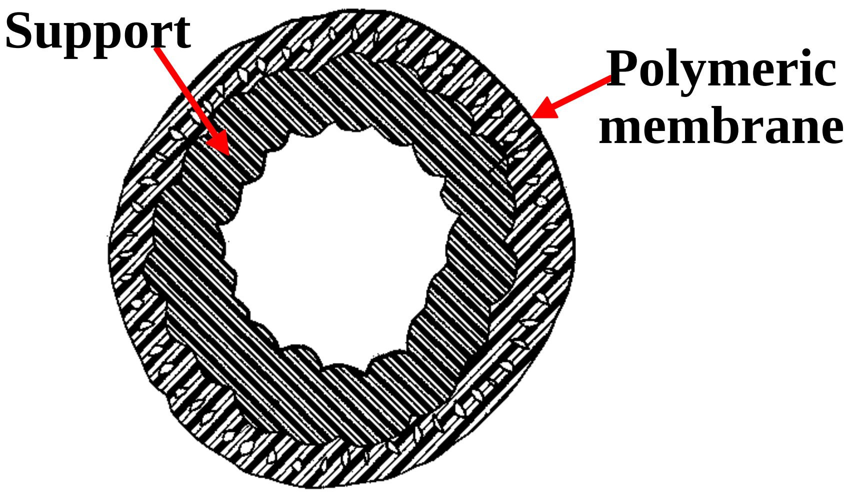
2 Different MBR Configurations: Side-stream (external) and submerged (internal)

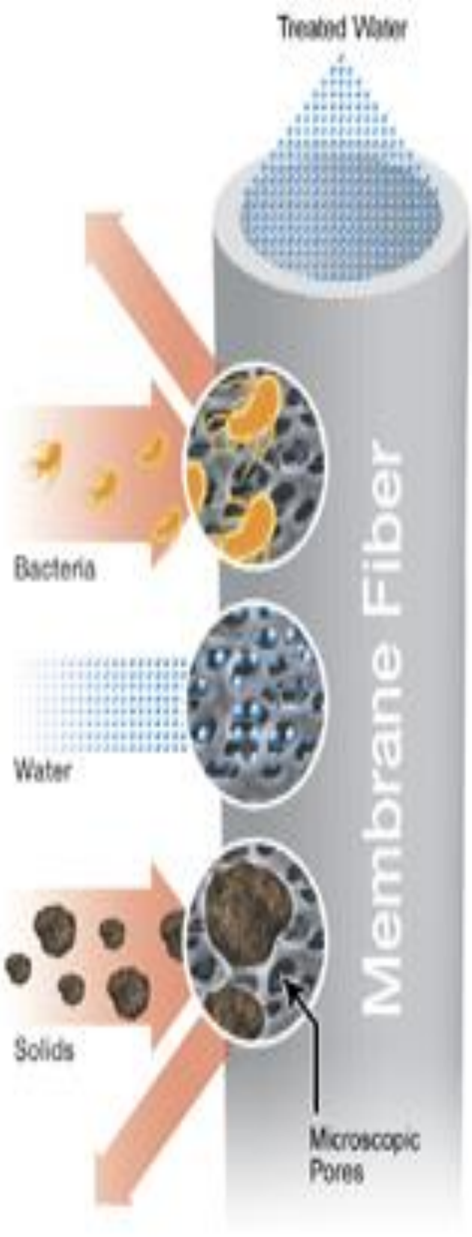


Process Scheme of MBRs



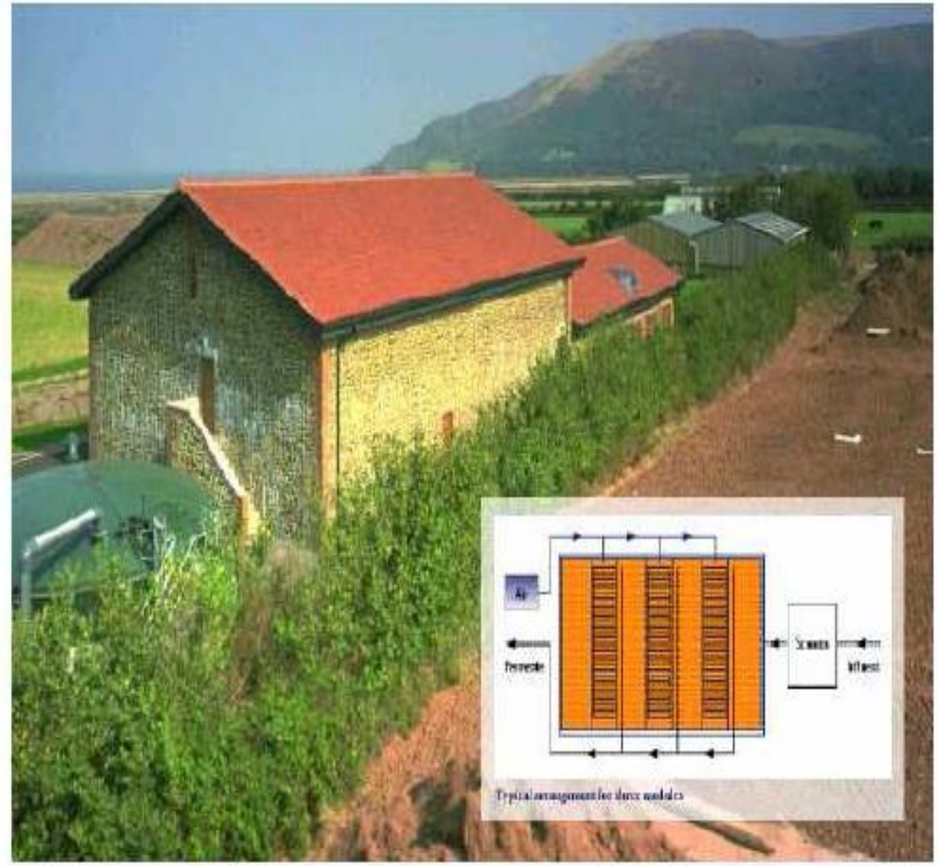
Membrane Fibers





A Typical Membrane Casette

MBR Plants



MBR sewage treatment plants designed to blend in with surrounding land uses (Chapman, S.; Leslie, G.; Law, I., Membrane Bioreactors for Municipal Wastewater Treatment – An Australian Perspective).

Advantages of MBRs

- High MLSS (12,000-15,000 mg/L) => low HRT => small reactor volume => small plant footprint area => <u>All within a single tank!!</u>
- Biomass separation is independent of settling; separation is via microfiltration or ultrafiltration. <u>No need for secondary clarification</u>. No settling problems such as sludge bulking . Not SVI-dependant.
- Biomass is completely retained, effluent TSS (< 1 mg/L) and turbidity (<0.5 NTU) is very low.
- Due to microfiltration or ultrafiltration, provides a <u>perfect physical disinfection</u>. Removals:
  - 5-6 log bacteria
  - 2-3 log viruses
  - Complete removal of pathogenic protozoa such as the chlorine-resistant *Cryptosporidium* and *Giardia.*

Advantages of MBRs

- Automated operation, operator requirements are reduced
- Due to elevated SRTs:
  - less susceptible to problems associated with nitrification and toxic organics
  - less biomass yield => less sludge
- Due to high MLSS, high loadings allowed
- Better SRT control since no escape of TSS as occasionally observed from secondary clarifiers
- Excellent effluent quality
- Existing plants can be easily retrofitted
- Can also remove nitrogen and phosphorus with the addition of anaerobic and anoxic zones

Typical MBR Effluent Quality

• BOD	< 2.0 mg/L
• TSS	< 2.0 mg/L
• NH_3-N	< 1.0 mg/L (with nitrifying MBRs)
• Total Phosphorus	< 0.1 mg/L (with inclusion of anaerobic zone)
• Total Nitrogen	< 3-10 mg/L (with inclusion of anoxic zone: denitrification)
• SDI	< 3.0
• Turbidity	< 0.5 NTU
• Total Coliforms	< 100 cfu/100 mL
• Fecal Coliforms	< 10 cfu/100 mL
• Coliform Reduction	> 5-6 log removal
• Virus Reduction	< 4 log removal

Disadvantages

- Since a single tank, mechanically complex
- Membrane fouling (if irreversible, problem!)
- Membrane Cleaning=> Chemicals, non-continuous permeate production
- Membrane replacement (operating costs)

Potential Uses for Reclaimed Wastewater

- Urban
- Industrial
- <u>Agricultural</u>
- Habitat restoration/enhancement and recreational uses
- Groundwater recharge

Urban Reuse

- Irrigation of public parks and recreation centers, athletic fields, schoolyards and playing fields, highway median and shoulders, and landscaped areas surrounding public building and facilities
- Irrigation of landscaped areas of single- and multi-family residences, general washdown, and other maintenance activities
- Irrigation of landscaped areas surrounding commercial, office, and industrial developments
- Irrigation of golf courses

Urban Reuse (Cont')

- Commercial uses such as vehicle washing facilities, window washing, and mixing water for pesticides and fertilizers
- Ornamental landscape uses and decorative water features such as fountains, reflecting pools, and waterfalls
- Dust control and concrete production for construction projects
- Fire protection
- Toilet and urinal flushing in commercial and industrial buildings

Industrial Reuse

- Evaporative cooling water
- Boiler-feed water
- Process water
- Irrigation and maintenance of plant grounds
- Tank cleanings/washings
- Others

Agricultural Reuse

- Agricultural irrigation represents approximately 40% of the total water demand in USA.
- Agricultural sector can be a significant user of reclaimed water.
- In 1998, approximately 182 mgd of reclaimed water was used for agricultural reuse in Florida.
- In areas where normal irrigation water use is restricted due to inadequate supply or severe drought conditions, reclaimed water would provide a reliable irrigation water source.
- Reclaimed water is currently used to irrigate both non-food and food crops.

Agricultural Reuse (Cont')

- Considerations for agricultural reuse:
  - Proper estimation of irrigation demands
  - Reclaimed water quality
    - TDS
    - Industrial discharges of potentially toxic compounds into the municipal sewer system
    - Saltwater (chlorides) infiltration into the sewer system in coastal areas
  - System reliability. Treatment and distribution facilities must operate reliably to meet permit conditions and the supply of reclaimed water to the agricultural user must be reliable in <u>quantity</u> and <u>quality</u>.

Agricultural Reuse (Cont')

- Impact of reclaimed water use on current agricultural operations.

- Reclaimed water <u>must be cost-competitive</u> with other irrigation water sources.

Groundwater Recharge

- Establishing saltwater intrusion barriers in coastal areas
- Providing further treatment via the soil/groundwater system for future reuse
- Augmenting potable or non-potable aquifers
- Providing storage of reclaimed water
- Controlling or preventing ground subsidence in areas that have been over-drafting aquifers

Bottomlines

- MBRs have evolved.
- With advances in polymer industry and decreasing membrane costs, has been employed exponentially in the last few years for wastewater reclamation and reuse.
- A perfect technology for draught areas where reclaimed wastewater should be reused.
- Large-scale applications and increasing product competition occur simultaneously.
- Seems that secondary clarifiers in conventional AS processes might be eliminated by the use of MBRs in the near future.
- Conventional AS systems can easily be upgraded to MBR systems.