Treatment of drinking water

Water: when is it drinkable?

The EPA has determined maximum contaminant levels for 90 substances on water. There are 7 types of bacterial/viral microorganisms; 7 disinfectants; **16 inorganic compounds**; 54 organic compounds; 4 radioactive isotopes.

U.S. Environmental Protection Agency Drinking Water Standards for Selected Substances

Substance	Maximum Contaminant Level (mg/L)
Primary standards: inorganic compounds	
Arsenic	0.010
Barium	2
Copper	1.3
Cyanide	0.2
Fluoride	4.0
Lead	0.015
Nitrate	10

Ground water contamination

Groundwater contamination is alarming : a contaminated underground aquifer may remain unusable for decades or longer.

Removal of contaminants requires technological efforts.

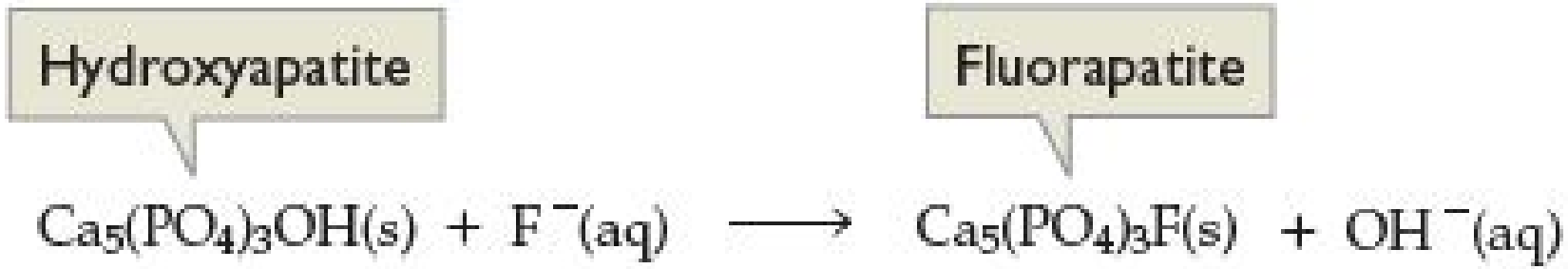
Major contaminants:

- Nitrates from fertilizers
- Volatile organic compounds
- Heavy metals from industrial effluents
- Leakage from underground storage tanks, including nuclear fuel

http://www.winnipeg.ca/waterandwaste/water/treatment/index.html

Fluoride vs. teeth

Tooth enamel is a complex calcium phosphate called hydroxyapatite.



Fluoride ions (F^-) are known to substitute OH^- (hydroxide) ions and to make the enamel harder.

The concentration of fluoride in most communities varies from 0.7 to 1 ppm.

This seems to reduce the occurrence of cavities by 50%.

MEMBRANES FOR WTPs

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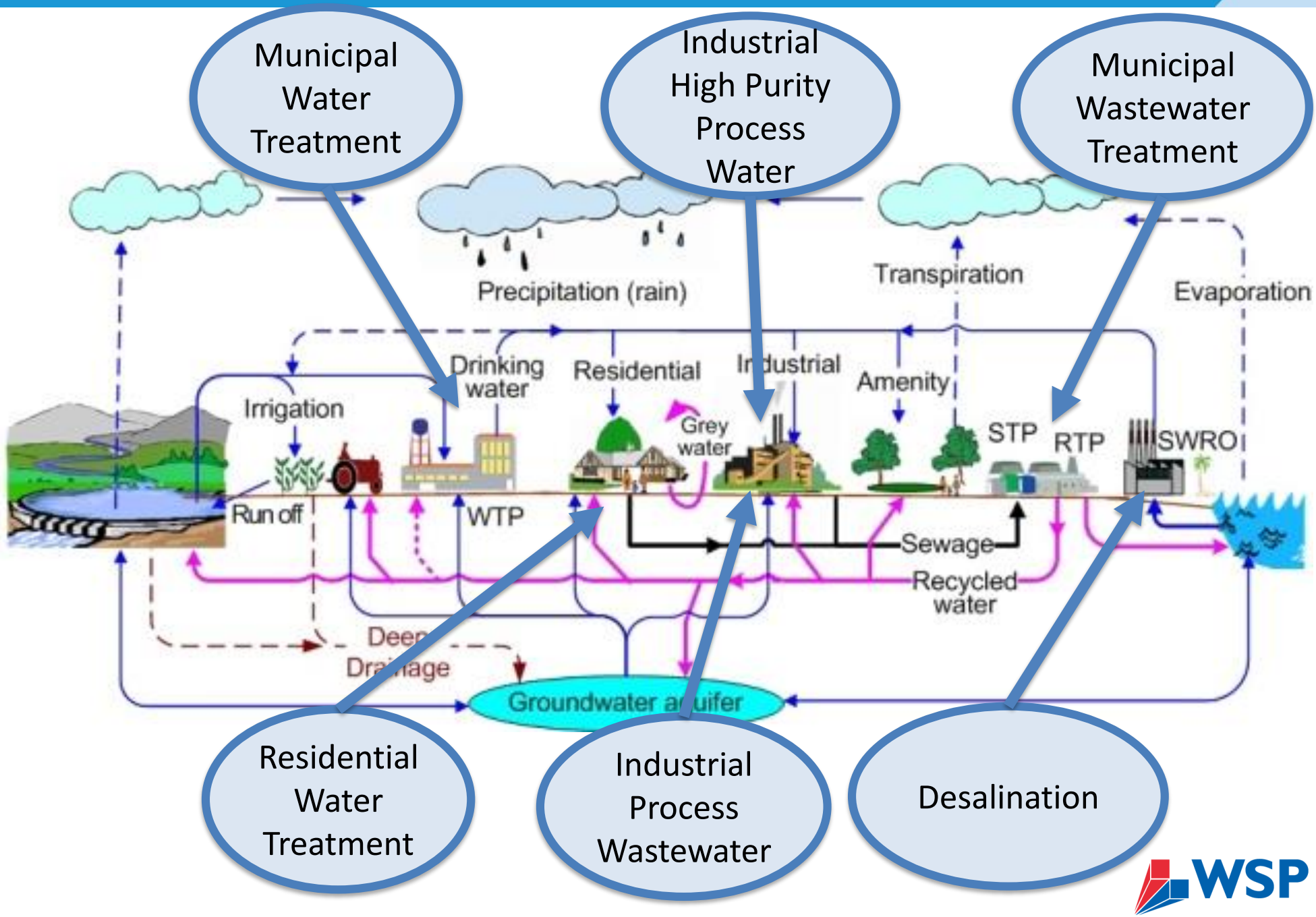
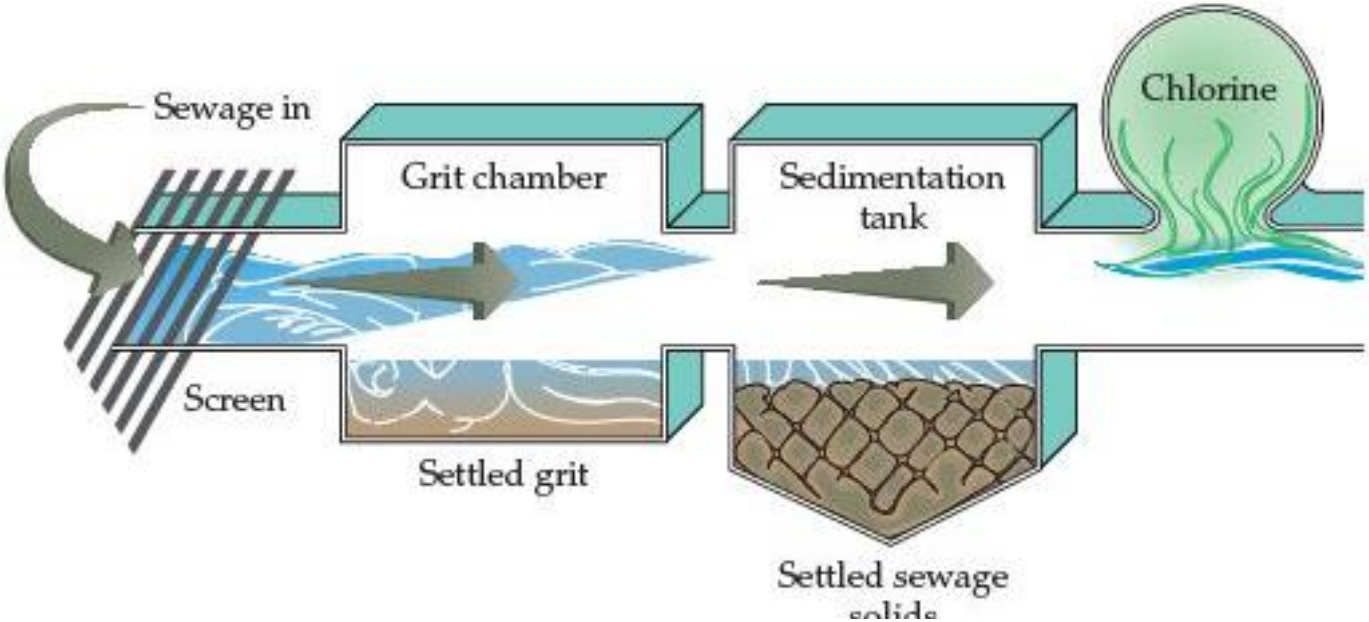
WATER AND WASTEWATER INFRASTRUCTURE
WSP CANADA INC

MEMBRANE USES FOR WATER TREATMENT

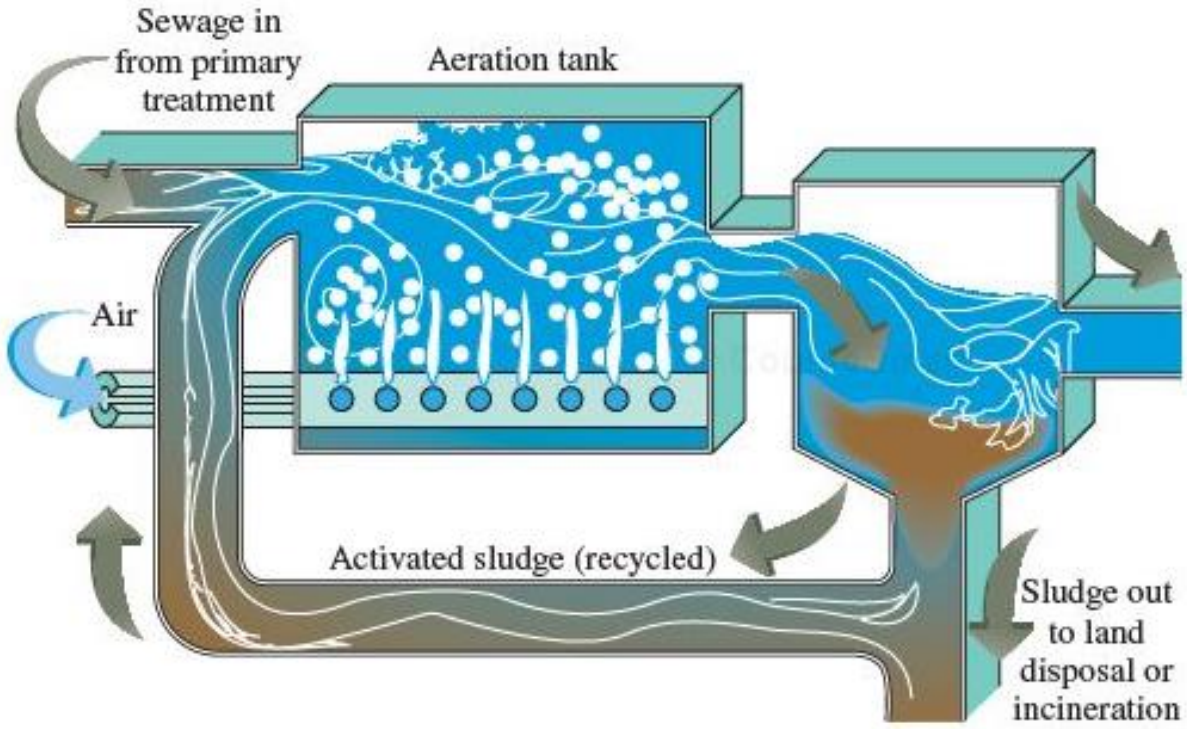


Wastewater treatment

Primary treatment



Secondary treatment



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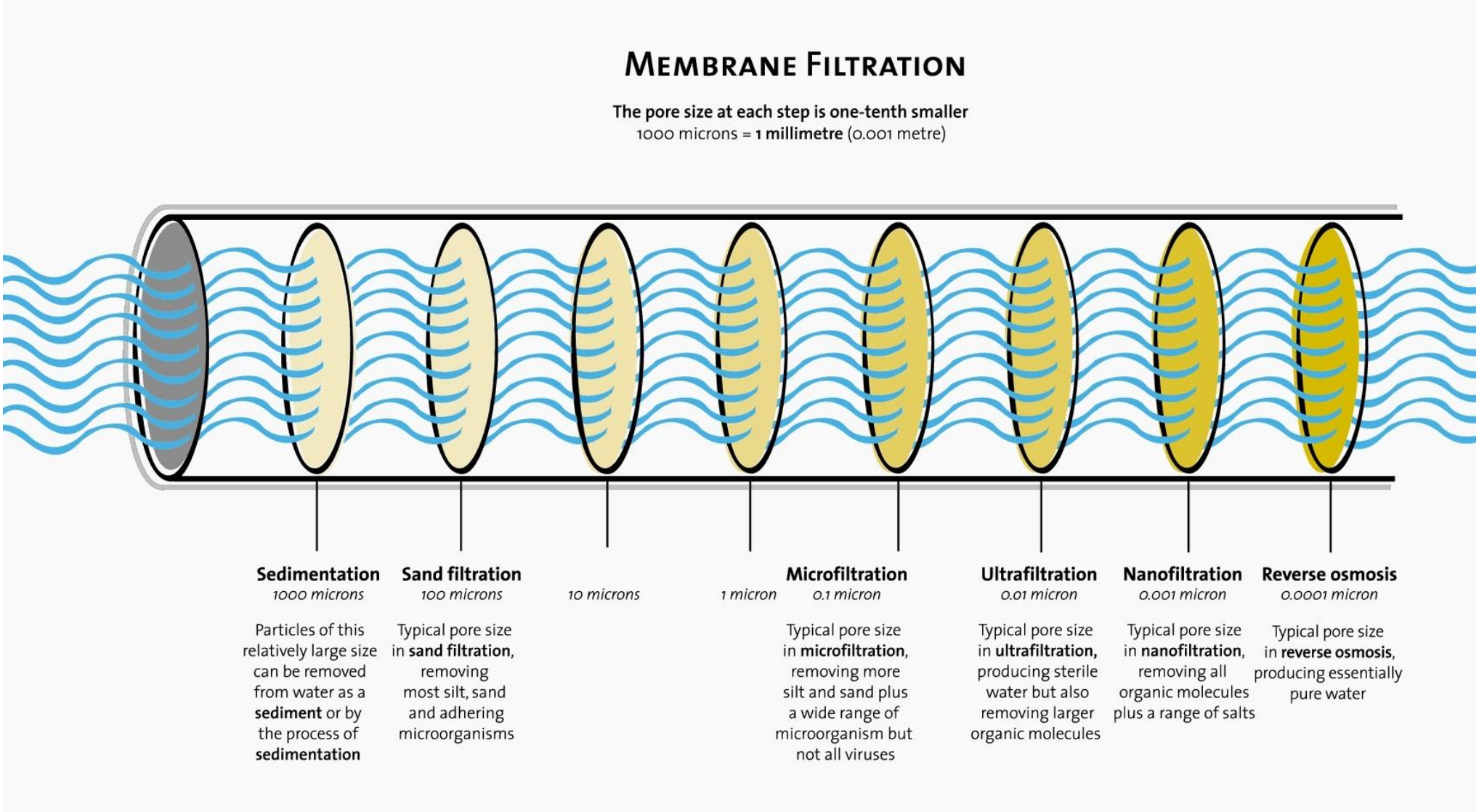
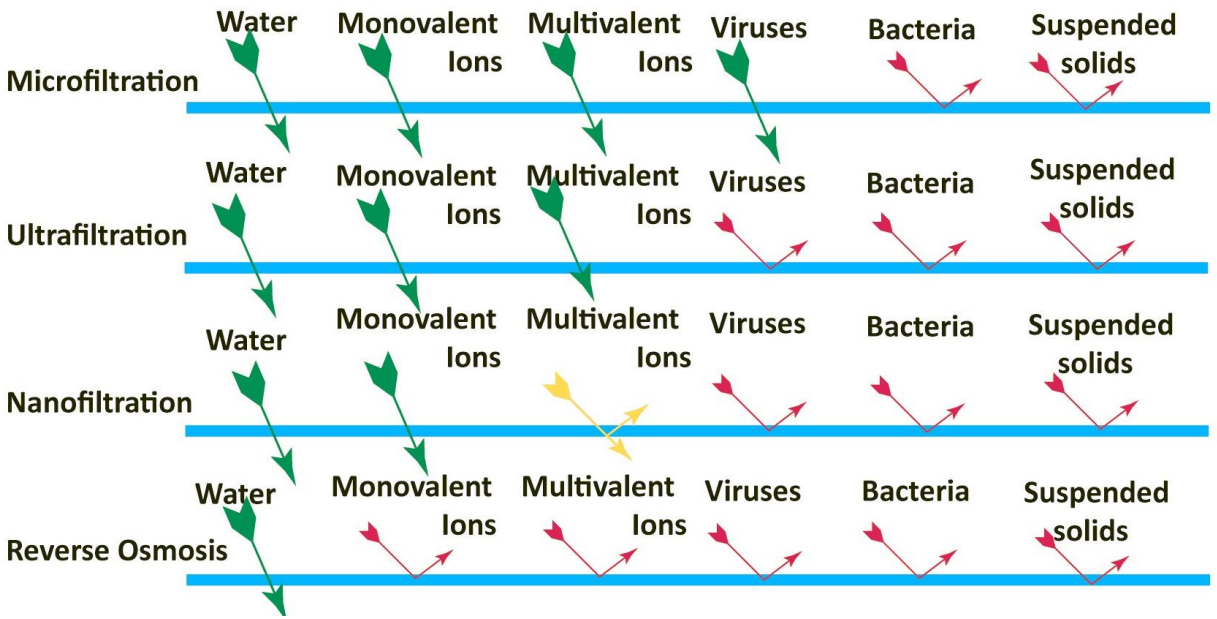


Membranes work by creating a physical separation

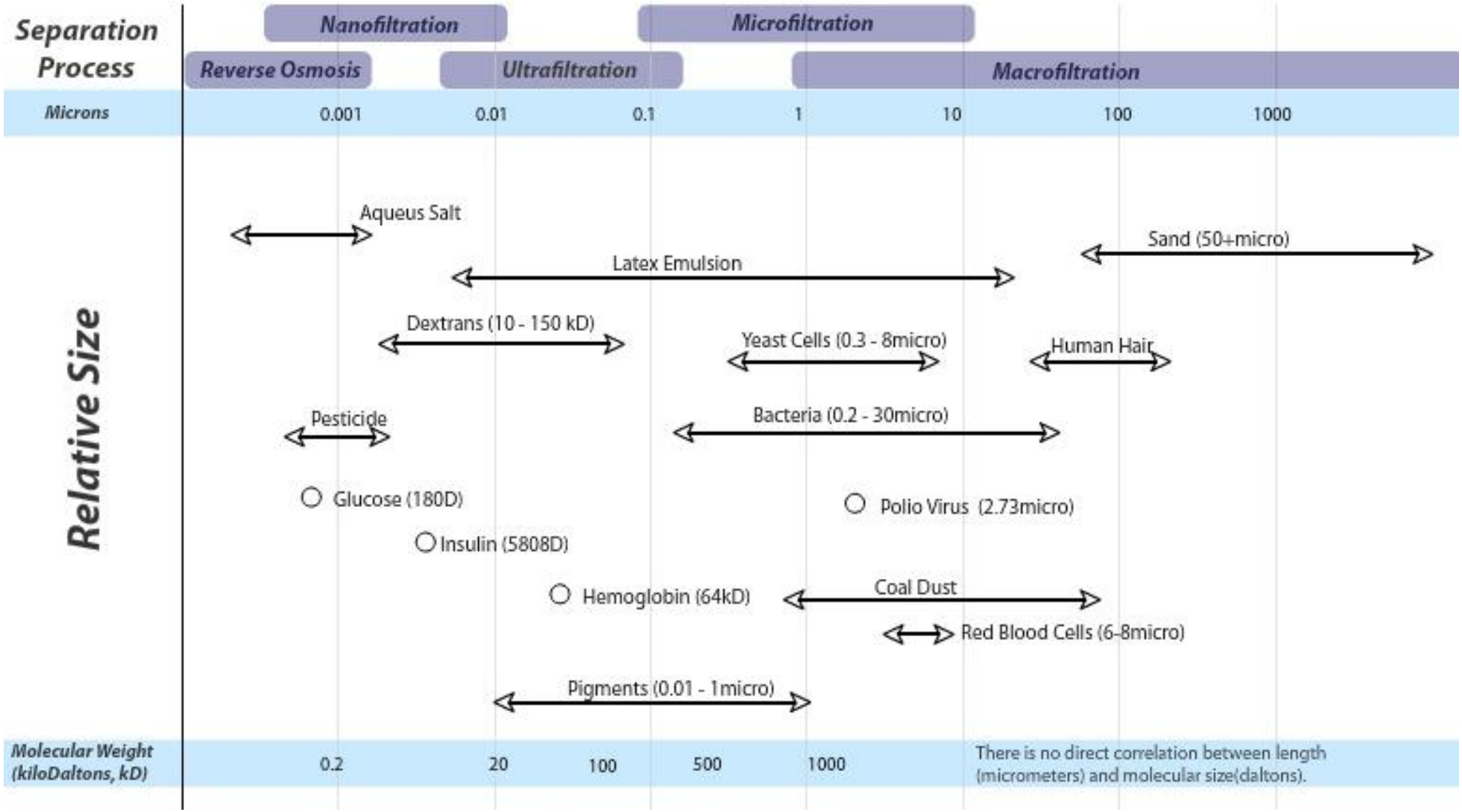
MEMBRANE PROCESSES

Generally, there are four common types of membrane processes:

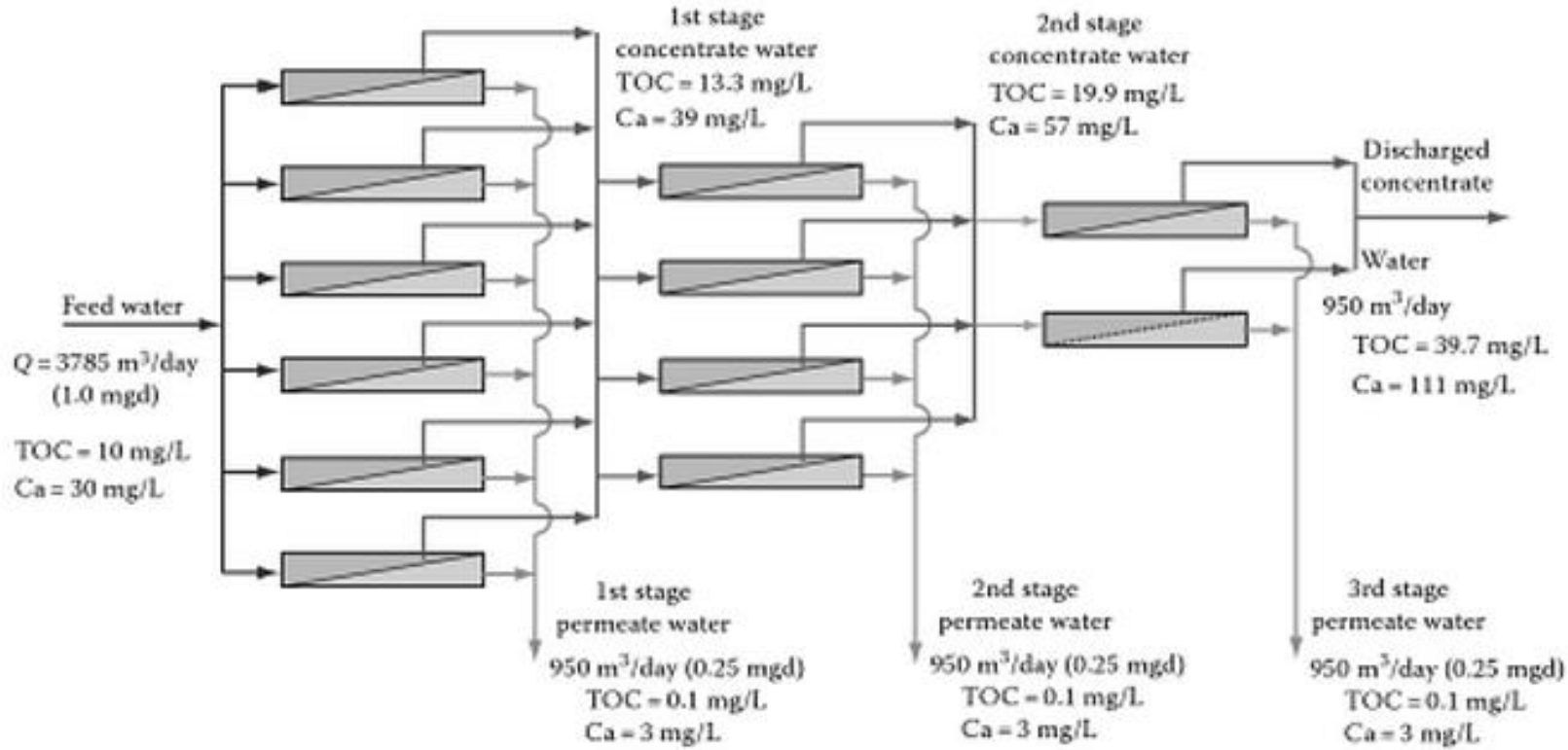
- **Microfiltration**
  - Particle exclusion (> 0.1 µm)
- **Ultrafiltration**
  - Macro-molecule exclusion MW between 2 kDa – 500 kDa
- **Nanofiltration**
  - Molecule exclusion (MW between 200 Da and 2 kDa)
  - Some multivalent ion exclusion
- **Reverse Osmosis**
  - Ion exclusion (monovalent ions)



RELATIVE FILTRATION SPECTRUM



“TREE” LAYOUT OF MEMBRANE FILTRATION



Typical System Recoveries for Different Membrane Types

Membrane Type	System Recovery (Fraction)
Reverse osmosis	0.20–0.80
Nanofiltration	0.60–0.90
Ultrafiltration	0.80–0.95+
Microfiltration	0.80–0.95+

Source: David Hendricks, Fundamentals of Water Treatment Unit Processes, IWA Publishing, 2013.

MANITOBA GROUNDWATER

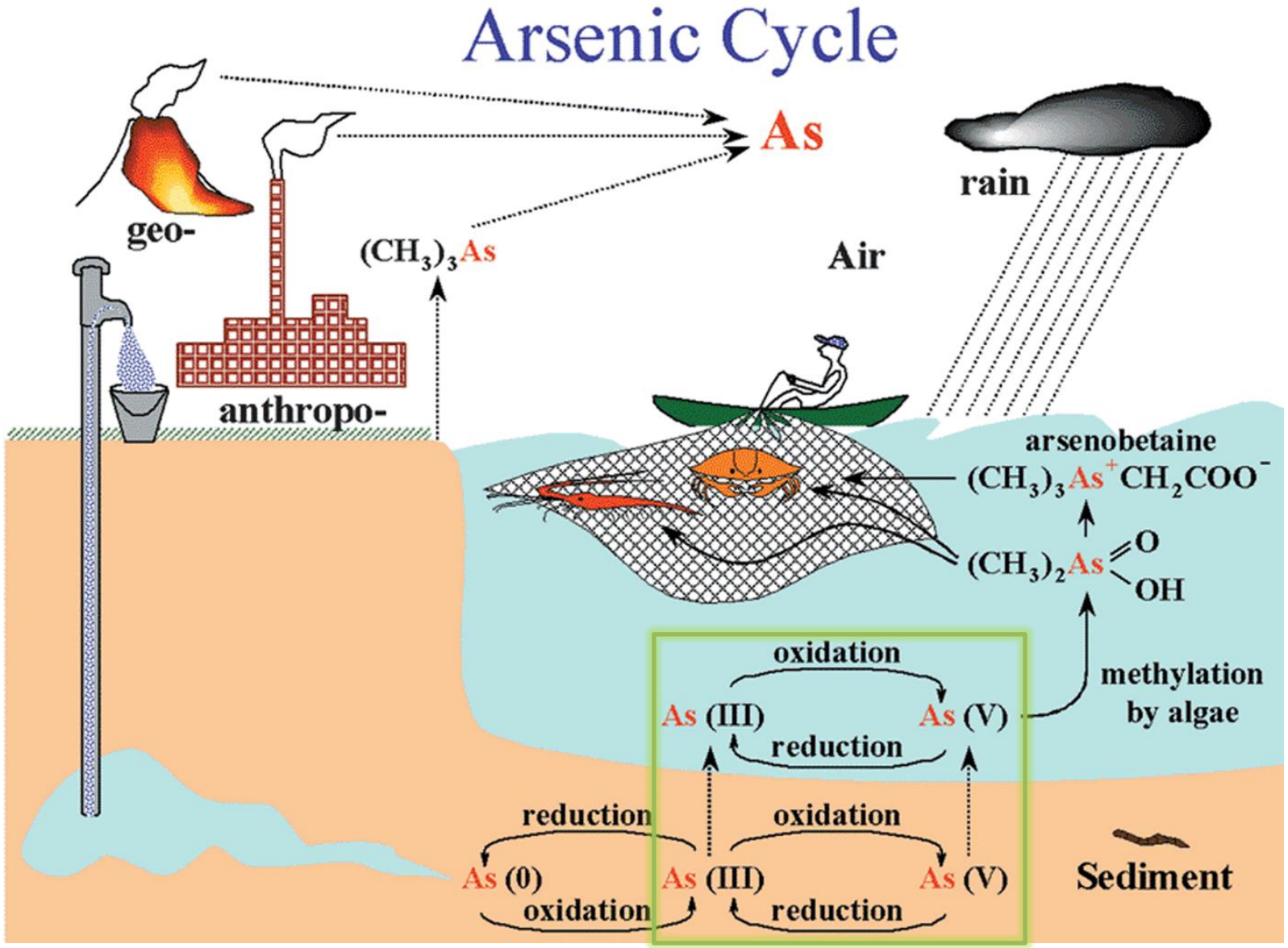
- Groundwater throughout the Province is typically good, however it is influenced by both natural and anthropogenic sources.
  - Erosion and weathering of soils, minerals, etc., mining, industries, etc.
- Arsenic is found in different parts of the Province, and even in different parts of the same aquifer.
- Classified as human carcinogen
  - GCDWQ MAC based on treatment achievability
  - Manitoba Drinking Water Quality Standards Regulation
  - **MAX 0.01 mg/L (10 µg/L)**

ARSENIC AND IT'S MOBILITY

IN GROUNDWATER

- Theories of arsenic mobilization:
  - Oxidation of As-bearing sulfides
  - Desorption of As from oxides and hydroxides
  - Release from geothermal waters
  - Leaching of As from sulfides by carbonate
- Source identification is difficult.
- Substantial verification is needed to distinguish mechanisms which release arsenic.

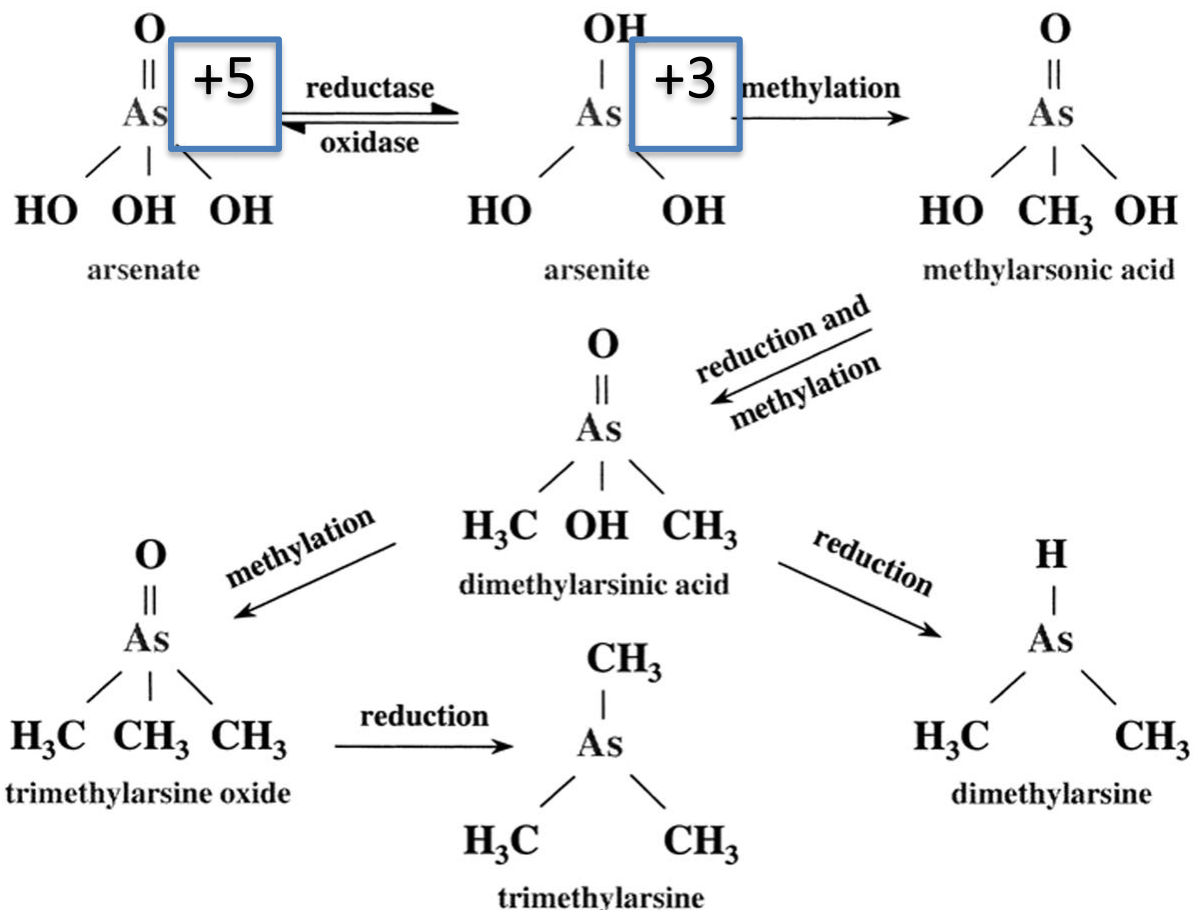
ARSENIC CYCLE



Source: Microbial arsenic: from geocycles to genes and enzymes Rita Mukhopadhyay, Barry P. Rosen, Le T. Phung, Simon Silver FEMS Microbiology Reviews Aug 2002

ARSENIC AND IT'S MOBILITY

- There are both organic and inorganic forms of arsenic found in nature.
- Arsenic is present in a number of different forms and oxidation states (-3, 0, +3, +5)



- In aqueous environments, dissolved arsenic is normally found as part of oxyanions in either arsenate (+5) or arsenite (+3) form.

ARSENIC AND MEMBRANE REMOVAL

- As anions, As(III) and As(V) are soluble and cannot be removed as ions by a MF or UF membrane. These forms are much smaller than the typical pore sizes associated with these membranes.

- As As_2O_3, As(III) has no net charge and thus is more difficult for membrane removal
  - Often design to oxidize As(III) to As(V) for membrane removal.
  - As(V) has a net charge, facilitating removal.

- Alternative is to coagulate prior to MF
  - Depends on design, scale, budget, blending, etc.

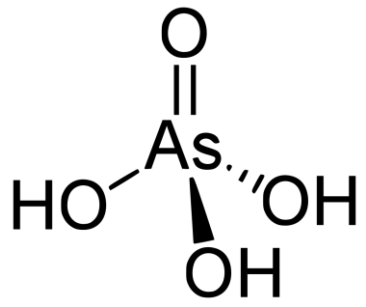
MEMBRANE ARSENIC REMOVAL

Design Factors To Consider

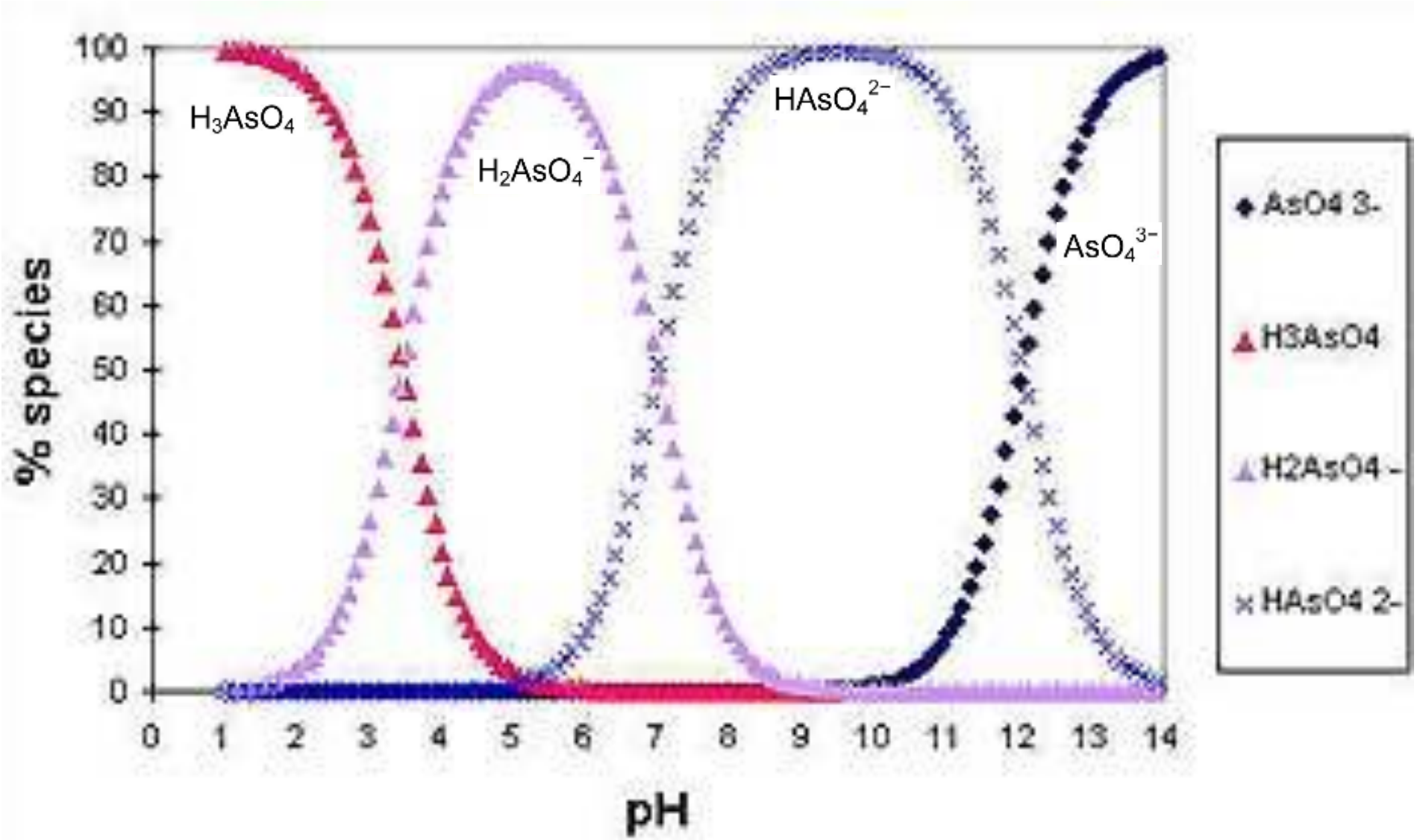
Water Chemistry
- pH
- As concentration
- As speciation
- Ionic strength
- Co-solutes

Physical Parameters
- Pressure
- Temperature
- Flow rate
- Recovery

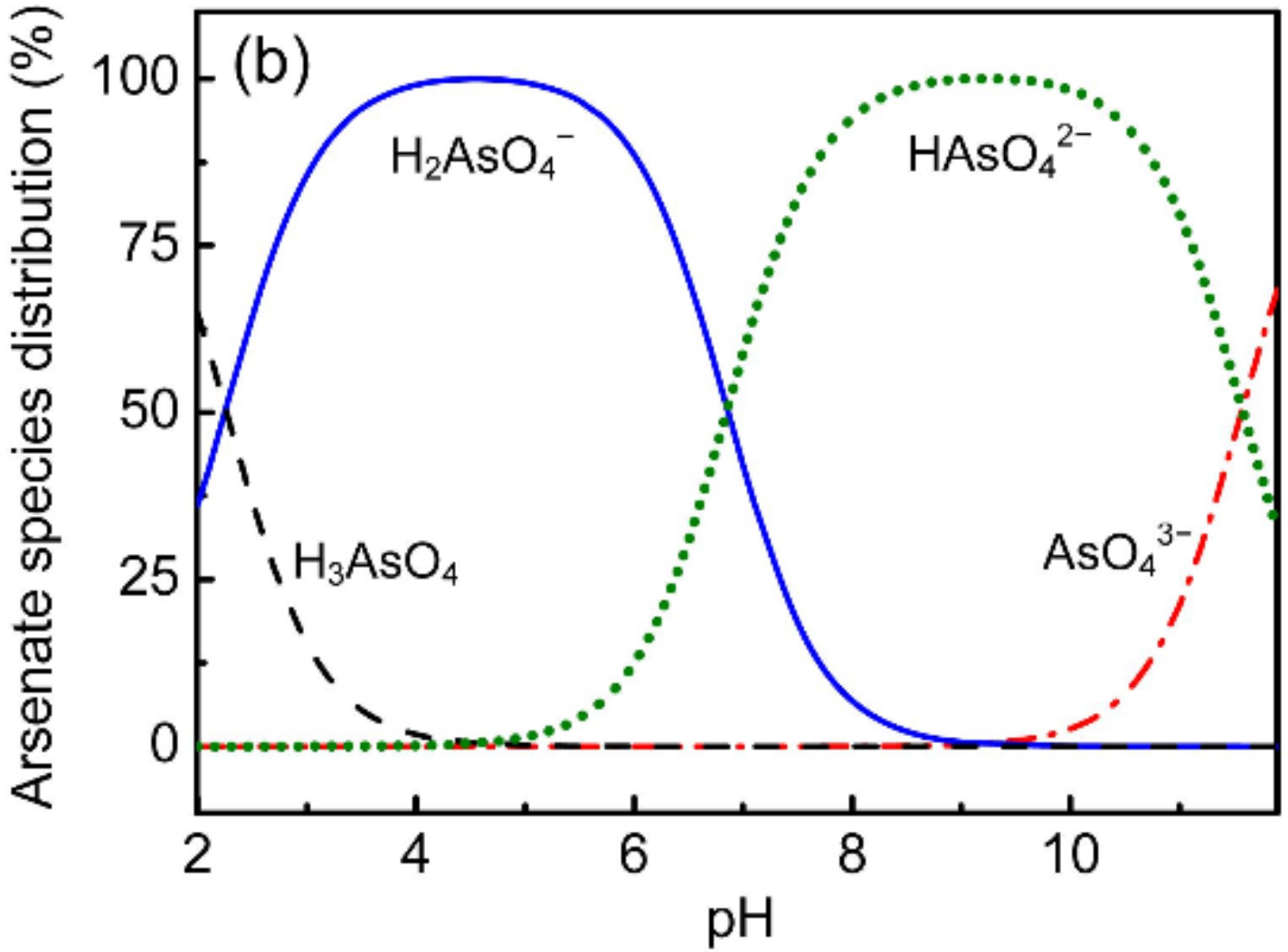
Membrane Characteristics
- MWCO
- Membrane surface charge
- Salt separation ability
- Hydrophobicity
- Fouling



Arsenic acid



http://www.jzus.zju.edu.cn/iparticle.php?doi=10.1631/jzus.A1400133



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