



Water Treatment and Chemical Safety/Security Seminar

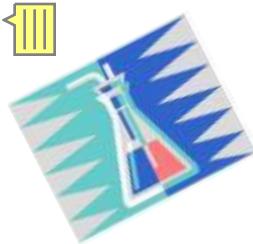
Baghdad, Iraq
6-7 April 2009



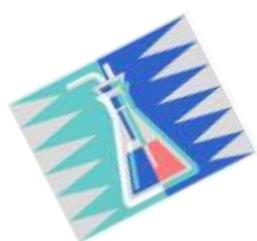
SAND No. 2009-????P

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.





Fundamentals of Chemical Laboratory Safety

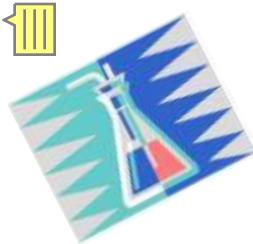


References



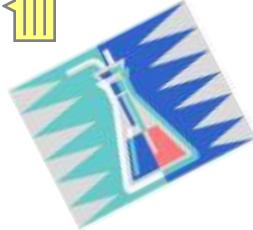
“Safety in Academic Laboratories, Vol.1 & 2,”
American Chemical Society, Washington DC, 2003,
handouts and available online:
<http://membership.acs.org/c/ccs/publications.htm>

“Prudent Practices in the Laboratory: Handling and Disposal of Chemicals,” National Academy Press, 1995, available online:
http://www.nap.edu/catalog.php?record_id=4911



Why worry about chemical safety and security?

- **Health and safety of people and environment**
- **Community relationships**
- **Reduce chance of accidental chemical release**
- **Avoid loss and damage to labs and equipment**
- **Prevent criminals and terrorists from getting dangerous chemicals**
 - **Wide variety of chemicals have been used**
 - **Wide variety of motivations for actions**
- **A deliberate attack on a chemical facility could release a large amount of hazardous chemicals**
 - **Injure or kill people in nearby areas**
 - **Eliminate jobs and economic assets**

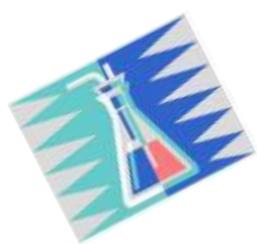


Bhopal: Pesticide plant chemical release

- One of the greatest chemical disasters in history, December 1984
- Union Carbide plant making Sevin released ~40 tonnes of methyl isocyanate in the middle of the night
- Low local demand for pesticides meant the plant was only partially running
- Some hardware was broken or turned off, including safety equipment
 - Safety measures and equipment far below US standards
- Plant in heavily populated area
- At least 3800 immediate deaths, 500,000 people exposed
 - 15,000-20,000 premature deaths since
- Large area contaminated
- Many issues still not resolved



* “The Bhopal disaster and its aftermath: a review”, Edward Broughton, *Environmental Health: A Global Access Science Source* 2005, 4:6, <http://www.ehjournal.net/content/4/1/6>, accessed 12/07



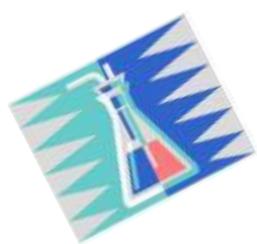
Chemical Laboratory Safety

Hazard---the potential to harm

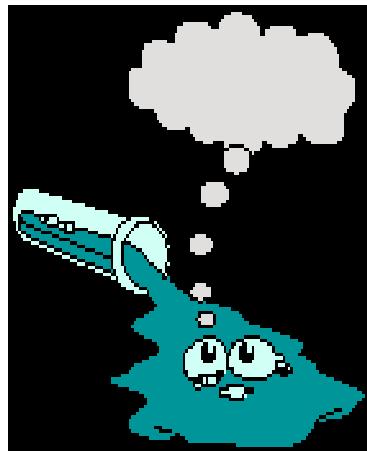


We want to avoid this.

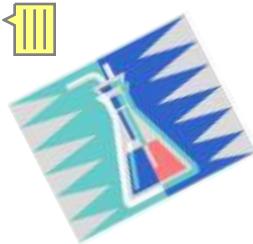
Risk---the probability that harm will result



Chemical Laboratory Hazards



- **Chemical hazards**
dusts, fumes, mists, vapors, gases
- **Physical hazards**
fire, electrical, radiation, pressure vibration, temperatures, noise,
- **Ergonomic hazards**
repetitive motion (pipetting), lifting, work areas (computers, instruments)
- **Biological hazards**
pathogens, blood or body fluids

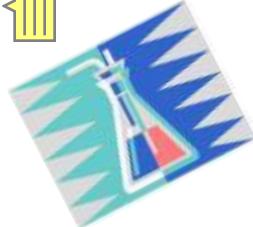


Chemical Laboratory Safety

Based on Industrial Hygiene Principles

- **Anticipation**
- **Recognition**
- **Evaluation**
- **Control**

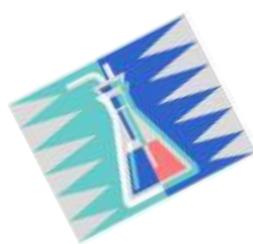
chemical hazards
physical hazards
ergonomic hazards
biological hazards



Anticipation

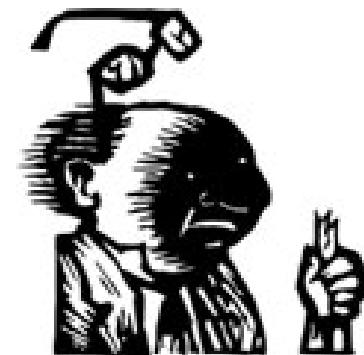
- **Plan Experiment in Advance**
 - Outline proposed experiment
 - What chemicals? How much?
 - What equipment?
 - Acquire safety information
 - MSDS (Material Safety Data Sheet)
 - REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals)
 - ICSCs (International Chemical Safety Cards)
 - Reference textbooks
 - Consult with Safety Office?

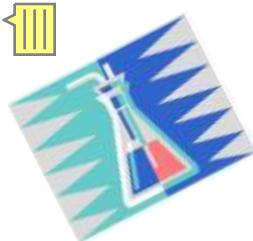




Recognition & Evaluation

- **What are the anticipated risks?**
 - Are the equipment & facilities adequate?
 - Is special equipment needed?
 - Are staff properly and sufficiently trained?
 - Who will do the experiment?
 - What kind of training do they need?
 - Can the experiment go wrong?
 - What would go wrong?
 - Is there a plan for this?



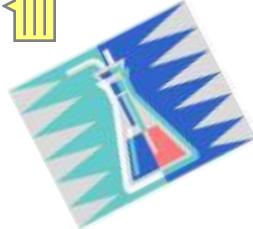


Control

- How are the risks controlled?



- Administrative controls
- Engineering controls
 - enclosure / isolation
 - ventilation / hoods
- Personal Protective Equipment (PPE)
- Emergency Plan



Recognition

Types of lab hazards

Chemical toxicity

Fire / explosion

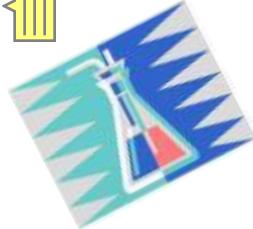
Physical hazards

Biohazards

Radiation

Special substances





Chemical Toxicity

Acute (short term, poisons, asthmagens)

cyanide

Strychnine

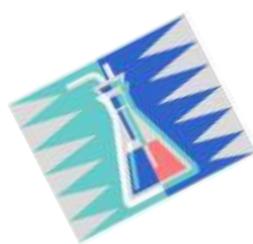
Chronic (long term, carcinogens, reproductive)

vinyl chloride (liver cancer)

asbestos (mesothelioma, lung cancer)

thalidomide (developmental birth defects)





Chemical Toxicity

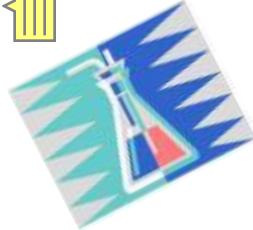
- **Toxicity depends on**
 - concentration (dose)
 - frequency
 - duration
 - route of exposure



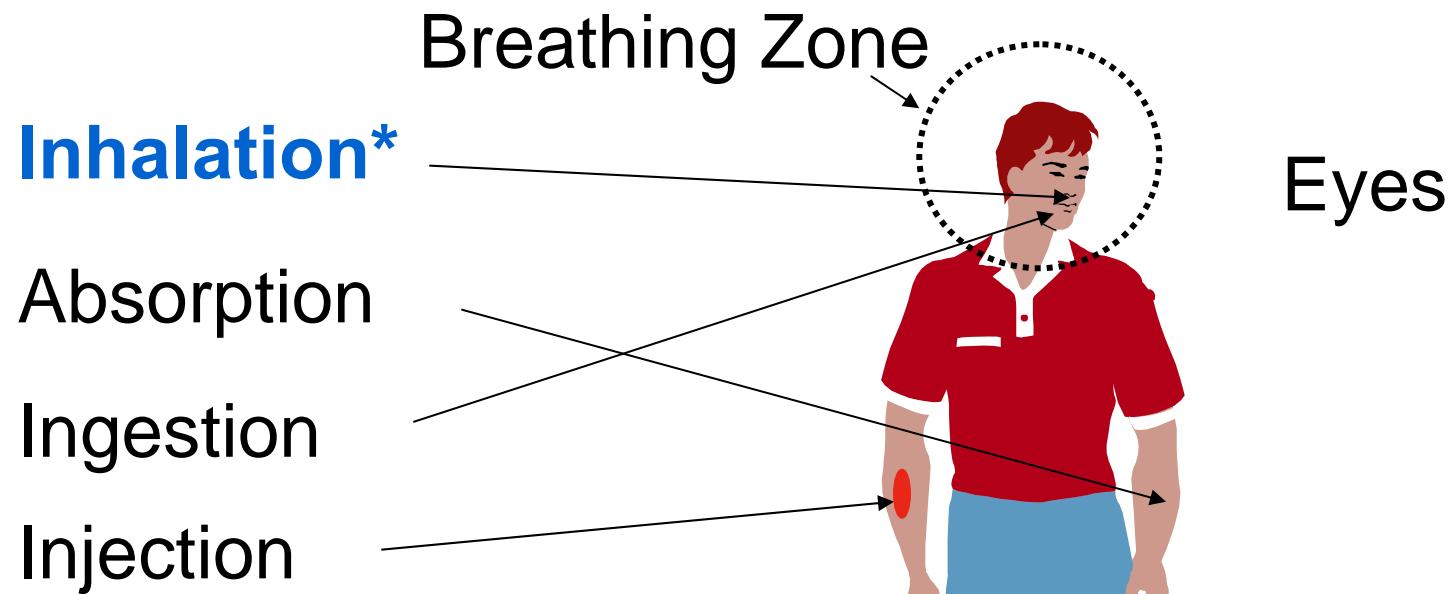
**“Dose makes the poison.
All substances have the
potential to harm.”**
Paracelsus ~1500 AD



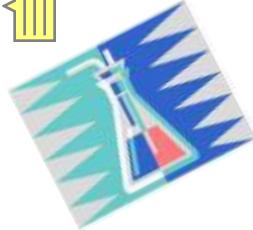
**300 mg aspirin = safe
3000 mg aspirin = toxic**



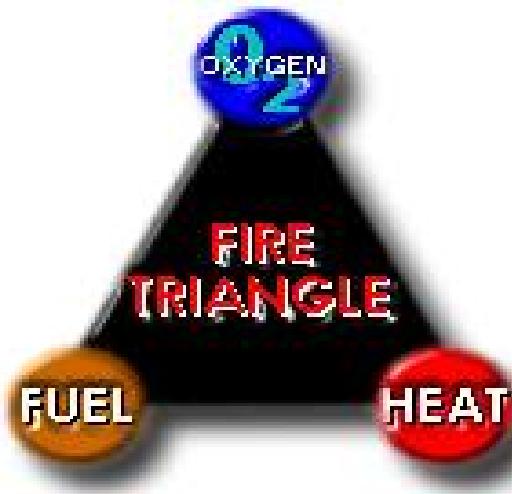
Routes of Exposure



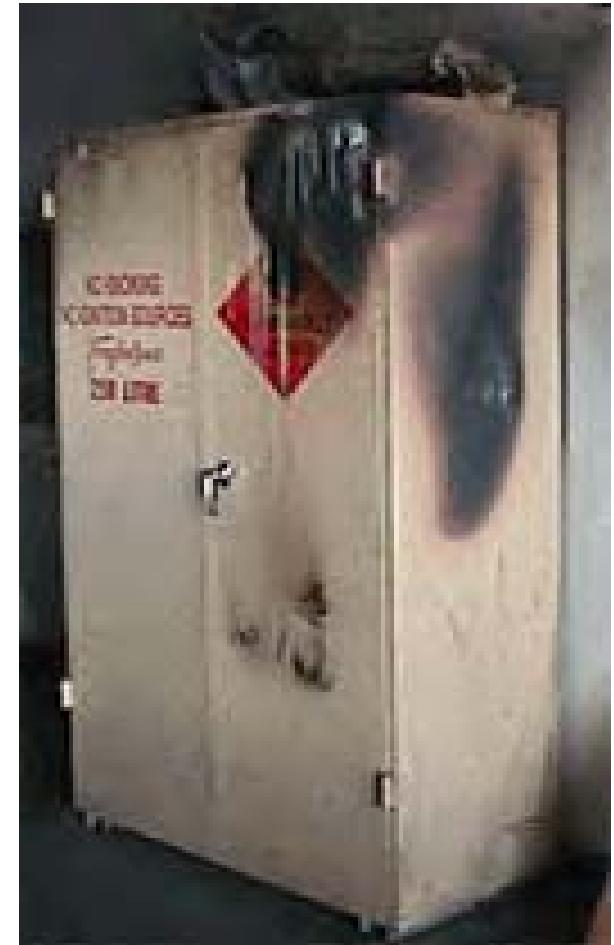
***Most important
route of entry**

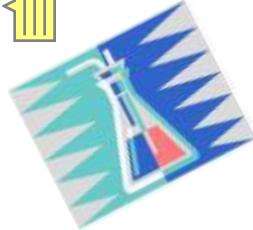


Fire and Explosion Hazards



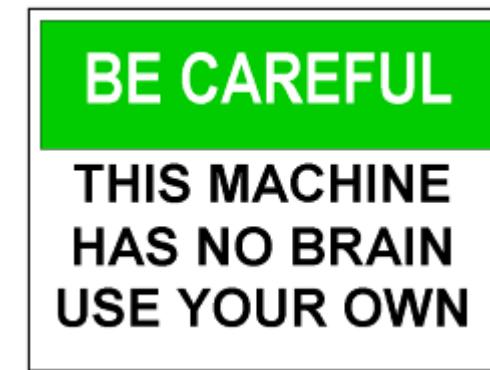
- Flammable solvents
- Pyrophorics
- Spontaneous combustion





Physical and Ergonomic Hazards

- Moving unguarded parts, pinches
 - vacuum pump belts
- **Broken glassware and sharps, cuts**
- Pressure apparatus
- Vacuum containers
- Dewar flasks
- Cryogenics
- High voltage equipment
- Computer workstations
- **Slips, trips & falls**





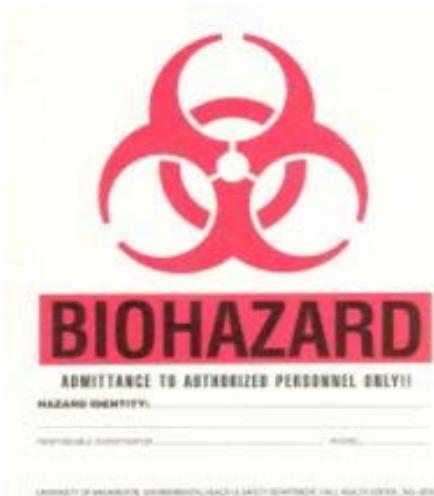
BioHazards

Blood borne pathogens

AIDS, HIV, Hepatitis, clinical chemistry labs

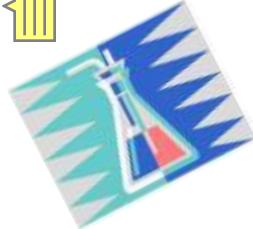
Recombinant DNA

Genetic engineering, cloning

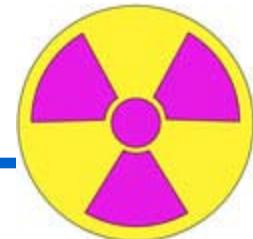


Work with animals

Zoonosis, diseases from animals



Radiation Hazards



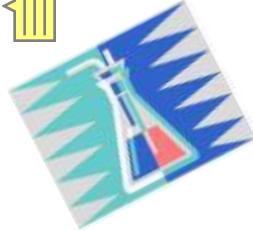
- **Ionizing Radiation**

alpha α , beta β , gamma γ , X-rays, neutrons

- **Radioactive isotopes**

tritium (H-3), carbon (C-14), sulfur (S-35),
phosphorus (P-32/33), iodine (I-135)





Radiation Hazards



Non-Ionizing Radiation

Ultraviolet (UV spectrometers)

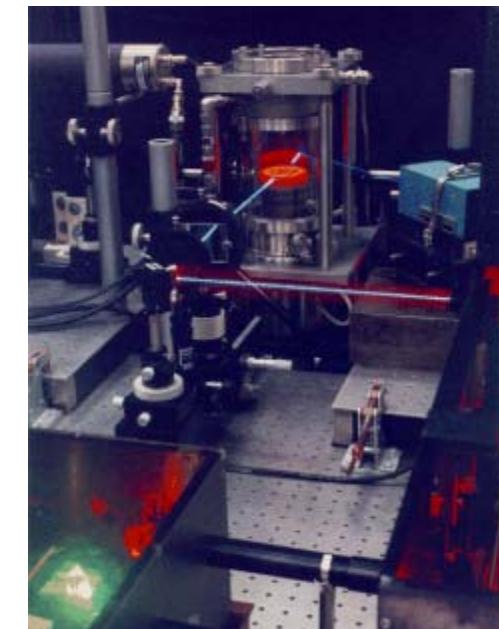
Magnetic (NMR, MRI)

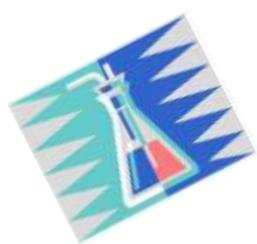
Microwave

(Heart pacemaker hazard)

Lasers

(eye protection required)





Special Chemical Substances

Controlled Substances

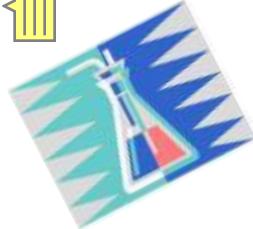
regulated drugs, psychotropic (hallucinogenic) substances, heroin



Chemical Surety (Warfare) Agents

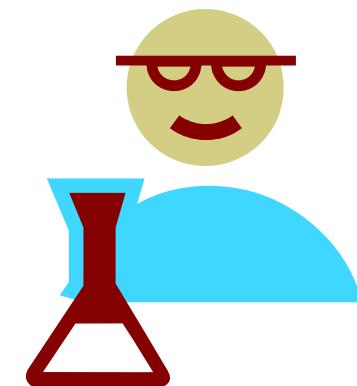
nerve gas, phosgene, riot control agents

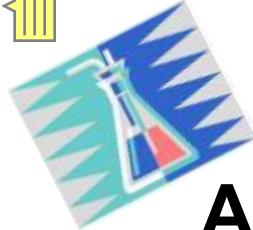




Evaluation & Control

- Administrative practices
organizational policies**
- Operational practices
work practices**
- Engineering controls
Hardware (ventilation,
barriers)**

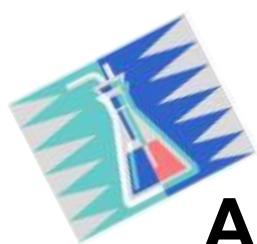




Administrative Practices: Lab Safety Policies

- ❖ **Have organizational safety practices**
 - **Apply to everybody**
 - **Don't work alone after hours**
 - **Specify when eye protection & PPE is required**
 - **Specify operations that require hood use**
 - **Specify required training**
 - **No mouth pipetting**
 - **No loose long hair or dangling attire**
- ❖ **Have a Safety Manual**

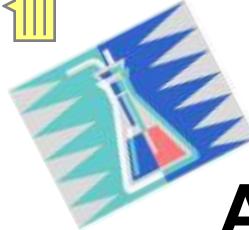




Administrative Practices: Lab Safety Policies

- No eating, drinking or smoking in laboratories
- Label all chemical containers
- Label refrigerators for chemicals
 - No Food
- Label explosion safe refrigerators
- Require periodic fire drills

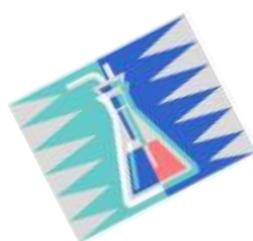




Administrative Practices: Lab Safety Policies

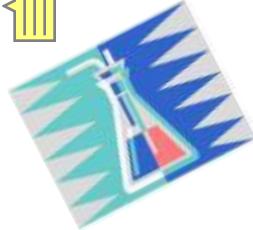
- Schedule routine, periodic maintenance and inspection of fume hoods
- Schedule routine, periodic maintenance of safety showers and eye wash stations
- Schedule routine, periodic maintenance of fire suppression/fighting equipment
- Post restricted areas with proper signs
 - radiation, biosafety, carcinogen, high voltage, lasers, authorized personnel only, etc.





Operational Practices: Safe Chemical Handling Procedures

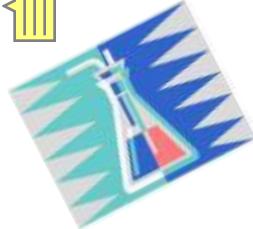
- **Packages opened only in labs, not in receiving area**
- **Receiving staff trained to look for signs of breakage or leaking shipments**
- **Receiving area has spill kits**
- **Mailroom alert for suspicious shipments**



Operational Practices: Safe Laboratory Procedures

- Schedule routine maintenance, calibration and inspection of all hoods, fire and safety equipment
- Schedule and participate in routine fire drills
- Train personnel in emergency response
- Wear PPE properly, don't just have it

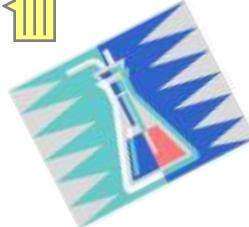




Operational Practices: Safe Laboratory Procedures



- **Use hoods properly**
 - 6" in from sash
 - in center of hood
 - work with hood sash at 12-18"
 - close sash when not in use
 - don't use for storage



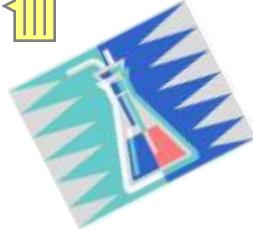
Operational Practices: Safe Laboratory Procedures

❖ Safely transport chemicals



- use container in a container concept
 - label all containers
 - inform driver of hazards
- provide contact names, phone numbers
 - provide MSDS





Operational Practices: Transfer Chemicals Properly

- Some flammable liquids accumulate a static electric charge
 - This can release a spark that ignites the liquid
- Bond metal dispensing and receiving containers together before pouring such liquids

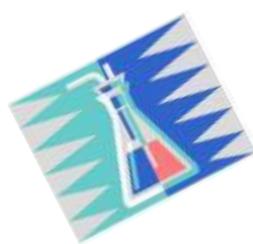


benzene

toluene

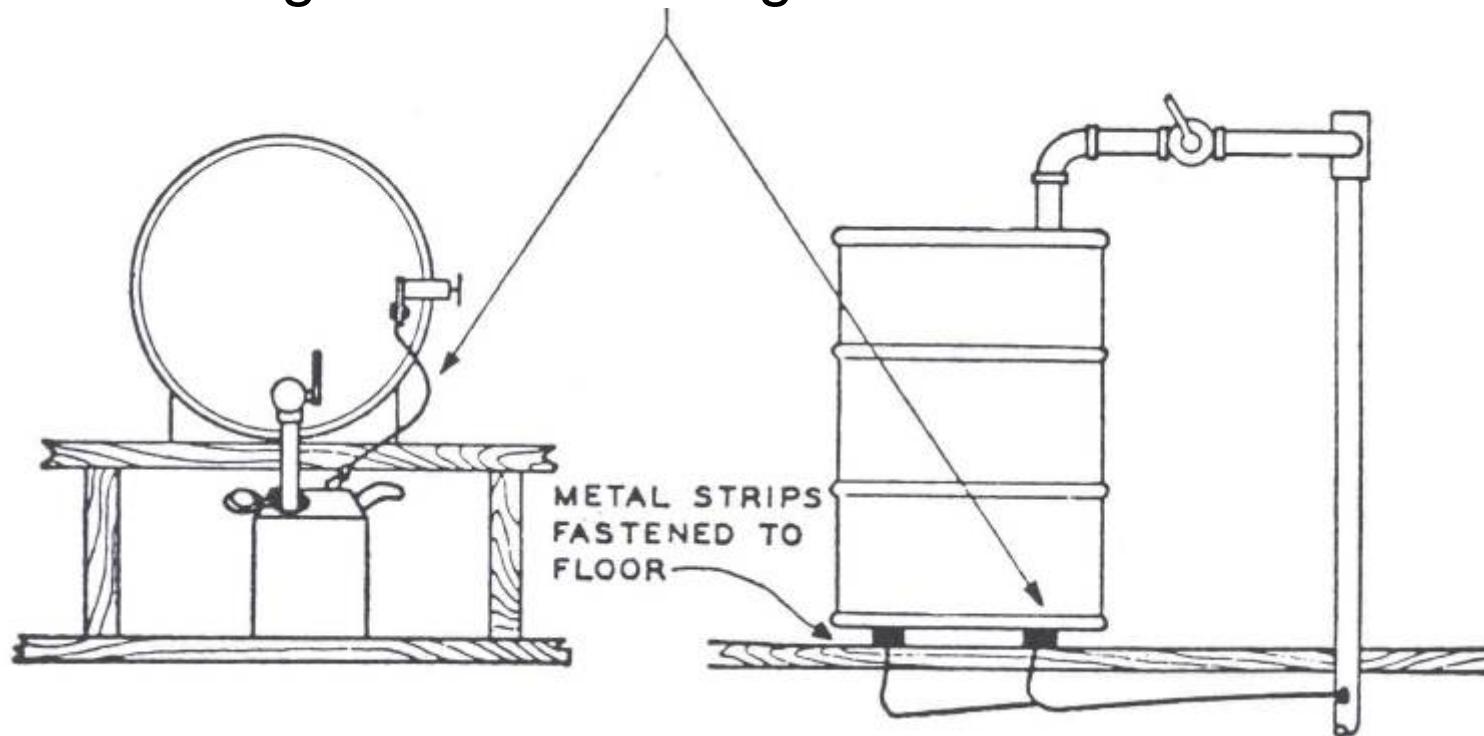
gasoline

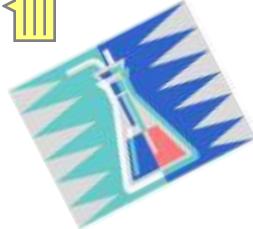
xylene



Operational Practices: Control of Static

Wire needed unless containers are already bonded together, or fill stem is always in metallic contact with receiving container during transfer



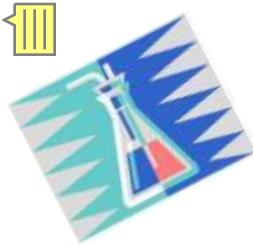


Operational Practices: Safe Laboratory Procedures



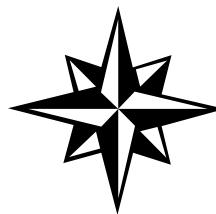
❖ Housekeeping

- label all containers
- clean-up spills
- eliminate trips hazards
- proper storage



Engineering Controls: Laboratory Containment Principles

Concept



Source



Path



Receiver



Control Used

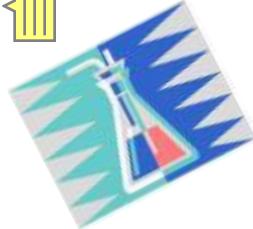
**Engineering
Control**



**Operational
Practices**



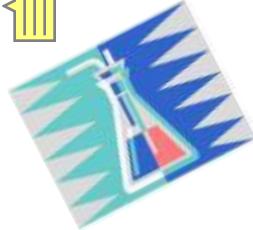
PPE



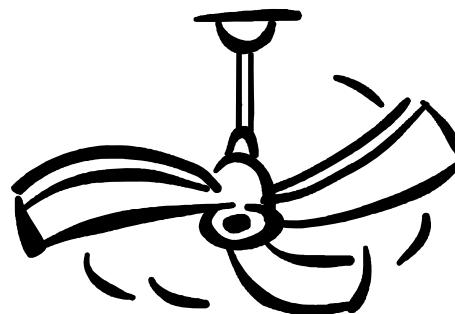
Engineering Controls

- 1. Change the process**
eliminate the hazard
- 2. Substitution**
Use non-hazardous substance instead of hazardous, such as toluene for benzene
- 3. Isolate or enclose the process or worker**
use a barrier
- 4. Ventilation**
dilution (general ventilation) - not good
local exhaust ventilation (LEV) - Preferred





Engineering Controls

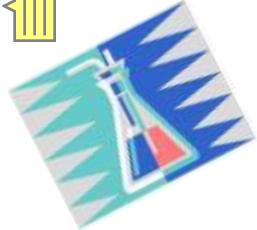


Dilution / general ventilation
not good

Local exhaust ventilation

Preferred



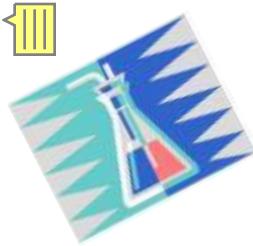


Engineering Controls

Laboratory hoods and ventilation are the basis of engineering controls.

But they must be properly: functioning, maintained and used!





Engineering Controls: Local exhaust

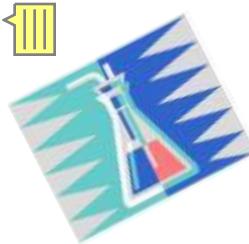
Local exhaust ventilation options include:

Snorkels



Vented enclosures





Engineering Controls: Local exhaust

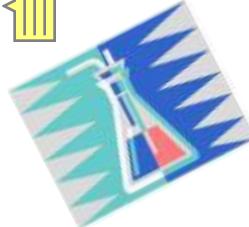
Local exhaust ventilation options include:

Glove boxes



Isolation chambers





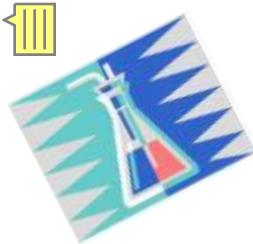
Engineering Controls: Local exhaust



- **Special barrier facilities:**
clean rooms, carcinogen rooms, weighing rooms



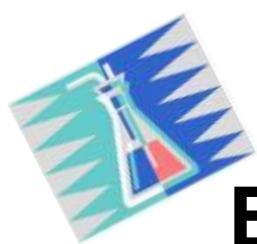
- **Safety shields:**
radiation shields, hood sashes, splash guards



Engineering Controls: Exhaust vents

Hood exhaust should not be blocked or deflected downward, but should exhaust straight up



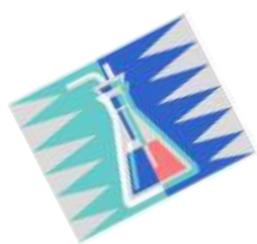


Engineering Controls: Exhaust vents

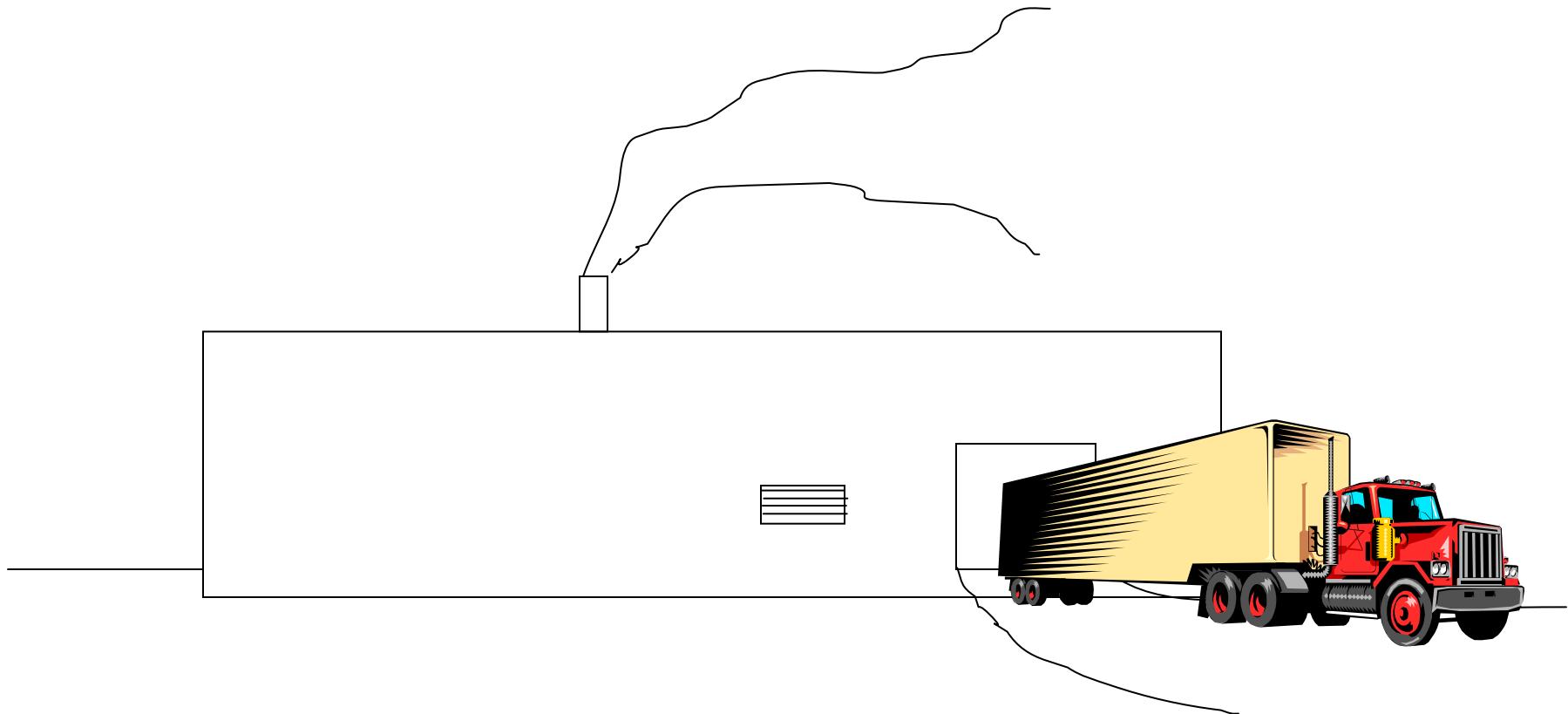


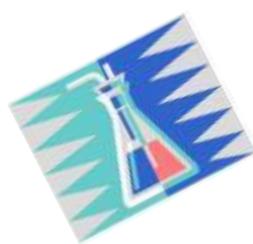
**Avoid exhaust
re-entrainment**

**Disperse
emissions
straight upward
and downwind!**

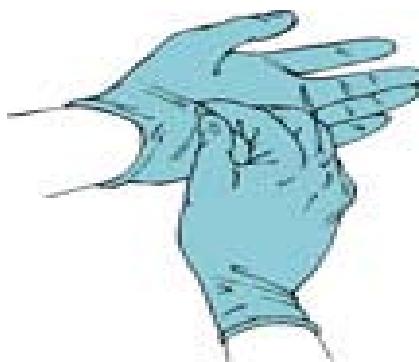


Engineering Controls: Avoid Exhaust Recirculation



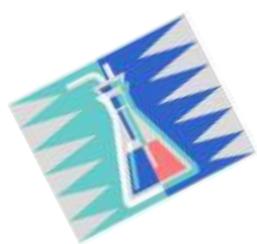


Engineering Controls: Personal Protective Equipment (PPE)

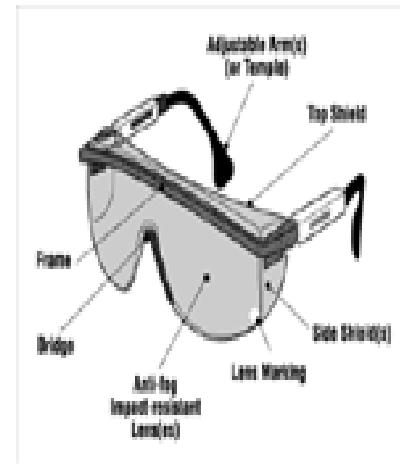


PPE includes:
eye protection,
gloves,
laboratory coats. etc.,
respirators,
appropriate foot protection





Engineering Controls: Personal Protective Equipment



**Eye protection
specific to the hazard**





Engineering Controls: Personal Protective Equipment



Gloves

must be chemical specific





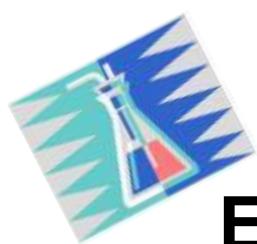
Engineering Controls: Personal Protective Equipment

- Laboratory coats

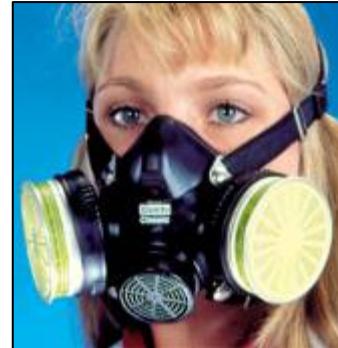
- aprons

- other protective clothing





Engineering Controls: Respiratory Protection



requires:
training
fit-testing

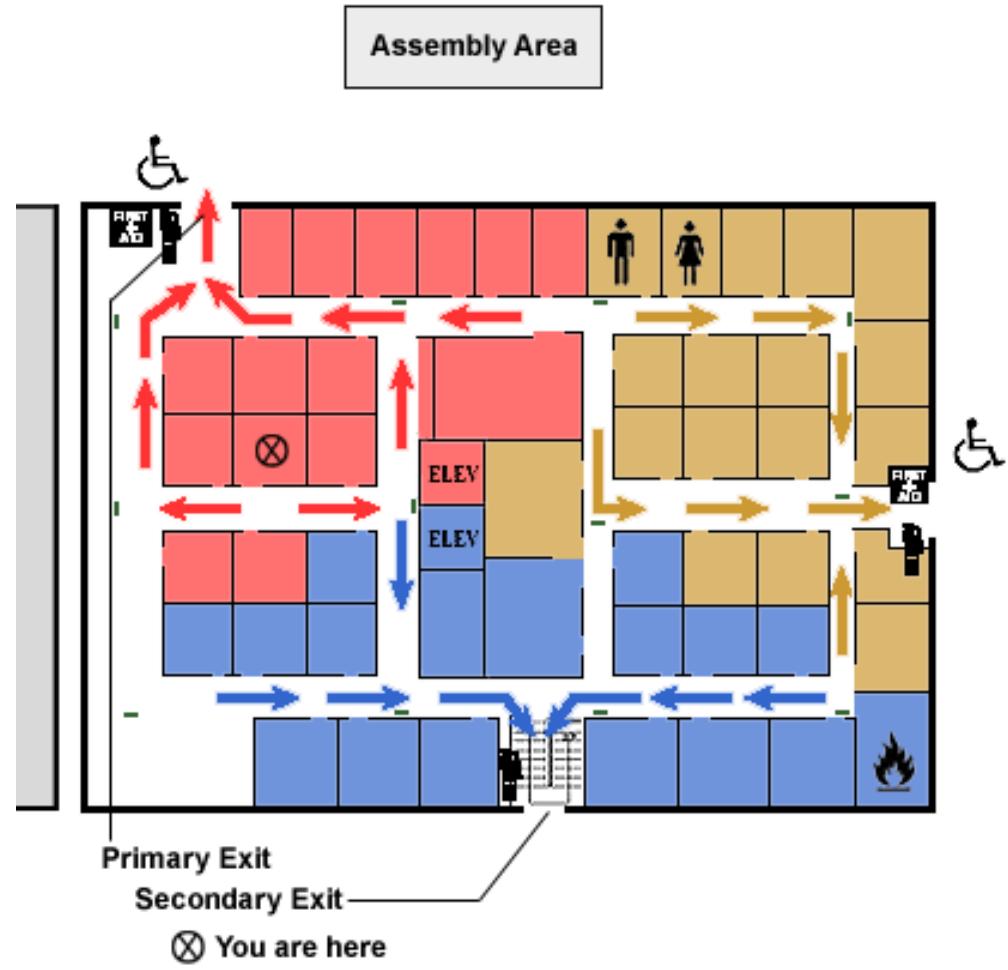
can provide a
false sense of
security





Emergency Planning & Response

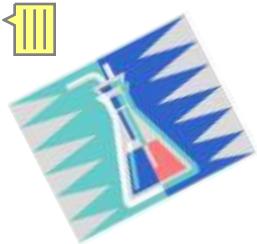
Have an
evacuation
plan
and
POST IT





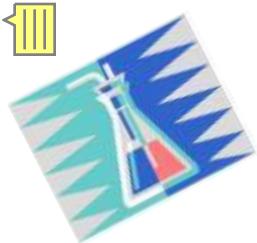
Lab Safety Activity:

What's Wrong With These Pictures?



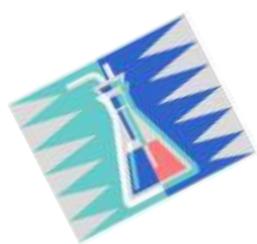
What's Wrong With This Picture?





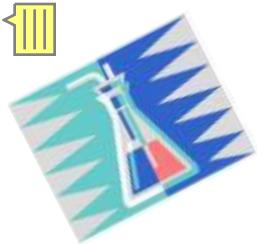
What's Wrong With This Picture?





What's Wrong With This Picture?





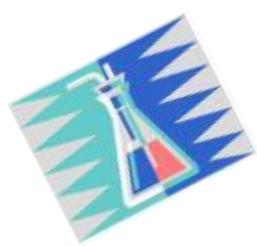
What's Wrong With This Picture?





What's Wrong With This Picture?





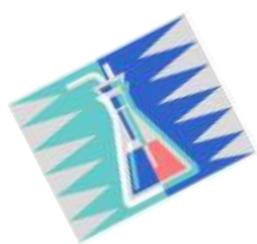
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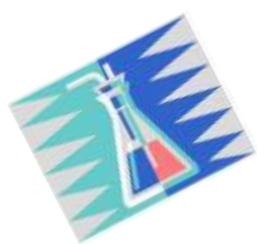
What's Wrong With This Picture?





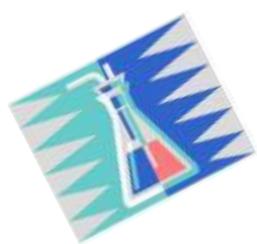
What's Wrong With This Picture?





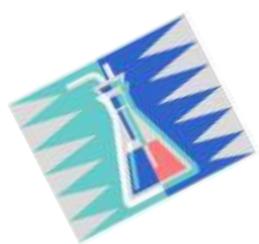
What's Wrong With This Picture?





What's Wrong With This Picture?





Break

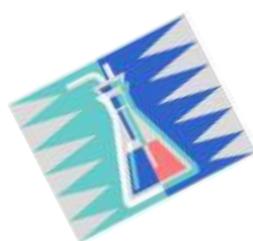


Fundamentals of Water Chemistry

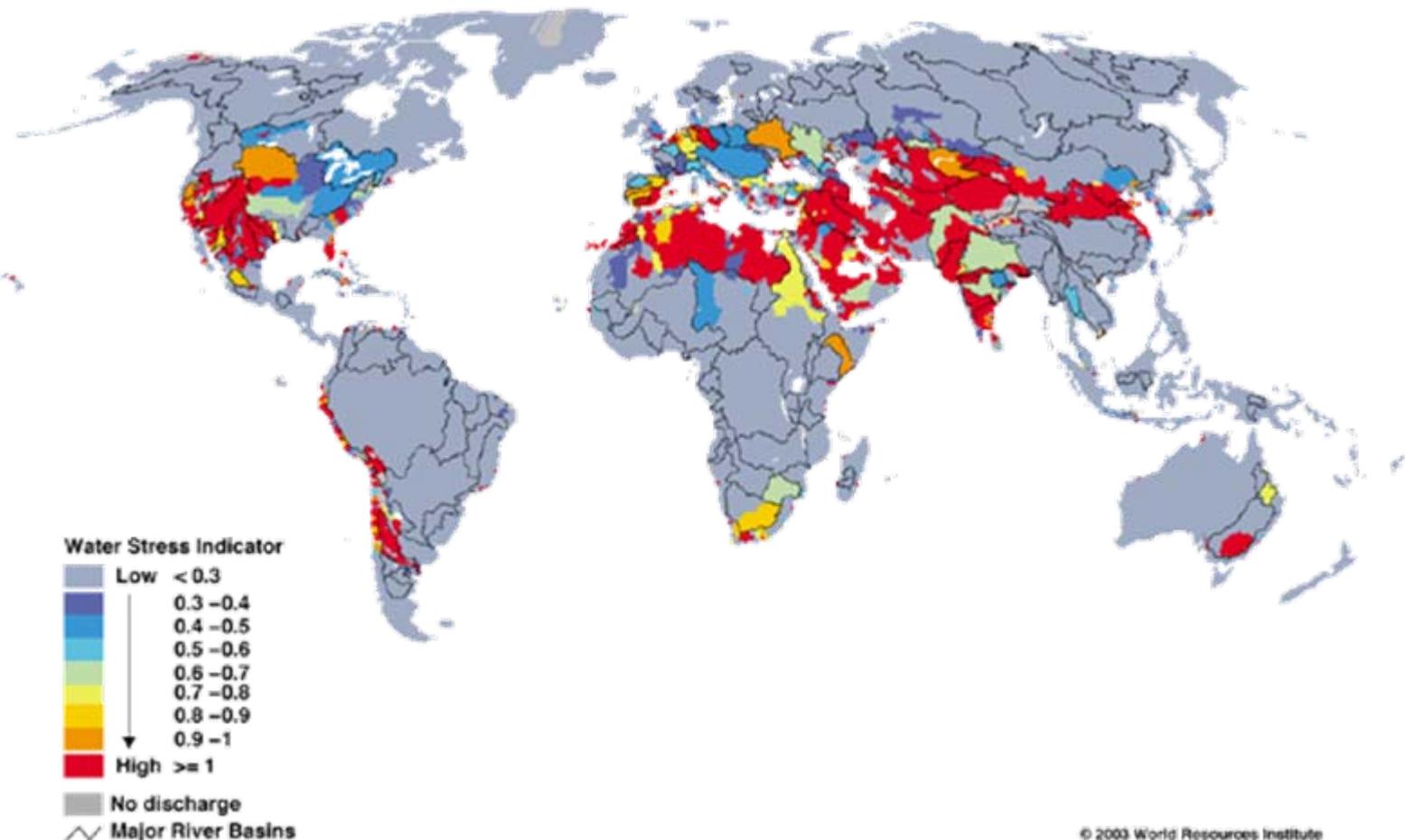


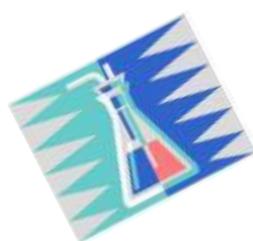
Fundamentals of Water Chemistry

- **Introduction – Water Scarcity and Purity**
- **Water laboratory – field and benchtop instruments**
- **Suspended solids in water (sediment, debris)**
- **Color, odor and taste**
- **Ions and dissolved substances (alkalinity, hardness, pH, dissolved organic matter, salinity, heavy metals)**
- **Organic contaminants (fuel hydrocarbons, pesticides, disinfection byproducts, personal care products, pharmaceuticals)**
- **Microbiological substances (Protists, bacteria, spores, virus)**
- **Disinfection**



Water stress – *river basins*





Water scarcity is a function of rainfall and population



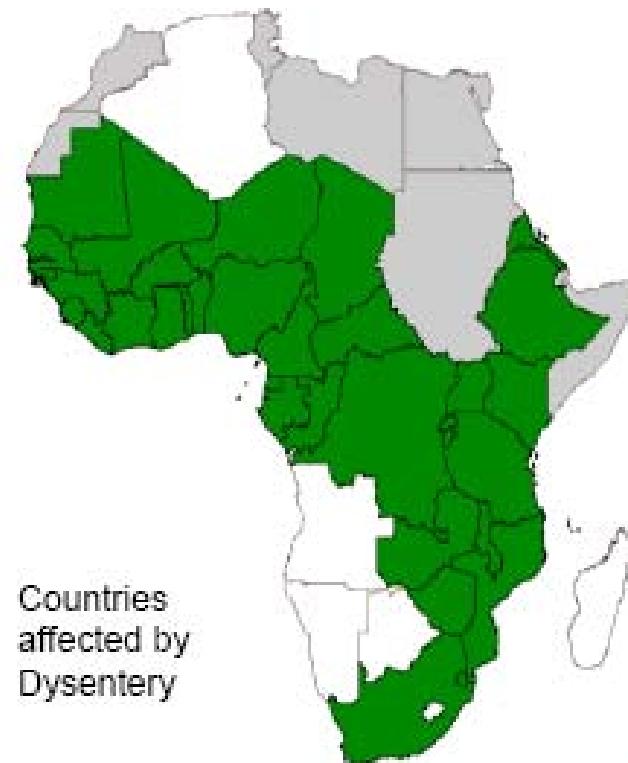
Source UNECA

Source: United Nations Economic Commission for Africa (UNECA), Addis Ababa; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999; Population Action International.

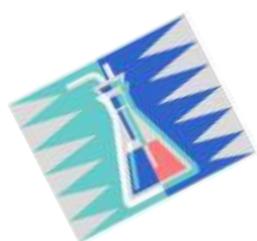


Water sanitation is an urgent problem

World: morbidity 2.5 billion, mortality 2.5 million



Source :WHO



Water treatment –large and small



Large water treatment plant – Erbil
Iraq completed July, 2006

Source: A Report on Reconstruction-Gulf Region
Division U.S. Army Corps of Engineers January
2004-September 2006



Small water treatment facility under
construction in Shamiyah, Iraq
Feb, 2009

Source: dvids
Photographer Senior Airman Eric Harris



A large village application-filtration / RO



New water filtration facility
in Kalamat Village March
9, 2009.

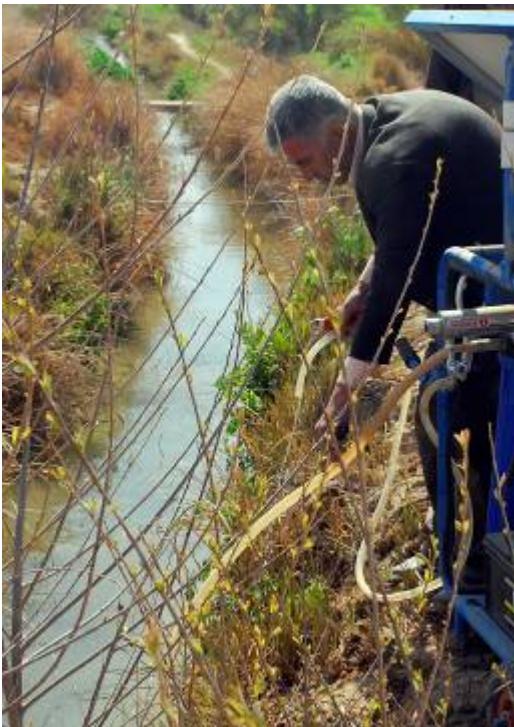


The new water filtration system in
Kalamat Village is designed to
purify 1,000 liters of water per hour

Source: dvids
Photographer Sgt. Joe Thompson

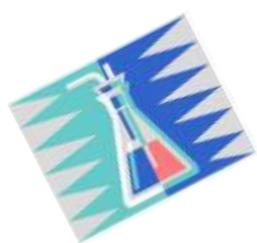


Very small solar powered filtration plant

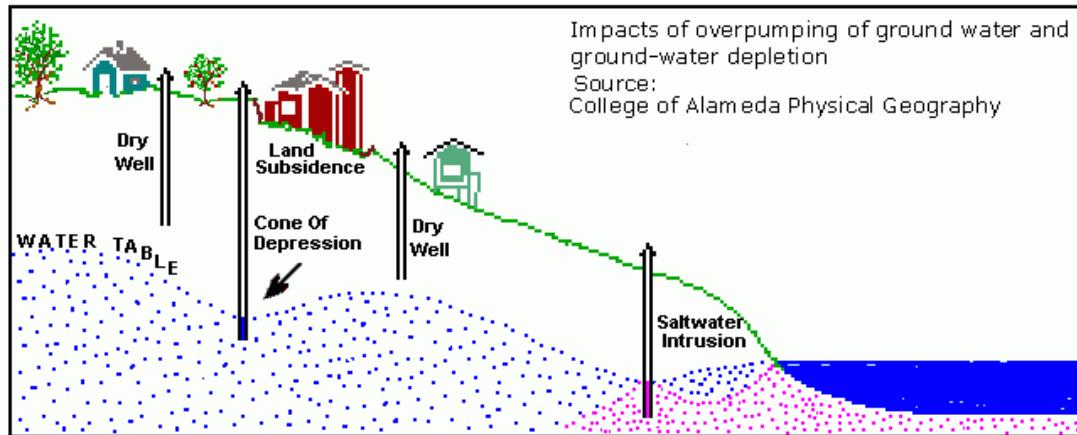


Example of a solar powered water treatment system for 150-200 villagers. Mahmudiyah Qada, Feb 2009

Source: dvids
Photographer Jamie Vernon



Groundwater depletion is a serious world-wide problem



California USA

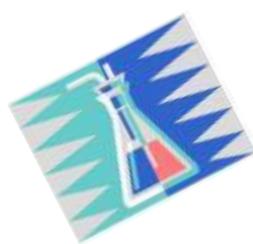


Groundwater depletion leads to:

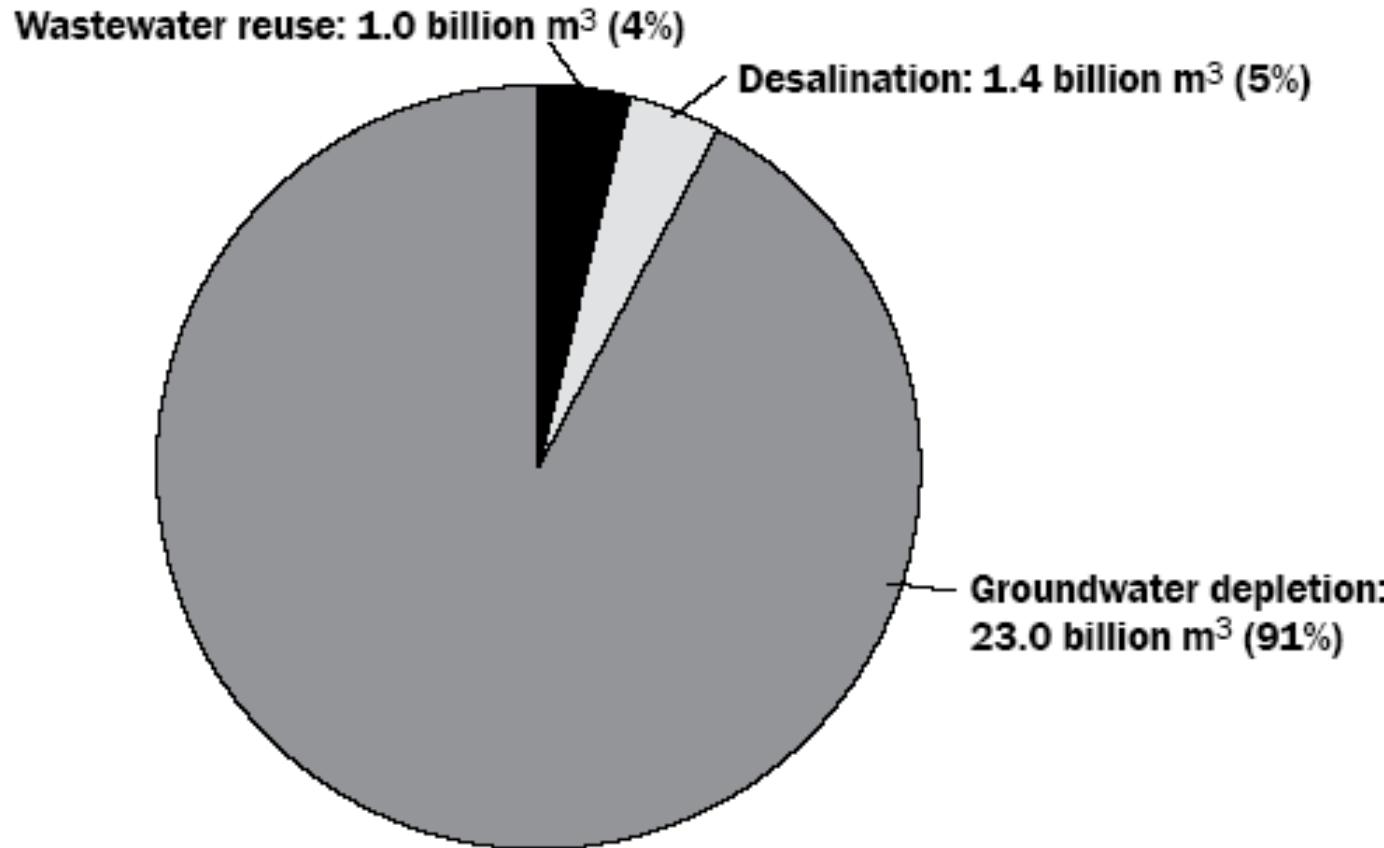
- **Dropping water table**
- **Soil salinization**
- **More energy for pumping**
- **Seawater intrusion**

Beijing and Jakarta are threatened by groundwater depletion

Source: USGS



Groundwater depletion in the Middle East and North Africa



Source: World Water Forum

Source: World Water Forum



Water laboratories can be furnished with lower cost equipment

Field Measurements – need on-site

Temperature (°C)

pH (1-14)

Dissolved oxygen (mg/L)

Benchtop Measurements -

Total suspended solids (mg/L)

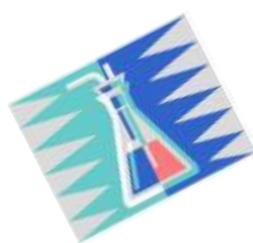
Total dissolved solids (mg/L)

Conductivity (siemens/cm)

Turbidity (nephelometric turbidity units)

Silica, iron, nitrates, nitrites, phosphate (mg/L)

Basic wet chemistry lab equipment



Portable instrumentation provides needed information



Temperature

pH

Dissolved Oxygen

Turbidity

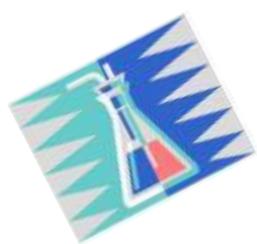
Conductivity

Alkalinity

Hardness

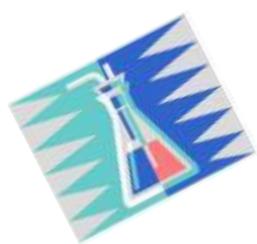


Example : Hach Co.



Sample preparation and storage important for accuracy and precision

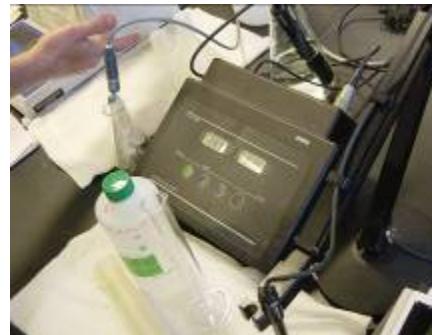




Benchtop instrumentation can be purchased for low price



**Portable
digital
titrator**



Conductivity

pH

Alkalinity
Hardness



Spectrometry

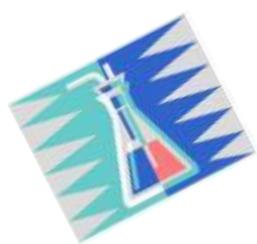
Iron

Silica

Total nitrogen



**Dissolved
Oxygen**



Suspended solids in water

Sediment

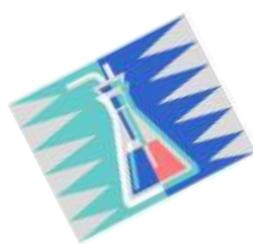
Soil - suspensions

Clay - colloidal

Organic matter

Plant Debris

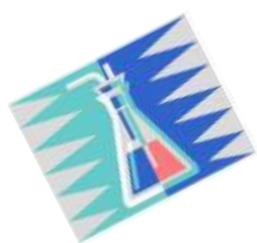
Animal Debris



Carbonate chemistry plays a large role in the water environment



- The calco-carbonic equilibrium allows water to come to equilibrium with the environment.
- This equilibrium provides a slight scaling potential to passivate distribution systems and slow corrosion.
- Water stability is measured by several types of indices
 - Langlier Saturation Index (LSI)
 - Ryznar Stability Index (RSI)



Color - common inorganic metals

Iron – Groundwater

Fe^{+2} in the ground (anaerobic) – Fe^{+3} in air - **red color**
(secondary standard = 0.3mg/L)



Removal – filtration or coagulation assisted filtration

Manganese - Groundwater

$\text{Mn} + \text{O}_2 \rightarrow \text{MnO}_2(\text{s})$ | air brown – black color
(secondary standard = 0.05mg/L)



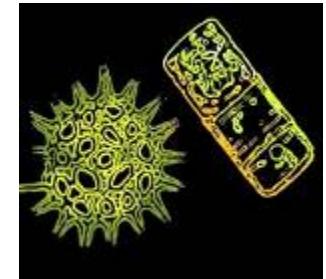
Precipitation onto filter media

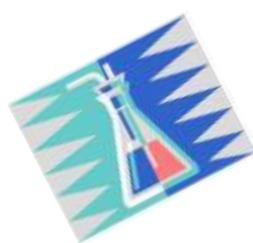


Odor and Taste - common causes

Surface water – lakes, ponds

- Algae – diatoms, blue-green, flagellates
- Actinomycetes – filamentous bacteria
 - Earthy moldy musty taste
 - Compounds – Geosmin and 2-methylisoborneol
 - Removal – coagulation, filtration, oxidation
- Disinfection byproducts
 - Produced by chlorination of natural organic matter (NOM – fulvic and humic acids)
 - Compounds- Trihalomethanes (THMs)
 - CHCl_3 , CHBrCl_2 , CHBr_2Cl , CHBr_3
 - Removal – Oxidation of NOM, Ozone, UV, adsorption on carbon





Measurements for water quality - Ions and dissolved substances

Alkalinity – Acid neutralizing capacity

Acidity – Base neutralizing capacity

Hardness – Ca^{++} , Mg^{++} salts

pH – Acidity

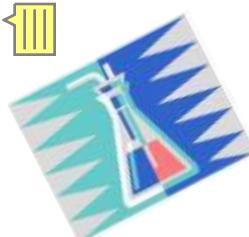
Dissolved organic matter – humic-fulvic acids

Salinity – Na^+ Cl^-

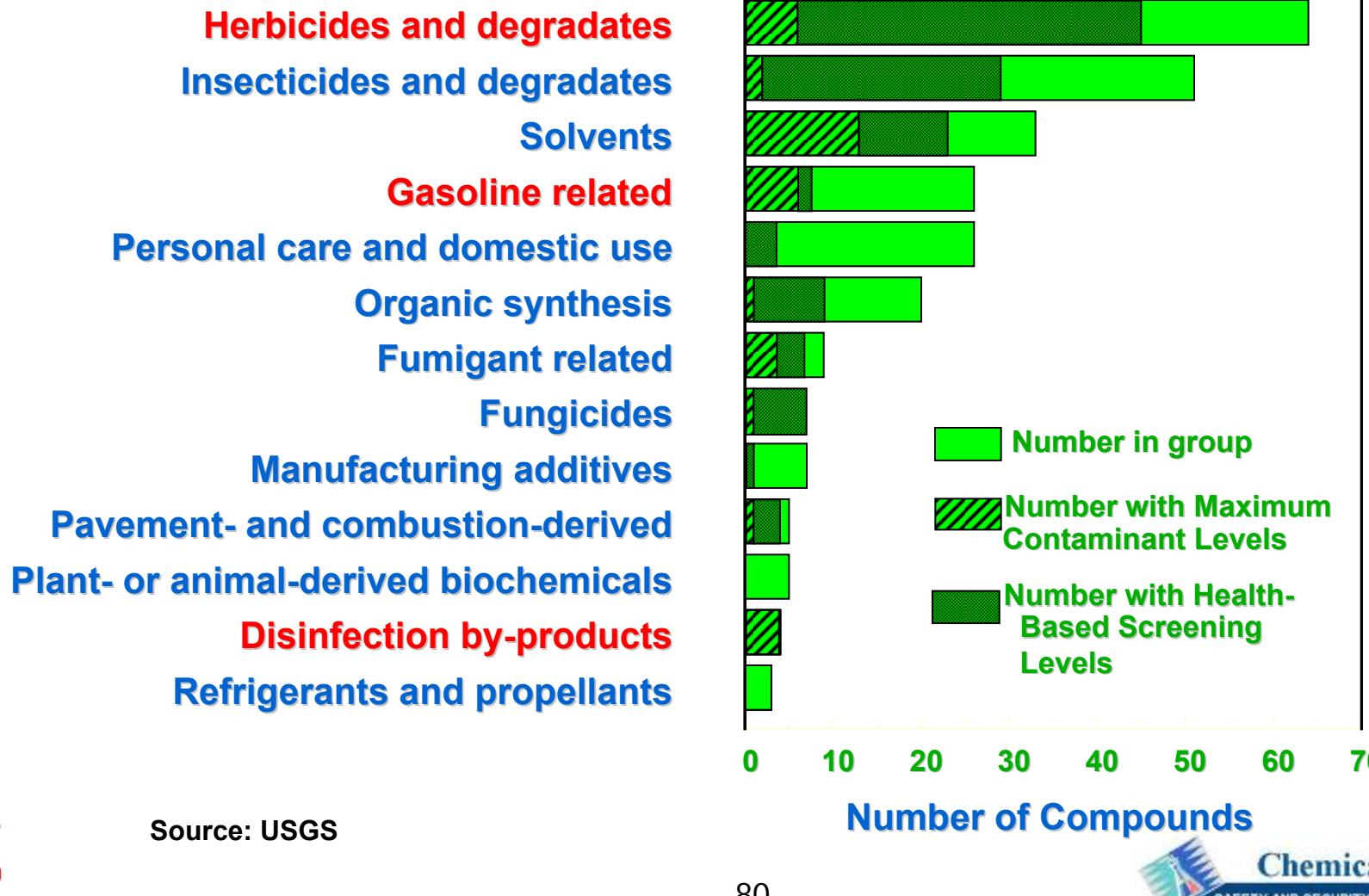
Cations – Na^+ , K^+ , Ca^{++} , Mg^{++} ,

Anions – Cl^- , HCO_3^- , SO_4^{2-}

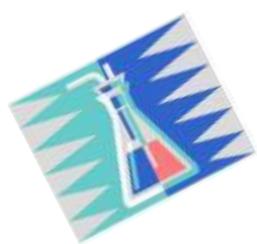
Heavy metals – Fe , Cu , Pb , As , Cd



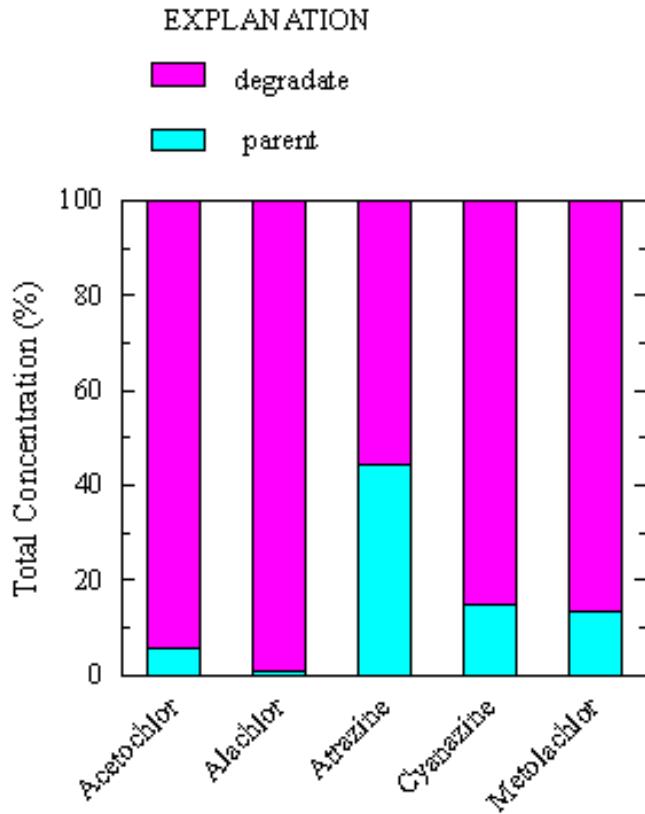
Organic compounds monitored



Source: USGS



Pesticide residues depend on degradation and prior use

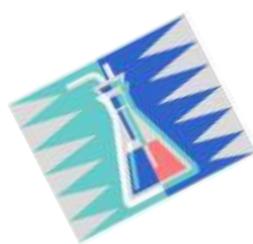


Common **herbicides** degrade in the environment



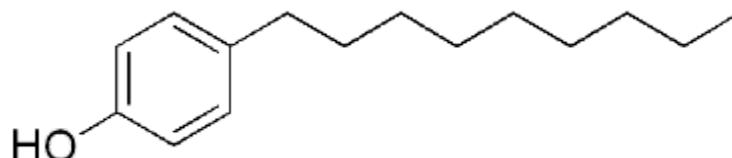
Chlorinated **insecticides** are slow to degrade (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex)

Other compounds are now used (organophosphorous)

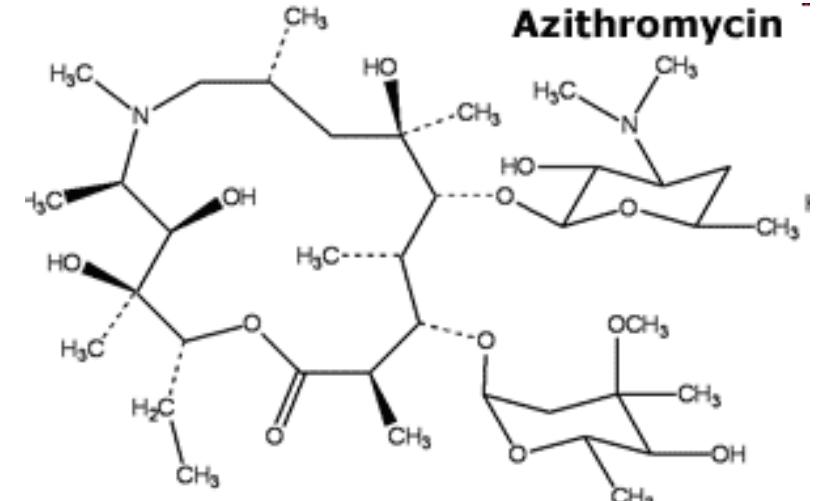


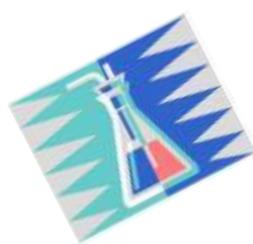
Pharmaceuticals and personal care products

- Human activity (e.g., bathing, shaving, swimming)
- Illicit drugs
- Veterinary drug use, especially antibiotics and steroids
- Agribusiness
- Residues from pharmaceutical manufacturing (well defined and controlled)
- Residues from hospitals



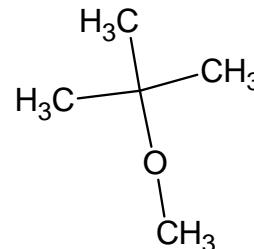
4-*n*-nonylphenol Detergent reagent

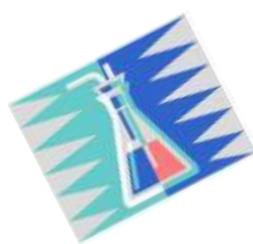




Petroleum products are everywhere - easily degraded

- **BTEX – Benzene, Toluene, Ethyl Benzene and Xylene**
- **MTBE – Very water soluble**
- **Used motor oil**
- **TPH – total petroleum hydrocarbons**
 - Gasoline
 - Diesel
 - Crude oil

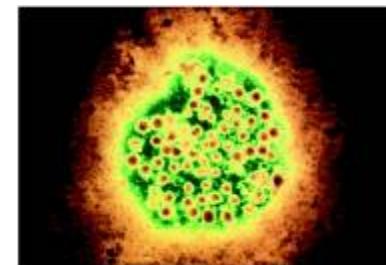




Microbiological contaminants are most important in public health



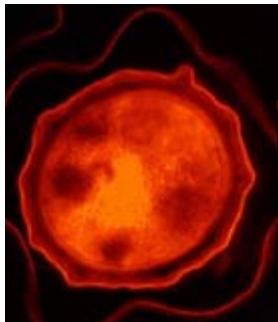
Cholera



Hepatitis A



Amoeba



Anthrax
spore



Cryptosporidium

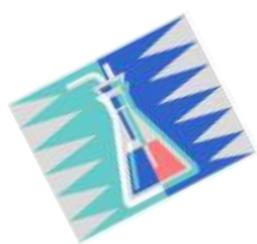


Giardia



Disinfection is the best way to remove these pathogens

- Primary means of disinfection use chlorine gas or a 12% hypochlorite solutions.
- Hypochlorite and other chlorinated oxidants can be produced electrolytically on-site
- Alternative disinfection schemes use ultraviolet radiation, ozone, chlorine dioxide, hydrogen peroxide, and combinations of these. (peroxone)



Fundamentals of Water Treatment

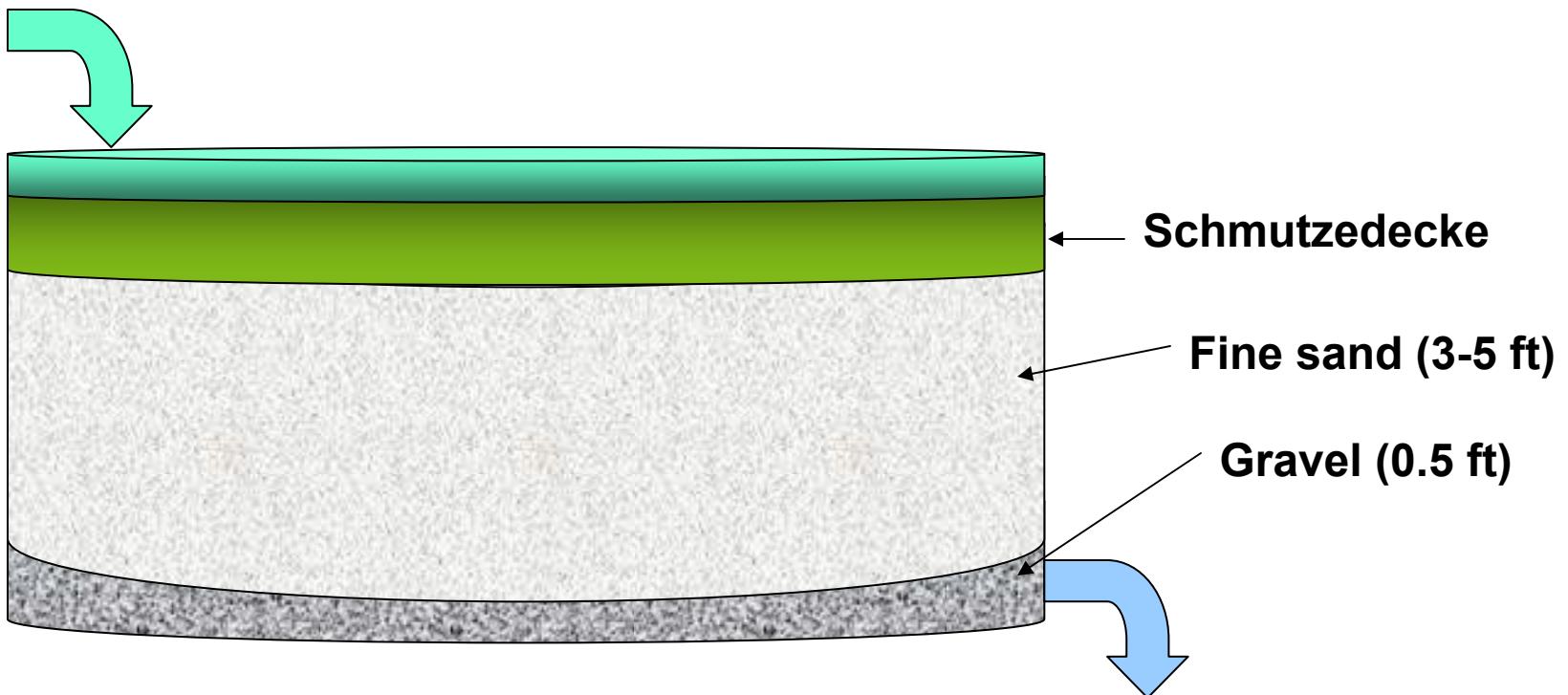


Fundamentals of Water Treatment

- **Slow sand filtration**
- **Sedimentation, coagulation, flocculation, settling, fast sand filtration**
- **Softening approaches – lime softening, membrane softening**
- **Filtration - membrane filtration (ultrafiltration, microfiltration)**
- **Disinfection - chlorine, UV, ozone, chlorine dioxide**
- **On-site generation**



Filtration - slow sand filtration



Low cost

Simple maintenance

Effective

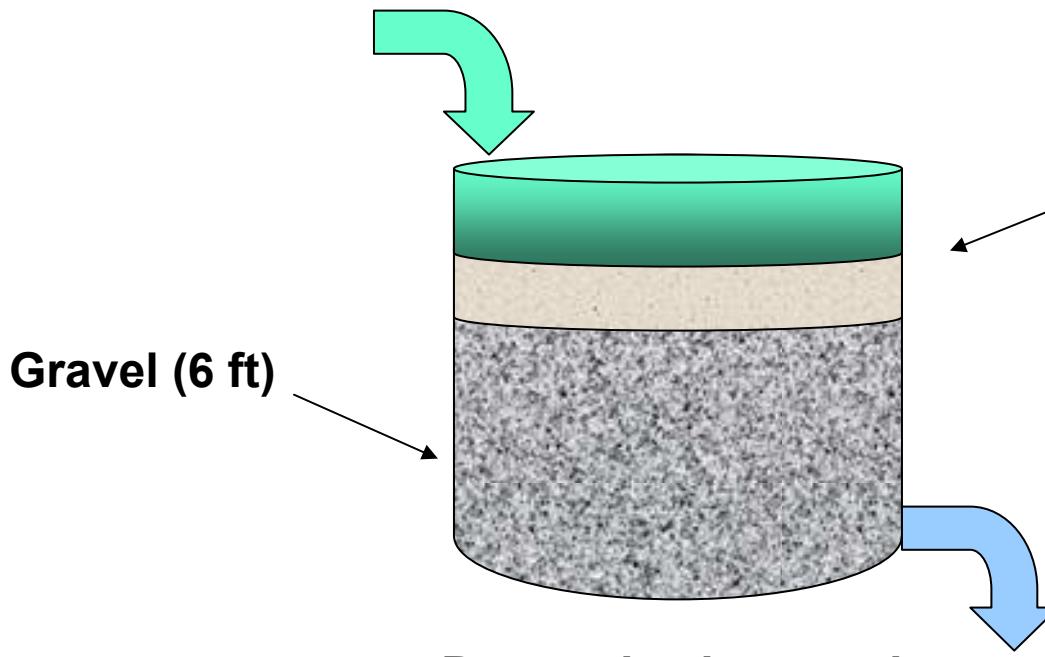


Sedimentation, coagulation, flocculation, settling

- Presedimentation is used to reduce surface water turbidity
- Historical treatment – Coagulation to reduce turbidity in water- followed by chlorination
 - Improved water appearance
 - Reduced cholera and typhoid
- Currently used to reduce
 - Turbidity
 - Natural Organic Matter (NOM)- and disinfection byproducts
 - Bacteria (specifically coliform)



Filtration - rapid sand filtration



Pressurized or gravity

Backwashed to clean

Can use granular activated carbon

Media / sand (2ft)

Media density (g/cm³)

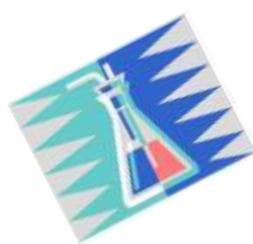
Silica 2.65

Anthracite 1.4-1.7

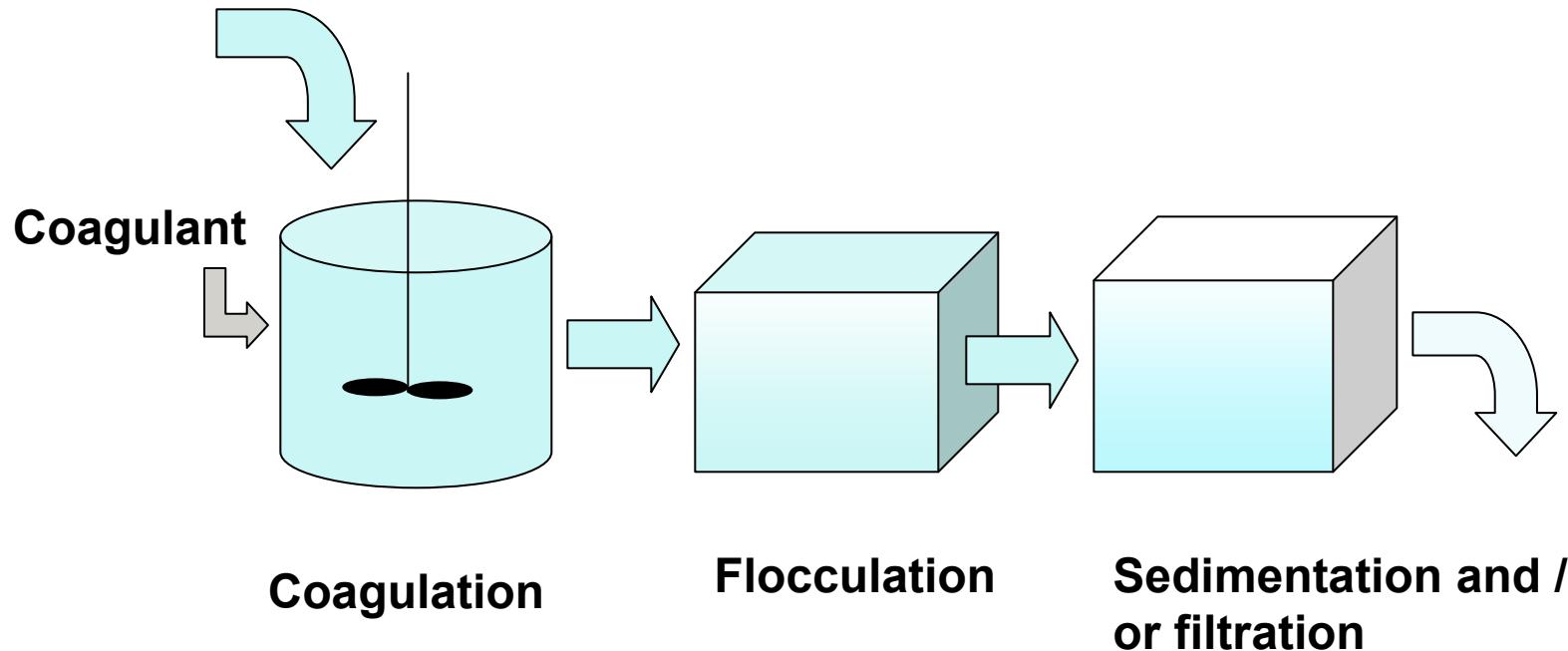
GAC 1.3-1.5

Garnet 3.6-4.2

Ilmenite 4.2-4.6



Coagulation filtration removes particles and dissolved organics



Removal of particles and natural organic matter (NOM), color, disinfection byproducts (DBP), iron, manganese, arsenic, taste, odor.

Granular activated carbon can be used as a filter *and absorber*, but regeneration may be different than sand media.



Effective coagulation filtration can be studied in jar tests

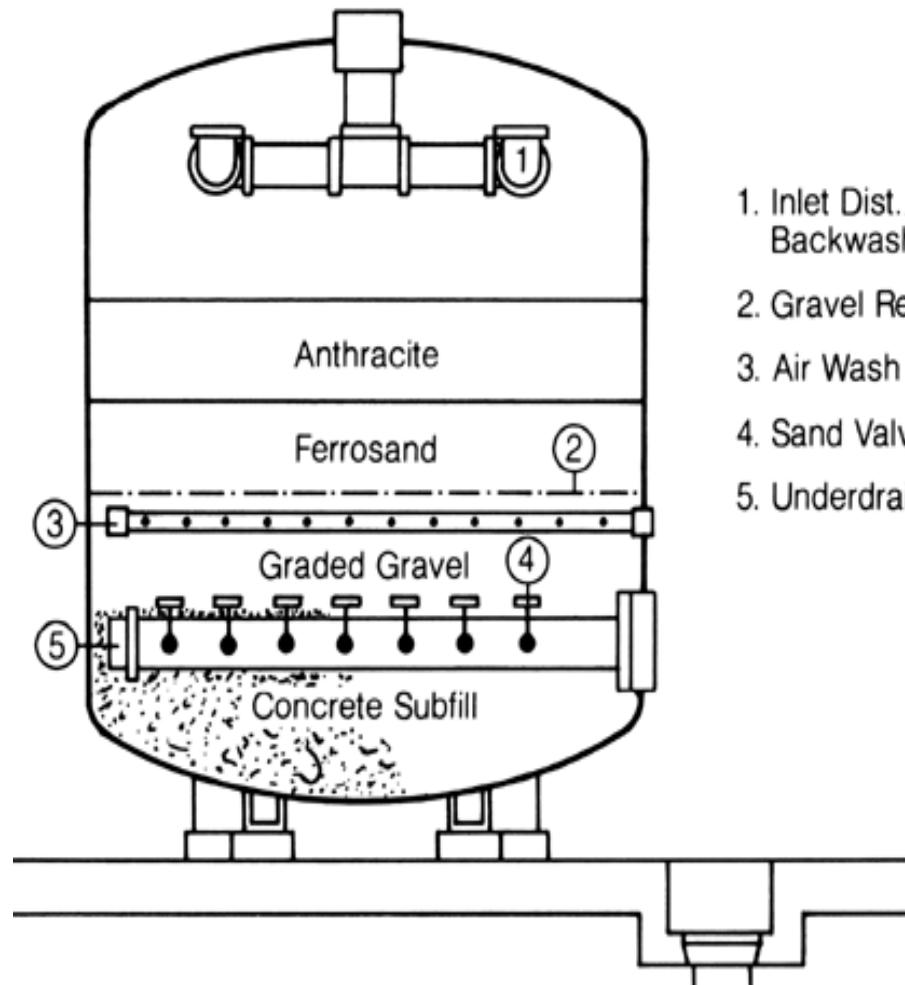


- Velocity gradient in the mixing basin
- Effective retention time in the mixing basin
- Velocity gradient in the flocculation basin
- Effective retention time in the flocculation basin
- Surface loading rate of sedimentation basin

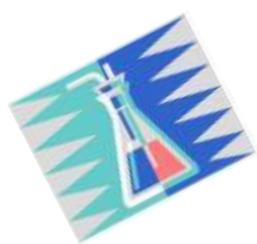
Source : AWWA Manual M37



Filtration - fast sand filtration



1. Inlet Dist./Backwash Collector
2. Gravel Retaining Screen
3. Air Wash Distributor
4. Sand Valves
5. Underdrain

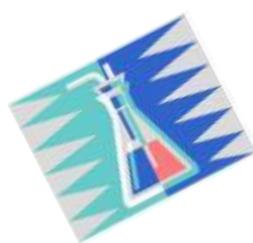


Manganese and iron removed by oxidation / Mn greensand

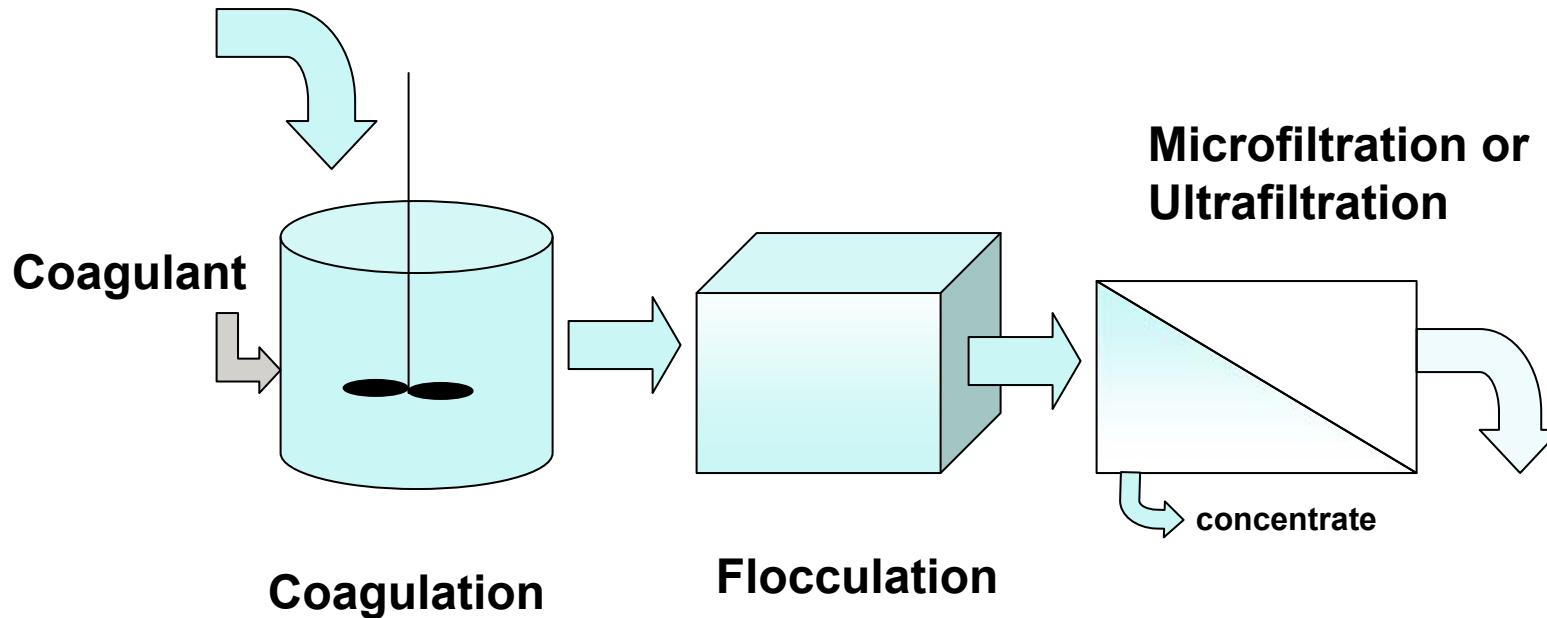


Iron and manganese often occur together in groundwater and can also be removed together in a precipitation filtration reactor

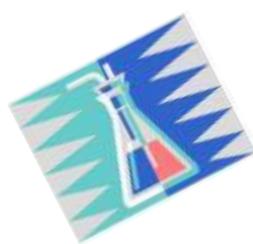
Removal - $Mn + MnO_2(s) \rightarrow 2 MnO(s)$
Precipitation onto filter media



Microfiltration and ultrafiltration can be used instead of sand filters



Membrane filtration normally uses hollow fiber bundles that can be submerged or pressurized. Can be backwashed.



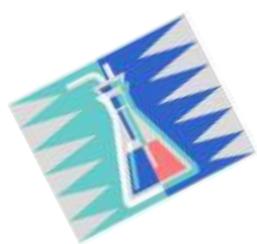
Membrane filtration microfiltration and ultrafiltration



**Pall Microfiltration
bank- pressurized**



**Zeeweek
Microfiltration
cassette- submerged**



Scale index for heat exchangers and membrane surfaces

Mineral scaling- Langelier Saturation Index

$$\text{LSI} = \text{pH} - \text{pHs}$$

$$\text{pHs} = (9.3 + A + B) - (C + D)$$

where:

$$A = (\text{Log10} [\text{TDS}] - 1) / 10$$

$$B = -13.12 \times \text{Log10} (\text{°C} + 273) + 34.55$$

$$C = \text{Log10} [\text{Ca}^{+2} \text{ as CaCO}_3] - 0.4$$

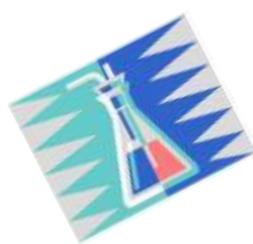
$$D = \text{Log10} [\text{alkalinity as CaCO}_3]$$

Items in blue
are needed for
calculation

$\text{LSI} < 0 \rightarrow \text{Water will dissolve CaCO}_3$

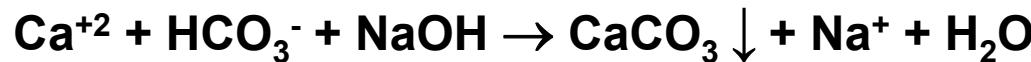
$\text{LSI} > 0 \rightarrow \text{Water will precipitate CaCO}_3$

$\text{LSI} \sim 0 \rightarrow \text{Water borderline for scaling}$



Chemical water softening reduces hardness in water

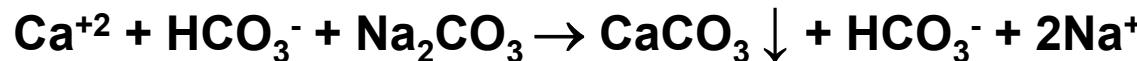
- **Caustic Soda (NaOH)**



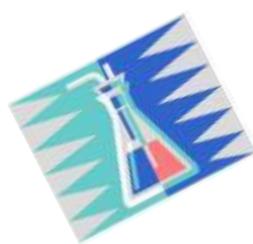
- **Lime Ca(OH)_2**



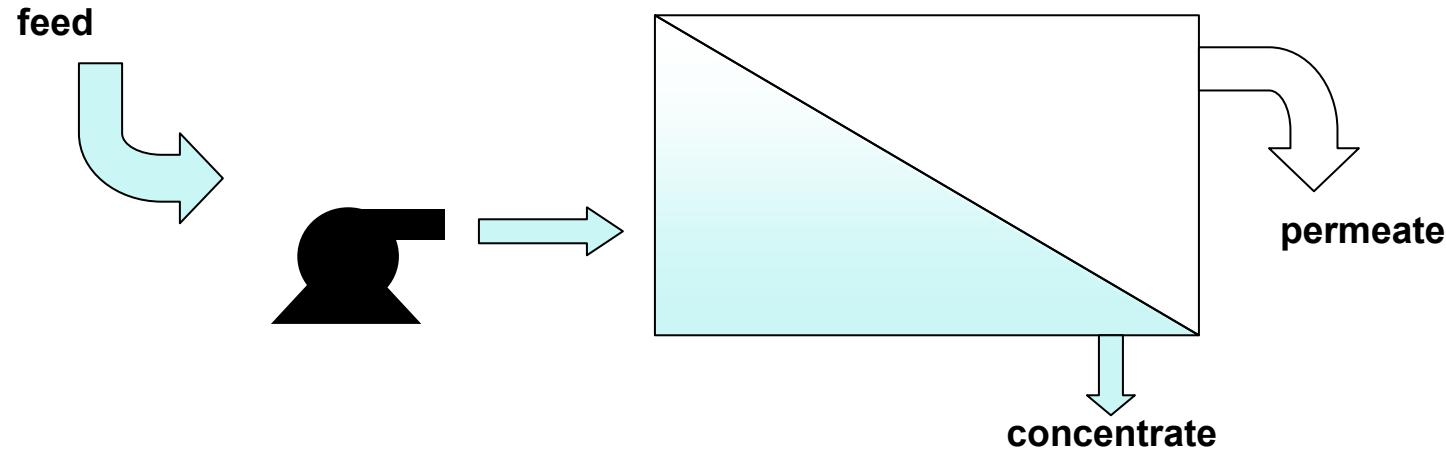
- **Soda (Na_2CO_3)**



Groundwater with high CO_2 content can be pre-aerated to reduce reagent addition

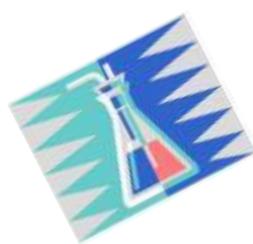


Membrane softening - nanofiltration rejects divalent ions



Ion	Feed (mg/L)	Perm (mg/L)	Rejection (%)
Ca	546	10	98
Mg	1532	28	98
SO ₄	2888	33	99
Na	11912	1806	85
Cl	19737	1806	91
Hardness	7755	140	98

Data : Desalination
and Water Reuse
Vol. 13/3



Chlorination is the most widely used method of disinfection

Chlorine- Cl₂

Least expensive, most hazardous, disinfection byproducts (DBP)

Sodium hypochlorite- NaOCl*

12% solution very common, corrosive, decomposes slowly, DBP

Calcium hypochlorite- Ca (OCl)₂

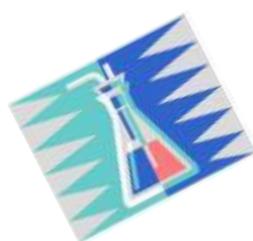
Powder, tends to clump, hard to handle, DBP

Chlorine dioxide – ClO₂

Generated on-site $2\text{NaClO}_2 + \text{Cl}_2 \rightarrow 2 \text{ClO}_2 + 2\text{NaCl}$

Care must be taken not to have a residual of chlorite (ClO₂⁻) or chlorate (ClO₃⁻)

*** Can be generated by electrical discharge - point of use**



Alternative disinfection

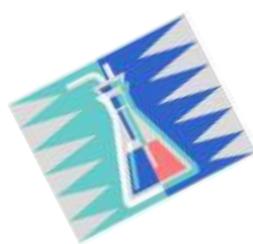
- Ultraviolet radiation – Hg vapor

UV- C radiation germicidal from 220-320 nm

Low pressure-high intensity use Hg-In amalgum-0.005 torr operate at 90-150°C

Medium pressure-high intensity produce polychromatic light and operate at 600-800°C

- Open channel and closed channel designs
- Shielding of lamps by particles, algae, oil and grease and scale is a problem
- UV is not an oxidation technique but a disinfection technique
- Advanced oxidation often work best when several oxidation steps are combined sequentially



Germicidal comparison of disinfection techniques*

	Bacteria	Virus	Protozoan cysts
Chlorine (free) (mg•min/L)	0.4-0.8	2.5-3.5	35-45
Chloramine (mg•min/L)	12-20	300-400	700-1000
Chlorine dioxide (mg•min/L)	8-10	2-4	14-16
Ozone (mg•min/L)	3-4	0.3-0.5	0.5-0.9
UV radiation (mJ/cm ²)	30-60	20-30	10-15

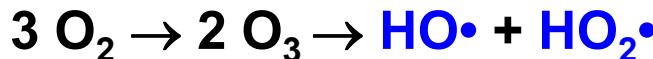
* 2 log inactivation. Source: Wastewater Engineering- Metcalf & Eddy



Advanced oxidation

Ozone

Generated by electrical discharge- point of use



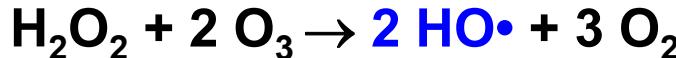
Transfer efficiency is a function of mixing chamber and diffusers

Ozone destructors needed to safely operate (offgas hazard)

Limited contact time due to rapid decomposition

Ozone / Hydrogen Peroxide (Peroxone)

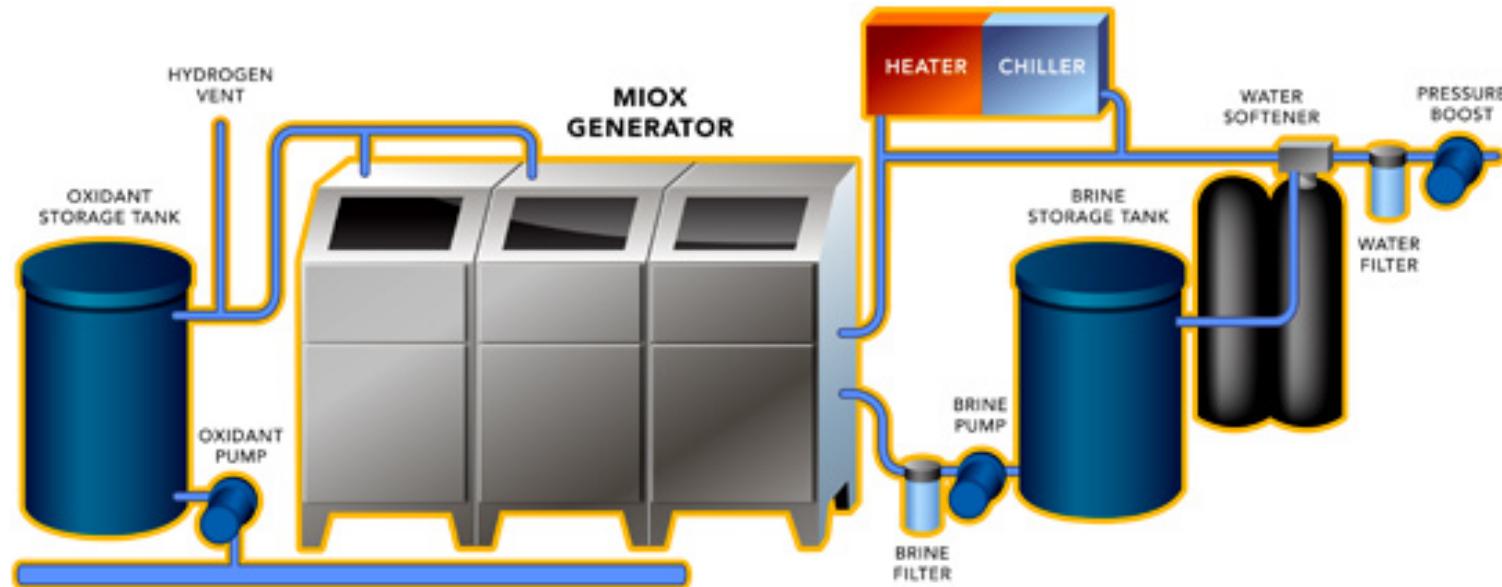
Peroxide addition accelerates ozone decomposition



Both of these methods leave no residual and do not create chlorinated DBP



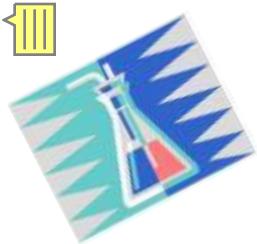
On-site mixed oxidant or hypochlorite generator



Oxidizers are formed by brine electrolysis in electrolysis cells



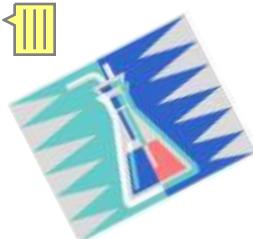
Lunch



Chemical and Waste Management



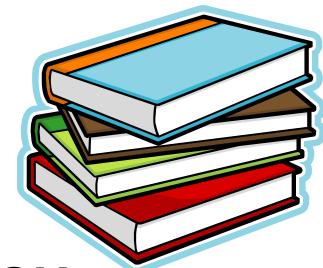
Best Practices



References

“Less is Better,” American Chemical Society, Washington DC, 2003, available online:

<http://membership.acs.org/c/ccs/publications.htm>

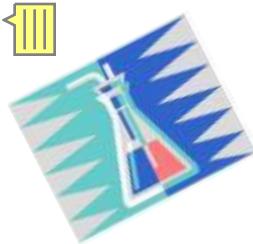


“School Chemistry Laboratory Safety Guide,” US NIOSH Publication 2007-107, Cincinnati, OH, 2006, available on-line:

<http://www.cpsc.gov/CPSCPUB/PUBS/NIOSH2007107.pdf>

“Prudent Practices in the Laboratory: Handling and Disposal of Chemicals,” National Academy Press, 1995, available online:

http://www.nap.edu/catalog.php?record_id=4911

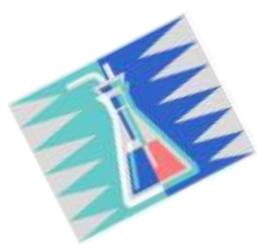


Chemical Management

Institute a Safety Program

- Have a Safety Manual
- Appoint a chemical safety officer for each major area/section/group/building
- Form a Safety Committee
- Have periodic safety training (films, etc)
- Have safety inspections
- Investigate serious accidents/incidents
- Follow-up!

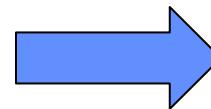




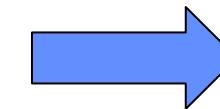
Cradle - to - grave care of chemicals



Receipt



Storage

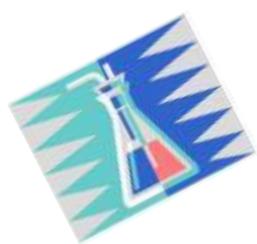


Use



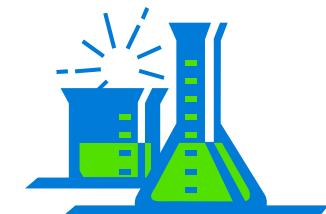
Disposal





Plan experiments in advance!

What chemicals are needed?



How much is needed?

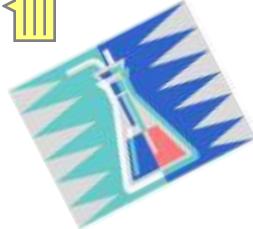
How will the chemicals be handled?



What are the reaction products?

How will the chemical be stored?

How will disposal take place?



Inventory management

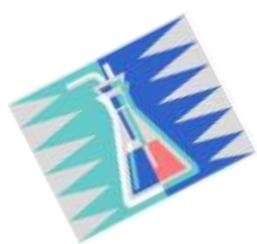
Less is Better !



- Order only what you need
- Reduce size of experiment
 - It cost less to store
 - It cost less to dispose



“Less is Better: Guide to minimizing waste in laboratories”, Task Force on Laboratory Environment, Health and Safety, American Chemical Society, 2002. http://membership.acs.org/C/CCS/pub_9.htm



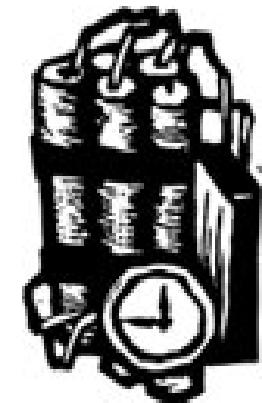
Inventory management

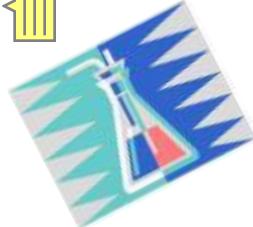


Less is Better !
It's Safer!

It may be cheaper to order **diethyl ether** in large containers

But, if it's opened for a long time—peroxides can form!





Inventory management

-R-O-O-R-

Peroxide Forming Chemicals

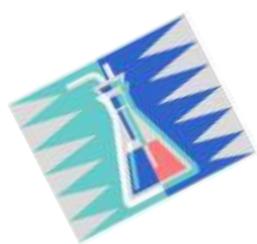
Even with inhibitors they can become dangerous over time

Examples: ethers, dioxane, tetrahydrofuran

- discard or test if unsure
 - label & date when received, when opened, and provide expiration date

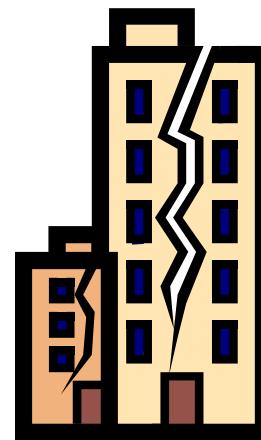


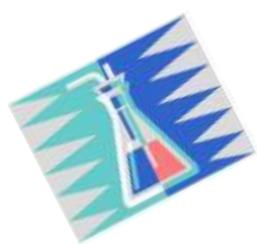
References: See for example,
http://www.med.cornell.edu/ehs/updates/peroxide_formers.htm



Chemical storage

- Protect chemicals during normal operations
- Protect chemicals during unexpected events
 - Floods
 - Tidal waves
 - Earthquakes
 - Typhoons
 - Hurricanes

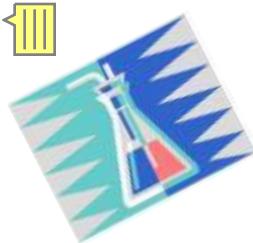




Chemical storage: Basic concepts

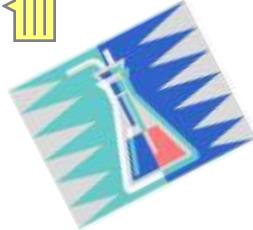
- Separate incompatible chemicals
- Separate flammables/explosives from ignition sources
- Use flammable storage cabinets for large quantities of flammable solvents
- Separate alkali metals from water
- Separate acids and bases





Use flammables storage cabinets

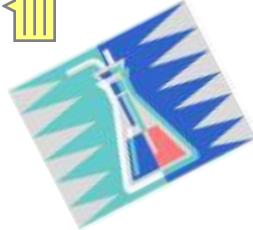




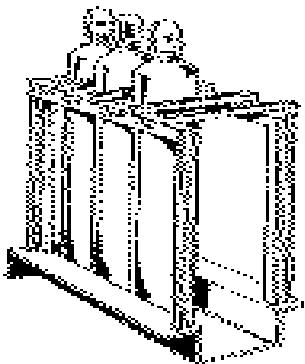
Chemical storage: Basic concepts

- Store nitric acid separately
- Store large containers on bottom shelves
- Lock up drugs, chemical surety agents, highly toxic chemicals
- Do not store food in refrigerators with chemicals



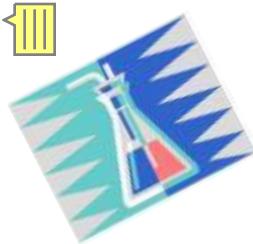


Chemical storage: Gas cylinders



- **Secure (chain/clamp) and separate gas cylinders**
 - Screw down cylinder caps
 - Store in well-ventilated area
 - Separate & label empty cylinders
 - Store empty cylinders separately
- **Separate flammable from reactive/oxidizing gases**





Improper gas cylinder storage/handling



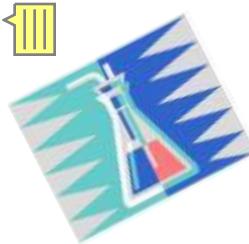


Gas Cylinders



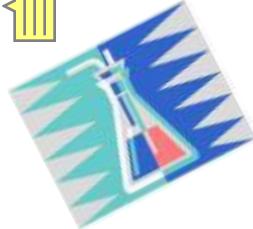
Exploded nitrogen cylinder





Chemical storage: Cryogenics

- **Store gases & cryogenics separately from other chemicals**
- **Store cryogenics (liquid nitrogen) & dry ice in well ventilated areas**
- **Use proper PPE (including eye protection) when handling & moving cryogenics**
- **Do not use cryogenics in closed areas**



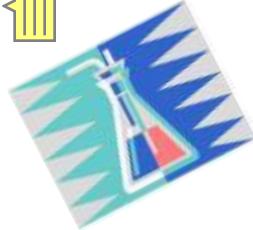
Chemical storage: Good practices

- Limit access
 - Label “Authorized Personnel Only”
 - Lock area/room/cabinets when not in use
- Be sure area is cool and well ventilated
- Secure storage shelves to wall or floor
- Shelves should have a $\frac{3}{4}$ ” front lip
 - In earthquake territory, have a rod several inches above shelf



- Separate incompatible chemicals
 - Organize chemicals by compatible groups
 - Alphabetize chemicals only within compatible groups

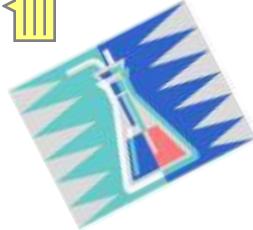




Chemical storage: Bad practices

- **Do Not Store Chemicals**
 - on top of cabinets
 - on floor
 - in hoods
 - with food or drinks
 - in refrigerators used for food
 - where there are wide variations in temperature, humidity or sunlight

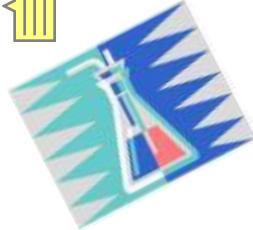




Chemical storage: Containers

- **Don't use chemical containers for food**
- **Don't use food containers for chemicals**
- **Be sure all containers are properly closed**
- **Wipe off outside of container before returning to storage area**
- **Transport/carry all containers safely**
 - **Preferably use outer protective container**





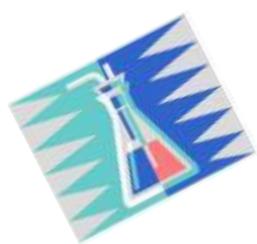
Improper chemical storage



**Never use hallways
for storage**

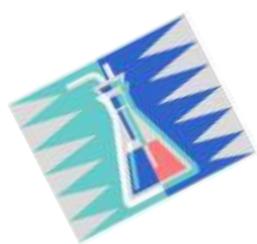
Safety Hazard!!

**Blocks exit path in
emergencies!!!**



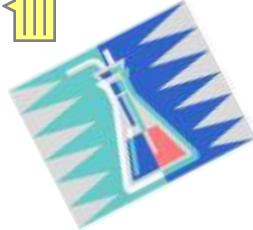
Suggested shelf storage groups: Organics

- Acids, anhydrides
- Alcohols, amides, amines
- Aldehydes, esters, hydrocarbons
- Ethers, ketones, halogenated hydrocarbons
- Epoxies, isocyanates
- Azides, peroxides
- Nitriles, sulfides, sulfoxides
- Cresols, phenols



Suggested shelf storage groups: Inorganics

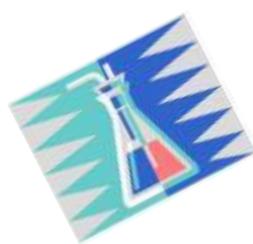
- Metals, hydrides
- Halides, halogens, phosphates, sulfates, sulfides
- Amides, azides, nitrates, nitrites
- Carbonates, hydroxides, oxides, silicates
- Chlorates, chlorites, perchlorates, peroxides
- Arsenates, cyanides, cyanates
- Borates, chromates, manganates
- Acids
- Arsenics, phosphorus, sulfur



Waste management: General guidelines

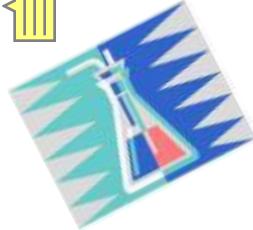
- Secure and lock waste storage area
- Post area
- Keep area well ventilated
- Provide fire extinguishers and alarms, spill kits
- Provide suitable PPE
- Provide eye wash, safety showers
- Do not work alone





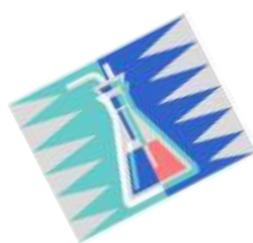
Waste management: General guidelines

- **Insure against leakage; dyke area if possible**
- **Label all chemicals, containers, vials**
- **Separate incompatible chemicals**
- **Keep gas cylinders separate**
- **Keep radioactive material separate**
- **Know how long waste can be stored**
- **Provide for timely pick up**



Dangerous waste management

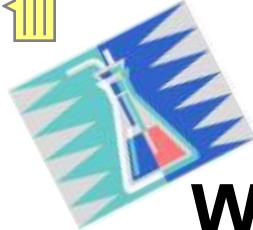




Waste management

- **Recycle, reuse, redistill if possible**
- **Dispose by incineration, if possible**
- **Incineration is NOT the same as open burning**

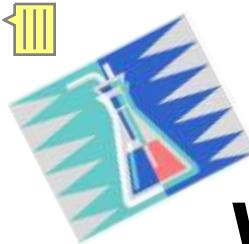




Waste management: Waste disposal service

- Is disposal service licensed?
- How will waste be transported?
- How will waste be packaged?
- Where will material be disposed?
- How will it be disposed?
- Maintain written records



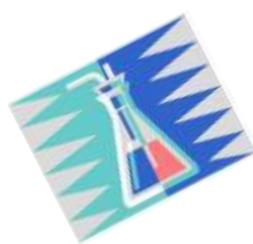


Waste management: Down the drain?

If legally allowed:

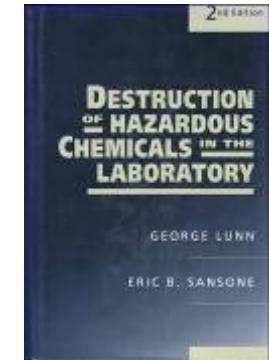
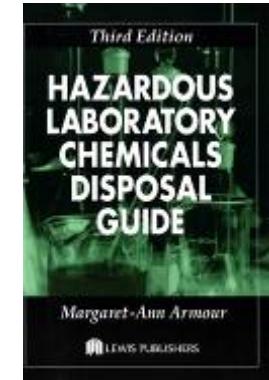
- Deactivate & neutralize some liquid wastes yourself
 - e.g., acids & bases
 - Don't corrode drain pipes
- Dilute with lots of water while pouring down the drain
- Be sure that you do not form more hazardous substances

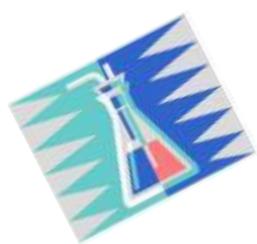




Waste management: Treatment in Lab?

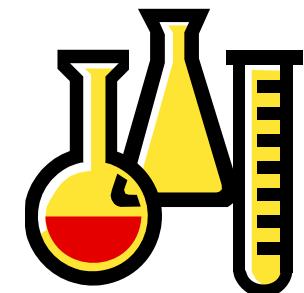
- **Destruction / neutralization of hazardous chemicals**
 - May or may not be allowed by regulations
 - Must be done by trained chemist
 - Specific to each chemical
- References:
 - “Procedures for the Laboratory-Scale Treatment of Surplus and Waste Chemicals, Section 7.D in Prudent Practices in the Laboratory: Handling and Disposal of Chemicals,” National Academy Press, 1995, available online:
http://www.nap.edu/catalog.php?record_id=4911
 - “Destruction of Hazardous Chemicals in the Laboratory, 2nd Edition”, George Lunn and Eric. B. Sansone, Wiley Interscience, 1994, ISBN 978-0471573999
 - “Hazardous Laboratory Chemicals Disposal Guide, Third Edition”, Margaret-Ann Armour, CRC Press, ISBN 978-1566705677
 - “Handbook of laboratory Waste Disposal”, Martin J. Pitt and Eva Pitt, Ellis Horwood, 1985, ISBN 0-85312-634-8 (out of print)





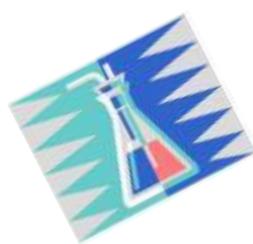
Chemical management

- Proper chemical management is an important part of laboratory safety and security
- Helps protect people, laboratories and the environment
- Can save money by avoiding duplicate chemical purchases





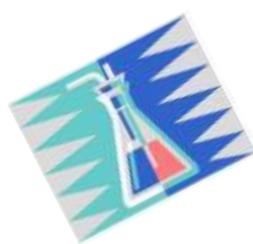
Components of Chemical Security and Relationships Between Chemical Safety and Security



Chemical Security

- **Is your Facility secure?**
- **How easy would it be for someone to steal chemicals?**
- **Are your chemistry stockrooms, classrooms and research labs always locked and secure?**
- **Is someone always there when these rooms are open?**
- **Do you check your orders when chemicals arrive to be sure some chemicals are not missing?**



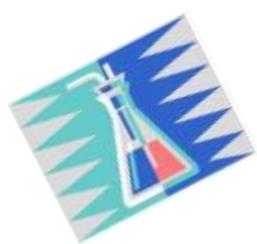


Components of Chemical Security

- Physical security of site
- Personnel management
- Information security
- Management of chemical security activities
- Allocation of chemical security responsibilities
- Development of emergency plans
- Chemical security training



Goal: Ensure that you don't accidentally help a criminal or a terrorist get dangerous chemicals



Chemical Security: Physical Site



LOCK UP!!

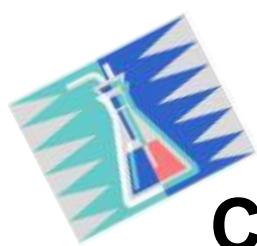
Controlled drugs



Chemical Surety Agents

Highly toxic chemicals

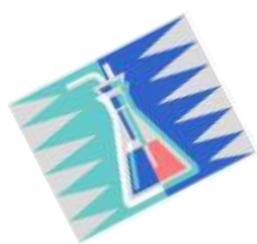




Chemical Security: Personnel Management

- **Guard against both Insider and Outsider threat**
- **Does anyone check on people entering the building?**
- **Who has keys? How do they get authorized?**
 - Building
 - Stockroom
 - Individual Labs
- **When someone leaves, do you make sure they turn in keys?**
- **Don't want people making duplicate keys**

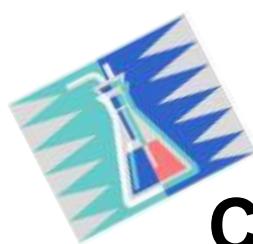




Chemical Security: Information security

- **How do you track chemical inventory?**
 - Is the information secured so unauthorized people can't read it or alter it?
- **Would you know if:**
 - some toxic chemicals disappeared overnight?
 - some toxic chemicals didn't arrive?
 - someone was ordering chemicals in the name of your institution but diverting them?

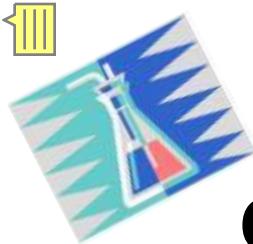




Chemical Security: Assign Responsibilities

- Identify people who will be responsible for various chemical security activities
 - Physical security and building modifications
 - Chemical tracking and reporting
 - Personnel and access management
 - Information management
 - Emergency planning
- Ensure that they have the time and resources to do the job
- Integrate with chemical safety responsibilities



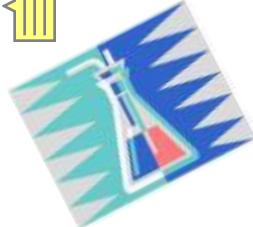


Chemical Security: Professional behavior

- A Chemical Professional needs to use their scientific knowledge in a responsible manner



- A Chemical Educator needs to train their students to use their scientific knowledge in a responsible manner



Relationships between chemical safety and security

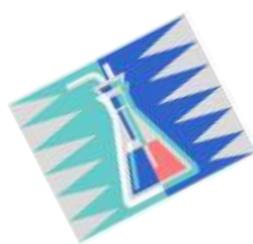
- Many practices are the same for chemical safety and security
- But there are a few areas of conflict





Good practices for both chemical safety and security

- **Minimize use of hazardous chemicals**
 - Replace with less-hazardous chemicals, if possible
 - Reduce scale of experiments
- **Minimize supply of hazardous chemicals on hand**
- **Restrict access to hazardous chemicals**
 - Know what you have
 - Know how to store, handle and dispose of what you have
 - Know who has access to materials, knowledge and expertise
- **Plan what to do in an emergency**



Conflicts between chemical safety and security: Information Sharing

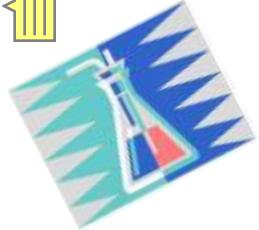
Science generally means sharing information widely, but this may not always be advisable

- **Safety**

- Label everything so people can recognize hazardous chemicals.
- Let community and especially emergency responders know what chemical dangers are there.
- Share knowledge about chemical hazards so people know to be alert.

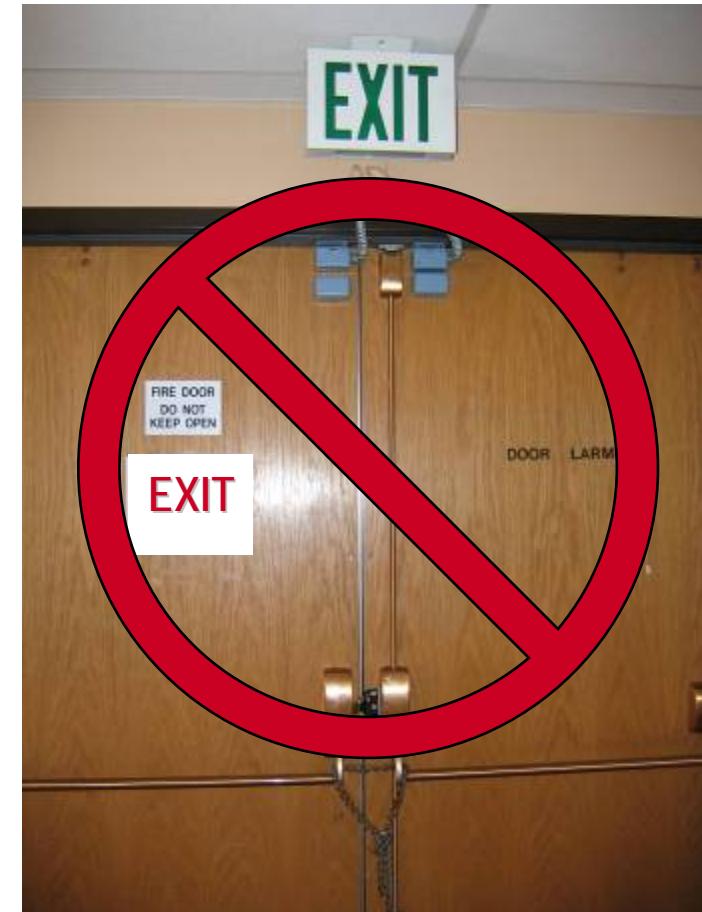
- **Security**

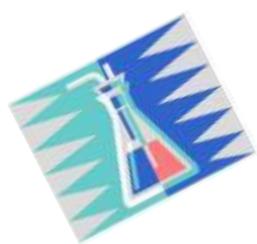
- Labels help identify targets for theft or attack.
- Sharing locations of chemicals can publicize targets for theft or attack.
- Sharing knowledge of chemical hazards could inspire harmful behavior (copy-cat criminals).



Conflicts between chemical safety and security: Facility exits

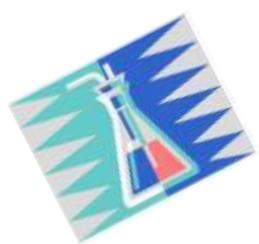
- Locking exit doors is secure, but not safe.
 - For **safety**, want people to be able to leave the facility quickly and by many routes.
 - For **security**, want to control exits as well as entrances so chemicals (or equipment) don't get taken.





Setting priorities

- **Labs need to be safe, secure and productive**
 - Policies and practices need to be flexible enough to allow for the uncertainties of research.
 - Policies and practices need to align with local laws, regulations, practices and culture. Can't just copy from somewhere else.
- **Use risk-based security and safety measures.**
 - Can't afford to defend against every imaginable hazard.
 - Identify threats, characterize facilities, identify alternatives, analyze costs vs. performance
- **Be alert for suspicious activities or inquiries**



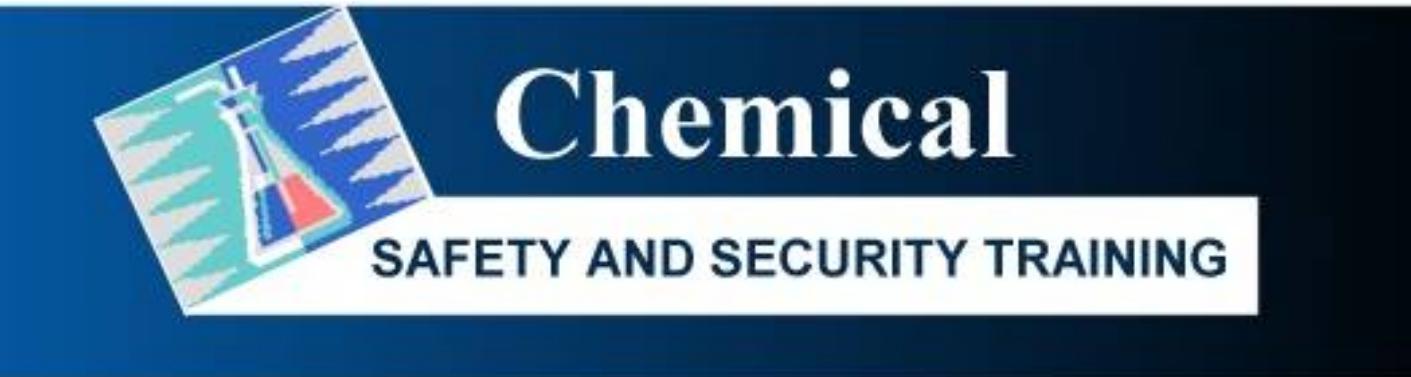
Break



Water Treatment Projects in Iraq



Breakout Discussion of Water Treatment Chemicals



Water Treatment and Chemical Safety/Security Seminar

Baghdad, Iraq
6-7 April 2009

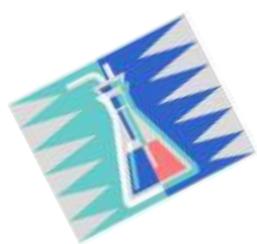


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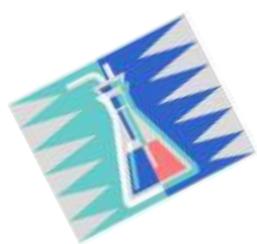
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

192



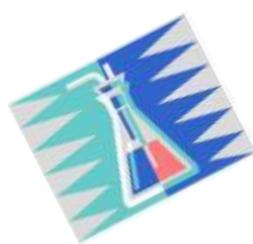


Fundamentals of Wastewater Treatment



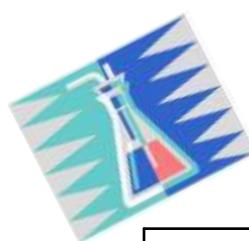
Wastewater Treatment

- Activated sludge processes
 - Fixed film and suspended processes
- Aerobic/anoxic/anaerobic processes modifications.
- Nutrient removal
 - nitrification / denitrification, phosphorous removal
- Water reuse and reclamation
 - membrane bioreactors
- Disinfection
- Satellite and On-site Wastewater Treatment



Wastewater contaminants

- **Bacteriological,**
 - **Vibrio Cholerae, Campylobacter, Salmonella , Shigella,**
- **Viruses**
 - **Hepatitis A, Norovirus**
- **Protozoan**
 - **Giardia, Cryptosporidium, Entamoeba**
- **Biological oxygen demand**
 - **Organic matter causes algae to thrive and deplete dissolved oxygen**
- **Nutrient removal to prevent eutrophication**
 - **Nitrogen and phosphorus from waste, and agriculture**



What does wastewater look like?

Measurement	Value	Units
Total Suspended Solids (TSS)	210	mg/L
BOD	190	mg/L
TOC	430	mg/L
COD	140	mg/L
Organic Nitrogen	15	mg/L
Free Ammonia	25	mg/L
Nitrite/Nitrate	0/0	mg/L
Phosphorous	7	mg/L
Total coliform	10^7 - 10^9	colonies/100mL
Fecal coliform	10^4 - 10^6	colonies/100mL
Cryptosporidium oocysts	0.1-10	no./100mL
Giardia Lamblia	0.1-100	no./100mL

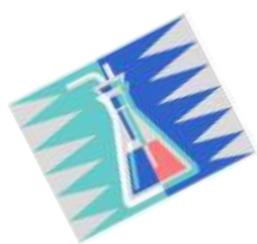
Source: Wastewater Engineering, Metcalf and Eddy- medium strength WW



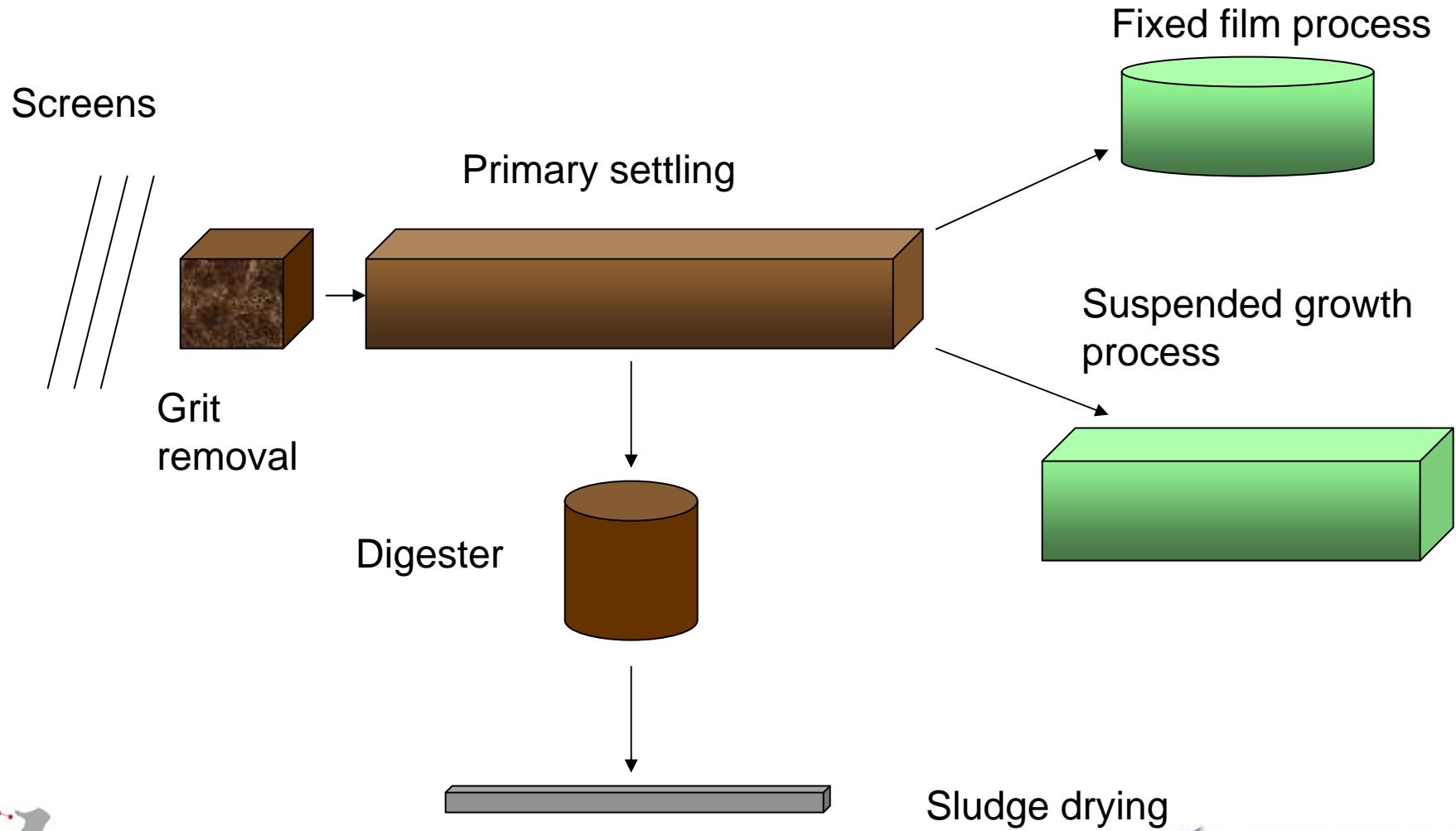
Routine bacterial testing consists of measuring indicator organisms

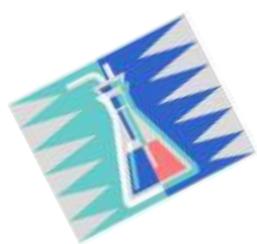
- Testing for pathogens directly is expensive and hazardous
- Indicators from the family *Enterobacteriaceae* are used (*E. Coli*, *Citrobacter*, *Enterobacter*, *Klebsiella*)
- Grow bacteria on a specified media and count the number of colonies after incubation
- Other assays are used and are approved by the US EPA (Colilert shown)



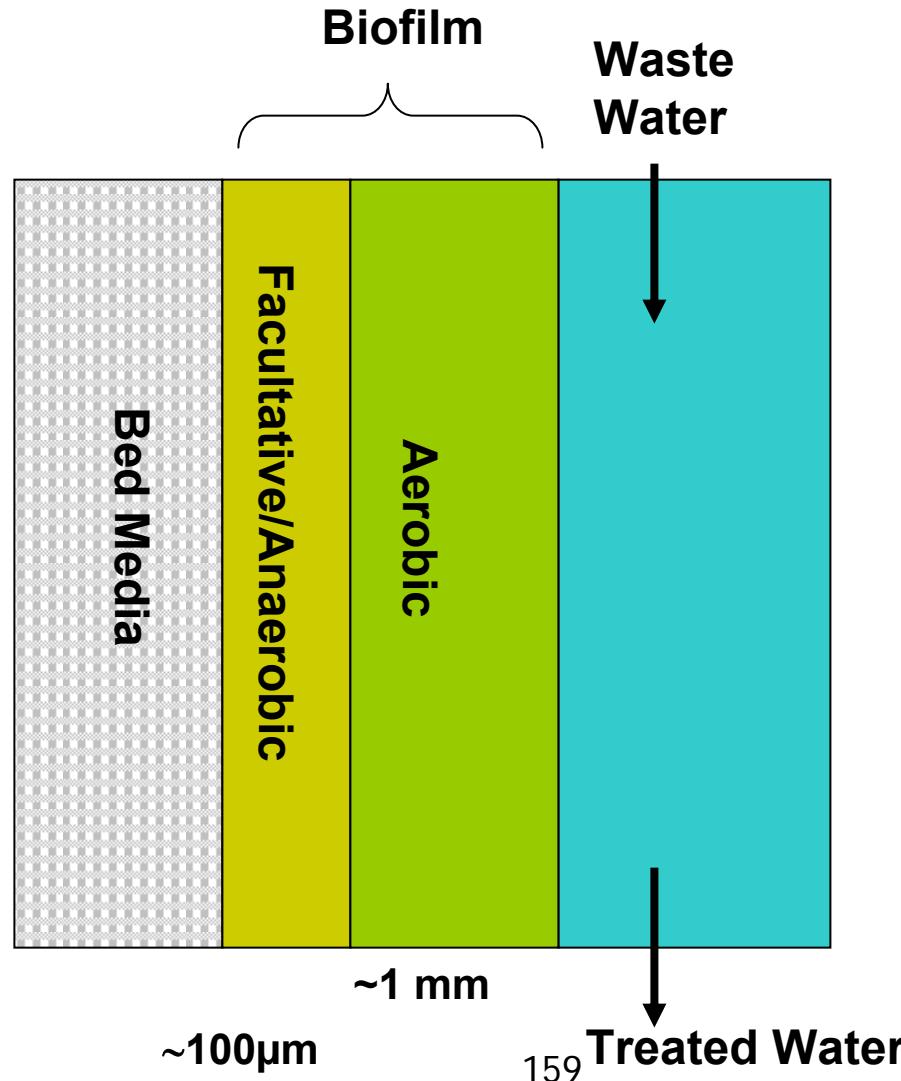


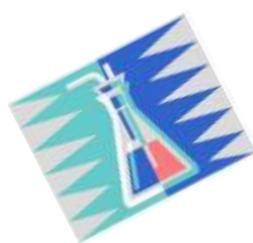
Initial steps in satellite and centralized wastewater treatment





Fixed film biological processes





Fixed film biological processes

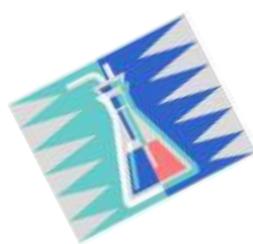


Trickling filter



Rotating biological contactor
(40% submerged rotates at 1-1.5 rpm)

Uses biofilm to treat water to remove BOD

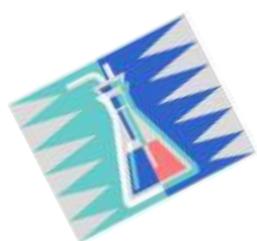


Trickling filter effectiveness

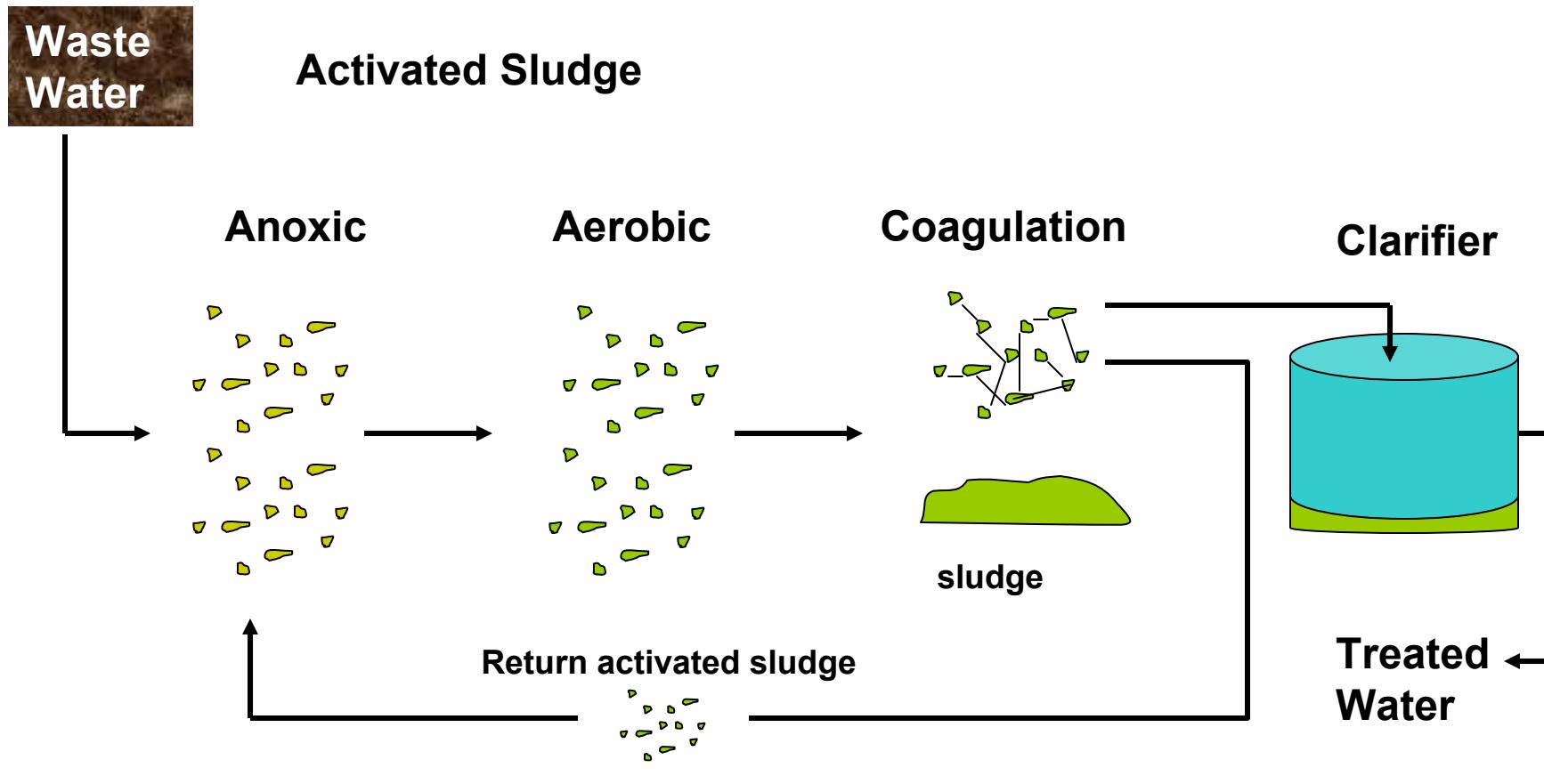
BOD⁵ removal rates for trickling filters

Filter Type	Hydraulic loading m³/m²day	BOD5 Removal (%)
Low Rate	1-4	80 - 90
Intermediate	4-10	50 - 70
High Rate	10-40	65 - 85
Roughing Filter		40 - 65

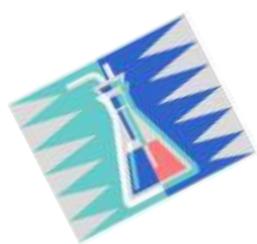
Source: Environmental Engineers Handbook, 1997.



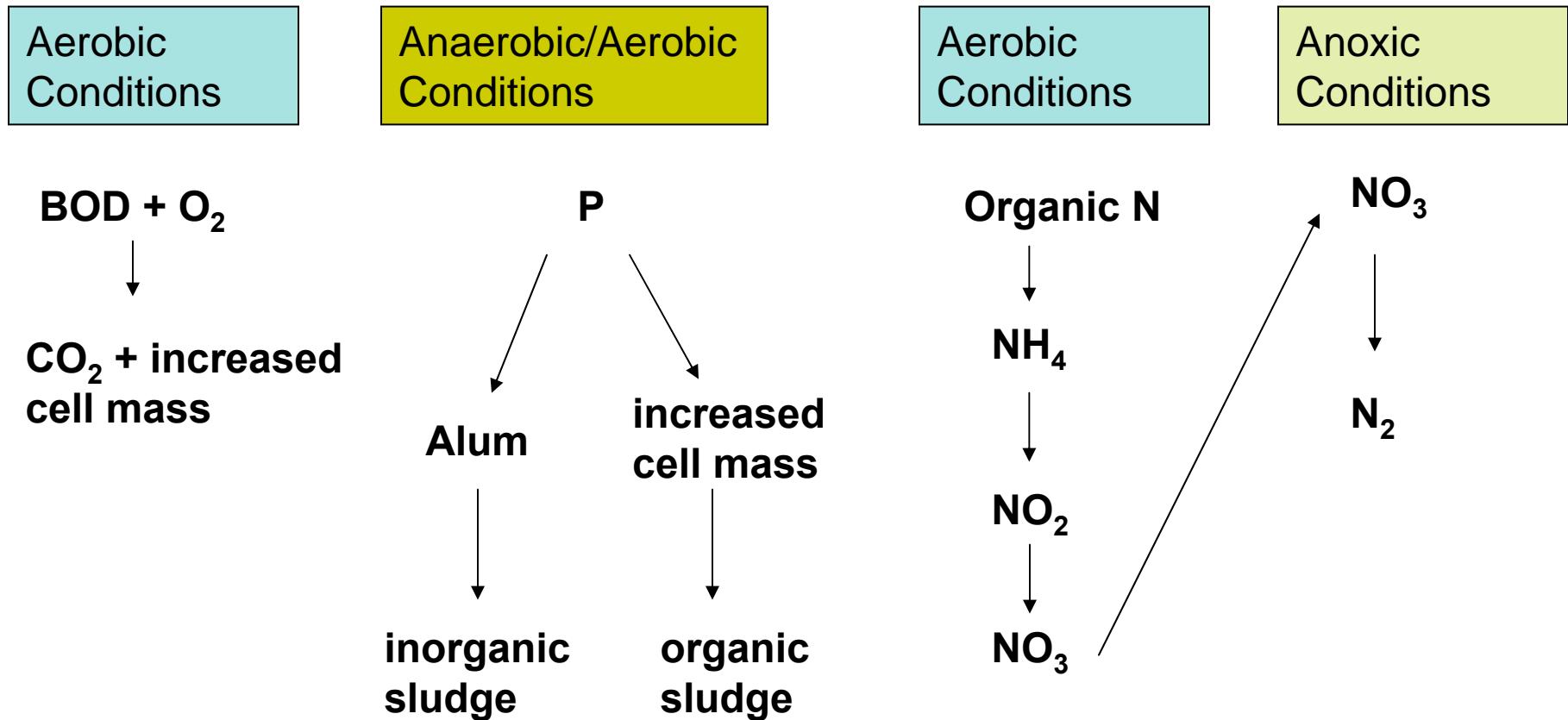
Suspended growth biological processes



Anoxic – no dissolved oxygen



BOD and nutrient (nitrogen and phosphorous) removal

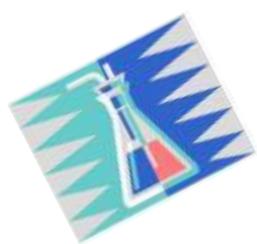




Suspended growth activated sludge processes requires energy



- Use forced air suspension of biological sludge to reduce BOD
- Largest expense for this process is the electrical energy required



Activated sludge process stages



Anoxic Basin



Aerobic Basin



Sedimentation



Final Clarification

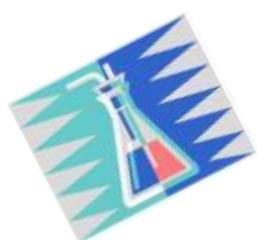


Anaerobic sludge digestion reduces solids - makes methane

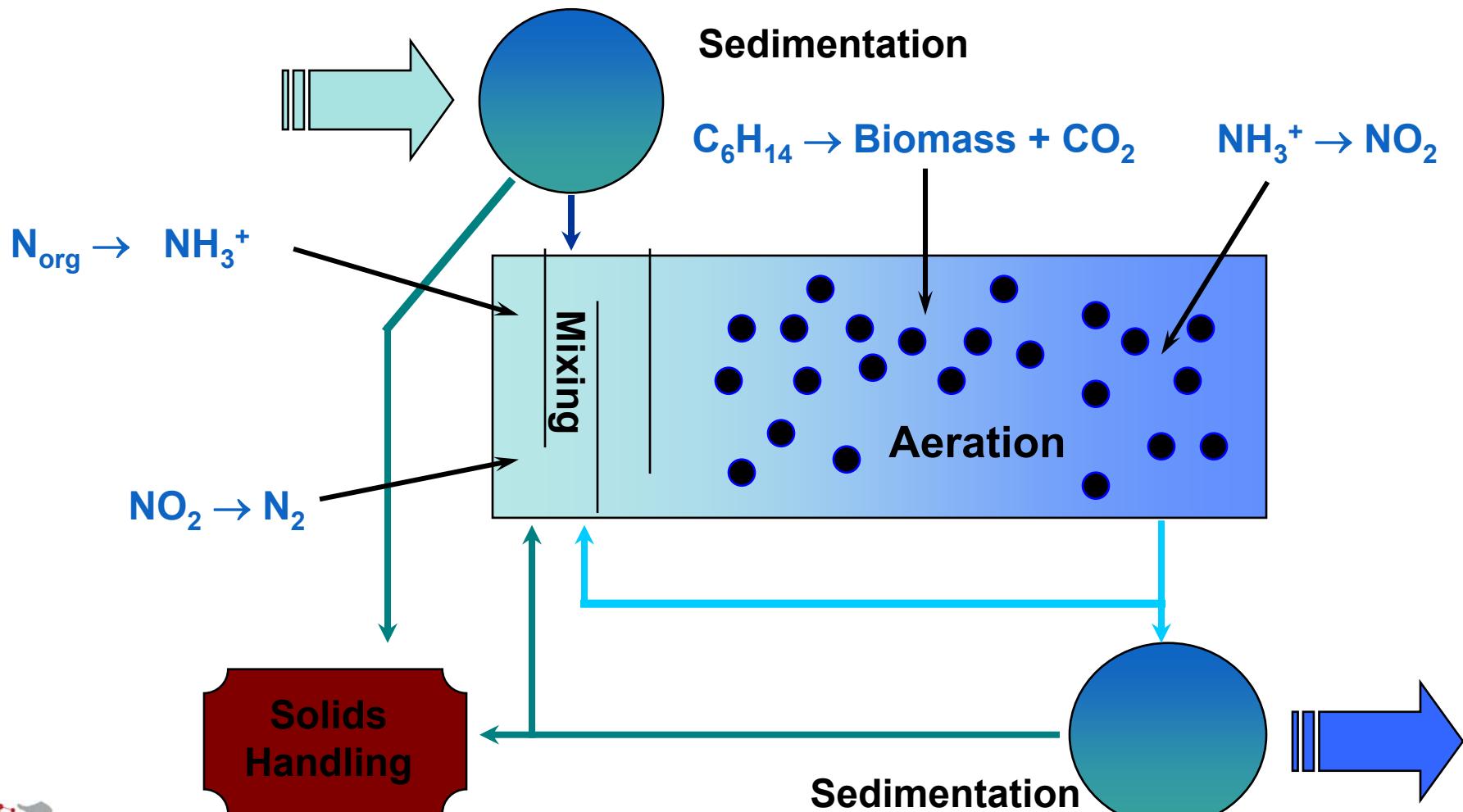


**Anaerobic sludge digestors
produce methane
(65% CH₄ - 35% CO₂)**

**On-site electricity is produced
with the methane 50% of plant
power (2.2MW)**



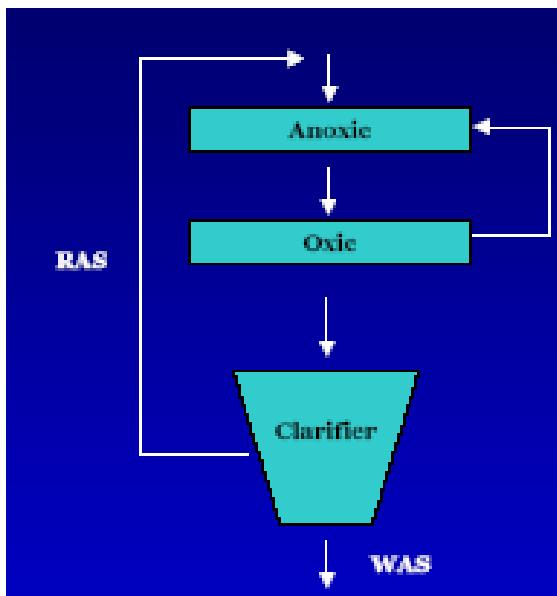
Liquid process train



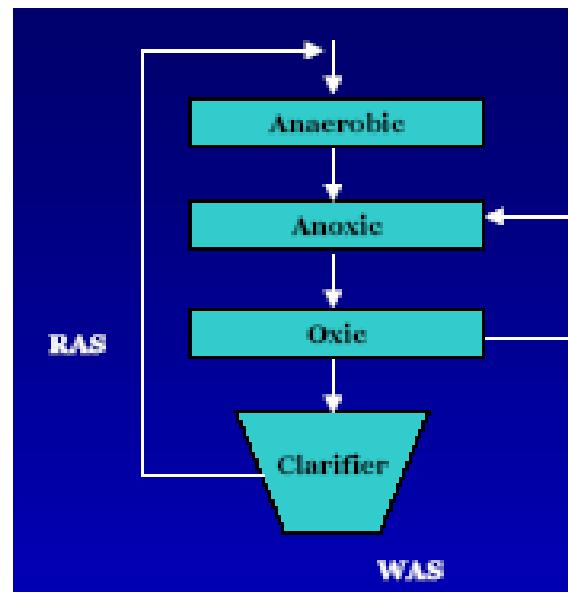


Exemplary process stages

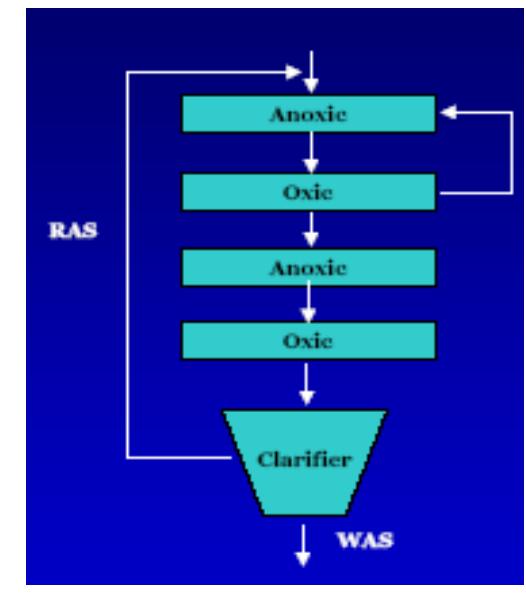
Modified Ludzak-
Ettinger (MLE Process)



A_2O



Bardenpho

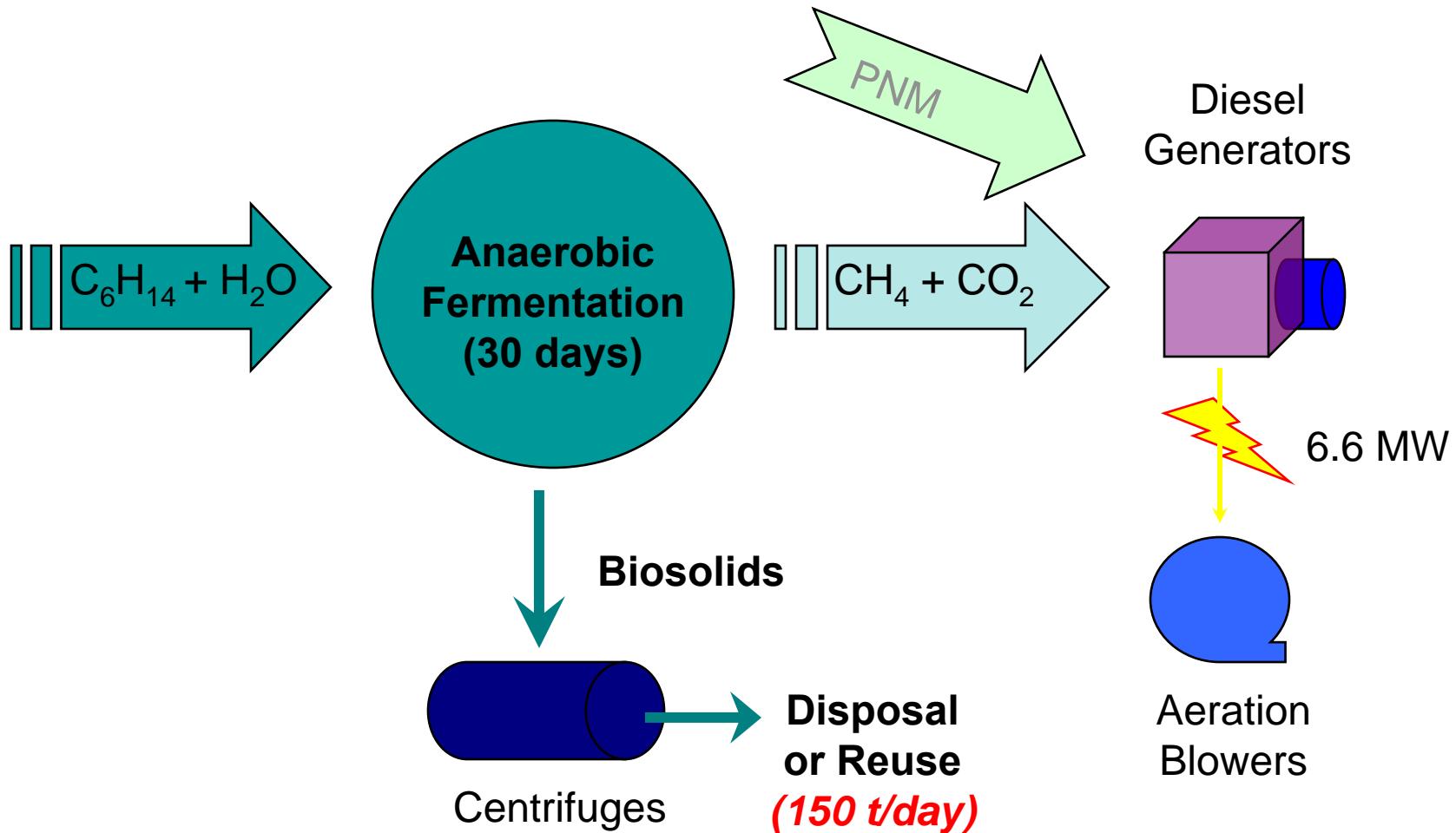


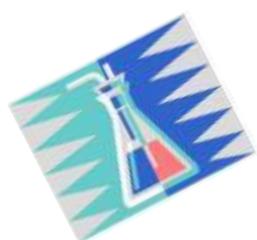
RAS = Return Activated Sludge

WAS = Waste Activated Sludge

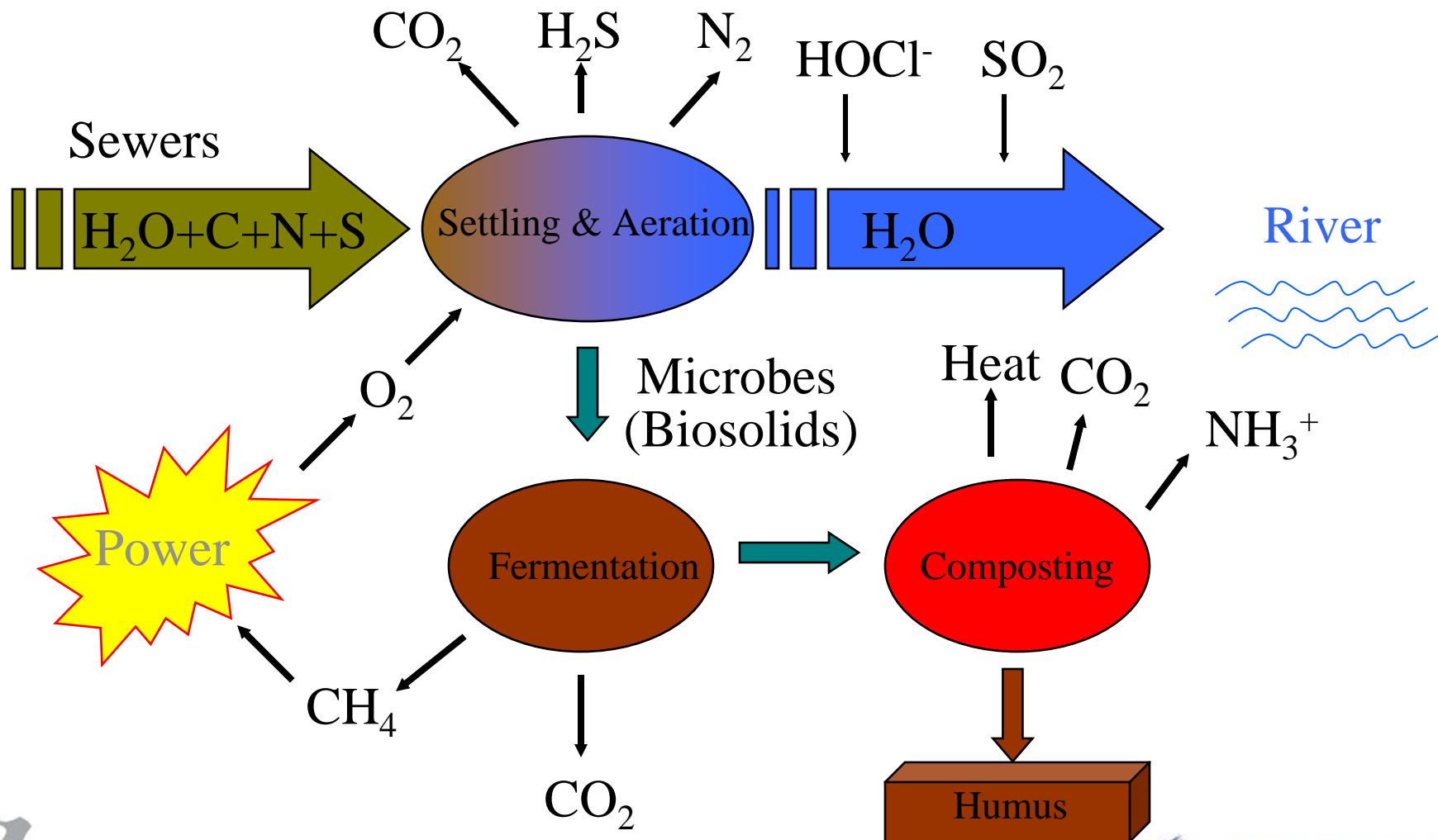


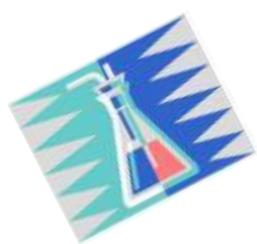
Solids handling involves anaerobic conditions





A Typical Process





Water reuse often uses membrane bioreactor with submerged membranes



Conventional activated sludge plant

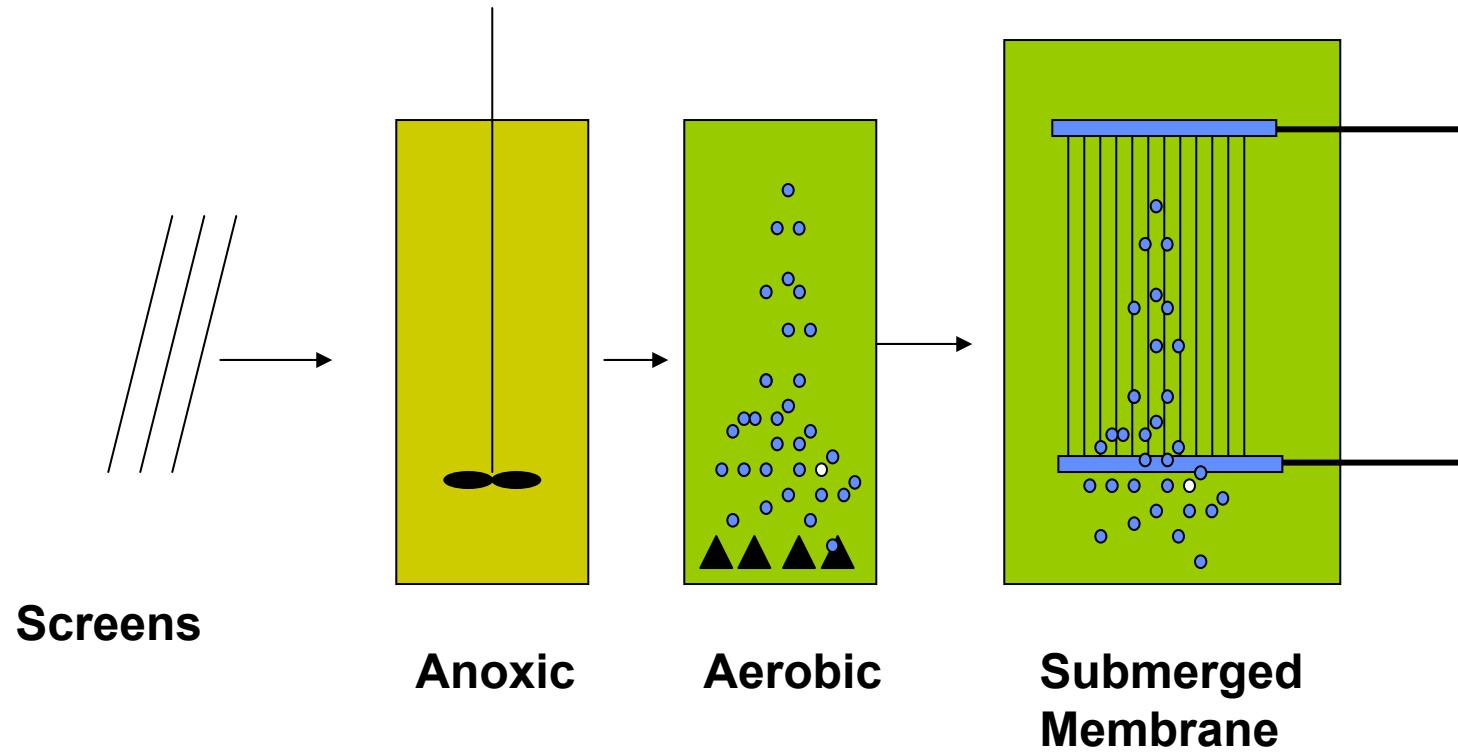


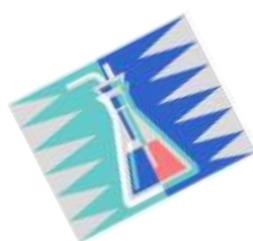
MBR membrane cassette

- Uses submerged hollow fiber membranes
- High Solids Retention Time membrane bioreactor

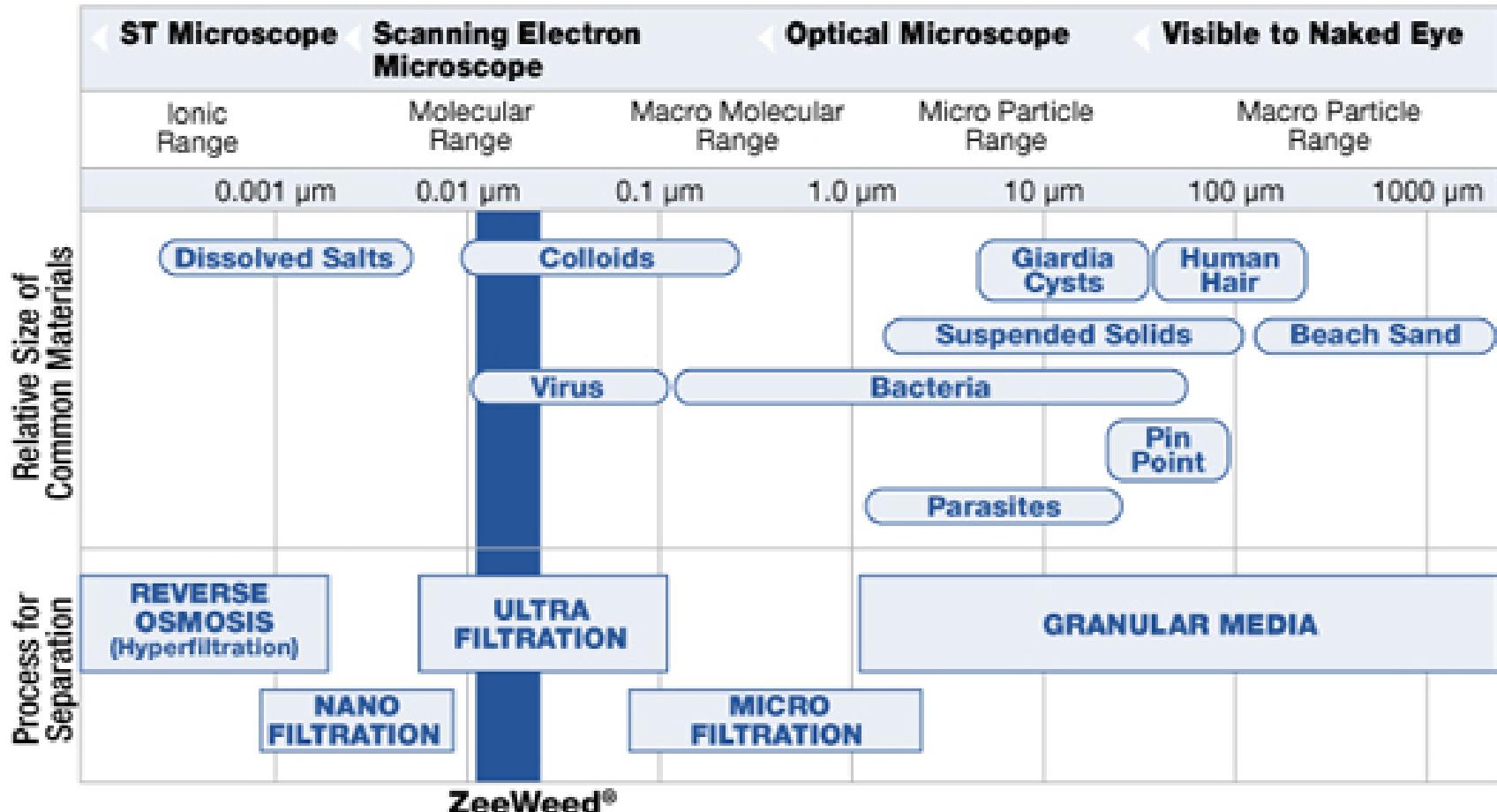


Membrane bioreactors offer small size, high rate of reaction for satellite WW

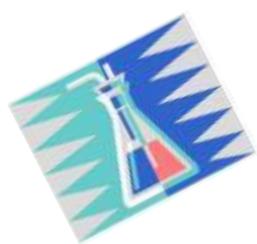




Membrane separation spectrum



Source: Zenon Membranes



Screen before membrane bio reactor





Kubota MBR pilot plant



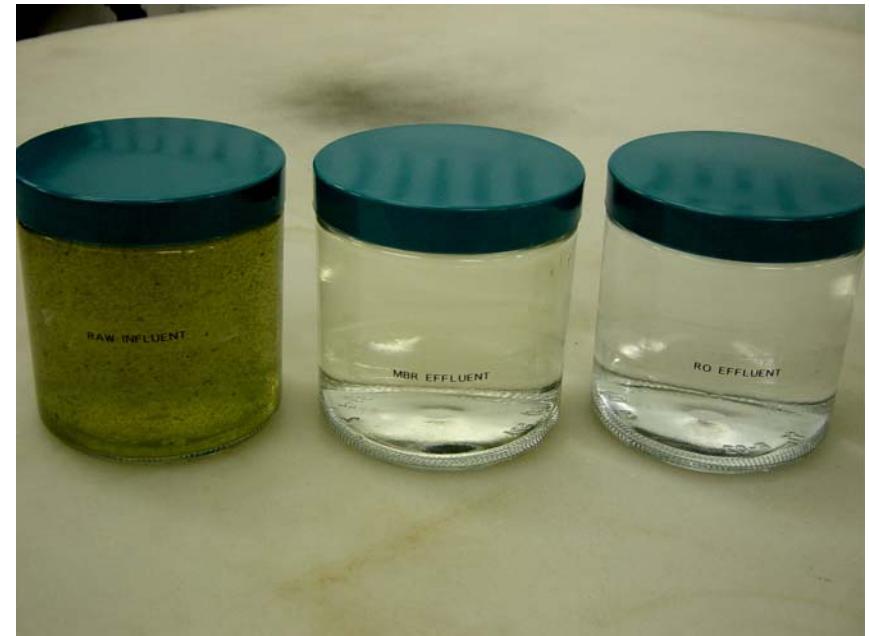


Raw feed and MBR product

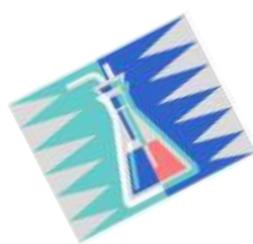




Reverse osmosis after MBR makes water suitable for groundwater recharge



RO treated water is better than most surface water sources



Hyperion Wastewater Plant

Los Angeles 450 mgd



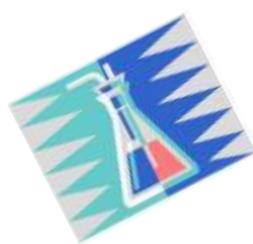
10% of discharge from this plant is sent to microfiltration plant to purify for groundwater injection



West Basin Microfiltration Plant (35 mgd from Hyperion)

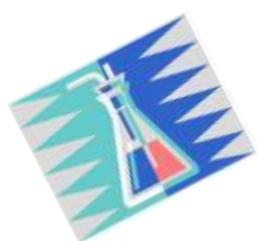


Submerged microfiltration for treated wastewater effluent



The final step is disinfection and discharge (no residual free chlorine)

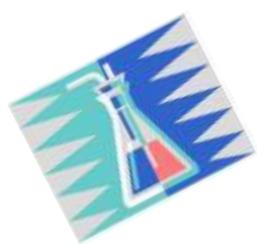
- Chlorination to kill the remaining pathogens
 - $\text{Cl}_2 \rightarrow \text{HOCl}$
- Dechlorination to remove chlorine
 - $\text{SO}_2 + \text{HOCl} + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{H}_2\text{SO}_4$
 - $\text{SO}_2 + \text{NH}_2\text{Cl} + 2\text{H}_2\text{O} \rightarrow \text{NH}_4\text{Cl} + \text{H}_2\text{SO}_4$
- UV radiation reduces chemical needs and chlorinated products



Effect of wastewater on disinfection

	Chlorine	Ozone	UV
BOD,COD,TOC	Chlorine demand	Ozone demand	Little effect
Oil and grease	Chlorine demand	Ozone demand	May block light
Nitrite	Forms NDMA	Oxidized	No effect
Nitrate	Forms chloramines	Reduce O ₃ effectiveness	No effect
Iron and Manganese	Oxidized	Oxidized	May block light
Forms disinfection byproducts	Yes	Yes, but nonchlorinated	No

Source: Wastewater Engineering- Metcalf & Eddy



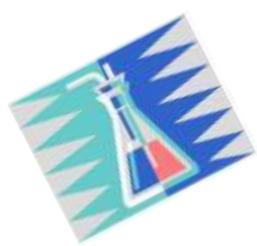
Satellite and on-site waste disposal

Satellite facilities are mid scale sewage treatment plants that treat waste near the point of generation

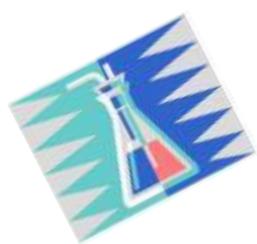
- **Lagoons**
- **Aeration ditches**
- **Trickling filters**
- **Membrane bioreactor**

On-site waste disposal is **septic tank system with drain field**

- **Provides low cost alternative**
- **Can be very effective**
- **Need little maintenance (but maintenance is important)**



Water Treatment Activity



Break



Introduction to Membranes

- Low pressure membranes
 - Ultrafiltration
 - Microfiltration
- High pressure membranes
 - Nanofiltration
 - Reverse osmosis
- Membrane fouling
 - Mineral scaling
 - Biofilm formation



Plate and frame membrane module

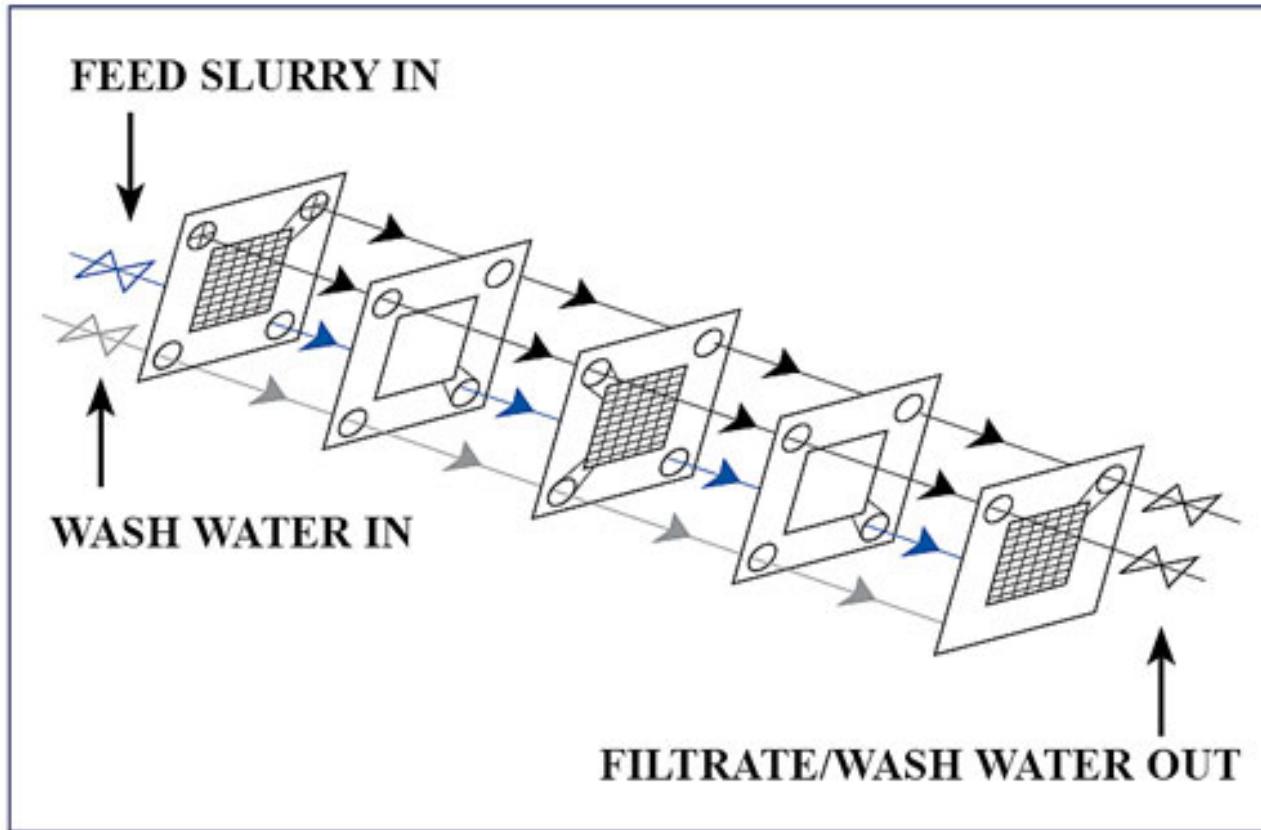
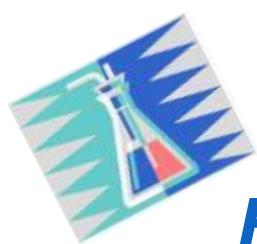
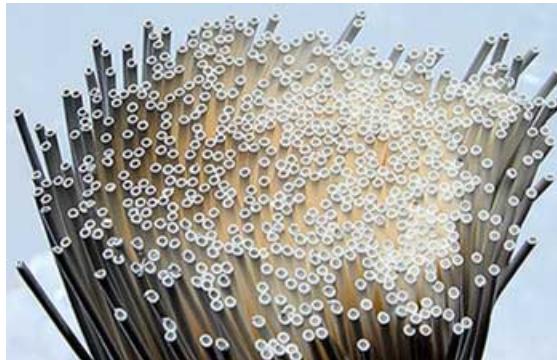


Diagram of flow path through the plate and frame filter.



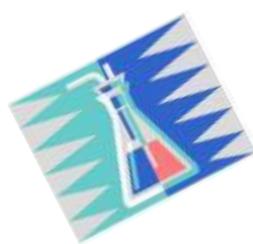
Hollow fiber units consist of tube bundles



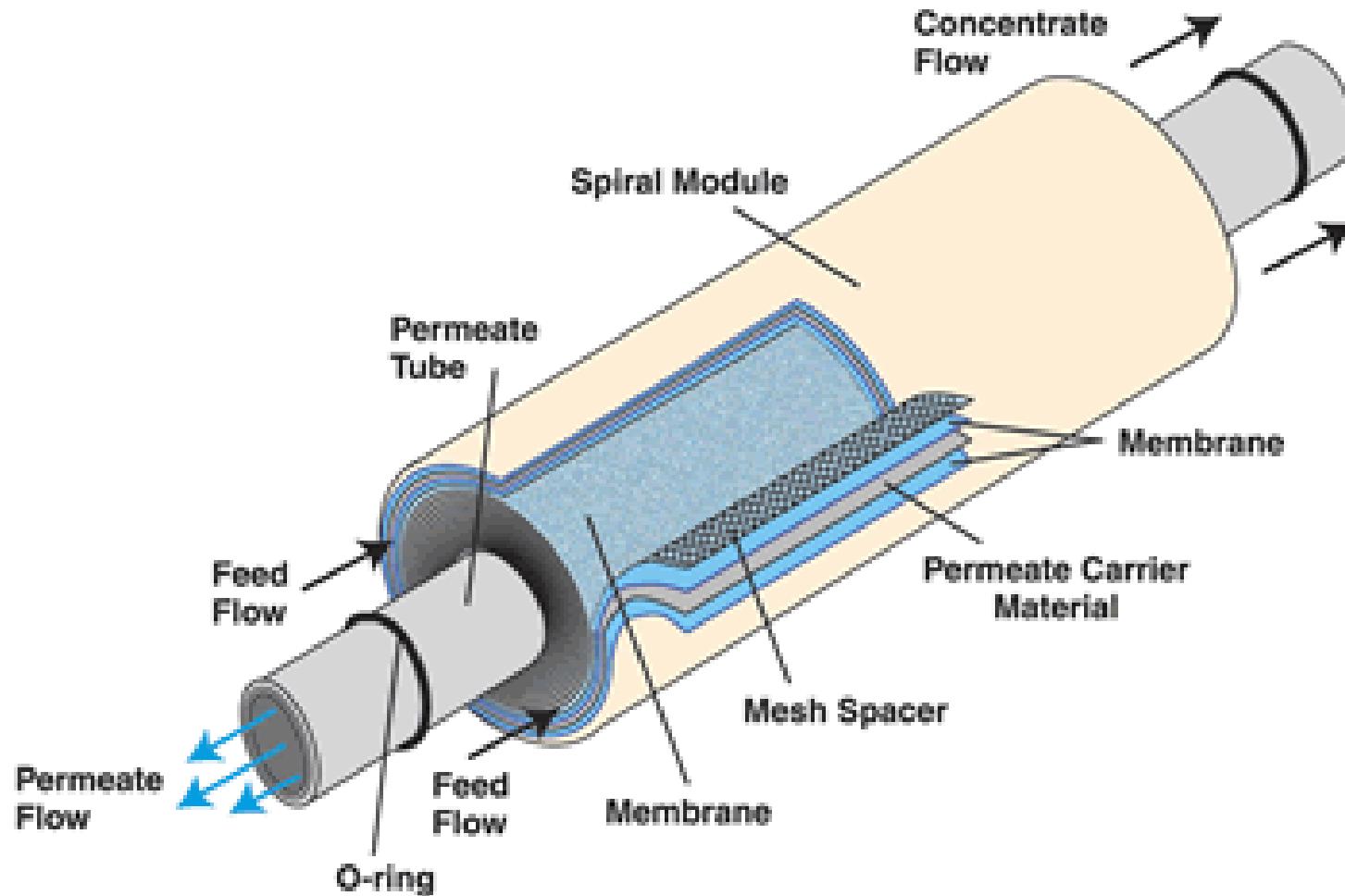
**Pressurized
in housing**

**Submerged
in cassette**





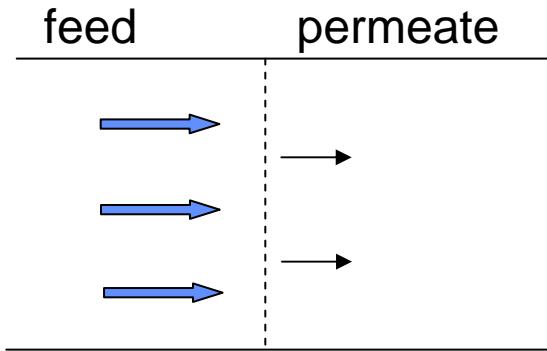
Spiral wound membrane has multiple flat sheet “leafs”



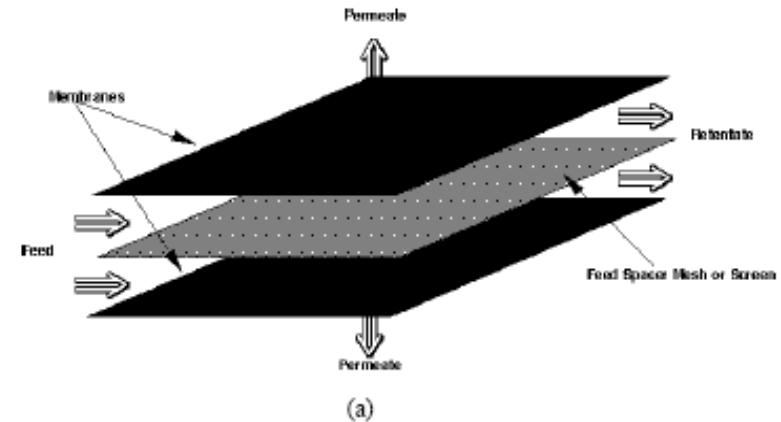


Three configurations: hollow fiber-spiral wound and plate and frame

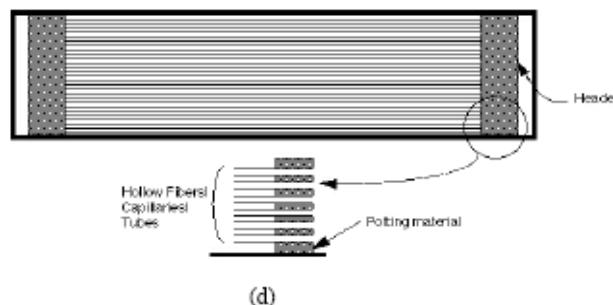
Dead-end membrane operation



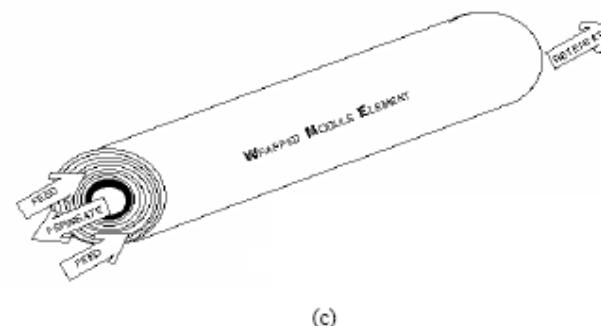
Cross-flow membrane operation



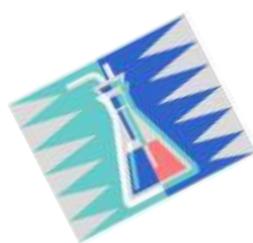
Typical membrane module construction:



Hollow fiber membrane module

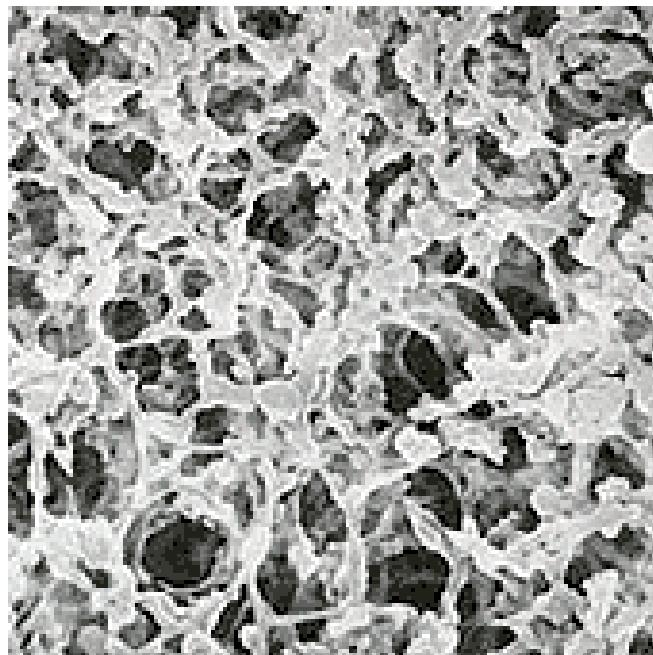


Spiral wound membrane module



Low pressure: porous membranes microfiltration, ultrafiltration

- Mean pore size ~ size rating of filter (.01 -10 micron)



Photos courtesy of
the American
Membrane
Technology
Association

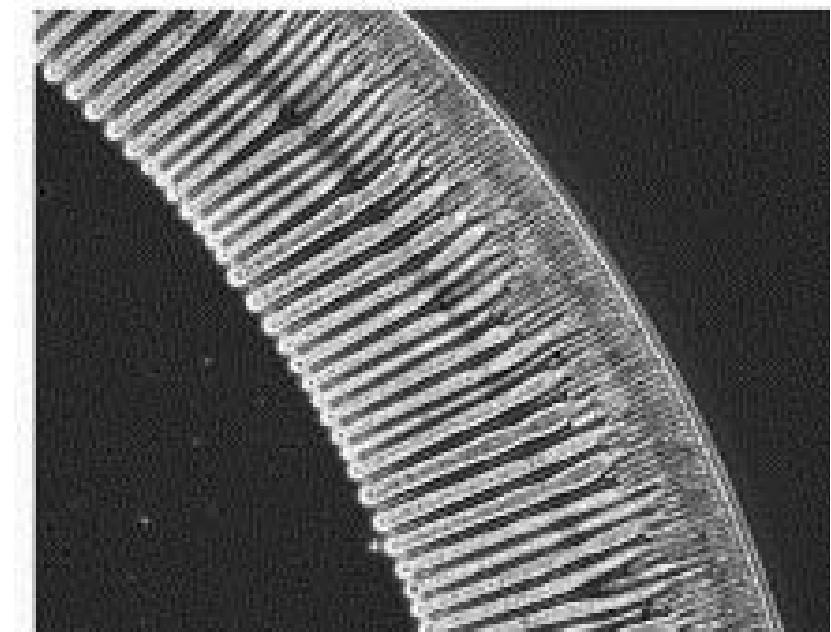
Low Pressure Membranes can be Backflushed



Hollow fiber technology

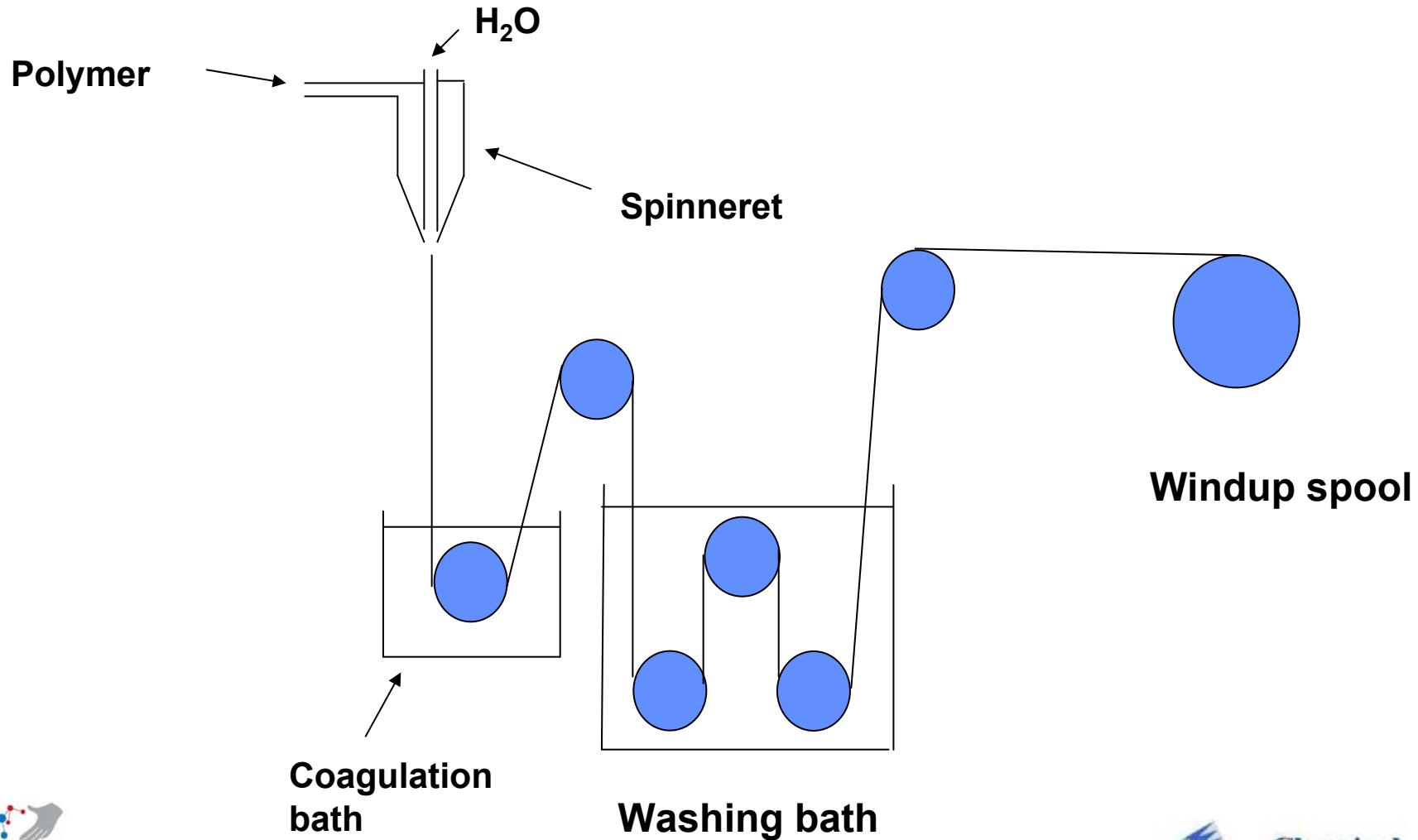
Two flow regimes in hollow fibre MF

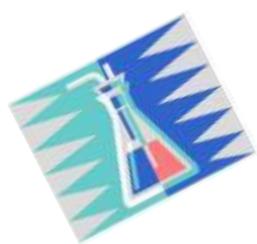
- inside-out:
 - water flows through a concentric channel or lumen
 - allows good control over module hydrodynamics
- outside-in:
 - more difficult to control flow channeling and/or dead-end zones
 - more difficult to flush the particles from the module when backwashing
 - usually lower head loss through the module



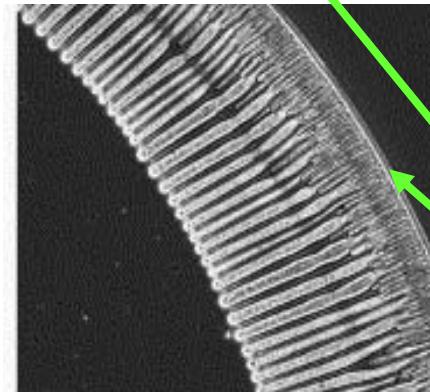
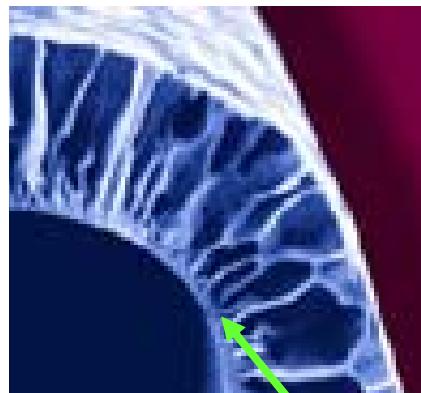


Hollow fiber membranes are made using a spinneret

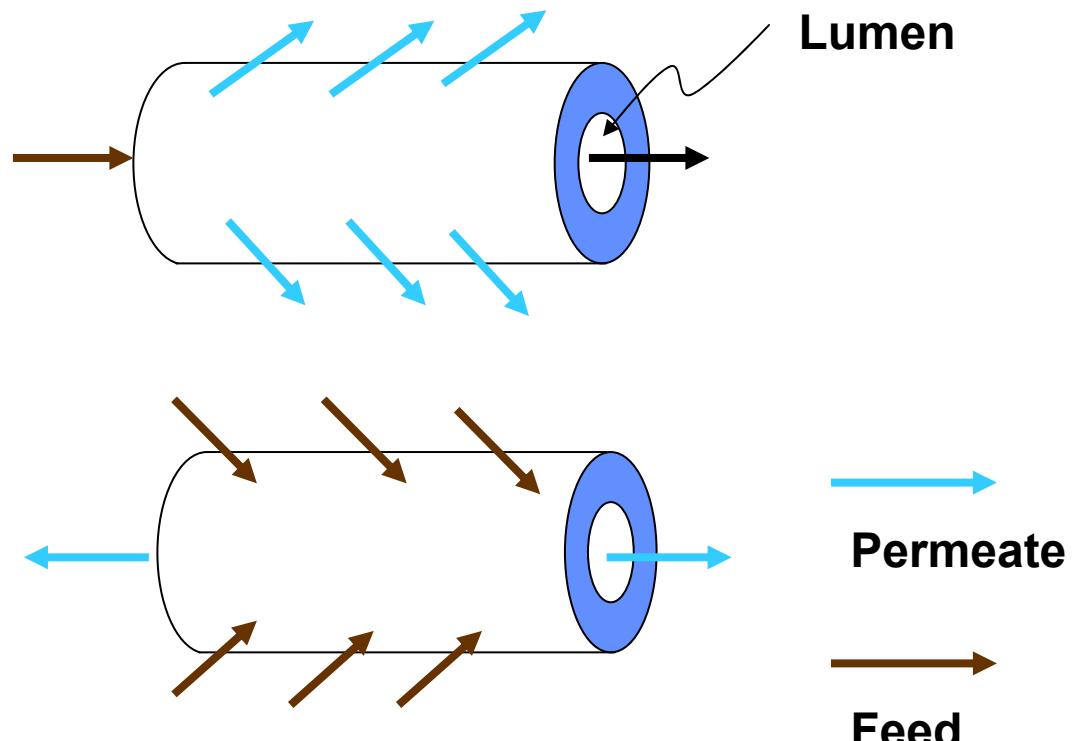




UF and MF membranes can be “inside-out” or “outside in”

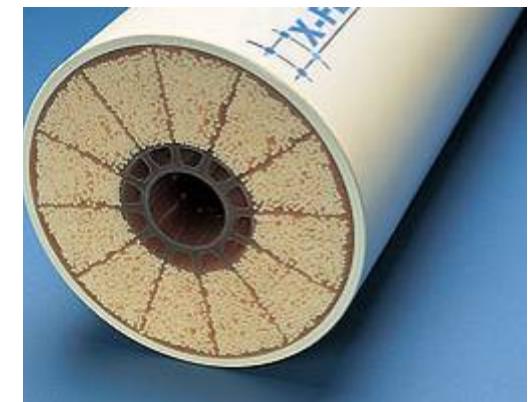
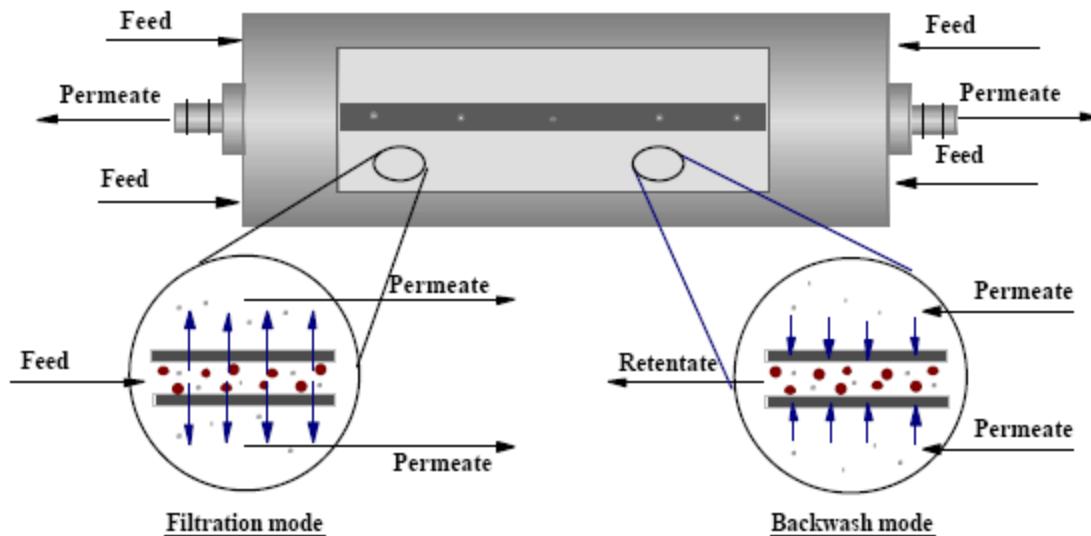


Skin



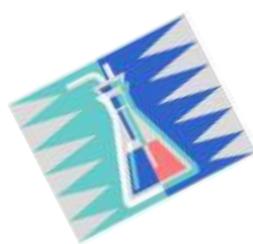


Norit – Capflow capillary membrane



Schematic view on waterflow in XIGA™ – Concept

Ultrafiltration- inside out



Zeeweed hollow fiber reinforced membrane for ultrafiltration

- Outside-in hollow fibre
- Shell-less module
- Open tank
- Gentle suction
- Air scouring
- Feed & purge at tank level

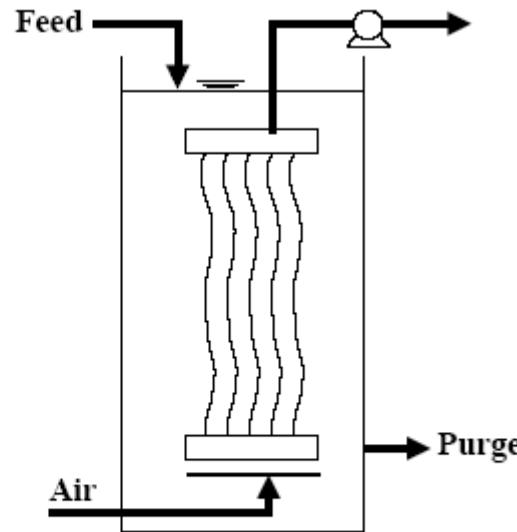
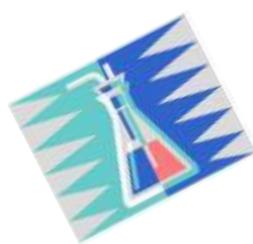


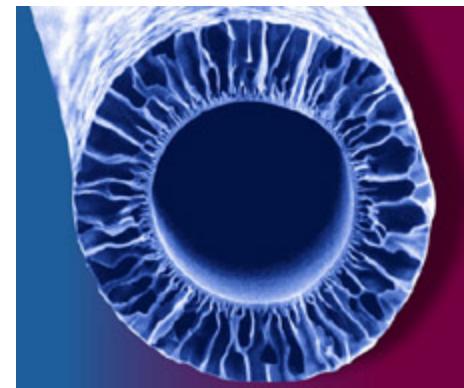
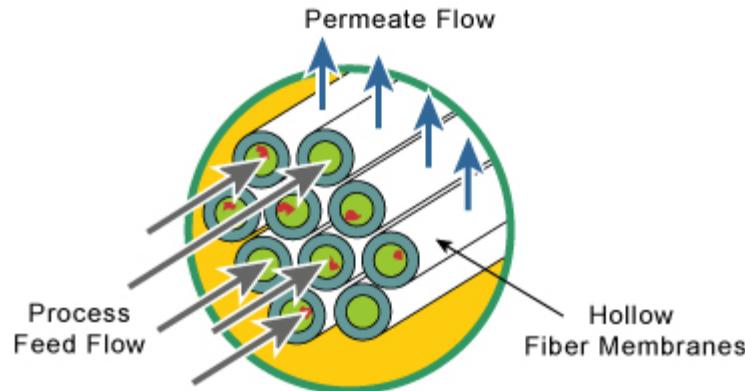
Figure 1. Principles of ZeeWeed® immersed membrane

Source : European Conference on Desalination and the Environment:
Water Shortage Lemesos (Limassol), Cyprus, May 28-31, 2001

Ultrafiltration- outside in



Koch Membrane Systems *hollow fiber reinforced membrane*



Ultrafiltration- inside out



Memcor (US Filter) submerged and pressurized systems

- Typical operating pressures
 - Pressurized systems: 20 to 30 psi
 - Submerged systems: 10 to 12 psi
- If run at the same flux and backwash interval.
 - pressurized system operated up to 22 psi
 - Submerged system operated up to 12 psi
 - Pressurized and submerged systems performance nearly identical if operating at a sound flux.
 - Results in similar cleaning intervals
 - Test has been repeated many times



Ultrafiltration - inside out and outside in

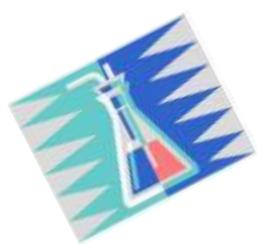


Pall Aria

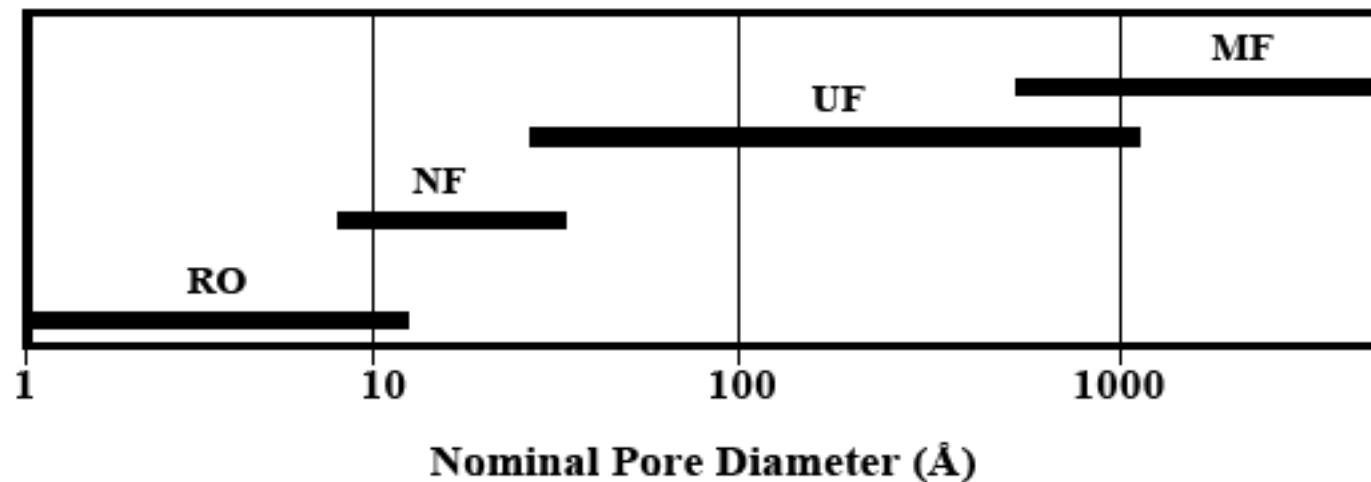
- Test effectiveness of Pall Aria system for pretreating Mediterranean seawater prior to reverse osmosis
- Long-term pilot testing at three locations
- Compare outcomes with
 - no pretreatment
 - pretreatment using coagulation with ferric chloride (FeCl_3)
 - enhanced flux maintenance (EFM) protocol with or without pretreatment



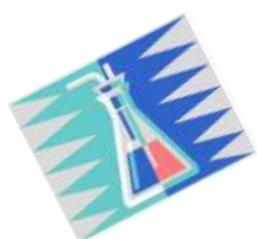
MF and UF- inside out



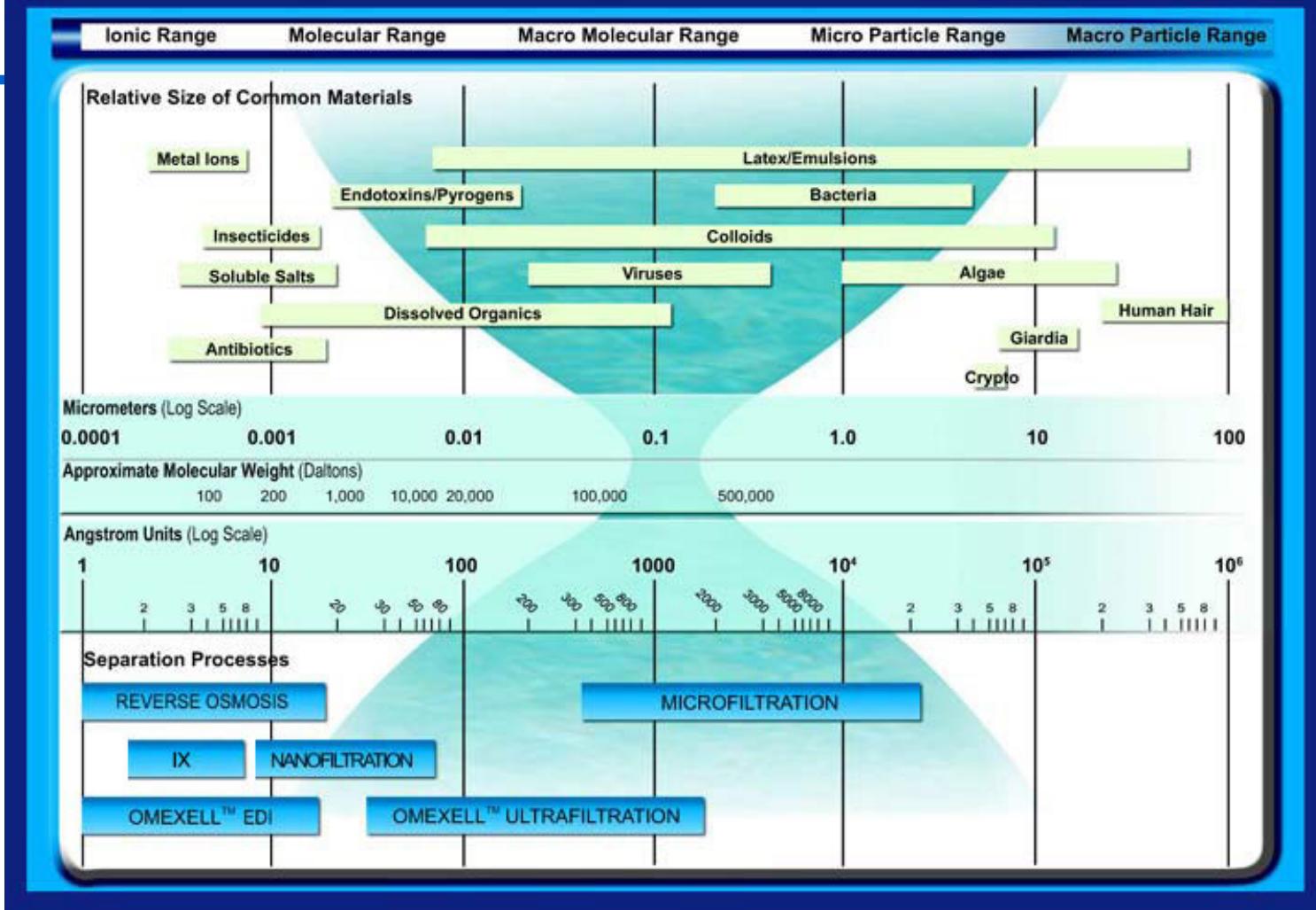
The membrane separation spectrum



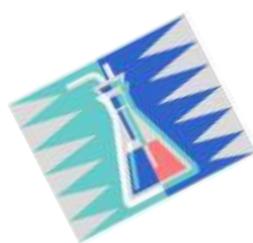
Source: Perry's Chemical Engineers Handbook



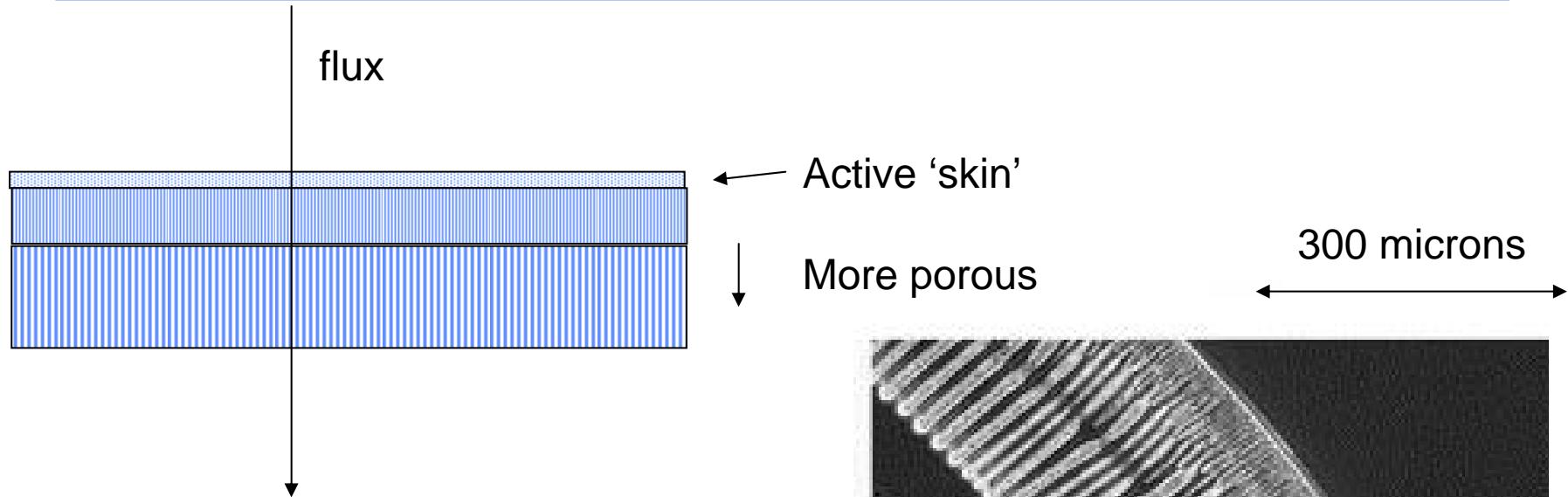
MEMBRANE FILTRATION SPECTRUM



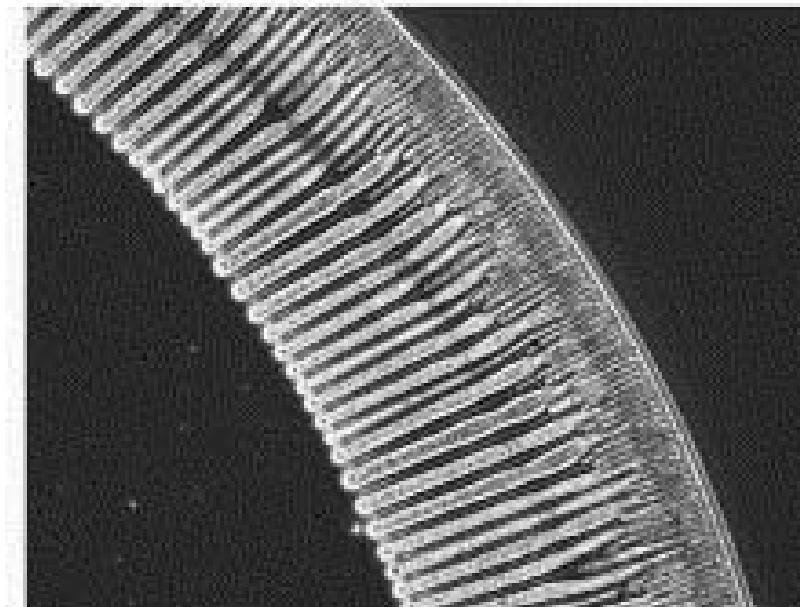
Source : DOW Water Solutions - <http://www.dow.com/liquidseps/prod/mfs2.htm>

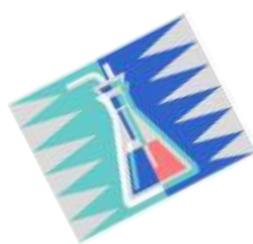


Assymmetric membranes can be made nonporous (RO) or porous (MF/UF)



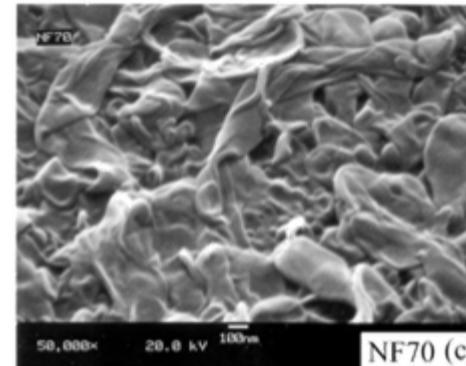
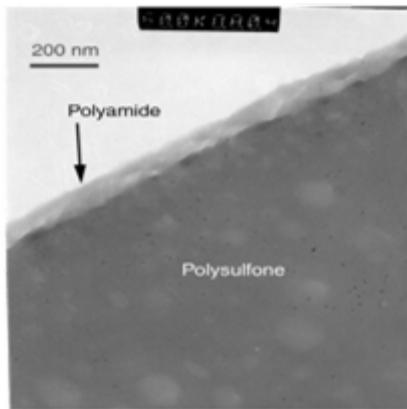
These membranes are not composites, but are cast with a skin and a more porous region. Often made by polymer phase inversion.



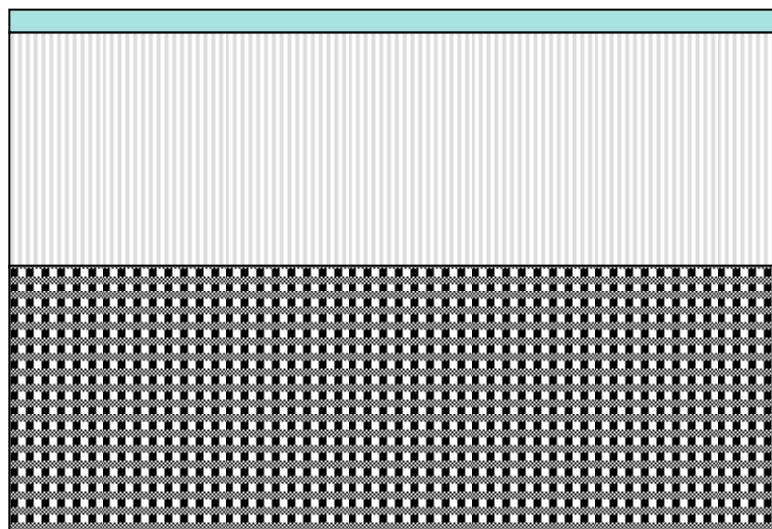


Non-porous membranes: nanofiltration, reverse osmosis-thin film composite

- thin, dense polymer coating on porous support (composites)



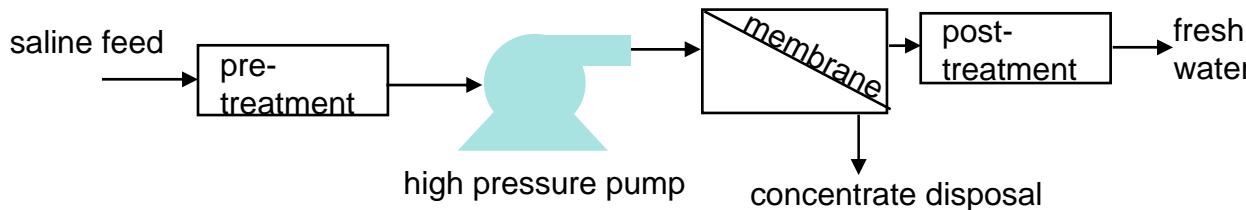
Surface morphology



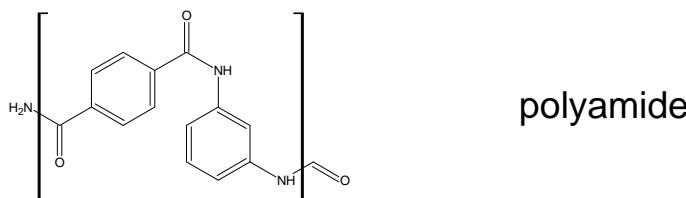
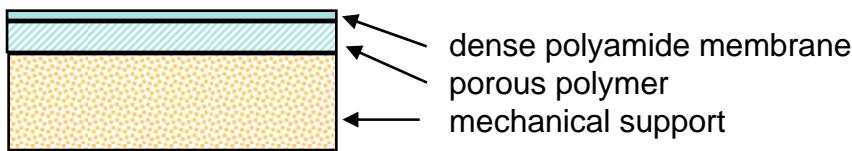
- ← Thin (100 - 200 nm) polyamide membrane
- ← Porous support (polysulfone uf membrane)
- ← Woven mechanical support



Membrane processes: reverse osmosis

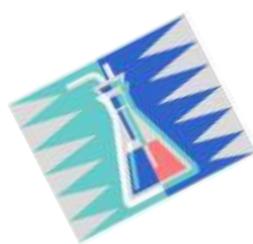


Thin film composite membrane

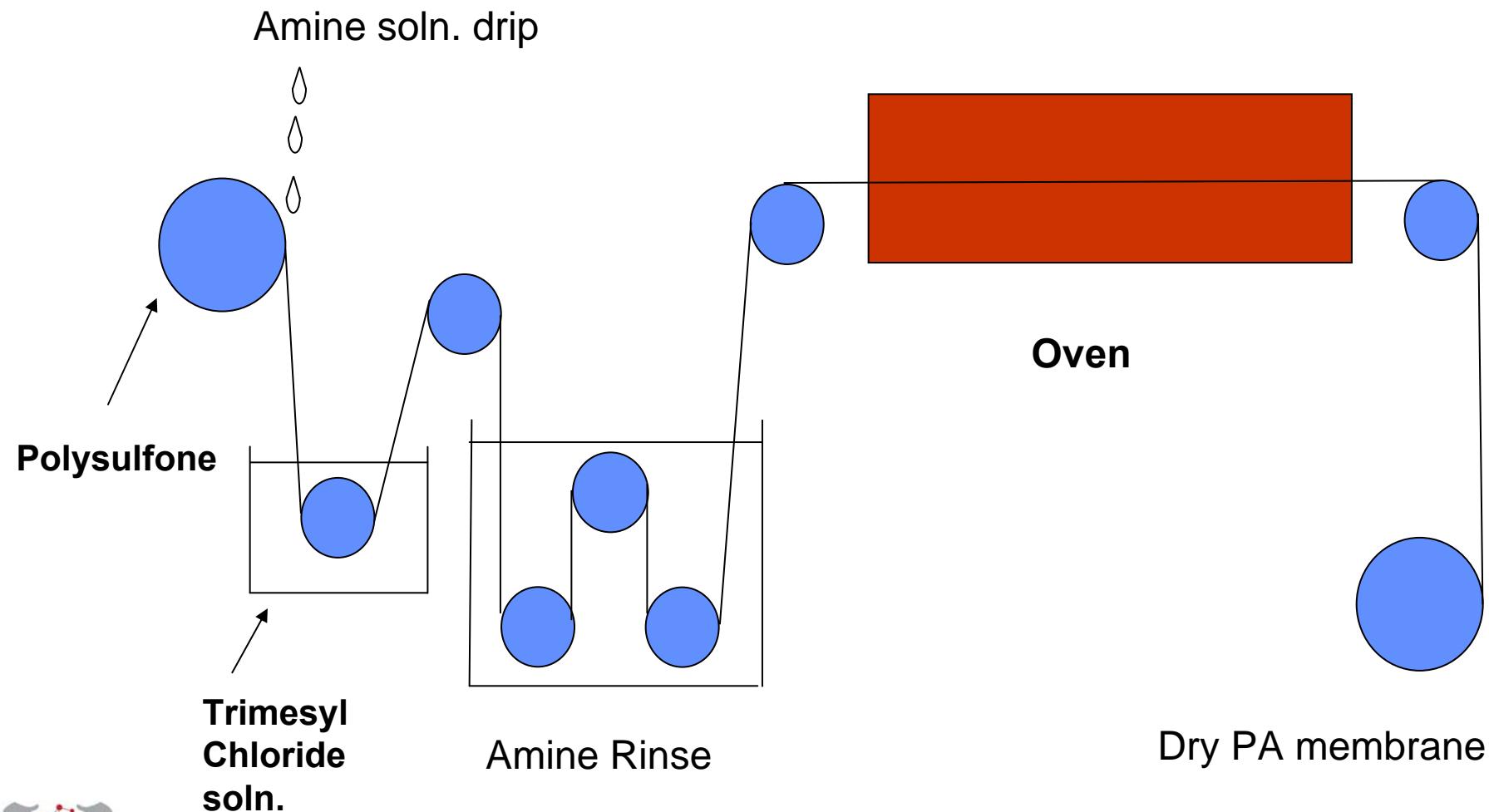


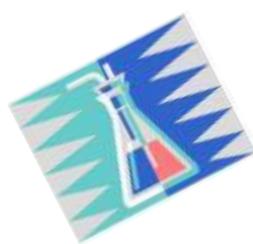
- energy use (pump) $\sim 10 - 50 \text{ kJ kg}^{-1}$
- concentration dependent
- energy recovery essential for seawater RO
- membranes susceptible to fouling; pre-treatment required
- polyamide membranes degraded by Cl_2

Tampa Bay Water - 25 mgd



Polyamide TFC membranes are made by *interfacial polymerization*

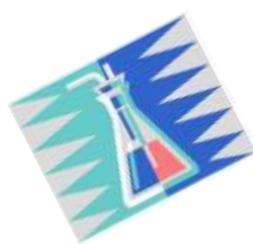




Typical RO installation: multiple spiral wound modules in series

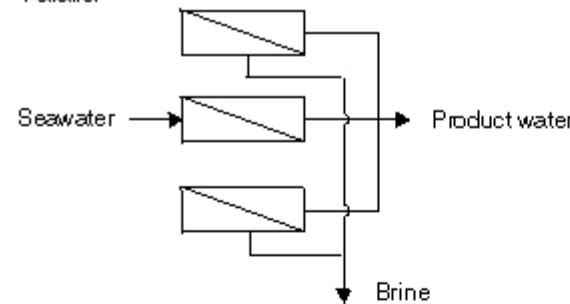


<http://www.ionics.com/technologies/ro/index.htm#>

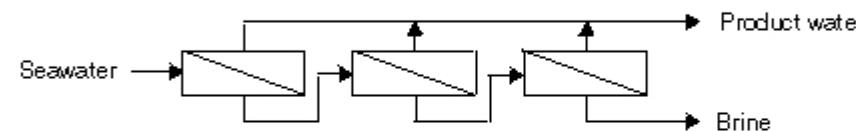


Configuration and staging of membranes

(i) Parallel



(ii) Reject series



(iii) Christmas tree

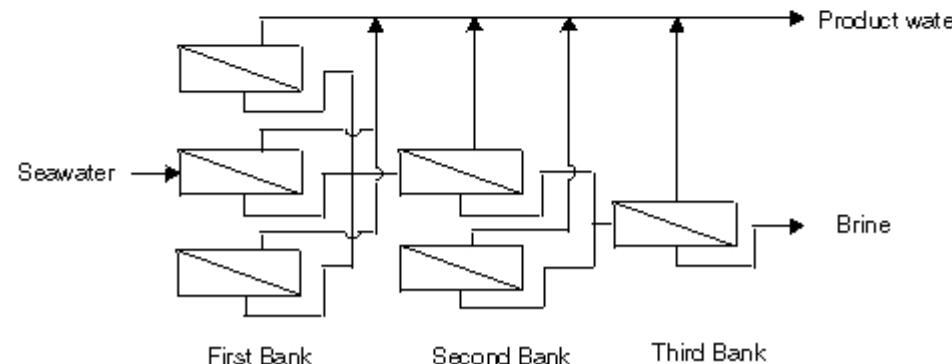
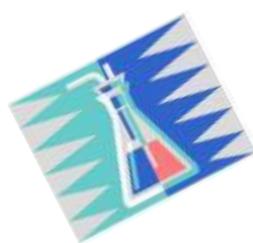
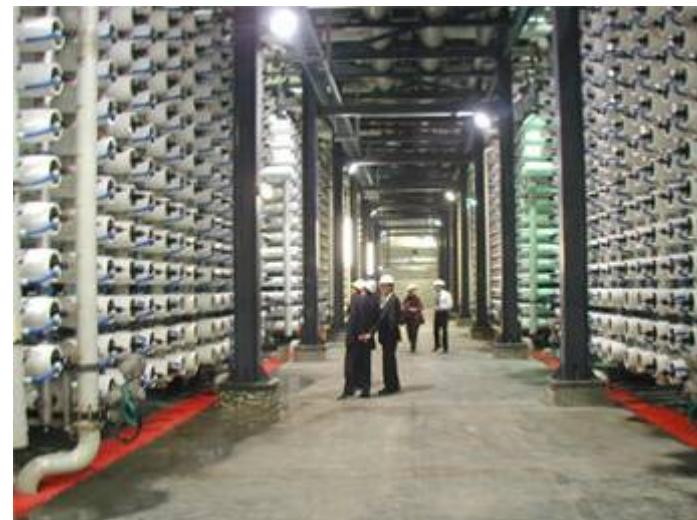


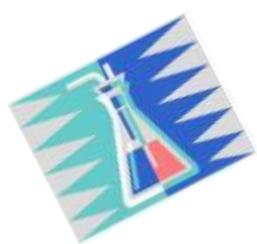
Figure 3 Arrangement of RO membrane modules



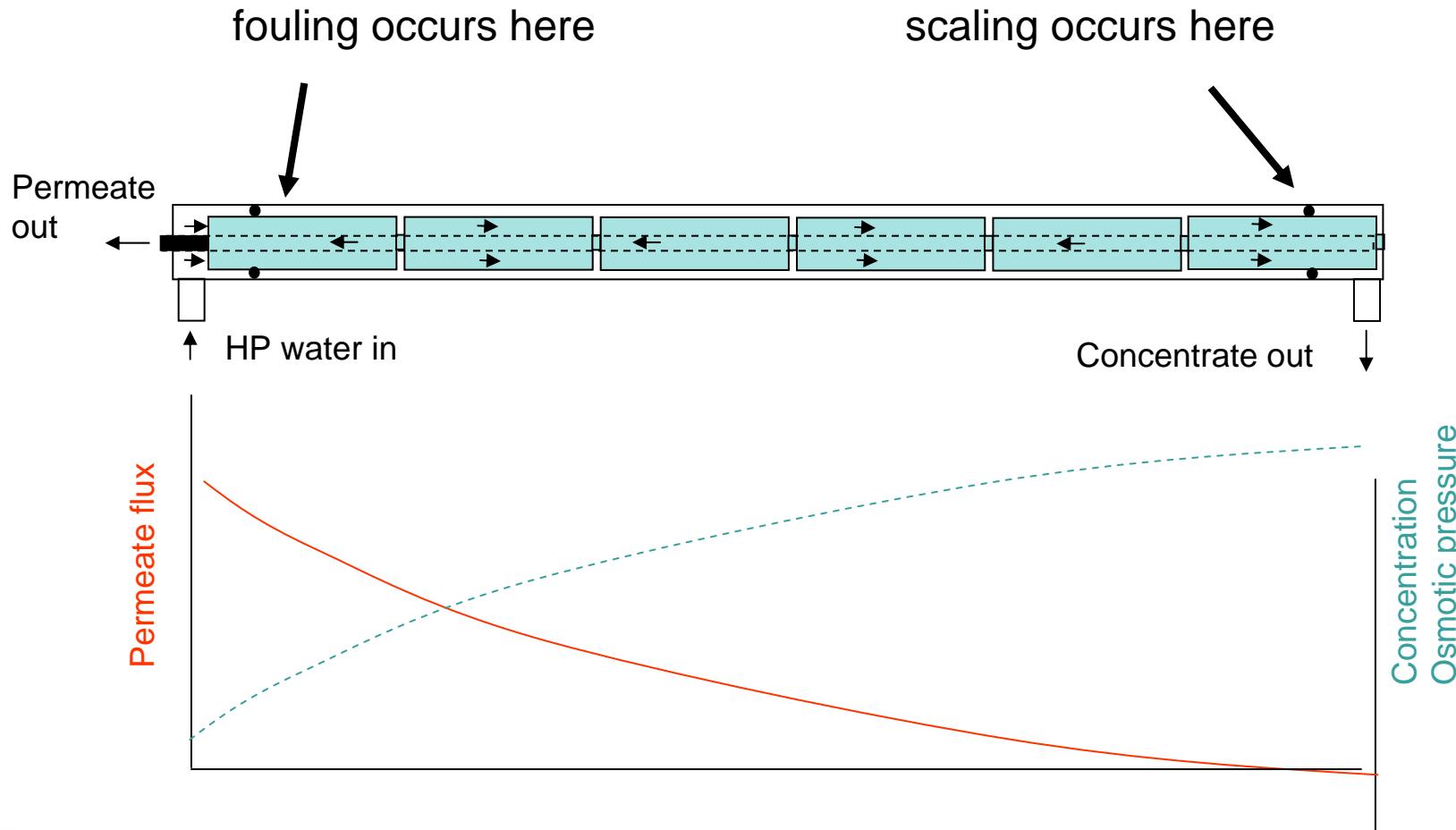
RO plants consist of membrane banks

Manufacturers: Dow-Koch-Toray-Hydranautics





Fouling is location dependent





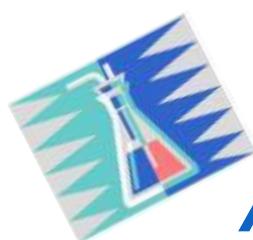
Mineral scale formation and biofouling reduce permeate flux



Source: UCLA

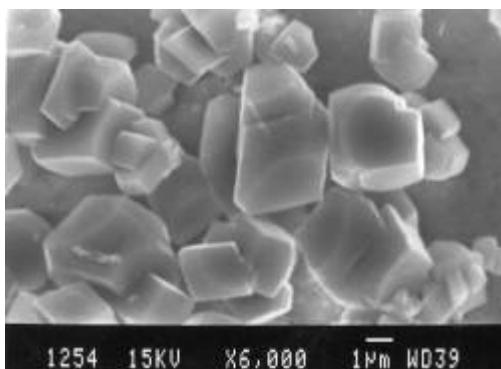


Source: Montana State University

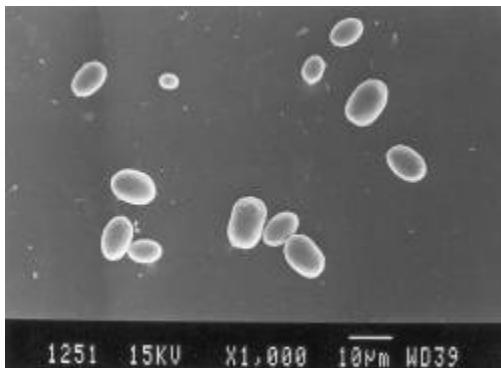


Antiscalant technology slows crystal growth

SEM micrographs of calcite precipitates

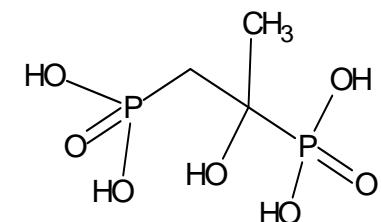


No inhibitor



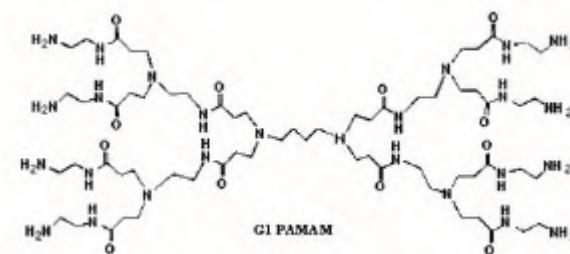
5 mg/L of a phosphonate inhibitor

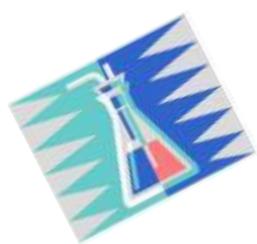
- Phosphonate (HEDP)



- Polyanion polymers

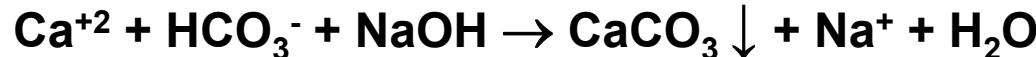
- Dendrimers





Water softening reduces membrane scaling and increase recovery (recycle operation)

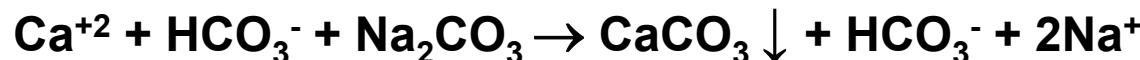
- **Caustic Soda NaOH**

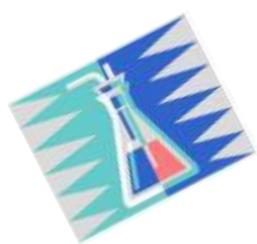


- **Lime Ca(OH)₂**



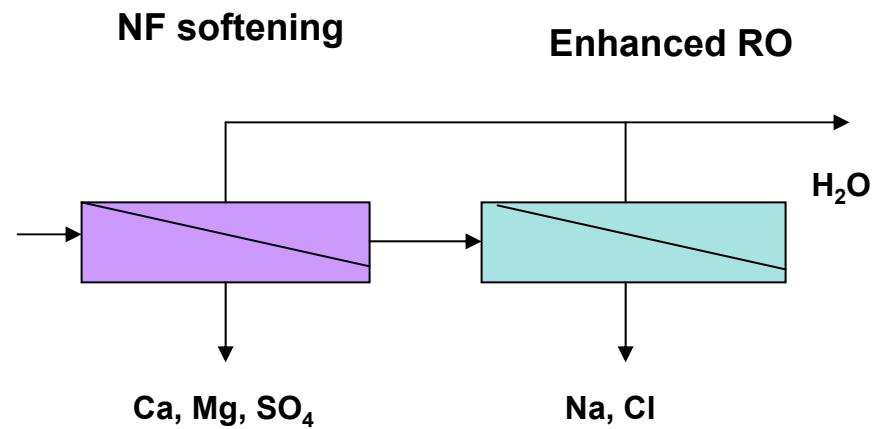
- **Soda Na₂CO₃**

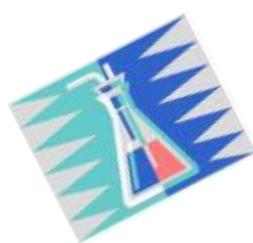




High rate nanofiltration softening

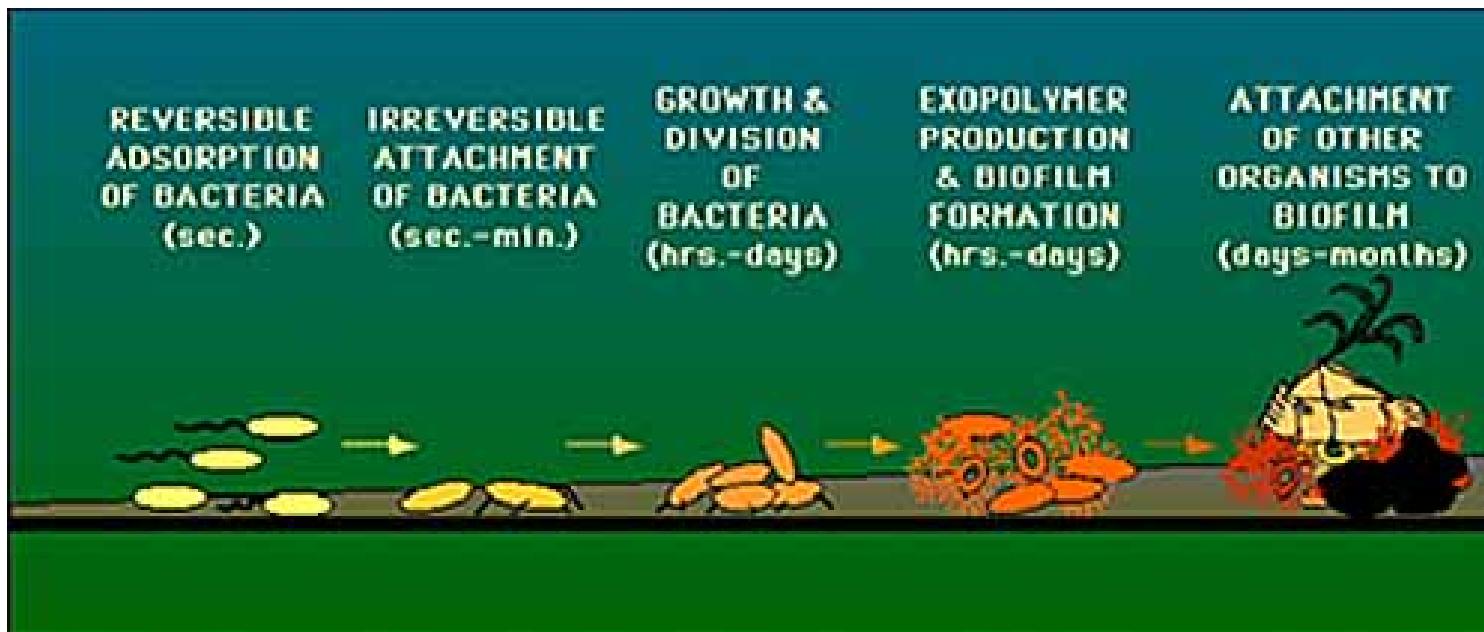
- Remove cations (Ca, Mg, Fe, Ba)
- Reduce nucleating sites for silica, while passing SiO_2
- Structure and charge of the components in solution affect NF

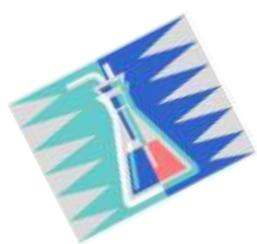




Biofouling is the largest challenge for high pressure membranes

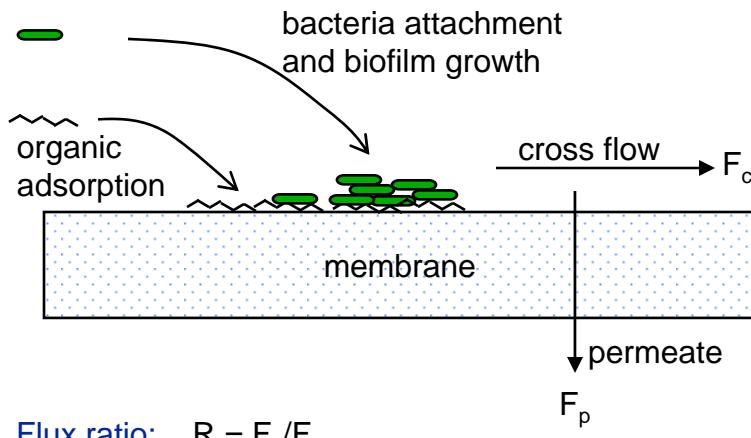
1. Inorganic/organic colloidal and suspended particles
2. Inorganic scaling (CaCO_3 , CaSO_4 , SiO_2)
3. Biofouling





Hydrodynamics and biofilm attachment

Attachment and adhesion
dependent on shear forces at
membrane surface:

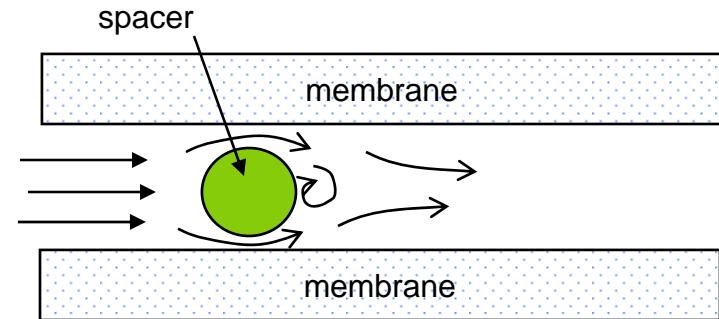


$$\text{Flux ratio: } R = F_c/F_p$$

High R: high shear force, low normal force
suppressed bacteria attachment;
low product recovery

Low R: low shear force, high normal force
high bacteria attachment, biofilm growth;
high product recovery

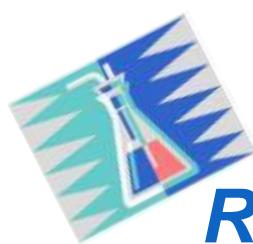
Shear forces and membrane
module construction:



- what is shear force at membrane surface?
- how does spacer design affect flow, shear forces?
- what is optimum spacer design?

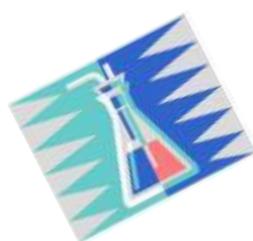
Needs:

- modeling of fluid flow, shear forces
- surfaces resistant to organic adsorption
- sensors for organic and bio content
- **measurement of fouling potential**
- biofilm prevention/remediation



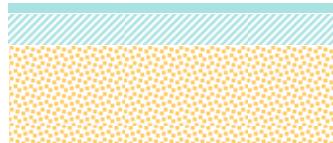
Reverse osmosis membranes - opportunities

- Reverse osmosis membranes suffer from fouling by biofilms
- Disinfection with oxidizing agents can destroy the TFC polyamide membranes
- New Research is aimed at making a chlorine tolerant RO membrane



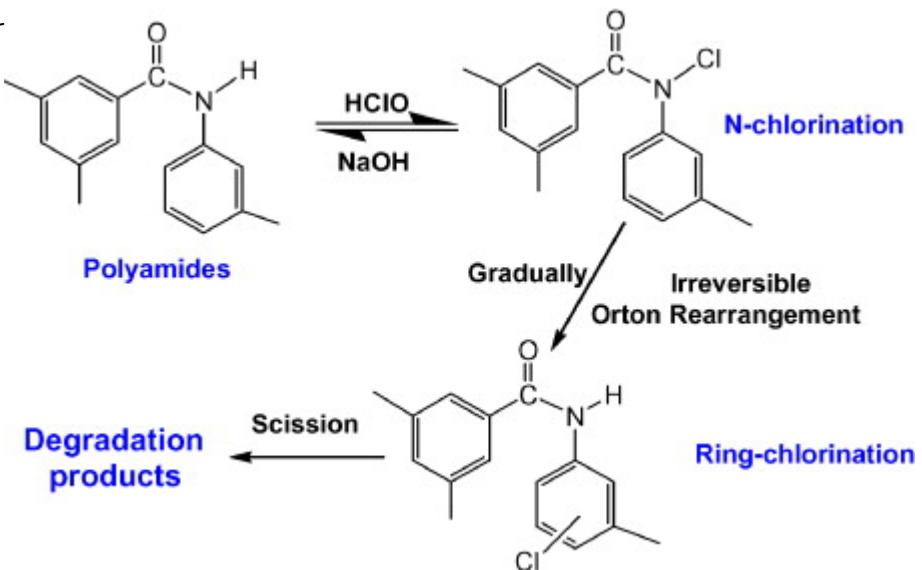
Membrane degradation by chlorine

Thin film composite membrane



dense polyamide membrane
porous polymer
mechanical support

Membrane degradation
proceeds by chlorination
of the amide followed by
ring chlorination



Journal of Membrane
Science, Volume 300, Issues
1-2, 15 August 2007, Pages
165-171



Chlorine tolerant membranes are being studied

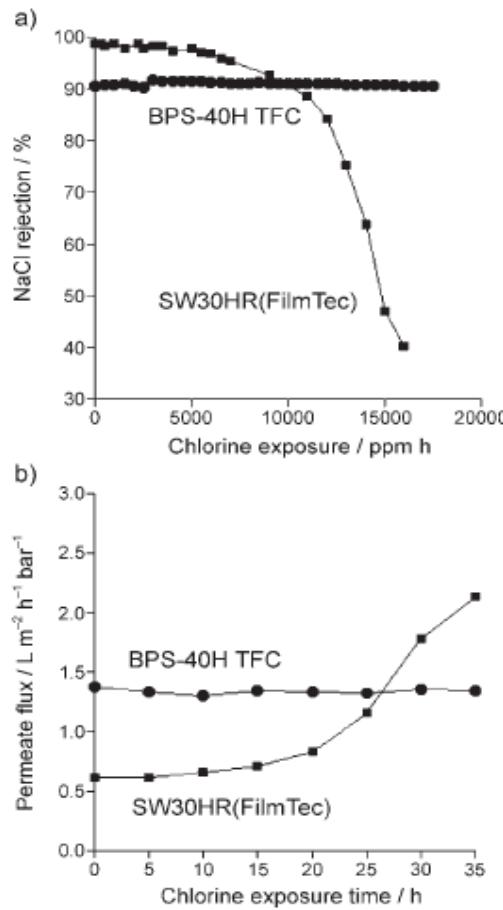


Figure 4. Effect of chlorine exposure on a) NaCl rejection and b) permeate flux of thin-film composite membranes of disulfonated copolymer (BPS-40H) at 25 °C. Feed pressure 27.6 bar, feed flow rate 3.8 L min^{-1} ($\text{Re}=4683$), feed composition 2000 ppm NaCl, cross-flow cell, pH 9.5, chlorine concentration = 500 ppm.

Angew. Chem. 2008, 120, 6108 –6113

A new polymer formulation holds promise as a chlorine tolerant RO membrane



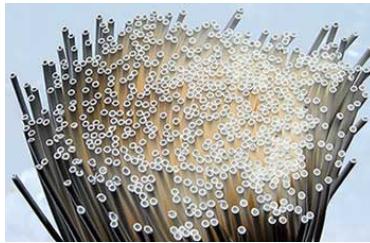
Summary of membranes for water treatment

	Membrane form	Polymer	Membrane pore (Å)	Separation mechanism	Back flushable	Chlorine tolerant	Use
MF	Hollow fiber	PES/PVDF/PP	800-5000	MW size	yes	yes	Turbidity-pathogens
UF	Hollow fiber	PES/PVDF/PP	50-1100	MW size	yes	yes	NOM-pathogens-colloids
NF	Spiral wound	TFC-PA	10-60	MW surface charge	no	no	Softening-NOM removal-desalination
RO	Spiral wound	TFC-PA	1-10	MW surface charge	no	no	Desalination

**PES-Polyether sulfone, PVDF-Polyvinylidene Fluoride, PP-Polypropylene, TFC-PA – Thin film composite with polyamide skin.
(Some older RO membranes are composed of cellulose triacetate)**

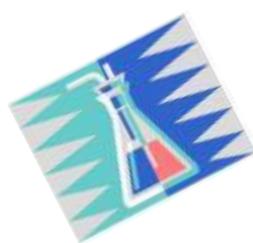


Membranes have revolutionized water treatment





Lunch



Introduction to Desalination

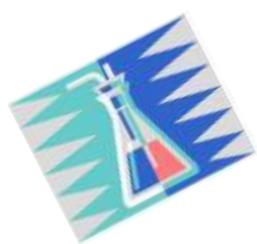
Thermal

- **Multiple Effect Distillation (MED)**
- **Multistage Flash (MSF)**
- **Vapor compression (thermal and mechanical)**
- **Solar**

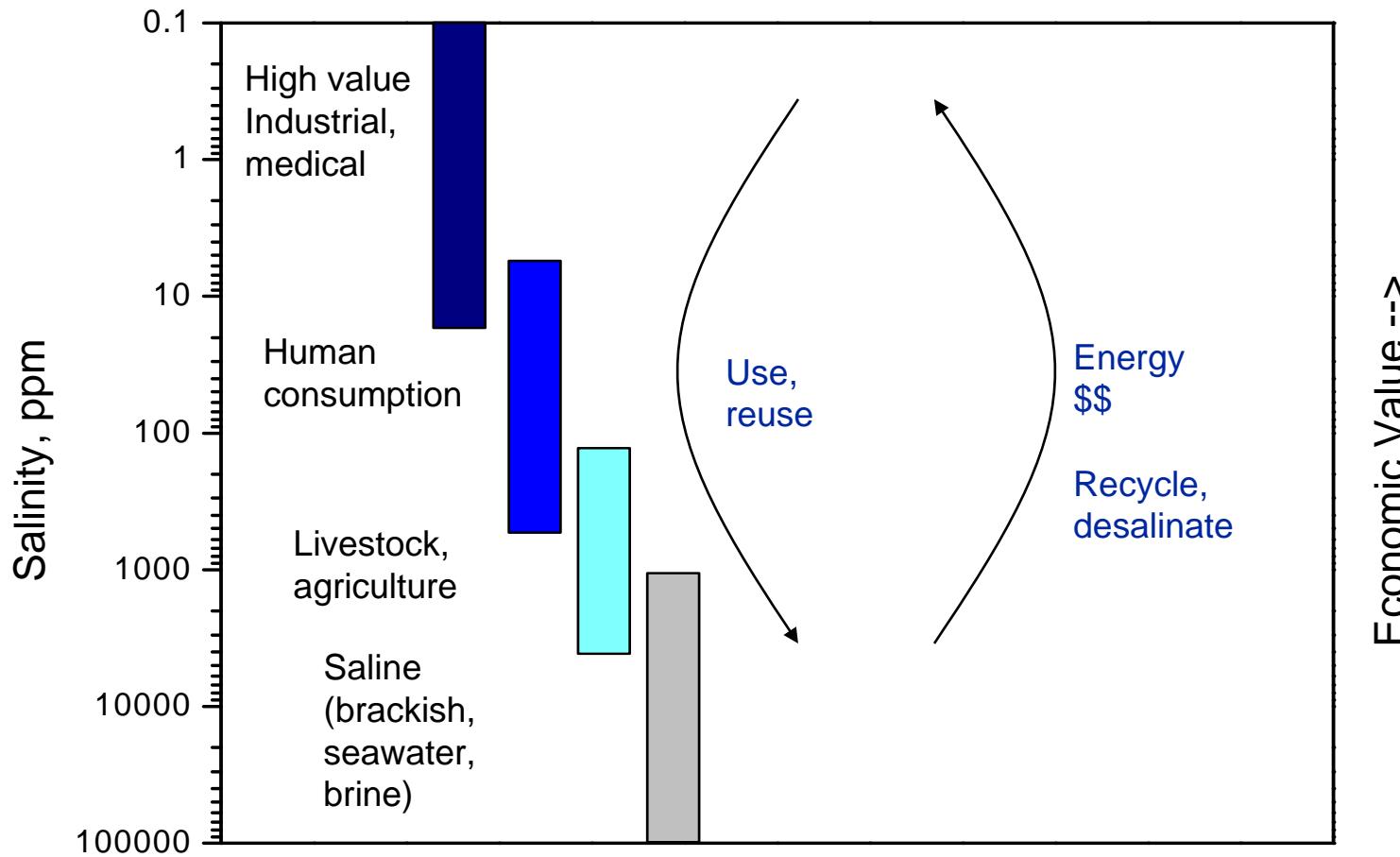
Electrodialysis/ Electrodialysis reversal

Reverse Osmosis

- **RO membrane and process basics**
- **Scaling and biofouling**
- **Energy recovery - Pelton wheels, turbines, work exchangers**
- **New RO process configurations**
- **Post-treatment - remineralization**
- **Boron removal**



Water is infinitely recyclable - at a cost



Cost of recycling < economic value of the water?



Salt

chemicals that dissolve in water to form ions:



measures:

- concentration = mol/liter (M) 1 mol = 1 molecular weight in grams
e.g. NaCl = 23 + 35 = 58 g
- weight % or ppm = weight solute/weight of water
e.g. 1 M NaCl = 58 g NaCl / 1000 g H₂O = 5.8% = 58000 ppm

Salinity Levels:

Seawater: ~35 g/L (0.6 M)

Brackish: ~1-5 g/L (0.08 M)

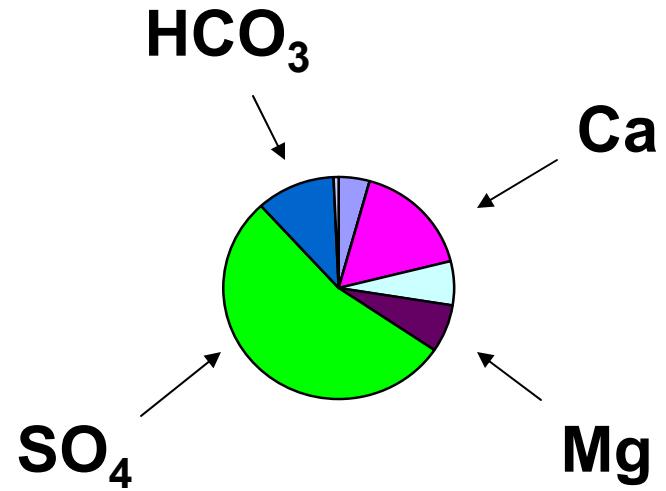
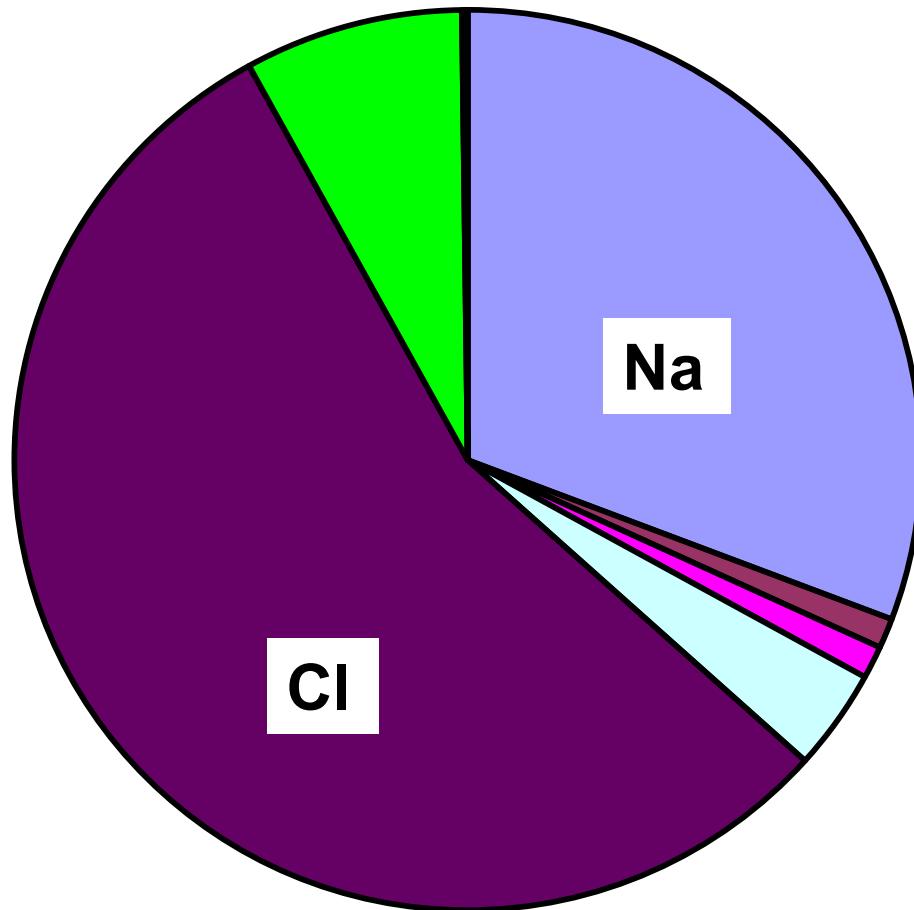
Potable: <0.5 g/L (0.008 M)

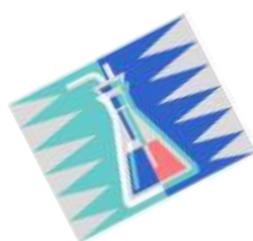
What else is in water?

- dissolved non-ionic species (SiO₂)
- dissolved organic compounds (polymers, drugs, biological materials, bacteria, viruses, etc.)
- suspended solids (particles, colloids)



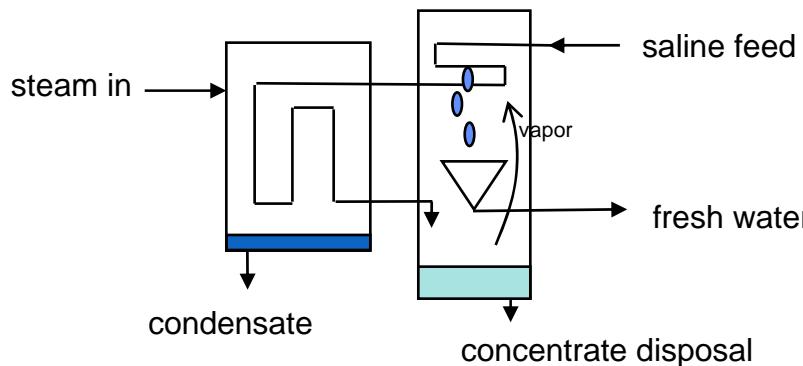
Seawater and brackish water are very different





Thermal processes: phase change

Flash evaporation



Taweelah, UAE - 258 mgd

Energy required to boil (or freeze) water:

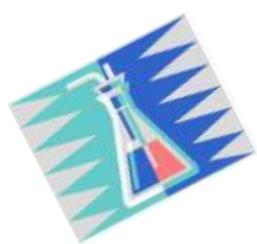
$$C_p = 4 \text{ kJ kg}^{-1} \text{ deg}^{-1}$$

$$\Delta H_{\text{vap}} = 2500 \text{ kJ kg}^{-1}$$

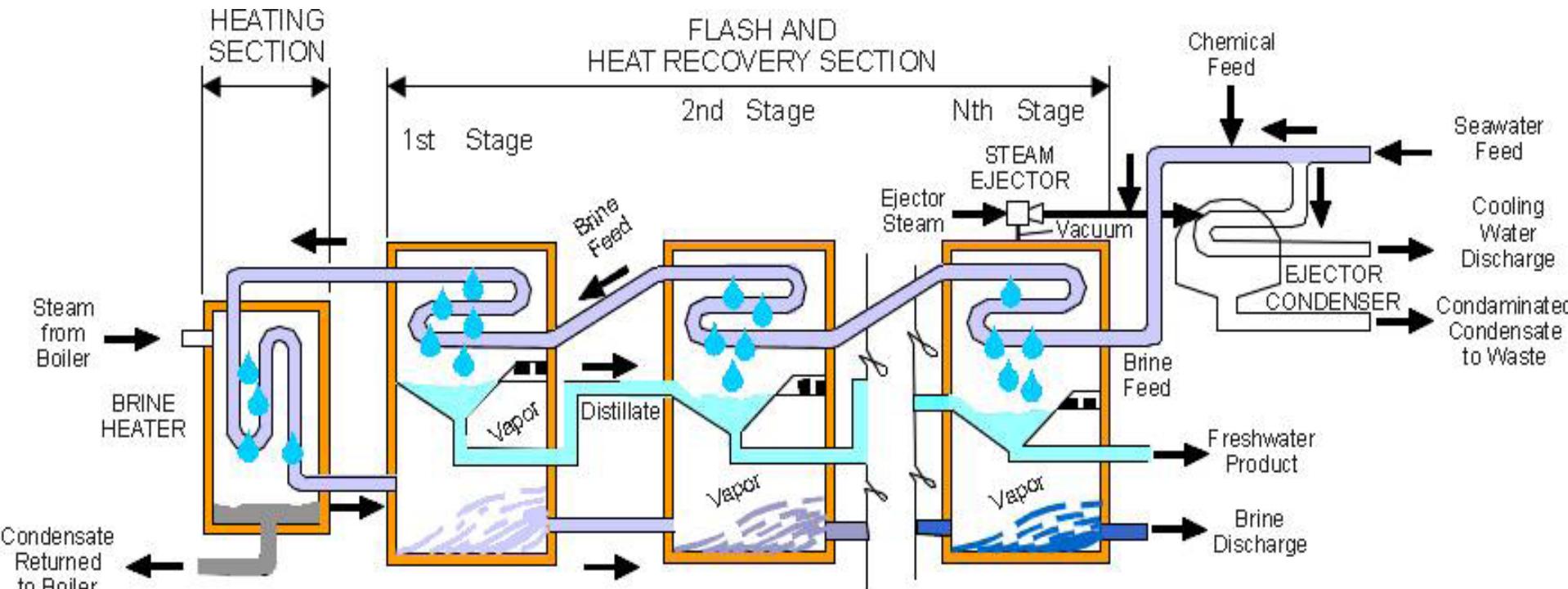
$$\Delta H_{\text{fus}} = 323 \text{ kJ kg}^{-1}$$

- large amount of energy necessary for phase change
- heat recovery essential
- typical energy use $\sim 250 \text{ kJ kg}^{-1}$ (conc. independent)
- distillation only makes sense if energy is cheap (Middle East) and salt conc. is high (seawater)
- freezing processes have slight advantage

Note: theoretical minimum energy required to extract fresh water = 3 kJ/kg!

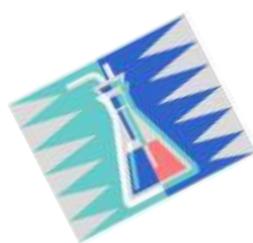


Multistage Flash Distillation - MSF

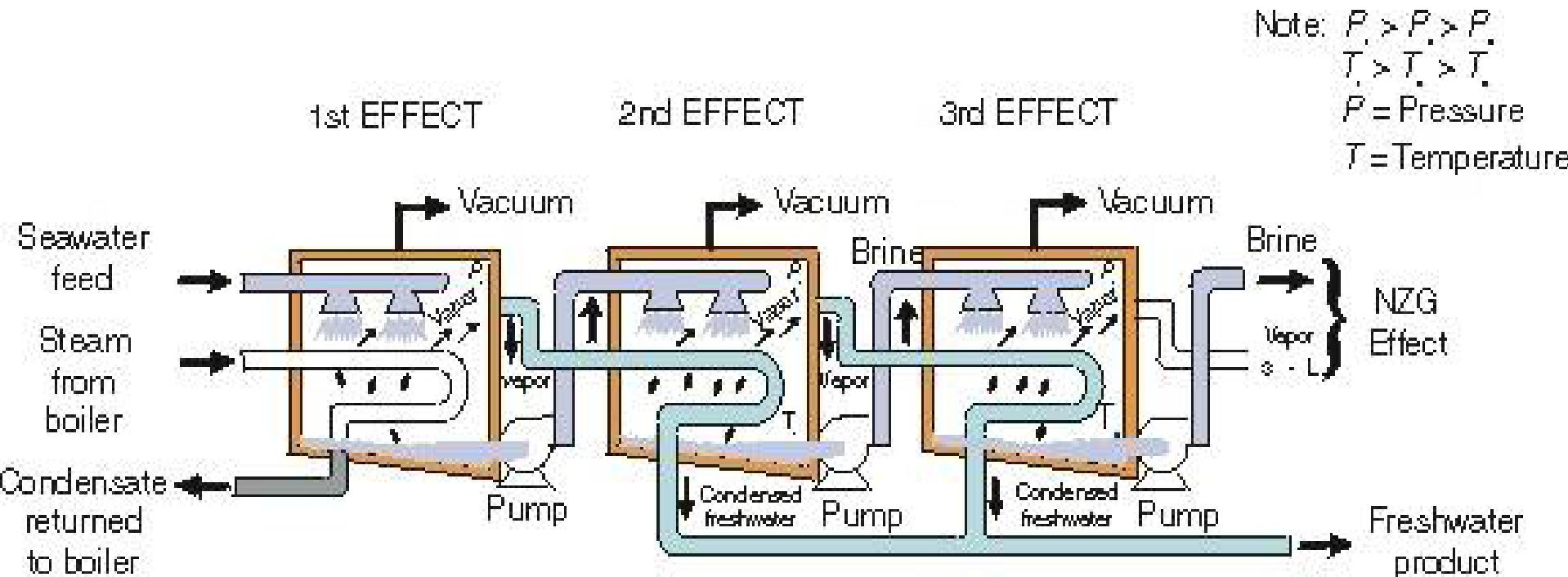


**Freshwater outside tube
bundle**

Source : IDA

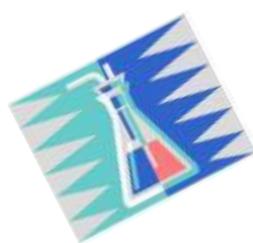


Multi Effect Distillation - MED



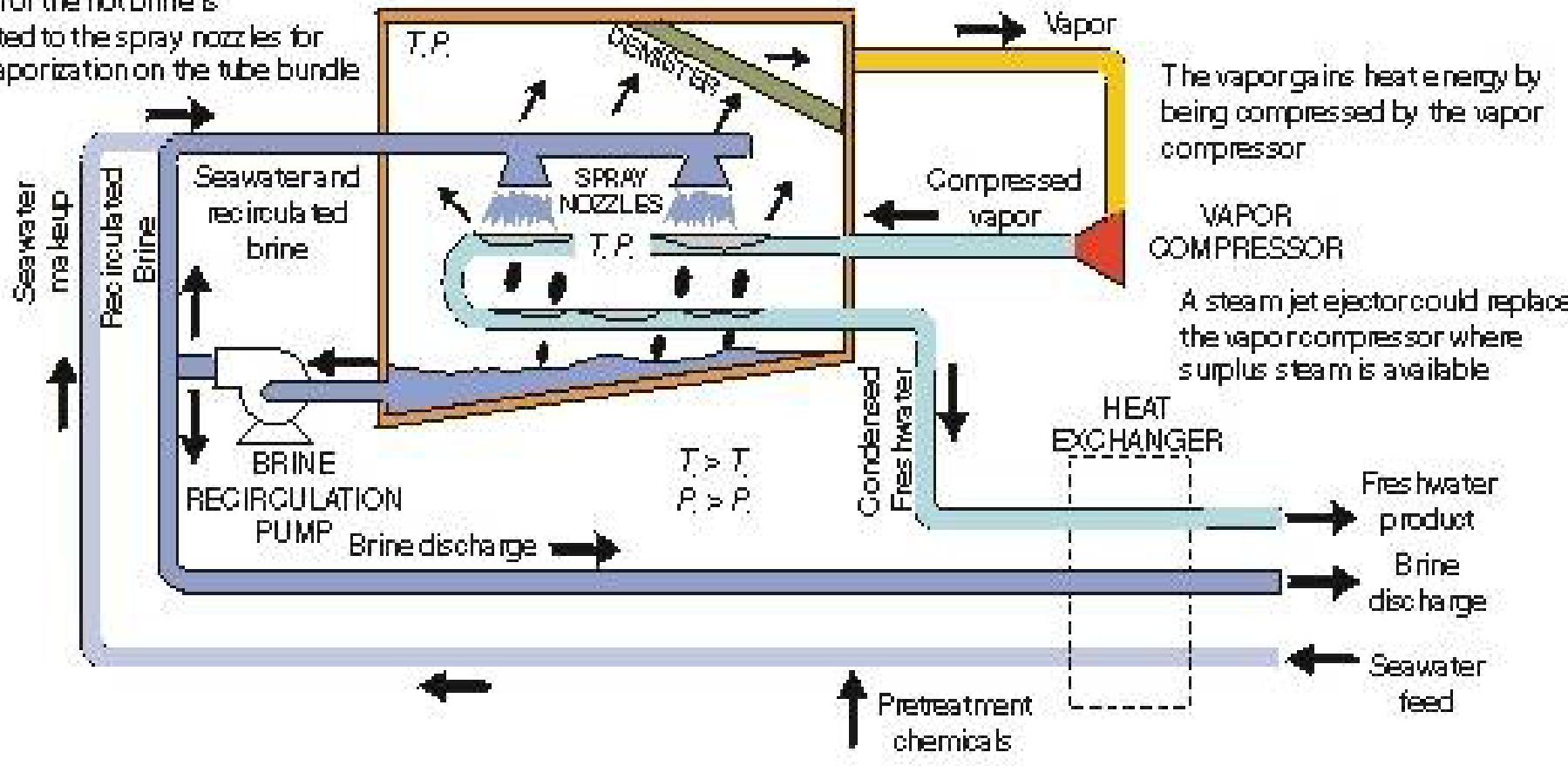
Freshwater inside tube bundle

Source: IDA



Vapor Compression - MVC and TVC

A portion of the hot brine is recirculated to the spray nozzles for further vaporization on the tube bundle

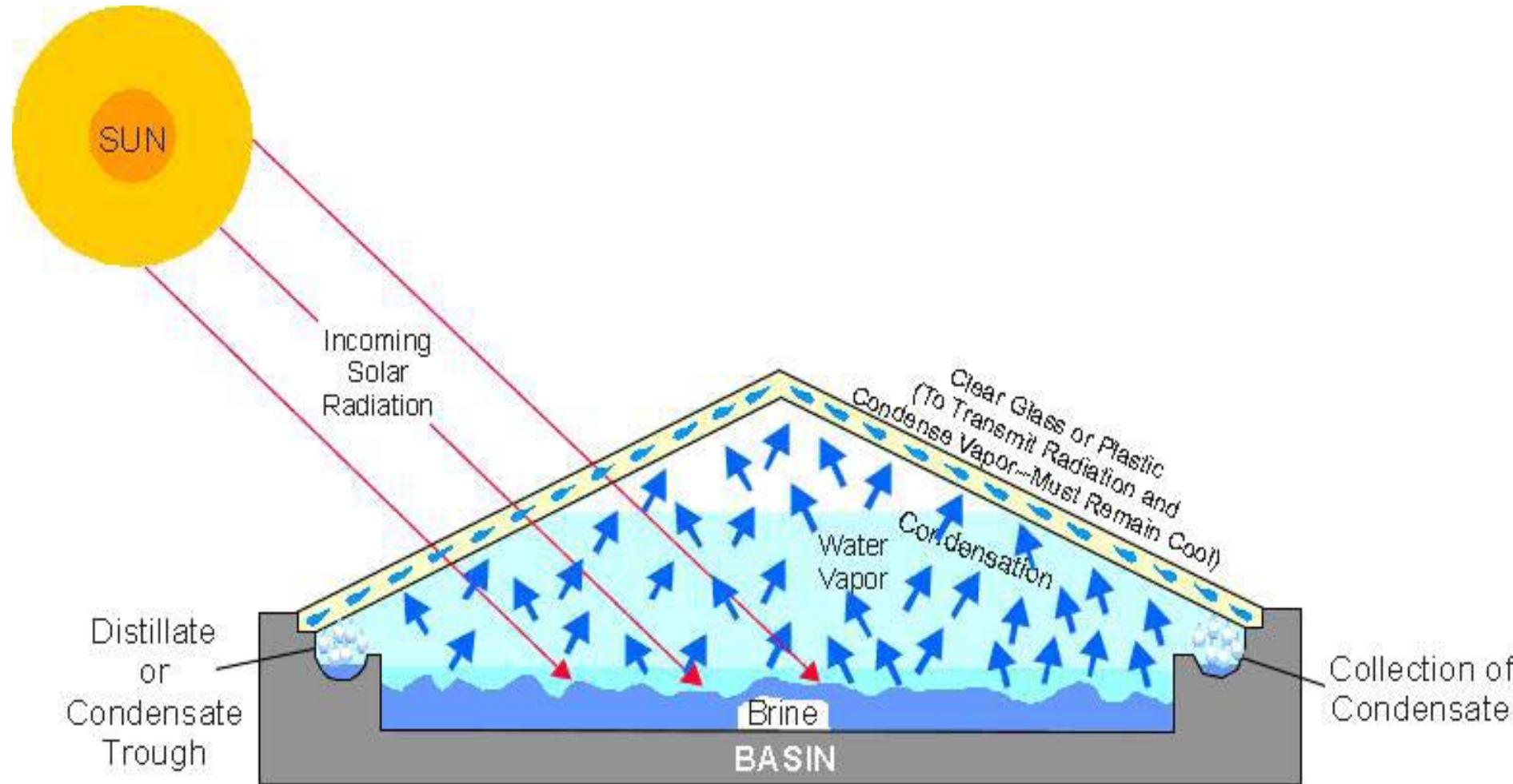


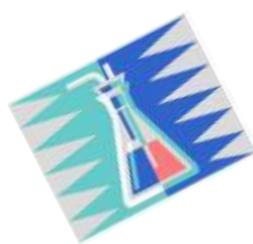
Freshwater inside tube bundle

Source: IDA



Solar desalination – large footprint required





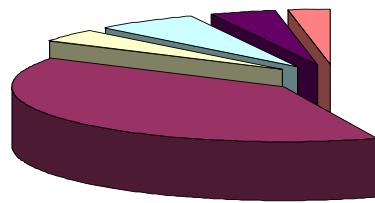
Gulf Cooperation Countries have the highest desalination capacity in the world



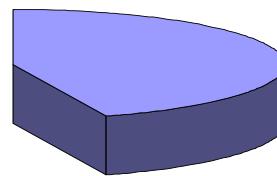
Tampa Bay
Florida



Jubail
Saudi
Arabia

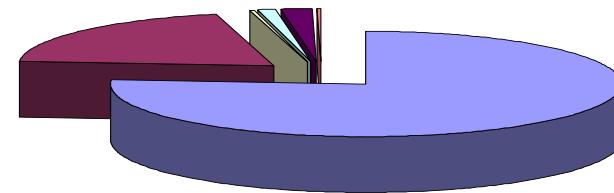


RO



MSF

World

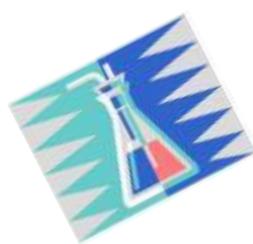


RO

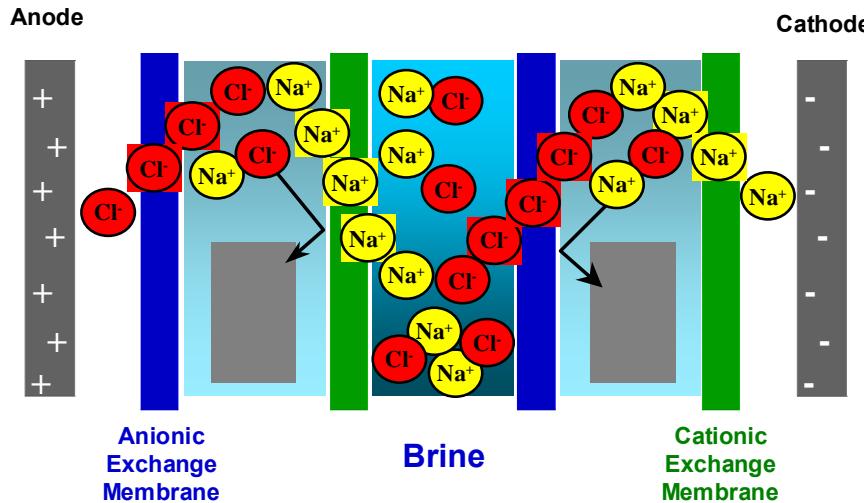
MSF

GCC
(46% of total)

Source-1998 IDA Inventory

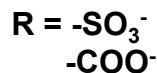
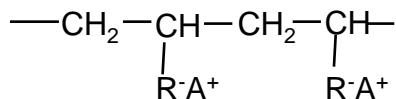


Electrodialysis uses ion exchange membranes and electromotive forces

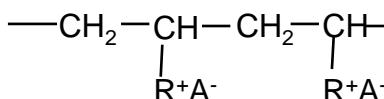


Ion exchange membranes: polyelectrolytes

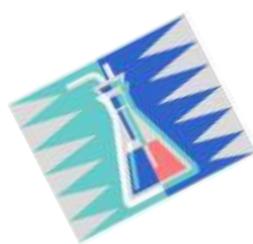
cation exchange



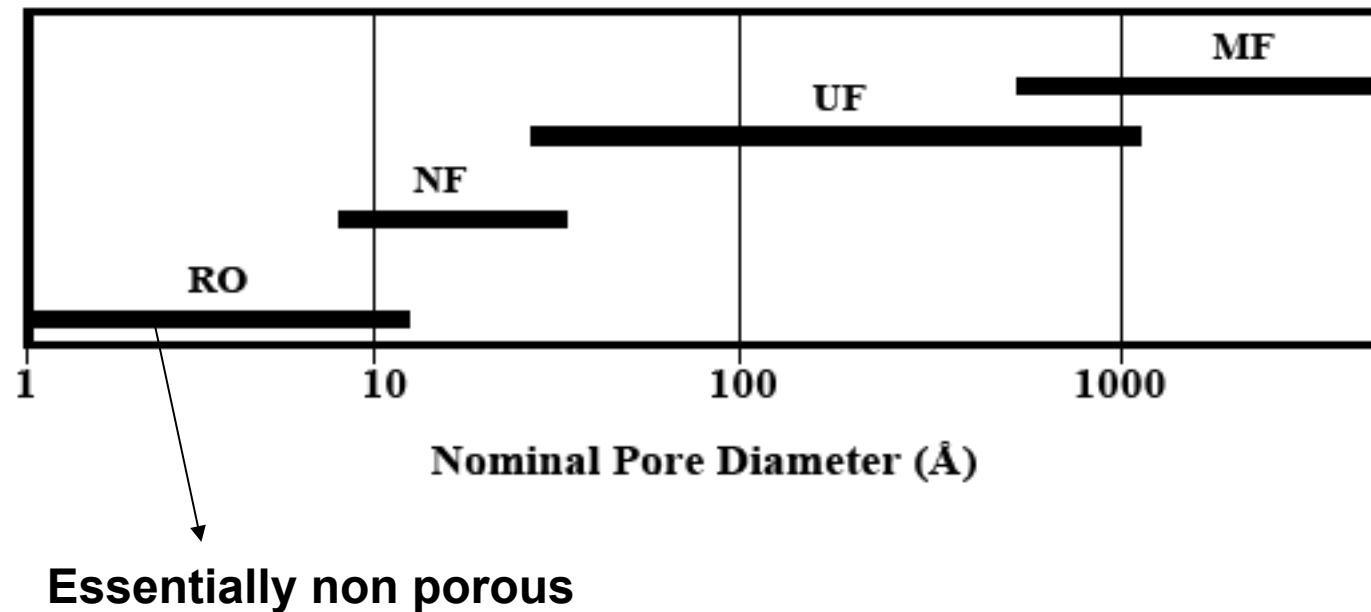
anion exchange



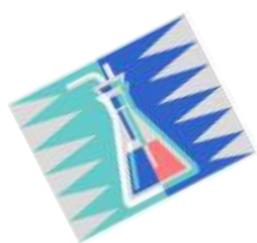
- major application is in chlor-alkali process
- energy use = I^2R ; **~5-10 kJ kg⁻¹** (conc. dependent)
- chemical stability, electrical resistance of membrane is crucial
- selective membranes for specific ions possible



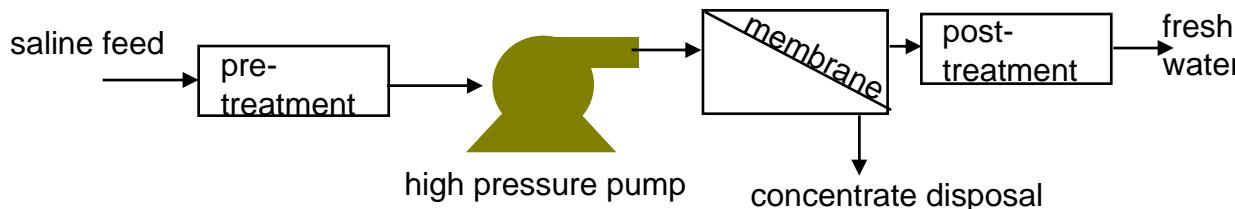
The membrane separation spectrum



Source: Perry's Chemical Engineers Handbook

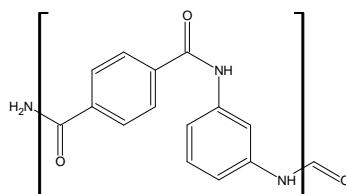
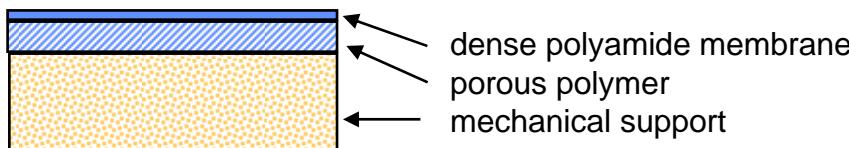


Membrane processes: reverse osmosis -nonporous



Tampa Bay Water - 25 mgd

Thin film composite membrane



polyamide

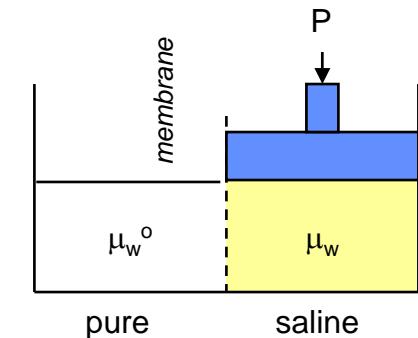
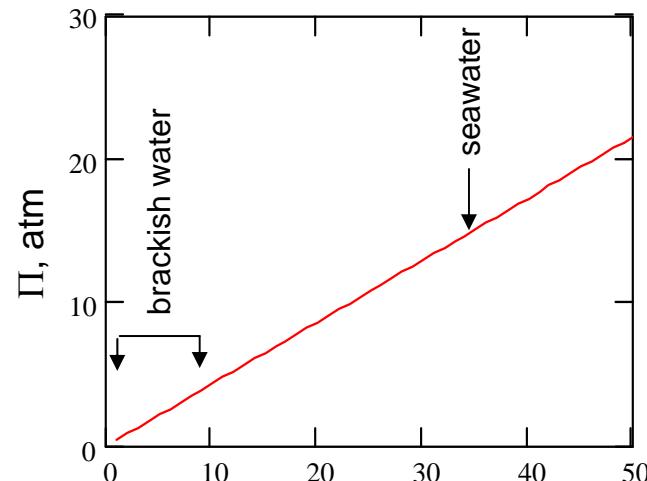
- **energy use (pump) ~ 10 – 50 kJ kg⁻¹**
- **concentration dependent**
- **energy recovery essential for seawater RO**
- **membranes susceptible to fouling; pre-treatment required**
- **polyamide membranes degraded by Cl₂**



Osmotic pressure obeys Van't Hoff's law

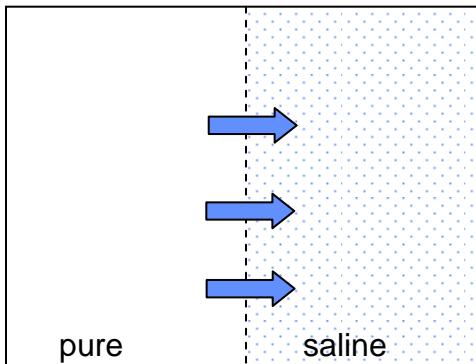
Osmotic pressure:

$$\Pi = n_s RT / V$$



Applied external pressure:

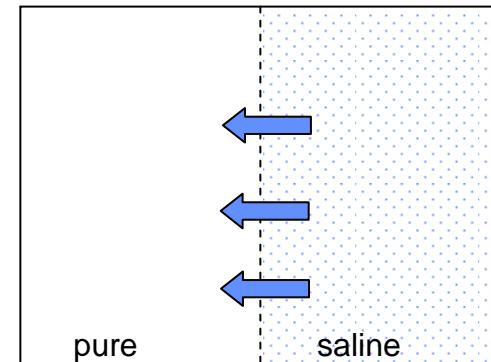
$$P < \Pi$$

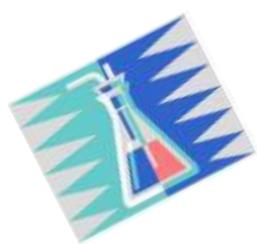


$$P = \Pi$$



$$P > \Pi$$



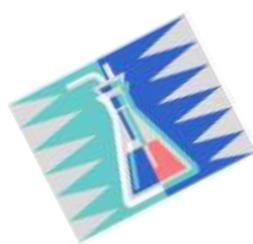


Modern RO membranes reject over 99% of salt

RO-Membrane	GFD	Salt				Cl reject %
		Conc mg/L	pressure psig	recovery %		
Filmtec SW30HR-380	15.8	32000	800	8		99.7
Koch TFC-SSHR SWRO -8	15.3	32800	800	7		99.75
Hydranautics SWC3+-8	17.5	32000	800	10		99.8
Toray SWRO TM820H	15.1	32000	800	8		99.75

GFD = gallons / ft² -day

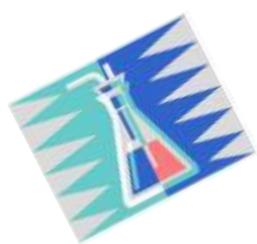
Source: manufacturers information



Typical RO installation: multiple spiral wound modules in series



<http://www.ionics.com/technologies/ro/index.htm#>



Preventing biofouling of RO membranes

- Large problem in the RO industry
- Fouling causes increased energy consumption, lower product output, shorter membrane life → higher cost



© MSU-CBE C. Wend & C. Abernathy

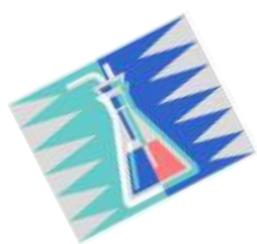
Fouled RO membrane

Courtesy: Tom Mayer Sandia National laboratories



Energy recovery

The waste stream is at high pressure and therefore has useful energy



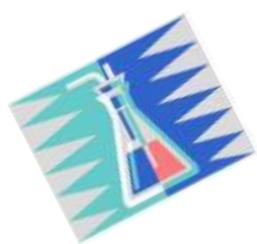
Centrifugal energy recovery



TurboCharger



Pelton Wheel



Work exchangers



<http://www.calder.ch/>

DWEER

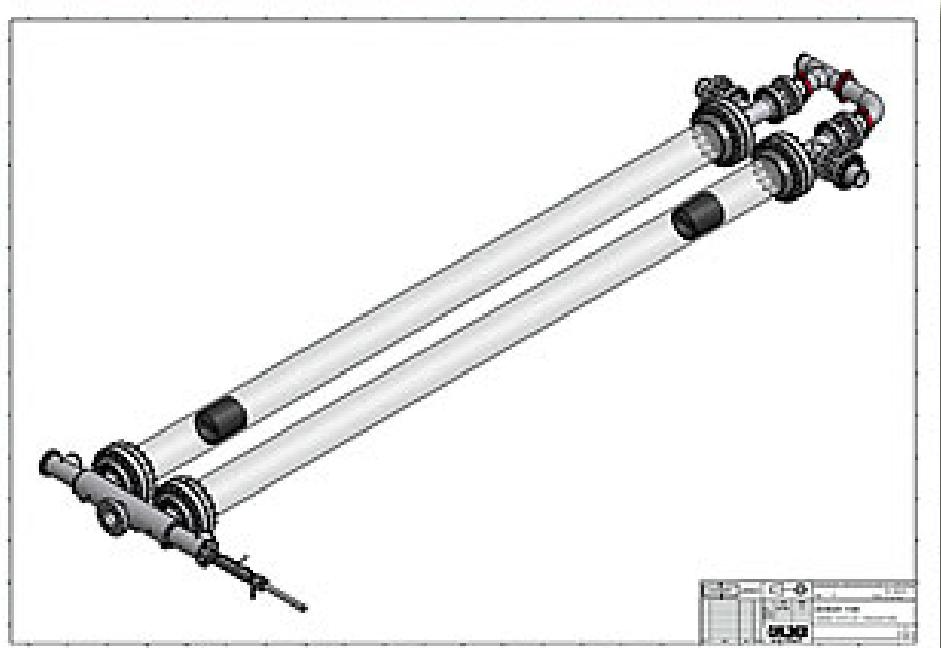


<http://www.energyrecovery.com/>

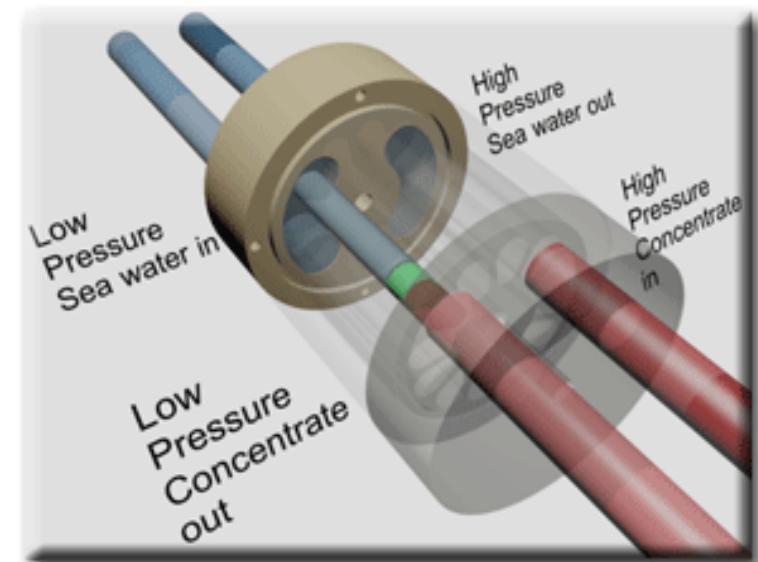
ERI



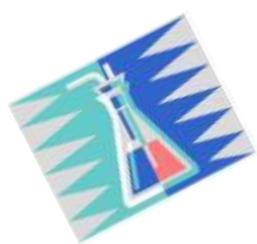
Work exchangers recover energy through piston devices



DWEER



ERI



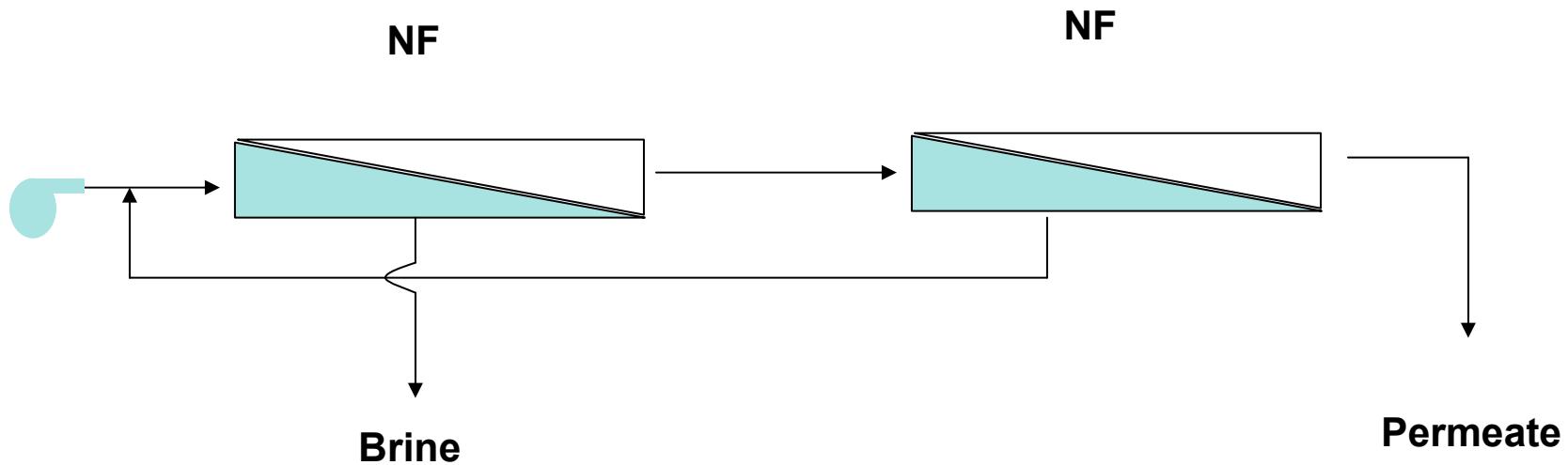
Various new desalination schemes are being proposed - process modifications

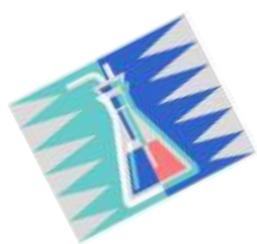
- **NF/NF - The Long Beach Method**
- **RO/RO - SWCC**
- **NF/RO - SWCC**
- **RO/RO – Brine Conversion**
- **RO/RO – Three Stage Cascade**



NF-NF treatment the Long Beach Method

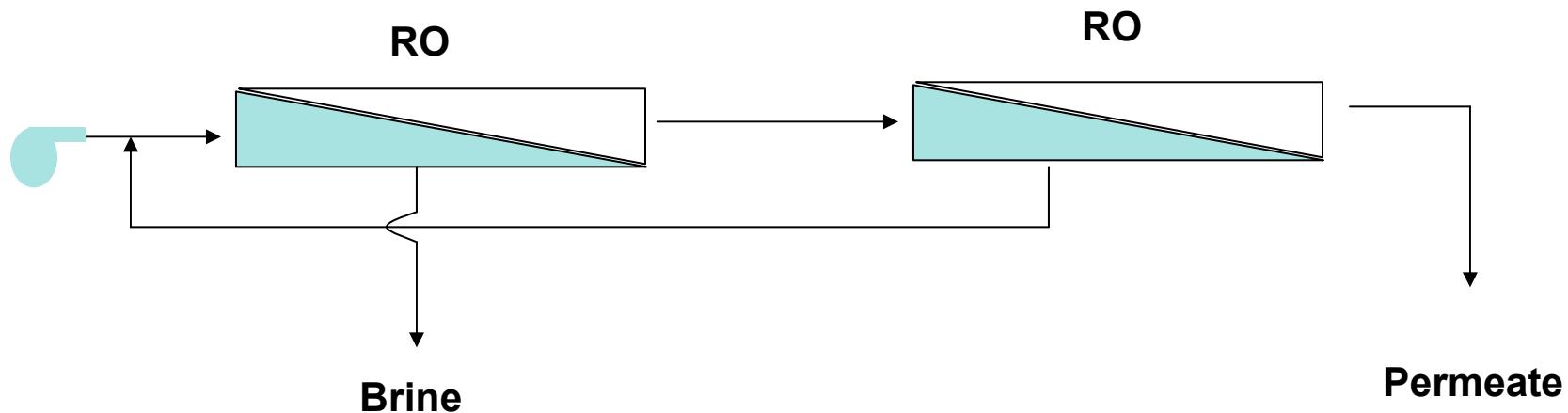
	NF	NF	Recovery
Recovery (%)	40	73	37
Pressure (psi)	560	230	
TDS feed (mg/L)	37480	3247	
TDS perm (mg/L)	3247	218	

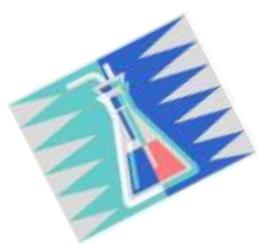




RO-RO treatment at SWCC

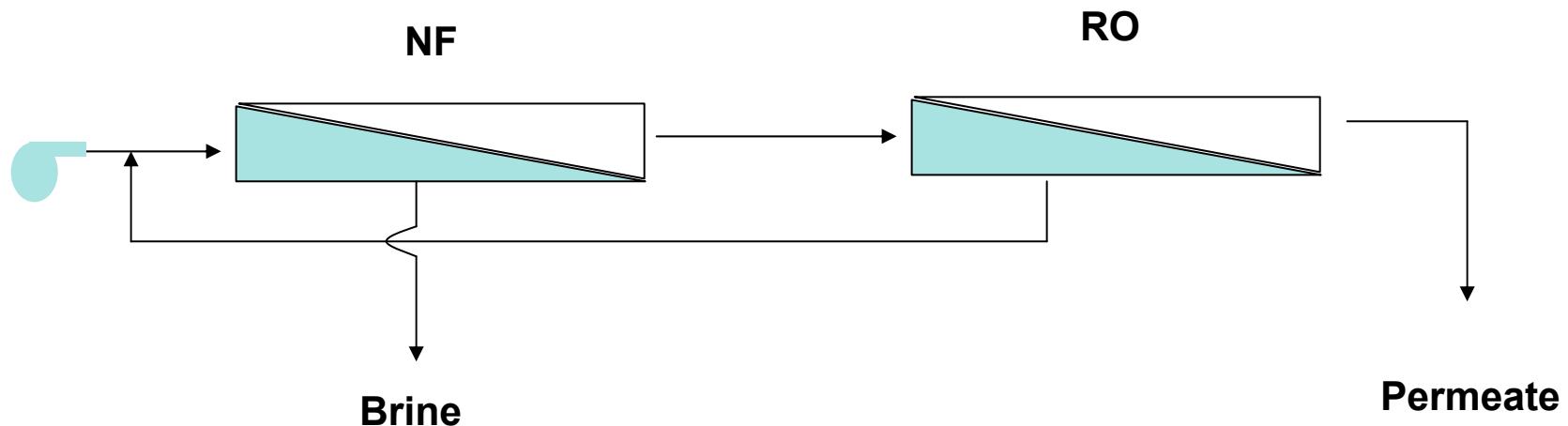
	RO	RO	Recovery
Recovery (%)	30	85	26
Pressure (psi)	942	435	
TDS feed (mg/L)	45460	720	
TDS perm (mg/L)	720	210	





Revised: NF-RO treatment at SWCC

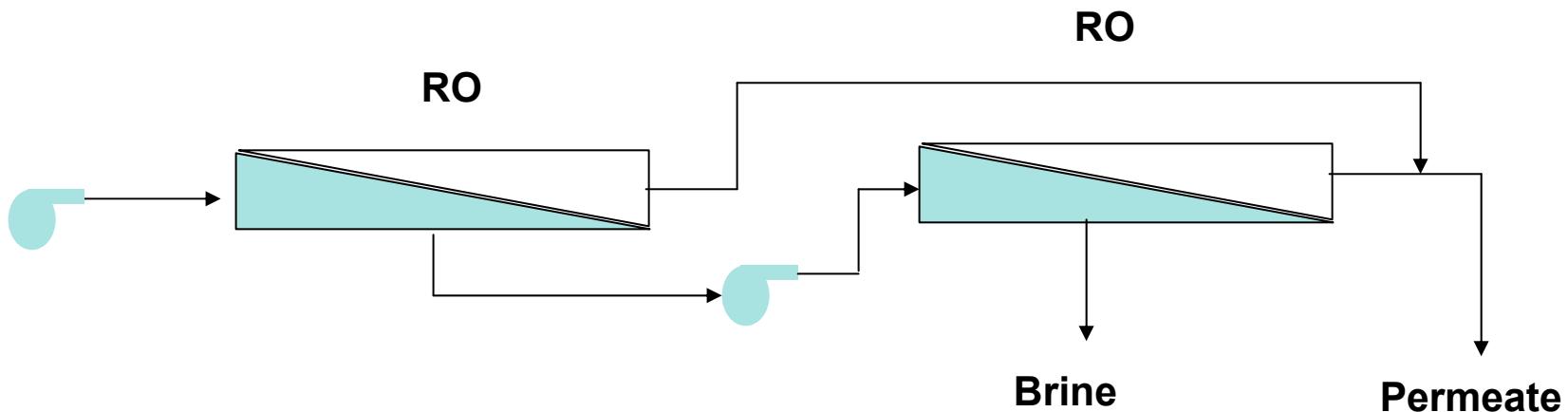
	NF	RO	Recovery
Recovery (%)	65	56	36
Pressure (psi)	363	930	
TDS feed (mg/L)	45460	28260	
TDS perm (mg/L)	28260	780	





Brine Conversion : RO-RO treatment (Toray UTC-80BCM)

	RO	RO	Recovery
Recovery (%)	40	33	60
Pressure (psi)	798	1280	
TDS feed (mg/L)	35000	58000	
TDS perm (mg/L)	100	250	



Journal of Membrane Science 183 (2001) 249–257



Comparison of various configurations

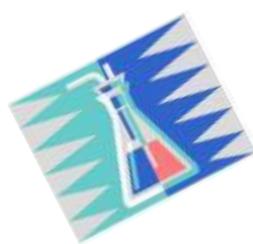
	NF		NF		RO		RO		Brine Conversion
Recovery	40	73	65	56	30	85	40	33	
Pressure	560	230	363	930	942	435	798	1280	
TDS feed	37480	3247	45460	28260	45460	720	35000	58000	
TDS perm	3247	218	28260	780	720	210	100	250	
	37%		36%		26%		60%		



Post-treatment is important to stabilize water

- Desalinated water is corrosive – has little buffering
 - Langelier index (LI)
 - Ryznar index (RI)
 - Saturation index (SI)
- It is tasteless – need calcium and bicarbonates
- It may be unusable for irrigation -
 - Sodium absorption ration (SAR)
$$\text{SAR} = [\text{Na}^+] / \{[[\text{Ca}^{+2}][\text{Mg}^{+2}]]/2\}^{0.5}$$

Desalination 165 (2004) 323-334



Remineralization involves restoring calco-carbonic balance

- **Filtration**

- Pass RO permeate across CaCO_3 , $\text{CaCO}_3/\text{MgCO}_3$ and CO_2 injection
- Next inject Na_2CO_3 to increase saturation index to 1.2 (slightly scaling)

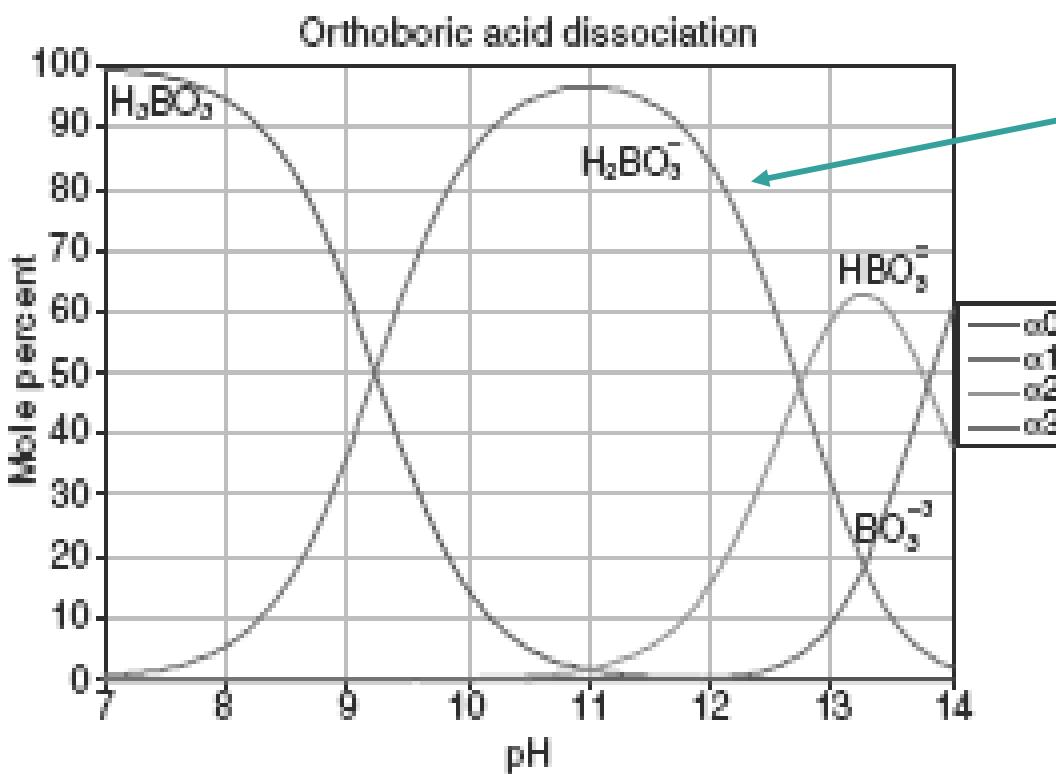
- **Injection**

- Na_2CO_3 , NaHCO_3 , CaCl_2 , $\text{Ca}(\text{OH})_2$
- Next inject CO_2

CO_2 stripping is not usually practiced



Boron rejection is pH dependent



Especially important for seawater permeate

Desalination 223 (2008) 10–16

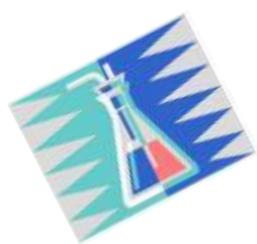
Dissociation at high pH leads to Boron rejection.

Increasing temperature decreases boron rejection as well.



Boron affects citrus

Source: Univ of Florida

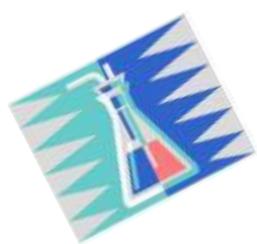


Demonstration

- **Introduction to Membrane Design Software**
- **ROSA – available at**
<http://www.dow.com/liquidseps/design/rosa.htm>



Break



International chemical control groups



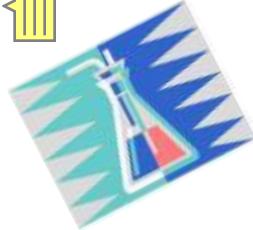
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Chemical weapons convention

The Australia Group

Export controls

UN Security Council Resolution 1540

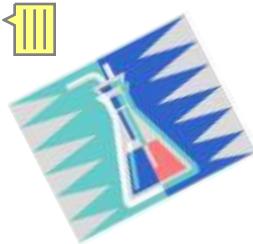


Organization for the prohibition of chemical weapons (OPCW)



- International group headquartered in The Hague, Netherlands
 - <https://www.opcw.org/index.html>
- Chemical weapons convention (CWC)
 - International treaty which bans the development, production, stockpiling, transfer and use of chemical weapons
- Promotes international cooperation in peaceful uses of chemistry
- Protecting each other

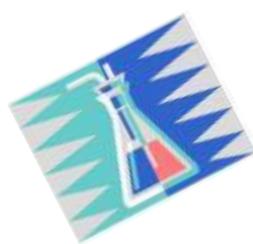




Chemical Weapons Convention (CWC)

- International treaty which bans the development, production, stockpiling, transfer and use of chemical weapons
 - Entered into force in April 1997 with 87 State Parties participating
 - Today: 183 nations have joined, 5 others have signed, only 7 have not taken any action.
 - Each nation enacts appropriate laws
 - Each nation agrees to assist other Member States





CWC: Destroy existing stockpiles and facilities

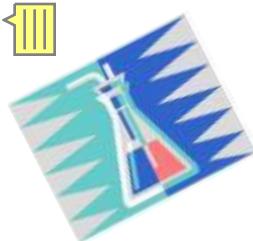
- Twelve States parties have declared CW production facilities.
 - Bosnia and Herzegovina
 - China
 - France
 - India
 - Islamic Republic of Iran
 - Japan
 - Libyan Arab Jamahiriya
 - Russian Federation
 - Serbia
 - United Kingdom of Great Britain and Northern Ireland
 - United States of America
 - another State Party
- As of August 2007, 42 of 65 declared CW production facilities have been certified as destroyed, 19 converted to peaceful purposes.
- As of August 2007, 23,912 metric tonnes of CW agent has been destroyed out of 71,330 metric tonnes declared.
- On 11 July 2007, the OPCW confirmed the destruction of the entire chemical weapons stockpile in Albania.
- Includes old and abandoned CW munitions



CWC: Prevent spread or production of new chemical weapons

- States declare and agree to inspections of many other chemical facilities, depending on chemical type and amount produced
- Over 3,000 inspections have taken place at 200 chemical weapon-related and over 850 industrial sites on the territory of 79 States Parties since April 1997
- Worldwide, over 5,000 industrial facilities are liable to inspection

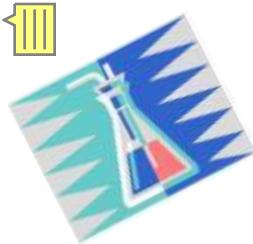




CWC: Chemicals on schedules subject to verification measures



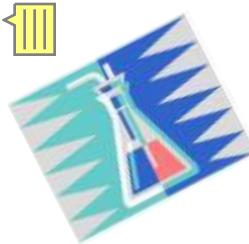
- **Schedule 1:**
 - Known CW agents
 - Highly toxic, closely related chemicals, or CWA precursors
 - Has little or no peaceful application
- **Schedule 2:**
 - Toxic enough to be used as a CWA
 - Precursor to or important for making a Schedule 1 chemical
 - Not made in large commercial quantities for peaceful purposes
- **Schedule 3:**
 - Has been used as a CWA
 - Precursor to, or important for making a Schedule 1 or 2 chemical
 - Is made in large commercial quantities for peaceful purposes
- **Unscheduled Discrete Organic Chemicals (UDOC)**
- **Lists of scheduled chemicals follow: also in documents on CD**



CWC: Reporting requirements

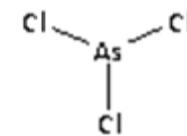
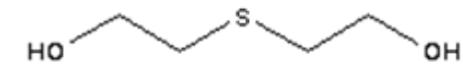
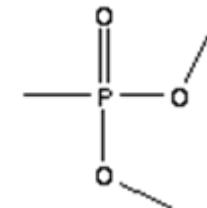
- Use/transfer of these chemicals is allowed for research, medical, or pharmaceutical purposes.
- Reporting requirements depend on facility type, chemical types and amounts.
 - “Other Facility” type, as defined in CWC documents, most relevant here
 - Amounts of chemicals that would require that your National Authority approve the work and report your institution annually to the OPCW
 - Schedule 1: 100 g aggregate
 - Schedule 2: 1 kg for 2A*, 100 kg for other 2A, 1 Tonne of 2B
 - Schedule 3: 30 Tonnes
 - UDOC: 30 or 200 Tonnes (lower number if contains P, S, or F)

Caution:
Your country might require reporting of lower amounts!

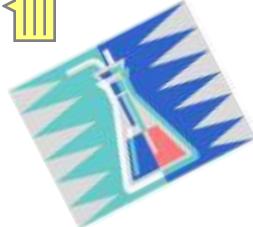


Many lab/industrial chemicals have dual uses

- **Dimethyl methyl phosphonate (DMMP)**
 - Flame retardant for:
 - building materials, furnishings, transportation equipment, electrical industry, upholstery
 - Nerve agent precursor
- **Thiodiglycol**
 - Dye carrier, ink solvent, lubricant, cosmetics, anti-arthritis drugs, plastics, stabilizers, antioxidants, photographic, copying, antistatic agent, epoxides, coatings, metal plating
 - Mustard gas precursor
- **Arsenic Trichloride**
 - Catalyst in CFC manufacture, semiconductor precursor, intermediate for pharmaceuticals, insecticides
 - Lewisite precursor



From: Chemical Weapons Convention: Implementation Assistance Programme Manual (on CD)



Schedule 1 Chemicals

A. Toxic chemicals

- (1) O-Alkyl (<C10, incl. cycloalkyl) alkyl (Me, Et, n-Pr or i-Pr)-phosphonofluoridates, e.g.
 - Sarin: O-Isopropyl methylphosphonofluoridate
 - Soman: O-Pinacolyl ethylphosphonofluoridate
- (2) O-Alkyl (<C10, incl. cycloalkyl) N,N-dialkyl (Me, Et, n-Pr or i-Pr) phosphoramidocyanides, e.g. Tabun: O-Ethyl N,N-dimethyl phosphoramidocyanide
- (3) O-Alkyl (H or <C10, incl. cycloalkyl) S-2-dialkyl (Me, Et, n-Pr or i-Pr)-aminoethyl alkyl (Me, Et, n-Pr or i-Pr) phosphonothiolates and corresponding alkylated or protonated salts, e.g. VX: O-Ethyl S-2-diisopropylaminoethyl methyl phosphonothiolate
- (4) Sulfur mustards:
 - 2-Chloroethylchloromethylsulfide
 - Mustard gas: Bis(2-chloroethyl)sulfide
 - Bis(2-chloroethylthio)methane
 - Sesquimustard: 1,2-Bis(2-chloroethylthio)ethane
 - 1,3-Bis(2-chloroethylthio)-n-propane
 - 1,4-Bis(2-chloroethylthio)-n-butane
 - 1,5-Bis(2-chloroethylthio)-n-pentane
 - Bis(2-chloroethylthiomethyl)ether
 - O-Mustard: Bis(2-chloroethylthioethyl)ether

• (5) Lewisites:

- Lewisite 1: 2-Chlorovinyldichloroarsine
- Lewisite 2: Bis(2-chlorovinyl)chloroarsine
- Lewisite 3: Tris(2-chlorovinyl)arsine

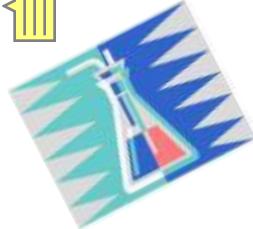
• (6) Nitrogen mustards:

- HN1: Bis(2-chloroethyl)ethylamine
- HN2: Bis(2-chloroethyl)methylamine
- HN3: Tris(2-chloroethyl)amine

- (7) Saxitoxin
- (8) Ricin

B. Precursors

- (9) Alkyl (Me, Et, n-Pr or i-Pr) phosphonyldifluorides, e.g. DF: Methylphosphonyldifluoride
- (10) O-Alkyl (H or <C10, incl. cycloalkyl) O-2-dialkyl (Me, Et, n-Pr or i-Pr)-aminoethyl alkyl (Me, Et, n-Pr or i-Pr) phosphonites and corresponding alkylated or protonated salts e.g. QL: O-Ethyl O-2-diisopropylaminoethyl methylphosphonite
- (11) Chlorosarin: O-Isopropyl methylphosphonochloridate
- (12) Chlorosoman: O-Pinacolyl methylphosphonochloridate



Schedule 2 Chemicals

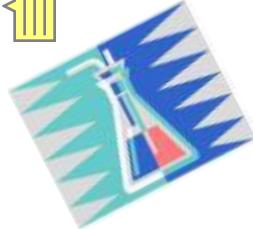
A. Toxic chemicals

- (1) Amiton: O,O-Diethyl S-[2-(diethylamino)ethyl] phosphorothiolate and corresponding alkylated or protonated salts
- (2) PFIB: 1,1,3,3,3-Pentafluoro-2-(trifluoromethyl)-1-propene
- (3) BZ: 3-Quinuclidinyl benzilate

B. Precursors

- (4) Chemicals, except for those listed in Schedule 1, containing a phosphorus atom to which is bonded one methyl, ethyl or propyl (normal or iso) group but not further carbon atoms, e.g.
 - ethylphosphonyl dichloride
 - dimethyl methylphosphonate
 - Exemption: Fonofos: O-Ethyl S-phenyl ethylphosphonothiolothionate
- (5) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) phosphoramidic dihalides
- (6) Dialkyl (Me, Et, n-Pr or i-Pr) N,N-dialkyl (Me, Et, n-Pr or i-Pr)-phosphoramidates

- (7) Arsenic trichloride
- (8) 2,2-Diphenyl-2-hydroxyacetic acid
- (9) Quinuclidin-3-ol
- (10) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) aminoethyl-2-chlorides and corresponding protonated salts
- (11) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) aminoethane-2-ols and corresponding protonated salts
 - Exemptions: N,N-Dimethylaminoethanol and corresponding protonated salts
 - N,N-Diethylaminoethanol and corresponding protonated salts
- (12) N,N-Dialkyl (Me, Et, n-Pr or i-Pr) aminoethane-2-thiols and corresponding protonated salts
- (13) Thiodiglycol: Bis(2-hydroxyethyl)sulfide
- (14) Pinacolyl alcohol: 3,3-Dimethylbutan-2-ol



Schedule 3 Chemicals

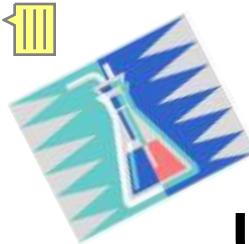
A. Toxic chemicals

- (1) Phosgene: Carbonyl dichloride
- (2) Cyanogen chloride
- (3) Hydrogen cyanide
- (4) Chloropicrin: Trichloronitromethane

B. Precursors

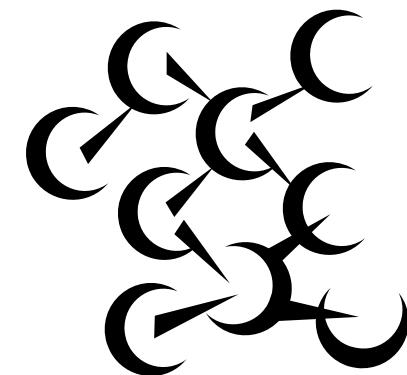
- (5) Phosphorus oxychloride
- (6) Phosphorus trichloride
- (7) Phosphorus pentachloride
- (8) Trimethyl phosphite
- (9) Triethyl phosphite
- (10) Dimethyl phosphite
- (11) Diethyl phosphite
- (12) Sulfur monochloride
- (13) Sulfur dichloride
- (14) Thionyl chloride
- (15) Ethyldiethanolamine
- (16) Methyltriethanolamine
- (17) Triethanolamine



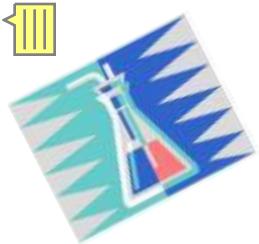


Unscheduled discrete organic chemicals (UDOC)

- Also subject to CWC reporting, but only for large amounts.
- "Discrete Organic Chemical" means any chemical belonging to the class of chemical compounds consisting of all compounds of carbon except for its oxides, sulfides and metal carbonates, identifiable by chemical name, by structural formula, if known, and by Chemical Abstracts Service registry number, if assigned.



From CWC text – on CD

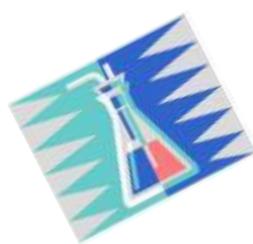


OPCW: Promotes international cooperation in peaceful uses of chemistry



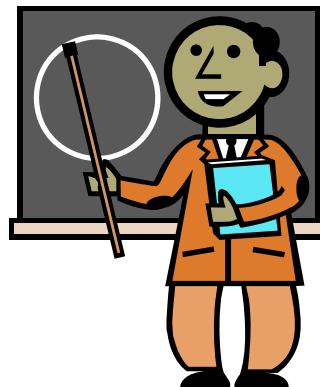
- Associates program
- Analytical skills development course
- Conference support program
- Research projects program
- Internship Support Program
- Laboratory Assistance Program
- Equipment Exchange Program

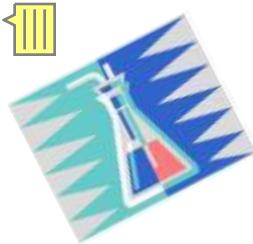




OPCW: Protecting each other

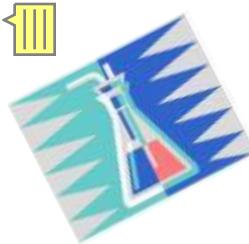
- Each member state can request assistance from other member states in the event of a threat or attack, including chemical terrorism
- This can take the form of expertise, training, materials, and/or equipment





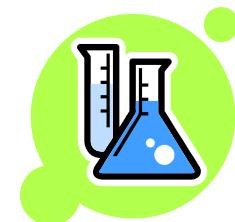
Australia Group

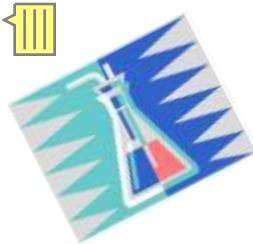
- An informal arrangement to minimize the risk of assisting chemical and biological weapon (CBW) proliferation.
 - Harmonising participating countries' national export licensing measures
 - Started in 1985 when Iraq CW program was found to have diverted chemicals and equipment from legitimate trade
- 40 nations plus European Commission participate



Australia Group: Export Controls

- **Controls exports of:**
 - 63+ Chemical weapon agent precursor chemicals
 - Dual-use chemical manufacturing facilities and equipment and related technology
 - Dual-use biological equipment and related technology
 - Biological agents
 - Plant pathogens
 - Animal pathogens
- **Includes no-undercut policy**
 - Countries won't approve an export that another member country denied





UN Security Council Resolution 1540

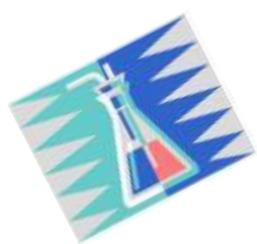
- **Unanimously passed on 28 April 2004**
- **Member States:**
 - must refrain from supporting non-State actors in developing, acquiring, manufacturing, possessing, transporting, transferring or using nuclear, chemical or biological weapons and their delivery systems.
 - must establish domestic controls to prevent the proliferation of nuclear, chemical and biological weapons, and their means of delivery, including by establishing appropriate controls over related materials.
- **Enhanced international cooperation on such efforts is encouraged, in accord with and promoting universal adherence to existing international non-proliferation treaties.**



Summary – update for water treatment part?

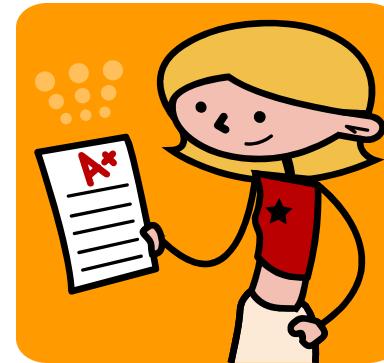
- **Chemical safety and security are important**
 - Chemistry laboratories are an attractive target for theft of chemicals
- **Chemical safety and security measures have a lot of overlap**
 - Attitudes and awareness
 - Policies
 - Physical additions/changes to buildings and labs

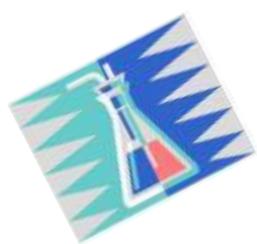




Course evaluation and feedback form

- Please help us improve this course by filling out and returning this form.





Thanks for coming!

- This work was funded by the U.S. Department of State Chemical Security Engagement Program
- We thank
 - Dr. Elizabeth Cameron
 - Mr. Carson Kuo
 - Anisha Quiroz
 - Nelson Couch, PhD

