An Overview of Current and Emerging Water Treatment Technologies

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Presentation Layout

Part I: Overview of water treatment technologies

Part II: Characteristic of drain rinsing water

Part III: Semiconductor wastewater treatment technologies

Part IV: Some ideas for treatment technologies

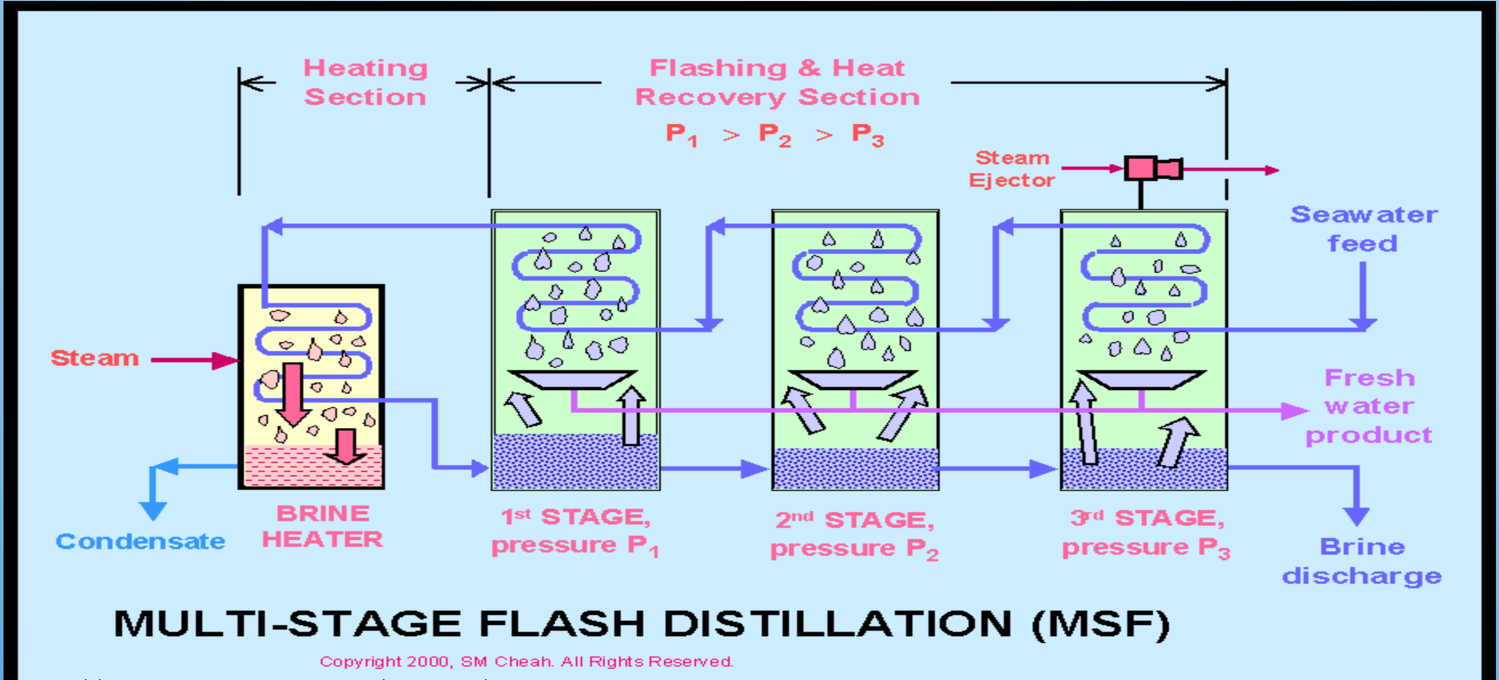
Part I:
Overview of water treatment technologies

Overview of Water Treatment Technologies

Traditional Thermal processes	Membrane processes	Non-traditional processes
• Multi-Effect Distillation (MED) • MED with vapour compression • Multi-stage flash evaporation (MSF)	• Reverse Osmosis (RO) • Electrodialysis (ED) • Electrodeionization (EDI) • Membrane Distillation (MD)	• Humidification Dehumidification (HDH) • Forward Osmosis (FO) • Freezing-Melting (FM) • Ion Exchange (IX)

Traditional Thermal processes

Multi-stage flash (MSF):

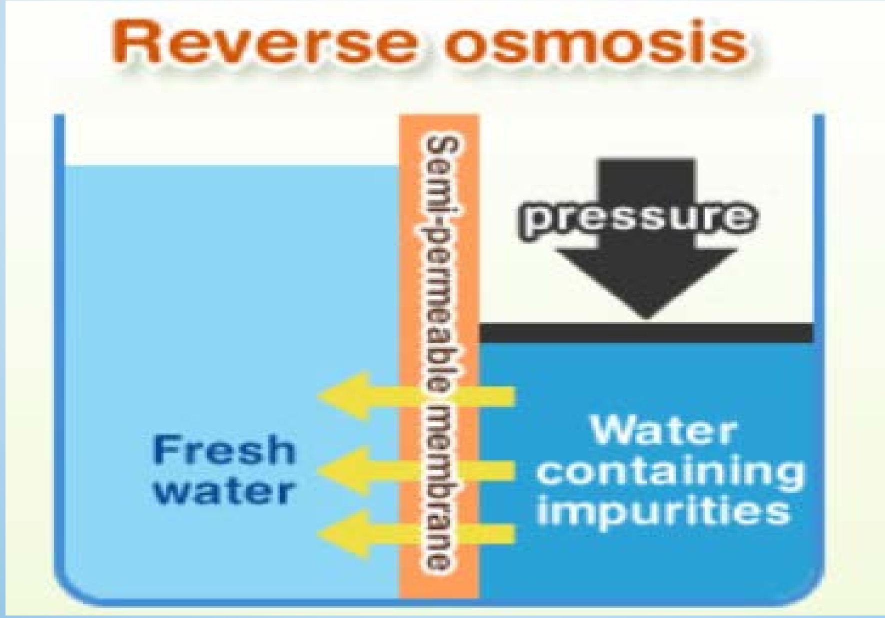


http://student.mathisasport.org/srittgers/desalination.html

Advantages	Disadvantages	Current status/research focus
• No pre-treatment • Less fouling and scaling problem compared with Multi-Effect Distillation (MED)	• Thermodynamic efficiency is lower than MED • Almost 70% of the input heat is lost during the process • High energy consumption	• Improvements in thermodynamics

Membrane processes

Reverse Osmosis (RO):

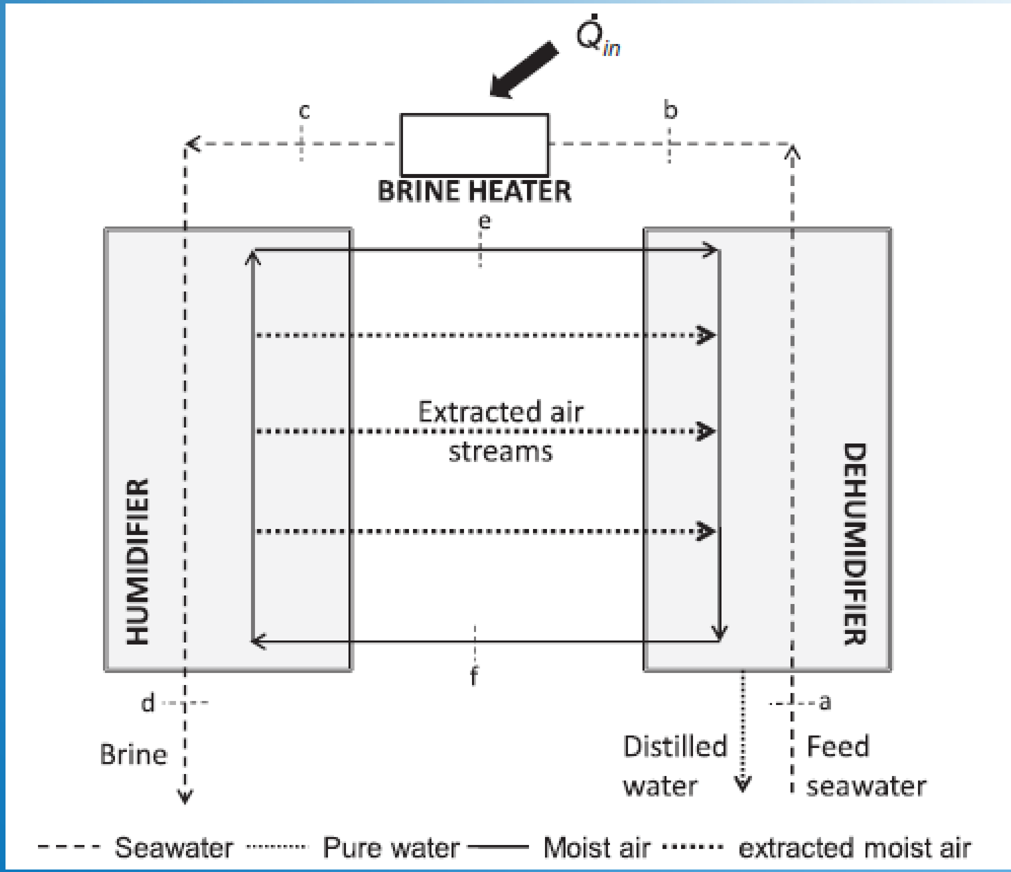


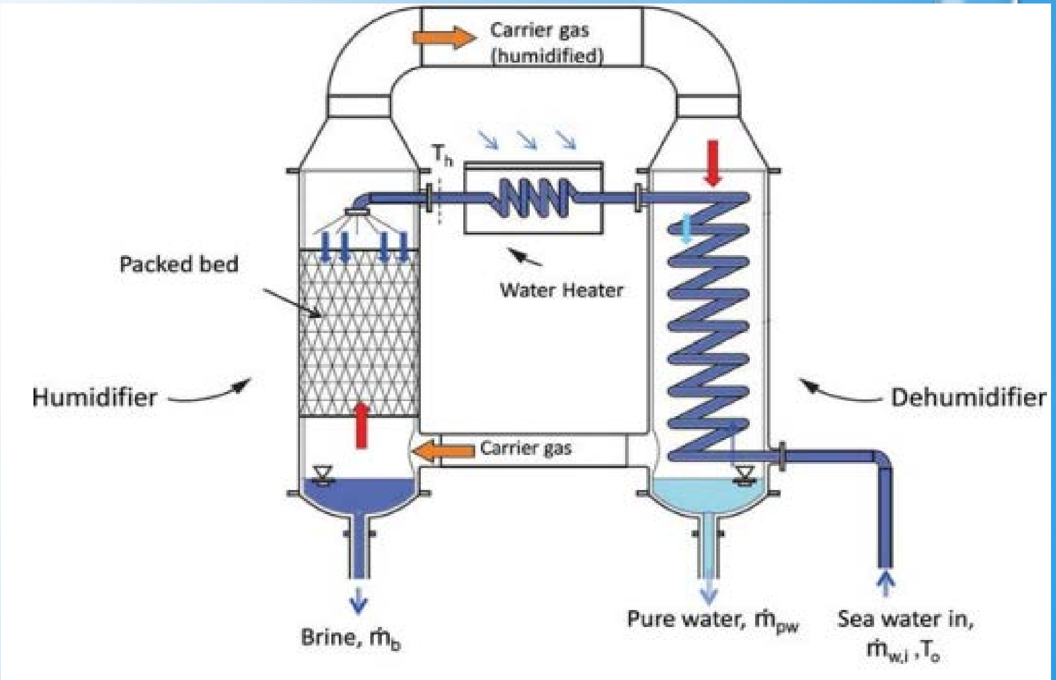
Advantages	Disadvantages	Current status/research focus
• **Low energy consumption** (no liquid phase change) **compared with** Multi-Effect Distillation (MED) • Pumping energy can be recovered • Able to separate many types of contaminants	• **High maintenance and cleaning** • Low permeate flux due to **membrane fouling** • **Need for high grade energy source (electricity)** • Pre-treatment requirement	• Fouling resistance as well as reduction in energy while maintaining or improving rejection

Non-traditional processes

Thermal processes

Humidification Dehumidification (HDH):





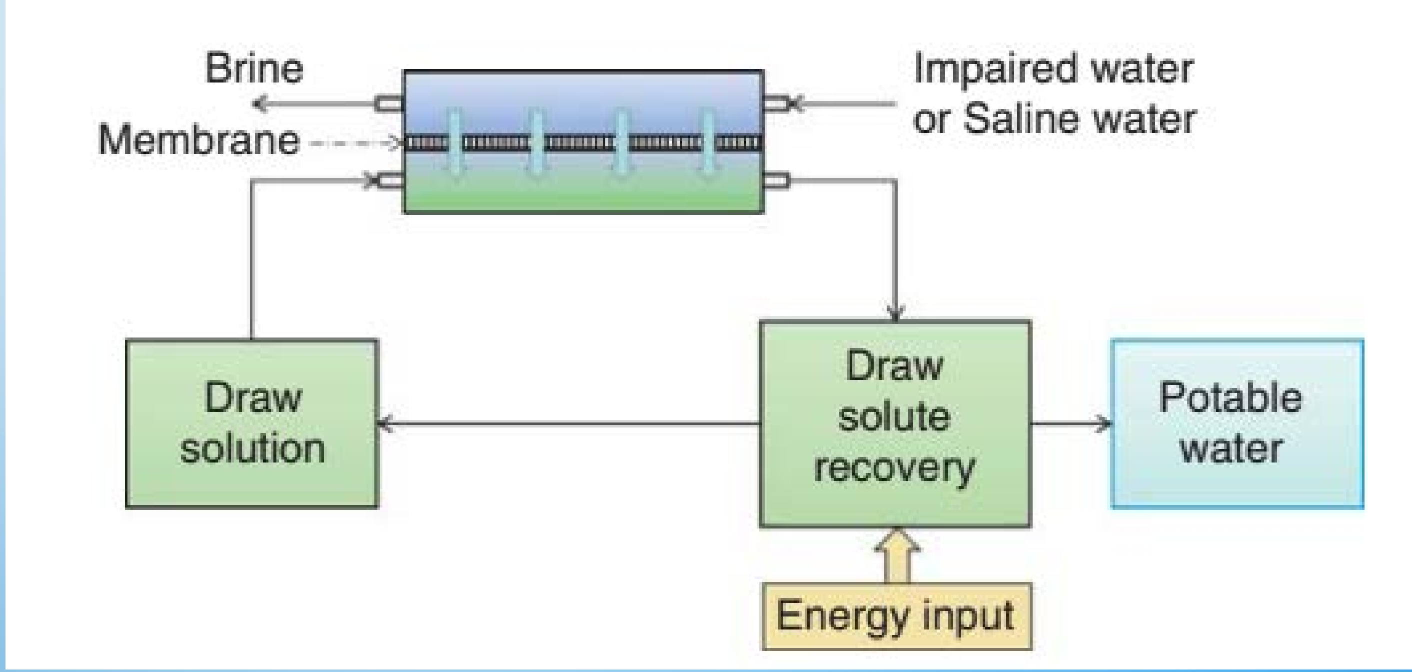
Advantages	Disadvantages	Current status/ research focus
• **Able to use waste heat sources** • Atmospheric pressure • Easily scale up	• Energy consumption	• Recent improvements have made it an economic solution • *Now is commercialized in fracking sites (company: **Gradiant**)*

Carrier Gas Extraction: patent at M.I.T. /2013

Non-traditional processes

Membrane processes

Forward Osmosis (FO):



Advantages	Disadvantages	Current status/ research focus
• **No external pressure** is required • **Highly fouling resistant and easily cleanable** • Energy consumption is similar to RO • **No need for high grade energy source**	• Thermal energy is necessary to regenerate the draw	• **Gaining commercial application for desalination, particularly since 2010**

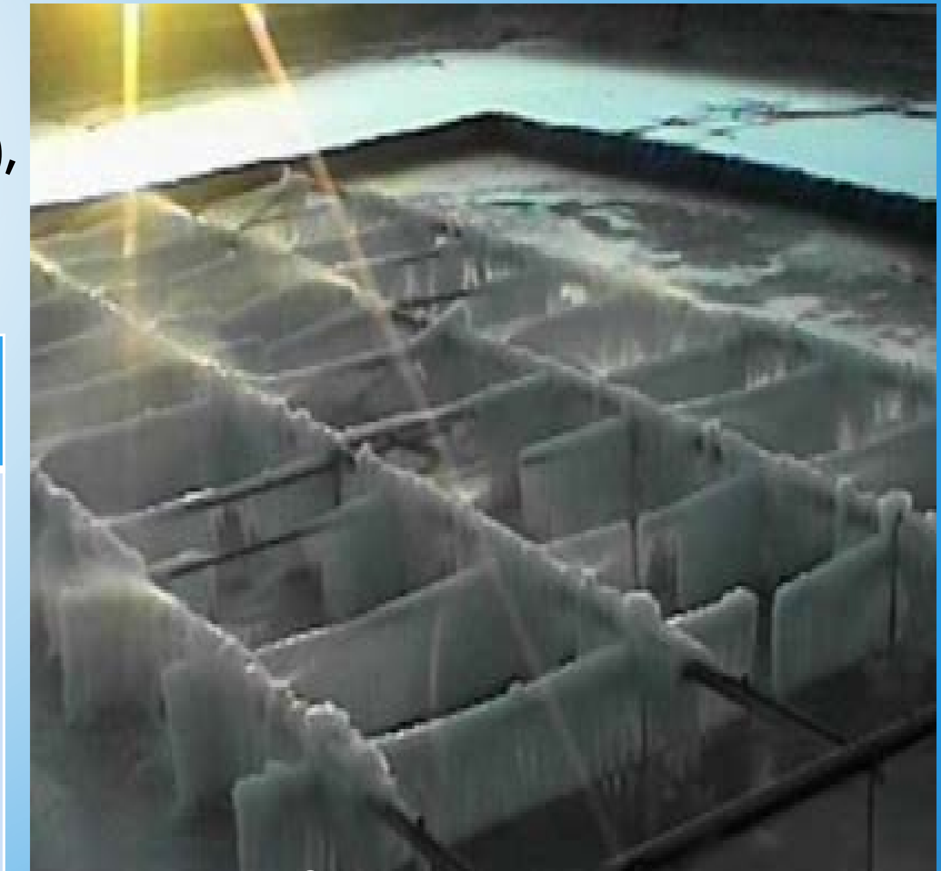
Desalination, water from water (2014)

Non-traditional processes

Freezing-Melting (FM):

- Relatively pure ice crystals form, and an unfrozen solution (brine), containing elevated concentrations of the dissolved constituents, drains from the ice.

Advantages	Disadvantage	Current status/ research focus
• Main advantage is **low energy requirement** (fusion energy 1/7 of evaporation energy) • **Less scaling and fouling problem** • **No need for pre-treatment** • 90% removal efficiency for: ✓ Total suspended solids (TSS) ✓ Total dissolved solids (TDS) ✓ Volatile organic compounds ✓ Heavy metals	**Ice separation**	• Under Development • **Currently limited to food processing**

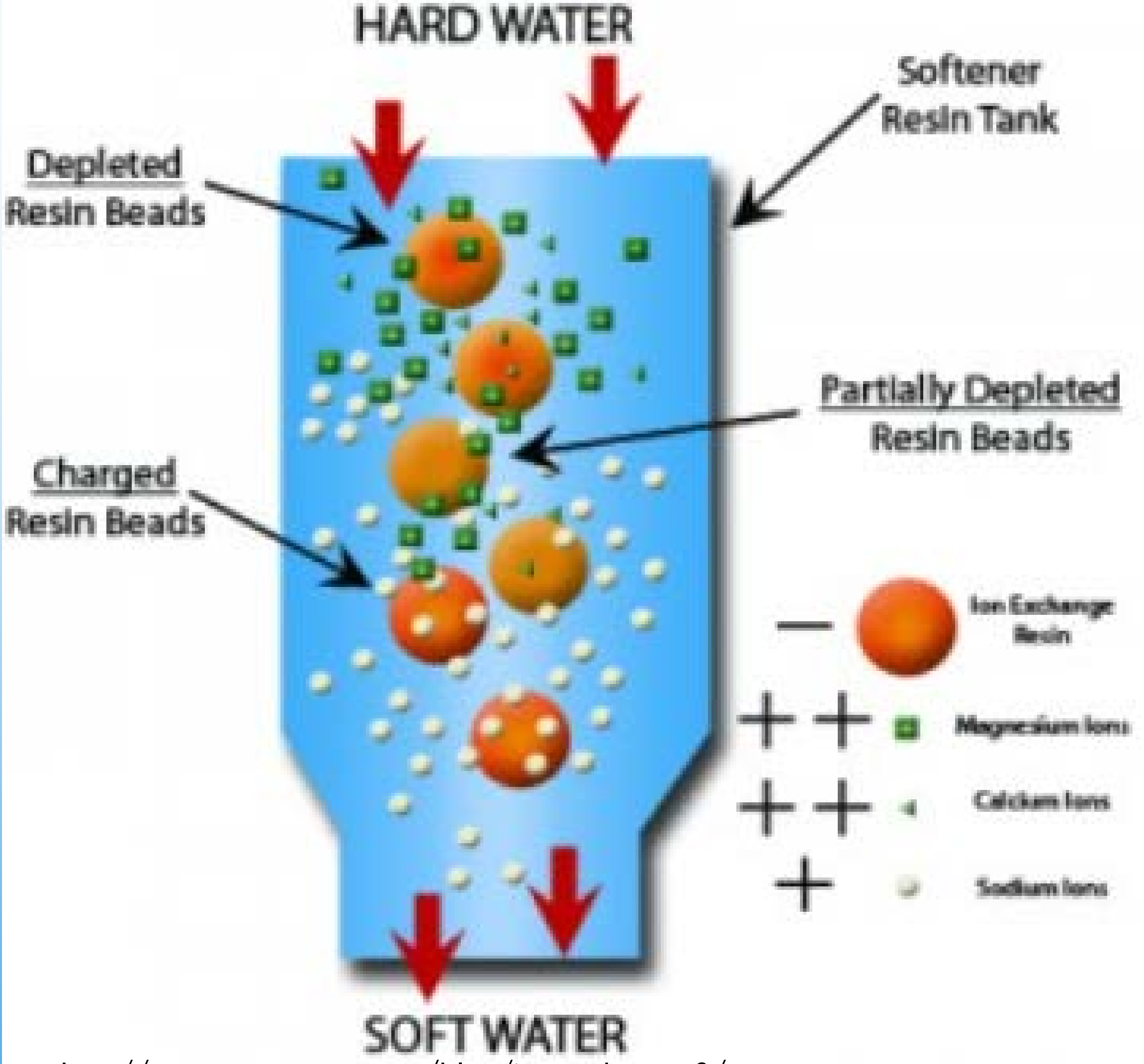


FTE® Field Performance
San Juan Basin, New Mexico 1996-1997

Non-traditional processes

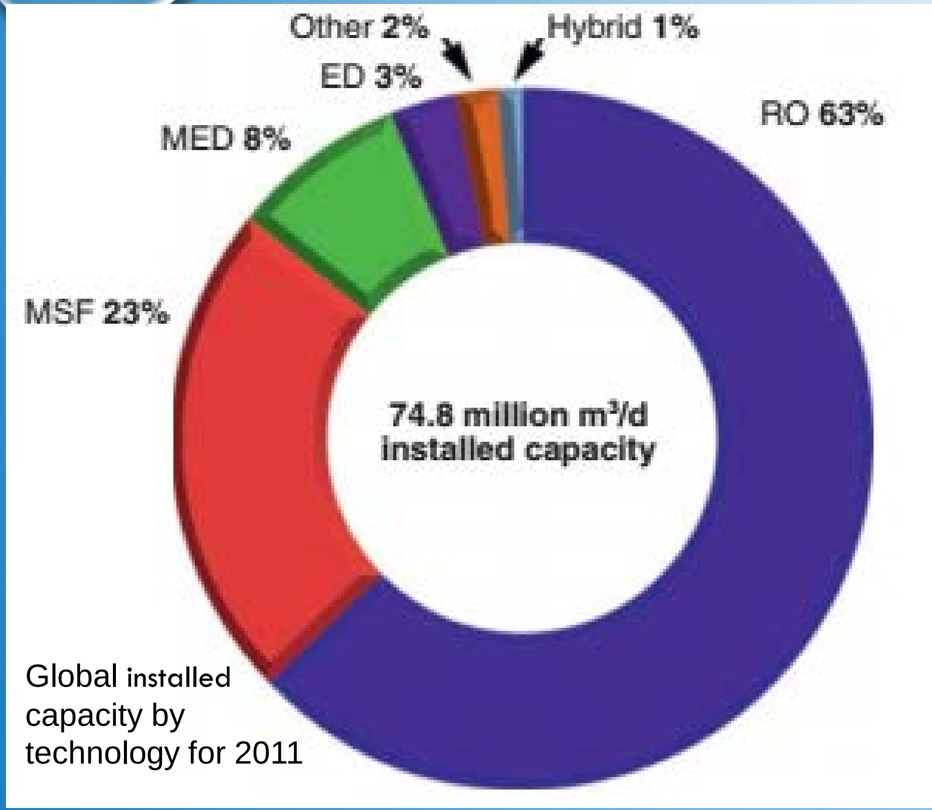
Ion Exchange (IX):

Advantages	Disadvantages
• Produce high purity water • High water recovery (~ 97-99%) • Robust	• Limited to relatively low-salinity water treatment applications • It is cost prohibitive • Use of chemicals for regeneration

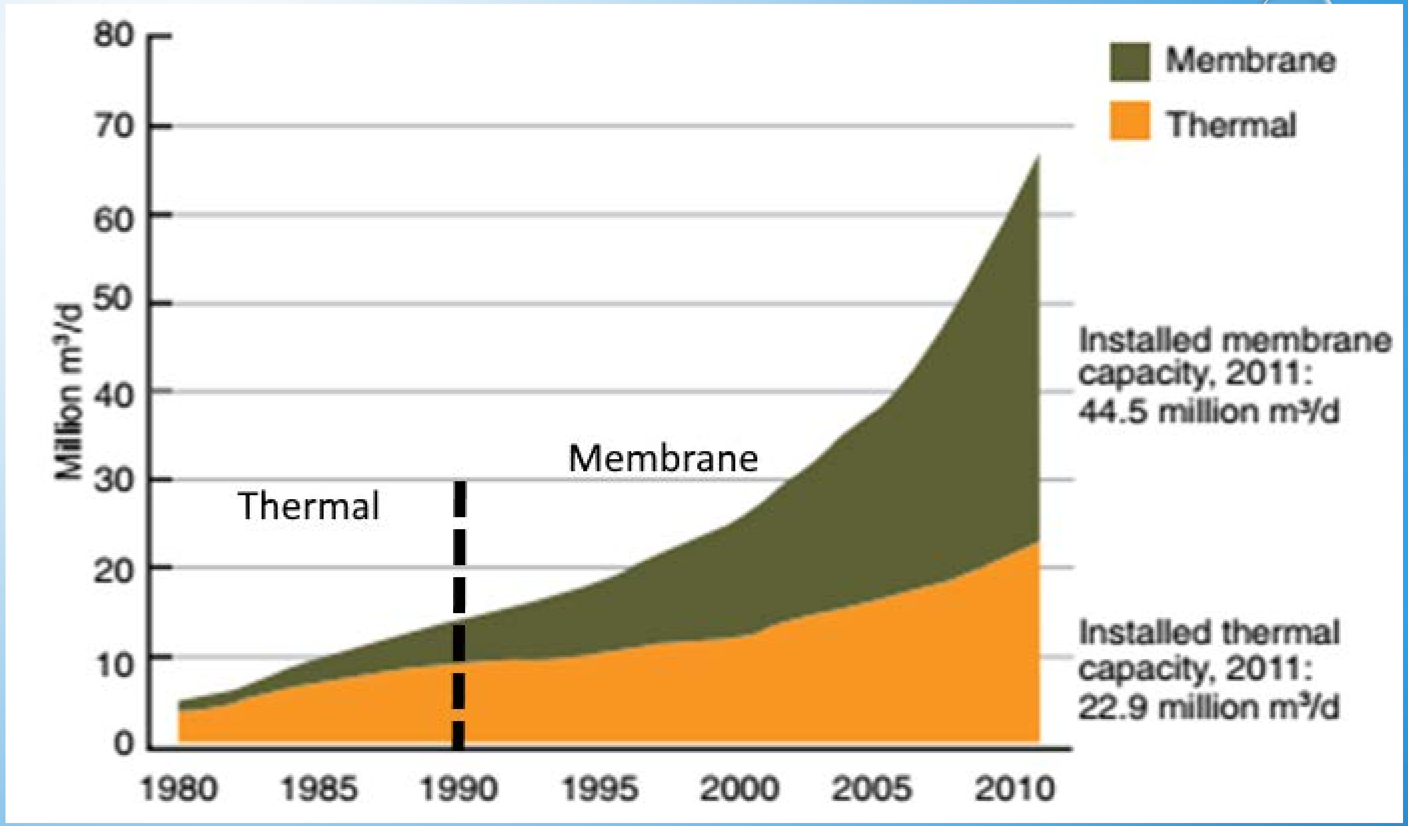


http://www.axeonwater.com/blog/ion-exchange-2/

Current Commercial Technologies



Global installed capacity by technology for 2011



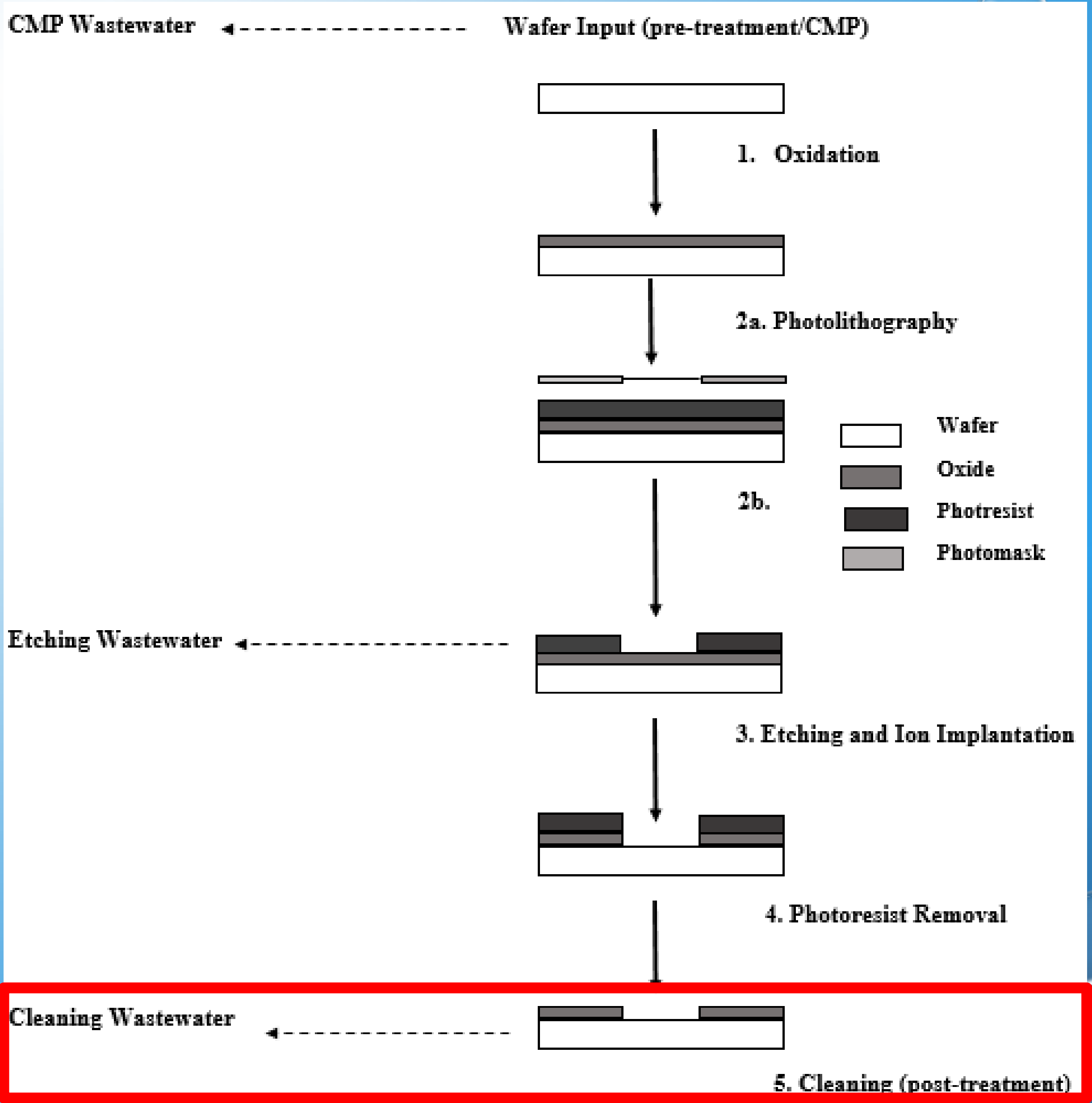
- Prior to 1990, membrane technologies made up less than 1/3 of the global water treatment capacity.
- Today, **membranes** account for just under **2/3 of the total installed treatment capacity**.
- Reverse Osmosis (RO) offers **smaller infrastructure**, and it is more **cost-effective** compared with traditional thermal processes.

Desalination, water from water (2014)

Part II:
Characteristic of drain rinsing water

Sampling of drain rinsing water

Preliminary and RCA clean	
Process and chemical ratio	Removal Goals
Preliminary cleaning; H_2SO_4/H_2O_2 (4:1)	Organic carbon, Photoresist material
DI water (UPW: Ultra Pure Water)	**Rinse**
HF (0.5%)	Oxides
DI water (UPW)	**Rinse**
RCA Standard Clean 1 (SC1); $NH_4OH/H_2O_2/H_2O$ (1:1:5) 70-90º C	Particles, organics, some metals
DI water (UPW)	**Rinse**
Standard Clean 2 (SC2); $HCl/H_2O_2/H_2O$ (1:1:6) 70-90˚C	Metals
DI water (UPW)	**Rinse**

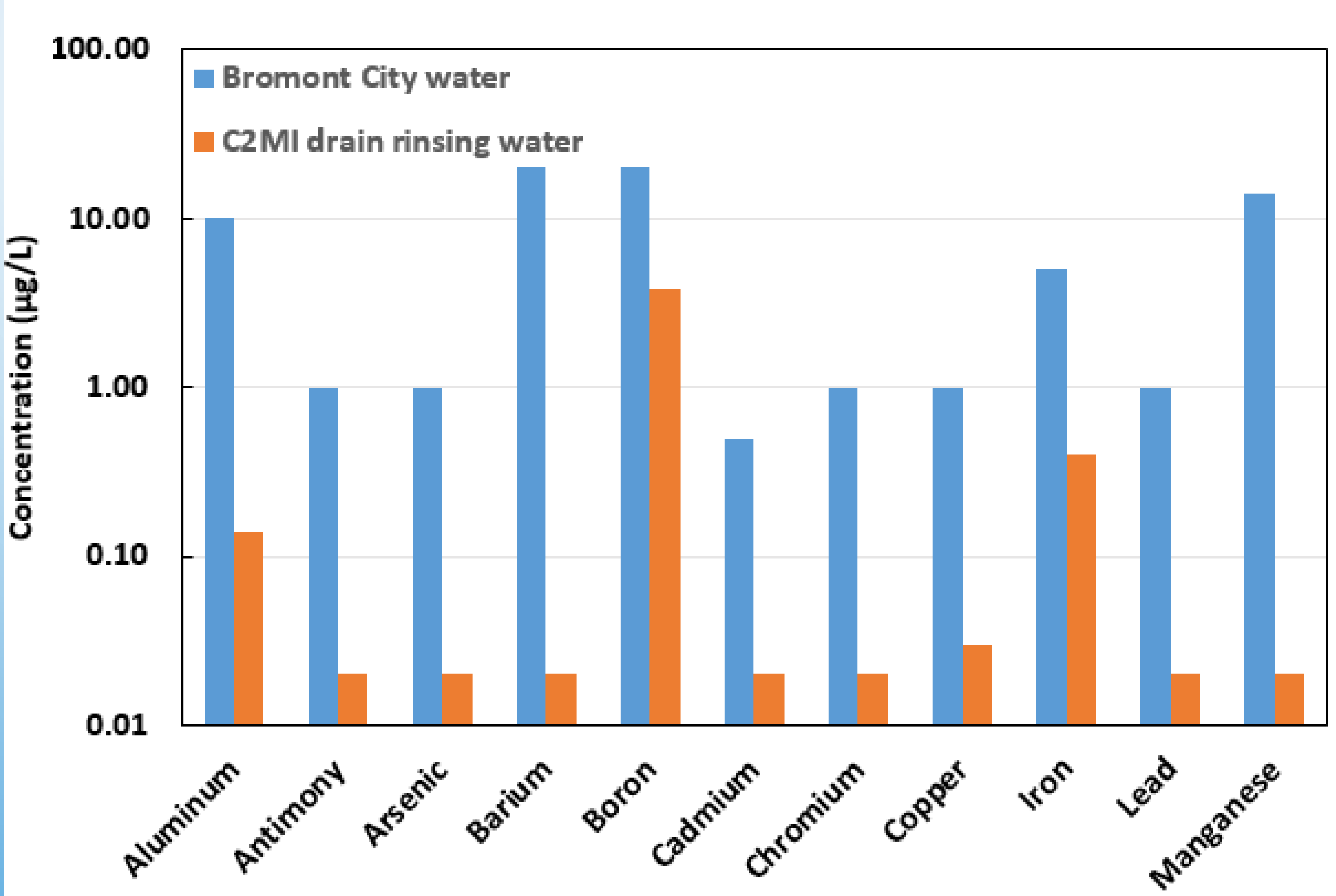


J. A. Gottschalk, Christiane; Libra and A. Saupe, *Ozonation of Water and Waste Water*. Wiley-VCH, 2010.

Characteristic of drain rinsing water

Drain rinsing water -C2MI:

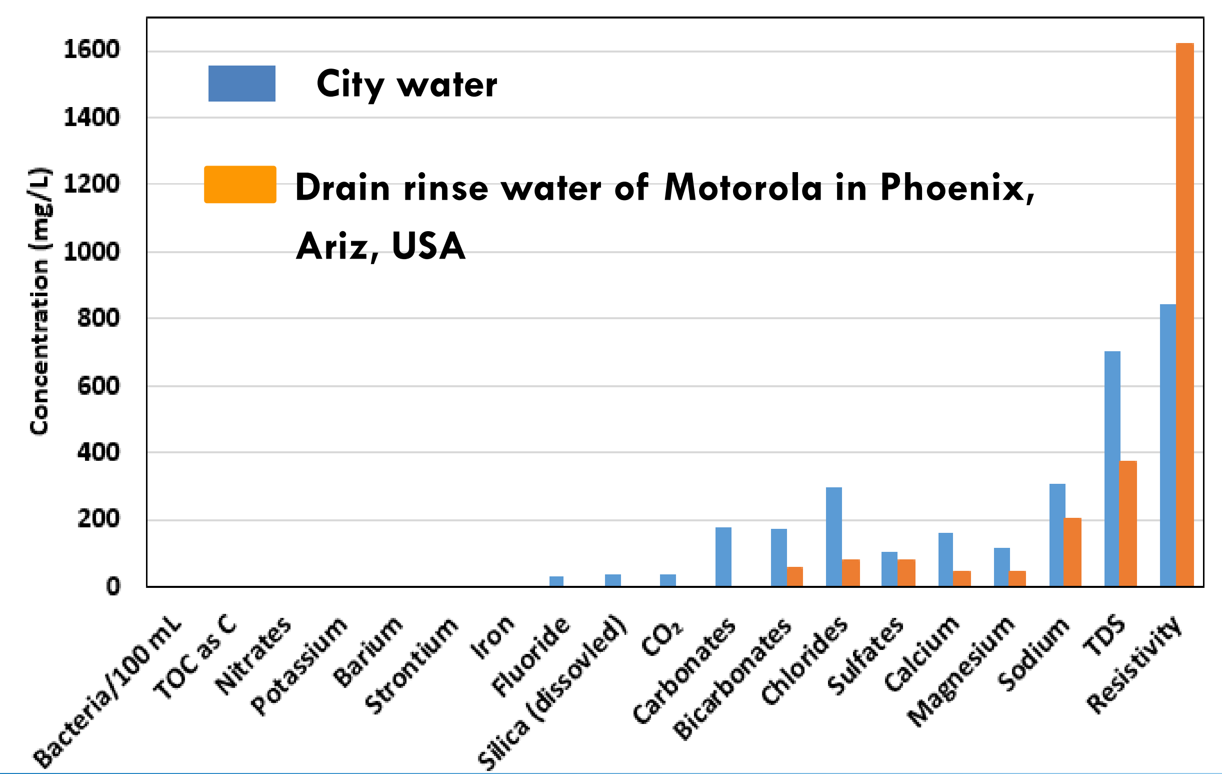
Water Quality Parameter	Rinsing water of C2MI
Turbidity (NTU)	0.07
pH	6-7
TOC (ppm)	0.1-0.9
COD (ppb)	0.03-0.12
Suspended solids > 0.45µm	0
Total Metal (ppb)	13.25
Sulphate (ppm)	<0.05
Fluoride (ppm)	<0.01
Chloride (ppm)	<0.05
Bromide (ppm)	<0.02
Nitrate (ppm)	<0.3
Phosphate (ppm)	<0.03

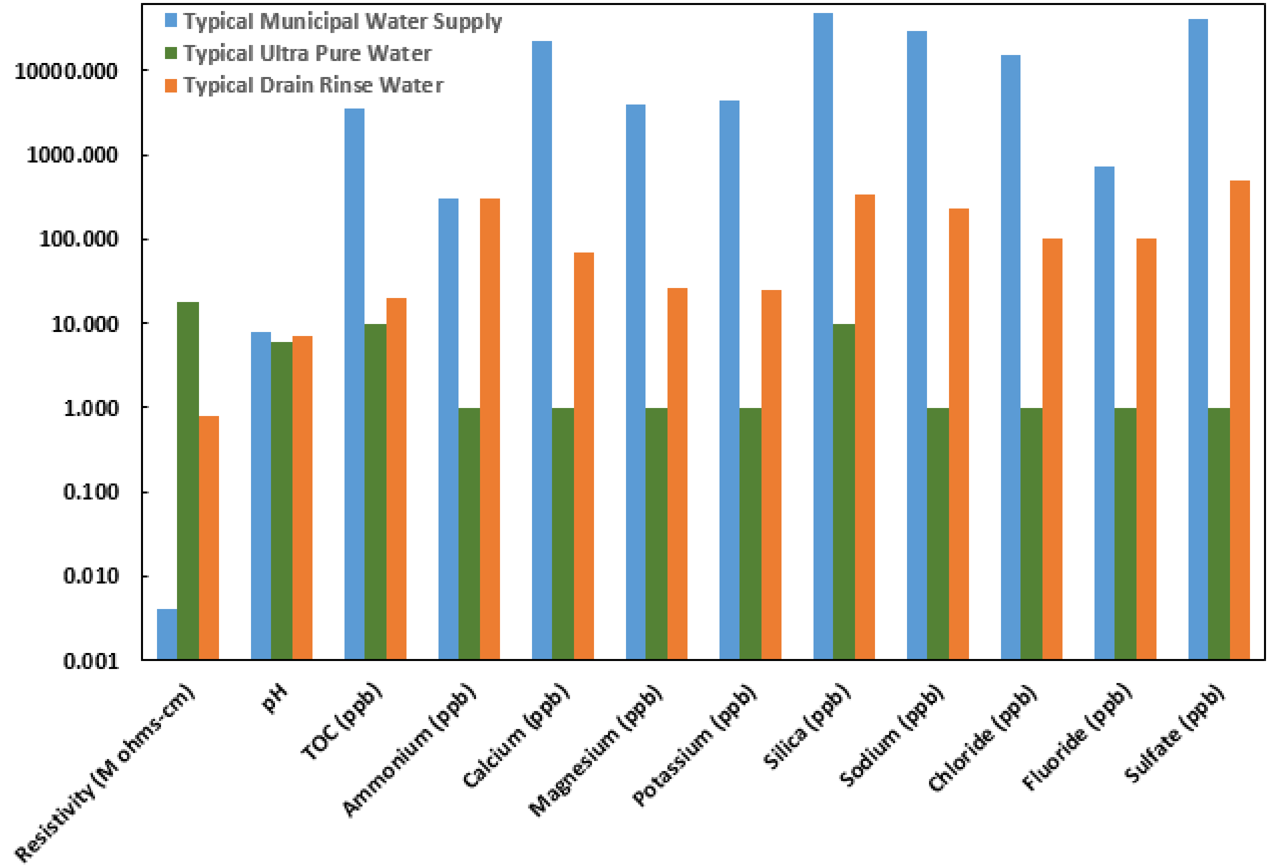


✓ **Drain rinse water contains small quantities of impurities**

Characteristic of drain rinsing water

Typical drain rinsing water quality comparison:





- ✓ **Drain rinse water of all fabrication plants contains small quantities of impurities**
- ✓ **Less impurities than municipal water**

Ref: DeGenova, J., "Recovery , reuse , and recycle of water in semiconductor wafer fabrication facilities," Environ. Prog., vol. 16, no. 4, 1997

Ref: R. Ajay and J. H. Ploeser, "Reusing rinse wastewater at a semiconductor plant," 1999

Part III:
Semiconductor wastewater treatment technologies

Semiconductor wastewater treatment:

Conventional treatment solutions:

Waste type/treatment	Physicochemical	Evapoconcentration	Biochemical reactor	Filtration	Adsorption	Neutralization
Diluted waste (acid/base and rinse water)						***
Fluoride and phosphorous waste	***					*
Nitrogenous Waste		***	***			*
Colloids (from CMP processes)	***			**		*
Suspended particles (grinding and sawing processes)	***			**		*
Heavy metals	***					*
Diluted organic wastes	**				**	*

Ref: Chemistry in Microelectronics, 2013

- **Neutralization**:
  - ✓ Adjusting pH in acid and alkaline solutions
- **Physicochemical:**
  - ✓ Typically based on the precipitation of metal hydroxides at variable pH.
  - ✓ Including: pH adjustment; coagulation/flocculation; and filtration
- **Bio-treatment:**
  - ✓ Based on growing bacteria
- **Evaporation:**
  - ✓ Energy intensive but economic when valorization of the wastes is possible

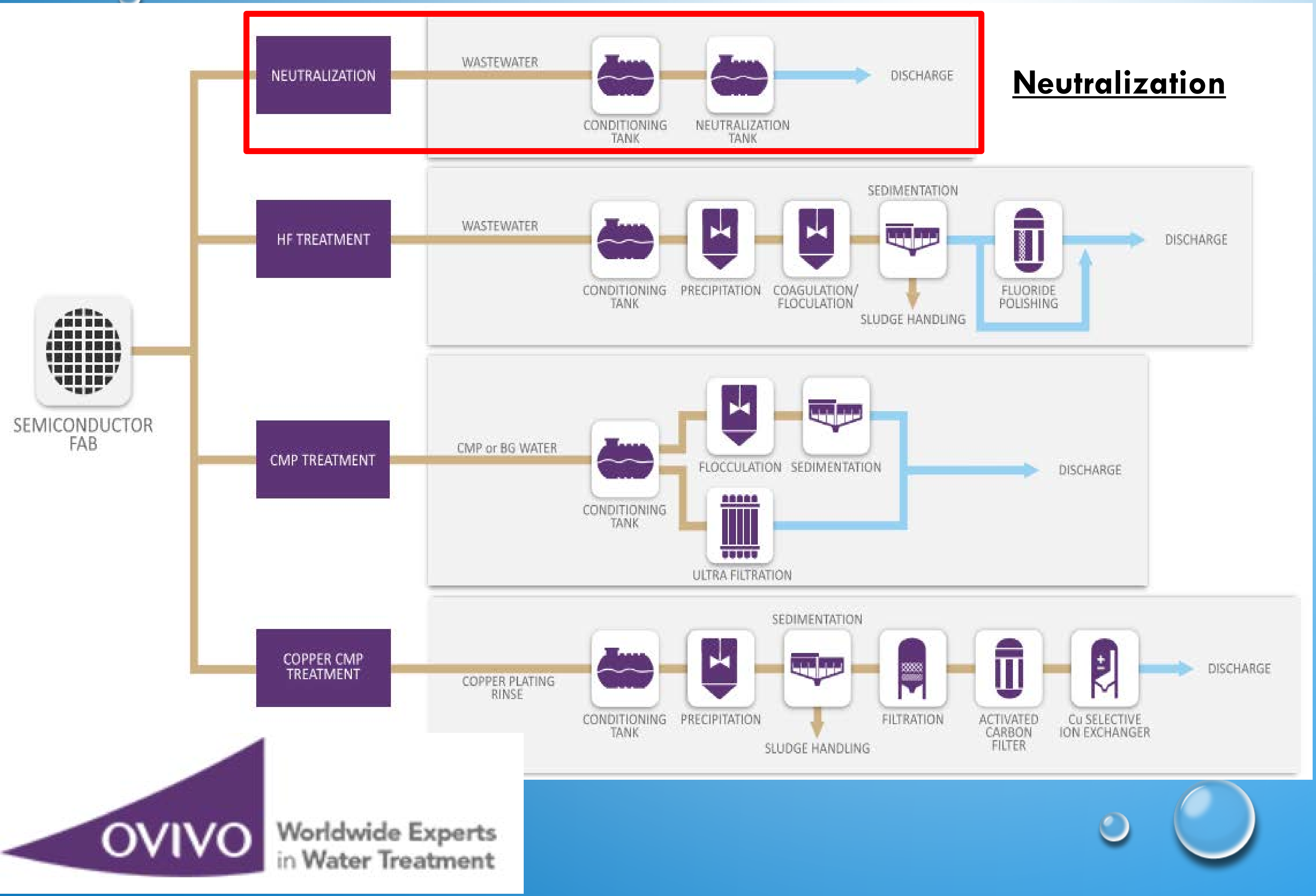
Most effective on concentrated solutions

Major wastewater streams in a semiconductor factory:

Rinsing water is discharged into environment or municipal sewers along with other wastes after neutralization

Semiconductor wastewater treatment:

Treatment solution for semiconductor wastewater via OVIVO:



Neutralization

- ✓ The main focus on separating materials mostly from **CMP wastewater**
- ✓ Treatment to meet **environmental discharge; not reuse**
- ✓ **Drain rinse water is discharged after neutralization process**
- ✓ The research is limited to remove specific materials **from CMP wastewater**

Water recovery and reuse opportunities for drain rinsing water

Water separation from drain rinse water **is economic:**

- ✓ It decreases the total water usage from municipal water due to reuse application as Ultra Pure Water (UPW) in fabrication process
- ✓ It decreases the volume of the wastewater to be treated by a third party
- ✓ Possibility of valorization of the effluents
- ✓ Possibility of using renewable energies for treatment

Part IV:
Some ideas for treatment technologies

Parameters for technology selection for drain rinsing water treatment:

- ✓ Able to produce UPW for reuse in fabrication process;
- ✓ Cost-effective;
- ✓ Robustness and low-maintenance;
- ✓ Easily scalable for treatment of large amount of drain rinse water;
- ✓ Minimum space requirement;
- ✓ Preferably use renewable energy.

Ideas for Treatment technology for semiconductor drain rinsing water treatment

Parameters / Treatment method	Minimum space requirement	Robustness and low-maintenance	Use renewable energy	Easily scalable	Cost-effective	Produce UPW
Humidification-Dehumidification (HDH)	-	-	*	*	*	*
Forward osmosis (FO)	*	*	*	*	*	*
Freezing-Melting (FM)	-	-	*	*	*	*
Reverse Osmosis (RO)	*	-	-	*		*
Ion Exchange (IX)	*	-	-	-	-	*

1) Forward Osmosis
2) Freezing-Melting
3) Humidification-dehumidification
4) Reverse Osmosis
5) Ion Exchange

Thank you

Questions?
Open Discussion!