Industrial Wastewater Reuse Technologies

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SAWEA

What Can Industry do to Conserve Water?

5 December, 2006

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Presentation Outline

- Technologies which can be applied to wastewater reuse.
- Understand how the wastewater is to be reused.
- The source and characteristics of the wastewater to be reused
- Alternatives sources for wastewater which can be reused.
- Common reuse application and technologies.
- Reusing wastewater does not mean the waste “Goes Away”.
- Understanding the limitations of reuse technologies.
- Piloting and bench scale studies.

Wastewater Reuse

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Almost any technology can be applied for water and wastewater reuse. This can include technologies like, but not limited to:

- Precipitation & Sedimentation
- Biological Treatment
- Media Filtration
- Membrane Filtration
- Ion Exchange
- Reverse Osmosis
- Disinfection
- Evaporation & Crystallization

How is the Wastewater to be Reused?

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In order to determine which wastewater reuse technologies can be used, you must understand the application the water or wastewater is to be reused in:

- Environmental constraints
- Mechanical constraints
  - Corrosion
  - Scaling
  - Biological Growth
- Cost constraints
  - Chemical costs
  - Capital costs

How is the Wastewater to be Reused?

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Potential areas of wastewater reuse:

- Irrigation
  - General - Landscape
  - Edible crops
- Boiler feed water
- Cooling water make-up
- Utility water
- Process water

How is the Wastewater to be Reused?

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Typical Maximum Concentrations Allowed in Circulating Water

Constituent	Concern	Maximum
Silica	Scale	150 mg/l SiO_2
Calcium	$CaSO_4$ Scale	1000 mg/l as $CaCO_3$ 400 mg/l as Ca
Phosphates	$Ca_3(PO_4)_2$ Scale	12 mg/l
Chloride	Corrosion	900 mg/l Cl
Total Dissolved Solids	Air Quality	Per PM-10
Suspended Solids	Deposition	10 mg/l TSS
pH	Scale, corrosion	< 8.5
Alkalinity	Scale	< 200 mg/l as $CaCO_3$

How is the Wastewater to be Reused?

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Petroleum Refinery WW Reuse System

	Wastewater After O/W Separation	CT Makeup Water Quality	RO Water to Boilers
pH, SU	6-9	6-9	6-9
Chloride, mg/l	480	480	24
Sulfate, mg/l	160	200	10
Phenols, mg/l	20	0.1	0.005
TDS, mg/l	2000	2000	100
TSS, mg/l	100	5	ND
Oil & Grease, mg/l	40	2.5	ND
BOD, m/l	300	10	1
COD, mg/l	600	60	2
Alkalinity as $CaCO_3$, mg/l	300	150	2
Silica as SiO2, mg/l	40	10	2
TOC, mg/l	150	20	2
Hardness, as CaCO3, mg	80	30	1.5
Fluoride, mg/l	0.04	0.1	0.001
Calcium, mg/l	40	0.02	1.0
Iron, mg/l	0.5	0.1	0.01
Magnesium, mg/l	4	0.002	0.2
Sodium, mg/l	360	400	20
Strontium, mg/l	1	0.5	0.05
NH3, ppm	7	<10	<10

Understand the Source and Characteristics of the Wastewater to be Reused

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Understand the source and quality of the wastewater to be reused.

- List all the potential sources of wastewater that can potentially be reused.
- Is the wastewater from a single source or from multiple sources?
- What is the quantity and quality of the wastewater from each source?
- What is the variability of the wastewater quality and quantity?

Understand the Source and Characteristics of the Wastewater to be Reused

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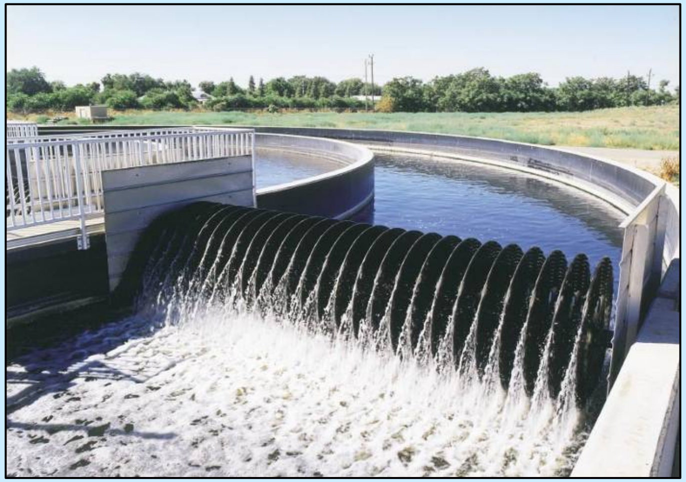
Think "Outside the Box". Don't just look at the combined wastewater from a facility for reuse. You should also look for the "Cleanest" wastewater source available which can be reused. In most cases, this source will:

- Required the fewest number of treatment steps or technologies.
- Will provide the most consistent wastewater quality.
- Be the least expensive to treat.



Alternatives Sources for Wastewater Which can be Reused

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Problem: A petroleum refinery wishes to reduce fresh water consumption at its desalter and requires a source of low TDS water.

The refinery wastewater has a relatively high TDS concentration and would likely require demineralization prior to reuse as desalter make-up water.

However, a segregated waste stream from the refineries sour water stripper is normally very low in TDS. While it may contain some nitrogen and sulfur compounds, as well as some minor concentration of hydrocarbons, these compounds normally do not cause problems with desalter operations.

Recommendation: Use stripped sour water for desalter make-up water. Reusing this water stream normally requires no additional treatment equipment. Reuse refinery wastewater in this application would require significant investment in water treatment equipment.

Alternatives Sources for Wastewater Which can be Reused

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Problems: A petrochemical plant wishes to reduce fresh water consumption at its boilers and cooling water system due to escalating costs and constraints on supplies to the facility.

The petrochemical wastewater has a high hydrocarbon and TDS concentration and would likely require extensive pretreatment prior to demineralization.

However, a nearby municipal wastewater treatment plant, which has primary treatment, secondary (biological treatment) and disinfection discharges to the ocean. This wastewater has no hydrocarbons and very low TDS.

Recommendation: Pipe the municipal wastewater effluent to the petrochemical plant where it will be treated with a combination of microfiltration and reverse osmosis to make boiler feed water.

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Those technologies which are normally applied after a conventional wastewater treatment system which includes primary and secondary treatment.

Wastewater Reuse Applications and Technologies

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Goal: Metals, Silica and Hardness Removal:

Reuse Applications: Irrigation water, cooling system make-up water, and boiler feed water.

Industries: Power plants, steel mills, machine shops, automotive, microelectronics, petroleum and chemical industries.

Technologies: Solids contact clarifiers, hot and warm lime softeners, ion exchange softeners, and cross flow microfiltration.

Solids Contact Clarifiers – Metals and Hardness Removal

- *Precipitate calcium, magnesium, barium, strontium, silica, phosphate and metals.*
- *Dissolved calcium and magnesium (hardness) reacts with lime (or NaOH) and soda ash to precipitate calcium carbonate and magnesium hydroxide:*

Cross Flow Microfiltration – Metals and Hardness Removal

- *Precipitate calcium, magnesium, barium, strontium, silica, phosphate and metals.*
- *Dissolved calcium and magnesium (hardness) reacts with lime (or NaOH) and soda ash to precipitate calcium carbonate and magnesium hydroxide:*

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Hot and Warm Line Softeners

- *Silica and Hardness Removal*
- *Dissolved silica is adsorbed by magnesium hydroxide precipitate. The "Mg: SiO2 ratio" (relative amount of Mg (mg/l as Mg) to SiO2 precipitated) ranges from 0.5 to 2.5 depending upon the initial and final silica concentrations and concentration of magnesium hydroxide floc.*

Ion Exchange Softeners

- *Hardness Removal*

Wastewater Reuse Applications and Technologies

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Goal: Suspended Solids Removal

Reuse Applications: Irrigation water, utility water, cooling system make-up water, and boiler feed water.

Industries: Power plants, steel mills, machine shops, food industry, automotive, microelectronics, petroleum and chemical industries.

Technologies: Media filtration and microfiltration.

Wastewater Reuse Applications and Technologies

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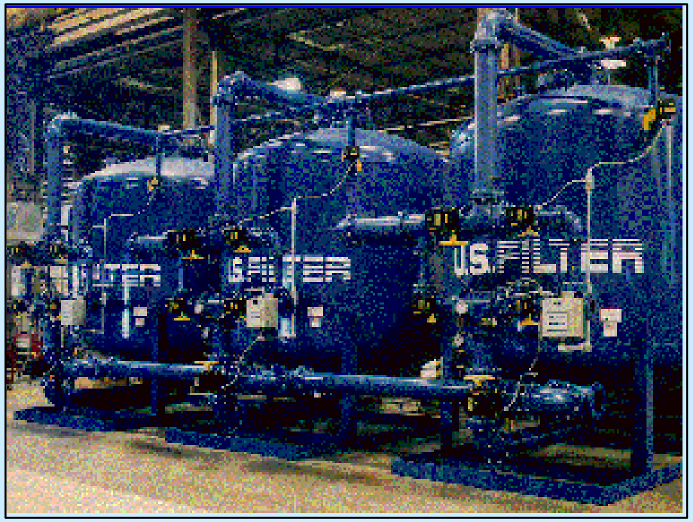
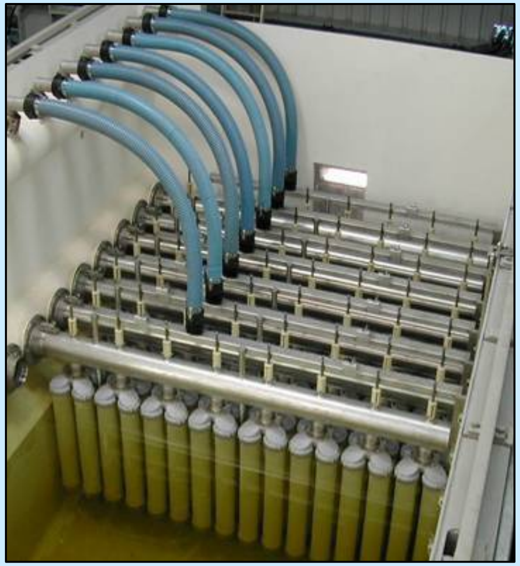
Media Filter -

- *Solids < 5-10 mg/L*
- *Turbidity < 1 NTU*
- *Particles 2 - 5 micron*
  98% removal
- *Requires coagulant or flocculent feed*



Microfiltration –

- *Completely remove unwanted solids greater than 0.1 micron.*
- *BOD < 5 mg/l, TSS < 1 mg/l*
- *Turbidity < 0.2 NTU*



Wastewater Reuse Applications and Technologies

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Goal: Disinfection

Reuse Applications: Irrigation water, utility water and petroleum water floods.

Industries: Municipal and petroleum industry.

Technologies: Chlorination and UV disinfection systems.

Wastewater Reuse Applications and Technologies

Goal: Dissolved solids removal.

Reuse Applications: Irrigation water, utility water, cooling tower make-up water, and boiler feed water.

Industries: Power plants, petroleum and chemical industry, oil production steam and water flood, automotive, microelectronics, and food industries.

Technologies: Reverse osmosis, ion exchange and evaporators.

Wastewater Reuse Applications and Technologies

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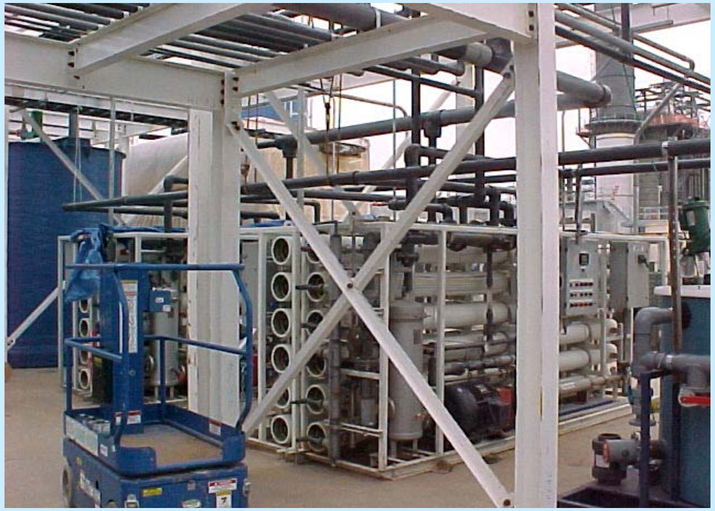
Reverse Osmosis

- *Typical limit on waste brine is 70 to 80,000 ppm at 1000 psi feed pressure.*



Ion Exchange

- *Removes a wide range of cations and anions which make up TDS in water.*

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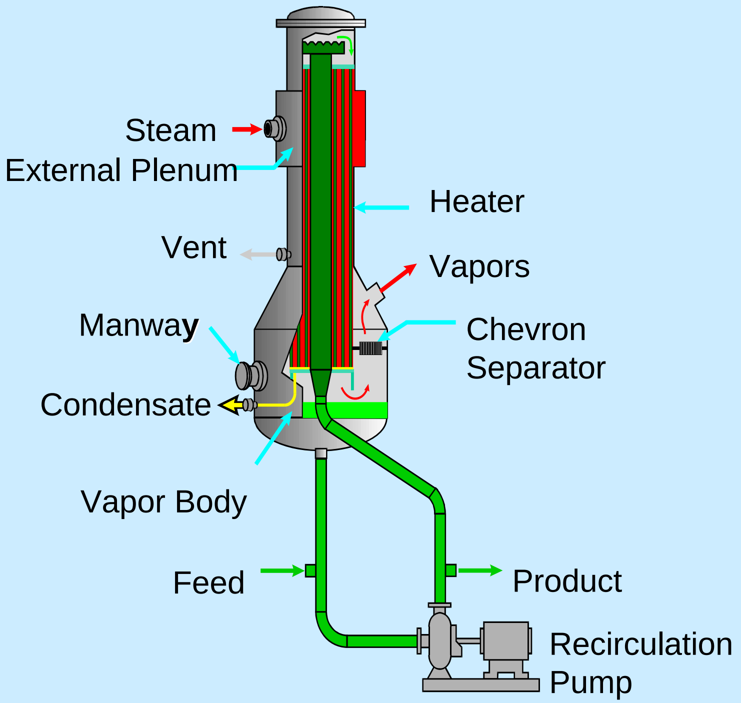
Evaporation / Brine Concentrators

- *Typically falling film type as the used for scale prevention.*
- *Pre-acidification can be used to minimize $CaCO_3$ scale formation.*



Wastewater Reuse Applications and Technologies

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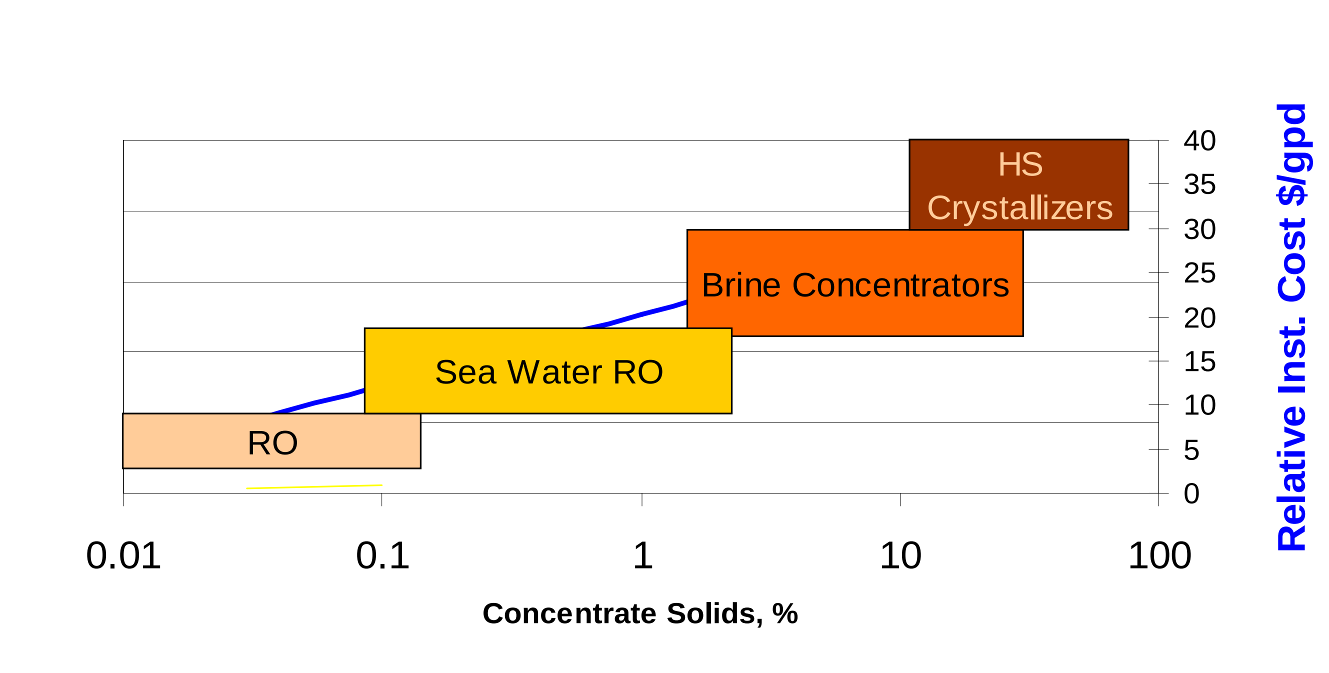
Comparison: Capital Cost and Power

Technology	Utility	Relative Capital
MF/RO	10 kWh/1000gal	1.0 $/gpm
Evaporation	70 kWh/1000gal	2.5 $/gpm
Crystallization	250 kWh/1000gal	5.0 $/gpm



What Happens to the “WASTE” in the Wastewater?

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There is no such thing as “Zero” waste discharge!

Reusing wastewater minimizes the amount of wastewater to be disposed of by concentrating the pollutants in the wastewater into a smaller volume.

What Happens to the "WASTE" in the Wastewater?

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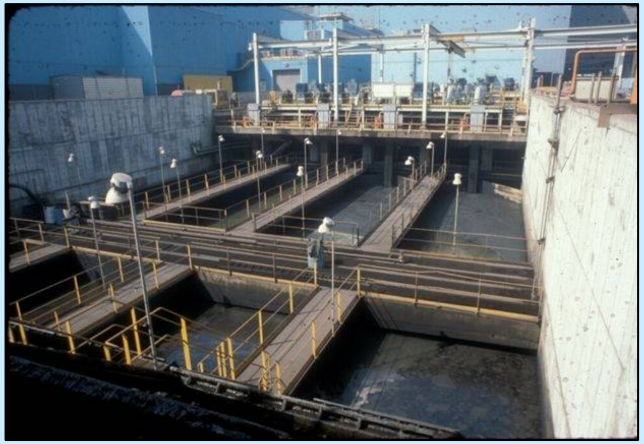
Some treatment processes physically separate and concentrate the "Waste" from the "Wastewater". This can include:

- *Oil/Water Separators – Produce a concentrated waste oil stream.*
- *Clarifiers and Filters – Produce a concentrated suspended solids stream.*



Oil Removal w/ Mill Scale Collector and Oil Belt Skimmers Steel Mill

Microfiltration – Metals Precipitation and Removal Power Plant ZLD System

What Happens to the "WASTE" in the Wastewater?

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Physical separation is sometime enhanced by chemical treatment for removal of:

- *Hardness*
- *Metals*

Hot Lime Softener - Silica Removal for Boiler Feed Water

Solids Contact Clarifier – Metals Removal Pipe Mill

What Happens to the "WASTE" in the Wastewater?

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Removal of dissolved organic contaminants and nutrients can be accomplished by biological treatment where:

- *The dissolved components are consumed by bacteria.*
- *The bacteria, in the form of suspended matter, is removed by a physical separation step.*

Fine Bubble Aeration – Paper Mill

What Happens to the "WASTE" in the Wastewater?

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Finally, dissolved solids are typically removed and concentrated by:

- *Reverse osmosis*
- *Brine concentrators*

Reverse Osmosis
TDS Removal

Brine Concentrator
Chemical Plant

What Happens to the "WASTE" in the Wastewater?

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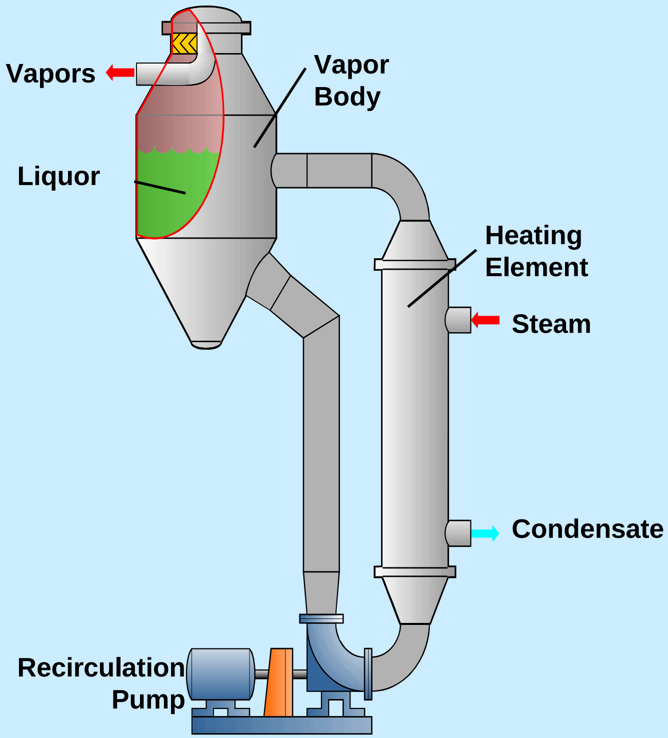
"Waste" which has been concentrated in liquid streams can be converted to solids streams by:

- *Evaporation Ponds*
- *Crystallizers*



Crystallizer

Constellation Energy's High Desert Power Project

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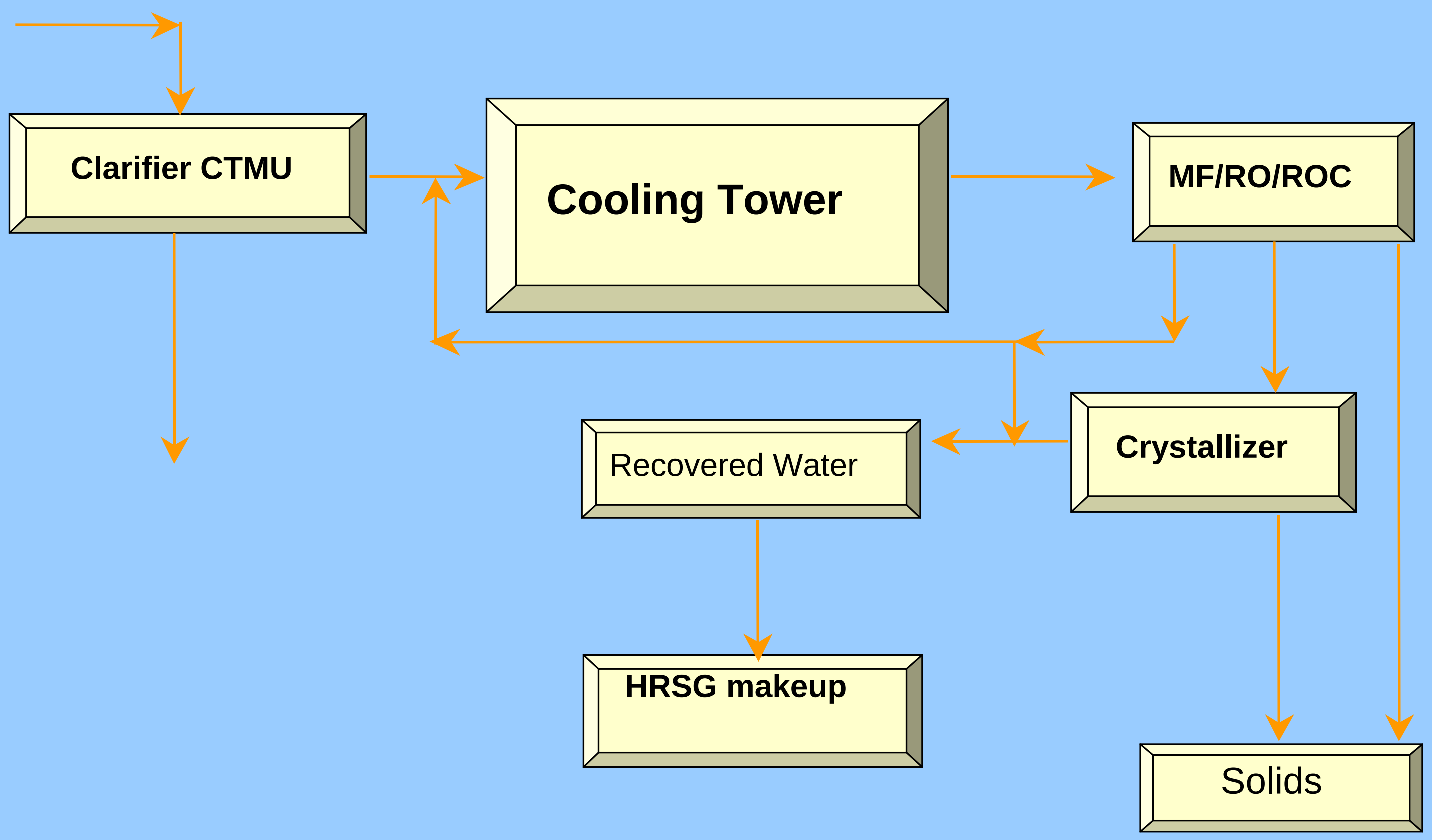
Cooling Tower Water Reuse System
Located in Victorville CA
750 MW Power Plant
Startup in July 2003



High Desert Power: Fate of Salts

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Stream Identification	Units	Blow down	µFilter Permeate (Blow down)	Primary RO Permeate	Primary RO Reject	ROC Permeate	ROC Reject
FLOW	gpm	557	551	422	148	68	80
Soluble Species							
Cations							
Ca	mg/l as ion	196	40	0	153	2	282
Mg	mg/l as ion	136	4	0	14	0	26
Na	mg/l as ion	883	1,326	28	5,027	96	9,229
Anions							
SO4	mg/l as ion	1,539	1,539	24	6,263	81	11,641
Cl	mg/l as ion	885	885	24	3,339	85	6,111
F	mg/l as ion	1	0	0	1	0	1
SiO2	mg/l as ion	146	10	1	37	3	67
Metals	mg/l as ion	4	0	-	4	0	10
Total	mg/l as ion	4,000	3,957	87	15,327	345	28,166

Protecting Reuse Technologies

Waste and wastewater treatment reuse technologies only work as well as the wastewater treatment systems in front of them.

Many reuse technologies are prone to:

- Scale formation
- Oil fouling
- Biological fouling

Poorly designed wastewater treatment systems can cause catostrophic failure of wastewater reuse technologies.

Protecting Reuse Technologies

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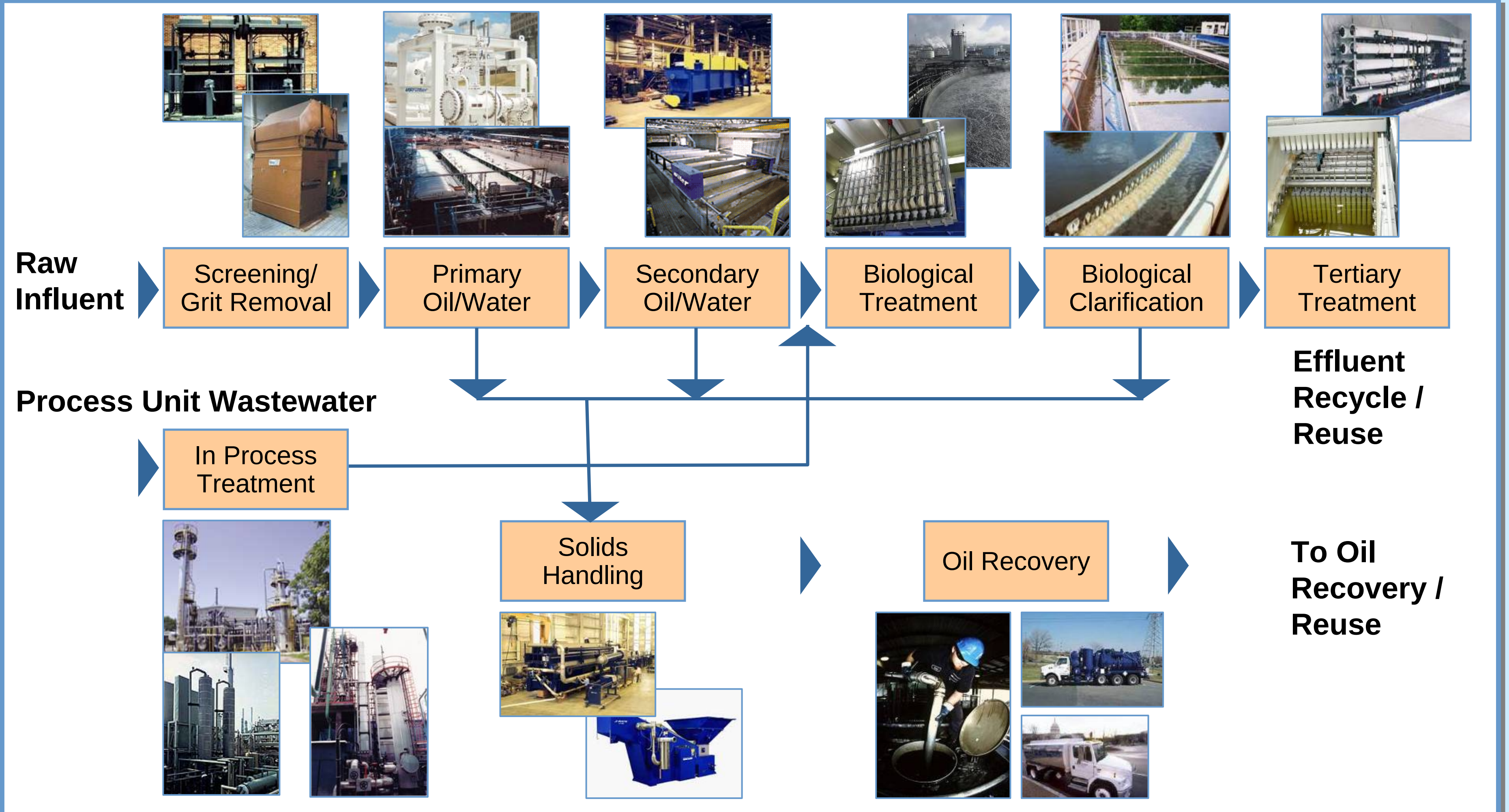
Design WWTP to work under the most difficult conditions.



Piloting and Bench Scale Studies

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When considering wastewater reuse, bench scale and field pilot studies can provide significant benefits.

Bench studies can provide a quick understanding if the wastewater has potential for reuse.

Piloting and Bench Scale Studies

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Field pilot studies, normally performed after bench studies, can operate under "normal" conditions. Experiencing daily variations in wastewater feed conditions and actual one site environmental conditions. Effects of long term operation on O&M of reuse components can also be determined.


Thank You!
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