Treated Effluent (TSE) Reuse Applications and Challenges

Saudi Arabia
Agenda

- General
- Treatment Technologies
- Cooling Towers Application
- Power Application
- Industry Application
- Brine Disposal
WATER REUSE DRIVERS

Water scarcity
- Drought
- Competition (cities, agriculture…)
- Irregular quality
- Salinity
- Exhaustion of resources

Regulation
- Limitations of water intake
- Discharge limits
- IPPC recommendations

Production needs
- Increase of production
- Anticipation of future development
- Safe and continuous supply
- Avoid production shutdown

Costs
- Water consumption costs
- Discharge fees
- Needs for large volumes

Image
- Environmental guidelines
- Shareholders expectations
- Public opinion
- Sustainable development

INCREASE DEMAND FOR WASTEWATER REUSE
### TSE CUSTOMER CATEGORIES AND USES

<table>
<thead>
<tr>
<th>Customer Categories</th>
<th>Typical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industries</td>
<td>Cooling Water</td>
</tr>
<tr>
<td>Mining</td>
<td>Industrial process water</td>
</tr>
<tr>
<td>Utilities</td>
<td>Cutting fluids</td>
</tr>
<tr>
<td>Industries</td>
<td>Cleaning / wash-downs</td>
</tr>
<tr>
<td></td>
<td>Concrete mixing</td>
</tr>
<tr>
<td></td>
<td>Irrigation</td>
</tr>
</tbody>
</table>

**Source:** [www.nwc.com.sa](http://www.nwc.com.sa)
The total value of TSE contracts is around 5.3 Billion SAR signed, this was achieved before TSE BU was spun off after incubation, as a separate Business Unit (BU) on 13th/October/2012. The TSE BU’s contracts of approximately 20 years duration with a total volume of 281,950 m3/day till October/2012 are as follows.

Source: www.nwc.com.sa
SEWAGE TREATMENT PROCESSES

- **Sewage Treatment Plant with activated sludge**
  - Pretreatment
  - Activated sludge
  - Clarification
  - Sand filtration
  - Disinfection

- **Sewage Treatment Plant with MBR**
  - Pretreatment
  - Aeration tank
  - Membrane tank
  - Maintenance & backwash tank
  - Pressurized air
  - Permeate

- **Sewage Treatment Plant with MBBR**
  - MBBR
  - Clarifier
  - Disc Filter
  - Excess sludge

- **Sewage Treatment Plant Anaerobic / Attached Growth**
Location:
- Characteristics of WWT
- Discharge
- System
TSE CHARACTERISTICS

Source: Saleem Al Saleem, King Saud University, Ms thesis
# TSE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PME-Costal</th>
<th>MOW-Central</th>
<th>MOW-TSE</th>
<th>TSE - TYP</th>
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<tbody>
<tr>
<td>TDS mg/l</td>
<td></td>
<td>2000-2500</td>
<td>2000-2500</td>
<td>800-2500</td>
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<tr>
<td>TSS mg/l</td>
<td>15</td>
<td>600</td>
<td>10</td>
<td>5-40</td>
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<tr>
<td>Turbidity NTU</td>
<td>75</td>
<td></td>
<td>5</td>
<td>2-30</td>
</tr>
<tr>
<td>BOD mg/l</td>
<td>25</td>
<td>500</td>
<td>10</td>
<td>5-30</td>
</tr>
<tr>
<td>NH3-N mg/l</td>
<td>1</td>
<td>80</td>
<td>5</td>
<td>1-30</td>
</tr>
<tr>
<td>NO3-N mg/l</td>
<td></td>
<td></td>
<td>10</td>
<td>5-40</td>
</tr>
<tr>
<td>PO4-P mg/l</td>
<td>1</td>
<td>25</td>
<td></td>
<td>&lt;15</td>
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</tbody>
</table>
TECHNOLOGIES FOR WATER REUSE

- **Biological**
- **Settling**
- **Filters**
- **MF / UF**
- **RO**
- **Sludge**
- **ZLD**
- **MBBR**
- **Anox-kaldness™**
- **Actiflo™ / Multiflo**
- **Disc Filters™**
- **3FM™**
- **Green-house Drying Beds**
- **Solia™**
- **Evaporators**
- **Evaled™**
- **Dewatering + Dryer**
- **Inos™**
- **Green-house STPs**
- **Organica™**
- **Anaerobic Treatment**
- **UASB™**
- **Biofilter**
- **Biostyr™**
- **Bioreactor**
- **Biosep™ or Crossflow**
- **MBR**
- **Benzine Treatment**
- **MPPE™**
- **RO skid**
- **UF skid**
- **RO skid for TSE**
- **Dryer**
- **Biocon™**
There is not a single specific technology for water REUSE: water REUSE is very often obtained after association of several processes/technologies adapted to each case.

The main Processes/Technologies implemented for water REUSE are usually:

- Clarification/Filtration.
- Membranes.
- Activated carbon.
- Biological Treatment
- UV/Ozone/Chlorination
- Evaportaion
Technologies for REUSE water - General Concept

**CLARIFICATION/FILTRATION**

For Removal of *Turbidity* and *Total Suspended Solids*.

- Conventional Sand Filter
- High Speed Flexible Fibre Filter
- Hydrotech Compact Disc Filter
CLARIFICATION/FILTRATION.

For Removal of Turbidity and Total Suspended Solids.

ULTRA FILTRATION

SCREEN FILTER

ACTIFLO
Technologies for REUSE water - General Concept

BIOLOGICAL TREATMENT

For Removal of BOD, COD, TOC.

MBR
Membrane Bio Reactor

MBBR
Moving Bed Bio Reactor

BIO FILTER
Technologies for REUSE water - General Concept

MEMBRANES

For Removal of Dissolved Solids.

Reverse Osmoses
Technologies for REUSE water - General Concept

**DISINFECTION & STERILIZATION**

For Removal of Micro-organism – **Bacterial & Algae**.

- Ultraviolet
- Ozone
- Chlorine Dosing System
Technologies for REUSE water - General Concept

**ACTIVATED CARBON**

For Removal of Organics.

![Granular Active Carbon Vessels](image1.png)

![Granular Active Carbon](image2.png)

*Note*: High carbon consumption is always a key factor when using active carbon.
Technologies for REUSE water - General Concept

- **EVAPORATORS AND CRISTALLIZERS**

  A technology for Zero Liquid Discharge (ZLD) to generate high quality water for upstream processes meanwhile no liquid waste and production of landfilable waste

  HPD® Cristallizer

  Evaled® Evaporator
Technologies for REUSE water - General Concept

Association of these technologies will depend most of the time of the following criteria:

- Type of pollutants into the water to be treated before REUSE.
- Plant capacity.
- Concentration of the pollutants into the water to be treated before REUSE.
- Usage of REUSED water after treatment.
- Land / Area / Space / Volume... available for the treatment plant.
- Cost of treatment
COOLING TOWERS

1 ton of cooling needs 0.3 m³
DISTRICT COOLING - TSE

Evaporation

Make-up water

Cooling water blow-down

Several process heat exchangers

Cold water

Hot water

Process in

Process out
TDS: 2500 ppm (corrosion)
TSS: 25 ppm (fouling)
NH4 < 1 (corrosion)
PO4 < 10 ppm (fouling)
Case Study: Filtration Requirement
World’s Largest District Cooling Plant; Haram

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Inlet</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>mg/L</td>
<td>10-13</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>BOD</td>
<td>Mg/L</td>
<td>10</td>
<td>&lt; 4</td>
</tr>
</tbody>
</table>

180 000 TR cooling capacity
Year of delivery: 2013 (ongoing)
Capacity: 44,000 m³/day
Technology: Hydrotech™
Case Study: BARCELONA (Spain) – REUSE for Agriculture & Aquifer

Process Flow Diagram of Chosen REUSE Treatment Line

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Inlet</th>
<th>Outlet</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$</td>
<td>$\leq 20$ mg/l</td>
<td>$\leq 5$ mg/l</td>
</tr>
<tr>
<td>TSS</td>
<td>$\leq 50$ mg/l</td>
<td>$\leq 5$ mg/l av. 2,4 mg/l</td>
</tr>
</tbody>
</table>

The ACTIFLO™ process
Settling by means of ballasted sand
Maximum treatment capacity: $3 \times 4,800$ m$^3$/t
Settling capacity: $120$ m$^3$/t

Tertiary filtration Hydrotech®
Maximum treatment capacity: $10 \times 1,440$ m$^3$/t
Mesh width: $10$ μm.
Case Study: BARCELONA (Spain) – REUSE for Agriculture & Aquifer

<table>
<thead>
<tr>
<th></th>
<th>Raw water</th>
<th>Actiflo™ outlet</th>
<th>Discfilter outlet</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbidity, NTU</strong></td>
<td>12.0-43.6</td>
<td>1.2-2.1</td>
<td>0.8-1.7</td>
<td>92-97</td>
</tr>
<tr>
<td><strong>TSS, mg/l</strong></td>
<td>15-56</td>
<td>2.9-5.1</td>
<td>&lt;2-3.7</td>
<td>81-94</td>
</tr>
<tr>
<td><strong>Total Phosphorus, mg P/l</strong></td>
<td>0.94-3.32</td>
<td>0.12-0.25</td>
<td>0.08-0.20</td>
<td>74-94</td>
</tr>
<tr>
<td><strong>COD, mg O₂/l</strong></td>
<td>57.6-112.3</td>
<td>&lt;30-54.9</td>
<td>&lt;30-52.0</td>
<td>36-67</td>
</tr>
<tr>
<td><strong>BOD₅, mg O₂/l</strong></td>
<td>9.0-10.0</td>
<td>&lt;3.0-4.0</td>
<td>&lt;3.0-4.0</td>
<td>56-80</td>
</tr>
<tr>
<td><strong>Total Coliforms, cfu/100 ml</strong></td>
<td>$2.3 \times 10^3 - 6.0 \times 10^6$</td>
<td>$3.2 \times 10^4 - 3.0 \times 10^5$</td>
<td>$7.0 \times 10^3 - 3.0 \times 10^5$</td>
<td>39.99</td>
</tr>
</tbody>
</table>
Case Study: BARCELONA (Spain) – REUSE for Agriculture & Aquifer
Case Study: TDS & NH4 Reduction Requirement

Water Reclamation Process Trains

Conventional X Membrane
MBR X UF
Case Study: KRANJJI (Singapore) – REUSE for Industry

Process Flow Diagram of Chosen REUSE Treatment Line

Water Reclamation Plant (WRP)

Secondary Effluent Sump

Hypochlorite

Equalisation Tank

Strainers

Backwash to Head of WRP

Microfiltration

Reverse Osmosis System
5 x 8MLD (2 Stage, 75% Recovery)

Product Water Tank

40,000 m³/day to wafer fabrication plants and other industries for non-potable reuse

UV
3 x 50%

Reject to Head of WRP

Micro filtered Storage

Anti-Scalant

<table>
<thead>
<tr>
<th>WW Parameter</th>
<th>Influent Quality</th>
<th>Effluent Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD&lt;sub&gt;5&lt;/sub&gt;</td>
<td>25 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>COD</td>
<td>70 mg/L</td>
<td>14 mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>20 mg/L</td>
<td>1 mg/L</td>
</tr>
<tr>
<td>Ammonia</td>
<td>33 mg/L</td>
<td>&lt; 3 mg/L</td>
</tr>
<tr>
<td>TP</td>
<td>5.2 mg/L</td>
<td>&lt; 0.46 mg/L</td>
</tr>
</tbody>
</table>
Case Study: NH3 Reduction Requirement

NH3/NH4
NH3/NO3 – STP performance
Net water consumption for power generation in thermal plant 7.6 L / 1 KWh
Understand | General process flow diagram

Seawater desalination

Other water sources:
- Surface water
- Groundwater

Industrial water production

Boiler feed water production

Boiler house

Cooling tower

Condensate polishing

Wastewater treatment plant

Scrubbing Wastewater

To WWTP

To WWTP

To WWTP

Mineral sludge treatment and recovery

Treated wastewater discharge or reuse

Rain water collecting

To WWTP
Understand | Detailed PFD for Power
Case Study: Power – HAIL II PP
Re-Use Industry
Reuse Industry
Overview of water uses – Steel Industry
Brine Treatment
Case Study: Mopco phase 2 – Brine Treatment

- Waste water RO reject
- Multiflow softener
- Cooling towers
- DM& Activated Carbon filters
- Piermeate 7 m³/h
- Brine water RO (1×10 m³)
- Filter press
- Intermediate tank (50 m³)
- 10 m³/h
- Cation regeneration waste
- Demineralization Unit (Existing)
- 1.5 - 2 T/D
- Solid waste
- Evaporator
- Maximum Distillate water 2.5 m³/h
- Evaporation ponds
- 0.5 – 1 m³/h
- 3 m³/h
- 0.1 m³/h
Case Study: Mopco phase 2 – Brine Treatment
REUSE, Key factors of success

Site analysis
- Identity: all water flows

Mass balance
- Character: Quantity
- Quality Parameter
- pH

Definition of Quality
- Usage: Product
- Operation
- Equipment
- pH

Process
- Develop: Combination
- Interaction
- Reduction
- Residue

Costs
- Conduct: Capex
- Opex
- Risk

Validation
- Validate: Reference
- Pilot test