Removing Salt From Coal Mine Wastewater in a Remote, Wet Area: Full Scale Experience

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Centralized ZLW treatment facility to handle water from six mine locations

All six mines located within Monongahela River Basin

Regulatory driver = Chlorides to < 218 mg/L

Solid wastes generated are disposed in on-site landfill

Treated effluent is discharged to creek and/or used as frac water
Contributing Mine Locations

18” Force Main collects water from 4 mines to the North

14” Force Main collects water from 2 mines to the South
The Project

• Centralized ZLW treatment facility is designed to treat 5 MGD (795 m³/h) of mine water

• Mine water, pretreated for metals removal where needed, conveyed from six source points to the facility through 32 miles of pipeline

• Executed through a Design-Build-Operate contract with Veolia

• June 2010 - Request for proposals issued

• April 2011 - Project awarded

• July 2011 - Construction began

• May 2013 - Full operation
### Design Basis - Influent Mine Water

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Original Design</th>
<th>Current Design¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Flow, gpm</td>
<td>3500 (795 m³/h)</td>
<td>2026 (460 m³/h)</td>
</tr>
<tr>
<td>pH, S.U.</td>
<td>5 - 10</td>
<td>7.39</td>
</tr>
<tr>
<td>Temperature, deg F</td>
<td>38 – 85 (3 – 30 deg C)</td>
<td>60 – 72 (15-22 deg C)</td>
</tr>
<tr>
<td>Calcium, mg/L</td>
<td>300</td>
<td>217</td>
</tr>
<tr>
<td>Magnesium, mg/L</td>
<td>200</td>
<td>104</td>
</tr>
<tr>
<td>Iron, mg/L</td>
<td>150</td>
<td>0.27</td>
</tr>
<tr>
<td>Manganese, mg/L</td>
<td>2</td>
<td>0.27</td>
</tr>
<tr>
<td>Alkalinity, mg/L CaCO₃</td>
<td>700 - 1200</td>
<td>891</td>
</tr>
<tr>
<td>Sulfate, mg/L</td>
<td>5,500</td>
<td>2700²</td>
</tr>
<tr>
<td>Chloride, mg/L</td>
<td>1,500</td>
<td>1530²</td>
</tr>
<tr>
<td>TDS, mg/L</td>
<td>10,000</td>
<td>8600</td>
</tr>
<tr>
<td>Silica, mg/L as SiO₂</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Note 1: Average Value based on the data collected between Jun 1st 2014 to Dec 31st 2014
Note 2: Average Value based on the data collected between Aug 20th, 2014 to Sep 5th, 2014
## Effluent Water Quality Requirements

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Maximum Effluent Concentration</th>
</tr>
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<tbody>
<tr>
<td>Chlorides, mg/L</td>
<td>&lt; 218</td>
</tr>
<tr>
<td>TDS, mg/L</td>
<td>&lt; 150 (^1)</td>
</tr>
<tr>
<td>pH, S.U.</td>
<td>6 to 9</td>
</tr>
<tr>
<td>Minimum Hardness, mg/l as CaCO(_3)</td>
<td>≥ 50</td>
</tr>
</tbody>
</table>

Note 1: Applied to product water prior to remineralization
The Process: Three Primary Components

- Raw Water Pretreatment System
- Reverse Osmosis System
- Thermal Brine Management System
Primary Objectives
1. Remove TDS and Chlorides
2. Zero Liquid Waste
Facility Overview

- Lime & Soda Ash Silos
- Multimedia Filters
- RO Trains
- Evaporator
- Crystallizer
- Raw Water Tank
- Softening System
- 1st Stage Clarifier
- Dewatering Building
Chemical Softening System

- Multi-stage process
- Two aeration tanks for precipitation of metals such as manganese and iron
- Crystallization tank for removal of alkalinity and hardness
- Draft-tube reactor design
  - Solids recycle
  - Reduce chemical consumption
  - Enhance particle growth and settling characteristics
- Conventional circular clarifier design
Multimedia Filter System

- Removes residual suspended solids in the effluent from upstream clarification and aluminum precipitation processes
- Backwash water is returned to the Raw Water Feed Tank
The Process Flow - RO System

Reverse Osmosis System

- RO Feed Tank, followed by Cartridge Filtration
- RO Skids designed to achieve chloride and TDS specifications while operating at a high recovery rate
  - Five parallel skids, each sized to handle 25% of the design flow, 1 standby
  - Thirty-one pressure vessels per skid, each with seven seawater RO membrane elements
- Permeate flows to Product Water Tank, which also collects distillate from Brine Management System
  - Prior to discharge, the Product Water Tank effluent is re-mineralized using carbon dioxide and lime water, to protect aquatic life
  - Discharged to creek, or to a truck loading station for reuse in energy-related operations.
- Reject is sent to the thermal Brine Management System
Evaporator

- Concentric falling film unit is divided into two sections with a low concentration side and a high concentration side
  - Split design to reduce overall power consumption by allowing a portion of the evaporation to occur at a lower boiling point rise than the final concentration
- Evaporator operates as a Mechanical Vapor Recompression System
  - Recycle of hot vapor in the system; minimize auxiliary steam
- Distillates from the Evaporator and Crystallizer are pumped through a Feed Preheater for heat transfer to the incoming brine
  - Heat exchanger for efficient energy utilization
Crystallization

- Crystallizer includes a vapor body, recirculation pump, and forces circulation heat exchanger
  - Vapors created by concentrating the slurry in the Crystallizer are recompressed and recirculated through the heater
  - As the brine concentration increases, the solution becomes supersaturated and salts precipitate, resulting in a brine slurry
  - A slip stream of the crystallizer slurry is sent to centrifuges for dewatering
- The result: Zero Liquid Waste
  - Dewatered salt cake is disposed in the on-site landfill along with the dewatered sludge from the softening processes
Thermal Brine Management System

- Heat Exchanger
- Crystallizer
- Evaporator
- Distillate Tank
• Dewatered Salt and Softening Sludge is brought separately to onsite landfill

• Dewatered Salt contains approximately 90 – 95% in solids concentration and Sludge contains 50 – 65% in solids concentration.

• Both passes paint filter press test

• Both Salt and Sludge are mixed before applied to landfill

• Leachate generated in landfill is collected in storage tank and metered back to thermal system
Ancillary Support Systems

• Chemical Storage and Feed Systems
• Lime Water Preparation System
• RO Membrane Clean-in-Place System
• Compressed Air System
• Electrical and Control Rooms
• Laboratory
• Communications Equipment
• Maintenance and Storage Areas
• Personnel Amenities
Feed Water Conductivity

Original Design Conductivity = 13,000 µs/cm
Current Avg Conductivity = 11,180 µs/cm
Product Water Conductivity

Product water Cond before Remineralization = 63 µs/cm

Final Effluent Discharge Cond = 142 µs/cm
Feed Water Chlorides

Current Avg Feed Chlorides = 1,530 mg/l
**Final Effluent Chlorides**

- **Final Effluent Chlorides** = 16 mg/l
Please Note:
- Waste Estimation for design condition was estimated based on 3500 gpm flow
- Waste Estimation for Current Average Condition was estimated based on 2026 gpm flow

## Estimated Waste Generation

<table>
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<tr>
<th>Waste</th>
<th>Design Condition</th>
<th>Current Average Condition</th>
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</thead>
<tbody>
<tr>
<td>Softening Sludge (on a 100% dry basis)</td>
<td>6,666 lb/hr (3,030 kg/hr)</td>
<td>2,200 lb/hr (1,000 kg/hr)</td>
</tr>
<tr>
<td>Salt (on a 100% dry basis)</td>
<td>17,500 lb/hr (7,954 kg/hr)</td>
<td>8,710 lb/hr (3,960 kg/hr)</td>
</tr>
<tr>
<td>Total Waste Generated (on 100% dry basis)</td>
<td>24,166 lb/hr (10,984 kg/hr)</td>
<td>10,910 lb/hr (4,960 kg/hr)</td>
</tr>
</tbody>
</table>
Summary

- Treatment process achieves > 99% removal of chlorides using state-of-the-art membrane technology
- Energy efficient evaporation and crystallization technology for brine management
- Solid waste generated onsite is disposed into onsite landfill and leachate generated at the landfill is sent back to the facility’s thermal treatment process
- Since no liquid waste leaves the property, this facility is termed as a “zero liquid waste” (ZLW) facility
Thank You!