Waste Water Treatment Unit for LNG Mega Trains Challenges

Mohsin M. Raja
Sr. Environmental Engineer

El-Hadi Bouchebri
Lead Process Engineer

Date: 22nd – 24th April 2012

DELIVERING LNG TO THE WORLD
Contents

- Key Drivers for Wastewater management/Minimization
- Background – Agreements with the MoE & QP
- Current Wastewater disposal routes
- Offshore / Onshore Block Diagram
- Waste Water Sources – Introduction
- Waste Water Reduction – Strategies / Selected Option
- KHI Removal – Introduction / Objectives / Bench Scale Tests
Key Drivers for Wastewater Management / Minimization

- Qatargas long-term aim to minimize water discharge and adopt best industry practices on sustainable wastewater use and reuse.

- Direction from Qatar Ministry of Environment (MoE) (and predecessor SCENR) to eliminate discharges to sea. Enshrined in State of Qatar Environmental Regulations (Exec. By-Law No.4 [2005] of Law No. 30, 2002).

- Qatargas Consent To Operate (Environmental Permits):
  - Previously discharge to sea allowed until RLC Treated Industrial Water (TIW) network operational
  - Now alternative QG disposal option to be evaluated (completed as part of feasibility study) and to be implemented as part of Compliance Action Plan (CAP)

- QP mandate to reduce injection rates to the Qatargas operated subsurface injection reservoir. QG exploring alternate use/disposal options for volumes reduced.

- Requirement to demonstrate steady progress with regulatory water discharge minimization requirements to QG Lenders.
Background – Agreements with the MoE & QP

- **2004**: Provision to discharge clean process streams included in QG2 and QG3&4. Consent to Construct issued by the MoE (formerly the SCENR) until the RLC Wastewater utilization facilities become operational.

- **2007**: RLC commences development of a Treated Industrial Water (TIW) network to receive all “irrigation water quality” treated wastewater from industrial facilities operating in the RLC for reuse for irrigation and landscaping. TIW expected to be constructed and operational by 2011 (initial forecast).

- **2008**: Waste Liquid Injection (WLI) Permits issued by QP/RLC for QG2 and QG3&4 wells. Injection rate allowance reduced by 37% from 6,000 m$^3$/day (design) to 3,800 m$^3$/day (permitted).
Background – Agreements with the MoE & QP

- **2009**: MoE permits discharge to sea of treated wastewater process streams until such time that MoE and RLC agree on a sustainable disposal option. Allowance included in 2010 QG2 and QG3&4 CTOs.

- **Nov. 2011**: QG2 and QG3&4 CTO renewals prohibiting discharge to sea. RLC informs tentative time frame for TIW delayed to 2016.

- **Feb. 2012**: CTOs revised to allow discharge to sea, Qatargas agreed to a time-bound Compliance Action Plan (CAP) to implement a sustainable and engineered wastewater reuse and disposal solution.
Mega Trains Waste water disposal routes

- QG2 and QG3&4 clean process streams (boiler blow down and condensate regeneration water) discharged to RLC surface water ditches from storm water ponds 2,700 M³/day (per CTO allowance until RLC TIW network or alternative QG disposal option implemented)

- Produced and plant process water at QG2 and QG3&4 is injected to a subsurface formation via a network of six subsurface injection wells (3,500 M³/day)
QG-2 Offshore Production Platforms – Sealines Overview

Field Layout Overview

DELIVERING LNG TO THE WORLD
QG-3&4 Offshore Production Platforms – Sealines Overview

Pipeline and cable layout

- PL7 from Shore to WHP7 – 66 Km
- WHP9 – WHP7 12 Km
- PL9-7 – 565 m
- WHP9 - WHP8 – 8 Km
- PL9-8 – 455 m
- PL8 from Shore to WHP8 – 63 Km

Main 38-inch pipelines from shore to WHP-7 and WHP-8, plus 2 x 22-inch spur lines connecting WHP-9 into main PL7 and PL8 pipelines

Composite cable - electrical power and fibre optic for communication

DELIVERING LNG TO THE WORLD
Loss of unit 33 leads to loss of LNG production
Waste Water Sources

LNG Mega trains use desalinated water as source of fresh water mainly for steam generation and other uses:

- Sources of waste water:
  - Sour water from offshore – HP sour water (containing KHI, MEG, CI and \( \text{H}_2\text{S} \))
  - Sour water from the onshore facilities – LP sour water (containing \( \text{H}_2\text{S} \))
  - Non-sour and oily water from units. (free of \( \text{H}_2\text{S} \))

Following slide explains the link between fresh water and waste water.
QG2, QG3&4 water and waste water flow diagram

Desalinated water from QGI/RLC

- Service water (utility hose station, etc.)
- Fresh cooling water makeup
- Potable water
- Condensate Polisher

Train 4 & 5 Suspect Condensate

- Activated Carbon Filter
- SRU 4 & 5 Steam generators
- Train 4 & 5 HRSGs
- Utilities Boilers

Condensate Polisher regeneration neutralization Pit

Contaminated Condensate to Waste water storage tank

- Backwash water to Waste water storage tank

Sea or irrigation (when ready)

Oily water Collection

Chemical treated waste water from unit 87

LWWI Project under construction

- UNIT 33
- Water from Offshore

HP sour water

- SW Degasser
- pH control system
- Coarse filtration
- Injection storage tank
- Fine filtration
- To Deep well injection

Waste Water storage tank

Contaminated condensate cooler

Oily water Treatment

LEGEND
CLEAN WATER STREAMS
OILY WATER STREAMS
UNIT 33
LP SOUR WATER

DELIVERING LNG TO THE WORLD
Waste Water Reduction Study – Strategies

- Various Waste water treatment strategies:
  - Re-Use: Suitable streams combined to meet irrigation water spec with minimum treatment
  - Recycle: Suitable streams combined to produce either Desalinated water or Polished water with proper treatment technology
  - Disposal: Minimize flow to deep well injection. HP sour water and reject effluent to meet the injection water specification
- Twelve options were identified using the above three strategies as guidelines.

### Shortlisted Options:

**Option-1**: De-oiling, H$_2$S removal; filtration stages (MMF & nutshell), MBR unit. MBR outlet to irrigation water tank if the re-use option is selected or RO unit to produce Desalinated water if recycle option is selected.

**Option-2**: De-oiling H$_2$S removal; Lime softening, extended aeration. filtration stages (MMF & ACF). Outlet to irrigation water tank if the re-use option is selected or RO unit to produce Desalinated water if recycle option is selected.

**Option-3**: Three streams are treated separately. de-oiling H$_2$S removal; MBR and RO units to produce desalinated water. The condensate polisher and Boiler Blow down are mixed with oily water and passes through corrugated Plate Interceptor (CPI), MMF to produce irrigation water.

- Option 1 is selected (to meet study objective of 50% injection water reduction)
- Option 2 not selected as lime softening requires more chemicals (higher chemical and sludge disposal costs).
- Option-3 does not have the flexibility since the streams are treated after segregation.
## Waste Water Reduction – Shortlisted Options

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Sour</td>
<td>Treatment Technology</td>
<td>Treatment Technology</td>
<td>Treatment Technology</td>
</tr>
<tr>
<td>Non Oily Water</td>
<td>Multimedia Filter</td>
<td>Multimedia/Activated</td>
<td>Multimedia Filter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbon Filter</td>
<td></td>
</tr>
<tr>
<td>Oily Water</td>
<td>De-Oiler + Multimedia Filter</td>
<td>Reverse Osmosis</td>
<td>Reverse Osmosis</td>
</tr>
<tr>
<td>De-Oiler + Multimedia Filter</td>
<td>Lime softening / Extended aeration / Filtration</td>
<td>De-Oiler + Multimedia Filter</td>
<td>De-Oiler / Reverse Osmosis</td>
</tr>
<tr>
<td>LP sour water</td>
<td>De-Oiler + Multimedia Filter</td>
<td>Membrane Bio-Reactor</td>
<td>Ultrafiltration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activated Carbon Filter</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>LP sour water</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>De-Oiler</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse Osmosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse Osmosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse Osmosis</td>
<td></td>
</tr>
<tr>
<td>Design Injection</td>
<td>QG2 - 57.6%</td>
<td>QG2 - 53.1%</td>
<td>QG2 - 52.5%</td>
</tr>
<tr>
<td>Volume Reduction</td>
<td>QG3&amp;4 - 60.1%</td>
<td>QG3&amp;4 - 58.2%</td>
<td>QG3&amp;4 - 50.9%</td>
</tr>
<tr>
<td></td>
<td>QG2 - 53.9%</td>
<td>QG3&amp;4 - 53.8%</td>
<td>QG3&amp;4 - 53.4%</td>
</tr>
<tr>
<td></td>
<td>QG2 - 47.4%</td>
<td>QG3&amp;4 - 47.2%</td>
<td>QG3&amp;4 - 53.4%</td>
</tr>
<tr>
<td></td>
<td>QG2 - 52.5%</td>
<td>QG3&amp;4 - 53.4%</td>
<td>QG3&amp;4 - 50.9%</td>
</tr>
</tbody>
</table>

**REUSE**

**RECYCLE**

Based on Techno-Economic feasibility study, Option 1 is selected
Waste Water Reduction – selected option

LP Sour water from units

LP SOUR WATER DRUM

LP SOUR WATER TANK

H₂S 50 ppm
O&G 100 ppm
TSS 70 ppm

H₂S 50 ppm
O&G 5 ppm
TSS 70 ppm

SOUR WATER DEGASSER

NNF

Waste Water Storage Tank

DE-OILER

O&G 5 ppm
TSS 40 ppm

O&G 300 ppm
TSS 40 ppm

DE-OILER

O&G 5 ppm
TSS 40 ppm

H₂S 0 ppm
O&G 5 ppm
TSS 70 ppm

NNF

WASTE WATER STORAGE TANK

Oily water from units

Equalization Tank

OILY WATER TREATMENT

DE-OILER

MULTI MEDIA FILTER

NUT SHELL FILTER

MAMBRANE BIO REACTOR

ULTRA FILTRATION

ACTIVATED CARBON FILTER

TREATMENT PACKAGE

H₂S 0 ppm
O&G 5 ppm
TSS 70 ppm

TSS 1 ppm

O&G 5 ppm
TSS 1 ppm

O&G 0 ppm
TSS 1 ppm

MULTI MEDIA FILTER

REVERSE OSMOSIS

DEALINATED WATER TANK

REJECT TDS 7900 ppm
TSS 50 ppm

IRRIGATION WATER TO DISTRIBUTION

IRRIGATION WATER TANK

IRRIGATION WATER TO DISTRIBUTION

Condensate Polishes Regen

Boilers Blowdown

pH CONTROL

RETENTION POND

NNF

SEA / IRRIGATION

EXISTING FACILITIES PROPOSED FACILITIES
**Introduction:**
- QG2 and QG3&4: wet gas from offshore through subsea pipelines. Pipelines dosed with Corrosion Inhibitor (CI) throughout the year.
- 110 to 120 days/year Kinetic Hydrate Inhibitor (KHI) is injected.
- QG2 injecting MEG and KHI during hydrate season Offshore and Onshore depending on ambient condition.
- All chemicals end up in water from offshore and are injected into the onshore deep wells.

**Objective:**
Remove KHI from HP Sour water
- QG2: KHI residual onshore is 0.75%wt (with 17.5% residual MEG)
- QG3&4: KHI residual onshore is 1.5%wt

**Bench Scale tests:**
- Identify Best Applicable Technology (BAT) to remove residual KHI.
- Qatargas/WPQ/TAMUQ collaborated to identify possible removal methods.
KHI Removal – Bench Scale Tests

Various removal methods attempted (KHI in De Ionized Water and Seawater). Following were successful.

a) Heating and Centrifugation  
b) Heating and coagulation

Produced water inside of hydrate season of QG2 and QG3&4 treated by above methods (Details provided in the following slides)
**KHI Removal – Bench Scale Methodology 1**

Removal of KHI from wastewater: Heating/Centrifugation & Activated Carbon

**Inlet KHI2-KHI3/4: 1.03% / 0.628%**

**Activated Carbon 0.1 g**

Wastewater aerated for 3-4 hours

Wastewater Heated at 85 C
Mixing speed 80 rpm for 30 min

Centrifugation 5000 rpm for 2 min
Temp 85-60 C

Wastewater Heated at 85 C
Mixing speed 80 rpm for 30 min

Centrifugation 5000 rpm for 2 min
Temp 85-60 C

Reaction time 30 min

Filter paper 2.7 µm pore size

**KHI2-KHI3/4 Efficiency ~ 47% / 51.5%**

**KHI2-KHI3/4 Efficiency ~ 13% / 3.5%**

**KHI2-KHI3/4 Efficiency ~ 31% / 37%**

**KHI2-KHI3/4 overall Efficiency ~ 91% / 92%**
Removal of KHI from wastewater: Heating/Coagulation & Activated Carbon

**Inlet KHI2-KHI3/4: 1.03% / 0.628%**

1. **Wastewater aerosated for 3-4 hours**
   - Adding: FeCl$_3$ = 100 ppm
   - Adjust: pH = 7.0
   - Heated at 85°C
   - Mixing speed 80 rpm for 30 min

2. **Filter paper 2.7 μm pore size**
   - KHI2-KHI3/4 Efficiency ~ 38.5% / 61%

3. **FeCl$_3$**
   - Wastewater
   - Adding: FeCl$_3$ = 100 ppm
   - Adjust: pH = 7.0
   - Heated at 85°C
   - Mixing speed 80 rpm for 30 min

4. **Filter paper 2.7 μm pore size**
   - KHI2-KHI3/4 Efficiency ~ 19% / 5.5%

5. **Activated Carbon 0.1 g**

6. **Reaction time 30 min**
   - Filter paper 2.7 μm pore size
   - KHI2-KHI3/4 Efficiency ~ 41.5% / 31.5%

**KHI2-KHI3/4 overall Efficiency ~ 99% / 98%**
Conclusion & Path Forward

Conclusion:
- Recycling part of LP sour and Non sour water flow rate will enhance sustainable reuse of wastewater, otherwise currently discharged to the sea.
- Removing chemicals from HP sour water will enhance the injection aquifer reservoir capacity.

Path Forward:
- 50% Injection reduction targeted for completion by 2015.
- Pilot tests to be performed at site during hydrate season (probable duration Dec 2012 – April 2013). This will help in arriving at full scale engineering solution for KHI removal.
Thank you