Industrial Waste Management and Water Treatment Opportunities
November 2018
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<thead>
<tr>
<th>Session Title</th>
<th>Presenter</th>
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<tr>
<td>Opening</td>
<td>Abdullah Al-Duaiji</td>
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<tr>
<td>Opportunity 1: Waste Management Technologies</td>
<td>Abdullah Al-Duaiji</td>
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<td>Opportunity 2: Mobile Waste Management Technologies</td>
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<td>Opportunity 3: Management of Special Types of Waste</td>
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<td>Subhi Al-Jeshi</td>
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<td>Abdulmalik Al-Sabti</td>
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Environmental Management Services Represent an Attractive Opportunity Given the current gaps, expected demand and localization potential

<table>
<thead>
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<th>Objective</th>
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<tr>
<td>To seek local environmentally acceptable and cost effective solutions that would:</td>
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<tr>
<td>▪ Meet Saudi Aramco and government Environmental regulations,</td>
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<td>▪ Minimize environmental and health risks,</td>
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<td>▪ Recover value from Saudi Aramco generated waste.</td>
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<thead>
<tr>
<th>Opportunities</th>
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<tr>
<td><strong>THE WASTE HIERARCHY</strong></td>
</tr>
<tr>
<td>Preferred Environmental Option</td>
</tr>
<tr>
<td>Prevention</td>
</tr>
<tr>
<td>Reuse</td>
</tr>
<tr>
<td>Recycle</td>
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<tr>
<td>Energy Recovery</td>
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<tr>
<td>Disposal</td>
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<tr>
<td>Least Preferred Environmental Option</td>
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</table>
Saudi Aramco’s Historical and Forecasted demand for Industrial Waste in (Tons) excluding Drilling and Workover waste.

Source: Saudi Aramco analysis
Historical and Forecasted Demand for Drilling Mixed Waste in (Tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Historical</th>
<th>Forecasted</th>
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<tr>
<td>2014</td>
<td>5,861,751</td>
<td>5,889,401</td>
</tr>
<tr>
<td>2015</td>
<td>5,834,101</td>
<td>5,986,175</td>
</tr>
<tr>
<td>2016</td>
<td>6,000,000</td>
<td>6,022,120</td>
</tr>
<tr>
<td>2017</td>
<td></td>
<td>6,058,065</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>6,094,009</td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td></td>
<td></td>
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</tbody>
</table>

Source: Saudi Aramco analysis
2017 Saudi Aramco Generated Industrial Waste Breakdown

- Contaminated Sand: 17%
- Oil-Based Mud Cuttings: 6%
- Oily sludge: 16%
- Oily wastewater: 13%
- Spent caustic: 6%
- Spent dessicant and adsorpect: 12%
- Others: 25%
Environmental Investment Opportunities

**Industrial Waste Management**

- Opportunity 1: Waste Management Technologies
- Opportunity 2: Mobile Waste Management Technologies
- Opportunity 3: Management of Special Types of Waste

**Water Treatment**

- Opportunity 4: Water Treatment Technologies
- Opportunity 5: Wastewater Treatment Technologies
Industrial Waste Management Opportunities
Opportunity 1. Waste Management Technologies

- Fully Integrated Waste Management Facilities
- Waste to Energy
- Recycle/Recover/Regenerate of Spent Catalyst.
- Manufacture of rubber substitute

Source: Saudi Aramco Internal Analysis
Opportunity 1. Waste Management Technologies

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Opportunity 1. Waste Management Technologies

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Recover

- Alumina
- Molybdenum
- Nickel
- Cobalt
- Vanadium
- Platinum

Source: Saudi Aramco Internal Analysis
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Opportunity 1. Waste Management Technologies

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21 MM Used Tires are generated annually
Opportunity 1. Waste Management Technologies

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- Manufacture of rubber substitute

Source: Saudi Aramco Internal Analysis
Opportunity 2. Mobile Waste Management Technologies

- Three-Phase Centrifuge for Recycling Oily sludge
- Recover Hydrocarbons from Oil Contaminated Sand
- Micro Auto Gasification Technology

Source: Saudi Aramco Internal Analysis
Opportunity 2. Mobile Waste Management Technologies

- **Three-Phase Centrifuge for Recycling Oily sludge**
- **Recover Hydrocarbons from Oil Contaminated Sand**
- **Micro Auto Gasification Technology**

A technology designed to separate the oily sludge into three main phases; Oil, Water and solid waste.

Source: Saudi Aramco Internal Analysis
Opportunity 2. Mobile Waste Management Technologies

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Source: Saudi Aramco Internal Analysis
Opportunity 3. Management of Special Types of Waste

- Drilling & Workover Waste
- Naturally Occurring Radioactive Materials (NORM) Waste
Opportunity 3. Management of Special Types of Waste

- Drilling & Workover Waste
- Naturally Occurring Radioactive Materials (NORM) Waste

Drilling waste impose a challenge to Company’s operations due to high quantities and complexity of generated drilling waste remotely.

Source: Saudi Aramco Internal Analysis
Opportunity 3. Management of Special Types of Waste

1. Drilling & Workover Waste

Source: Saudi Aramco Internal Analysis
Water Treatment’s Opportunities
Opportunity 4. Water Treatment Technologies

Cartridge filters are used to remove particulate matter from RO membrane feedwater.

MEMBRANE DESALINATION SYSTEMS

WATER DEMINERALIZATION SYSTEMS

WATER DISINFECTION SYSTEMS

Source: Saudi Aramco Internal Analysis
Cartridge filters are used to remove particulate matter from the feed to RO membranes. They are placed before RO membrane to prevent membrane fouling. The cartridge filters porosity are 5 microns and upwards.

Source: Saudi Aramco Internal Analysis
Water treatment and desalination membranes include:

**RO Membranes:**
- Polyamide, cellulose acetate/cellulose triacetate.
- Configuration: Spiral wound.
- Size: 8 inch diameter

**Nano Membranes:**
- Polysulfone, cellulose acetate, thin film composite.
- Configuration: Spiral wound, Hollow fine fiber/capillary.
- Size: 4/8/10 inch diameter

**Ultrafiltration Membranes:**
- Configuration: Spiral wound, Hollow fiber/capillary.
- Material: polysulfone, Polyethersulfone, Polycrylonitrile, cellulose acetate. Pressure rating: < 200 psig

**Microfiltration Membranes:**
- Configuration: dead-end cartridge filters.
- Rating: nominal or absolute; Size: 1-100 micron.
- String Wound Polypropylene, pleated polypropylene & polyester, Resin Bonded Cellulose, PVDF, polysulfone.

Source: Saudi Aramco Internal Analysis
Membrane desalination system includes fully integrated system to desalinate seawater or brackish water. It includes:

Reverse Osmosis (RO) or Nano Filtration (NF) systems. The skid includes:

- Membrane elements housed in pressure vessels and a high pressure pump
- A pretreatment system to achieve the required feed water quality
- A clean in place (CIP) system to facilitate membrane cleaning,
- A post-treatment system to achieve the required product quality.
- The specifications of the system are covered in Saudi Aramco standard 32-SAMSS-033.

Source: Saudi Aramco Internal Analysis
Water demineralization is used in utilities to polish RO desalinated water to produce demineralized makeup water for boiler feed water.

The system consists mainly of:

I. **Ion Exchange Systems**
   - Cation Exchangers
   - Anion Exchangers
   - Mixed bed Ion exchangers
   - Regeneration Systems

II. **Softeners:**
   - For hardness removal and water softening

IV. **Condensate Polishers:**
   - For steam condensate polishing

Source: Saudi Aramco Internal Analysis
Water disinfection systems used in Aramco include:

- Sodium hypochlorite generator
- Chlorine dioxide generator
- UV system.

Source: Saudi Aramco Internal Analysis
Opportunity 5. Wastewater Treatment Opportunities

- Wastewater Packaged Treatment Systems
- Wastewater Preliminary Treatment & Seawater Screening
- Wastewater Media Filters
- Wastewater Equipment
- Spent Caustic Minimization and Treatment Technology Solutions

Source: Saudi Aramco Internal Analysis
Opportunity 5. Wastewater Treatment Opportunities

Wastewater Packaged Treatment Systems

A prefabricated complete biological wastewater treatment system that complies with Saudi Aramco Engineering Standards for Wastewater Treatment, Reuse and Disposal
Opportunity 5. Wastewater Treatment Opportunities

Wastewater Preliminary Treatment & Seawater Screening

- Mechanical Coarse Bar
- Screen Degritter
- Fine Screen
- Sanitary Wastewater Grinder
- Seawater Intake Screening Systems
Opportunity 5. Wastewater Treatment Opportunities

Wastewater Media Filters

A single or multi-layer bed filter:

- Use one or multiple selected grades of filter media
- Remove suspended solids and other microorganisms from incoming feed water/wastewater

Source: Saudi Aramco Internal Analysis
Opportunity 5. Wastewater Treatment Opportunities

Wastewater Equipment

- Water & Wastewater Aeration and Degassing
- Clarifier Solids Collection Equipment
- Sanitary Sludge Dewatering
- Wastewater Odor Control
Opportunity 5. Wastewater Treatment Opportunities

Wastewater Equipment

- Oily Water Primary Separators
- Oil/Water Separation- Dissolved Air Flotation (DAF) / Induced Air Flotation (IAF)
- Oil/Water-Oil Skimmers
- Oily Wastewater Centrifugal
Providing environmentally safe and cost-effective treatment technologies of spent caustic waste effluents to reduce the volume of spent caustic generated from Merox unit source.
Key messages

- Presented investment opportunities in support of establishing multiple services related to Industrial Waste Management and Water Treatment.
- Promote in-kingdom acceptable and cost effective Environmental Services.
- We invite interested companies to engage with us and send us their Expression of Interest to establish a local provider for environmental services in Saudi Arabia.

In case you are interested in discussing this opportunity further, please contact:

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Thank you