ZERO EFFLUENT DISCHARGE AND EFFLUENT RECYCLE IN HYDROCARBON INDUSTRY: An Integrated Approach to Sustainable Environment

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Head – Environment Division
**WHY EFFLUENT RECYCLE?**

**Statutory**
- Effluent to be treated & recycled within the premises
- Cap on fresh water intake

**CSR**
- To conserve the limited fresh water available
- To protect the deteriorating water quality

**Benefits**
- Recovered water can fill the gap between water demand & water supply
- Less water intake means less water supply charges (municipal water supply charges are substantially high or intake is far away)
HISTORICAL CHALLENGES

• Effluent Recycle in hydro-carbon industry was first introduced in the late nineties of the twentieth century

• No reference of effluent recycle plants in hydrocarbon industry worldwide were available

• Lack of technical know-how

• Refinery effluent hard to treat, Not easily biodegradable, can foul the membranes in effluent recycle plant
EIL’s ROLE

**Study**

- Various treatment processes studied vis-à-vis the potential end-users requirement
- Various technologies studied with respect to their merits & demerits for being adopted as potential technologies for effluent treatment & recycle

**Treatability Studies / Pilot Plants in Association with Clients & System Suppliers**

- Photochemical Oxidation Plant using H$_2$O$_2$ in presence of UV rays at MRPL – Mangalore
- High Efficiency Reverse Osmosis Plant at IOCL-Panipat

**Full Scale Plant**

- First effluent recycle plant in Indian hydrocarbon industry for IOCL-PREP commissioned in 2006. Plant designed to produce D.M. Water
METHODOLOGY

- A carefully prepared Overall Water Balance is the key to effective & most economical effluent recycle plant

- Various effluents streams (process effluents, spent caustic, CTBD, regeneration wastes, etc.) are segregated & separately collected based on their quality

- Potential end-users for treated water are identified

- Based on the feed effluent quality/quantity and end-users requirements, treatment scheme is finalized and water balance is prepared keeping a watch on TDS levels

- A part of the water/reject is recycled for being utilized in the green belt within the premises, while controlling the TDS levels
CASE STUDIES

- **IOCL – Panipat Refinery Expansion Project (PREP)**
  - Effluent Recycle Plant commissioned in the year 2005-2006

- **HPCL, Mumbai Refinery – Integrated Effluent Treatment Plant**
  - Effluent Recycle Plant commissioned in the year 2010

- **IOCL – Panipat Naptha Cracker Project (PNCP)**
  - Effluent Recycle Plant commissioned in the year 2009-2010

- **HMEL – Guru Gobind Singh Refinery project, Bhatinda**
  - Effluent Recycle Plant commissioned in the year 2011
IOCL–PREP Effluent Recycle Plant

**Parameters**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Blended Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, m³/hr</td>
<td>900</td>
</tr>
<tr>
<td>COD, ppm</td>
<td>150</td>
</tr>
<tr>
<td>BOD₃, ppm</td>
<td>10</td>
</tr>
<tr>
<td>Oil, ppm</td>
<td>10</td>
</tr>
<tr>
<td>TDS, ppm</td>
<td>1786</td>
</tr>
<tr>
<td>Silica as SiO₂, ppm</td>
<td>98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treated Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow, m³/hr</td>
<td>764</td>
</tr>
<tr>
<td>TDS, ppm</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Conductivity, µ mho/cm</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Silica as SiO₂, ppm</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Oil, BOD &amp; COD</td>
<td>NIL</td>
</tr>
</tbody>
</table>

**Note:** The final reject from the plant is blended with fire-fighting water, or used for irrigation (blended with low TDS water) of the green belt within the refinery complex.
**HPCL, Mumbai Refinery – Integrated ETP**

### Blended Effluent Parameters

- **Flow, m³/hr**: 300
- **COD, ppm**: 1700
- **BOD₃, ppm**: 1000
- **Oil, ppm**: 1000 - 20000
- **TDS, ppm**: 5000
- **TSS, ppm**: 200
- **Silica as SiO₂, ppm**: 25

### Treated Water Parameters

- **Flow, m³/hr**: 204
- **TDS, ppm**: <120
- **Turbidity, NTU**: <0.1
- **Silica as SiO₂, ppm**: <1.0

### Flow Diagram

- **Effluent**
  - **API Separators**
  - **TPI Separators**
  - **Flash Mixer**
  - **Flocculation Tank**
  - **Membrane Bio Reactor**
  - **Sequential Batch Reactor**
  - **pH Adjustment Tank**
  - **Dissolved Air Floatation Tank**
  - **Cartridge Filter**
  - **RO SKIDS**
  - **RO Reject Disposal to sea**
  - **Raw Water Make Up**

**Chemical Reagents**

- **Alum**
- **Caustic**
- **H₂O₂**
- **HCl**

**Process Notes**

- **Parameters**
- **Flow, m³/hr**
- **COD, ppm**
- **BOD₃, ppm**
- **Oil, ppm**
- **TDS, ppm**
- **TSS, ppm**
- **Silica as SiO₂, ppm**
IOCL–PNCP Effluent Recycle Plant

Parameters | Blended Effluent
---|---
Flow, m³/hr | 871
COD, ppm | 125
BOD₃, ppm | 10
Oil, ppm | 5
TDS, ppm | 800
Reactive Silica as SiO₂, ppm | 98
Colloidal Silica as SiO₂, ppm | 2

Parameters | Treated Water
---|---
TDS, ppm | <0.1
Reactive Silica as SiO₂, ppm | <0.01
Colloidal Silica as SiO₂, ppm | <0.01
Conductivity, μ mho/cm | <0.2
Oil, BOD & COD | NIL

```
High Rate Solid Contact Clarifier

FeCl₃

Dolomite Lime

Polyelectrolyte

Sludge for Dewatering

Mixed Bed

Degasser Tower

DM Water

RO - II

Permeate

RO - I

Permeate

Reject

Fire Water blend / Irrigation

Reject

Raw Water Make-up
```
HMEL – Bhatinda Refinery, Effluent Recycle Plant

- **FeCl₃**
- **NaOCl**
- **Polyelectrolyte**
- **Effluent**
- **Permeate**
- **Regeneration Waste**
- **DM Water**
- **Mixed Bed**
- **Solid Contact Clarifier**
- **Dual Media Filters**
- **Hardness Removal Unit - I**
- **Hardness Removal Unit - II**
- **High Efficiency RO-I**
- **High Efficiency RO-II**
- **Degasser Tower**
- **Evaporator System**
- **Distillate**
- **Sludge for Dewatering**
- **Concentrated Liquor to Solar Pond**
- **Reject to Solar Pond**

13 April 2012
<table>
<thead>
<tr>
<th>Cost Head</th>
<th>Cost (in INR)</th>
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<tbody>
<tr>
<td>Total Investment 1)</td>
<td>71.22 Crores</td>
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<tr>
<td>Electro-mechanical Equipment</td>
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<tr>
<td>Civil works</td>
<td>14.22 Crores</td>
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<td>Manpower [INR/m$^3$]</td>
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<td>Chemicals [INR/m$^3$]</td>
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<td>Electrical Power [INR/m$^3$]</td>
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<tr>
<td>Maintenance &amp; other expenses [INR/m$^3$]</td>
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<tr>
<td>Operating costs [INR/m$^3$]</td>
<td>18.15</td>
</tr>
<tr>
<td>Capital Costs [INR/m$^3$] 2)</td>
<td>17.25</td>
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<tr>
<td><strong>Reclamation costs (OPEX + CAPEX) for demineralised water</strong> [INR/m$^3$]</td>
<td>35.4 3)</td>
</tr>
</tbody>
</table>

1) Including price raises indexed in line with annual inflation up to 2009 - 2010;
2) Electro-mechanical equipment: 15 years, 10% interest; civil works: 25 years, 10% interest
3) Actual costs for the entire process
Lesson Learnt from Past experience

Know your water quality

Importance of pre treatment based on fluctuation of water quality

Oil removal from effluent – A big challenge !!!

Zero oil requirement before RO

Know ! what can harm your membranes – Ions, Bacterial growth or cleaning chemicals or operating conditions
Technological Advancement

Effective Biological process for treatment such as Bio petro clean in combination with SBR or MBR.

Technological Advancement

Advance oil removal process such as Mycelx/TORR which acts as complete barrier for oil before RO.

Use of advance analysis and control for optimum usage of the chemicals.
Current technology - Activated Sludge

Limitations:

- Very expensive CAPEX (applicable only for large capacities)
- Sludge creation bottlenecks – Expensive OPEX
- Sensitive to fluctuations
- Exposed to frequent upsets
Effective Biological process for treatment

Bio petro clean
BPC – next bioremediation generation

ACT - Automatic Chemostat Treatment

One step forward in bioremediation technologies

Automated Continuance Flow

Advantages:
- Low CAPEX
- Lower OPEX
- Minimal sludge produced
- Tolerant to fluctuations
- Simple / auto process
- No Upsets (process control)
- Modular / flexible
BPC’s Technology

Major difference

- Tailored (Natural) bacterial cocktail
- Low bacterial concentration throughout the process
- Closed loop - monitoring & control

A potent solution for the existing challenges in wastewater treatment
BPC technology advantages

- **Simplicity**
  - Reduces CAPEX
    - No Sludge reconciling
    - In some cases, no need for pre treatment
  - Reduces OPEX
    - Reduced sludge by more then 60%
    - Reduced chemical usage
    - Automation prevents upsets

- **Flexibility leads to Better performance**
  - Treats high levels of contaminants (TOC/COD)
  - High Ammonia levels
  - High Phenols
  - Treats different salinity levels
What does it look like? Before & After
Advance oil removal process

Mycelx/ TORR barrier for oil before RO.
## Oil Removal Technologies

<table>
<thead>
<tr>
<th>SNo.</th>
<th>Category</th>
<th>Parameters</th>
<th>Weight Age (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>Necessary RQMT</td>
<td>Acceptability of Feed &amp; Utility</td>
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<tr>
<td>2</td>
<td>Cost Involved</td>
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<td>40</td>
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<td>3</td>
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<td>Less Space Requirement</td>
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<td>4</td>
<td></td>
<td>Low Chemical Requirement</td>
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<td>5</td>
<td></td>
<td>Capital &amp; Operating Costs</td>
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<tr>
<td>6</td>
<td>Technical Features</td>
<td>Patents &amp; Proprietary Equipment</td>
<td>5</td>
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<tr>
<td>7</td>
<td></td>
<td>Safety Measures &amp; Automation</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Universality of Technology</td>
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<td>9</td>
<td></td>
<td>Extent of Modular Structure</td>
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<td>Reuse/Recycle/Recovery Chances</td>
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<td>Environmental Requirements</td>
<td>Operating Conditions</td>
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<td>12</td>
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<td>Low Sludge Generation</td>
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<td>13</td>
<td></td>
<td>Low VOC Emissions</td>
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<td></td>
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<td>Ability to Handle Fluctuating Feed</td>
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</table>
## OIL REMOVAL TECHNOLOGIES

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Necessary Rqmts</th>
<th>Cost Involved</th>
<th>Technical Features</th>
<th>Environment Requirements</th>
<th>Total</th>
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<td>Hydro cyclone</td>
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<td>2</td>
<td>50</td>
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<td>Centrifuge</td>
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<td>9</td>
<td>65</td>
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<td>Cyclosep</td>
<td>15</td>
<td>27</td>
<td>6</td>
<td>3</td>
<td>51</td>
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<td>Hydromem</td>
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<td>26</td>
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<td>9</td>
<td>8</td>
<td>60</td>
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<td>19</td>
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<td>3</td>
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<td>microfiltration</td>
<td>20</td>
<td>17</td>
<td>13</td>
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<td>50</td>
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<td>Yaz-dehydrate</td>
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<td>12</td>
<td>4</td>
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<td>Crudesorb</td>
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<td>Electrocoagulation</td>
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<td>19</td>
<td>9</td>
<td>8</td>
<td>56</td>
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<tr>
<td>RPA TORR</td>
<td>20</td>
<td>29</td>
<td>23</td>
<td>15</td>
<td>87</td>
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<tr>
<td>Hydroflokk</td>
<td>12</td>
<td>23</td>
<td>6</td>
<td>8</td>
<td>49</td>
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<tr>
<td>MyCelx</td>
<td>20</td>
<td>34</td>
<td>24</td>
<td>15</td>
<td>93</td>
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</tbody>
</table>
Overview of MyCelx / TORR Technologies
## SABIC – IBN SINA – Process Waste Water Recycling

### Table

<table>
<thead>
<tr>
<th>From FCC Total O&amp;G</th>
<th>Post MyCelx Coalescer Total O&amp;G</th>
<th>Post MyCelx Polisher Total O&amp;G</th>
</tr>
</thead>
<tbody>
<tr>
<td>43 ppm</td>
<td>6 ppm</td>
<td>0.7 ppm</td>
</tr>
<tr>
<td>500,000 ppm</td>
<td>13.5 ppm</td>
<td>0.4 ppm</td>
</tr>
<tr>
<td>1491 ppm</td>
<td>10 ppm</td>
<td>0.6 ppm</td>
</tr>
</tbody>
</table>
MyCelx – Advantages

Advantages of MyCelx

- Permanent Removal of Oil
- Guaranteed No Sheen
- Smallest Foot Print
- Standard Capacity – Robust in Handling Concentrations
- Low Capital and Operating Cost
- Activates only in Presence of Oil
- Low Pressure Drop – less than 2 psi
- Very Low Waste – 1/10th of GAC
- Easy to Operate
Contaminants Removed By MyCelx

- Oils & Condensate – Light, Heavy
- Gasoline Range Organics, Diesel Range Organics
- Tar, Asphaltenes, Creosotes, Waxes
- Polyaromatic Hydrocarbons (PAH’s)
- Polychlorinated Bisphenyl’s (PCB’s)
- Water Soluble Oils (WSO’s)
- Oil Coated Iron Sulfides
Water Treatment By TORR

1. Adsorption
2. Coalescence
3. Desorption
4. Gravity Separation

TORR™ OPERATING PRINCIPLES

OILY PRODUCED WATER ➔ ADSORPTION ➔ COALESCENCE ➔ DESORPTION ➔ TREATED WATER ➔ GRAVITY SEPARATION
Water Treatment By TORR

Benefits of TORR Technology treatment systems:

- A unique technology that separates and recovers non-soluble dispersed oil in water with approximately 2 microns in diameter and larger.
- Recovers the oil for reuse or recycling, thus reducing the expensive disposal costs associated with sludge, spent filter media, etc.
- Accomplishes oil separation and recovery without the need for chemicals or heat, thus operational costs are minimal.
- Energy requirements for pumping the oily water are minimal since the TORR system’s pressure drop across the process is low.
- Effectively treat temporary upset conditions with little or no effect on the performance of the system and the quality of the water.
Bridging the Technology Gap
Where Does MyCelx/TORR Fits in?

Technology Gap
Based on 99% Removal Efficiency

<table>
<thead>
<tr>
<th>Free Oil Removal</th>
<th>Dispersed Oil Removal</th>
<th>Emulsified and Soluble Oil Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 microns</td>
<td>25 microns</td>
<td>10 microns</td>
</tr>
<tr>
<td>API/CPI Separators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocyclones, DAF/IGF/EAF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nut Shell Filters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TORR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MyCelx Oil Removal Process</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please note: The above chart is not applicable to solid particle removal.

Disclaimer: The above chart is based on the operational characteristics of the equipment verified in the field over long operational periods and is not solely based on claims by respective vendors.
### MyCelx / TORR Vs Other Technologies

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MyCelx / TORR</th>
<th>Oil Water Separator</th>
<th>Clay / Carbon</th>
<th>Multimedia</th>
<th>Air Flotation Cells</th>
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</thead>
<tbody>
<tr>
<td>Mode of oil removal</td>
<td>Chemical affinity / Adsorption</td>
<td>Physical separation</td>
<td>Physical adsorption</td>
<td>Physical adsorption</td>
<td>Physical separation</td>
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<tr>
<td>Performance Certification</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Limitations on oil removal</td>
<td>Complete oil Removal (free and emulsified)</td>
<td>Removes only free oil. Suitable only for &gt; 50 ppm.</td>
<td>Fouls and plugs. Desorbs oil causing oil sheen</td>
<td>Fouls and plugs. Desorbs oil causing oil sheen</td>
<td>Removes free oil. Needs chemicals. Generates waste</td>
</tr>
<tr>
<td>Oil Removal to &lt; 1 ppm</td>
<td>Yes/ &gt;2 PPM</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>X/3X</td>
<td>3-10 X</td>
<td>3-5 X</td>
<td>3-5 X</td>
<td>7-10 X</td>
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<td>Operating Costs</td>
<td>Y/ 0.5Y</td>
<td>NA</td>
<td>3-10 Y</td>
<td>NA</td>
<td>3-6 Y</td>
</tr>
<tr>
<td>Footprint and Size</td>
<td>Z</td>
<td>20 Z</td>
<td>5 Z</td>
<td>5 Z</td>
<td>10 Z</td>
</tr>
</tbody>
</table>
Positioning
- Post IGF
- Post Walnut Shell
- Post Hydrocyclone
- Stand alone for discharge to sewer
- Pre R.O./U.F/MBR
- Post Electro Coagulation
- Post API/CPI

Applications
- Produced water, Frac Water and Flow Back Water
- Refinery process Water
- Cooling water return
- Bilge Water
- Pre R.O systems
- Condensate Treatment
- Storm water Inserts
CONCLUSION

- Effluent Recycle Plants are need of the day

- Recycling & reuse of effluent after treatment in multi-barrier systems is feasible. The reclaimed water can be used as fresh water make-up or can be further polished for recycling as boiler feed water.

- Every Recycle plant is a tailor made plant and depends a lot on many factors such as legal requirement, management policy, location of the plant, feed effluent quality & quantity, availability of utilities, end use requirement etc

- EIL can provide a total solution to the problem, wherein, an optimal solution is obtained for viable implementation
CONCLUSION

Path Ahead:

- Selection of advanced technology should be based on reduced carbon footprint of the process

- Future water management system should be based on low or no chemical usages. Magnetic hydrodynamics is one such approach which can minimize chemical requirement in the cooling water treatment system

- Reject management/TDS reduction techniques shall also require new approaches such as Phyco-remediation based technology having almost nil on Energy consumption
Thank You

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