Outline

- **Industrial water**
  - Usage
  - Treatment and recycle

- **Industrial wastewater treatment, recycle and reuse**
  - Some general comments
  - Fertilizer Industry Wastewater Treatment
  - *Hydrodynamic Cavitation - An emerging technology*

- **Future trends**
  - Hybrid technologies

- **Summary**
Water Usage

• Key usage [INDIA]
  - Drinking and other domestic uses [\(< 10 \%\)]
  - Agriculture [\(> 80 \%\)]
  - Industry [\(\sim 10 \%\)]

  - Since 1950, world population has doubled – water consumption has increased SIX fold

  - Industrial consumption is expected to grow rapidly

  - Focus of this talk is on industrial waste water treatment, recycle and reuse
    • With specific emphasis on Fertilizer chemical industry
Key Issues

• Availability of fresh water
  - Reducing day by day
  - Industries facing closure due to non-availability of water

• Increasingly stricter regulations on discharged water
  - Industries are facing closure due to non-compliance with the regulations

• Essential to adapt effective water treatment processes for complying with regulations and for meeting the daily water requirements!
Key Issues in Wastewater Treatment

• Can we avoid liquid discharge?
  – Dream of zero liquid discharge

• Can we reuse treated water?
  – At least as cooling water or boiler make-up if not as process water

• How to manage process economics?
  – In terms of money & space

Where is space for process plant?

Treatment cost: ~ X paise/lit
Industrial Wastewater Treatment - Challenges

• Highly Polluting Industries

- Cement
- Thermal Power plants
- Distilleries
- **Fertilizers**
- Tanneries
- Dye/Dye Intermediates/ Textile

- Oil refineries
- Petrochemicals
- Iron and Steel
- Pulp and Paper
- Pesticides
Wastewater from Fertilizer Industry

Typical fertilizer complex includes manufacturing plants for ammonia, acids, alcohol and fertilizers

• Presence of –
  - Organics, alcohols
  - Ammonia
  - Nitrates
  - Phosphorous
  - Other heavy metals

Wastewater treatment is a complex problem from environmental pollution point of view

*Existing practices employ different physico-chemical/ Biological methods of treatment*
Industrial Water Treatment

- **Physical methods**
  - Screening, settling
  - Filtration/ membrane separation

- **Chemical methods**
  - Oxidation: chemical, electrical-chemical oxidation
  - Neutralization

- **Physico-chemical methods**
  - Coagulation
  - Sorption, ion exchange
  - Extraction, Membrane separations, cavitation

- **Tertiary/ Polishing**

**Hybrid technologies**

- **Basic clean-up/ physical methods**
  - Removes 85% - 95% of BOD/COD and TSS
  - Removes 20% - 40% P
  - Removes 0% - 50% N

- **Removes > 99% of pollutants**
Key Technologies

- Coagulation

- Adsorption/ ion exchange

- Membranes

- Biological
  - Anaerobic/ aerobic

- Oxidation
  - Fenton, ozonation, wet air oxidation

- Hydrodynamic cavitation
Adsorption

• Inorganic adsorbents
  - Zeolites
    • A, X, Y, ZSM-5, silicalite, ALPO
  - Oxides
    • Silica, alumina

• Organic adsorbents
  - Activated carbon
    • powder, granules, molecular sieves, carbon fibre
  - Polymeric adsorbents
  - Ion exchange resins
  - Biomass

Development of modified adsorbents for Wastewater Treatment for removal of pollutants
Industrial Wastewater Treatment- *Strategy*

- Characterization of wastewater and identify important Effluent Treatment options.
  - Devising schemes for effective separation of organics, inorganics etc.
  - Evaluating suitable methods, materials and processes
  - Evaluating process viability under various conditions

- Evaluating physico-chemical methods for real life problems:
  - Hydrodynamic Cavitation/Adsorption/Ion exchange/ coagulation/ membrane separation/solvent extraction studies on real applications...
    - *in isolation and in combination.*

- Development of Integrated approach for Industrial applications
## Characterization of Effluents

<table>
<thead>
<tr>
<th>Effluent Stream</th>
<th>Initial COD (ppm)</th>
<th>Initial NH$_3$-N (ppm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125000</td>
<td>2</td>
<td>pH 7-8, Colored, characteristic odor, low TDS/TSS, presence of alcohols/organics</td>
</tr>
<tr>
<td>2</td>
<td>946</td>
<td>1710</td>
<td>Very high AN</td>
</tr>
<tr>
<td>3</td>
<td>460</td>
<td>86</td>
<td>pH 10.6, Low TSS, TDS&lt;2000</td>
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<tr>
<td>4</td>
<td>130</td>
<td>1330</td>
<td>pH 10, High AN, Very low TDS/TSS</td>
</tr>
<tr>
<td>5</td>
<td>44</td>
<td>530</td>
<td>pH 9.6, Low COD</td>
</tr>
<tr>
<td>6</td>
<td>170</td>
<td>276</td>
<td>pH 11, TDS&lt;2000</td>
</tr>
</tbody>
</table>
Key Results - Fertilizer Industry
Industrial effluent treatment using Adsorption

Low COD, Low AN Stream

COD reduction of 80% can be obtained using GS2x while ~80% reduction in AN can be obtained using TAC adsorbent.

All adsorbents show more or less satisfactory removal of COD and AN for this stream.
Key Results - Fertilizer Industry
Industrial effluent treatment using Adsorption

Low COD, Very high AN Stream

COD reduction of 80% can be obtained using TAC while only ~30% reduction in AN can be obtained using TAC adsorbent.

All adsorbents show less satisfactory removal of AN for this stream.
Key Results - Fertilizer Industry
Industrial effluent treatment using Adsorption

Low COD, High AN Stream

COD reduction of 80% can be obtained using TAC while only ~35% reduction in AN can be obtained using TAC adsorbent.

All adsorbents show less satisfactory removal of AN for this stream.
Key Results - Fertilizer Industry
Industrial effluent treatment using Adsorption

Low COD, High AN Stream

Near complete AN removal (~98%) with X7000H and ~50% reduction with TAC.

Selection of adsorbent is most crucial.

Interestingly, cavitation using vortex diode also yields 87% removal of AN similar to adsorption.
Cavitation? Progress of Cavitation Process

Cavitation Involves:

1. Formation of cavities
2. Growth of cavities
3. Implosion of cavities

With implosion of cavities, localized high T (~10000 K) and High P (~1000 atm) are created, consequently generating OH radicals and subsequent oxidation reactions.
Experimental Pilot Plant Facility at CSIR-NCL, Pune (1 m³/h capacity)

Cavitation Devices

• Orifice/ ventury

• Diode: CSIR – NCL technology

1st Hour: Pressure drop- 0.5 kg/cm² (flow rate of 380 LPH)

After 1 hr: 2.0 kg/cm² (flow rate of 780 LPH)
Comparison of adsorption and Cavitation for Different effluent streams

<table>
<thead>
<tr>
<th>Effluent Stream</th>
<th>Initial COD (ppm)</th>
<th>Initial NH₃-N (ppm)</th>
<th>% Reduction</th>
<th>COD</th>
<th>NH₃-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Adsorption</td>
<td>Cavitation</td>
<td>Adsorption</td>
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<td>125000</td>
<td>2</td>
<td>--</td>
<td>85</td>
<td>NA</td>
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</table>
Conclusions...

• Hydrodynamic cavitation using vortex diode appears to be an effective method for the treatment of industrial wastewaters.

• A very high removal of COD and AN can be obtained using adsorption and hydrodynamic cavitation-vortex diode.

• Adsorption, though effective for removal of both COD and AN, selection of adsorbent is most crucial.

• Where, hydrodynamic cavitation, alone, is not satisfactory for complete treatment, it can be easily combined practically with all other methods of treatment.
Emerging Technologies & Process Integration

- Hybrid technologies
  - Cavitation + Adsorption
  - Cavitation + Coagulation
  - Cavitation + Oxidation
  - Cavitation + Biological treatment
  - Cavitation + Membrane separation

Cavitation + Ion exchange
Summary

• Ready solutions available only in few cases
• Process integration required:
  • Continuous improvements in
    • Process Separations
      • (New processes/ process modifications/ Materials/ Material modifications /Devices/ Engineering Designs/ Hybrid systems)
    • Industrial wastewater treatment, recycle & reuse
      • (Laboratory studies, pilot plant experiments on real effluents)
      • Need to work on industrial effluents
      • Required- COD reduction, colour reduction and reduction in ammoniacal nitrogen
  • The findings here are expected to be useful not just for fertilizer industry wastewater streams but also for chemical industry effluents, in general....