Our Understanding

• Nutrients in the SF Bay are a growing concern for the Bay Area water quality

• BACWA and its 37 members have been working collectively to tackle the Bay Area nutrient removal issue

• BACWA has recently established new 3-level nutrient removal standards

<table>
<thead>
<tr>
<th>New Standards</th>
<th>Ammonia</th>
<th>Total Nitrogen</th>
<th>Total Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Varies by Facility</td>
<td>Varies by Facility</td>
<td>Varies by Facility</td>
</tr>
<tr>
<td>Level 2</td>
<td>2mg N/L</td>
<td>15mg N/L</td>
<td>1.0 mg P/L</td>
</tr>
<tr>
<td>Level 3</td>
<td>2mg N/L</td>
<td>6mg N/L</td>
<td>0.3 mg P/L</td>
</tr>
</tbody>
</table>
BACWA’s Recommended Upgrade Strategy

• Phased, cost-effective transition from the optimization stage (Level 1) to Level 3 upgrade

• Achieve Level 2 and 3 nutrient removal standards with minimal capital investment to improve existing facilities

• Technologies with minimal additional footprints preferred due to limited space

• Minimize GHG emission impacts

• Consider both new emerging and conventional nutrient removal technologies that can significantly reduce both capital and operating costs
RABAC Technology Key Features
RABAC Technology Is Combined Attached Growth and Suspended Growth Process

Rotating Bio Contactor (RABAC Unit)

Biological Reaction Basin (BRB)
RABAC Technology Is Aerobic Treatment Process

LEGEND:
- : Water treatment
- : Sludge treatment

Microorganism activator

Raw Water Influent

RABAC Unit

BIOLOGICAL REACTION BASIN

Return Sludge

Recycle

Treated Water Effluent

Excess Sludge disposal

LEGEND

: Water treatment

: Sludge treatment
Bacillus spp. Is Predominant Microorganism

- Rod shaped bacteria found in natural air, water and soil
- S. Korea and Japan used them for over 100 years for Kimchi and Miso
- Most widely used bacteria for producing antibiotics, probiotics and biopesticides
- We control the bacteria’s lifecycle of germination-growth-endorsporulation for efficient wastewater treatment
Nitrogen Removal

• Nitrogen removal rate exceeds 90%
• High removal rate is combination of:
  1) Aerobic autotrophic nitrification to anaerobic heterotrophic denitrification (conventional)
  2) Aerobic autotrophic nitrification to anaerobic autotrophic denitrification
  3) Aerobic heterotrophic nitrification to anaerobic heterotrophic denitrification (when BOD/N > 5)
  4) Anammox (when BOD/N is comparatively low)

• *B. Licheniformis, B. Fastidiosus, B. Pasteruii, B. Sphericuss* are main Bacillus spp. for nitrogen removal
Phosphorus Removal

• T-P removal rate exceeds 85%

• In general, when DO=0.1 mg/L, microbes start ingesting P to maintain their cells and metabolism; their activity reaches maximum level (luxury uptake) when DO=0.5 mg/L.

• RABAC process maintains DO level at 0.5 mg/L on average, so the process always reveals luxury uptake of phosphorus by Bacillus spp.

• Bacillus spp. consume more phosphorus than activated sludge microbes do due to thick cell structure
RABAC Technology Performance Results

<table>
<thead>
<tr>
<th>Item</th>
<th>Sewage</th>
<th>Dairy Manure</th>
<th>Food Processing Wastewater</th>
<th>Leachate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In</td>
<td>Out</td>
<td>In</td>
<td>Out</td>
</tr>
<tr>
<td>BOD</td>
<td>128.6</td>
<td>5.2</td>
<td>26,022</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>89.1</td>
<td>7.4</td>
<td>7,496</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS</td>
<td>142.9</td>
<td>3.7</td>
<td>24,370</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-N</td>
<td>32.4</td>
<td>7.4</td>
<td>4,281</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-P</td>
<td>2.9</td>
<td>0.5</td>
<td>724</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Neither chemicals nor filtration were used.

Source: Eco-Star Award Test Results, S. Korea Ministry of Environment (2003~2007)
• Proven Technology
  - 30 successful commercial applications in S. Korea, Japan and China

• Low CAPEX and Less Footprint
  - No nitrification-denitrification zones needed
  - Less air blowers, no chemical dosing equipment
  - No deodorization, disinfection facility needed
  - Less civil work due to RABAC replacing 50% of BRB

• Low OPEX
  - Semi-permanent durability of RABAC biocontactors
  - Low energy consumption due to low DO level
  - No chemical costs for phosphorus removal and denitrification
  - Less biosolid production and revenue from composting
  - Less manpower from simple operational requirements
# Representative Municipal Wastewater Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Capacity</th>
<th>Location</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyongtaek City Tongbok Sewage Treatment Plant</td>
<td>12.0 mgd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Pyongtaek City Jangdang Advanced Sewage Treatment Plant</td>
<td>6.6 mgd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Pyongtaek City Anjung Advanced Sewage Treatment Plant</td>
<td>5.3 mgd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Kunmmming City Sewage Treatment Plant</td>
<td>1.3 mgd</td>
<td>China</td>
<td>Design</td>
</tr>
<tr>
<td>Korea Maritime University Sewage Treatment Plant</td>
<td>237,000 gd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Busan Sansung Sewage Treatment Plant</td>
<td>127,000 gd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Busan Haguen Sewage Treatment Plant</td>
<td>40,000 gd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Busan House of Children Sewage Treatment Plant</td>
<td>31,700 gd</td>
<td>S. Korea</td>
<td>Operation</td>
</tr>
</tbody>
</table>
Potential RABAC Pilot Facility
DISCUSSION TOPICS

1. Joint RABAC Pilot with Stanford Codiga Center

2. Potential RABAC Pilot on BACWA Member Site

3. Primary Funding Source: RABAC Technology Inc.

4. Potential Supplemental Funding
Additional Slides
RABAC Unit Enhances Treatment Efficiency

- High density retiform disc of Polyvinylidene Chloride with 50 mm thickness
- Light weight, low energy consumption
- Semi-permanent
- Very high treatment capacity per unit disc area due to very thick biomass (20~30mm)
- Highly concentrated biofilm (10,000~30,000mg/L) allows handling of inflow fluctuations and variant BOD loadings even under cold temperature
- Highly contaminated pollutant BOD>20,000 mg/L can be treated in aerobic conditions without dilution
Biological Reaction Basin

- Decremental aeration from chamber 1 (DO=1.0) to chamber 4 (DO=0.1)
- Bacillus concentration control

<table>
<thead>
<tr>
<th>BOD (mg/L)</th>
<th>Bacillus concentration (/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100~2,000</td>
<td>$10^6$~$10^8$</td>
</tr>
<tr>
<td>2,000~5,000</td>
<td>$10^7$~$10^9$</td>
</tr>
<tr>
<td>Over 5,000</td>
<td>$10^9$~$10^{12}$</td>
</tr>
</tbody>
</table>
Organic Compound Biodegradation

Bacillus spp. produce various enzymes to remove BOD:

- Starch: Amylase, Isoamylase, Glucosidase
- Pectin: Polygalacturaonate Lyase
- Protein: Metallo Carboxypetidase, Serine Protease, Metalloprotease, Rennet
- Cellulose: Cellulase
- Fat: Lipase

Most Bacillus spp. produce catalase and superoxide dismutase to help hydrolysis of organic compounds that are difficult to biodegrade.

- Polyphenol, Tannin, Lignin in winery wastewater
- Fat, Oil, Grease along with lipolytic enzymes
- Hydrocarbon compounds: methane and other petroleum compound
Fundamentally Different from Conventional BNR Processes

- Simple aerobic process: no complicated process for nitrification, denitrification and phosphorus removal
- Simultaneous removal of nitrogen and phosphorus
- No carbon sources needed for denitrification
- No chemicals needed for phosphorus removal
- No coagulants needed for filamentous bulking removal
- Less biosolids (80%)
- Easy to meet BACWA Level 2 and Level 3 effluent standards
  - No SRT control required
  - MLSS: 2,500~3,000mg/L
  - DO level between 1mg/L and 0.1 mg/L maintaining 0.5 ppm on average
## No Deodorization Facility Needed

<table>
<thead>
<tr>
<th>Odor material</th>
<th>Chemical Formula</th>
<th>Industrial Discharging Standard</th>
<th>Other Discharging Standard</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>Under 2</td>
<td>Under 1</td>
<td></td>
</tr>
<tr>
<td>Methyl Mercaptan</td>
<td>CH₃SH</td>
<td>Under 0.004</td>
<td>Under 0.002</td>
<td></td>
</tr>
<tr>
<td>Hydrogen Sulfide</td>
<td>H₂S</td>
<td>Under 0.06</td>
<td>Under 0.02</td>
<td>RABAC Tech meets S. Korean standards without extra deodorization facilities</td>
</tr>
<tr>
<td>Dimethyl Sulfide</td>
<td>(CH₃)₂S</td>
<td>Under 0.05</td>
<td>Under 0.01</td>
<td></td>
</tr>
<tr>
<td>Dimethyl Disulfide</td>
<td>(CH₃)₂S₂</td>
<td>Under 0.03</td>
<td>Under 0.009</td>
<td></td>
</tr>
<tr>
<td>Trimethylamine</td>
<td>(CH₃)₃N</td>
<td>Under 0.02</td>
<td>Under 0.005</td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>CH₃CHO</td>
<td>Under 0.1</td>
<td>Under 005</td>
<td></td>
</tr>
</tbody>
</table>
## Industrial Wastewater Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Capacity</th>
<th>Location</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lotte Confectionery Waste Water Treatment Plant</td>
<td>160,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Ham &amp; Milk Waste Water Treatment Plant</td>
<td>340,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Freshdelica Waste Water Treatment Plant</td>
<td>53,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Chilsung Waste Water Treatment Plant</td>
<td>400,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Samkang Waste Water Treatment Plant</td>
<td>480,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Freshdelica Waste Water Treatment Plant</td>
<td>40,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Lotte Freshdelica Waste Water Treatment Plant</td>
<td>53,000g/d</td>
<td>Korea</td>
<td>Operation</td>
</tr>
</tbody>
</table>
## Septic/Leachate Wastewater Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Capacity</th>
<th>Location</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yongin Night Soil &amp; Livestock Sewage Treatment Plant</td>
<td>24,000gd</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Busan Umgung Night Soil &amp; Septic Treatment Plant</td>
<td>2,600gd</td>
<td>Korea</td>
<td>Pilot</td>
</tr>
<tr>
<td>Sanggok Leachate Treatment Plant</td>
<td>1320gd</td>
<td>Korea</td>
<td>Pilot</td>
</tr>
<tr>
<td>Sanggok Leachate Treatment Plant</td>
<td>530,000gd</td>
<td>Korea</td>
<td>Operation</td>
</tr>
<tr>
<td>Japan Night Soil &amp; Septic Treatment Plant</td>
<td>340,000gd</td>
<td>Japan</td>
<td>Operation</td>
</tr>
<tr>
<td>Busan Umgung Night Soil &amp; Septic Treatment Plant</td>
<td>925,000gd</td>
<td>Korea</td>
<td>Operation</td>
</tr>
</tbody>
</table>
Preliminary RABAC Retrofit Proposal to Central San
Preliminary Retrofitting Study for Central San

- Significant retrofitting cost savings:
  - RABAC can meet BACWA Level 2 using existing facilities and BACWA Level 3 with minor expansion of the secondary treatment process.

- Not much additional land required for RABAC retrofitting

- Simple operation
  - No complicated nitrogen and phosphorus removal processes needed

- Stable and consistent treatment efficiency despite fluctuations in flow rates

- Significant operational cost savings
  - Less aeration time, no chemical and carbon sources dosing
  - No UV treatment needed for Suisan Bay discharge (number of e-coli <30/ml)

- No foul odors

- Low GHG emission effect (less energy consumption, no chemicals, less incineration)
### Influent Characteristics and RABAC Upgrade

Guaranteed Effluent Quality

<table>
<thead>
<tr>
<th>Items</th>
<th>Influent at Primary MMDW~MMWW</th>
<th>Influent at Secondary MMDW~MMWW</th>
<th>(Alt1) Upgrade without Expansion Design Capacity Avg: 40 mgd Max: 100 mgd</th>
<th>(Alt2) Upgrade with Expansion Design Capacity Avg: 70 mgd Max: 127 mgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>cBOD</td>
<td>255~172</td>
<td>158~119 (3)</td>
<td>8 (5)</td>
<td>8</td>
</tr>
<tr>
<td>TSS</td>
<td>280~189</td>
<td>76~66 (4)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Ammonia</td>
<td>31~21</td>
<td>31~21</td>
<td>1 (2 (7))</td>
<td>1 (2 (8))</td>
</tr>
<tr>
<td>TKN (6)</td>
<td>55</td>
<td>55</td>
<td>10 (15 (7))</td>
<td>6 (8)</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>8.8~5.9</td>
<td>8.8~5.9</td>
<td>0.5 (1 (7))</td>
<td>0.3 (8)</td>
</tr>
</tbody>
</table>

1) Data: CWMP TP-6
2) BOD=1.32*CBOD
3) % cBOD removal at primary 38% and 31% in Summer and Winter, respectively
4) % TSS removal at primary 73% and 65% in Summer and Winter, respectively
5) BOD
6) BACWA Nutrient Reduction Study, CCCSD, Table 2-2
7) BACWA Level 2
8) BACWA Level 3
Project Descriptions

1. Re-consolidate Contaminated Soils to Basin A South
2. Raw Wastewater Diversion and Drain-back System
3. Levee Raising
4. BACWA Level 1 Optimization
5. *Future BACWA Level 2 and 3 Nutrient Removal
6. *Refinery Recycled Water (MBR+RO+UV)
7. Filter Plant Improvements
8. Solids Handling Improvements
9. Add Digesters and FOG/HSW Receiving Station
10. Replace MHF with FBI
11. UV Replacement
12. Aeration Upgrade: Electric Blowers, Diffusers, Air Piping
13. Primary R&R
14. Secondary Clarifier R&R
15. Add New PSTs and Aerated Grit Tank
16. Secondary Hydraulic Improvements
17. DAFT R&R
18. *Filter Plant Expansion for Concord Community Reuse
19. Clearwell Improvements
20. Influent Pump Improvements
21. *Future CEC Removal

* Potential improvements identified but not included in the CIP
Project Descriptions

1. Re-consolidate Contaminated Soil to Basin A South
2. Levee Raising
3. DAFWA Level 1 Optimization
4. Filter Plant Improvements
5. Solids Handling Improvements
6. Replace MHF with FBB
7. UV Replacement
8. Aeration Upgrade: Electric Blowers, Diffusers, Air piping
9. Primary R&R
10. Secondary Clarifier R&R
11. DAFTR R&R
12. Clearwell Improvements
13. Influent Pump Improvements
14. Planned New Facilities (RABAC)

Potential Improvements identified but not include in the CIP

EXISTING FACILITIES
NEW FACILITIES TO BE ADDED