Indicator bacteria:
Deer Island disinfection and dilution
at outfall protect Mass Bay

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Structure of today’s presentation

• Deer Island: [Dave]
  Plant, permit, current bacterial indicators

• Massachusetts Bay: [Dan]
  Bacteria in receiving waters

• Deer Island and Massachusetts Bay - Synthesis [Dave]
  Implications on compliance and operational issues
Deer Island: Overview

- Provides wastewater treatment for 2.3 million people in Metro Boston (43 communities)
- Average design flow 361 MGD, maximum capacity 1310 MGD
- Activated sludge secondary treatment
- Disinfection by sodium hypochlorite
- Dechlorination by sodium bisulfite
• NPDES permit issued in 2000 when first operational
  – includes **minimum 70-fold dilution** factor, confirmed by oceanographic field studies (Hunt et al., 2010)
Deer Island: Fecal coliform permit limits & sampling

• Permit limits effluent **fecal coliform** at Deer Island
  Limit calculated as:
  
  200 CFU/100mL \textit{Fecal coliform water quality standard in 2000 for primary contact recreation (swimming)}
  
  \[ \times \ 70 \text{ Dilution factor in permit} \]

  \[ = 14,000 \text{ CFU/100mL } \textit{Fecal coliform limit} \]

• Samples collected 365 days/year, 3 times/day
• Lab analyses use standard EPA-approved methods
• Collection and analysis by MWRA staff
Deer Island: Fecal coliform, 2008-14

43% of all tests were non-detects

99th percentile was 151 CFU/100mL

Maximum was 501 CFU/100mL

No permit violations 2008-14 (only violations were in 12/2001 and 4/2004)
Mass Bay: Receiving water bacteria monitoring

- **Fecal coliform** monitoring for **shellfishing** water quality
  - attached to Deer Island permit
  - MA Dept Marine Fisheries and US Food & Drug Admin
  - receiving waters *geometric mean* $< 14$ CFU/100mL

- Anticipating potential future limit, MWRA added **Enterococcus**
  - Recreational swimming in Mass Bay is unusual
  - Primary contact recreation standard: *geometric mean* $< 35$ CFU/100mL

Boston Light Swim
(annual event for distance-swimming enthusiasts)
MWRA staff and vessel

- One day, 11 stations

Two types:

- **Conditional**: Routine monthly surveys
- **Adverse**: As-needed for treatment plant operational issues
  - Infrequent (19 Adverse surveys over 16 years)
Mass Bay: Surface and near-seafloor sampling

Water depths at the 11 stations vary from 15 m to 50 m.

Outfall site: ~30 m (~100 ft) deep

**Winter**
- Unstratified, vertically mixed/uniform
- **Surface** samples (1 m deep)

**Late Spring - Early Fall**
- Stratified, less-dense layered over denser
- Sample **surface** and **near-seafloor** (2 m off bottom)
Vast majority (89%) of samples are non-detects

Annual means well below shellfishing standard

Similar results for outfall, nearfield, and coastal stations

Similar results for Adverse and Conditional surveys
Mass Bay: *Enterococcus* annual mean results

Similar results to Fecal coliform:

- Vast majority (91%) of samples are non-detects
- Annual means well below swimming standard

Similar results for outfall, nearfield, and coastal stations

Similar results for Adverse and Conditional surveys
Weak differences between surface and near-seafloor.

As expected: higher near seafloor at outfall stations; stratification reduces dilution.

Even near-seafloor at outfall stations: vast majority of samples (89-90%) are non-detects.

Ranges: 95% conf. ints.
Deer Island: Effluent *Enterococcus*

- *Enterococcus* not in current permit
- Expected in next permit
- MWRA samples *Enterococcus* at same times/locations as fecal coliform
- Analyzed by IDEXX Enterolert® since 2007
Deer Island: **Potential future** *Enterococcus* permit limits

- Current Massachusetts **marine receiving water** *Enterococcus* standards:
  - Geometric mean: 35 col/100mL
  - Single sample: 104 col/100mL

- Potential limits for **effluent**, using 70-fold dilution factor:
  
<table>
<thead>
<tr>
<th>Geometric mean</th>
<th>Single sample</th>
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<tbody>
<tr>
<td>35 col/100mL</td>
<td>104 col/100mL</td>
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<tr>
<td>X 70</td>
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<td>= 2,450 col/100mL</td>
<td>= 7,280 col/100mL</td>
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<td><em>Current standard</em></td>
<td><em>Dilution factor</em></td>
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Deer Island: *Enterococcus* by month, 2008-14

Distribution plot of single *Enterococcus* samples from 2008-2014, by month

**Strong seasonal pattern:**
- high in late winter and early spring
- low in late summer and early fall
Deer Island: *Enterococcus* by monthly geometric mean, 2008-14

Monthly geometric means, 2008-2014

All years show same seasonal pattern
Synthesis: Counts in effluent and receiving waters, 2008-14

Effluent:
- Strongly seasonal
- Peak in late winter

Receiving waters:
- Very low levels
- Vast majority non-detects
- **Not seasonal like effluent**

ND = Not detected in Feb or Oct 2008-2014
Synthesis: Outfall minor influence on bay bacteria levels

- Deer Island effluent bacteria levels
  - Fecal coliform: low levels, well within permit limits
  - Enterococcus: **strongly seasonal**, lowest in summer

- Mass Bay bacteria levels (both fecal coliform and Enterococcus): 
  - Very low, dominated by non-detects
  - Water quality standards very consistently met
  - Similar among outfall, nearfield, and coastal areas
  - Routine and adverse surveys similar
  - **Not seasonal** like effluent (even at the outfall location)

- All these factors support the conclusion that Deer Island effluent released at the outfall has very minor influence on bay bacteria levels
Long contact times and high effluent temperatures increase disinfection effectiveness.

**Late winter:**
- high flow
- short contact time
- low temperature
→ High *Enterococcus*

**Late summer:**
- low flow
- long contact time
- high temperature
→ Low *Enterococcus*
Deer Island: Temperature, contact time, and *Enterococcus*

- **Upper detection limit:** 24200 MPN/100mL
- **Effluent single sample (potential):** 7280 MPN/100mL
- **Effluent geometric mean (potential):** 2450 MPN/100mL
- **Receiving water single sample:** 104 MPN/100mL

**Exceed potential single-sample limit:***
- Short contact time
- Low temperature
Implications: Managing effluent *Enterococcus* levels

- Cannot increase contact time
- Increased chlorination?
- Seasonal limits?
Implications: Side effects of increased chlorination

• Possible increased toxicity
  – Permit requires monthly toxicity tests

• Increased chemical costs

• Increase truck traffic through Winthrop for chemical delivery
  – Higher chance of accidents
  – Increased traffic congestion
  – Higher greenhouse gas emissions
  – Unhappy neighbors
Final conclusions

• **Effluent at Deer Island:**
  – Fecal coliform: very low and in full compliance
  – *Enterococcus*: not yet regulated, but...
    • Strongly seasonal with high levels in late winter
    • If/when regulated, may require operational changes

• **Mass Bay**
  – Both fecal coliform and *Enterococcus* levels have met water quality standards very consistently year-round
  – Outfall has very minor influence

• **Potential operational changes would have negative consequences with likely little impact on protection of receiving waters**
• Technical reports:

• All are available online at MWRA website:
  [http://www.mwra.state.ma.us/harbor/enquad/trlist.html](http://www.mwra.state.ma.us/harbor/enquad/trlist.html)
Contact us

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Questions?