Relationship Between Bacteria and Conventional Water Quality Parameters

Hanadi S. Rifai, Ph. D., P. E., F. ASCE
Professor and Director
Environmental Engineering Graduate Program
Civil and Environmental Engineering

TX Watershed Coordinator Roundtable
July 27, 2011
OUTLINE

- Conventional water quality parameters
- Data for Houston Metro
- High resolution monitoring data in White Oak
- Data for tidal metro segments
- Data for a coastal watershed
- Summary and conclusions
OUTLINE

• **Conventional water quality parameters**
  • Data for Houston Metro
  • High resolution monitoring data in White Oak
  • Data for tidal metro segments
  • Data for a coastal watershed
  • Summary and conclusions
## Conventional Water Quality Parameters

<table>
<thead>
<tr>
<th><strong>Physical</strong></th>
<th><strong>Chemical</strong></th>
<th><strong>Biological</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Suspended Solids</strong></td>
<td><strong>Taste, color, odor</strong></td>
<td><strong>Biochemical Oxygen Demand Pathogens</strong></td>
</tr>
<tr>
<td><strong>Total Dissolved Solids</strong></td>
<td><strong>Total Organic Carbon</strong></td>
<td></td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td><strong>Dissolved Oxygen</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td><strong>Ammonia/nitrate</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Turbidity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solar Radiation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conductivity</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*UNIVERSITY of HOUSTON*
Suspended Solids

An increase in the amount of sediment causes:

- Increase of turbidity
- Decrease of light penetration
- Increase in amount of bacteria
- Increase in solids settled on the bottom which destroys animal habitats
Oxygen Demanding Material

- **Dissolved Oxygen (DO)** critical for fish and other higher forms of aquatic life.
- **Oxygen Demanding Material** can be oxidized thus consuming DO – Examples: BOD, COD.
- Almost all naturally occurring organic matter contributes to the depletion of DO.
Pathogenic Organisms

- Bacteria, viruses, and protozoa from diseased persons or animals
- Water unsafe for drinking, swimming, and fishing
- Antibiotic-resistant bacteria are most dangerous
- Bacteria found in urban and rural environments with no observable pattern
- Examples: E. Coli, Salmonella (typhoid fever), Shigella (dyentery), Cryptosporisium (protozoa), and Giardia (protozoa)
Temperature

- Temperature affects dissolved oxygen and microorganisms.
- Oxygen use speeds up as the temperature increases and slows down as the temperature decreases.
- Oxygen use caused by the metabolism of microorganisms.
OUTLINE

• Conventional water quality parameters
• Data for Houston Metro
• High resolution monitoring data in White Oak
• Data for tidal metro segments
• Data for a coastal watershed
• Summary and conclusions
**Geometric Mean E. coli Levels**

Brays & Whiteoak > Buffalo > Halls > Sims & Greens

2,400 MPN/dL > 2,000 MPN/dL > 1,600 MPN/dL > 600 MPN/dL

Data record: 2001 – 2008
E. coli concentrations: Change Over Time

Data record: 2001 – 2008

Legend

Trends
- EC Decreasing with Time
- EC Increasing with Time
- No Trend with Time

Colors:
- Sims Bayou
- Halls Bayou
- Brays Bayou
- Buffalo Bayou
- White Oak Bayou
- Eastern Houston
- Greens Bayou

North Arrow
Miles

0 2.5 5 10
E. coli Trends with Temperature

Data record: 2001 – 2008
Warm temperatures: 24 to 32°C
Cool temperatures: 12 to 18°C
E. coli Trends with Rainfall

Data record: 2001 - 2008
NA: Data Not Available
## Multiple Linear Regression – WO Bayou

### Coefficients of Predictor Variables

<table>
<thead>
<tr>
<th>Site</th>
<th>Day</th>
<th>Ln Flow</th>
<th>Temperature (°C)</th>
<th>TSS (mg/L)</th>
<th>SC</th>
<th>pH</th>
<th>Turbidity</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>11387</td>
<td>0.01</td>
<td>0.16</td>
<td>-0.46</td>
<td>-0.01</td>
<td>0.28</td>
<td>-0.13</td>
<td>0.01</td>
<td>0.30</td>
</tr>
<tr>
<td>11387 US</td>
<td>-0.01</td>
<td>-0.84</td>
<td>0.01</td>
<td>-0.34</td>
<td>-2.94*</td>
<td>-0.56</td>
<td>-0.07</td>
<td>0.19</td>
</tr>
<tr>
<td>16594</td>
<td>0.01</td>
<td>-0.85*</td>
<td>-0.41*</td>
<td>-0.02</td>
<td>-3.96*</td>
<td>-1.88</td>
<td>NA</td>
<td>0.52</td>
</tr>
<tr>
<td>8074250</td>
<td>0.01</td>
<td>-1.04</td>
<td>-0.51</td>
<td>0.03</td>
<td>-3.47*</td>
<td>-1.48</td>
<td>NA</td>
<td>0.49</td>
</tr>
<tr>
<td>16593</td>
<td>-0.01</td>
<td>NA</td>
<td>-0.07</td>
<td>0.00</td>
<td>-2.33</td>
<td>0.00</td>
<td>0.03</td>
<td>0.17</td>
</tr>
<tr>
<td>8074150</td>
<td>-0.02</td>
<td>NA</td>
<td>-0.55</td>
<td>0.01</td>
<td>-2.27*</td>
<td>0.47</td>
<td>0.00</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**Blue values indicate statistical significance at 95% confidence level**

* Statistically significant at 90% confidence level
OUTLINE

• Conventional water quality parameters
• Data for Houston Metro
• **High resolution monitoring data in White Oak**
• Data for tidal metro segments
• Data for a coastal watershed
• Summary and conclusions
Data from 3 Month Daily Sampling in WO
**Spatial Variability in 3-Month Data**

- **Upstream locations** had lower median and geometric mean *E. coli* concentrations.
- **Downstream locations** had similar variability of *E. coli* concentrations.
Monitor pH, DO, Conductivity, and Temperature

(A) Automated Sampler
(B) Peristaltic Pump
(C) Rain Gage

Solar Panel to Power Equipment

Suction Line

Sonde

Flow Through Cell

Data Logger Transmitter
Inside the Stormbox

- Multiprobe
- Automated sampler
- 24 Bottle configuration
- Sampler Display
- Solar Power Port
- Rain Gage Port
- Interrogator Port
- Flow Module
High-resolution Sampling Sites
E. coli Conc. at Site BG – Dry Weather

**E. coli**

**BG 01**

**E. coli (MPN/dL)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/1/09 6:00</td>
<td>22</td>
</tr>
<tr>
<td>6/1/09 8:00</td>
<td>24</td>
</tr>
<tr>
<td>6/1/09 10:00</td>
<td>26</td>
</tr>
<tr>
<td>6/1/09 12:00</td>
<td>28</td>
</tr>
<tr>
<td>6/1/09 14:00</td>
<td>30</td>
</tr>
<tr>
<td>6/1/09 16:00</td>
<td>32</td>
</tr>
<tr>
<td>6/1/09 18:00</td>
<td>34</td>
</tr>
</tbody>
</table>

**BG 02**

**E. coli (MPN/dL)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/1/09 6:00</td>
<td>22</td>
</tr>
<tr>
<td>6/1/09 8:00</td>
<td>24</td>
</tr>
<tr>
<td>6/1/09 10:00</td>
<td>26</td>
</tr>
<tr>
<td>6/1/09 12:00</td>
<td>28</td>
</tr>
<tr>
<td>6/1/09 14:00</td>
<td>30</td>
</tr>
<tr>
<td>6/1/09 16:00</td>
<td>32</td>
</tr>
<tr>
<td>6/1/09 18:00</td>
<td>34</td>
</tr>
</tbody>
</table>

**BG 05**

**E. coli (MPN/dL)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/18/10 6:00</td>
<td>13</td>
</tr>
<tr>
<td>3/18/10 18:00</td>
<td>15</td>
</tr>
<tr>
<td>3/19/10 6:00</td>
<td>17</td>
</tr>
</tbody>
</table>

**BG 06**

**E. coli (MPN/dL)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Water Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/24/10 6:00</td>
<td>24</td>
</tr>
<tr>
<td>5/24/10 18:00</td>
<td>26</td>
</tr>
<tr>
<td>5/25/10 6:00</td>
<td>28</td>
</tr>
</tbody>
</table>

**Legend**

- **E. coli**
- 394 MPN/dL Std.
- Temperature (°C)
E. coli Concentration at Site HB – Dry Weather

- **Site HB 01**: 
  - Graph showing E. coli concentration (MPN/dL) and water temperature (°C) over time.
  - Data points for different dates: 5/8/09, 5/10/09, 5/12/09, 5/14/09, 5/16/09.
  - E. coli concentration ranges from 100 to 100,000 MPN/dL.

- **Site HB 02**: 
  - Graph showing E. coli concentration (MPN/dL) and water temperature (°C) over time.
  - Data points for different dates: 5/8/09, 5/10/09, 5/12/09, 5/14/09, 5/16/09.
  - E. coli concentration ranges from 100 to 10,000 MPN/dL.

- **Site HB 03**: 
  - Graph showing E. coli concentration (MPN/dL) and water temperature (°C) over time.
  - Data points for different dates: 1/19/10, 1/21/10.
  - E. coli concentration ranges from 100 to 100,000 MPN/dL.

- **Site HB 04**: 
  - Graph showing E. coli concentration (MPN/dL) and water temperature (°C) over time.
  - Data points for different dates: 2/2/10, 2/4/10, 2/6/10.
  - E. coli concentration ranges from 100 to 10,000 MPN/dL.

Legend:
- **E. coli**: Red line
- **394 MPN/dL Std.**: Black dashed line
- **Temperature**: Pink line
Solar Radiation Effects on *E. coli*

**Source of Solar Radiation Data**
## Storm Event Monitoring

**Location: 11387 @ Heights**

<table>
<thead>
<tr>
<th>Date</th>
<th>Event #</th>
<th>Rainfall (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/22/2009</td>
<td>HB 05</td>
<td>0.60</td>
</tr>
<tr>
<td>8/13/2009</td>
<td>HB 06</td>
<td>0.43</td>
</tr>
<tr>
<td>8/22/2009</td>
<td>HB 07</td>
<td>1.07</td>
</tr>
<tr>
<td>9/22/2009</td>
<td>HB 08</td>
<td>1.62</td>
</tr>
<tr>
<td>10/2/2009</td>
<td>HB 09</td>
<td>1.54</td>
</tr>
<tr>
<td>2/09/2010</td>
<td>HB 10</td>
<td>0.12</td>
</tr>
</tbody>
</table>
**Storm Events @ HB Site**

**HB 05**
- Rainfall: 0.28 inch*
- Attenuation due to Temperature
- Attenuation due to flow

**HB 06**
- Rainfall: 0.43 inch*

**HB 09**
- Rainfall: 1.54 inch*

*NOT TO SCALE*
WO Bayou – Real Time Monitoring
EC and Turbidity – Rain Event
8/12/09

EC
Turbidity
OUTLINE

- **Conventional water quality parameters**
- **Data for Houston Metro**
- **High resolution monitoring data in White Oak**
- **Data for tidal metro segments**
- **Data for a coastal watershed**
- **Summary and conclusions**
Tidal Metro Segments
Enterococci Geomean Concentration (cfu/dL)

- 23-35
- 36-70
- 71-168
- 169-202
Indicator Bacteria & Temp – Tidal Metro
INDICATOR BACTERIA AND TSS – TIDAL METRO

![Graphs showing bacteria concentration vs TSS for segments 1005, 1006, and 1007. Each graph represents data for different bacterial species (EC, ENT, FC) across various TSS levels (0-10, 11-25, 26-100, 100+) in a logarithmic scale.](image-url)
INDICATOR BACTERIA & SALINITY
TIDAL METRO
OUTLINE

- CONVENTIONAL WATER QUALITY PARAMETERS
- DATA FOR HOUSTON METRO
- HIGH RESOLUTION MONITORING DATA IN WHITE OAK
- DATA FOR TIDAL METRO SEGMENTS
- DATA FOR A COASTAL WATERSHED
- SUMMARY AND CONCLUSIONS
**Dissolved Oxygen Geometric Mean**

Dissolved Oxygen concentration (mg/L)
- 4.5 - 6.0
- 6.1 - 8.0
- 8.1 - 10.0
- 10.1 - 12.0
- 12.1 - 14.5

Map showing dissolved oxygen concentrations in different areas, including Clear Creek, Gum Bayou, and Lower Galveston Bay.
*E. coli and ENT - Dickinson*

Graph showing the distribution of E. coli and ENT along the main stem and tributary of Dickinson Bayou. The graphs display the number of organisms (MPN/100 mL or #/100 mL) as a function of distance from the mouth of Dickinson Bayou (miles). Data points are labeled for Segment ID 1103 and 1104. The graphs also indicate GCHD Data*.
EC and ENT and DO
Dickinson Bayou
ENT AND SALINITY IN DICKINSON

**Segment 1103**

- Minimum: 0.1
- 25th Percentile: 1
- Median: 10
- 75th Percentile: 100
- Maximum: 1,000

Salinity (µS/cm)
- <3 ppt (freshwater)
- 3 to 16 ppt (brackish)
- >16 ppt (sea water)

**Segment 1104**

- Minimum: 0.1
- 25th Percentile: 10
- Median: 100
- 75th Percentile: 1,000
- Maximum: 10,000

Salinity (µS/cm)
- <3 ppt (freshwater)
- 3 to 16 ppt (brackish)
- >16 ppt (sea water)

(n=2)
Summary and Conclusions

- As watersheds urbanize, less correlation between biological water quality and other parameters
- Correlation may be observed at high resolution scale, e.g., EC and turbidity during storm event
- Some conventional water quality parameters no longer sufficient indicators, e.g., TSS
- Other indicators needed for urbanizing watersheds to characterize particulate, biological, and chemical water quality
Acknowledgements

- HGAC and HCFCDD
- Texas Commission on Environmental Quality (TCEQ)
- US EPA
- The Houston Endowment, Inc.
- NSF GK-12 Program
- Researchers: D. Lakshmanan

Texas Commission on Environmental Quality

Houston Endowment Inc.
A Philanthropy Endowed by Mr. and Mrs. Jesse H. Jones

NSF
GK-12
GRADUATE STEM FELLOWS IN K-12 EDUCATION