Droplet Size Distribution in Wave Tank Studies on Dispersant Effectiveness

Zhengkai Li, Kenneth Lee, Paul Kepkay, Tom King
Center for Offshore Oil and Gas Environmental Research
Fisheries & Oceans Canada, Dartmouth NS, CANADA

Michel C. Boufadel
Civil and Environmental Engineering Department
Temple University, Philadelphia PA, U.S.A.

Albert D. Venosa
National Risk Management Research Laboratory
Environmental Protection Agency, Cincinnati OH, U.S.A.
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• Team members:

• Supporting engineers:
  Dan Moffatt, Merle Pittman
Wave Tank Facilities at BIO

- Wave generation paddle
- Oil slick
- Oil dispersant
- Energy absorbers
- LISST
Wave Tank Facilities at BIO
Factorial Experimental Design

- **Factors:**
  - Dispersants: Corexit, SPC, Water (control)
  - Waves: regular non-breaking wave; spilling breaker, plunging breaker,
  - Oil types: MESA, ANS

- **Effectiveness indicators:**
  - Oil concentration
  - Droplet size distribution

- **Analytical methods**
  - Ultraviolet Spectrophotometry
  - Ultraviolet Fluorometry
  - Laser In-Situ Scattering and Transiometry
  - Epifluorescent microscopy
## Factorial Experimental Design Matrix

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dispersants</th>
<th>Oils</th>
<th>Waves</th>
<th>Replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>MESA</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>2</td>
<td>Corexit</td>
<td>MESA</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>3</td>
<td>SPC</td>
<td>MESA</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>4</td>
<td>Water</td>
<td>ANS</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>5</td>
<td>Corexit</td>
<td>ANS</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>6</td>
<td>SPC</td>
<td>ANS</td>
<td>Regular</td>
<td>A, B, C</td>
</tr>
<tr>
<td>7</td>
<td>Water</td>
<td>MESA</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>8</td>
<td>Corexit</td>
<td>MESA</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>9</td>
<td>SPC</td>
<td>MESA</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>10</td>
<td>Water</td>
<td>ANS</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>11</td>
<td>Corexit</td>
<td>ANS</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>12</td>
<td>SPC</td>
<td>ANS</td>
<td>Spilling</td>
<td>A, B, C</td>
</tr>
<tr>
<td>13</td>
<td>Water</td>
<td>MESA</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
<tr>
<td>14</td>
<td>Corexit</td>
<td>MESA</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
<tr>
<td>15</td>
<td>SPC</td>
<td>MESA</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
<tr>
<td>16</td>
<td>Water</td>
<td>ANS</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
<tr>
<td>17</td>
<td>Corexit</td>
<td>ANS</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
<tr>
<td>18</td>
<td>SPC</td>
<td>ANS</td>
<td>Plunging</td>
<td>A, B, C</td>
</tr>
</tbody>
</table>
Particle Size Distribution Measured with LISST-100X (no dispersant)
Particle Size Distribution Measured with LISST-100X (with Dispersant)

\[ \text{TOC} = \sum n_i \cdot C_i \]

\[ \text{MMD} = \frac{\sum m_i \cdot d_i}{M} \]
Total Oil Concentration under Spilling Breakers w/o Dispersant
Mass Mean Diameter under Spilling Breakers w/o Dispersantant

Time (min)

0 2 0 4 0 6 0 8 0 1 0 0 1 2 0

M

0 100 200 300 400 500

surface middle bottom
Total Oil Concentration under Spilling Breakers with Dispersant
Mass Mean Diameter under Spilling Breakers with Dispersant

![Graph showing Mass Mean Diameter over time with different layers: surface, middle, and bottom.](image-url)
Total Oil Concentration under Regular Non-breaking Waves

Total oil concentration as a function of time and depth (regular wave; no dispersant control)

Total oil concentration as a function of time and depth (regular wave; with Corexit 9500)
Mass Mean Diameter under Regular Non-Breaking Waves

Mass mean diameter as a function of time and depth (regular wave; no dispersant control)

Mass mean diameter as a function of time and depth (regular wave; with Corexit 9500)
Total Oil Concentration under Spilling Breakers

Total oil concentration as a function of time and depth (spilling breaker; no dispersant control)

Total oil concentration as a function of time and depth (spilling breaker; with Corexit 9500)
Mass Mean Diameter under Spilling Breakers

Mass mean diameter as a function of time and depth (spilling breaker; no dispersant control)

Mass mean diameter as a function of time and depth (spilling breaker; with Corexit 9500)
Total Oil Concentration under Plunging Breakers

- Total oil concentration as a function of time and depth (plunging breaker; no dispersant control)
- Total oil concentration as a function of time and depth (plunging breaker; with Corexit 9500)
Mass Mean Diameter under Plunging Breakers

Total oil concentration as a function of time and depth
(plunging breaker; no dispersant control)

Total oil concentration as a function of time and depth
(Plunging breaker; with Corexit 9500)
Effects of Waves, Dispersants, and Oil Type on MMD Near Bottom after 2 h Dispersion
Effects of Waves, Dispersants, and Oil Type on MMD Near Bottom after 2 h Dispersion
## Effects of Waves, Dispersants, and Oil Types on Dispersed Oil Droplet Size

<table>
<thead>
<tr>
<th>Factors</th>
<th>Df</th>
<th>Sm of Sq</th>
<th>Mean Sq</th>
<th>F Value</th>
<th>Pr (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersant</td>
<td>2</td>
<td>8711.662</td>
<td>4355.831</td>
<td>17.57963</td>
<td>0.0000585</td>
</tr>
<tr>
<td>Wave</td>
<td>2</td>
<td>6461.343</td>
<td>3230.671</td>
<td>13.03862</td>
<td>0.0003159</td>
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<tr>
<td>Oil</td>
<td>1</td>
<td>2.555</td>
<td>2.555</td>
<td>0.01031</td>
<td>0.9202444</td>
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<tr>
<td>Dispersant : Wave</td>
<td>4</td>
<td>2531.817</td>
<td>632.954</td>
<td>2.55453</td>
<td>0.0744745</td>
</tr>
<tr>
<td>Dispersant : Oil</td>
<td>2</td>
<td>254.805</td>
<td>127.403</td>
<td>0.51418</td>
<td>0.6065120</td>
</tr>
<tr>
<td>Wave : Oil</td>
<td>2</td>
<td>1460.530</td>
<td>730.265</td>
<td>2.94727</td>
<td>0.0781206</td>
</tr>
<tr>
<td>Dispersant : Wave : Oil</td>
<td>4</td>
<td>3704.931</td>
<td>926.233</td>
<td>3.73817</td>
<td>0.0220105</td>
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<tr>
<td>Residuals</td>
<td>18</td>
<td>4459.988</td>
<td>247.777</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Oil Distribution in the Wave Tank Under Regular Waves

UVF oil concentration as a function of distance and depth
(regular wave, no dispersant control)

UVF oil concentration as a function of distance and depth
(regular wave, with Corexit 9500)
Oil Distribution in the Wave Tank Under Spilling Breakers

UVF oil concentration as a function of distance and depth
(spilling breaker; no dispersant control)

UVF oil concentration as a function of distance and depth
(spilling breaker; with Corexit 9500)
Oil Distribution in the Wave Tank Under Plunging Breakers

UVF oil concentration as a function of distance and depth (plunging breaker; no dispersant control)

UVF oil concentration as a function of distance and depth (plunging breaker; with Corexit 9500)
Conclusions

• Dispersants:
  - Dispersant reduced oil droplet size and the accelerated the break up of large oil into small oil droplets
  - Dispersant increased the dispersed oil concentration
  - The two tested chemical dispersants are similar in their effectiveness from the preliminary data analysis

• Waves:
  - Plunging and spilling breaking waves increased oil concentration compared to non-breaking wave
  - Breaking waves also decreased oil droplet size

• Oils:
  - No significant effect of tested oil types on dispersed oil concentration and droplet size distribution