Post-atomization Impact Behavior of COREXIT® 9500 and COREXIT® 9527 on Oil Slicks

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Mrs. Rebecca Ebert
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- Entomology Department – OARDC – OSU
Application Technology

- **Atomization**

  Water, still air, TeeJet 8003

- **Impaction**

  Impaction on poinsettia leaf
Atomization

Wavy Sheet Disintegration

Edge of sheet

Secondary droplet disintegration
The Dose Transfer Process

- **Spray Tank**
  - Mixing & Agitation
  - Atomization
    - Equipment/Application
    - Physical Properties
    - Evaporation
    - Micrometeorological Conditions

- **Impaction**
  - Drift
  - Volatilization
  - Redistribution
    - losses
    - wind
    - losses
    - reflection, shatter, and splash

- **Retention**
  - Chemical Penetration of slick

- **Dispersal**
  - Distribution of droplets over surface
  - Emulsion Formation
  - Encounter Probability
  - Biological Effect
    - Toxicity
    - Degradation

- **Losses**
Introduction

- What is the maximum droplet size that does not penetrate an oil slick?
- Oil composition
- Physical Properties
- Impaction energy
- Slick Thickness
- Scale
The Right Scales

- Time
- Size and Volume
- Area
The impaction process on a hard surface

Impaction, deformation, and initial recovery of a 330 μm diameter water droplet impacting a glass surface. Time interval between successive frames 0.1 ms.
## Size and Volume

<table>
<thead>
<tr>
<th>Diameter (µm)</th>
<th>Volume (µl)</th>
<th>Number per Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.000000052</td>
<td>7.23E+12</td>
</tr>
<tr>
<td>50</td>
<td>0.00006545</td>
<td>5.78E+10</td>
</tr>
<tr>
<td>100</td>
<td>0.00052360</td>
<td>7.23E+09</td>
</tr>
<tr>
<td>500</td>
<td>0.06544985</td>
<td>5.78E+07</td>
</tr>
<tr>
<td>1000</td>
<td>0.52359878</td>
<td>7.23E+06</td>
</tr>
<tr>
<td>1500</td>
<td>1.76714587</td>
<td>2.14E+06</td>
</tr>
</tbody>
</table>
Droplets per cm² given an application rate of 1 gallon per acre

<table>
<thead>
<tr>
<th>Diameter (µm)</th>
<th>Number per Gallon</th>
<th>Number cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7.23E+12</td>
<td>1.79E+05</td>
</tr>
<tr>
<td>50</td>
<td>5.78E+10</td>
<td>1.43E+03</td>
</tr>
<tr>
<td>100</td>
<td>7.23E+09</td>
<td>1.79E+02</td>
</tr>
<tr>
<td>500</td>
<td>5.78E+07</td>
<td>1.43E+00</td>
</tr>
<tr>
<td>1000</td>
<td>7.23E+06</td>
<td>1.79E-01</td>
</tr>
<tr>
<td>1500</td>
<td>2.14E+06</td>
<td>5.29E-02</td>
</tr>
</tbody>
</table>

563 µm will provide 1 droplet per cm²
Laboratory set-up
Options

- Droplets could act as marbles, penetrating and continuing into the water column.
- Droplets could shatter upon impact, thereby mixing with the water column.
- Droplets could retain cohesion, float, and remain at the water-oil interface.
Penetration: Glass spheres

- No chemical interactions
- No physical interactions
- Surface deformation and recovery

A: Time zero, bead is just above surface
B: Maximum width of displacement
C: Glass bead continues down and the filament connecting bead to surface is thinnest.
D: A thin stream of liquid is seen above surface
E: Initial droplets continue up beyond the picture frame.
F: Ligament is at maximum extension and droplets form along its entire length.
Chemical interactions

- Physical interactions
- Droplet Cohesion

3.21 mm 9500 into 2mm soybean

3.42mm 9527 into water
The Impaction Process

- No Oil
- Soybean Oil
- 0.3mm Fuel Oil
Dispersant Impaction into Water

- All material rises to the surface

### Corexit 9500

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.011</td>
<td>0.051</td>
<td>0.053</td>
<td>0.112</td>
<td>0.294</td>
<td>0.514</td>
<td>0.680</td>
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</table>

### Corexit 9527

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.010</td>
<td>0.044</td>
<td>0.048</td>
<td>0.097</td>
<td>0.224</td>
<td>0.405</td>
<td>0.762</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th></th>
<th>9500</th>
<th>9527</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (C)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Droplet Size (mm)</td>
<td>1.33</td>
<td>1.04</td>
</tr>
<tr>
<td>Velocity (m s⁻¹)</td>
<td>2.57</td>
<td>4.26</td>
</tr>
<tr>
<td>% of Terminal V</td>
<td>52%</td>
<td>97%</td>
</tr>
<tr>
<td>Energy (uJ)</td>
<td>3.91</td>
<td>5.24</td>
</tr>
<tr>
<td>Energy/area (J m⁻²)</td>
<td>2.80</td>
<td>6.16</td>
</tr>
<tr>
<td>Max Depth (mm) in B</td>
<td>5.34</td>
<td>5.01</td>
</tr>
<tr>
<td>Max Height (mm) in C</td>
<td>7.15</td>
<td>5.30</td>
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</tbody>
</table>
Impaction Energy

A 3.37 and a 3.32 mm droplet of Corexit 9500 impacting a 0.5 mm ISO380 slick from 107 and 30 cm respectively.

### Height 107 cm

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.007</td>
<td>0.021</td>
<td>0.034</td>
<td>0.100</td>
<td>0.174</td>
<td>0.183</td>
<td>0.212</td>
<td>0.221</td>
<td>0.304</td>
<td>0.383</td>
<td>1.089</td>
</tr>
</tbody>
</table>

### Height 30 cm

<table>
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<tr>
<th>A</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.015</td>
<td>0.029</td>
<td>0.068</td>
<td>0.091</td>
<td>0.136</td>
<td>0.208</td>
<td>0.338</td>
<td>0.502</td>
</tr>
</tbody>
</table>

### Data Table

<table>
<thead>
<tr>
<th></th>
<th>107</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>Droplet Size (mm)</td>
<td>3.37</td>
<td>3.32</td>
</tr>
<tr>
<td>Velocity (m s⁻¹)</td>
<td>5.44</td>
<td>2.69</td>
</tr>
<tr>
<td>% of Terminal V</td>
<td>66%</td>
<td>33%</td>
</tr>
<tr>
<td>Energy (uJ)</td>
<td>281.54</td>
<td>67.96</td>
</tr>
<tr>
<td>Energy/area (J m⁻²)</td>
<td>31.59</td>
<td>7.83</td>
</tr>
<tr>
<td>Max Depth (mm)</td>
<td>20.34</td>
<td>9.72</td>
</tr>
<tr>
<td>Max Height (mm)</td>
<td>16.33</td>
<td>14.70</td>
</tr>
</tbody>
</table>
Conclusion

- Droplets up to 1000 µm will not penetrate an oil slick and disperse into the underlying water column. They do not have the energy.
- This is a conservative estimate because it does not take into account the energy absorption by the oil slick and does not account for any oil in the slick coating the penetrating droplet.
- Our estimate does not account for subsurface turbulence at the oil-water interface.
The following is atomization as a mixture design: 8 slides
Dose does not equate to efficacy in any simple way in our greenhouse studies.

Are there missing components to the dose-response model?
A Digression: Mixture Designs

General Relationship: the total is the sum of the parts

\[ %V_1 + %V_2 + %V_3 + \ldots + %V_n = 100\% \]

500 ml Water + 500 ml Ethanol = 1000 ml Ethanol

Factorial Model

50% Water + 50% Ethanol = 33% Water + 66% Ethanol

Mixture Model
Atomization: A Mixture Design?

Assuming monosized droplets

\[
\text{Quantity} \propto \left(\frac{4}{3}\pi\right)r^3NC
\]

The relationship needs to be additive

\[
\log(\text{Quantity}) \propto 3\log(r) + \log(N) + \log(C)
\]
Graphing The Mixture Model

- 100% Number
- Increasing concentration
- Centroid
- Increasing size
- 100% Size
- 100% Concentration
- Increasing number
Effect of Toxicant Distribution

1) Pesticide Dose Simulator (PDS) Model: strategic model simulating a chewing insect herbivore feeding on leaves treated with discrete toxicant deposits. The model was originally tested using Diamondback moth feeding on cabbage.

2) Cabbage looper feeding on cabbage treated with fipronil
Range in Efficacy

<table>
<thead>
<tr>
<th>Replication</th>
<th>PDS Model</th>
<th>Bioassay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range in Efficacy with no change in quantity.</td>
<td>18 to 95%</td>
<td>9% to 70%</td>
</tr>
</tbody>
</table>

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Simulation Time in Minutes

Percent Mortality

- Maximum Mortality
- Average Mortality
- Minimum Mortality
PDS Model Results

Percent Mortality

- 0-8%
- 8-16%
- 16-26%
- 26-36%
- 36-47%
- 47-58%
- 58-71%
- 71-85%
- 85-100%

Number

Size

Concentration
Bioassay Results

Percent Mortality

Size: 160 to 2436 mm
Number: 1 to 1800
Concentration: 0.3 g/l to pure formulation
Conclusion

1) Toxicant distribution can be modeled as a mixture of:
   a) Size of Droplets
   b) Numbers of Droplets
   c) Toxicant concentration
2) Toxicant distribution significantly affects efficacy.
3) Optimal distribution is a few very toxic deposits.
4) How does oil droplet size influence toxicity to marine ecosystems?
5) How does oil droplet size influence colonization and degradation rates?