Investigations of micro- and nanoplastic toxicity using a model aquatic invertebrate and a model insect

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Plastics enter soils via direct application on cropland, wastewater biosolids, release from landfills, etc...

Plastic litter breaks down into secondary microplastics and nanoplastics.

Tufenkji and Emelko *Encyclopedia Env Health* 2010
Need for Studies on Freshwater and Terrestrial Animals

Few studies of micro/nanoplastic uptake in terrestrial or freshwater organisms

- **Daphnia magna** (water flea)
  - Transparent, fast reproduction, cheap and easy to work with.

- **Drosophila melanogaster** (fruit fly)
  - Genetic, proteomic, and physiological similarities to humans.

Study 1. Chronic Effects of Leachate of Weathered Plastic

80 g plastic debris/L

20 days

filtration

100%
Study 1. Chronic Effects of Leachate of Weathered Plastic

20 days

80 g plastic debris/L

100% filtration

48 h acute test

100% 50% 10% 0%

X 3

PET
Nylon
Polypropylene
Polyethylene
Study 1. Chronic Effects of Leachate of Weathered Plastic

80 g plastic debris/L filtration

20 days

48 h acute test

100% 50% 10% 0%

X 3

10 day chronic test

PET
Polypropylene
Nylon
Polyethylene

100% 100% 0%

X 10

X 10
Secondary Microplastics and Nanoplastics in Leachate

There are 500 times more nanoplastics than microplastics.

Several metals are detected at concentrations $< \text{LC}_{50}$ in *Daphnia*.

A complex mixture of organic compounds, including bisphenol A is released from the plastics.

Leachate Affects Growth, Reproduction, and Physiology

- No significant mortality
- Increased body size
- Increased fecundity
- Decreased appendage beat
- Increased swimming distance
- No change in heart beat
- No change in swimming distance

Observed sublethal effects due to mixture of microplastics, nanoplastics and leached chemicals.

Study 2. Acute Effects of Food Packaging Debris


plastic teabags

372 g plastic packaging/L

T = 95 °C
t = 5 minutes

Decant

Teabag leachate

100%
Food Packaging Releases High Levels of MPs and NPs

Dried Teabag Leachate

mean diameter
~ 25 \( \mu \)m

mean diameter
~ 100 nm

~ 2 \( \times \) 10\(^6\) particles/teabag

~ 15 \( \times \) 10\(^9\) particles/teabag

When drinking 1 cup of tea, a person can ingest:

2 million micro-sized plastics

15 billion sub-micron plastics

Study 2. Acute Effects of Food Packaging Debris

Food Packaging Debris Affects Fly Survival and Behavior

PET teabag leachate

Female flies are more susceptible than male flies.
Food Packaging Debris Affects Fly Survival and Behavior

PET teabag leachate

Flies climbing above 10 cm (%)

Male | Female
--- | ---
Control | 10% | 20% | 100%

SEM of fruit fly eyes

SEM of fruit fly legs
Concluding Remarks

• Bulk plastics can degrade into millions of microparticles and billions of nanoparticles.

• Weathered plastic leachate can exhibit low toxicity but can impact growth, reproduction and feeding behavior.

• Plastic use in food packagings can lead to undesirable contamination of foods with high levels of micro- and nanoplastics.
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We have a funded postdoc position in ecotoxicology. Please contact me!

visit us: www.biocolloid.mcgill.ca
Extra Slides
Scanning electron microscopy is used to image plastic particles on the carapace and antenna of Daphnia.
Secondary Microplastics and Nanoplastics in Leachate


![Image of microplastics and nanoplastics in leachate](image)

- **2,500×**
  - **21.2×10⁶** particles/mL
  - Particle diameter (nm): 4000 nm

- **100,000×**
  - **10.8×10⁹** particles/mL
  - Particle diameter (nm): 1000 nm

Graphs showing the distribution of particle diameters for both conditions.
## Chemical Contaminants in Leachate

<table>
<thead>
<tr>
<th>Proposed formula</th>
<th>Tentative identity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ESI+</strong>&lt;br&gt;&lt;br&gt;<code>C_9 H_{19} NO_4</code></td>
<td>Dexpanthenol</td>
</tr>
<tr>
<td><code>C_8 H_{19} NO_2</code></td>
<td>N-Butyldiethanolamine</td>
</tr>
<tr>
<td><code>C_{17} H_{26} O_3</code></td>
<td>4-Nonylphenoxycetic acid</td>
</tr>
<tr>
<td><code>C_{20} H_{34} O_4</code></td>
<td>1,4-Bis{2-[(2-methyl-2-propanyl)peroxy]-2-propanyl}benzene</td>
</tr>
<tr>
<td><code>C_{22} H_{30} O_4</code></td>
<td>Bis(4-methylcyclohexyl) phthalate (4-Methalate)</td>
</tr>
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</tr>
<tr>
<td><code>C_{20} H_{30} O_2</code></td>
<td>Abietic acid</td>
</tr>
<tr>
<td><strong>ESI-</strong>&lt;br&gt;&lt;br&gt;<code>C_7 H_{8} O_3 S</code></td>
<td>Toluene sulfonic acid</td>
</tr>
<tr>
<td><code>C_{13} H_{22} O_4</code></td>
<td>Dibutyl itaconate</td>
</tr>
<tr>
<td><code>C_7 H_{7} NO_3</code></td>
<td>5-Aminosalicylic acid</td>
</tr>
<tr>
<td><code>C_{13} H_{16} O_4</code></td>
<td>Monopentyl phthalate</td>
</tr>
<tr>
<td><code>C_{20} H_{22} O_3</code></td>
<td>Avobenzone</td>
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<tr>
<td><code>C_{12} H_{16} O_3</code></td>
<td>2,2-Diethoxyacetophenone</td>
</tr>
<tr>
<td><code>C_{15} H_{16} O_2</code></td>
<td>Bisphenol A (BPA)*</td>
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