Apr 5th, 4:00 PM - 4:15 PM

Effects of environmentally realistic concentrations of neonicotinoid insecticides on an aquatic invertebrate community

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Effects of environmentally realistic concentrations of neonicotinoid insecticides on an aquatic invertebrate community

Claire Duchet, Alyssa Kraft, Cailin MacKenzie, John D. Stark
Introduction

- Neonicotinoid insecticides represent 24% of the global market, and their use is increasing globally.

- Clothianidin, imidacloprid, thiamethoxam are the most commonly-used neonicotinoids on corn and soybeans.

- Imidacloprid is also used privately: lawn and garden care, and topical flea medicines.
Introduction

- Used against insect pests but toxic to non-target organisms (e.g. crustaceans, bees, flies, birds)

Acetylcholinesterase (AChE) breaks down acetylcholine (Ach), preventing overstimulation and blockage of acetylcholine receptors.

Mode of action of neonicotinoids.

Introduction

- Not intended for direct use in water bodies, but they may enter in the aquatic compartment via spray drift, runoff or leaching.

- Soluble in water, persistent in soil, and may be found in surface waters and drinking water (Klarish et al., 2017).
Introduction

- In Canada, wetlands close to agricultural fields (Anderson et al., 2015):
  - 3.11 µg/L clothianidin,
  - 0.256 µg/L imidacloprid,
  - 1.49 µg/L thiamethoxam.

- In Western Washington, imidacloprid almost always detected in surface water (WSDA source):
  - usually <0.1 µg/L, but >1 µg/L in some cases,
  - 1.74 µg/L in the Big Ditch slough, a creek providing habitat for salmons in the Skagit wildlife area.
Objective

- Very few data about the effects of mixture of neonicotinoids available.

- Neonicotinoid contamination induce a top-down trophic cascade in a community dominated by invertebrate predators (Miles et al., 2017).

- **Our objective:** to test the effect of a mixture of imidacloprid, clothianidin and thiamethoxam on an aquatic invertebrate community.

- **Hypothesis:** By affecting predators, indirect positive effect on herbivores.
Preliminary experiment

Test in control conditions on *Ceriodaphnia dubia* (semi-static test): imidacloprid (0.256 µg/L), clothianidin (3.11 µg/L), thiamethoxam (1.49 µg/L), and the mixture.

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**Survival following 8-d exposure**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of surviving adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>9</td>
</tr>
<tr>
<td>Clothianidin</td>
<td>8</td>
</tr>
<tr>
<td>Thiamethoxam</td>
<td>7</td>
</tr>
<tr>
<td>Mixture</td>
<td>6</td>
</tr>
</tbody>
</table>

**Reproduction following 8-d exposure**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of neonates / female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>20</td>
</tr>
<tr>
<td>Imidacloprid</td>
<td>18</td>
</tr>
<tr>
<td>Clothianidin</td>
<td>16</td>
</tr>
<tr>
<td>Thiamethoxam</td>
<td>14</td>
</tr>
<tr>
<td>Mixture</td>
<td>12</td>
</tr>
</tbody>
</table>

*: Significant differences between the treatment and control (Tukey’s HSD test, p < 0.05).
Materials and methods
Materials and methods

- 60 L well water
- 50 mL pond water
- 66 cm tub
- 76 L tub
- 20 g dry oak leaves
- 2 g rabbit food
- 38 cm height
- 66 cm width
Materials and methods

**Setting up**
Well water + pond water + leaf litter

**Macroinvertebrates**
(predators)

**Treatment**
- imidaclorpid (0.256 µg/L)
- clothianidin (3.11 µg/L)
- thiamethoxam (1.49 µg/L)
- mixture

**Sampling dates** (from 9/13/17 to 10/11/2017)
- 0-d
- 2-d
- 7-d
- 14-d
- 28-d
- (...)
Materials and methods

On each sampling date:

- Environmental parameters (pH, conductivity, dissolved oxygen, temperature)
- Invertebrate sampling
- Water samples for chemical analysis
- Water samples for chlorophyll \( a \) concentrations
- Dipteren colonization (mosquito oviposition habitat selection): every 2 days
Results

Concentrations of the neonicotinoids over time
Results

Community:

Active dispersers (10 taxa):
- mosquitoes (Culex pipiens, Culiseta longiareolata),
- non-biting midges (Chironomids),
- biting-midges (Ceratopogonidae),
- ephidridae larvae,
- mayflies (Ephemeroptera),
- odonates,
- water beetle (Hydrophilidae),
- water boatmen (Anisops sardea),
- hydracarians.
Results

Community:

Passive dispersers (11 taxa):

- Copepods (cyclopoids).

Cladocerans:

- *Scapholeberis, Chydorus, Pleuroxus, Ceriodaphnia, Daphnia, Simocephalus, Alona, Macrothricidae, Diaphanosoma*.

Ostracods.
Results

- **Species evenness**

![Graph showing species evenness over sampling dates]

RM ANOVA: $F_{4, 20} = 0.38, p = 0.82$
Results

- **Effect on taxa richness**

<table>
<thead>
<tr>
<th>Sampling dates</th>
<th>Control</th>
<th>Imidacloprid</th>
<th>Clothianidin</th>
<th>Thiamethoxam</th>
<th>Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Day 2</td>
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<td>Day 7</td>
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<tr>
<td>Day 21</td>
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<td></td>
</tr>
</tbody>
</table>

*: Significant differences between the treatment and control (Fisher’s LSD test following RM ANOVA, p < 0.05).
Results

Herbivore biomass

*: Significant differences between the treatment and control (Fisher’s LSD test following RM ANOVA, p < 0.05).
Conclusions - Perspectives

- Effects on the community:
  - Decrease of the active dispersers 3 weeks after exposure to the mixture
  - Increase of the passive dispersers 1 week after exposure to imidacloprid and 3 weeks after exposure to thiamethoxam
  - Increase of the zooplankton biomass 3 weeks after exposure due to lack of predators?

- Still have to analyze the chlorophyll a data

- Next study: run the experiment in early stage population development (late spring / early summer)
Acknowledgments and Funding

- Funding: Stormwater strategic initiative program

Thank you!
Questions?

References

Anderson, J., Dubetz, C. and Palace, V. 2015 Neonicotinoids in the Canadian aquatic environment: a literature review on current use products with a focus on fate, exposure, and biological effects. Science of the Total Environment, 505: 409-422.

