Pesticide Risk Assessment and Management for Pollinators

Jeffrey Jenkins
Department of Environmental and Molecular Toxicology
Oregon State University
EPA Pesticide Risk Assessment and Management Under FIFRA/FQPA

- Quasi risk-benefit balancing statutes
- Determine risks to human health and the environment:
  - *Toxicity* to humans and wildlife
  - Opportunities for *exposure*
- Registration/Re-registration decision
- Mitigate risks with label restrictions/mandates
- Generally not site-specific
EPA Pesticide Risk Assessment

Risk = f (exposure, toxicity)

Source: Purdue University Pesticides Program
Risk: Conceptual Framework

Opportunities for Pesticide Exposure

Human-Wildlife Risk

Human/wildlife Susceptibility and Behavior
Hazard vs Risk: Margin of Exposure

Target Margin of Exposure: toxicity/exposure $\geq 100$
(dose that causes harm 100 times greater than exposure)
Risk Assessment and Management

Source: EPA Office of Research and Development.
FIFRA/FQPA Federal – State Partnerships designed to Achieve Safe and Beneficial Pesticide Use

- Risk assessment
- Risk management
- Risk mitigation
- Individual action

Potential Pesticide Risks

Risk reduction through integrated protection programs:
- Risk characterization through sound science
- Cost effective requirements to insure safe use
- Clear understanding of label restrictions and use mandates
- Informed decision-making at the frontline of pesticide use

Safe & Beneficial Use
Pesticide Benefit-Risk Assessment

Environmental fate:

Persistence (how long does it last)
Re-distribution in the environment (where does it go)

Maximum efficacy/minimum environmental impact:

→ apply to target only
→ effective pest control
→ minimal impact on beneficials/non-target sp.
→ no movement from site
→ degrades to non-toxic products
Chemical fate processes

- wind erosion
- interception
- volatilization
- drift
- runoff
- photodegradation
- wash off
- Plant uptake
- sorption to soil particles
- microbial or chemical degradation
- leach toward groundwater
Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modelling structure and tools.

Chemical Fate → Bioavailability → Exposure

Adapted from R. P. Schwarzenbach et al., Science 313, 1072-1077 (2006)
Pesticide Fate

• Field dissipation: sum of chemical and biological processes including:
  – Chemical degradation
  – Microbial degradation
  – Plant uptake – metabolism
  – Photodegradation
  – Volatilization
Pesticide Dissipation in the Environment

Assumption: competing dissipation processes roughly conform to 1\textsuperscript{st} order degradation kinetics

How fast and which pathway predominates depends on chemical properties and environmental conditions

Pesticide Fate Processes

- Volatile loss
- Photo-degradation
- Plant uptake – Metabolism
- Chemical degradation
- Microbial degradation
- Leaching/runoff

Amount

Time

wind erosion

wash off

volatilization

drift

runoff

sorption to soil particles

microbial or chemical degradation

Plant uptake

leach toward groundwater
Transfer of agrochemicals to the target

R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72
Spray deposit of thiacloprid on a barley leaf (electron micrograph).

R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72
Agrochemical Spray deposit on the leaf surface

R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72
Pesticide partitioning between leaf surface deposit, moisture, and air.
Systemic pesticides are soluble enough in water that they can be absorbed by a plant and moved around in its tissues.

Systemic pesticides can be applied to the soil beneath a plant and transported in the xylem to reach pests that are otherwise hard to kill.

When systemic pesticides are applied to the soil, beneficial insects, birds, pets, and people are much less likely to encounter the pesticide in the form of residues or spray drift.
Systemic Pesticides

Guttation - loss of liquid water from uninjured leaf margins due to root pressure, may contain dissolved substances, only occurs in some plants (grasses, tomato).
“Ascend does more than just kill fire ants—it can actually cause an immediate halt to viable egg production, preventing the colony’s growth.”

(both lethal and sublethal effects on fitness and survival)
Ascend® Fire Ant Bait

**BROADCAST APPLICATION:** Apply Ascend as evenly as possible to turf, lawns and non-crop areas at a rate of 1 lb. of bait per acre (0.4 oz. of bait per 1000 sq. ft. or 1.8 oz. of bait per 5000 sq. ft.).

1 lb bait/acre = 454 grams bait/acre
0.011% a.i. = 0.00011 x 454 = 0.050 grams (50 mg) a.i./acre

Active Ingredient (a.i.) – Avermectin B1a, a macrocyclic lactone isolated from *Streptomyces avermitilis* with broad spectrum anthelmintic and insecticidal activity, affects neuromuscular transmission resulting in paralysis due to reduction in excitatory postsynaptic potentials associated with binding to glutamate-gated chloride channels.

Avermectin mode of action – paralyses fire ant queen ovipositor, “halts egg production”.
The queen’s job is to lay eggs. She controls the colony using pheromones.

The oldest worker ants are foragers who collect food for the colony.

50 mg/acre avermectin is efficacious because of it’s:

- mode of action
- potency
- persistence
- forager ant behavior.
Risk: Conceptual Framework

Pesticide Use Practices

Human-Wildlife Risk

Human/wildlife Susceptibility and Behavior
Integrate Available Information

Source and Exposure Characteristics

Ecosystem Potentially at Risk

Ecological Effects

PROBLEM FORMULATION

Assessment Endpoints

Analysis Plan

Conceptual Model

Characterization of Exposure

Measures of Exposure

Characterization of Ecological Effects

Measures of Ecosystem And Receptor Characteristics

Measures of Effect

ANALYSIS

Exposure Analysis

Ecological Response Analysis

Exposure Profile

Stressor-Response Profile

RISK CHARACTERIZATION

Risk Estimation

Risk Description

Communicating Results to the Risk Manager

Risk Management

Planning (Risk Assessor/Risk Manager Dialogue)

1. Management Goals
2. Management Options
3. Scope, Complexity, and Focus
4. Resources
5. Scheduling

FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT

As Necessary

Acquire Data,

Iterate Process,

Monitor Results
Risk quotient (RQ) method

• Estimated environmental concentrations (EECs) based on maximum application rates are divided by acute and chronic toxicity values.

\[ RQ = \frac{EEC}{LC_{50}} \text{ or } \frac{EEC}{EC_{50}} \]

EEC – Expected Environmental Concentration
LC\textsubscript{50} – Median lethal concentration
EC\textsubscript{50} – Median effective concentration for sublethal effects

• Level of concern: RQ ranges from 0.05 (ESA) to 1
GUIDANCE OF EFSA

Guidance on the risk assessment of plant protection products on bees (Apis mellifera, Bombus spp. and solitary bees)¹

European Food Safety Authority²

European Food Safety Authority (EFSA), Parma, Italy

This scientific output, published on 5 August 2013, replaces the earlier version published on 4 July 2013*.

ABSTRACT

The Guidance is intended to provide guidance for notifiers and authorities in the context of the review of plant protection products (PPPs) and their active substances under Regulation (EC) 1107/2009. The scientific opinion on the science behind the development of a risk assessment of plant protection products on bees (Apis mellifera, Bombus spp. and solitary bees) provided the scientific basis for the development of the Guidance. Specific Protection Goals were agreed in consultation with the Standing Committee on the Food Chain and Animal Health. The Guidance suggests a tiered risk assessment scheme with a sample and cost-effective first tier to more complex higher tier studies under field conditions. Each of the tiers will have to ensure that the appropriate level of protection is achieved.

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KEY WORDS

honey bee, risk assessment, pesticides, Apis mellifera, Bombus, solitary bees

1 On request from European Commission, Question No EFSA-Q-2011-00418, approved on 27 June 2013.
2 Correspondence: pesticides.par@efsa.europa.eu
3 Acknowledgement: EFSA wishes to thank the members of the working group: Edward Arnold, Jan Hesemann, Mark Cook, Robert Littke, Pål H. Gjøsæter, Jacoba Wassenaar and the hosting expert Joe Everitt for the preparatory work on this scientific output and EFSA staff Franzi Starzel, Maria Arenas, Caoilinn Smurte, Agnes Rahm and Olaf Moolenaar-Paris for the support provided to this scientific output.
4 Editorial revisions were made to the main title, the header as on the page 2 onwards, the abstract, the keywords and the acknowledgement.
6 Available online: www.efsa.europa.eu/efsajournal

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FIGURE 3: Conceptual model for bee risk assessment. Adapted from Fischer and Moriarty [41] and US Environmental Protection Agency [42].
Neonicotinoids Mode of action

• Derivatives of nicotine (first insecticide use - France 1690)
• Mode of action - disrupt the nervous system by binding to postsynaptic nicotinic acetylcholine receptors.
• Toxic effects: modified feeding behavior, paralysis, and subsequent death.
• At low doses – neurobehavioral effects?

nicotine

Imidacloroprid
Neonicotinoids application methods

• Application methods
  – Seed treatments (dust, systemic in plant)
  – Soil application (soil insects, systemic in plant)
  – Foliar application (surface residues, systemic in plant)
Neonicotinoids environmental fate

- High water solubility
- Low volatility
- Long half-life
- Systemic in plants
# Imidacloprid Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Molecular weight</td>
<td>255.7</td>
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<tr>
<td>Water solubility</td>
<td>514 mg/L (20°C at pH 7)</td>
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<tr>
<td>Vapor pressure</td>
<td>1.00 x 10^-7 mmHg (20°C)</td>
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<tr>
<td>Hydrolysis half-life</td>
<td>&gt;30 days (25°C at pH 7)</td>
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<tr>
<td>Aqueous photolysis half-life</td>
<td>&lt;1 hour (24°C at pH 7)</td>
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<tr>
<td>Anaerobic half-life</td>
<td>27.1 days</td>
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<tr>
<td>Aerobic half-life</td>
<td>997 days</td>
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<tr>
<td>Soil photolysis half-life</td>
<td>38.9 days</td>
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<tr>
<td>Field dissipation half-life</td>
<td>26.5 – 229 days</td>
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<tr>
<td>Henry's constant</td>
<td>6.5 x 10^-11 atm m^3/mole (20°C)</td>
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<tr>
<td>Octanol-water coefficient (K_{ow})</td>
<td>3.7</td>
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<tr>
<td>Soil adsorption coefficient:</td>
<td></td>
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<tr>
<td>K_d</td>
<td>0.956–4.18</td>
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<tr>
<td>K_{oc}</td>
<td>132–310</td>
</tr>
</tbody>
</table>

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1 Environmental Fate of Imidacloprid, California Department of Pesticide Regulation 2006
Neonicotinoids and Pollinators

- Exposure pathways
  - Seed treatment: dust
  - Systemic: pollen, nectar, guttation water
  - Foliar: foliar residues, pollen, nectar, guttation water
  - Foraging behavior amplifies individual exposure and hive exposure.
Neonicotinoids and Pollinators

• While acute lethal effects are of concern

• Major concern is for sub-lethal and chronic effects on fitness and survival.

• These outcomes that may not be adequately addressed by current risk assessment methods.
Neonicotinoids and Pollinators

- Sublethal effects of concern include:
  - disorientation and difficulties in returning back to the hive (homing ability)
  - reduced foraging and travel
  - impaired memory and learning
  - failure to communicate properly with nestmates
Neonicotinoids and Pollinators

- The feeding, communication, reproduction, hygiene and immune response systems of social insects are highly complex.

- Study results can be confused by a wide variety of biological and geographic factors affecting the treated colonies and the untreated control colonies.
Neonicotinoids and Pollinators – Lab and Field Studies

• Discrepancy between clear lab results and inconclusive or negative field results.

• Few lab studies conducted at environmentally relevant levels and patterns of exposure.

• Field study levels and patterns of exposure are not well understood and/or confounded with other stressors (i.e., disease and parasites).
Field study methodological obstacles

- What floral resources are available?
- What levels of pesticide residues are in the pollen and nectar collected?
- Do the hives all display similar levels of disease and parasites which can affect hive health?
- Is there considerable mortality or abnormal behavior observed in the control hives?
Ag Production in Zollner Creek Watershed

Total Units: 893
CSIRO bee-tagging project

Systemic Spread and Propagation of a Plant-Pathogenic Virus in European Honeybees, Apis mellifera

JI Lian Li, R. Scott Comman, Jay D. Evans, Jeffery S. Pettis, Yan Zhao, Charles Murphy, Wen Jun Peng, Jie Wu, Michele Hamilton, Humberto F. Boncristiani Jr., Liang Zhou, John Hammond, Yan Ping Chen

Key Laboratory of Pollinating Insect Biology of the Ministry of Agriculture, Institute of Apicultural Research, Chinese Academy of Agricultural Science, Beijing, China; Department of Agriculture, ARS, Bee Research Laboratory, Beltsville, Maryland, USA; Department of Agriculture, ARS Molecular Plant Pathology Laboratory, Beltsville, Maryland, USA; Department of Agriculture, ARS, Soybean Genomic & Improvement Laboratory, Beltsville, Maryland, USA; Department of Biology, University North Carolina at Greensboro, Greensboro, North Carolina, USA; Department of Pediatrics, Emory University School of Medicine, Atlanta, Georgia, USA; Department of Agriculture, ARS, Floral and Nursery Plants Research Unit, Beltsville, Maryland, USA

IMPORANCE Pathogen host shifts represent a major source of new infectious diseases. Here we provide evidence that a pollen-borne plant virus, tobacco ringspot virus (TRSV), also replicates in honeybees and that the virus systemically invades and replicates in different body parts. In addition, the virus was detected inside the body of parasitic Varroa mites, which consume bee hemolymph, suggesting that Varroa mites may play a role in facilitating the spread of the virus in bee colonies. This study represents the first evidence that honeybees exposed to virus-contaminated pollen could also be infected and raises awareness of potential risks of new viral disease emergence due to host shift events. About 5% of known plant viruses are pollen transmitted, and these are potential sources of future host-jumping viruses. The findings from this study showcase the need for increased surveillance for potential host-jumping events as an integrated part of insect pollinator management programs.

A. Weak Colonies

B. Strong Colonies

![Graphs showing infection rates in weak and strong honeybee colonies over time.](image-url)
Zombie Bees\(^1\)

- Parasitic fly - *Apocephalus Borealis*
- Inserts eggs in honeybees, bumblebees
- Bees fly around in a disoriented way, get attracted to light, and then fall down and wander around like zombies.
- When parasite eggs hatch bees die.

\(^1\) [www.zombeewatch.org](http://www.zombeewatch.org)
Conclusions

• Uncertainty in ecological risk assessment is uniquely large relative to other science-based policy areas.

• EPA/USDA identified pollinator risks include pesticides, parasites, and poor forage

• Current understanding of the risks to pollinators associated with pesticide use is inadequate.

• Resources should be allocated to a better understanding of:
  – Pesticide patterns of use.
  – Pesticide distribution and fate at a scale relevant to pollinator exposure (bioavailability of systemic pesticides).
  – Pollinator occurrence and behavior that determines exposure.
  – Pesticide adverse effects on pollinator fitness and survival.
International experts swarm to London for bee health 'summit'

• January 22nd, 2014

• Leading researchers from around the world are meeting in London this week for a three-day "summit" on the impact of pesticides on bee health. The meeting – which includes experts from academia, industry and government, as well as beekeepers and conservation organizations – will discuss the latest research on bee health, identify gaps in the science and attempt to build consensus.

• The meeting (22-24 January 2014), organized by the Biochemical Society, British Ecological Society and the Society for Experimental Biology, will conclude with an open scientific discussion bringing stakeholders and journalists together with researchers to debate the issues in public, a 'first' for a meeting of this kind.
AVAAZ.org: 3 million to Save the Bees

Target Wilsonville
June 30, 2013
Re-evaluation of Neonicotinoid Insecticides

12 June 2012

Pesticide Action Network UK
Sub-lethal and chronic effects of neonicotinoids on bees and other pollinators

This factsheet summarises current knowledge about sub-lethal (i.e. non-lethal) effects of these insecticides and possible impacts of exposure to very low doses over time. It discusses the difficulties in extrapolating results which demonstrate harm in laboratory and semi-field studies to the reality in the field - one of the main controversies in the neonicotinoid debate - and implications of the latest research findings.

Slight but important effects from doses that do not kill bees directly

Sub-lethal effects in bees and other pollinators are likely to be under-estimated as the field (neonicotinoid and neonicotinoid resistance) Honeycomb (honeycomb) levels in managed hives have been documented in recent years, and cases of honeycomb have been reported in certain pollinators in semi-field trials. Sub-lethal effects reported in the semi-field environment include changes in pollinator behaviour in honeybees.

www.pen-uk.org

Environmental Toxicology and Chemistry

How to Reduce Bee Poisoning from Pesticides

A Review of Research into the Effects of Neonicotinoid Insecticides on Bees, with Recommendations for Action

ARE NEONICOTINOID KILLING BEES?

Friends of the Earth