Pesticide Risk Assessment and Management for Pollinators

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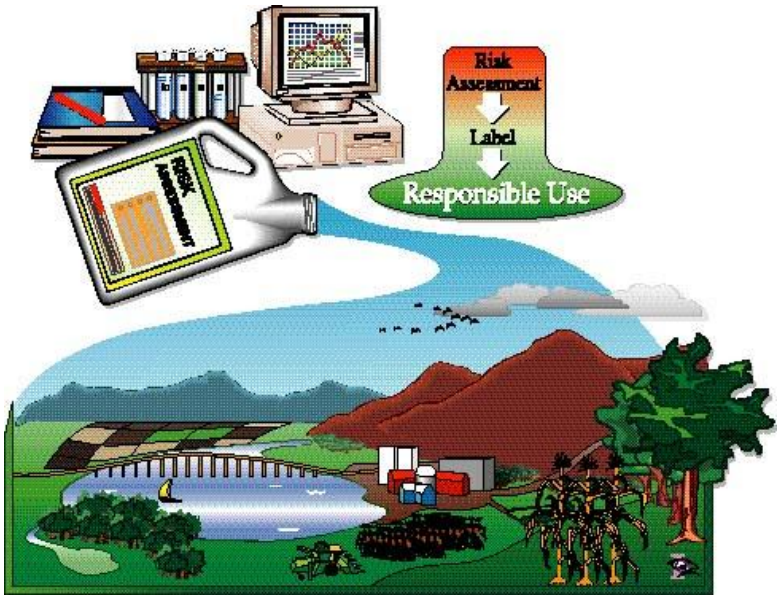
EPA Pesticide Risk Assessment and Management Under FIFRA/FQPA

- 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

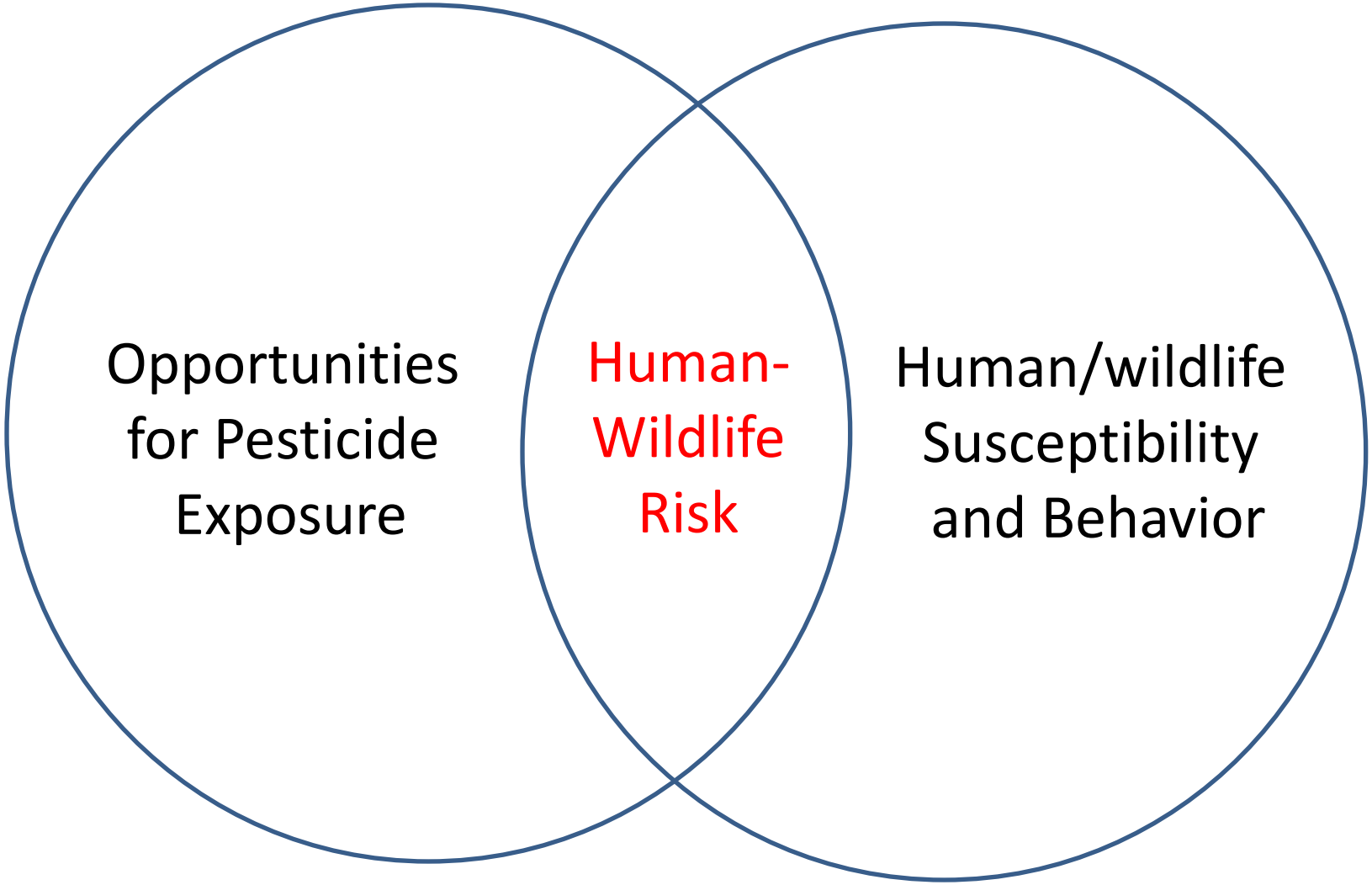
EPA Pesticide Risk Assessment

Source: Purdue University Pesticides Program

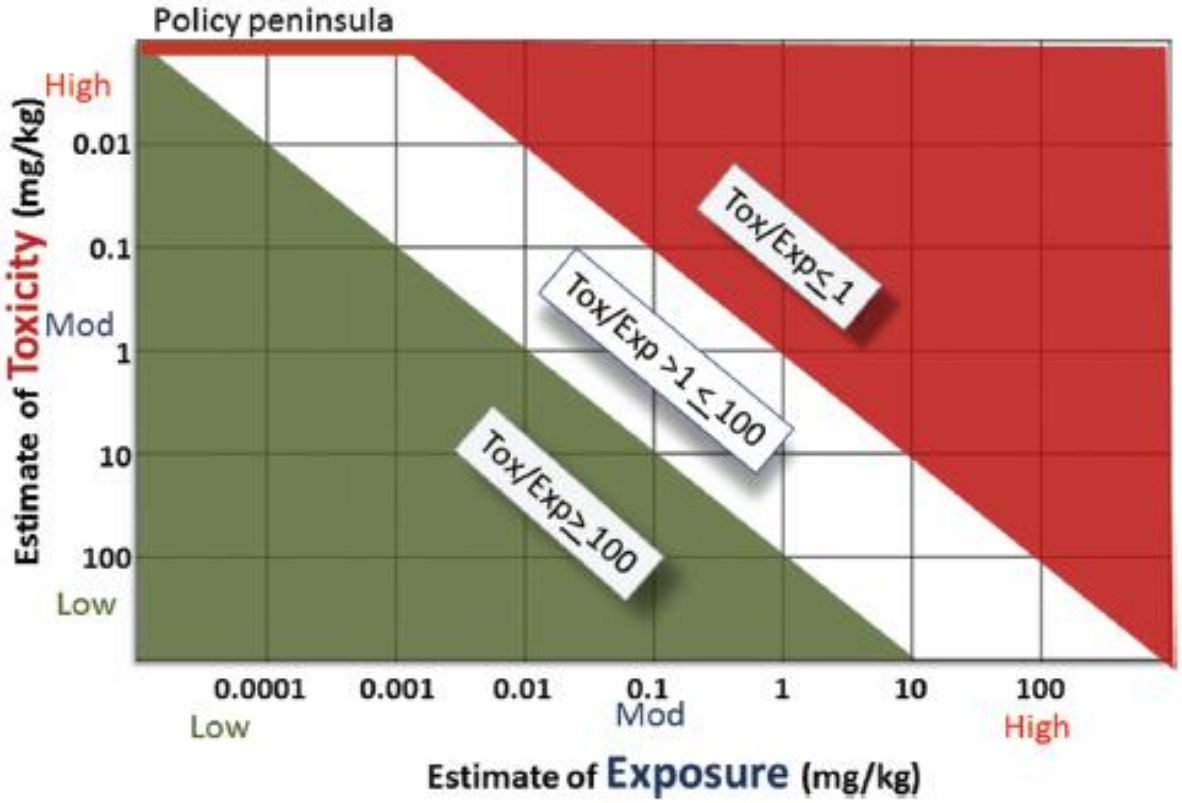


Risk = f (exposure, toxicity)

Risk: Conceptual Framework



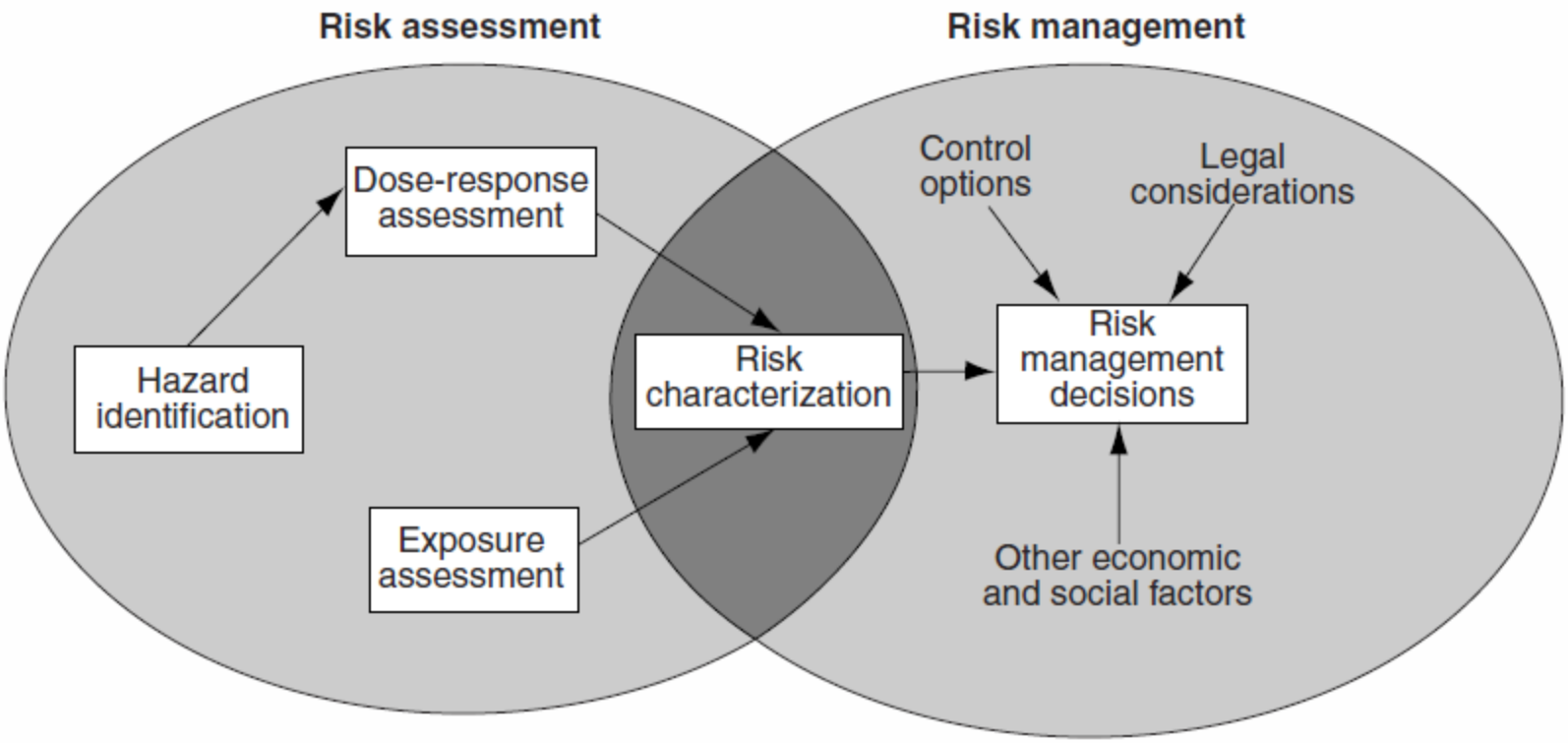
Hazard vs Risk: Margin of Exposure



Target Margin of Exposure: toxicity/exposure ≥ 100

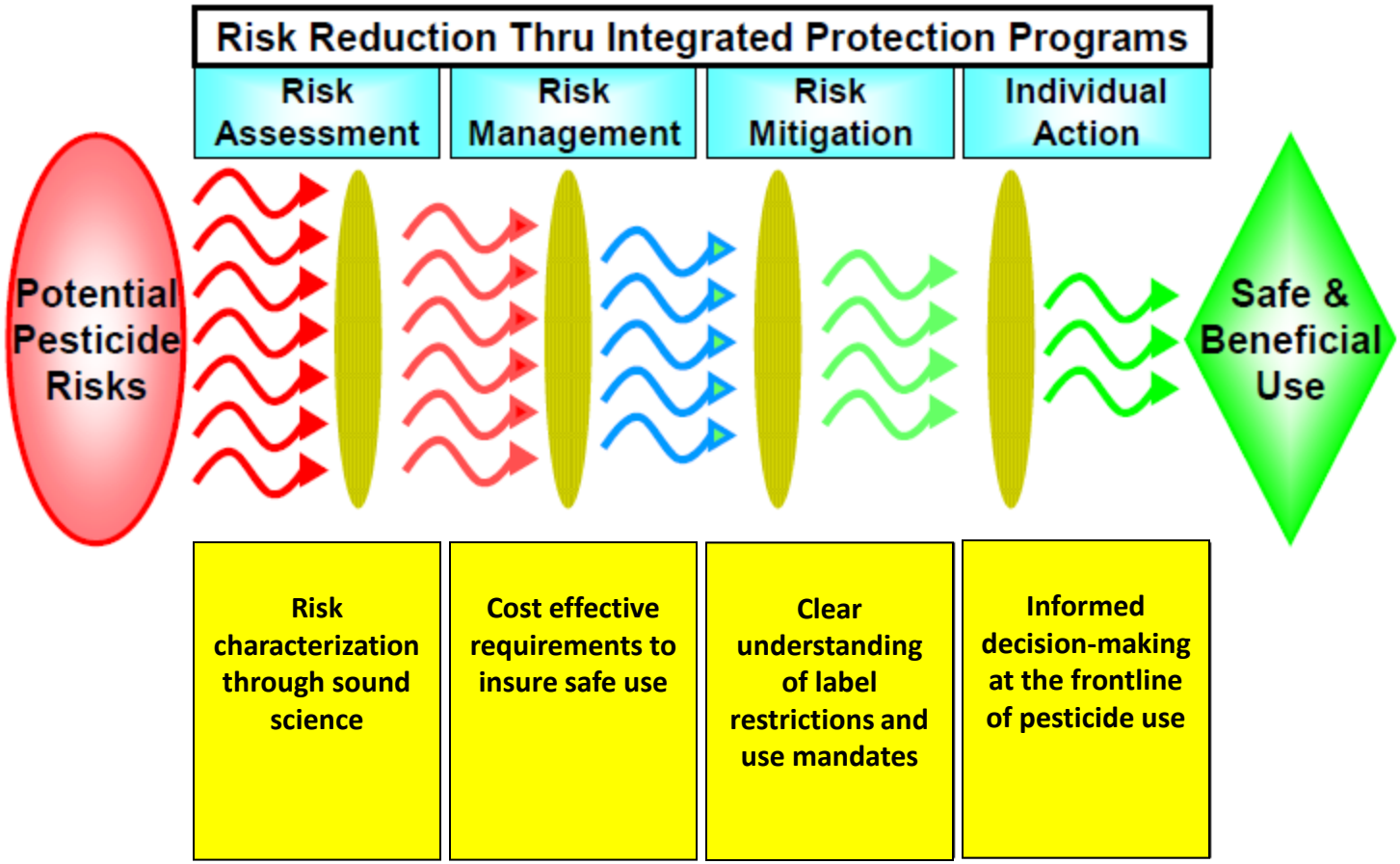
(dose that causes harm 100 times greater than exposure)

Risk Assessment and Management



Source: EPA Office of Research and Development.

FIFRA/FQPA Federal – State Partnerships designed to Achieve Safe and Beneficial Pesticide Use



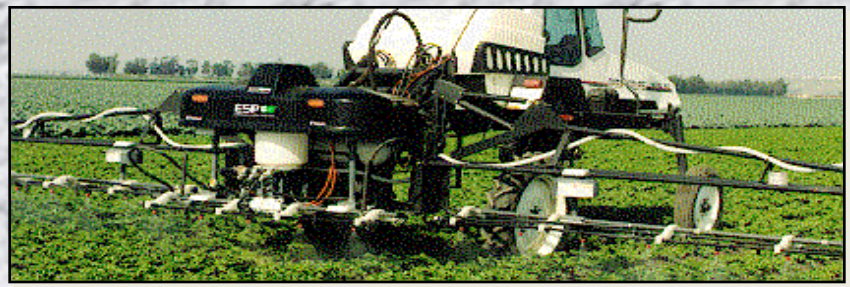
Pesticide Benefit-Risk Assessment

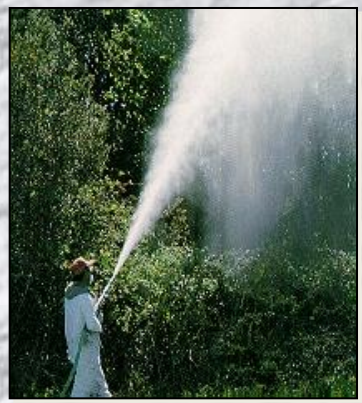
Environmental fate:

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

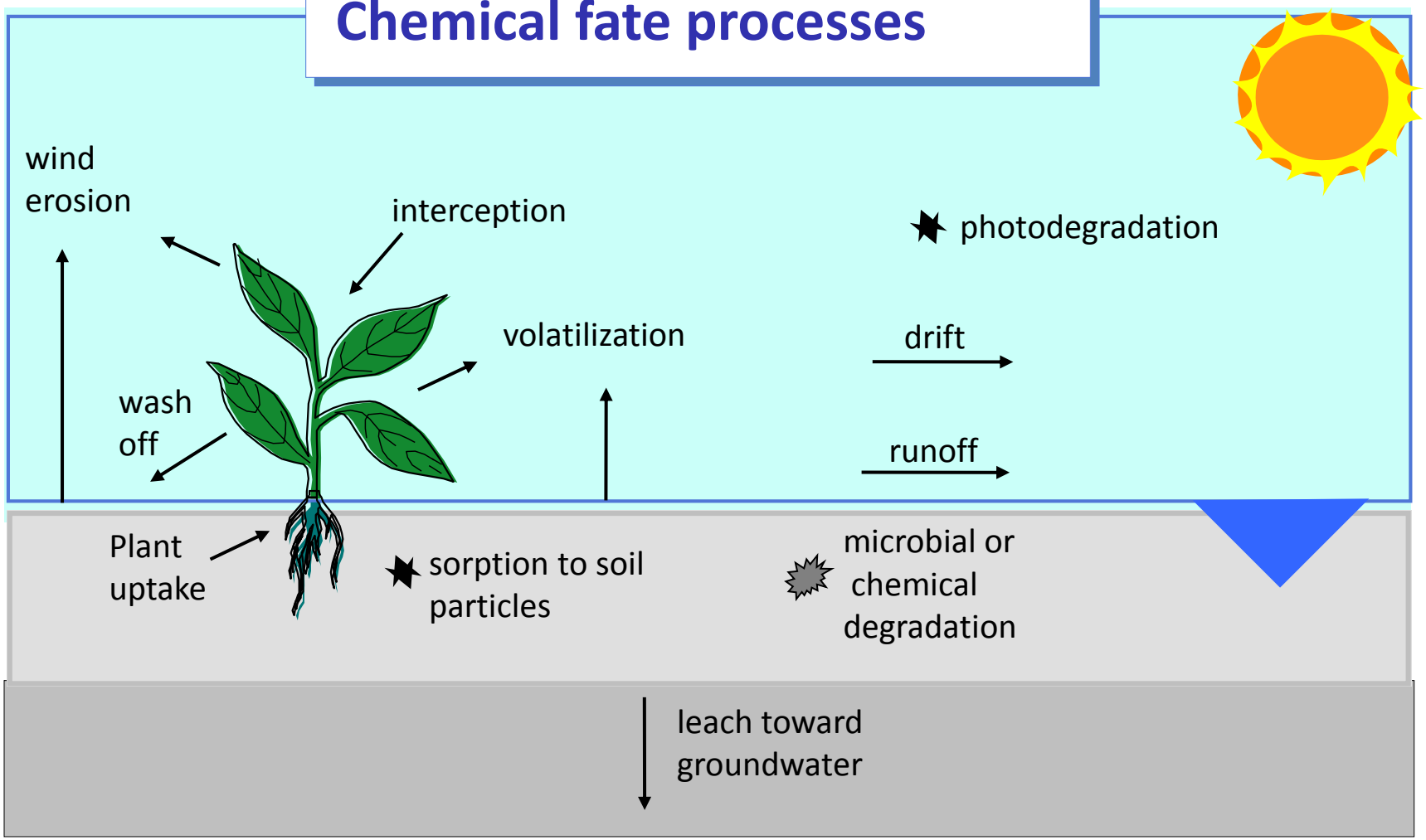
Maximum efficacy/minimum environmental impact:

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

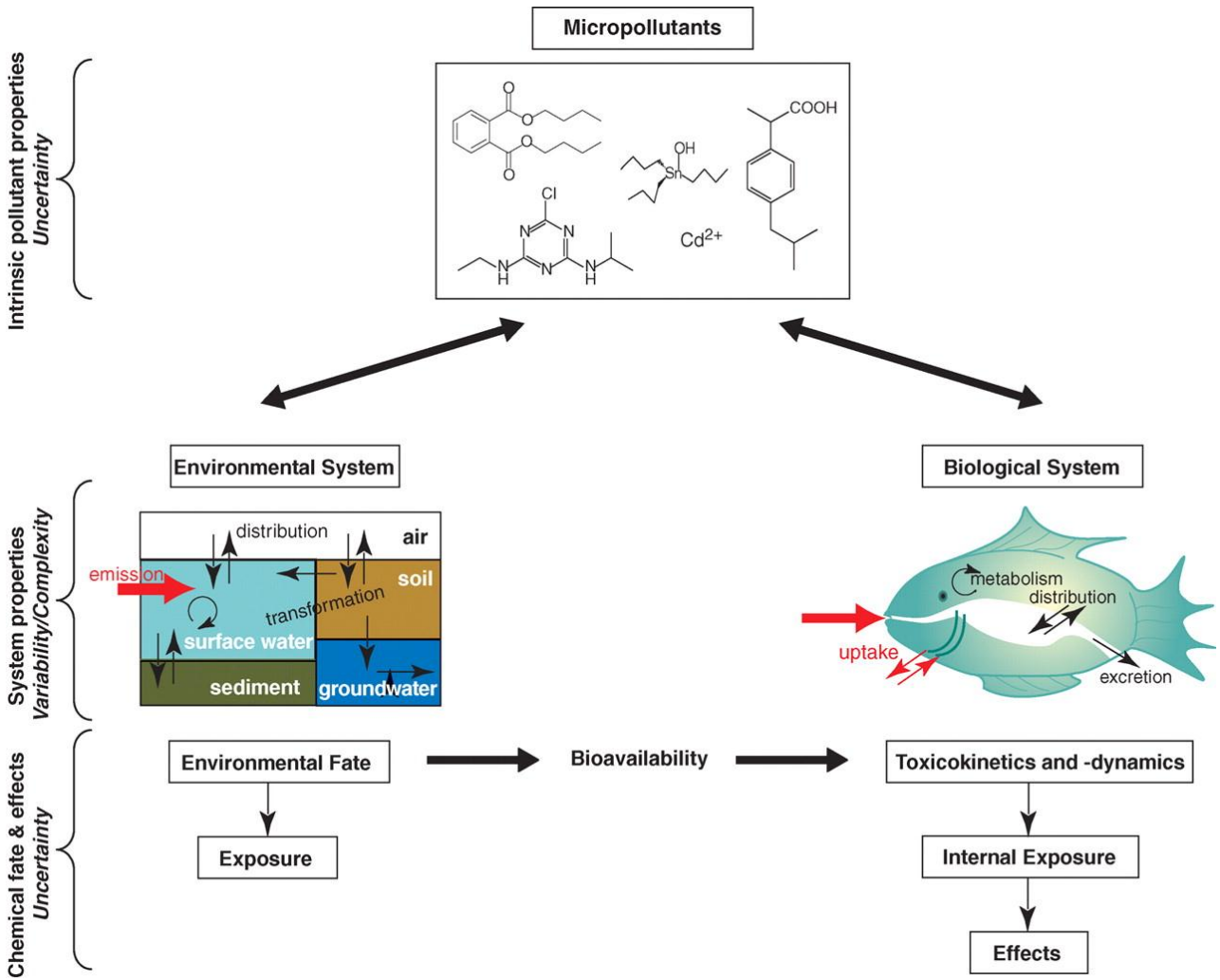




Chemical fate processes



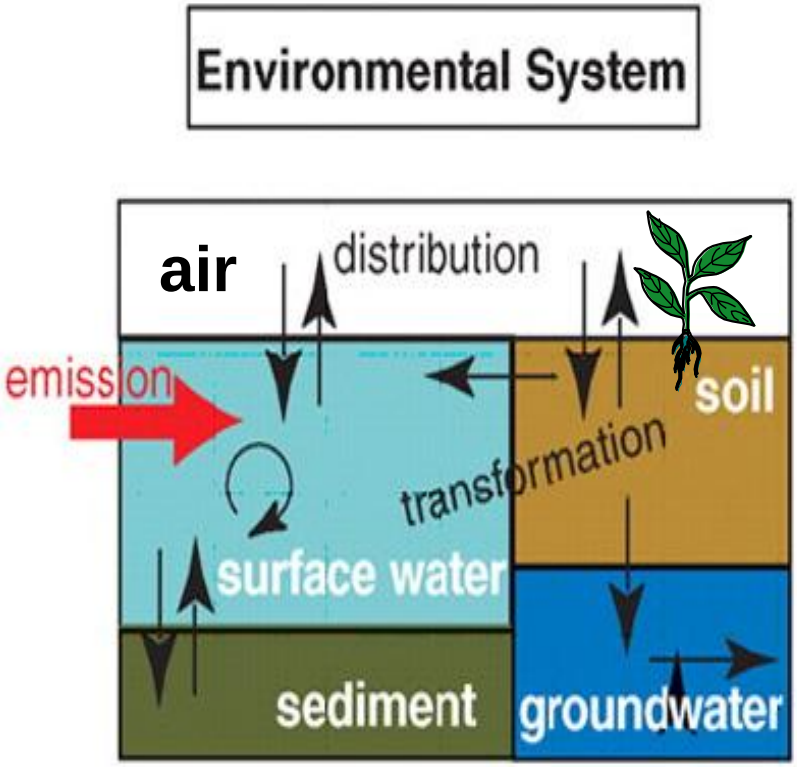
Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modelling structure and tools

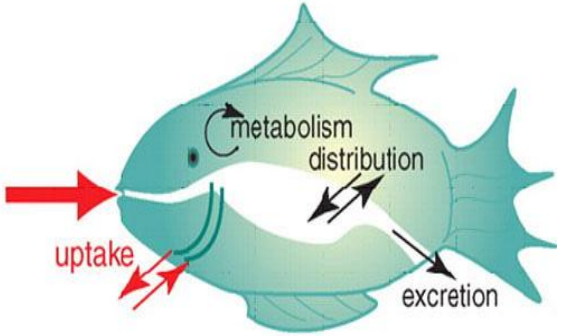


R. P. Schwarzenbach et al., Science 313, 1072 -1077 (2006)

Published by AAAS

Chemical Fate ⟶ Bioavailability ⟶ Exposure



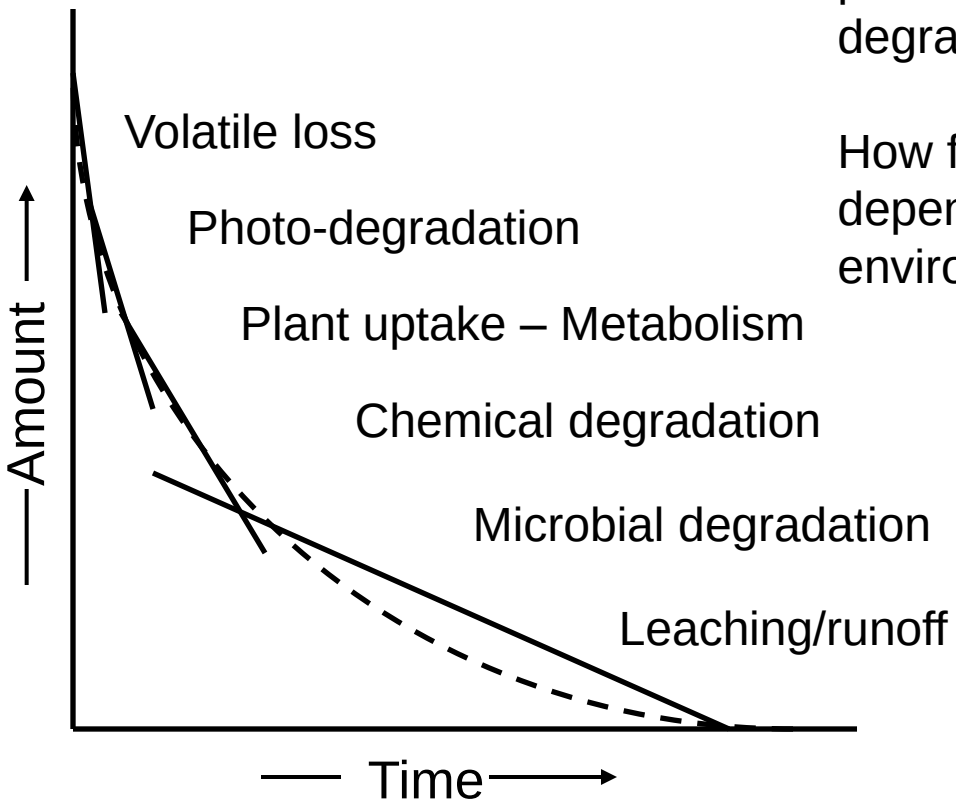


Adapted from R. P. Schwarzenbach et al., Science 313, 1072 -1077 (2006)

Pesticide Fate

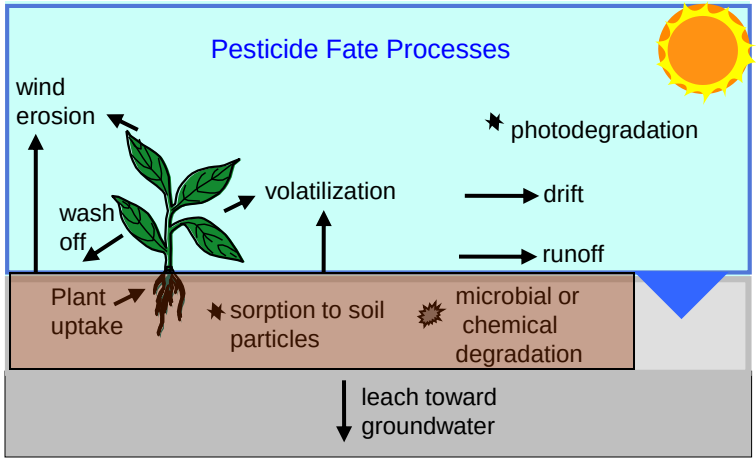
- Field dissipation: sum of chemical and biological processes including:
  - Chemical degradation
  - Microbial degradation
  - Plant uptake – metabolism
  - Photodegradation
  - Volatilization

Pesticide Dissipation in the Environment

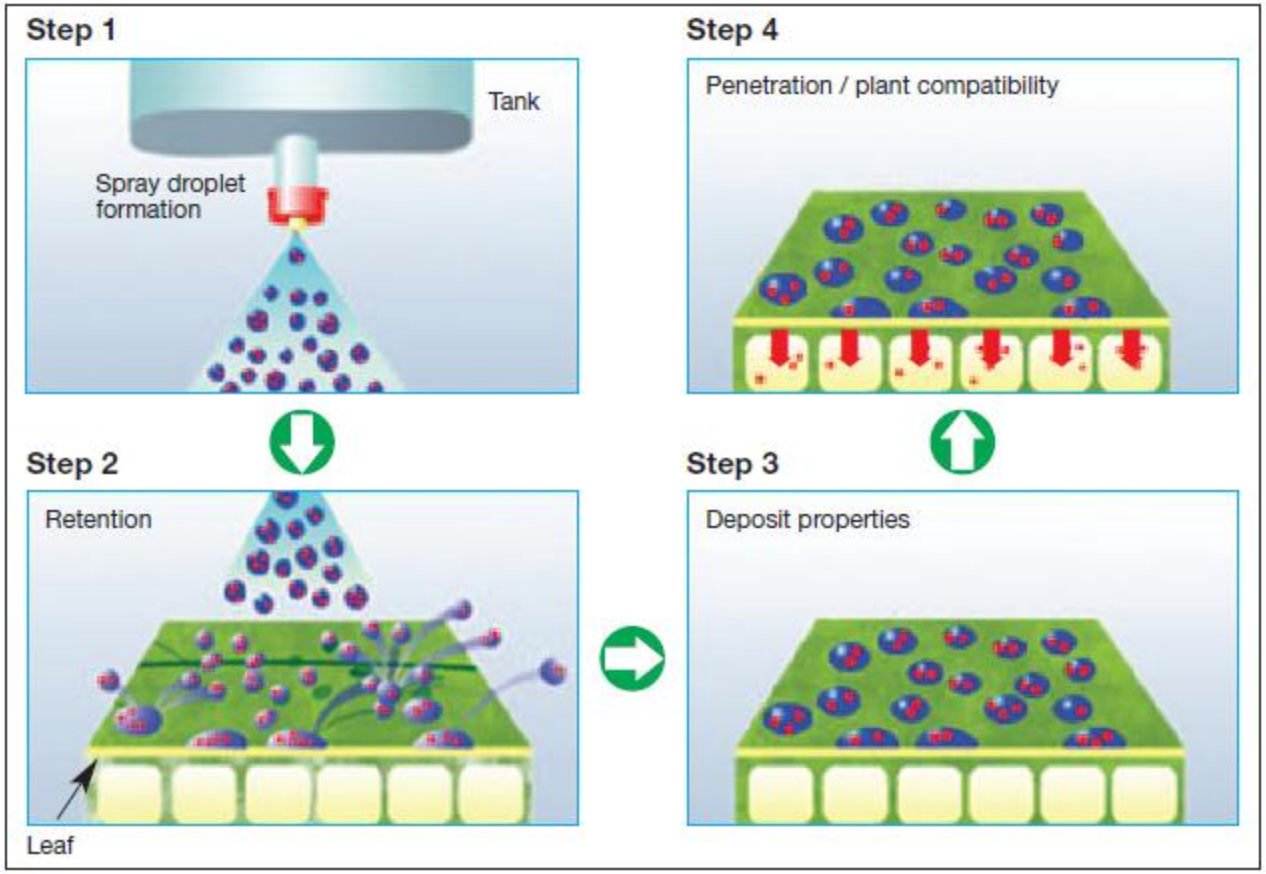


Assumption: competing dissipation processes roughly conform to 1st order degradation kinetics

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

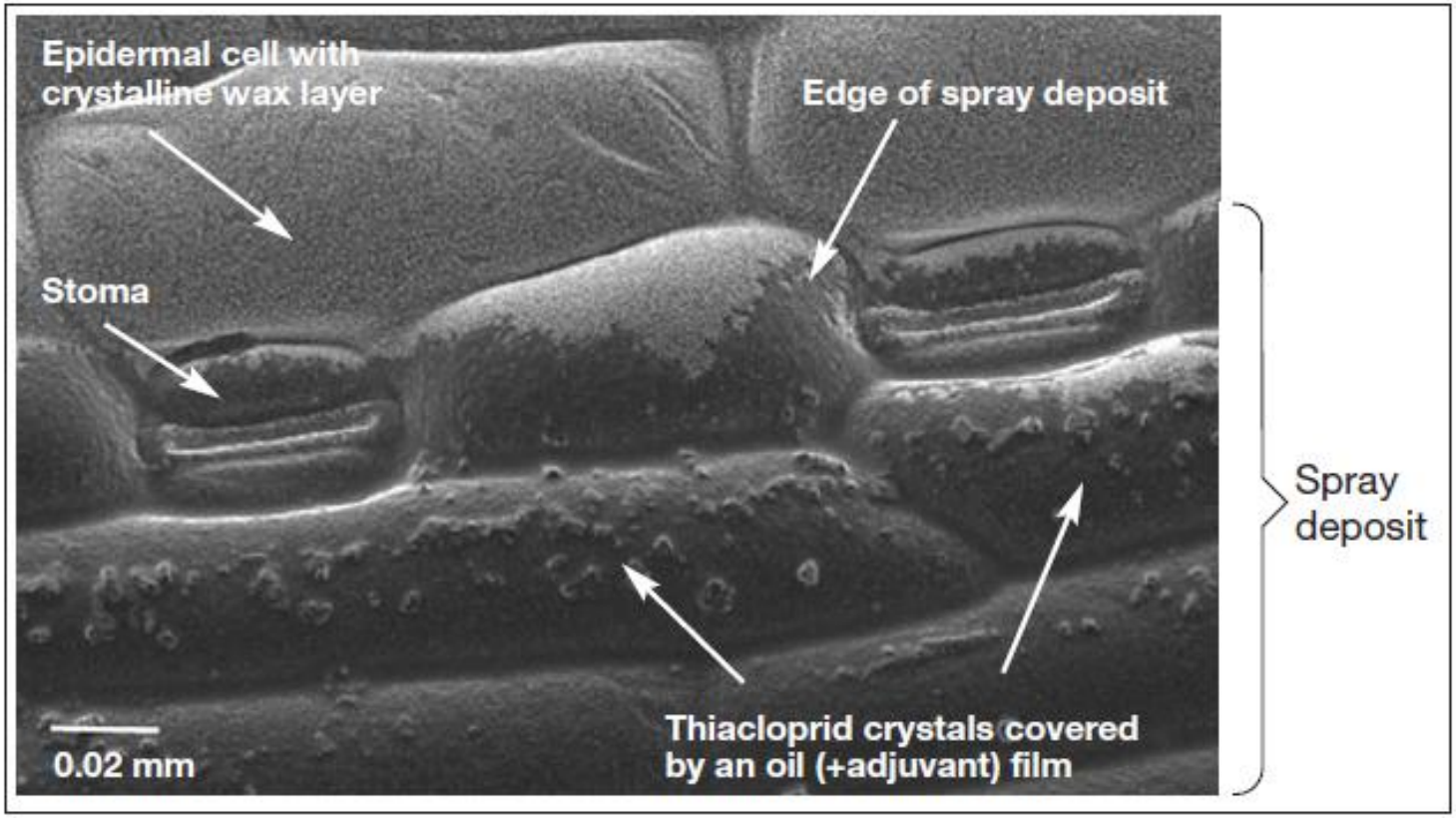


Transfer of agrochemicals to the target



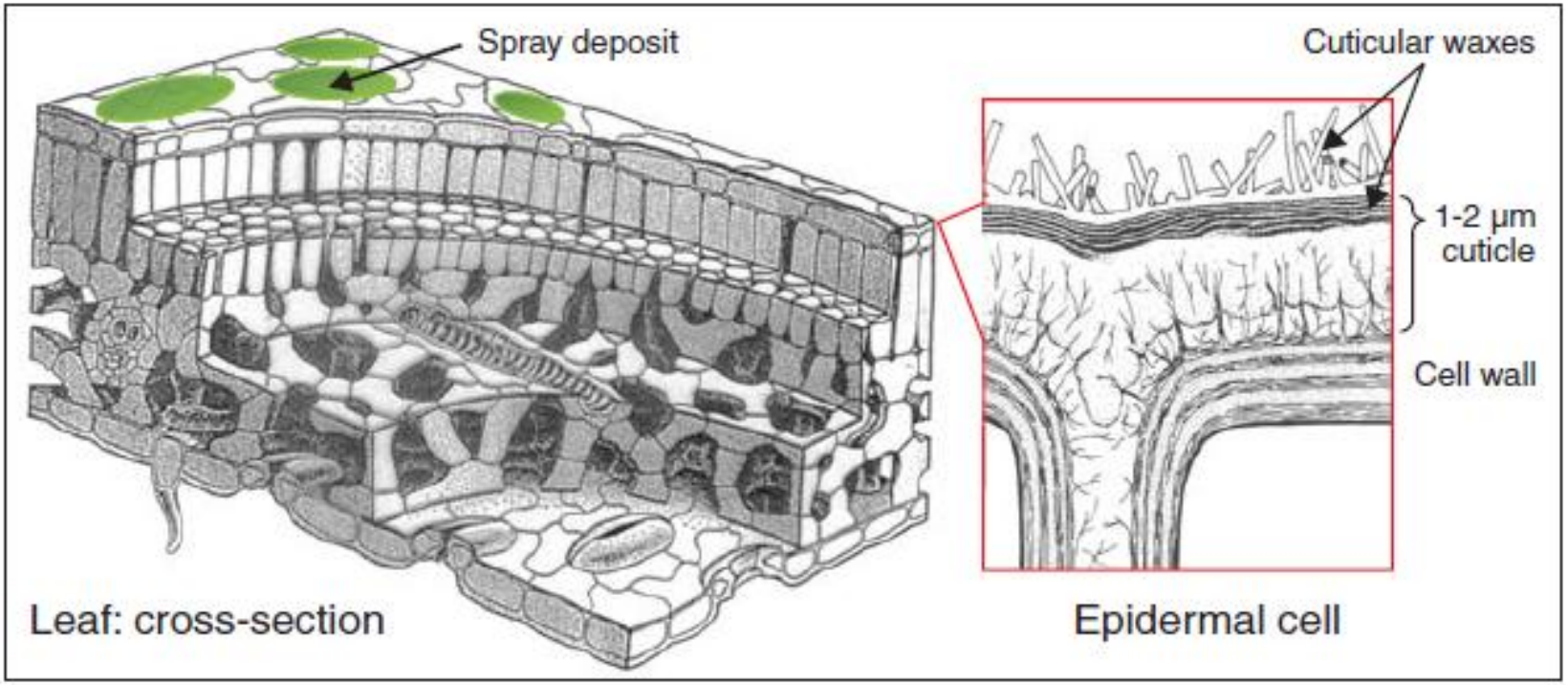
R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72

Spray deposit of thiacloprid on a barley leaf (electron micrograph).



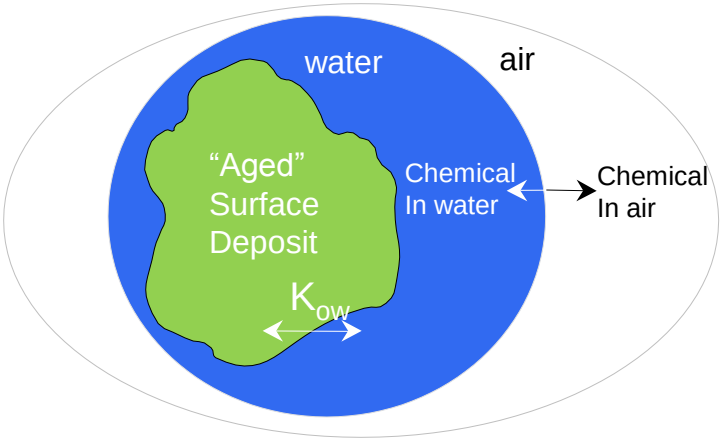
R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72

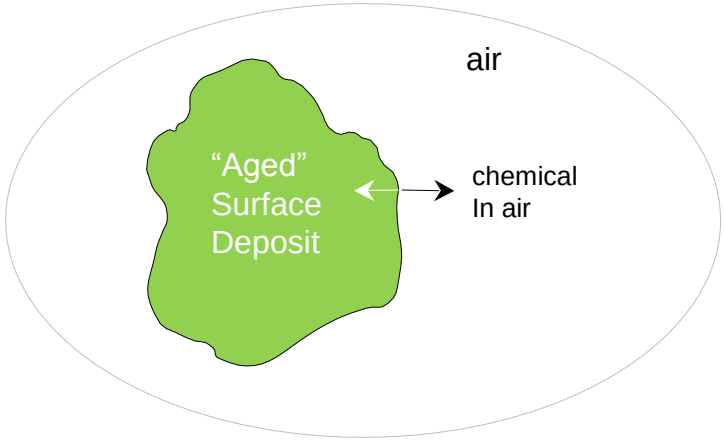
Agrochemical Spray deposit on the leaf surface

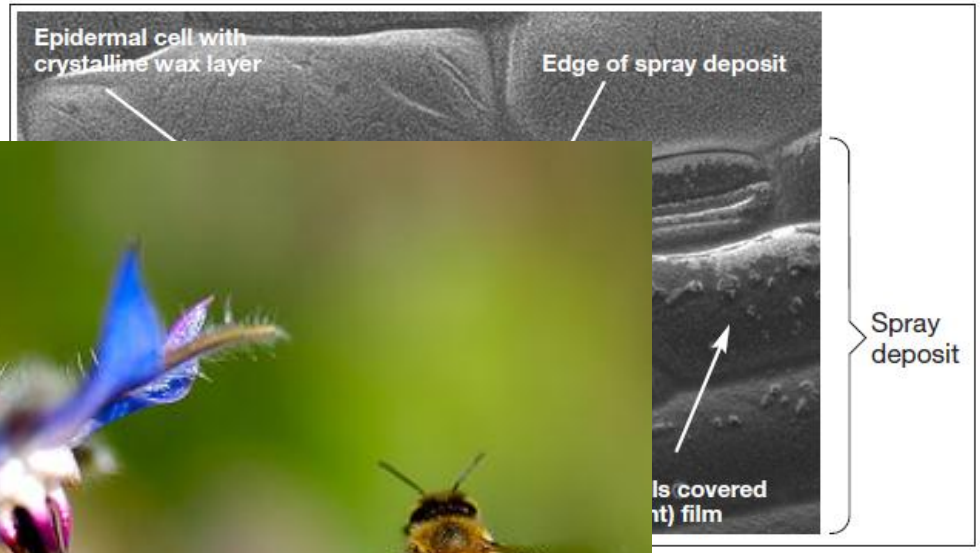


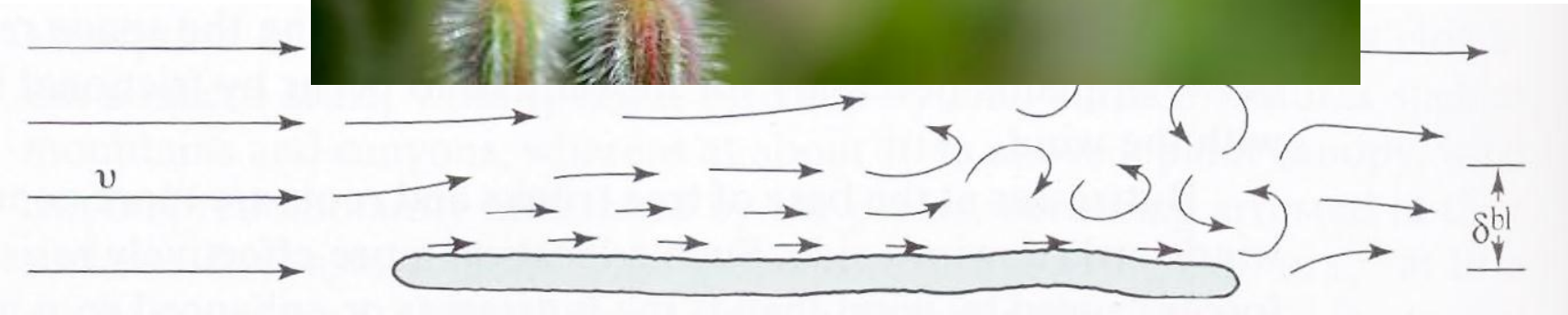
R. Pontzen, Pflanzenschutz-Nachrichten Bayer 59/2006, 1, p 63-72

Pesticide partitioning between leaf surface deposit, moisture, and air






Epidermal cell with
crystalline wax layer
Edge of spray deposit
Spray
deposit
ls covered
nt) film

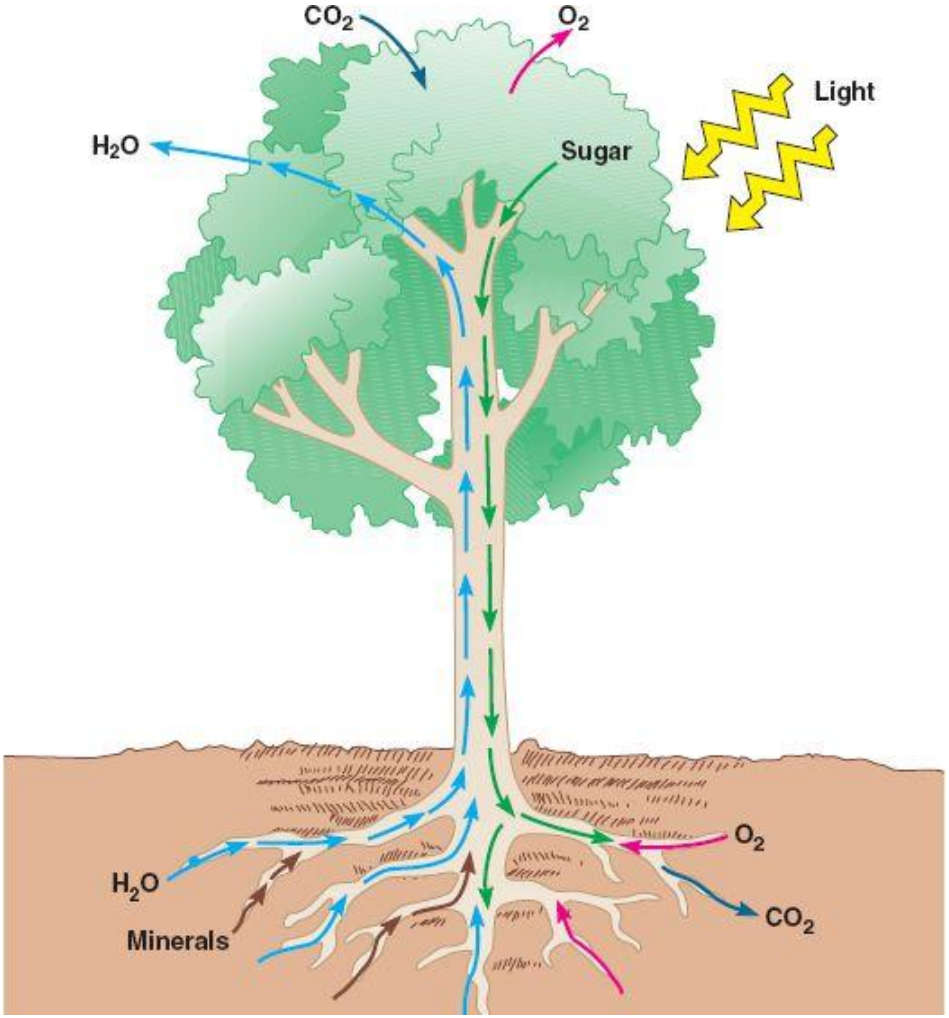

υ
δ^{bl}

Systemic Pesticides

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).

Prescription Treatment® brand

ASCEND®

Fire Ant Bait

Formula 1

KILLS: Fire Ants, Pharaoh Ants and Related Ants, Indoors and Outdoors.

TO CONTROL IMPORTED FIRE ANTS on Turf, Lawns, and Other Non-Crop Areas such as Parks and Golf Courses and Imported Fire Ants and Pharaoh Ants Indoors In Homes and the Non-Food/Feed Areas of Commercial Buildings, Warehouses, Hotels, Food Storage Areas, Inedible Product Areas of Meat Packing Plants, Motels, Schools, Supermarkets and the Non-Patient Areas of Hospitals and Nursing Homes.

ACTIVE INGREDIENT:

Abamectin* B_1 ..... 0.011%

OTHER INGREDIENTS: 99.989%

*U.S. Pat. 4,310,519

TOTAL: 100.000%

"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.).

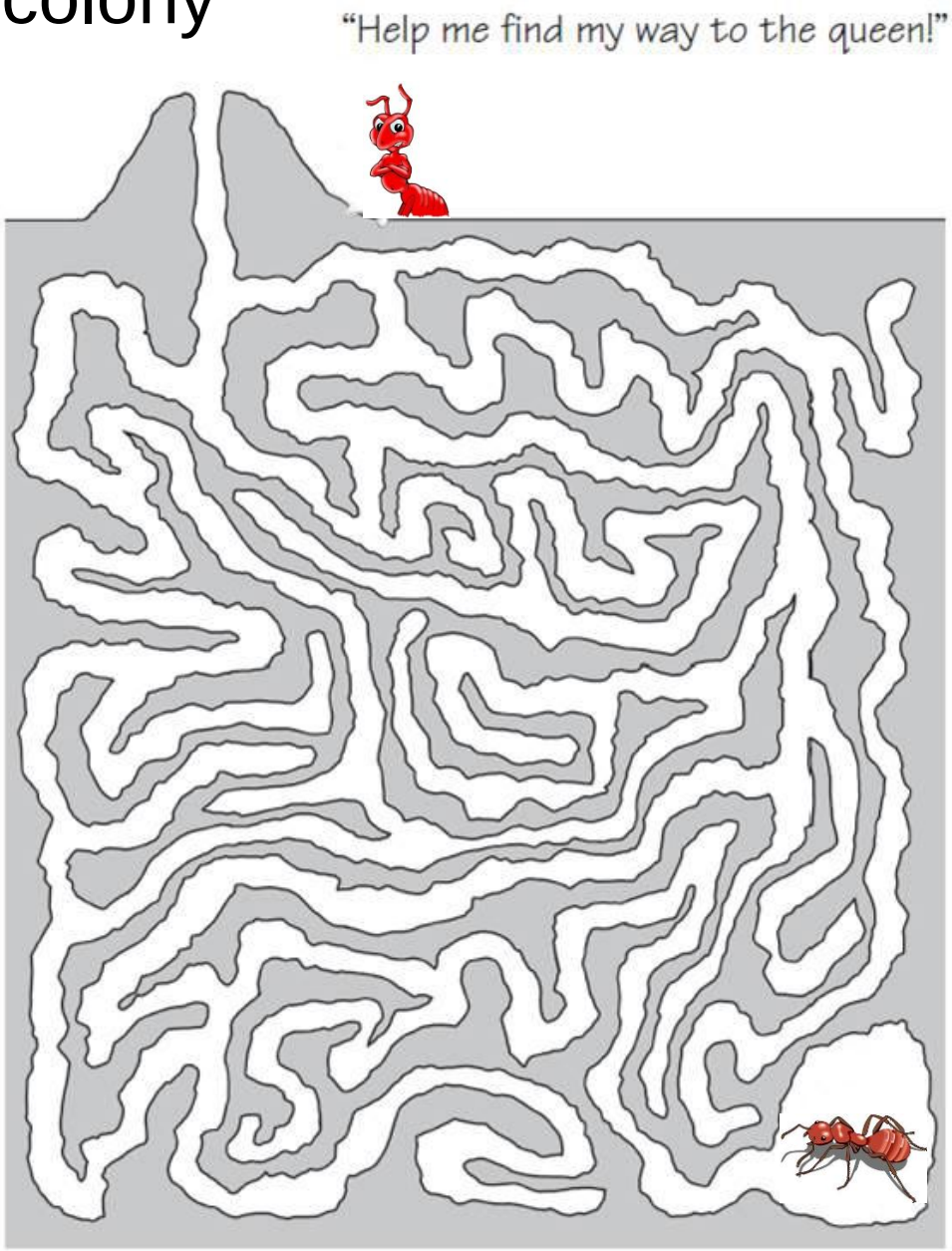
1 lb bait/acre = 454 grams bait/acre

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”.

Fire ant ground-dwelling colony



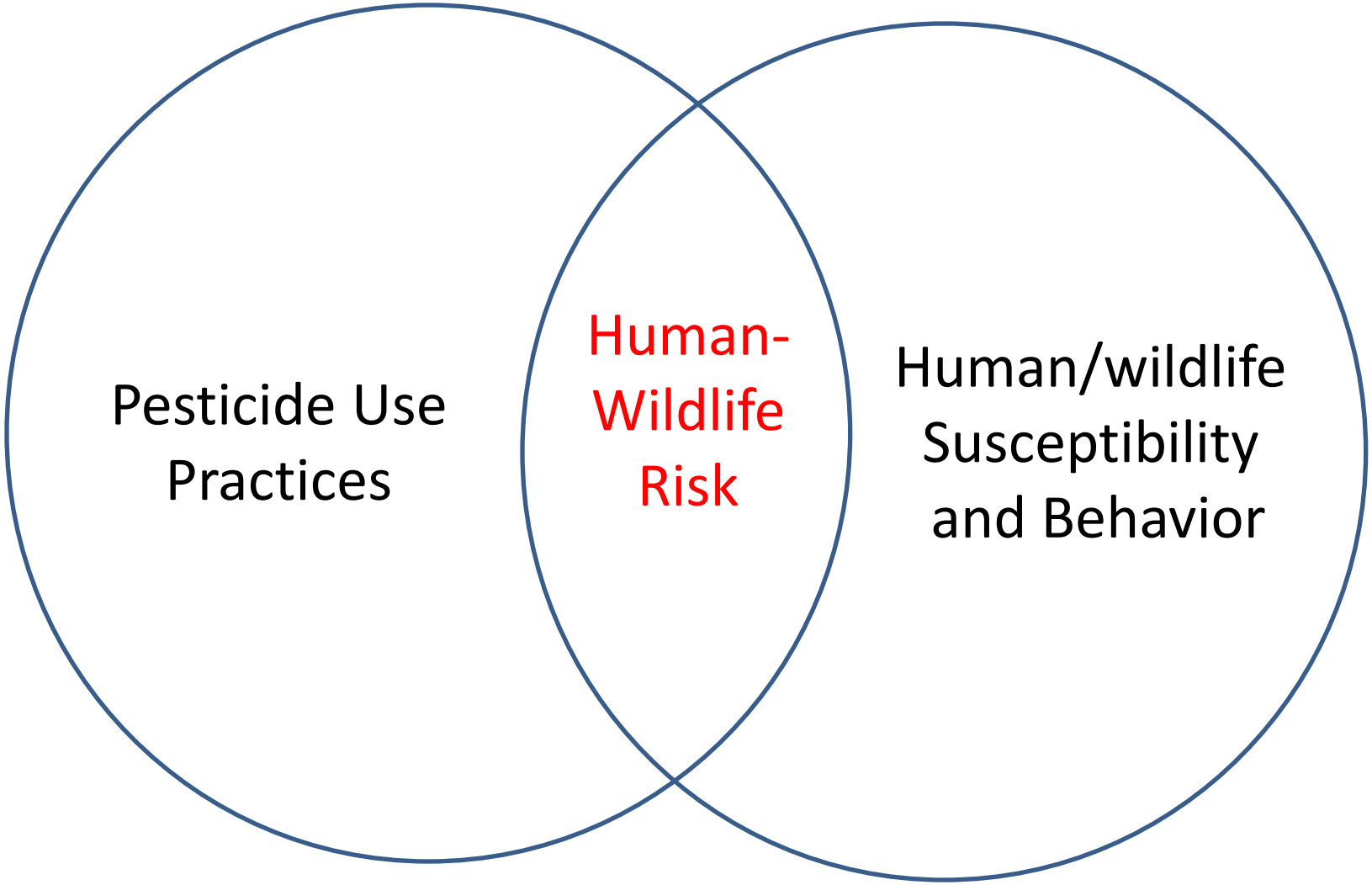
The queen's job is to lay eggs. She controls the colony using pheromones.

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

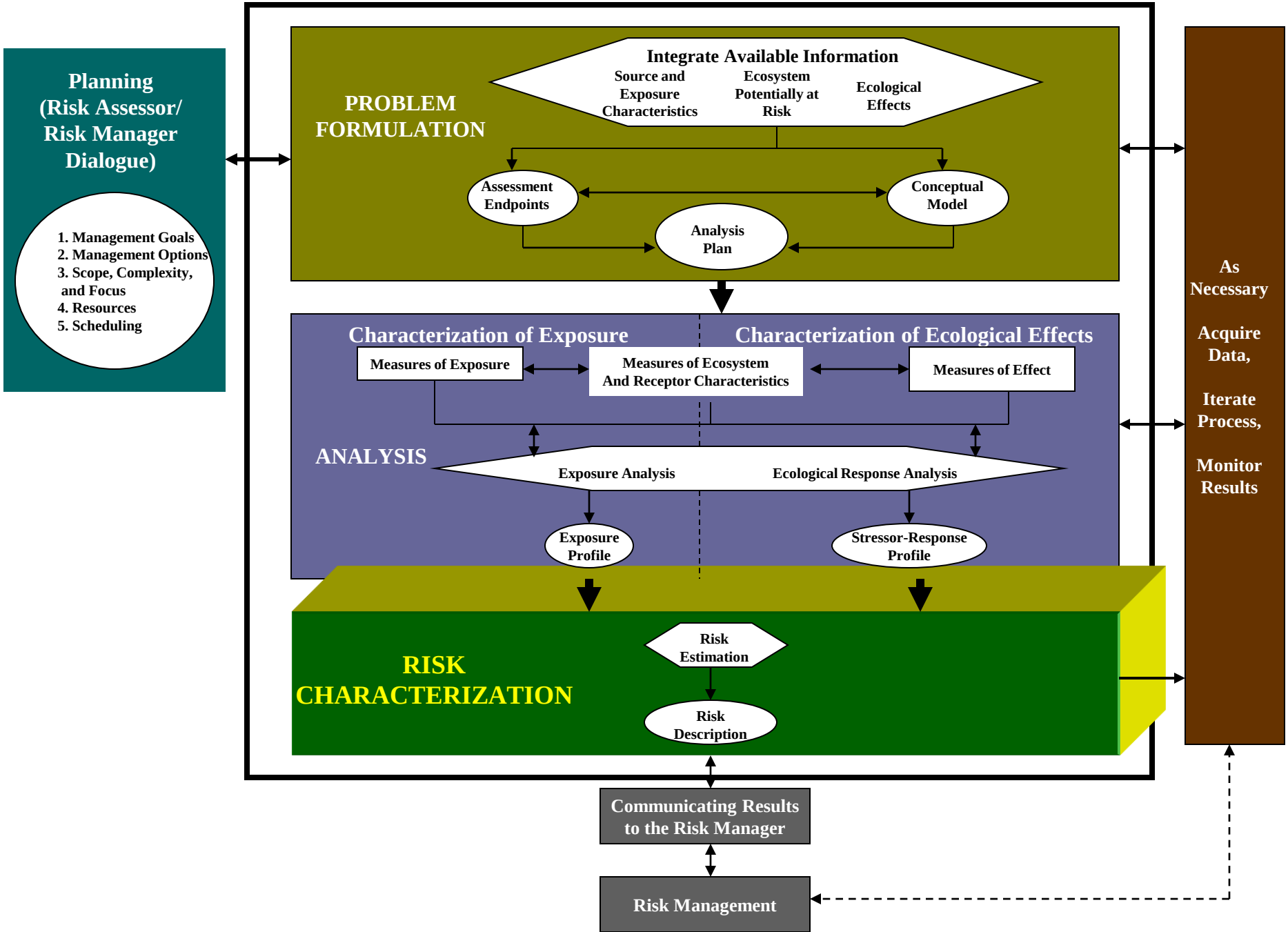
50 mg/acre avermectin is efficacious because of it's:

mode of action
potency
persistence
forager ant behavior.

Risk: Conceptual Framework



FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT



Risk quotient (RQ) method

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

$$RQ = EEC/LC_{50} \text{ or } EC_{50}$$

EEC – Expected Environmental Concentration

LC_{50} – Median lethal concentration

EC_{50} – Median effective concentration for sublethal effects

- Level of concern: RQ ranges from 0.05 (ESA) to 1

White Paper in Support of the Proposed Risk Assessment Process for Bees

Submitted to the FIFRA Scientific Advisory Panel for Review and Comment

September 11 – 14, 2012

Office of Chemical Safety and Pollution Prevention
Office of Pesticide Programs
Environmental Fate and Effects Division
Washington, D. C.
September 11, 2012

Environmental Assessment Directorate
Pest Management Regulatory Agency
Health Canada
Ottawa, Canada K1A 0K9

California Department of Pesticide Regulation
Sacramento, California

European Food Safety Authority

EFSA Journal 2013;11(7):3295

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 Authority[2,3]

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 simple 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 bees, 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.ppr@efsa.europa.eu

[3] Acknowledgement: EFSA wishes to thank the members of the working group: Gérard Arnold, Jos Boesten, Mark Clook, Robert Luttik, Fabio Sgolastra, Jacoba Wassenberg and the hearing expert Jens Pistorius for the preparatory work on this scientific output and EFSA staff: Franz Streissl, Maria Arena, Csaba Szentes, Agnès Rortais and Olaf Mosbach-Schulz for the support provided to this scientific output.

* Editorial revisions were made to the main title, the header as on the page 2 onwards, the abstract, the keywords and the acknowledgement.

Suggested citation: European Food Safety Authority, 2013. Guidance on the risk assessment of plant protection products on bees (*Apis mellifera*, *Bombus* spp. and solitary bees). EFSA Journal 2013;11(7):3295, 266 pp. doi:10.2903/j.efsa.2013.3295.
Available online: www.efsa.europa.eu/efsajournal

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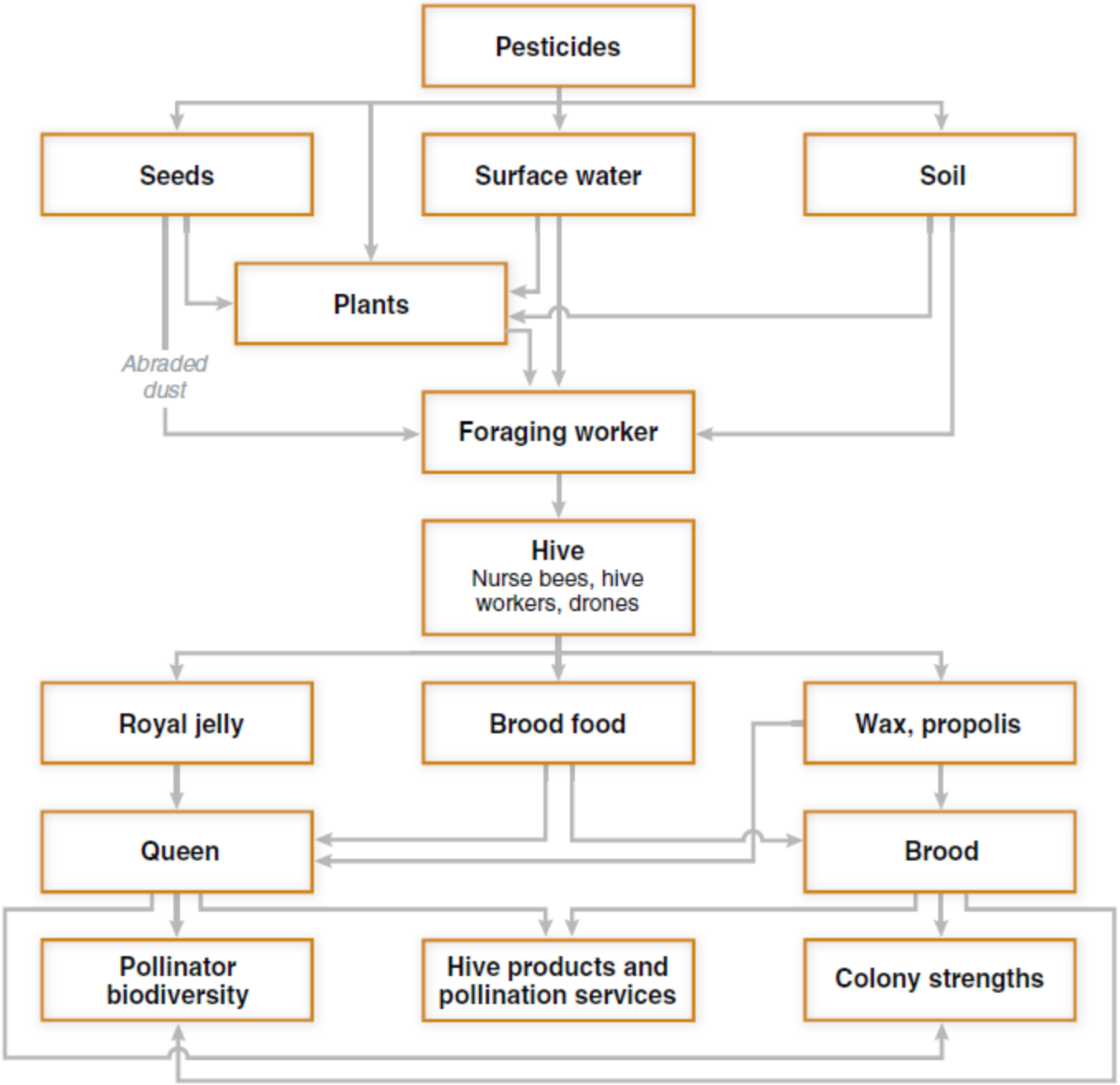
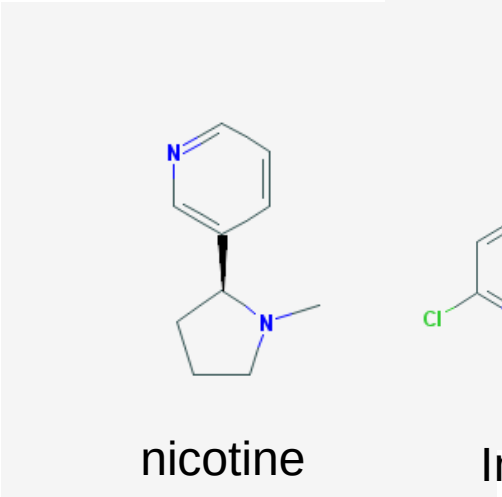


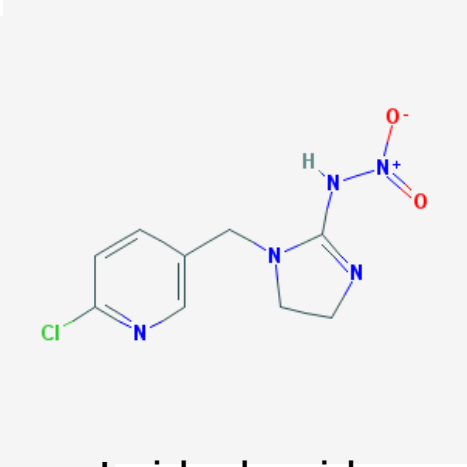
FIGURE 3: Conceptual model for bee risk assessment. Adapted from Fischer and Moriarty [41] and US Environmental Protection Agency [42].

Neonicotinoids Mode of action

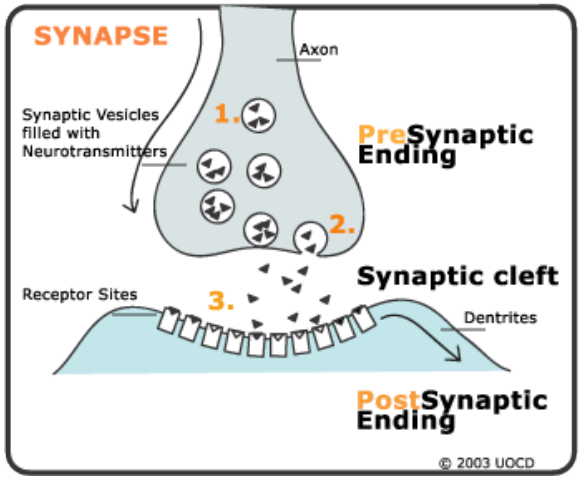
- Derivatives of nicotine (first insecticide use - France 1690)
- Mode of action - disrupt the nervous system by binding to postsynaptic nicotinic acetylcholine receptors.
- Toxic effects: modified feeding behavior, paralysis, and subsequent death.
- At low doses – neurobehavioral effects?



nicotine



Imidacloprid



1. Synaptic Vesicles filled with Neurotransmitters in the tip of the Axon.
2. Fusing of Synaptic Vesicles' Membrane and Nerve Ending Membrane resulting in the release of Neurotransmitters into the Synaptic Cleft.
3. Uptake of Neurotransmitters by the Receptor Sites. They lock into eachother perfectly.

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[1]

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

[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 nest mates

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.

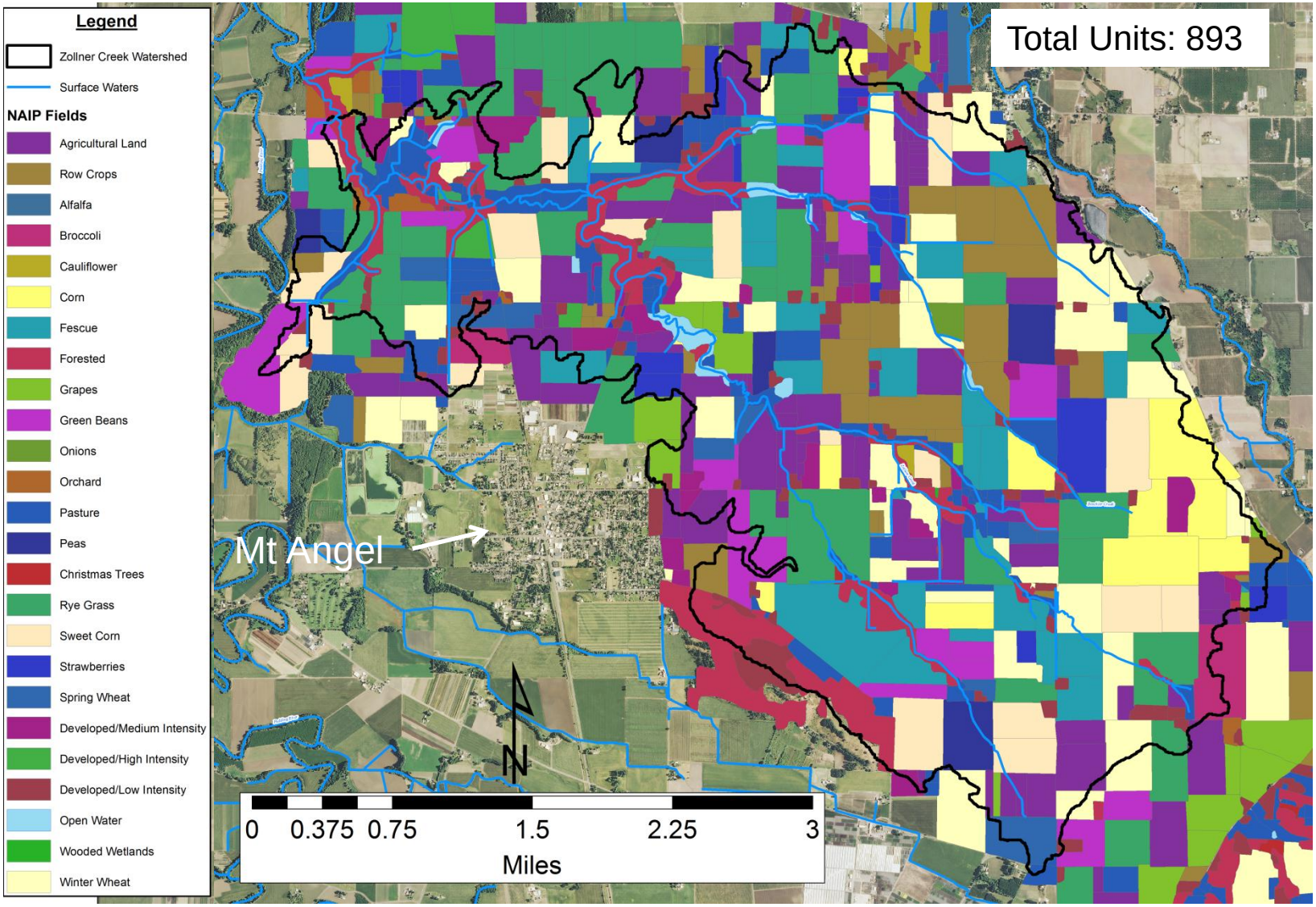
Neonicotinoids and Pollinators – Lab and Field Studies

- 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



CSIRO bee-tagging project

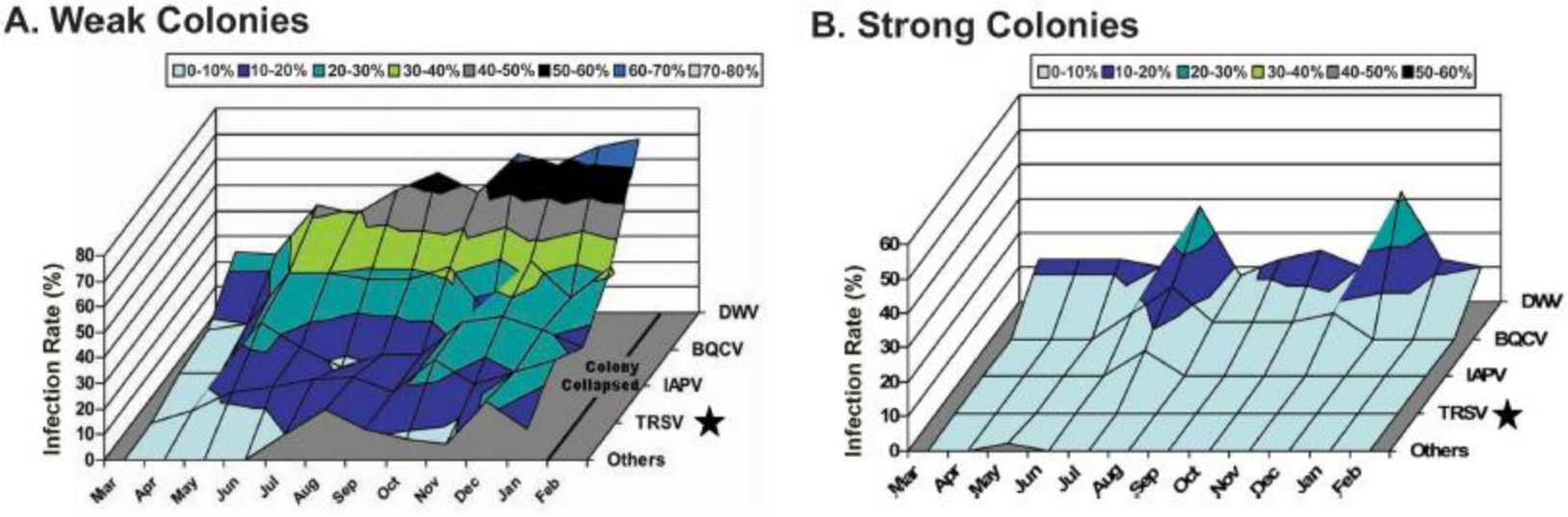
New Research on Honeybee Viral Infection – January 21, 2014

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

Ji Lian Li,[a] R. Scott Cornman,[b] Jay D. Evans,[b] Jeffery S. Pettis,[b] Yan Zhao,[c] Charles Murphy,[d] Wen Jun Peng,[a] Jie Wu,[a] Michele Hamilton,[b] Humberto F. Boncristiani Jr.,[e] Liang Zhou,[f] John Hammond,[g] Yan Ping Chen[b]

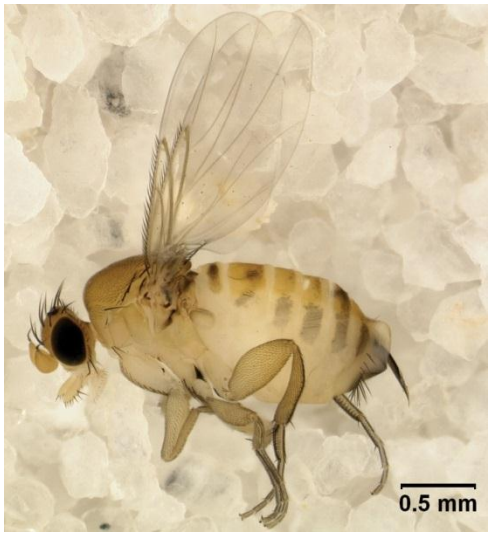
Key Laboratory of Pollinating Insect Biology of the Ministry of Agriculture, Institute of Apicultural Research, Chinese Academy of Agricultural Science, Beijing, China[a]; Department of Agriculture, ARS, Bee Research Laboratory, Beltsville, Maryland, USA[b]; Department of Agriculture, ARS Molecular Plant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

IMPORTANCE 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.



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

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'

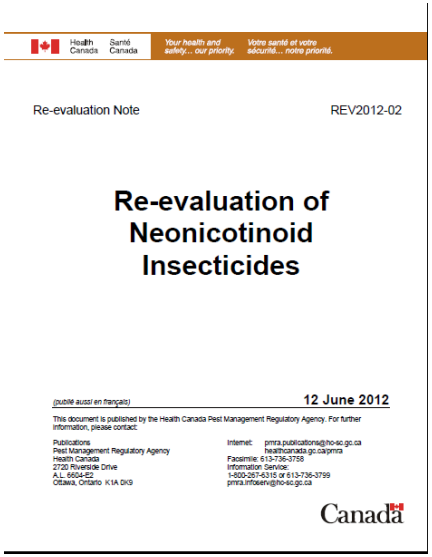
- January 22nd, 2014

- 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



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Re-evaluation Note REV2012-02

Re-evaluation of Neonicotinoid Insecticides

(publié aussi en français) **12 June 2012**

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Sub-lethal and chronic effects of neonicotinoids on bees and other pollinators

Bee Declines & Pesticides **factsheet 2**

This factsheet summarises current knowledge about sub-lethal (i.e. non-fatal) 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 neonics debate – and implications of the latest research findings.

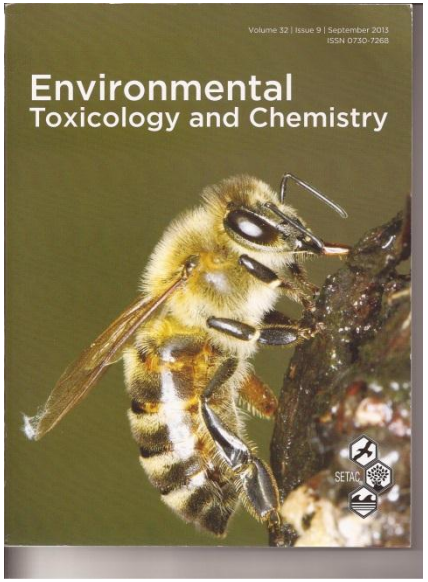
Credit: Graham White

Subtle but important effects from doses that do not kill bees outright

Sub-lethal toxicity to bees and other pollinators is the most likely exposure scenario in the field from neonicotinoid seed treatments[1,2] because generally the concentrations that are found in pollen and nectar from seed-treated plants are too low to cause immediate bee deaths from acute poisoning[3,4]. However, lethally toxic levels in seed coating dust released at sowing stage have been documented in several countries (see Factsheet 1 on exposure routes) and found in stored pollen in some US hives[5].

Sub-lethal effects reported in the scientific literature[6] include a range of behavioural disturbances in honeybees:

www.pan-uk.org



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Environmental Toxicology and Chemistry

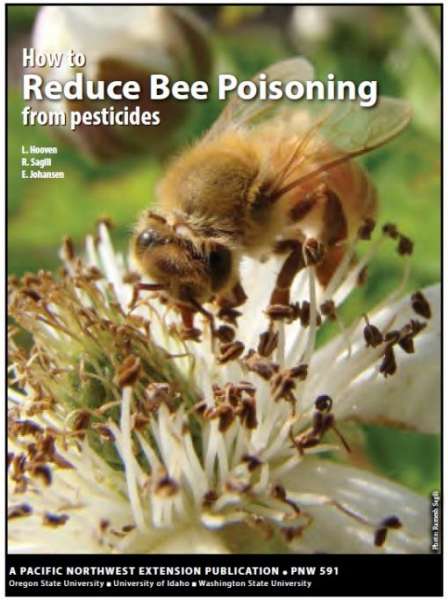
SETAC

Gardeners Beware:

Bee-Toxic Pesticides Found in "Bee-Friendly" Plants Sold at Garden Centers Nationwide

Friends of the Earth

BeeAction.org



How to Reduce Bee Poisoning from pesticides

L. Hooven
R. Sagili
E. Johansen

Photo: Ramesh Sagili

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ARE NEONICOTINOIDS KILLING BEES?

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

Jennifer Hopwood, Mace Vaughan, Matthew Shepherd, David Biddinger, Eric Mader, Scott Hoffman Black, and Celeste Mazzacano

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