

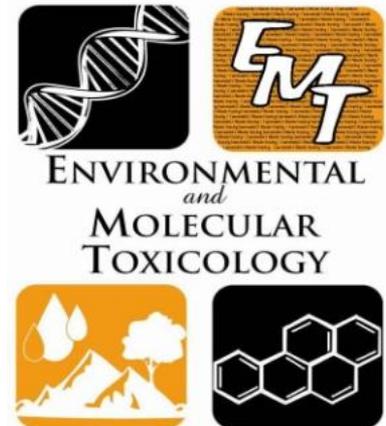
Ecological Risk Assessment at U.S. EPA



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U.S. Environmental Protection Agency (EPA) Pesticide Risk Assessment

- Determine risks of adverse impacts to human health and the environment:
 - **Toxicity** to humans and wildlife
 - Opportunities for **exposure**
- Registration/Re-registration decision
- Mitigate risks with label restrictions



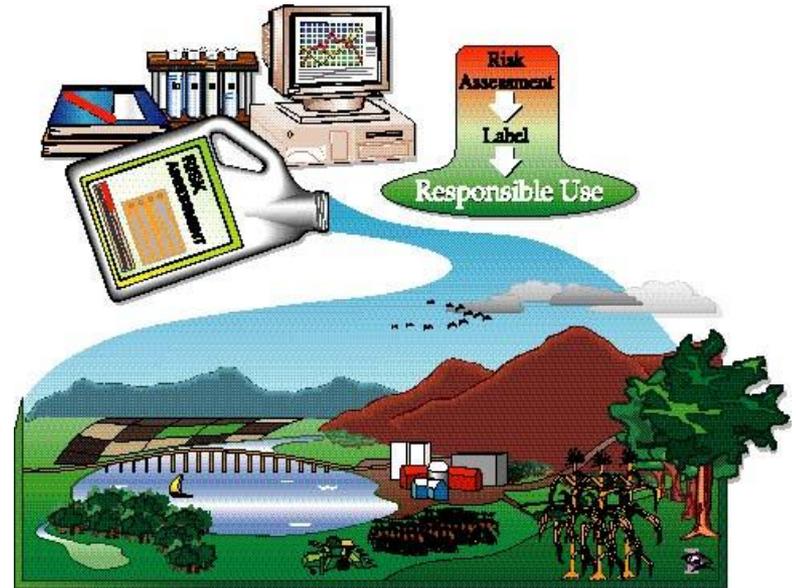
Crop or Site-specific Risk Assessment

- Human health and environmental resources of concern
- Pest management practices
- Pesticide use practices: why, when, where, how, how much, how often
 - pesticide use practices
 - Landscape characteristics (land cover, soils)
 - hydraulic loading (irrigation or rainfall)
 - pesticide toxicity to humans/wildlife

Pest and pesticide management

- Understanding pesticide fate and effects, what scale?
 - **Field scale**: efficacy, impact on beneficials, potential for off-site movement.
 - **Watershed scale**: integration of field level impacts, particular emphasis on water quality.
 - **Regional scale**: integration of watershed-airshed level effects, long range transport of persistent pesticides.

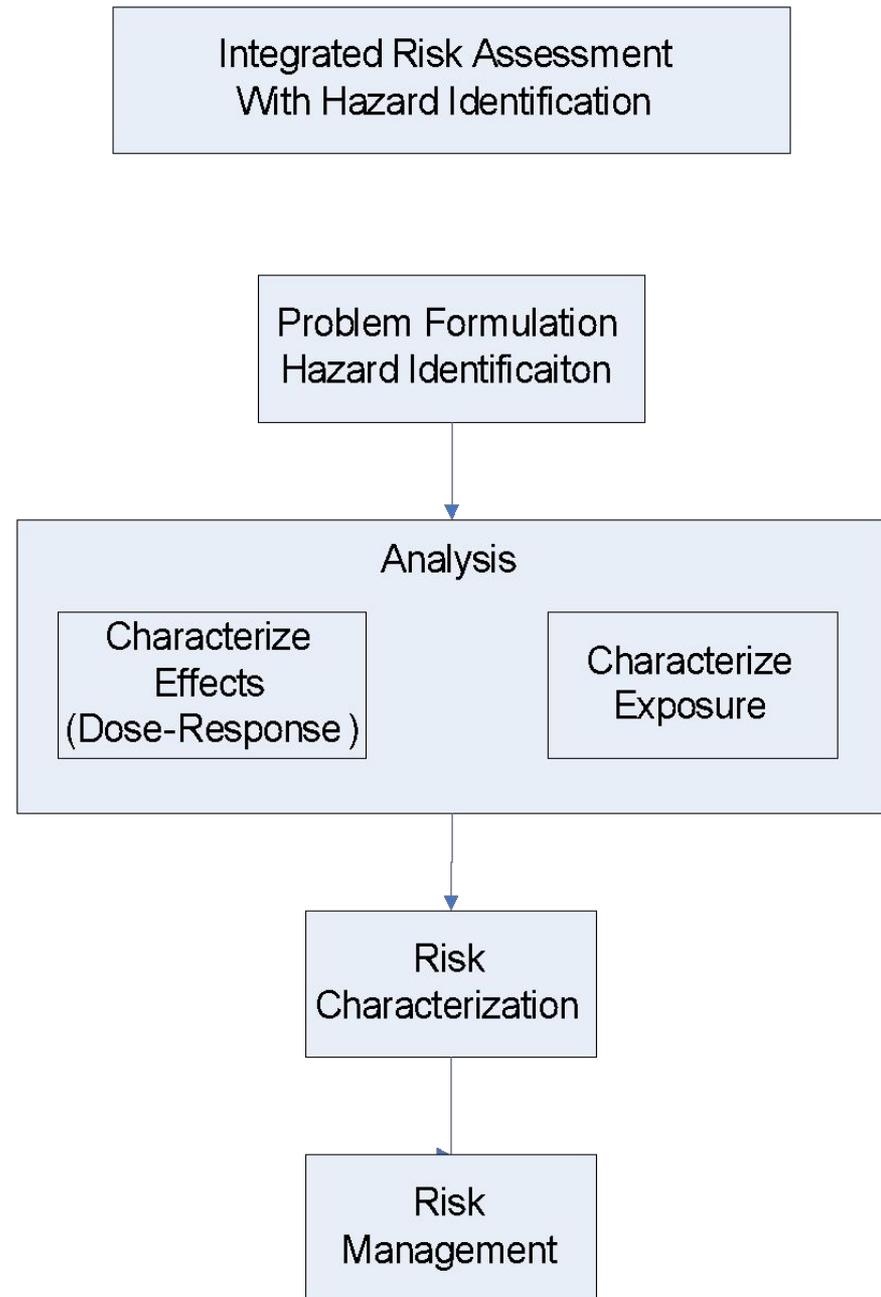
U.S. EPA Pesticide Risk Assessment



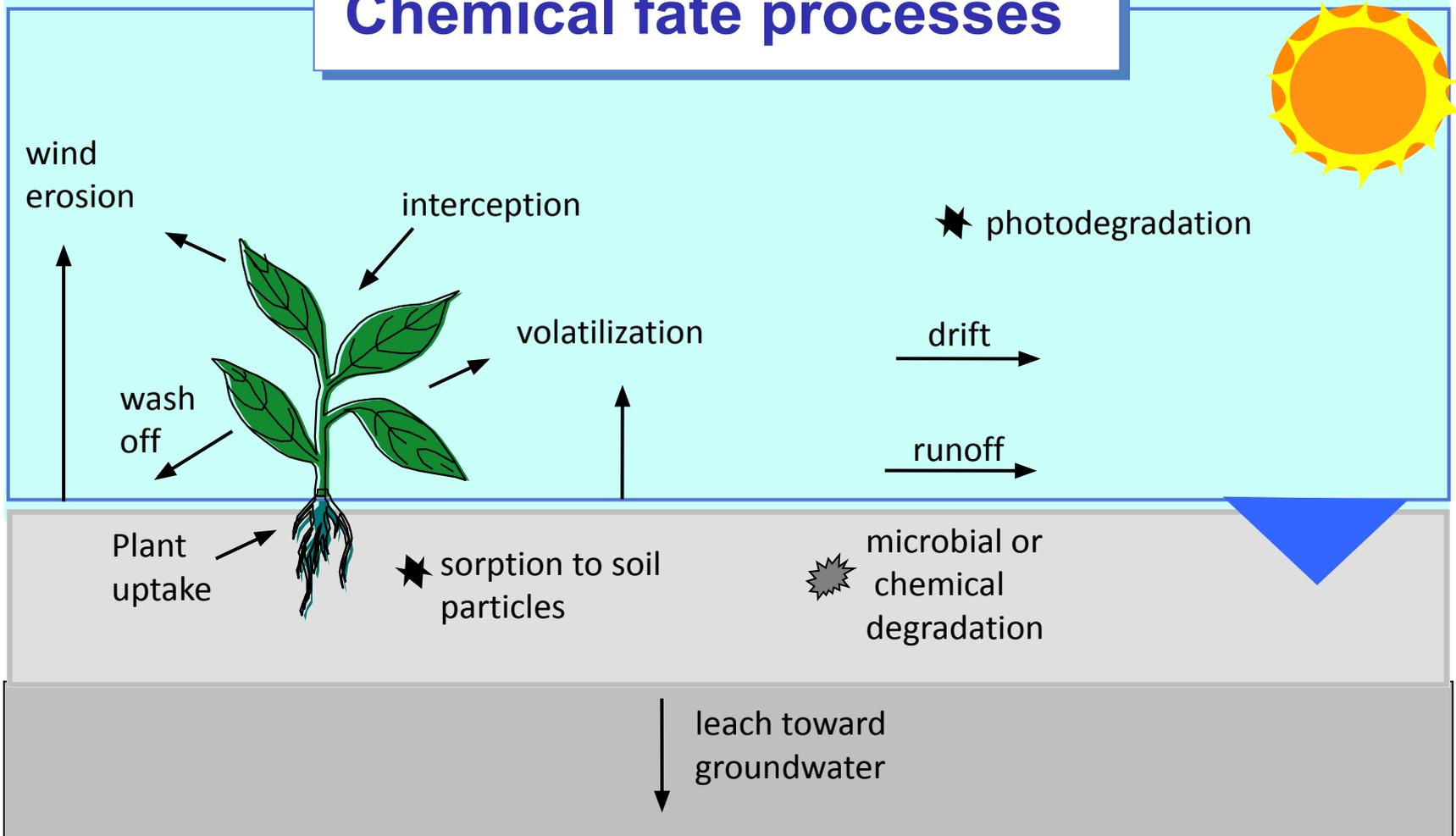
$$\text{Risk} = f(\text{exposure, toxicity})$$

Source: Purdue University Pesticides Program

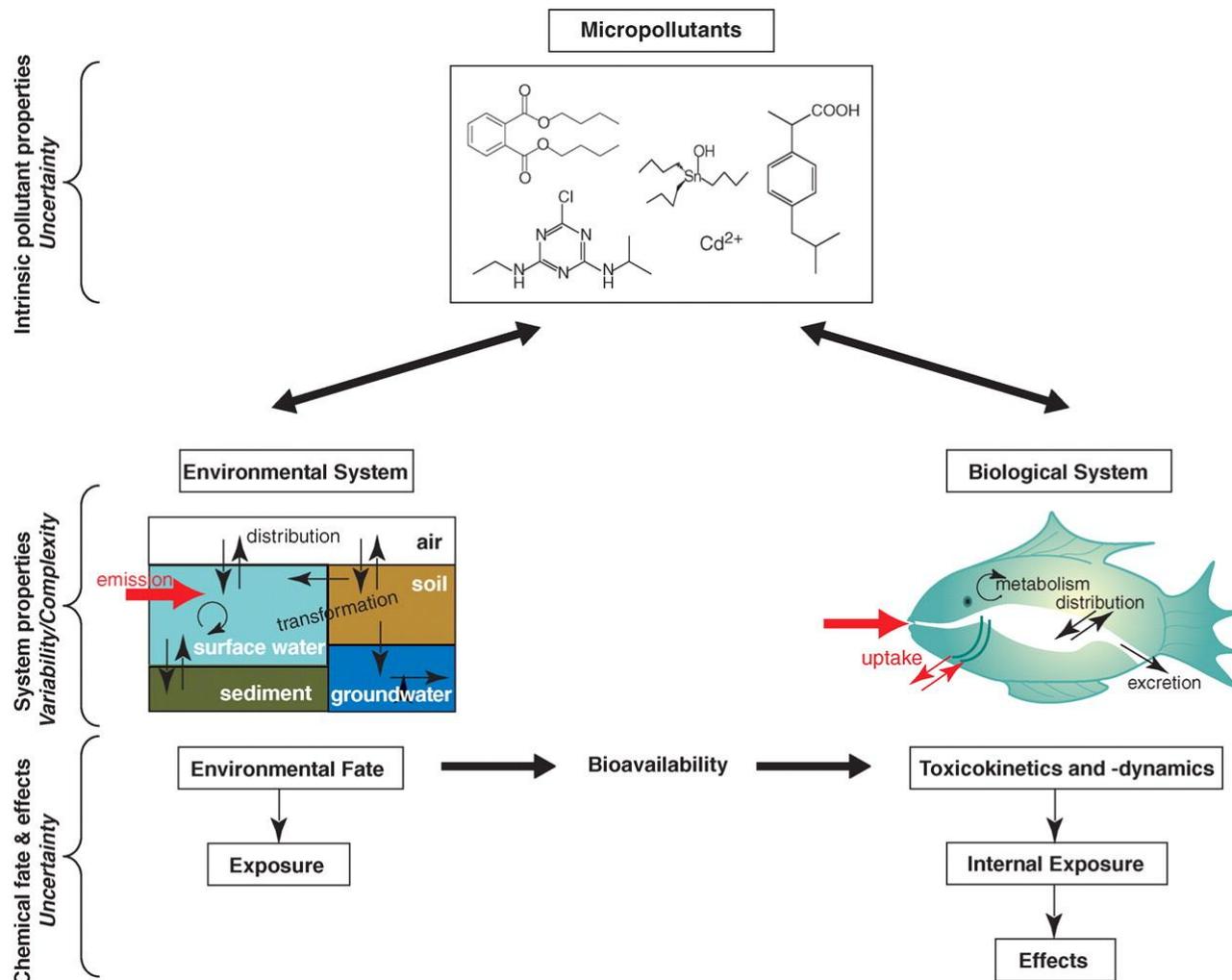
Human Health and Ecological Risk Assessment at U.S. EPA



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)

Exposure Assessment

- Exposure assessment lies along a continuum:
- From pesticide introduction into the environment;
- to external dose; then internal dose;
- to occurrence of subcellular changes; and
- expression of a biological effect within the exposed individual.

Pesticide Ecological Risk Assessment

Commonly based on the sensitivity of standardized organisms (surrogate species)

Easy to culture

Short life cycles

Sensitive to contaminants



Hyaella azteca



Daphnia sp.



Fat head minnow



Rainbow trout

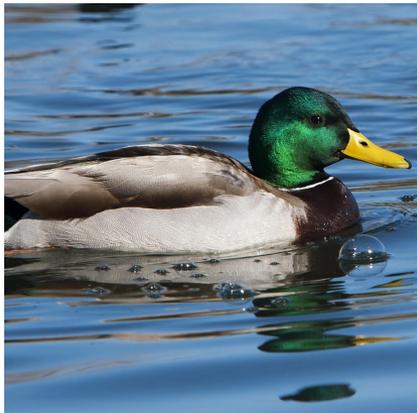
Terrestrial Surrogate Species



Bobwhite Quail



Canary



Mallard duck



Honeybee *Apis mellifera*



Domestic Norwegian rat

Pesticide Aquatic Test Species

- Freshwater species¹
 - Rainbow Trout - Cold-water
 - Bluegill Sunfish, Fathead Minnow - Warm-water
 - Daphnids (e.g., *Daphnia magna*)
 - Amphipods² (e.g., *Hyalella Azteca*)
 - Mollusks (bivalves, snails)
- Saltwater species¹
 - Sheepshead Minnow
 - Mysid Shrimp
 - Oysters Mussels
 - Amphipods² (benthic - live in sediment)

¹Surrogate for vertebrates

²Benthic - live in sediment

Pesticide Terrestrial Test Species

- Birds¹
 - Bobwhite quail
 - Mallard duck
 - Canary
- Mammals: Norwegian Rat
- Invertebrates & Microorganisms
 - Honey Bees
 - Earthworms
 - Soil microorganisms (community toxicity).

¹Surrogate for terrestrial amphibians and reptiles

Surrogate Species

- Respond well to husbandry under laboratory conditions minimizing distress while maintaining health for precise observation of toxic effects.
- Toxicity testing on surrogate species used to estimate adverse effects (survival, growth, and reproduction) on all species of concern.
- Scale dose from test species to receptors of interest - scale single dose (acute studies) or daily applied dose (chronic studies) in proportion to body weight (mg/kg).

Ecological Risk Characterization

- Exposure assessment – monitoring, environmental fate modeling
- Most sensitive toxicity endpoint for surrogate species, extrapolated to all species of concern (receptors)
- Determine the ecological risks for varying pesticide use scenarios
- Models are used to extrapolate measured and modeled pesticide fate data to estimate receptor exposure (dietary and contact) for all plausible pathways.

Integration of Exposure and Effects: Risk quotient (RQ) method

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

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

$$RQ = EEC/LD_{50} \text{ or } ED_{50}$$

EEC – Expected Environmental Concentration

Aquatic Risk Assessment

LC_{50} – Median lethal concentration

EC_{50} – Median effective concentration for sublethal effects

Terrestrial Risk Assessment

LD_{50} – Median lethal dose (mg/kg body weight)

ED_{50} – Median effective dose for sublethal effects

Aquatic Ecological Risk Levels of Concern

EEC – Expected Environmental Concentration

LC₅₀ – Median lethal concentration

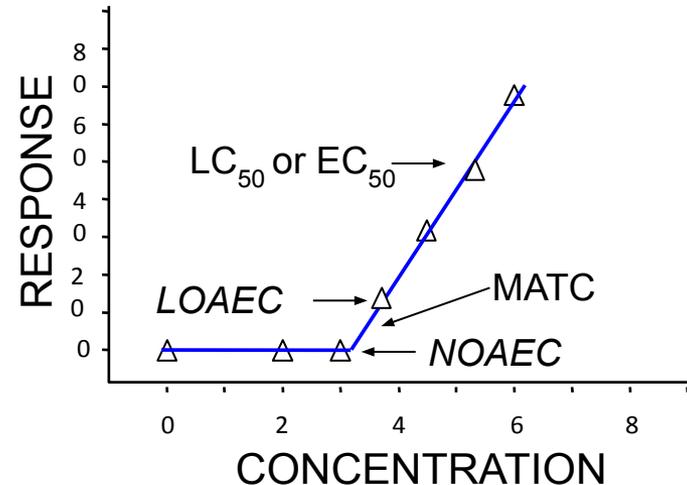
EC₅₀ – Median effective concentration for sublethal adverse effects

NOAEC - No Observable Adverse Effect Concentration

LOAEC – Lowest Observable Adverse Effect Concentration

MATC – Maximum Acceptable Toxicant Concentration - the threshold of significant effects on survival, growth or reproduction: usually based on chronic exposure (partial or complete life cycle) and the most sensitive endpoint where toxic effects are observed.

MATC is often estimated from the geometric mean of the NOAEC and LOAEC. Used to assess risk from chronic exposure.



Terrestrial Ecological Risk Levels of Concern

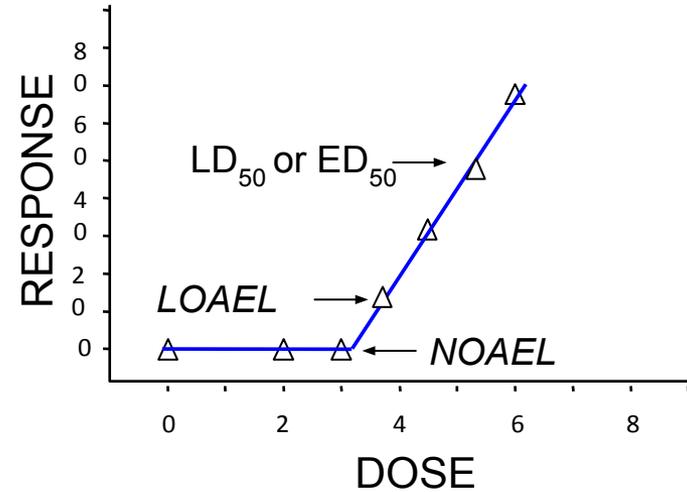
EEC – Expected Environmental Concentration

LD_{50} – Median lethal dose (mg/kg body weight)

ED_{50} – Median effective dose for sublethal adverse effects

NOAEL - No Observable Adverse Effect level

LOAEL – Lowest Observable Adverse Effect level



Risk Assessment Methods and LOCs¹

- The risk assessment methods used to evaluate potential risk are based on the RQ, which is compared to LOCs for the the following risk presumption categories:
- (1) **Acute high** - Potential for acute risk is high, and regulatory action may be warranted in addition to restricted use classification;
- (2) **Acute Restricted Use** - Potential for acute risk is high, but this may be mitigated through restricted use classification;
- (3) **Acute Listed Species** - Potential for acute risk to listed species is high, and regulatory action may be warranted, and
- (4) **Chronic Risk** - Potential for chronic risk is high, and regulatory action may be warranted.

¹Levels of concern

Ecotoxicity test values

- The ecotoxicity test values (i.e., measurement endpoints) used in the acute and chronic risk quotients are derived from the results of required short-term laboratory studies.
 - LC_{50} - fish and birds,
 - LD_{50} - birds and mammals,
 - EC_{50} - aquatic plants and aquatic invertebrates,
 - EC_{25} - terrestrial plants.

Ecotoxicity test values

- Examples of toxicity test effect levels derived from the results of both acute (single dose) and chronic (long-term) laboratory studies that assess chronic effects are:
 - LOAEC - fish, and aquatic invertebrates,
 - NOAEC - fish and aquatic invertebrates,
 - MATC - fish and aquatic invertebrates.
 - LOAEL - Birds, mammals, terrestrial invertebrates
 - NOAEL - Birds, mammals, terrestrial invertebrates

EPA Risk Presumptions for Birds and Wild Mammals

Risk Presumption	Risk Quotient	Level of Concern
Acute High-Risk Scenario	EEC ¹ /LC50 or LD50/sqft ² or LD50/day ³	0.5
Acute Restricted Use	EEC/LC50 or LD50/sqft or LD50/day (or LD50 < 50 mg/kg)	0.1
Acute Listed Species	EEC/LC50 or LD50/sqft or LD50/day	0.05
Chronic Risk	EEC/NOAEC or NOAEL	1

¹Abbreviation for Estimated Environmental Concentration (ppm) on avian/mammalian food items

² mg/sqft divided by LD50 times weight of bird

³ mg of toxicant consumed per day divided by LD50 times weight of bird

Regulatory Action to Mitigate Risks to Birds and Wild Mammals

- Acute RQ > 0.5 - may warrant regulatory action in addition to restricted use classification
- Acute RQ > 0.1 - mitigated through restricted use classification
- **Acute Listed Species RQ > 0.05** - Endangered or threatened species may be potentially affected¹
- Chronic RQ > 1 - may warrant regulatory action, listed species may potentially be affected through chronic exposure

¹Determination required under the Endangered Species Act

Pesticides and Pollinators – Conceptual Model

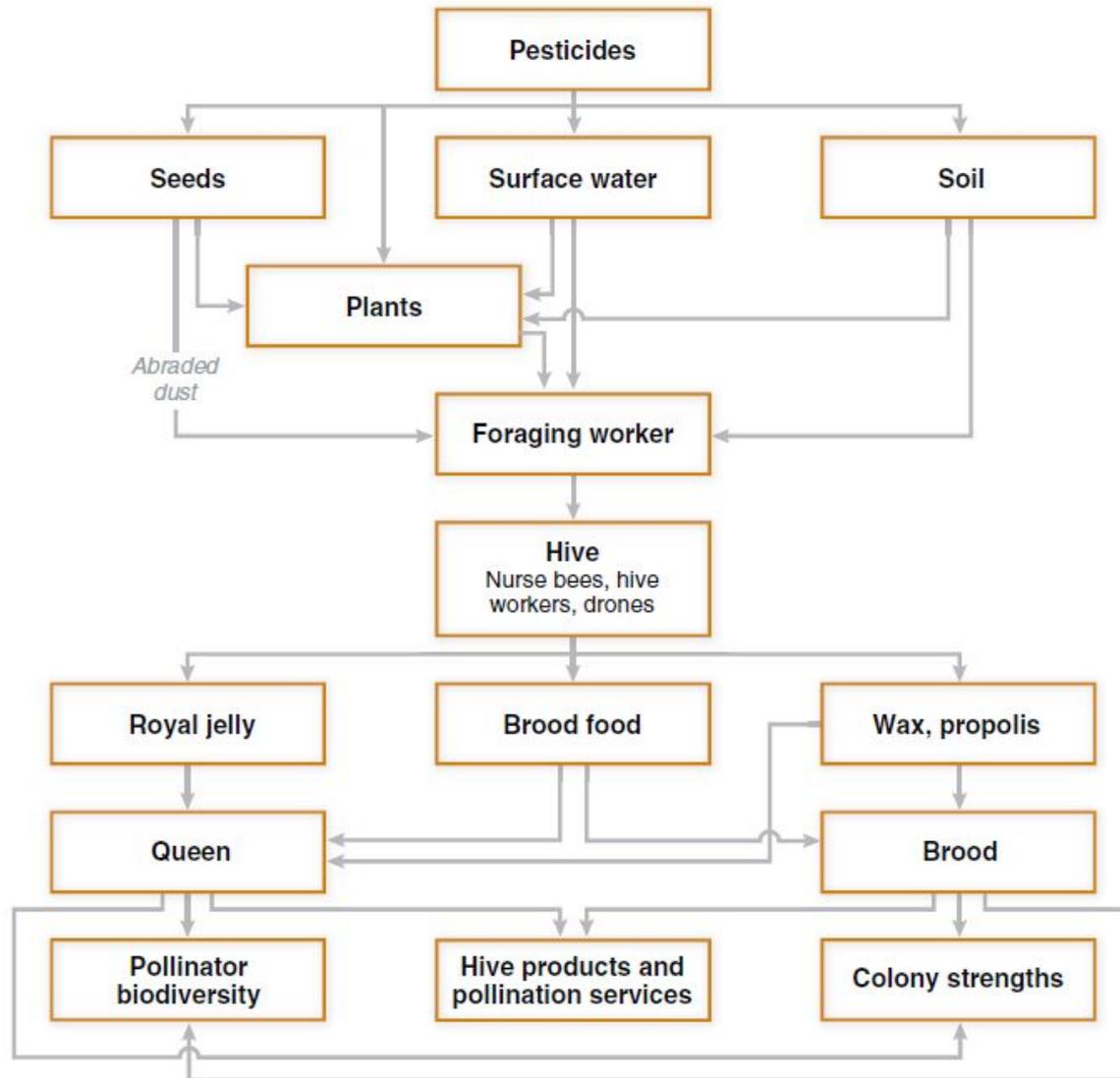


FIGURE 3: Conceptual model for bee risk assessment. Adapted from Fischer and Moriarty [41] and US Environmental Protection Agency [42].

Pesticides and Pollinators

- Application methods of interest
 - Seed treatments (dust, systemic in plant)
 - Soil application of systemic pesticides
 - Foliar application (surface residues, systemic in plant)

Pesticides 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.



Pesticides and Pollinators



- While acute lethal effects are of concern
- Major concern is for sub-lethal and chronic effects on fitness and survival.
- Current risk assessment methods are designed to address these concerns.

Pesticides 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

Pesticides 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.

Pesticides and Pollinators – Lab and Field Studies

- Discrepancy between clear lab results and inconclusive or negative field results.
- Lab studies should be conducted at environmentally relevant levels and patterns of exposure.
- Due to foraging behavior field study levels and patterns of exposure are challenging 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?

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 challenging.
- 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.



AFRICA

EUROPE

EUROPE

Mediterranean Sea

MOROCCO

TUNISIA

A S

Madeira (PT)

Strait of Gibraltar
Mountains

Tropic of Cancer

CAPE VE

Equator

Equator

A

Tropic of Ca

0 500 1000 Km
0 250 500 Miles

Great Karoo

LESOTHO

Cape of Good Hope

Draken

- River
- Lake
- Mountain Peak

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(Updated on 18th January, 2013)

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