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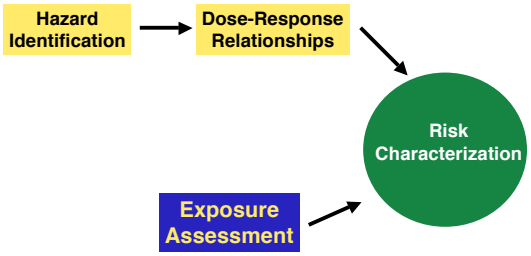
ES/RP 531
Fundamentals of Environmental Toxicology

Lecture 25
Ecological Risk Characterization
EPA's Deterministic Methods

Eco-Risk
A Horse of a Different Color?

- The Dilemma
  - Millions of species to protect
  - Infinitesimal exposure scenarios
- EPA's Solution: **Deterministic Risk Assessment**
  - Choose the most sensitive species studied
    - Focus on acute toxicity (use LC50)
    - Focus on chronic toxicity (use NOEC)
  - Use modeling to estimate residue levels
  - Use differential safety factors depending on the nontarget organisms to be protected
    - For ex., use a larger safety factor if endangered species are of concern

Risk Assessment--
Testing the Probability of Harm



Scientific Components
of Eco Risk Assessment

- Hazard Identification
  - What are the relevant endpoints?
- Dose-response relationship
  - What is the response relative to magnitude of dose and frequency and duration of exposure?
- Exposure assessment
  - What is the distribution of environmental residues?

The Soft Underbelly of
Risk Assessment

- **Risk Characterization**
  - Can be calculated objectively as exposure relative to some defined toxicological endpoint (LC50, NOAEC)
  - Risk quotient (RQ) approach for decision making
    - RQ = exposure (ppb)/tox endpoint (ppb)
- However, whether the RQ is judged acceptable or unacceptable depends on risk management objectives

An "Acceptable" Risk Quotient (RQ)

American Toad **LC_{50}**

Atrazine Concentration Lethal to
50% of Exposed American Toads
10,700 μg/L (ppb), water

Maximum Atrazine ppb = 120 (= EEC)

$$\mathbf{RQ} = \frac{EEC}{LC_{50}} = \frac{120}{10700} = 0.011$$

EPA decides the acceptability of the RQ

Toxicology-- Hazard Identification

- Endpoints
  - Death
  - Adverse Developmental & Reproductive Outcomes

Dose-Response Assessment

- Determining the most sensitive species and its toxicological endpoint
  - Acute Toxicity
    - Based on lethality over specified time
    - LC50 (aquatic or dietary terrestrial)
    - LD50 (birds/mammals)
  - Chronic Toxicity
    - Use life cycle tests (developmental/reproductive endpoints)
    - NOAEC (or NOEC)
    - NOAEL if dose controlled

Exposure Assessment

- EPA uses a nomogram to generate data on food resources of terrestrial animals
  - Based on a database of direct overspray studies conducted over 30 years ago and updated in 1994
- EPA uses modeling to generate residue data for exposure of aquatic organisms
  - Pesticide Root Zone Model **(PRZM)**
    - Models runoff from a 10 ha watershed into a static pond of 1 ha x 2 m deep
  - Exposure Assessment Modeling System **(EXAMS)**
    - Models residues within the pond
    - Does not account for volatilization or volume changes (for ex., in running water)

The "Kenaga" Nomogram for Estimating Terrestrial Exposure

Food Items	Maximum EEC (ppm)	Mean EEC (ppm)
Short grass	240	85
Tall grass	110	36
Broadleaf/forage plants; small insects	135	45
Fruits, pods, seeds, large insects	15	7

Need to know proportion of body weight consumed per day

EPA's Pesticide Eco Risk Characterization Guidelines

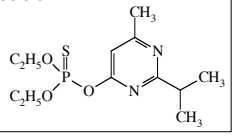
"Safe" level is based on use classification & organism status

Risk Category	Risk Quotient (RQ) Calculation	Level of Concern (LOC)	Effective Safety Factor
Acute High	EEC/LC50	**0.5**	2
Acute Restricted	EEC/LC50	**0.1**	10
Endangered Species	EEC/LC50	**0.05**	20
Chronic	EEC/NOEC	**1**	1

EEC = "Expected" Environmental Concentration

EPA's Ecorisk Assessment for Diazinon

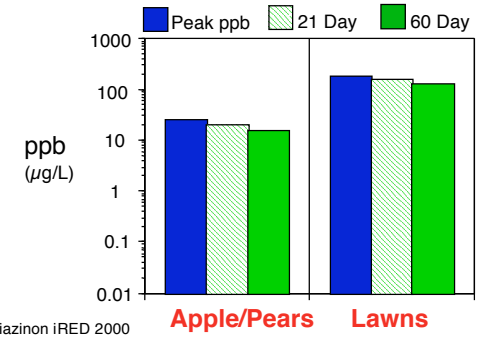
- Ecorisk characterizations for pesticides are published in a document called the Registration Eligibility Decision (RED)
- Includes human health and ecological fate and effects assessments
- Starts with overview of chemical, registration history, uses
- Discusses environmental chemistry & fate
- Discusses terrestrial and aquatic toxicity data & choice of most sensitive species
- Discusses results of exposure modeling
- Lists resulting RQs
- Discusses management decision



The Most Sensitive Aquatic Species Chosen by EPA in the Diazinon EcoRA

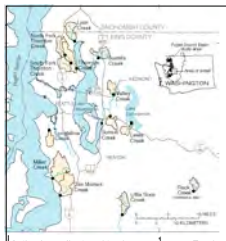
Species	Acute Toxicity LC50 (µg/L)	Chronic Toxicity NOEC (µg/L)
Rainbow Trout	90	--
Brook Trout	--	0.55
Scud	0.2	--
Water flea	--	0.17

Modeled Concentrations of Diazinon in Water Two Application/Use Scenarios



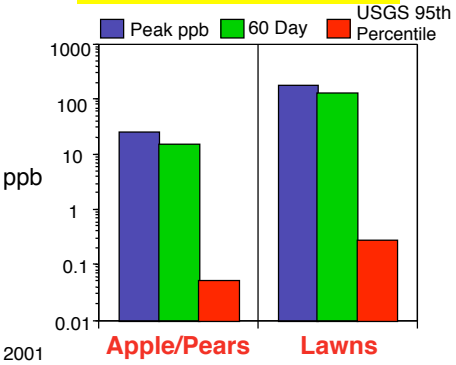
Diazinon iRED 2000

Puget Sound USGS NAWQ Results: Insecticides



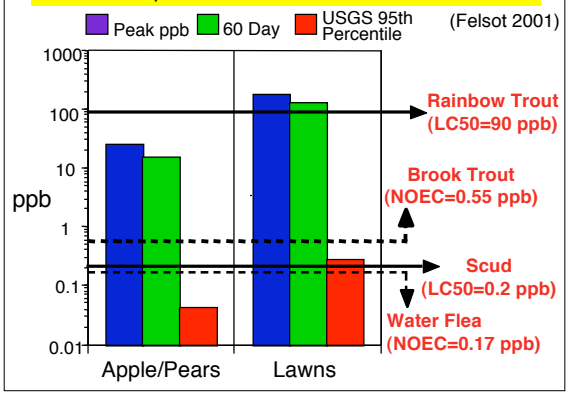
Active ingredient and trade name[1] example in parentheses	Freshwater aquatic-life criteria, in parts per billion -- no aquatic-life criteria exist: Acute	Chronic	RMC	Concentration, in parts per billion (ppb): RMC, recommended maximum concentration; Chronic aquatic-life criteria: 0.001	0.01	0.1	1	10
Insecticide								
Carbaryl (Sevin)	[4] 0.17	[4] 0.017	[2] 0.02					
Chlorpyrifos (Dursban)	[3,7] 0.083	[3,7] 0.041	[2] 0.001					
Diazinon (Diazinon)	[6] 0.16	[6] 0.04	[2] 0.009					
gamma-HCH (Lindane)	[3] 0.95	[7] 0.08	[2] 0.02					
Malathion (Malathion)	--	[3] 0.1	[2] 0.008					

Modeled vs. Empirical Residues of Diazinon in Water



Felsot 2001

Diazinon Exposure Relative to Hazard Benchmarks



Risk Characterization Guidelines

Risk Category	RQ Calculation	Level of Concern	Effective Safety Factor
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Endangered Species	EEC/LC50	**0.05**	20
Chronic	EEC/NOAEC	**1**	1

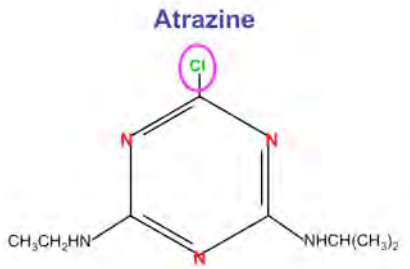
RQs for Diazinon
Modeled and Empirical Residue Levels

Exposure Scenario	Exposure Duration	Fish	Invertebrates
Apple/Pear	Acute	0.28	126
Apple/Pear	Chronic	28	121
Lawns	Acute	2.0	912
Lawns	Chronic	235	928
	USGS 95th%tile		
Urban Sites	Acute	0.01	1.2
Urban Sites	Chronic	0.44	1.4
Agric. Sites	Acute	0.0005	0.21
Agric. Sites	Chronic	0.08	0.25

EPA "Decisions" for Diazinon

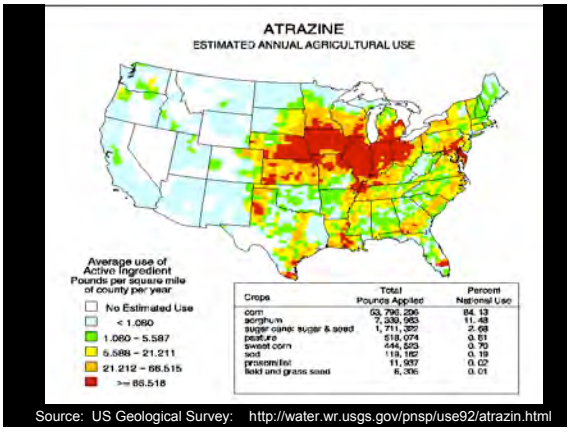
- Based on EPA modeled exposure (the EEC), all RQ's far exceeded the levels of concern
  - However, the RQ's were orders of magnitude lower if the USGS NAWQA database data were used
  - Nevertheless, the RQ's for endangered species concern would still be exceeded
- Because most of the diazinon hits were in urban watersheds (with the exception of the San Joaquin River Basin in California), EPA focused on mitigation in these areas
  - Basically, the manufacturer of diazinon decided to pull the pesticide off the urban use market
  - EPA restricted use and applications rates in other crops with registrations

Atrazine EcoRisk Assessment



Atrazine
Ecological Toxicity Endpoints

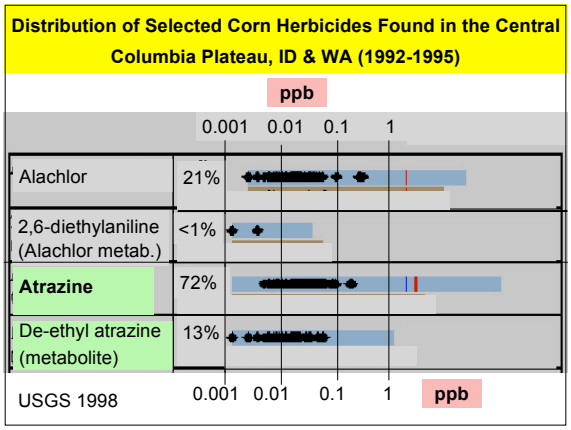
Species	Acute Toxicity (LD50 or LC50)	Chronic Toxicity (NOAEC)
Birds	940 mg/kg	225 ppm
Mammals	1869 mg/kg	10 ppm
Honey Bees	96.7 µg/L	---
Fish	5300 µg/L	65 ppb
Aquatic Invertebrates	720 µg/L	60 ppb
Aquatic Plants	18 µg/L	**2.3 ppb**

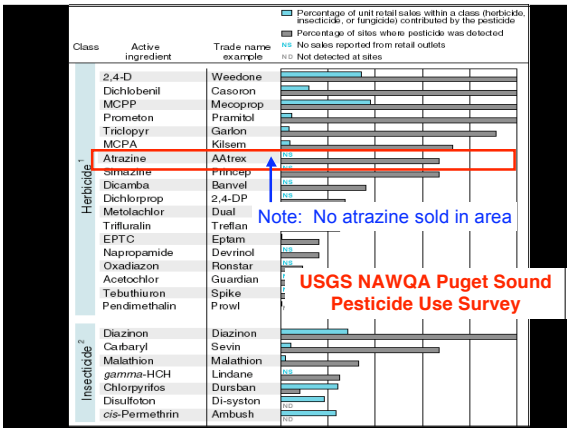


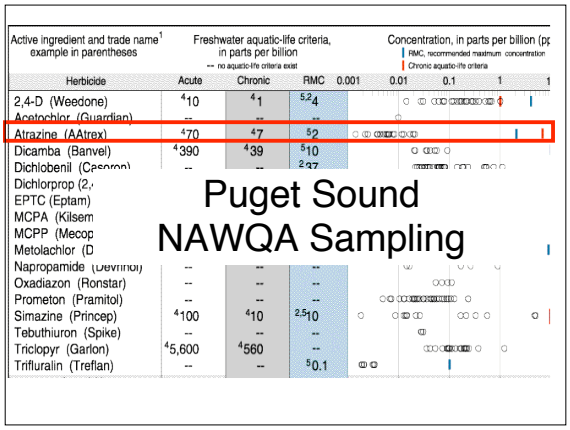
Source: US Geological Survey: http://water.wr.usgs.gov/pnsp/use92/atrazin.html

EPA Documents--
Aquatic Persistence

- The half-life in six field studies (lakes, mesocosm, and experimental pond) varies from 41 to 237 days with a mean of 159 days.
- Modeling studies
  - After 90 days, EPA predicts a 6-ft deep pond will contain 19 ppb atrazine, assuming an adjacent 1 lb AI/acre application







USGS NAWQA Program Data U.S. Perspective--Surface Waters

Percentile Concentration (µg/L) of Atrazine Resides

Indicator Site	Maximum	99th	95th	90th	50th
Agriculture	120	13	3.25	1.2	0.027
Urban	14	2.75	0.65	0.33	0.041
Integrator	27	12.5	5.35	1.95	0.062

Risk Characterization Guidelines

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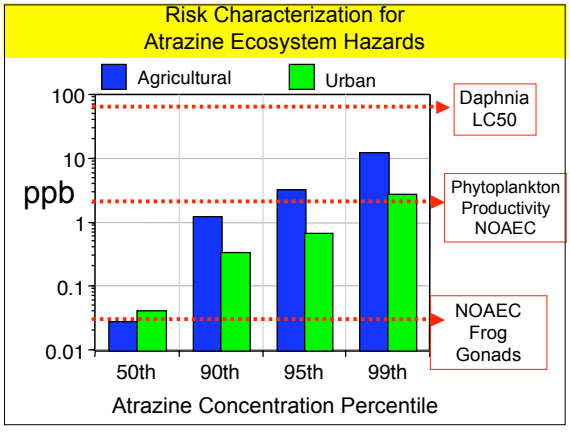
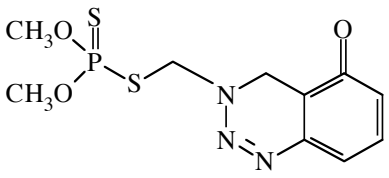


EPA's Risk Characterization Conclusions

- In areas of high atrazine use, exposure is sufficient to result in…
  - Direct acute effects on terrestrial plants
  - Direct effects on aquatic plants and reductions in primary productivity
  - Reductions in populations of aquatic macrophytes, invertebrates & fish
  - Changes in structural and functional characteristics of aquatic communities due to indirect effects

Azinphos-methyl Ecorisk Assessment



Threatened or Endangered Species Listings in Salmon Recovery Regions

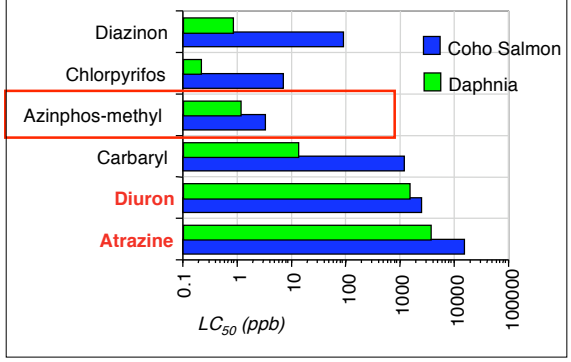
Management Forced by the Endangered Species Act

- Lawsuit filed by WA Toxics Coalition
  - EPA found "not in compliance" with Endangered Species Act
- Injunction filed to require a no-spray buffer zone around salmon-bearing water bodies
  - Pertains to pesticides EPA deems "may affect" salmon
  - Aerial application: 300 ft no spray buffer
  - Ground application: 60 ft no spray buffer

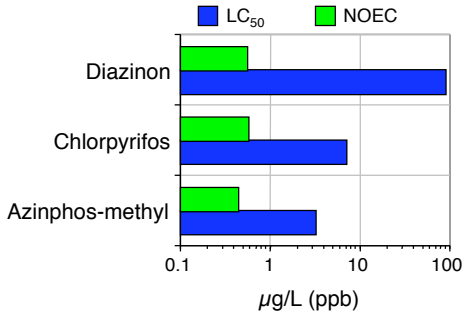
EPA Determination: May Effect

Acrolein	**Diazinon**	Metolachlor
Azinphos-methyl	Dichlobenil	Oryzalin
Bensulide	Diuron	**Phorate**
Carbaryl	**Fenbutatin Oxide**	Prometryne
Chlorpyrifos	**Methomyl**	**Propargite**

Acute Toxicity (LC_{50}) of Pesticides to Coho Salmon (or closely related spp.) and Daphnia



Toxicological Endpoints for Fish Spp.



EPA Models Guthion Exposure

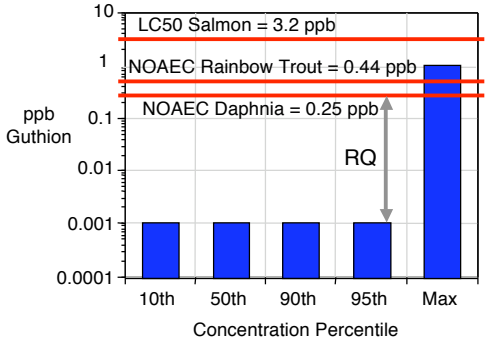
- Using Guthion as an example, EPA assumed no aquatic breakdown (data were not available)
- Estimated peak concentration (right after spraying an orchard) as 13.9 ppb
  - 60 days later, the concentration is 9 ppb
- To be "safe" for endangered species, EPA said the concentration would have to be 0.06 ppb or less
  - Safe residue is based on the most sensitive fish spp. (Brook trout, LC50=1.2 ppb) and a 20-fold safety factor
  - i.e., Acceptable RQ = 0.06 ppb/1.2 ppb = 0.05

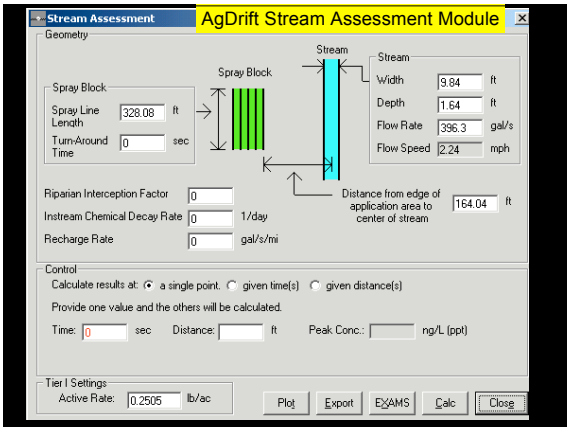
Exposure Assessment

Concentration Distribution of Pesticides
NAWQA Program--All Surface Water Sites

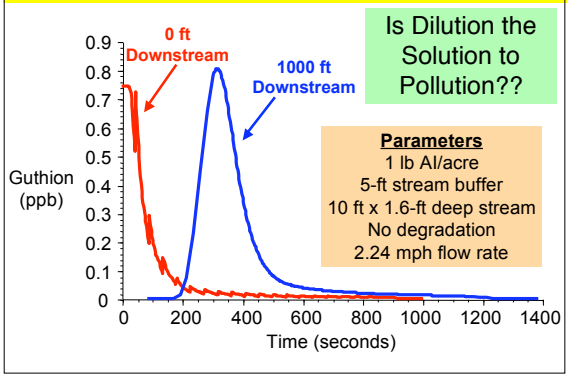
Pesticide	10th	50th	90th	95th	Maximum
atrazine	<0.001	0.03	0.70	2.00	120.0
deethyl	<0.002	0.10	0.10	0.17	1.1
diuron	<0.02	<0.02	0.03	0.22	14.0
metolachlor	<0.002	0.01	0.33	0.91	70.0
carbaryl	<0.003	<0.003	0.01	0.06	5.5
carbofuran	<0.003	<0.003	<0.003	0.02	9.7
azinphos-methyl	<0.001	<0.001	<0.001	<0.001	1.0
chlorpyrifos	<0.004	<0.004	0.01	0.03	0.4
diazinon	<0.002	<0.002	0.05	0.13	3.8

Distribution of Azinphos-methyl (Guthion) Residues in U.S. Surface Water (USGS NAWQA Program)





Guthion (azinphos-methyl) Residues in a Flowing Stream Following an Airblast Sprayer Application to an Orchard



Is Dilution the Solution to Pollution??

Parameters
1 lb AI/acre
5-ft stream buffer
10 ft x 1.6-ft deep stream
No degradation
2.24 mph flow rate

The Bottom Ecorisk Line

- Nearly all OP insecticides exceed EPA's Levels of Concern for aquatic exposure
- However, the picture is not as bleak if real data are used
- Herbicides and fungicides are more likely to be below EPAs LOCs

Consequences of Exceeding EPA's Levels of Concern

- Label Changes
  - Increased demands for lower rates
  - New formulations
  - Increased re-entry intervals
  - No spray buffer zones
  - Cancelled uses
  - ???????