Environmental Safety of Pesticides

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Pesticide use is tightly regulated in most countries because

- Pesticides are intentionally released to the environment
- designed to show considerable biological activity

Use is permitted only for specific purposes:
defined
crop-pest-time-dose-combinations
evaluated and found safe

Legally speaking....

"Registration is granted, if

- the product is sufficiently suited for the purpose intended for....
- does not give rise to significant adverse effects"

Aspects of Pesticide Safety

Exposure

- dermal
  contamination
  penetration
- inhalation

Toxicity

- acute
- subacute
- chronic
- mutagenicity
- reproduction
- metabolism
  in animals

Residues

- fate in plants
- residue analysis
  methods
- A.I. and
  metabolites
- residues in food

Environmental Fate

- hydrolysis
- photolysis
- degradation in
  soil and water
- mobility in soil
- volatility
- bioaccumulation

Ecotoxicity

- birds
- fish
- crustaceans
- algae
- aquatic plants
- earthworms
- soil microbes
- beneficial
  arthropods
- bees

Applicator Safety Assessment

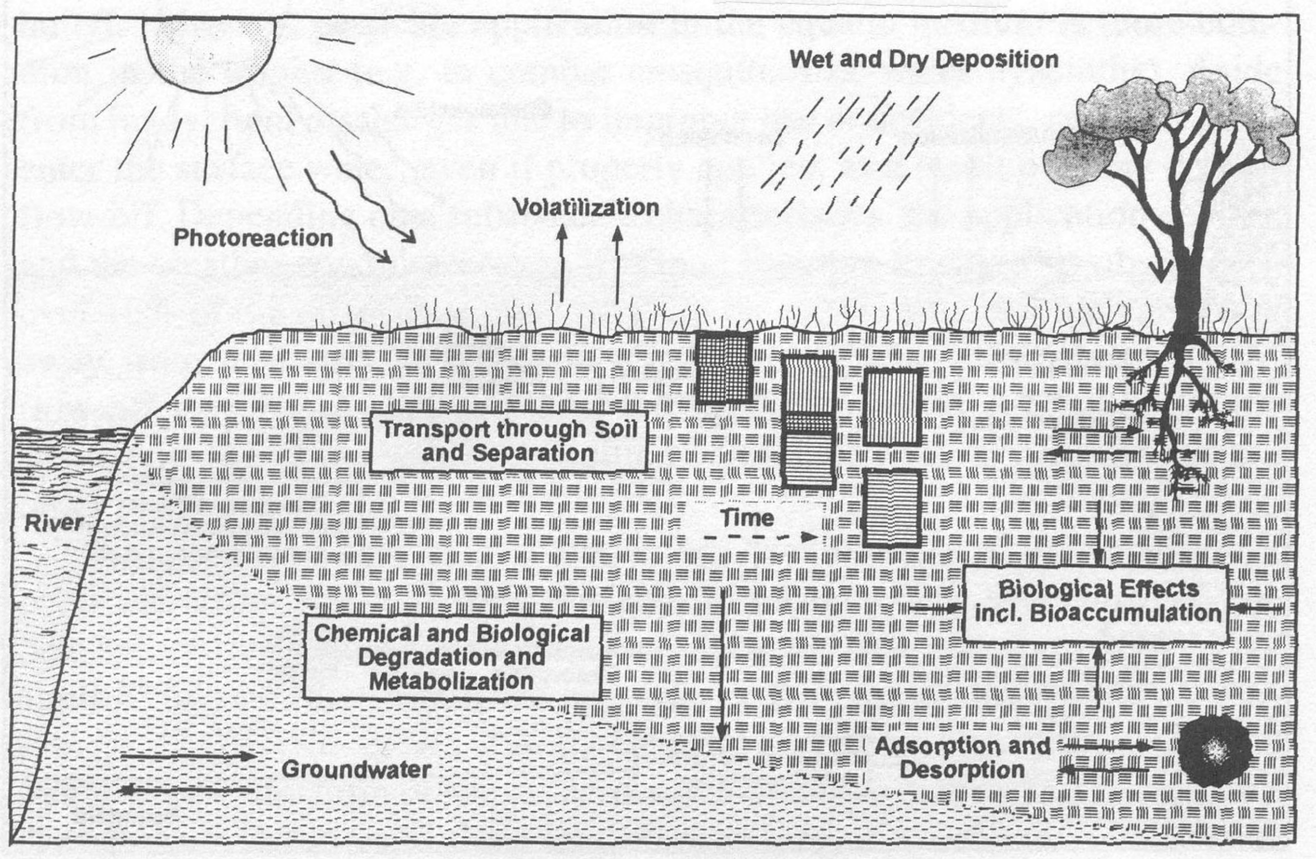
Consumer Safety Assessment

Environmental Safety Assessment

FAW

the assessment team is confronted with....

- an amazing complexity of environmental processes....



•and a “data-rich” situation....

Structured approach to reduce the complexity processes in soil: biodegradation, photolysis, sorption

1.1 laboratory studies using 14C-labeled compounds to provide

- complete mass balance (route)
- identification of metabolites (rates)
- mobility in soil of parent and metabolites

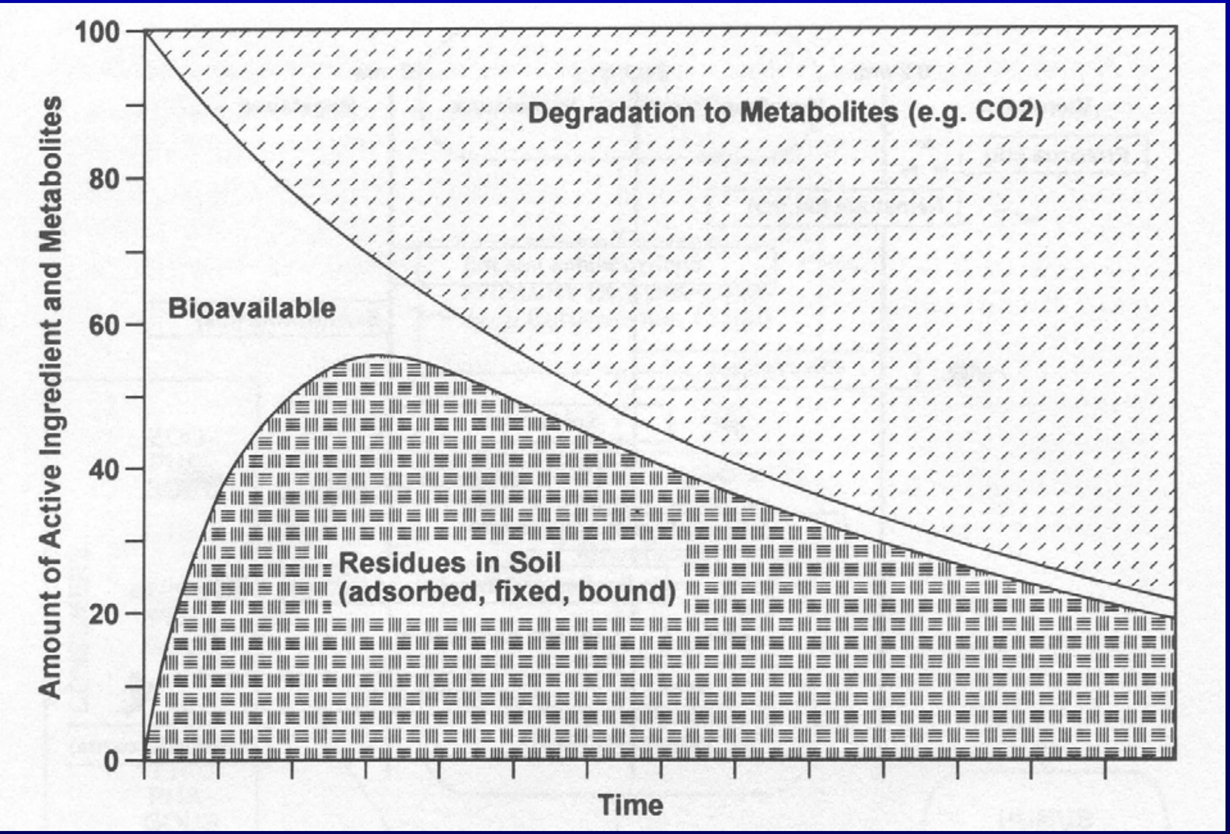
1.2 field studies giving information on

- dissipation of active compound and metabolites
- accumulation in soil
- lysimeter/field leaching study

2. processes in water and water-sediment systems:
· hydrolysis,
· photolysis,
· behaviour in a water-sediment system

3. processes in air:
· evaporation from surfaces (soil, leaves)
· atmospheric lifetime

Degradation in soil: use of ^{14}C-labeled compounds allows establishment of routes and rates (mass balances)



Decision Making Scheme and Tier-wise Approach for Fate in Soil

Soil degradation studies in the laboratory

↓

$dt50_{lab}$ > 60 d (20 °C) or $dt50_{lab}$ > 90 d (10 °C)

↓

Field dissipation studies (normally four soils)

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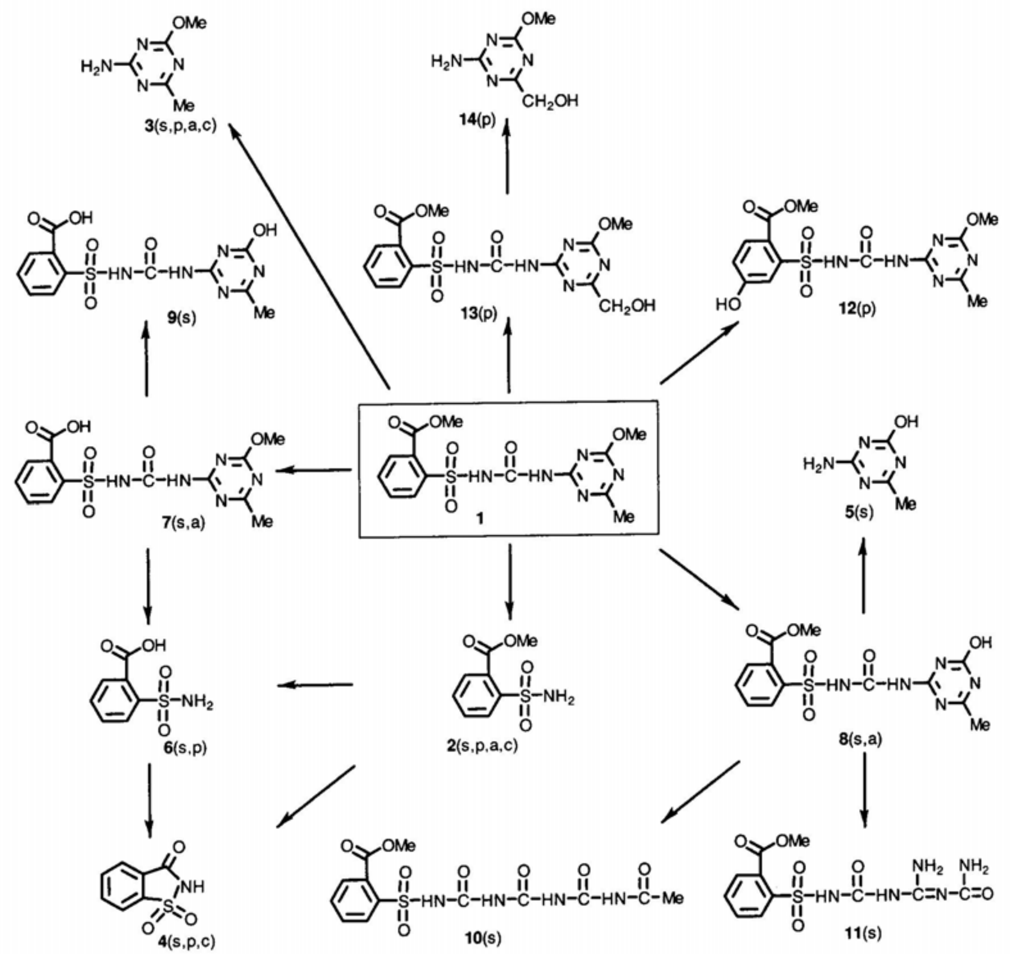
$dt50_{field}$ > 3 months and $dt90_{field}$ > one year

Example: fate of the herbicide metsulfuron-me in soil (selective herbicide in grain, approx. 10 g/ha)



Scheme 1 Metabolic pathways of metsulfuron methyl.

Route of degradation of metsulfuron-me in soil: (data from published EU review)

Aerobic: Mineralization after 100 days	32 % (phenyl, 112d, 1 soil) 11.4% (triazine, 90d, 1 soil) 10% (triazine amine, 1 soil) - 38% (65w)
Non-extractable residues	12 - 25% (phenyl, 98d, 3 soils) 17.6% (triazine, 90d, 1 soil) 6% (triazine amine, 1 soil) - 10% (65w)
Relevant metabolites above 10% of applied active substance: name and/or code % of applied (range and maximum)	4 soils IN-D5803: Ester Sulfonamide max. 17% (4w), <4% (24w) IN-D5119: Acic sulfonamide <10% (16%, 24w, 1 soil) IN-B5685: Phenylurea, max. 17% (14w) IN-00581: Saccarin max. 41% (8w), <33% (14w) 1 soil IN-A4098: Triazine amine, max. 33% (12w) IN-NC148: carbamoyl guanidine max. 16% (12w), <3% (52w) IN-B5067: O-desmethyl metsulfuron, max. 11% (10d), <2% (52w)

Rate of metsulfuron-me

Laboratory studies: DT50lab (20°C, aerobic)	Metsulfuron 22°C, aerobic 23 - 29d (2 soils) 25°C, aerobic 20 - 51d (mean, 31.6d, 7 soils) 25°C, sterile 61 - 405d (7 soils) Triazine amine 25°C, aerobic 210d (1 soil) Other metabolites: no DT50 value provided. Saccharin is persistent; ester sulfonamide is not persistent (DT50<< 1 month); O-desmethyl metsulfuron methyl and carbamoyl guanidine are less persistent than saccharin.
DT90lab (20°C, aerobic)	22°C, aerobic 76 - 98d (2 soils) 25°C, aerobic 94 - 320d (2 soils) 25°C, sterile 203 - 1344d (7 soils)
DT50lab (10°C, aerobic)	no data
DT50lab (20°C, anaerobic)	no data

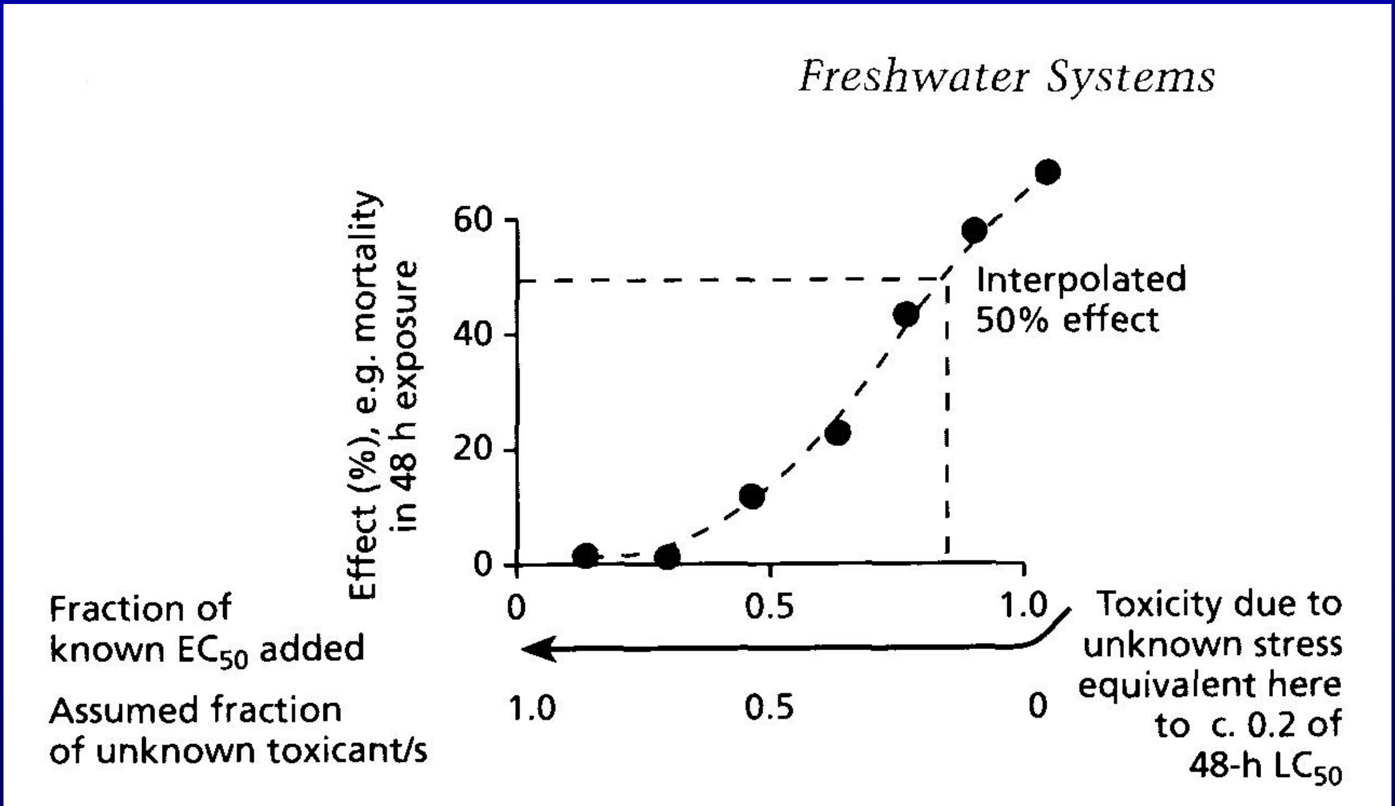
Estimation of Predicted Environmental Concentrations (PECs)
using generic environment/realistic worst case scenarios

PECsoil: use of models (PELMO) or simple first order degradation

PEC_{water} use of models drift estimation (Ganzelmeyer) leaching, run off

and comparison to ecotoxicity data of selected organisms

Typical dosis-effect curve in aquatic tests



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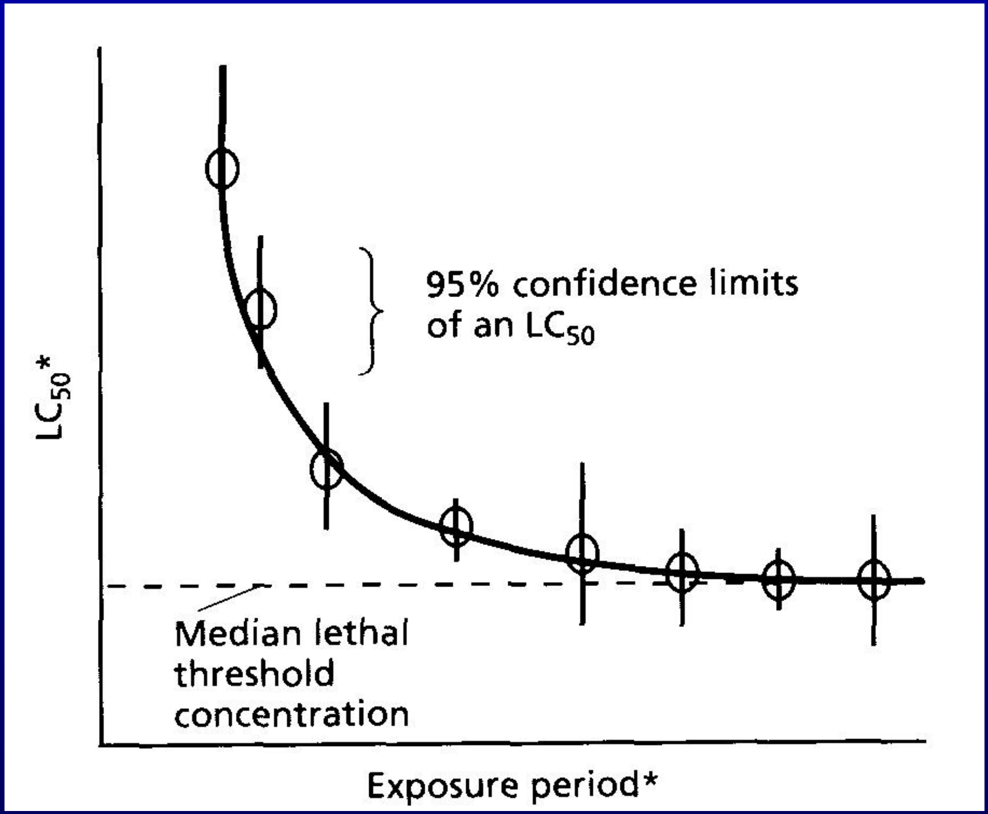
Typical exposure period-response relationship in aquatic tests



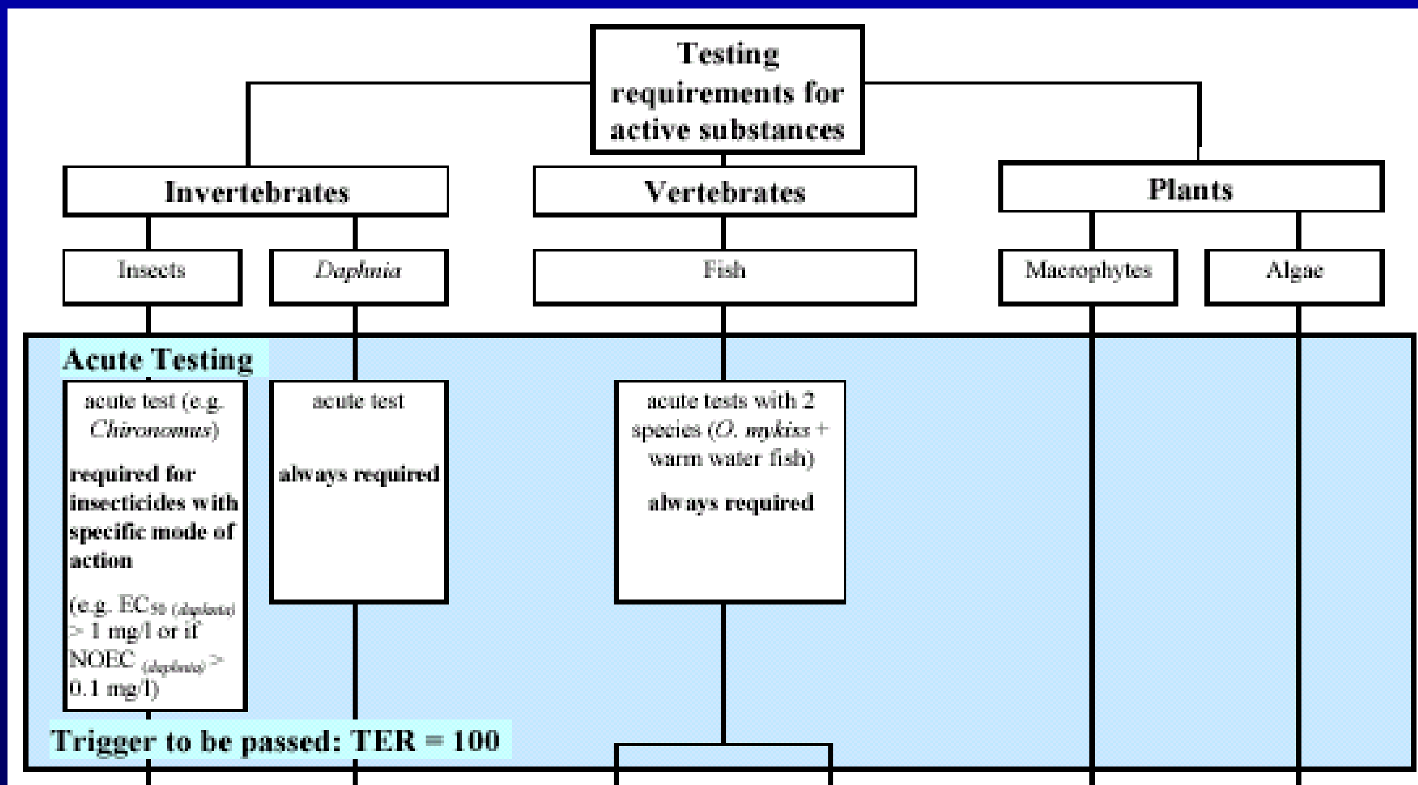
Striking a balance:

- possible toxicity on non-target organisms expressed as effect concentrations (NOEC, EC_{50})

- Initial and time-weighted average concentrations are compared to effect concentrations by a toxicity-exposure ratio TER

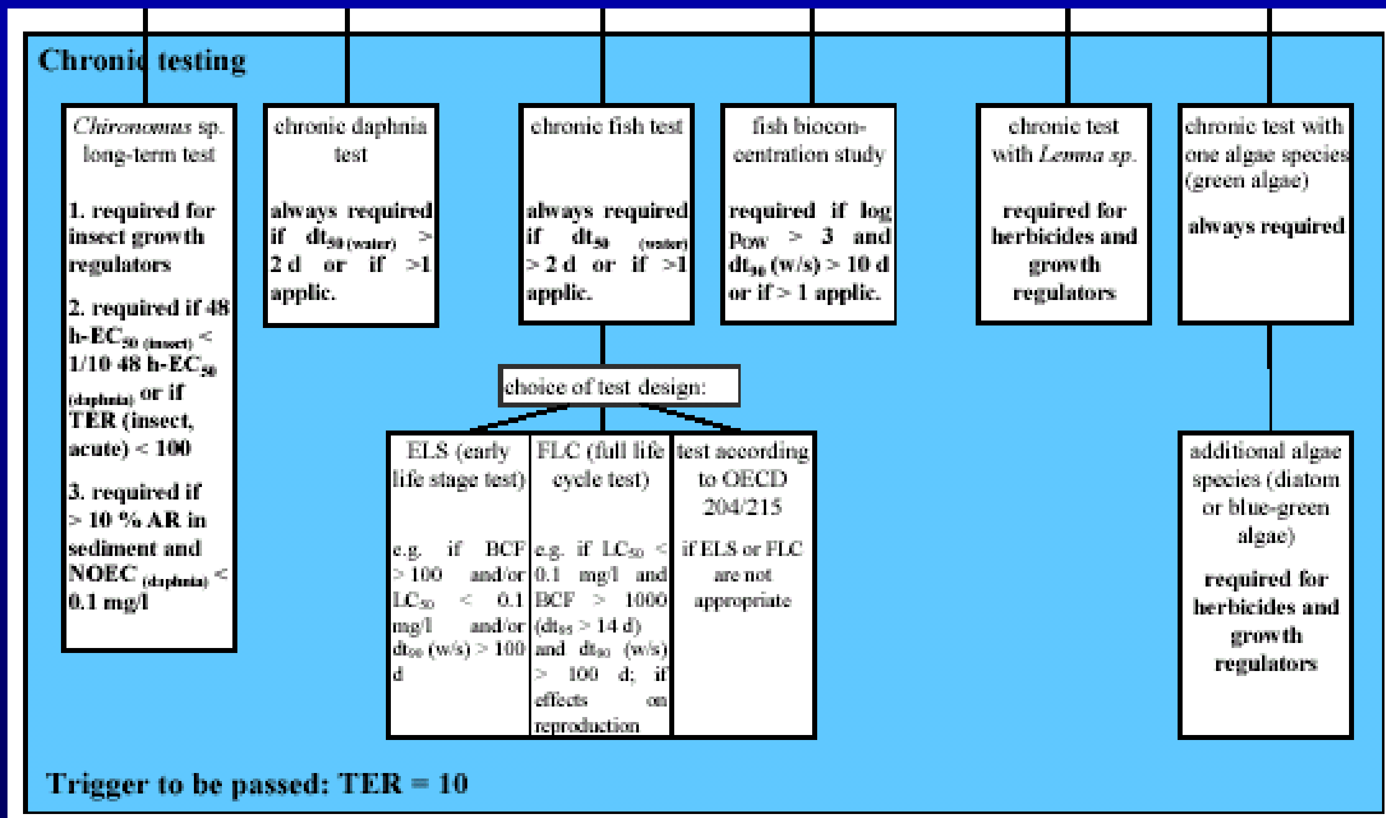
- TER > 100 are considered to be safe

Evaluation of effects on non-target-organisms: First Tier



Expression of Risk as Toxicity-Exposure Ratio (TER)

Higher tier is triggered by TER > 100



Effects of metsulfuron-me on aquatic organisms

Acute toxicity fish	LC_{50} (96 h) > 150 mg/l
Chronic toxicity fish	NOEC (21 d) 68 mg/l
Bioaccumulation fish	whole fish < 1 (low P_{ow} = -1.7 at pH)
Acute toxicity invertebrate	EC_{50} (48 h D. magna) > 150 mg/l
Chronic toxicity invertebrate	NOEC (21d, daphnids) 150 mg/l
Acute toxicity algae	EC_{50} (72 h S. capricorn.) 0.045 mg/l
Acute toxicity on aquatic plants	EC_{50} (L. gibba) 0.00036 mg/l
Acute toxicity on sediment dwelling organisms	not required

Estimation of PECwater with different scenarios

	no buffer zone (4.0% drift)		3 m buffer zone (1.0% drift)		5 m buffer zone (0.6% drift)	
days after max. concentration (after application)	PEC_{sw} (µg / L)	PEC_{sed} (µg / kg)	PEC_{sw} (µg / L)	PEC_{sed} (µg / kg)	PEC_{sw} (µg / L)	PEC_{sed} (µg / kg)
initial	**0.200**	0.174	**0.050**	0.044	**0.030**	0.026

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Assuming a 3 m buffer zone:

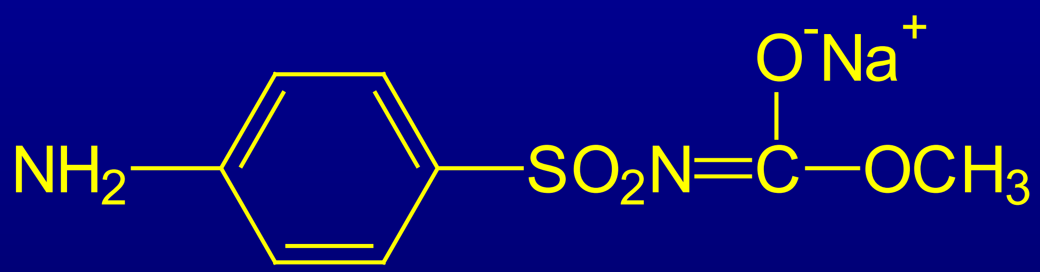
Estimation TER for fish: $3.6 \cdot 10^5$
Estimation TER for Lemna (aquatic plant): 0.9

note how the highly specific mode of action of the sulfonylurea herbicide is expressed in the corresponding TER values

Case Study:

Comparison of possible contamination of groundwater through application of asulam in spring or autumn

Asulam is used in pastures to control Rumex spp. at rates of 2.8 kg ai/ha



Asulam is weakly adsorbed and degraded with typical half lifes of 8 – 28 d.

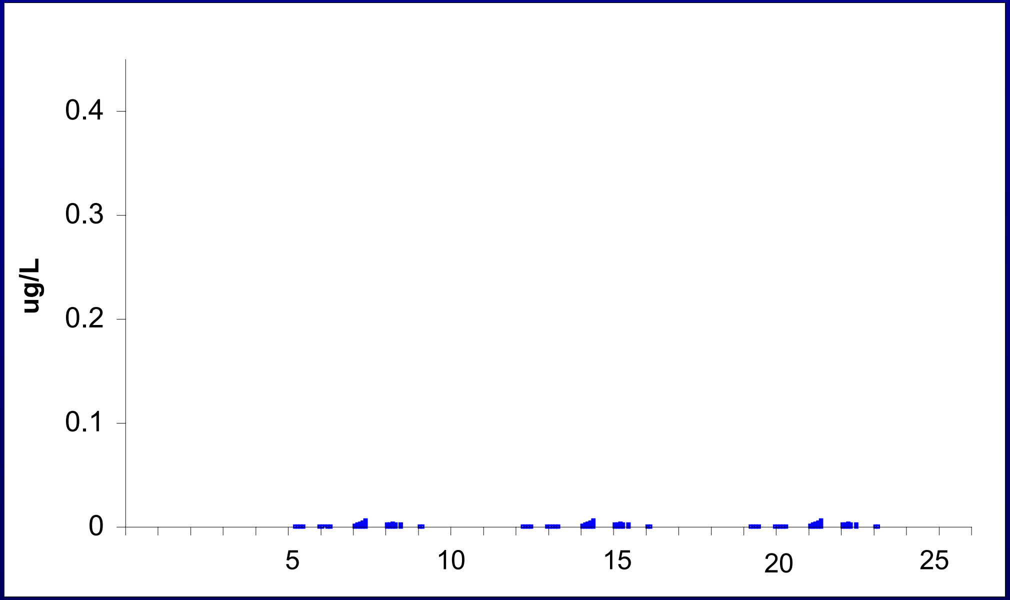
Problem: Use of asulam in spring leads to contamination of honey via nectar

Question: is a use in autumn (mid-october) safe?

Answer: Modelling of PEC_{GW} using a numerical model (PELMO). Application in late spring:

Frühlingsanwendung

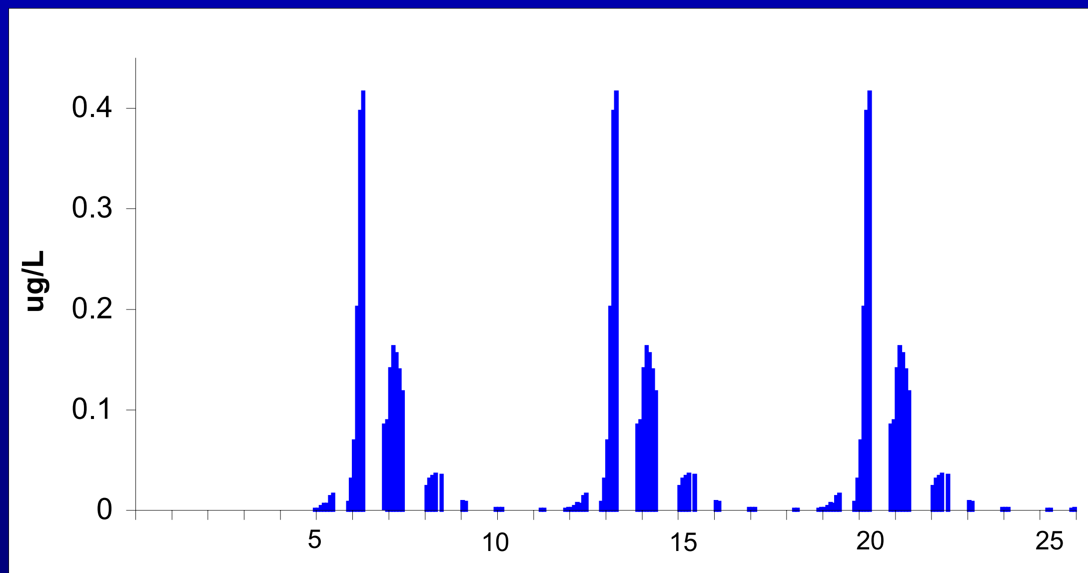
K_{OC}= 40, DT_{50} = 14d



Application in mid October:

Herbstanwendung

K_{OC}= 40, DT_{50} = 14d



Note the difference in the PEC_{GW} due to increased net percolation of water in soil

Conclusions:

- The size and complexity of the data set for modern pesticides can be compared to that for new drugs
- The environmental safety of pesticides is a multi-disciplinary task involving chemists, environmental chemists and biologists
- The foundation of data requirements is clearly defined, but the extrapolation to “real environment” calls for in depth expert knowledge
- Pre-registration evaluation of environmental safety can profit from post-registration environmental monitoring.

Thank you for your attention!