Introduction to Ecotoxicology

Francesca Tencalla

Outline

1. What is ecotoxicology?
   - Definition
   - Main objectives
   - Similarities and differences with human toxicology
   - How did it develop as a discipline?

2. Environmental risk assessment
   - Basic principles
   - Problem formulation
   - Hazard assessment
   - Exposure assessment
   - Characterising risk

3. Example of environmental risk assessment

BelTOX

Definition (1)

A branch of toxicology concerned with:

"the study of toxic effects, caused by natural or synthetic pollutants, to the constituents of ecosystems (animal, vegetable and microbial), in an integral context"

(**Ref:** Truhaut, R. 1977, "Eco-Toxicology - Objectives, Principles and Perspectives", Ecotoxicology and Environmental Safety, vol. 1, no. 2, pp. 151-173.)

BelTOX

Definition (2)

- Ecotoxicology is a young discipline, first defined by René Truhaut in 1969
- Ecotoxicology attempts to integrate **eco**logy and **toxicology**

Definition (3)

Ecotoxicology uses tools from other disciplines:

- Environmental sciences
- Ecology
- Aquatic and terrestrial toxicology
- Molecular, animal and plant biology
- Analytical chemistry
- Statistics & mathematical modeling
- …a wealth of tools from different disciplines to study the effects of pollutants in an ecosystem

BelTOX

Main Objectives

- Obtain data for risk assessment and environmental management
- Meet legal requirements for the development and release of new products into the environment
- Develop empirical or theoretical principles to improve knowledge of the behaviour and effects of chemicals in living systems

BelTOX

Similarities with Human Toxicology

=

- Interdisciplinary science, includes many sub-specialties
- Used in the same areas (foods & food contaminants, drugs, pesticides, consumer goods and chemicals)
- Definition of protection goals is socially/ politically driven

Differences with Human Toxicology (1)

≠

- Protection goals are broader:
  - Protection not of an « individual » or even of « individual species » but « structures and functions in an ecosystem »

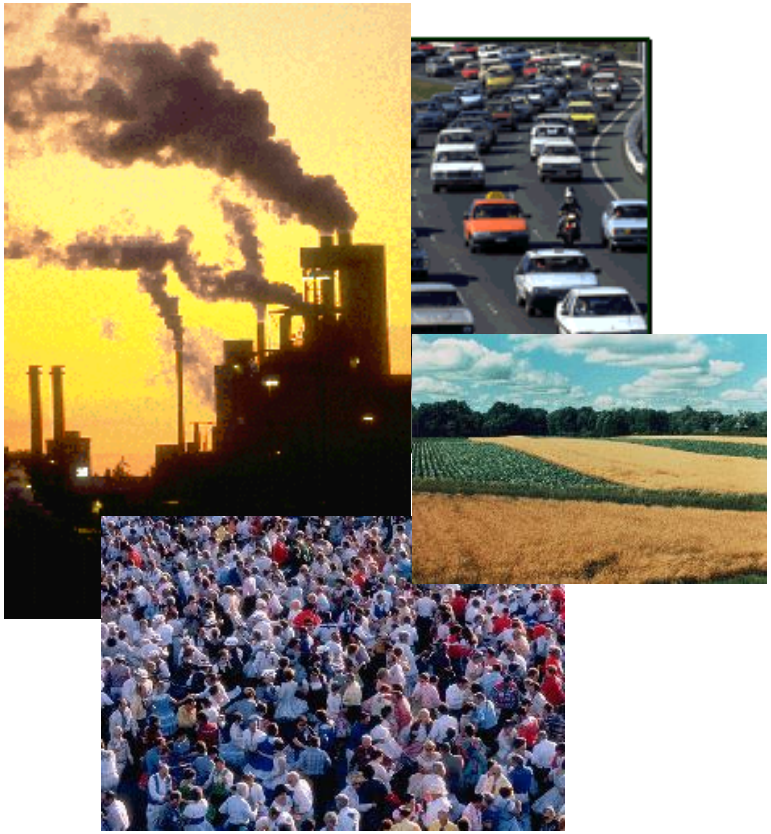
Differences with Human Toxicology (2)

≠

- Protection goals are different:
  - Protection not of an « individual » or even of « individual species » but « structures and functions in an ecosystem »
- Evaluation methods and background comparative data is sometimes missing

BelTOX

How did it Develop as a Discipline?

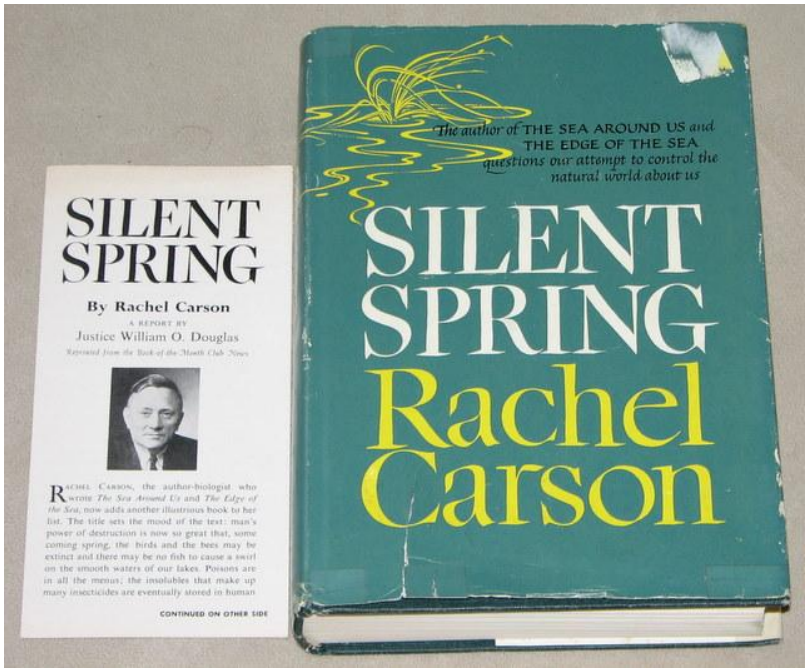


- After WWII, increasing concern about the impact of toxic discharges into the environment:
  - Toxicology expanded to environmental toxicology,
  - Then to ecotoxicology

How did it Develop as a Discipline?

Carson's Government Photo (1940s)

- Catalysed by the publication in 1962 of **“Silent Spring”** by Rachel Carson:
  - extrapolation from single-organism effects to effects at the whole ecosystem and the "balance of nature“



Outline

1. What is ecotoxicology?
   - Definition
   - Main objectives
   - Similarities and differences with human toxicology
   - How did it develop as a discipline?

2. Environmental risk assessment
   - Basic principles
   - Problem formulation
   - Hazard assessment
   - Exposure assessment
   - Characterising risk

3. Example of environmental risk assessment
   - Pharmaceuticals

BelTOX

Basic Principles (1)

- Environmental risk assessment characterizes the potential adverse effects of human-caused changes on the environment
- For example:
  - Introduction of a new chemical
  - Import of a new species
  - Changes to a landscape

Basic Principles (2)

- Used by:
  - Industry
  - Government regulatory agencies/legislators
  - Organisations involved in environmental protection
  - …

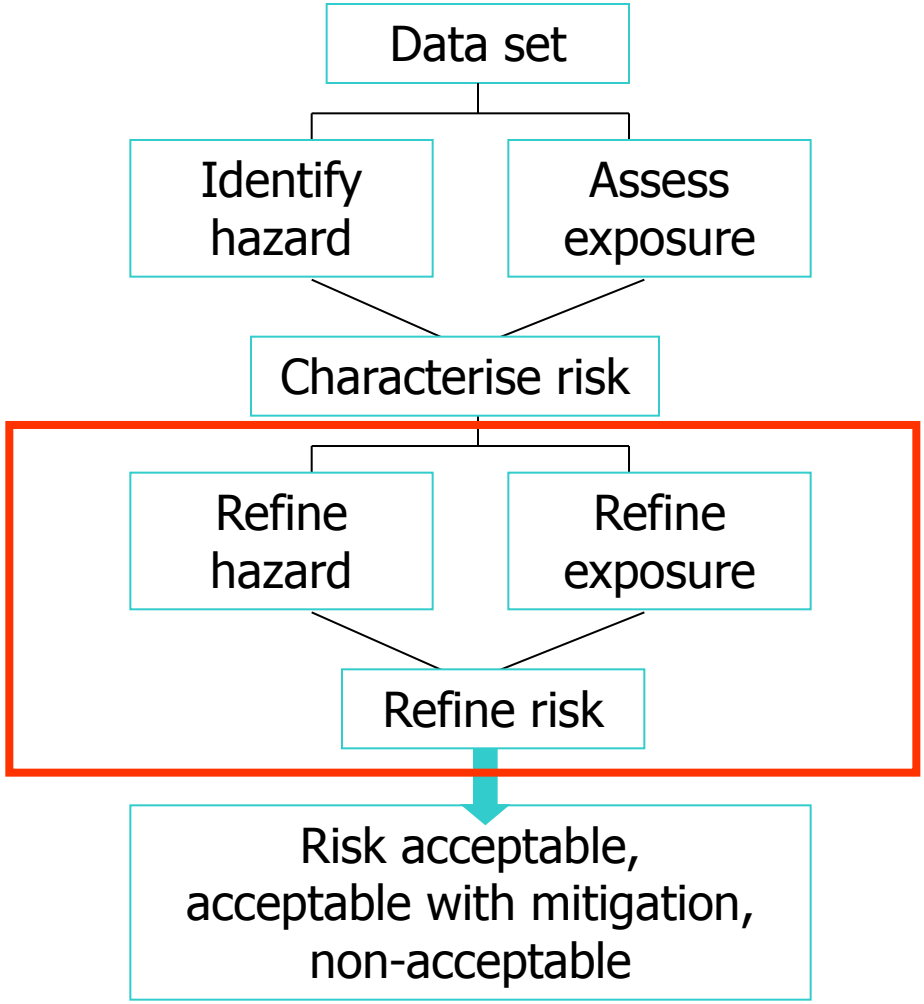
Basic Principles (3)

- Basic steps:
  - Problem formulation
  - Hazard identification
  - Exposure assessment
  - Risk characterisation

Risk= f(hazard, exposure)

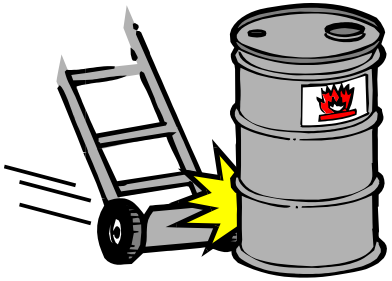
Basic Principles (4)

Risk assessment is an iterative process



Problem Formulation

- What type of agent? (chemical, biocide, pesticide, crop…)
- What information is available on this agent?
- What is the relevant legislation?



Hazard identification

Hazard = intrinsic capacity
of a substance to cause harm

Paracelsus,
1493-1541

« All things are poison and nothing is without poison, only the dose permits something not to be poisonous »

Toxicity

Kitchen salt ***Botulism toxin***

BelTOX

Hazard Identification

Hazard = intrinsic capacity
of a substance to cause harm

Determined based on:

(Q)SARs

Testing

(Q)SAR: (quantitative) structure activity relationship

BelTOX

Testing

- Tests on single species under artificial (laboratory) conditions
  - Variable duration: acute, long-term, life-cycle
  - ‘Worst-case conditions’
- Extended laboratory or semi-field testing (model ecosystems)
- Field testing

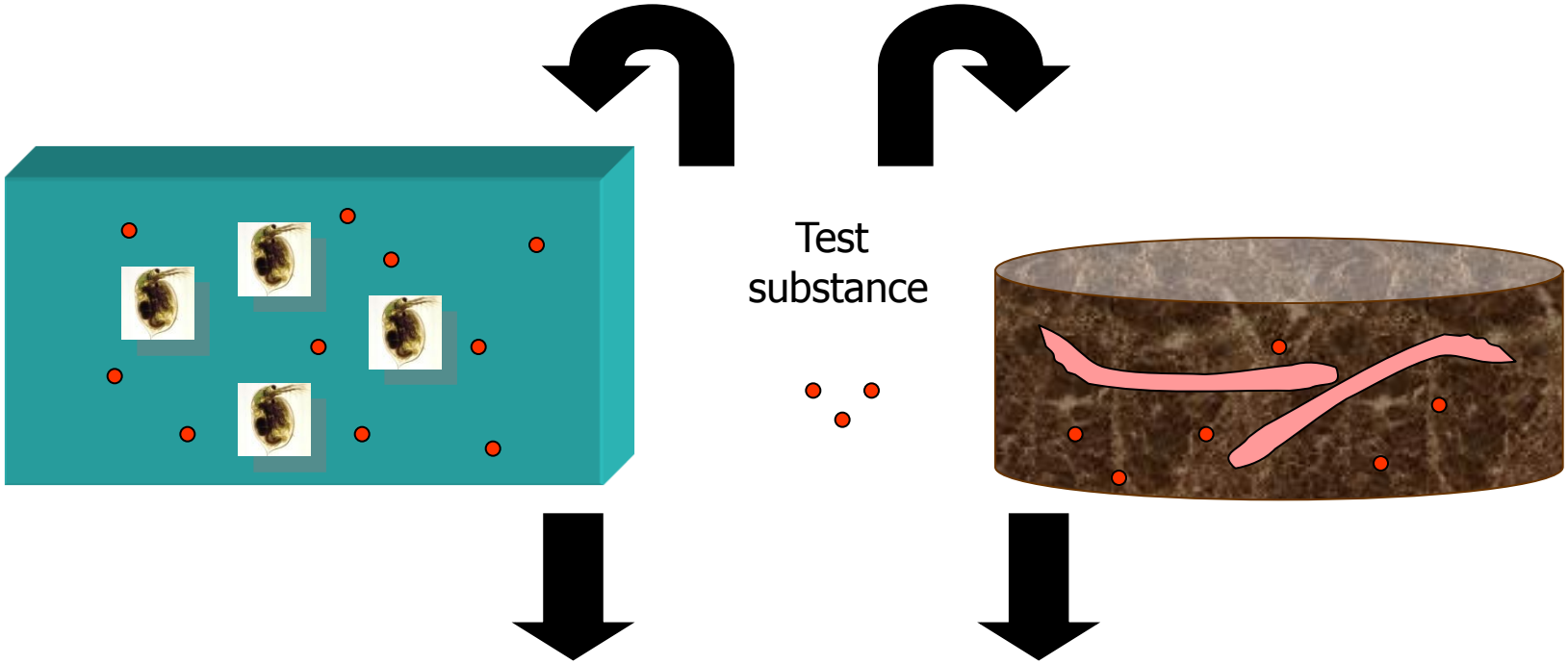
→ **Extrapolate to whole environment**

BelTOX

Testing principles

- Standardized protocols (for ex. OECD methods) and
- Use of Good Laboratory Practices (GLP)

Testing principles



Dose which causes and effect on 50% of the individuals (mortality, immobilisation, growth)

=

EC50, LC50

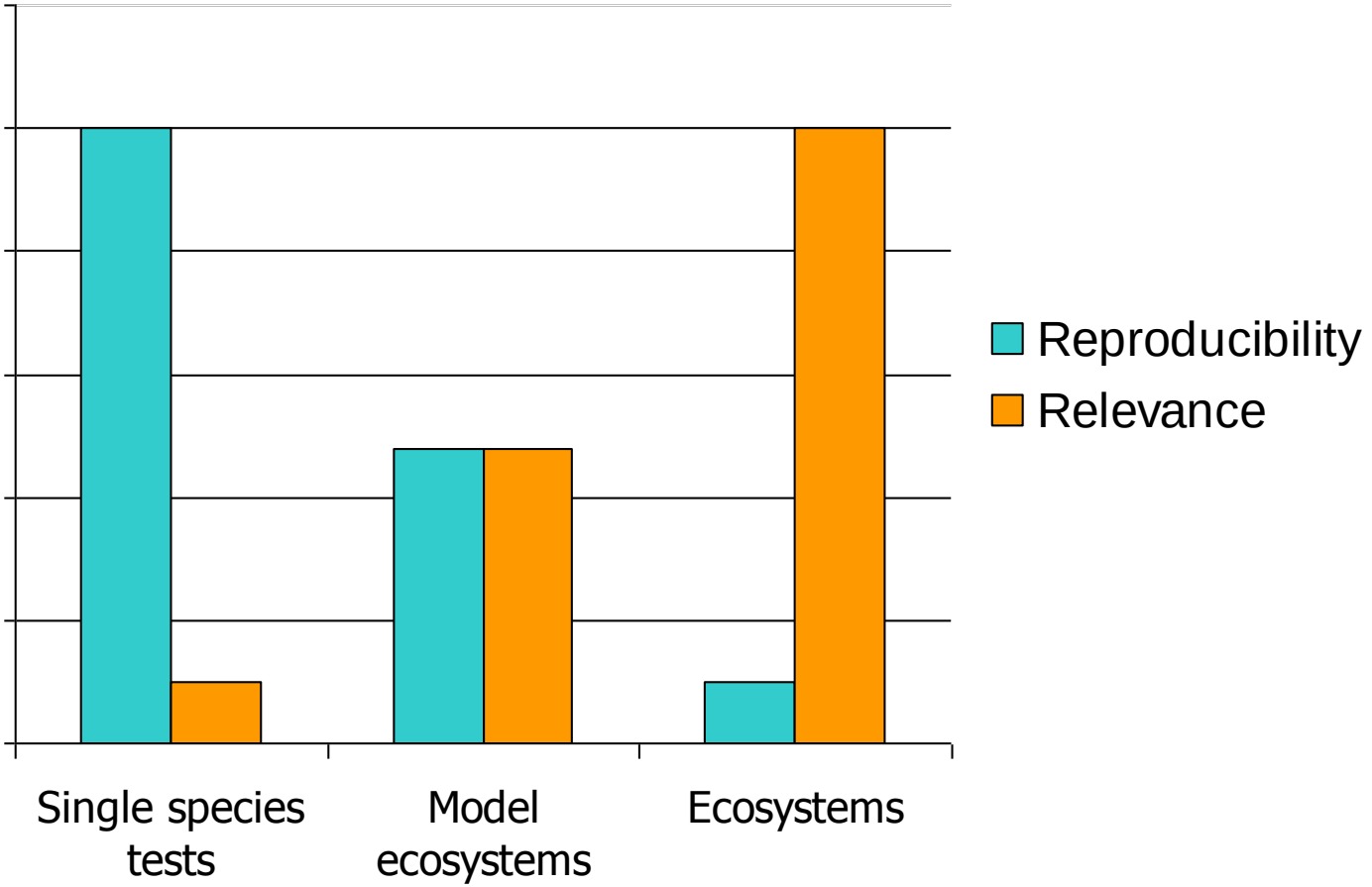
BelTOX

Endpoints

- EC50
  - Effects Concentration for 50% of population
    - e.g. 48h Daphnia effect (immobilization), 96/120h algae EC50
- LD50
  - Lethal Dose to 50% of test population
    - e.g. avian acute oral LD50
- LC50
  - Lethal Concentration to 50% of test population
    - e.g. 96h fish study, avian acute LC50 (dietary)
- NOEC
  - No Observed Effect Concentration
    - e.g. 21d Daphnia reproduction study

BelTOX

Laboratory vs Field



(From: Lehrbuch der Toxikologie, Marquardt & Schäfer eds (1994))

What Species?

- Aquatic
  - Fish
  - Aquatic invertebrates
  - Algae
  - Aquatic plants
  - Benthic invertebrates
- Terrestrial
  - Birds
  - Other terrestrial vertebrates
  - Bees and other non-target arthropods
  - Earthworms and soil macrofauna
  - Soil microorganisms
  - Non-target plants

Surrogate Species

Aquatic

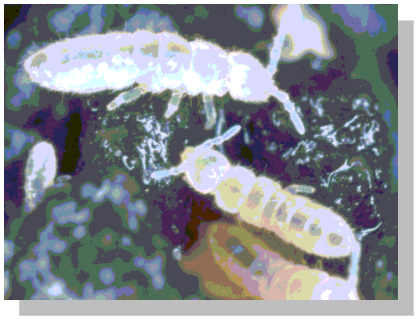
- Fish
  - Rainbow trout, bluegill sunfish
- Aquatic invertebrates
  - Water flea *(Daphnia sp.)*
- Algae
  - Green algae *(Selenastrum capricornutum)*
- Aquatic plants
  - Lemna sp.
- Benthic invertebrates
  - Midge larvae *(Chironomus sp.)*

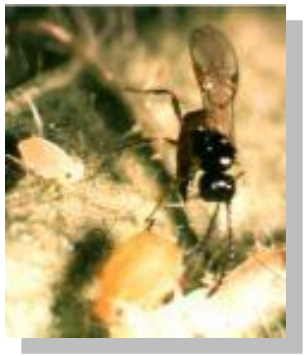
BelTOX

Surrogate Species

Terrestrial

- Birds and other vertebrates
  - Quail
  - Rat
- Arthropods
  - Bees
  - Mites *(T. pyri)*
  - Parasitic wasp (A. rhopalosiphi)
- Soil organisms
  - Earthworms
  - Springtails





Test Guidelines

- Mainly standard guidelines from internationally recognised bodies (OECD, SETAC, EPPO, others)
- Conducted where possible according to Good Laboratory Practices (GLP)

Exposure Assessment

Route, magnitude and duration of exposure

Determined based on:

Calculation/ Modelling

Testing/ Monitoring

Route and Magnitude

- Which environmental compartments?
  - Air
  - Surface & groundwater
  - Soil
- Determination of « Predicted Environmental Concentrations » (PECs)
  - PEC air
  - PEC surface water / groundwater
  - PEC soil

Duration

- Determination in the relevant environmental compartments of:
  - DT50: 50% dissipation time
  - DT90: 90% dissipation time

Important Parameters

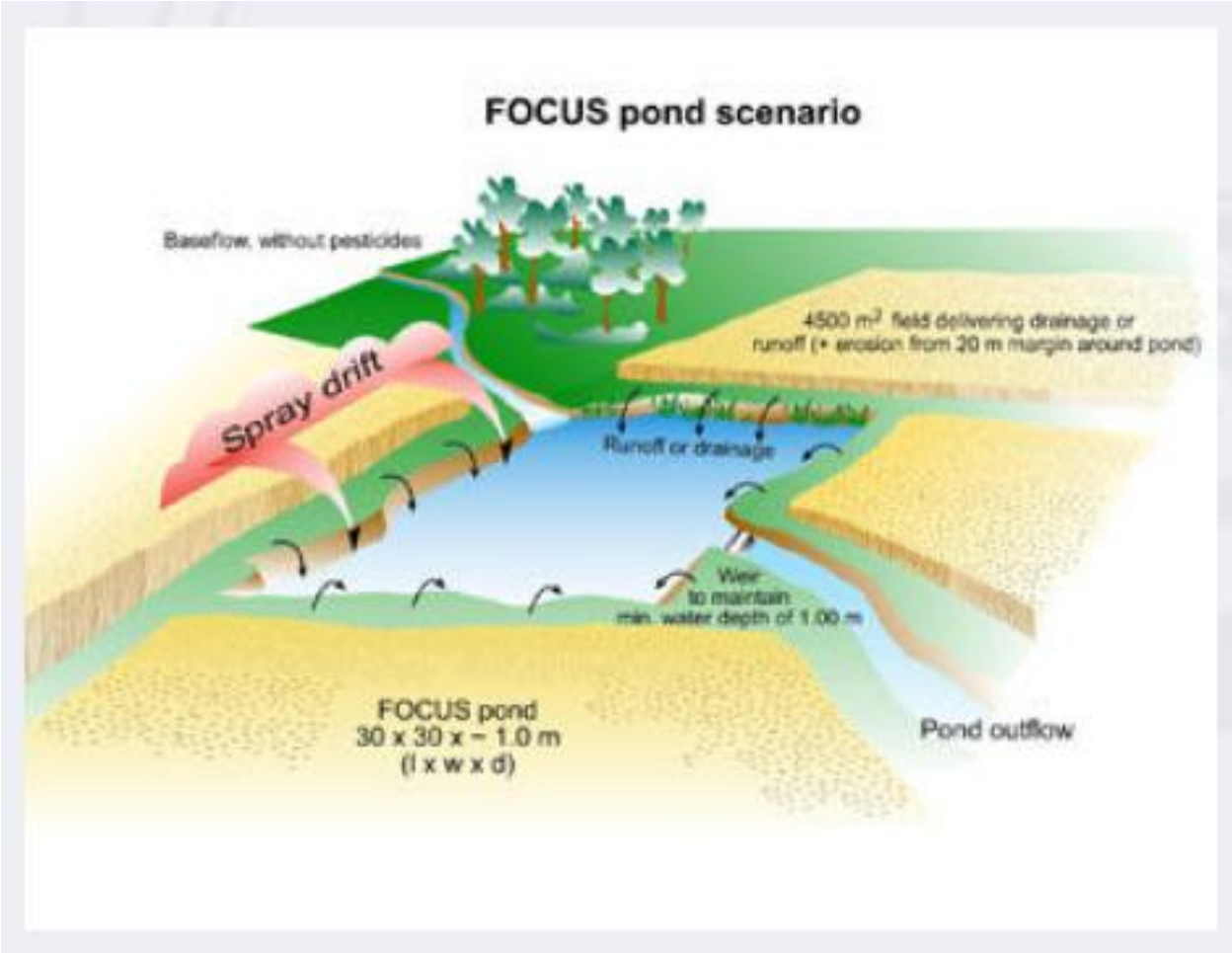
- Air
  - Volatility
  - Photolysis
- Water
  - Solubility
  - Hydrolysis
  - Photolysis
  - Partition coefficient
  - Biodegradation
  - Bioaccumulation
- Soil
  - Photolysis
  - Aerobic & anaerobic metabolism
  - Adsorption/desorption
  - Field dissipation

BelTOX

Modelling

- Down the drain chemicals:
- Pesticides:
  - Water: MACRO, PELMO, PEARL, PRZM, SWASH, TOXWA…

Modelling Scenario: an Example



Testing

- Laboratory or mesocosm studies
- Field studies
- Monitoring