UNIVERSITEIT GENT

BIOMATH
Department of Applied Mathematics, Biometrics and Process Control

Concepts and state of the art in chemical (ecological) risk assessment

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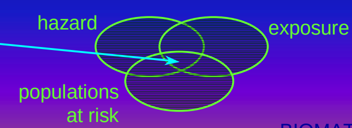
Definitions

- Hazard: Object with the potential for creating undesirable adverse consequences
- Exposure: Situation of vulnerability to hazards
- Risk: Probability of an adverse effect due to some hazardous situation (+ severity of the adverse consequence)



Definitions

- Risk = P x S — P = probability of occurrence; S = severity of occurrence
- Risk = f(I) x f(p) - f(d) — f(I) = intrinsic risk factor; f(p) = presence factor; f(d) = defense factor
- Risk = hazard / (prevention measures)
- Risk = f(hazard, exposure, safeguards)

Risk assessment

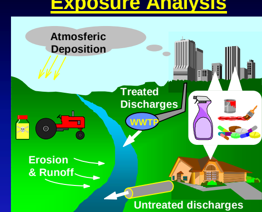
- Answer 3 questions:
  - What could potentially go wrong ?
  - What are the chances for this to happen ?
  - What are anticipated consequences if this happens ?
- Provides information needed for risk management
- Risk assessment process
  - --> Hazard identification
  - --> Effects assessment
  - --> Exposure assessment
  - --> Risk characterization

Risk assessment

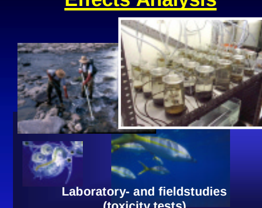
- Iterative, tiered approach:
  - screening level: - conservative - simple models - default parameters
  - detailed level: if screening level indicates risk

Ecological risk assessment

Exposure Analysis



Effects Analysis



Predicted Environmental Concentration (PEC)

Predicted No Effect Concentration (PNEC)

YES, potential risk

I: Hazard identification

- Qualitative assessment of - contaminant sources
  - list of contaminants present
- Identification of principal hazards
- Design of sampling/analysis program
- Collection/analysis of environmental samples
- Recording/reporting of lab results
- Selection criteria:
  - positively detected in at least one sample
  - detected significantly higher levels than blank/background
  - historically associated with the situation
  - daughter chemicals are found (biodegradation products)

II: Effects evaluation

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Estimation of the relationship between
dose/level of exposure to a substance
and the incidence/severity of an effect

- NOAEL: no observed adverse effect level
- LOAEL: lowest observed adverse effect level

NOAEL < LOAEL

- LC_{10}, LC_{50}, LC_{90}: percentage lethal concentration

III: Exposure evaluation

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Estimation of the magnitude of actual/potential
receptor exposures to environmental contaminants,
the frequency/duration of these exposures,
the nature/size of the population potentially at risk
and the pathways by which PAR may be exposed

physical/chemical properties of the contaminant
==> chemical distribution, intake, metabolism, excretion, residence time, half-life, breakdown to ...

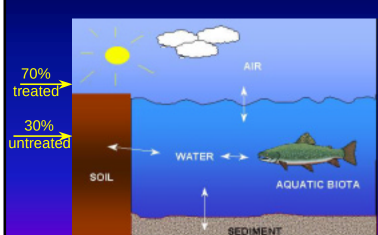
III: Exposure evaluation

- Modelling fate and behaviour
  - transport
  - transformation, degradation and decay
  - cross-media transfers (sorption, volatilization, …)
  - biological uptake/bio-accumulation

MANY MODELS OF DIFFERENT COMPLEXITY

III. Exposure evaluation

- current methods: multimedia fate models
  = chemical partitioning + decay in generic 'unit world'



- no uncertainty
- no spatial variability
- no temporal variability
- **low accuracy** (factor 1000)

IV. Risk characterization

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Estimation of the probable incidence
of adverse impacts to potential receptors
under a set of exposure conditions
that are associated with a hazard situation

$$\text{EcoRisk} = \frac{\text{exposure conc. or estimated daily dose}}{\text{benchmark ecotoxicity parameter (e.g. } LC_{50}\text{)}}$$

to be compared with critical value: 1

Drawbacks of current ERA

- These screening risk analysis approaches are:
  - conservative because of safety factors, worst cases
  - not so realistic & transparant
  - don't stimulate further research
  - don't distinguish between uncertainty and variability
  - risk should be a probability instead of yes/no result

>> Use of more probabilistic approaches

Probabilistic Risk Assessment

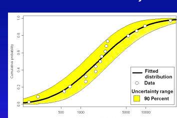
- Originated in the nuclear industry

Risk (consequence/time)
=
frequency (event/time) x magnitude (consequence/event)

- Accidents, events, failures, NOT: continuous exposure

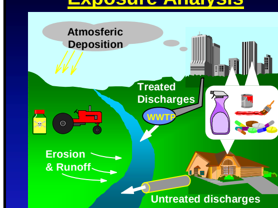
Uncertainty & Variability

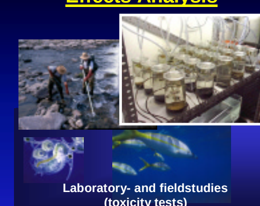
- Variability: true (known) heterogeneity in characteristics due to individual differences (not reducible through further measurements)
- Uncertainty: distributions describe lack of knowledge (reducible through further measurements)
- E.g. - parameters
  - completeness of study or scenario's
  - model
    - extrapolation from test species to ecological/human effects
    - mixtures of toxicants ?
    - background concentration
    - sampling errors lead to data uncertainty



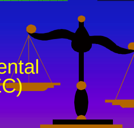
Ecological risk assessment

Exposure Analysis | **Effects Analysis**





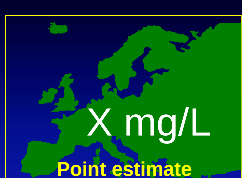
Predicted Environmental Concentration (PEC)



Predicted No Effect Concentration (PNEC)

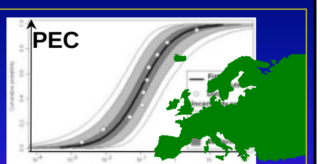
YES, potential risk

Include variability & uncertainty



Make more realistic

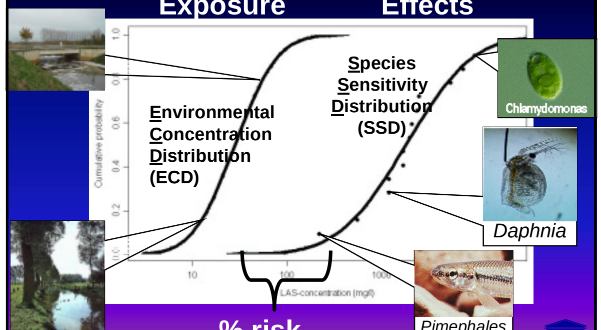
Probabilistic approach



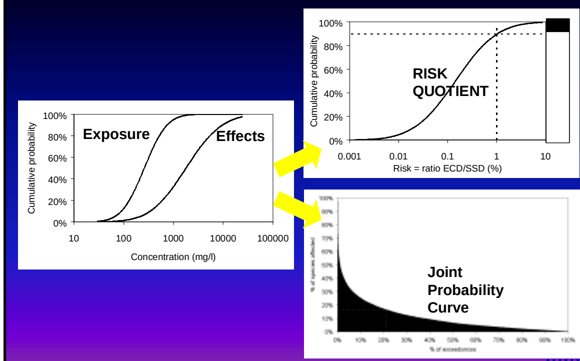
spatial + temporal + other variability & uncertainty

Probabilistic risk assessment

Exposure **Effects**



Risk calculation

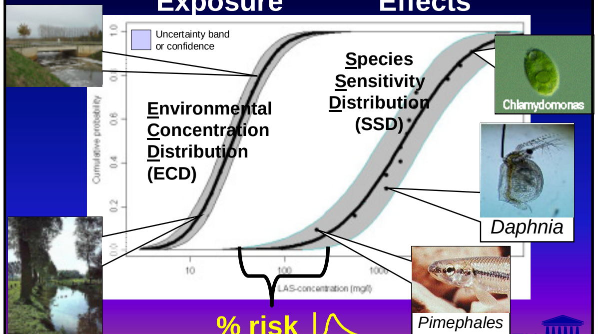


Ecological risk calculation

- RISK = ECD / SSD = quotient of 2 random variables
  ⇒ percentage or probability measure for the risk
- Definition:
  « Probability that the Environmental Concentration (EC) exceeds the Species Sensitivity (SS) »

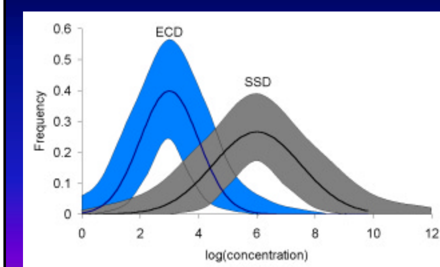
  Risk = P(EC > SS)

PERA: Introducing uncertainty



Drawback PERA

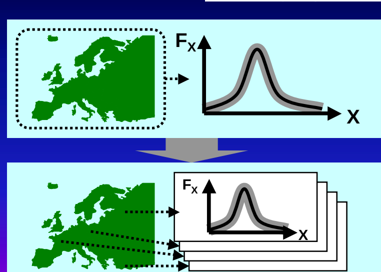
> spatial variation is quite high
> large variances >> RISK = P(EC > SS)



(European) risk = 33%
+
90% confidence interval: 25-52%

Geo-referencing X

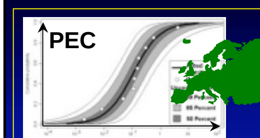
Variability represented in distribution:



- spatial
- temporal
- other…

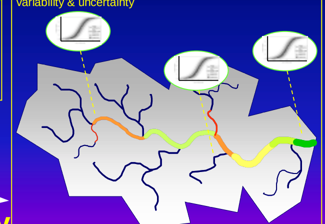
- temporal
- other...

Reduce spatial variability

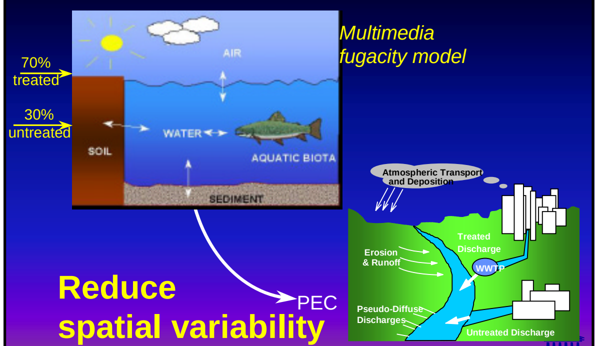


spatial + temporal + other variability & uncertainty

Reduce spatial variability



Reduce spatial variability



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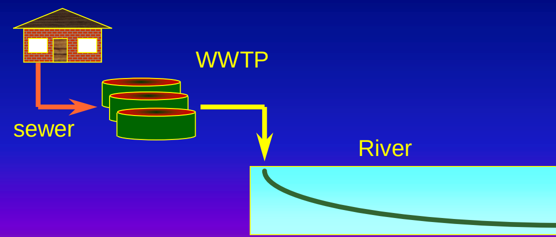
Aquatic Exposure for point sources GREAT-ER 1.0

- Chemical Emissions
  - Product Consumption
  - Sewage Treatment
- River Fate Processes
  - Dilution + Transport
  - In-stream Removal



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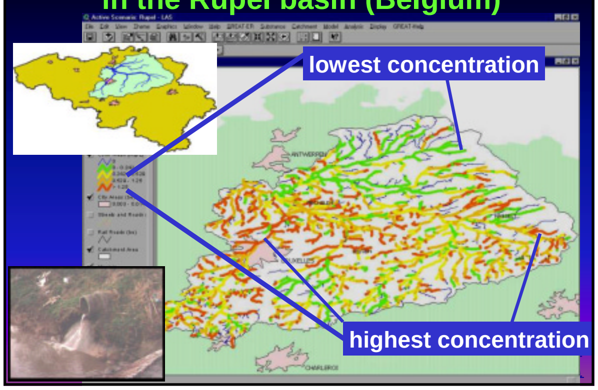
Case study on LAS (detergent) in the Rupel basin (Belgium)



Lessons for Integrated Urban Wastewater Management

- Risk should be a probability rather than Y/N
- Make distinction between uncertainty and variability
- Probabilistic approaches are gaining attention in the chemical risk assessment field
- Major limitations on the effects side:
  - no (or few) risk assessments for chemical mixtures
  - bio-availability
  - adaptation to environment
  - composition of the ecosystem to control
- "Explicitation"/Elimination of variability
  - Spatial variability → geo-referencing
  - Temporal variability → dynamic fate models

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