Ecotoxicology & ERA

Applied ecotoxicology

Ecological (Environmental) Risk Assessment
Environmental Impact Assessment

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Problems to discuss

- Environmental **risk** *vs.* environmental **impact**
- How to assess the environmental risk of a specific environmental pollution?
  - Detailed and general environmental risk indices
  - Integrated environmental risk indexes
- How to study the ecological impact of ecosystem pollution?
  - Influence of pollution on ecosystem processes
  - Examples of the studies

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Ecological Risk Assessment (ERA) vs. environmental Impact Assessment (IA)

- *Ecological Risk Assessment* – the process for evaluating how likely it is that the environment might be impacted as a result of exposure to one or more environmental stressors, such as chemicals, land-use change, disease, and invasive species
- *Environmental impact assessment* – the evaluation of actual effects of ongoing human-driven activities on ecosystems

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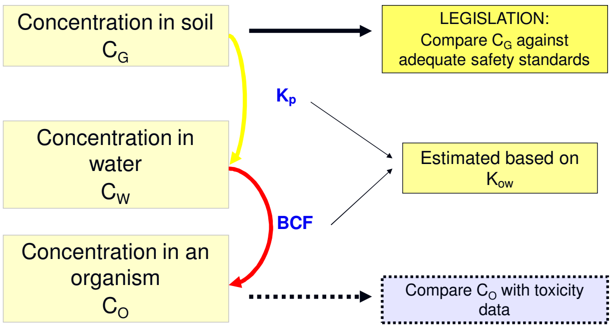
ERA: the procedure currently used to assess the toxicity of chemicals



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Problems with safety standards

- For legislative purposes, concentrations in the environment and not in organisms are used → due to the differences in the bioavailability of chemicals in different environments, the results may be seriously different from the reality
- The partition coefficients (K_p) may substantially differ from those predicted from the K_{ow} due to:
  - The "aging" effect (gradual binding of increasing fraction of a toxicant)
  - The presence of highly absorbent materials (e.g. soot, charcoal, petroleum residues, etc.)

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Alternative methods – risk indices

- Environmental risk indices
  - indicators are variables that provide information about other variables that are difficult to measure
  - provide information about complex systems in a simplified and easier-to-understand form
  - present information about a complex system in a synthetic form
  - are used in many European Commission directives for risk characterization (PEC/PNEC)
  - they combine the information on the concentration of a substance in the environment and its toxicity

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Why do we need risk indices?

- Legal purposes: e.g. registration of pesticides
- Classification of chemicals in terms of the risk they pose to the environment
- Identification of particularly sensitive areas
- Setting priorities in environmental monitoring and nature protection
- Providing information to users in an easy to understand form
- Selecting pesticides that are less harmful to the environment

Ecological Risk Assessment (ERA)
Detailed indices: PEC/NOEC

Assessment of concentration in the environment → **PEC** (Predicted Environmental Concentration)

Assessment of toxicity to a species → **NOEC** (No-Observed Effect Concentration)

Risk assessment (ERA) for a species
HQ = PEC/NOEC

HQ – Hazard Quotient

Ecological Risk Assessment (ERA)
General indices: PEC/PNEC

Assessment of concentration in the environment → **PEC** (Predicted Environmental Concentration)

Impact assessment → **PNEC** (Predicted No Effect Concentration)

Risk assessment (ERA) for a community
HQ = PEC/PNEC

HQ – Hazard Quotient

PNEC and Assessment Factors (AF)

PNEC is deterministically evaluated by applying an appropriate AF to the lowest relevant observed value within the available toxicity data set (i.e., the most sensitive tested species and the most sensitive relevant endpoint)

- AF = uncertainty factor based on the precautionary principle due to multiple sources of uncertainties
- AFs are intended to account for:
  - intra- and interlaboratory variation in toxicity data
  - intra- and interspecies variation in the toxicity data (biological variance)
  - laboratory data to field impact extrapolation
  - short-term to long-term toxicity extrapolation

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PNECs and Assessment Factors (AF)

Available data	AF
At least one short-term $L(E)C_{50}$ from each of three trophic levels (fish, invertebrates (preferred Daphnia), and algae)	1000
One long-term EC_{10} or NOEC (either fish or Daphnia)	100
Two long-term results (e.g., EC_{10} or NOECs) from species representing two trophic levels (fish and/or Daphnia and/or algae)	50
Long-term results (e.g., EC_{10} or NOECs) from at least three species (normally fish, Daphnia, and algae) representing three trophic levels	10

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Ecological Risk Assessment (ERA)
Integrated indices

- Calculated on the basis of simple algorithms, taking into account the predicted concentration in the environment and the various effects of toxicants in various groups of organisms
- Individual effects are assigned different weights (e.g. due to their importance for the functioning of the ecosystem or for humans)

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Examples of integrated indices

*Short Term Pesticides Risk Index for the Surface Water System (**PRISW-1**)*

PEC: surface drift (D) + subsurface runoff (S)

D = A × F — A – application (dose per unit area); F – fraction moving as a drift (~4%)

S – calculated on the basis of a soil pesticide movement model

Algae (A) EC50/PEC	RANK	Daphnia (B) EC50/PEC	RANK	Fish (C) LC50/PEC	RANK
>1000	0	>1000	0	>1000	0
1000 – 100	1	1000 - 100	1	1000 - 100	1
10 – 100	2	10 - 100	2	100 - 10	2
10 – 1	4	10 - 1	4	10 - 1	4
<1	8	<1	8	<1	8
	W = 3		W = 4		W = 5.5

PRISW-1 = (A × 3) + (B × 4) + (C × 5.5) → range 0 - 100

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Examples of integrated indices

*Short Term Pesticides Risk Index for the Hypogean Soil System (**PRIHS-1**)*

PEC (mg/kg soil) = MA/750

MA: maximum application (dose per ha)

(750 because: 10 000 m² × 5 cm × 1.5 g/cm³ = 750 000 kg)

Earthworms (A) EC50/PEC	RANK	Beneficial arthropods (B) × MA=% effect	RANK	Mammals (C) LD50/PEC	RANK
>1000	0	2 MA = 0	0	>1000	0
1000 – 100	1	0 <MA<30	2	1000 - 100	1
100 – 10	2	MA>30	4	100 - 10	2
10 – 1	4	0,5 MA>30	8	10 - 1	4
<1	8			<1	8
	W = 5.5		W = 5		W = 2

PRIHS-1 = (A × 5.5) + (B × 5) + (C × 2) → range 0 - 100

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Examples of integrated indices

*Long Term Pesticides Risk Index for the Hypogean Soil System (**PRIHS-2**)*

$$PEC_t \text{ (mg/kg soil)} = PEC_0 (1-e^{-kt})/kt$$

t: duration of the ecotoxicological test (e.g. 14 days for earthworms); $k = \ln_2/DT_{50}$

Earthworms (A)		Microorganisms (B)		Beneficial arthropods (C)		Mammals (D)	
NOEC/ PEC (14 d)	RANK	x MA = % effect	RANK	x MA = %efektu	RANK	NOEL/ DietC	RANK
>1000	0	2 MA = 0	0	2 MA = 0	0	>1000	0
1000-100	1	0 < MA < 25	2	0 < MA < 30	2	1000-100	1
100-10	2	MA >25	4	MA >30	4	100-10	2
10-1	4	0,5 MA >25	8	0,5 MA >30	8	10-1	4
>1	8					>1	8
	W = 4		W = 4		W = 3		W = 1.5

PRIHS-2 = (A × 4) + (B × 4) + (C × 3) + (D × 1.5) → range 0 - 100

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Problems with indices of this kind

- **Arbitrariness:** ranks and weights are assigned arbitrarily → the need to validate these values with numerous tests
- **No data** for many species and whole groups of organisms (e.g. microorganisms, beneficial arthropods)
- **Reliability of data**: significant discrepancies in published data for the same organisms and the same substances

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Advantages of general and integrated indexes

- Convenient for pre-classification of chemicals in terms of their toxicity to "generalized community" → possibility of relative ecological risk assessment
- They allow the risk of different chemicals in the same environment to be compared
- They allow the risk posed by the same substance in different environments to be compared

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Disadvantages of general and integrated indices

- They are **too general** - they do not take into account the specificity of different habitats
- They are based on standard ecotoxicological assays
- Nobody knows what they really mean for the community/ecosystem
- It is not known to what extent the homeostatic mechanisms of an ecosystem can affect conclusions based on laboratory assays

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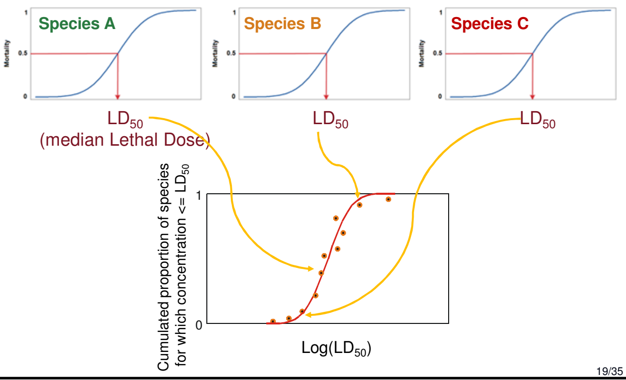
Indices for individual communities

Constructing Species Sensitivity Distribution curve (SSD)



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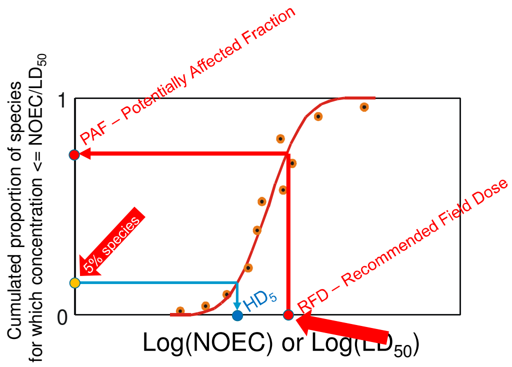
Indices for individual communities

Species Sensitivity Distributions (SSD) in ERA



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Advantages of the SSD approach

- Possibility of using SSD curves for specific groups of organisms (different environments, trophic levels and taxonomic groups)
- Possibility to check whether keystone species have been included in the risk assessment
- Possibility to assess the impact on biodiversity
- The possibility of (theoretically) assessing the impact on the functioning of the ecosystem

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Disadvantages of SSD approach

- SSD is traditionally constructed and, consequently, PAF and HC_5 are calculated on the basis of an unreliable NOEC measure, derived from simple laboratory tests
  - but other solutions are possible – e.g., using LC_{50} etc.
- Estimating SSDs for each individual ecosystem requires the collection of a huge amount of data

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Databases to be used in constructing SSD curves

- EXTOXNET (http://extoxnet.orst.edu)
- EPA – AQUIRE (http://www.epa.gov/ecotox)
- RIVM (http://www.rivm.nl)
- PAN (http://www.pesticideinfo.org)

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Examples of EU research programs we participated in

ALARM:

Assessing Large-Scale Environmental Risks with Tested Methods – 12 mln Euro/5 years

NoMiracle:

Novel Methods for Integrated Risk Assessment of Cumulative Stressors in Europe – 10 mln Euro/5 years

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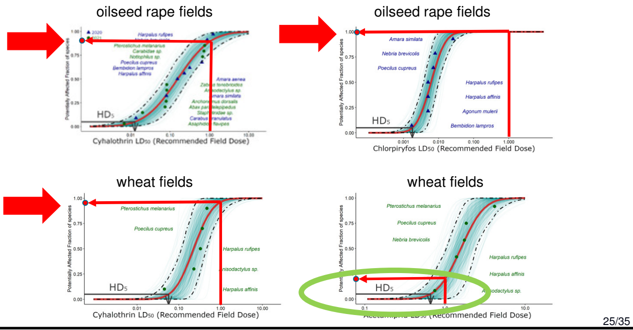
Examples from our backyard (ERA): Ecological Risk Assessment for insecticides

SSD curves for sensitivity of beneficial beetle communities towards λ-cyhalothrin, chlorpyriphos and acetamiprid in Poland



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Examples from our backyard (EIA): environmental impact assessment of the contamination by "Bolesław" metal smelter

- "Bolesław" smelter → contamination of soils in a large area around the smelter mainly with metals (Zn, Cu, Pb, etc.), but also acidification of the environment, changes in the balance of sulfur and nitrogen.
  - → Has pollution damaged the functioning of ecosystems?
  - → Which factors have the greatest impact on the functioning of the soil environment?
  - → What indicators to measure?

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EIA: The impact of "Bolesław" smelter on the soil subsystem

- Chemical analyses
- Measurements of the total activity of soil microorganisms
- Measurements of the biomass of soil microorganisms
- Measurements of the functional diversity of soil microbial communities
- Measurements of the total activity of destruents
- Research on the influence of contamination on invertebrate communities

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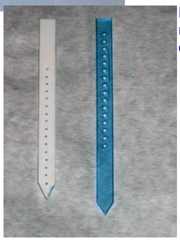
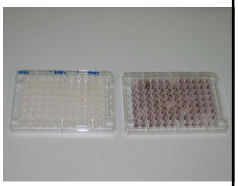
The kit for measuring respiration rate of soil microorganisms

"Mesocosm" for experiments on soil microbial communities



Bait-lamina strips to measure the activity of destruents



BIOLOG plates for measuring the activity of various groups of soil microorganisms

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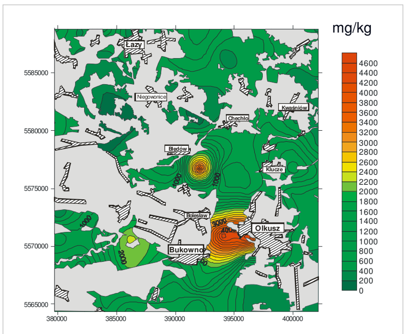
Contamination of soils with zinc in the vicinity of "Bolesław" smelter



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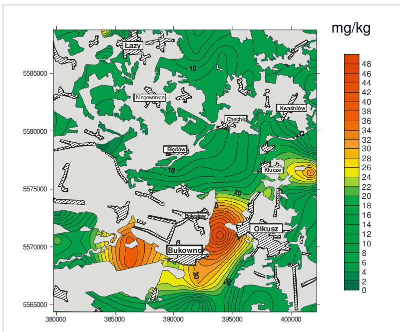
Contamination of soils with cadmium in the vicinity of "Bolesław" smelter



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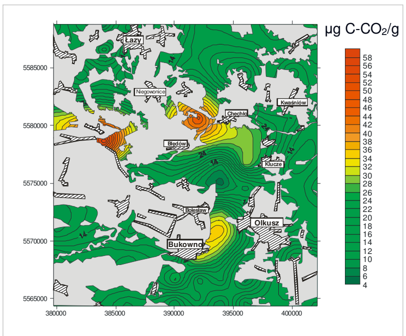
EIA: The respiration rate of soil microorganisms in the vicinity of "Bolesław" smelter



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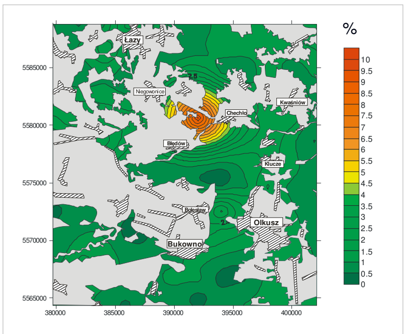
EIA: Microbial carbon as % of organic carbon in soils in the vicinity of "Bolesław" smelter



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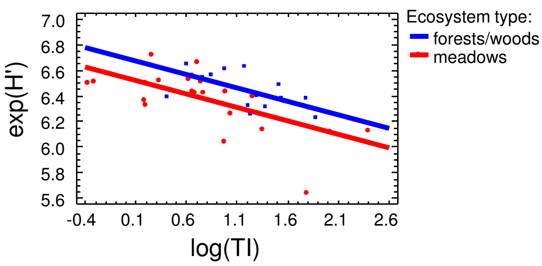
EIA: The impact of metal contamination on the functional diversity of meadow and forest soil microorganisms (for 4 smelters in PL and UK)



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Summary

- In Ecological Risk Assessment it is necessary to use indices of expected effects → Hazard Quotients (HQ)
- Risk indices can be general (but less precise) or specific (more precise but with limited generality)
- One of the most general and widely used is the PEC/PNEC index
- To account for uncertainty in estimates of "safe concentrations" the Assessment Factors (AF) are used
- Integrated indices allow for taking into account various features of the habitat and importance of different organisms
- SSD approach is probably the best method for assessment of environmental risk and impact for whole communities
- The environmental impact assessment should take into account functional effects - e.g. the changes in microbiological processes in ecosystems

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Remember to evaluate the course in USOS – you will help your younger colleagues!

Exam: 30.01, 11:30-13:00, room: 1.1.1

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