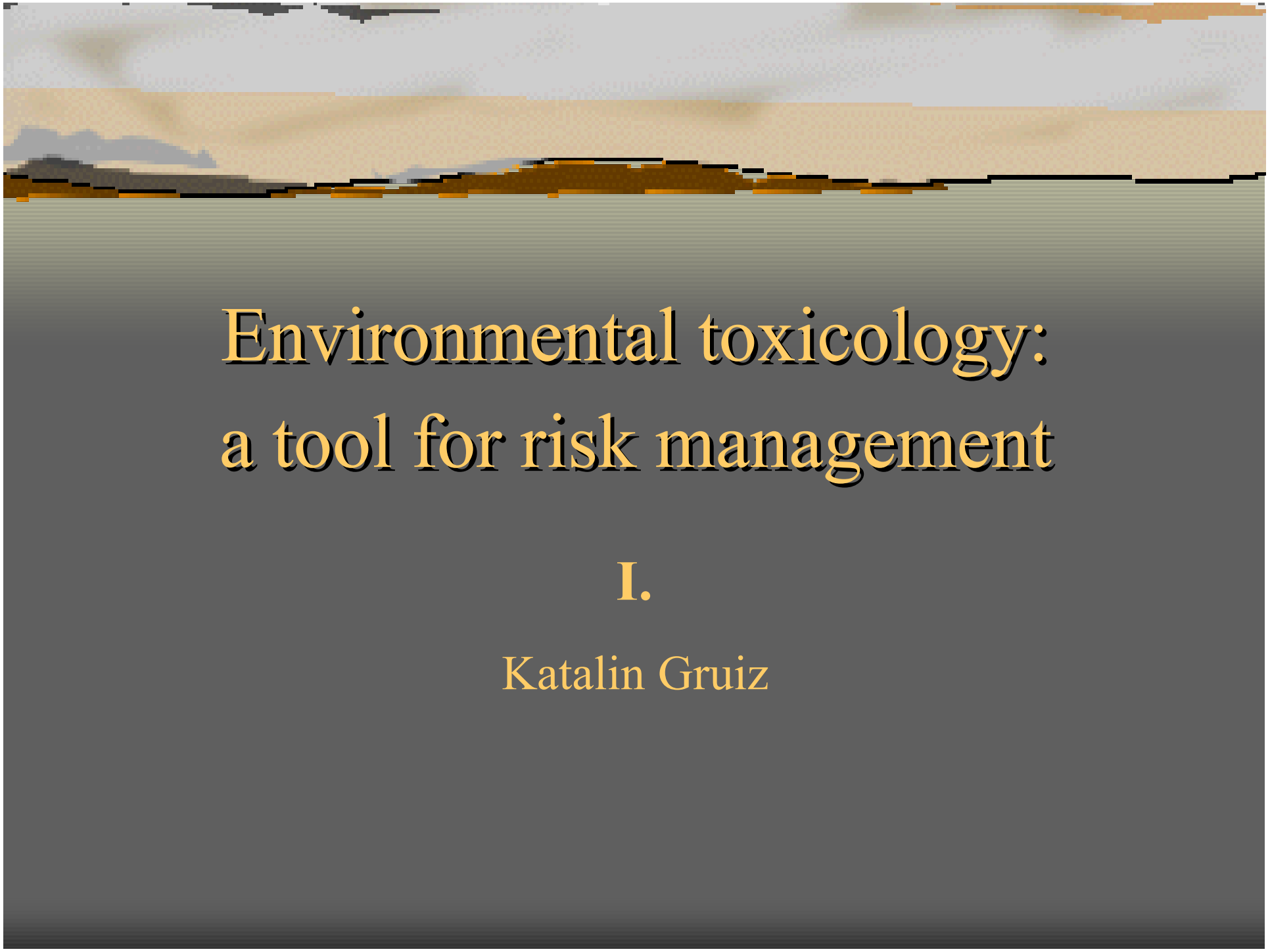


Environmental toxicology: a tool for risk management

I.

Katalin Gruiz

Environmental toxicology: it`s position and role

- **Environmental toxicology** is the study of the impacts of chemical substances (potential and actual pollutants) upon the structure and function of ecological system, including man.
- **Ecological system** is defined as a complex system from the molecular level, through individual organisms and communities to the ecosystem.
- Environmental toxicology requires **multidisciplinary** approach of a variety of specialists.
- Use of the results of environmental toxicology for: the prediction of hazard and risk of single chemicals and contaminated environment and supporting decision making of environmental management & policy
  - To establish environmental quality criteria
  - To design monitoring systems
  - To select risk reduction measures

Environmental toxicology: the multidisciplinary approach

- Components of environmental toxicology
  - Analytical chemistry
  - Biology
  - Biochemistry
  - Biometrics
  - Chemistry, chemical engineering
  - Ecology
  - Evolutionary Biology
  - Limnology
  - Marine Biology and Oceanography
  - Mathematical and Computer Modeling
  - Meteorology
  - Microbiology
  - Molecular genetics
  - Pharmacokinetics
  - Physiology
  - Population biology
  - Risk Assessment
  - Risk management

Position and role of environmental toxicology

Identification of hazard
Assessment risk

categorization and priorisation
generic and site specific RA

Prevention
Remediation
Restricted use

legislation.
monitoring
wwtp
limitation in production and use

Interaction of a chemical substance (xenobiotic) with the ecosystem I.

1. Introduction of the xenobiotic into the environment
   - Biotransformation
   - Mixed function oxidases
   - DNA repair enzymes
   - Enzyme induction
   - Hydrolases
2. Interaction with the site of action
   - DNA/RNA
   - Key enzymes
   - Membrane receptors
   - Biochemical integrity
3. Biochemical parameters
   - Stress proteins
   - Acetylcholin-esterase inhibition
   - Immun-suppression
   - Metabolic indicators
   - Methallothionein production
4. Physiological and behavioral characteristics
   - Chromosomal damage
   - Carcinogenic
   - Reproductive success
   - Mortality
   - Lesion and necrosis
   - Teratogenic effects
   - Behavioral alterations
   - Compensatory behaviors

Interaction of a chemical substance (xenobiotic) with the ecosystem II.

5. Population parameters
   - Population density
   - Productivity
   - Mating success
   - Alterations in genetic structure
   - Competitive alterations
6. Community parameters
   - Structure
   - Diversity
   - Energy transfer efficiency
   - Stability?
   - Successional state
   - Chemical parameters

7. ECOSYSTEM EFFECTS

Concentration - response

- Endpoint of the measurement

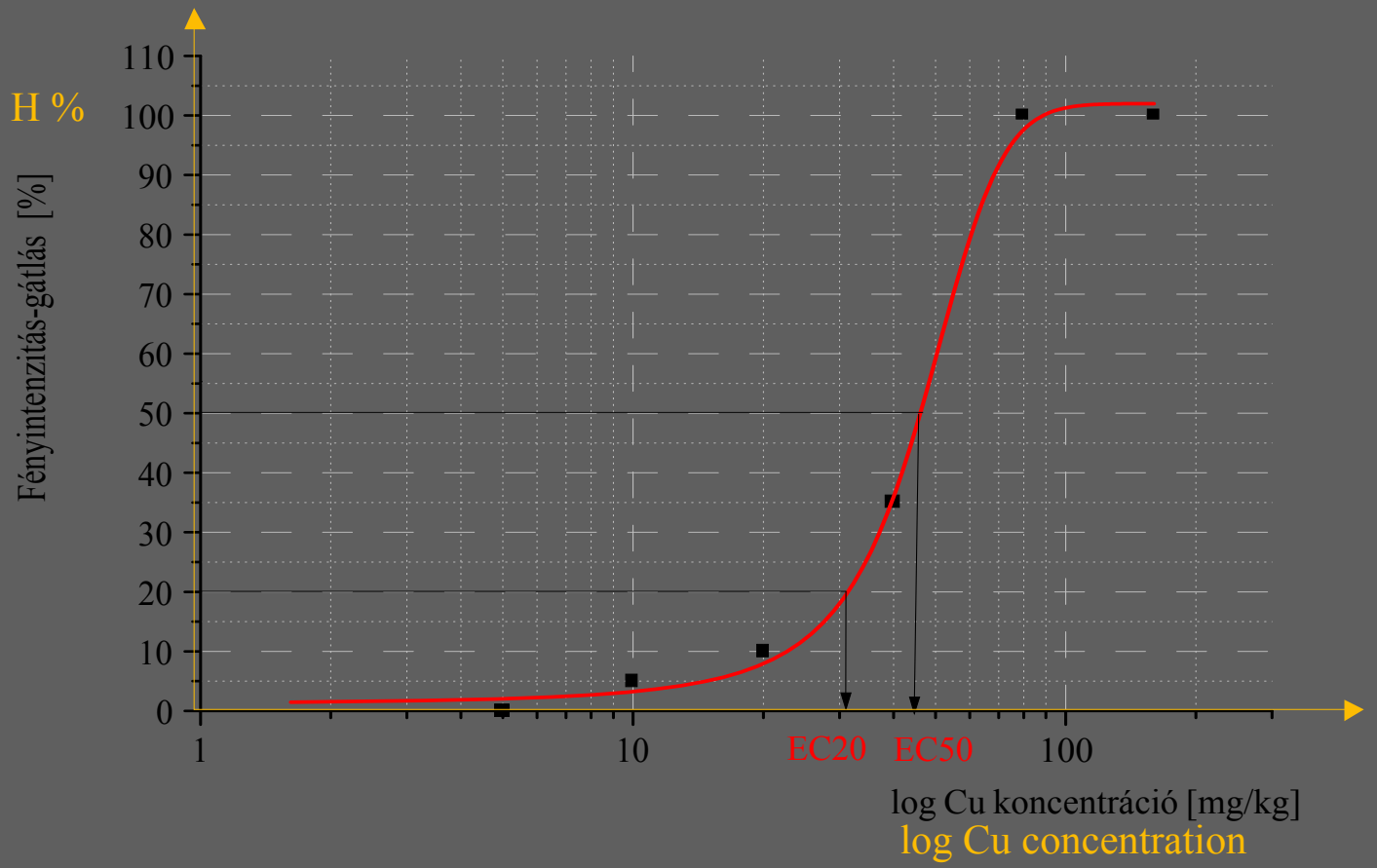
  All the enlisted biochemical, physiological, behavioral, population, community parameters and ecosystem effects can function as endpoint.

- Endpoint of the test evaluation

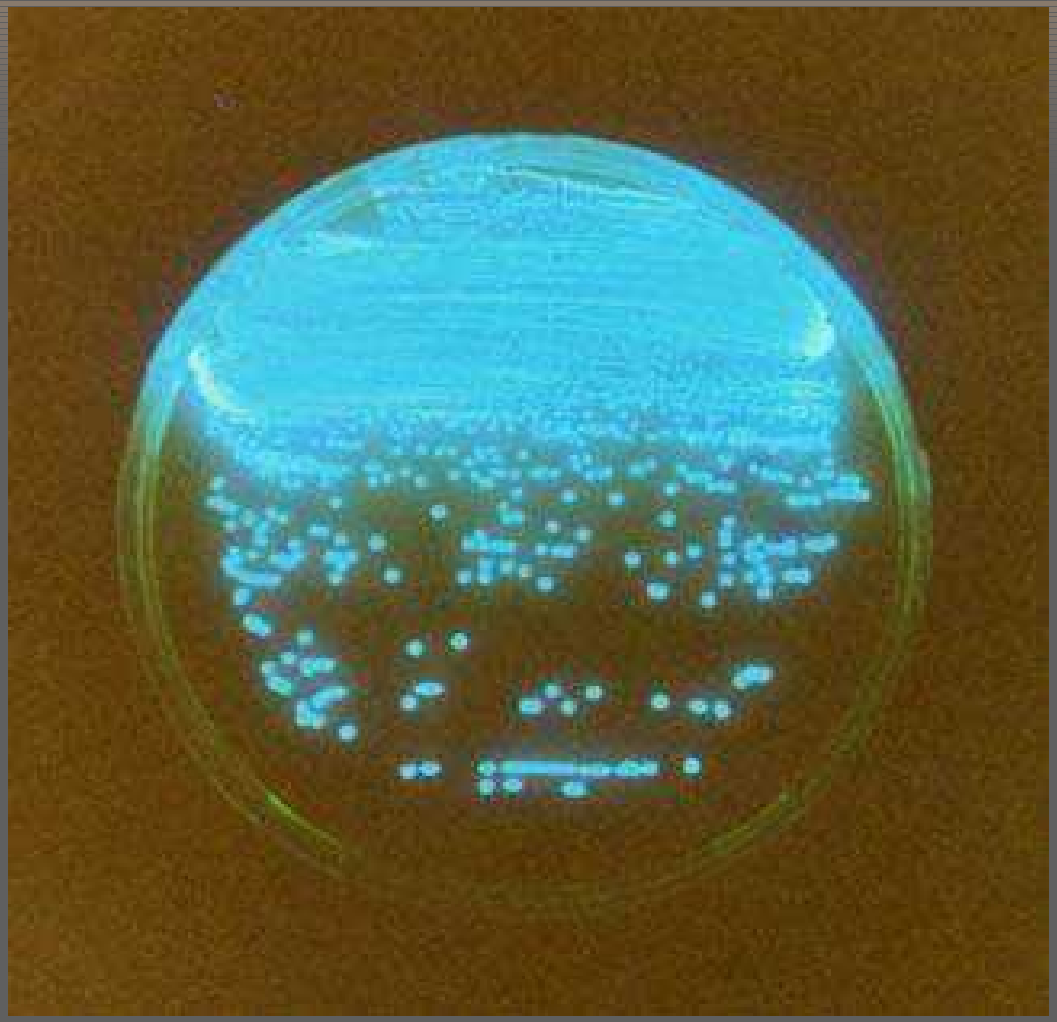
  Characteristic concentrations (levels) can be determined from the concentration - response or dose - response curve

  - **EC_{20}, EC_{50}**: the concentration that has an effect of 20 % / 50 % on the measured endpoint, eg.luminescence intensity, respiration rate, dehydrogenase activity, etc. – this value is estimated by graphical or computational means
  - **ED_{20} / ED_{50}**: the dose that has an effect of 20 % / 50 % on the measured endpoint
  - **LC_{20} / LC_{50}**: the concentration that causes mortality in 20 / 50 % of the testorganisms - estimated by graphical or computational means
  - **LD_{20} / LD_{50}** : the dose that causes mortality in 20 / 50 % of the testorganisms - estimated by graphical or computational means
  - **NOEC / NOEL**: No Observed Effects Concentration / Level, determined by graphical or statistical methods
  - **NOAEC / NOAEL**: No Observed Adverse Effects Concentration / Level, determined by graphical or statistical methods
  - **LOEC / LOEL**: Lowest Observed Adverse Effects Concentration / Level, determined by graphical or statistical methods
  - **MATC**: Maximum allowable toxicant concentration, determined by graphical or statistical methods
  - **NOEC < MATC < LOEC**

Concentartion - response curve: luminescence inhibition of Vibrio fischeri



Culture of the luminobacterium Vibrio fischeri



$FMNH_2 + O_2 + RCHO \xrightarrow{\text{luciferase enzyme}} h\nu\ (490\ nm) + FMN + H_2O + RCOOH$

$FMNH_2$: reduced flavine-mononucleotide, RCHO: luciferine: long chain aldehyde: light emitter

Classification of ecotoxicological tests

- Number of species
  - Single species
  - Multispecies
- Type of the test organism
  - Bacterial cells
  - Algae
  - Fungi
  - Plants
  - Animals
  - Multispecies
- Tested ecosystem
  - Aquatic ecosystem
  - Terrestrial ecosystem
- Exposure scenario
  - Whole-body test
  - Feeding studies
  - Injection of a controlled amount (intramuscular, intravenous)
  - Placement of a controlled amount into the stomach by a tube (gavage)

Classification of ecotoxicological tests

- Test duration
  - Short-term = acute
  - Long-term = chronic
- Type of ecotoxicological tests:
  - Lab bioassay (acute and chronic toxicity, mutagenicity, teratogenicity etc.tests)
  - Microcosm, mesocosm (multispecies toxicity tests)
  - *In situ* biomonitoring (active, passive)
  - Diversity
  - Biodegradation,
  - Bioaccumulation tests etc.
- Most commonly measured endpoints
  - Toxicity tests: growth (cell number, mass production, root lenghts, chlorophyll content), survival, mortality, immobilisation, respiration: O_2 consumption, CO_2 production, enzyme activities, ATP production, reproduction, luminescence etc.
  - Mutagenicity tests: number of mutants, number of revertants, chromosome abnormalities
  - Carcinogenicity tests: tumors,
  - Teratogenicity tests: reproductive success, cytogenetic characteristics
  - Biodegradation tests: consumption of O_2, substrates, production of endproducts, CO_2,
  - Bioaccumulation tests: chemical analysis of accumulated substances

Classification of ecotoxicological tests

- Tested environmental elements and phases
  - Water, pore water
  - Liquid phase extracts, eluates, leacheates etc.
  - Solid phase samples: whole soil, whole sediment
- Aim of ecotoxicological testing
  - Screening toxicity, mutagenicity, teratogenesis of single chemicals
  - Establishing effect based environmental quality criteria
  - Biomonitoring (integrated monitoring)
  - Early warning system
  - Screening toxicity, mutagenicity, teratogenesis of environmental samples
  - Screening toxicity, mutagenicity, teratogenesis of mixtures, waste materials
  - Direct, effect based decision making

Statistical evaluation of ecotoxicological tests

- Evaluation of acute toxicity tests
  - Graphical interpolation
  - Probit methodmm
  - Logit method
  - Moving average

  Computer programs
  - TOXSTAT
  - SAS-PROBIT
  - SPSS-PROBIT
  - DULUTH-TOX etc
- Data analysis for chronic toxicity tests
  - ANOVA: Analysis of variance: determines the concentrations that are significantly different in effect of the untreated control
- Data analysis of multispecies toxicity tests

  Multivariate techniques for the exploration of patterns within ecological data sets
  - PCA: principal components analysis (assumption: linearity)
  - DPC: detrended principal components (a polynome is used to remove nonlinearity)
  - NMDS: nonmetric, multidimensional scaling (nonlinearity is considered using ranks)
  - RDA: PCA coup;ed with redundency analysis
  - **Clustering**: grouping by similarities: algoritm has no knowledge about treatment groups
  - **Divergence:** between treatment groups
  - NCAA: nonmetric clustering and and association analysis: a multivariate derivative of artificial intelligence