Aquatic Ecotoxicology

Ralf Schulz
Some definitions for ecotoxicology?

- the study of the pathways of exposure, uptake and effects of chemical agents on natural ecosystems (Connell et al. 1999)
- the study of harmful effects of chemicals upon ecosystems (Walker et al. 2001)
- Auswirkungen von Chemikalien auf die belebte Umwelt (Fent 2003)
- Kombination von Ökologie und Toxikologie
- dilution paradigm: the solution to pollution is dilution
- boomerang paradigm: what you throw away can come back and hurt you
- Truhaut 1977: Ecotoxicology is the branch of toxicology concerned with the effects of pollutants on the constituents of ecosystems in an integrated context.
Ecotoxicology as an environmental science discipline

Case study: Pesticides in water and fishes

- physics: Input, distribution, dissipation
- chemistry: chemical properties, sorption, bioaccumulation
- biology: Ecology, effects on ecosystems, biodiversity
- human sciences: toxicology, epidemiology
- geo sciences: climate, landuse, upscaling
- economics: economical implications
- social sciences: risk management and risk communication, legislation and normative approaches
- engineering: measures to mitigate the risk
Lecture Aquatic ecotoxicology

• General objectives:
  - Environmental chemistry: exposure (see also Roland Kubiak)
  - Aquatic ecotoxicology: effects (see also Carsten Brühl)
  - Risk assessment and management (see also Jörn Wogram & Peter Dohmen)
  - Understanding and critical evaluation of scientific information
Sources of information

- Books (university library)
  Fent, K.: Ökotoxikologie. Thieme 2003
  Parlar, H: Chemische Ökotoxikologie, 1995
  Schüürmann, G., Markert, B: Ecotoxicology, 1998
  Clements, W.: Community ecotoxicology, 2002

- Journals (UWS library and internet data bases)
  Umweltwissenschaften und Schadstoff-Forschung UWSF
  Environmental Science and Technology, ES&T (ACS)
  Environmental Toxicology and Chemistry, ET&C (SETAC)
  Ecotoxicology and Environmental Safety
  Environmental Pollution
  et al.
Sources of information contd.

- **Scientific societies**
  - SETAC – Society of Environmental Toxicology and Chemistry
  - SETAC-GLB – German Language Branch e.V.
  - GDCh – Gesellschaft Deutscher Chemiker, Fachgruppe Umweltchemie und Ökotoxikologie

- **English in environmental and natural sciences**
Organisational aspects

• Dates

WS 07/08: until 17th February 2008
tuesday 12:00 h to 13:30 h
not on 12.12. and maybe some other dates
however, some lectures by external guests during the winter term

• Please come and attend the lectures!

• Not only lecture by myself: strong focus on interaction and
discussion and questions by yourself!
Organisational aspects contd.

• The lectures Aquatic Ecotoxicology and Terrestrial Ecotoxicology together form one module (you´ll receive one mark)

• Anybody who only wants to have a certificate of attendance (but no mark)?

• Requirements for a mark in this module:
  1. You´ll receive a list of topics in each lecture
   Each of you will make a literature survey for one topic in one of the lectures
   Select ONE english paper and give a SHORT (5 to 10 minutes) talk (30% of the mark)
  2. Oral test at the end in one of the lectures: either aquatic or terrestrial depending on what you took for your talk (70% of the mark, decision soon)
Introduction: Phenomenons and principles

Accidents with chemicals
What happened?

- November 1986 Fire in a storage hall of a chemical company in Basel Schweizerhalle
  - Storage of 1300 tons of ca. 90 different chemicals
  - Mainly organophosphorous insecticides (OPs) and organomercury compounds
  - 10-40 tons of OP entered the river Rhein upstream of Basel
  - 20-55 kg of Org Hg entered the river Rhein
  - Complete mixing only after about 4.7 km

Introduction - Accidents with chemicals
Aus: „Die Zeit“, 14.11.1986
### Introduced chemicals

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Fracht eingeleitet (kg)</th>
<th>Konzentration im Rhein (µg/L)</th>
<th>Forelle LC₅₀ (µg/L)</th>
<th>Karpfen LC₅₀ (µg/L)</th>
<th>Daphnien EC₅₀ (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organophosphate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Disulfoton (S. 40)</td>
<td>3000–8900</td>
<td>600</td>
<td>6000</td>
<td>11 500</td>
<td>13</td>
</tr>
<tr>
<td>Etrimfos (II)</td>
<td>290–1800</td>
<td>50</td>
<td>24</td>
<td>–</td>
<td>3,8</td>
</tr>
<tr>
<td>Parathion (III)</td>
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<td>200</td>
<td>2000</td>
<td>–</td>
<td>0,6–2,5</td>
</tr>
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<td>4700</td>
<td>6 400–8 800</td>
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</tr>
<tr>
<td>Thiometon (S. 40)</td>
<td>1 200–3 900</td>
<td>500</td>
<td>8000</td>
<td>13 200</td>
<td>8 000</td>
</tr>
<tr>
<td><strong>Andere</strong></td>
<td></td>
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<tr>
<td>Dinitrocreol (DNOC)</td>
<td>660–200</td>
<td>100–4 301</td>
<td>66–1 250</td>
<td>–</td>
<td>14</td>
</tr>
<tr>
<td>Endosulfan (I)</td>
<td>20– 60</td>
<td>3– 131</td>
<td>1,4</td>
<td>–</td>
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</table>
Load of disulfoton

Introduction - Accidents with chemicals

Fent 2003
Concentrations of disulfoton

![Graph showing concentrations of disulfoton](image)
Environmental chemistry aspects

• **Half-life time**
  Dichlorvos: some h
  Disulfoton: 30-50 d

• **Fate**
  OPs: relative fast degradation
  Org Hg: dissoziation, adsorption to TOC, Fixation in sediments

• **Transport, persistence**
  OPs: up to several 100 km
  Org Hg: few km, long-term contamination of sediments in Basel (desorption)
### Toxicity of the introduced chemicals

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Introduction - Accidents with chemicals

Fent 2003
Ecological consequences

• Fishes and invertebrates
  Mortality on a 40-50 km stretch
  Effects on some invertebrates at up to 480 km downstream
  Vertebrates: Hydrolysis of OPs to carbon acids
  Invertebrates: Oxidation of OPs to oxon
  Eels: Mortality up to 400 km downstream
  Recolonisation: almost complete within 6 to 12 months

• Ducks
  Mortality in Basel after 3 months

Introduction - Accidents with chemicals
Why did the eels react very sensitive?

Eel and disulfoton: 96 h LC$_{50}$: 40 µg/L

Why did the eel at KA show a mortality of 100% (Max. Concn: < 40 µg/L)?
Differences in toxicity of the introduced chemicals

- Aldrin (V)
- Chlorpyrifos (VI)
- Dichlorvos (S. 40)
- Dieldrin (VII)
- Endosulfan (S. 77)
- Endrin (VIII)
- Fenitrothion (S. 80)
- Parathion (S. 77)
- Permethrin (S. 75)

Acute Toxicity [mg/L]
Why did the ducks react only after 3 months?

- Indirect effect via the food chain
  - Zebra mussels (Dreikantmuscheln) accumulated 50-130 µg OP/g body weight
  - 100 g of mussel fresh weight is the effective dose
  - 1 kg of mussel fresh weight is consumed daily
Recolonisation, e.g. Trichoptera (caddis flies)

Introduction - Accidents with chemicals

Fig. 6. Adult *H. contubernalis* caught in light traps and the number of exuviae collected in weekly samples near location 8 at Kampen during 1985–1987.
Lessons learned from the accident: Some principles

- **Exposure**
  Chemical properties determine distribution, fate and transport
  Short half-life and transport: Acute Exposure

- **Effects**
  Dose: Time x Concentration
  Acute toxicity varies greatly (factor of 1000 between compounds)
  Species specificity (factors of 10-100 between species)
  Combined effects: mixture toxicity for eels in Karlsruhe
  Indirect effects
  Recolonisation

- **Risk assessment**
  Eels vs. standard test species
  Lab vs. field

Introduction - Accidents with chemicals
Lecture content

• Introduction
  Phenomenons and principles

• Exposure (Environmental chemistry)
  Classes of chemicals
  Routes of entry (into non-target ecosystems)
  Fate, Degradation

• Effects on individuals
  Toxicity tests, effect classes
  Biochemical and physiological reactions
  Biomarker
  Combined effects
Lecture content contd.

• Effects on populations and communities
  Characteristics of populations: interactions
  Characteristics of communities: indirect effects
  Mikro- and mesocosms
  In situ systems
  Field studies: Ecosystem effects

• Risk assessment and risk management
  Risk assessment schemes
  Probabilistic approaches
  Registration of compounds
  Risk mitigation strategies
See you next week!