

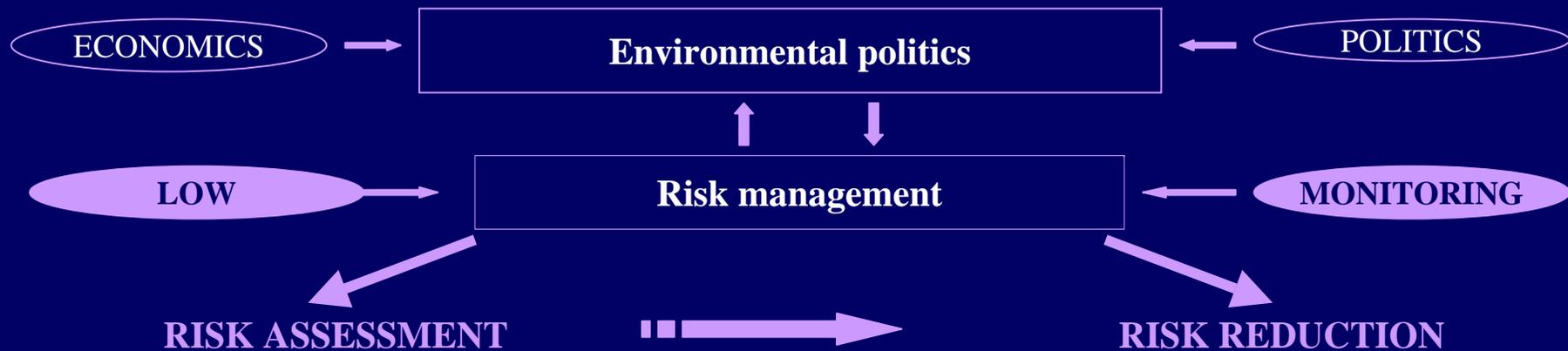
Environmental microbiology and biotechnology

**Risk assessment and risk
reduction of chemicals
in the environment**

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Tools of environmental management



1. HAZARD IDENTIFICATION

2. RISK ASSESSMENT

Generic / site specific

Qualitative/ Quantitative

Ecological / Human health

1. PREVENTION

2. RESTRICTION

3. REMEDIATION

Physico-chemical technologies

Bioremediation

Ecotechnologies

Risk assessment of contaminated sites

For the **risk assessment** of contaminated sites is necessary

- **integrated risk model of the site**
- **integrated site assessment and risk assessment**
- **site specific quantitative risk assessment**

For the design of the **risk reduction** we have to know all possible risk reduction possibilities :

- **intervention,**
- **prevention,**
- **remediation.**

For the selection of the best one cost-benefit assessment is necessary.

Tasks before risk reduction

1. **Site assessment or monitoring**
2. **Interpretation of the results, risk assessment,**
3. **Acute and long term risks, risk trends**
4. **Risk reduction measures (prevention, restriction, remediation)and their cost-benefit assessment**
5. **Selection of the suitable measure or the combination of measures**

Tasks and questions

- 1. How long the site has been contaminated?**
- 2. Extent of contamination**
- 3. Which environmental compartments are attached?**
- 4. Identification of environmental compartments and phases**
- 5. Identification of contaminants**
- 6. Physical, chemical and biological characterisation of contaminants**
- 7. Land use**
- 8. Hydrogeology of the site**
- 9. Sensitivity of the site**
- 10. The ecosystem of the site**
- 11. Microbiology of the soil of the site**

Tasks and questions

12. Risk quantification

13. Time frame of the risk

14. Urgency of risk reduction

15. Future land use

16. Target quality criteria

17. Inventory of technologies, which are able to fulfil target Quality Criteria

18. Comparative cost-benefit assessment of the suitable technologies

19. Testing and evaluating the proper technologies, to find the best possible

20. Planning and application of the proper one

21. Technology-monitoring

22. After-monitoring

Classification of soil remediation technologies

Sequence of the point of views is important

- 1. Mobilisation or immobilisation of the contaminant**
- 2. According to environmental compartments: soil gas, subsurface water, soil, sediment, etc.**
- 3. According to soil phases: soil air, soil moisture, ground water, solid phase, separate phase of the contaminant, more phases together: 2 or 3 phases**
- 4. Remediation can be based on natural soil processes?**
- 5. It may be: *in situ* or *ex situ* or a combination**
- 6. Remediation may apply physico-chemical, thermal or biological processes**
- 7. Type of technology-monitoring**
- 8. Land use during the remediation**
- 9. Environmental risk of the remediation technology itself**

Scale of natural processes in soil bioengineering

NA: Natural Attenuation

MNA: Monitored Natural Attenuation

ENA: Enhanced Natural Attenuation

In situ bioremediation

Ex situ bioremediation

Fate and nature of organic contaminants in the soil

Behaviour of organic contaminants in the soil is similar to any natural organic matter.

1. Form: gas or vapour, dissolved in water, emulsion in water and solid.

Gasous or vapour form contaminants may be part of the soil gas, dissolved in the soil (ground water or sorbed on the solid surface of soil particles.

Liquid form contaminants occur in vapour form, in dissolved form (in soil water or in ground water), in a film form on the solid surface of the solid particles or as a separate layer under or below the water table.

The solid phase contaminant according to its grain size and physico-chemical characteristics a.) mixed to the soil particles, b.) sorbed on the surface of soil particles c.) bound to the matrix with different forces, like covalent bounds in the humus. On the surface of the soil particles all the forms: gaseous, vapour form, liquid and solid contaminants can be bound.

2. Organic contaminants can be mineralised in the soil, it means that energy is produced from them, their C, N and P content will be reused by living organisms, e.g. plants.

Organic contaminants can be cometabolised: they are degraded by microbes without energy production.

Persistent contaminants are not degraded or metabolised.

Some organic contaminants can be built into the biomass, into microbial cells or plant tissues.

They can be built into the humus material. From the degradable fraction of the humus they can be mobilised again

They can be built into the structural part of the humus, where mobilisation has only a little chance

Fossilisation: final separation and elimination from the element-cycles

Natural attenuation:

Hydrolysis: alcohol with water

Substitution: with nucleophilic agents

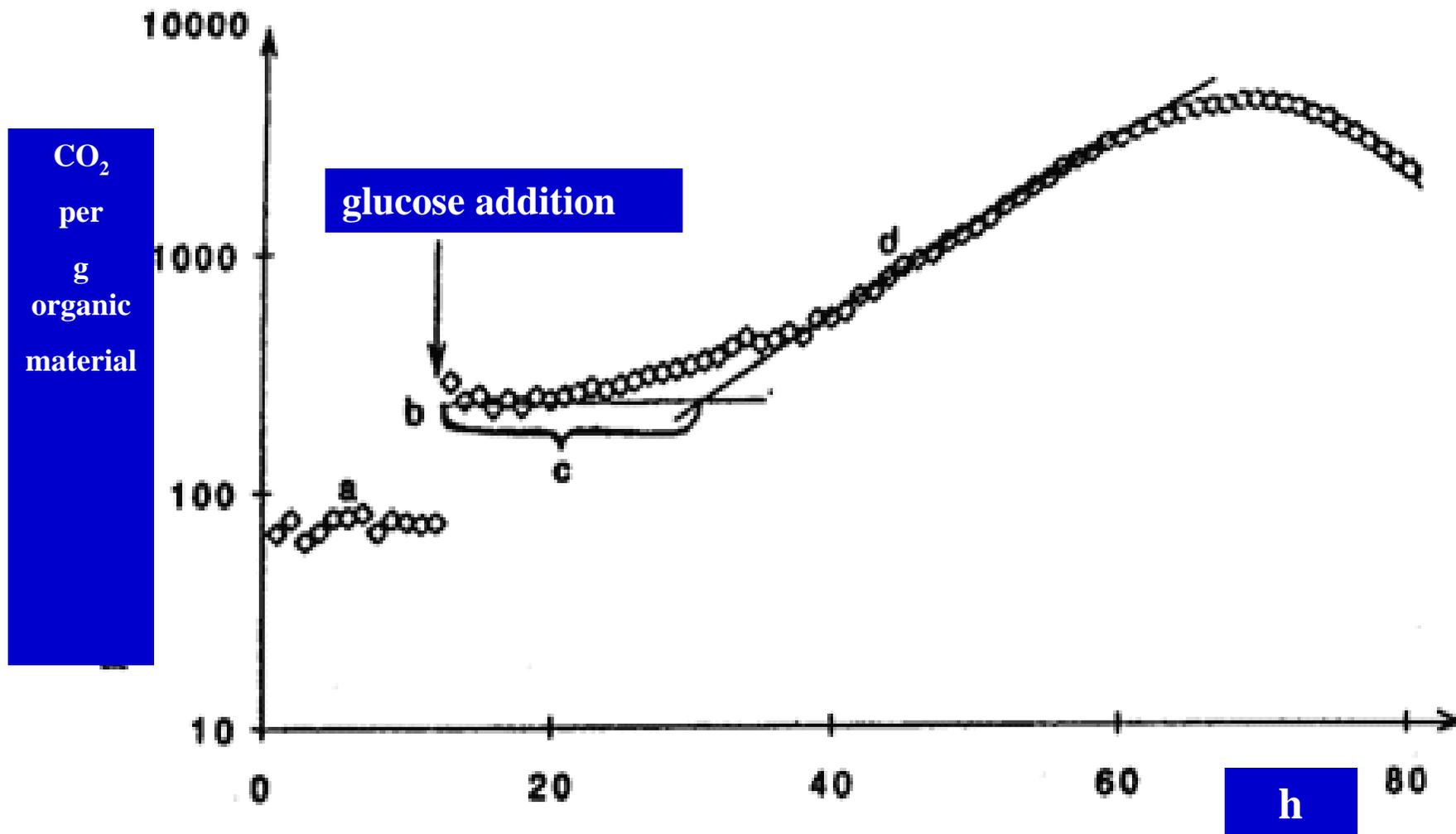
Elimination: elimination of substituents, the result is double bond

Oxidation / reduction, electron transport

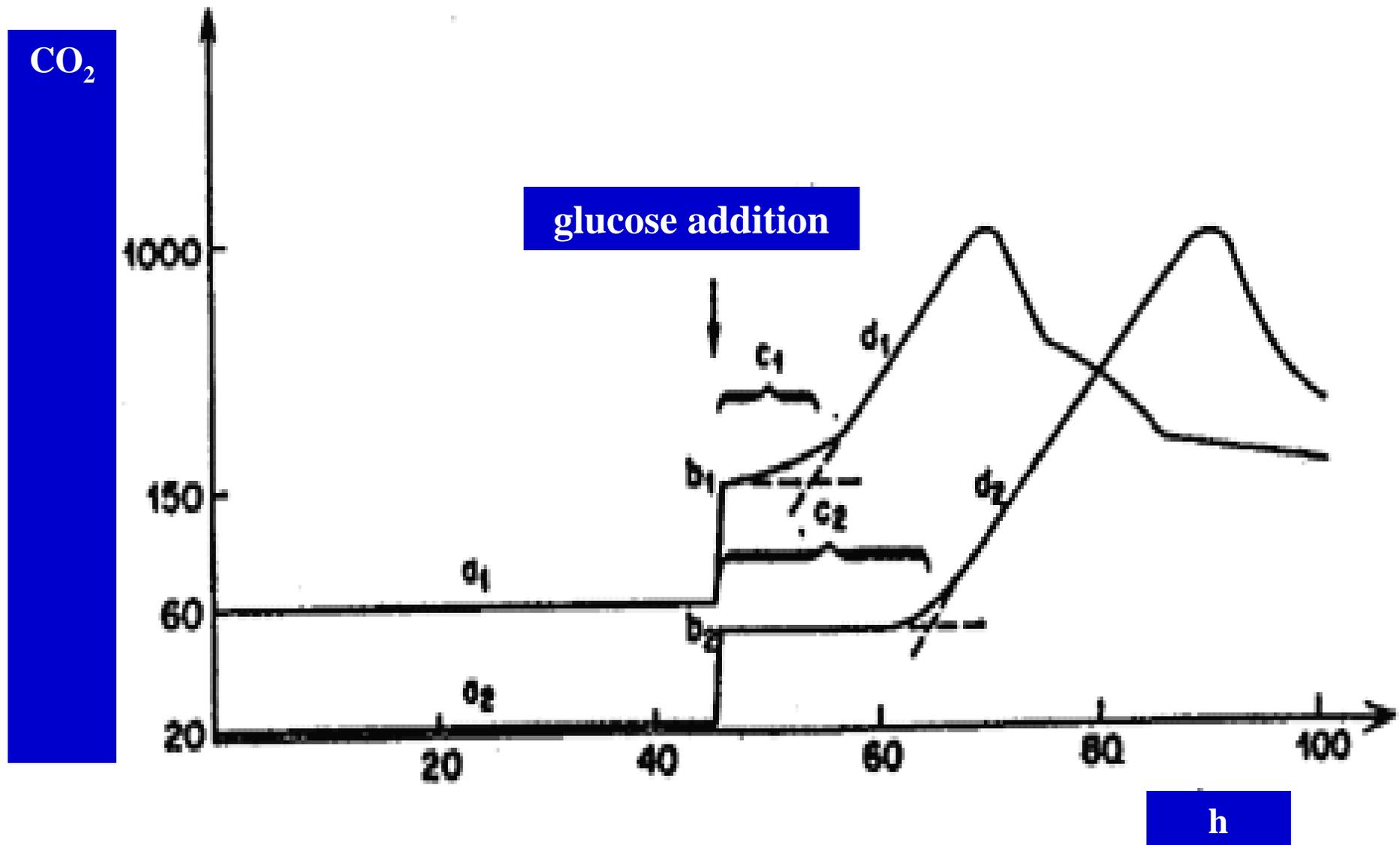
During Natural Attenuation of the biodegradable organic contaminants biodegradation is the main process

- **Biodegradability is an immanent characteristic of the compound: MW, polarity**
- **Real biodegradation depends on the genetics and physiology of the soil microbes**
- **and the environmental parameters, like T, pH, redox, nutrients**
- **The organic contaminant should be dissolved or dispersed in water to be bioavailable**
- **The form and the amount of oxygen (air, NO_3 , SO_4) determines respiration forms. Fe can serve as electron acceptor.**
- **During Natural Attenuation or any biodegradation in soil 3-4 mg of free or dissolved oxygen is necessary for the complete biodegradation of 1 mg of hydrocarbon into CO_2 and water.**

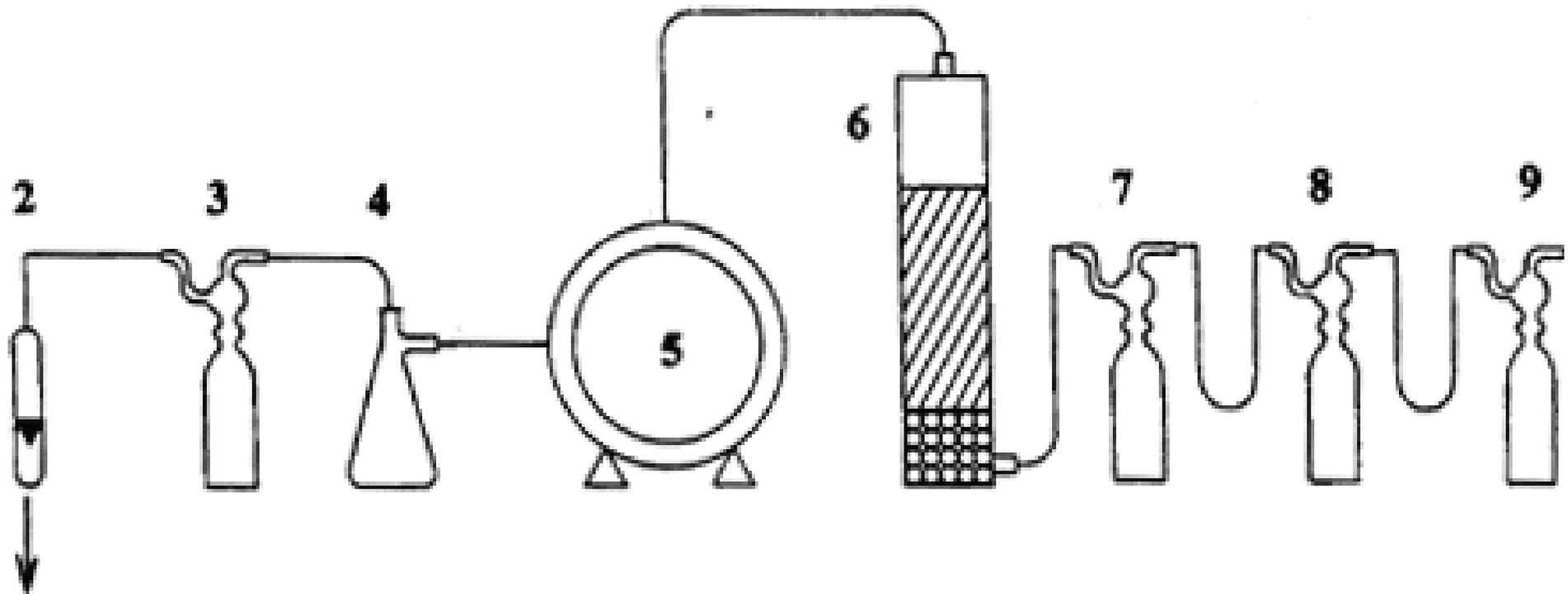
Soil respiration before and after substrate (glucose) addition (Torstensson, 1994)



Respiration of metal contaminated (c_2) and noncontaminated (c_1) soil before and after substrate addition (Torstensson, 1994)



Measuring soil respiration



1

1. Air exhaust

2. Vacuum-pump

3. CO₂ absorption

4. Puffer-vessel

5. Gasometer

6. Column-reactor

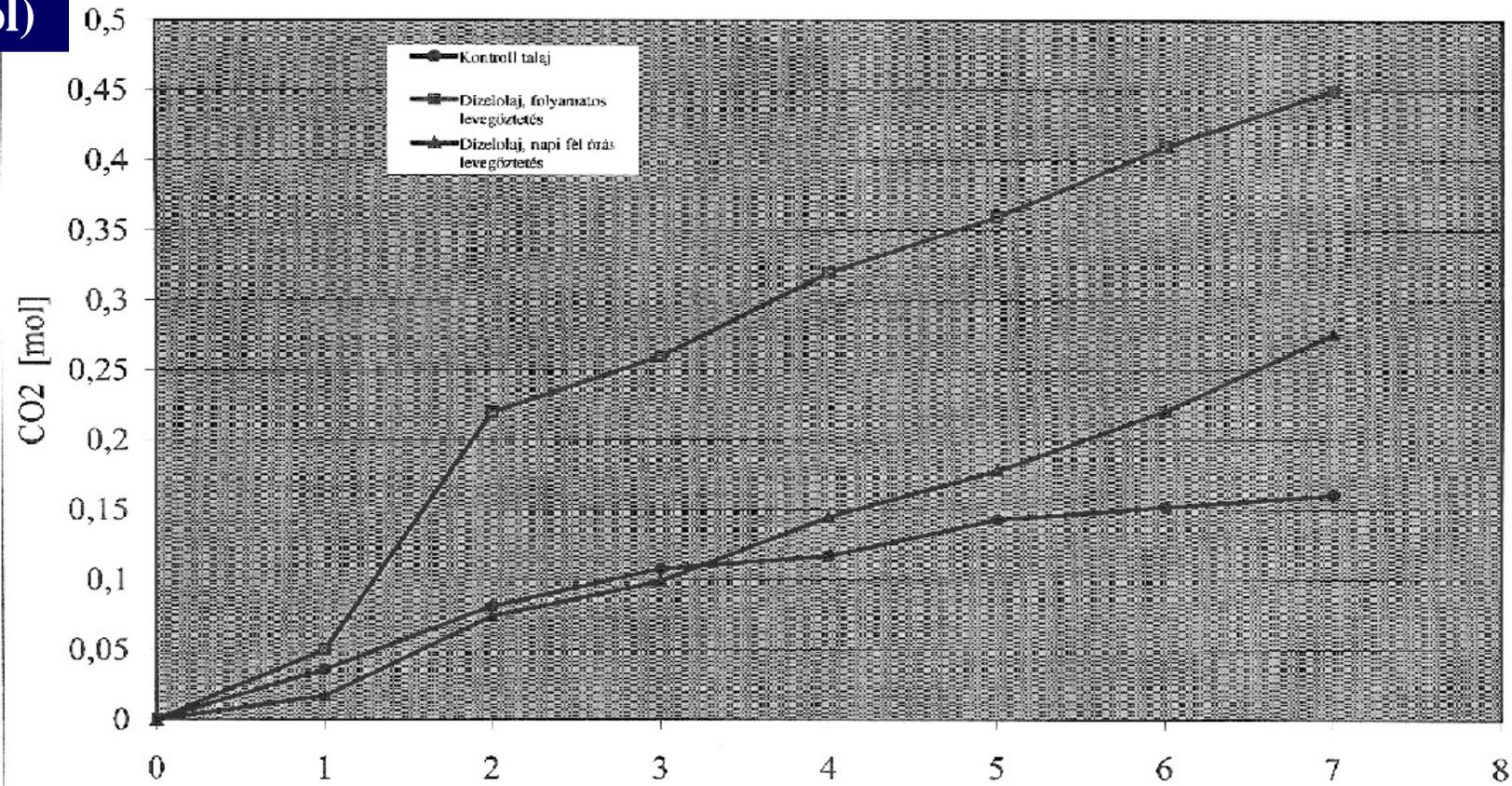
7. Washer

8, 9. CO₂ absorber

10. Air inlet

Diesel-oil biodegradation depending on the scale of aeration of the soil

CO₂
(mol)



Time (days)

22. ábra

Fate and nature of inorganic contaminants

The fate of the inorganic contaminants (toxic metals) is similar to the fate of natural inorganic compounds, which serve as nutrients for plants.

Their bounding, mobilisation, biological uptake and chemical changes are summarised below:

- 1. They can be built in the atomic or molecular grid of silicates, oxides and hydroxides, they may exist in ionic forms and in complexes**
- 2. Metals in the atomic or molecular grid are present mainly in particle form pollutants, or in unweathered rock, most frequently in silicates as substituent of Si, Fe or Al, sometimes of Ca, Mg or K. They can be mobilised from these minerals during the weathering of the rocks, when they are transformed into soluble ionic forms. These mobile ionic metal forms are infiltrated into deeper layers of leached and transported into other environmental elements, like surface waters of soils.**
- 3. Toxic metals in oxides and hydroxides may substitute Fe and Al. They are mobilised during weathering and soil acidification.**
- 4. Ionic metal forms are dissolved in the ground water or in the soil moisture, or they are sorbed on the surface of the clay minerals or the humus by ionic bounds. They are exchangeable.**

Organo-metallic complexes are generally bound to the humus, and are mobile

Ionic and complex metal-forms are mobile, exchangeable and biologically available

Metals bound into oxides are moderately mobile and available.

Metals bound into the atomic or molecular grid have low mobility and availability

Metal forms are able to transform into each other

The partition of the metal forms between soil phases depends on pH, redox and moisture

Sorption (ad-, ab- and chemisorption) results in solid form pollution

Mechanisms of accumulation of metals in organisms

- biosorption to the cell-wall components**
- extracellular complexation (e.g. *Rhizobium sp.*)**
- intracellular bounding**
- plasmid dependent accumulation**
- bounding to the periplasmic peptidoglucane**

Accumulation often associates to resistance

The complicate forms and situation in the soil is further complicated by the non-equilibrium state, continuously changing climatic and meteorological parameters

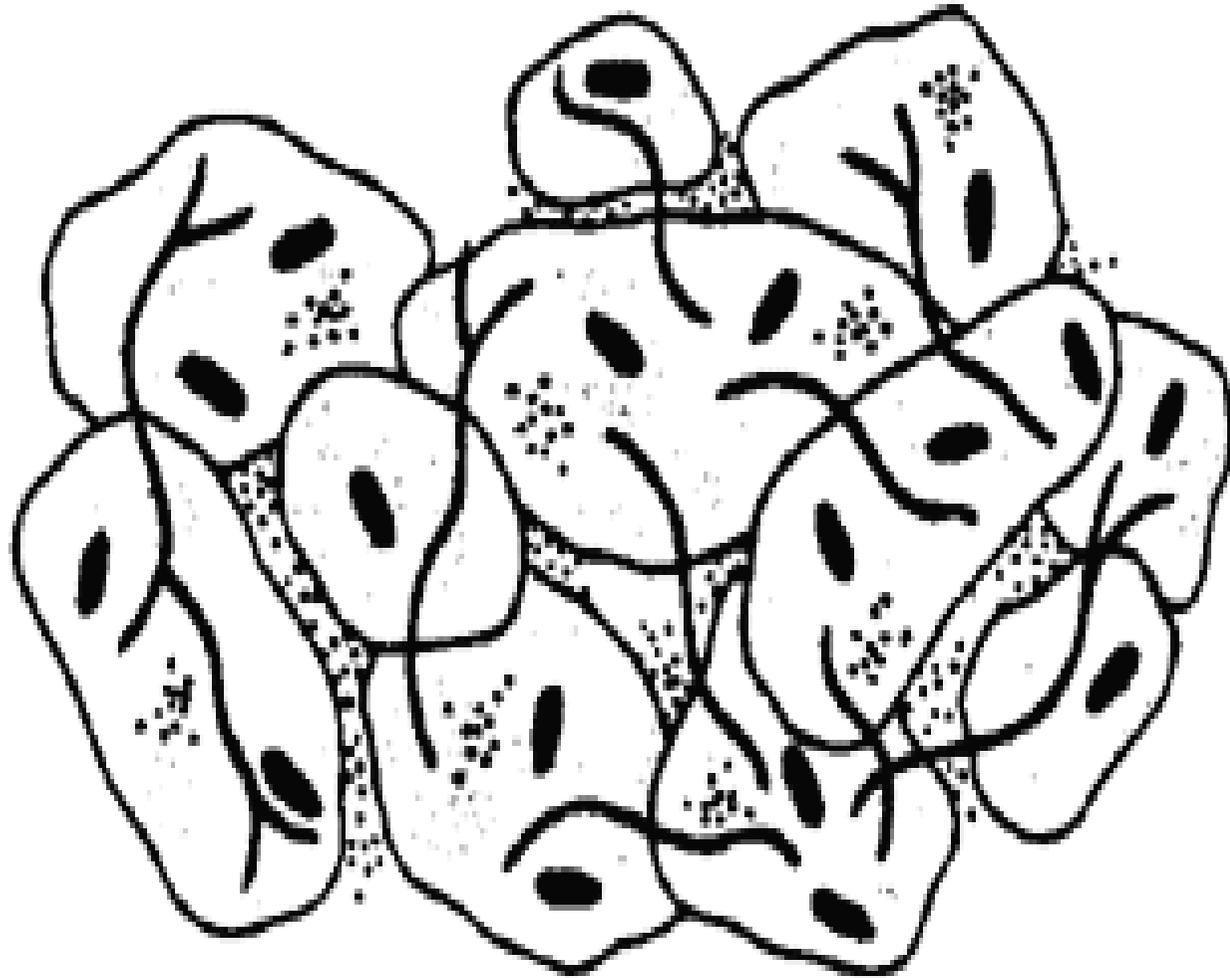
Bioaccumulation in plants

Secondary poisoning through food and feed plants!

Mechanisms of accumulation in plant:

- **Precipitation in the rhizosphere no much chemical substance in root and shoot (eg. *Epilobium sp.*)**
- **concentration in the root, no transfer into shoot, stem and leaves (eg. *Elytrigia repens, Poa annua, Scirpus holoschenus*)**
- **only in stem and leaves (eg. *Inula viscosa, Euphorbia dendroides, Arundo donax*)**
- **immobilising in vacuola**
- **immobilising in the cell wall**
- **an isolated reserve in stem and leaves: excluded from plant metabolism (eg. *Cistus salviifolius, Helichrysum italicus*).**

Microbes on the surface of soil particles



bacterial cells

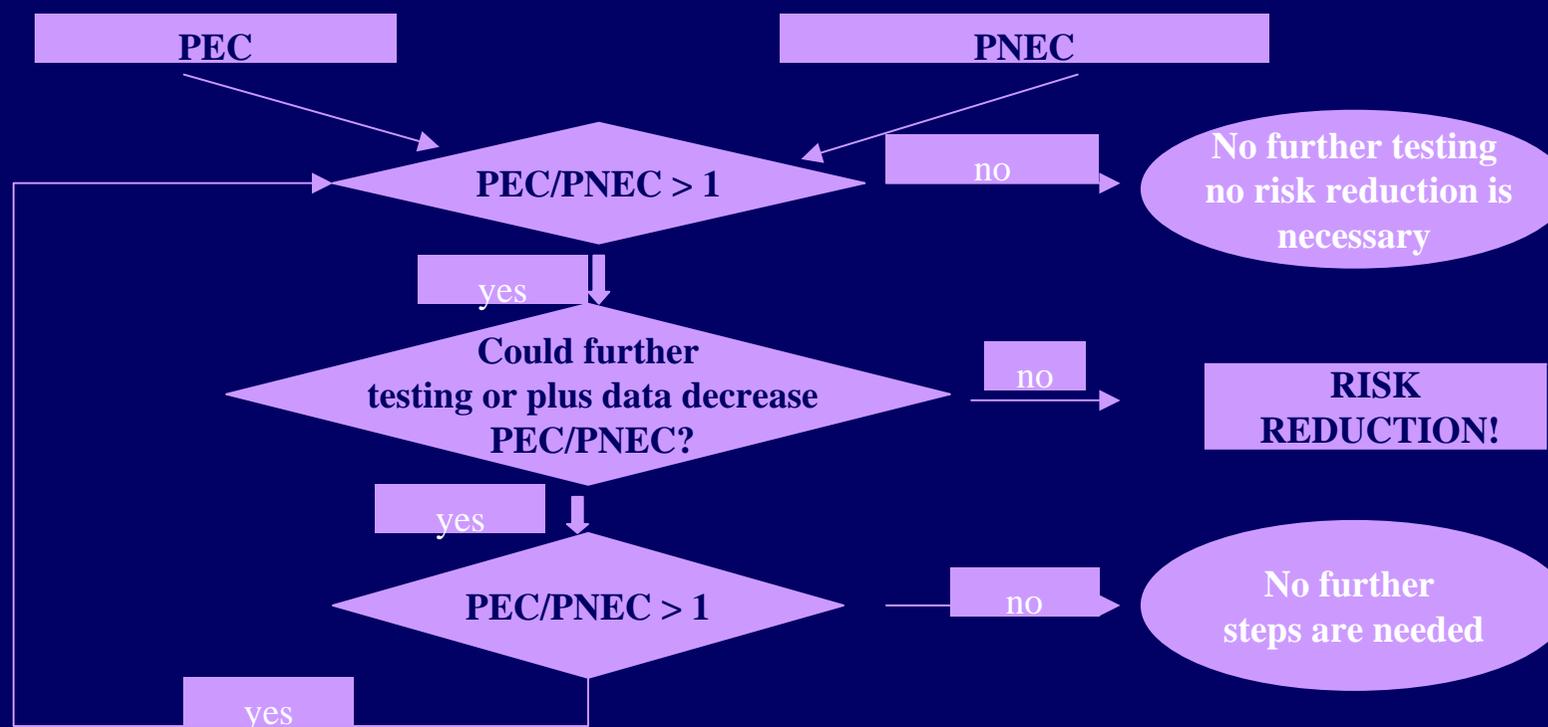
filamentous fu

protozoan

Quantitative environmental risk assessment of substances

Characteristics:

- gradual procedure (cost effective),
- iterative
- it uses worst case estimation (pessimistic model)
- it works also in case of lack of data (exclusion)



RQ values and their interpretation

RQ = PEC/PNEC	Hazard
< 0,001	negligable
0,001 – 0,1	low
0,1 - 1	mild
1 - 10	high
>= 10	very high

Integrated Risk Model

Theoretical structure (generic or site specific)

