Innovative Decision Support Tools for Risk Based Management of the Environment in Hungary

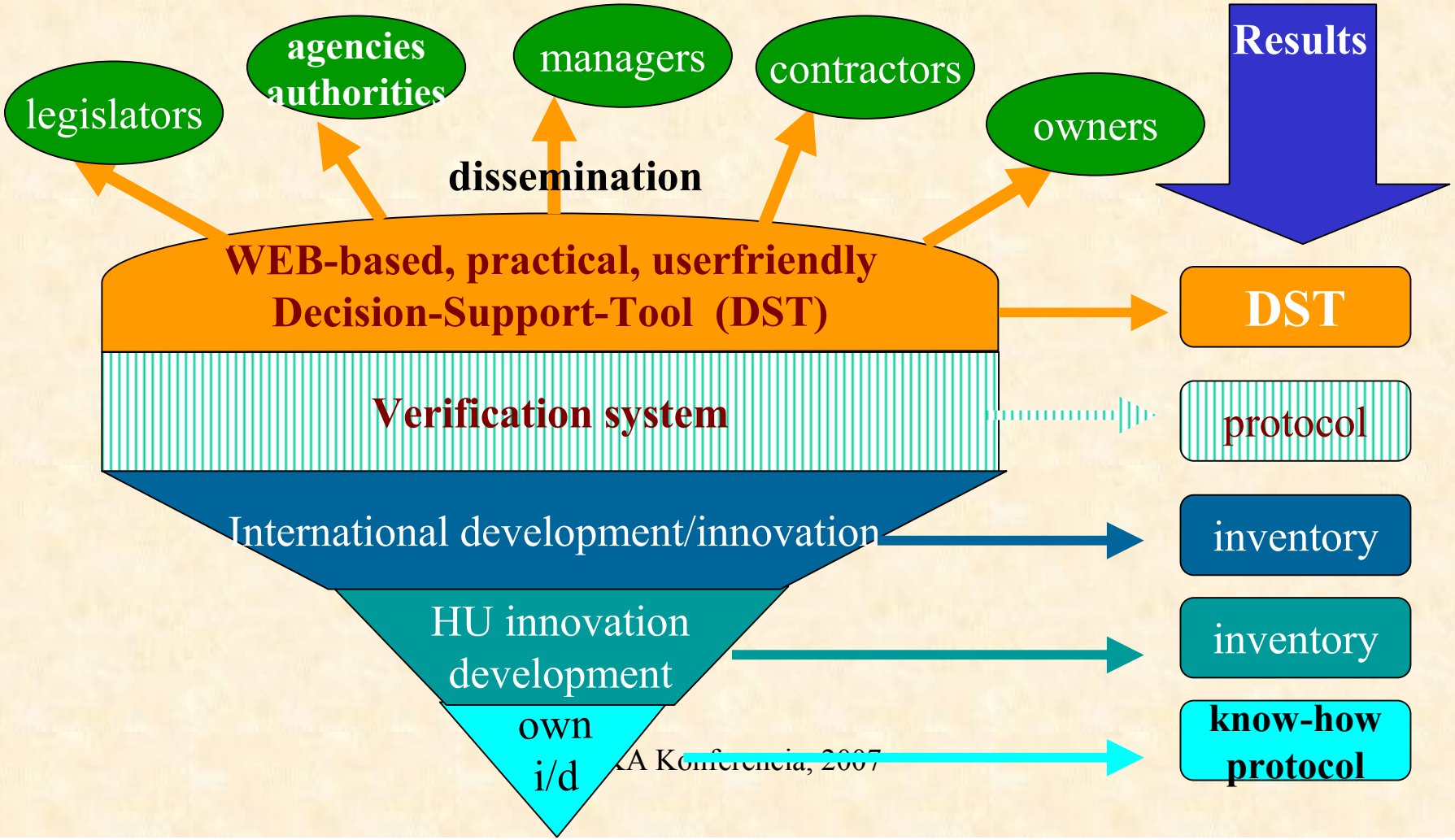
Modern Mérnöki Eszköztár Kockázatközpontú Környezetmenedzsment Alapjául

MOKKA

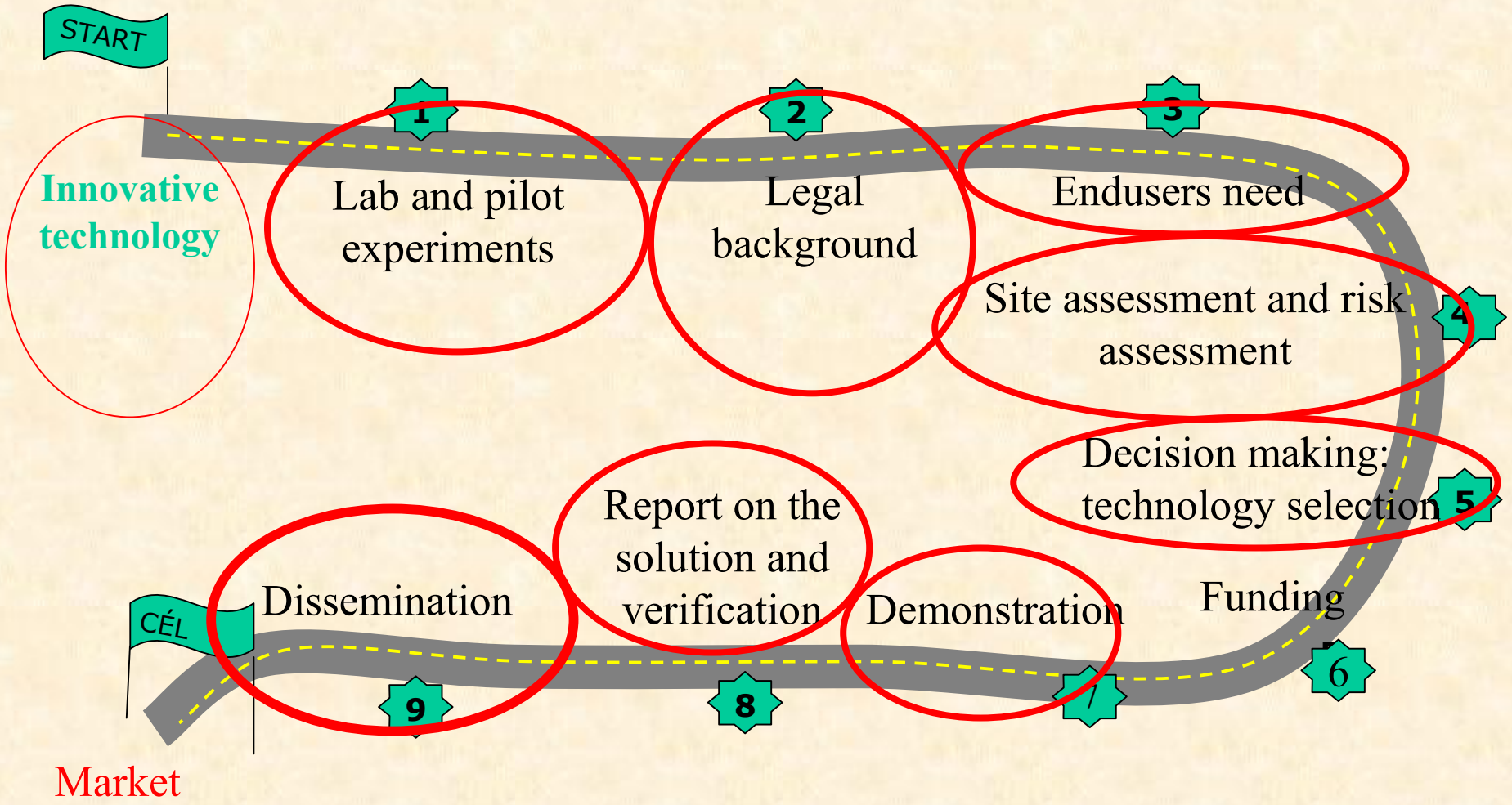
MOKKA Konferencia, 2007

MOKKA R&D scheme and expected results

The fundament includes the developments by the consortium-members: RA & RR.
The database of methods/technologies: full HU and selected EU
Data-base will be integrated into the WEB-based Decision-Support-Tool (DST)

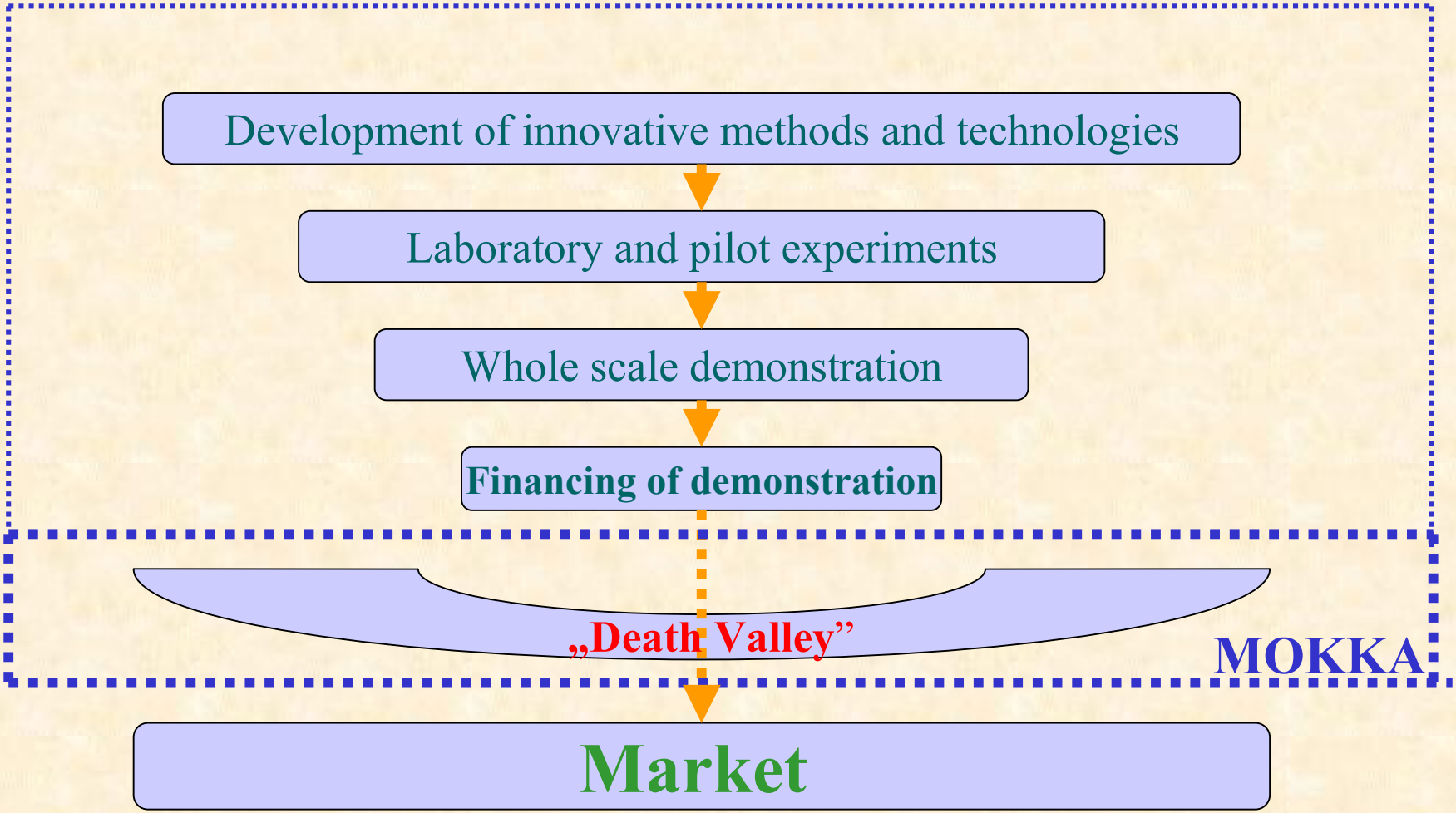


From the research to the market

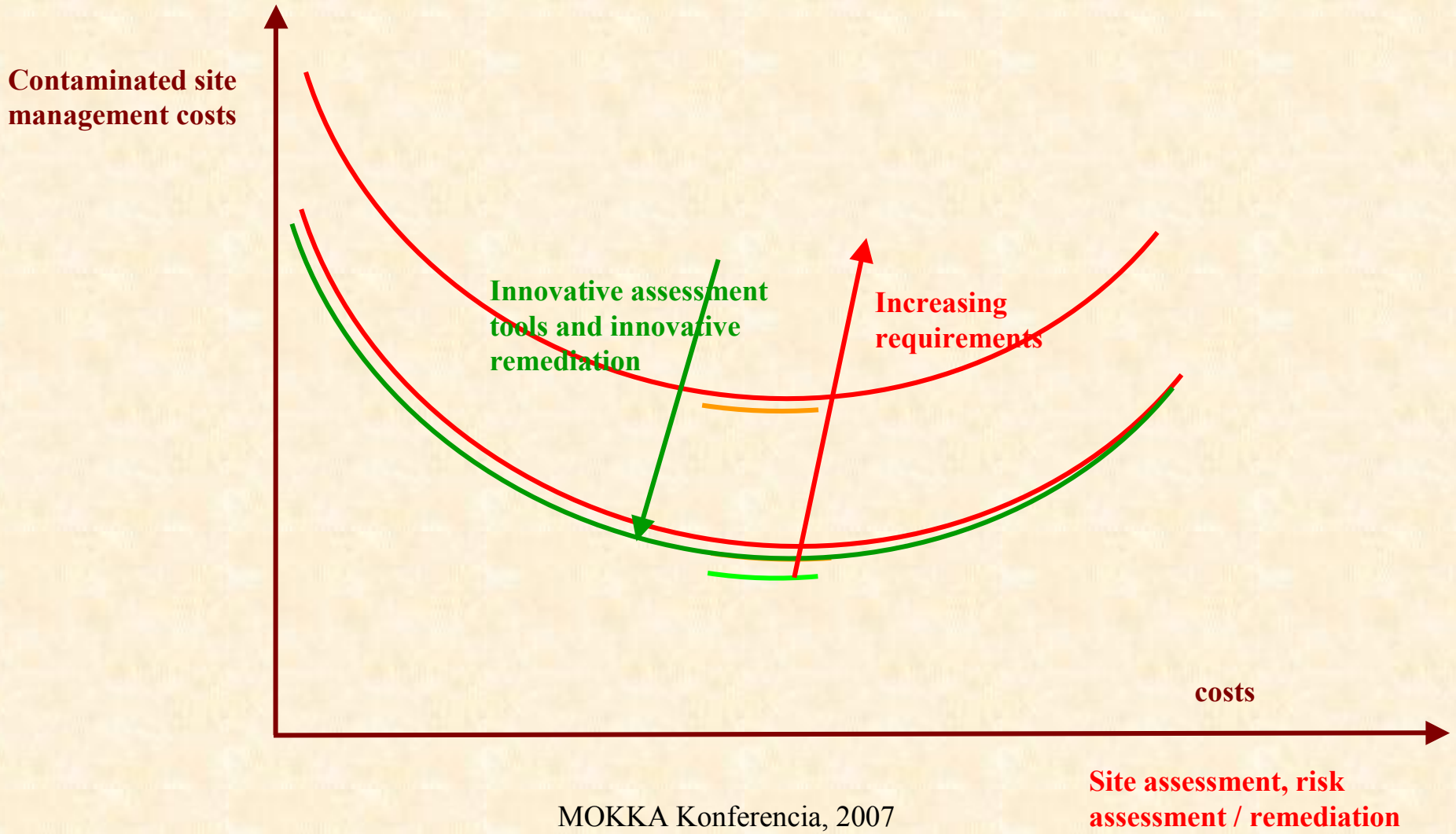


Innovation and practice

Most of the innovative methods/technologies are not put into parctice.
The highest loss is caused by those, which disappear in the „Death Valley”
after funding and demonstration.
MOKKA aims to support the survival of innovation and its market success.

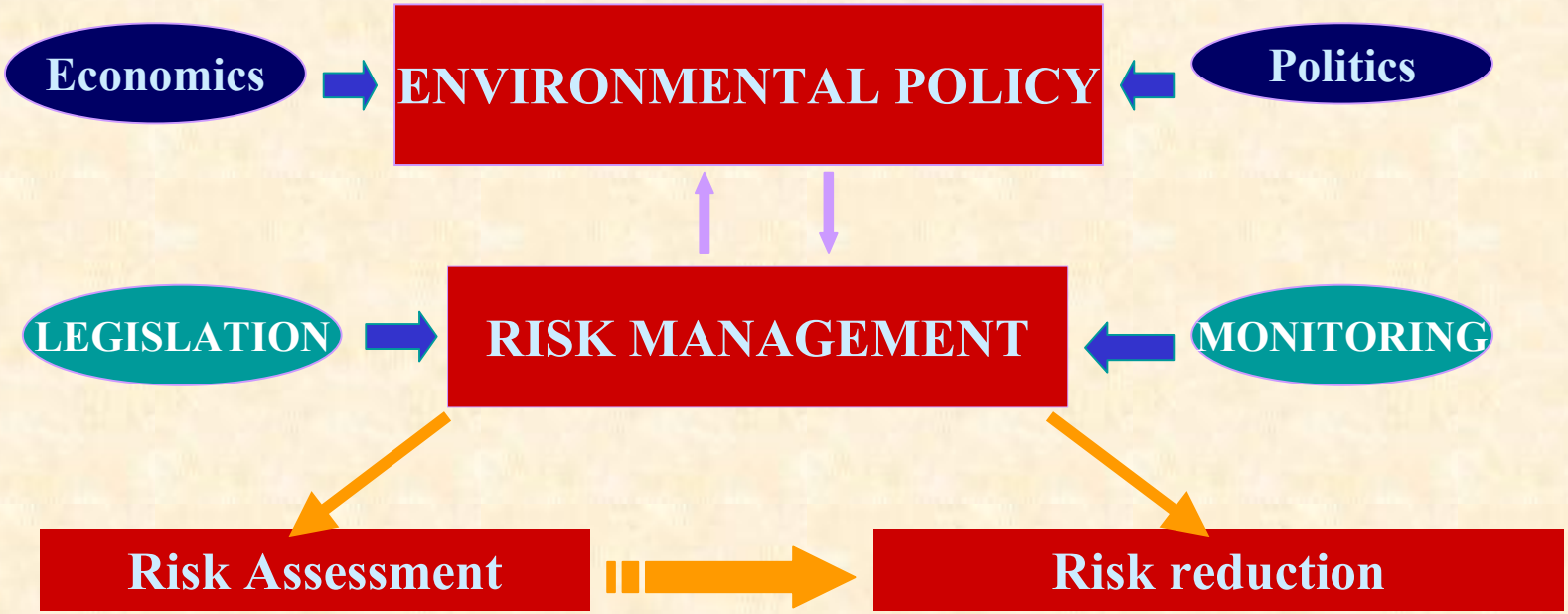


Increasing requirements - cost efficient solutions



Tasks of Environmental Risk Management

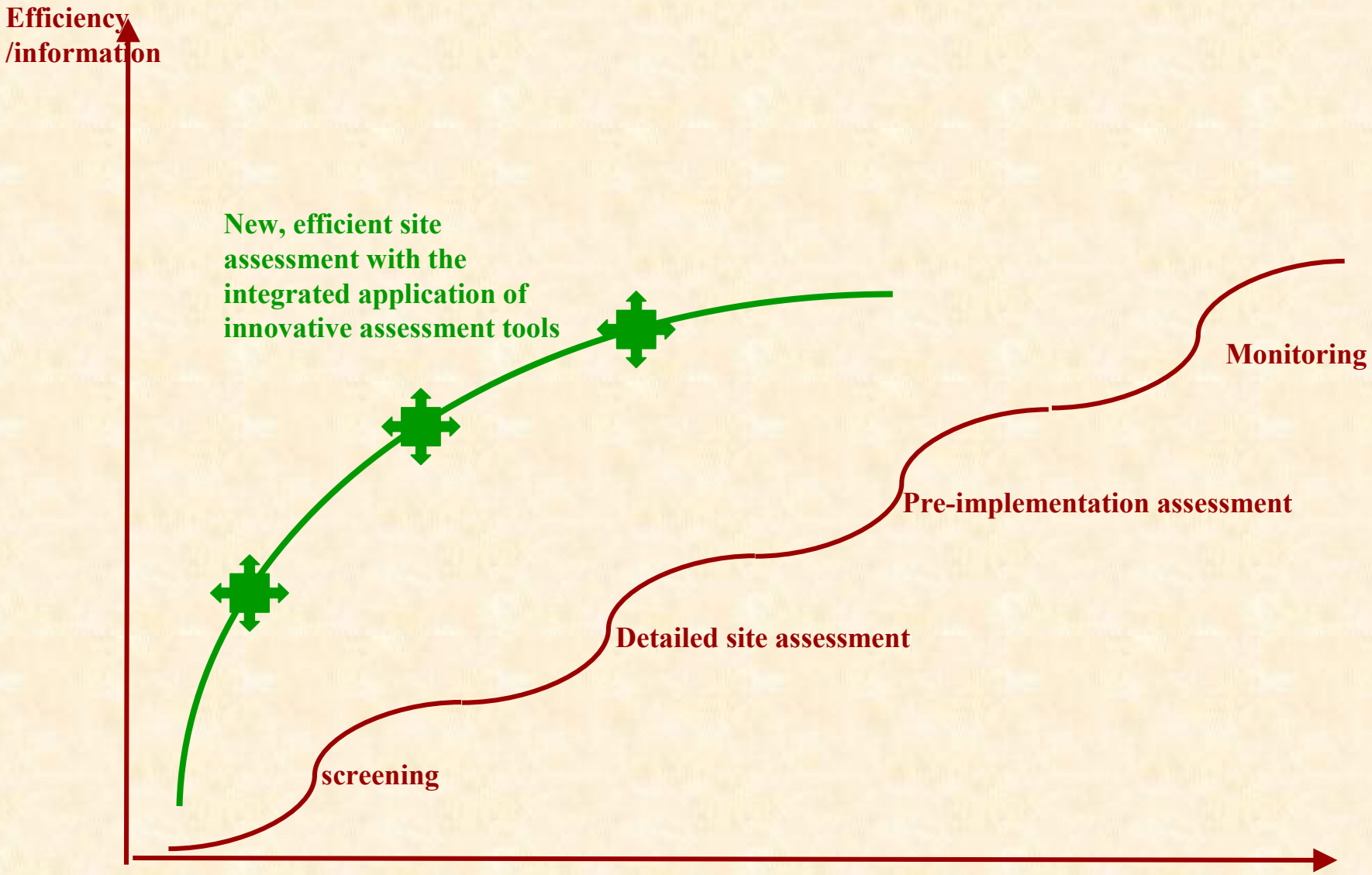
Environmental policy's main tool is environmental risk management (ERM).
ERM is supported by the legislation and by environmental monitoring.
ERM has two main tasks: Risk Assessment (RA) and Risk Reduction (RR).
RR plan is based on the comparison of the assessed and the acceptable risk.



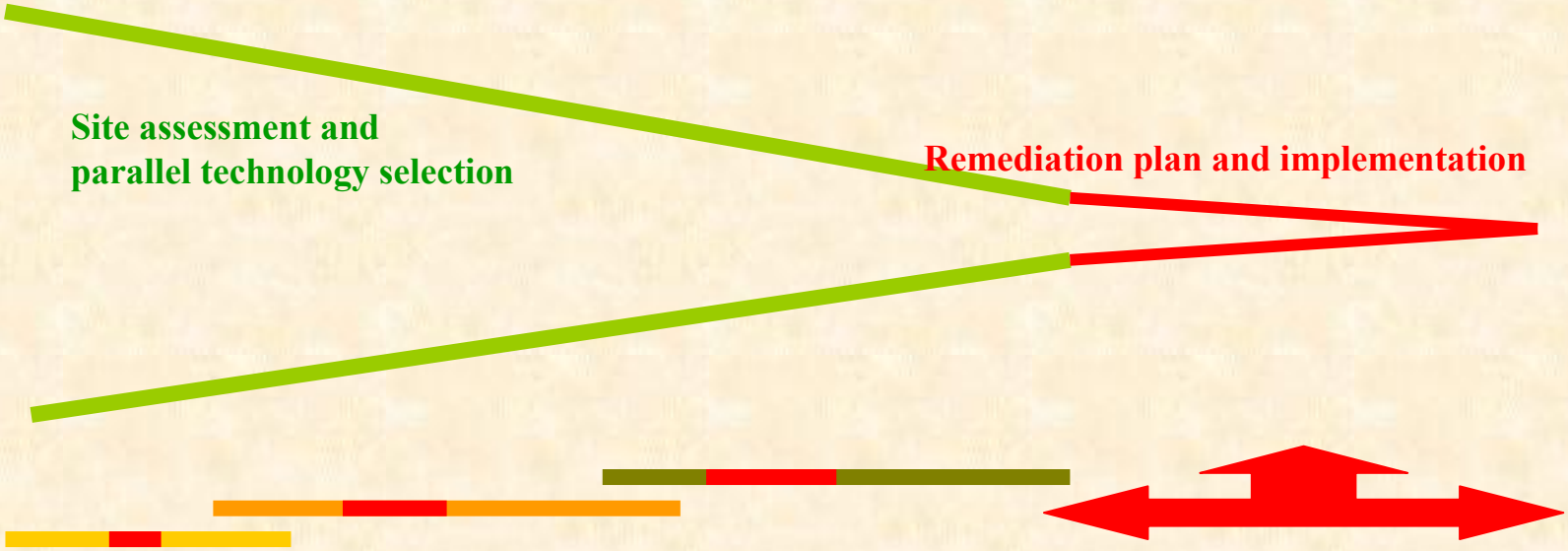
MOKKA project aims

- Better chance for Risk Based Environmental Management
- Developing Risk Assessment and Risk Reduction methods
- Increasing trust towards innovation
- Control, verification and validation of the new methods
- Making information available by electronic database
- Establishing a user friendly Decision Support Tool
- Supporting the market entry of innovative methods/technologies.

More efficient site assessment



Integrated site assessment in aid of the selection of remediation technology



Assessment type	Contaminant-specific	Site-specific	Interaction-specific	Intervention-specific dynamic testing
Expected result	Contaminant quantity and quality Identification of contaminated elements and phases, etc.	Soil type, hydrogeological, biological characteristics, etc.	Biodegradation, partition between phases food chain effects, etc.	Technology selection Technological parameters for planning Discharge and risk control Cost estimation, etc.

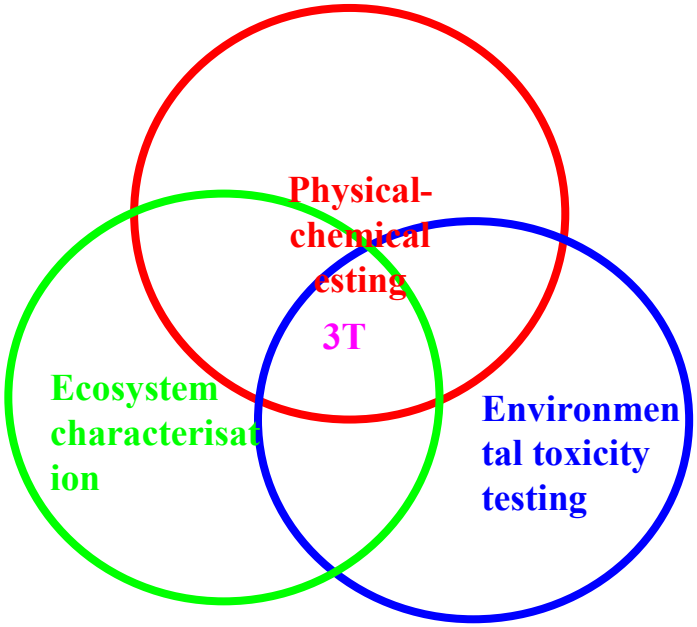
 Red: technology-related elements

Integrated tool-system of the risk management

COMPLEX RISK MANAGEMENT

INTERPRETATION TOOLS

Assessment tools



TRANSPORT MODELS

GIS-MODELS

INTEGRATED RISK MODEL

SITE SPECIFIC RISK ASSESSMENT

STATISTIC TOOLS

DECISION SUPPORT SYSTEM

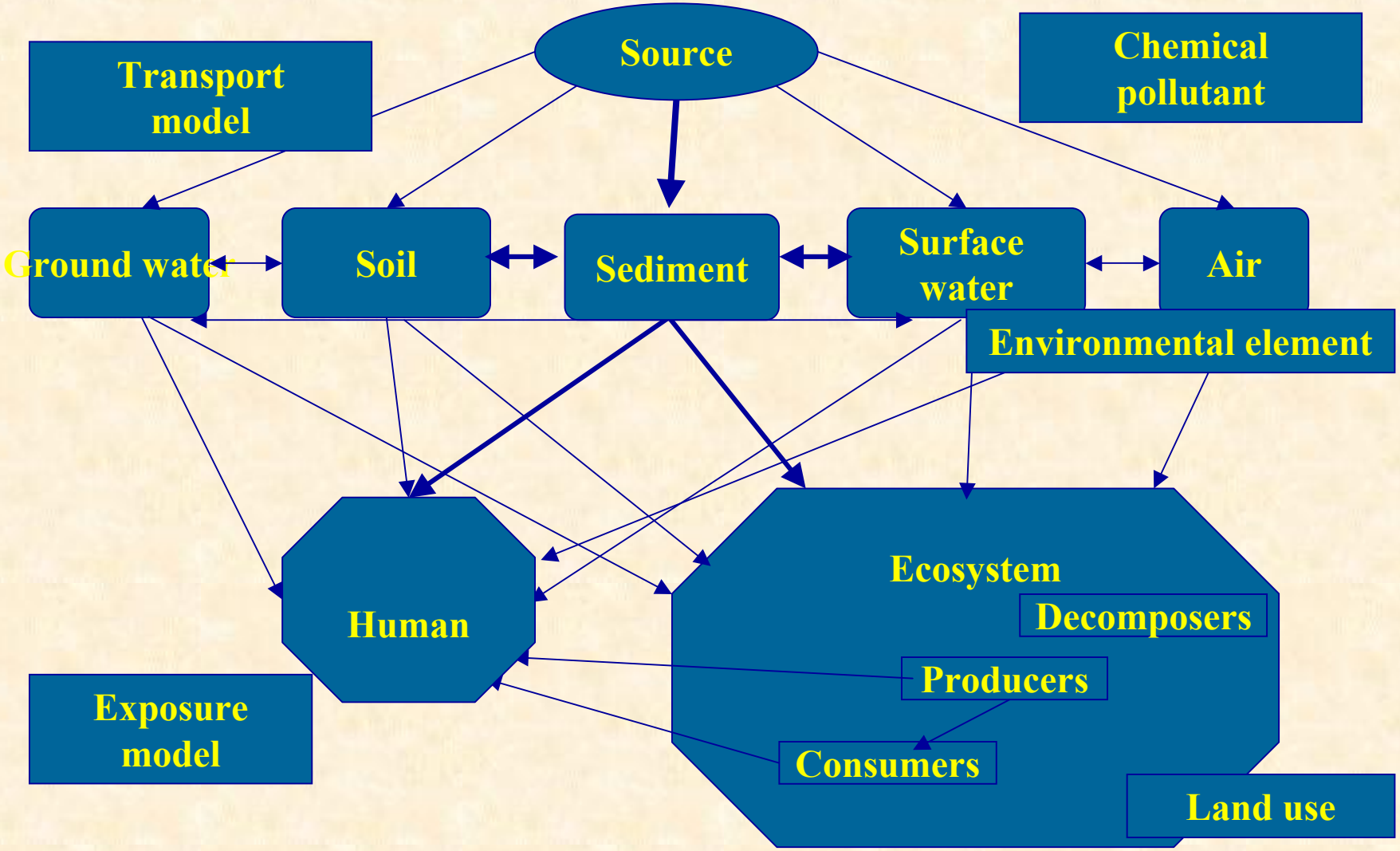
CONCEPTUAL MODEL

ASSESSMENT TOOL-BOX

EVALUATION OF THE REMEDIATION ALTERNATIVES

OPTIMISING DATA EVALUATION

Integrated Risk Model



Participants' own developments in Risk Assessment tools

- Biological, ecological and chemical early warning systems
- In situ measurement of site specific effects of chemicals
- Testing of partition, biodegradation, bioaccumulation, etc.
- In situ testing of environmental parameters, like pH and redoxpotential
- Integrated assessment by using chemical, biological and ecological testing, the TRIAD approach
- Refinement of transport modeling by GIS based methods and partition, biodegradation, bioaccumulation
- Control, verification and validation of the the new methods

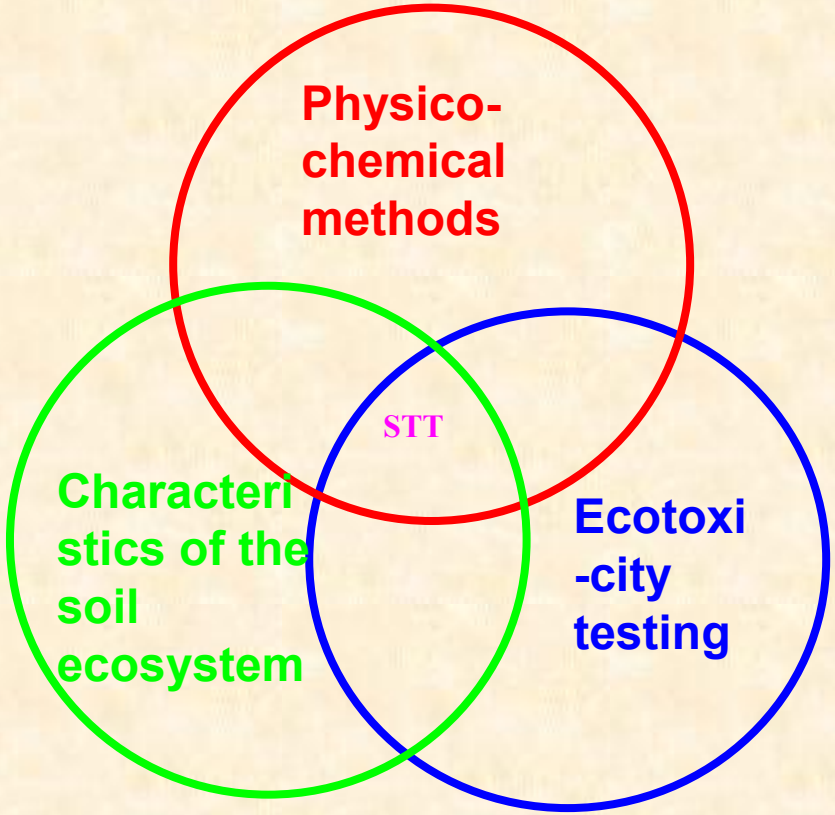
Ecotoxicity testing of contaminated soil

Ecotoxicity testing gives solutions for many of the environmental analyses problems

- integrates interactions between toxicants in case of mixed contaminants
- integrates interactions between toxicant and matrix, toxicants and biota
- is able to measure extract or whole soil
- measures bioavailable ratio of the contaminant, different of the chemically available ratio
- measures chemically not measurable toxicants by their effect
- measures the effects of chemicals not included into the analytical programme

Direct contact makes possible integration of the interactions between contaminant, soil matrix and the test organism!

SoilTestingTriad



STT, the SoilTestingTriad

Importance of physico-chemical, biological methods and toxicity testing is the same. They are complementary. They give information on the quality and quantity of contaminant, the characteristics of the soil, the biological status of the soil, the activity, vitality and adaptive behaviour of the soil, about the effects, mobility, bio-availability, biodegradability of the contaminant. They are able to show the response of the soil for external effects.

Availability of tailings samples

	Azotobacter agile **dehydrogenase enzyme activity**	***Sinapis alba*** **seed germination and root elongation**	***Photobacterium phosphoreum*** **bioluminescence test**
Upper layer of the tailing material (mixed with soil) [M2]	Very toxic	Toxic	Very toxic
Inner layer of the tailing material (inert) [M6]	Non toxic	Slightly toxic	Non toxic

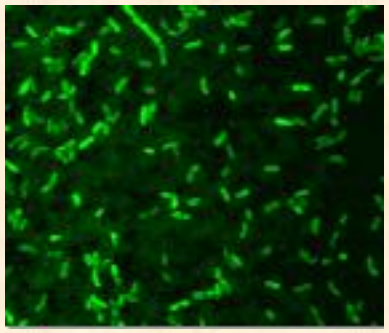
Availability - weathering

Layer	pH	Total metal mg/kg			Mobile metal mg/kg		
		Zn	Pb	Cu	Zn	Pb	Cu
Greyish flotation tailings	7,0	31 858	4 971	2 450	3,4	1,2	0,6
Red layer	7,1	2 248	481	114	4,3	0,1	0,0
Yellow layer	7,3	7 571	2 766	984	3,9	1,7	0,6
Soil cover	4,7	603	186	72	42,2	1,9	0,5

Vibrio fischeri bacterial testorganism

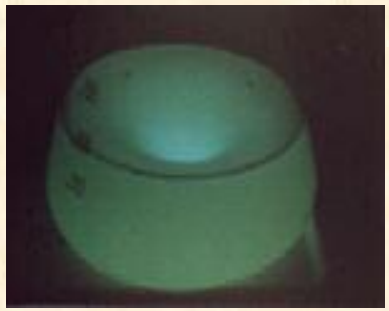
- Testorganism: *Vibrio fischeri* NRRLB – 11177

  Vibrio fischeri is a common marine organism and can routinely be isolated from fresh fish. Under optimum growth conditions, it is a very brightly growing species.



Micrograph: fluorescently stained cells

Liquid culture in well lit place

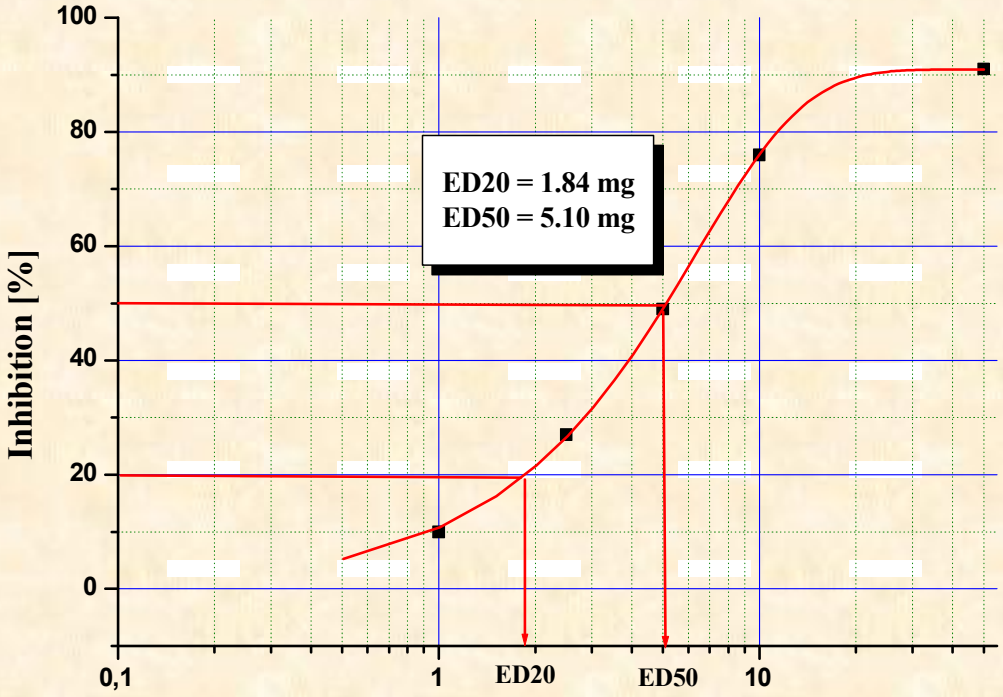


Liquid culture in darkness

On Petri plates with solid medium

Vibrio fischeri bioluminescence inhibition test for the testing of the toxicity of whole soil Evaluation and interpretation

Dose-response curve of a contaminated soil sample



Characterization of the contaminated soil on the bases of the ΣCu_{20} / ΣCu_{50}

ΣCu_{20} [mg Cu / kg soil]	ΣCu_{50} [mg Cu / kg soil]	Characterization
< 80	< 120	Non toxic
80-250	120-300	Slightly toxic
250-400	300-500	Toxic
> 400	> 500	Very toxic

Folsomia candida (*Collembola*) animal testorganism

- Test method requires a sufficient number of sub-adult animals at the same age (12-14 days old)

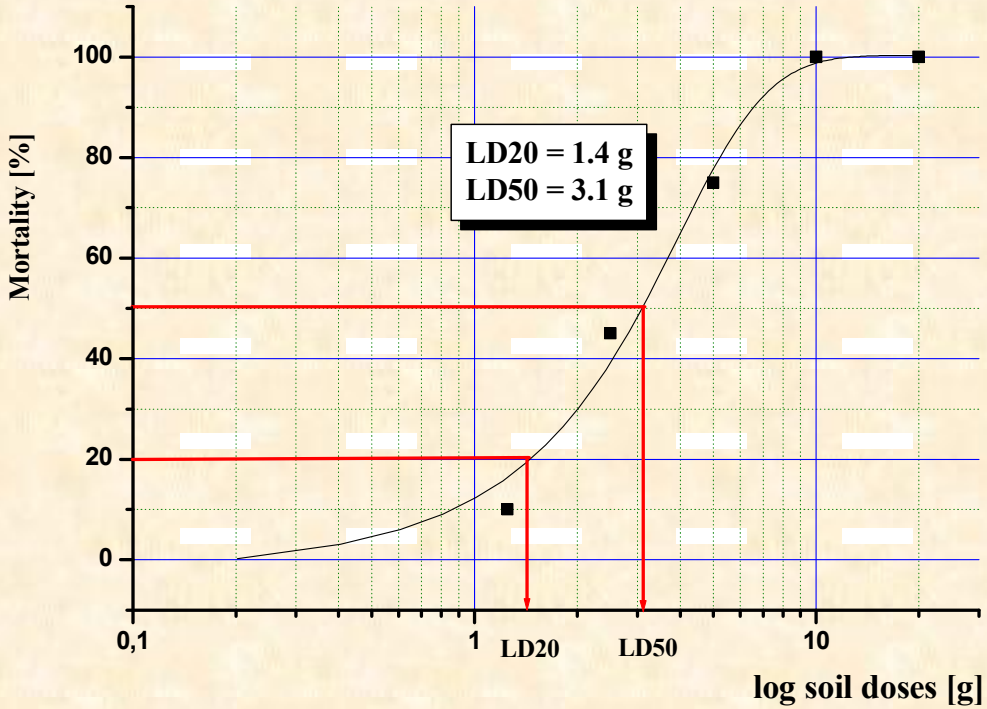
Adult female (1.8 mm) with eggs

Adult females (2 mm in length) with juveniles

Adult female (2.0 mm).

Folsomia candida mortality test for whole soil Evaluation and interpretation

Dose-response curve by the use of Origin 6.0 software



Characterization of the contaminated soil samples on the bases of the LD_{20} and LD_{50} values

LD_{20} [g]	*LD_{50} [g]*	*Characterization*
> 20	> 20	Non toxic
12-20	16-20	Slightly toxic
2-12	4-16	Toxic
< 2	< 4	Very toxic

MOKKA Konferencia, 2007

Participants' own developments: Risk Reduction/Remediation

- Modern bio/eco-engineering methods
- Risk based target quality of the environment
- Risk reduction by prevention and restriction
- Risk Reduction by Remediation
  - utilisation of natural processes
  - in situ remediation methods
  - integrated approach
  - reactor approach
- Control, technology-monitoring and verification of the the new technologies

MOBILISATION OF THE CONTAMINANT

Contaminant's chemical characteristics	Contaminated soil air	Contaminated subsurface water	Contaminated solid phase
Volatile	Remediation based on biodegradation Air exhaust	Remediation based on biodegradation Stripping	Remediation based on biodegradation Soil vapour extraction Thermal desorption
Water soluble	Remediation based on biodegradation Soil vapour extraction	Based on biodegradation Based on chemical ox/red Fitoremedition Pump and treat PRB	Based on biodegradation Based on chemical ox/red Fitoremediation Soil washing Elektrokinetic procedure, Etc.
Sorbable	Remediation based on biodegradation Soil vapour extraction	Remediation based on biodegradation Based on chemical ox/red Desorption + Pump and treat	Based on biodegradation Biológiai kioldás Fitoremediation Chemical extraction Wet fractionating Thermal desorption Incineration/pirolysis Vitrification, etc.

IMMOBILISATION OF THE CONTAMINANT

Contaminant	Contaminated soil air	Contaminated subsurface water	Contaminated solid phase
Volatile	Isolation Chemical immobilisation	Biological immobilisation Chemical immobilisation	Gazadsorption on solid phase Chemical immobilisat.
Water soluble	Isolation Chemical immobilisation (precipitation, sorption, etc.)	Biological immobilisation Rhizofiltration Physico-Chemical immobilisation Oxidation/reduction	Biological immobilisat. Fitostabilisation Physico-Chemical immobilisation Oxidation/reduction
Sorbable		Biological immobilisation Rhizofiltration Szorpció növelése Physico-Chemical immobilisation Oxidation/reduction	Biológiai immobil. Fitostabilizáció Fitostabilisation Physico-Chemical immobilisation Oxidation/reduction Vitrification, ceramic production

EURODEMO

EURODEMO aims to be the principal European co-ordination action for soil and groundwater remediation technology demonstrations, by:

- **preparing a detailed database of remediation projects demonstrating (innovative / promising) remediation technologies,**
- **creating a database of funding resources available for demonstration projects,**
- **working to reduce the barriers which hamper the use of promising soil and groundwater remediation technologies, and**
- **promoting the harmonisation of quality criteria for the reporting of soil and groundwater remediation demonstration projects.**

MOKKA developments

1. **In situ and ex situ remediation based on biodegradation and combined with flushing and soil washing**
   For soils contaminated with inherently biodagradable contaminants

2. **Combined chemical and phytostabilisation**
   For toxic metals contaminated soil

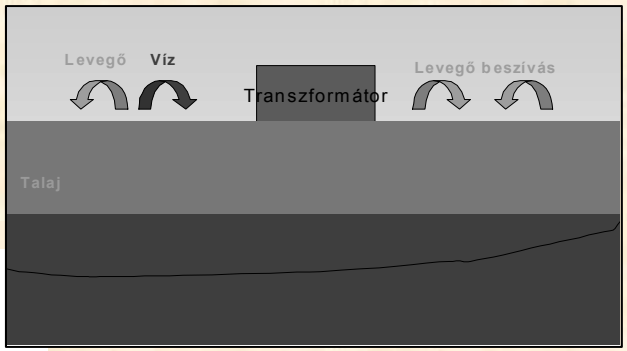
3. **Fitoremediation combined with revitalisation**
   For the revegetation of diffusely contaminated sites

Keywords: sustainability, control and monitoring, regulation, environmnetal risk of the remediation, verification, env. efficiency, cost efficiency, cost-benefit

Scale-up: from the laboratory to the field

Cyclodextrin enhanced bioremediation of hydrocarbons contaminated soil

30 m^3 , 50 t of contaminated soil



Field application

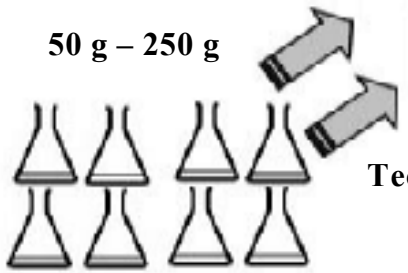
In situ CycloDextrin Technology – ***CDT***

47 weeks

40 kg

250 g – 500 g

50 g – 250 g



Pilot-scale laboratory technological experiments

42 weeks

Technological experiments in microcosms

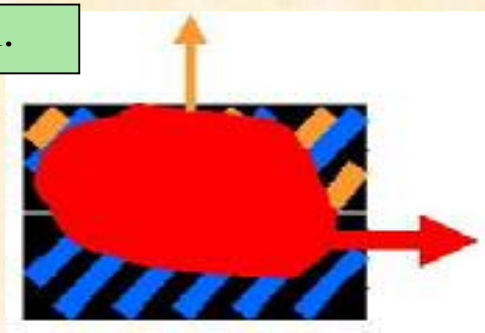
4–10 weeks

Biodegradation experiments

1–3 weeks

Uniform scheme for better explanation and understanding of the technologies: complex technology for transformer oil contaminated soil

1.



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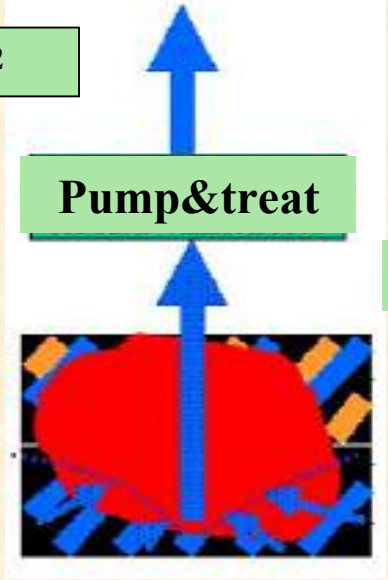

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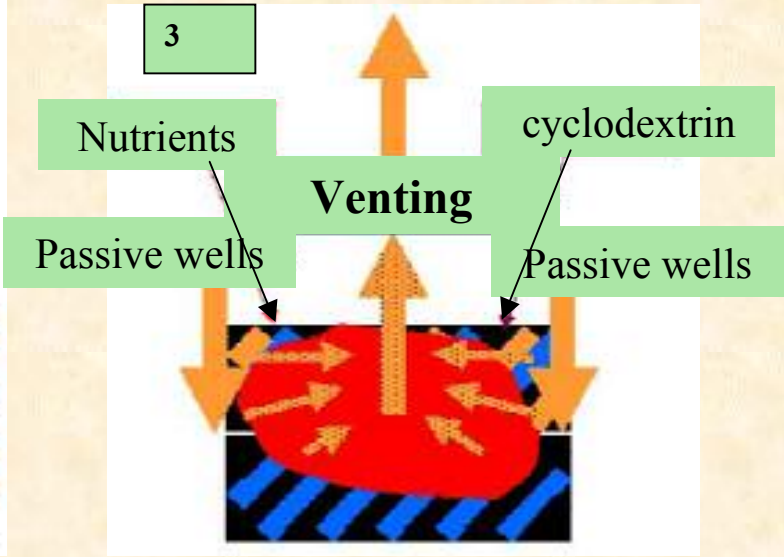

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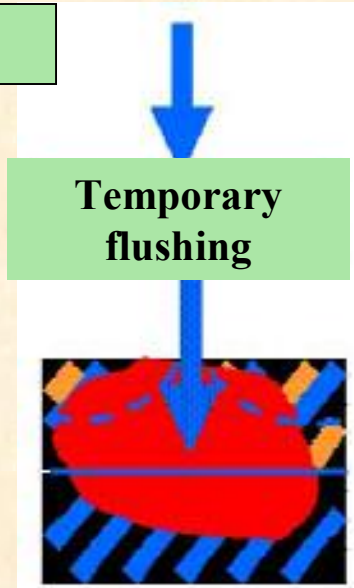

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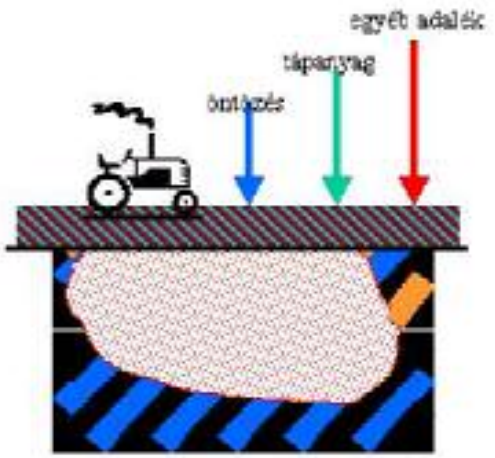
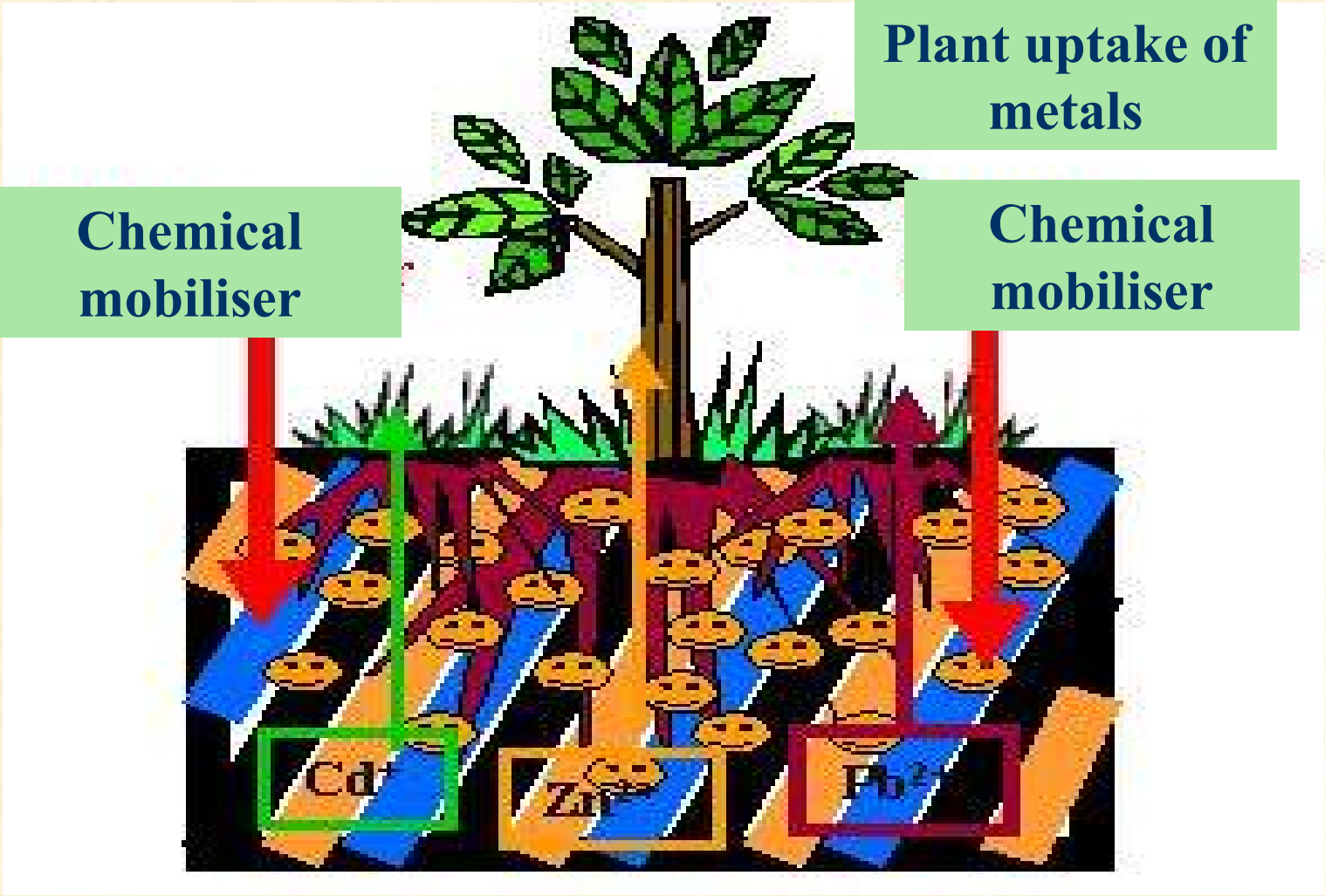


1. Soil vapor extraction
2. Pump end treat of the GW
3. Bioventing and nutrient supply
4. Temporary flushing
5. Agrotechnical treatment of the surface soil

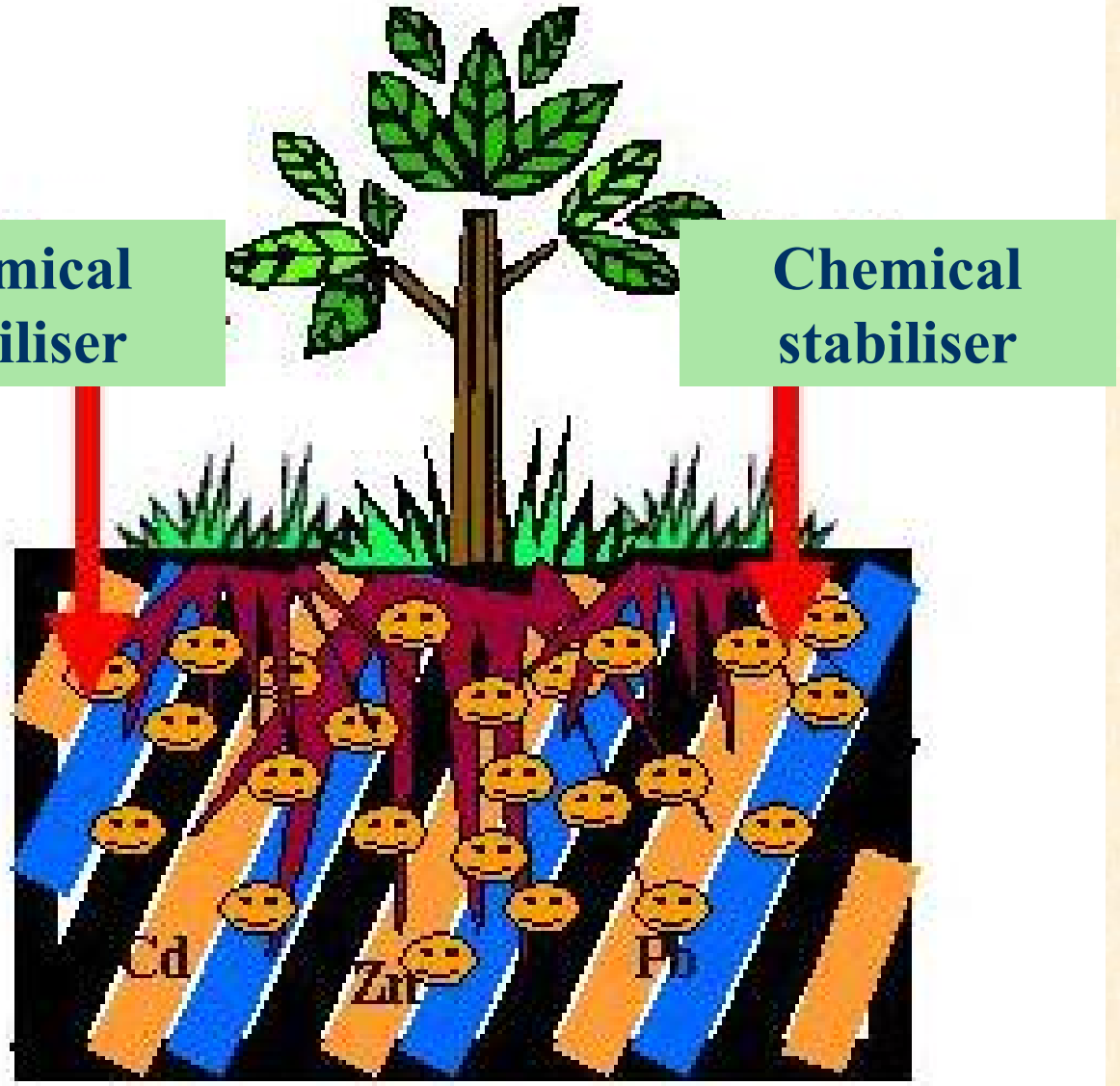
Uniform scheme for better explanation and understanding of the technologies: phytoextraction



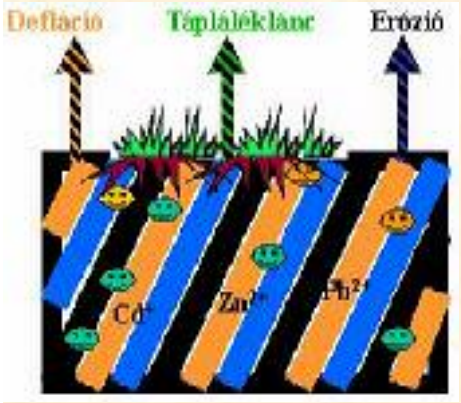
Uniform scheme for better explanation and understanding of the technologies: phytostabilisation

Chemical stabiliser

Chemical stabiliser

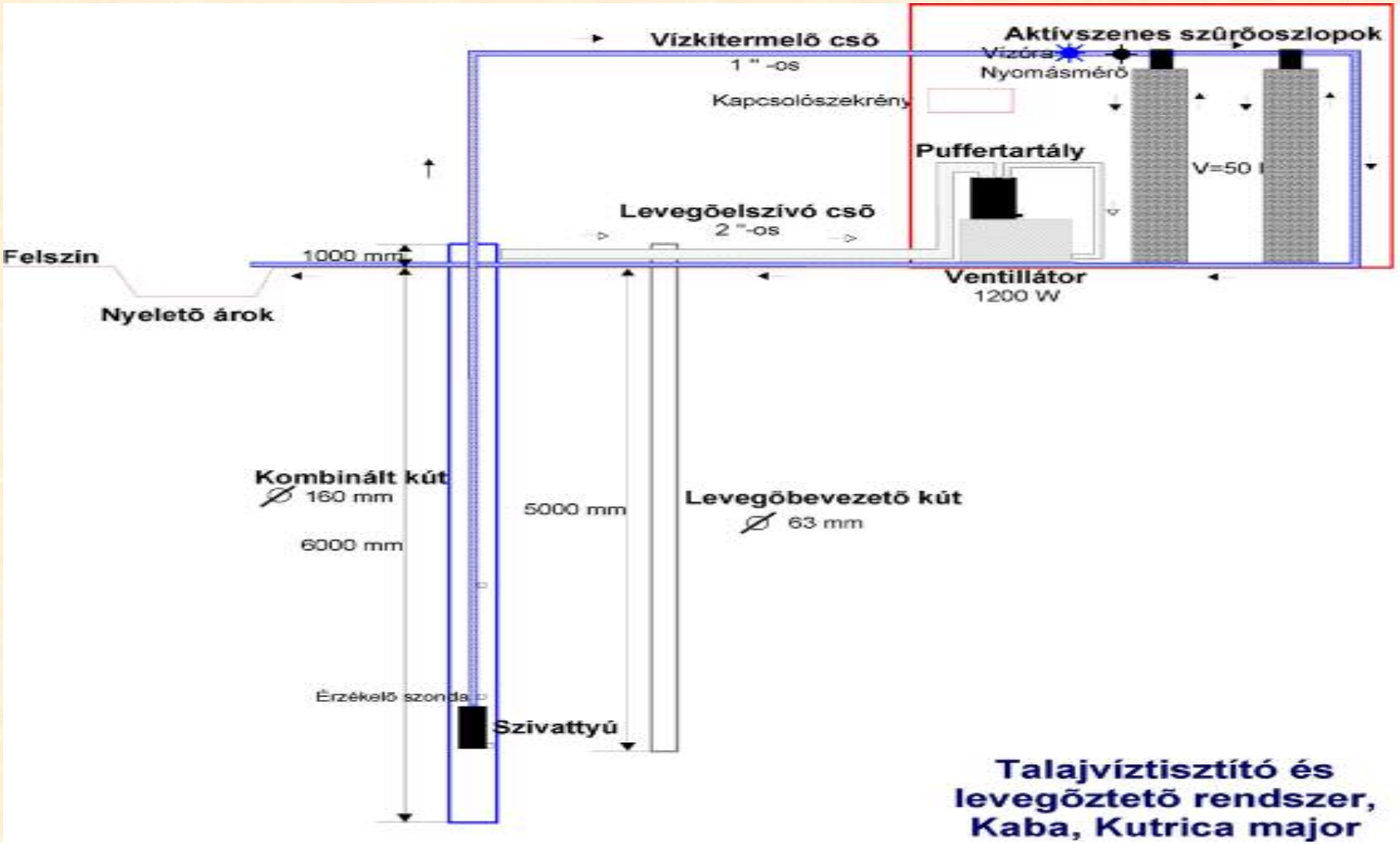


Before remediation



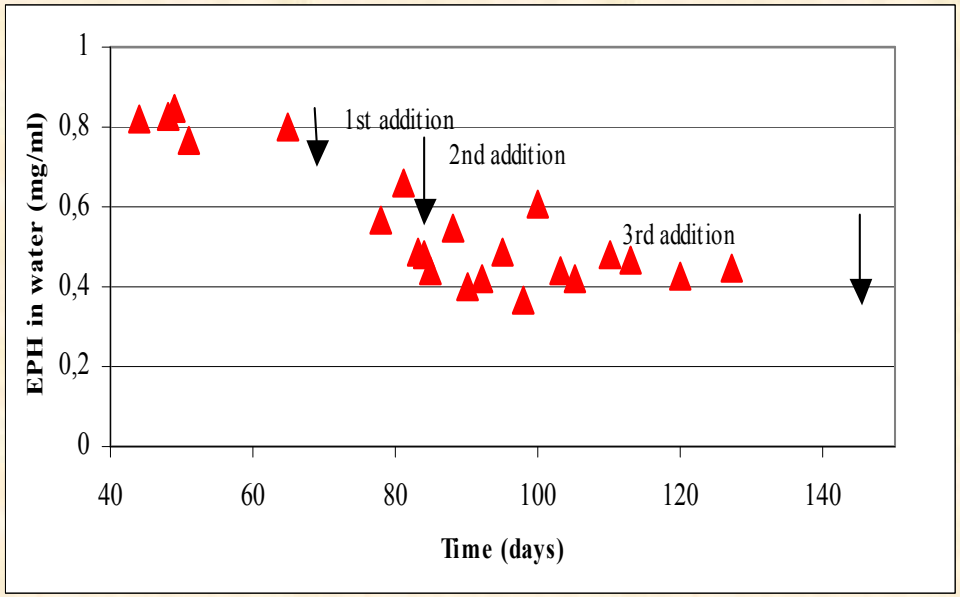
CDT technology

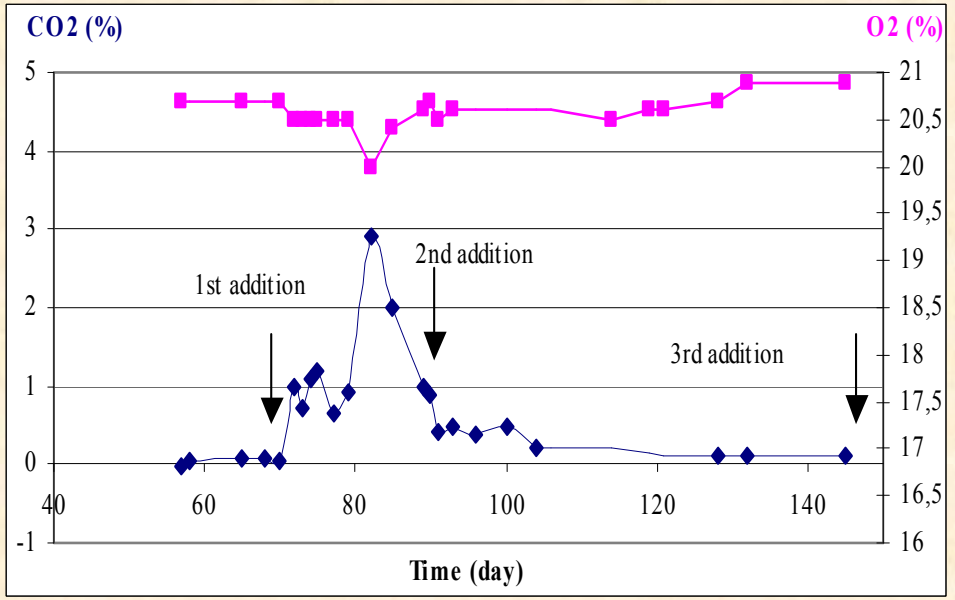
Soil gas and water exhaust with a combined well, ex situ water treatment and in situ bioventing of the vadouse zone with temporaray flushing. Additives: nutrients and cyclodextrin (RAMEB)

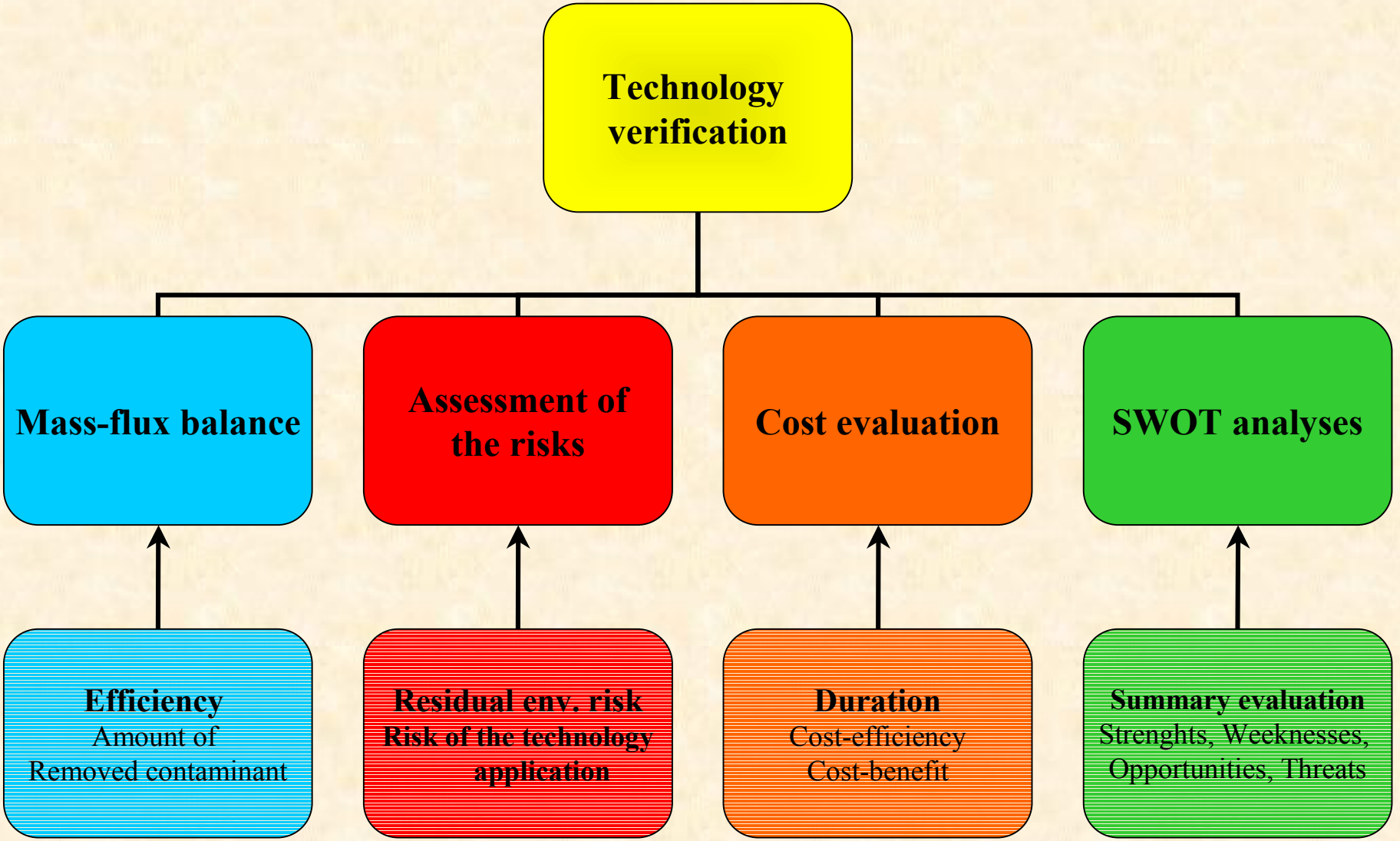


The CDT technology

Technology-monitoring:
monitoring of the mobile soil-phases: GW and soil gas






Technology verification
Mass-flux balance
Assessment of the risks
Cost evaluation
SWOT analyses
Efficiency
Amount of Removed contaminant
Residual env. risk
Risk of the technology application
Duration
Cost-efficiency
Cost-benefit
Summary evaluation
Strenghts, Weeknesses, Opportunities, Threats

CDT: mass balance of the contaminant

S —*biodegradation, water treatment*→ *T*

S: substrate (contaminant))

P: product (cell mass, CO_2, degraded cont.)

- Treated soil mass: 50 t
- TPH in soil conc.: 25 000 mg/kg
- TPH mass: 1 250 t

$$C_7H_{12} + 5\,O_2 + NH_3 = C_5H_7N + 2CO_2 + 4\,H_2O$$

96 160 14 113 (sejttömeg)

Removed by biodegradation: 1 149 kg

- Treated water: 1 000 m^3
- TPH in water, conc.: 1 mg/dm^3
- TPH in water, mass: 1 000 g /1000 m^3

Removed by water treatment: 2 kg

- **Contaminant to be removed: 1 251 kg**

Total removed: 1 151 kg

Residual measured mass of contaminant in the soil after finishing remediation: **12 kg**

Residual environmental risk and risks of the technology

1. **Residual environmental risk:** exotoxicity: negativ
   concentration: under SQC

2. **Risks of the in situ technology-application**

   - Emission of the technology: mobilisation, change of water level, in situ washing, additives, etc.

   Prevention by : stable depression, stepwise addition of nutrients and CD

   - Global risks of the technology: energy consumption, duration

Cost evaluation

- **Cost: time requirement and costs of additives**
  With CD: 1–1,5 years; without CD: 2–3 years

- **Cost efficiency: for the evaluation of the technological alternatives**
  MNA: 15 years
  Dig and Dump: 2 month, but probabaly water treatment: 1–2,5 years
  Ex-situ, on site soil treatment + water treatment: 2,5 years
  Pump and treat: in situ soil washing + ex situ water treatment 10 years
  Pump and treat: in situ soil washing with CD: 5 years
  In situ bioventing: 2,5 years
  In situ bioventilláció + CD: RAMEB 1,5 years

- **Cost-benefit assessment: considering future utilisation**

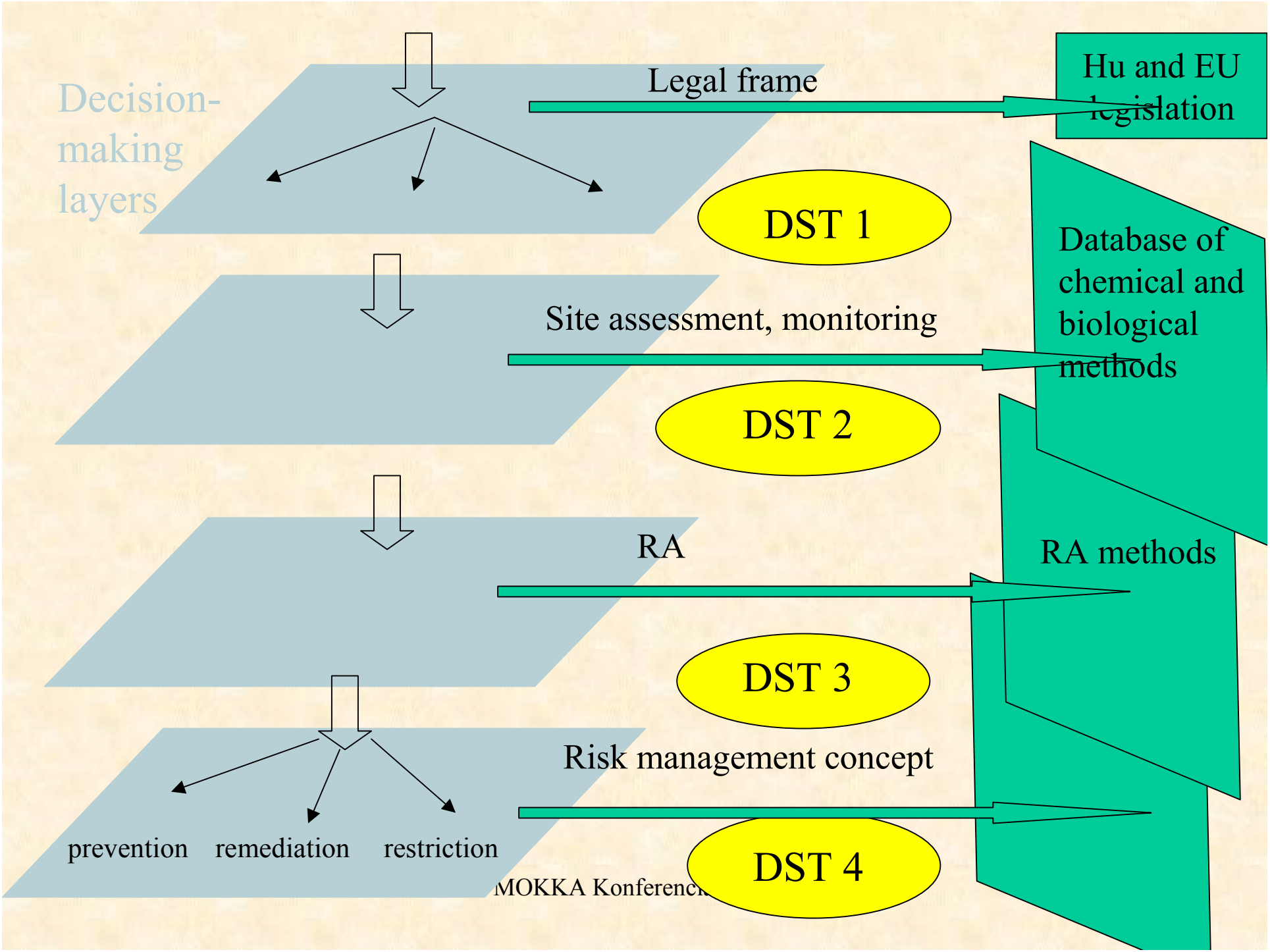
Cost-efficiency of the alternatives: specific costs

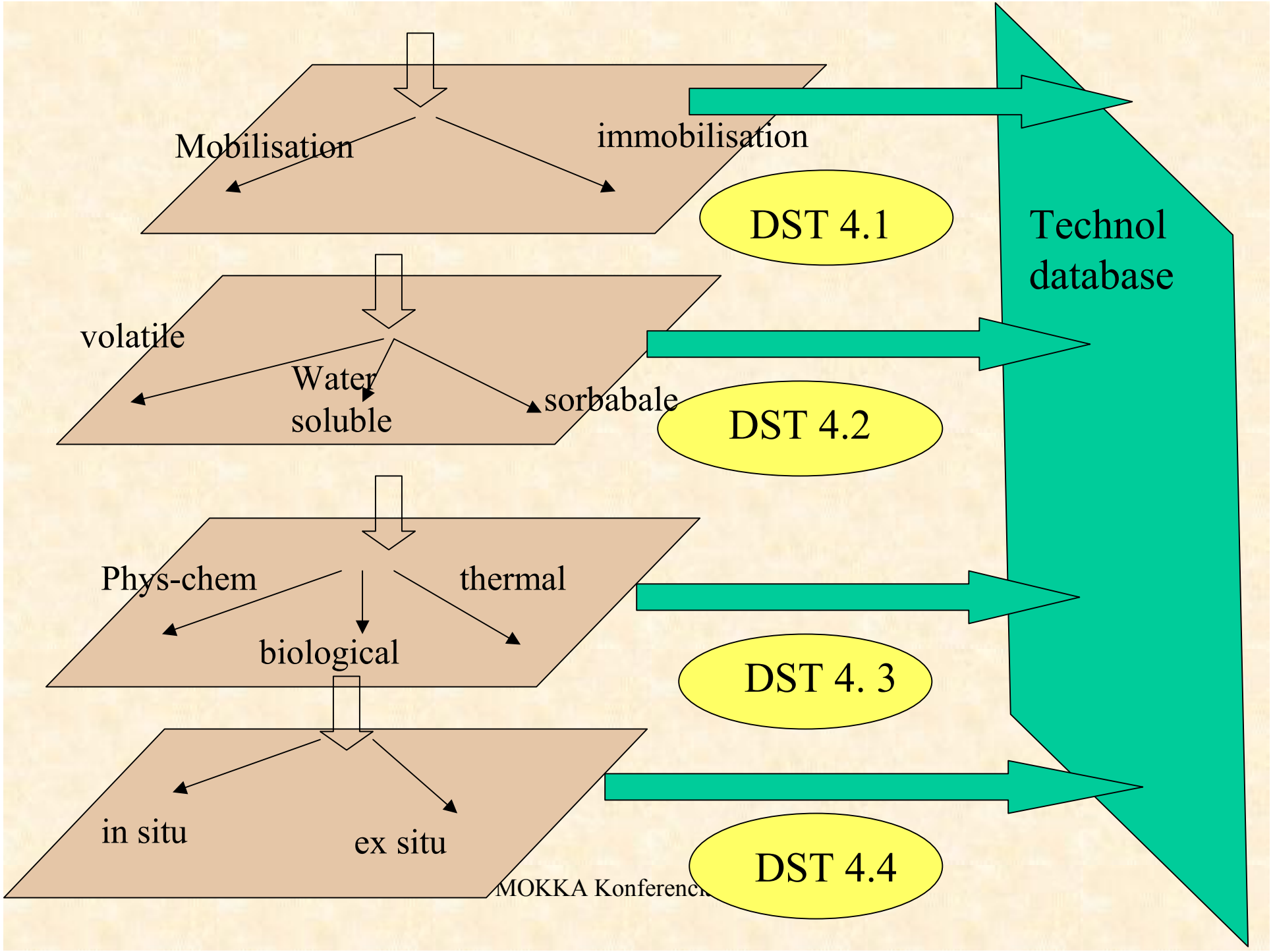
Alternatives: / Activities	"0" MNA	Dig and dump	*Ex situ* on site	*In situ* soil washing+ *ex situ* water tr	*In situ* bio-venting	*In situ* bio-venting +RAMEB
Treatment time	*15 év*	*0*	*2,5 év*	*10 év*	*2,5 év*	*1,5 év*
Soil mass (t)		*1 000*	*1 000*	*1 000*	*1 000*	*1 000*
Site assessment	300	300	300	300	300	300
Risk assessment	300	300	300	300	300	300
Planning	-	100	1 000	1 000	1 000	1 000
Soil excavation	-	3 000	3 000	-	-	-
Transport	-	5 000	-	-	-	-
New soil	-	10 000	-	-	-	-
Implementation	-	-	1 500	1 500	2 500	2 500
Maintenance	-	-	5 000	20 000	3 000	1 800
Alternative washing*				*10 000		
Treatment plant cost	-	5 000	-	-	-	-
Technology-monitoring	15 év mon. 4 500	-	750	450	750	450
Aftercare		300	300	3 000	900	900
CD/ (other additives)	-	-	-	- (*2 000)	-	5 400
Pump and treat implement		3 000		3 000	3 000	3 000

MOKKA database

5 sub-data-bases:

1. **Legal background**
2. **Site assessment and risk assessment methodology: chemical analytical and biological tetsmethods**
3. **Modelling: transport models, GIS models**
4. **Technological database: soil, GW, sediment remediation**
5. **Risk assessment methodologies**


Decision-making layers
Legal frame
Hu and EU legislation
DST 1
Database of chemical and biological methods
Site assessment, monitoring
DST 2
RA
RA methods
DST 3
Risk management concept
prevention
remediation
restriction
DST 4

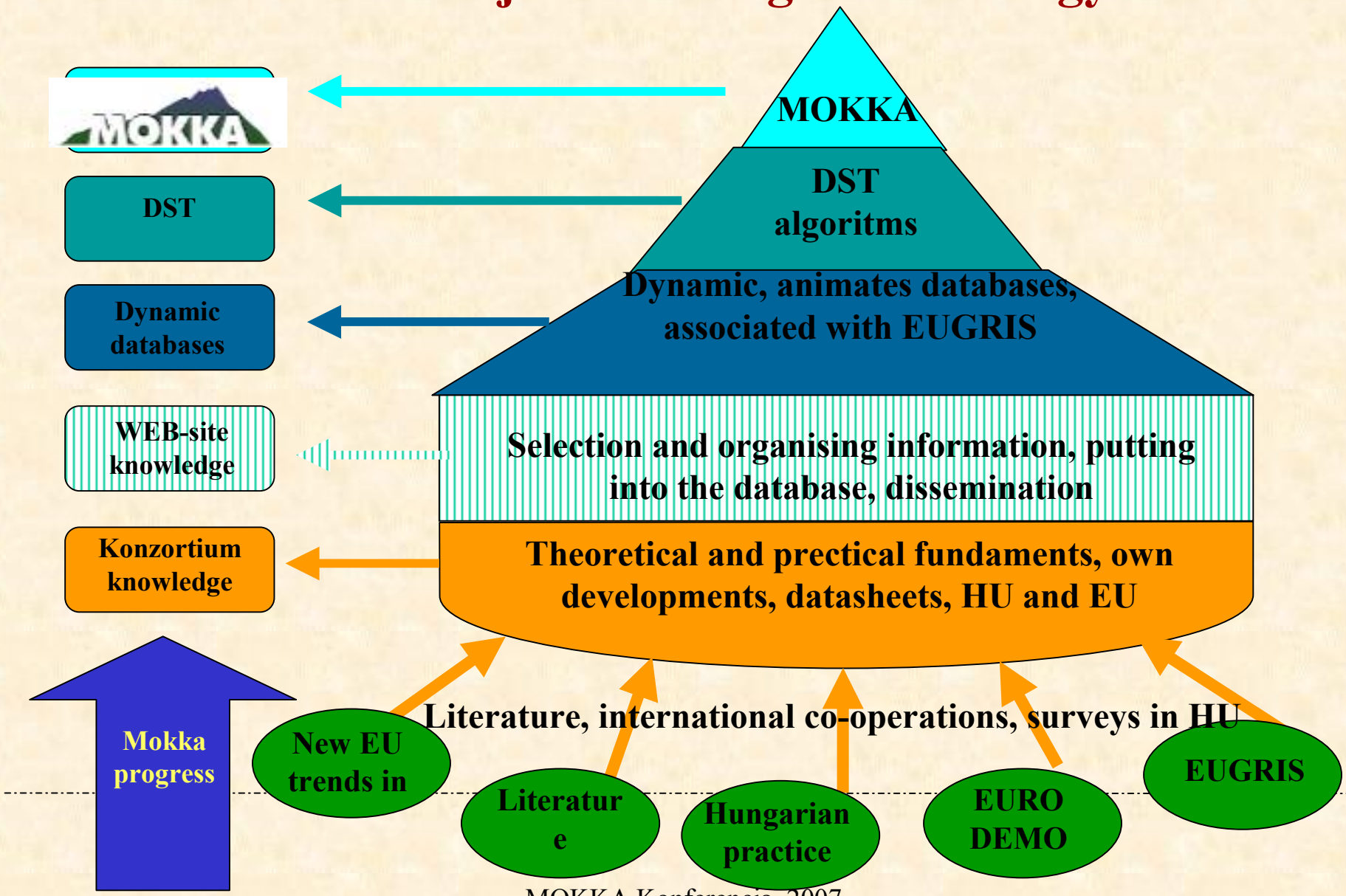

Mobilisation
immobilisation
DST 4.1
Technol database
volatile
Water soluble
sorbabale
DST 4.2
Phys-chem
thermal
biological
DST 4. 3
in situ
ex situ
DST 4.4

DST: decision support tool

DST types, e.g. for the technology selection

- **Verbal: focal points, alternatives**
- **Decision tree: yes or not, branches**
- **Key: pathway**
- **Matrix: multidimension**

MOKKA Project working methodology



Participants:

SME	Aqua Concorde Water Analysis and Water Technology Ltd
SME	CycloLab Cyclodextrin R&D Laboratory Ltd
SME	DigiKom Ltd
University	Budapest **University** of Technology and Economics
R&D	Research Institute for Soil Science and Agricultural Chemistry of the **Hungarian Academy of Sciences**
NGO	VITUKI
NGO	Association of Environmental Enterprises
Enterprise	VITUKI CONSULT Co.
	TNO Built Environment and Geosciences, The Netherlands
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A kutatást a KPI, NKFP 3/020/2005 projekt finaszírozta

The MOKKA team

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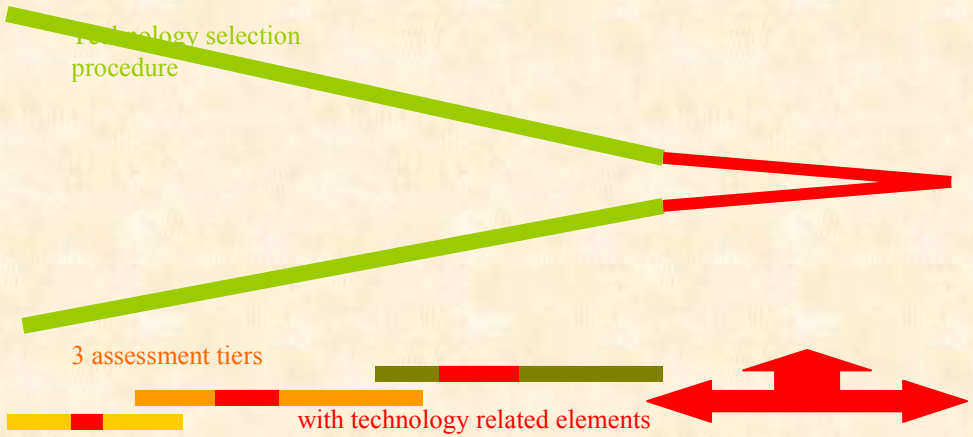
A technológiaválasztást előkészítő felmérés a terület integrált felmérésének része



Type of assessment

contaminant specific	site specific	interaction specific	intervention specific

Expected result

contaminant		hydrogeology	partition	Final remediation selection
contaminated soil phases	soil type	biodegradation biota		Technological parameter planning food chain Risk/emission control
etc.			etc.	etc. Cost calculation