Quantitative Risk Assessment as part of the GIS based Environmental Risk Management of diffuse pollution of mining origin in Gyöngyösoroszi, Hungary

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„DIFPOLMINE" Diffuse Pollution from Mining Activities

Consortium partners: ADEME (France)
IRH Environment (France),
Hasselt University (Belgium),
BME (Hungary)

Duration: 2002–2006

ONE OF THE OBJECTIVES OF THE DIFPOLMINE PROJECT:

- to demonstrate the transferability of the Difpolmine methodology(Salsigne site) to other mining sites.

FOCUS OF THE WORK IN GYÖNGYÖSOROSZI, HUNGARY

- to work out a risk and GIS (Geographical Information System) based catchment scale management concept to point and diffuse pollution of mining origin that substantiates a risk based remediation approach.

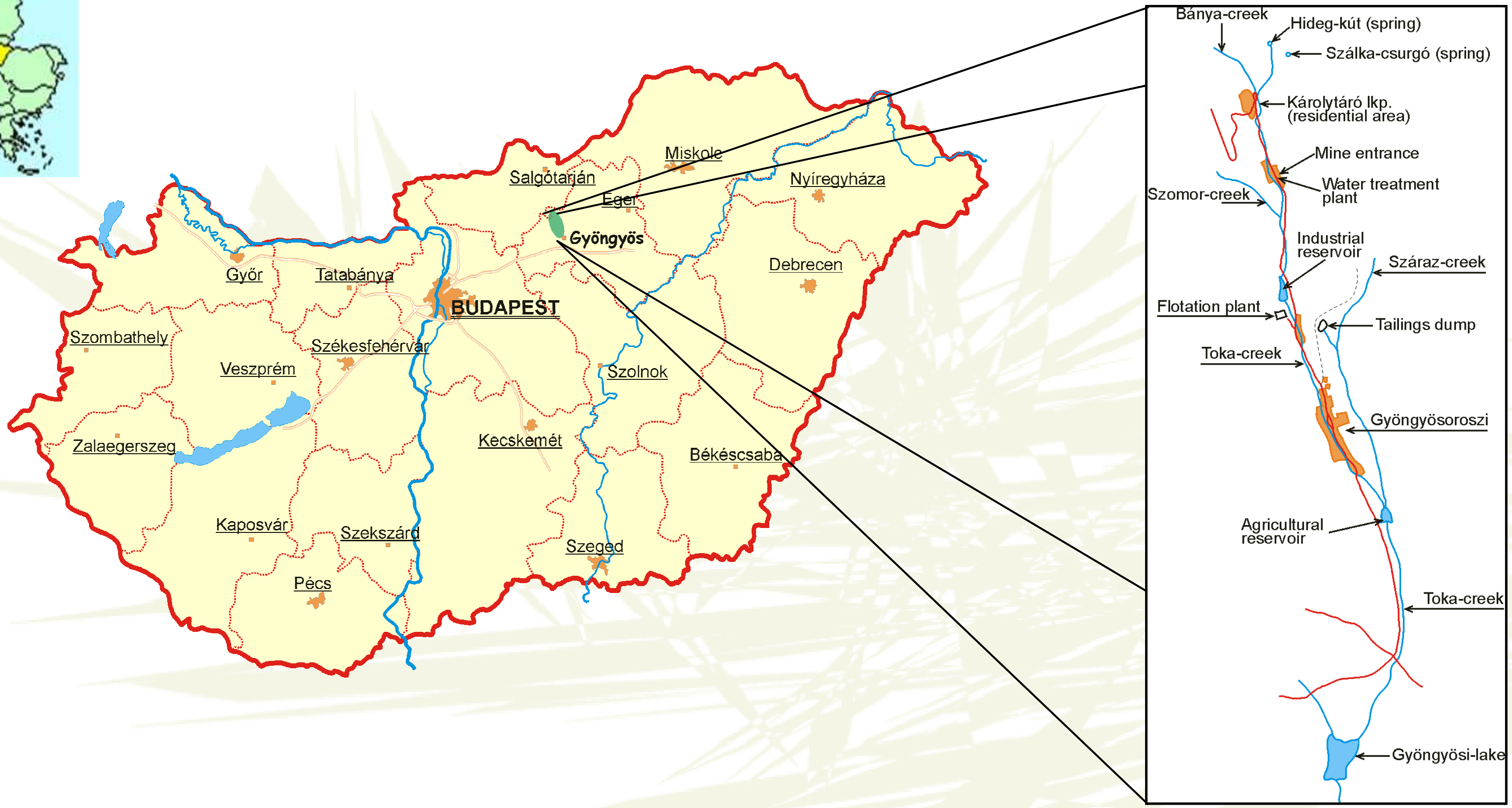
OBJECTIVE OF THIS PRESENTATION

- **Assessment of the quantitative risk**, the third tier of the catchment scale environmental risk assessment methodology.
- Forecasting the targeted Risk Reduction scale function of the site specific Maximum Permitted Emission.

LOCATION OF THE DEMONSTRATION SITE IN HUNGARY, GYÖNGYÖSOROSZI, TOKA CREEK WATER CATCHMENT

Northern Toka catchment area: 10km^2

Total Toka catchment area: 25 km^2



General features

Status: Mining started in the middle ages, ceased in 1985. Remediation started in 2005

Pollution sources: point and diffuse (mine waste dumps)

Pollutants: Cd, Zn, Pb, Cu, As from exploited sulphide ore veins of hydrothermal origin

Host rock: pyroxene andesite of Miocene age overlain by Tertiary formations

Processes: erosion, weathering, argillization of the andesite rock, complex chemical and biological oxidation of pyrite containing material in contact with rainwater and runoff resulting metal loaded acidic leachate, partition

Studied area: 10 km^2

Average annual precipitation: 756 mm/year

Surface runoff: dominant transport route due to topography

Toka flowrate: 2450 m^3/day/ km^2
creeks in the catchment have water only seasonally

Infiltration rate: high in the andesite rock and low in the clayee Tertiary formation

Metal sorption of the soil: metals bound already in the upper 30-50cm of the clayee debris like soil, pollutants migrate only by diffusion.

Basis of the concept: integrated conceptual risk model, including the point and diffuse sources, the transport routes and the land-use specific exposure routes and the receptors.

- Dominant risk: Metal content of the sources
- Main pollutant transport pathway: Surface runoff and surface water system
- Most exposed receptors: Members of the water ecosystem

Main components of the approach:

- the conceptual model,
- GIS based transport modelling,
- microcosm experiments
- three tiered iterative risk assessment
- risk reduction planning

Three tiered, iterative, site specific Environmental Risk Assessment

1.Qualitative Risk Asssessment → Ranking based on risk score

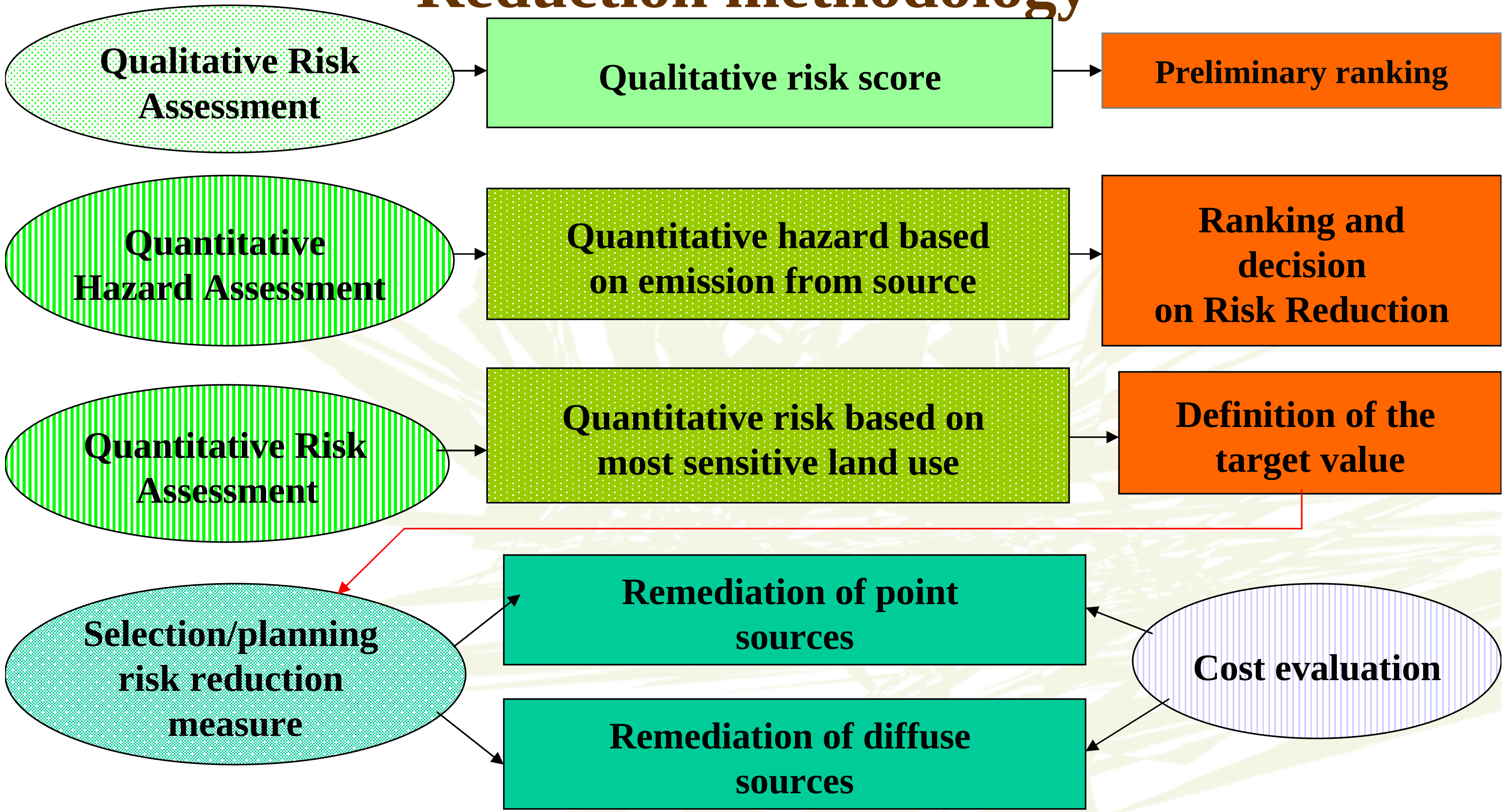
2.GIS technology (ESRI ArcView GIS software) based Quantitative Hazard Assessment → Refined ranking on the basis of the emission

3.Quantitative Risk Assessment

→ Quantitative risk considering non-sensitive water use

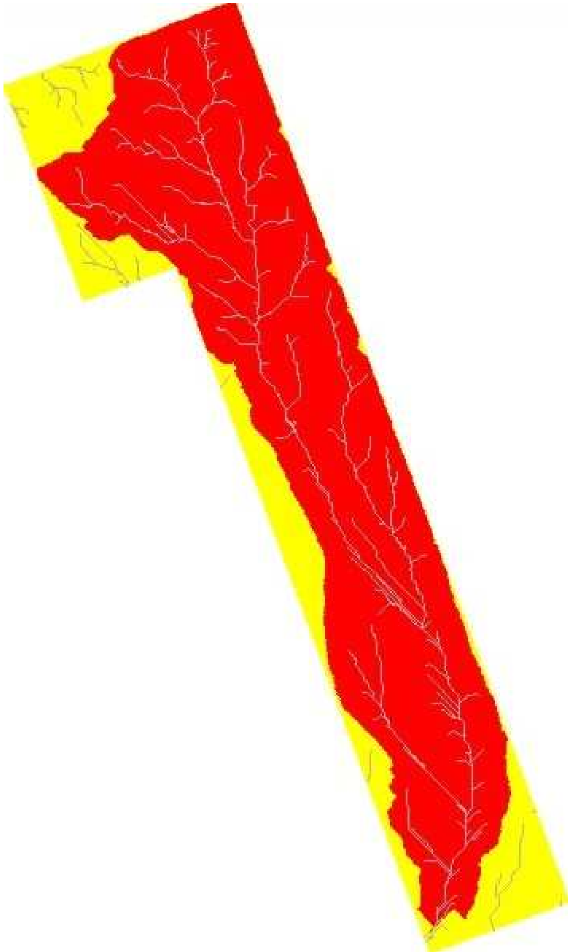
→ Calculation of the target concentration for remediation

Scheme of the Risk Assessment and Risk Reduction methodology



Preliminary qualitative risk assessment

Pollution source	Risk score	Tons	Comments
Tailings flotation dam, flotation t.	99	4 000 000	isolation
Industrial reservoir, sediment	93	70 000	to be removed
Ore transportation route, ore	92	30 000	to be removed
Precipitate storage, lime precipit.	90,8	50 000	to be removed
Agricultural reservoir, sediment	88,8	30 000	to be removed
Mud retention, mixed sediment	85,5	30 000	to be removed
Altáró waste dump, mine waste	84,5	1 100 000	remediation
Károly waste dump, mine waste	81,5	16 000	to be removed
Gyöngyös-Rédei reservoir, sed.	81,3	30 000	to be removed
Toka creek , sediment	>80	35 000	to be removed
Új Károly-gallery, mine wastel.	79,5	8 000	to be removed
Új Károly-galery, mine waste II.	79,5	800	to be removed
Emergency dam, various wastes	78,3	3 000	to be removed
Péter-Pál shaft, mine waste	75,8	16 100	to be removed
Katalin gallery, mine waste	73,5	5 000	to be removed
14 different waste dumps	55–70	10 000	remediation
15 different waste dumps	>50	10 000	revegetation



Flow Accumulation map of the Toka catchment

The GIS approach enabled calculation of the **pollution flux/emission** at individual source level and at water catchment scale

Emission = runoff volume* X emitted metal concentration**

***** resulted from the **Flow Accumulation** (function of the watershed size and annual precipitation)

** from the microcosm leaching test.

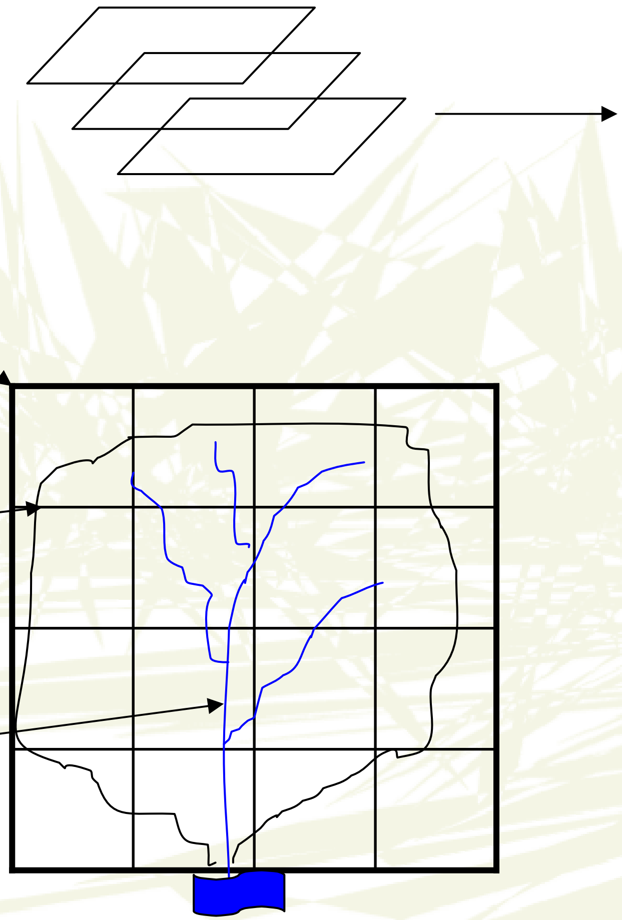
GIS principle and its use in the model

Maps, layers with local input parameters: metal pollution, vegetation

Digital Elevation Model: grid of 100 m^2 squares

Catchment border

Water collection network

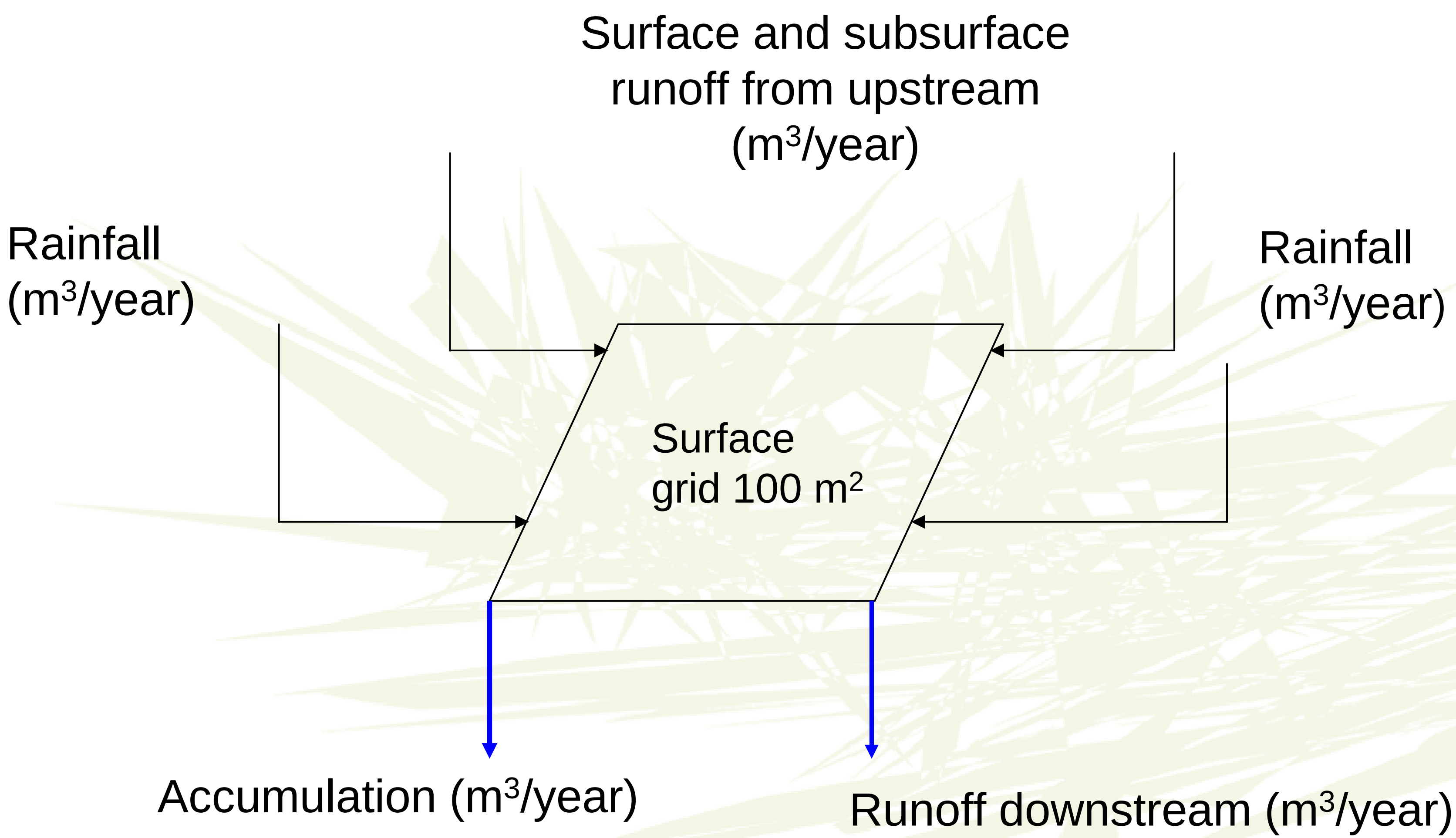


Estimation of local parameters

Integration of the local parameters at catchment scale

Use of GIS in the Runoff Model

Spatial scale: catchment



Quantitative Hazard Assessment

Surface area of the waste dumps and of their watershed: based on GIS Flow Accumulation Model

Waste dump	Surface area	Watershed area	Runoff volume	Run-through volume
	m^2	m^2	m^3/year	m^3/year
Sum of 15 point sources	192 000	664 000	63 000	216 000
Residual diffuse from removed point sources	68 000	622 000	22 000	203 000
Sum of 14 diffuse sources to remediate	5 000	160 000	1 600	52 000
Sum of 15 diffuse sources to revegetate	19 000	180 000	6 300	58 680

Characterisation of the Quantitative Risk:

RQ= PEC/PNEC

Where:
RQ: Risk Quotient
PEC: Predicted Environmental Concentration
PNEC: Predicted No Effect Environmental Concentration

Target of risk reduction: RQ≤1

RQ: Risk Quotient in the Toka water catchment

RQ = PEC/PNEC

where:

PEC: Estimated from measured concentration of the Toka

As: 50 µg/l Cd: 2 µg/l Pb: 30 µg/l Zn: 800 µg/l

PNEC: Effect-based Quality Criteria for non-sensitive ecological water use (EBQCmax)

As: 10 µg/l Cd: 1 µg/l Pb: 10 µg/l Zn: 100 µg/l

→ **RQ>1**

RQ_{As}: 5 **RQ_{Cd} : 2** **RQ_{Pb} : 3** **RQ_{Zn} : 8**

Waste dump

Estimated emitted concentration from the pollution sources of the total catchment

minimum	**As:**	**150 µg/l**	**Cd:**	**100 µg/l**
	Pb:	**100 µg/l**	**Zn:**	**25 000 µg/l**

Natural Risk Reduction Capacity of the site ($NRRC_{min}$)

As:	***3.0 (66%)***	***Cd:***	***50 (98%)***
Pb:	***3.4 (70%)***	***Zn:***	***30 (97%)***

Toka creek

outflow of the catchment

Toka PEC

As:	**50 µg/l**	**Cd:**	**2 µg/l**
Pb:	**30 µg/l**	**Zn:**	**800 µg/l**

Calculated Maximum Permitted Emission values (**MPE**) from the pollution sources to reach the EBQC levels in the Toka creek

As:	**30 µg/l**	**Cd:**	**50 µg/l**
Pb:	**34 µg/l**	**Zn:**	**3 000 µg/l**

Waste Dump

Natural Risk Reduction Capacity of the site ($NRRC_{min}$)

As:	3.0 (66%)	Cd:	50 (98%)
Pb:	3.4 (70%)	Zn:	30 (97%)

Toka creek

EBQC Toka (PNEC)

As:	10 µg/l	Cd:	1 µg/l
Pb:	10 µg/l	Zn:	100 µg/l

Only the NRRC of the site alone is not enough to reduce the metal concentration in the Toka water to the EBQC (PNEC) levels

Toka creek measured concentration (PEC)

As: 50 µg/l Cd: 2 µg/l

Pb: 30 µg/l Zn: 800 µg/l

Risk reduction

Removal, containment, confinement of **point sources**

combined chemical and phyto-remediation of the **diffuse & residual sources**

Targeted Effect-based Quality Criteria ($EBQC_{max}$)(PNEC)

As: 10 µg/l Cd: 1 µg/l

Pb: 10 µg/l Zn: 100 µg/l

Maximum Emission from sources (microcosm experiments)

As: 750 µg/l Cd: 1 200 µg/l Pb: 3 600 µg/l Zn: 163 000 µg/l

Necessary Risk Reduction Scale

As: 96% Cd: 96 %

Pb: 99% Zn: 98%

Maximum Permitted Emission from the sources (MPE) to reach EBQC=PNEC in the Toka creek

As: 30 µg/l Cd: 50 µg/l Pb: 34 µg/l Zn: 3 000 µg/l

•Point sources: excavation, containment, confinement

•Residual and diffuse sources: combined chemical and phyto-stabilisation

- immobilisation / stabilisation of contaminants in soil was modeled in microcosms to determine the most efficient amendment to be added to the soil.
- the efficiency of the stabilisation process was characterised by the metal content of the water- and different acidic extracts of the treated soil.
- 5 w% flyash addition decreased the water soluble Cd and Zn concentration of the amended soil by 99% (4 months after addition).

EMISSION REDUCED BY CHEMICAL STABILISATION COMPARED TO THE MAXIMUM PERMITTED EMISSION

Maximum Emission from the sources

As: 750 µg/l Cd: 1 200 µg/l Pb: 3 600 µg/l Zn: 163 000 µg/l

Chemical Stabilisation

As: 33% Cd: 99% Pb: 50% Zn: 99%

Emission reduced after chemical stabilisation

As: 502 µg/l Cd: 12 µg/l Pb: 1 500 µg/l Zn: 1 630 µg /l

Maximum Permitted Emission (MPE) to reach the EBQC=PNEC in the Toka creek

As: 30 µg/lit Cd: 50 µg/lit Pb: 34 µg/lit Zn: 3 000 µg/lit

Necessary Risk Reduction in % from Maximum Emission to reach the Maximum Permitted Emission (MPE) in the Toka creek

As: 96% **Cd: 96%** **Pb: 99%** **Zn: 98%**

Risk reduction % by chemical stabilisation

As: 33% **Cd: 99%** **Pb: 50%** **Zn: 99%**

Remaining necessary risk reduction by phyto-stabilisation in % from the Maximum Emission

As: 63% **Cd: 0%** **Pb: 49%** **Zn: 0%**

- The approach is part of a three tiered, iterative, PEC/PNEC based Risk Assessement methodology.
- GIS based approach, the tool of environmental quantitative hazard assessment, enables risk characterisation from the source level to catchment scale.
- The QRA concept calculates not only the relative and absolute risk values but makes possible planning of the risk reduction scale.
- The NRRC of the site is not sufficient to reduce the risk to the PNEC level
- Chemical stabilisation can reduce metal emission such as in case of Cd and Zn (mobile metals) the RQ≤1.

- In case of As and Pb, quantitative risk cannot be reduced only by chemical stabilisation, additionally erosion control by phyto-stabilisation is needed (As and Pb are bound to the solid phase, like soil or sediment).

- The ongoing phyto-stabilisation field experiments will validate the estimated risk reduction scale.

THANK YOU FOR YOUR ATTENTION!

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