Environmental Risk Management of an Abandoned Mining Site in Hungary

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SUMMARY

An Environmental Risk Management methodology was developed at catchment scale, using as model-site the Toka watershed area, an abandoned Pb and Zn sulphide ore mine in Gyöngyösoroszi, NE Hungary (Fig 1). Mining had ceased for 20 years, but mine closure and remediation activities started only in 2005.

The Risk Management concept is based on the integrated conceptual risk model, including point and diffuse sources, transport routes and land-use specific exposure routes and the receptors.

The mobile Cd and Zn content of the mine waste, soil and sediment transported by water pose the highest **environmental risk** in the area. The toxic metals originate from the mined sulphide ore veins hosted in Miocene age andesite rocks. 1–3 pH leachate is being produced around the waste rock heaps due to the complex chemical and biological oxidation of the pyrite containing material in contact with rainwater and runoff. The main pollutant **transport pathway** is the surface runoff and surface water system. The most exposed **receptors** are the members of the water ecosystem.

The approach is „GIS based" (Geographical Information System) and „catchment scale", using a three tiered, iterative Environmental Risk Assessment methodology. The model parameters of metal transport were determined in leaching microcosms (Table 2).

The risk reduction concept aims at reducing the runoff water quantity and contamination by removal of the point sources and chemical & phytostabilisation of the residual and diffuse pollution. In planning the risk reduction scale (Fig. 6) a generic catchment scale parameter, the Natural Risk Reduction Capacity (NRRC), as well as the efficiencies of the remediation by chemical stabilisation were taken into account. The NRRC of the site is a conservative estimate comparing the minimum heavy metal concentration of the leachate (Table 2) with the metal concentration in the surface water (PEC).

The joint effect of chemical stabilisation and the NRRC of the site is high enough to reduce Cd and Zn emission even in case of the most polluted waste (Table 2) such as to comply with the target concentration (PNEC), that is an Effect Based Quality Criteria (EBQC) for non-sensitive ecological water use (Fig. 6)).

To reduce Pb and As to the targeted concentration the joint effect of NRRC and chemical stabilisation is not enough in case of a maximum emission scenario, but the additional phytostabilisation is able to mitigate risk by reducing solid erosion. The effect of phytostabilisation will be estimated from the results of the ongoing field experiments.

Fig. 1 Location of the studied abandoned mining site and distribution of the mine facilities and settlements along the Toka creek

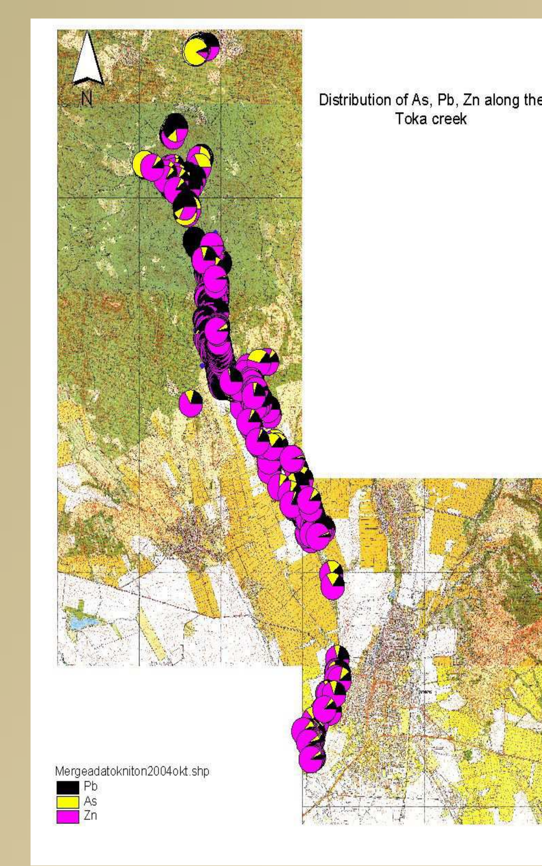

Fig. 2 Distribution of As, Pb and Zn in the soil along the Toka creek

THREE TIERED, ITERATIVE, SITE SPECIFIC ENVIRONMENTAL RISK ASSESSMENT

1. Qualitative Risk Assessment → Ranking based on risk score
2. GIS technology (GIS software ESRI ArcView USA) based Quantitative Hazard Assessment → Refined ranking on the basis of metal emission
3. Quantitative Risk Assessment → Quantitative risk considering non-sensitive water use; Calculation of the target concentration for remediation

Table 1 Runoff from direct rain and upstream flow (GIS Flow Accumulation)

Pollution sources	Surface area m^2	Watershed area m^2	Direct precipitation m^3/year	Runoff from upstream m^3/year
Sum of point sources (15)	197 000	822 000	64 000	270 000
Residual from point sources (15)	68 000	622 000	22 000	203 000
Residual + diffuse sources (15 + 14)	24 000	200 000	8 000	70 000

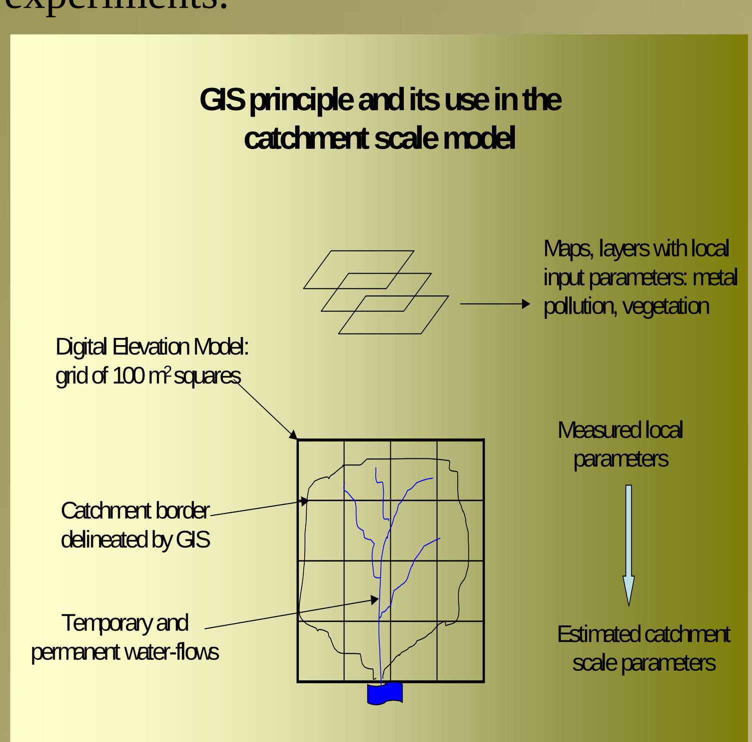

Fig. 3 GIS principle at catchment scale

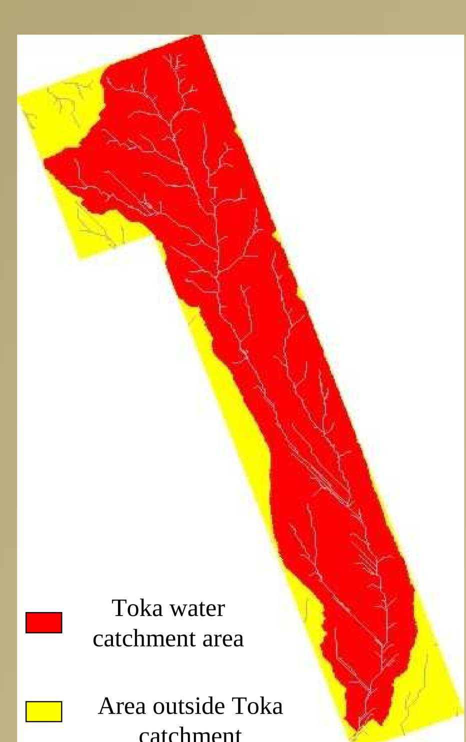

Fig. 4 Flow Accumulation Model

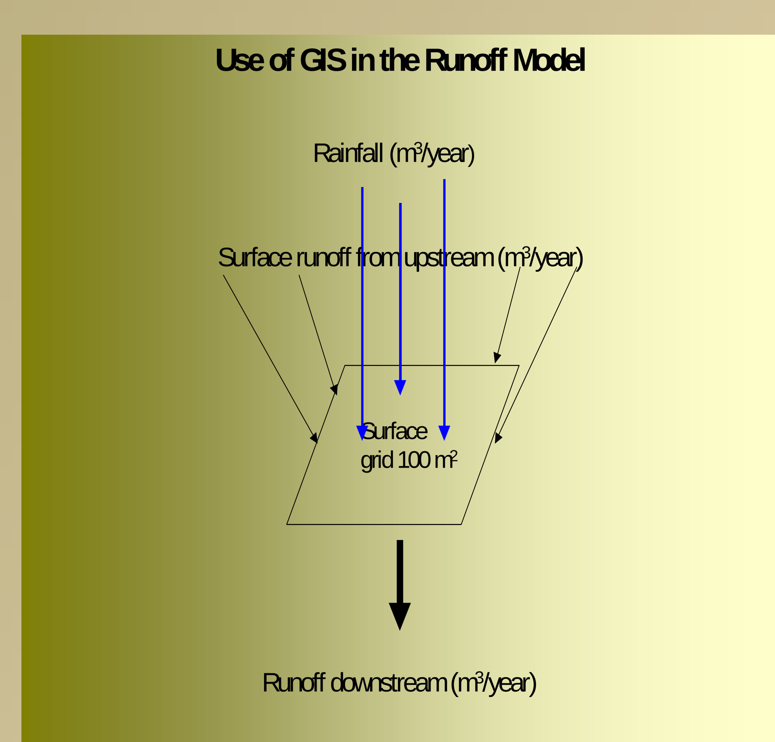

Fig. 5 Runoff model at grid scale

Table 2 Metal concentration of mine wastes and leachates in microcosm test*

Metals	Total metal** (minimum) [mg/kg]	Total metal** (medium) [mg/kg]	Total metal** (maximum) [mg/kg]	Minimum emission [µg/L]	Medium emission [µg/L]	Maximum emission [µg/L]
As	44	100	216	150	340	750
Cd	1	3	12	100	300	1 200
Pb	295	600	13 100	100	203	3 600
Zn	370	800	2 155	25 000	54 135	163 000

*Amount of mine waste in the microcosm test: 4.5 kg * Leachate: 1.3L *Leaching time: 3 months
**aqua regia extract ICP-MS

QUANTITATIVE HAZARD ASSESSMENT

The GIS approach enabled calculation of **pollution emission** at individual source level and at water catchment scale (Figs. 3, 4, 5)

Emission = runoff volume* x emitted metal concentration**

* from the Flow Accumulation (Table 1) (function of the watershed size and annual rainfall (756 mm/year)

**from the microcosm leaching test (Table 2)

QUANTITATIVE RISK ASSESSMENT

RQ: Risk Quotient in the Toka water catchment

RQ = PEC/PNEC

PEC (Predicted Environmental Concentration): calculated from measured concentrations of the Toka
As: 50 µg/L Cd: 2 µg/L Pb: 30 µg/L Zn: 800 µg/L

PNEC (Predicted No Effect Environmental Concentration): Effect Based Quality Criteria ($EBQC_{max}$) for non-sensitive ecological water use, calculated from measured toxicity, literature and regulatory data
As: 10 µg/L Cd: 1 µg/L Pb: 10 µg/L Zn: 100 µg/L

→ $\mathbf{RQ_{each\ metal} > 1}$

$\mathbf{RQ_{As}: 5}$ $\mathbf{RQ_{Cd}: 2}$ $\mathbf{RQ_{Pb}: 3}$ $\mathbf{RQ_{Zn}: 8}$

Target of Risk Reduction: $\mathbf{RQ_{each\ metal} \leq 1}$

EMISSION REDUCED BY THE JOINT EFFECT OF CHEMICAL STABILISATION AND THE NATURAL RISK REDUCTION CAPACITY OF THE SITE

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: 1 800 µg/L Zn: 1 630 µg /L

Natural Risk Reduction Capacity of the site
As: 1/3.0 Cd: 1/50 Pb: 1/3.4 Zn: 1/30

Emission reduced further by the Natural Risk Reduction Capacity of the site
As: 167 µg/L Cd: 0,24 µg/L Pb: 529 µg/L Zn: 54 µg /L

Maximum Permitted Emission to comply with the EBQC = PNEC for the Toka creek
As: 30 µg/L Cd: 50 µg/L Pb: 34 µg/L Zn: 3 000 µg/L

Fig. 6 Scheme of emission reduction and comparison with the Maximum Permitted Emission: Cd and Zn fulfil the EBQC, As and Pb will be reduced mitigating erosion by phytostabilisation (not discussed in this paper)

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