Complex Risk Management of mine waste at the Hungarian model site of the „DIFPOLMINE" Project

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DIFPOLMINE Diffuse Pollution from Mining Activities

MŰEGYETEM 1782

SUMMARY

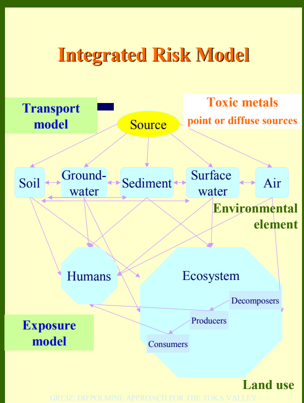
The Toka catchment area, a former base metal mining site in Gyöngyösoroszi, Hungary, was selected to demonstrate the adaptation potential of the Difpolmine approach applied to diffuse pollution of mining origin at the Salsigne (France) site. The postmining activities at the Hungarian site include the management of both the point and diffuse sources. The highest environmental risk is represented by the mobile Cd and Zn in the waste, soil, sediment and water. The main transport route is the runoff water.

An integrated risk model was created, which shows the pollutant transport pathways from the source, the targeted environmental elements and the exposure of the receptors function of the land use. The approach is „GIS based" and „catchment scale", using a tiered, iterative Environmental Risk Assessment methodology.

The **First Tier** uses a site specific relative risk assessment methodology, resulting in marks. These marks were used for preparing inventory and setting priority. **Second Tier** includes a GIS-based hazard assessment, considering quality (type, metal content) and quantity (surface, volume) of the source, yearly precipitation and the volume of the GIS-based indirect (upstream) runoff-water. Result of the Second Tier is the emitted metal amount from the individual point or diffuse sources or any subarea. The emitted metal amount was used to rank the sources and to select the best fitting risk reduction measure. In the **Third Tier** the PEC/PNEC approach was applied: a catchment scale method for the calculation of the actual risk value at any point of the site. The keypoint of the catchment is the Toka creek, the outflow of the watershed.

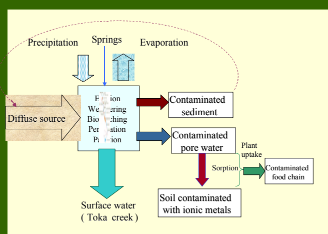
The Water Balance was the basis for the quantification of the Flux of Pollutants and estimation of the Quantitative Risk using the GIS Flow Accumulation Model. Historical data, on site measurement data, and lab test data were used. The Flow Accumulation Model shows the integrated flow of the runoff per area, function of the topography. The target quality of the surface water was extrapolated from effect data on the relevant members of the water-ecosystem. The target emission from the sources after remediation was calculated from the ecological target quality of the surface-water using the GIS-based transport model.

INTEGRATED CONCEPTUAL RISK MODEL OF THE TOKA CATCHMENT



Integrated Risk Model of the Toka catchment

The runoff water was considered to be the main pollution pathway in the model, given the topography (steep slopes), hydrogeology (high infiltration rate) and geology of the area and the site specific processes due to the mineralogical composition of the ore, mine waste material and country rock (leaching, bioleaching, partition). The conceptual model shows, that the risk posed by the contaminants leached out from the pollution sources is distributed amongst the surface waters, subsurface waters and plant uptake.



The transport model of the catchment

QUANTITATIVE RISK ASSESSMENT

The site-specific quantitative parameters for description of the risk are: rain water directly on the surface of the pollution source, subsurface runoff running through the pollution source and metal amount leached out and transported from the pollution source. The calculated emitted metal load was the basis for determining the contribution to the total risk of each pollution source. The GIS approach enabled calculation of the pollution flux of every individual source using the runoff volume derived from the Flow Accumulation (function of the watershed size and annual precipitation) and the metal concentration of the leachate from the microcosm leaching test. The Table below shows the calculated yearly emission of various sources (point, diffuse, residual diffuse) using the runoff water volume from precipiation and indirect flow and the metal concentration of the emitted leachate of the microcosms.

Yearly average and maximum metal amount emitted from the pollution sources by the runoff

Pollution sources	Surface area m^2	Watershed area m^2	Runoff from precipitation m^3/year	Runoff from indirect flow m^3/year	Emitted metal with precipitation *** (kg)					Emitted metal with indirect flow**** (kg)				
					As	Cd	Cu	Pb	Zn	As	Cd	Cu	Pb	Zn
Sum of 15 point sources	197 000	822 000	64 000	270 000	22–45	19–77	51–301	13–230	3 464–10 432	46–100	41–162	108–637	27–483	7 308–22 077
Sum of 14+15 diffuse sources	24 000	200 000	8 000	70 000	3–6	2–10	6–38	2–29	433–1 304	12–26	11–42	28–165	7–125	1894–5 723
Residual diffuse (15)	68 000	622 000	22 000	203 000	7–16	7–26	18–103	4–479	1 190–3 597	35–75	30–122	61–47	20–313	5 495–16 579

* diffuse I: chemical +phytostabilisation ** diffuse II: revegetation *** see microcosm leaching test **** see microcosm leaching test

TARGET

The postmining management of mining wastes is a timely issue in Europe, but the uniform methodology for preparing inventories and ranking of the wastes is still missing. Using a Hungarian base metal mining area as model site, our aim was to develop all postmining management steps.

- Development of a risk based management concept
- Tiered Risk Assessment methodology for pollution sources (point and diffuse mine waste dumps) and the total catchment, with
- GIS based transport model calibrated by the site specific water balance
- Creation of land-use specific target values.
- Demonstration of Remediation by combined chemical & phytostabilisation or by simple phytostabilisation and revitalisation of the waste or soil.

RISK REDUCTION BY COMBINED CHEMICAL & PHYTOSTABILISATION

After excavation and/or confinement of hazardous wastes of point sources the combined chemical & phytostabilisation will be applied to the diffuse sources and to the residual waste after removal of the point sources. To select the most suitable chemical stabiliser and optimise the technological parameters laboratory microcosm experiments are being performed. The effect of various chemical stabilisers on the metal mobility and bioavailability is modelled. The microcosm tests were monitored by an integrated methodology, which combines physico-chemical analysis and bio-ecotoxicological tests. The selected chemical additive should be capable of reducing mobility, solubility and biological availability of toxic metals on long term. The experiments have been run for 25 months. Samples were taken at 21 days, 3 months and 25 months intervals. Limestone, lime, phosphate, lignit, alginit, fly-ash and the mixture of these were tested. In agreement with the results of chemical analyses the ecotoxicity testing confirmed highest efficiency of fly ash. The concentration of mobile Cd and Zn decreased on long term by 65–99,7 %.

Selection of the most efficient chemical stabiliser based on 25 month microcosm tests (only fly ash is shown)

Soil samples from the stabilisation microcosms		Metal content (mg/kg) or (%)				
Untreated soil and soil treated with flyash	MU	As	Cd	Cu	Pb	Zn
Total metal content* of untreated Gyo soil, of the flyash and of the treated soil (mg metaltotal/kgsoil)						
Total metal content of the untreated Gyo soil	mg/kg	363	6,54	336	1702	1203
Total metal content of the flyash	mg/kg	18,8	0,874	25,9	18,3	223
Total metal content in soil treated with 2% FA GYPA 2%	mg/kg	385	6,74	366	1768	1267
Total metal content in soil treated with 5% FA GYPA 5%	mg/kg	360	6,47	337	1701	1222
Water soluble metal content** of the Gyöngyösoroszi soil and the fly ash						
Gyo soil; initial metal content without flyash	mg/kg	<DL	1,47	0,55	0,02	140
PA flyash; initial metal content	mg/kg	<DL	<DL	<DL	0,09	0,43
Calculated water soluble metal content of the mixture of soil and flyash (mg metalws/kgsoil)						
GYPA1 soil+1% flyash; calculated metal content	mg/kg	<DL	1,45	0,55	0,02	139
GYPA2 soil+2% flyash; calculated metal content	mg/kg	<DL	1,44	0,54	0,02	138
GYPA5 soil+5% flyash; calculated metal content	mg/kg	<DL	1,39	0,53	0,02	133
Measured water soluble metal metal content of the mixture of soil and flyash (mg metalws/kgsoil)						
GYPA1 soil+1% flyash; measured metal content	mg/kg	<DL	0,40	0,26	<DL	48
GYPA2 soil+2% flyash; measured metal content	mg/kg	<DL	0,16	0,22	<DL	10
GYPA5 soil+5% flyash; measured metal content	mg/kg	<DL	0,00	0,29	<DL	0,32
Difference between calculated and measured metal content of treated soil (mg metalws/kg soil)						
GYPA1 calculated – GYPA 1% measured	mg/kg	<DL	1,05	0,29	<DL	91
GYPA2 calculated – GYPA 2% measured	mg/kg	<DL	1,28	0,33	<DL	127
GYPA5 calculated – GYPA 5% measured	mg/kg	<DL	1,39	0,23	<DL	133
Difference between calculated and measured metal content of treated soil (%)						
GYPA1 calculated – GYPA 1% measured	%	<DL	72	53	<DL	66
GYPA2 calculated – GYPA 2% measured	%	<DL	89	60	<DL	93
GYPA5 calculated – GYPA 5% measured	%	<DL	99,7	44	<DL	99,7
Plant uptake in the bioaccumulation tests*** (mg $metal_{total}$/kg plant)						
Metal content of testplant* on Gyo untreated soil	mg/kg	0,006	1,38	17,8	9,3	336
Metal content of testplant grown on GYPA2%	mg/kg	0,006	0,80	20,2	6,0	168
Metal content of testplant grown on GYPA5%	mg/kg	0,006	0,70	19,7	5,0	133
Plant-soil bioconcentration factor ($BCF = Cplant_{total}/Csoil_{total}$)						
BCF of testplant grown on Gyo untreated soil		~0	0,21	0,05	0,01	0,28
BCF of testplant grown on GYPA+2% fly ash		~0	0,12	0,06	~0	0,13
BCF of testplant grown on GYPA+5% fly ash		~0	0,11	0,06	~0	0,11

* Total metal content: extraction from soil by aqua regia, * from plant by cc.HNO_3+ cc.H_2O_2
** Water soluble metal content: extraction with water (1:10)
*** 5-days bioaccumulation test developed for monitoring the stabilisation process

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STAGES AND OUTCOME OF THE WORK

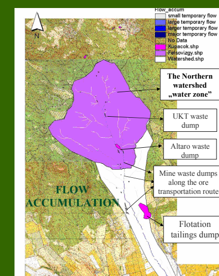
- Integrated conceptual risk model of the Toka catchment.
- Tiered Environmental Risk Assesment Methodology for metal-mining wastes.
- Inventory of pollution sources using historical documents and site assessment and their first ranking by a mark-system.
- GIS based Quantitative Hazard and Risk Assessment to calculate actual risk of sources, sub-areas and the total catchment. 15 waste dumps and sediment of reservoirs to be removed, other 30 ranked, 15 are negligable.
- Determination of the acceptable land-use specific target risk and planning the risk reduction measures to reach this.
- Simulation of the effects of the removal or non- removal of any point or diffuse source by the GIS-based risk model.
- In case of diffuse and remaining pollutant sources the combined chemical & phytostabilisation is the BAT for Risk Reduction. Selection of the most efficient chemical stabiliser (fly ash) is based on laboratory microcosm tests.
- 15 waste sources (point and diffuse) will be remedied by the combined chemical and phytostabilisation an other 15 by only phytostabilisation.
- The suitable chemical stabiliser & plant(s)combination will be selected in 2006 based on the results of field experiments.

QUANTITATIVE RISK ASSESMENT

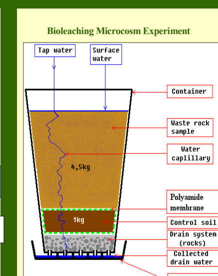
Water Balance and Pollution Transport

In-coming water	Type of incoming water	% of total incoming	Amount of incoming water type	Water form and components
	Precipitation	100%	20 712 m^3/ day/10 km^2	Rain, snow
	Infiltrated water	43,3%	8 972 m^3/ day/10 km^2	Pore water, soil moisture
	Subsurface runoff	15,6%	3 248 m^3/ day/10 km^2	Runoff water
	Surface runoff	15,6%	3 241 m^3/ day/10 km^2	Runoff water
	Water in biomass	3,7%	767 m^3/ day/10 km^2	Plant water
	Vapour	10,00%	2 451 m^3/ day/10 km^2	Evapo transpiration
	Outflow from the water zone	11,8%	2 451 m^3/ day/10 km^2	Toka creek
TOTAL		100%	20 718 m^3/ day/10 km^2	

Water Balance of the Catchment



GIS Flow Accumulation model



Bioleaching microcosm

Total metal concentration in the typical mine wastes used in the bioleaching microcosm test

Metals	Total metal (minimum) mg/kg	Total metal (medium) mg/kg	Total metal (maximum) mg/kg
As	44	100	216
Cd	1	3	12
Cu	25	50	107
Pb	295	600	13 100
Zn	370	800	2 155

*Aqua regia extract, ICP MS)

Estimated metal emission of the waste sources Metal concentration of the microcosm leachates

Metals	Minimum emission µg/lit	Average emission µg/lit	Maximum emission µg/lit
As	150	340	700
Cd	100	300	1 200
Cu	400	800	4 710
Pb	100	203	3 600
Zn	25 000	54 135	163 000

CONCLUSIONS

A complex risk management tool was established for the postmining management of the mine wastes of the Toka water catchment. The Hungarian methodology utilised the results of the DIFPOLMINE project, the GIS based pollution mapping and transport modelling and the combined chemical & phytoremediation for reducing th risk of diffuse and remaining pollution sources. In spite of the fact that the Toka catchment area differs in many aspects from the Salsigne site, the main concept and the modern Environmental Risk Assessment and Risk Reduction methodologies could be adapted.

The Hungarian methodology was worked out on catchment scale basis, but it is applicable for point or diffuse sources or subareas, considering them little „catchments". The same methodology is adaptable to regional scale, where the dominant risk is represented by the metal content of the surface water.

The risk reduction concept is based on reducing the runoff water quantity and quality by removal of the point sources and chemical & phytostabilisation of the residual and diffuse pollution. The scale of reduction is calculated from the target value, created by the same, site specific, GIS-based, catchment scale risk model. The only water which needs direct treatment is the mine water: this will be treated by liming or by alternative mine-water treatment technologies, like passive treatment using Reducing and Alkalinity producing System (RAPS).