



PRE-MINING ENVIRONMENTAL GEOCHEMICAL SURVEY OF A MINERALISED WATERSHED IN NORTH GREECE

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Presentation Overview

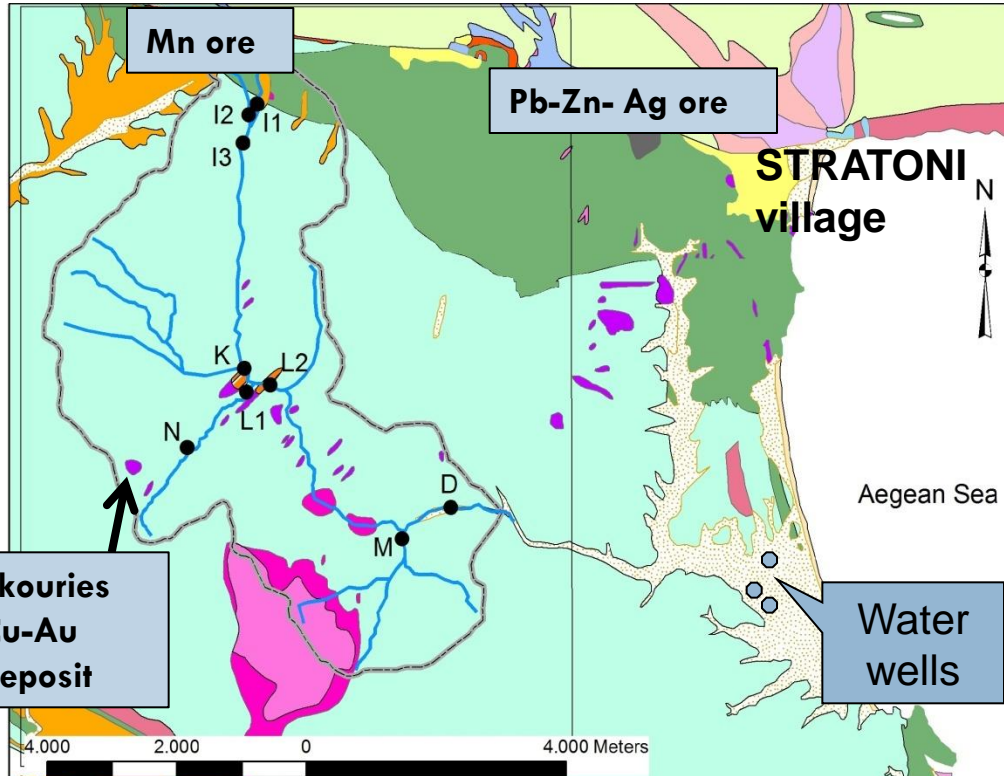


- Area description- Research motivation

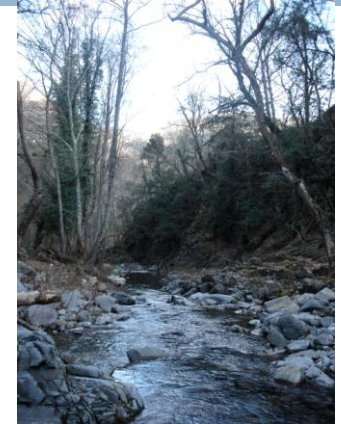
- Baseline geochemistry of
 - Soil
 - Stream sediment
 - Stream water

- Preliminary PHREEQC application for metal transport modeling

Description of mineralised watershed of Piavitsa



Legend		
Mine tailings	Amphibolites	Aureole of aplitic dykes and sills
Coastal deposits	Amphibolites alternating with gneiss	Biotite-muscovite granite
Alluvial deposits	Two-mica gneiss	Two mica and biotite granite
Holocene deposits	Biotite gneiss	Granodiorite of Stratoni
Pleistocene deposits	Upper marble horizon	Diorite
Neogene deposits	Marble horizon	Diorite porphyry
Area of important gossan	Lower marble horizon	Quartz-diorite porphyry
	Marbles of Vertiskos formation	Volcanic breccia
		Piavitsa watershed
		Stream
		● stream water / sediment sample



- Watershed area: 2.24 km²
- Elevation: 100- 650 m
- Deciduous forest with oak and beech
- Mild Mediterranean climate
- Annual rainfall: 650 mm



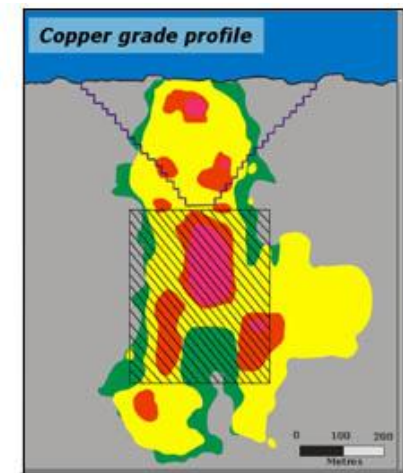
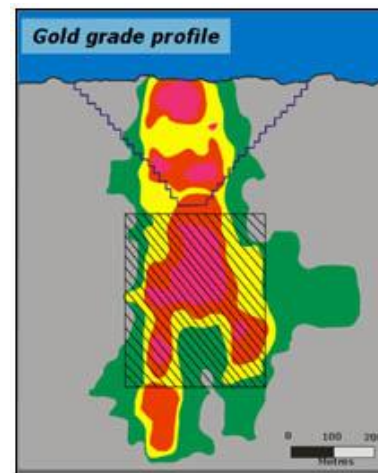
Skouries Cu-Au deposit

Plan to mine 146 Mt Mine life over 30 years

Reserves	'000t	Au g/t	Au Moz	Cu %	Cu '000t
Proven	34,444	1.25	1.38	0.68	233
Probable	103,918	0.66	2.21	0.48	503
Total	138,362	0.81	3.59	0.53	736
Resources					
Measured	39,480	1.24	1.57	0.67	266
Indicated	206,870	0.57	3.77	0.45	939
Total	246,350	0.67	5.34	0.49	1,205
Inferred	115,777	0.22	0.83	0.25	288

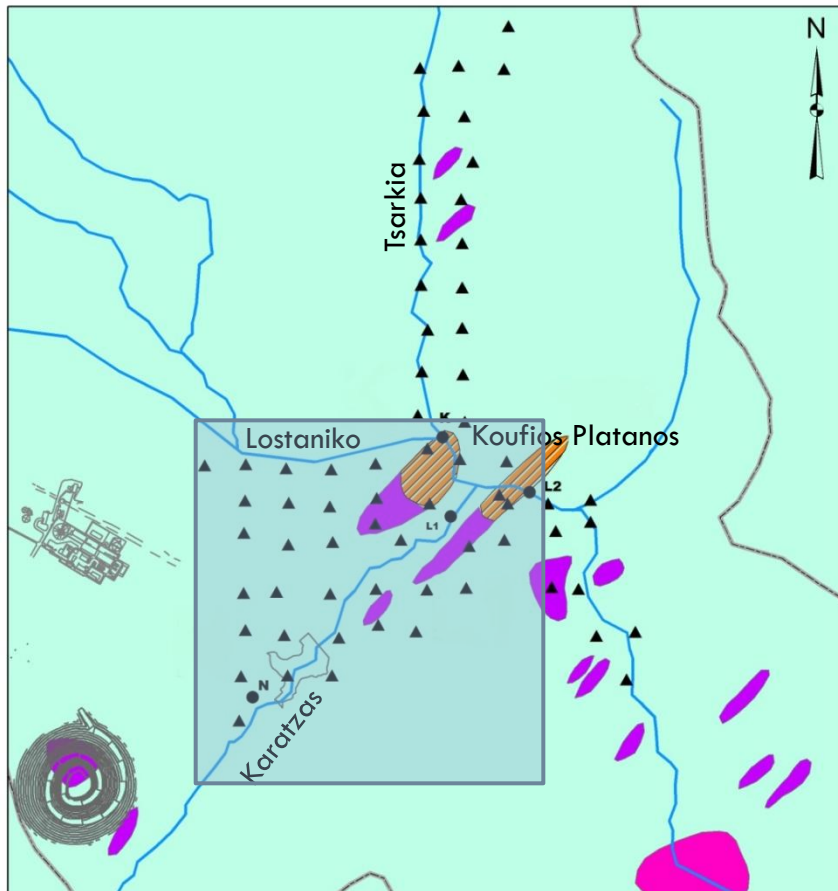


(source: www.egolfields.com)



Soil sampling

- 65 surface soil samples (0-25 cm) on 200x200 m grid
- 3 fold composite samples
- 8 sampling duplicates

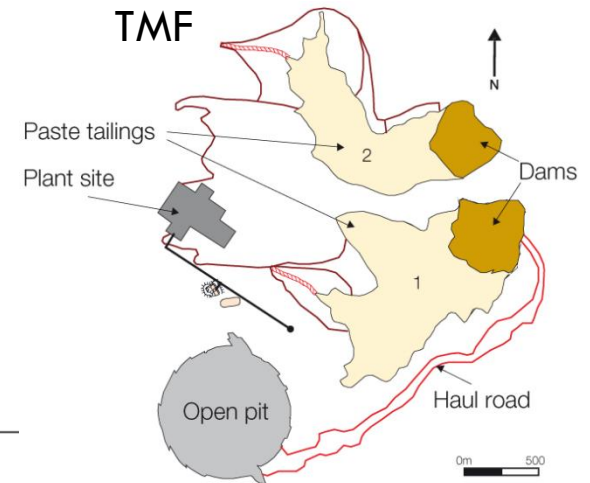


35 million tn waste
46 million tn of tailings

Legend

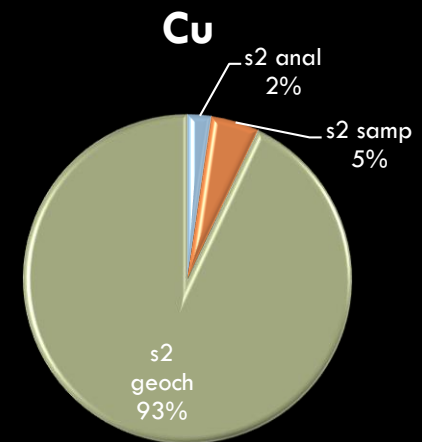
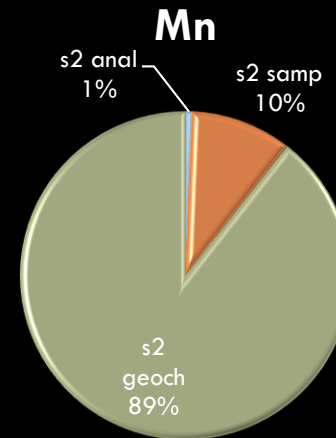
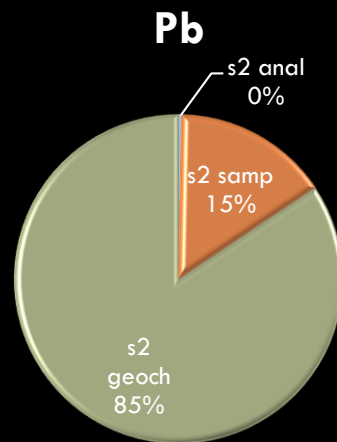
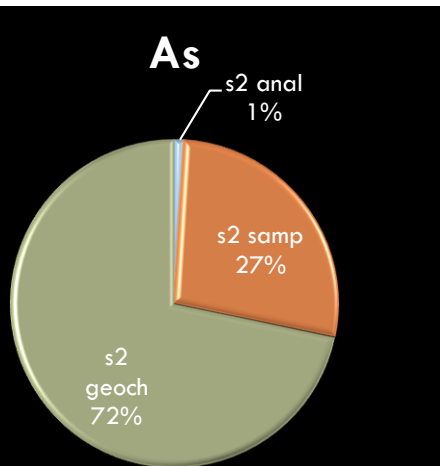
- ▲ soil sample
 - stream water / sediment sample
 - Planned open pit
 - Planned ore mill site
 - Stream
 - Piavitsa watershed
- Rock type
- Two-mica gneiss
 - Diorite
 - Diorite porphyry
 - Quartz-diorite porphyry
 - Volcanic breccia

400 200 0 400 Meters



Soil characteristics

- Sandy- loamy soil (60-75% sand)
- Positive NP & NNP (5-17)
- Near neutral soil pH

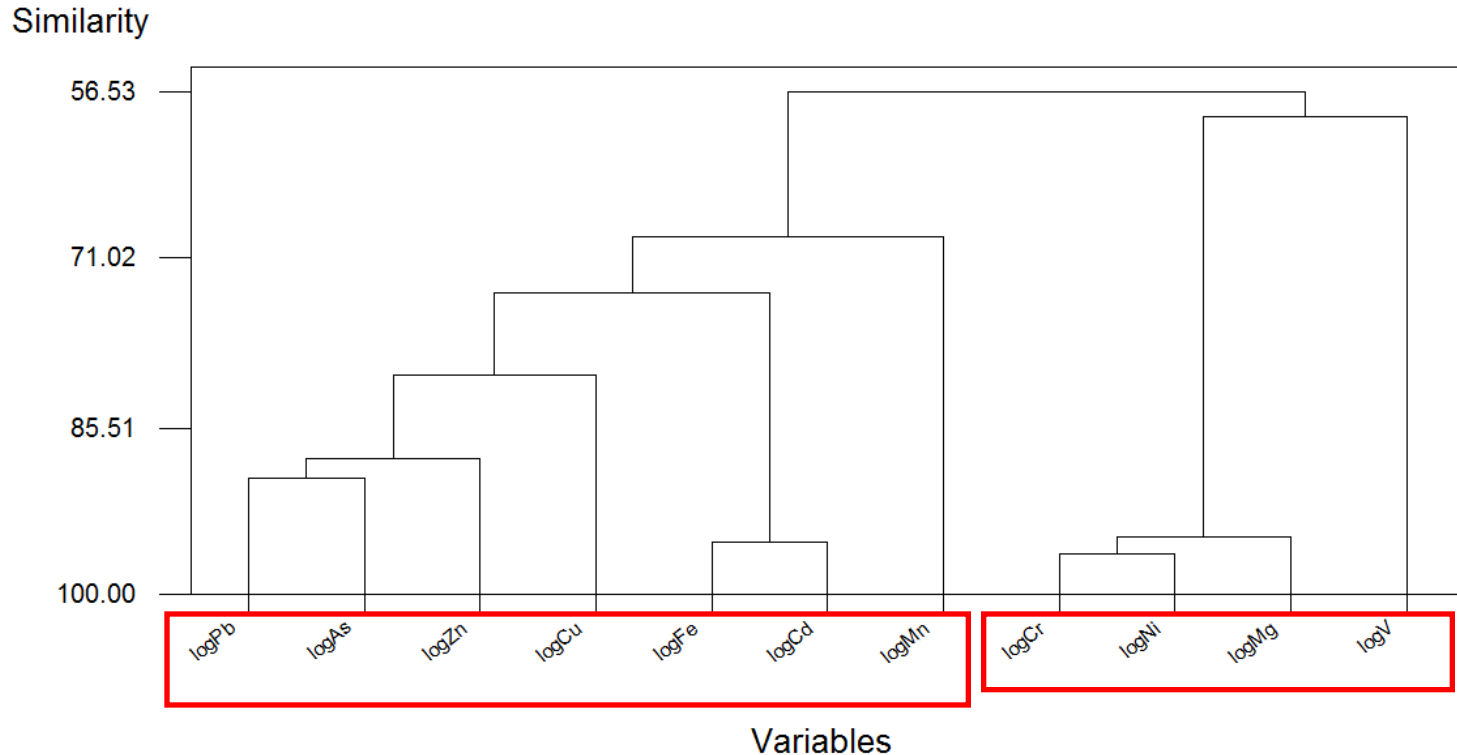


Total elemental concentrations in soil (mg/ kg)

(n= 65) HNO₃-HClO₄-HCl dissolution, ICP-AES

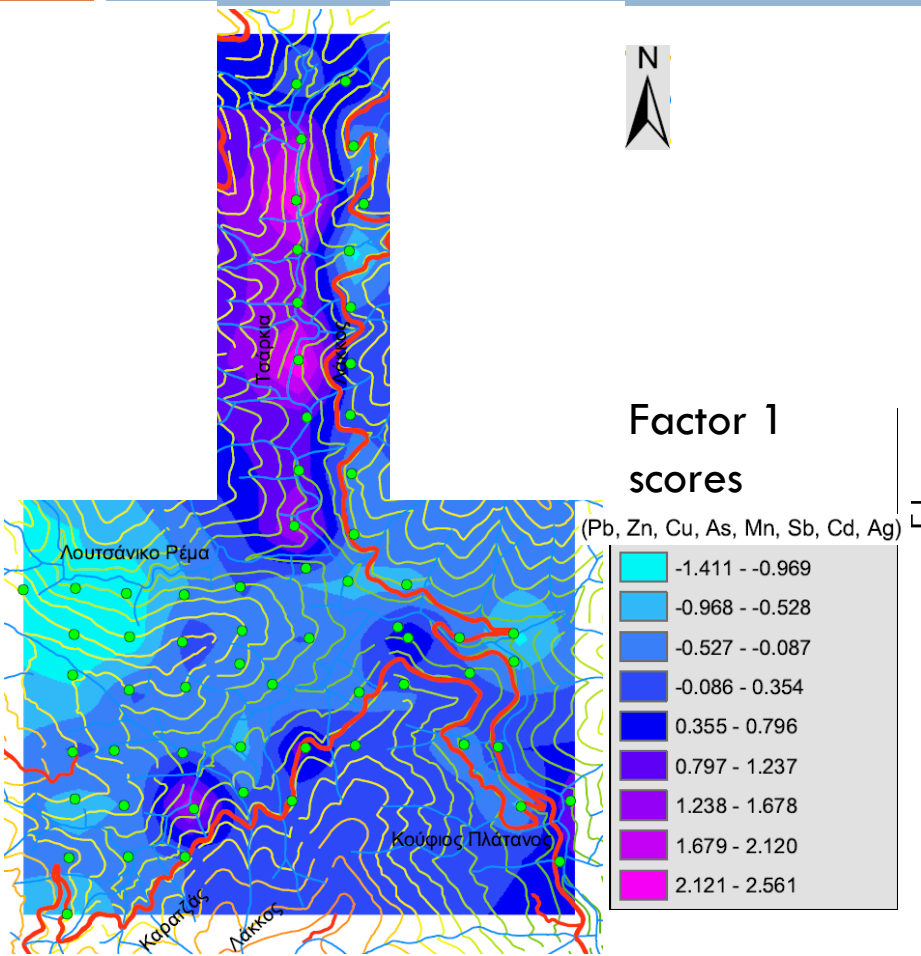
Element	Mean	Median	St.Dev.	Wider area median
Pb	526	295	815	325
Zn	350	231	346	240
Cu	49	45	19	104
As	165	126	147	119
Cd	16	16	3	1.3
Mn	1774	1410	1843	1501
Fe	43548	43100	6779	59500
Ni	247	136	218	69
Cr	279	175	194	178

Geochemical processes affecting soil composition



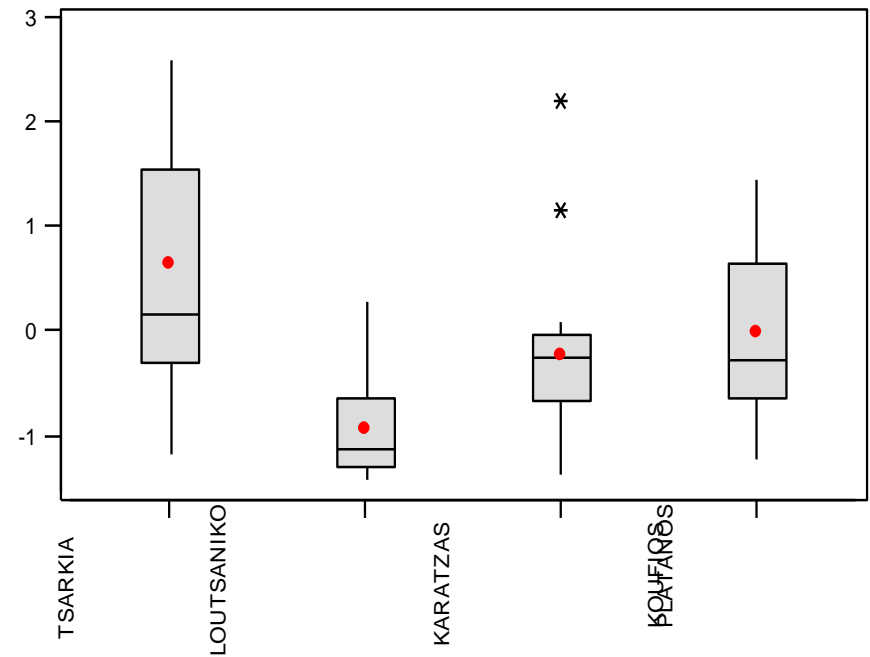
- Elements related to sulphide mineralisation
- Elements related to metamorphic rocks

Soil mapping based on factor analysis

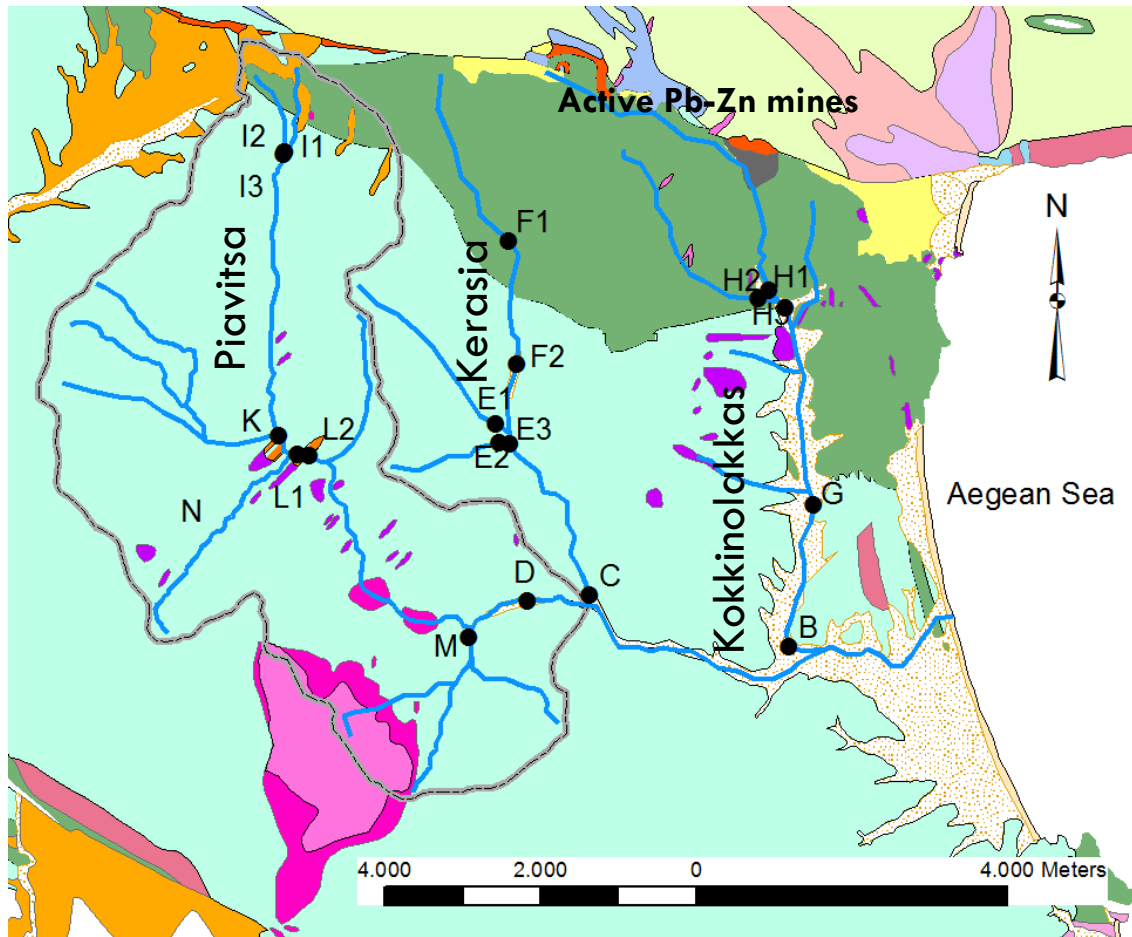


IDW, power = 2, output grid cell 200 m

Factor 1 scores by sub-basin within Piavitsa



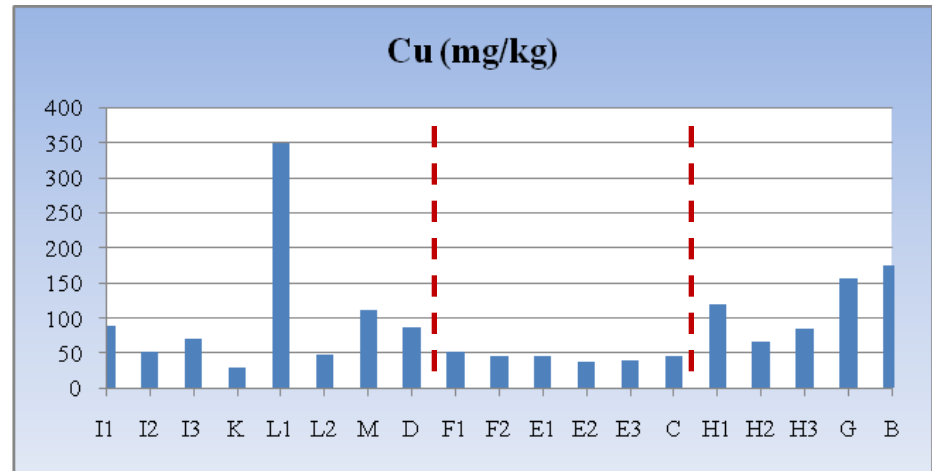
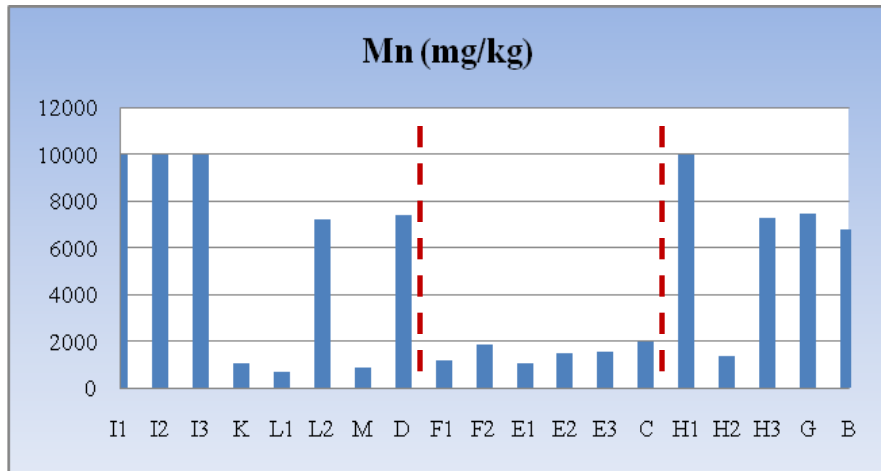
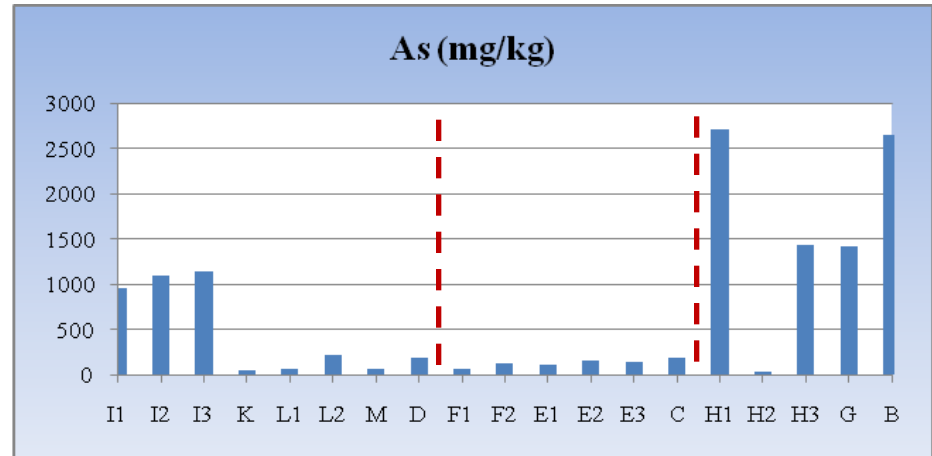
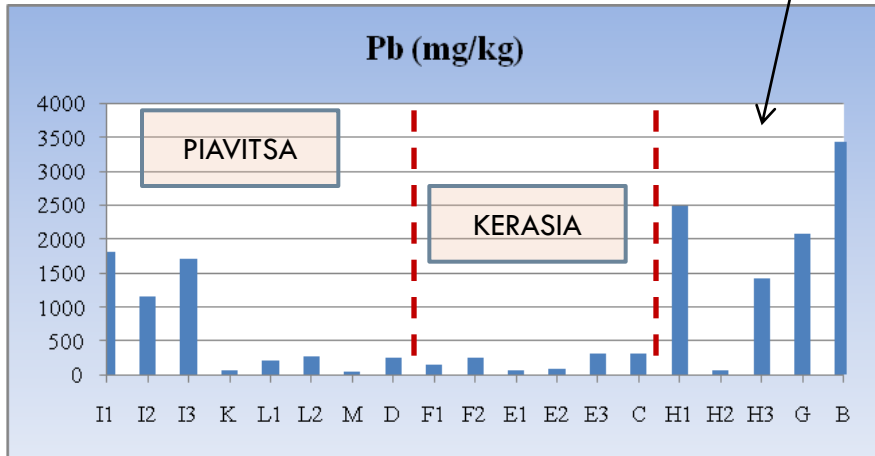
Stream sediment sampling



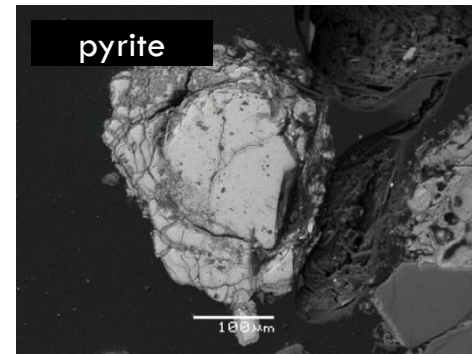
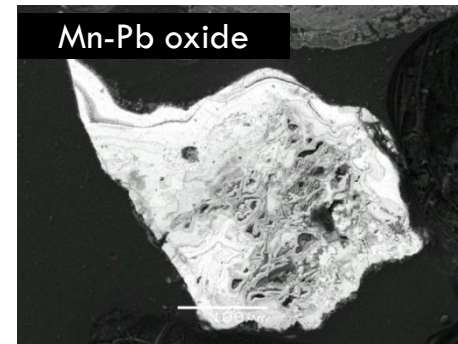
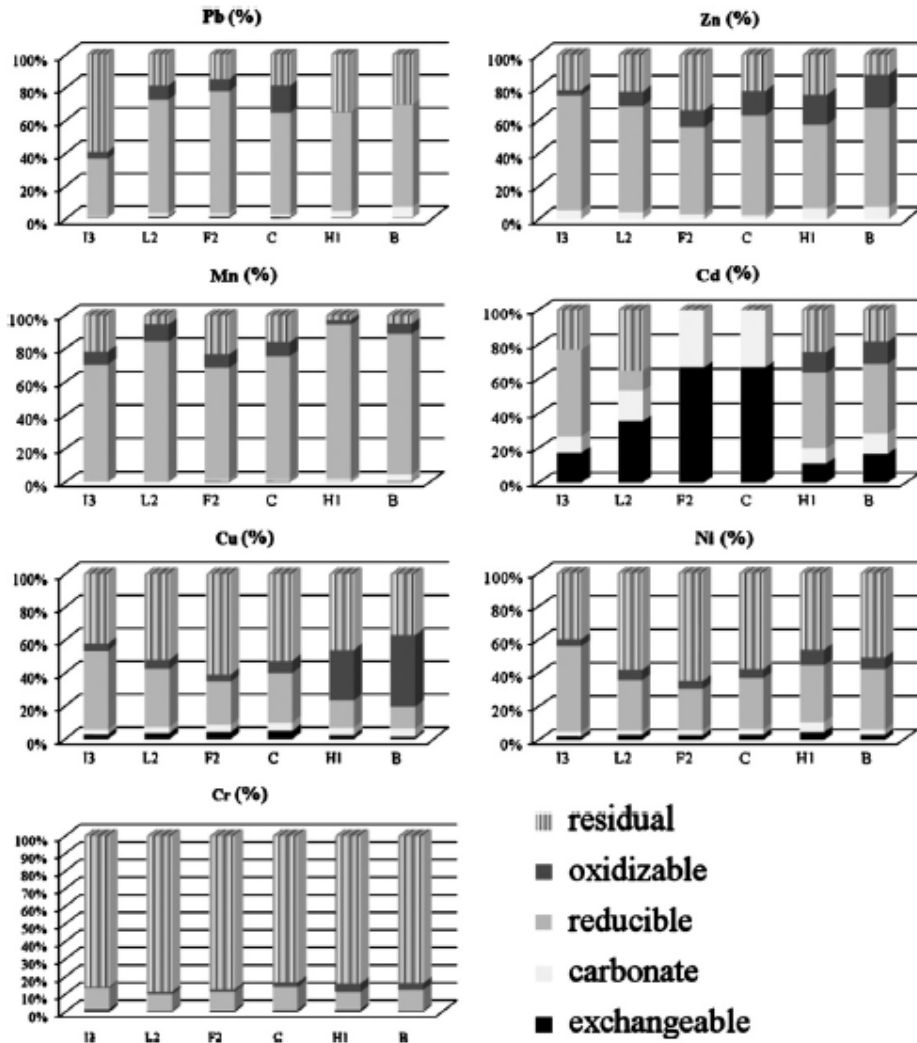
- Three parallel streams N-S direction
- Steep gradient – boulder bed material
- Kokkinolakkas draining active Pb-Zn mines
- Nineteen stream sediment samples along streams
- Mineralogy and chemical analysis on $-150 \mu\text{m}$ fraction
- Total dissolution – ICP-AES measurement

Stream sediment elemental concentrations by sub-basin

KOKKINOLAKKAS

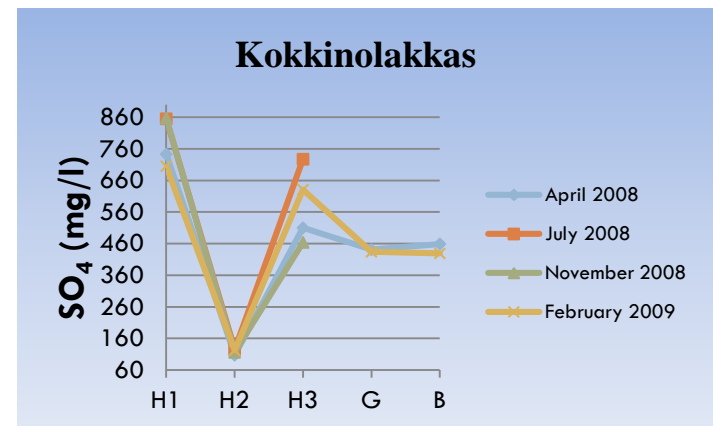
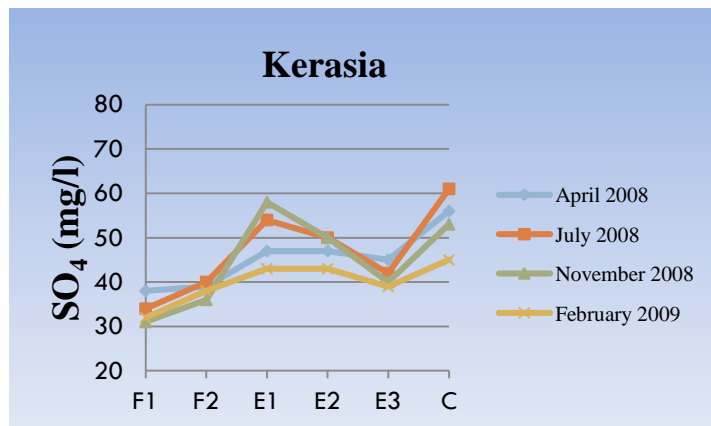
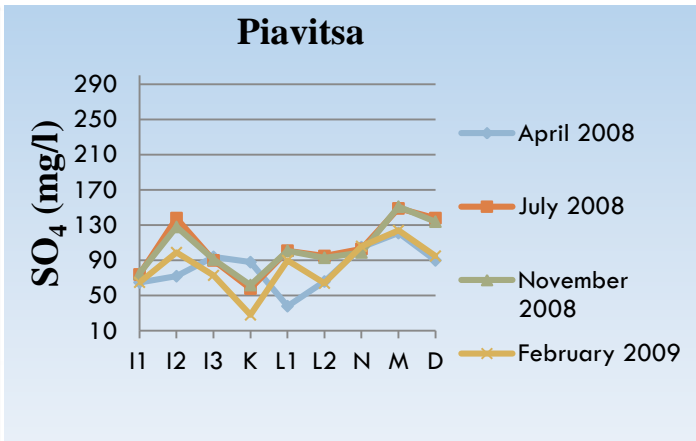
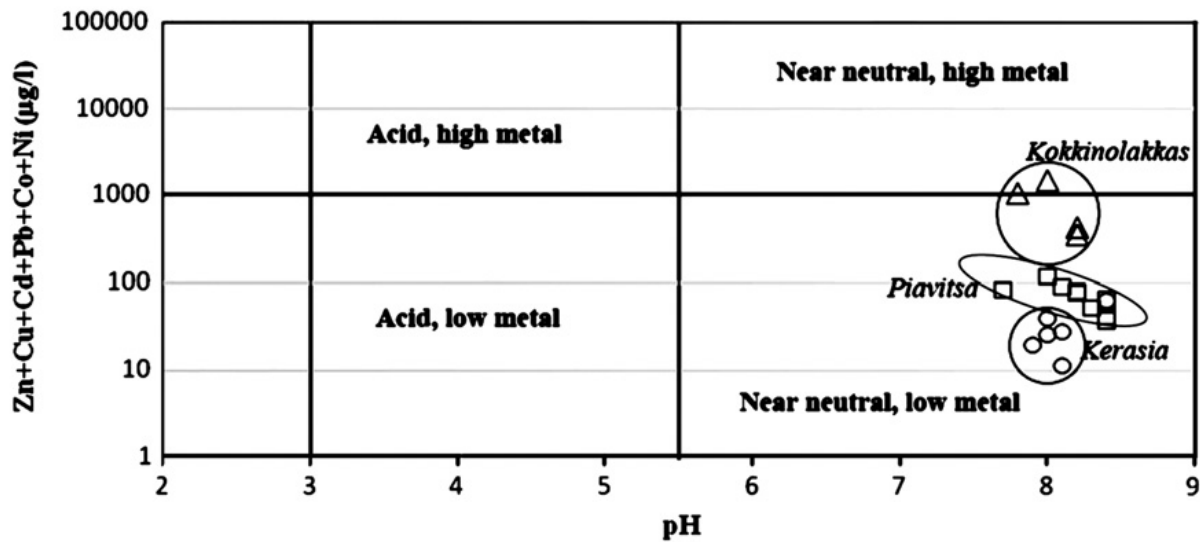


Metal partitioning in stream sediment samples



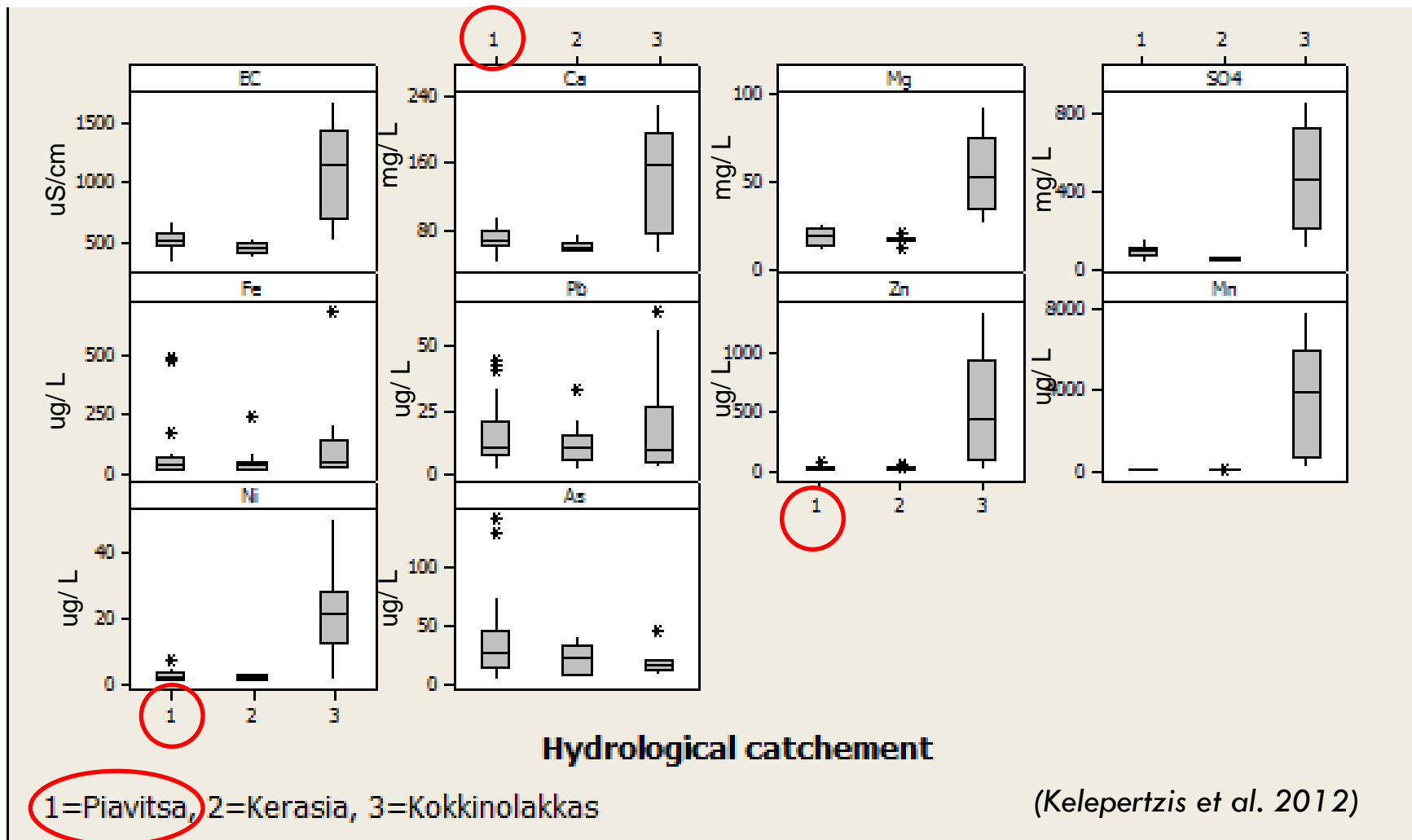
(Kelepertzis et al. 2012)

Stream water quality (20 sampling locations – filtered samples 0.45 μm - ICP-MS analysis)



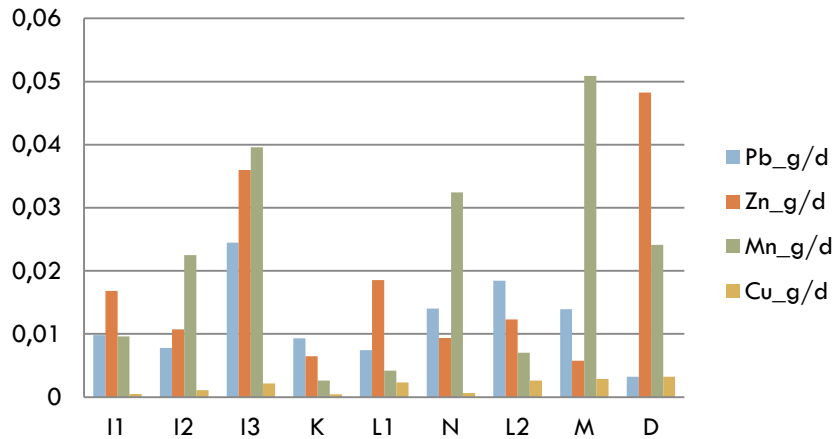
(Kelepertzis et al. 2012)

Water quality comparison between sub-basins

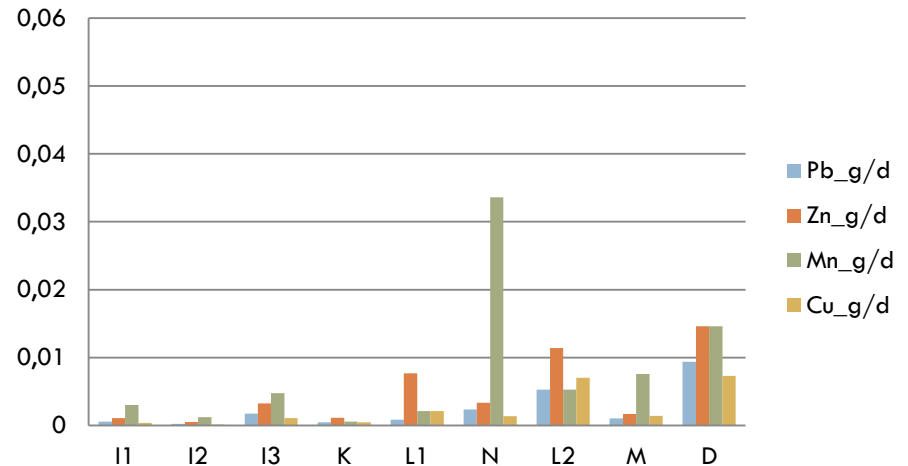


Seasonal variation of metal loadings in Piavitsa stream water

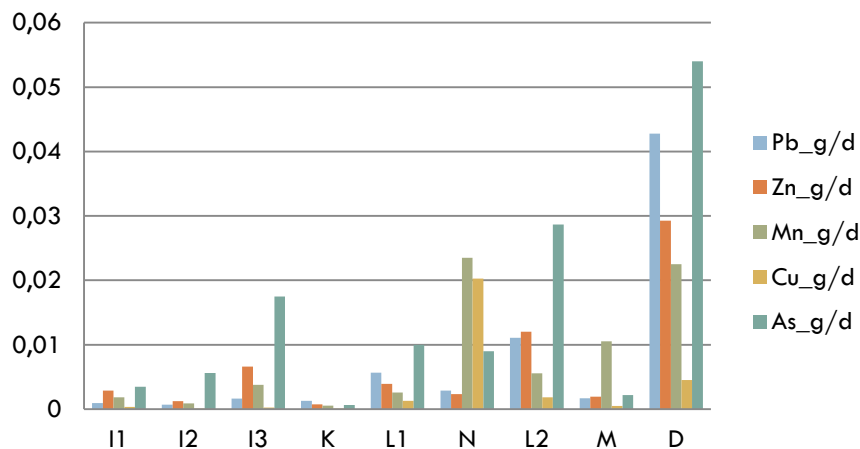
April 08



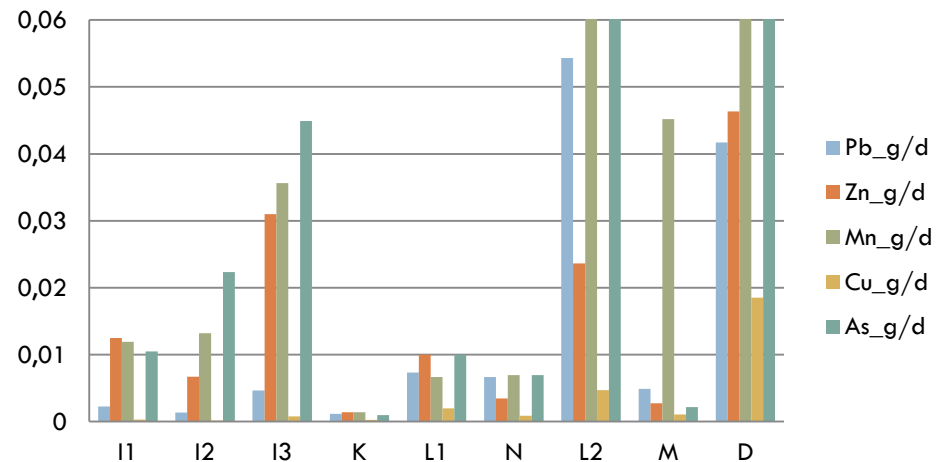
July 08



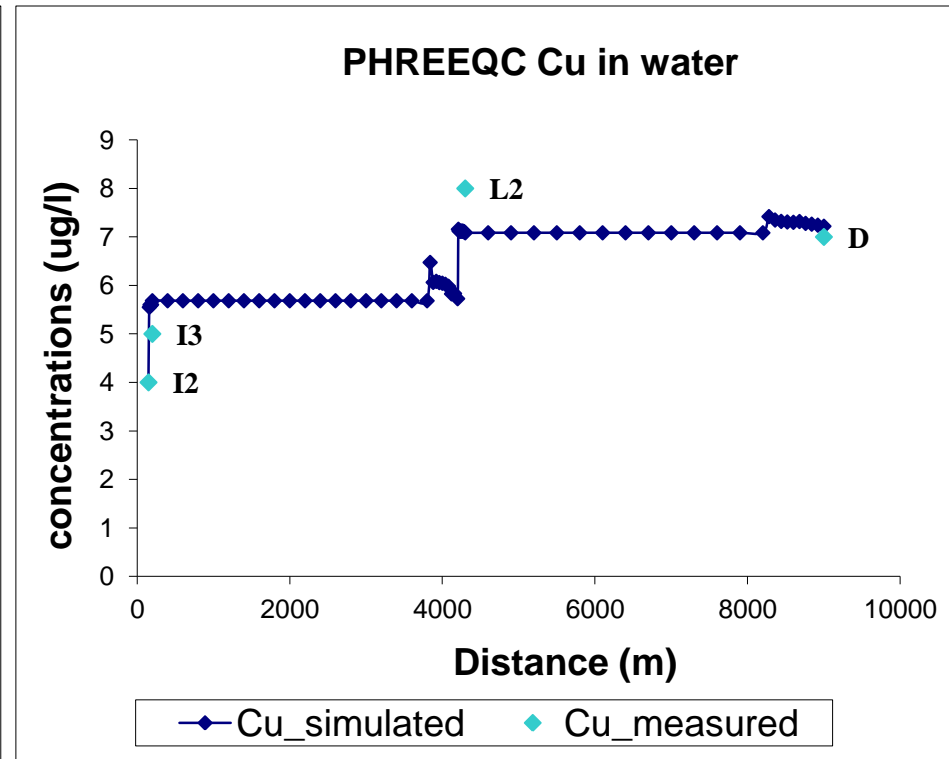
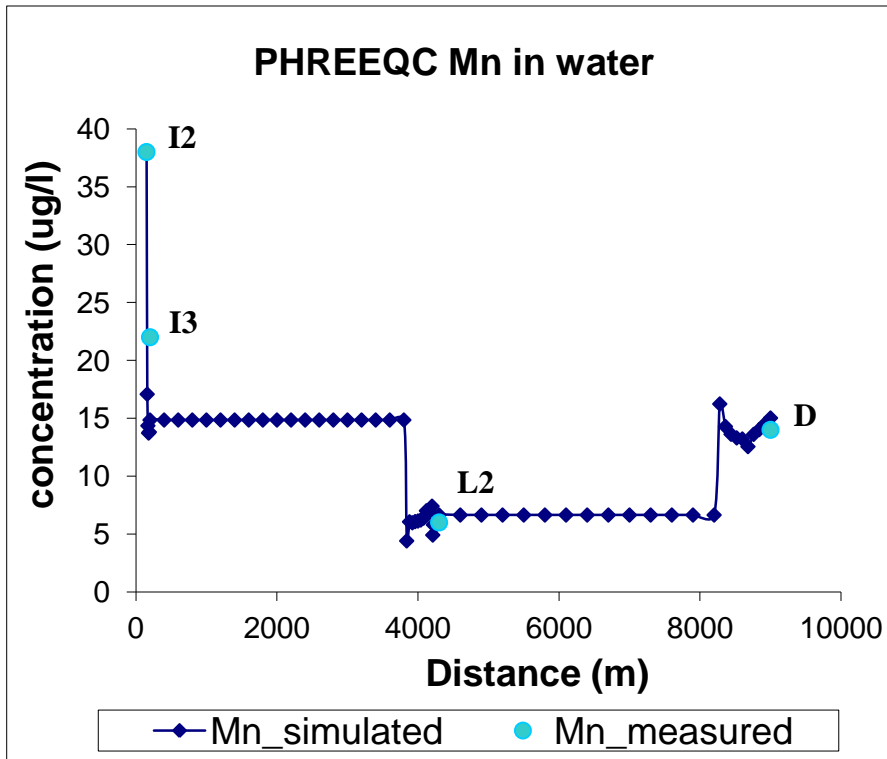
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February 09



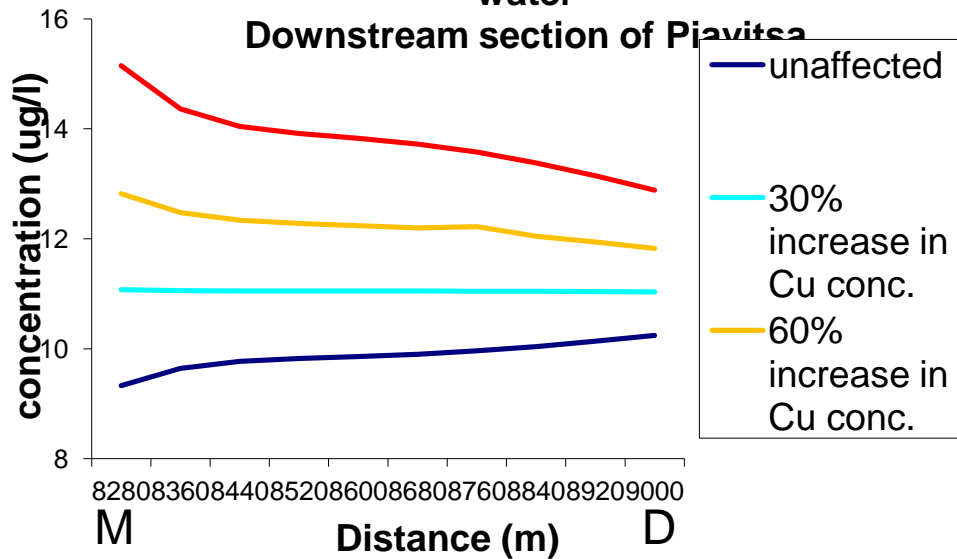
PHREEQC modeling in Piavitsa streamwater



- low flow conditions, no effect of sudden storms
- transport by PHREEQC
- mix solutions at tributaries
- adjustment by adding Mn-oxide & Cu-oxide phases into the system
- needs refinement = dense sampling, observation of seepage inflow

Use of data for predicting future change

Effect of increasing Cu concentration in water
Downstream section of Pjavitsa



- Sustainable mining / environmental protection
- Mine timelife scale = reduced flow
- Longer timescale = change of contaminant input
- Key role of Mn oxides
- Effects of pH change

Conclusions – Further work

- Unique opportunity to study a changing environment and gather pre-mining data
- Methodology guided by exposure targets and mining development plan
- Geochemical baseline established for soil, stream sediment and water → realistic remediation targets in the future
- Health baseline data?
- Need to better understand geochemical processes affecting metal transport
- Need for synoptic sampling for providing spatially detailed water chemistry profile in the streams and continuous monitoring



Thank you