DO LICHEN BIOACCUMULATION DATA TELL THE TRUTH?

Luca Paoli, Andrea Vannini, Fabrizio Monaci, Stefano Loppi

Department of Life Sciences, University of Siena
via Mattioli, 4 – 53100 Siena (Italy); paoli4@unisi.it

UNIVERSITÀ DI SIENA 1240

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- Lichens are known as reliable bioaccumulators of inorganic and organic atmospheric pollutants.
- They are especially effective in trapping trace elements from the surrounding environment
- It has been demonstrated that the concentrations of trace elements in lichen thalli are correlated with the environmental levels of these elements.

Incinerators and lichens

Bioaccumulation in native thalli of the lichen *Flavoparmelia caperata*

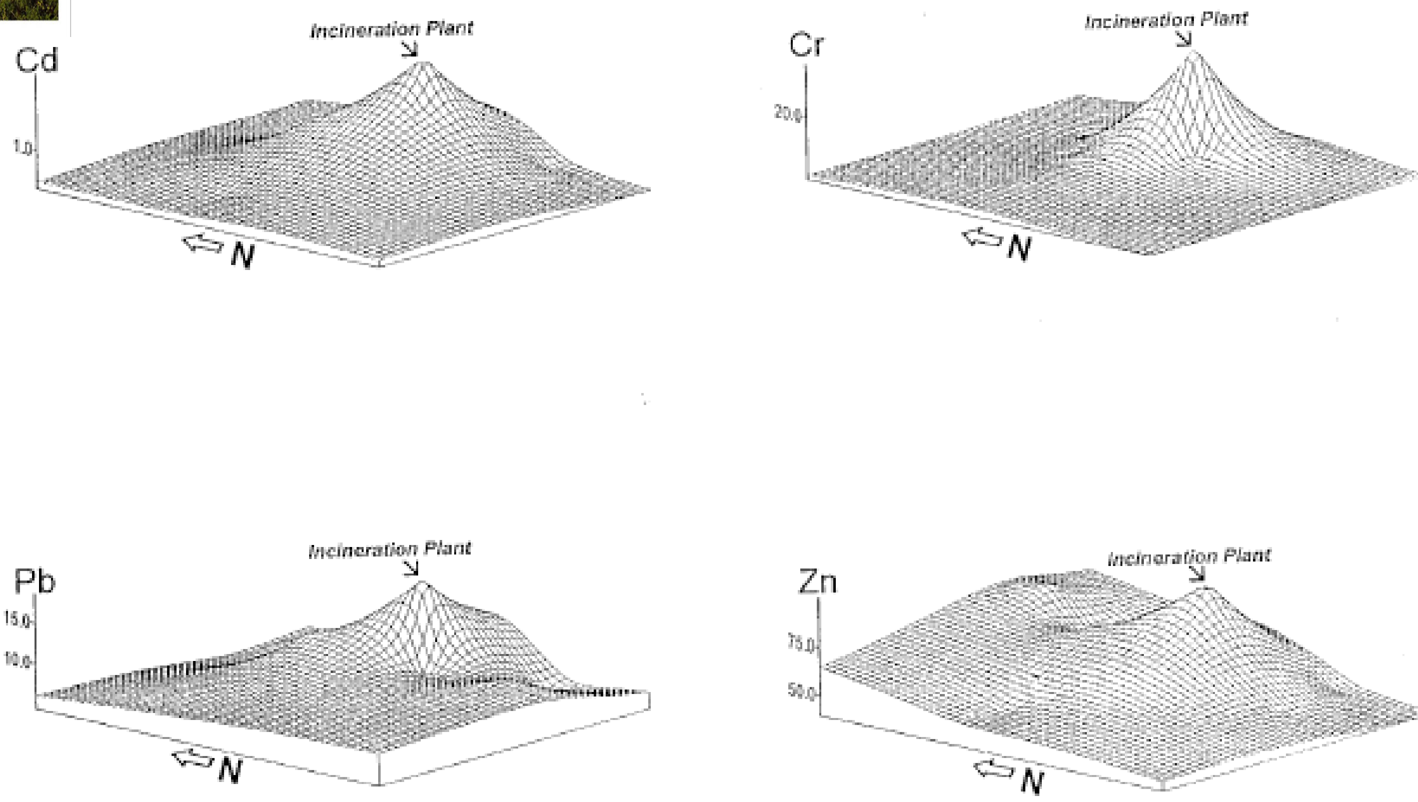


Figure 3. Three-dimensional distribution maps of Cd, Cr, Pb and Zn in the study area.

Incinerators and lichens

ACCUMULATION OF HEAVY METALS IN EPIPHYTIC LICHENS NEAR A MUNICIPAL SOLID WASTE INCINERATOR (CENTRAL ITALY)

S. LOPPI[1]*, E. PUTORTÌ[1], S. A. PIRINTSOS[2] and V. DE DOMINICIS[1]

Environmental Monitoring and Assessment **61:** 361–371, 2000.

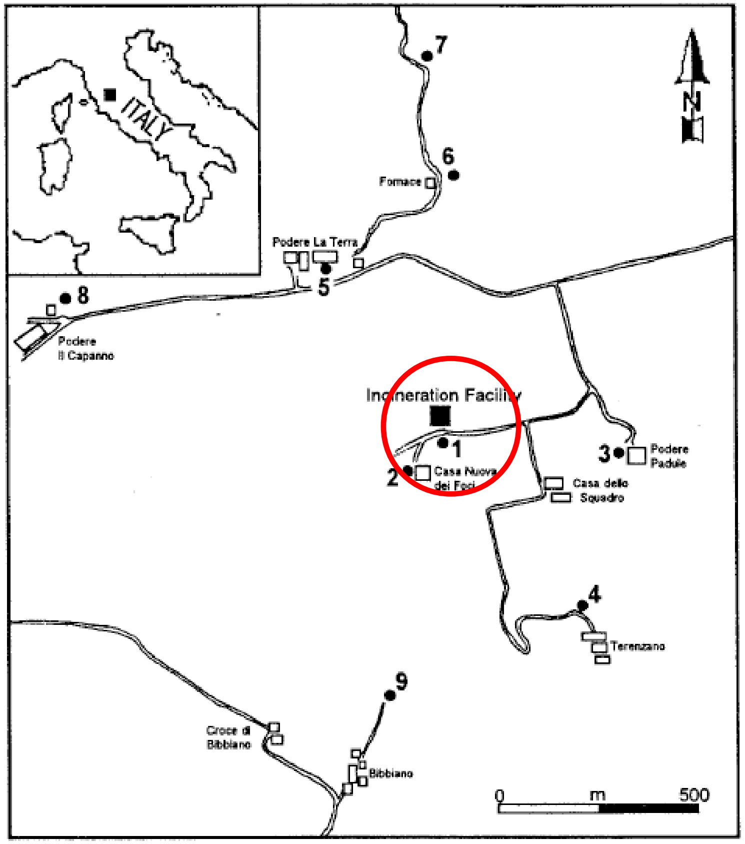


Figure 1. Map of the study area with location of sampling sites.

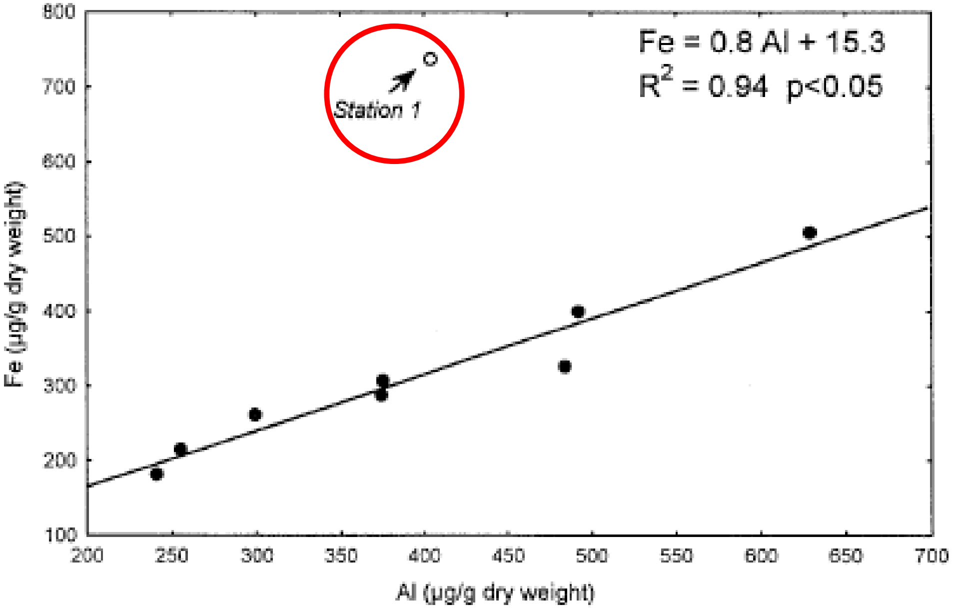
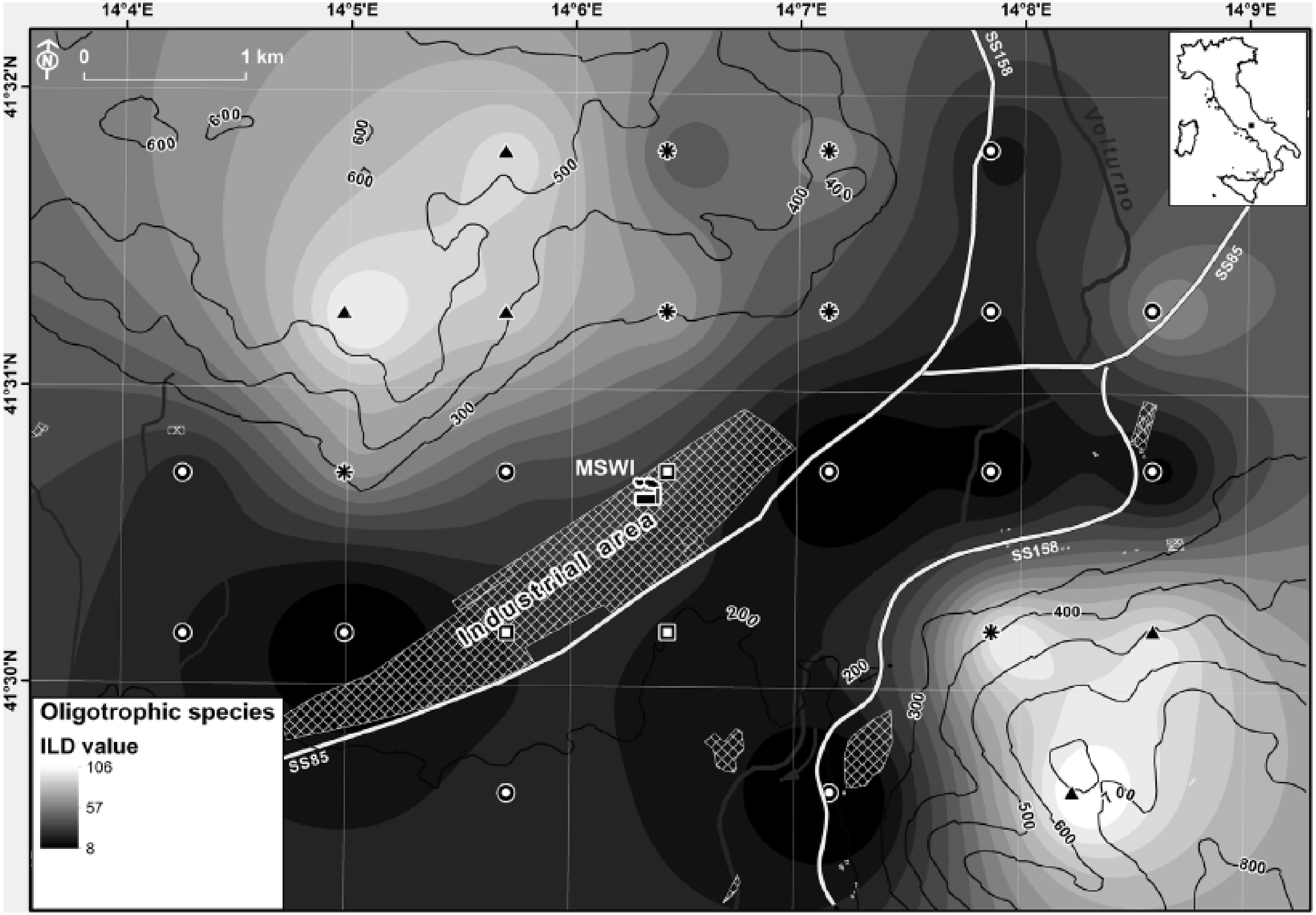


Figure 2. Correlation between the concentrations of Al and Fe in the lichen *Parmelia caperata*.

Incinerators and lichens

L. Paoli et al. / Ecological Indicators 52 (2015) 362–370



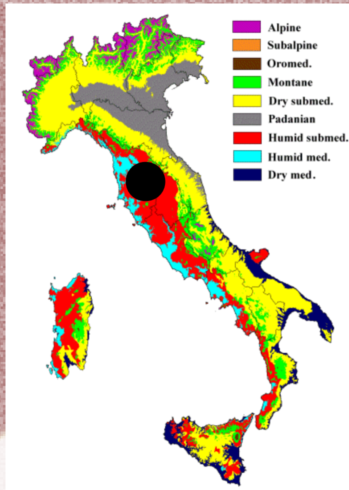
Incinerators and lichens

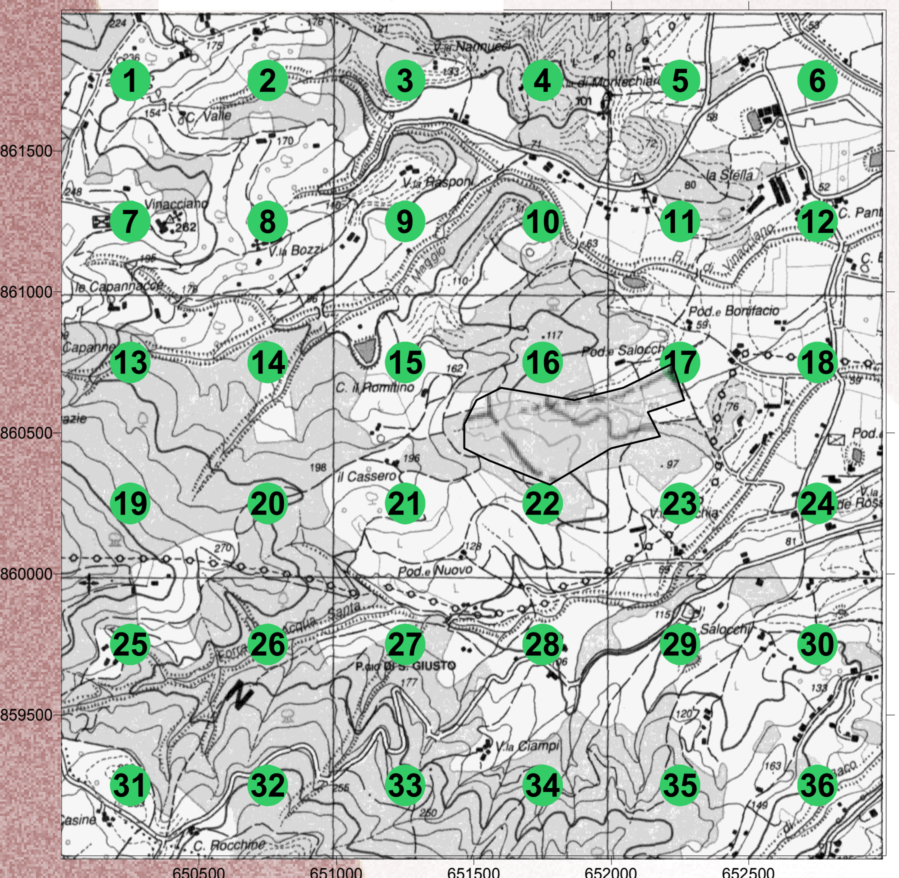
Transplanted lichens (6 months - *Evernia prunastri*) and soil samples

Enrichment Factors = $(X_L/R_L)/(X_S/R_S)$

Elements	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Sb**	**As**	**Co**	**V**	**Tl**	**Mn**	**Hg**
EF	1.05	0.7	2.01	0.38	1.42	0.94	0.26	0.1	0.33	0.75	0.03	15.37

Landfilling and lichens





Landfilling and lichens

Paoli et al. 2015. Waste Management 42: 67–73.

Table 3
Content of trace elements (µg/g) in the lichen *Flavoparmelia caperata* as a function of distance from the landfill. Heavy metals were interpreted in terms of air pollution according to the intervals given in Table 1.

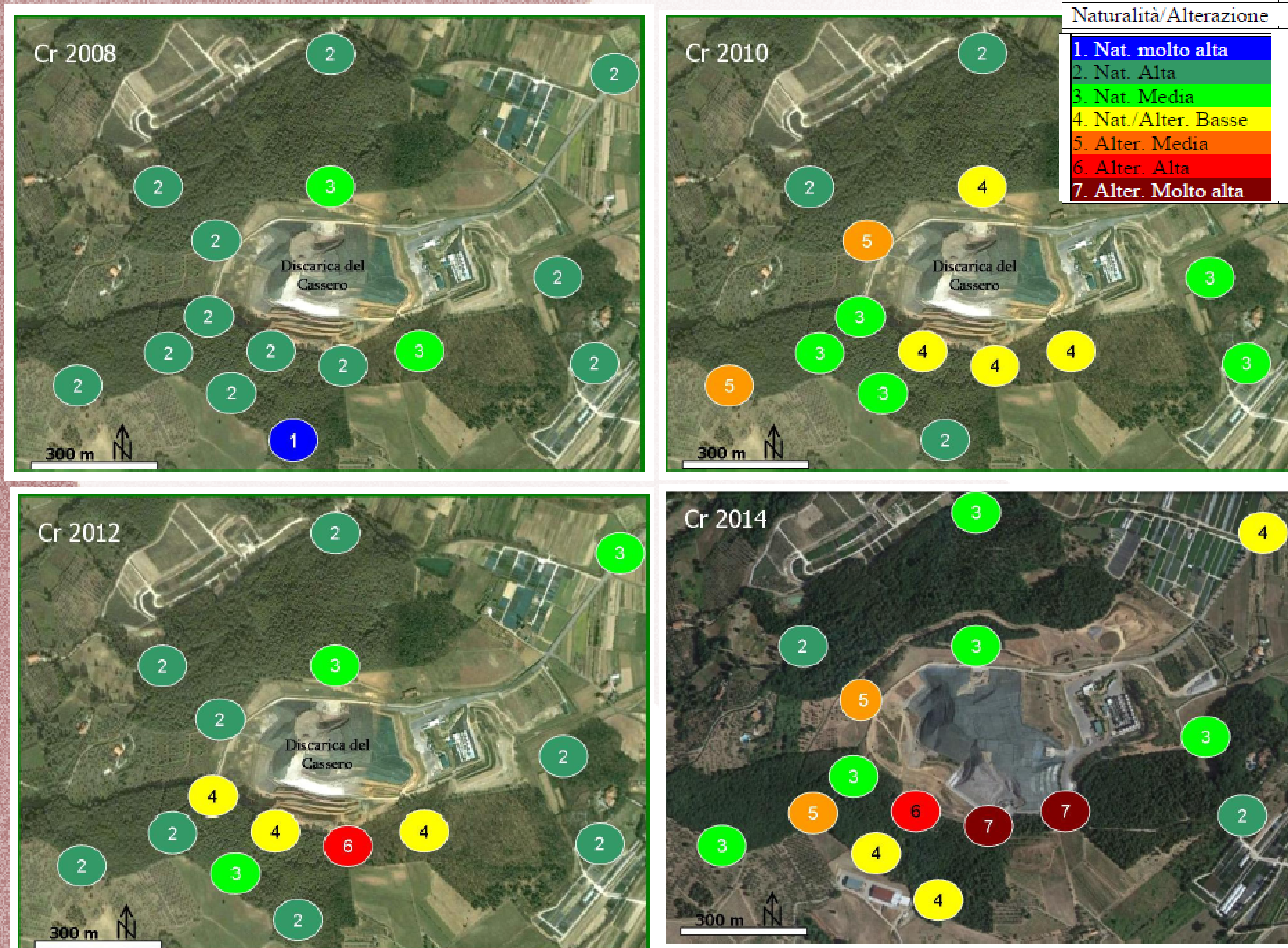
Elements	Landfill	200 m	1500 m	ANOVA
As	0.49 ± 0.10^{a} Low	0.31 ± 0.05^{b} Very low	0.18 ± 0.031^{c} Very low	$F = 29.12$ $P = 0.000$
Cd	0.62 ± 0.01^{a} Moderate	0.37 ± 0.01^{b} Low	0.24 ± 0.03^{c} Very low	$F = 32.35$ $P = 0.000$
Cr	7.5 ± 4.2^{a} High	2.2 ± 0.3^{b} Low	1.3 ± 0.2^{b} Very low	$F = 13.32$ $P = 0.003$
Cu	17.8 ± 6.8^{a} Moderate	9.9 ± 1.0^{b} Low	6.6 ± 0.1^{b} Very low	$F = 13.08$ $P = 0.000$
Fe	1092 ± 413^{a} Moderate	525 ± 20^{b} Low	275 ± 7^{b} Very low	$F = 18.67$ $P = 0.000$
Ni	6.0 ± 1.6^{a} High	3.6 ± 0.3^{b} Moderate	4.4 ± 0.2^{ab} Moderate	$F = 13.82$ $P = 0.000$
Pb	22.9 ± 12.6^{a} Low	6.9 ± 2.4^{b} Very low	3.1 ± 0.1^{b} Very low	$F = 13.61$ $P = 0.000$
Zn	79.5 ± 27.1^{a} Moderate	47.5 ± 6.1^{b} Low	33.6 ± 2.4^{b} Very low	$F = 13.02$ $P = 0.000$

Landfilling and lichens

Assessment of physiological effects: stress signals were observed in lichens growing in front of the facility, i.e. discoloration, necrosis, membrane lipid peroxidation, lower ergosterol content, higher dehydrogenase activity, decreased photosynthetic efficiency, altered chlorophyll integrity and production of secondary metabolites.

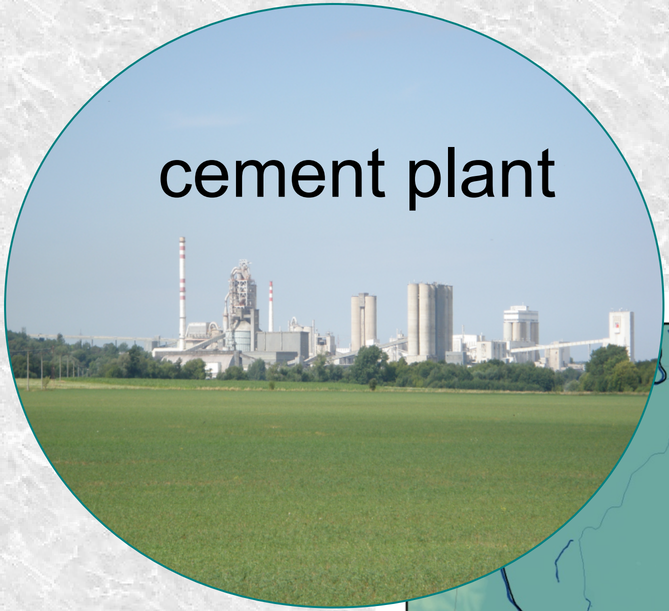
Table 4
Physiological parameters in the lichen *Flavoparmelia caperata* as a function of distance from the landfill: chlorophyll integrity ($OD_{435/415}$), potential quantum yield of PSII as indicator of photosynthetic efficiency (F_v/F_m), dehydrogenase activity as indicator of lichen viability (A_{492}/g dw), TBARS, thiobarbituric acid reactive substances (µmol/g dw), ergosterol content (mg/g dw), caperatic and usnic acid (% dw). Significant differences between sites ($P < 0.05$) are indicated by a different letter.

Parameters	landfill	200 m	1500 m	ANOVA
$OD_{435/415}$	0.95 ± 0.02^{a}	1.02 ± 0.04^{b}	1.07 ± 0.03^{b}	$F = 25.68$ $P = 0.000$
F_v/F_m	0.68 ± 0.10	0.73 ± 0.04	0.76 ± 0.02	$F = 2.026$ $P = 0.161$
Dehydrogenase	7.9 ± 3.4^{a}	5.3 ± 1.3^{b}	4.1 ± 1.6^{b}	$F = 3.79$ $P = 0.042$
TBARS	19.8 ± 4.6^{a}	14.7 ± 3.5^{a}	7.3 ± 1.4^{b}	$F = 12.41$ $P = 0.000$
Ergosterol	0.39 ± 0.09^{a}	0.43 ± 0.05^{a}	0.64 ± 0.11^{b}	$F = 8.639$ $P = 0.007$
Caperatic acid (% dw)	4.7 ± 3.2^{a}	7.7 ± 0.9^{ab}	8.6 ± 0.8^{b}	$F = 3.74$ $P = 0.048$
usnic acid (% dw)	1.37 ± 0.14^{a}	1.07 ± 0.31^{c}	1.19 ± 0.31^{ab}	$F = 10.08$ $P = 0.003$



Naturalità/Alterazione	Cr (µg/g)
1. Nat. molto alta	< 1,2
2. Nat. Alta	2,2
3. Nat. Media	4,0
4. Nat./Alter. Basse	6,0
5. Alter. Media	9,0
6. Alter. Alta	16,0
7. Alter. Molto alta	>16

Cement and lichens



40 km NE
of Bratislava
(Slovakia)

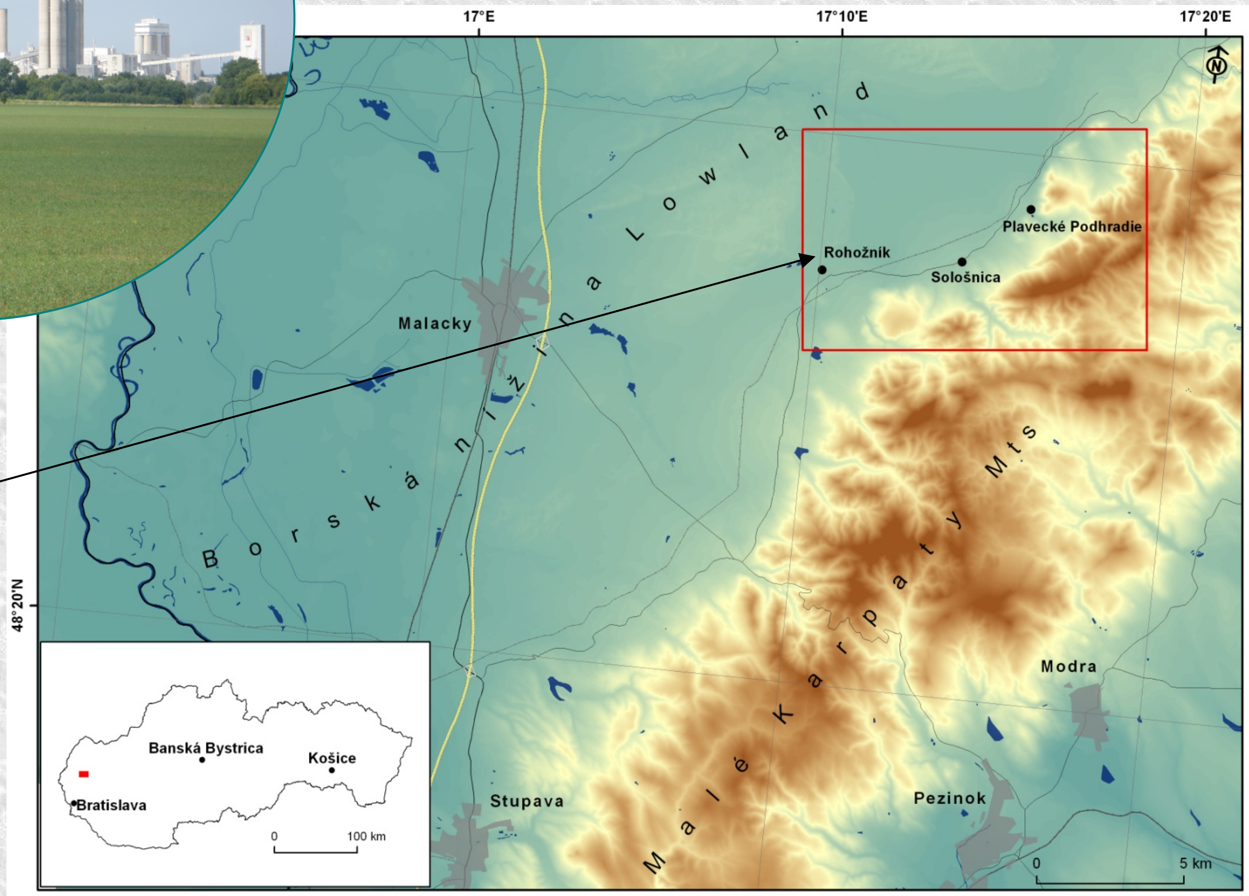


Image D. Senko.

Sources of pollution

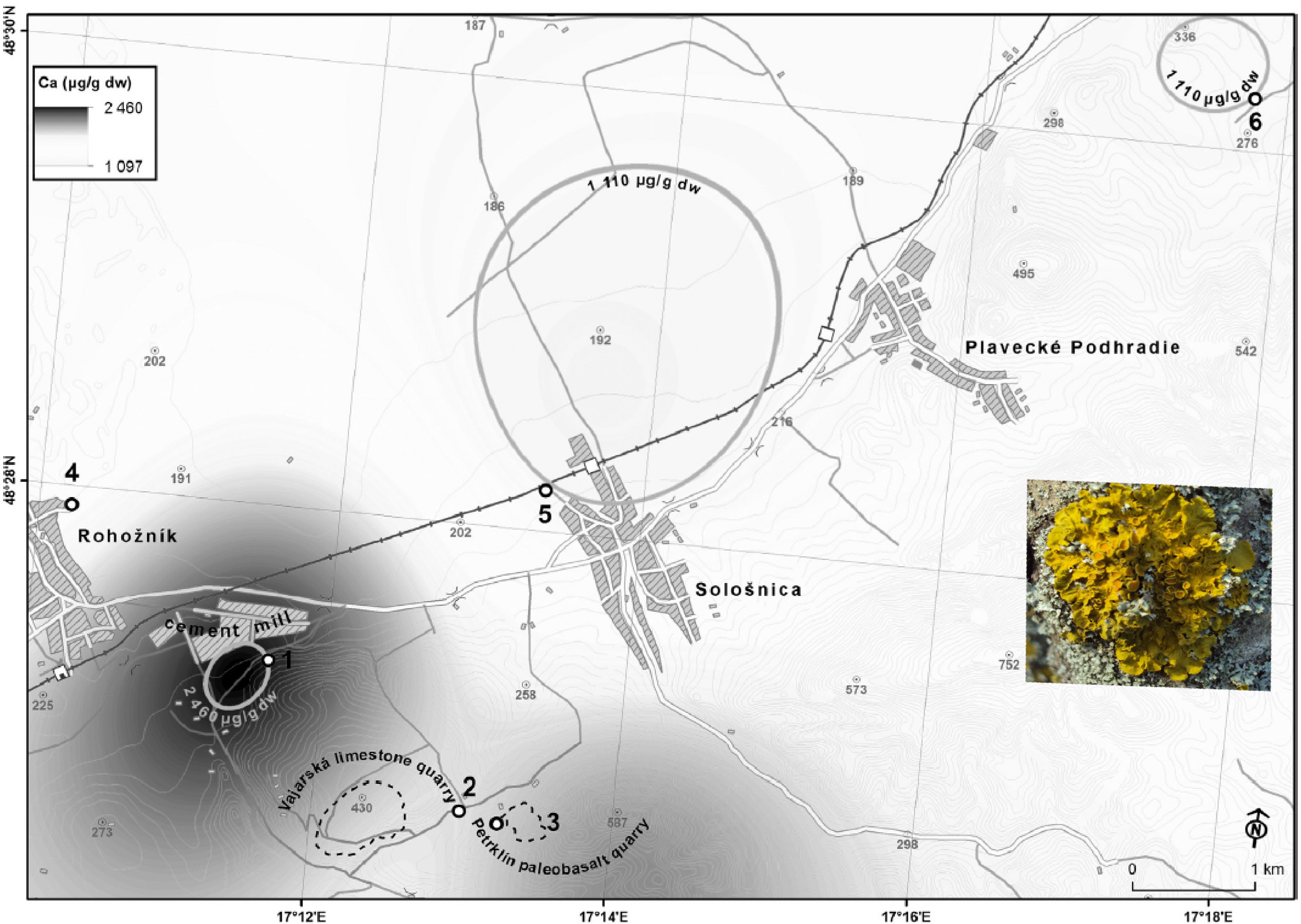
A cement industry is a source of dust pollution, from quarrying and grinding of the raw material, kiln operations, transportation, packing and dispatch of the cement. Airborne pollutants related to combustion processes are also emitted, especially during kiln operations and power generation, including SO_2, NO_x, particulate matter, heavy metals and potentially dioxins and furans in case of waste burning.

dust

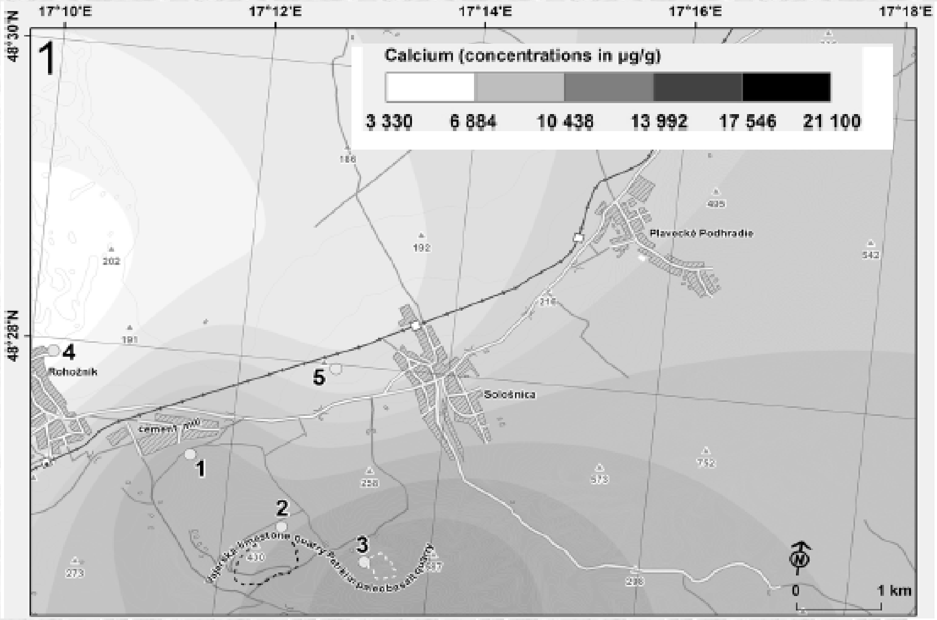
Atmospheric pollutants

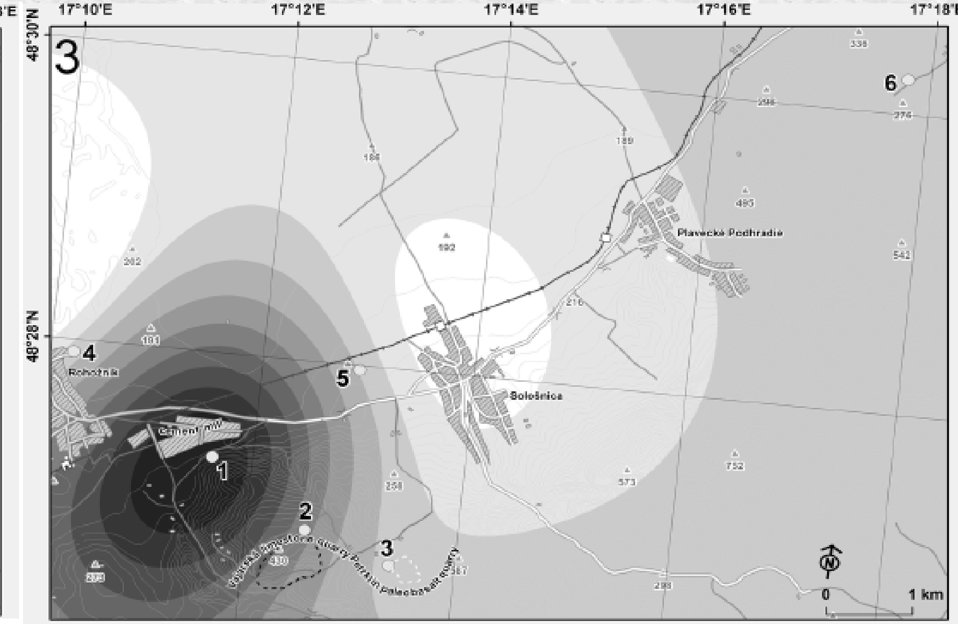
Exhaust gases and dust released to the atmosphere from cement plants may degrade air quality and create considerable environmental pollution

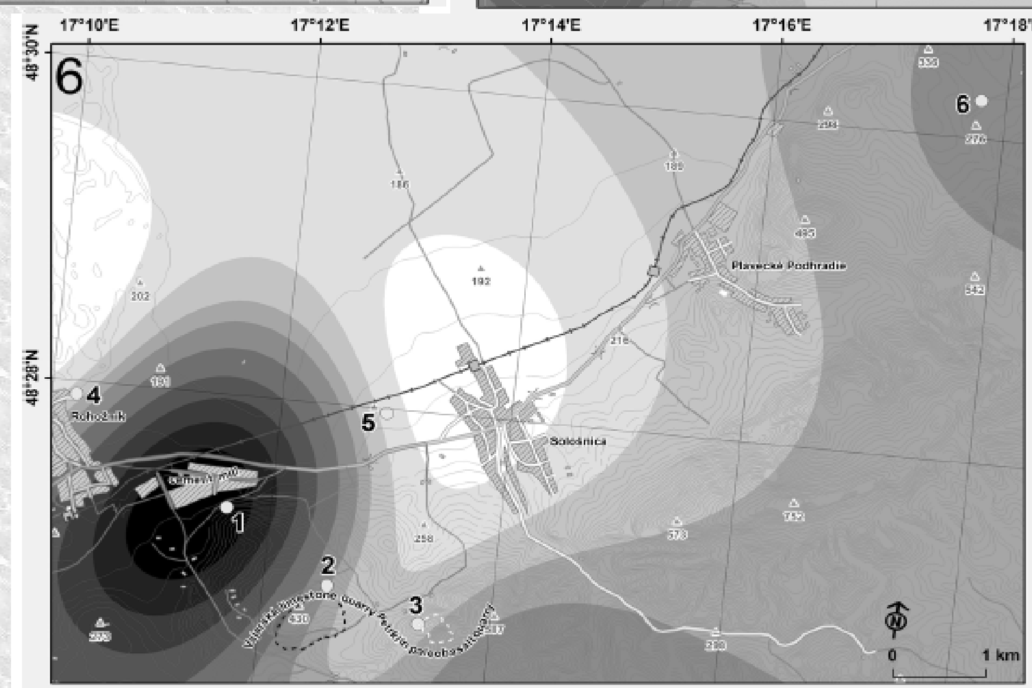
Ca content in native *X. parietina*



Ca content in transplanted *E. prunastri*







Bioaccumulation: *E. prunastri* transplants

Exposed to Control (EC) ratios indicated that the number of chemical elements with a significant accumulation in *E. prunastri* increased along with the duration of the exposure

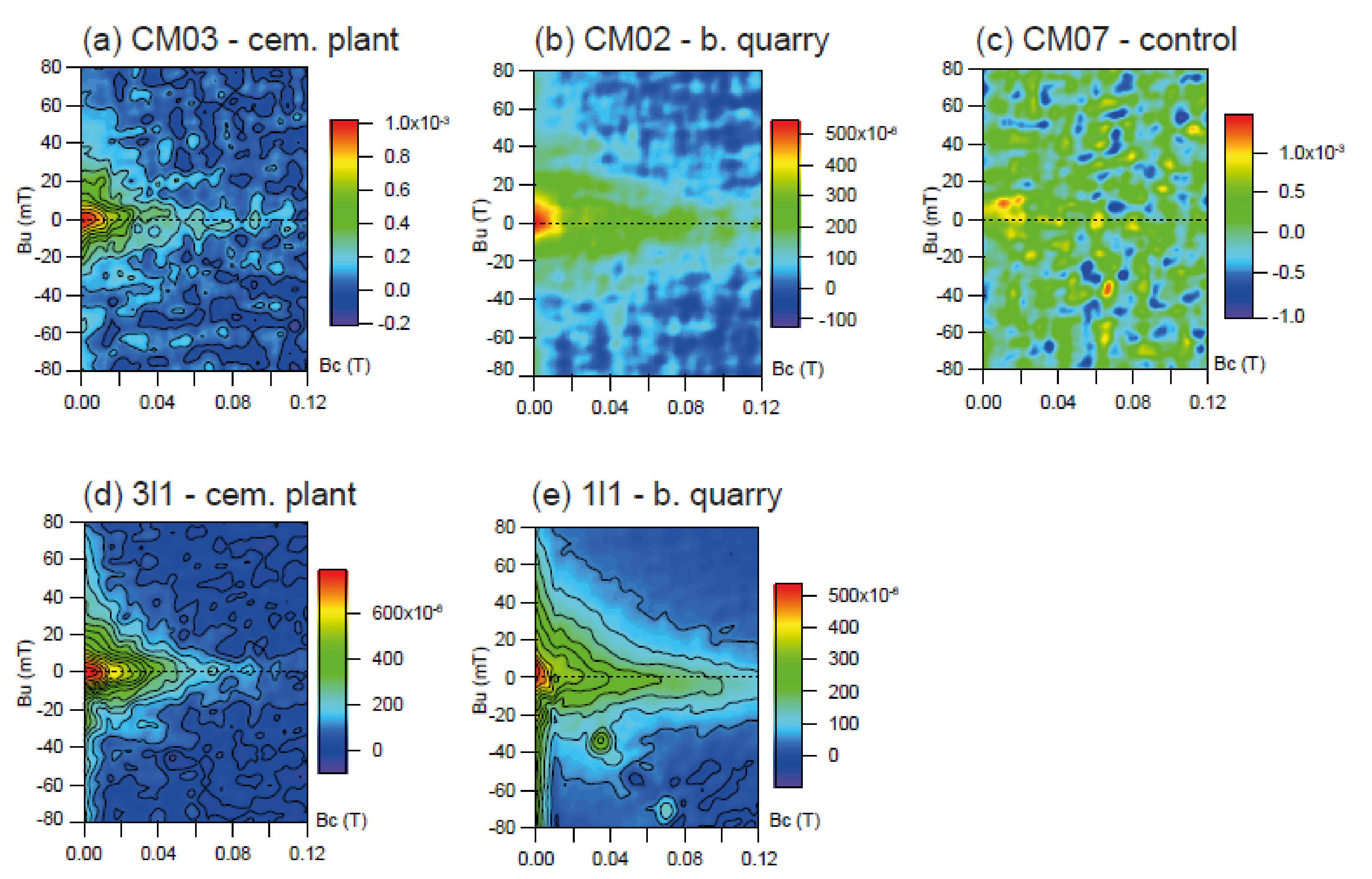
Accumulated elements according to Exposed to Control ratios in thalli of *Evernia prunastri* transplanted in the study area (EC = 1.25 – 1.75; *EC = >1.75 – 3; **EC > 3)

Sampling sites	days	Accumulated elements
Cement mill	30	Ca, As*, Fe, Ni**, Ti, V, Zn
	90	Ca**, As**, Cr, Cd, Fe*, Mn, Ni, Pb, Ti*, V*, Zn
	180	Ca**, As**, Cr, Cd, Fe, Ni, Pb, S*, Ti, V*, Zn
Limestone quarry	30	Ca, Al, Cd, Ni
	90	Ca*, Al*, As*, Cd, Fe, Hg, Ni*, Pb, V, Zn
	180	Ca, Al*, As*, Cd, Hg*, Ni**, Pb*, S, Zn*
Paleobasalt quarry	30	Ca*, Al**, As*, Fe**, Mn, Ni, Ti**, V*
	90	Ca, As*, Cd, Fe**, Mn, Ni*, Pb, Ti**, V*, Zn
	180	Ca, Al*, As**, Cd*, Cu*, Cd, Fe**, Hg*, Mn*, Ni*, Pb*, S*, Ti*, V*, Zn*
Urban (1.5 km)	30	Ni
	90	Al*, As, Ni**, Zn
	180	Ca, Al*, As*, Fe, Hg, Ni*, Pb, S*, Zn
Agricultural (> 3 km)	30	Al*, As, Zn
	90	As*, Cd, Cr, Fe, Ni, Pb*, S, V, Zn*
	180	Ca, As*, Cd, Cu, Fe, Ni*, Pb*, S*, Zn*

Magnetic properties

Transplanted lichens

Native lichens

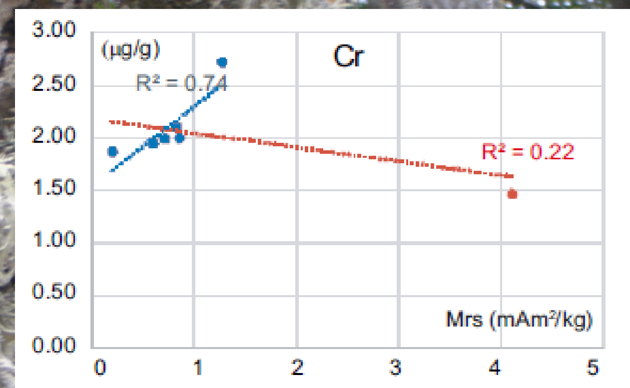


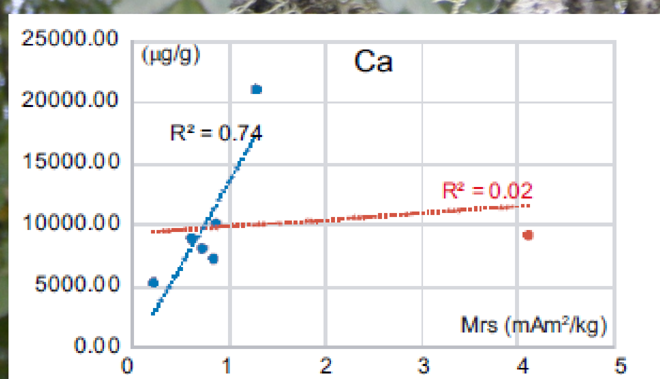
Environ Sci Pollut Res
DOI 10.1007/s11356-016-6203-6

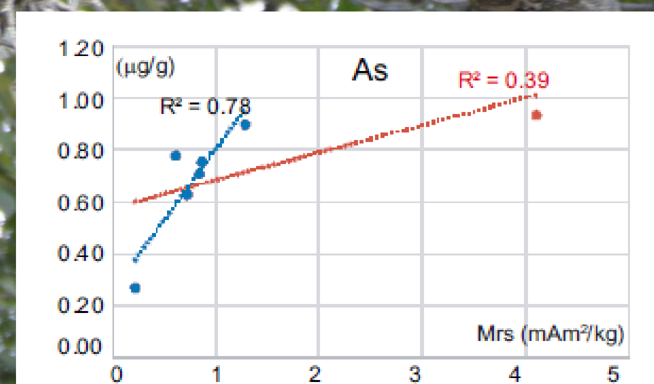
BIOMONITORING OF ATMOSPHERIC POLLUTION: POSSIBILITIES AND FUTURE CHALLENGES

Magnetic properties and element concentrations in lichens exposed to airborne pollutants released during cement production

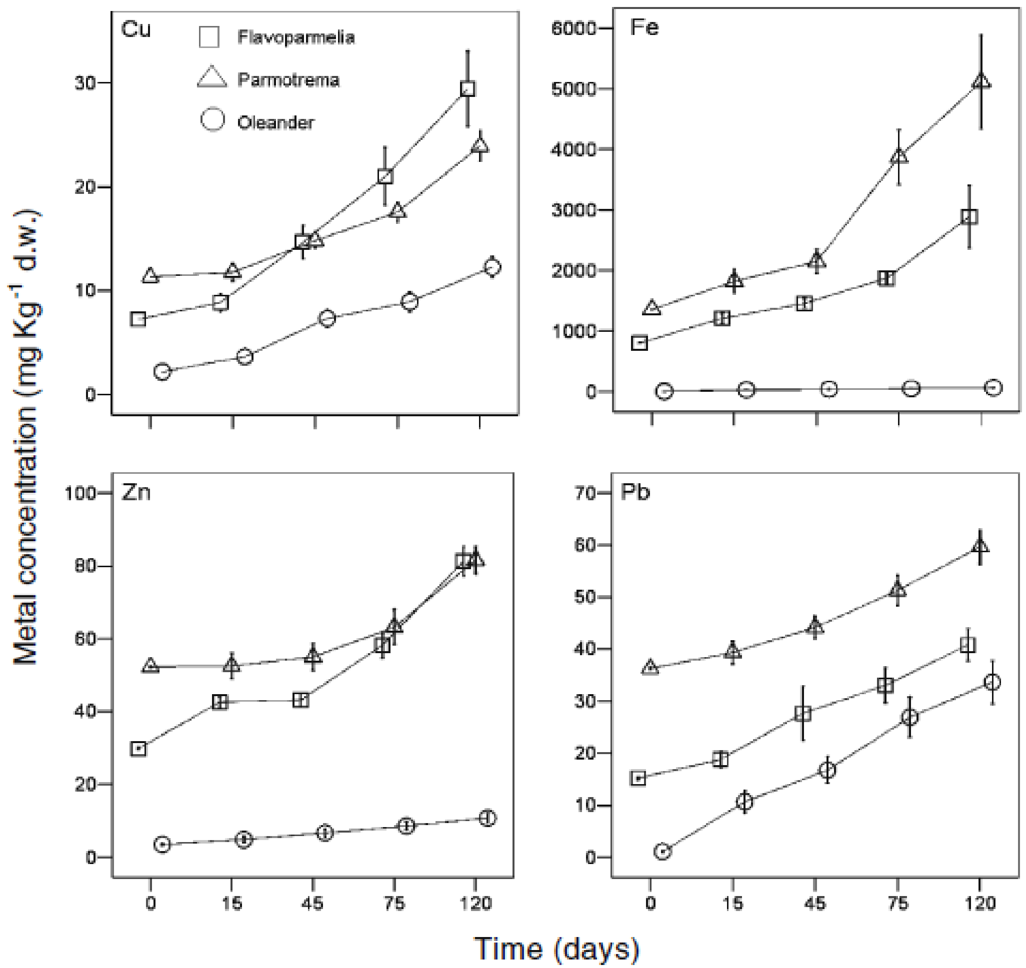
Luca Paoli[1] · Aldo Winkler[2] · Anna Guttová[3] · Leonardo Sagnotti[2] · Alice Grassi[1] · Anna Lackovičová[3] · Dušan Senko[3] · Stefano Loppi[1]



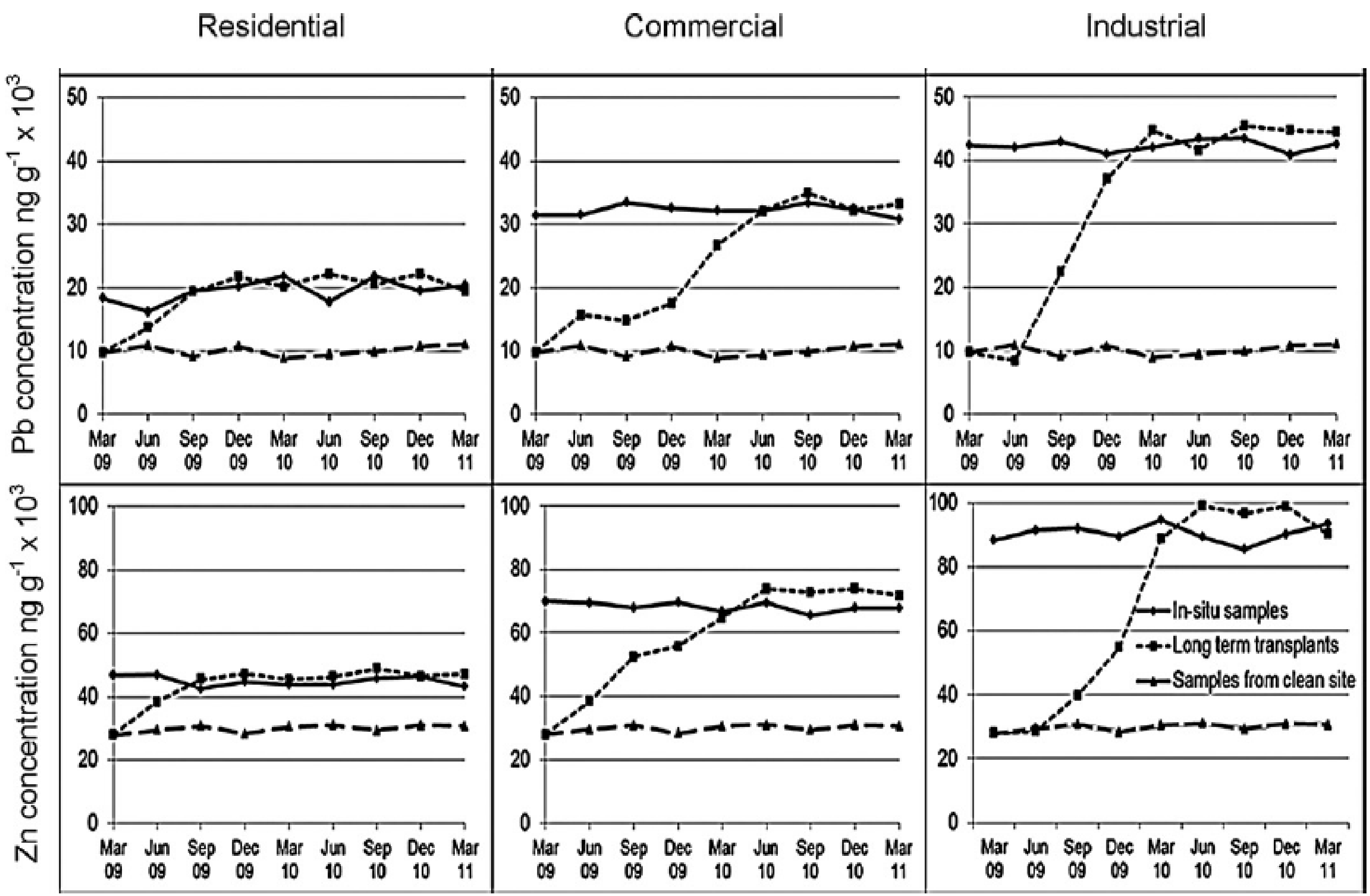




Traffic and lichens



Aprile et al., 2009. Environ Monit Assess
DOI 10.1007/s10661-009-0796-x


Residential
Commercial
Industrial
Pb concentration ng g^{-1} x 10^3
Zn concentration ng g^{-1} x 10^3
Mar 09
Jun 09
Sep 09
Dec 09
Mar 10
Jun 10
Sep 10
Dec 10
Mar 11
In-situ samples
Long term transplants
Samples from clean site

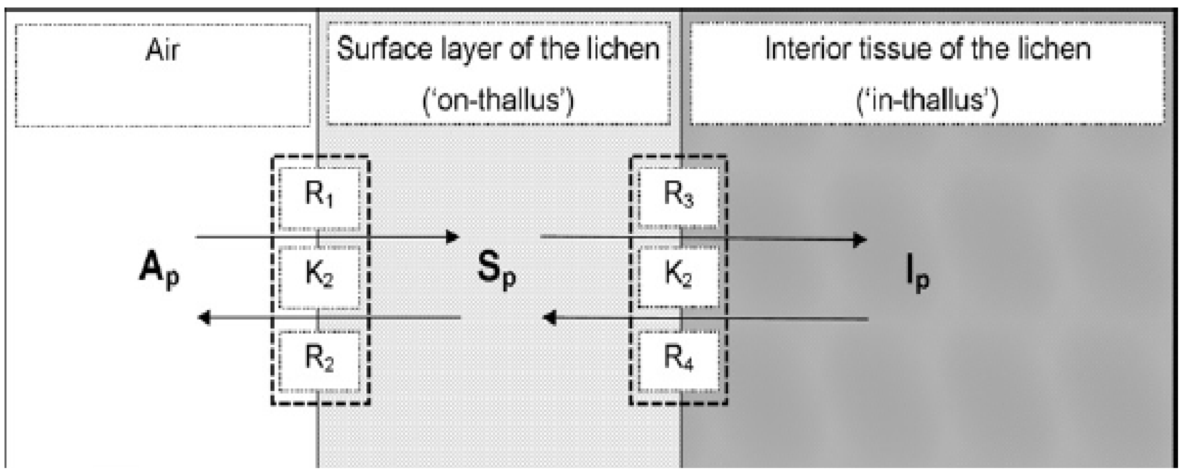
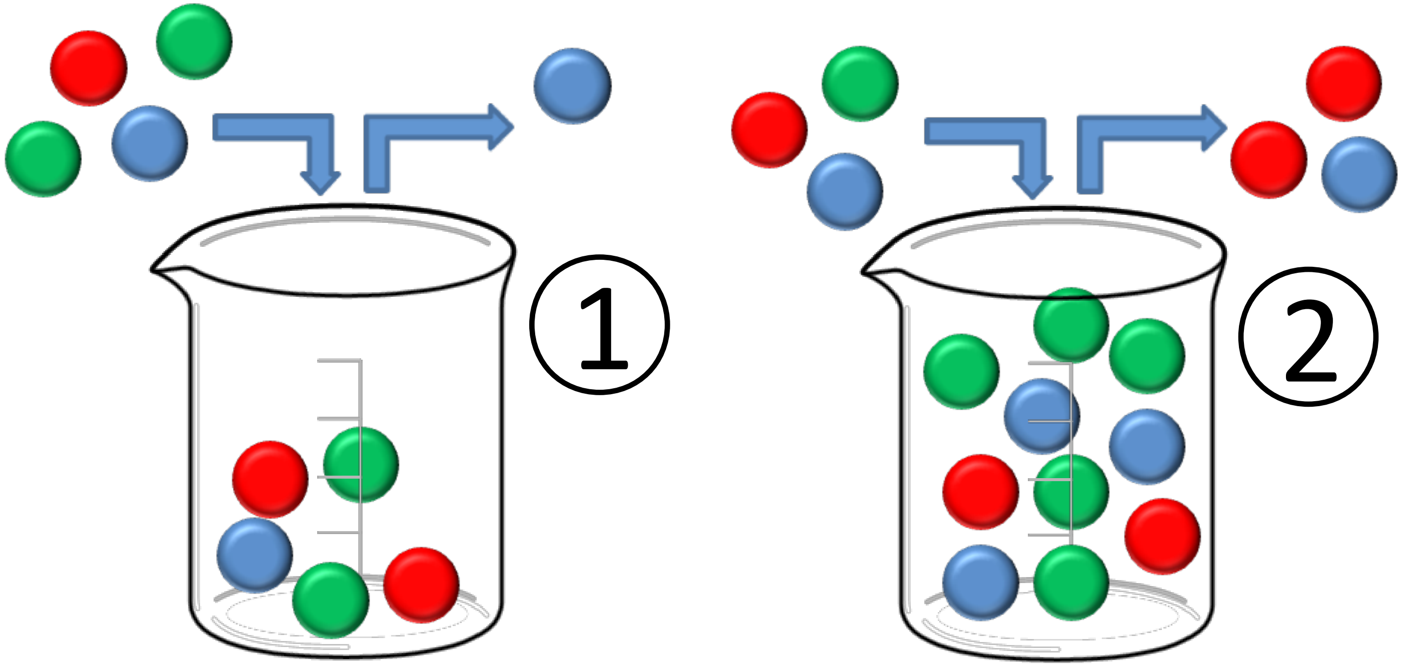


Fig. 1. A conceptual lichen–air model of how the lichen thallus achieves equilibrium with mean pollution level of ambient air. Pollutant concentrations in the atmosphere, surface layer of the thallus and the interior tissue of the thallus are A_p, S_p, and I_p, respectively. K_1 and K_2 are equilibrium constants. R is pollution accumulation rate, from air to surface layer (R_1), surface layer to air (R_2), surface layer to interior tissue (R_3), and interior to surface layer (R_4).

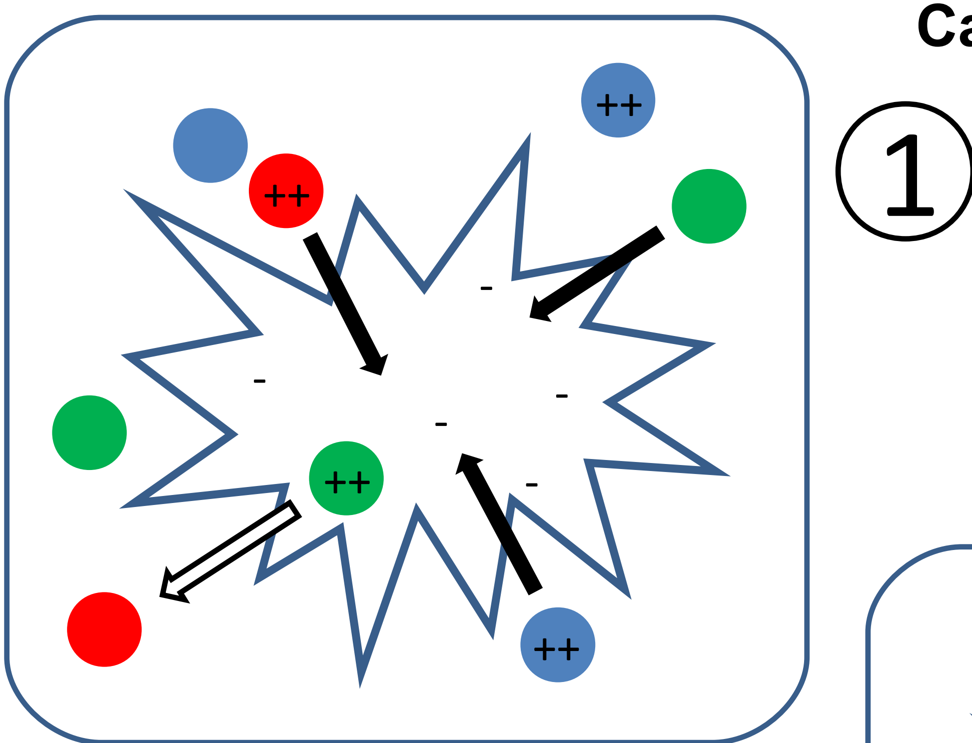
Heavy metals in the lichen thallus may occur as...

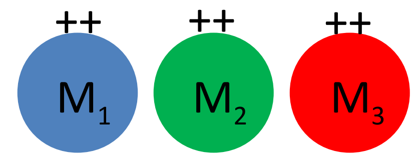
- particles adsorbed on the cortex or within intercellular spaces;
- ions bound to extracellular and intracellular exchange sites;
- soluble intracellular ions.



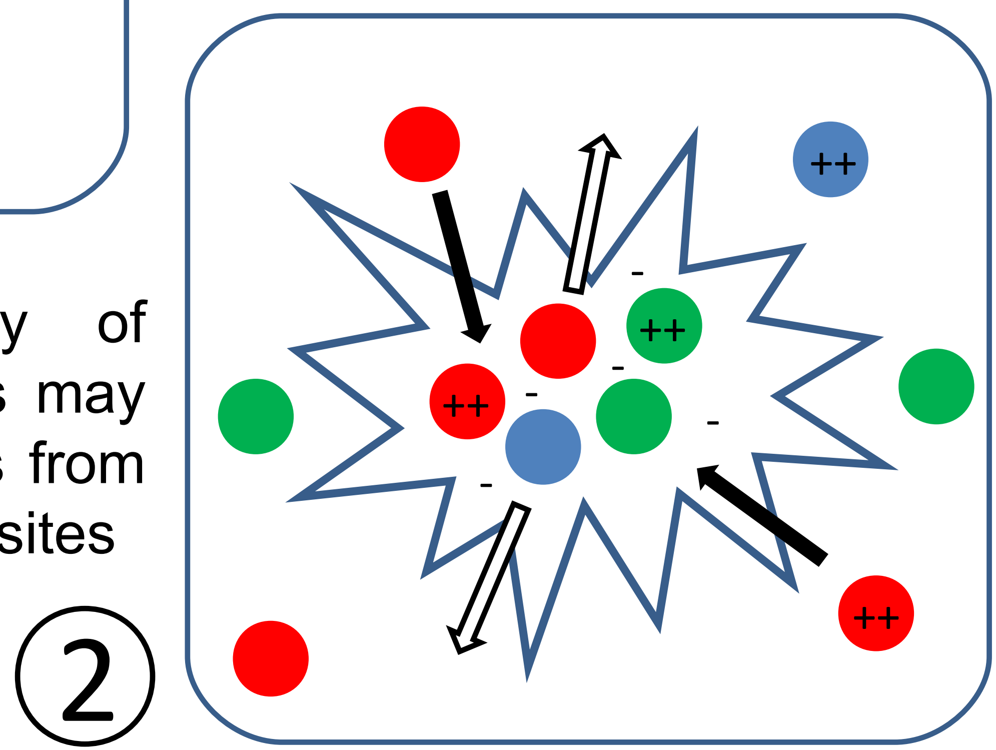
the uptake of soluble cations may occur by means of passive reversible binding to anionic sites.

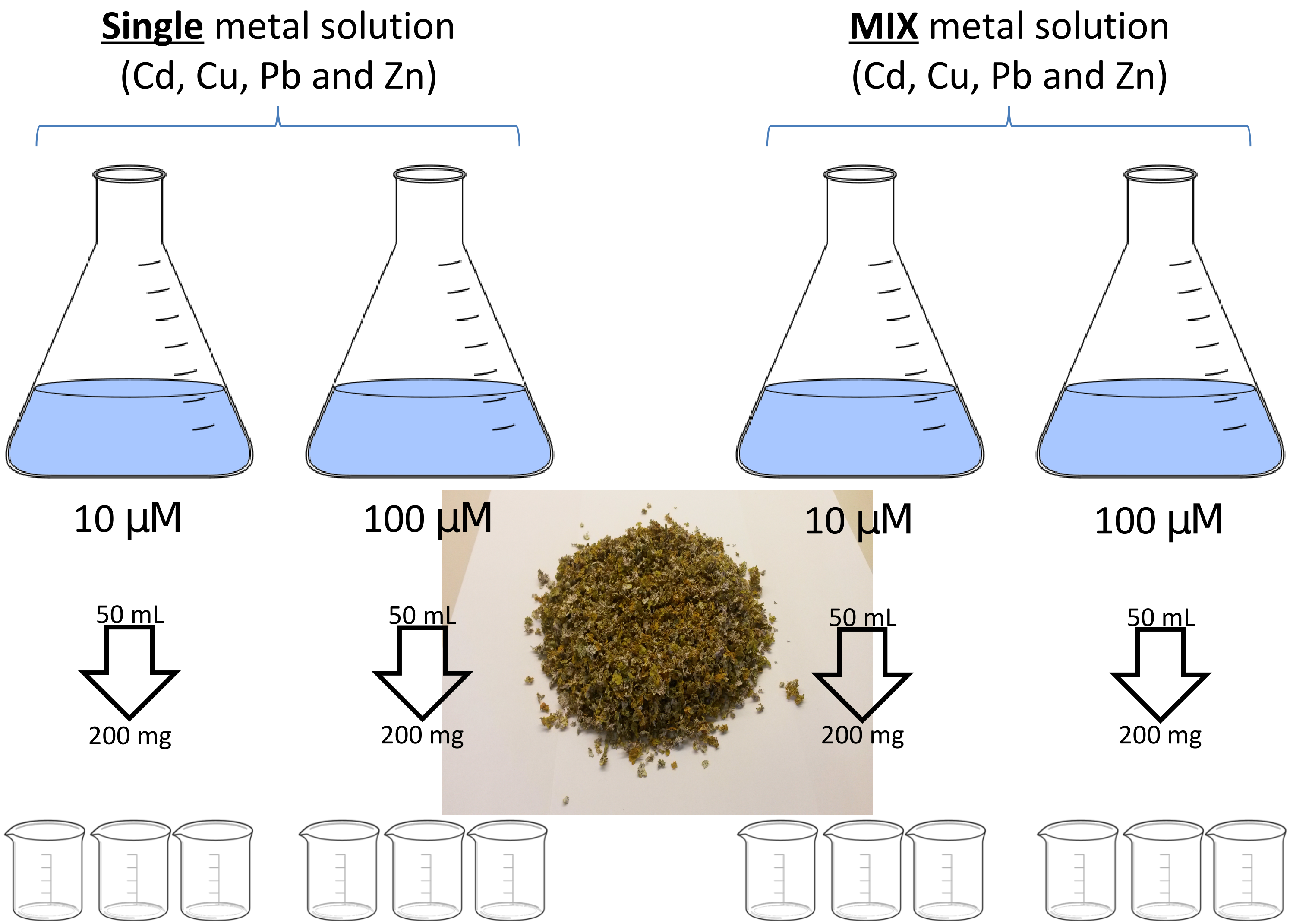
Cation exchange properties





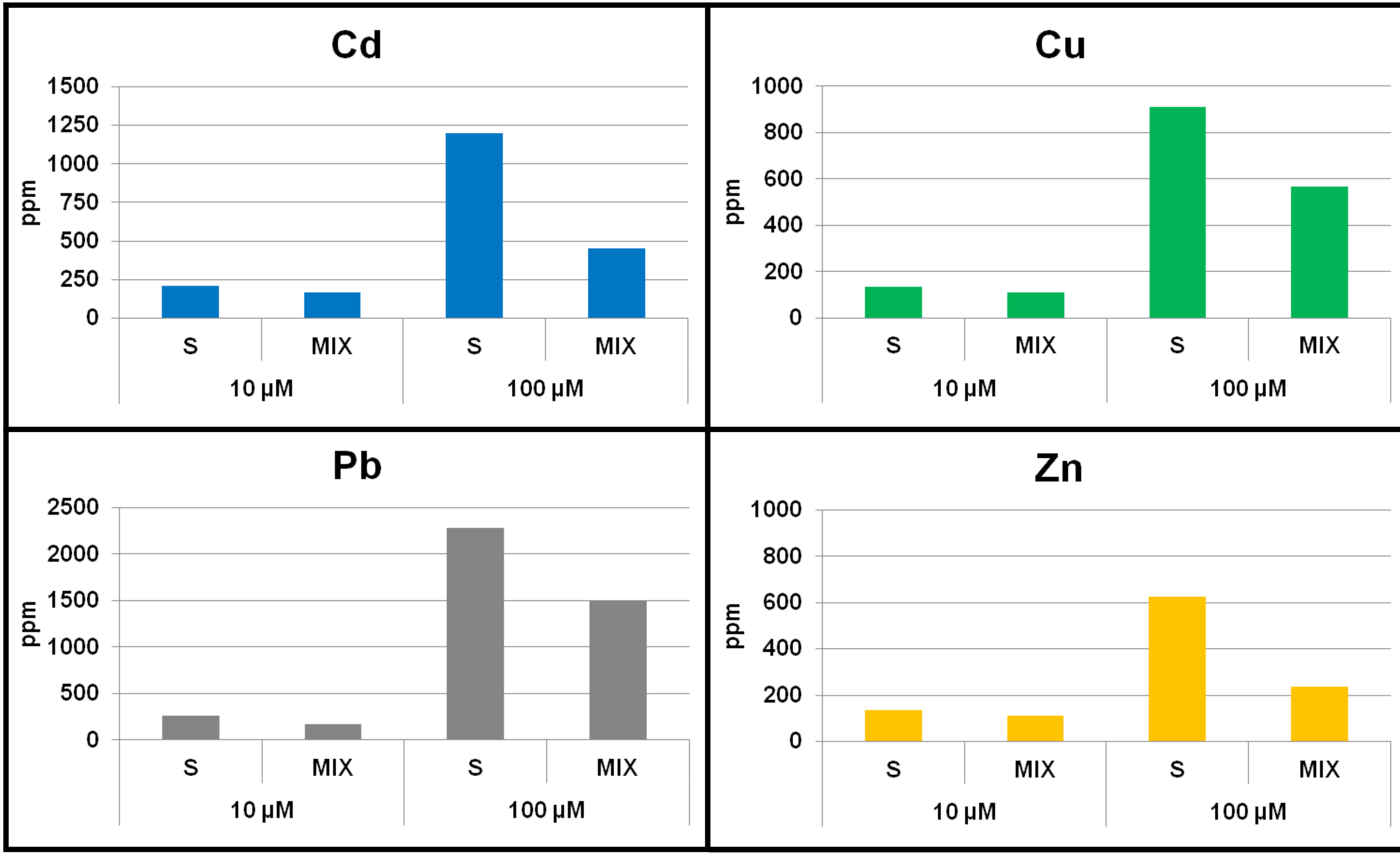
The contemporary supply of positively charged elements may displace the original cations from their extracellular exchange sites



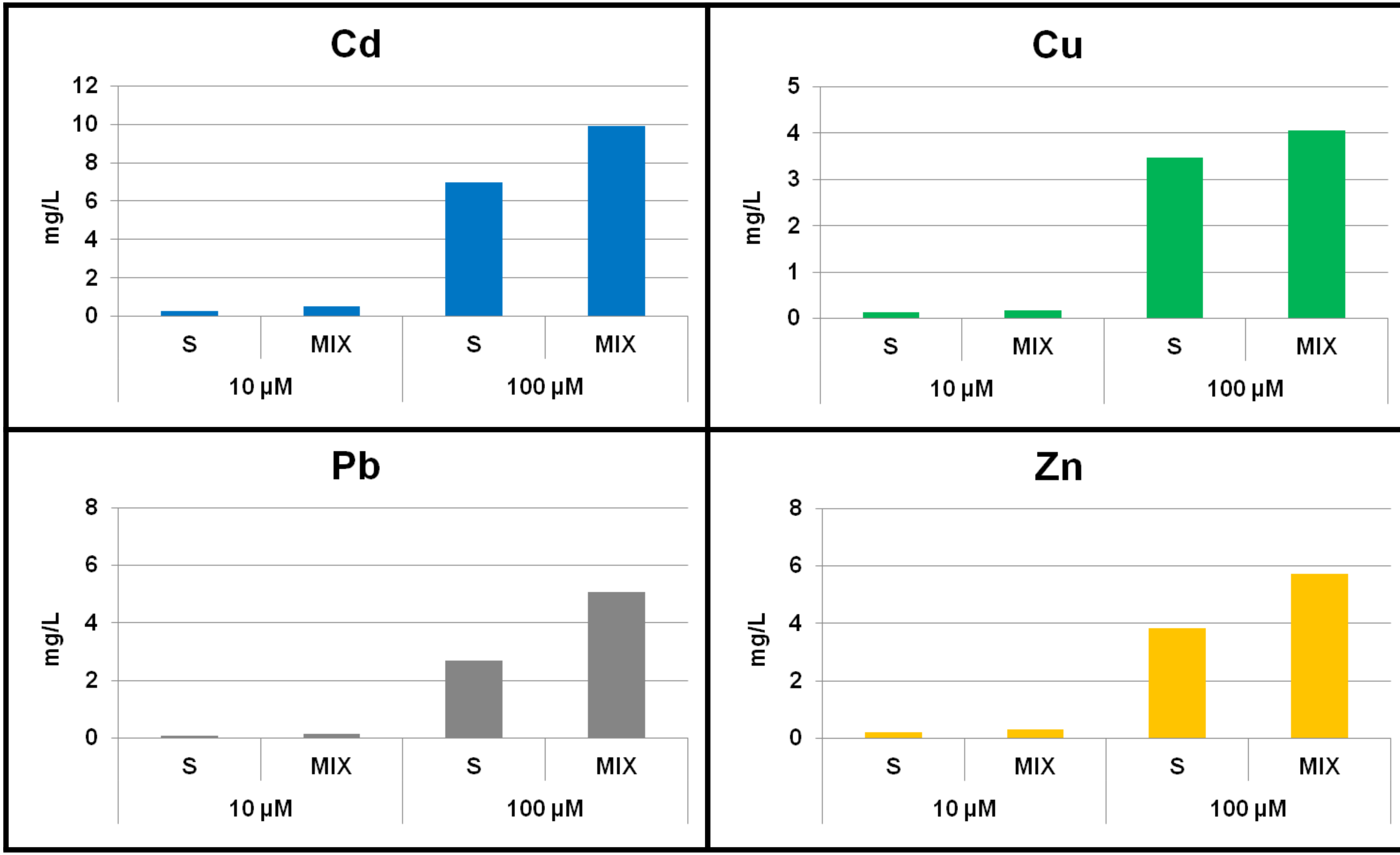


Single metal solution
(Cd, Cu, Pb and Zn)
MIX metal solution
(Cd, Cu, Pb and Zn)
10 µM
100 µM
10 µM
100 µM
50 mL
200 mg
50 mL
200 mg
50 mL
200 mg
50 mL
200 mg

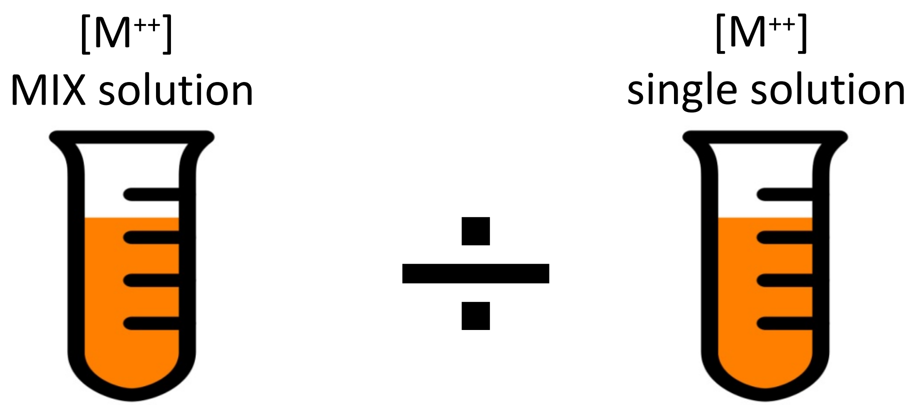
Concentrations in lichen thalli



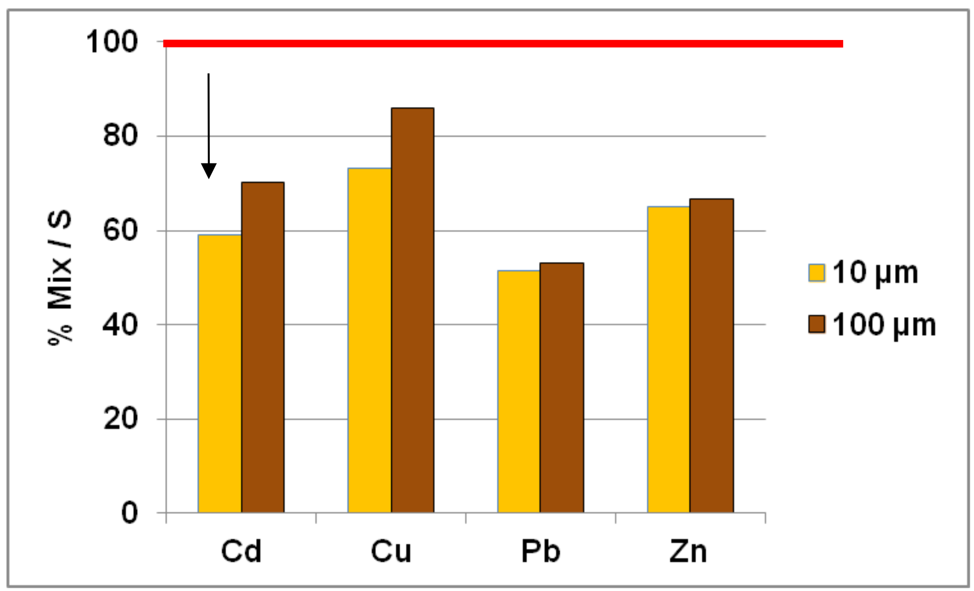
Solutions

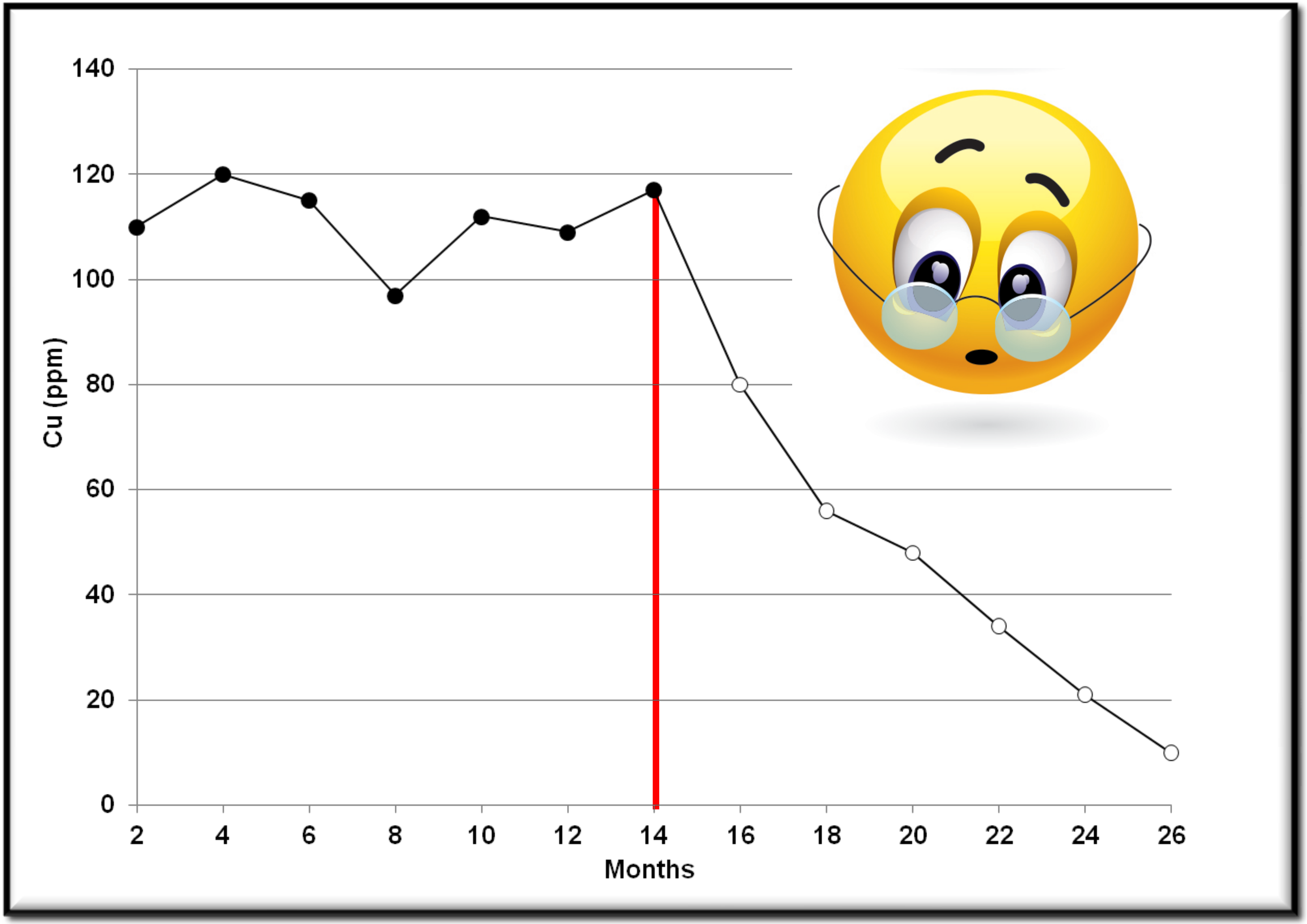


Cd
mg/L
12
10
8
6
4
2
0
S
MIX
S
MIX
10 µM
100 µM
Cu
mg/L
5
4
3
2
1
0
S
MIX
S
MIX
10 µM
100 µM
Pb
mg/L
8
6
4
2
0
S
MIX
S
MIX
10 µM
100 µM
Zn
mg/L
8
6
4
2
0
S
MIX
S
MIX
10 µM
100 µM

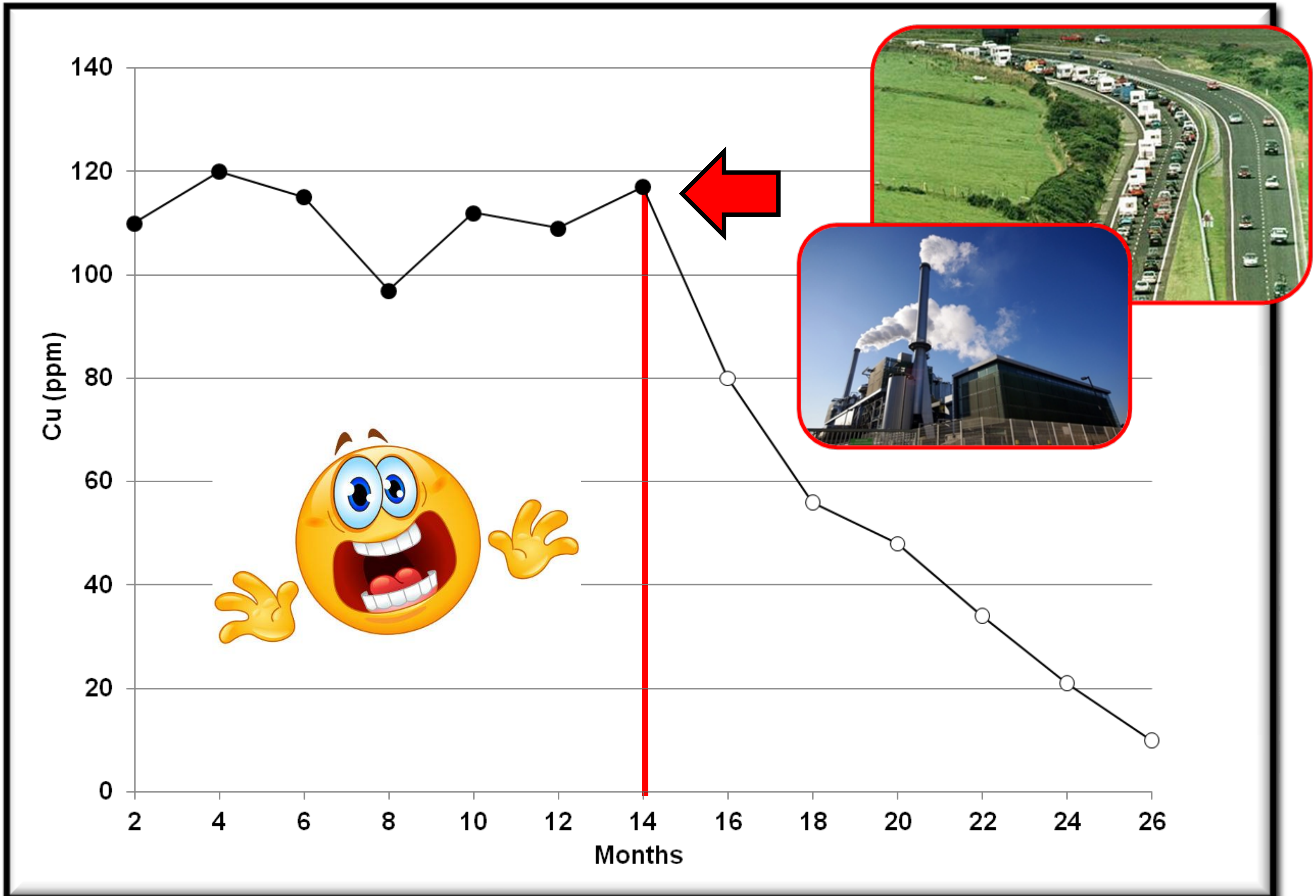


Estimating the loss...

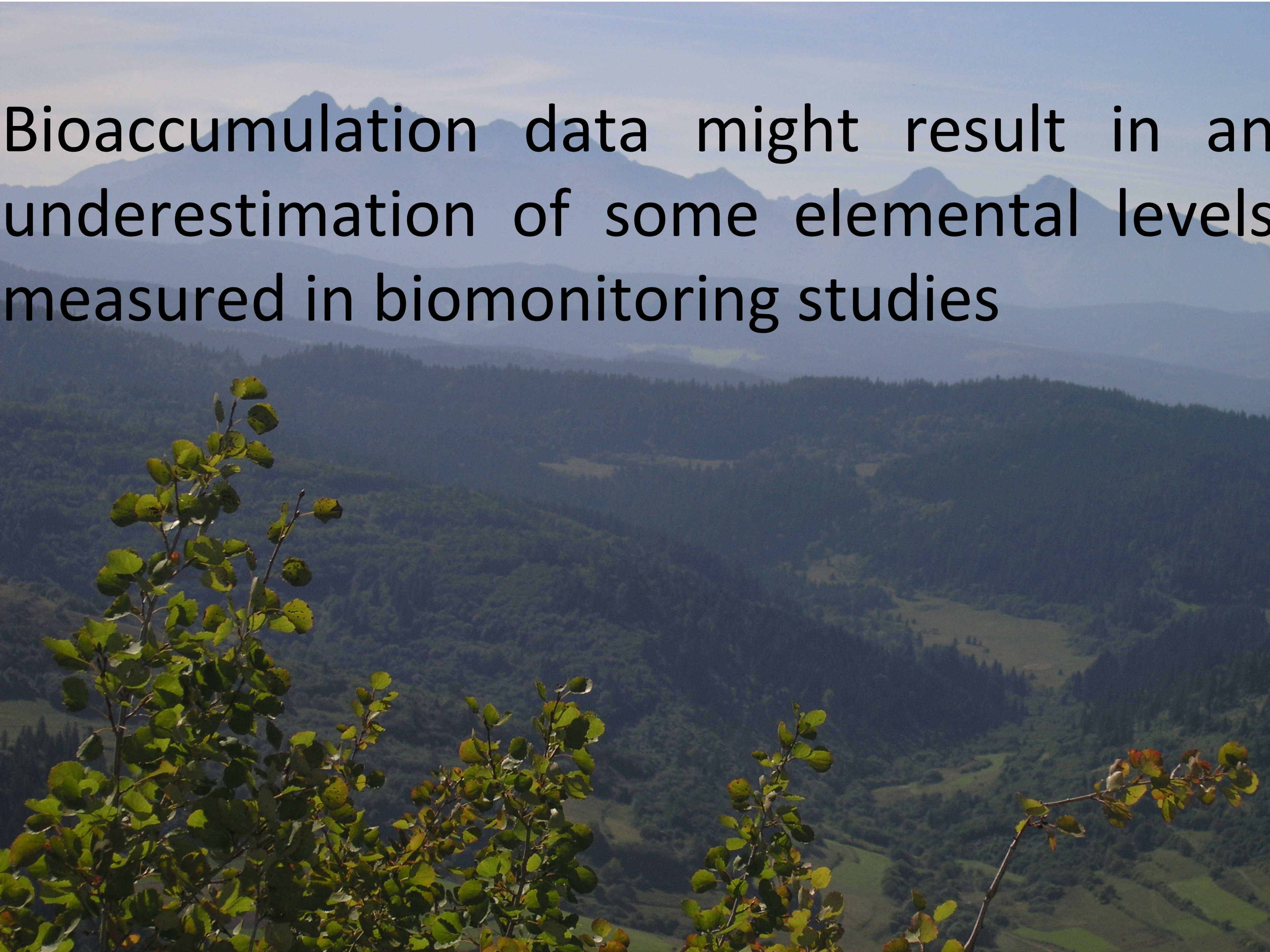




Cu (ppm)
140
120
100
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Months


Cu (ppm)
140
120
100
80
60
40
20
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Months

Bioaccumulation data might result in an underestimation of some elemental levels measured in biomonitoring studies




Спасибо!