Assessment of vertical contamination of Cd, Pb and Zn in soils around a former ore smelter in Wallonia, Belgium

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AMANDINE LIÉNARD* & GILLES COLINET

University of Liege – Gembloux Agro-Bio Tech – Water-Soil-Plant Systems

Gembloux Agro-Bio Tech
Université de Liège

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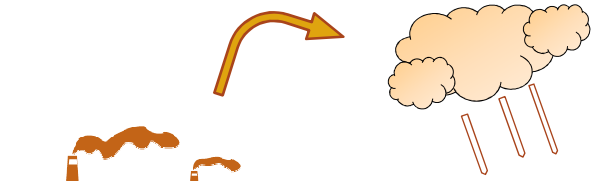
Study context

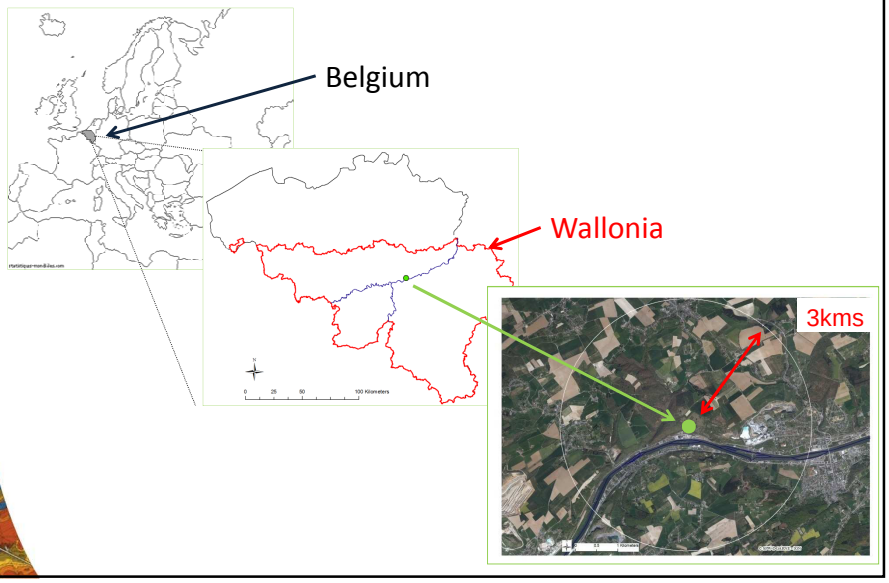


Contaminations of ecosystems by fallouts of particulate metallic trace elements (MTE)

Cd-Pb-Zn

Hosted ore treatment factory

Study area - Localization



Study area - Characteristics

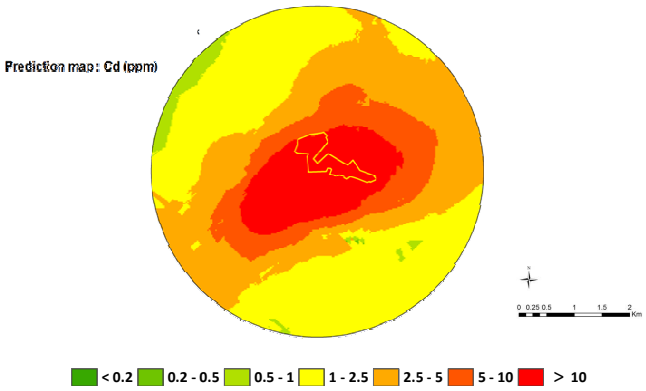
Forests

Crops

Grasslands

Village

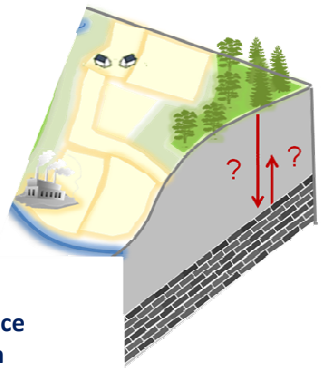
Background



- Evidence of surface contamination of Cd, Pb, Zn and Cu
- Use of enrichment factors (natural> <anthropogenic)
- Significant contribution of distance, land use and type of soil

Objectives

Fate of trace elements in contaminated profiles

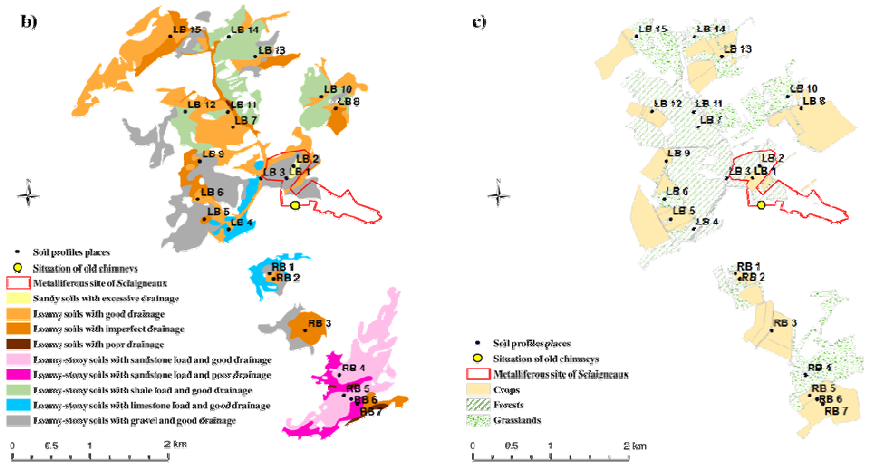


Characterization of trace elements contents in profiles

Availability of trace elements in profiles

Enrichment / Vertical impoverishment factors

Sampling strategy



→ 7 soil types and 3 land uses

Methodology

i. 22 profiles : 85 horizons (depth max. 1.2 m)

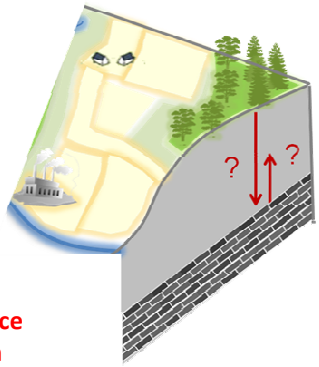
ii. <u>Chemical analyses</u> :

- pH_{KCl}
- Total Organic Carbon, N
- Pseudo-total (Aqua regia) and available (AA + EDTA (pH4.65)) contents in Ca-Mg-K-Fe-Al-Mn & Cd-Cu-Pb-Zn

iii. <u>Statistical analyses</u> (Anova, Correlation,…)

First objective

Fate of trace elements in contaminated profiles



Characterization of trace elements contents in profiles

Availability of trace elements in profiles

Enrichment / Vertical impoverishment factors

Content of traces elements

Soil parameters	Samples	Min	Max	Mean	Median	SD	CV (%)
Cd	Surface	0.66	63.5	8.34	2.42	15.8	190
	Depth	0.66	12.6	2.25	0.66	3.86	172
	Profile	0.66	63.5	5.33	0.98	11.0	207
Co	Surface	4.10	23.0	11.9	11.2	4.30	36.1
	Depth	0.41	27.0	11.4	11.4	5.54	48.7
	Profile	0.41	27.0	11.9	11.8	4.75	39.8
Cr	Surface	3.40	44.0	26.8	26.5	7.94	29.6
	Depth	1.22	37.0	24.7	24.5	8.93	36.2
	Profile	1.22	44.0	24.9	25.0	8.20	33.0
Cu	Surface	8.63	189	34.5	18.1	42.3	123
	Depth	4.05	32.8	16.2	16.2	5.91	36.4
	Profile	3.46	189	22.7	16.6	23.7	105
Mn	Surface	122	2798	874	780	536	61.3
	Depth	27.0	1457	619	730	367	59.3
	Profile	25.0	2798	715	737	414	57.9
Ni	Surface	8.10	75.3	26.8	24.0	14.3	53.3
	Depth	2.30	57.0	31.3	30.3	13.9	44.4
	Profile	2.30	75.3	30.9	30.7	14.6	47.2
Pb	Surface	23.0	5084	688	115	1225	178
	Depth	6.00	10521	554	28.0	2233	403
	Profile	6.00	10521	565	79.0	1695	300
Zn	Surface	99.0	3774	774	322	1037	134
	Depth	43.0	3785	435	166	799	184
	Profile	41.7	4038	531	203	896	169

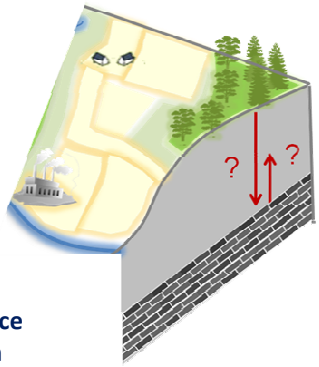
Unit: mg/kg

High contents

Normal contents

Second objective

Fate of trace elements in contaminated profiles



Characterization of trace elements contents in profiles

Availability of trace elements in profiles

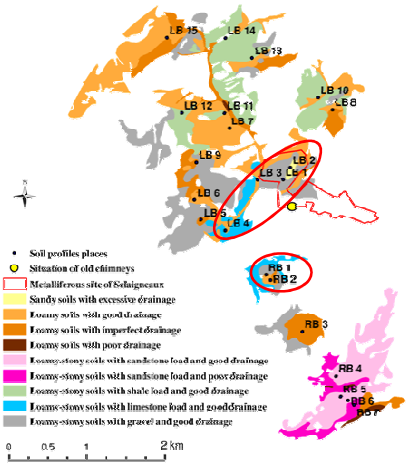
Enrichment / Vertical impoverishment factors

Enrichment of traces elements

$$\text{Enrichment factor} = \frac{[El]_{sample} / [Al]_{sample}}{[El]_{crust} / [Al]_{crust}}$$

1) EF < 2 : deficiency to minimal enrichment;
2) 2 ≤ EF < 5 : moderate enrichment;
3) 5 ≤ EF < 20 : significant enrichment;
4) 20 ≤ EF ≤ 40 : very high enrichment
5) EF > 40 : extremely high enrichment

Enrichment of traces elements



-Topsoil of 6 profiles are extremely contaminated by Cd, Pb and Zn with EF > 40

- 100% of horizons are minimum enriched in Cd, Pb or Zn

-Enrichment order : Cd >> Pb > Zn

Vertical impoverishment factor

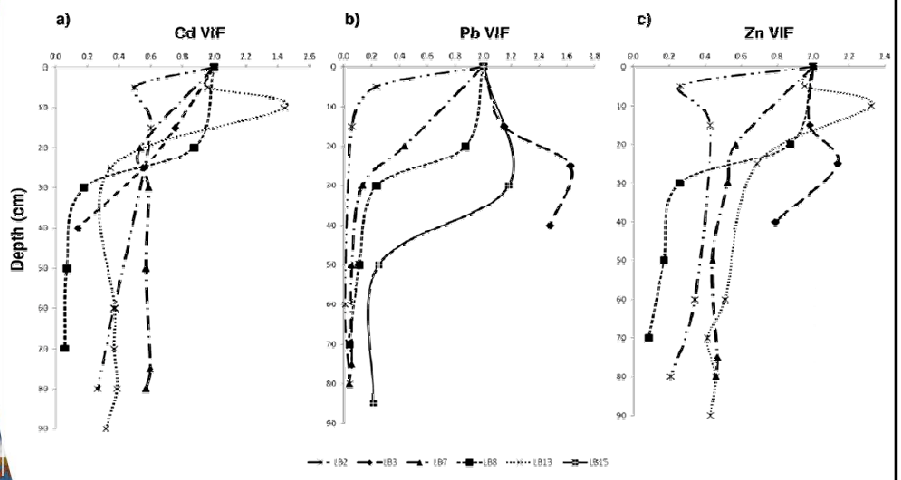
$$\text{Vertical impoverishment factor} = \frac{[El]horizon / [Al]horizon}{[El]surface / [Al]surface}$$

To allow estimation of the vertical extent of contamination within one profile.

Topsoil is the reference horizon.

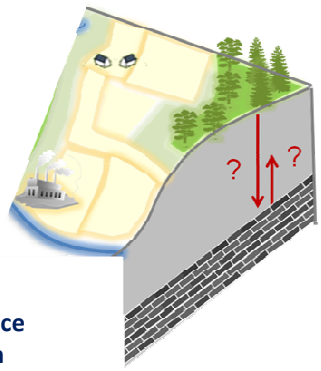
1) VIF < 1 : studied horizon is depleted relative to the surface horizon
2) VIF > 1 : studied horizon is enriched compared with the topsoil

Vertical impoverishment factor



Third objective

Fate of trace elements in contaminated profiles



Characterization of trace elements contents in profiles

Availability of trace elements in profiles

Enrichment / Vertical impoverishment factors

Availability of trace elements

Availability ratio (AR) = $\frac{Ca}{Ct} \times 10^2$

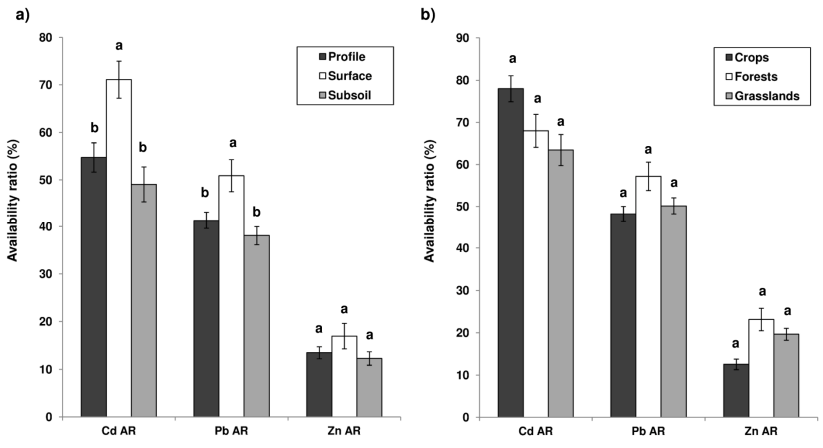
→ Percentage of available fraction to total metal concentration in soil

	pH_{KCl}	TOC	Cd AR	Pb AR
TOC	0.163			
Cd AR	0.204	0.331 **		
Pb AR	0.287 **	0.501 ***	0.480 ***	
Zn AR	0.248 *	0.499 ***	0.546 ***	0.620 ***

(N = 85) (* p < 0.05, ** p < 0.01 and *** p < 0.001)
TOC : total organic carbone

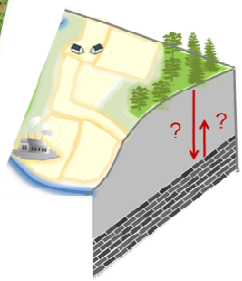
Availability of trace elements

AR Cd >> AR Pb > AR Zn



Mean availability ratio (AR) for Cd, Pb and Zn in a) topsoil horizons (Surface, N = 22), subsoil horizons (N = 63) and all horizons (Profile, N = 85) and b) topsoils of crops (N = 10), forests (N = 5) and grasslands (N = 7) (+/– mean standard error)

Conclusions



Fate of trace elements in contaminated profiles

1) Strong contamination of topsoil and also very high levels deeper in some profiles
2) Contaminant transfer in the profiles → no systematic migration
3) All results suggest that Cd, Pb and Zn contents in profiles are due to past human activities
4) Redistribution along profiles through lixiviation of contaminants is not an important phenomenon.

Thank you for your attention…

… any questions ?

Amandine Liénard – Amandine.Lienard@ulg.ac.be
Gilles Colinet – Gilles.Colinet@ulg.ac.be