Edaphic characterization of a contaminated site (Prayon, Belgium) and remediation strategy : influence of inputs on plant growth and trace elements speciation

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I – Context and objectives

The study site is located in Belgium, in the valley of the Vesdre river, near Liège city, in the Walloon Region (fig. 1).

The industry of metallic transformation in this area has progressively enriched the study site in trace elements, especially Zn, Cd and Pb.
These contaminations have enabled the establishment of a metalliferous flora, but there are bare areas. In order to evaluate and limit the risks of trace metal dispersion in the environment, an edaphologic characterization and two experimentations using plants and soils treatments were conducted. The objective is to obtain elements for a remediation strategy appropriated to the site. Indeed, the establishment of a vegetable cover can immobilize contaminants on site, and reduce losses via erosion or percolation through the soil. The addition of inputs to soils can reduce the mobility and bioavailability of trace elements and favour vegetation colonization.

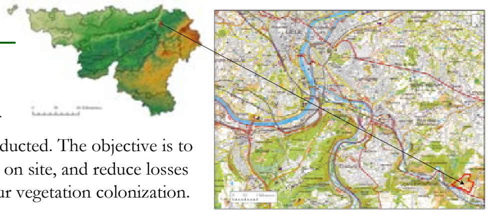

Fig. 1 : Prayon localisation in the Walloon Region

II – Edaphic characterization

Sample collection

Prayon site is rather heterogeneous in terms of geology, relief and vegetation.
We would the samples were collected in order to represent the soil diversity.
So, « environmental units » were delimited (fig. 2), homogeneous for different criteria. These criteria, the « factors of stratification », are 6 in number : Land occupation – Vegetal formation – Geology – Surface type – Slope – Exposition.

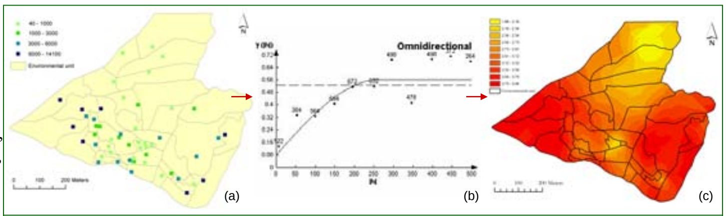

Fig. 3 : (a) available Zn distribution (mg/kg), (b) semivariogram, (c) log(available Zn) kriged map

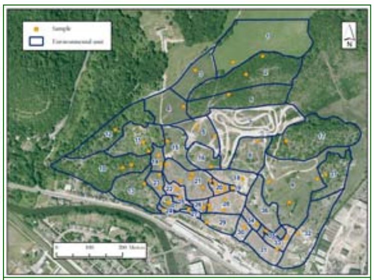

Fig. 2 : Sampling collection on Prayon site

Spatial distribution of edaphic parameters

Prayon is highly contaminated in Zn, Cd, Pb and Cu and the spatial dispersion of the contamination is very heterogeneous. It is the same for the other studied parameters (pH, TOC, Ca, Mg, K).
Representation of pollutants by geostatistic, that permit values interpolation (fig. 3), shows that there are a contaminants source distance effect in the distribution and redistributions of these with erosion: particules eroded in the center of the site find themselves at the bottom of the slope. The higher values are found on calcarous bed-rocks, left and right hand sides on the map (fig. 3(c)).

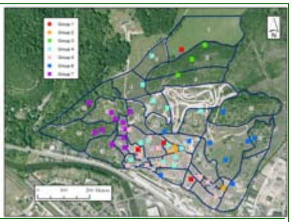

Fig. 4 : Site stratification by multivariate analysis

Delimitation of site groups for management

Soils parameters mesured in laboratory (pH, in water and KCl - TOC (C-Springer-Klee Method) - Available Ca, Mg, K, Zn, Cd, Pb, Cu (NH4-Acetate+EDTA, pH 4.65)) and stratification factors can be used to establish groups for the phytostabilization strategy. The stratification of the space is fundamental because the soil parameters distribution is heterogeneous so the proposed strategy must be adapted to the intrinsic characteristics of each group.

Seven groups were obtained by multivariable classification with edaphic parameters, and two are very clear: group 6 on Frasnian limestone and group 7 on Tournaisian dolomites (fig. 4). Groups obtained with stratification factors showed well the heterogeneity of the trace metals distribution (fig. 5).

Fig. 5 : Site stratification by vegetable formation
(0) bare soil, (1) herbaceous veg, (2) herb. and ligneous veg., (4) ligneous veg.

III – Inputs influence on *Agrostis capillaris* L. vigour and on Zn, Cd, Pb and Cu speciation

Soils and plants used in the experiments

Table 1 : Soils principal characteristics

	"R" soil	"N" soil	"C" soil
Environmental unit	20	14	36
pH H2O	5.2	5.4	7.4
pH KCl	4.1	5.1	7.1
TOC (%)	0.31	9.49	5.99
Exchangeable Ca (mg/100g)	26.0	17.0	305.0
Exchangeable Mg (mg/100g)	6.0	3.2	3.6
Exchangeable Na (mg/100g)	1.2	4.1	1.2
Exchangeable K (mg/100g)	6.8	2.2	18.0
CEC (méq/100g)	6.2	11.0	21.0
Saturation ratio (%)	32.7	12.3	76.5
Available Zn (mg/kg)	98.5	1460.0	13250.0
Available Cd (mg/kg)	1.41	5.55	151.31
Available Pb (mg/kg)	391.5	9489.5	1241.2
Available Cu (mg/kg)	5.2	373.1	258.1
Vegetation development	Bare area	Bare area	Herbaceous
Rocks	Famennian red shale	Tailings	Frasnian limestone

Three soils were taken from three constrasted « environmental units » (table 1).
In the same places, a pseudometallophyte plant, *Agrostis capillaris* L., was collected.
Every clump of *A. capillaris* was separated in little plantules (fig. 6), that could be re-planted for the experiment.
144 pots with 3 plantules (48 pots by soil) were set up in the greenhouse and watered (80% of field capacity) for two months.
Each week, mesures of different vigour parameters (i.e. growth, general state, rejection an inflorescence presence) have been collected.

Treatments used on soils

Four traitments were used (%w/w) : steel shots (5%), compost (10%), lime (0.2%) and chemical fertilizer (0.2%).

Sequential extraction procedure

Table 2 : Sequential extraction procedure

	EXTRACTOR	FORM
1	CaCl2	easily exchangeable
2	CH3COONa - CH3COOH	carbonates linked
3	Na4P2O7,10H2O	complexing organic matter linked
4	NH2OH, HCl - HNO3	easily reducible oxydes linked
5	NH4NO3-HNO3	organic matter linked
6	NH2OH, HCl - CH3COOH	well crystallised oxydes linked
7	HClO4 - HF - HCl	residual

Fig. 6 : Experimentation with *A. capillaris*

Main results

A. capillaris mortality was very high in the experimentation (65%).
But in spite of that, results showed that *A. capillaris* vigour is highly influenced by its origin, and by the substratum:
best results were obtained by using individuals which came from Famennian red shale (environmental unit 20) and with the « N » soil, the wastes from metal industry (environmental unit 14). The inputs addition showed no significant positive influence on the plants vigour, except for the compost.

Trace elements (Zn, Cd, Pb and Cu) distribution on the different carrier phases in soils was highly influenced by the type of soil (fig. 7). The addition of compost (« m ») and lime (« c ») showed a diminution effect on easily exchangeable trace elements. The speciation evolved with time too. Nevertheless, the treatment and time effects are more marked on « R » soil (Famennien red shale) and « N » soil (industrial wastes) than on « C » soil (Frasnian limestone).

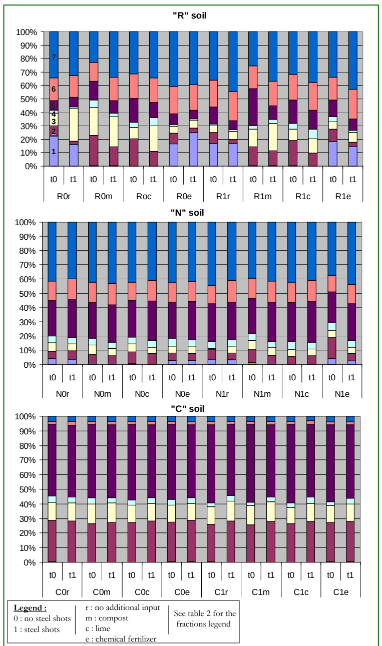

Fig. 7 : Zn fractionation in soils at the beginning of the experimentation (t0) and after two months (t1)

IV – Conclusions and prospect

Prayon is a site very contaminated with trace metals and presents a large diversity of situations (geology, relief, vegetation, contamination). The need of elaborating a space structuration was feeled, for the sampling collection but especially for the remediation. It is necessary to modulate the phytosabilization strategy according to intrinsic characteristics of each homogeneous area.

For *A. capillaris*, the three used soils are not equal on the plants vigour. In addition to this, the taking origin is also influential on the plants recovery. For all the inputs brought in soils, only compost has a marked good influence on *A. capillaris*.
Sequential extraction for trace metals has showed that the contaminants distribution on the carrier phases is different, fonction of type of soil, but a mobility diminution is effective with compost and lime utilisation.

Used organic matter is, with a first approach, the most appropriated treatment to ensure stabilisation of soil metals and revegetalisation at this site.