Phytoremediation of contaminated sites in urban environment : preliminary results of a study focussed on Lubumbashi.

COLINET Gilles[1], SAAD Layla[2], CUBAKA Alfred[3], NGONGO Michel[4], MAHY G.[2], VERBRUGGEN N.[3], BOCK L.[1], MEERTS P.[5]

1 Laboratoire de Géopédologie - Gembloux Agricultural University, Passage des déportés 2, B-5030 Belgium, colinet.g@fsagx.ac.be
2 Laboratoire d'Ecologie - Gembloux Agricultural University, Belgium.
3 Laboratoire de Physiologie et de Génétique moléculaire des plantes – Université Libre de Bruxelles, Belgium.
4 Faculté d'agronomie - Université de Lubumbashi, Democratic republic of Congo.
5 Laboratoire de Génétique et Ecologie végétales – Université Libre de Bruxelles, Belgium.

Keywords: Contaminated sites, cuprophilic flora, Katanga, pedogeochemistry, phytoremediation, trace elements.

Abstract
A specific flora has developped in Central Africa on soils which are naturally rich in Cu and Co. Mining and ore treatment activities in the Katanga province (RDC) have generated contaminations which endanger ecosystem viability and/or human health. A survey of edaphic conditions prevailing for plant growing on natural metalliferous outcrops, the « copper hills », in mining sites (quarries), and in contaminated areas around metal smelters, is conducted as a first stage of a phytoremediation-based research programme. Soluble, available and total content in some metallic trace elements have been measured. The first results show a relatively high heterogeneity inside and between sites. But the main finding is related to the very different nature of contamination between the three types of sites. This point constitutes an additionnal difficulty that should be taken into account for the selection of metallophytic species from the copper hills or the quarries in order to vegetalize a site contaminated by atmospheric fall outs from metal smelters in Lubumbashi.

Introduction

Due to mineralization occurrence, rocks rich in Cu, Co, Zn, Cd, Pb, and other trace elements (TE) outcrop in the Katanga province (RDC). The incidences of high concentrations in rocks and soils on the development of a specific flora have already been studied (e.g. Duvigneaud and Denayer - De Smet, 1963; Malaisse *et al*., 1994; Leteinturier, 2002). Mining activities have generated a dispersion of the contaminants, which locally can endanger viability of ecosystems, and even human health through water, air, and food contaminations. The general objective of the REMEDLU research project in Lubumbashi is to progress in the knowledge of the biology of endemic metallicolous species in order to use some of them for phyto-remediation operations in urban contaminated sites. This study deals with the edaphic conditions for plant growing in natural metalliferous outcrops, in mining sites (quarries), and in contaminated areas around metal smelters.

Materials and methods

Soil and rocks samples were taken on the field in order to evaluate (i) the geochemical potential from the lithology, the levels of TE contents and their variability in soils (ii) between various quarries and contaminated areas, and (iii) inside sites. Additionnally, the forms taken by the contaminants in the soil were studied through the chemical fractionation of selected samples.

Soluble ($CaCl_2$ 0.01N), mobilizable (CH_3COONH_4-EDTA 1N, pH 4.65) and total ($HF+HClO_4+HCl$) contents in Cu, Zn, Pb, Co, and Cd have been measured in 26 sites. 2 to 12 soil samples from the rhizosphere of metallicolous plants were taken at each site. Additionnally, 18 samples, representing 3 plots X 3 points x 2 depths, were taken in two sites to investigate within site diversity of mobilizable trace contents.

The TE content of 16 representative soil samples has been fractionnated according to a 6-steps sequential extraction protocol.

Results and discussion

Trace contents
The total contents of rocks, quarries, and contaminated sites are high compared to those observed in most soils (Fig 1). Results confirm the strong lithologic potential for Cu and Co contents.

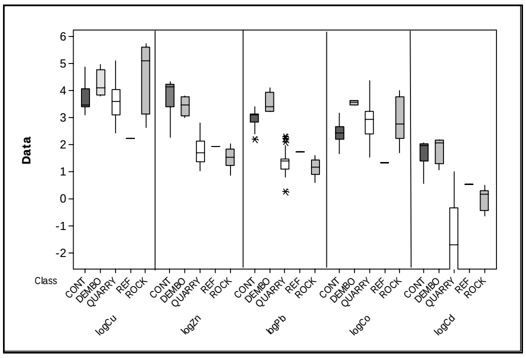

Figure 1. Total TE contents (log_{10} scales) of metalliferous sites (CONTaminated, DEMBO, QUARRY) compared to rocks and uncontaminated reference value (REF).

There are significant linear relationships between total, mobilizable, and soluble contents for every element (Table 1), with the exception of mobilizable and soluble Cu contents. The soluble fraction depends on total content and other factors, among which is the pH for Cu and Cd (Table 1).

Table 1. Pearson correlation between total (T), mobilizable (m), soluble (s) contents and pH.

	Cu	Zn	Pb	Co	Cd
T/m	**0.921**	**0.982**	**0.936**	*0.394*	**0.849**
T/s	0.261	**0.422**	**0.720**	0.269	**0.669**
m/s		*0.323*	**0.542**	**0.480**	**0.453**
T/pH		*0.378*	0.332		**0.527**
m/pH		0.314		0.303	0.367
s/pH	**-0.428**				*0.398*

Between-site differenciation

The total contents of rocks, quarries, and contaminated sites are higher than the reference uncontaminated site (REF) for Cu and Co (Figs. 1 and 2). For Zn, Pb, and Cd, only “dembos” and contaminated sites present significatively higher contents compared to REF. The studied “dembos” should therefore be distinguished from the quarries group because they present more similarities with contaminated sites (Fig. 2). These results suggest that difficulties for plant transfers from quarries to contaminated sites could occur due to differences in ecological stresses.

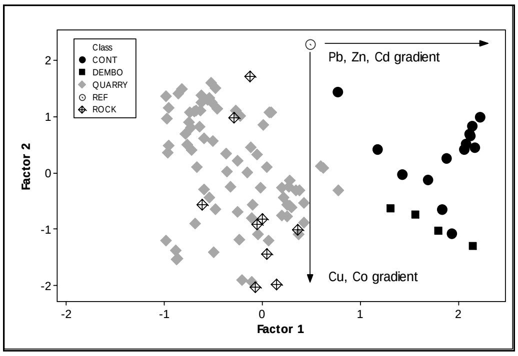

Figure 2. ACP-based factorial analysis of total TE content in metalliferous sites.

Within-site variability

The exercise conducted on the filling-up of Kassombo and Etoile mines shows that there is also an important diversity of TE content inside one given quarry. The idea of a site-specific chemical signature should be considered with care. The depth (0-2 or 3-5 cm) is also a significant factor for every element but Cd.

Forms of contaminants

The fractionation of TE shows a significantely different signature from site to site, which confirms the need for a typology of contaminations.

Conclusions

More research is needed about (i) the characterization of the rhizosphere actual properties in contaminated sites, (ii) their influence as limitation factors for plant growing, and (iii) the ways to improve edaphic conditions.

References

Duvigneaud P., Denaeyer-De Smet S. (1963). Cuivre et végétation au Katanga. *Bull. Soc. R. Bot. Belg.* 96, p. 92–231.

Leteinturier B. *Evaluation du potentiel phyto-cénotique des gisements cuprifères d’Afrique centro-australe en vue de la phytoremédiation de sites pollués par l’activité minière*. PhD thesis FUSAGx, Gembloux, 361p.

Malaisse F., Brooks R.R., Baker A.J.M. (1994). Diversity of vegetation communities in relation to soil heavy metal content at the Shinklobwe copper/cobalt/uranium mineralization, Upper Shaba, Zaïre. *Belg. Journ. Bot.*, 127(1): 3-16.