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Nerium oleander as a means to monitor and minimize the effects of pollution

Abstract

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Vegetation is very important to stabilize and minimize the effects of pollution. Industrialized areas near the city of Huelva, southwest Spain, have both soil and atmospheric pollution. Contaminants move off-site following wind direction, spreading the contamination beyond its original centre. This study checks the possibility of using *Nerium oleander* L. to minimize the effects of soil and atmospheric pollution. Samples were collected along three transects running along the prevailing wind directions (NE, NW and SE), and a fourth against wind direction (SW); a control site (Bkg) was chosen for comparison. Leaves and roots, together with soil samples were collected and the concentration of Cu, Fe, Mn, Pb and Zn was determined. This species is useful to fix Fe and Pb from soil through roots. Leaf Cu, Fe and Mn concentration are directly correlated with those in roots. No correlation between metal content in soil and root and/or soil-and leaf were found except for Pb, for which there was a positive correlation between soil and root concentration; when the contamination level is high this species is able to reflect the environmental quality.

Introduction

Industrial activities generate large amounts of pollutants. The direct effects include air, water and soil pollution. The use of vegetation can be a cheap means for pollution control when the appropriate species is chosen. Phytostabilization is a common phytoremediation technique that uses plants to clean up metal-contaminated soils. Phytoremediation includes a lot of techniques that use plants to clean up polluted sites or render harmless environmental contaminants (Wong 2003). They differ in the way plants can remove, immobilize or degrade pollutants, as well as the type of contaminants that plant species can target; it has been proposed as a cost-effective, environmentally friendly alternative technology (Lasat 2002).

The phytostabilization is based on the immobilization of trace elements through the plant root system reducing metal mobility. In this remediation technique, the choice of appropriate plant species is very important to ensure a self-sustainable vegetation cover (Pichtel & al. 2000; Wong 2003).

The possibility of using herbaceous plants to remove and fix metals from soils has received considerable attention but not many studies have been made using trees and shrubs (Punshon & Dickinson 1997). Plants can also intercept atmospheric contaminants directly from the air by leaf accumulation or absorption and, therefore, they are used in biomonitoring studies (Bargagli 1995). It is known that *Nerium oleander* L. is a species suitable to use as a biomonitor (Sawidis & al. 1995; Aksoy & Öztürk 1997; Rossini Oliva & Valdés 2003; Rossini Oliva & Mingorance 2004). This evergreen species is widespread in Huelva province and survives close to the industrial complexes, where few other plant species grow.

The objective of this study was to investigate the use of *Nerium oleander* L. to minimize soil and atmospheric pollution.

Material and methods

Sample collection

The samples of *Nerium oleander* leaves, roots and soil were collected in different contaminated sites at different distances (0.5, 1, 2, 4, 6, 8 km) along four transects from the industrial complex of Huelva city, Southwest of Spain. Three transects running to the dominant wind direction (SE, NW and NE) from the industrial complex and another against wind direction (SW) were selected. A control site (Bkg) 40 km away from the industrial focus was sampled to establish the normal element contents in *N. oleander*.

The sample collection, including plants and soils, were carried out according to Rossini Oliva & Mingorance (2004). No root samples were collected along the NE transect or at the control site.

Sample preparation and analysis

Aliquots of the samples were digested in a closed microwave digestion system (Milestone MLS 1200) using HNO_3 and H_20_2 mixture (Mingorance & al. 1993) for plants and *aqua regia* for soil (Bettinelli & al. 1989). The total concentrations of elements (Cu, Fe, Mn, Pb and Zn) were determined by simultaneous inductively coupled plasma mass spectrometry (ICP/MS). All metal concentration values reported are based on soil or plant dry weight.

The accuracy of the soil and plant analysis was determined by the analysis of *Citrus* leaves (NIST 1572), pine needles (NIST 1575), sewage sludge amended soil (BCR 143) and Montana soil (NIST 2711). Regression analysis between the reference and obtained metal concentration shows good recoveries (slope of the regression line is 1.05±0.020). The precision of the analysis was determined by RSD giving values between 2-8%.

Statistical evaluation of the data was done by using SPSS v. 11.5 (Illinois, USA)

Results and discussion

Leaf, root and soil mean concentration along the transects is shown in Figure 1. Concentration is expressed as the mean value between the different sampling points of each transect. Leaf mean concentration of Cu was significantly higher ($p < 0.05$) than those in the control site (Fig. 1). This indicates an accumulation of Cu by this species. In the case of Fe, no differences were found between the concentration at the control site and the other sampling sites; Mn concentration in the SW transect was significantly lower than in the control; concentration was significantly higher than at the control for Pb in the NE transect and for Zn in the NW transect. The Pb values are very dispersed and this may be the reason why differences with respect to the control site were not very significant.

A significant positive correlation ($p<0.05$) was found between leaf and root content for Cu ($R= 0.87$), Mn ($R= 0.90$) and Fe ($R= 0.73$), indicating that leaf concentration has a direct relationship to the root contents. No correlation was found between the soil and either root or leaf contents, except for Pb between the soil and root ($R= 0.63$). This seems

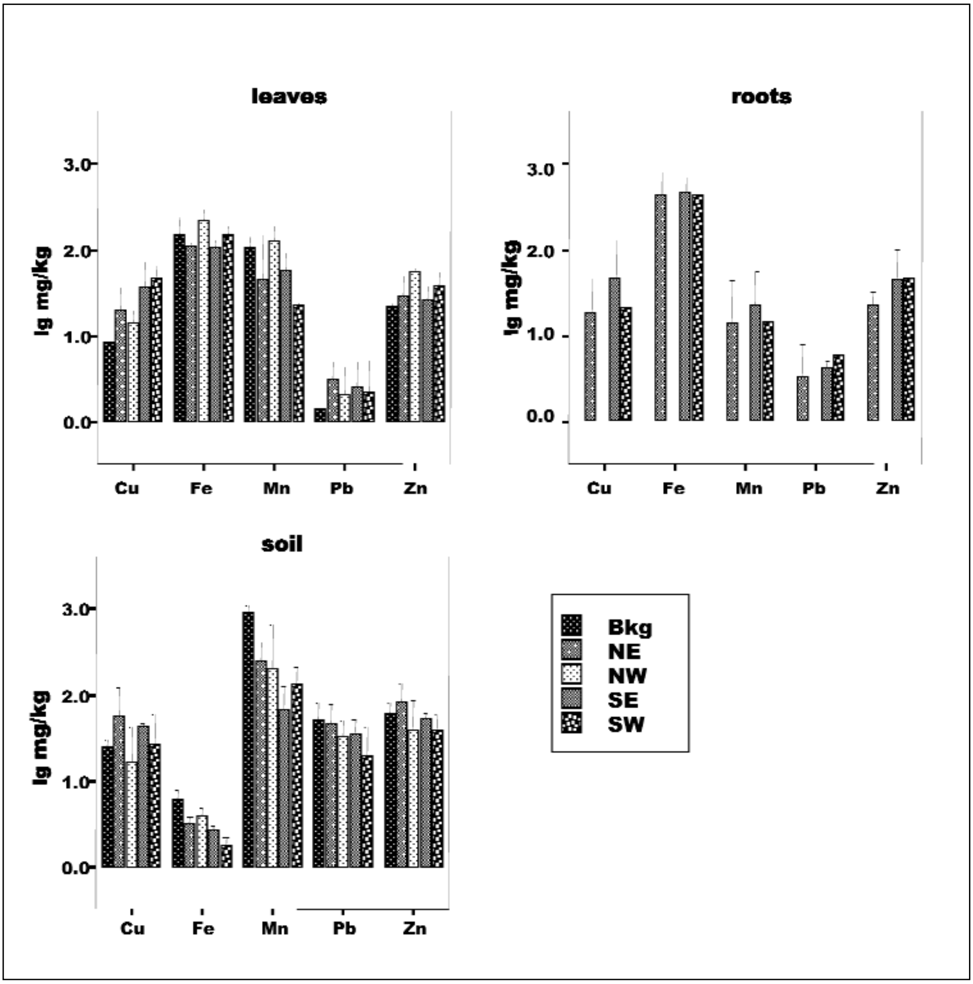

Fig. 1 Mean metal concentrations in leaves, roots and soil along transects (NE, SE, SW, NW) and at the control site (Bkg).

to indicate that metal content in plant tissues is not just a function of the total metal content of the soil, but also of the form in which it occurs, physiological transport barriers, and climatic factors.

The transfer factor (TF), defined as the ratio of root metal concentration in relation to that in leaves is presented in Table 1. Table 1 shows that the element Mn has a TF value lower than 1, which indicates that it is easily translocated within plants. The same result was obtained in southern Spain by using *Cynodon dactylon* (Madejón 2004). For Cu, it was not possible to establish a common pattern: plants growing in the SW transect easily translocate Cu (TF<1) and those growing in NE and SE transects are able to maintain a balance between leaf and root concentrations (TF close to 1). For Zn, TF values for SE and NE transects are close to 1 and for SW it is >1. The last case indicates a low transfer mobility of Zn from roots to leaves. On the other hand, the TF values higher than 1 for Fe and Pb indicate higher accumulation in the roots. This suggests that *N. oleander* is useful in removing Fe and Pb from soil.

The mobility ratio (MR) is defined as the leaf/soil metal concentration. According to Baker (1981) this species can be classified as an excluder of Cu, Mn, Fe and Pb, since the MR is lower than 1 (Tab. 1), except for Mn in NW transect and Cu in SW, NW and SE transects indicating that this species is able to maintain a low metal concentration in the leaf and that translocation is minimal.

This species can be considered as an accumulator, for only 20% of the cases, both Mn and Cu, which indicated a higher accumulation in leaf than in soil. It can also be considered as an indicator for Cu in another 40% of the cases, which means that the internal content reflects the external concentration. Mingorance & al. (2007) found that oleander acts as Cu and Zn indicator and as excluder for Al, Ba, Cr, Fe and Pb. In relation to Zn, this species is excluder in 40% of the cases and can be considered as a bioindicator for 60% of the cases.

Table 1. The mobility ratio (MR) and transfer factor (TF, >1 in bold) in *Nerium oleander* along transects (NE, SE, SW, NW) and at the control site (Bkg).

	MR					TF		
Elements	NE	SE	SW	NW	Bkg	NE	SE	SW
Cu	0.36	1.0	2.5	0.97	0.30	1.0	1.3	0.54
Fe	0.008	0.008	0.006	0.021	0.003	3.9	4.5	3.3
Mn	0.11	0.98	0.16	2.3	0.11	0.36	0.27	0.59
Pb	0.047	0.056	0.15	0.063	0.09	1.8	1.7	23
Zn	0.38	1.0	1.1	1.6	0.35	0.90	1.3	1.6

For all elements studied, the species has an excluder behavior at the control site, suggesting that leaves of *N. oleander* are able to reflect quantitative aspects of environment quality when pollution levels are high.

Conclusions

Nerium oleander L. can fix Fe and Pb from the soil by root accumulation. In addition, the leaves uptake atmospheric pollution by direct absorption from the air and by translocation from roots. The amount of Cu, Fe and Mn in the leaves is directly related to the root content but is independent of soil content. In relation to the resistance mechanisms of this species to the studied elements, it can be considered as an excluder for Cu, Fe Mn, and Pb. It can also be considered to be a partial accumulator (20%) for Cu and Mn, and as a bioindicator of Cu (40%). In addition, it is a partial excluder (40%) and a partial bioindicator (60%) for Zn. The study demonstrates that in the absence of high contamination, the species acts as an excluder which means that it needs a high pollution level to supply information on the quantitative aspects of changes in environment quality.

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