CHEMOSPHERE

Chemosphere 62 (2006) 1311–1323

www.elsevier.com/locate/chemosphere

Evaluation of the phytotoxicity of contaminated sediments deposited "on soil": II. Impact of water draining from deposits on the development and physiological status of neighbouring plants at growth stage

Jean-Philippe Bedell *, Annelise Briant, Cécile Delolme, Laurent Lassabatère, Yves Perrodin

Laboratoire des Sciences de l'Environnement, Ecole Nationale des Travaux Publics de l'Etat, Rue Maurice Audin, 69518 Vaulx-en-Velin Cedex, France

Received 25 October 2004; received in revised form 16 June 2005; accepted 1 July 2005
Available online 16 September 2005

Abstract

As part of a study of the phytotoxic risk of spreading contaminated sediments "on soil", a laboratory experiment was carried out to assess the impact of water draining from sediments on peripheral vegetation. Drainage water was obtained in the laboratory by settling three sediments with different pollutants levels, and the supernatant solutions (respectively A1, B1, C1 drainage waters) were used as soaking water for maize (*Zea maïs* L.) and ryegrass (*Lolium perenne* L.). The physicochemical characteristics of the supernatant water, particularly metal contents, showed a pattern of contamination, with C1 > A1 > B1. The plants tested were grown on soil for 21 days, before being soaked for another 21-day period with drainage water (treatments) and distilled water (control). Biomass parameters (fresh weight, length, etc.), enzymatic activity [glutamine synthetase (GS), phosphoenolpyruvate carboxylase (PEPc)] and Zn, Cu, Cd and Cr contents were measured on both the shoots and roots of each plant.

Biomass parameters were stimulated by C1, not affected by A1 and decreased with B1 for maize, whereas they increased for ryegrass in all the treatments. Compared to the control, GS activity was stimulated by C1 in the shoots of both plants and inhibited by treatments B1 and C1 in maize roots. PEPc activity in ryegrass was 1.5–5 times higher with contaminated water treatment, while contrasting effects were observed in maize plants. Both plants showed greater accumulation of chromium and zinc than cadmium and copper. Treatment A1 was found to be less active on plant growth and have a lower impact on the physiological status (enzymatic activities) of both plants. Treatment C1 stimulated the growth and physiological status of the plants, especially in shoots, with higher metal accumulation values in both plants. Treatment B1 was found to show more variable effects on growth indices, enzymatic activity and metal accumulation according to plant species.

Keywords: Drainage water; Dredged sediment; Enzymatic activities; Growth; Heavy metal contents; Maize; Ryegrass

* Corresponding author. Tel.: +33 4 7204 7081; fax: +33 4 7204 7743.
E-mail address: bedell@entpe.fr (J.-P. Bedell).

0045-6535/$ - see front matter
doi:10.1016/j.chemosphere.2005.07.012

1. Introduction

Waterway management raises the question of the fate of dredged materials. When contaminated by metals or synthetic organic compounds, dredged sediments may have negative impacts on host ecosystems. Thus depositing dredged materials on soils, a rather common method of disposal in France, can be toxic for neighbouring plants. Tack et al. (1999) studied the leaching behaviour of Cd, Cu, Pb and Zn in surface soils sampled from abandoned dredged sediment disposal sites, and showed that Zn and Cd expressed the highest potential leachability. Evaluating the risk for plants can be carried out by studying individuals or communities in situ and samples taken from a natural population. Moreover, confined upland disposal sites of dredged material, which can become highly prolific wildlife habitats, make predicting potential contamination essential. Biological material may be also used in experiments where certain test plants of known physiology and reaction can be grown on sediment both in the natural environment (Marseille et al., 2000a) and under controlled conditions to assess its toxicity (Van Driel et al., 1995; Van Noordwijk et al., 1995; Marseille et al., 2000b). In laboratory studies, the most common parameter used to evaluate the impact of contaminants (such as heavy metal toxicity/tolerance) on plants is root growth, since roots usually respond more rapidly to the presence of metal, this response being the consequence of a direct effect of the metal on the root itself (Siedlecka et al., 2001). Some test plants can be used to assess the phytotoxicity in a global risk assessment approach. *Lolium multiflorum* var. italicum and especially *Phaseolus vulgaris* L. cv. Limburgse vroege were used successfully to estimate the phytotoxicity of contaminated soils based on their morphological (shoot length, root weight, etc.) and physiological changes such as enzyme activity modification (Vangronsveld and Clijsters, 1992). Seed germination and seedling growth tests have also been used to monitor the ecotoxicology of soils contaminated with organic chemicals during bioremediation processes (Debus and Hund, 1997; Salanitro et al., 1997; Knoke et al., 1999). Such tests have been used recently to study the inhibitory effect of ragweed-inflorescence extract on the germination of *Amaranthus hypochondriacs*(Brückner et al., 2003) and evaluate the impact of olive-mill wastewater on wheat (Casa et al., 2003). Moreover, recent works have evaluated and proposed protocols for higher plant seed germination in order to use them in an ecotoxicological assessment of soils (Gong et al., 2001). A similar approach was applied to solid wastes with an evaluation of plants grown directly on solid waste or soaked with leachates (Ferrari et al., 1999). Results obtained by Lagriffoul et al. (1998) on maize seedlings showed that in contrast with growth parameters, the measurement of enzyme activities may be included as early biomarkers in a plant bioassay to assess the phytotoxicity of Cd-contaminated soils. Trace elements Zn, Pb, Cu, Cd, Ni and Cr are toxic and cause growth inhibition, biomass decrease and modification of the metabolic activity and physiology of the plant (Clijsters et al., 1991; Samantary, 2002). If the metallic content is low (in μM) the plant tends to adapt by increasing its respiration. This was confirmed by the increase in some Krebs cycle enzyme contents and/or activity (such as peroxidase, malate dehydrogenase, etc.) in *Silene italica* and *Glycine max* in the presence of Cd, Zn and Ni (Van Assche and Clijsters, 1990; Siedlecka et al., 2001). A study of biochemical responses of Cr-tolerant and Cr-sensitive mung bean cultivars grown with various contents of chromium, showed an increase of different enzyme activities, such as catalase and glucose-6 phosphate dehydrogenase (Samantary, 2002). In 14-day old maize grown in a nutrient solution containing different copper (i.e. 0.01–10 M) and cadmium concentrations (i.e. 0.001–25 M), changes in peroxidase, glutamate deshydrogenase, and malic enzyme activity occurred at lower concentrations of these two metals (Mocquot et al., 1996; Lagriffoul et al., 1998). Both nickel and cadmium assimilation showed an increase of glucose-6 phosphate, glutamate dehydorgenase and malic enzyme activity in a Ni-tolerant and Ni-sensitive population of S*ilene italica* (Mattioni et al., 1997). Following on from these different works that discussed the use of enzyme activity as a bioindicator in the case of trace element pollution, here we propose to test two enzymes, GS and PEPc, as bioindicators of the nitrogen and carbon cycle.

The application of sewage sludge to land is another illustration of the need to evaluate potential risk to plants. The sediment in our study is a sludge containing large amounts of nitrogen and phosphorous but also potentially toxic elements (PTEs) as described by Alloway (1995), Oudeh et al. (2002), and Chyi and Phillips (2002). PTEs can contain trace elements such as copper, nickel and Zinc, as well as cadmium, lead and mercury, which can be considered as phytotoxins (Alloway, 1995).

Oudeh et al. (2002) studied the effect of PTEs in sewage sludge on *Allium amelosrasum* without observing any symptoms of toxicity or deficiency in plants; moreover plant growth was markedly higher in their grassland soils experiment. Stimulation of plant length and biomass was also observed after the application of sediment dredged from an urban canal in a study by Chen et al. (2002) using a pot experiment with *Brassica chinensis* L.

Regarding plant tests, exposure to contaminants can occur during various stages of the life of a plant, from germination through vegetative growth to reproduction. Different plant parts can be affected within a life phase, such as bark, leaves and flowers, and roots, depending