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Introduction

Potentially toxic trace elements (PTTE) such as As, Cu, Cr and Zn can be in excess in contaminated soils at wood preservation sites, especially when Cu-based salts, i.e. Cu sulphate and chromate copper arsenate (CCA) have been long term used as preservatives against insects and fungi which may result in soil phytotoxicity (Kumpiene et al., 2008). In comparison with conventional techniques, phytoremediation technologies are less invasive and low-cost and able to restore the physical and chemical properties of PTTE-contaminated soils and the cascade of biological processes and functions leading to remediated ecosystem (Mench et al., 2010). Among phytoremediation options, (1) phytostabilisation, singly and in combination with mineral and organic amendments (i.e. aided phytostabilisation) aims at decreasing both the labile PTTE pool and providing nutrient supply and (2) phytoextraction which uses tolerant plants and their associated microorganisms aims at extracting and translocating PTTE from the soil to the harvestable plant parts. *Salicaceae*, willows and poplars, have been shown to be efficient for phytostabilisation of PTTE (Vamerali et al., 2009): they have a high and rapid biomass production and PTTE confinement in their roots provides them a metal(loid)s tolerance. This study aimed at investigating the efficiency of both phytoremediation options (i) on the mobility and bioavailability of Cu in contaminated soils and (ii) the tolerance of *Salix purpurea* to Cu.

Methods

The wood preservation site is located in southwest France, in the Gironde county (44° 43’N; 0°30’W). This anthroposol is developed on an alluvial soil in terrace (Fluvisol). Copper is the main contaminant in topsoils, with total soil concentrations between 65 and 2600 mg kg^{-1}, showing considerable spatial variation. The “aided phytostabilisation” serie consisted of a single incorporation of compost (5% w/w) or dolomitic limestone (0.2% w/w), or both mixed, or no amendment in the contaminated soil ([Cu]=674 mg kg^{-1}). The “phytoextraction” serie consisted of six amended soils followed by a crop rotation with tobacco and sunflower for 4 years and characterized by an increasing total soil Cu concentration, i.e. 163, 268, 382, 518, 753 and 1170 mg kg^{-1} (Hattab-Hambli et al., 2016). Another soil, located on the same alluvial terrace at 2.3 km from the site was sampled and used as a control soil. For each treatment, potted soils in triplicates were vegetalised by one cutting of *Salix purperea*, and 3 other potted soils were left without vegetation for comparison. Soil pore water (SPW) was collected after 21, 37 and 57 days by using soil moisture samplers (Rhizon™). Electrical conductivity and pH were measured as well as major cations and anions together with total dissolved Cu concentrations. At the end of the growth period (57 days), all formed organs of *Salix* were collected (leaves, stems and roots) and dried to measure their dry weight and Cu concentrations were measured by ICP-AES in the different organs. Additionally a sequential extraction scheme for Cu was applied for the different soils.

Results

In the contaminated soil, Cu is mainly located in the oxidizable fraction, i.e. associated with Fe- and Mn-(hydr)oxides, and to a lesser extent, to the fraction linked with organic matter (Le Forestier et al., 2016). In all cases, the pH increased by one unit in soil pore water, whereas the total dissolved Cu concentrations decreased over time. *Salix* biomass is similar in all soils and Cu concentrations varied between 750 à 1600 μg g^{-1} in roots, in comparison to 10-20 μg g^{-1} in stems and leaves. In the phytoextraction serie, the increased total soil Cu concentrations are correlated with the increase of the total dissolved Cu concentrations, but similar Cu contents were trapped in the *Salix* roots.

Conclusion

Whatever the initial studied Cu soil concentration, the growth of *Salix purpurea* was possible. Copper was mainly accumulated into the root system of the tested willows avoiding the contamination of their aerial organs.

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