Chemosphere 152 (2016) 407–414

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

How physical alteration of technic materials affects mobility and phytoavailabilty of metals in urban soils?

Hicham El Khalil [a, b, c], Christophe Schwartz [b, c], Ouafae El Hamiani [a], Catherine Sirguey [b, c], Jochen Kubiniok [d], Ali Boularbah [a, *]

[a] Université Cadi Ayyad, Faculté des Sciences et Techniques, Laboratoire Aliments, Environnement et Santé, Boulevard Abdelkrim Khattabi, BP 549, 40000 Marrakech, Morocco
[b] Université de Lorraine, Laboratoire Sols et Environnement, UMR 1120, F-54518 Vandœuvre-lès-Nancy, France
[c] INRA, Laboratoire Sols et Environnement, UMR 1120, F-54518 Vandœuvre-lès-Nancy, France
[d] Universität des Saarlandes, Physische Geographie und Umweltforschung, Postfach 151150, D-66041 Saarbrücken, Germany

HIGHLIGHTS

- Wastes/technic materials are present in the coarse fraction of urban topsoils.
- Technic materials contribute to metal contamination of urban Technosols.
- Forced physical alteration of artefacts enhances phytoavailability of metals.
- In long term, the risk of metal transfer from urban soils to plants could increase.

ARTICLE INFO

Article history:
Received 20 June 2015
Received in revised form
20 February 2016
Accepted 28 February 2016
Available online 19 March 2016

Handling Editor: X. Cao

Keywords:
Technosols
Artefacts
Alteration
Metals
Phytoavailability

ABSTRACT

One fundamental characteristic distinguishing urban soils from natural soils is the presence of technic materials or artefacts underlining the influence of human activity. These technic materials have different nature (organic or inorganic) and origins. They contribute to the enrichment of the soil solution by metallic trace elements. The present study aims to determine the effect of physical alteration of the technic coarse fraction on the bioavailability of metallic trace elements in urban Technosols. In general, results show that physical alteration increases the metallic trace elements water extractible concentrations of technic materials. The ability of lettuce to accumulate metallic trace elements, even at low concentrations, underlines the capacity of technic materials to contaminate the anthropised soil solution by bioavailable metals. The highest metal levels, accumulated by the various organs of the lettuce (leaves and roots), were measured in plants grown in presence of metallic particles mixtures. This indicates that the majority of metallic trace elements released by this technic constituent is bioavailable and explains the low plant biomass obtained. The abundant part of metallic trace elements released by the other technic constituents (building materials, bones, wood, plastic and fabric-paper) remains less bioavailable. Under anthropised soil conditions, technic materials have a significant effect on the metallic trace elements behavior. They impact the flow of these metallic elements in Technosols, which can increase their bioavailability and, therefore, the contamination of the food chain.

1. Introduction

The contribution of the technic coarse fraction of Technosols in transfer of metals to plants is rarely considered mainly with a view of long term of physical alteration of artefacts, which may contribute to enrichment of soil solution with metals, thus enhancing their phytoavailability. In urban areas, soils are often altered dramatically by human activities where the soils potentially receive considerable amounts of wastes and associated pollution. For example, mining activities, spreading of liquid and solid wastes, building and road construction intensely affect the composition of soil. The addition of anthropogenic materials (e.g. gravel, bricks, ashes, glass, rubble) to soils during the growth of cities makes an

* Corresponding author.
E-mail address: a.boularbah@uca.ac.ma (A. Boularbah).

http://dx.doi.org/10.1016/j.chemosphere.2016.02.116
0045-6535/

impact on soil formation and evolution (Bullock and Gregory, 1991; Effland and Pouyat, 1997; Craul, 1999; Möller et al., 2005). The concept of urban soils has thus been introduced in the soil classification as a group qualified as Anthrosols (IUSS-WRB, 2014). Anthrosols are described as soils with agricultural use, which have been affected by intensive practices. Nevertheless, the complexity of urban soils composition and their non-agricultural origin required a new reference group of soils that was introduced in the IUSS-WRB as Technosols in 2006. This included most of the urban soils and designated the strongly anthropised soils with the properties and pedogenesis dominated by technic materials with more than 20% of artefacts in the upper 100 cm of the soil profile. In cities, Technosols present specific physicochemical characteristics strongly related to their land use and associated to the technical materials (Morel et al., 2005; Wong et al., 2006; El Khalil et al., 2008a; El Khalil et al., 2008b; Park et al., 2011; El Khalil et al., 2013; Nehls et al., 2013). These characteristics modify the pedogenetic processes (Craul, 1999; Sánchez-Marañòn et al., 2002; Norra and Stüben, 2003; Huot et al., 2013) in form of aggregations (Jangorzo et al., 2013; Jangorzo et al., 2014), chemical weathering of soil constituents (Huot et al., 2013), and transfer of elements including pollutants (El Khalil et al., 2008b; Norra et al., 2008, El Khalil et al., 2013; Howard et al., 2013). The dynamic of metals depends on their origin and their speciation (Adriano, 1986; Senesi et al., 1999; Morel et al., 2005; Wong et al., 2006; El Khalil et al., 2008a; Dong et al., 2010; Xia et al., 2011). The description of this dynamic is necessary to predict both mobility and bioavailability of metals and their potential transfer to the food chain. Indeed, the urban soils constitute a growing support of agricultural and gardening activities (Beavington, 1975; Morel et al., 1999, 2005; Séré et al., 2008, 2010; Park et al., 2011). Several edible plants, grown on urban soils, can accumulate heavy metals leading to the contamination of the food chain (McLaughlin et al., 1999; Devkota and Schmidt, 2000; Davydova, 2005; Kabata-Pendias, 2004; Sharma et al., 2007; El Hamiani et al., 2010, 2015). Technic materials present in both fine and coarse fraction of urban soils constitute a major vector of metals. As an example, urban and suburban soils of Marrakech, Morocco, contain considerable amounts of technic materials (up to 14%) (El Khalil et al., 2008b). The coarse technic materials usually neglected in chemical analysis, contributes to the enrichment of the soil solution by metallic pollutants (El Khalil et al., 2008b). The progressive alteration of these technic elements to ultrafine fraction may induce the increase of metals released in soil solution and could be the result of the natural weathering conditions and/or accidental action due to human activity. The alteration phenomenon may probably require a long period of time, depending on several factors such the nature of these materials, the physicochemical and biological properties of the soils. The aim of the present study is then to determine the effect of an accelerated alteration of the technic coarse fraction of Technosols on the dynamics of metallic trace elements in the soil-plant system. A simplified approach, submitting the coarse technic material representative for urban soils to accelerated artificial alteration, is proposed. Ultrafine technic materials mixed with sand and fertilizers are used as a substrate for plant growth. The contribution of the technic ultrafine fraction on mobility and phytoavailability of heavy metals is determined both by a selective metal extraction from the solid phase and a plant biotest.

2. Materials and methods

2.1. Technic materials

The technic materials were obtained from 58 urban and suburban topsoils collected from Marrakech city (El Khalil et al., 2008b; El Khalil et al., 2013). The sampling strategy of urban topsoils was directed by the historical knowledge of the city, which allowed a zoning in various sectors characterized by different ages and varying contemporary land uses (El Khalil et al., 2008b). The sampling sites were selected according to the impact of current land use types (residential districts, suburban and urban agriculture, market-gardening, industry) and according to the superposition of land uses over time. The soil samples (5 kg per sampling site) were collected in the topsoil, air-dried, homogenized and sieved to 2 mm. The technic coarse fraction (>2 mm) was separated from the natural coarse fraction by manual sorting. For chemical analytical methods, samples of technic coarse fraction were homogenized to an adequate degree of analytical fineness. Average samples of the main technic fractions (bones, building materials, glass, metal, paper-fabrics, plastic, and wood) were separated from the soils and weighed. Each sample was crushed using successively a crusher and a mill to respectively fine and ultrafine size reduction (jaw crusher BB100, Retsch and mixer-mill MM400, Retsch). The jaw crusher is used for the pre-crushing and a final fineness of ~5 μm is obtained with the bench-top ball-mill. The choice of grinding tools and accessories was made to provide for contamination-free and reliable sample preparation prior to laboratory analysis. The ultrafine material was stored before metal analysis and used as an amendment to sand in a plant growth experiment.

2.2. Fine fractions observation

The presence of technic materials in the fine fraction of urban soils was identified using binocular microscope observations (×10 magnification). One gram of each soil sample was uniformly distributed in a Petri dish. Based on the observations recorded, most representative pictures of the composition of the fine fractions were selected (Fig. 1).

2.3. Soil amendment by the ultrafine fraction of technic materials

Five grams of each technic material ultrafine fraction (glass, plastic, metallic materials, paper-fabrics, building materials, wood and bones) were added to 15 g of sand (sable de Fontainebleau, Carlo Erba Reagents, Italy) with a particle size between 500 and 800 μm, in four replicates. Due to the small quantities of plastic and paper-fabric materials obtained, only 2 g of ultrafine fraction of these materials were used as amendment to sand. Pots were wetted at field capacity and incubated at room temperature for 10 days before seed sowing.

2.4. Seed germination and plant growth experiment

Lettuce is an annual or biennial temperate plant of the *Asteraceae* family and is widely cultivated in Morocco as a leaf vegetable. After sowing 5 lettuce seeds (*Lactuca sativa*, variety "Reine de Mai") in each pot (polyethylene vial, 27 mm diameter x 60 mm high), the pots were watered using distilled water and placed in the dark until germination (48 h). After germination, pots were poured with a free of trace elements nutritive solution (Table 1) (Mullins and Sommers, 1986). The pots were transferred in a phytotronic chamber with a photoperiod of 16 h (day) and 8 h (night). Temperature was set 25 °C during the day and 18 °C at night and the air-humidity was fixed at 70%. During the period of culture (1 month), pots were wetted once a week with 2 ml of the nutritive solution.