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Urban soil pollution in Damascus, Syria: concentrations and patterns of heavy metals in the soils of the Damascus Ghouta

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Abstract

The objective of the study was to assess the extent and severity of heavy metal contamination of arable soils of the Damascus Ghouta, an area with intensive agricultural production. We examined the present degree and spatial distribution of heavy metal concentrations in 51 soil profiles and in 22 topsoil samples in the Damascus Ghouta. The soils were digested with aqua regia for heavy metal analysis. Pb, Cu and Zn concentrations in the topsoils exhibited anthropogenic increased values. The major sources for the heavy metal contamination in Damascus city are most possibly emissions from vehicles. These emissions transported by air and sewage water together with household and industrial sewage effluents have been considered to be responsible for the increased heavy metal concentrations found in the soils of the central Barada area. However, the values were in most cases below tolerable values of soil for agricultural use. Cr concentrations up to 1800 mg kg^{-1} were found near a tannery industrial estate. Concerning the health risk of the population bioavailability and mobility of heavy metals seems to be of minor importance, based on the soil properties found in the study area. However, direct ingestion of soil, e.g., by children and inhalation of dust may contribute largely to the accumulation of heavy metal in human and livestock.

Keywords: Heavy metal; Effluent irrigation; Car emissions; Tanneries; Arable soils

1. Introduction

Soil pollution of agricultural areas surrounding big cities is a major environmental problem. The Damascus Ghouta is an area with intensive agricultural and horticultural production surrounds Damascus city in the East. It is one of the major agricultural areas of Syria. Based on the water shortage in the area, parts of the Ghouta are irrigated with treated but also untreated sewage effluents from Damascus city.

Continuous urbanisation of Damascus leads to an increased pollution of soil and water resources and

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thus a growing risk for heavy metal uptake by human and livestock.

Atmospheric deposition reflected by high heavy metal concentrations in urban dust (e.g., Li et al., 2001) is one of the core sources of heavy metal accumulation in urban soils. Key heavy metals are thereby Pb from leaded gasoline, Cu, Zn and Cd from car components, tyre abrasion, lubricants and industrial and incinerator emissions (Markus and McBratney, 1996; Thornton, 1991; Wilcke et al., 1998).

Furthermore, tanneries and other small to large factories are possible sources for soil pollution. These factories discharge their effluents into the branches of the Barada River, which is used for irrigation and drains into the Damascus Ghouta. Chromium, for example, has been found to accumulate at a progressive rate in soils affected by sewage water from tanneries (Davis et al., 1994; Song et al., 2000). Especially if waste contains significant quantities of metals in form of inorganic salt, leaching to groundwater is more likely to be a potential problem (Cameron et al., 1997).

Assessing the potential health risk of the population different uptake pathways have to be considered. Bioavailability and mobility of heavy metals which are strongly dependent on soil pH are oft reported to be important pathways. In some soils, e.g., Na^+-rich soils, in situ mobilization of colloid particles can be important, if in soil solution a decrease in ionic strength, an increase in solution pH, or a replacement of divalent cations by monovalent cations as Na^+ occurs (Gasser et al., 1994; Kretzschmar et al., 1997). On the other hand, clayey soils with a moderate alkaline pH and a high $CaCo_3$ content are usually considered to have a low heavy metal mobility and bioavailability based on the high binding capacity (e.g., Cameron et al., 1997).

Next to bioavailability and possible uptake through water sources direct uptake pathways can be important. Contaminated soil can be ingested directly by, e.g., playing children, the consumption of not adequately cleaned field crops and grazing animals. Most of the metals ingested by humans and animals are excreted and only small proportions are actually retained in the body tissues (Cameron et al., 1997). Depending on duration and frequency of a potential ingestion of soil, especially at polluted sites, the uptake of heavy metals with soil can, however, result in serious health risks. Children at the age between 1 and 8 are of specific concern for this pathway. A study in the USA near by an Arsenic contaminated area revealed that children between 1 and 6 years take up in average 117 mg/day and in the 90th percentile 277 mg/day (Walker and Griffin, 1998). The maximum was 899 mg/day. In the German legislation, it is assumed that children with 10 kg weight take up 0.5 g soil/day (Queitsch, 1999). The frequency of a potential uptake varies for different regions depending on the climatic conditions and cultural habits. In Germany 240 days, while in parts of the USA 365 days are assumed. Against the background of threshold values for a potential health interference aqua regia extraction as a safe and common measure for the maximum extractability of heavy metal by a human body can be used to calculate threshold values for soils. For Cr, for example, the value is 200 mg kg^{-1} soil.

A further direct pathway of heavy metal uptake is inhalation. Especially under the dry conditions found in Damascus city with a higher presents of dust in the urban atmosphere this pathway can be important.

An essential prerequisite to identify and reduce possible risks for food production and for humans in Damascus city and the Damascus Ghouta is a substantial pool of information about soil contamination in the area. Therefore, the objectives of the study were to determine the concentrations and spatial distribution of heavy metals (Co, Cr, Cu, Ni, Pb, Zn), to assess the heavy metal contamination in the soils of the Damascus Ghouta and to identify the risk of heavy metal uptake by the population.

2. Materials and methods

2.1. Study area and experimental design

The study area is part of the Damascus Ghouta, an area surrounding Damascus city in the East with intensive agricultural and horticultural production. The Barada and the Ahwash are the main rivers crossing the Ghouta. They originate from the Anti-Lebanon-Mountains. The average precipitation is about 225 mm/year. The main potential evapotranspiration is more than 1000 mm/year.