DISTRIBUTION AND SEQUENTIAL EXTRACTION OF SOME HEAVY METALS FROM SOILS IRRIGATED WITH WASTEWATER FROM MEXICO CITY

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(Received 3 July 1995; accepted 15 June 1996)

Abstract. A sequential extraction procedure was used to fractionate Cu, Cd, Pb and Zn in 4 soil profiles into the designated forms of water soluble + exchangeable, organically bound, carbonate and Mn oxides bound. Soil profiles were obtained from the Rural Development District 063, State of Hidalgo, which have been irrigated with wastewater coming out of the basin of Mexico. The total heavy metal contents range as follows: Cu, 8.9 to 86.5 mg kg⁻¹; Cd, 0.86 to 5.07 mg kg⁻¹; Pb, 18.1 to 131.7 mg kg⁻¹; and Zn, 101 to 235.5 mg kg⁻¹. The highest concentrations of total heavy metals were found in the surface layers at all soil profiles. Sequential chemical fractionation indicated that the four metals were predominantly associated with the organic fraction at most soil samples. The contents in all fractions of the four metals showed a decrease with depth which has been explained by the variations in the organic matter and CaCO₃ contents in the different layers of soils. These soil properties were also the most important variables in the biological availability of the metals in these soils.

Key words: depth metal distribution, metal fractionation, soil Cd, soil Cu, soil Pb, soil Zn, wastewaters irrigation

1. Introduction

Trace elements in soils are present in different chemical forms because they are associated to diverse organic and inorganic components of the soils. These different chemical forms are principally the following: a) soluble, b) exchangeable, c) retained by the organic matter, d) occluded by Fe-Mn oxides, e) coprecipitated with metal oxides, carbonates, phosphates, sulfides, and f) as ions in crystal lattices of primary and secondary minerals (Graña et al., 1991), this have some variations that depend on the different authors. The relative impact of elevated metal levels on soil-plant-animal systems will be controlled by the dominant forms of the metals that are present (Levy et al., 1992). In order to assess the chemical species of trace elements in soils some researchers often use procedures of selective extraction that, although they present limitations, provide information concerning the origin, way of existence, biological availability, mobilization and transport of heavy metals (Tessier et al., 1979). The types of reactions that are likely to control the partitioning of metals in soils are: a) adsorption and desorption, b) precipitation and solubilization, c) surface complex formation, d) ion exchange, e) penetration in the crystal structure of minerals, and f) biological mobilization and immobilization (Chao, 1984 cited by Levy et al., 1992). The sequential fractionation procedures to

examine the solid and solution phase of soils are subject to analytical limitations such as nonselectivity of extractants and trace element readsoption among phases during extraction (Rendell et al., 1980; Kheboian and Baver, 1987). However, such procedures result in useful qualitative to semiquantitative estimates of the chemical forms of heavy metals. The concentrations of heavy metals such as Cu, Zn, Mn, Cr, Cd, Co, Ni, and Pb in soils of Mezquital Valley have been determined by some researchers (Gutiérrez, 1982; Cajuste et al., 1989, 1991; Hernández et al., 1989; Mejia et al., 1990; Flores et al., 1990, 1992). However, it is desirable to have information about the depthwise distribution of the different forms of some elements in soils of this Valley. Hence, the objectives of this study were to determine the total, organically bound, Mn oxide bound, soluble and exchangeable metals distribution in the soils, in four soil profiles which have had different periods of wastewater irrigation and the relationships of these forms with some selected properties of the soils. The metals chosen were Cu, Cd, Pb, and Zn because some previous studies in this area showed high concentrations of these metals but the values were reported as totals and the authors of the present work considered that partitioning of these metals is very important for agriculture. The data gathered from this study will allow the evaluation of soil management techniques to limit the mobility and plant availability of these trace metals.

2. Materials and Methods

2.1. Description of Study Area

Since the beginning of this century wastewater from Mexico City and its metropolitan area have been used in the Rural Development District 063 in the Mezquital Valley, Hidalgo State. This irrigation district is localized 109 km north of Mexico City. The wastewaters have to flow this distance and then they are stored in three interconnected dams. This in itself is a primary water treatment. These wastewaters have pH values which range from 7.1 to 8.3. A general description of the area is given by Flores et al. (1992). The climate corresponds to the most humid of the arid climates, with a mean annual rainfall of 502 mm, and a mean annual temperature of 17.4 °C. The predominating soils are the Eutric Vertisols, Haplic and Calcaric Phaeozems, and Rendzic and Mollic Leptosols (Hernández et al., 1993). The general soil characteristics of Irrigation District 063 show pH-values ranging from 6.86 to 8.60 with some values higher than 9. The electric conductivity in the saturation extract ranges between 1.0 and 3.4 mS cm\(^{-1}\), but at some sites with ground water near to the surface and clayed soil textures, salinization has occurred due to impeded drainage conditions, having electric conductivities from 8 to 40 mS cm\(^{-1}\). These sites represent approximately 2000 ha of the whole area. Each soil unit has a great variability in its CaCO\(_3\) contents. Gutiérrez et al. (1994) reported lower values than those found by the authors of this work. The soils have medium to