Plant-soil interactions of sludge-borne heavy metals and the effect on maize (*Zea mays* L.) seedling growth

BJ Henning[1], HG Snyman[2]* and TAS Aveling[3]

[1] *Department of Botany, University of Pretoria, Pretoria 0001, South Africa*

[2] *ERWAT Chair in Wastewater Management, Water Utilisation Section, Department of Chemical Engineering, University of Pretoria, Pretoria 0002, South Africa*

[3] *Department of Microbiology and Plant Pathology, Forestry and Agricultural Biotechnology Institute, University of Pretoria, Pretoria 0002, South Africa*

Abstract

The use of sewage sludge as an organic fertiliser under South African conditions is an alternative disposal route to sacrificial land disposal. However, the lack of research done under South African conditions and the conservative nature of the heavy metal guidelines, when interpreted as total metal content is limiting the agricultural use of sludge. A glasshouse experiment, which forms part of a greater project, was conducted to characterise soil-plant interactions of the main sludge-borne heavy metals (Pb, Cd, Zn and Cu) in two sludges (low metal and high metal) to different soil types (clayey, loamy and sandy) on maize seedlings. Growth differences, heavy metal accumulation in plant parts and soil-metal concentrations (total and potentially available) were determined. The low metal sludge treatment showed the highest yield for maize seedlings when compared to controls (soil unamended and inorganic fertiliser added). The amendment of sludge to the soil did indicate higher heavy metal content, although the increase was not as predicted, owing to the difficulty of obtaining a representative sample in the soil. Except for Cd, heavy metal values in the soils (at the beginning and end of experiment) exceeded guidelines due to very high background values in the soil. No negative effects of heavy metal contamination in plant parts of the crops could be proven. Results showed that application of sludge to different soils could be useful in order to increase crop growth over a 28 d period in the glasshouse. Soil, plant and water quality monitoring, together with the prevention of metals entering the plant, is a prerequisite in order to prevent potential health hazards of sludge application to agricultural land.

Introduction

The application of sewage sludge to agricultural land as an alternative to sacrificial land disposal is not a new concept and has been practised throughout the world for the last few decades. The long-term benefits of the application of sewage sludge to land are, however, frequently limited by potentially harmful elements such as heavy metals and human pathogens. Toxic heavy metals, in particular Cd, Cu, Zn, Ni and Pb are frequently present in high concentrations in sewage sludge (Schmidt, 1997). Heavy metals may be transmitted in the food chain and, because of their high toxicity, present a threat to crop production and animal and human health (Korentejar, 1991). However, through previous research done, it appeared that adding sludge to the soil promotes plant growth significantly more than when commercial fertiliser is added. Christodoulakis and Margaris (1996) showed that plant height increased in maize individuals by 77% in the sludge amended treatment compared to 25% in the case of the commercial fertiliser amendment. Previous research done by Snyman et al. (1998) and Henning et al. (1999) has also demonstrated the short-term beneficial agricultural utilisation of sewage sludge concerning heavy metal contamination risk and the cultivation of maize under South African conditions.

According to the 1997 guidelines (WRC, 1997), the current standards for the unrestricted use of sludge on agricultural soils, cannot be attained within a reasonable framework of affordability and applied technology. Snyman et al. (1999) concluded that none of the wastewater treatment works in S.A. could comply with the Cu, Pb and Zn levels in sludge which is intended for unrestrictive use in terms of the total metal content. Investigations that illustrate the benefits of sewage sludge are extremely important, since there is still a general reluctance among agriculturists to recognise the economic value of the sewage sludge in order to improve the soil organic status without contaminating the environment (Korentejar, 1991). As part of a greater research programme, this study was proposed to assess the effect of sewage sludge on growth and yield of maize (*Zea mays* L.) seedlings under glasshouse conditions. Heavy metal concentrations (total and potentially bioavailable) were monitored in the sludge and soil to characterise plant-soil interactions of the sludge-borne heavy metals on different soil types.

Materials and methods

Collection, treatment and analysis of dewatered sewage sludge

Dewatered sludge samples were collected from two different wastewater treatment plants (WWTP) at the East Rand Water Care Company (ERWAT) representing a low metal sludge (Sludge 1) and a high metal sludge (Sludge 2). The low metal sludge (50:50 anaerobic digested sludge and thickened waste-activated domestic sludge) was collected over a period of 4 h from the beltpress facility, while the high metal sludge (anaerobic digested domestic and industrial sludge) was collected from the drying beds after the sludge was left to dry for two weeks. Analyses were done for

* To whom all correspondence should be addressed.

☎(011) 929-7130; fax (011) 929-7031; e-mail: heidis@erwat.co.za

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