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Heavy metal accumulation in calcareous soil and sorghum plants after addition of sulphur-containing waste as a soil amendment in Turkey

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Abstract

The purpose of this work was to evaluate the effect of sulphur containing industrial waste with respect to heavy metals on calcareous clay soil and sorghum (*Sorghum bicolor* L.) plant, as soil amendment. Pot experiment was established with a rate of 0, 20, 40, 60 t ha^{-1} air dry waste and 0.5, 1.0, 1.5 t ha^{-1} elemental sulphur and 0.5 t ha^{-1} sulphur + 20 t ha^{-1} waste. The use of waste on the soil with high $CaCO_3$ and clay content did not create heavy metal (Ni, Cr, Co and Cd) build-up or toxicity. Even after the application of the high level of waste, it could not be seen any important toxic element accumulation in sorghum plant. Although the sulphur-rich waste, approximately up to 1 million t in the vicinity of Keçiborlu Sulphur Factory Isparta/Turkey, can be considered as amendment product for reclamation of saline-sodic and calcareous soils common in Turkey and other countries, repeated waste applications would result in different heavy metal accumulation rates. Therefore, it is needed to be examined with long term field experiments and different crops.

Keywords: Heavy metals; Industrial wastes; Soil amendment; Sulphur; Sorghum; *Sorghum bicolor* L.; Ni; Cr; Pb; Cd

1. Introduction

Heavy metals are natural components of the earth crust (Wedepohl, 1991). In addition to this native origin, some heavy metals may be supplied to soils by atmospheric deposition and by agronomic practices such as fertilizer and pesticide applications as well as the disposal of municipal wastes such as composts and sewage sludge on agricultural land (Cramer et al., 1981; Sauerbeck, 1985; Schmidt and Sticher, 1991).

The uptake of heavy metals by plants depend on their concentration in soil. However, the uptake of heavy metals from soil is not a simple function of total soil heavy metal content. Soil factors govern the plant availability of heavy metals. Some investigations showed that the availability of heavy metals to plants

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depends on several soil characteristics which affect the binding and mobility of metals in soil. These include soil pH, ion exchange properties, drainage status as well as clay and organic matter content (Berrow and Burridge, 1991; Sauerbeck and Lübben, 1991).

On the other hand some investigations clearly demonstrated that the plant itself plays an active role towards mobilizing and uptake of metals bound in soil with considerable differences among plant species and cultivars (Helal, 1990; Hinsley et al., 1978; Mench et al., 1989; Petterson, 1977). Plant characteristics and activities may affect heavy metal uptake in several ways. These include the modification of soil properties related to heavy metal availability, the control of heavy metal transfer across cell membranes, the binding of metals in various plant tissues, and the interaction between the nutritional status of the plant as well as environmental stress conditions with these activities.

In recent years, the use of various urban and industrial waste materials for soil reclamation and soil productivity has attracted an increasing amount of interest. However, besides the benefits offered by such waste, it may also incorporate various risks, because of its heavy metal content. The use of such waste is recommended under conditions that the risks can be kept at acceptable levels. This approach is also considered to be very important for eliminating certain problems and difficulties created by this kind of waste.

Saline-sodic soils are known to cover 1.5 million ha in Turkey. These soils have partially or entirely lost their productivity in time and great amount of amendment products is needed for their reclamation. Albeit, the researches are going on about this kind of amendment products. Number of studies have claimed that Keçiborlu sulphur factory waste, which is approximately amounting up to 1 million t, can be used for this purpose (Bahçeci, 1989; Sönmez, 1988). Investigations are still being carried out to recycle Keçiborlu Sulphur Factory waste by evaluating its reclamation effects on soil productivity but these investigations do not take into account its heavy metal content and consequent problems.

On the other hand most of the soils in Turkey are highly calcareous and as a result has a high pH. 22% of the soils contain less than 1%, 20.4% of the soils contain between 1% and 5%, and 57.6% of the soils contain more than 5% calcium carbonate. Especially, those in the Mediterranean Region are highly calcareous (Anonymous, 1984). The use of elemental sulphur or waste containing sulphur is a potential treatment for soils with a high pH. In a field experiment conducted by Kaplan and Orman (1998), sulphur factory flotation waste was applied to extremely calcareous soil (37.3% $CaCO_3$) at levels of 20, 40, 60 and 100 t ha^{-1} and the pH of the soil was measured on a temporal basis after 5, 10, 38 and 58 weeks. They showed that the pH of the soil differed from that of the control sample in proportion to the amount of waste used and the period of time, and they found that possible reduction of pH is minimum 0.21 and maximum 0.79 units. In the course of determining potential the use of this waste for both soil pH reduction and the reclamation of saline-sodic soils, investigations must consider whether it poses heavy metal risk or not, which is a matter of economic and environmental importance.

The aim of this article is to evaluate the use of sulphur factory waste containing sulphur and heavy metals in calcareous clay soil, principally with respect to toxic elements.

2. Materials and methods

Pot experiment was conducted with calcareous clay soil taken from West Mediterranean Region in Turkey. The soil was classified as Lithic Xerorthent. Soil was air dried and passed through a 4 mm sieve. A total of 5 kg of sieved soil was placed in pots with holes at the bottom. The details of the experiment were previously reported by Kaplan and Orman (1998).

Basic properties of the soil used in the pot experiment are as follows; clay 47.4%, $CaCO_3$ 37.3%, $pH_{(H_2O)}$ 7.88, EC 2.49 dS/m, organic matter 2.58%.

The results of the chemical analysis of the sulphur factory flotation waste used in the experiment are given in Table 1.

The experiment was carried out according to the randomized plot design with three replicates in the greenhouse conditions and eight different treatments which were applied in the equivalents of 0; 20 (W1), 40 (W2), and 60 (W3) t ha^{-1} of waste; 0.5 (S1), 1.0 (S2), and 1.5 (S3) t ha^{-1} of elemental S; and mixture of 20 t ha^{-1} (W1) and 0.5 t ha^{-1} (S1) of waste and S. Ten weeks after applications, sorghum (*Sorghum bicolor* L.) was planted (7–8 seeds pot^{-1}). After