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5- SUMMARY AND CONCLUSION

Heavy metals pollution of soil causes many environmental and human health problems. Recent reports have drawn the attention to the importance of organic matter as an outstanding natural and safe means controlling such metals behavior in soils. These elements bound on insoluble humic substances are relatively immobile. Humic carboxylic-COOH, phenolic-OH and other oxygenic functional (reactive) groups are mainly involved in the formation of metal-humic (organo–mineral) complexes and thus reducing the intensity of soil pollution. Consideration, therefore, has been directed towards using organic materials and their metabolites, resulted via microbial decomposition, for controlling the activity of heavy metals in the affected soils, in a process known as "Bioremediation".

Therefore, the present investigation has been carried out, in pot experiments, to evaluate bioremediation of a chemically polluted soil with a number of heavy metals. and its reflection on plant growth.

Samples of an alluvial clay soil were collected from the surface layer (0-30 cm) of the Experimental Farm, Fac. of Agric., Minufiya University, and packed in plastic pots. The soil was intentionally polluted with a mixture of heavy metals, i.e. Zn+ Pb+ Cu, each in the form of acetate, at two collective levels, referring to their permissible safe levels, i.e. the permissible (120, 70 & 50 mg kg^{-1} soil, respectively) and their duplicate. Organic materials, namely compost, biogas manure and humic acid, were added at rates of 5 & 10 g organic carbon per kilogram soil. Also, the interaction between the organic additives and the heavy metals introduced to the soil, has been studied to determine its reflection on plant growth and pollution control.

Faba bean "*Vicia faba*" and maize "*Zea mays*" crops were chosen as test plants. Faba bean growing plants were uprooted at the two periods i.e. 45 and 90 days after planting, as well as those for maize took place at 30 and 60 days. Plant height, dry weight and nutrient (NPK) and heavy metal (Zn, Pb & Cu) contents of both crops(and nodule numbers of faba bean roots), as well as dehydrogenase activity in the polluted soil were determined at each sampling time. Contents of the assigned heavy metals remained in the soil were assessed at the end of the experimental duration. The standard recommended cultivation practices, including chemical fertilization, the specific diazotroph (*Rhizobium leguminosarum*) inoculation of faba bean seeds and irrigation.. etc., had been performed in the present study.

The obtained results could be summarized as follows:

1- Application of each of the organic materials (compost, biogas manure or humic acid) to the natural soil (un-polluted), considerably increased the faba bean and maize plant height, dry weight, nutrient contents, root nodules (of faba bean) and dehydrogenase activity in soil, as compared with the artificially polluted soil, at both periods of plant growth. Such results improved with increasing the applied dose of the organic amendments.
2- Humic acid had a superior influence on all growth parameters of both faba bean and maize plants, at the first growth period. Effect of the different forms of organic substances could be arranged as follows: humic acid > biogas > compost > un-amended soil. However, at the latter growth period, compost replaced humic acid in the superiority concern.
3- addition of the heavy metals blend (Zn+ Pb+ Cu) to the natural soil, at their lower level (the upper permissible safe limit), in absence of organic supplements, caused a little decrease in the experimental measures, at both sampling times.
4- At the higher level of the pollutants(double permissible) added to the organics un-amended soil, corresponding decreases certainly occurred in the dry weights of the plants, as well as in the macronutrients (NPK) and heavy metals (Zn, Pb and Cu) concentrations in shoot tissues and their

uptake, numbers of faba bean root nodules and soil dehydrogenase activity. Data revealed that maize plants were negatively more affected by soil pollution, at the two growth periods especially at the higher level of heavy metals composite ,than the faba bean plants.

5- As a result of organic materials application to the soil polluted with such heavy metals, the harmful effects upon plant height, dry weight, nutrients absorption, root nodulation and soil dehydrogenase activity had been reduced, seriously at the higher level. However, values of the experimental measures generally improved at the lower pollution level. Efficiency order of the used organic substances on limiting the hazardous action of the heavy metals could be ranked as follows: humic acid > biogas manure > compost > organic un-treated soil, at the first plant sampling, but compost exchanged place with humic acid lately.
6- Increasing the dose of organic amendments from 5g to 10g O.C kg^{-1} soil to the heavy metals treated soil had resulted in a more effective alleviation of the adverse effect of soil pollution and consequently leading to a better plant growth.
7- Absorption capacity for the determined nutrients showed that, phosphorus in faba bean and potassium in maize, exhibited higher positive responses to the bioremediation process.
8- Analysis of the soil at termination of the experiments, confirmed the positive effect of the applied organic supplements on diminishing the bioavailability of the introduced polluting elements in the subjected soil and thus lowering the contents of such composing elements in the growing plants. Compost was the most efficient in capturing such metals in soil, at this phase, in an opposite reflection on their mobility.

As a conclusion, the present work provided a further evidence confirming the role of type and amount of organic materials in controlling the undesirable action of heavy metals in soil, and thus bioremediation of the chemically polluted soil. Presence of humic substances, polycarboxylic organic acids, phenols and some other metabolites (containing oxygenous functional groups), derived through decomposition of organic materials, by the chemoorganotrophic microbial population in soil, are behind diminishing the activity of heavy metals via chelation processes. Hence, for the short term, humic acid is suitable (as it is short persistent), but for the long term compost is better (long persistent), as bioremediators. This is undoubtedly in favour of the availability of nutrients and plant absorption for a flourished vegetative growth and higher crop yield quantitatively and qualitatively. Soil properties, plant kind and nature, cultivation practices and type and contents of heavy metals contributed to the efficiency of bioremediation process. Besides the type and amount of organic amendments to be used, time and method of application, as well as economic feasibility, should be considered.