Immobilization of potentially toxic metals in acid and alkaline soil using charcoal, activated carbon and biochar

E.E. Golia[1], O.D. Kantzou, S. Papadimou, M.A. Chartodiplomenou and N. Tsiropoulos[2]

[1] Laboratory of Soil Science,
Department of Agriculture, Crop Production and Rural Environment
Fytokou Road, 36 446 N. Ionia Magnesias, Volos, Greece

[2]Laboratory of Analytical Chemistry and Pesticides Laboratory,
Department of Agriculture, Crop Production and Rural Environment
Fytokou Road, 36 446 N. Ionia Magnesias, Volos, Greece

Keywords: lignite, amendments, heavy metals
Presenting author email: egol@uth.gr

Charcoal (lignite), activated carbon and biochar, are three forms of carbon that have a lot of common properties, with very similar composition and methods of production (Břendová *et al*, 2016). Biochar is a carbon-rich solid that is particularly derived from organic matter (from plants) that is heated in an absence of oxygen environment. It is intended for agricultural use, and is typically applied as a soil ameliorative. Charcoal (lignite) is also a carbon-rich solid that is derived from biomass in a similar manner (Pentari et *al*, 2009). Activated carbon is a carbon-rich solid that is derived from biomass or other carbonaceous substances, using pyrolysis. A carbon material is also “activated” by processes that greatly increase the surface area of the material, allowing it to adsorb a larger quantity of molecules.

Important physicochemical properties of charcoal (lignite), activated carbon and biochar such as favourable pH, high water holding capacity, low bulk density, and in the most cases, the presence of substantial plant nutrients makes them potential soil ameliorant for immobilizing metals in contaminated soils (Klucakova & Pavlikova 2017).

In the present study soil amelioratives were applied at 2% application rate. Soil properties were measured (AOAC 1984) while pseudo-total concentration of metals was determined using the Aqua Regia (HCl-HNO3, 3:1) method (ISO/DIS 11466 1994). Furthermore, DTPA extraction method was used to evaluate the available soil fraction of metals studied and to investigate the change caused by the solids used. Two soil samples were chosen, an acid and an alkaline one, that have almost the same background metal levels.

In the following Figures 1 & 2 the concentrations of Cu, Cr, Zn and Ni in control soil and in the soil-amendments mixtures used, in acid (Figure 1) and alkaline (Figure 2) are presented

In acidic soil the changes were much more pronounced than in alkaline. This is probably due to the fact that the addition of solids caused an increase in soil reaction (Anwar et al, 2009). This results in reduced mobility and therefore the availability of minerals more in acidic and less in alkaline soils (Simmler *et al*, 2013).

In dead, the pot experiment conducted in the present study demonstrated that applying charcoal (lignite) significantly reduced available Cr (22,3%), Cu (37,5%), Ni (16,6 %) and Zn (28,5%), in contaminated acid soil, primarily through increased soil pH. The capacity of lignite and lignite-soil mixtures to sorb metals at various soil pH and metals loadings showed that over a pH range of 6 - 8, metals sorption by lignite was 1 - 2 orders of magnitude greater than in the control soil. This may be due to preferential binding of metals to organic sulphur in lignite along with their content in humic and fulvic acids (Pekar & Klucakova, 2008).

The addition of activated carbon and biochar have been shown to reveal a very high affinity and capacity for sorbing mostly Cu and Zn, both in acid and alkaline soils (O'Connor *et al*, 2018) Active charcoal has proven to be effective at reducing high concentrations of soluble Cu in contaminated soils. The formation of a different complex in the carbon phase can be hypothesized. Also, the formation of a metal hydroxide at the surface of carbon can be assumed. The high efficiency of biochar in reducing the solubility of Cu, Cr and Zn might be caused by its relatively high alkalinity and high organic matter content (Hagemann *et al*, 2018).

DTPA extractable metals concentration was decreased by Cr (32,3% and 23,8%), Cu (55% and 34,6%), Ni (25% and 16,6%) and Zn (52,8% and 40%) when biochar was applied in acid and alkaline soils respectively. The same reduction (not significant $p<0.01$) was also observed when activated carbon was used in the soil samples. In figures 1&2 a significant reduction of metals content was observed in the rate Cu>Zn>Cr>Ni, when the three amelioratives were studied. Biochar caused the greater reduction, along with activated carbon following by lignite application.

Therefore, biochar and activated carbon can both be considered as an efficient strategy to ameliorate the hazardous effects and to enhance the toxic results of the mobile metals. So they can be recommended for reducing the adverse environmental effects of heavy metals in moderately contaminated Greek soils.

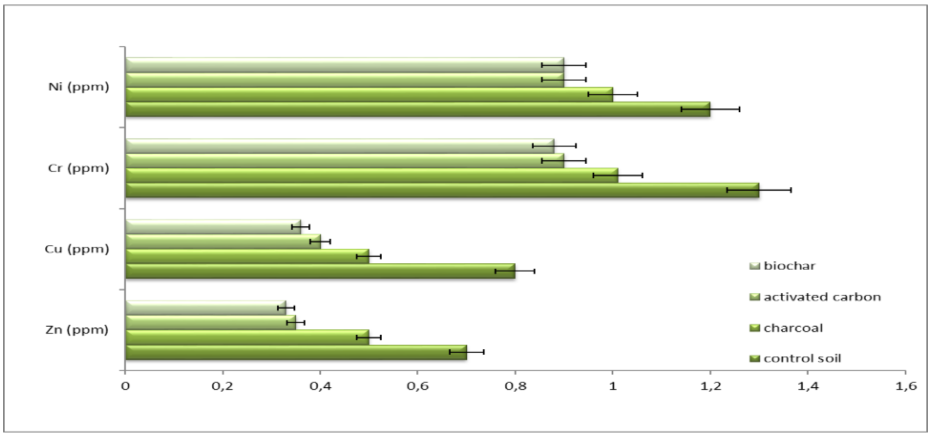

Figure 1. Available (DTPA extractable) metals concentrations (mg/kg dry soil) in an acid soil

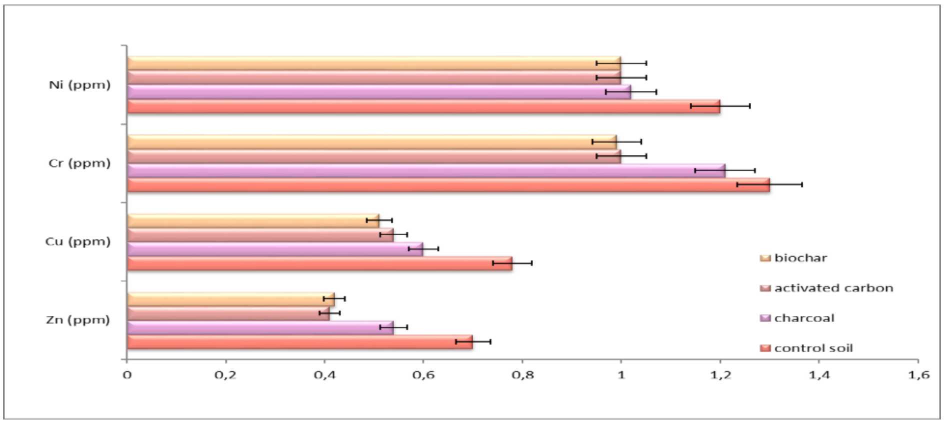

Figure 2. Available (DTPA extractable) metals concentrations (mg/kg dry soil) in an alkaline soil

The combination between solids used and their mixing ratio should be further investigated in order to achieve the maximum possible immobilization of potentially toxic elements and to minimize their adverse effects on the environment and humans.

REFERENCES

Anwar J., Shafique U., Salman M., Anzano J.M. 2009. Removal of chromium (III) by using coal as adsorbent. Journal of Hazardous Materials 171(1-3):797-801

AOAC (1984) Official method of analysis 14th Ed. Sidney Williams. Ass of official chemists, Inc. Virginia, USA

Břendová K., Zemanová V., Pavlíková D., Tlustoš P. 2016. Utilization of biochar and activated carbon to reduce Cd, Pb and Zn phytoavailability and phytotoxicity for plants. Journal of Environmental Management 181:637-645

Hagemann N., Spokas K., Schmidt H-P., Kägi R., Böhler M.A., Bucheli T.D. 2018. Activated Carbon, Biochar and Charcoal: Linkages and Synergies across Pyrogenic Carbon's ABCs. Water, 10, 182

ISO/DIS 11466 (1994) In Environment Soil Quality. ISO standards compendium, Switzerland

Klucakova M., Pavlikova M. 2017. Lignitic Humic Acids as Environmentally-Friendly Adsorbent for Heavy Metals. Journal of Chemistry 2017(3):1-5

O'Connor D., Peng T., Zhang J., Tsang D.C.W., Alessi D. S., Shen Z., Bolan N. S., Houa D. 2018. Biochar application for the remediation of heavy metal polluted land: A review of in situ field trials. Science of the Total Environment 619–620, 815–826

Pekar M., Klucakova M. 2008. Comparison of Copper Sorption on Lignite and on Soils of Different Types and Their Humic Acids. Environmental Engineering Science 25(8):1123-1128

Pentari D., Perdikatsis V., Katsimicha D., Kanaki A., 2009. Sorption properties of low calorific value Greek lignites: Removal of lead, cadmium, zinc and copper ions from aqueous solutions. Journal of Hazardous Materials 168(2-3):1017-21

Simmler M., Ciadamidaro L., Schulin R., Robinson B.H. 2013. Lignite Reduces the Solubility and Plant Uptake of Cadmium in Pasturelands. Environmental Science & Technology, 47(9)