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Ecotoxicological characteristic of a soil polluted by radioactive elements and heavy metals before and after its bioremediation

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Cinnamon soils from southeastern Bulgaria are heavily polluted with radionuclides (uranium, radium) and toxic heavy metals (copper and lead) due to the winds transportation of fine particles from flotation dumps to the soil surface. As a result of this, the polluted soils are characterized by a slightly alkaline pH (7.82) and positive net neutralization potential (+136.8 kg $CaCO_3$/t). A fresh sample of cinnamon soil was subjected to remediation under laboratory conditions in four lysimeters each containing 70 kg of soil. The preliminary study revealed that most of the pollutants were presented as carbonate, reducible and oxidisable mobility fractions, i.e. pollutants ions were specifically adsorbed by carbonate and ferric iron minerals or were capsulated in sulfides. The applied soil treatment was connected with leaching of the pollutants located mainly in the horizon A, their transportation through the soil profile as soluble forms, and their precipitation in the rich-in-clay subhorizon B3. The efficiency of leaching depended on the activity of the indigenous microflora and on the chemical processes connected with solubilization of pollutants and formation of stable complexes with some organic compounds, chloride and hydrocarbonate ions. These processes were considerably enhanced by adding hay to the horizon A and irrigating the soil with water solutions containing the above-mentioned ions and some nutrients. After 18 months of treatment, each of the soil profiles in the different lysimeters was divided into five sections reflecting the different soil layers. The soil in these sections was subjected to a detailed chemical analysis and the data obtained were compared with the relevant data obtained before the start of the experiment. The best leaching of pollutants from horizon A was measured in the variants where soil mulching was applied. For example, the best leaching of lead (54.5 %) was found in the variant combining this technique and irrigation with solutions containing only nutrients. The best leaching of uranium (66.3 %), radium (62.5 %), and copper (15.1 %) were measured in the variant in which the soil was subjected to mulching and irrigation with alkaline solutions containing hydocarbonate ions. Despite the higher removal of these pollutants from the soil, the acute soil toxicity towards earthworms (Lumbricus terrestris) was higher in comparison to the toxicity of soil that had been treated in the other variant. Furthermore, the highly alkaline soil pH (10.47) that was determined due to the applied alkaline leaching resulted in an acute soil toxicity to oats (Avena sativa) and clover (Trifolium repens) that was even higher in comparison to the toxicity of the non-treated soil. These data revealed that the soil detoxification was depended not only on the decrease of the total concentration and on the bioavailable forms of above-mentioned pollutants but also on the changes that had taken place in chemical and geotechnical properties of the treated soil.