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Bioremediation in situ of a soil polluted by radionuclides and heavy metals

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An experimental plot containing soil heavily polluted with radioactive elements (uranium, radium) and toxic heavy metals (copper, zinc, cadmium, lead) was subjected to in-situ treatment based on the activity of the indigenous soil microflora. The soil was characterized by a negative net neutralization potential and the soil pH was in the acidic pH range (from 3.5 to 5). The pollutants were located mainly in the upper soil layers (mainly in the horizon A) and were present mainly in forms susceptible to biological and/or chemical leaching. The treatment was connected with the dissolution of pollutants in the upper soil horizons and their transfer into the deeply located soil layers (mainly to the horizon $B_2$where they were immobilized as different insoluble compounds). The dissolution of pollutants was connected with the activity of both chemolithotrophic and heterotrophic aerobic microorganisms. This activity was enhanced by suitable changes in the levels of some essential environmental factors such as oxygen, water and nutrient contents in the upper soil layers. The transfer of the dissolved pollutants to the horizon B_2 was carried out by periodic irrigation of the soil with water acidified to pH about 3 - 3.5 with sulphuric acid. The immobilization of pollutants in the horizon $B_2$was a result of the activity of the anaerobic sulphate-reducing bacteria inhabiting this soil horizon. This activity was enhanced by injecting water solutions of dissolved organic compounds (mainly acetate and lactate) and ammonium phosphate through vertical pipes to the above-mentioned soil horizon.

It was found that within an 18-month experimental period most of the pollutants were removed from the horizon A and their residual concentrations were decreased below

the relevant permissible levels. The dissolved heavy metals were precipitated in the horizon B_2 as the relevant insoluble sulphides, and the dissolved uranium was precipitated in the same horizon mainly as uraninite (UO_2). The concentrations of pollutants in the effluents from the soil profile were lower than the relevant permissible levels.

Another plot of soil with the same extent of pollution was used as a control. The processes of natural attenuation in this plot were monitored for a period of about 5 years. There was a small decrease in the contents of the above-mentioned pollutants but their residual concentrations were still much higher than the relevant permissible levels.