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Mobile forms of metals bonded to soil particle-size fractions in a small erosional landform: concentrations and lateral distributions

Olga Samonova and Elena Aseyeva
Lomonosov Moscow State University, Faculty of Geography, Moscow, Russian Federation (aseyeva@mail.ru)

Small erosional landforms such as gullies and U-shaped dry valleys play a significant role in sediment transport within river basins and therefore attract much attention in studies of soil erosion. However, geochemical features of these systems related to overland flow of soil material have not been analyzed in detail yet. The present study focuses on the lateral distribution of relatively mobile forms of metals bonded to specific soil particle-size fractions. The study object is a monolithic (loamy) dry U-shaped valley ("balka" in Russian), located in the mixed forest zone of European Russia. In total 50 bulk samples of surface soil horizons were taken along the balka's three cross-sections and in longitudinal direction. Eleven samples were selected for physical separation into certain particle-size groups: 0.25-0.05mm (fine sand), 0.05-0.01mm (coarse silt), 0.01-0.001mm (medium and fine silt), and <0.001mm (clay). The separated solid phases were analyzed for total concentrations of Fe, Mn, Cu, Ni, Co, Cr, Zn, Pb and their mobile forms extracted by 1N HNO_3.
Across the studied particle-size fractions the clay showed the highest average concentrations of the metals' mobile forms, while the fine sand fraction on average was the most depleted in Cu, Zn, Pb, Co, Ni, and the coarse silt fraction in mobile Cr, Mn, Fe. The highest variations in metal concentrations were registered in the fine sand fraction (Fe – 85%, Mn – 83%, Zn – 62%) and in the medium and fine silt fraction (Co – 105%, Ni – 58%, Cr – 40%). The metal mobility (estimated as the ratio between the extracted metal concentration and its total content) tends to increase from the coarser to finer fractions. The clay fraction demonstrated the highest proportions of mobile Mn (126%), Pb (63%), Co (19%), Ni (14%), Cr (10%), however the mobility of Cu and Fe was at its highest in the medium and fine silt fraction (62% and 25%, respectively), while Zn mobility was at its maximum (36%) in the coarse silt fraction.
The analysis of the mobile forms' lateral distribution revealed that on the balka's slopes certain soil particle-size fractions were depleted in metals relative to the adjacent catchment area. Such trends were found for Cu in the fine sand fraction, for Fe in the medium and fine silt fraction, for Fe and Co in the clay. At the same time certain fractions separated from soils of these positions showed clear enrichment in Mn and Fe (the fine sand fraction), Mn, Zn, Pb (the coarse silt fraction), Co, Mn, Ni (the medium and fine silt fraction). Relative enrichment in mobile forms of metals was also registered in the balka's bottom (compared to the slope positions), mainly in the fine sand and the clay fractions. Along the bottom, in downslope direction, some elements showed a linear negative trend (Co in the medium and fine silt fraction, Zn and Cu in the clay). The positive trend manifested as concentration rise in downward direction was found only for mobile Fe and Mn in the medium and fine silt fraction.