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Distribution of metals in various particle-size fractions in topsoil of a gully system (European Russia, forest zone)

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Being depressions in a relief gullies often serve as locations for illegal dumping of hazardous substances, which may be mobilized, retained or recycled during the transport. In the present study we analyze concentrations and distributions of Fe, Ti and potentially hazardous trace elements in various grain-size fractions of a gully's topsoil and focus on examination of spatial variations and grain-size effect. The study object is located in the southern taiga zone of European Russia and represents a relatively young erosional landform, incised in Quaternary deposits. It has a simple rhomboid plan view and the length of about 200 m. Sampling of cross-sectional and longitudinal sequences of soils was performed. In total 25 samples of surface soil horizons were collected in different positions of the system including its internal (slopes, bottom, detrial fan) and external (watershed) units. The distributions of Fe, Ti, Mn, Cu, Ni, Co, Cr, Zn, Pb, Zr were analyzed in undifferentiated samples and in particle-size fractions: coarse and medium sand (1-0,25 mm), fine and very fine sand (0,25-0,05 mm), coarse silt (0,05-0,01 mm), medium and fine silt (0,01-0,001 mm) and clay (<0,001 mm).

The concentrations of the studied metals in total sample population vary differently in each particle-size fraction: for the majority of elements the variations are diminishing from coarser to finer fractions. Clearly defined relationship between fraction size and metal concentrations is typical of Ti and Zr. The highest levels of Ti are found in silt fractions, while concentrations of Zr show highest values in coarse silt and finer sand fraction. The concentrations of many elements (Mn, Co, Ni, Cr, Zn) are generally higher in clay fractions than in other fractions while the concentrations of Cu and Pb are higher in medium and fine silt.

The comparison between the samples collected in different landform positions revealed that soil material in the gully's bottom in all size fractions (except of clay) is enriched with Ti and Zr when compared to slope unit. Finer fractions (clay and silt) have statistically higher levels of Cu, Ni, Co, Fe but are characterized by lesser concentrations of Zn and Cr. Sandy fractions of the bottom unit have higher concentrations of the majority of elements. Such spatial differences between geochemistry of specific fractions in topsoil of the major system units – slopes and bottom – may be derived from geochemical transformation of soil particles during transport but also be a result of the landform incision into mineralogically different strata.

Elements' distributions in the longitudinal sequence of soils in the bottom unit have revealed some linear trends. Major changes in geochemical composition take place in sand fractions: there is a downward decrease of Mn, Pb, Co concentrations in coarse and medium sand and Mn, Co, Ni, Zr in fine sand. The content of Pb in silt fractions is decreasing as well. Such spatial patterns imply that the longitudinal transport of sediments may result in general losses of elements and the most prominent geochemical transformation takes place mainly in coarser fractions.