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Contamination of soils with heavy metals and metalloids in the vicinity of the Erdenet copper-molybdenum mining area in Mongolia

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The present study was conducted to assess soil contamination taking place in Erdenet, the Mongolian city with a gigantic ore-mining and ore-dressing complex that was founded mainly to exploit the area's huge deposits of copper and molybdenum ore. The objectives of the study were: (1) to determine the content of heavy metals and metalloids (HMs) in soils of background and urban landscapes and to evaluate environmental hazard of HMs pollution; (2) to compile geochemical maps and to define zones with anomalously high concentrations of toxic elements in the city, (3) to identify spatial patterns and leading factors of pollutant accumulation.

Sampling was performed in 2011 using regular spacing of 500-700m. In total 225 samples were collected from surface soil horizons (0 – 10 cm) in different functional areas of the city and in the background area located 5-6km from the city. The sampling scheme in background area took into account the topography and geological heterogeneity of the study area. The bulk contents of HMs in soil samples were analyzed by mass spectrometry and inductively coupled mass spectrometry (ICP-MS).

Background concentrations of HMs were estimated for several soil groups formed on specific parent rocks and were compared with their global abundances in soils. The pollution of urban soils was evaluated using background soils as reference objects. Associations of HMs were identified according to the enrichment factor (EF) values and using cluster analysis with complete linkage algorithm. Visualization of soil-geochemical data was performed by local interpolation or kriging method in MapInfo 11.5 and Surfer 11. Multiple regression analysis (decision trees method) was applied to determine soil properties and landscape factors that may control HMs accumulation in soils.

Background soils formed on granite and granodiorite of Permian-Selenga complex occupy the largest area and are characterized by high concentrations of V, Cr, Co, Ni, Zn, Sr, Cu, Zn, Mo and W. The lowest concentrations of the elements are typical of soils formed on triassic volcanic suite and sub-volcanic intrusions. Urban soils are heavily polluted in industrial zone, where accumulation of Mo (EF=10.7) and Cu (10.6) are the highest among other elements (Se, As, Sb, W, EF=2.4-1.5). The mining area and the landscapes in its immediate vicinity are characterized by high and dangerous level of multi-elemental contamination while the most part of the urban territory has low level of contamination. Soils in all functional zones, with the exception of the ger district, have elevated concentrations of Mo, Cu and Se.

Three geochemical associations W-Bi-Cd-Sn-Zn-Pb; Cu-As-Sb-Mo and V-Co-Sr-Cr-Ni have been identified in urban soils. The maximum concentrations of the elements in the first two groups are typical of the disturbed soils adjacent to the plant and tailings area (EFs for individual elements range from1.4 to1080). Statistical analysis revealed that such soil characteristics as grain-size distribution, pH, humus content have a direct impact on HMs fixation in urban soils while the influence of landscape factors (topography, lithology, functional assignment) is not so evident.