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ASSESSMENT OF THE ECOLOGICAL STATUS AND TECHNOGENIC CONTAMINATION OF UZHHOROD URBAN SOILS WITH MOBILE FORMS OF HEAVY METALS

ONYSHCHUK Iryna[1], https://orcid.org/0000-0002-2847-8570
KYCHKYRUK Olga[1], https://orcid.org/0000-0002-0558-16
BODNARIUK Ruslana[2], https://orcid.org/0009-0003-5923-2009
VAKERYCH Mykhailo[2,3,*], https://orcid.org/0000-0002-3268-7797
HASYNETS Yaroslava[2], https://orcid.org/0000-0003-4325-4695
SCHWARTAU Victor[4], https://orcid.org/0000-0001-7402-5559

[1]Zhytomyr Ivan Franko State University, Zhytomyr, Ukraine
[2]Uzhgorod National University, Uzhhorod, Ukraine
[3]Transcarpathian Research Expert and Forensic Center of the Ministry of Internal Affairs of Ukraine, Uzhgorod, Ukraine
[4]Institute of Plant Physiology and Genetics of the National Academy of Sciences of Ukraine, Kyiv, Ukraine,
**Corresponding e-mail: mykhailo.vakerich@uzhnu.edu.ua*

The rapid expansion of urban ecosystems and the intensification of automobile traffic flows exert a significant anthropogenic load on the biosphere. In this context, the soil cover of residential and traffic areas (urbanozems) functions as a sink/deposition medium and a reliable indicator of the urban environmental status. Mobile (bioavailable) compounds of heavy metals pose the greatest ecological and toxicological threat, as they are readily accessible to plant organisms, capable of migrating through adjacent links of trophic chains, and characterized by pronounced phytotoxicity.

A geochemical assessment of the scale of technogenic transformation of soils in Uzhhorod was carried out by monitoring the concentrations of mobile forms of iron (Fe), copper (Cu), lead (Pb), cadmium (Cd), manganese (Mn), nickel (Ni), and zinc (Zn). Primary material sampling was performed within two functionally contrasting locations: a relatively pristine recreational zone (the territory of the Botanical Garden) and areas with high traffic density (Sobranetska, Zankovetskoi, and Mynaiska Streets, Mytna Square, and Svobody Avenue).

Mobile metal complexes were extracted from the substrate using a conventional extraction method with an acetate-ammonium buffer solution at a fixed pH of 4,8/5,0.

Quantitative analysis of the obtained extracts was performed using atomic absorption spectrometry. Final concentrations were calculated in mg/kg of dry weight (applying a transformation factor of 10), and the resulting datasets were verified against the current maximum permissible concentrations (MPCs) mandated in Ukraine.

The study revealed a clear spatial differentiation in ecotoxicant distribution, determined by the specific land use and traffic volume of urban areas. The most critical environmental trend was identified for mobile compounds of cadmium and nickel: their content in the substrates of the traffic-urbanized sector consistently exceeds the sanitary limits by 2.0–3.6 and 2.1–3.0 times, respectively. Peak cadmium concentrations are confined to zones of chronic traffic congestion and heavy vehicle movement (the transit border zone of Mytna Square), whereas nickel accumulation exhibits an exclusively technogenic origin driven by diesel engine emissions. Local hotspots of excessive zinc accumulation were also recorded along major highways, triggered by the wear of vehicle tires and the corrosion of galvanized elements of urban infrastructure.

Conversely, the distribution of mobile copper forms is diffuse and stable throughout the residential area, remaining within the regional geochemical background, which indicates the absence of local industrial sources of Cu emission. Lead levels at most urban monitoring sites balance on the brink of the threshold; however, a pronounced local anomaly (exceeding the MPC by 1.8 times) was identified in an isolated section of the Botanical Garden. This localized spike correlates with a massive increase in mobile iron content and high manganese mobility.

The nature of this anomaly within the recreational site is natural-anthropogenic and can be attributed to the lithological heterogeneity of the substrate (likely historical localized waste dumping), local profile acidification under mature stands, and the hydrological regime of the site, which stimulates reductive processes and element mobilization.

Thus, the urbanozems of the traffic and residential zones of Uzhhorod experience intense multi-element pressure from the transport infrastructure. Chronic excess of mobile cadmium and nickel forms on all studied streets represents a key ecological risk for the urban environment. Although the ecosystem of the Botanical Garden generally functions as a protective bio-barrier, the identified micro-hotspots of high iron and lead concentrations dictate the need for detailed micro-zonal studies to verify the acid-base properties (pH) and particle-size distribution of the substrates.

Keywords: urban soils, mobile forms of heavy metals, soil contamination, atomic absorption spectrometry