ABSTRACT: ***Quantifying magnetic properties of soils to evaluate sustainable hazards from heavy metal pollution due to military activities in Ukraine***

On 24 February 2022, Russia invaded Ukraine in a major escalation of the Russo-Ukrainian War. As massive strikes and a large ground invasion were launched, Russian forces constantly bombed both military and civilian targets far from the front line, including electrical and water infrastructure. By late 2022, Ukraine retook territories in the north, and partially in the south-east. Large areas in Ukraine undergo missile attacks and artillery shelling. Weapon residues and small size particulate matter in Ukrainian cities, rural areas and agricultural lands are sources of lead (Pb; leaded ammunition), copper (Cu; unleaded), and depleted uranium. As a consequence, military activity results in soil contamination with Pb and Cu, as well as other heavy metals (HM) with subsequent metal translocation to water, thus increasing the risk of human exposure. Thus, military activity contributes to environmental pollution, which needs to be properly assessed. We propose to use the magnetic method as a tool for quantification of soil pollution with military-related HM emissions. An increasing body of literature discusses topsoil magnetic measurements used as a proxy for HMs pollution from industrial and urban sources. Hopefully, magnetic methods could be applied in areas of battle fields, small-arm shooting ranges, artillery, mortar and rocket ranges, and grenade courts. The goal of the project is to elaborate novel strategies for the assessment of military-related soil pollution, based on a combination of magnetic and geochemical methods and represented in geoinformation models of polluted regions. The action plan includes in-situ magnetometer surveys and magnetic susceptibility mapping, soil sampling and laboratory magnetic and geochemical measurements. Polluted soils and surface deposits will be studied comparatively to unpolluted ones at the areas affected by the war in Ukraine. Field measurements and sampling will be performed within 2 types of polygons: 1) agricultural lands at the recaptured regions, used to be massively shelled (outskirts of Balakliia town in Kharkiv region, outskirts of Borodianka town in Kyiv region); 2) cities, experienced numerous artillery attacks (Kharkiv, Chernihiv, Zaporizhzhya, Mykolaiv). High-resolution magnetic survey will be performed to outline zones of shelling recognized by anomalies at hit sites and ‘spike’ anomalies sourced by iron pieces. Filed magnetic susceptibility mapping aims to quantify iron emissions deposited in the topsoil. Soil samples will be collected from metallic iron-enriched and pure zones. Magnetic parameters will be measured on soil samples for evaluation of concentration of magnetic matter and its identification. Elemental analysis will be performed on limited number of samples using inductively coupled plasma activation source in the laboratory. Morphology and qualitative elemental composition of single particles will be examined through scanning electron microscopy supplemented by analysis of chemical composition using energy-dispersive X-ray spectroscopy. We will assess by geoinformation modelling of spatial distribution of military-related pollution. Maps of heavy metal contents in the topsoil will be created based on proved reliable correlations between HM and magnetic parameters. The application of the results to the environmental pollution assessment, military hazard evaluation and quantification of soil degradation will accelerate the development of Ukraine's post-war recovery strategy.