The impact of rocket attacks in the Lviv region on sustainable development and statistical forecasts of environmental consequences

Kateryna Petrushka[1], Ihor Petrushka[2]

1. Department of Ecology and Sustainable Environmental Management, Lviv Polytechnic National University, UKRAINE, Lviv, 12 S. Bandera Street, 12, E-mail: Kateryna.I.Petrushka@lpnu.ua

2. Department of Ecological Safety and Nature Protection Activity, Lviv Polytechnic National University, UKRAINE, Lviv,12 S. Bandera Street, E-mail: Ihor.M.Petrushka@lpnu.ua

Abstract – The considers assessment of concentrations and potential environmental risk of heavy metals in urban soils affected by terrorist attacks in the city of Lviv. The soil samples taken by the concentric circles method were analyzed by X-ray fluorescence analyzer Expert-3L.The main studied elements were Cd, Cr, Cu, Ni, Pb, and Zn.

Keywords – soil, heavy metals, environmental risks, Pearson coefficient.

Introduction

Recent military operations in Ukraine have made our country one of the countries most polluted by ammunition in the world. The aggressor (the russian federation) has already caused and continues to cause enormous damage to the population and infrastructure of settlements where hostilities continue. But war also affects the environment. It is currently impossible to fully assess the impact of military and terrorist actions on the environment due to the lack of accurate information. However, it is well known that during the detonation of rockets and artillery shells, a number of chemical compounds are formed: carbon monoxide (CO), carbon dioxide (CO_2), water vapor (H_2O), brown gas (NO), nitrous oxide (N_2O), nitrogen dioxide NO_2), formaldehyde (CH_2O), cyanic acid vapors (HCN), nitrogen (N_2), as well as a large number of toxic organic substances that oxidize surrounding soils, wood, peat, and buildings. Metal fragments of projectiles that fall into the environment are also not safe and are completely inert. Cast iron with steel admixtures is the most common material for ammunition production and contains not only standard iron and carbon, but also sulfur and copper. These substances enter the soil and can migrate to groundwater and, as a result, enter the food chain, affecting both animals and humans. On a smaller scale (but with a greater variety of impacts), the source of pollution is also defused military equipment, aircraft, and other remnants of hostilities. Despite the fact that explosive devices that did not explode during shelling are dangerous, they enter into a chemical reaction with other elements, which leads to contamination of the soil, and therefore - groundwater, the atmosphere. These substances enter the soil and can migrate to groundwater and, as a result, enter the food chain, affecting both animals and humans.

Results and discussion

Statistical values were evaluated using one-way analysis of variance (STATISTICA) to test whether there was a significant difference between samples in blast locations. The Pearson Correlation Index (PCI) was used to determine the amount and manner of association between heavy metals in sediments and their possible sources. Similarity between heavy metal levels was determined using cluster analysis (CA) [1], [2]. Principal component analysis (PCA) was performed to reduce the data sets and find new factors. SPSS 22 software was used to perform all these statistical analyses. Descriptive statistics of selected heavy metal datasets for soil samples are shown in Table 1. A high standard deviation reflects a skewed distribution and a high degree of variation. For Cd, Cr, Cu and Zn, the concentrations were not normally distributed, showing a skewed distribution. Therefore, for these items, medians were used instead of means, as they would describe such distributions more accurately. The order of occurrence of heavy metals measured in the studied soils follows the sequence Zn>Pb>Ni>Cu>Cr>Cd>Ti. All measured metals except Cr show higher concentrations than the calculated world average value for uncontaminated soils.

Table 1

Basic statistical data on the concentration of heavy metals in the soil (mg/kg)

Element	Minimum	Maximum	Mean	Median of ranked series	Error	Mean value of uncontaminated soils
Cd	5.6	29.38	18.77	-0.93	±1.23	0.53
Cr	9.8	39.2	33.02	-0.88	±31.23	83
Cu	20.86	126.5	59.57	0.79	±14.33	24
Ni	9.8	34.8	16.65	-0.43	±31.65	34
Pb	9,8	59,7	34.42	0,35	±41.28	44
Zn	37.29	140.45	111.16	0.76	±35.93	100
Ti	7.4	37.3	22.46	0.86	±12.53	5.7

The obtained data of the statistical analysis regarding the Pearson coefficient are shown in Table 2. The correlation coefficient takes values from −1 to 1. A value of +1 means that the relationship between X and Y is linear, and all points of the function lie on a straight line that represents the increase in Y as X increases. A value of −1 means that all points lie on a straight line that reflects the decrease of Y with the increase of X. If the Pearson correlation coefficient 0, then there is no linear correlation between the variables. Different authors [3], [4] offer other approaches to the interpretation of the value of the correlation coefficient. At the same time, all criteria are somewhat conditional and should not be interpreted too meticulously [4]. The interpretation of correlation depends on the context and purpose. For example, a correlation coefficient of 0.9 may be very low in the case of studying the laws of physics using high-end equipment, but may be interpreted as very high in the humanities, where many other factors are involved.

Table 2

Interpretations of the value of the Pearson correlation coefficient

Correlation	Negative	Positive
None	−0.09 to 0.0	0,0 to 0.09
Low	−0.3 to −0.1	0,1 to 0.3
Medium	−0.5 to −0.3	0,3 to 0.5
High	−1.0 to −0.5	0,5 to 1.0

Analyzing the values of the Pearson coefficient, we can claim a significant anthropogenic impact on the environment of such metals as lead in the presence of all the listed metals except cadmium in relation to lead (Cd=-0.37); cadmium in relation to copper (Cu=-0.11); copper in relation to cadmium (Cd=-0.11); zinc relative to cadmium (Cd=-0.56); chromium in relation to cadmium (Cd=-0.32) and titanium in relation to copper (Cu=-0.34). Taking into account the phenomenon of synergism of the studied elements, it is possible to predict the strengthening of the toxic effect of heavy metals on the environment, in particular, taking into account the value of the Pearson coefficient, this applies primarily to Pb, Zn, Cr and Ti in Fig. 1.

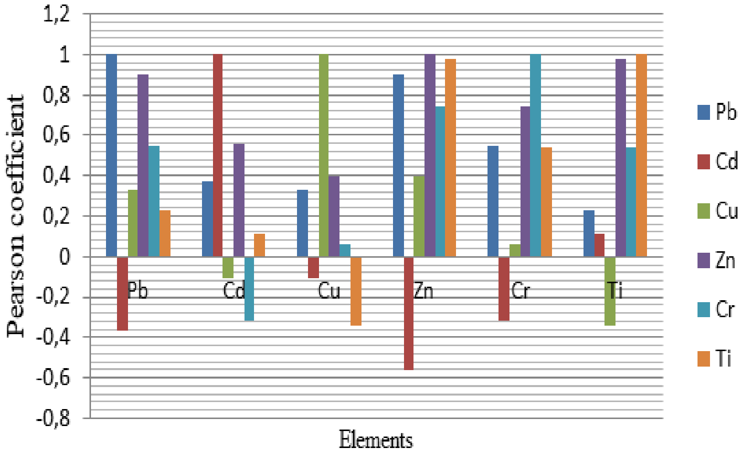

Fig.1. The value of the Pearson coefficients of the studied soil elements.

The foci of soil contamination with heavy metals after the rocket attacks on Lviv in 2022 indicate a significant level of danger not only in the current period and will affect future generations. That significantly changes the postulates of sustainable development of the entire society. All of the listed elements affect the environment.

Conclusions

Based on the obtained data, taking into account the value of the ecological risk index of each of the elements, the value of the comprehensive assessment of the level of soil pollution based on the Nemerov index (Ps=48.64 – a very high level of pollution) exceeds the value of Ps>3 by 15 times. The highest environmental risk factor (Er) is created by cadmium (Cd). The investigated elements in relation to the environmental risk factor can be arranged in the following sequence: Cd>Cu>Pb>Ni>Zn>Cr>Ti. That is, we can claim that all the detected elements in the soil create a significant and very high level of soil pollution in the places of rocket attacks. For Cd (very high contamination), which significantly exceeds the values given in the classification, it was found at the explosion site on the surface of the crater. Using the minimum values of potential environmental risk (Ri), only two elements have a low coefficient of potential environmental risk (Ri<40) – titanium and chromium. All other investigated elements have significant and very high environmental risk potential.

References

[1] Lee, C.S., Li, X., Shi, W., Cheung, S.C., & Thornton, I. (2006). Metal Contamination in Urban, Suburban, and Country Park Soils of Hong Kong: A Study Based on GIS and Multivariate Statistics, *Science of the Total Environment*, *356*, 45-61. DOI: 10.1016/j.scitotenv.2005.03.024

[2] Hameed, A.M., Obaidy, J. Al, Athmar, A. M., & Mashhadi, Al. (2013). Heavy Metal Contaminations in Urban Soil within Baghdad City, Iraq, *Journal of Environmental Protection*, *4*(1), 72-82. DOI: 10.4236/jep.2013.41008

[3] Chakraborty, R., Zaman, S., Mukhopadhyay, N., Banerjee, K., & Mitra, A. (2009). Seasonal Variation of Zn, Cu and Pb in the Estuarine Stretch of West Bengal, Indian. *Journal of Marine Science*, *38*(1), 104-109.

[4] Smith, D.G. (1986). Heavy Metals in the New Zealand Aquatic Environment: A Review, Water Quality Centre, Ministry of Works and Development, Wellington, New Zealand.