https://doi.org/10.26565/2410-7360-2022-57-23
UDC 502.5:614
Received 5 September 2022
Accepted 12 November 2022

Environmental assessment of soil contamination by trace metals

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ABSTRACT

The main purpose. The purpose of this research is to develop a method for determining the level of heavy metal contamination in the soil. For this end, the following tasks are set:
- to develop a method for the integrated assessment of heavy metal contamination in the soil at the regional and local levels;
- to identify the most heavy metal contaminated regions of Ukraine;
- to estimate the level of hazard of heavy metal contamination in the soil for territories with different types of land use;
- to assess the pollution of soils with heavy metals as a result of hostilities in Donetsk and Luhansk regions.

Methodology. The method takes into account the soil morphology, genezises, trace metals background concentrations and based on the development of the self-purification index for various soils in different regions of Ukraine. According to the proposed method soils have been classified by trace metals contamination.

Results. At the local level, trace metals in soils were assessed for urban recreational areas, highways and roads, landfills and industrial zones. The soils in recreational areas were classified as ‘good’, highways and roads are classified as ‘satisfactory’ and ‘poor’, industrial and landfill was classified as ‘very poor’ according to the trace metals contamination. At the regional level, the highest contamination Class was given to the soils of Donetsk and Luhansk regions due to the highest density of industrial areas and performed military activities. The environmental assessment of trace metals contamination in soils due to the military activity was performed for these regions. The results of trace metals determination in Kharkiv according to this method indicate that the most dangerous areas are domestic waste landfills and facilities of the industrial companies. Recreation zones are ranked in Class 2. and the territory near the highways are assessed in quality Class 2 and 3. Assessment of the hazard level of trace metal contamination in the soil by the proposed method will allow making a scientifically substantiated decision on the priority of implementation of environmental measures.

Scientific novelty. The paper presents a new method of assessing soil contamination with heavy metals at the regional and local level. The advantage of this method is taking into account the hazard class of pollutants and the self-cleaning index. A new classification of the level of danger of soil contamination with heavy metals has been developed.

Practical significance. The use of the proposed methodological approach will contribute to obtaining comparable data when assessing the level of soil contamination by heavy metals and determining the priority of implementing environmental protection measures and increasing the level of environmental safety, which is especially relevant for the post-war recovery of our country.

Keywords*: soil contamination; trace metals; environmental assessment; military actions.*

In cites: Rybalova Olha, Korobkova Hanna, Chynchyk Oleksandr, Stryzhak Tatyana, Bondar Oleksandr (2022). Environmental assessment of soil contamination by trace metals. Visnyk of V. N. Karazin Kharkiv National University, series "Geology. Geography. Ecology", (57), 307-320. https://doi.org/10.26565/2410-7360-2022-57-23

1. Introduction

With the development of modern urbanization and industrialization, environmental pollution with trace metals is identified as one of the main concerns in modern society. Intensification of agricultural land use, development of industrial production, accumulation of industrial and domestic wastes has led to trace metal contamination in the soil. Concentrations of metals in the soil grow at an alarming pace and affect plant growth, development of soil microflora, food safety and public health. Toxicity of metals has direct consequences for flora, which is an integral part of ecosystems. Biochemical, physiological and metabolic processes are changing in plants that grow in regions with high levels of metal contamination. The accumulation of trace metals can lead to significant toxic effects on the components of the environment and human health. That is why the method for assessing trace metal contamination in the soil, presented in this paper, is an urgent task for determining the level of environmental hazard and developing appropriate environmental protection measures.

2. Analysis of Reference Data and Problem Statement

The soil pollution by trace metals is determined as main economic and environmental concerns for sustainable development due to the growing urban, agricultural and industrial activities worldwide (Rodríguez-Eugenio, N., McLaughlin, M., Pennock, D., 2018). Agricultural land uses (by fertilizing) development of industrial production which implies accumulation of industrial and domestic wastes have led to trace metals contamination in the soils of developing and developed countries (Ogundele L. T. et al., 2019, Sodango T. H. et al., 2018, Tchounwou P. B. et al., 2014). High concentrations of metals were found in many industrial big cities, clearly indicating a significant contribution from both the metallurgical industry and smelt mining to the contamination of urban soils. (Cheng H. et al., 2014.).

High contamination of soils by trace metals influence plant growth, soil environment, food safety and public health (Zhang X. et al., 2015, Zwolak A. et al., 2019.). Studies in many regions worldwide showed that biochemical, physiological and metabolic processes are changing in plants growing in regions with high levels of metal contamination (Rodríguez-Eugenio N. et al., 2018). Studies indicated that trace metal contamination negatively affects the activity of soil enzymes by reducing the content of chlorophyll (Marchand L. et al., 2014) and the microbial population of the soil (Aoyama M., Tanaka R. 2013). Microorganisms play a key role in maintaining soil fertility and involved in all aspects of N cycling, including N2 fixation, nitrification, denitrification and ammonification. (Rashid M. I. et al., 2016, Vystavna Y. et al., 2017). Many microbial ecology studies have demonstrated profound changes in community composition caused by environmental pollution (Azarbad H. et al., 2016). However. their number can decrease significantly when exposed to stress factors such as extreme temperatures, pH, salinity and presence of some chemicals, including trace metals (Aljerf L. et al., 2018). The viability of microorganisms decreases with increasing levels of trace metal contamination. Research of scientists (Alengebawy A. et al., 2021) is showed that trace metal pollution of the soil has a significant impact on the structure of the microbial community.

Concentrations of trace metals and the degree of oxidation significantly affect the genotoxic reactions of plants. In the article (Patnaik A.R et al. 2013) inhibition of root growth with Cr (VI) was correlated with the dose-dependent increase in generation of reactive oxygen species (ROS), cell death, lipid peroxidation, repression of antioxidative enzymes (catalase, superoxide dismutase, ascorbate peroxidase), induction of DNA damage, chromosome aberrations or micronuclei in root cells. Additionally, soil contamination is co-responsible of the trace metals accumulation in crops and groundwater pollution posing environmental and health risks (Mominul I. M., et al. 2018). For example, it is dangerous to grow agricultural products in areas contaminated with tracetrace metals. (Kumar P. et al., 2019). Trace metal toxicity has direct consequences for flora by dissimilars mechanims affecting physiological, biochemical and metabolic (Chibuike, G. U., Obiora S. C. (2014). The accumulation of trace metals leads to significant toxic effects on environmental components and human health has been reported (Li, C., Zhou, et al. (2019). The author claims that the concentration of trace metals in the surface horizons of the soils of pine forests increases several times and exceeds the background values as a result of the mineralization of the forest litter from the burning of grassy vegetation. Trace metals are also transmitted via the food chain over a period of time. Trace metals (Rehman A., Nazir S., Irshad R. et al. 2021). Research works (Niassy S., Diarra K. 2012, Sulaiman, F.R., Hamzah, H.A., 2018) are found that the accumulation of cadmium in plants is special meaning. since it settles in high concentration on the leaves, which can be used to feed animals or people. Among anthropogenic activities, the highest trace metals contamination of soils occurs due to expanded use of agrochemicals (Malik Z. et al., 2017, Vystavna Y. et al. 2014), dispersion or spread of sewage sludge, organic waste, manure, industrial waste, irrigation by sewage water or used ones (Sharma B. et al., 2017, Srivastava. V. et al. 2016, Tóth. G. et al. 2016). Moreover, atmospheric emissions from fuels burning or issued from industrial processes participate to the phenomena (Masindi V., 2018). Another soil contamination sources can be generated by various accidences and military activities (Clausen J. et al. 2004). Conflit areas are concerned for different reasons.

Papers (Pospelov B. et al., 2018, Tiutiunyk. V.Vet al. 2018) proposed a systematic approach to assess the readiness of civil defense to action in emergencies. Authors have also developed measures to eliminate fires or reduce their impact on the environment (Andronov V et al., 2017, Dubinin. D. et al., 2017, Dubinin D. et al. 2018). However, the Ukrainian state authorities do not have the capacity to carry out fire and environmental measures in the occupied territories of Donetsk and Luhansk regions.

The soil contamination with trace metals in Ukrainian regions has been reported in national environmental reports (Ukraine Country Environmental Analysis, 2016) and scientific papers (Voitiuk Yu. et al. 2014).

Military actions could lead to pollution of the environment, destruction of landscapes, reduction of biodiversity and emergency incidents at industrial enterprises and infrastructural facilities. The environmental consequences of military conflicts in the former Yugoslavia, Afghanistan and the Middle East are studied in the paper (Global Report on Internal Displacement, 2022) under the United Nations Environment Program (UNEP). The impact of military conflicts in Georgia, Syria and Iraq on the state of the environment was also explored. The main danger in circumstances of the conflict was the feasibility of environmental pollution due to accidents and serious disruptions of industrial and other enterprises in the region.

There were located about 4500 potentially hazardous industrial facilities in Donetsk and Luhansk regions by the beginning of the conflict in parts of eastern Ukraine. According to the OSCE in the period from 2014 to 2017, more than 500 emergency incidents have been recorded in this region (Environmental Assessment…, 2017). Because of hostilities, the construction of fortifications, explosions and the burning of ammunition, the surface soil is disturbed, the using of damaged lands because of hostilities will be hampered by the need of their remediation, mine clearance and destruction of ammunition.

In part of the territory of Donetsk and Lugansk regions that are still not controlled by the Ukrainian government, ecological monitoring is not carried out and there is no reliable information about damage to industrial enterprises, housing and communal services and infrastructure facilities. Therefore, the analysis of the impact of hostilities on the state of the environment in the Donetsk and Lugansk regions was carried out on the basis of the materials of the OSCE projects in Ukraine presented in the works (Environmental Assessment…, 2017, Dubinin D. et al, 2018, Global Report on Internal Displacement, 2022).

Likewise, within the framework of the project "Environmental Assessment and Recovery Priorities for Eastern Ukraine" carried out by the OSCE Project Coordinator in Ukraine with the financial support of the Governments of Canada and Australia, in collaboration with the Zoï Environment Network (Switzerland), materials for desk and field studies were presented (Environmental Assessment …, 2017). This material is presented the only monitoring research of the occupied territory in the public domain, where showed the concentration of pollutants and the corresponding background values. Other studies of soil contamination in a conflict zone are presened in (Rashid M. I. et al., 2016, Vasenko O.G. et al. 2015). There noted that the chemical substances, which ended up in the soil, are very dispersed, which will contribute to their quick distribution, namely, into ground waters and from there — into surface waters.

An analysis of modern methodological approaches to determining the hazard level of trace metal contamination in the soil shows the relevance of the research presented in this paper.

3. The Method of Determining the Hazard Level of Trace Metal Contamination in the Soil

3.1. The Method of Integrated Assessment of Trace Metal Contamination in the Soil at the Regional and Local Levels

Determination of the hazard level of soil contamination is an important task which, according to the methodological guidelines in the paper (Methodical Instruction No. MU-4266-87), is solved by estimating the total index of soil chemical pollution (*Zc*) by the formula (Methodical Instruction No. MU-4266-87):

$$Z_c = \sum_{j=1}^{n} K_c - (n-1) \qquad (1)$$

where n is an- amount of pollutants;

Kc is a coefficient of concentration of pollutants, which is determined by the formula (Methodical Instruction No. MU-4266-87):

$$K_c = \frac{C_i}{C_{bi}} \qquad (2)$$

where *Ci* is the concentration of the i-th pollutant in the soil, mg/kg;

Cbi is the background concentration of the i-th pollutant in the soil, mg/kg.

This method for assessing chemical contamination in the soil by *Zc* is widely used by experts in Ukraine and Russia.

The advantages of this method include the fact that the multiplicity of the excess of the background concentration is determined, but it is not clear why to deduct the amount of pollutants from the sum of coefficients of the concentration of chemical elements in the formula (1).

The content of trace metals in the soil is influenced by both anthropogenic and natural factors, including features of soil formation processes, soil genesis, landscape and geographical factors. Therefore, at the local level, it is required to determine the level of trace metal contamination in the soil against background concentrations. At the regional level, it is almost impossible to accomplish, due to a large number of soil with different characteristics. In addition, official information on the content of trace metals in the soil is submitted in multiplicity of excess of MACs.

The gap in the integrated assessment of the chemical soil contamination presented in the methodology guidelines (Methodical Instruction No.MU-4266-87, 1987) is a lack of consideration of the substances hazard class. This paper (Rybalova O.V., Korobkina K.M. 2017), proposes to assess the level of chemical contamination of soil, taking into account the hazard class of substances, but limiting it to the substances excessing the background concentration, to calculate the integral soil contamination pollution index (IS).

We believe that to assess the level of trace metal contamination in the soil, all pollutants need to be integrated with due regard to the hazard class and the self-purification index.

We propose to determine the index of soil contamination by trace metals (ISHM) by the formula:

$$ISHM = IHMC \times SSPI \qquad (3)$$

where ISHM is an indicator of soil contamination by trace metals, a dimensionless value;

IHMC is an index of trace metal content, a dimensionless value;

SSPI is a soil self-purification index, a dimensionless value.

At the local level, the index of trace metal content (IHMC) is determined by the formula:

$$IHMC = \sum_n j \times \frac{C_i}{C_{bi}}, \qquad (4)$$

where j is a coefficient taking into account the substance hazard class: for Grade 1 the value is 2,35; for Grade 2 the value is 1,28; for Grade 3 the value is 1; for other substances this value is 0.87.

At the regional level, the index of trace metal content (IHMC) is determined by the formula:

$$IHMC = \sum_n j \times \frac{C_i}{C_{MPCi}}, \qquad (5)$$

where C_{MPCi} is the maximum permissible concentration (MPC) of the i-th pollutant in the soil, mg/kg.

We suggest to determine the level of trace metal contamination in the soil as shown in table. 1.

The method of the integrated assessment of the qualitative state of soils, presented in this paper, is intended for use in determining the hazard level of trace metal contamination in the soil.

The method of the integrated assessment of the qualitative state of soils, presented in this paper, is intended for use in determining the hazard level of trace metal contamination in the soil and provides the opportunity to apply software for automated calculation of trace metal contamination in the soil (ISHM) and determination of the priority of implementation of environmental measures.

Table 1

Characteristics of heavy metal contamination in the soil

Index (ISHM)	Quality Grade	Soil State
< 5	1	High
5.1 – 10	2	Good
10.1 – 15	3	Moderate
15.1 – 20	4	Poor
> 20	5	Bad

4. Results of Assessment of the Hazard Level of Trace Metal Contamination in the Soil

4.1. Integral Assessment of Trace Metal Contamination in the Soil at the Regional Level

Data on the soil quality is provided in the National Report on the State of the Environment in Ukraine (National Report…, 2017; Malik Z. et al. 2017), regional reports and environmental passports of the regions. According to the formulas (3) and (5), based on official monitoring data, an indicator of soils contamination by trace metals (ISHM) has been determined. The results of assessing the current state of trace metal contamination in the soils of Ukraine are given in Fig. 1.

Calculations have shown that the most contaminated territories are large industrial centers: Donetsk, Dnipropetrovsk, Zaporizhzhia and Luhansk regions (Fig. 2). Such figures are predetermined by the large number of environmentally hazardous industrial companies located in these industrial regions.

4.2. Integral Assessment of Trace Metal Contamination in the Soil at the Local Level for Different Types of Land Use

To determine the hazard level of trace metal contamination, soil samples were collected at four locations of the recreational zones of Kharkiv, three different locations along the highways, near the municipal waste landfill and the territory of the industrial company.

Sampling locations are shown on fig. 2. Samples were collected from surface layer of soil in 10 points across each sampling location. Then point samples were mixed on sampling place and 500 g of sample were taken to laboratory. After hominization procedure 500 mg of sample were digested by microwave

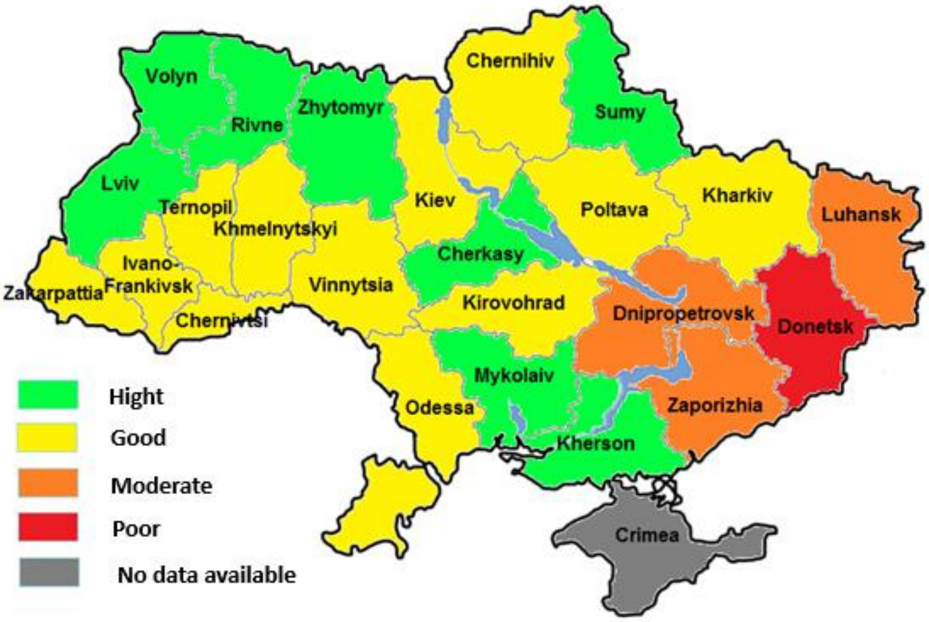

Fig. 1. Proposed classification of trace metal contamination of the soil in Ukraine

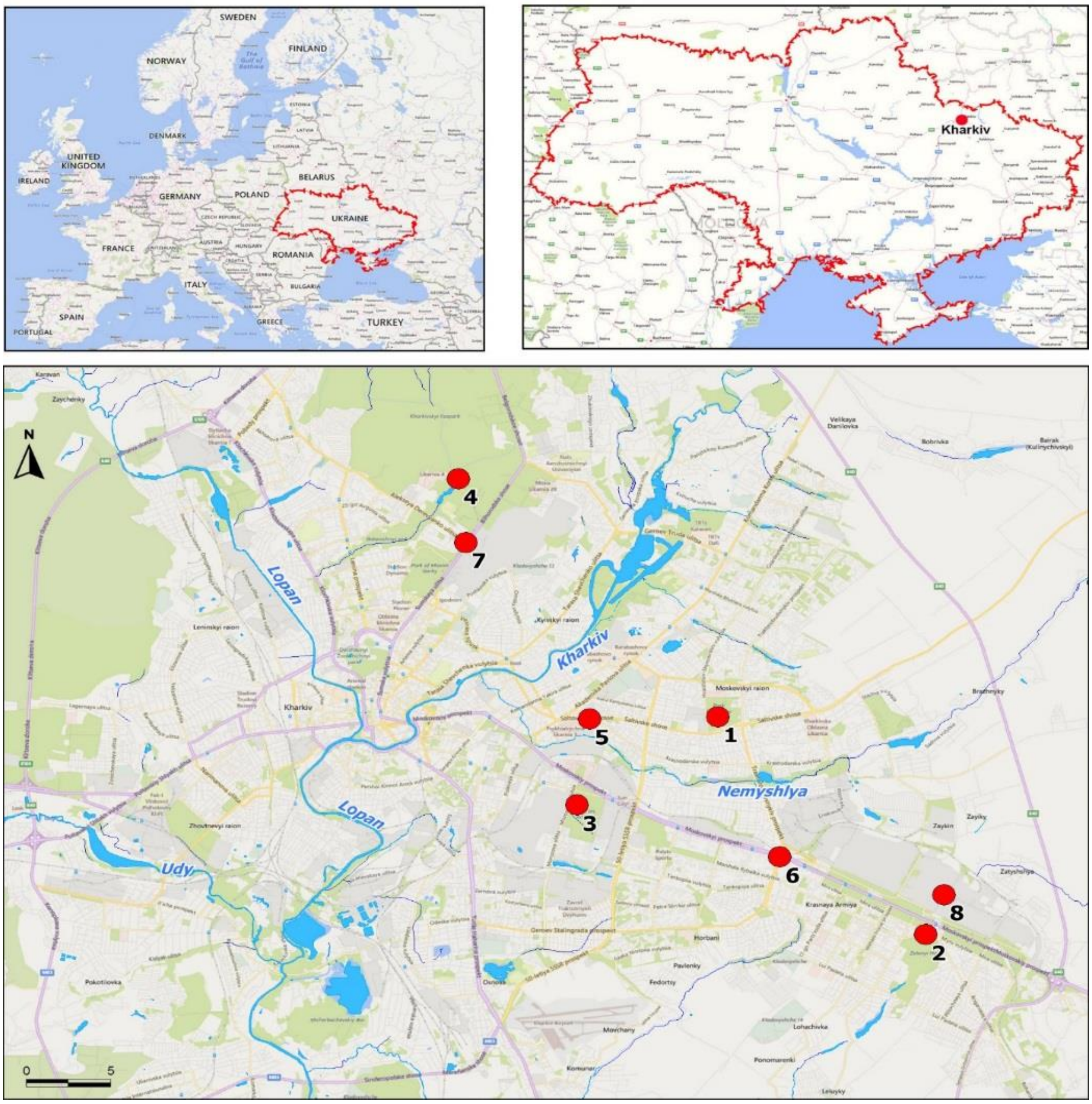

Fig. 2. Sampling points: 1- Park 1; 2 - Park 2; 3 - Park 3; 4 - Park 4; 5 - Highway 1; 6 - Highway 2; 7 - Highway 3; 8 -Industrial company

radiation assisted EPA 3051A method (Method 7000B, 2007). The microwave assisted acid digestion were carried out on Ethos Easy instrument (Milestone, Italy) with adding 10 ml of nitric acid 69% (Suprapur® for trace metal analysis, Merck Millipore). All solutions were made on bidistilled water (Grade 2, ISO 3696:1987). Impurities of reagent were controlled by using reagent blank solutions.

The metal content in the solutions obtained during sample preparation was determined by method of atomic absorption spectrometry with flame atomization (Method 3051A (SW-846), 2007) on fast sequential atomic absorption spectrometer AA 240FS (Agilent, USA). Calibration and measurement procedure were atomized by using SIPS and SPS4 autosamplers (Agilent, USA). Single standard solution 5 mg/l of determined elements were made from multielement standard solution 1000 mg/l of 23 elements (ICP multi-element standard solution IV, Merck).

Kharkiv is a large industrially developed city of Ukraine with enterprises of machine-building, chemical and construction industries, which causes a significant negative impact on the environment. In order to assess the level of soil pollution with trace metals at the local level, using a new methodology, sites were selected for sampling soils with different levels of anthropogenic load: 4 local parks, 3 highways, a household waste dump and the territory of an industrial enterprise.

The content of trace metals is determined by atomic absorption spectrophotometry with flame atomization on the Hitachi Z-8000. The results of determining the index of trace metal contamination in the soil by formulas (3) and (4) are given in Figure 3.

The ranking of the sampling points for the index of soils contamination by trace metals in the soil (ISHM) showed that the most polluted soils are in the municipal waste landfill and industrial companies areas (Fig. 3).

The level of trace metal contamination in the soil in the recreational areas of Kharkiv city corresponds to the 2nd grade, i.e. good. In places of sampling near highways, the level of trace metal contamination in the soil corresponds to grades 2 and 3, i.e. good and moderate. The level of trace metal contamination in the soil of the municipal waste landfill and industrial companies corresponds to grade 5, i.e. very poor.

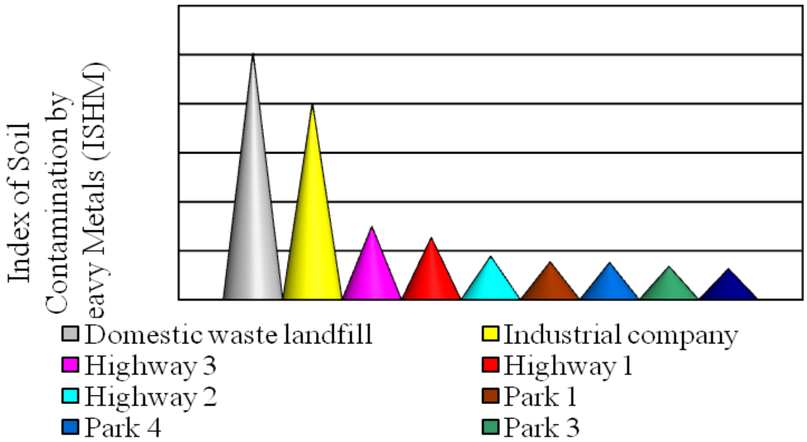

Fig. 3. Ranking of sampling locations in Kharkiv by the index of soils contamination by heavy metals (ISHM)

4.3. Integral Assessment of Trace Metal Contamination in the Soil as a Result of Hostilities in the East of Ukraine

Military actions in the East of Ukraine led to pollution of the environment, destruction of landscapes, reduction of biodiversity and emergency incidents at industrial enterprises and infrastructural facilities.

The environmental consequences of military conflicts in the former Yugoslavia, Afghanistan and the Middle East are studied in the paper (Global Report …, 2022). under the United Nations Environment Program (UNEP). The impact of military conflicts in Georgia, Syria and Iraq on the state of the environment was also explored.

The impact of hostilitiess on the state of the environment in the East of Ukraine is featured by the fact that Donetsk and Luhansk regions are industrially developed regions, where up to 4,500 potentially dangerous industrial sites were located before the beginning of hostilities. According to the OSCE in the period from 2014 till 2017, more than 500 emergency incidents have been recorded in this region (Environmental Assessment …, 2017).

Papers (Pospelov B. et al., 2018, Tiutiunyk. V. Vet al. 2018) proposed a systematic approach to assessing the readiness of civil defense to action in emergencies. Authors have also developed measures to eliminate fires or reduce their impact on the environment (Andronov V. et al., 2017, Dubinin. D., et al., 2017, Dubinin D. et al. 2018). But the Ukrainian state authorities do not have the capacity to carry out fire and environmental measures in the occupied territories of Donetsk and Luhansk oblasts.

The impact of military actions on the state of the environment in Donetsk and Luhansk regions was analyzed based on the materials of the OSCE projects in Ukraine presented in this paper (Environmental Assessment …, 2017, Pospelov B. et al., 2018).

It should be noted that in the areas of Donetsk and Luhansk regions currently not under the control of the Ukrainian government, no environmental monitoring is conducted and thus no reliable information on damages to industrial companies, housing and communal services and infrastructural facilities is available. But within the framework of the project "Environmental Assessment and Recovery Priorities for Eastern Ukraine" carried out by the OSCE Project Coordinator in Ukraine, with the financial support of the Governments of Canada and Australia, in collaboration with the Zoï Environment Network (Switzerland), materials for desk and field studies were presented (Environmental Assessment …, 2017). Based on these materials, trace metal contamination in the soil is assessed by the new method. The ranking of research objects by the value of trace metal contamination in the soil (ISHM) has showed that the territory near the Sloviansk TV and Radio Center and Luhansk TPP is in the worst condition (Fig. 4).

The high value of trace metal contamination in the soil (ISHM) in the territory of the Sloviansk TV and Radio Center is caused by excess concentration of strontium by 116 times and mercury by 2.2 times compared to the background values. According to field studies presented in the paper (Environmental Assessment …, 2017), in the territory of Luhansk TPP, an excessive concentration of strontium by 12.8 times and mercury by 16.7 times over the background value have been detected. The average values of the trace metalconcentrations s in the soil of the studied areasexceeded the background values by 0,9-1,7 times.

In Table 2, the factors of possible impact of hostilities on the state of trace metal contamination in the soil are given.

As shown in Table 2, the largest number of military equipment was used precisely in the territory of the Sloviansk TV and Radio Center and Luhansk TPP.

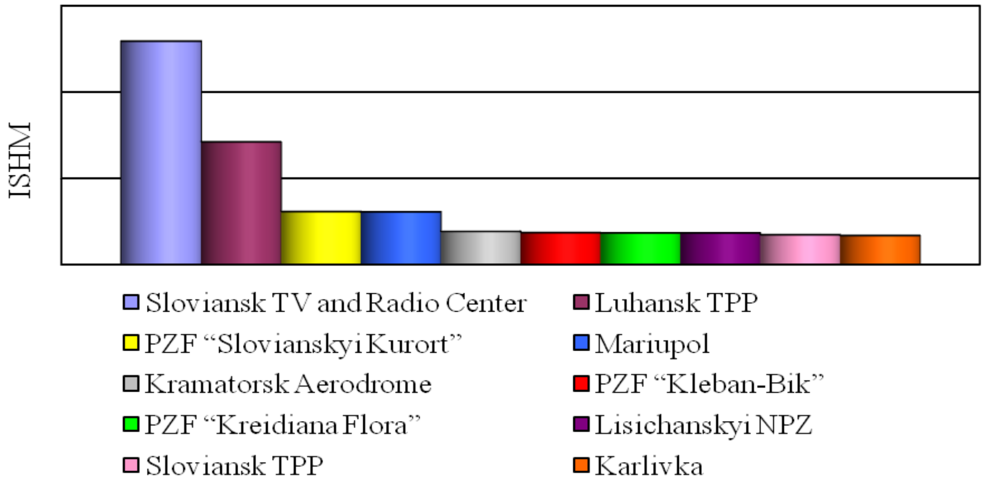

Fig. 4. Ranking of researched areas by the impact of hostilities in eastern Ukraine in terms of the value of heavy metal contamination in the soil (ISHM)

Table 2

Possible factors of heavy metal contamination in the soil in the territory of hostilities in Donetsk and Luhansk regions (eastern Ukraine)

Sampling ground for soil	Factors of possible impact of military actions
Sloviansk TV and Radio Center	Small arms, grenades, artillery, armored vehicles
Luhansk TPP	Small arms, grenades, artillery, MLRs, other factors
PZF "Slovianskyi Kurort"	Small arms, grenades, artillery, armored vehicles
Mariupol	Artillery, MLRs
Kramatorsk Aerodrome	MLRs, other factors
PZF "Kleban-Bik"	Armored vehicles
PZF "Kreidiana Flora"	Small arms, grenades, artillery, and other factors
Lisichanskyi NPZ	MLRs, other factors
Sloviansk TPP	Artillery, other factors
Karlivka	Small arms, grenades, armored vehicles

Obviously, for the real determination of the impact of military actions on the state of the environment, including soils, we need to have more detailed information on the military equipment used during the conflict, the number and extent of emergency incidents and their environmental consequences, as well as regular data of environmental monitoring. But even a preliminary assessment of the hazard level of trace metal contamination in the soil made with the date provided by the OSCE, which grounds on the determination of ISHM by the new method, indicates the urgency of conducting rehabilitation measures on environmental protection.

But even a preliminary assessment of the hazard level of trace metal contamination in the soil made with the date provided by the OSCE, which grounds on the determination of ISHM by the new method, indicates the urgency of conducting rehabilitation measures on environmental protection.

5. Discussion

Trace metal contamination in the soil poses a serious threat to the environment on the global scale. The method of the integrated assessment of trace metal contamination in the soil at the regional and local levels is proposed.

The method for estimating the integral index of trace metal contamination in the soil (ISHM) at the local level involves the summation of the multiplicity of the excess of background concentrations. taking into account the hazard class and the self-purification index. At the regional level. this method differs in the fact that official sources of information on the state of the environment provide data on the state of trace metal contamination in the soil in multiplicity of excess of MACs. But it provides the opportunity to apply software for automated calculation of trace metal contamination in the soil (ISHM) and determination of the priority of implementation of environmental measures.

This assessment of soil contamination by trace metals in Kharkiv made with the application of new method under the various influence of anthropogenic factors has showed the dangerous impact of the industry and the location of household waste landfills.

The application of the soil contamination method at the regional level has indicated a high level of hazard especially in the industrially developed regions of Ukraine.

In particular, in the east of Ukraine, in the largest industrial regions of the country, namely Donetsk and Luhansk, with the highest concentration of environmentally hazardous industrial sites; the ongoing hostilities since 2014 do constitute a threat to the environment.

According to (Environmental Assessment …, 2017), the content of trace metals in soil samples taken in areas of military operations (mainly in funnels for a short time after the cessation of hostilities), in most cases exceeded the background value by 1.2 - 12 times. Pursuant to these data, of the seven studied metals, only the content of cadmium (4.4 times) and lead (on average 1.2 times) exceeded the regional average.

The main data based on study (Environmental Assessment …, 2017), presented on figure 5 below:

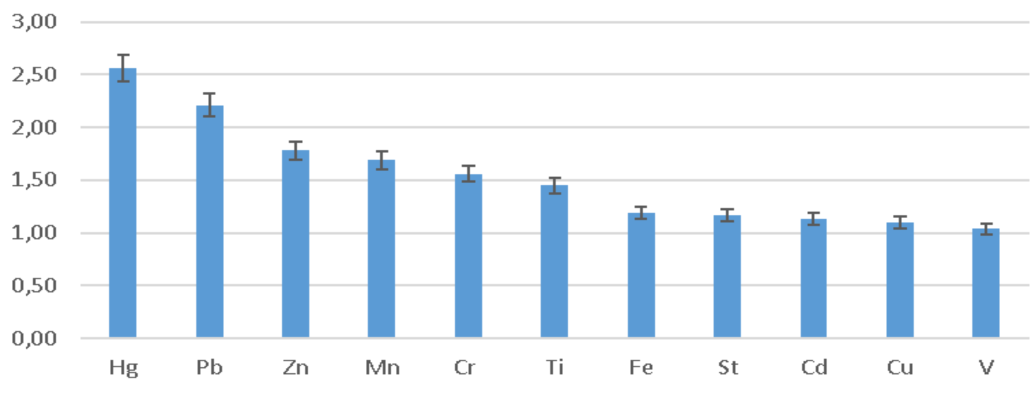

Fig. 5. The calculated multiplicity of excess concentrations of trace metal in the zone of influence of hostilities over background concentrations

Indeed, to determine the actual impact of hostilities on the state of the environment in the Donetsk and Luhansk regions of Ukraine requires more studies. While this territory is not under the control of the Ukrainian authorities, this is impossible. In the work (Environmental Assessment …, 2017) data from the field's studies are presented. Impact on soil pollution was provided not only weapons, but also - also emergencies, including accidents at industrial enterprises.

Among many industrial enterprises in the conflict zone, the most environmentally hazardous plants were damaged because of hostilities: Because of military maneuvers or exercises, the construction of fortifications, explosions and the burning of ammunition, the surface soil is disturbed.

The results of the assessment of trace metal contamination in the soil (ISHM) showed the highest level of pollution in the territory of the Sloviansk TV and Radio Center and Luhansk TPP. where the largest amount of military equipment was used. Thus. more detailed research is required to determine the actual impact of hostilities on the state of the environment in Donetsk and Luhansk regions of Ukraine. The assessment of trace metal contamination in the soil by the new method makes it possible to determine the priority of the implementation of measures for the restoration of land affected by the military actions.

Obviously, for the real determination of the impact of military actions on the state of the environment, including soils, we need to have more detailed information on the military equipment used during the conflict, the number and extent of emergency incidents and their environmental consequences, as well as regular data of environmental monitoring.

6. Conclusions

1. The new method of assessment of the level of trace metal contamination in the soil at the regional and local levels is proposed. The advantage of this method between another is consideration of the hazard class of pollutants and the self-purification index and determination of the integral index of trace metal contamination in the soil (ISHM) at the local level. It is proposed to determine the multiplicity of excess background concentrations.

2. For determination of the hazard level it was chosen four locations at the recreational areas of Kharkiv city: three locations near the highways, at the municipal waste landfill and at the territory of an industrial company. The content of trace metals in the samples was determined by atomic absorption spectrophotometry with flame atomization with the use of Hitachi Z-8000. Ranking of territories by the value of trace metal contamination in the soil (ISHM) showed that the most dangerous areas are domestic waste landfills and facilities of the industrial companies (Class 5 «Bad»). Recreation zones are ranked in Class 2 «Good». the territory near the highways are assessed in quality Class 2 «Good».

3. Assessment of the level of trace metal contamination in the soil at East of Ukraine showed that industrial regions are in the concerning condition: Donetsk (quality Class 4 «Poor»). Dnipropetrovsk (quality Class 3 «Moderate»). Zaporizhzhia and Luhansk region (quality Class 3 «Moderate»).

4. Based on the monitoring data of the OSCE in Ukraine, trace metal contamination in the soil is assessed by the new method. The ranking of researched areas by the value of trace metal contamination in the soil (ISHM) showed that the territories of the Sloviansk TV and radio station and Luhansk TPP are in the most dangerous condition. Assessment of the hazard level of trace metal contamination in the soil by the proposed method will allow to make a scientifically substantiated decision on the priority of implementation of environmental measures.

5. The use of the proposed methodological approach will facilitate obtaining of comparable data in assessing the level of contamination in the soil and identification of areas for safe recreational use or cultivation of agricultural crops.

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Екологічна оцінка забруднення ґрунтів важкими металами

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Метою даного дослідження є розробка методу визначення рівня забруднення ґрунту важкими металами. Для цього ставляться наступні завдання: розробити методику комплексної оцінки забруднення ґрунту важкими металами на регіональному та локальному рівнях; визначити найбільш забруднені важкими металами регіони України; оцінити рівень небезпеки забруднення ґрунту важкими металами для територій з різними типами землекористування; оцінити забруднення ґрунтів важкими металами внаслідок бойових дій у Донецькій та Луганській областях. У зв'язку з різними морфологічними особливостями ґрунту і процесами ґрунтоутворення показано необхідність урахування фонових концентрацій та індексу самоочищення для оцінки рівня небезпеки забруднення ґрунтів важкими металами. Розроблена класифікація рівня небезпеки забруднення ґрунтів важкими металами. Дана оцінка забруднення ґрунтів важкими металами на місцевому рівні для рекреаційних зон міста, автодоріг, звалища побутових відходів і території промислового підприємства. Оцінка забруднення ґрунтів важкими металами на місцевому рівні показала, що в найгіршому стані знаходяться території промислового підприємства і звалища побутових відходів (5 клас – дуже поганий стан). Території рекреаційних зон віднесено до 2 класу (добрий стан), автодоріг – до 3 і 4 класу (відповідно задовільний і поганий стан). Розрахунок показників забруднення ґрунтів важкими металами на регіональному рівні за новим методом показав, що в найбільш небезпечному стані знаходяться території індустріальних центрів України. Дана оцінка забруднення ґрунтів важкими металами для територій Донецької і Луганської областей внаслідок впливу бойових дій за новим методом. Визначено чинники впливу бойових дій на стан забруднення ґрунтів важкими металами. В роботі представлено новий метод оцінки забруднення ґрунтів важкими металами на регіональному та місцевому рівні. Перевагою цього методу є урахування класу небезпеки забруднюючих речовин та індексу самоочищення. Розроблена нова класифікація рівня небезпеки забруднення ґрунтів важкими металами. Використання запропонованого методичного підходу буде сприяти одержанню порівнянних даних при оцінці рівня забруднення ґрунту важкими металами й визначенню пріоритетності впровадження природоохоронних заходів і підвищення рівня екологічної безпеки, що особливо актуально для післявоєнного відновлення нашої країни.

***Ключові слова**: забруднення ґрунтів, важкі метали, інтегральна оцінка, вплив бойових дій.*

Внесок авторів: всі автори зробили рівний внесок у цю роботу

Надійшла 5 вересня 2022 р.
Прийнята 12 листопада 2022 р.