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Soil Quality Evaluation in Urban Ecosystems during the Covid-19 Pandemic

Nataliia Mironova [1], Olha Yefremova [1], Halyna Biletska [1], Ihor Bloshchynskyi [2*], Ihor Koshelnyk [2], Serhii Sych [2], Maksym Filippov [2], Serhii Sinkevych [2], Vasyl Kravchuk [2]

[1] *Department of Ecology and Biological Education, Faculty of Humanities and Education, Khmelnytskyi National University, Khmelnytskyi, Ukraine.*

[2] *Bohdan Khmelnytskyi National Academy of the State Border Guard Service of Ukraine, Ukraine.*

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Abstract

The article considers the changes in some agrochemical parameters and the content of plumbum in the soil cover of a medium-sized urban ecosystem after the introduction of quarantine measures in connection with the Covid-19 pandemic. It has been determined that the blocking of anthropogenic activity did not affect the content of humus. There were changes in soil pH, which led to the transition from an alkaline reaction to a neutral one. The amount of fertilizer elements (NPK) in the soil in the post-quarantine period has been increased. The content of the mobile (active) form of plumbum within the city has been halved on average. In general, the impact of quarantine from Covid-19 on the condition of the soil cover as well as on air and surface water can be preliminary considered as positive.

Keywords: Covid-19; Soil; Urban Ecosystem; Active Soil Reaction; NPK; Plumbum.

1. Introduction

An outbreak of a new infectious disease of the coronavirus family, called Covid-19, was detected in Wuhan (China) in late December 2019. In January 2020, the WHO (World Health Organization) confirmed the droplet spread of infection and on January 30 declared a state of emergency throughout the entire world. Outbreaks took place in Iran, Italy, and other countries in February, and on March 11, the WHO described the global Covid-19 outbreak as a pandemic. As of August 8, 2020, the total number of Covid-19 cases in the world was 19.4 million people [1]. In Ukraine, the disease was first confirmed on March 3, 2020; as of August 8, 2020, the total number of Covid-19 cases according to the Ministry of Health (MOH) in Ukraine is 79751 [2]. Khmelnytskyi oblast with Khmelnytskyi city regional centre is located in the western part of Ukraine and currently ranks 15th in terms of morbidity, although it directly borders on oblasts with a high degree of infection of residents (Chernivtsi, Rivne, and Ternopil oblasts).

In order to reduce the spread of Covid-19, the governments of many countries have closed places with large concentrations of people, such as public transport, educational and catering establishments, enterprises, business and shopping centres, parks, etc. Quarantine was introduced on March 11, 2020 in Ukraine. The application of such strict quarantine measures has not only affected economic activity and the social sphere but has also contributed to the unexpected effects of environmental changes.

* Corresponding author: i.bloshch@gmail.com

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2. Literature Review

Currently, studies of Covid-19 and the state of the environment are conducted in two directions, the first involving the study of the impact of environmental factors (primarily such as temperature, humidity and air pollution, etc.) upon the survival and spread of coronavirus and these factors interrelation with morbidity [3-5]. The second direction is the study of unprecedented changes in the state of the environment because of quarantine. In the latter case, both positive and negative consequences of the impact of social isolation upon the environment are stated.

The greatest positive impact in the countries of the Eurasian continent and the United States is determined for atmospheric air due to the reduction of its pollution by combustion products because of traffic (road, air) cessation, as well as a sharp decline in the work of industrial enterprises [6-9]. According to NASA (National Aeronautics and Space Administration, USA), pollution in some epicentres of Covid-19, such as Wuhan, Italy, Spain, USA, in terms of NO_2 and CO_2 content etc. decreased by 30% [10-12]. At the same time, as a negative consequence for the air is the increase in the concentration of dust particles because of the increased use of wood for heating and cooking in the conditions of social isolation [3].

The Covid-19 pandemic and related quarantine measures have also had a positive impact upon surface water quality, as reduced water traffic and the use of water bodies for tourism have significantly increased water transparency and reduced its pollution by primarily suspended substances [13, 14].

At the same time, there are no data on changes in the quality of soil cover. Researchers suggest that the quality of land resources will deteriorate due to the need to bury large amounts of organic waste generated in the fast food industry in the result of these facilities closure. There are also fears that an increase in the amount of disposable medicines will lead to the accumulation of medical waste, which is characterized by a low degree of decomposition, and will cause them to enter the soil, especially in countries with low waste management culture [3].

Although soil is known to be one of the most stable components of the natural environment compared to air and water, in our opinion, an unprecedented lockdown could potentially cause changes in its characteristics (especially among the indicators that are more labile as to the influence of anthropogenic factors).

Considering the problems of soil change due to the Covid-19 pandemic, in our opinion, we should pay attention to urban soils as an important component of urban ecosystems functioning, since urban soils are a leading factor in the formation of green areas of cities. The Covid-19 pandemic has made it possible to understand the importance of the latter, as parks, squares and other public greenery, when visited while maintaining social distance, mitigate a person's reaction to a changed form of civic activity and various forms of isolation. Living in homes without available nearby trees, grass and other natural attributes tends to increase problems compared to those living in greener areas. Such findings apply to the current situation where the final endpoint of pandemic stress does not exist [15].

Studies of transformational processes of natural soils in urban areas in general have been conducted by many scientists [16-25]. Given the fact that urban soils play an important role in accepting air pollution from emissions from vehicles and industrial enterprises, as well as the fact that in the context of the Covid-19 pandemic there were changes in these anthropogenic factors, quantitative changes in agro-ecological indicators of soils of the territories under quarantine are possible.

Due to the fact that quarantine restrictions have been introduced throughout Ukraine to the same extent since March 2020, regardless of the level of morbidity, the reduction of the anthropogenic factor, and consequently the potential changes in soil properties, occurred symmetrically. From this point of view, it is of scientific interest to study urban soils of medium-scale urban ecosystems, which are the most numerous in Ukraine. Such urban ecosystems include the city of Khmelnytskyi i.e. the administrative centre of Khmelnytskyi oblast. The city covers an area of 86 km^2; its population is about 270 thousand people. It is an industrial, commercial and cultural centre of Podillia, located on the banks of the Southern Bug River, which flows into the Black Sea.

The city is typical among the oblast centres of western and central Ukraine in terms of socio-economic indicators. The largest share in the structure of industrial production of the city is occupied by the machine-building and food industries, as well as construction. In general, industry-related factors of the urban ecosystem of the city of Khmelnytskyi are formed due to industrial enterprises, transport and community facilities influence upon the environment.

The natural soils of the city of Khmelnytskyi were formed mainly on carbonate forest deposits, the most common are forest-steppe podzolic soils, which combine light gray forest, gray forest and dark gray podzolic soils. The expansion of the city leads to a steady reduction in the area of land with natural soils due to their transformation into urban lands. Today, more than half of the territory of Khmelnytskyi is occupied by anthropogenic sediments (embankments, including soils of bulk structures, artificial road surfaces, mineral dumps, planar cultural layer, sediments of artificial reservoirs).

Today, a powerful factor influencing the geochemical background of soils of the urban ecosystem of the city of Khmelnytskyi is the emissions of industrial enterprises and vehicles.

3. The Purpose and Objectives of the Research

The purpose of the research is to assess the condition of the soils of the city of Khmelnytskyi in terms of agrochemical parameters (acidity, content of humus and food elements) and in terms of the content of plumbum. To achieve the purpose, 9 trial areas were laid from which soil samples were taken in August 2019 and June 2020. Trial areas were laid out on the territory of the city in such a way that they included different types of anthropogenic impact, typical for medium-scale urban ecosystems to obtain adequate average values (see Figure 1): manufacturing areas (trial area 1 - automatic molding machines production plant; trial area 2 - packaging polymer products production plant; recreational areas (trial area 3 - city park, trial area 4 - arboretum); floodplaini (trial area 5 - floodplain of the river Ploska, which flows into the river Southern Buh within the city, trial area 6 - water protection zone of the lake, located on one of the nameless tributaries of the Southern Bug river); transport highways (trial area 7 - the main highway of the South-Western part of the city, trial area 8 - the highway of the central part of the city, trial area 9 - the main highway of the South-Eastern part of the city).

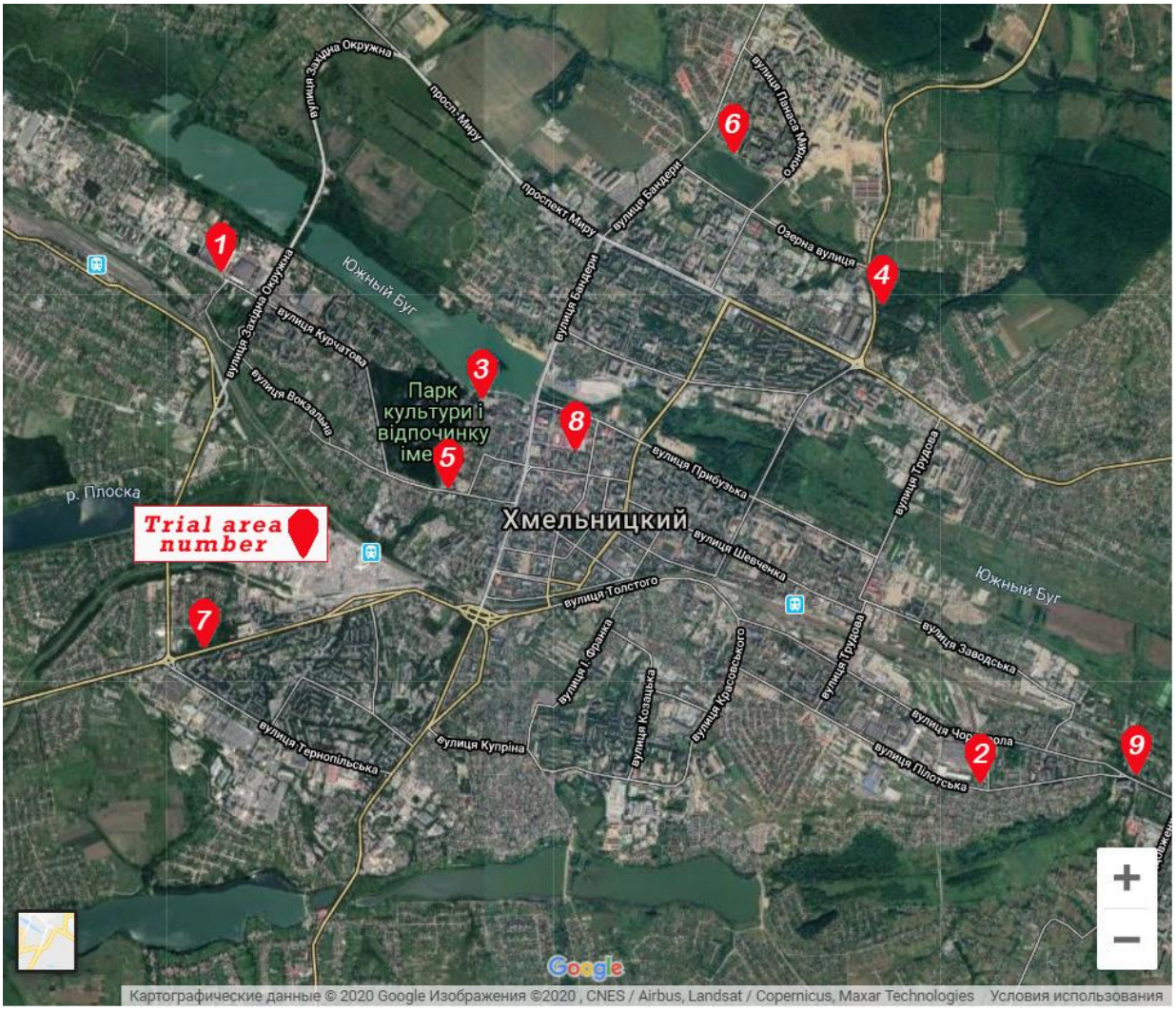


Figure 1. Sketch map of trial areas for soil sampling

Sampling and determination of agrochemical parameters of soils and the content of plumbum were carried out in accordance with regulatory and technical documents of Ukraine (DSTU) and ISO.

4. Results and Discussion

4.1. Changes in Agrochemical Parameters

The ability of the soil to create conditions for plant development is determined by an integrated indicator called fertility, and includes, first of all, agrochemical indicators, which include soil acidity, content of humus and nutritious matters. Soil

acidity (or alkalinity) is an important factor that has a significant impact on plant growth and development, as well as microbiological, chemical and biological soil processes. It largely influences the assimilation of soil nutrients and fertilizers by plants, mineralization of organic matter, fertilizer efficiency, yield and its quality. Soil acidity also affects the availability of chemical elements to plants. The determined indicators of soil acidity before and after the introduction of quarantine are shown in Table 1.

Table 1. Soil pH and hydrolytic acidity

Trial area number	Before quarantine	After the introduction of restrictive measures	
	pH (CSI), device unit	pH (CSI), device unit	hydrolytic acidity, mg-eq /100 g
1	7.53	6.86	0.56
2	7.78	6.91	0.53
3	7.35	6.32	0.96
4	3.83	3.84	1.31
5	7.56	6.87	0.61
6	7.58	6.88	0.59
7	7.60	7.19	0.64
8	7.85	6.84	0.85
9	7.92	7.02	0.68

The main feature of the soil is the presence of a specific group of organic substances in it such as humic compounds, which are formed during the decomposition and humification of organic residues. The content of humus in urban soils varies depending on its amount in the original natural soil, as well as the use of mineral and organic fertilizers, the introduction of organic waste, and so on. The obtained data on the average humus content in the soil cover of the city of Khmelnytskyi are: before quarantine -3.96%, after quarantine -3.90%. Together with the humus content, the integrated soil fertility index is supplemented by data on the content of fertilizer elements (NPK). The changes in these indicators are shown in Figures 2 to 4, they are quite significant compared to the content of humus.

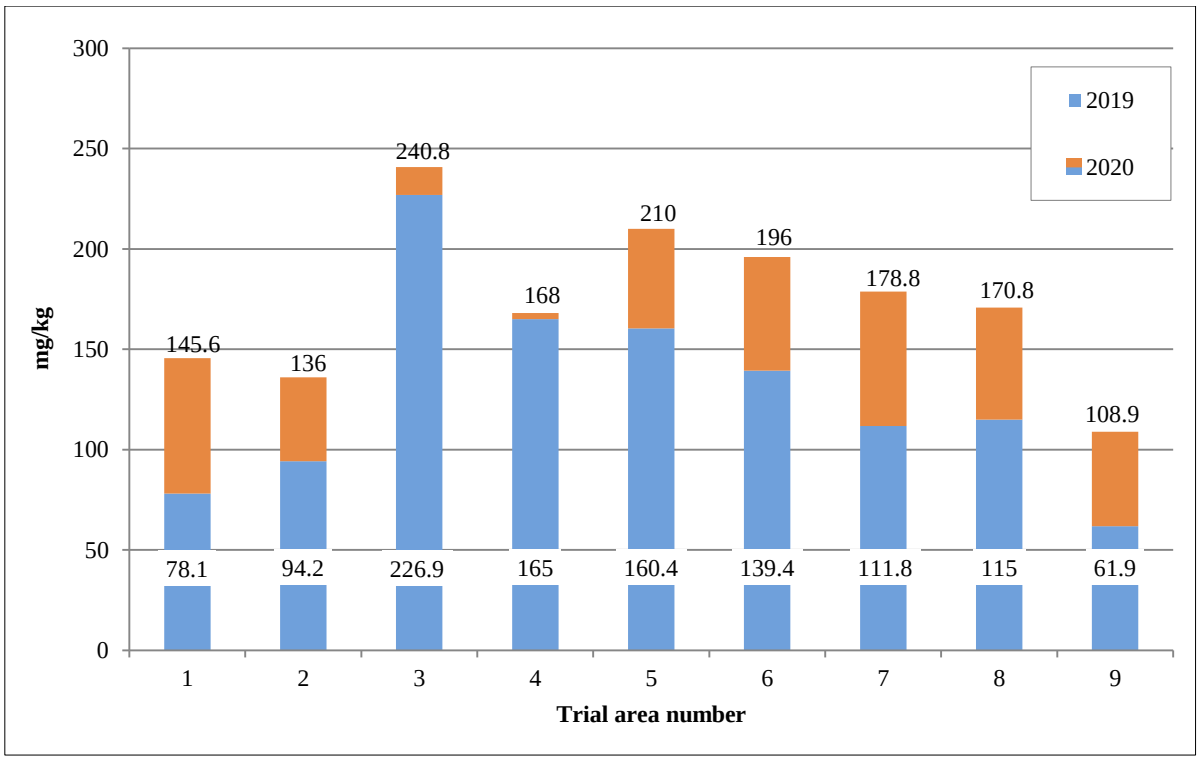
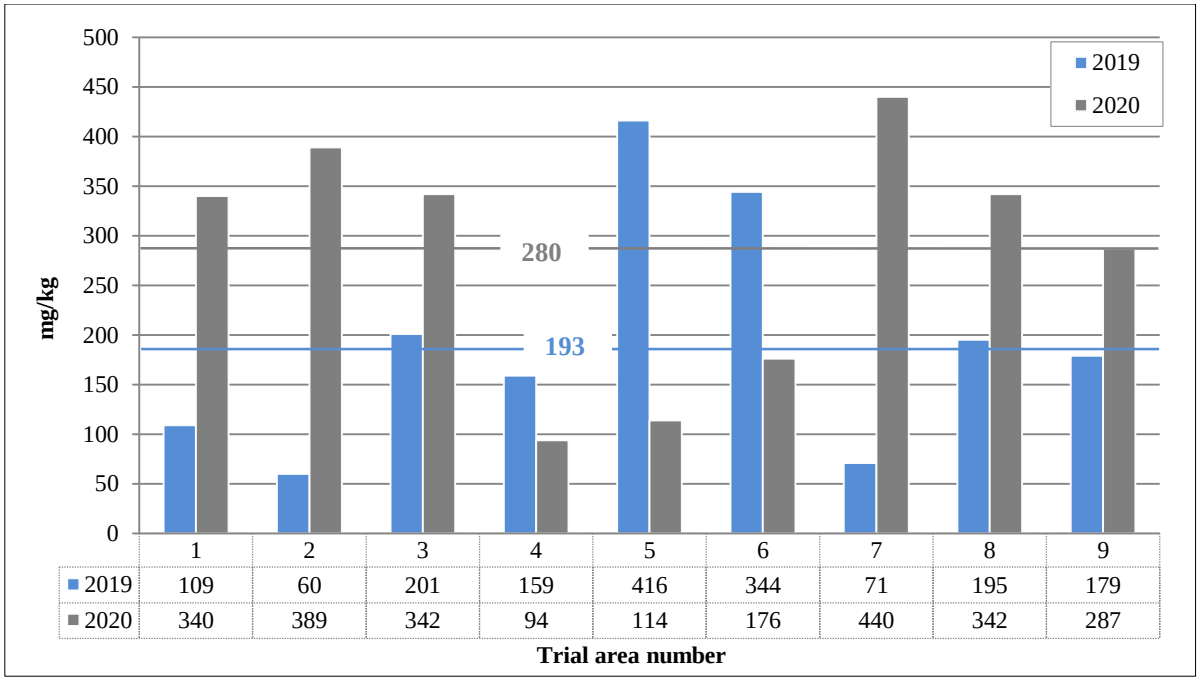


Figure 2. The content of alkaline hydrolysed nitrogen (N)



	1	2	3	4	5	6	7	8	9
2019	109	60	201	159	416	344	71	195	179
2020	340	389	342	94	114	176	440	342	287

Figure 3. The content of phosphorus (P2O5)

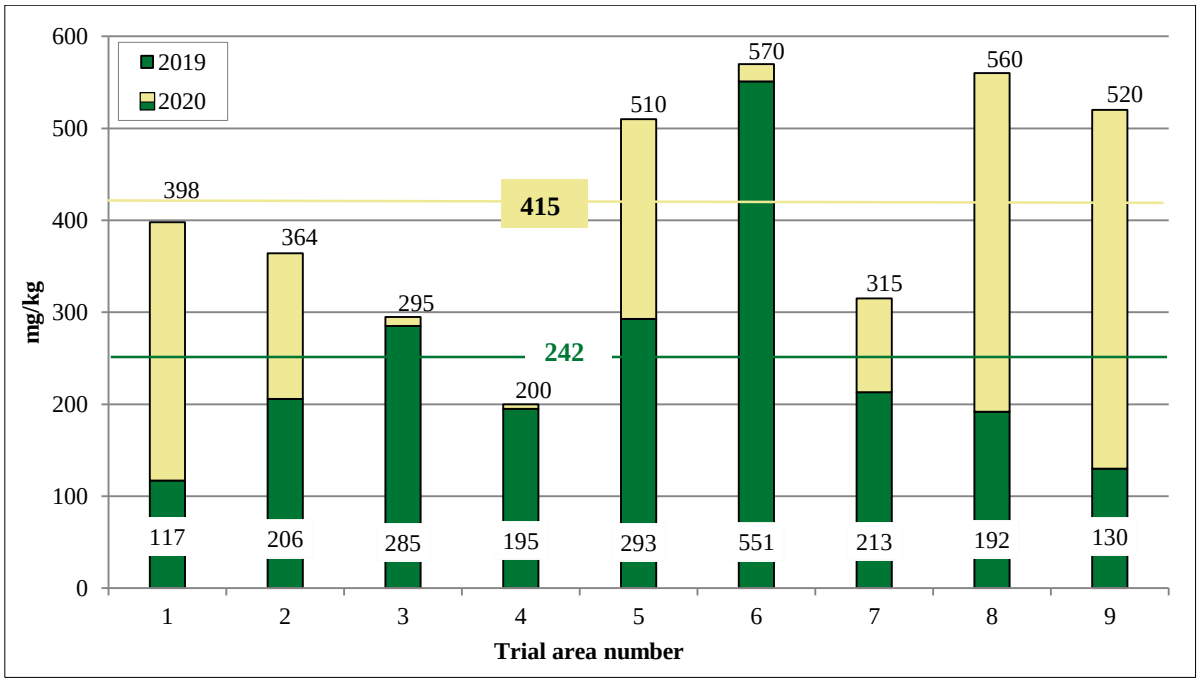


Figure 4. The content of potassium (K2O)

4.2. Changes in Soil Contamination with Plumbum

The content of heavy metals is an important criterion that characterizes the anthropogenic impact on soils. The presence of one or another element of this group depends on the peculiarities of the development of the industrial complex of the urban ecosystem. But along with this, there are metals that are universal satellites of the urban habitat. Such elements include plumbum, the content of mobile form of which in the urban soils of the city of Khmelnytskyi is shown in Table 2.

Table 2. The content of mobile and total forms of plumbum (Pb) in Khmelnytskyi soils, mg/kg

Trial area number	1	2	3	4	5	6	7	8	9	The average value within the city
The content of mobile form before quarantine	8.0	12.8	4.8	5.0	3.1	3.2	9.4	4.8	9.6	6.7
The content of mobile form after quarantine	3.0	9.5	1.9	2.6	3.0	1.7	8.0	2.32	1.22	3.7

The typical pH values of soil reaction equal 3.5-6.3 for natural soils of the territory where the city of Khmelnytskyi is located. According to the quarantined data, alkaline soils predominate in the city (Table 1). The trial area 4 is the exception, which is a large forestland (arboretum), where the soil has an acid reaction close to natural values. This indicates the slightest changes in this edaphotope under the influence of urban and technogenesis. This is also facilitated by the spread of forest vegetation typical of the forest-steppe zone in this area, while in other areas the urban flora, which differs from the natural one, predominates. Quarantine restrictions did not affect this indicator in the arboretum, but in other trial areas and in the city as a whole pH decreased by about 10%, which can be considered a positive factor because there was a shift in bearing power of soil from alkaline to neutral. Additionally, the determined indicators of hydrolytic acidity within the trial areas after quarantine are small, which indicates the absence of active acidification processes.

As a rule, the content of organic matter in urban soils is higher than in underlying soils. The content of humus reaches values up to 12%, and on average from 4% to 6% within all ancient urban soils, especially in the soils of parks, squares, gardens. Sometimes "old bulk" soils acquire the character of black earth soil [26]. The quantified average content of humus within the city before the quarantine (3.96%) is higher than in the natural soils of this area (2-3%). The highest values are determined within recreational and floodplain areas, which is due to measures to improve plant growth in these areas of the city. The formation of humus is also facilitated by the constant natural transformation of plant residues and the minimal impact of industrial enterprises and transport. The lowest values, which correspond to the natural underlying soils indicators, were recorded in the trial areas located in the industrial zone. The introduction of strict restrictions had little effect on the content of humus (3.90%), which is quite predictable, as deeper changes in this component of the soil due to the complexity and duration of the humus formation process may occur later in response to changes in more labile parameters.

The content of nutrients such as nitrogen, phosphorus, potassium is important for the provision of soil ecosystem services. The predominant amount of nitrogen enters the soil due to the decomposition of plant and animal remains. According to the literature, the content of total nitrogen in soils is 0.03-0.50% [27, 28]. The alkaline hydrolysed nitrogen content is used to characterize the availability of this chemical element and its availability to plants, which is closely correlated with the content of humus, total nitrogen content and nitrification ability [27]. According to the obtained data (Figure 2), the soil cover of the city of Khmelnytskyi is characterized by a low content of alkaline hydrolysed nitrogen (128.1 mg/kg).

As it has already been mentioned, after the introduction of quarantine the content of nutrients, including alkaline hydrolysed nitrogen, has significantly changed, namely the average content has increased by almost 25%. It is noteworthy that the largest changes occurred in areas where the nitrogen content was the lowest due to significant anthropogenic impact (trial areas of industrial zones, highways), and in areas with relatively less impact, the increase in concentrations was small. It is obvious that in areas with a strong influence of transport and industry, the conditions for the accumulation of nitrogen, primarily due to the activity of microorganisms, are unfavourable. Therefore, reducing the impact of these anthropogenic factors has ensured the creation of conditions that are similar to those common in recreational areas and water protection zones. We can predict the factors whose intensity decreased due to quarantine: a decrease in soil compaction and, in turn, an increase in air permeability, as well as a shift in soil pH towards a neutral value, which probably created more favourable conditions for microorganisms that convert nitrogen compounds. To confirm this assumption, studies of soil microflora are needed.

Phosphorus in the soil occurs in two forms – mineral and organic. A significant proportion of soil phosphorus is in hard-to-reach forms, which become available to plants due to the action of root secretions and microorganisms. The increase in phosphorus content in the soil after quarantine restrictions is 30% on average (Figure 3). There is the same trend as for nitrogen, i.e., the largest increase in concentration is characteristic of areas with strong anthropogenic impact. The reasons are likely to be the same. At the same time, in areas with less anthropogenic impact, a symmetrical decrease in the concentration of phosphorus is observed, despite the fact that its content before quarantine was one of the largest in these areas.

Potassium is the third most important nutrient for plants after nitrogen and phosphorus. Water-soluble and directly exchangeable potassium is well absorbed by plants and is considered a mobile form of potassium [28]. Some scientists note a high supply of urban soils and weakly disturbed soils with potassium, where its content can be about 40 mg/100 g of soil and more [26]. The average content of mobile forms of potassium in the urban soils of Khmelnytskyi (Figure 4) is high (242 mg/kg), and after quarantine, similar to nitrogen, it has increased in all areas and reached an average of 415 mg/kg. The largest growth is characteristic of areas with significant influence from transport and industry. Thus, in contrast to nitrogen, the supply of phosphorus and potassium to the soil cover of the city of Khmelnytskyi is high, and after quarantine it may increase hypothetically due to changes in the course of microbiological processes.

The proposed data on agrochemical indicators and assumptions about their changes are not final and require additional studies of the mechanisms that are the driving force of such changes, but already prove the positive impact of social constraints upon the agrochemical status of urban soils. Plumbum does not belong to the group of physiologically necessary elements, but it is the most common heavy metal in the soils of urban ecosystems, primarily due to transport emissions. The highest content of active plumbum in the pre-quarantine period was determined in the industrial zone and in areas near highways (Table 2), and the lowest in the samples of trial areas of recreational areas and water protection zones.

The content of plumbum is near industrial enterprises, 1.6–6.4 times higher than its concentration in recreational areas. Given that the maximum allowable concentration (MAC) for mobile forms of plumbum in Ukraine is 6 mg/kg, most of the city (industrial zone, highways) is characterized by exceeding the MAC (by 1.3-2.1 times).

The content of total form in soils during the quarantine period was not determined, as it is obvious that such changes are long-lasting. The determination of the content of mobile form of plumbum in the soil after the introduction of restrictive measures showed an almost twice-average decrease in its concentration within the city, which proves an indirect positive effect of quarantine due to Covid-19 for urban ecosystems in general and for urban soils in particular.

5. Conclusions

The Covid-19 pandemic has changed people's lifestyles and negatively affected all spheres of human society. At the same time, its positive environmental impact due to the introduction of economic and social restrictions was unexpected, as the state of air and surface waters has significantly improved due to strict quarantine and blocking of industry, transport, tourism and other industries. In our opinion, these changes should have affected the soil cover of urban ecosystems at different levels. Our studies of changes in soil indicators in the urban ecosystem of the city of Khmelnytskyi made it possible to draw the following preliminary conclusions:

- Because of the quarantine, the pH of the soil changed by 10%, and the reaction went from being alkaline to being neutral;
- The content of humus has not changed and is about 4%, which is estimated as average;
- The soil cover of the city of Khmelnytskyi is characterized by a low content of alkaline hydrolysed nitrogen and a high content of phosphorus and potassium. Nutrient matters (NPK) in the post-quarantine period increased quantitatively; nitrogen increased by 25%, phosphorus by 30%, and potassium almost doubled. The largest growth was observed within the trial areas located in the industrial zone and on highways, which may be due to changes in soil structure. Changes in these parameters can also be influenced by a decrease in soil pH, as this indicator determines the conditions of soil reactions, affecting the solubility and ionization of compounds, which, in turn, changes the enzymatic activity of biota;
- The content of mobile lead determined in the pre-quarantine period in the territory near industrial enterprises is the highest and exceeds its concentration in recreational areas by 1.6-6.4 times. In the area near industrial enterprises, the content of the mobile form of plumbum is also the highest and 1.6-6.4 times higher than its concentration in recreational areas. The determination of the content of the mobile form of plumbum in the soil after the introduction of restrictive measures showed an almost twice-average decrease in its concentration within the city, which proves an indirect positive effect for urban soils from the introduction of quarantine due to Covid-19;
- Changes in soil cover indicators of medium-sized urban ecosystems require further long-term monitoring and in-depth study of certain parameters.

6. Declarations

6.1. Author Contributions

Conceptualization, H.B. and N.M.; methodology, O.Y.; software, I.B.; validation, S.S., M.F. and Se.S.; formal analysis, I.K.; investigation, O.Y.; resources, V.K..; data curation, H.B.; writing—original draft preparation, N.M.; writing—review and editing, I.B.; visualization, M.F. and Se.S.; supervision, S.S. and I.K.; project administration, Va.K., and N.M. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

6.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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