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«_____»_____2025 p.

FINAL SCIENTIFIC AND TECHNICAL REPORT
According to the Memorandum dated July 9, 2024 № NUR/MON 2024405 3 UNICEF representative UKRAINE

"On the consequences of the fire caused by enemy shelling of the oil depot of LLC "KhNB - Reserve", located at: 3 Yenakiivska Street, Kharkiv."

BOOK 1. Final Scientific and Technical Report

on the topic: "Reducing anthropogenic impact on soils and the groundwater aquifer as a result of oil products spilling into the Nemyshlya River valley as a result of the bombing and fire at the oil depot to be implemented in Kharkiv, Kotelna Street."

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Kharkiv – 2025

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INTRODUCTION

This report serves as the final summary of the research conducted by the SCIENTIFIC RESEARCH INSTITUTION "UKRAINIAN SCIENTIFIC RESEARCH INSTITUTE OF ECOLOGICAL PROBLEMS" (USRIEP) during the period of July – December 2024 and January – April 2025. The research was carried out within the framework of activities outlined in the memorandum dated July 9, 2024 (No. NUR/MON 2024405 3), signed with UNICEF representative office in Ukraine. The project is titled: “Reduced anthropogenic impact on soils and the groundwater aquifer as a result of oil products spilling into the Nemyshlya River valley as a result of the bombing and fire at the oil depot to be implemented in Kharkiv, Kotelna Street” and was executed by the Scientific Research Institution "Ukrainian Scientific Research Institute of Ecological Problems (USRIEP).

The object of the environmental-hydrogeological and sociological investigations, conducted as part of a monitoring study, included surface and groundwater, soils, bottom sediments of the Nemyshlya River, as well as the surrounding social environment.

The primary aim of this study is to provide a scientifically grounded assessment of the consequences of the explosion at the oil depot of LLC “KhNB - Reserve” in Kharkiv for soils, surface and groundwater, and the bottom sediments of the Nemyshlya River. It includes analysis of the temporal dynamics of petroleum contamination intensity and the identification of the most hazardous environmental and socio-economic living conditions experienced by affected residents.

Assessment of petroleum contamination levels in soils, surface and groundwater, and riverbed sediments of the Nemyshlya River was planned through a series of monitoring studies based on a specifically developed program. The evaluation of social and economic living conditions and the demographic characteristics of the affected population was performed through survey data analysis.

The organization and implementation of environmental and social impact monitoring due to the oil depot explosion in Kharkiv involved the following activities:

1. Sampling of groundwater (inspection of wells, individual boreholes, catchments, and water supply standpipes) within the contamination zone.
2. Sampling of surface water from the Nemyshlya River at points where groundwater discharges into the river.
3. Soil sampling in residential areas affected by the explosion.
4. Chemical and analytical assessment of groundwater and surface water for petroleum products, heavy metals, and macrocomponents.

5. Chemical and analytical assessment of soil and bottom sediments of the Nemyshlya River for petroleum products, heavy metals, and macrocomponents.
6. Visualization of survey results and identification of the most hazardous environmental and socio-economic living conditions.

The targeted objectives of this study were accomplished through a comprehensive field research campaign in accordance with the outlined tasks. As part of the monitoring program, USRIEP staff organized and carried out expeditions to conduct on-site investigations.

In laboratory settings, chemical-analytical studies were conducted to determine the chemical composition of soils, surface and groundwater, including the content of specific contaminants – petroleum products and heavy metals.

The findings from field surveys and laboratory analyses of environmental samples formed the foundational data for this report. These results were further processed and analyzed to assess technogenic alterations in the environmental condition and the living standards of the local population.

Fieldwork, the main scope of on-site investigations, chemical-analytical testing of collected samples, systematization of initial reconnaissance observations, ecological assessment, and preparation of the final report were all carried out by USRIEP specialists. The socio-economic research component was conducted by experts from the SCIENTIFIC AND TECHNICAL PRODUCTION COMPANY “UKRAINE” LLC (STPC “UKRAINE” LLC).

This report was prepared by the staff of the Laboratory of Ecological Hydrogeology and Assessment of the Ecological State of Territories and the Laboratory of Ecological and Analytical Research on the consolidated results of USRIEP’s monitoring activities.

PART 1 ASSESSMENT OF ENVIRONMENTAL POLLUTION IN AREAS AFFECTED BY THE OIL DEPOT EXPLOSION IN THE NEMYSHLYANSKYI DISTRICT OF KHARKIV FOR THE PERIOD JULY – DECEMBER 2024 AND JANUARY – APRIL 2025 (COVERING SUMMER, AUTUMN, AND WINTER LOW-WATER SEASONS, AND THE SPRING FLOOD PERIOD)

1. Background

In February 2024, an oil depot in the city of Kharkiv, storing over 3,800 tons of fuel and lubricants, was attacked by enemy UAVs. As a result of the explosion, nearly 3,000 tons of diesel fuel and gasoline leaked from above-ground tanks and ignited. A mixture of fuel and melted snow entered the Nemyshlya River, causing pollution not only to the Nemyshlya itself, but also to the Kharkiv, Lopan, and Udy rivers. Additionally, petroleum products contaminated the soils in areas of dense residential development. The emergency environmental protection measures introduced during the critical phase by the Kharkiv city administration, the Nemyshlyanskyi district administration, scientific institutions in Kharkiv, and others helped transition the acute environmental contamination to a stage of chronic pollution.

In order to ensure environmentally acceptable living conditions – especially for children – scientists faced the urgent task of assessing the intensity and scale of the consequences of the oil depot explosion. Addressing this issue requires the implementation of a monitoring program and the acquisition of data on the current condition of groundwater, surface waters, soils, bottom sediments of the Nemyshlya River, and the socio-economic living conditions of the affected population.

The results of these monitoring studies will serve as an environmental basis for ensuring civil protection in response to the catastrophic situation in the Nemyshlyanskyi district of Kharkiv. Given that children are among the residents of the affected areas, the United Nations Children's Fund (hereafter UNICEF) provided support to the Scientific Research Institution "Ukrainian Scientific Research Institute of Ecological Problems" (USRIEP) in implementing measures to reduce the anthropogenic impact on soils and the groundwater aquifer. This support enabled research and monitoring activities to be conducted throughout a hydrological year (from October 10, 2024, to June 9, 2025).

According to the UNICEF work plan under the Memorandum dated July 9, 2024 № UKR/MOU 2024405 with UNICEF Representative Ukraine was planned to conduct chemical and analytical analysis of soil samples; monitoring of contamination levels; assessment of the penetration depth of petroleum products

within the aeration zone; and evaluation of the likelihood and extent of their migration from the aeration zone into the groundwater aquifers.

2. Current state of groundwater

2.1 Assessment of groundwater quality in wells, individual boreholes, and water standpipes

Groundwater monitoring was conducted throughout 2024 – 2025 during summer low-water periods (July, August), autumn low-water periods (September, October, November), winter low-water periods (December, January, February), and the spring flood period (March, April), all under conditions of chronic environmental contamination.

As part of a comprehensive monitoring program aimed at assessing the environmental consequences of the oil depot explosion in the Nemyshlyanskyi district of Kharkiv, groundwater samples were collected within the pollution zone for chemical composition analysis and contamination intensity assessment. Specifically, the samples were analyzed for macrocomponents and specific contaminants – namely petroleum products and heavy metals.

Sampling of groundwater in 2024–2025 was carried out in wells, individual boreholes, and water intake columns located on Zapovidna Street, 54; Plidna Street, 28; Tankova Street, 129; 1st Plidnyi Lane, 9; as well as in a captured spring at 66 Zapovidna Street (Fig. 2.1.1).

2.1.1 Assessment of groundwater quality based on chemical indicators

Depending on the sampling period, the chemical composition of groundwater in the specified locations varied. During the ***low-water*** period: in wells and boreholes, water was characterized by *sodium bicarbonate* (C^{Na}) composition (summer low-water period:); *calcium bicarbonate* (C^{Ca}) (autumn low-water period); *magnesium bicarbonate* (C^{Mg}) *and calcium bicarbonate* (C^{Ca}) – during the winter low-water period.

In water standpipes, the water was predominantly of the calcium bicarbonate (C^{Ca}) and *calcium-magnesium bicarbonate* (C^{CaMg}) types. In a spring with a catchment structure, the water was of *sodium bicarbonate* (C^{Na}) and *calcium bicarbonate* (C^{Ca}) types.

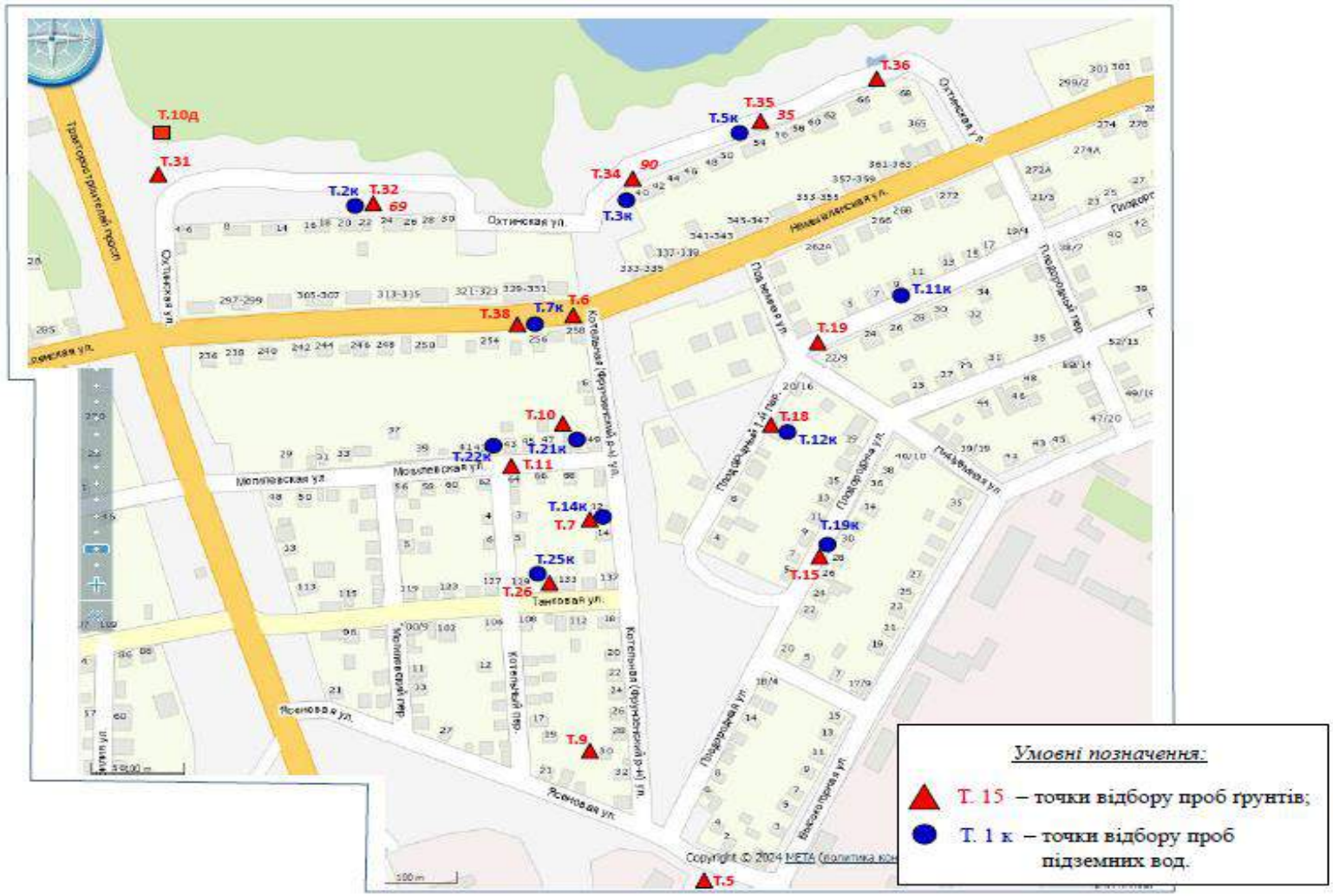


Figure 2.1.1. Schematic of soil and groundwater sampling location in the area of contamination

In the spring, the types of groundwater changed slightly compared to the low-water period: In wells and boreholes, water, as in the period of low water, was characterized by *bicarbonate-sodium (C^{Na})* type; in water intake columns - by *bicarbonate-calcium (C^{Ca}), bicarbonate-sodium (C^{Na})* and occasionally *sulfate-bicarbonate* calcium (SC^{Ca}) types; in a captured spring - by *bicarbonate-sodium (C^{Na})* type. That is, in the spring, there is a slight predominance of *sodium* in the cationic composition of groundwater.

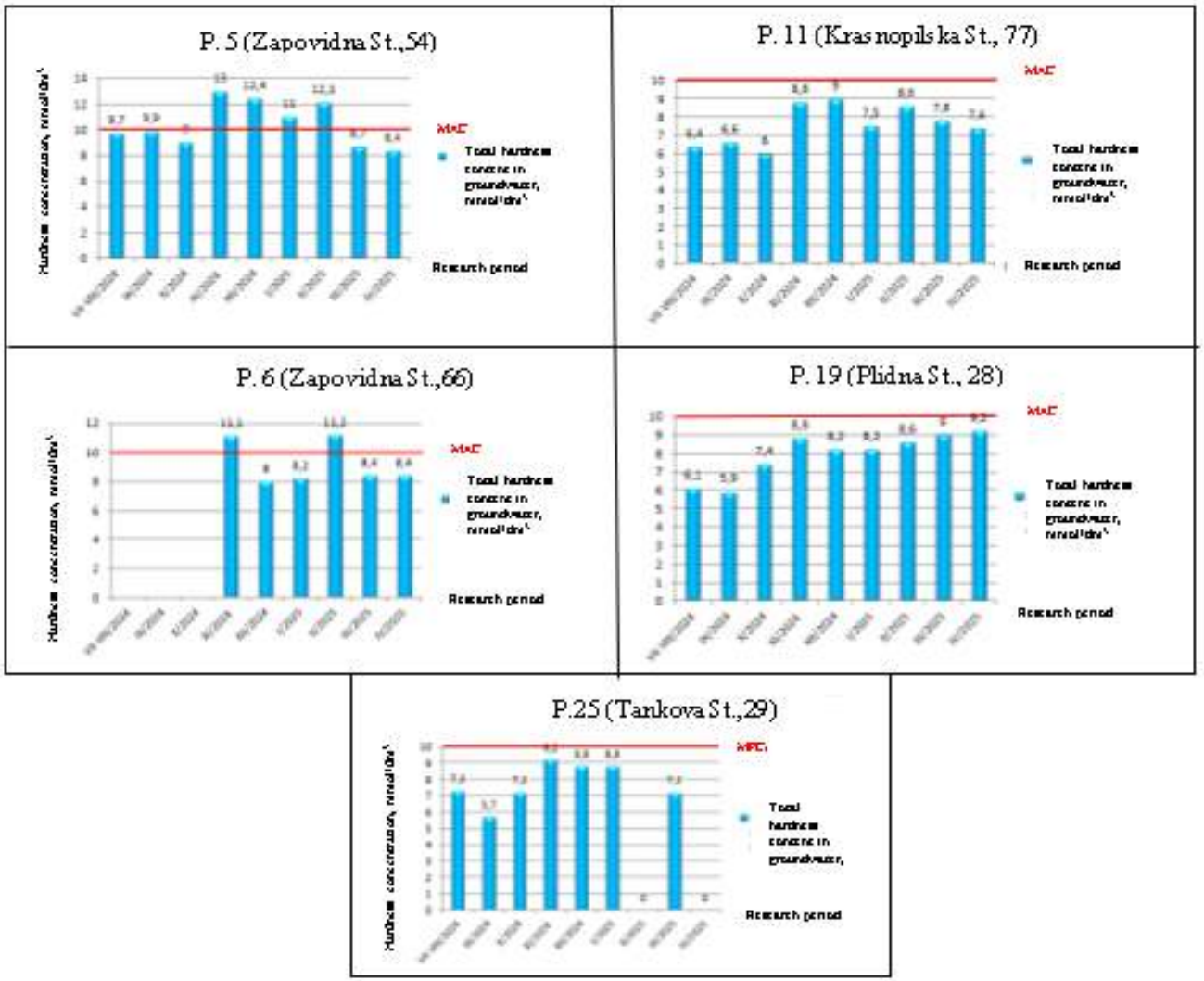
General Indicators. In terms of active reaction (pH), groundwater in wells during the summer low-water period was predominantly neutral (pH = 7.00–7.34), with occasional instances of being slightly alkaline (pH = 7.64). In the autumn low-water period, water reaction ranged from neutral (pH = 6.94–7.4) to slightly alkaline (pH = 7.64). In winter, the water remained neutral (pH = 7.20). In standpipes, groundwater was neutral (pH = 6.85–7.50) during the winter low-water season, and mostly slightly alkaline (pH = 7.77–7.96) during the spring flood. In boreholes, water was neutral (pH = 6.78–7.11). Overall, based on the pH (active reaction) index, groundwater was predominantly neutral throughout the monitoring period, with pH values ranging from 6.78 to 7.96.

According to the *total hardness indicator*, water in **wells** during the *summer and autumn low-water periods* is characterized as *very hard*, with values of 9.7 mmol/dm³ and 9.0–13.0 mmol/dm³, respectively; during the *winter low-water period*, it is also *very hard* (11.0–12.4 mmol/dm³); during the *spring flood period*, it is classified as *hard* (8.4–8.7 mmol/dm³). In **boreholes,** water is *hard* (8.8 mmol/dm³); in **water intake columns**, it is *hard* in both the *summer and autumn periods* (6.4–8.8 mmol/dm³) and in winter (7.5–9.0 mmol/dm³); in the **captured spring**, water is *hard* in January (8.2 mmol/dm³) and *very hard* in February (11.2 mmol/dm³). In the spring period, groundwater is classified as *hard* in wells (8.4–8.7 mmol/dm³), in boreholes (8.2 mmol/dm³), in water intake columns (7.4–9.2 mmol/dm³), and in the captured spring (8.4 mmol/dm³) (Fig. 2.1.1.1).

Mineralization indicators. Over the course of the study period, water mineralization varied depending on usage conditions.

In **wells**, during the *summer low-water period*, water mineralization was 1.33 g/dm³; during the *autumn low-water period*, it ranged from 1.05 to 1.11 g/dm³; in the *winter period*, it ranged from 1.15 to 1.24 g/dm³; and during the *spring flood period*, from 1.10 to 1.14 g/dm³.

In **boreholes**, water mineralization was 0.78 g/dm³ during the *summer low-water period*; 0.75 to 0.88 g/dm³ during the *autumn low-water period*; 0.62 to 0.69 g/dm³ during the *winter low-water period*; and 0.88 g/dm³ during the *spring flood period.*



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Figure 2.1.1.1. Dynamics of changes in the hardness of total groundwater for the study period (September 2024 - April 2025)

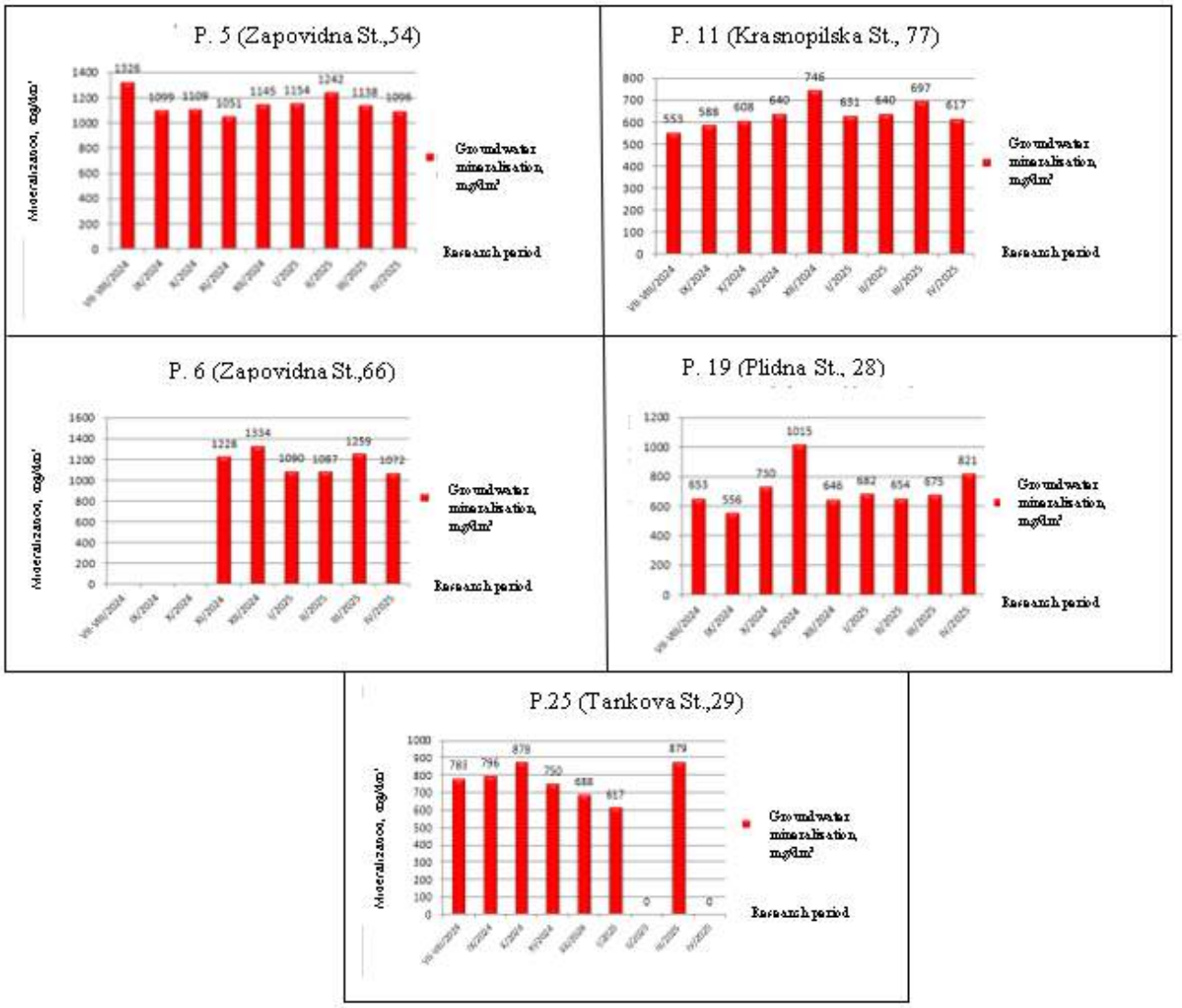


Figure 2.1.1.2. Dynamics of changes in groundwater salinity for the study period (September 2024 - April 2025)

In **water standpipes**, the mineralization of water remained nearly unchanged and amounted to 0.55 g/dm³ during the summer period; 0.56–1.02 g/dm³ in the autumn; 0.64–0.70 g/dm³ in the winter; and 0.68–0.70 g/dm³ in March and 0.62–0.82 g/dm³ in April during the spring period. The mineralization of spring water was 1.09 g/dm³ in both January and February, 1.26 g/dm³ in March, and 1.07 g/dm³ in April (Fig. 2.1.1.2).

Chloride concentrations did not exceed the regulatory limits established by DSanPiN 2.2.4-171-10 and ranged from 31.9 to 92.3 mg/dm³ during the winter period, and from 28.4 to 71.0 mg/dm³ during the spring period (Fig. 2.1.1.3).

During the winter low-water period, ***sulfate*** concentrations in groundwater remained within regulatory limits and amounted to 211.2–220.8 mg/dm³ in well water; 76.8–144.0 mg/dm³ in water intake columns; 86.4 mg/dm³ in the borehole on Tankova Street, 129; and 201.6–220.8 mg/dm³ in the spring water. During the spring flood period, ***sulfate*** concentrations in groundwater increased (Fig. 2.1.1.4) and reached 268.8–283.2 mg/dm³ in well water; 163.2–216.0 mg/dm³ in water intake columns; 235.2 mg/dm³ in the borehole on Tankova Street, 129; and 230.4–240.0 mg/dm³ in the spring water [1].

Biogenic substances. The concentrations of *nitrogen and phosphorus* compounds in the collected groundwater samples during the monitoring period were both within and above the Maximum Allowable Concentrations (MAC). Exceedances were recorded only during the summer period, specifically for *nitrites* and *phosphates* in wells [2]. *Nitrite* concentrations in wells were as follows: at Zapovidna St., 54 – 25.05 mg/dm³ (9.41 MAC), and at Nemyshlyanska St., 256A – 39.37 mg/dm³ (14.8 MAC). *Phosphate* concentrations reached 4.94 mg/dm³ (1.35 MAC) at Zapovidna St., 40, and 7.70 mg/dm³ (2.11 MAC) at Zapovidna St., 54. *Nitrite* concentrations in the summer also exceeded acceptable levels in the borehole at Mohylianska St., 43/1 – 93.06 mg/dm³ (1.86 MAC), and again in January (53.0 mg/dm³ – 1.06 MAC) and April (55.1 mg/dm³ – 1.10 MAC). *Ammonium ion* (NH_4) concentrations in wells during summer ranged from undetectable (<0.15 mg/dm³) to 0.19–0.53 mg/dm³. In boreholes and water-lifting columns, ammonium was not detected.

The concentration of *ammonium ions (NH_4)* in the spring period was recorded in all other sampling points at *less* than 0.15 mg/dm³, indicating their absence. The content of *nitrites* (NO_2) *in wells, boreholes, standpipes, and the captured spring in April* was recorded at levels *below* 0.03 mg/dm³. In March, only in the standpipe (P.11 – 1st Plidnyi Lane, 9), the nitrite concentration was 0.05 mg/dm³ (0.1 MAC). Therefore, during the spring monitoring period, nitrites were considered absent in the groundwater. The concentration of *nitrates (NO_3)* in March ranged from 3.58 mg/dm³ to 17.90 mg/dm³ in wells and standpipes, while in the captured spring



Figure 2.1.1.3. Dynamics of changes in groundwater chloride concentrations for the study period (September 2024 - April 2025)

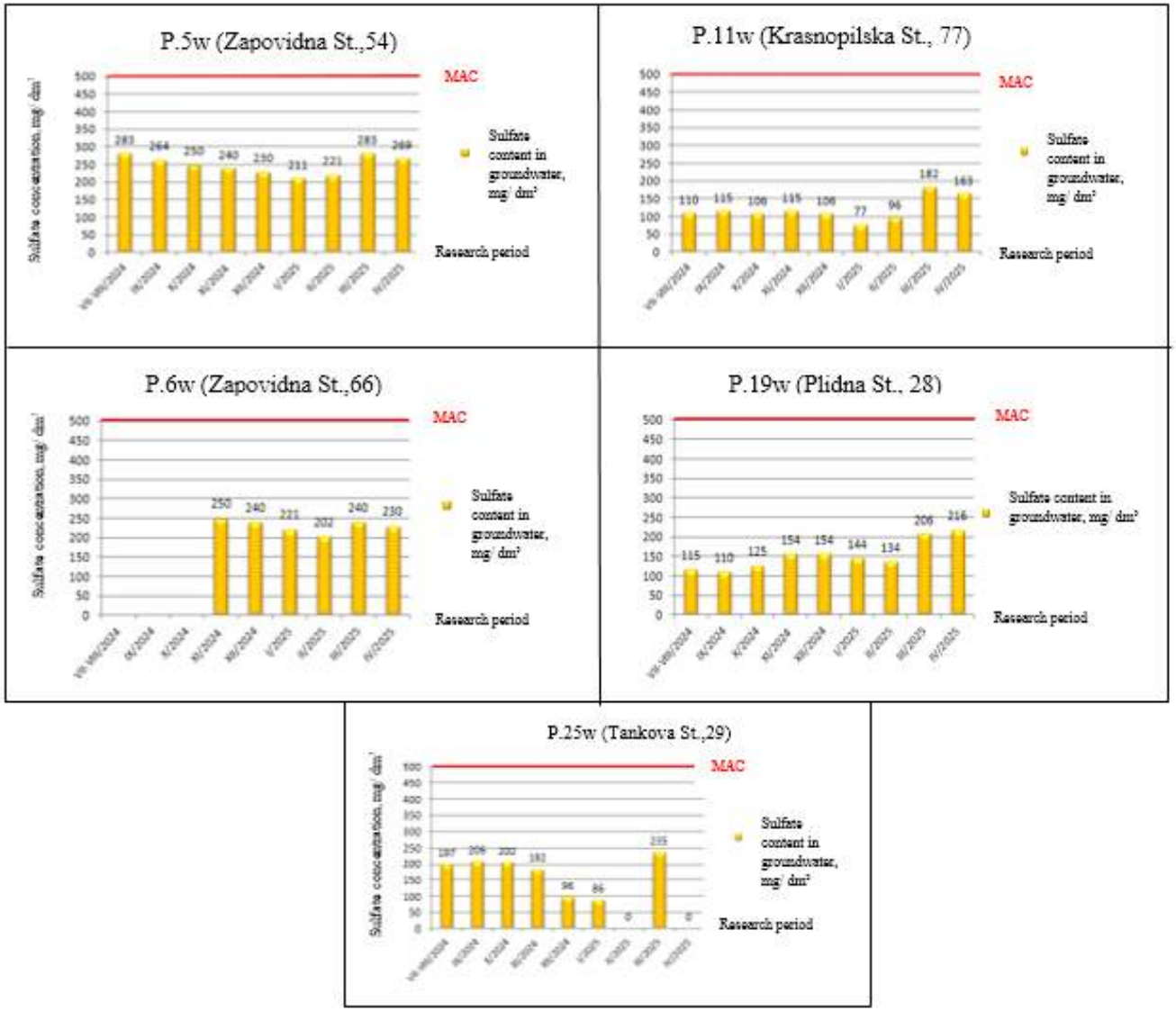


Figure 2.1.1.4. Dynamics of changes in groundwater sulfate concentrations for the study period (September 2024 - April 2025)

on Zapovidna Street, 66, it reached 44.75 mg/dm³, remaining below the MAC. In April, the nitrate content in spring water was 48.4 mg/dm³, which not exceeded the MAC for drinking water (0.97 MAC) [2]. *Nitrates* were absent in the borehole water on Tankova Street, 129. *Phosphates* (PO_4) were present in concentrations ranging from 0.45 mg/dm³ to 1.76 mg/dm³ in March and from 0.78 mg/dm³ to 1.84 mg/dm³ in April, all of which did not exceed the MAC for drinking water.

Biogenic substances. The content of ammonium ions (NH_4) in well water ranged from below detection (<0.15 mg/dm³) to 0.19–0.53 mg/dm³, while in boreholes and standpipes, ammonium ions were absent.

The *nitrite* content *(NO_2)* in boreholes and standpipes was generally below the method's sensitivity limit, except for wells on Zapovidna Street, 22 and 54, and on Nemyshlyanska Street, 256A, where critical concentrations were recorded at 1.03 mg/dm³, 25.05 mg/dm³, and 39.37 mg/dm³, respectively (2 MAC, 50,01 MAC, 78,74 MAC).

Nitrates (NO_3) were recorded in concentrations ranging from undetectable (<0.5 mg/dm³) to 1.78–34.82 mg/dm³, except for P.21w (well on Mohylevska Street, 49) and P.22w (well on Mohylevska Street, 43/1), where nitrate concentrations reached 50.1 mg/dm³ (1.00 MAC) and 93.06 mg/dm³ (1.86 MAC), respectively. These values exceed the MAC (according to DSanPiN 2.2.4-171-10 – 50.0 mg/dm³) for groundwater used by the local population from dug wells.

Summary. The mineralization of groundwater during the study period ranged between 0.55 and 1.33 g/dm³, which complies with regulatory requirements [2]. None of the samples showed exceedance of MAC for salt content. Similarly, chloride and sulfate concentrations were below MAC values (Figs. 2.1.1.3, 2.1.1.4). Groundwater, both during low-water and spring flood periods, is classified as fresh.

2.1.2 Level of groundwater contamination by petroleum products

During the summer low-water period, the presence of *petroleum products* in *groundwater from wells* was not detected, and the same applies to the autumn and winter periods. However, in *boreholes* located on Plidna Street, 28, and 1st Plidnyi Lane, 16, petroleum products appeared in November in concentrations of 0.16–0.26 mg/dm³ (1.6–2.6 MAC), and in December on Tankova Street, 129, the concentration reached 0.27 mg/dm³ (2.7 MAC), which does not comply with regulatory requirements for drinking water. It should also be noted that the concentration of *petroleum products* in the water of *standpipes* increased from being *undetectable* in autumn to 0.41 mg/dm³ (4.1 MAC) in the winter period (1st Plidnyi Lane, 9). In the *standpipe* on Plidna Street, 28, concentrations increased from *undetectable* to 0.45 mg/dm³ (4.5 MAC).

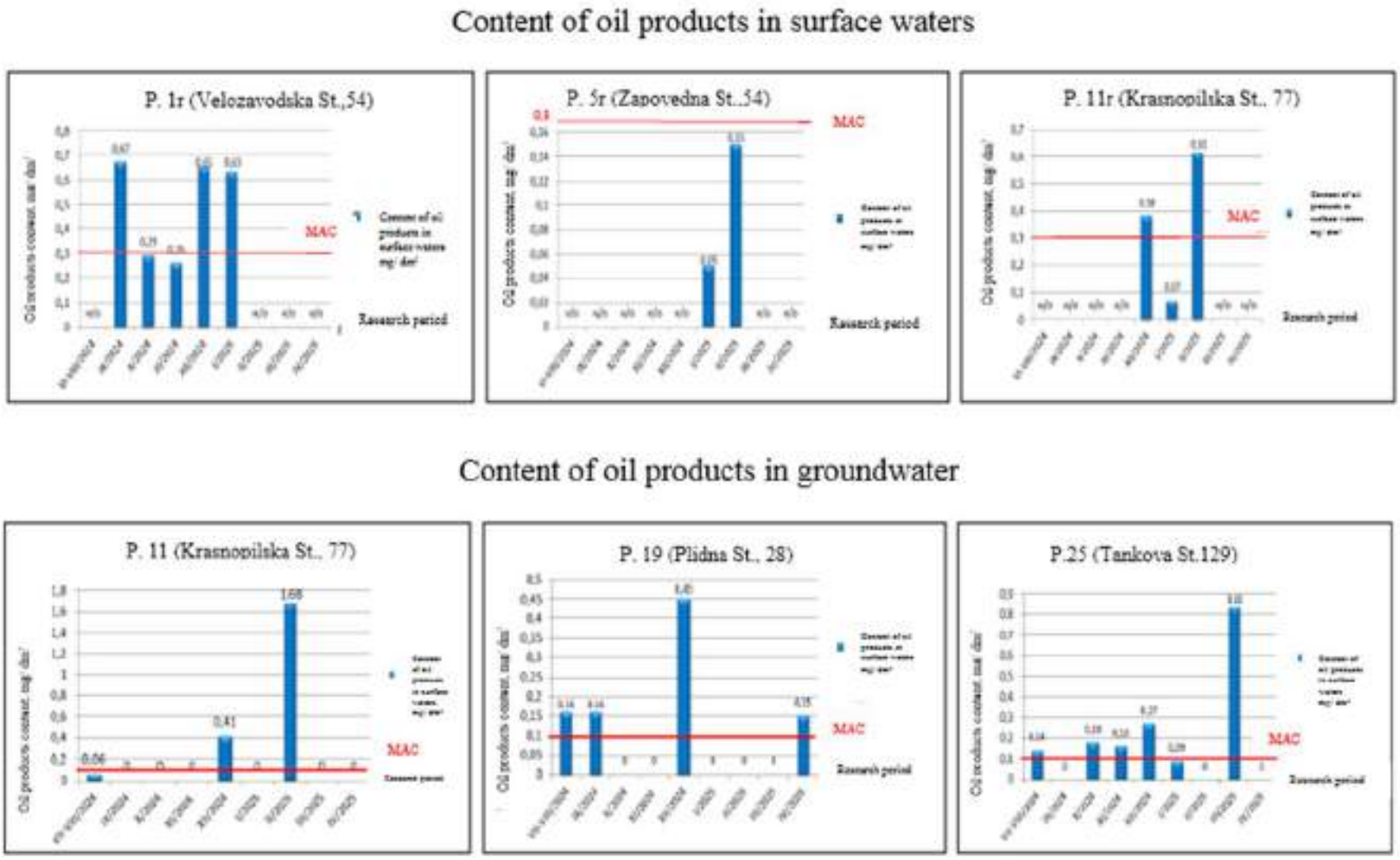


Figure 2.1.2.1. Dynamics of changes in the concentration of oil products in surface and groundwater for the study period (September 2024 - April 2025)

At the *captured spring* on Zapovidna Street, 66, petroleum products at a concentration of 0.21 mg/dm³ (2.1 MAC) were detected only in December, during the winter low-water period.

In January, oil products were absent in the well, standpipes, and the captured spring. They were detected only in the borehole on Tankova Street, 129, with a concentration of 0.09 mg/dm³, which does not exceed the MAC for drinking water [1,5].

In February, petroleum products appeared at concentrations significantly exceeding the MAC for drinking water: in the *well* on Zapovidna Street, 54 – 0.43 mg/dm³ (4.3 MAC); in the *standpipe* on 1st Plidnyi Lane, 9 – 1.68 mg/dm³ (16.8 MAC); and in the *spring water* on Zapovidna Street, 66 – 0.64 mg/dm³ (6.4 MAC). At the same time, petroleum products were not detected in the standpipe water on Plidna Street, 28.

In March, *petroleum products* were detected only in the borehole on Tankova Street, 129 – 0.83 mg/dm³ (8.3 MAC), and in April – in the *standpipe* on Plidna Street, 28 – 0.15 mg/dm³ (1.5 MAC). In other points, *petroleum products* were not detected (Fig. 2.1.2.1).

Summary. The ecological situation developing in the aquatic environment of the affected area is rather hazardous and requires continued monitoring of changes in oil product concentrations in drinking water, as well as control over their occurrence in other water sources (water supply) – including wells, boreholes, and standpipes.

Summary. The environmental situation forming in the aquatic environment of the affected area is rather hazardous and requires ongoing monitoring of changes in petroleum product concentrations in drinking water, as well as monitoring of their appearance in other water sources used by the population (wells, boreholes, and standpipes).

2.1.3 Assessment of groundwater quality based on heavy metal content

During the study period, *heavy metal* concentrations in groundwater from dug wells, standpipes, and private household boreholes varied depending on their geographic location. Apart from manganese, metal concentrations in groundwater during the summer, autumn, winter, and spring periods did not exceed MAC and varied within the following ranges (mg/dm³) (Figs. 2.1.3.1 – 2.1.3.5):

- Manganese – 0.0094-0.21 mg/dm³ (< MAC to 2.1 MAC). An exceedance of the MAC was recorded only in the borehole on Tankova Street, 129; a concentration at the level of 1 MAC was recorded in the well on Zapovidna Street, 54.

- Boron – 0.084–0.43 mg/dm³, with the highest value in the well on Zapovidna

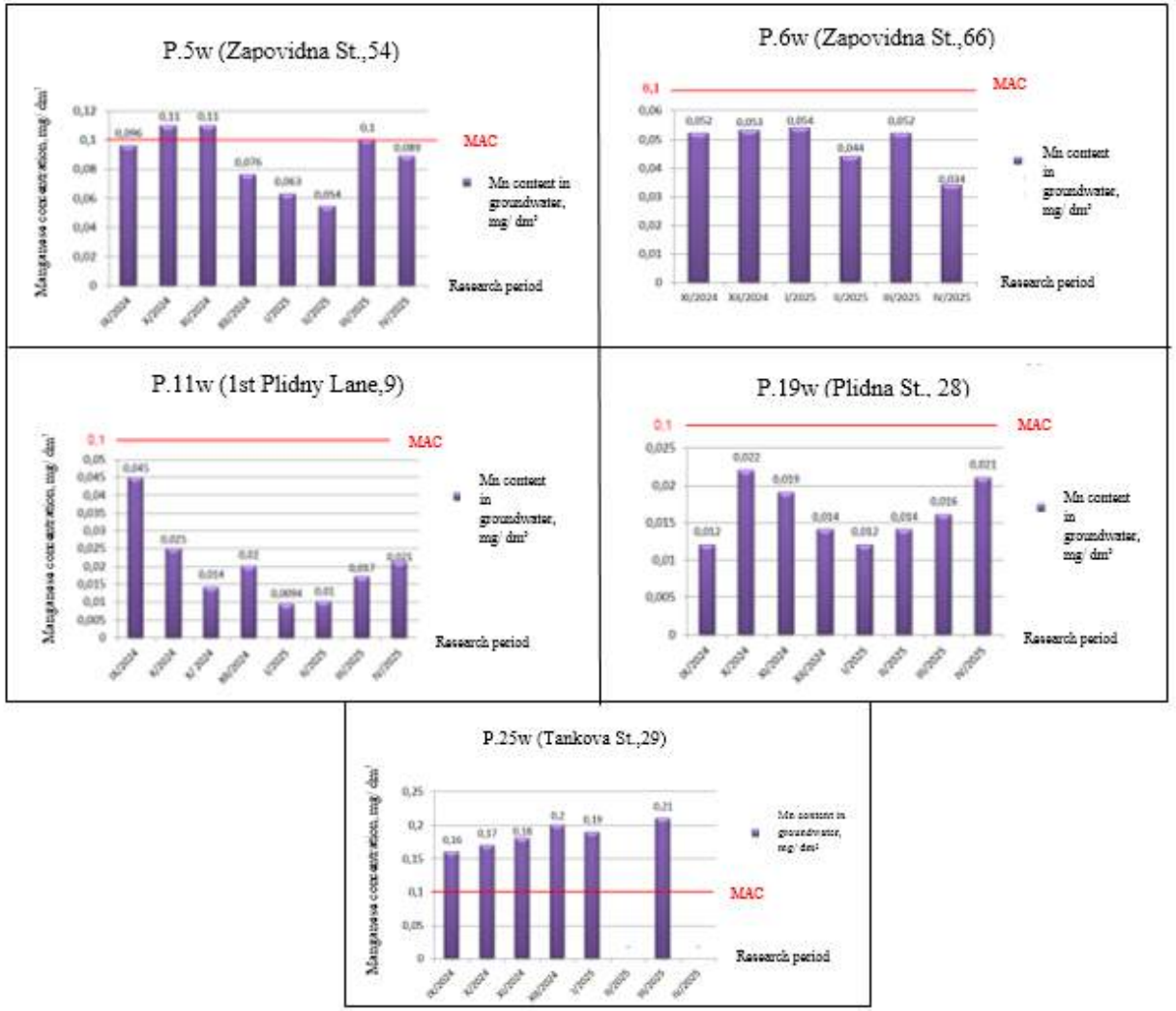


Figure 2.1.3.1. Dynamics of changes in manganese concentrations in groundwater for the study period (September 2024-April 2025)

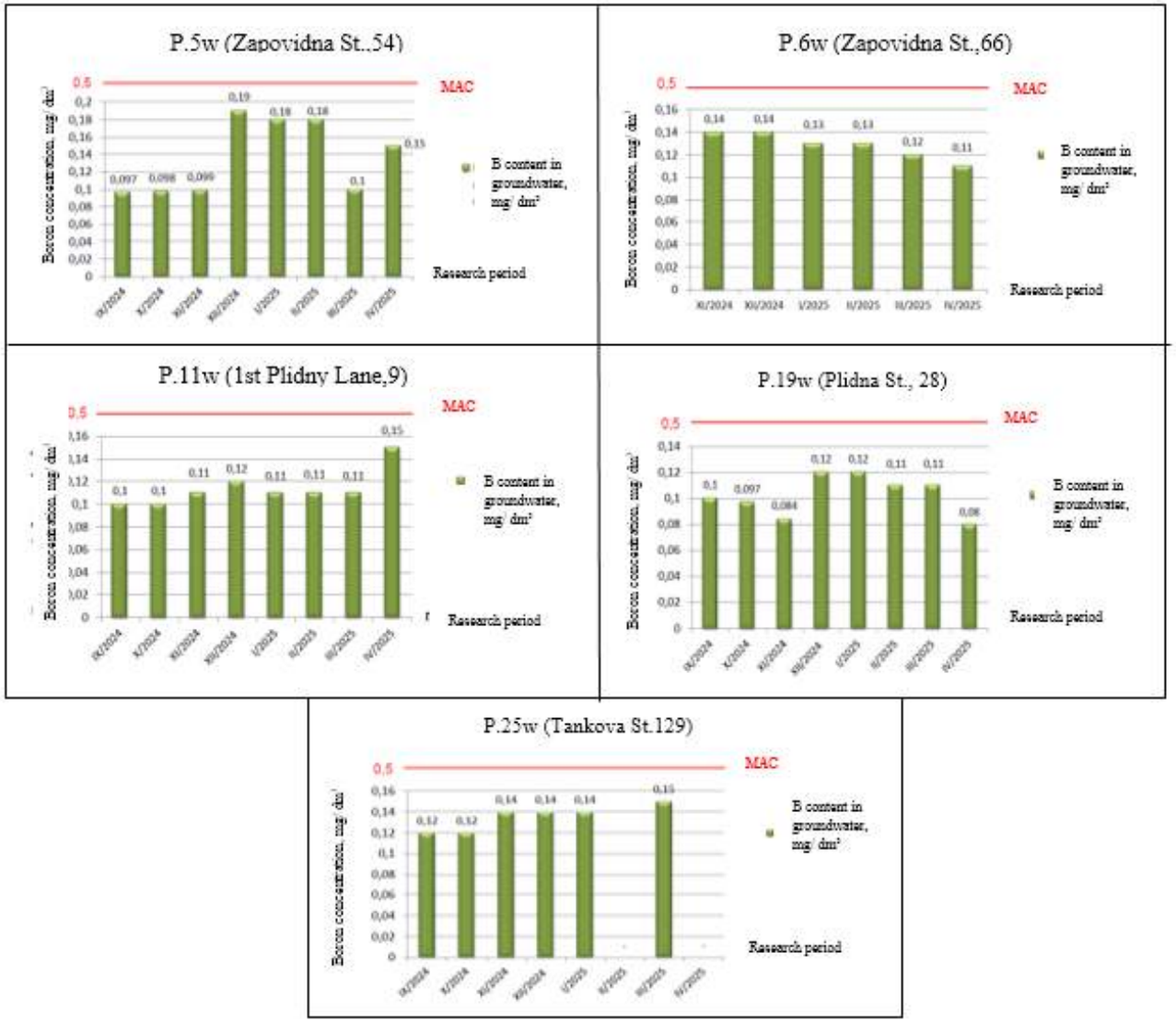


Figure 2.1.3.2. Dynamics of changes in boron concentrations in groundwater for the study period (September 2024 – April 2025)

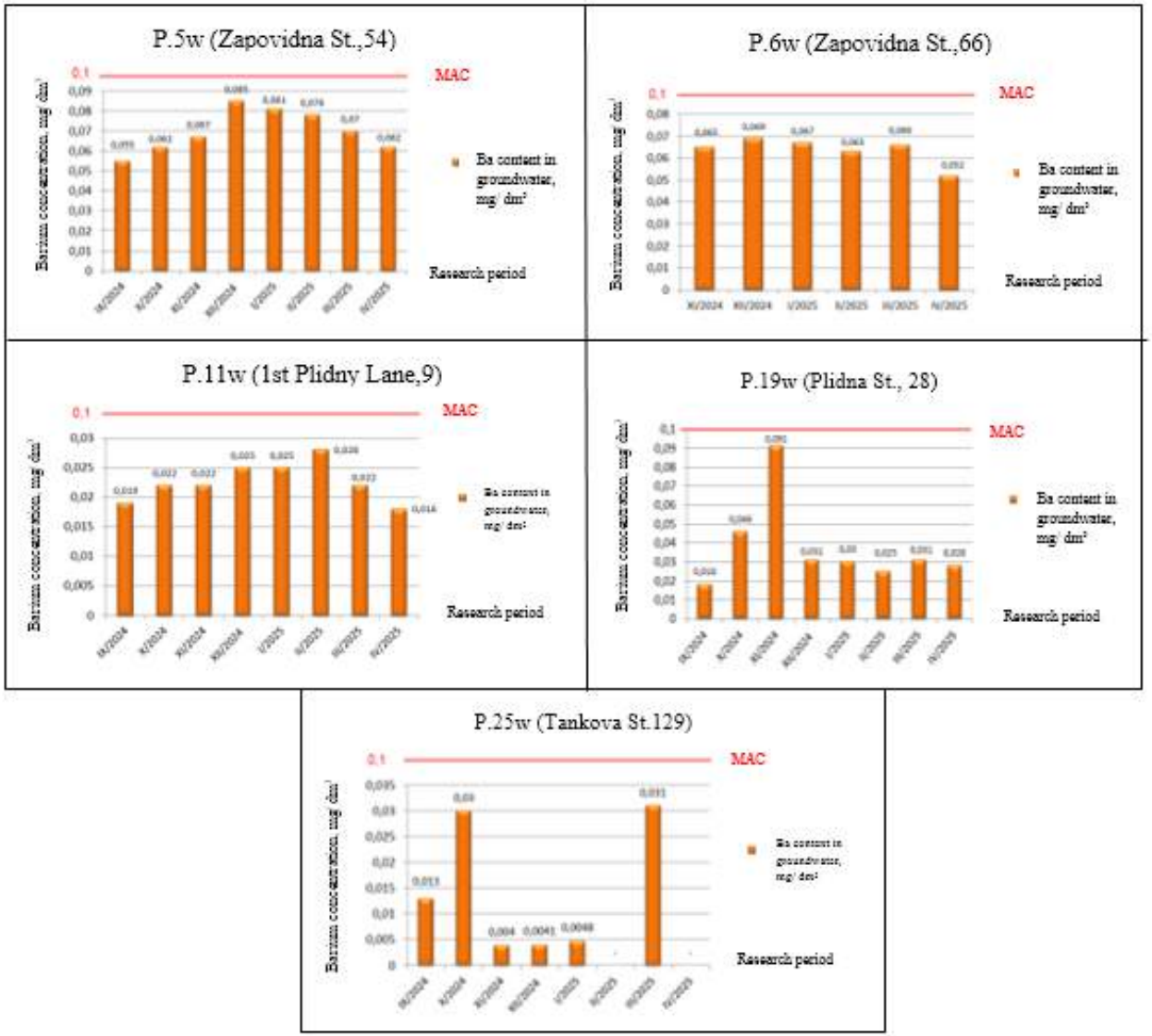


Figure 2.1.3.3. Dynamics of changes in barium concentrations in groundwater for the study period (September 2024 - April 2025)

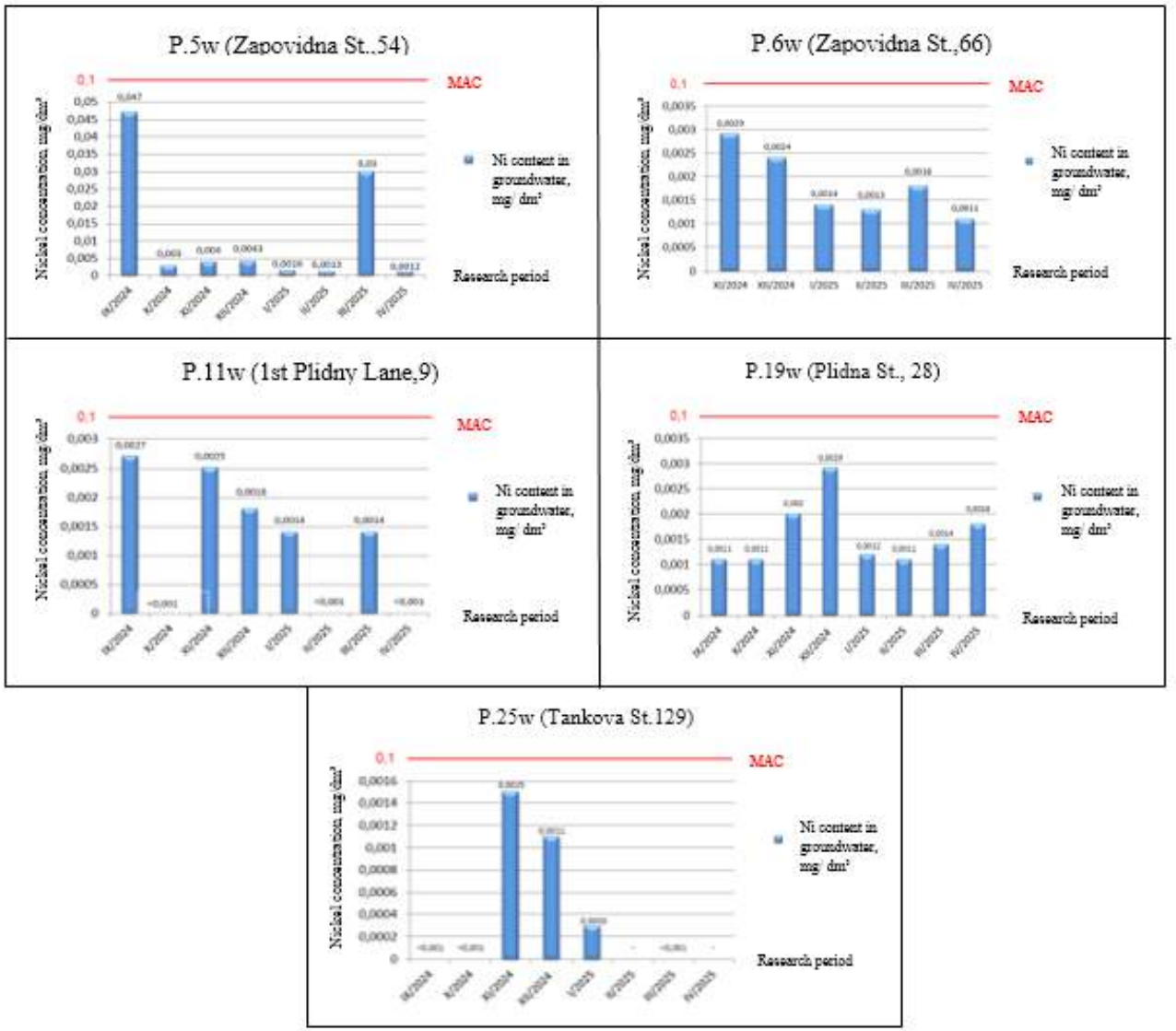


Figure 2.1.3.4. Dynamics of changes in nickel concentrations in groundwater over the study period (September 2024 - April 2025)

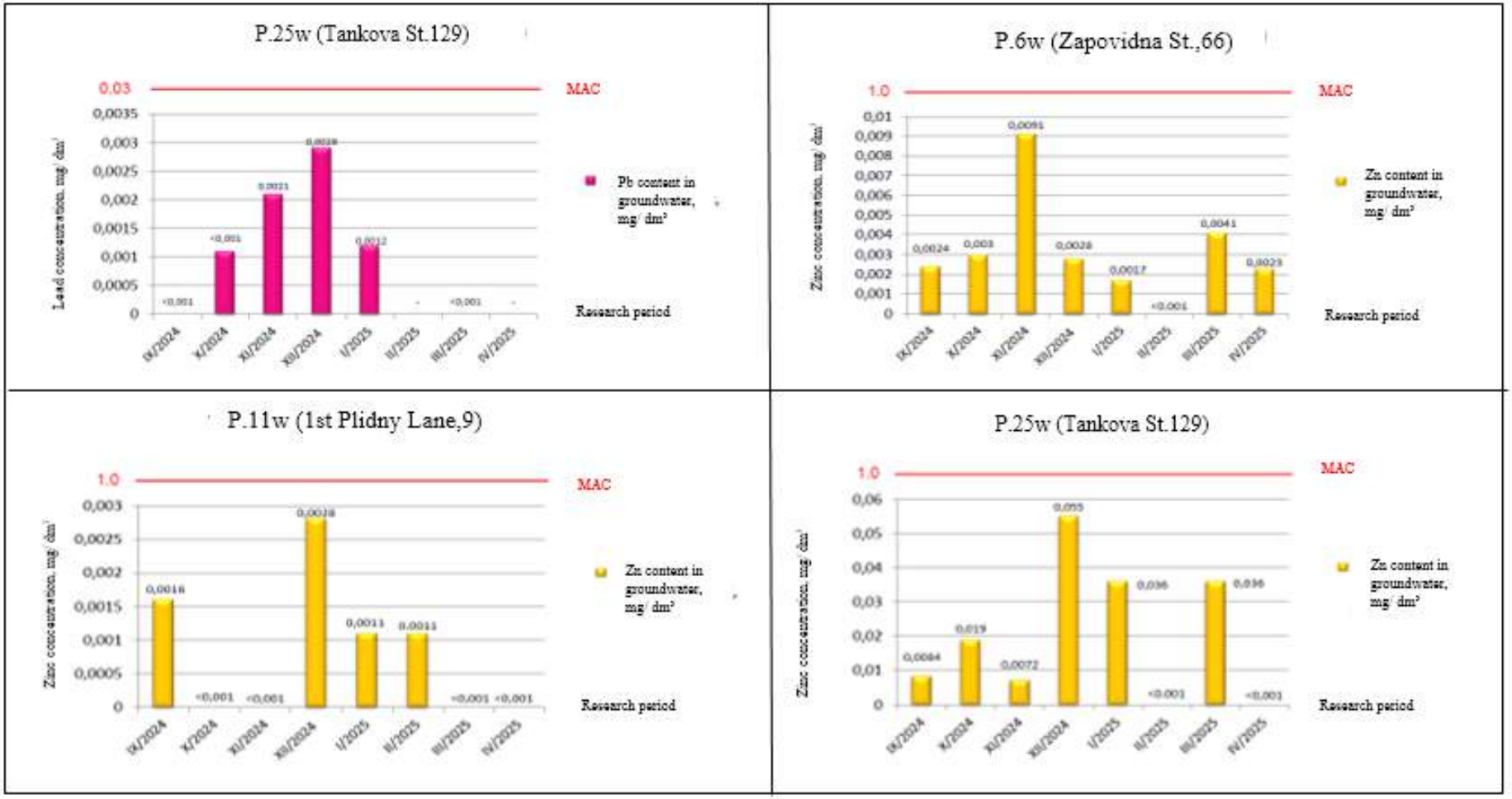


Figure 2.1.3.5. Dynamics of changes in zinc and lead concentrations in groundwater for the study period (September 2024 - April 2025)

Street, 54 and the lowest in the borehole on Tankova Street, 129.

- Barium – ranged from 0.0031–0.091 mg/dm³ in the borehole (P.25) to 0.0014–0.0018 mg/dm³ in the standpipes and the well on Zapovidna Street, 54.

- Nickel – ranged from below 0.001 mg/dm³ to 0.0011–0.0043 mg/dm³, with the highest concentration found in the well on Zapovidna Street, 54 in January.

- Zinc – ranged from below 0.001 mg/dm³ to 0.001–0.036 mg/dm³, with the highest concentration in the borehole on Tankova Street, 129.

Lead was detected during the autumn period only in the well on Zapovidna Street, 54 (0.00073 mg/dm³), and in the borehole on Tankova Street, 129 in the autumn, winter (0.0012 mg/dm³), and spring periods, with concentrations of 0.0011–0.0021 mg/dm³ and 0.0029 mg/dm³, respectively – well below the MAC.

Concentrations of lead in groundwater samples from points P.5w, P.6w, P.11w, and P.19w, cadmium (P.5w, P.6w, P.11w, P.19w, P.25w), and zinc (P.6w, P.19w) throughout the entire study period were recorded at levels below 0.001 mg/dm³, 0.0001 mg/dm³, and 0.001 mg/dm³ respectively, which are below the detection limit of the measuring instruments.

Cadmium was not detected in any sample (concentrations were at the level of 0.0001 mg/dm^3) (Tables B.6–B.7, Annex B, and A.5–A.12, Annex A in Book 2, Annexes (1st–3rd stages of 2024–2025) - previous reports in Ukrainian).

2.1.4 Depth of groundwater levels in dug wells and private boreholes within the study area

The depth of groundwater levels in the study area during the monitoring period depended on the relief features, water usage patterns, and the hydrogeological regime.

In the impact zone of the fire caused by the explosion at the Kharkiv Oil Depot LLC “KhNB - Reserve” measurements of groundwater levels were carried out only in those private wells and boreholes where access was granted by property owners—namely, wells on Zapovidna Street, 54 and 22 (P.5w and P.7w), and a borehole on Tankova Street, 129 (P.25w).

According to the results of measurements, in the summer of 2024, the water level in these wells was 1.40 m, in the autumn and winter, respectively, 1.35 m and 1.37 m. In the spring flood period (March 2025), the groundwater level in the wells was measured at depths of 1.14 m and 1.17 m (P.5w, P.7w), indicating a seasonal rise typical for spring conditions.

The groundwater level in the borehole (P.25w) ranged from 41 m to 42 m depending on its operational regime during the monitoring period.

Summary. According to the results of groundwater level depth measurements

throughout the entire monitoring period (2024 – 2025), it can be noted that during both the summer-autumn low-water period (July – September 2024) and the autumn-winter low-water period (October – December 2024 – January 2025), groundwater levels remained at nearly the same depth. In April 2025, the water level rose. Thus, the groundwater levels in *wells* varied depending on their location within the study area, the water use regime, and - significantly - on climatic conditions.

In *boreholes*, the groundwater level depth changed depending on usage patterns and climatic conditions.

3 Current state and quality of surface waters

3.1 Salt content in the surface waters of the Nemyshlya River, and the concentrations of petroleum products and heavy metals during the summer, autumn, and winter low-water periods and the spring flood of 2024–2025.

Surface water research in the Nemyshlya River during 2024–2025 was conducted by collecting river water samples at three hydrological monitoring points: in the vicinity of Velozavodska Street (P.1r), Zapovidna Street, 54 (P. 5r), and near the bridge on Krasnopilska Street, 77 (P. 11r), for chemical analysis of macrocomponents, petroleum products, and heavy metals (Fig. 3.1.1).

3.1.1 Assessment of surface water quality in the Nemyshlya River based on hydrochemical indicators

According to the research results, the macrocomponents composition of surface waters sampled in the above-mentioned sites is characterized by *bicarbonate-sodium* **(C^{Na})** (summer low water), *bicarbonate-calcium* **(C^{Ca})** and *bicarbonate-sodium* (autumn low water); predominantly *bicarbonate-calcium* **(C^{Ca})** (winter low water); *bicarbonate-sodium* **(C^{Na})** and *bicarbonate-calcium-sodium* **(C^{NaCa})** (spring low water) water types.

General Indicators. According to pH values, the water in the Nemyshlya River was predominantly slightly alkaline, ranging from pH 6.88 to 8.5: in July–August (summer low-water period), slightly alkaline (pH 7.53–7.95); in September–November (autumn low-water period), neutral to slightly alkaline (pH 7.02–7.90); in December–January (winter low-water), neutral to slightly alkaline (pH 6.88–8.10); and in March–April (spring flooding), ranging from neutral (pH 7.04–7.38) to slightly alkaline (pH 7.59) and alkaline (pH 8.34–8.50). The following indicators meet regulatory requirements [5].

According to the *total hardness* indicator, water throughout the study period

Умовні позначення:

Т. 1 р – точки відбору проб поверхневих вод;

Т. 1 д – точки відбору проб донних відкладень.

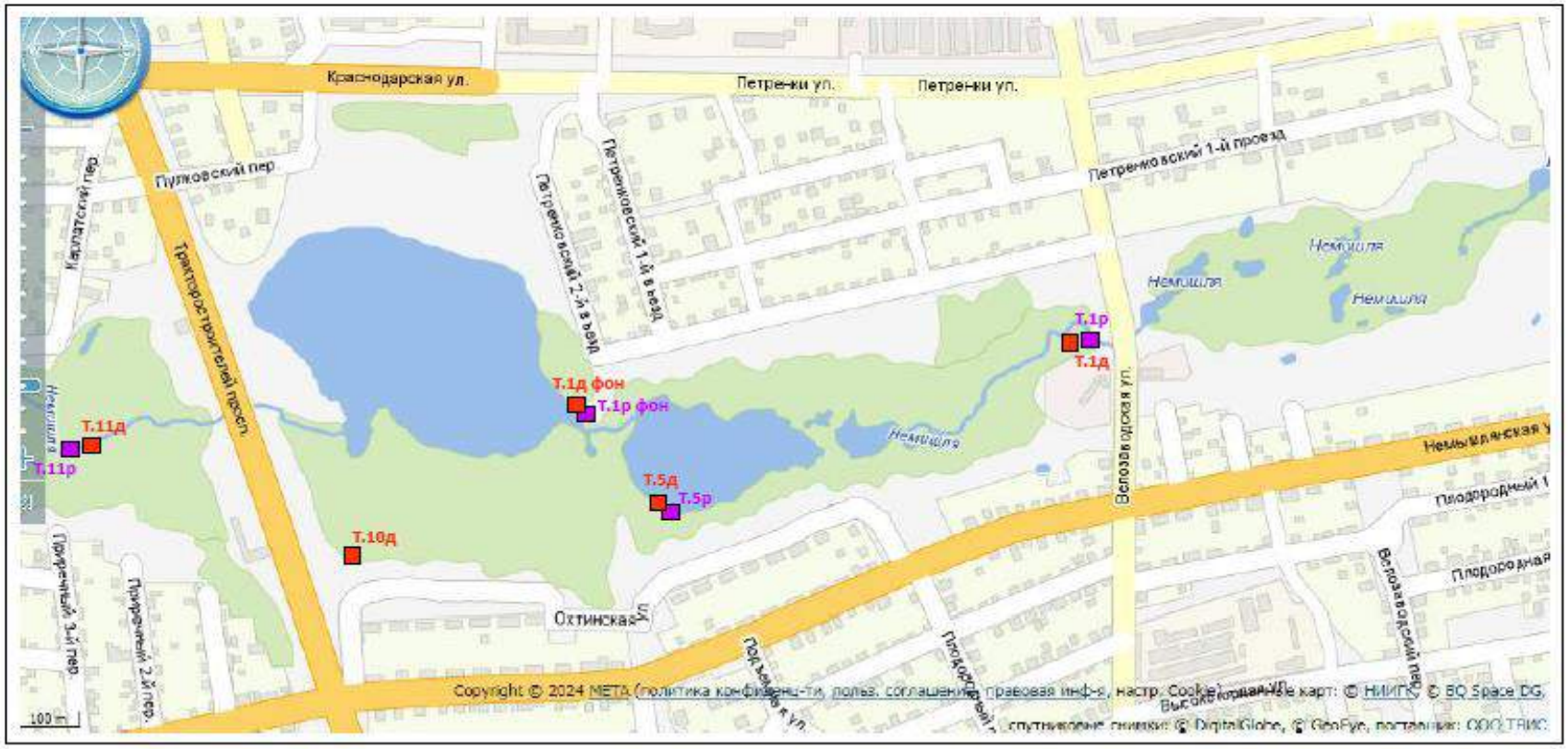


Figure 3.1.1. Layout of surface water and bottom sediment sampling points in the Nemyshlya River within the contamination hotspot.

was classified as *hard to very hard:* during the summer low-water period, it was characterized as *hard to very hard (8.2–8.8; 9.2–9.6 mmol/dm³);* during the autumn low-water period – *as hard* (8.4 mmol/dm³) and *very hard* (9.6–10.6 mmol/dm³); during the winter low-water period – as *very hard* in the area of *Velozavodska Street* (10.2–11.8 mmol/dm³) and *Krasnopilska Street* (10.6–12.2 mmol/dm³), and *hard* (8.4–8.8 mmol/dm³) in the area of *Zapovidna Street.* During the spring flood period (March–April), the *total hardness* of river water in all sections was classified as very hard and ranged from 9.2 to 10.8 mmol/dm³.

Mineralization indicators. The mineralization of river water varied seasonally: *in summer* it ranged from 1.10 to 1.16 g/dm³; *in autumn* – from 1.14 to 1.24 g/dm³; *in winter* – from 0.94 to 1.17 g/dm³; and *in spring* – from 1.00 to 1.22 g/dm³ (Fig. 3.1.1.1). Accordingly, the dry residue varied from 0.86 to 0.92 g/dm³ in summer; from 0.82 to 0.97 g/dm³ in autumn; from 0.70 to 0.91 g/dm³ in winter; and from 0.80 to 0.95 g/dm³ in March and April.

Both during low-water periods and the spring flood, the water was predominantly fresh. No exceedances of the maximum permissible concentrations (MACs) for total dissolved solids were recorded in any sample. Chloride and sulfate levels also remained below MACs.

Chloride and sulfate concentrations did not exceed the maximum permissible concentrations in any sampling section during summer-autumn or winter low-water periods, nor during the spring flood [2].

Chloride concentrations varied from 67.4–99.4 mg/dm³ in summer to 56.8–95.1 mg/dm³ in autumn; from 53.2 to 95.8 mg/dm³ in winter; and from 46.1 to 81.6 mg/dm³ in spring. *Sulfate* concentrations ranged from 249.6 to 350.4 mg/dm³ in summer and 220.8 to 288.0 mg/dm³ in autumn; from 172.8–192.4 mg/dm³ to 220.8–240.0 mg/dm³ in winter; and from 259.2 to 283.2 mg/dm³ in spring (March, April) (Fig. 3.1.1.2 – 3.1.1.3).

Biogenic substances. The concentrations of *nitrogen and phosphorus* compounds in water samples taken during the monitoring period remained within the MACs established for drinking and domestic use [2,5], except for *ammonium and phosphate* ions. *Ammonium* levels exceeded MACs during the summer low-water period - 2.14 mg/dm³ (4.28 MAC). A minor exceedance of *phosphate* concentration during the summer low-flow period – 3.65 mg/dm³ (1.04 MAC)—was recorded at only one sampling point, located near Zapovidna St., 54 (P. 5r).

Ammonium ions (NH_4) in the summer period were recorded at concentrations of 0.19–2.14 mg/dm³ (0.38-4.28 MAC); in spring, the concentration was below 0.15 mg/dm³, indicating their absence.

Nitrite (NO_2) concentrations in summer ranged from 0.07 to 1.07 mg/dm³ (2.01 MAC); in spring – from below detection to 0.04–0.08 mg/dm³, which is an

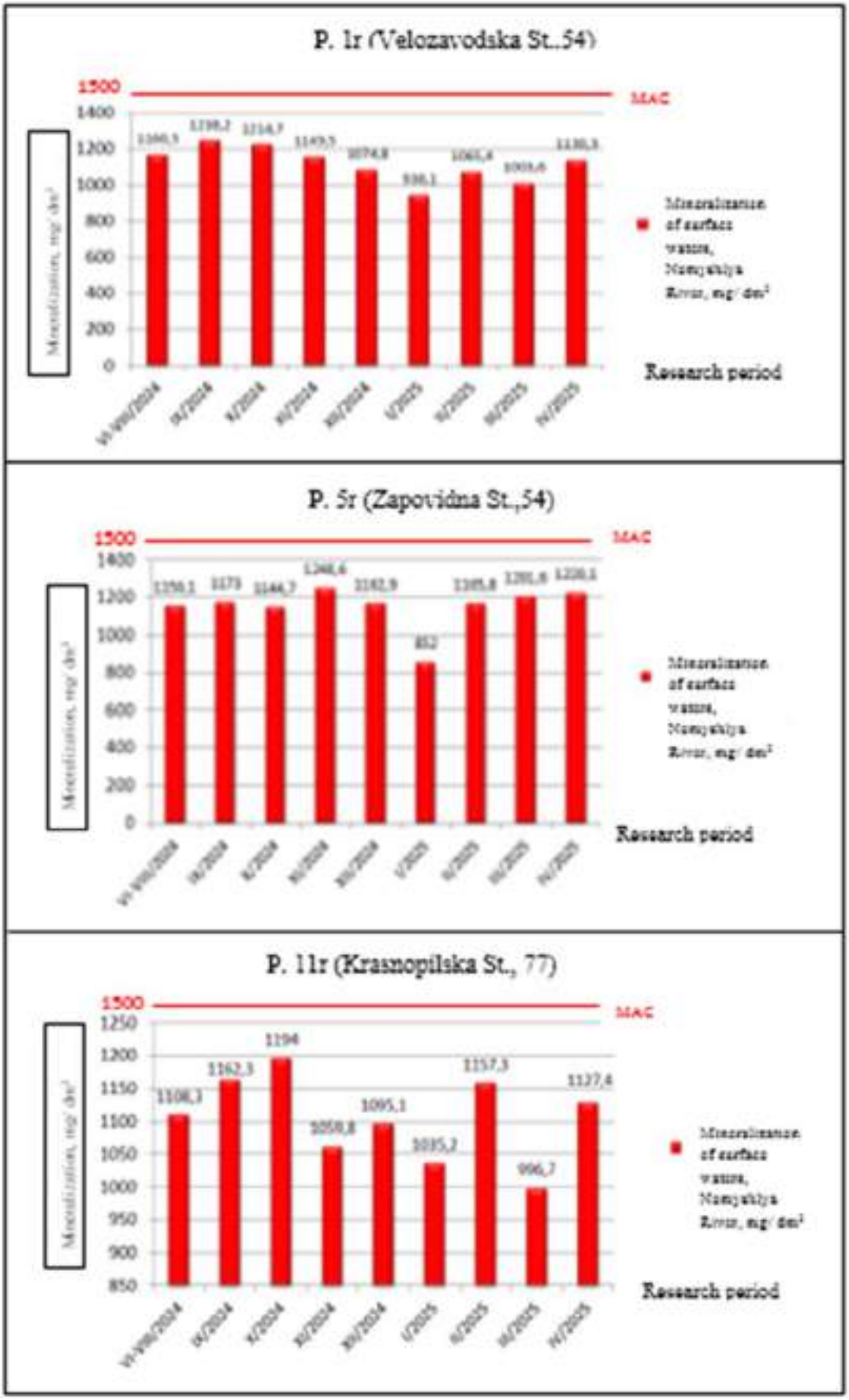


Figure 3.1.1.1. Dynamics of changes in the value of surface water salinity for the study period (September 2024 - April 2025)

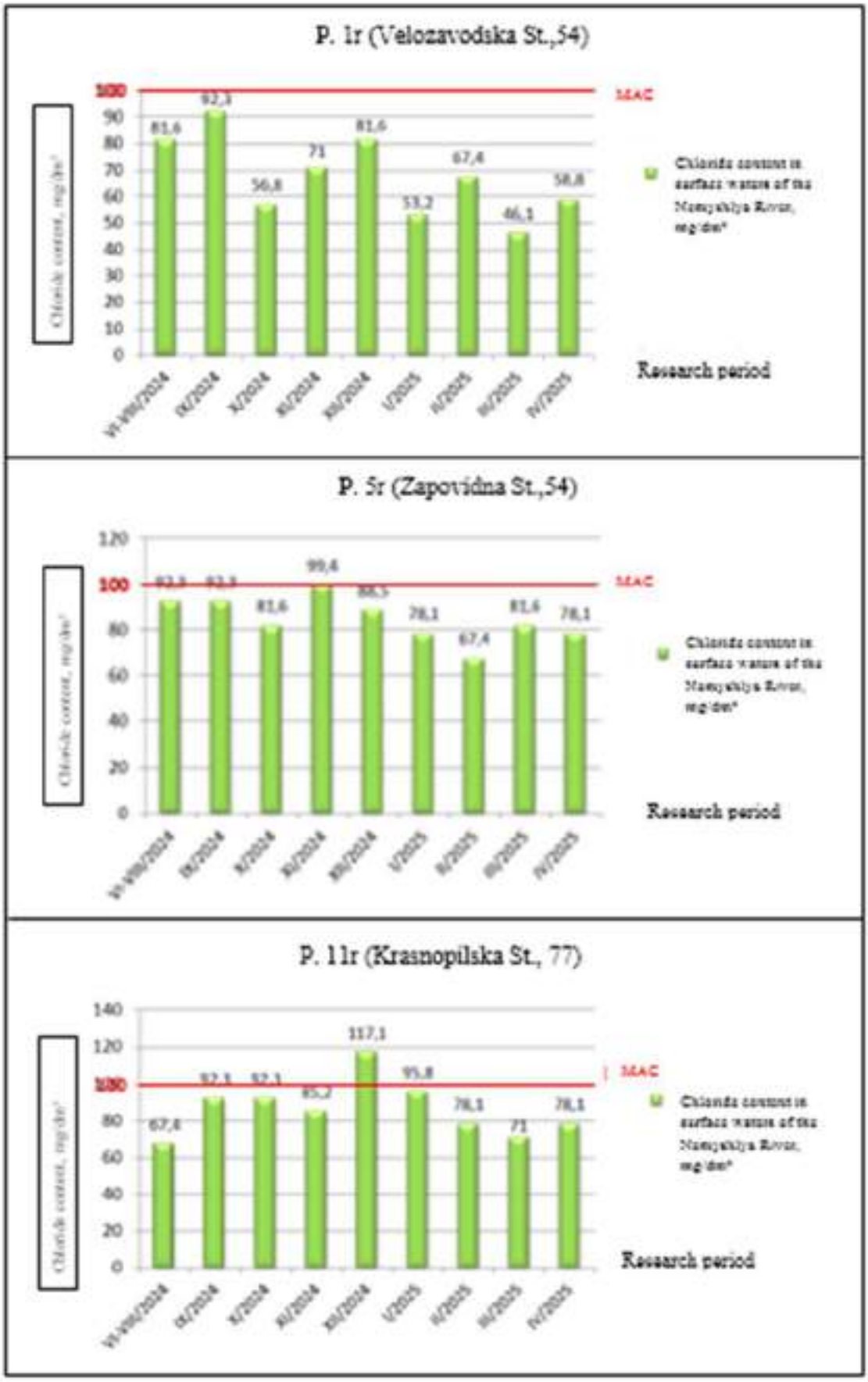


Figure 3.1.1.2. Dynamics of changes in chloride concentrations in surface waters for the study period (September 2024 – April 2025)

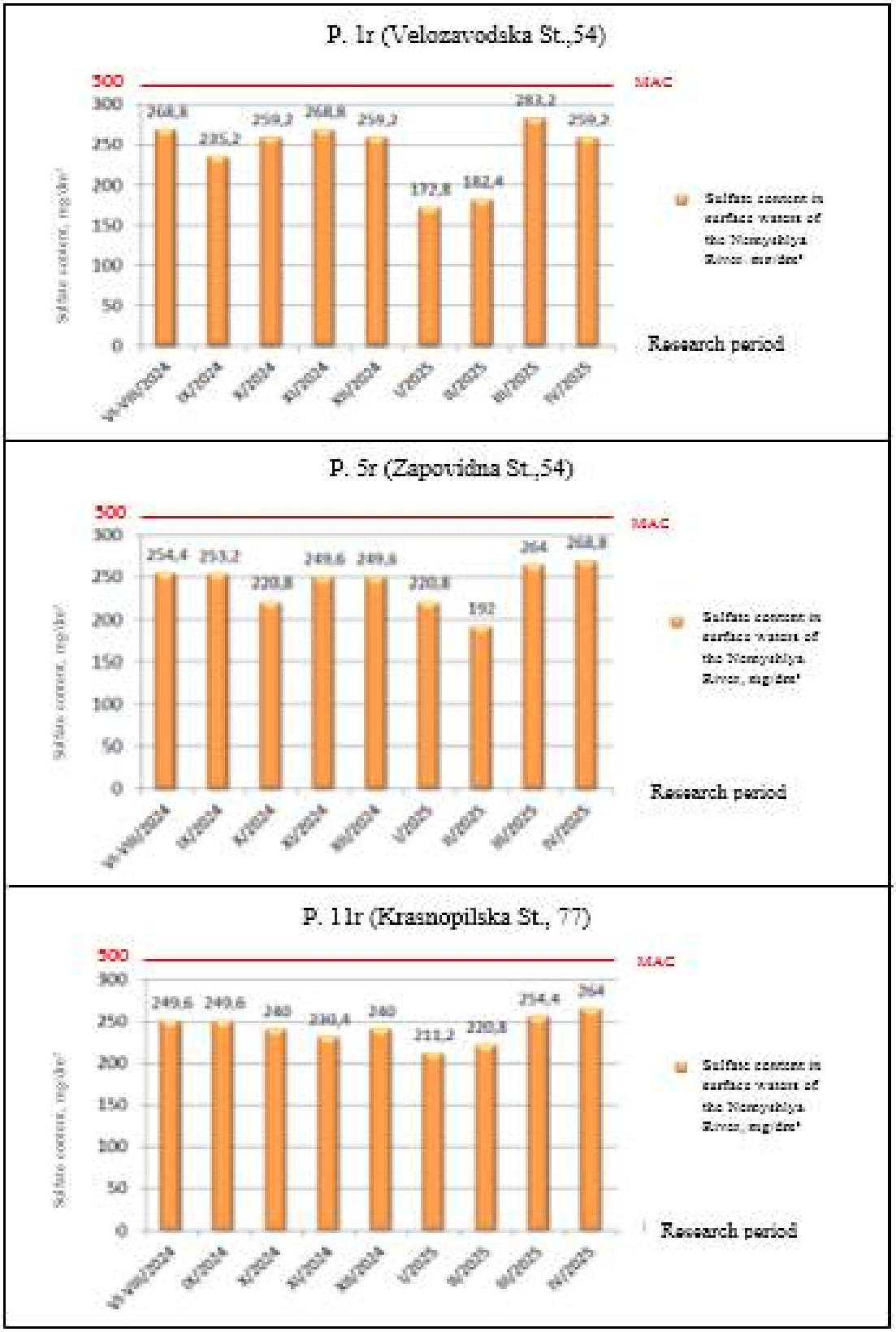


Figure 3.1.1.3. Dynamics of changes in sulfate concentrations in surface waters for the study period (September 2024 – April 2025)

order of magnitude lower than the MAC. *Nitrate (NO_3)* concentrations ranged from undetectable to 2.50 mg/dm³ in summer, and from 11.48 to 42.62 mg/dm³ in spring which is within regulatory requirements [5].

Phosphates (PO_4) during the summer ranged from 1.35 to 3.65 mg/dm³ (0.39–1.04 MAC); in spring – from 1.08 to 1.67 mg/dm³ (0.31-0.48 MAC) in March, and from 1.66 to 2.18 mg/dm³ (0.47-0.62 MAC) in April. According to [2], the listed group of biogenic substances predominantly remained within regulatory limits.

3.1.2 Level of surface water pollution by petroleum products in the Nemyshlya River

Petroleum products in the surface waters of the Nemyshlya River during the study period were recorded at concentrations ranging from *below* 0.05 mg/dm³ (i.e., not detected) to 0.05–0.67 mg/dm³ (2.23 MAC). During the summer low-water period, petroleum products were absent in all monitoring sections. During the autumn low-water period, they were observed only at site P. 1r, with concentrations varying from *non-detectable* to 0.26–0.67 mg/dm³ (0.87–2.23 MAC). In the winter period, petroleum products were detected at all sites, with concentrations ranging from 0.05–0.15 mg/dm³ to 0.38–0.65 mg/dm³ (from below the MAC up to 1.27–2.17 MAC).

It is worth noting that at sites P. 5r and P. 11r (near Zapovidna Street 42 and Krasnopilska Street 77, respectively), *petroleum product* concentrations in January were 0.05 and 0.07 mg/dm³, which is below the MAC for water intended for domestic and recreational use [5]. Only in the industrial zone near Velozavodska Street (site P. 1r) were petroleum products recorded at 0.63–0.65 mg/dm³ (2.1–2.17 MAC). In February, concentrations at these sites reached 0.15 mg/dm³ and 0.61 mg/dm³ (0.5 and 2.03 MAC, respectively). During the spring flood (March–April), petroleum products were absent in all river water samples from the mentioned sites (Fig. 2.1.2.1 – Section 2.1).

***Summary*.** In the spring period, the river water showed signs of self-purification from petroleum products previously detected in elevated concentrations during the winter low-water period. However, considering the significant contamination of soils in the catchment area, their reappearance cannot be ruled out during the summer-autumn or winter low-water periods of 2025.

3.1.3 Assessment of surface water quality in the Nemyshlya River by heavy metal content

Heavy metals in the surface waters of the Nemyshlya River were monitored

at three sampling sites. The temporal dynamics of heavy metal concentrations are shown in Figs. 3.1.3.1–3.1.3.6.

During the study period, the concentrations of metals in the river water varied downstream across the sampling sites within the following ranges:

- Manganese – from 0.071 mg/dm³ to 0.76 mg/dm³, or 0.71 to 7.6 MAC;
- Boron – 0.12–0.22 mg/dm³ (0.24–0.44 MAC);
- Zinc – 0.0022–0.0174 mg/dm³ (0.0022–0.0174 MAC);
- Barium – 0.038–0.100 mg/dm³ (0.38–1.00 MAC);
- Nickel – 0.0012–0.0050 mg/dm³ (0.012–0.050 MAC);
- Lead – *less than* 0.001–0.0026 mg/dm³ (*below* MAC – 0.09 MAC);
- Cadmium – *less than* 0.0001 mg/dm³ (below the detection limit of the instrument).

According to the research results, among the listed heavy metals, only manganese exceeded the MAC in all sampling sites for water bodies intended for household and recreational use [5]. During the autumn low-water period, its concentrations ranged from 1.1 to 7.6 MAC; during the winter low-water period – from 1.8 to 4.8 MAC; and during the spring flood – from 2.8 to 4.2 MAC.

4 CURRENT STATE AND QUALITY OF BOTTOM SEDIMENTS OF THE NEMYSHLYA RIVER

As part of the integrated environmental monitoring of natural components, bottom sediment samples were collected from the Nemyshlya River to assess their chemical composition and the extent of contamination by petroleum products and heavy metals. Samples were taken at the same locations as surface water sampling during the summer low-water period (July, August), autumn low-water period (September, October, November), winter low-water period (December 2024, January, February 2025), and spring flood period (March, April 2025).

4.1 Salinity and Content of Petroleum Products and Heavy Metals in Bottom Sediments of the Nemyshlya River During Summer, Autumn, and Winter Low-Water Periods and Spring Flood

4.1.1 Assessment of Bottom Sediment Quality Based on the Chemical Parameters of Their Aqueous Extract

The assessment of the bottom sediments' salinity was performed by determining the concentration of chemical elements in their aqueous extract. Sediment samples were collected from monitoring sites located in the areas of

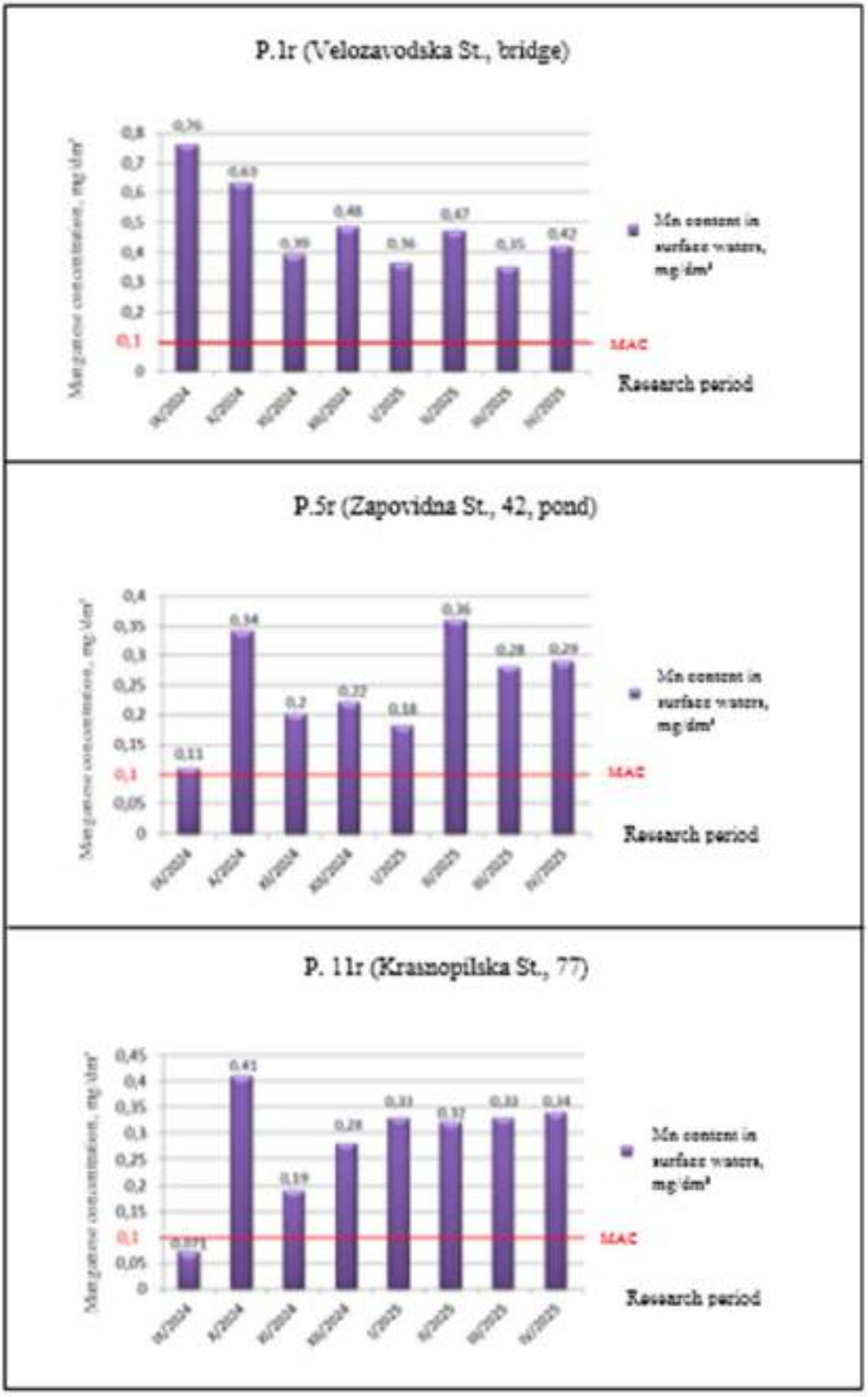


Figure 3.1.3.1. Dynamics of manganese concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

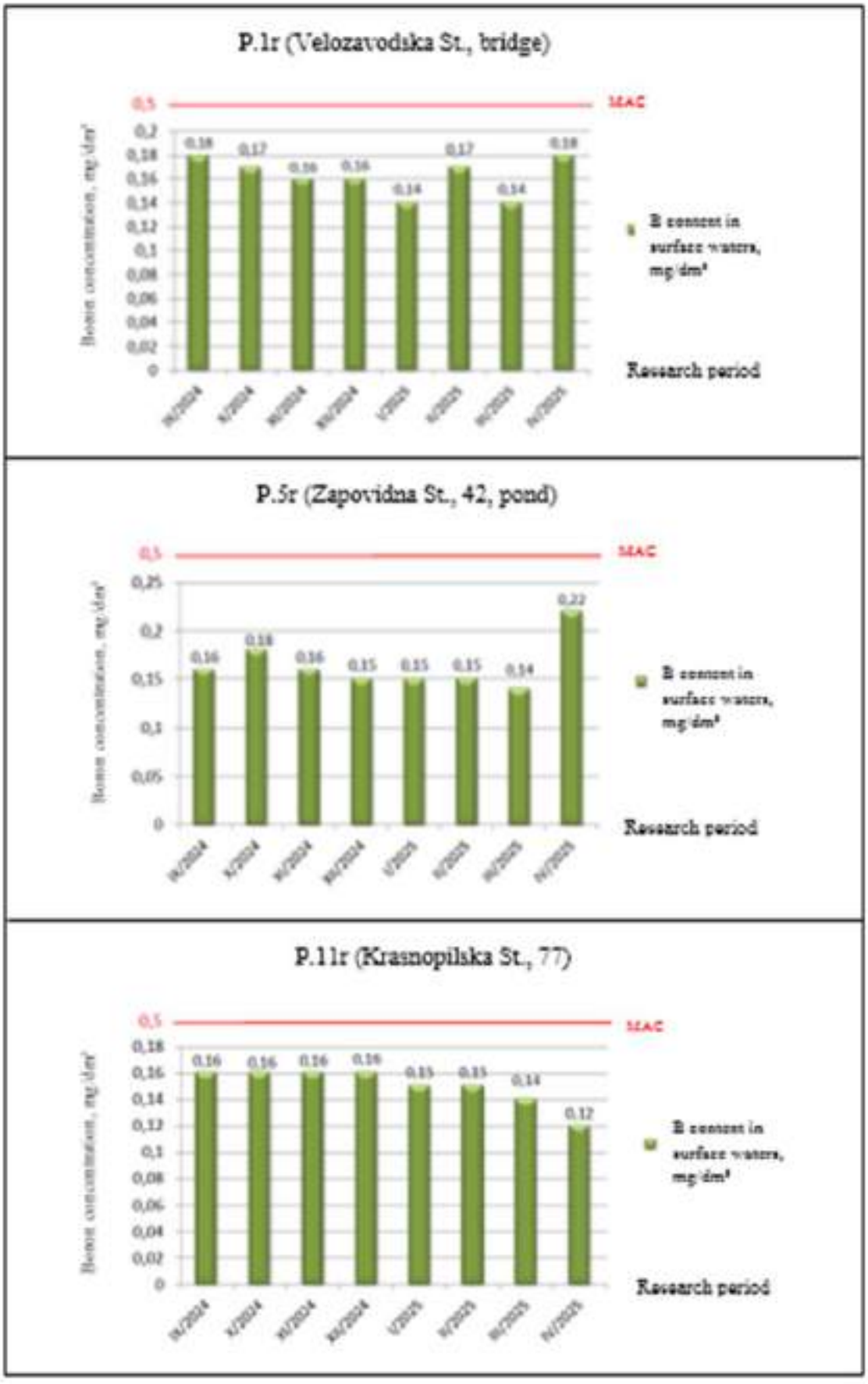


Figure 3.1.3.2. Dynamics of changes in boron concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

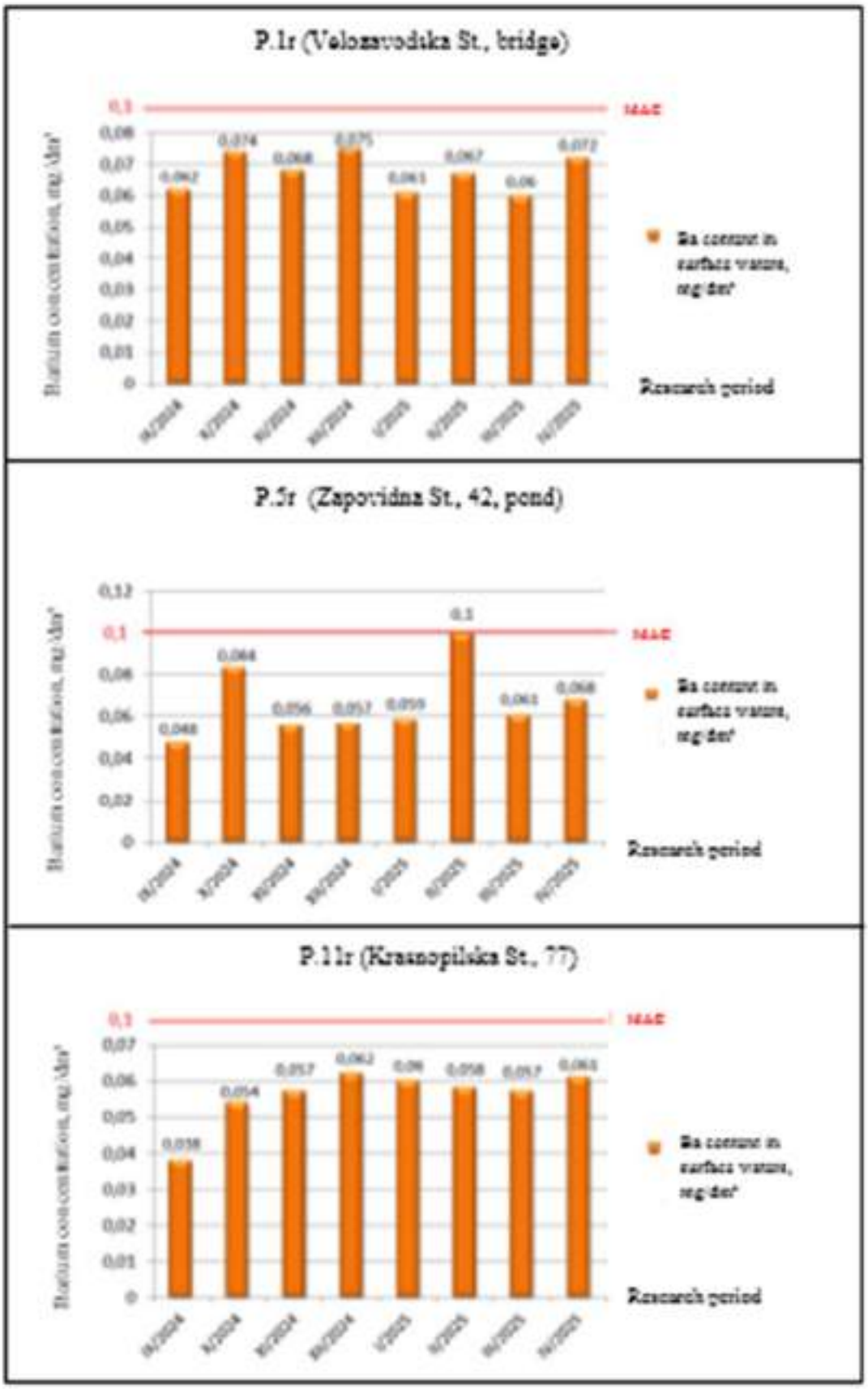


Figure 3.1.3.3. Dynamics of changes in barium concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

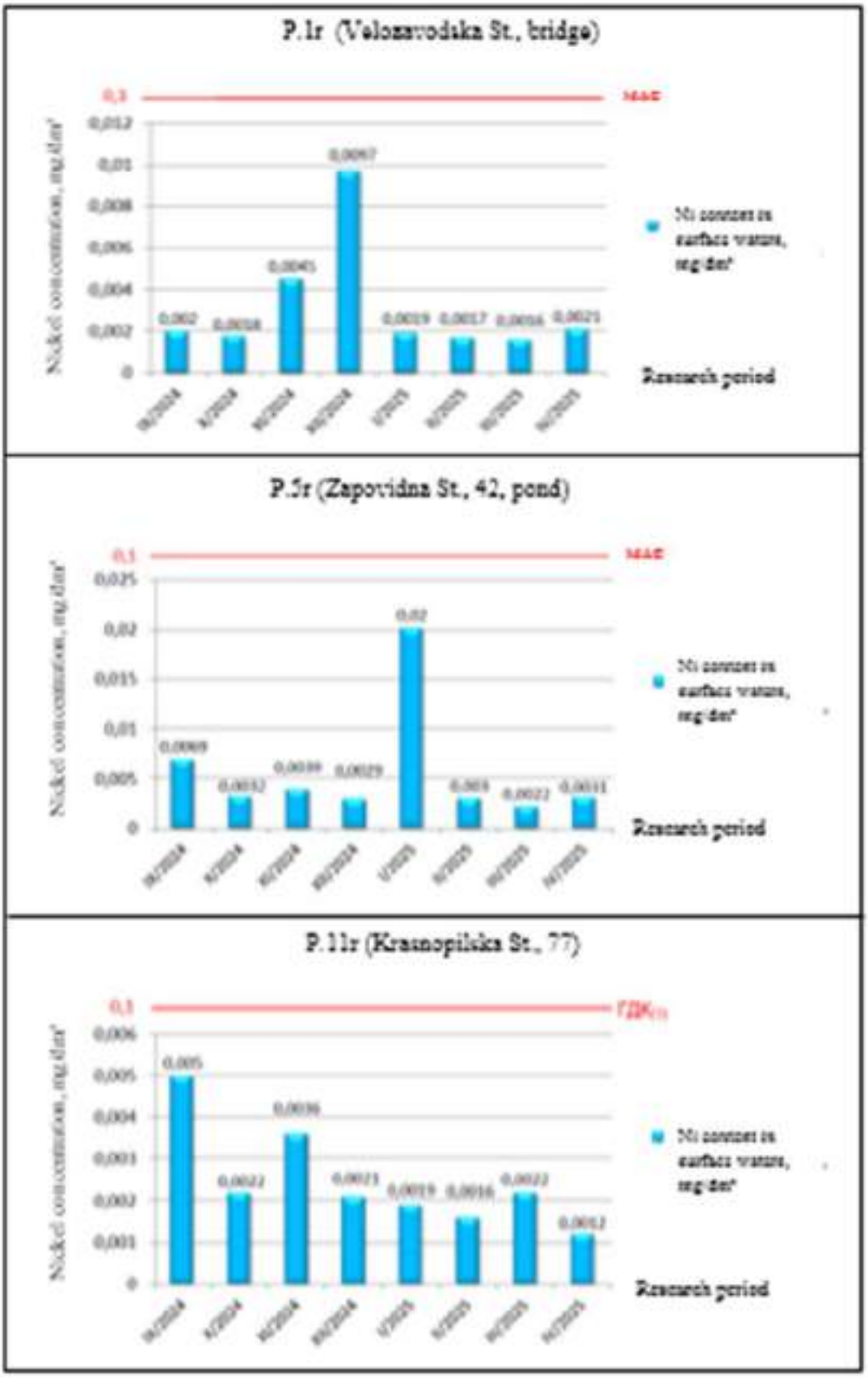


Figure 3.1.3.4. Dynamics of changes in nickel concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

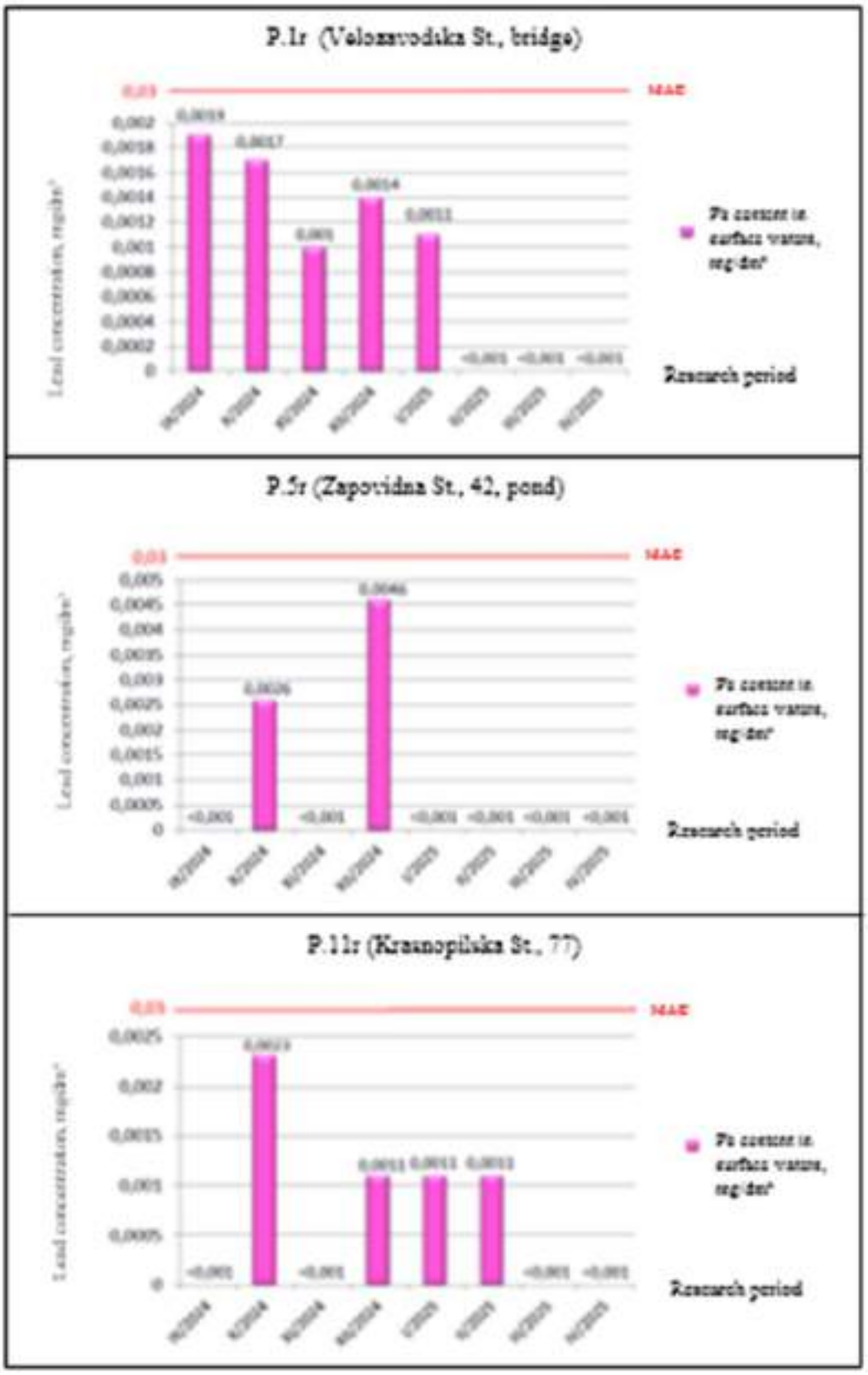


Figure 3.1.3.5. Dynamics of changes in lead concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

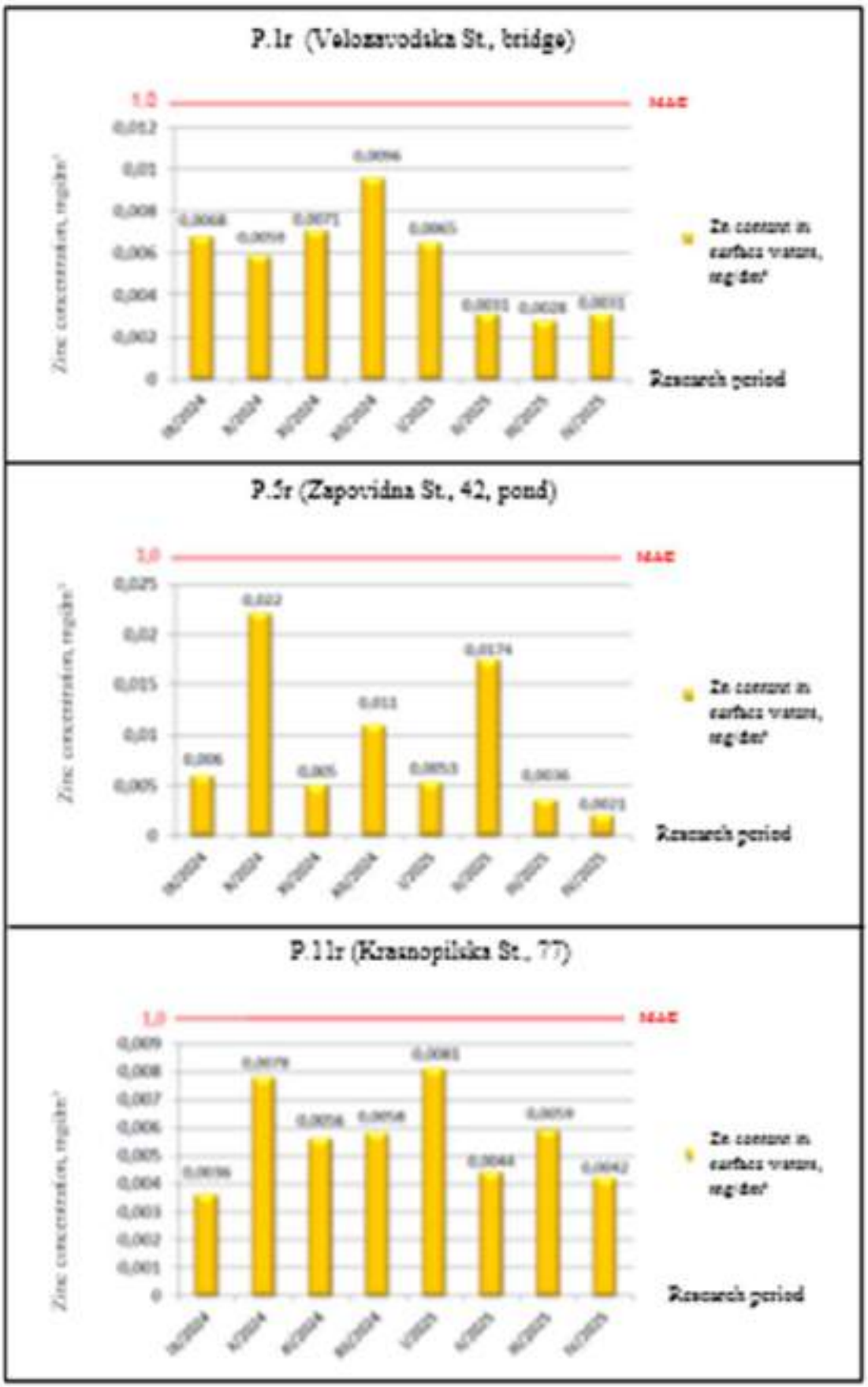


Figure 3.1.3.6. Dynamics of changes in zinc concentrations in surface waters of the Nemyshlya River for the study period (September 2024 – April 2025)

Velozavodska Street (site P. 1b), Zapovidna Street, 42 (site P. 5b), and Krasnopilska Street, 77 (site P. 11b) (Fig. 3.1.1, Section 3.1).

According to the results, in summer, autumn, winter, and spring periods, the macrocomponent composition of the aqueous extract of bottom sediments in the specified sites was characterized by *bicarbonate-calcium-sodium* (C^{CaNa}), *bicarbonate-sodium* (C^{Na}), and *bicarbonate-calcium* (C^{Ca}) water types.

General parameters. According to the active reaction (pH), the aqueous extract of bottom sediments in the Nemyshlya River during the summer low-water period was neutral (pH = 7.24-7.36); during the autumn low-water period – predominantly slightly alkaline (pH = 7.60-7.92); during the winter low-water and spring flood periods – slightly alkaline (pH = 7.96). Overall, the pH of the aqueous extract ranged between 7.24 and 7.96, predominantly indicating a slightly alkaline reaction.

In terms of *total hardness*, the aqueous extracts of bottom sediments were characterized as follows: during the summer, autumn, and winter low-water periods – *very soft* (1.4–1.6 mmol/100 g) in site P. 1b (Velozavodska St.); *soft* (1.8–2.6 mmol/100 g) in autumn; *very soft* again in winter (1.4–1.6 mmol/100 g); and during the spring – *soft* (2.2–2.6 mmol/100 g) in sites P. 5b and P. 11b, and *very soft* (1.8 mmol/100 g) in site P. 11b (Krasnopilska St.,77).

Mineralization indicators. The mineralization of aqueous extracts of bottom sediments along the downstream stretch of the Nemyshlya River – from Velozavodska St. to Krasnopilska St. – ranged from 0.23 g/100 g to 0.30 g/100 g during the autumn low-water period; from 0.23 g/100 g to 0.27–0.29 g/100 g in the winter low-water period; and from 0.23 g/100 g to 0.25 g/100 g during the spring flood period (Fig. 4.1.1.1). At the same time, the residue after evaporation remained nearly unchanged, ranging from 0.20 to 0.23 g/100 g. The concentrations of *chlorides and sulfates* in all samples did not exceed regulatory standards in accordance with the Resolution of the Cabinet of Ministers of Ukraine dated December 15, 2021, № 1325 [3], and during the winter period ranged from 28.4 mg/100 g to 35.5 mg/100 g for *chlorides*, and from 48.0 mg/100 g to 67.2 mg/100 g for *sulfates*. In the spring period: 28.4 mg/100 g for *chlorides*, and from 48.0 mg/100 g to 57.6 mg/100 g for *sulfates*.

Biogenic substances. During the summer low-flow period, ammonium ions were present in the water extract of bottom sediments at concentrations ranging from 0.10 mg/100 g (0.2 MAC) to 1.73-2.92 mg/100 g (3.46-5.84 MAC), i.e., both within and significantly exceeding the MAC. In the spring period, ammonium ion concentrations did not exceed the MAC at sampling point P. 1b (near Velozavodska St.) – 0.18 mg/100 g – and at P. No. 11b (near Krasnopilska St., 77) – 0.45 mg/100 g (0.9 MAC). At P. 5b (near Zapovidna St., 42), the concentration of ammonium ions

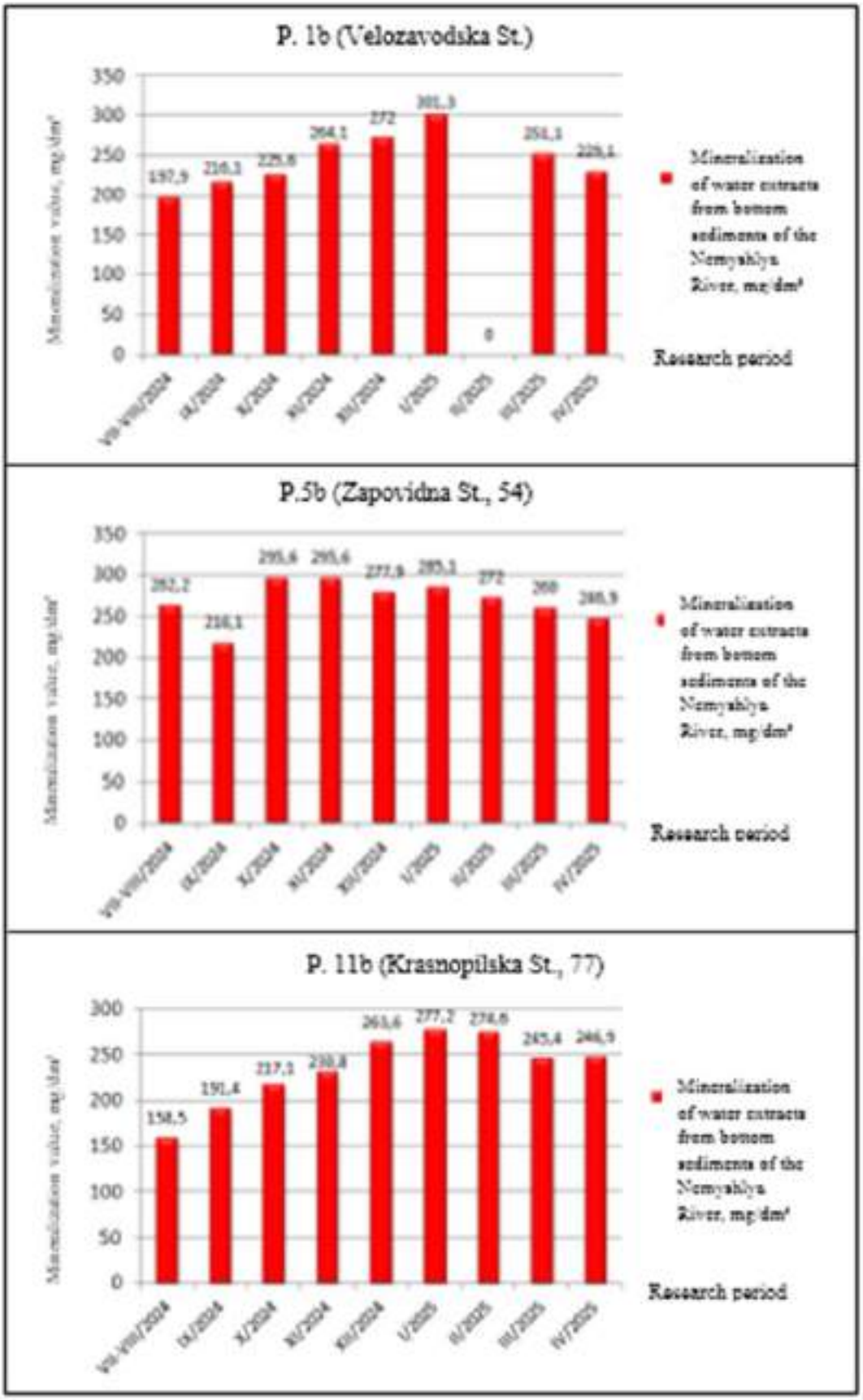


Figure 4.1.1.1. Dynamics of changes in the mineralization of water extracts from bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

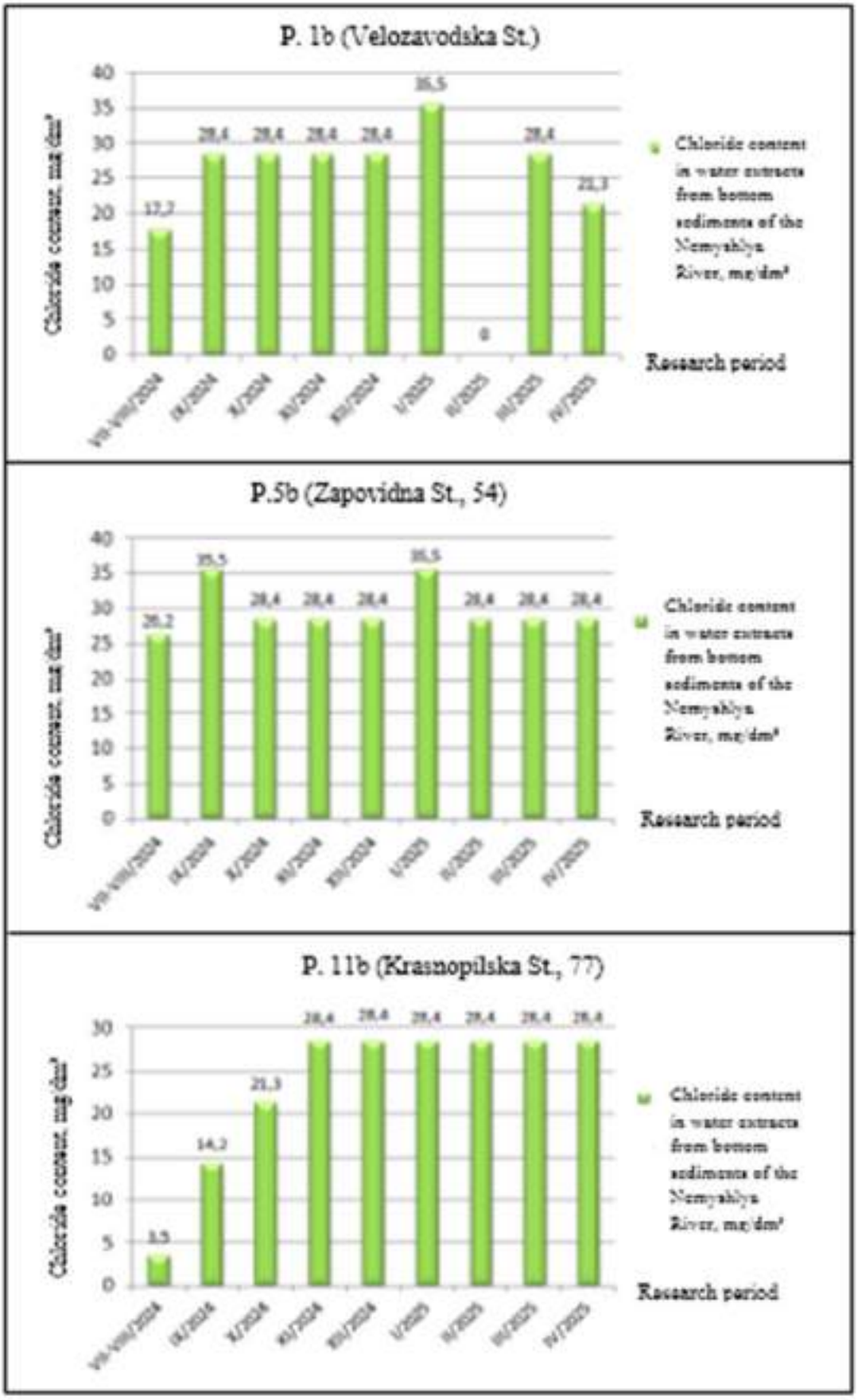


Figure 4.1.1.2. Dynamics of changes in chloride concentrations in water extracts from bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

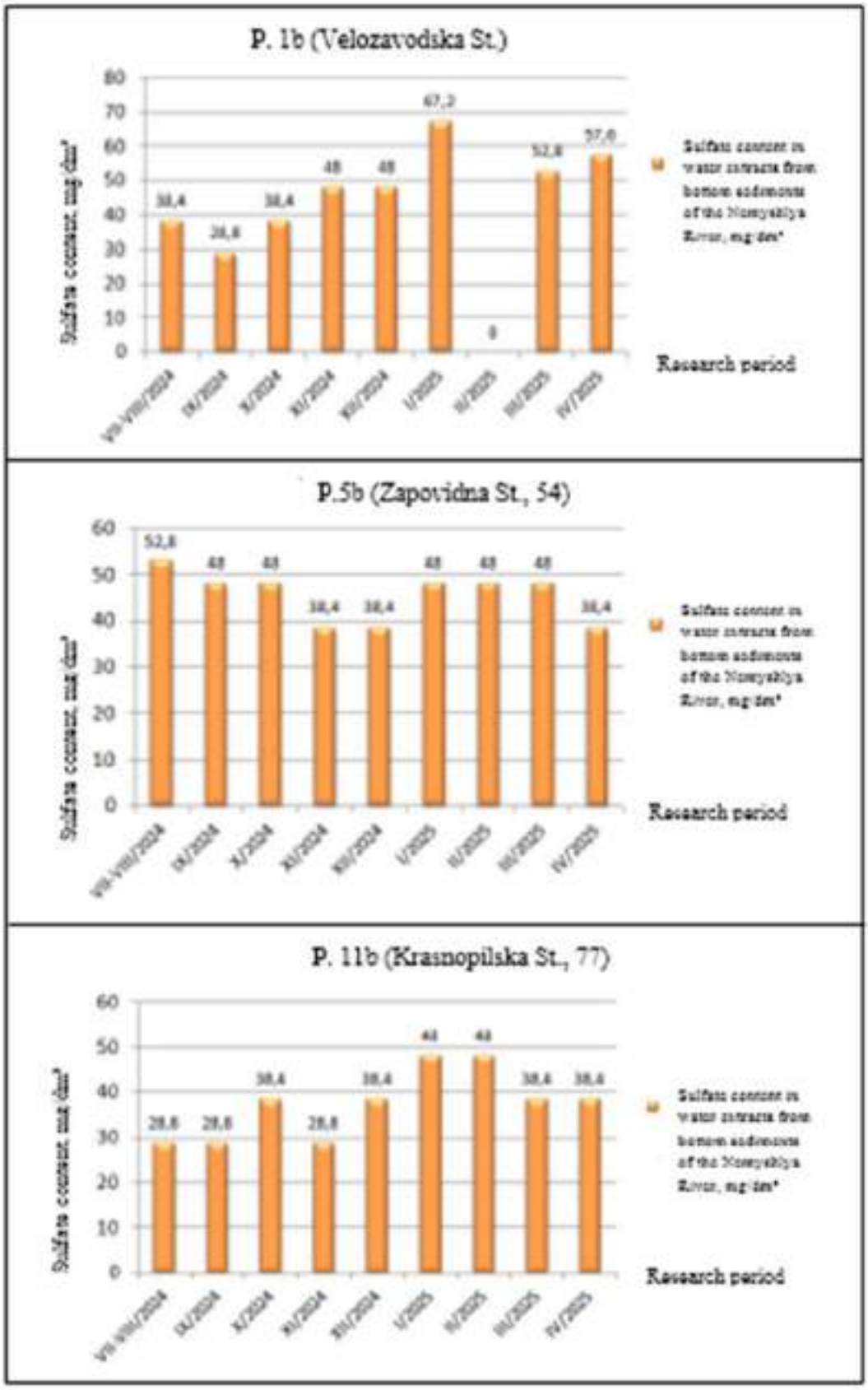


Figure 4.1.1.3. Dynamics of changes in sulfate concentrations in water extracts from bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

reached 1.26 mg/100 g (2.52 MAC). Thus, in the spring period, MAC exceedance was recorded at only one sampling point. Nitrite concentrations in the water extract varied from non-detectable to 0.07 mg/100 g; nitrate concentrations ranged from 0.53 mg/100 g to 0.89-2.72 mg/100 g, all well below the MAC.

Phosphate content increased downstream from 1.14 mg/100 g to 1.44 mg/100 g and 1.5 mg/100 g at sampling points P.1b, P. 5b, and P. 11b, respectively – also below the MAC [5].

No exceedance of MAC was observed for salt content in any sample (Figs. 4.1.1.2 and 4.1.1.3). The aqueous extracts, both during low-water periods and the spring flood, were classified as fresh water.

4.1.2 Level of petroleum product contamination in the bottom sediments of the Nemyshlya River

During the ***summer low-water period*** (July–August 2024), the concentration of *petroleum products* in the bottom sediments of the Nemyshlya River varied depending on the sampling locations, ranging from 211 mg/kg (site P. 1b) to 1370 mg/kg (2.74 MAC) at site P. 5b, and up to 3564 mg/kg (7.13 MAC) at site P. 11b.

During the ***autumn low-water period***, the *petroleum product* content in bottom sediments varied downstream and was as follows (Fig. 4.1.2.1):

- In September: 653 mg/kg (1.31 MAC) at site P. 1b, 1540 mg/kg (3.08 MAC) at site P. 5b, and 170 mg/kg (*below* MAC) at site P. 11b;
- In October: 599 mg/kg (1.20 MAC) at site P. 1b, 245 mg/kg (*below* MAC) at site P. 5b, and 342 mg/kg (*below* MAC) at site P. 11b;
- In November: 2470 mg/kg (4.94 MAC) at site P. 1b, 3063 mg/kg (6.13 MAC) at site P. 5b, and 179 mg/kg (*below* MAC) at site P. 11b.

During the ***winter low-water period*** (December 2024 – January, February 2025), *petroleum product* concentrations in bottom sediments were:

- In December: 1282 mg/kg (2.56 MAC) at site P. 1b, 824 mg/kg (1.65 MAC) at site P. 5b, and 180 mg/kg (*below* MAC) at site P. 11b;
- In January: 825 mg/kg (1.65 MAC) at site P. 1b, 556 mg/kg (1.11 MAC) at site P. 5b, and 64.0 mg/kg (*below* MAC) at site P. 11b;
- In February: 3063 mg/kg (6.13 MAC) at site P. 5b, and 295.0 mg/kg (*below* MAC) at site P. 11b. The maximum concentration was recorded in the area of Zavodska Street, 54 (sites P. 5b and P. 11b).

During the ***spring flood period*** (March – April 2025), the content of *petroleum products* in the bottom sediments at sites P. 1b, P. 5b, and P. 11b (downstream along the Nemyshlya River) varied as follows: 812.0 – 1099 mg/kg (1.62–2.20 MAC),

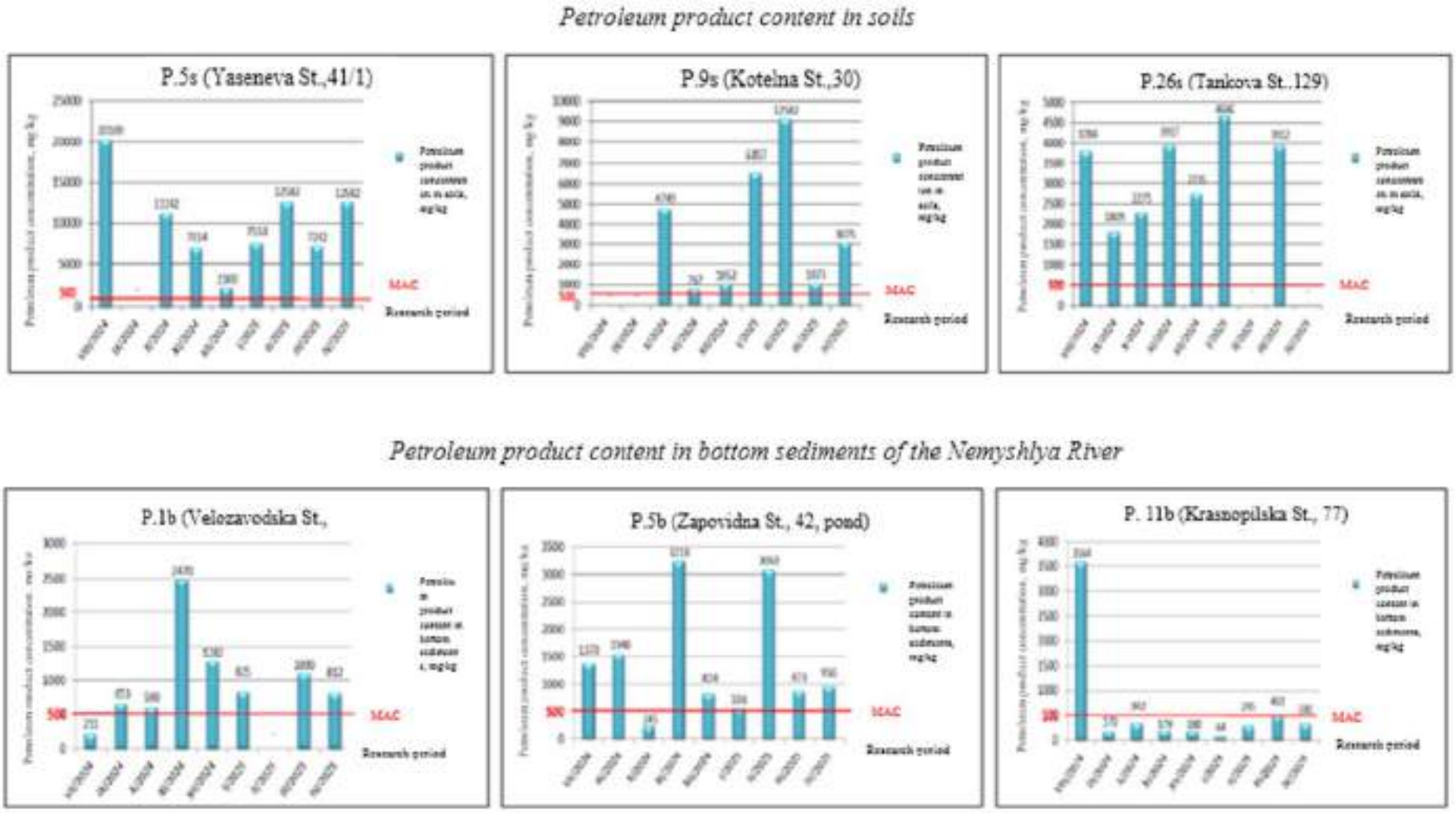


Figure 4.1.2.1. Dynamics of changes in petroleum product concentrations in soils and bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

873.0–956.0 mg/kg (1.75–1.91 MAC), and 330.0–492.0 mg/kg (*below* MAC), respectively.

Throughout the study period, the highest concentrations of petroleum products in bottom sediments were recorded at site P. 5b (Zapovidna Street, 42).

It should be noted that this site is located in a section of the Nemyshlya River that flows along an area with maximum petroleum contamination. In contrast, site P. 11b (Krasnopilska Street, 77), which is outside the pollution hotspot, showed concentrations of *petroleum products* below the MAC (ranging from 64.0 mg/kg to 492.0 mg/kg), significantly lower compared to sites P. 1b (Velozavodska Street, 812–1099 mg/kg) and P. 5b (Zapovidna Street, 556.0–3063.0 mg/kg) (Fig. 4.1.2.1), (tables D3-D5, Annex D, C4-C6 Annex C, and C5-C8, Annex C in Book 2, Annexes (1st–3rd stages of 2024–2025) - previous reports in Ukrainian).

Overall, the results of the monitoring studies indicate significant contamination of the bottom sediments of the Nemyshlya River with petroleum products, which, as a consequence, confirms that these sediments serve as a source of secondary pollution of the river water by this specific contaminant.

4.1.3 Assessment of bottom sediment quality based on heavy metal content

Heavy metals in the bottom sediments of the Nemyshlya River were analyzed at three sampling points (Fig. 3.1.1, Section 3), and several of them were found in significant concentrations (Figs. 4.1.3.1– 4.1.3.6).

During the summer–autumn and winter low-water periods, as well as the spring flood period, the concentrations of metals in bottom sediments downstream exceeded the MACs for *zinc, nickel, and boron*, and in isolated cases also *for barium and lead.*

It should be noted that at sites P. 1b and P. 11b, during both the winter and spring periods, only *zinc* concentrations exceeded the MACs, reaching 41.1–66.0 mg/kg (1.79–2.87 MACs) and 42.0–69.0 mg/kg (1.83–3.0 MACs), respectively (Fig. 4.1.3.6). In samples taken during the winter period, exceedances were recorded only for boron (33–48 mg/kg; 1.1–1.6 MACs) and *barium* (230 mg/kg; 1.1 MACs) at site P. 5b (Zapovidna St., 54). At this location, significantly elevated *zinc* concentrations were also recorded—148 mg/kg (6.43 MACs).

In the spring period, exceedances of *boron* (32.0–43.0 mg/kg; 1.07–1.43 MACs), *zinc* (151.0–170.0 mg/kg; 6.57–7.39 MACs), and *nickel* (5.8–23.0 mg/kg) were observed at site P. 5b (Zapovidna St., 54). The lowest concentrations were typical for the reference site P. 1b (Velozavodska St.), while the highest concentrations were recorded at P. 5b (Zapovidna St., 54).

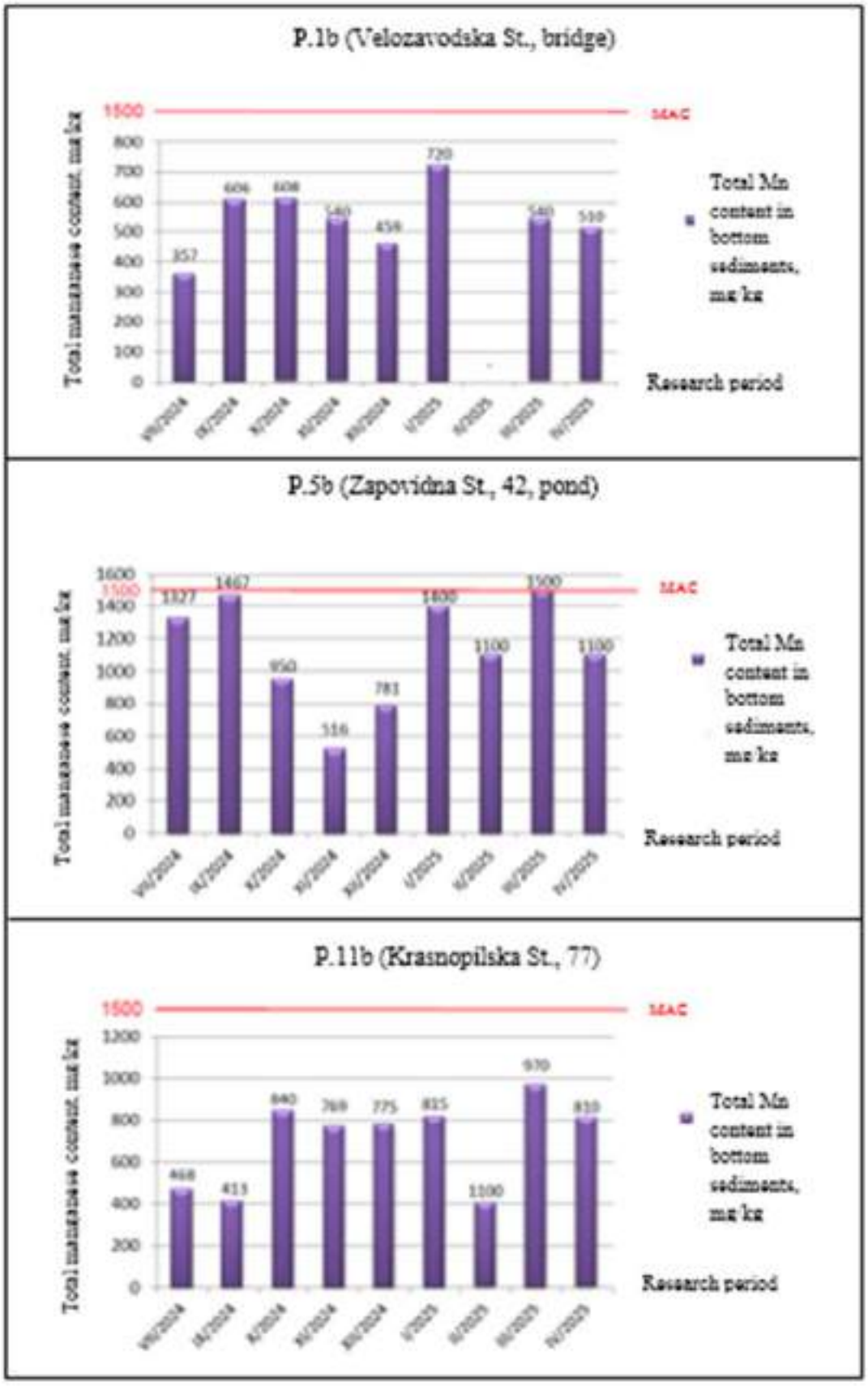


Figure 4.1.3.1. Dynamics of changes in total manganese content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

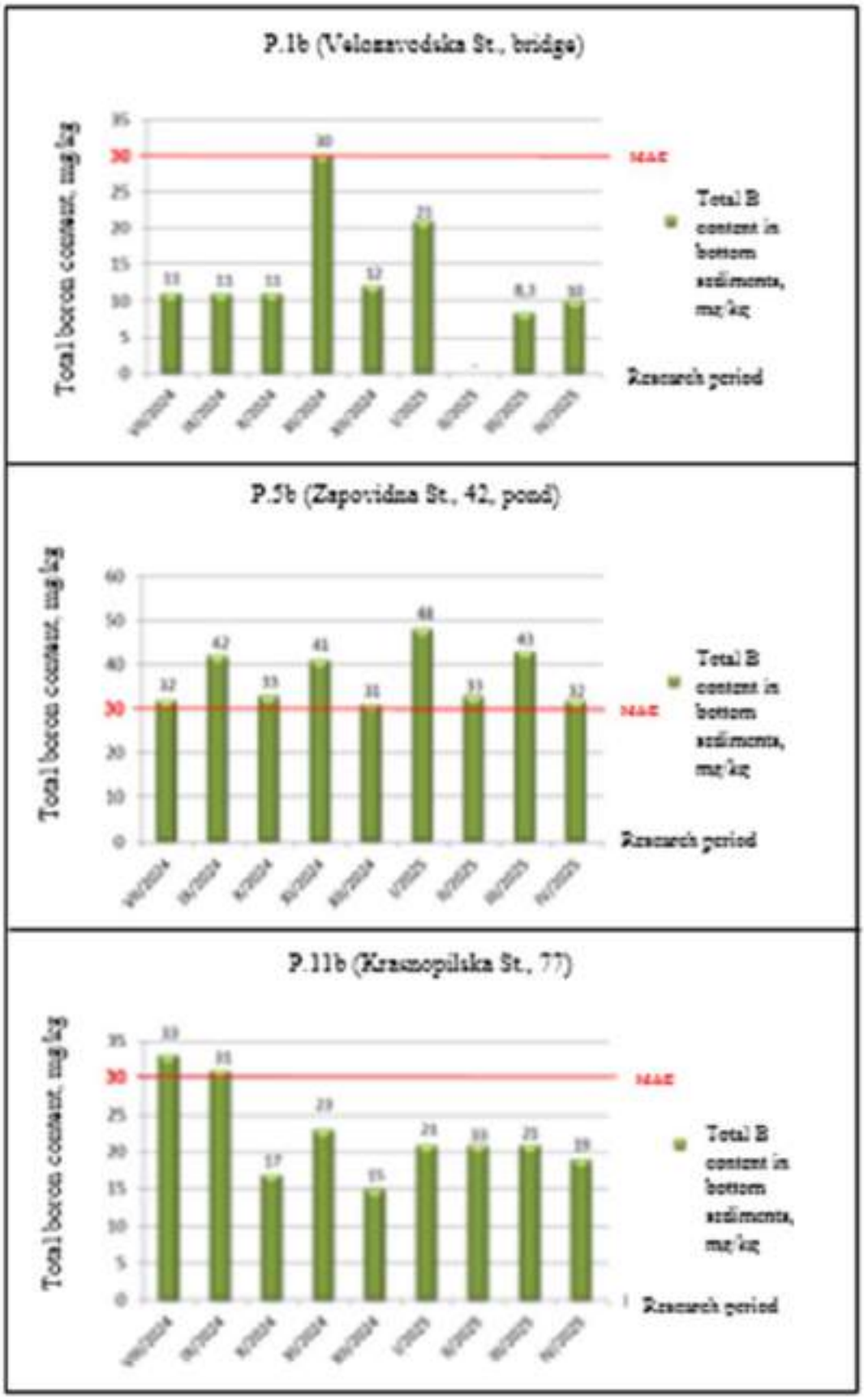


Figure 4.1.3.2. Dynamics of changes in total boron content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

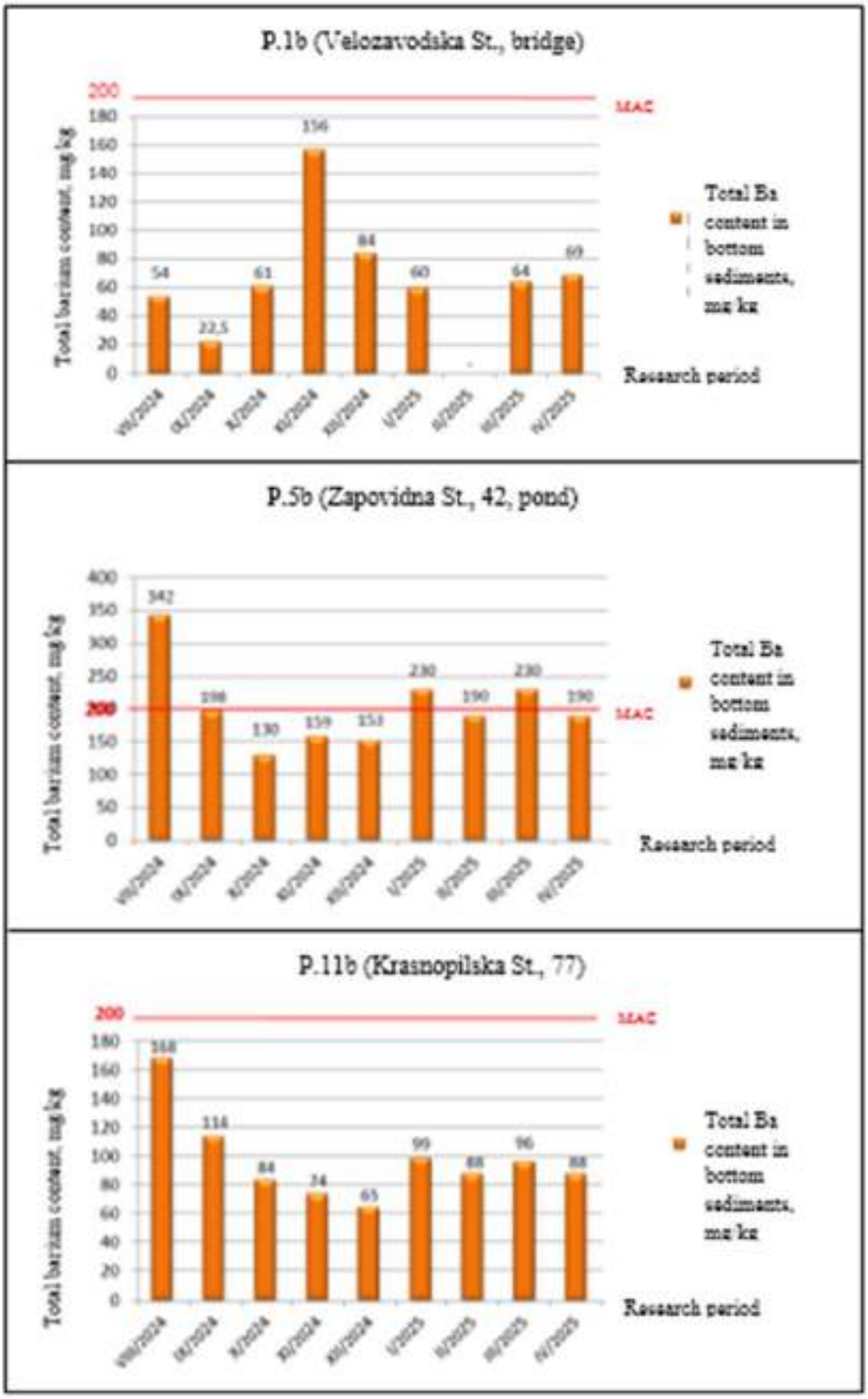


Figure 4.1.3.3. Dynamics of changes in total barium content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

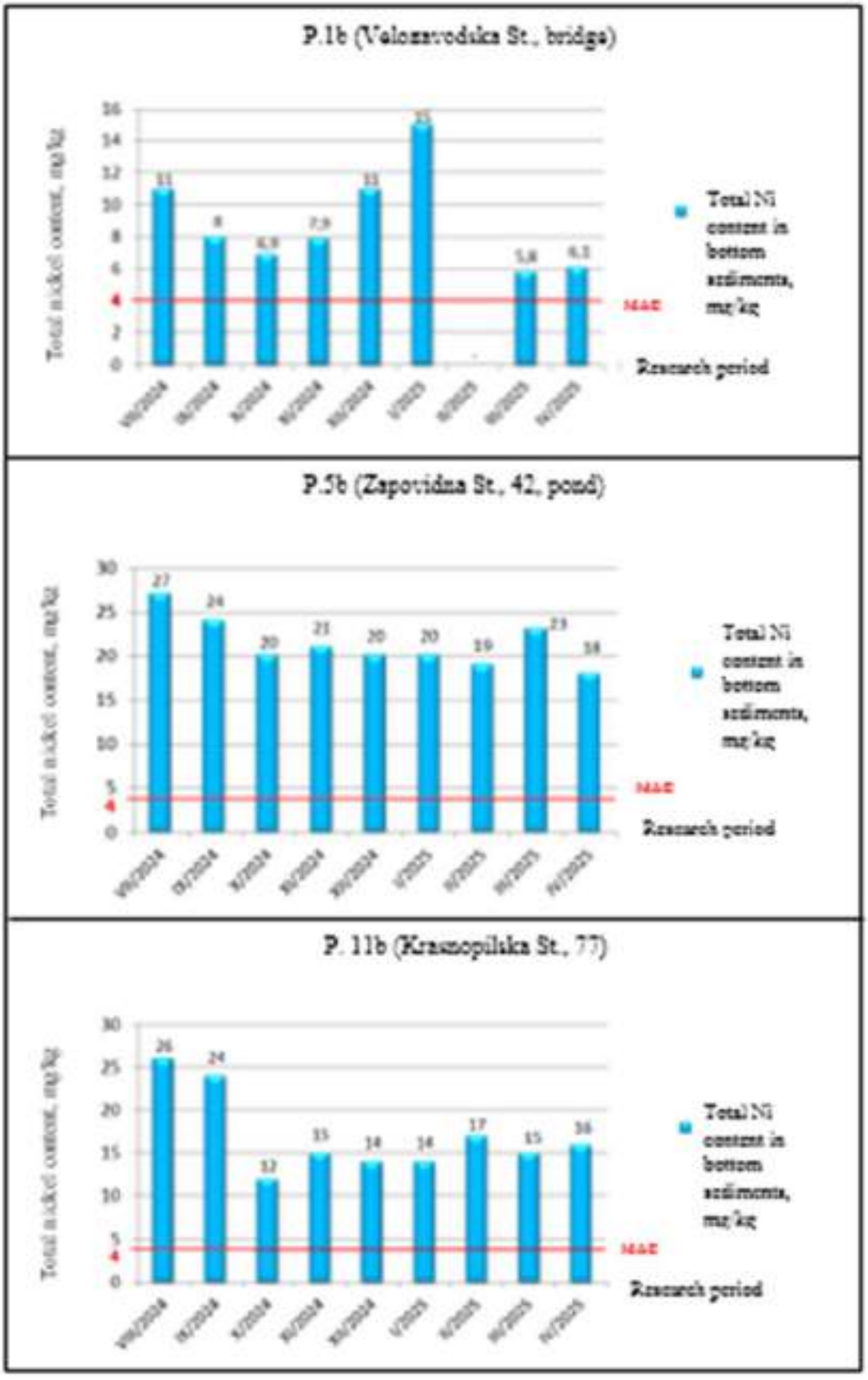


Figure 4.1.3.4. Dynamics of changes in total nickel content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

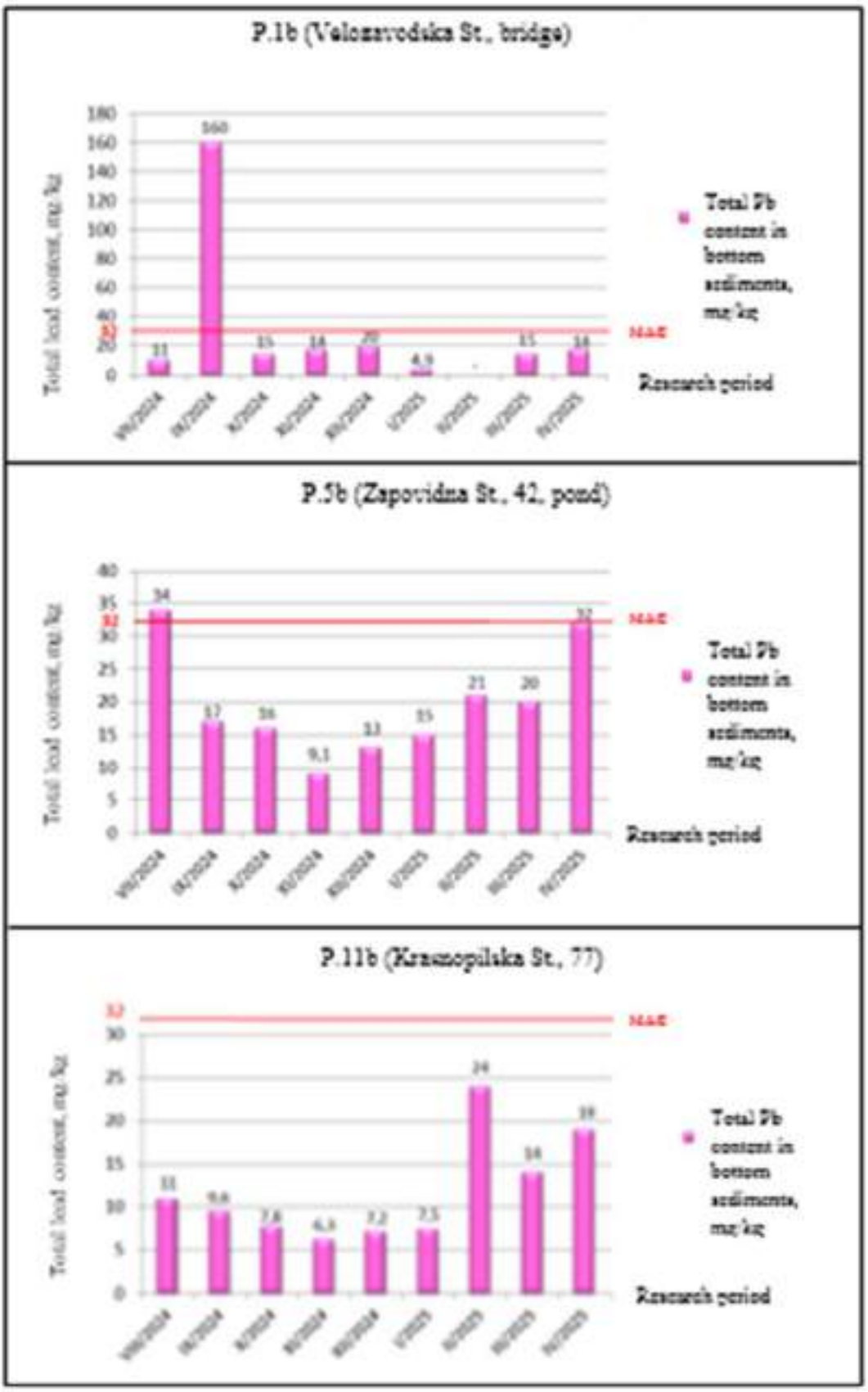


Figure 4.1.3.5. Dynamics of changes in total lead content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

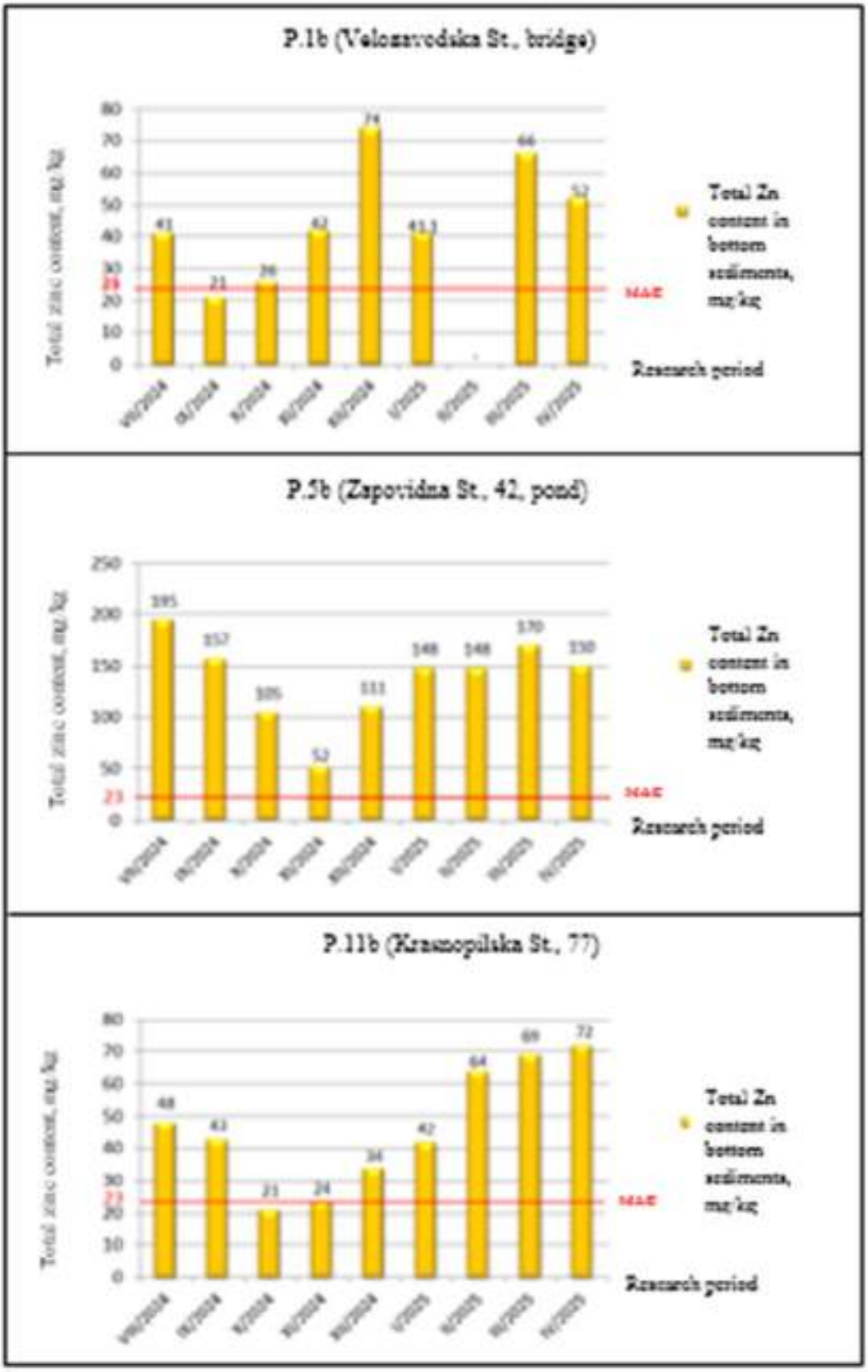


Figure 4.1.3.6. Dynamics of changes in total zinc content in bottom sediments of the Nemyshlya River for the study period (September 2024 – April 2025)

Moreover, compared to the winter period, *zinc* concentrations increased in all sites during the spring period. Across the entire 2025 study period, the highest concentrations of both *nickel and zinc* in bottom sediments were recorded at site P. 5b (Zapovidna St., 54).

The calculated values of the technogenic geochemical load coefficients *(Ki = =C/MAC)* for heavy metals in the bottom sediments of the Nemyshlya River are presented in Table 4.3.1.1.

Table 4.3.1.1 - Limits of fluctuations of the value (Ki) for the bottom sediments of the Nemyshlya River

Season of the year, month	*Ki=-<1-1,0*	*Ki=<1-1,06*	*Ki = <1–1,71*		*Ki = 1,04–8,48*	
	Mn	*Pb*	*B*	*Ba*	*Ni*	*Zn*
Low-water summer period	0,24-0,88	0,34-1,06	0,37-1,10	0,27-1,71	2,75-6,75	1,78-8,48
Low-water autumn period	0,28-0,98	0,29-0,53	0,37-1,40	0,11-0,99	1,73-6,00	1,04-6,83
Low-water winter period	0,31-0,93	0,16-0,75	0,40-1,60	0,30-1,15	2,75-5,00	1,48-6,43
Spring flood period	0,34-1,00	0,44-1,00	0,28-1,43	0,31-1,15	1,45-5,75	2,26-7,39

The obtained values of the technogenic geochemical load coefficients *(Ki)* indicate the absence of contamination of bottom sediments with such heavy metals as *manganese* and *lead*, a relatively low level of pollution by *boron*, and significant contamination by *nickel* and *zinc*.

The lowest concentrations relative to the MAC were recorded for *manganese* and *lead*, while the highest – for *nickel* and *zinc*.

Summary to Section 3. The results of the monitoring studies indicate that bottom sediments at all sampling sites serve as a source of secondary pollution of the Nemyshlya River water by both heavy metals – particularly *zinc*, *nickel*, and *boron* – and *petroleum products*. This poses a threat both to the overall river ecosystem and to aquatic organisms in particular.

5. CURRENT STATE AND QUALITY OF THE SOIL COVER

To assess the environmental condition of the soils during the low-water periods in summer, autumn, and winter, as well as during the spring flood, soil samples were collected within the pollution epicenter — on private plots located at 129 Tankova Street (surface layer), 30 Kotelna Street (depth 0.00–0.15 m), and 41/1 Yaseneva Street (surface layer) (Fig. 2.1.1, Section 2).

The purpose of soil sampling was to determine the macrocomponent composition of aqueous extracts, in order to identify the characteristics of salinity and contamination by petroleum products and heavy metals.

5.1 Soil salinity and levels of soil contamination by petroleum products and heavy metals during low-water periods and spring flood (2024–2025)

The level of soil contamination was assessed based on monitoring data related to soil salinity, the content of petroleum products, heavy metals (*manganese, boron, barium, nickel, lead, cadmium, and zinc*), as well as data on radiation pollution (*gamma and beta dose rates*).

During the first stage of the study, in the low-water summer period (July–August 2024), observations were carried out to determine the intensity of soil contamination by petroleum products and heavy metals at various depths. Soil samples were collected from streets located at or near the explosion epicenter (Table 5.1.1).

Table 5.1.1 – Petroleum product content in soils depending on sampling depth during the low-water summer period (July–August) and at the beginning of the autumn low-water period (September) 2024

Street Name	Petroleum Products Content at 0.15 m Depth, mg/kg	Petroleum Products Content at 0.5 m Depth, mg/kg	Petroleum Products Content at 1.0 m Depth, mg/kg
Zapovidna St., 22*	15,0	69,0	90,0
Zapovidna St., 54*	35,0	-	-
Nemyshlyanska St., 256*	15,0	-	-
Mohylianska St., 64**	248,0	65,0	30,0
Tankova St., 129**	3784,0 (7,7 MAC)	3463,0 (6,9 MAC)	-
Yaseneva St., 41/1**	20109,0 (40,2 MAC)	2746, 0 (5,49 MAC)	5533,0 (11,07 MAC)
1st Plidnyi Ln., 22/9**	65,0	35,0	35,0
1st Plidnyi Ln., 16**	64,0	104,0	1746,0 (3,49 MAC)
Plidna St., 28**	49,5	10,0	10,0
Velozavodska St.***	1080,0 (2,16 MAC)	-	-
Tankova St., 129***	1809,0 (3,62 MAC)	3951,0 (7,90 MAC)	442,0
MAC according to [ ]	***500,0 мг/кг***		***0,06***

*Note: Month of soil sampling: * – July 2024; ** – August 2024; *** – early September 2024.*

According to the obtained results, specific sites were selected for continued

monitoring during the autumn and winter low-water seasons and the spring flood. Further observations were carried out at three locations with the highest levels of petroleum product contamination: private plots at Yaseneva Street, 41/1 (P. 5s), Kotelna Street, 30 (P. 9s), and Tankova Street, 129 (P. 26s) (Fig. 2.1.1, Section 2).

5.1.1 Assessment of soil quality based on chemical indicators of aqueous extracts

The aqueous extract of soils sampled at the specified sites was characterized by a *bicarbonate* anion composition and variable cation composition depending on the sampling period. Magnesium ion dominance was observed during the summer low-water period; calcium cation dominance – during the autumn and winter low-water periods; and a combination of sodium and calcium cation dominance – during the spring flood period. Accordingly, based on the chemical composition, the following types of aqueous extracts were identified: *bicarbonate-magnesium* (C^{Mg}), *bicarbonate-calcium* (C^{Ca}), *bicarbonate-sodium* (C^{Na}), and *bicarbonate-calcium-sodium* (C^{CaNa}).

General indicators. According to the values of active reaction (pH), the soil water extract during the summer low-water period was *neutral* (pH = 7.16) and *slightly alkaline* (pH = 7.62–7.67); during the autumn low-water period – also *neutral* (pH = 7.11–7.36) and *slightly alkaline* (pH = 7.88–7.93); during the winter low-water period – *neutral* (pH = 7.22); and during the spring flood – *neutral* (pH = = 6.92–7.06). In general, the soils within the study area were found to be *neutral* to *slightly alkaline* in reaction, with pH values ranging from 6.92 to 7.93.

The *total hardness* of the soil water extracts during the study period was classified as *soft*, both during the low-water seasons and the spring flood. *Total hardness* values ranged from 1.6–1.8 mmol/100 g to 2.0–2.8 mmol/100 g (Fig. 5.1.1.1).

Mineralization indicators. According to the research results, during the summer low-water period, the mineralization of soil water extracts ranged from 0.18 to 0.29 g/100 g; during the autumn low-water period – from 0.16 to 0.37 g/100 g; during the winter low-water period – from 0.24 to 0.34 g/100 g; and during the spring flood – 0.27 g/100 g (Fig. 5.1.1.2), (Tables D.1 – D3, Annex D in Book 2, Annexes (1st–3rd stages of 2024–2025) - previous reports in Ukrainian). The dry residue correspondingly varied within 0.13–0.26 g/100 g in the summer period; 0.13–0.32 g/100 g in the autumn; and 0.22–0.27 g/100 g in the winter period.

The soil water extracts are classified as fresh, with minimal salt content. Throughout both the low-water periods and the spring flood, no exceedances of the MAC for total dissolved solids were recorded in any of the samples. The

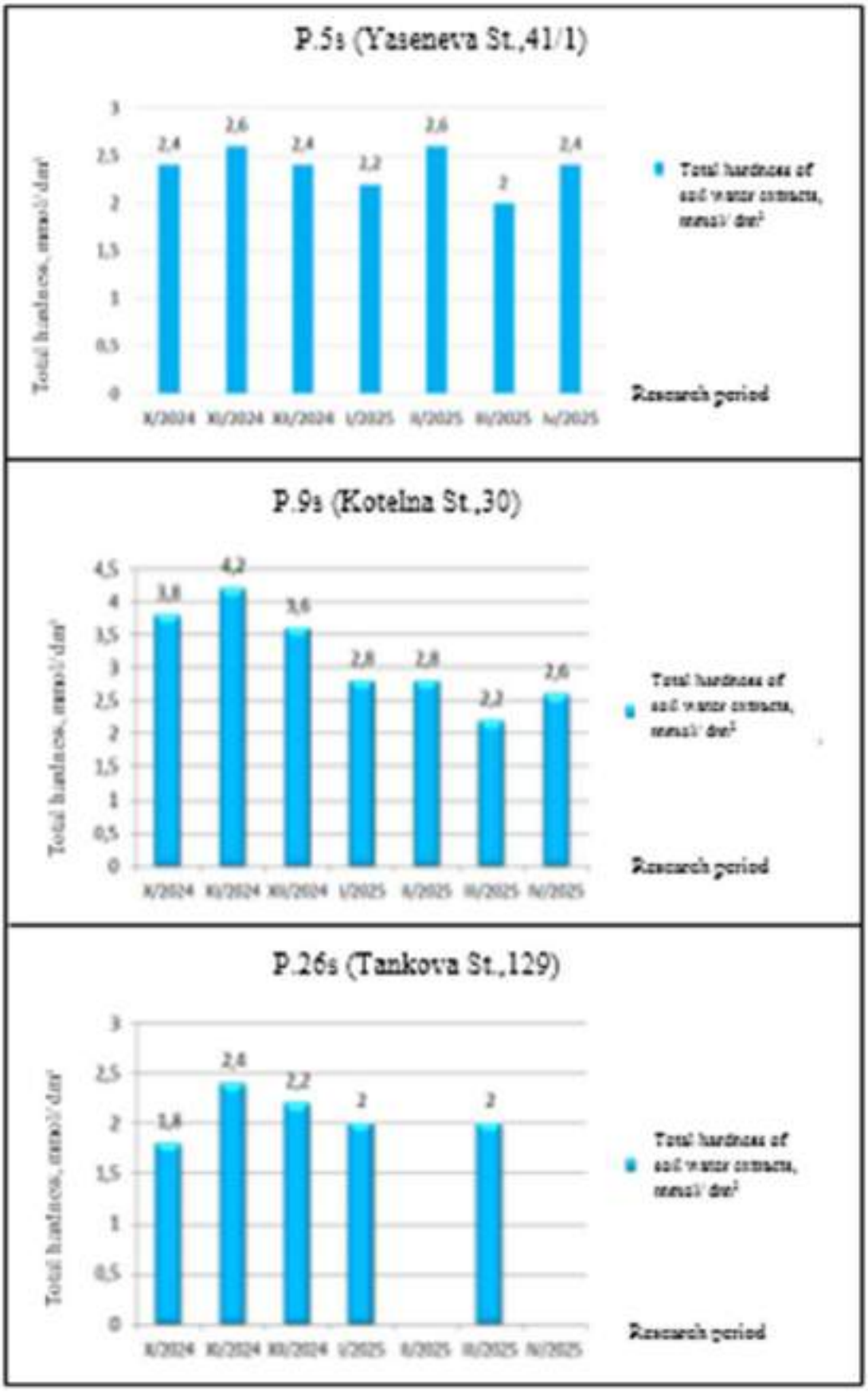


Figure 5.1.1.1. Dynamics of changes in the total hardness aqueous soil extracts for the study period (September 2024 - April 2025)

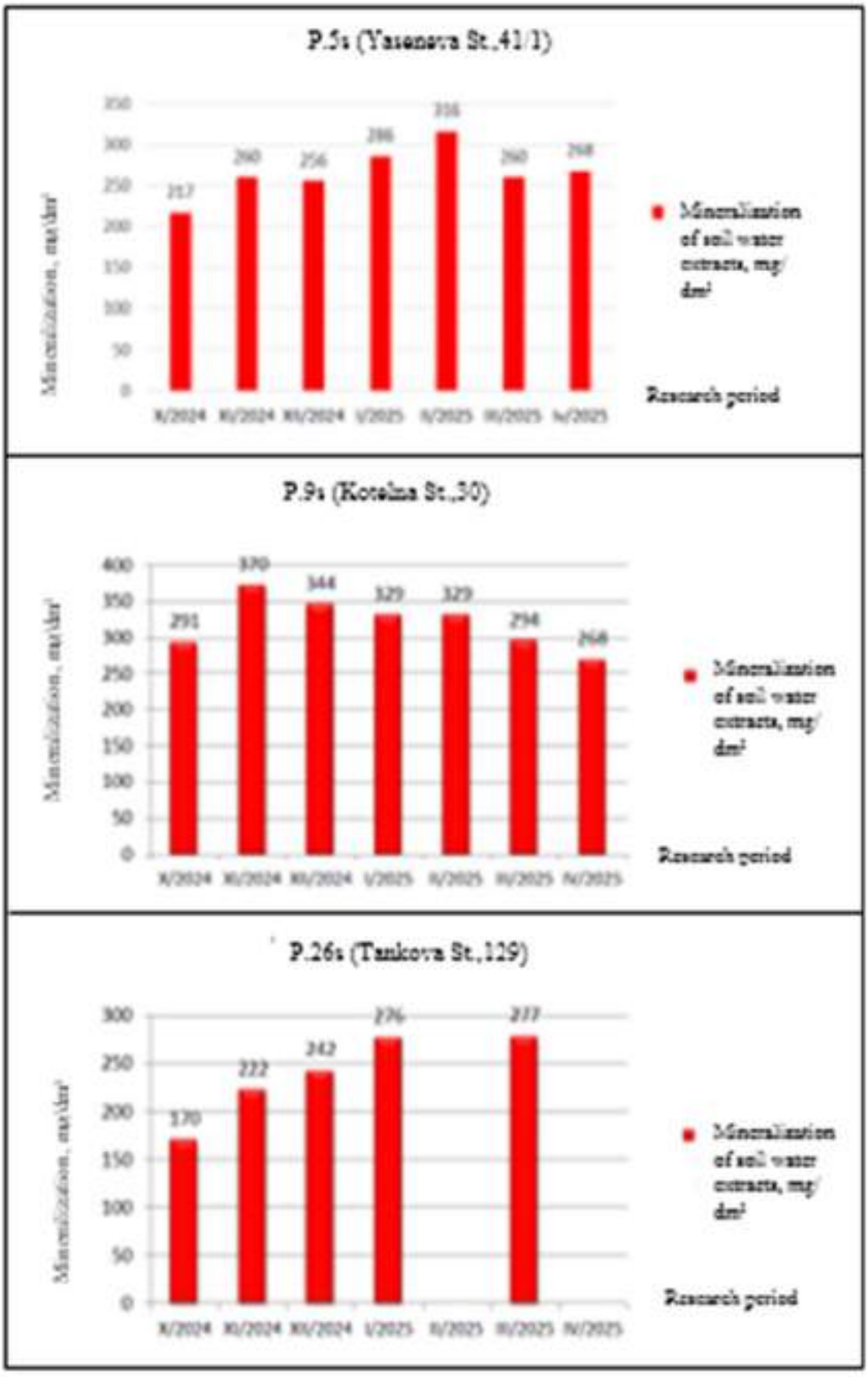


Figure 5.1.1.2. Dynamics of changes in the value of mineralization of aqueous soil extracts for the study period (September 2024 - April 2025)

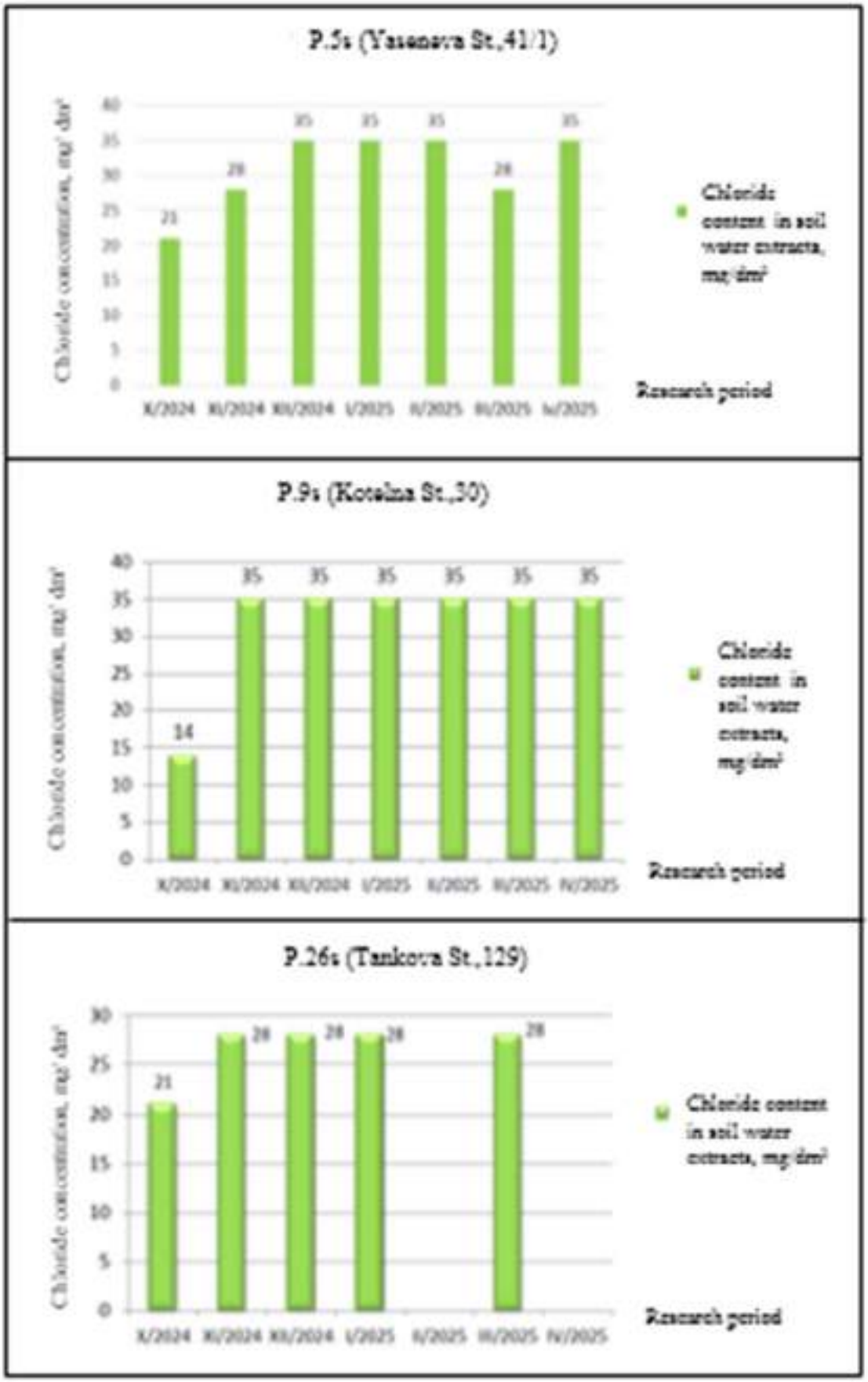


Figure 5.1.1.3. Dynamics of changes in chloride concentrations in aqueous soil extracts for the study period (September 2024 - April 2025)

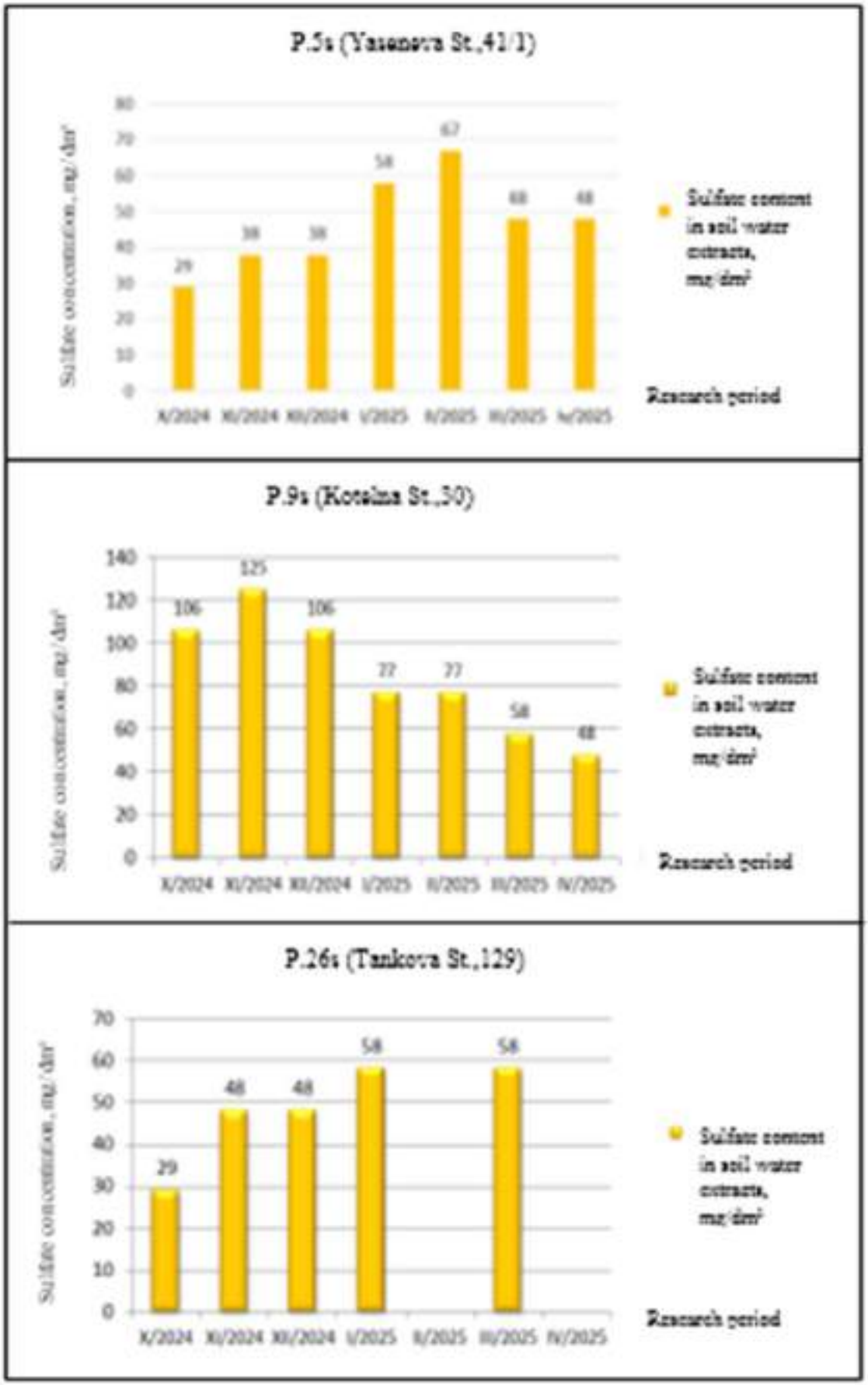


Figure 5.1.1.4. Dynamics of changes in sulfate concentrations in aqueous soil extracts for the study period (September 2024 - April 2025)

concentrations of chlorides and sulfates remained below regulatory thresholds [3].

Chloride and sulfate concentrations in all samples did not exceed the established standards, varying between 10.06–14.2 mg/100 g and 23.4–35.5 mg/100 g (*chlorides*), and from 19.2–48.0 mg/100 g up to 124.3 mg/100 g (*sulfates*) during the monitoring period (Figs. 5.1.1.3, 5.1.1.4).

Biogenic substances. From the standpoint of the potential infiltration of soil solution into groundwater, the content of nitrogen and phosphorus compounds was assessed in accordance with the requirements of [2] for wells and individual boreholes. Over the monitoring period, the concentrations of ammonium ions (NH_4) in the soil solution were recorded at levels ranging from 0.09-0.35 mg/100 g to 0.81-0.95 mg/100 g (0.31-0.37 MAC), i.e., within the MAC.

Nitrite concentrations (NO_2) ranged from less than 0.03 mg/100 g to 0.87 mg/100 g (1.74 MAC). Nitrate concentrations (NO_3) were recorded between 0.64 mg/100 g and 32.64 mg/100 g, which is below the MAC. Phosphate concentrations ranged from 0.36 mg/100 g to 2.68 mg/100 g (0.10-0.77 MAC), i.e., within the MAC. Thus, the concentrations of biogenic substances in soil water extracts were generally within the maximum allowable limits [2].

5.1.2 Level of soil contamination by petroleum products

The concentration of petroleum products in the soils of the residential area located within or near the explosion epicenter (Fig. 2.1.1, Section 2) during the period of chronic environmental contamination was characterized by values that significantly exceeded the maximum allowable concentrations (MAC) [3] (Fig. 4.1.2.1, Section 4), (Tables D.4-D.7, Annex D in Book 2, Annexes (1st-3rd stages of 2024-2025) - previous reports in Ukrainian).

During the summer low-water period, the highest concentration of petroleum products was recorded on ***Yaseneva Street, 41/1*** and amounted to 20,109 mg/kg (40.22 MAC) at a depth of 0.15 m. At a depth of 0.5 m, the concentration reached 2,746 mg/kg (5.49 MAC), and at 1.0 m – 5,533 mg/kg (11.07 MAC). On Tankova Street, 129, in July, the concentration was 3,784.0 mg/kg (7.7 MAC) at 0.15 m depth, 3,463.0 mg/kg (6.9 MAC) at 0.5 m, and 1,746 mg/kg (3.49 MAC) at 1.0 m on a private property on ***1st Plidnyi Lane, 16***. On ***Velozavodska Street,*** in the surface soil layer, the concentration of petroleum products was 1,080.0 mg/kg (2.16 MAC).

In the samples collected during the autumn low-water period, the concentration of petroleum products on ***Tankova Street, 129*** decreased to 1,809 mg/kg (3.62 MAC), while at a depth of 0.5 m it slightly increased to 3,951 mg/kg (7.90 MAC).

On other streets, the concentrations in soil samples were significantly lower, with values of 248 mg/kg in the surface layer, 65–69 mg/kg at a depth of 0.5 m, and 30–90 mg/kg at 1.0 m, which did not exceed the MAC according to regulatory standards [3] (Table 5.1.1, Fig. 4.1.2.1).

During the winter low-water period, on ***Yaseneva Street, 41/1,*** the concentration of petroleum products in the surface layer of the soil was 2,100–2,735 mg/kg (4.20–5.47 MAC) in December, 7,553 mg/kg (15.11 MAC) in January, and 12,582 mg/kg (25.16 MAC) in February. On ***Kotelna Street, 30,*** at a depth of 0.15 m, concentrations reached 1,052 mg/kg (2.01 MAC) in December, 6,497 mg/kg (13.0 MAC) in January, and 3,075 mg/kg (6.15 MAC) in February. On ***Tankova Street, 129,*** the surface layer contained 2,735 mg/kg of petroleum products in December and 4,646 mg/kg (9.3 MAC) in January (Fig. 4.1.2.1, Section 4).

In soil samples collected during the spring period (March–April), the petroleum product content was as follows:

- *in the surface layer* on *Yaseneva Street, 41/1* – 7,242 mg/kg (14.48 MAC) in March and 4,830 mg/kg (9.66 MAC) in April; on *Kotelna Street, 30* – 1,073 mg/kg (2.15 MAC) in March and 895 mg/kg (1.79 MAC) in April; on *Tankova Street, 129* – 3,912 mg/kg (7.82 MAC) in March.

The maximum concentration of petroleum products in the soil during the winter and spring periods was recorded on *Yaseneva Street, 41/1* and amounted to 12,582 mg/kg (25.16 MAC) in the surface soil layer in February and 7,553 mg/kg (15.1 MAC) in January. On other streets, the concentrations during the same period were lower but still exceeded MAC by 1.79 to 12.99 times.

Summary. The temporal and spatial dynamics of petroleum product concentrations in soils (Fig. 4.1.2.1, Section 4) indicate that their levels are practically independent of seasonal changes. The intensity of soil contamination is very high, both in the surface layer and at depths of 0.5 m and 1.0 m.

5.1.3 Level of soil contamination by heavy metals

The primary data used for assessing the condition of the soil cover included monitoring results of heavy metal content (*manganese, boron, barium, nickel, lead, cadmium, and zinc*) in the soils during low-water periods and the spring flood of 2024–2025.

The temporal dynamics of heavy metal concentrations in soils within the contaminated area on Yaseneva Street, 41/1, Kotelna Street, 30, and Tankova Street, 129 are shown in Figs. 5.1.3.1–5.1.3.4.

Analysis of these figures indicates that during both low-water periods and the spring flood, the *total concentrations* of heavy metals in the surface layer of the soil

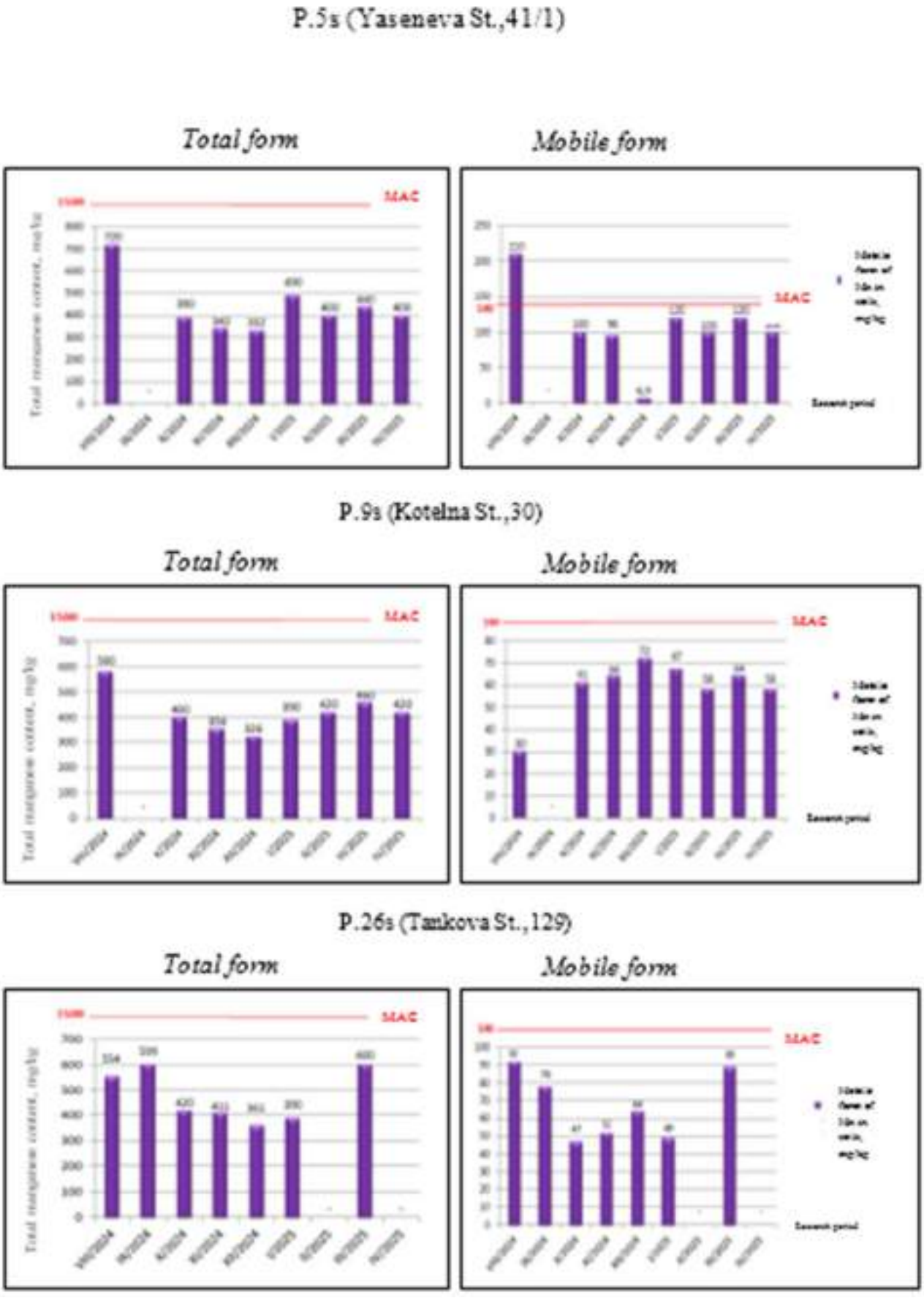


Figure 5.1.3.1. Dynamics of changes in manganese concentrations in soils for the study period (August 2024 - April 2025)

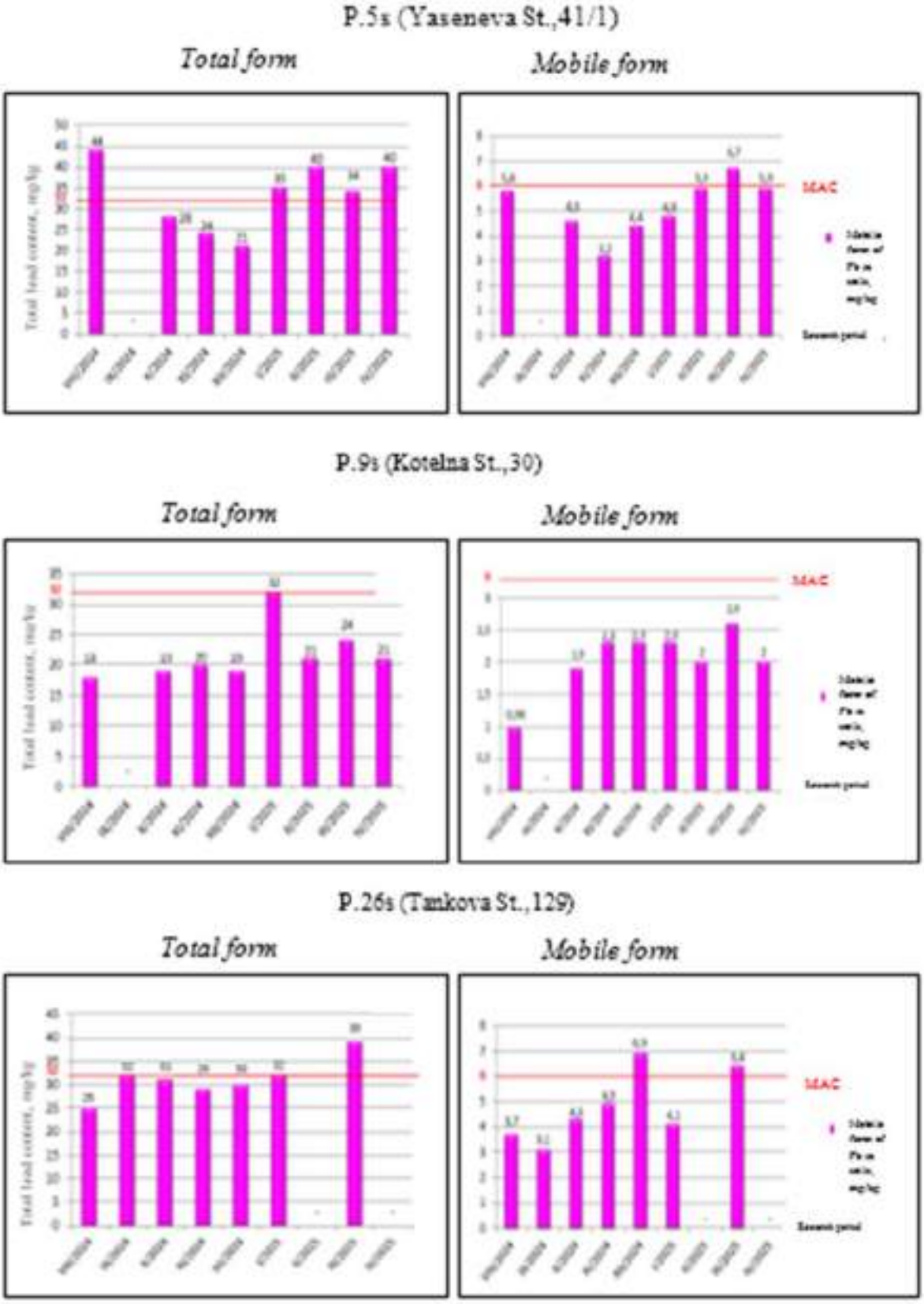


Figure 5.1.3.2. Dynamics of changes in lead concentrations in soils for the study period (August 2024 - April 2025)

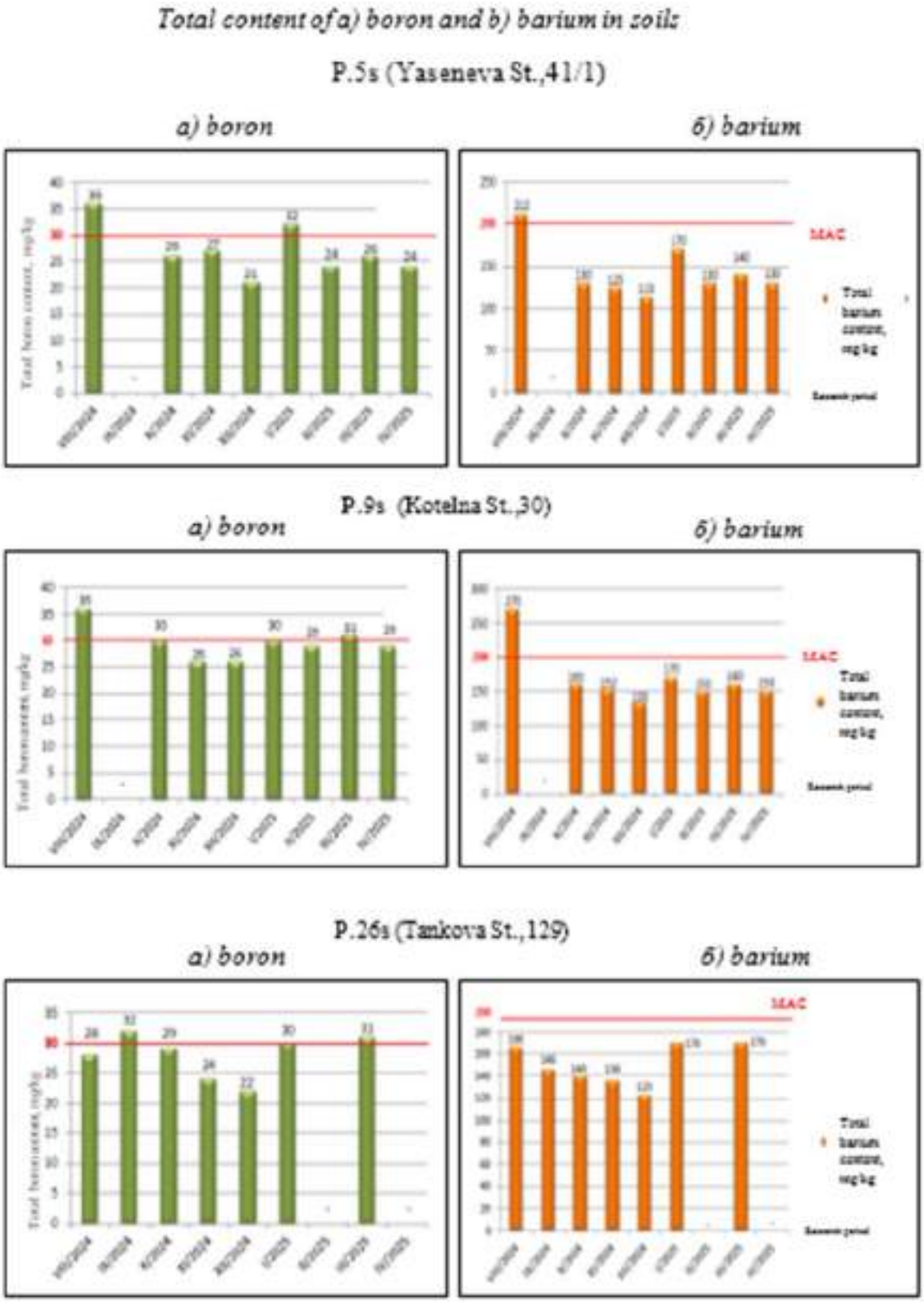


Figure 5.1.3.3. Dynamics of changes in the content of boron and barium in soils for the study period (August 2024 - April 2025)

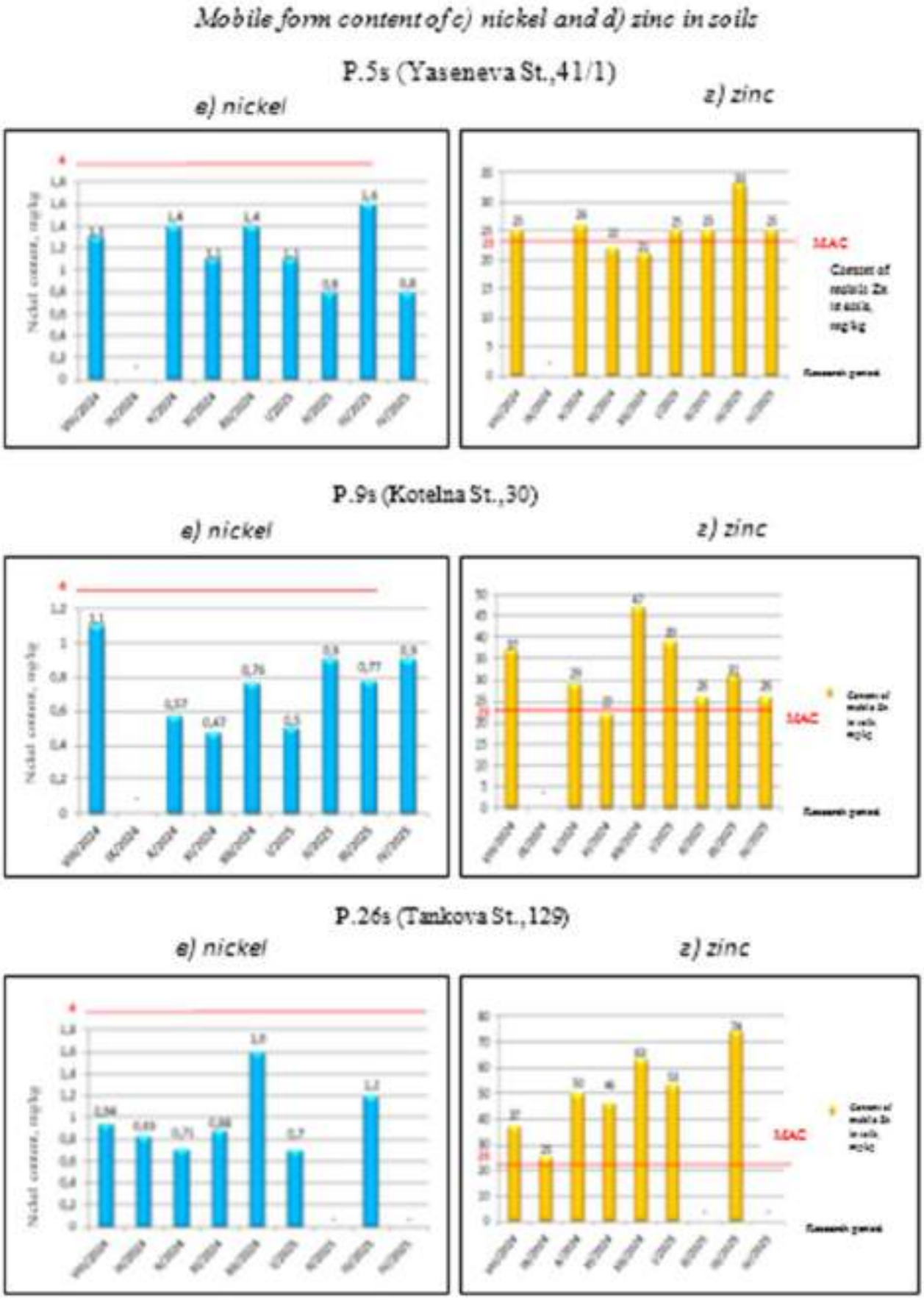


Figure 5.1.3.4. Dynamics of changes in the concentrations of nickel and zinc in soils for the study period (August 2024 - April 2025)

cover were either within the MAC (for *manganese and barium*) or exceeded the MAC (for *nickel and zinc*, and in isolated cases – for *boron and lead*) [3]. The highest concentrations were recorded for *zinc and nickel* (Fig. 5.1.3.4).

The range of heavy metal concentrations over time. Throughout the entire monitoring period, in soil samples collected from the surface layer and at a depth of 0.15 m on the aforementioned streets, exceedances of the MAC were consistently recorded for both total and mobile forms of *zinc*. The total zinc content varied spatially and temporally, mainly ranging from 26.0–72.0 mg/kg (1.13–3.13 MAC) to 105–170 mg/kg (4.57–7.39 MAC). The elevated levels of mobile zinc ranged from 25.0–47.0 mg/kg (1.09–2.04 MAC) to 50–74 mg/kg (2.17–3.22 MAC).

Throughout the entire study period, the concentrations of the total form of *nickel* in soil consistently exceeded the maximum allowable concentration (MAC), ranging from 5.8–20 mg/kg (1.4–5.0 MAC) up to 27–42.2 mg/kg (6.75–10.55 MAC). The content of the mobile form of *nickel* did not exceed the MAC in any of the soil samples, with concentrations varying within 0.5–1.4 mg/kg (0.13–0.35 MAC). Exceedances of MAC for the total content of *boron* (32–36 mg/kg) and *lead* (34–44 mg/kg) were recorded only in isolated samples, corresponding to 1.07–1.25 MAC and 1.06–1.25 MAC, respectively.

Spatial distribution of heavy metal concentrations. In sampling point P. 5 (at a household plot on Yaseneva Street, 41/1), minor exceedances of MAC were recorded for the total content of *boron* (32–36 mg/kg or 1.07-1.2 MAC) and *lead* (35 - 40 mg/kg or 1.1 - 1.25 MAC). The concentration of the mobile form of *lead* exceeded the MAC only in one sample taken in March and amounted to 6.7 mg/kg (1.12 MAC). At the same time, the mobile form of zinc consistently exceeded the regulatory limit throughout the study period (January – April 2024 – 2025), ranging from 25.0 to 33.0 mg/kg (1.09 -1.43 MAC).

In sampling point P. 9 (Kotelna Street, 30), the total content of metals at a depth of 0.15 m did not exceed the MAC in any sample, except for nickel and zinc. For the mobile form, only *zinc* showed exceedances of MAC, ranging from 25.0 to 47.0 mg/kg (1.09 - 2.04 MAC). In sampling point P. 26 (Tankova Street, 129), minor exceedances were observed for the total content of *boron* (31 - 36 mg/kg), which corresponds to 1.0–1.2 MAC, and for *lead* (39 mg/kg), observed only in one sample during the spring flood period. Regarding the mobile form, exceedances were recorded for *zinc* – 53.0 - 74.0 mg/kg (2.30 - 3.10 MAC), and a slight exceedance was observed for lead – 6.4 mg/kg (1.07 MAC) in one sample from the spring flood period. The calculated values of the technogenic geochemical load coefficients (K_i) for soils, based on total and mobile metal content, are presented in Tables 5.1.3.1 and 5.1.3.2.

Table 5.1.3.1 – Ranges of Ki values for soil cover (total forms)

Season of the year, month	*Ki=-<1-1,0*	*Ki=<1-1,38*	*Ki = <1–1,43*		*Ki = 1–8,48*	
	Mn	*Pb*	*B*	*Ba*	*Ni*	*Zn*
Low-water summer period	0,33-0,48	0,56-1,38	0,93-1,20	0,83-1,35	2,75-6,75	1,78-8,48
Low-water autumn period	0,24-0,40	0,59-1,00	0,11-0,87	0,65-0,80	1,75-8,00	0,91-6,83
Low-water winter period	0,22-0,33	0,59-1,25	0,80-1,20	0,57-0,85	2,75-5,00	1,48-6,43
Spring flood period	0,27-0,40	0,60-1,25	0,28-1,43	0,65-0,85	1,45-4,50	2,26-7,39

The values (K_i) presented in Table 5.1.3.1 indicate no contamination of soils by the total content of *manganese and barium*, a relatively low level of contamination by *boron and lead*, and significant contamination by the total content of *nickel and zinc*. For *nickel*, the K_i values reach 4.50–8.0; for *zinc* – 6.43–8.48.

Table 5.1.3.2 – Ranges of K_i values for soil cover (mobile forms)

Season of the year, month	*Ki=-<1-1,5*	*Ki=<1-1,15*	*Ki = <1–3,22*	
	Mn	*Pb*	*Ni*	*Zn*
Low-water summer period	0,21-1,5	0,16-0,62	0,24-0,33	1,09-1,61
Low-water autumn period	0,34-0,71	0,32-0,82	0,12-0,35	0,96-2,17
Low-water winter period	0,49-0,86	0,38-1,15	0,13-0,35	0,91-2,04
Spring flood period	0,41-0,80	0,33-1,12	0,19-0,40	1,09-3,22

According to the values (K_i) in Table 5.1.3.2, the contamination level of soils by the mobile forms of *manganese and lead* is minor; throughout the entire study period, the K_i values generally did not exceed 1.0, ranging between 0.21–0.86 for *manganese* and 0.16–0.33 for lead. The maximum value of K_i = 1.5 for *manganese* was observed only during the summer low-water period, while for *lead*, values of K_i = 1.15 and K_i = 1.12 were recorded in the winter and spring low-water periods, respectively. For *nickel*, the K_i value remained below 1.0, indicating that the soil condition complies with sanitary and hygienic standards (no contamination) [3]. In contrast, for the mobile form of *zinc*, soils are considered contaminated, with K_i values predominantly ranging between 1.09 and 3.22.

5.1.4 Radiation status of the soil cover and bottom sediments of the Nemyshlya River (July 2024 – April 2025)

To assess radioactive contamination, soil samples were taken from private plots located on Tankova Street, 129; Kotelna Street, 30; and Yaseneva Street, 41/1. Bottom sediment samples were collected from the Nemyshlya River at surface water sampling stations in the areas of Velozavodska Street (industrial zone), Zapovidna Street, 54, and Krasnopilska Street, 77.

Throughout the study period – including the summer (July - August), autumn (September - November), winter (December - February), and spring (March - April) seasons – gamma and beta radiation doses in all soil and sediment samples remained within background levels and did not exceed the regulatory limits [4].

Soils. The *gamma radiation* dose in soils during the summer low-water period (July - August) ranged from 6.0 to 14.0 μR/h; during the autumn low-water period (September - November) – 5.7 to 12.0 μR/h; during the winter low-water period (December - February) – 6.0 to 10.0 μR/h; and during the spring flood period (March - April) – 6.2 to 9.8 μR/h.

The *beta radiation* dose in soils during the summer low-water period was 1.8 to 3.6 particles/min/cm²; in the autumn low-water period – 2.0 to 3.4 particles/min/cm²; in the winter low-water period – 1.8 to 3.2 particles/min/cm²; and in the spring flood period – 2.4 to 3.4 particles/min/cm².

Bottom sediments. The *gamma radiation* dose in bottom sediments during the summer low-water period was 6.0 to 11.0 μR/h; in the autumn low-water period – 5.2 to 9.0 μR/h; in the winter low-water period – 5.0 to 8.4 μR/h; and in the spring flood period – 4.8 to 8.0 μR/h.

The *beta radiation* dose in bottom sediments during the summer low-water period ranged from 1.8 to 2.4 particles/min/cm²; during the autumn low-water period – 1.8 to 3.2 particles/min/cm²; during the winter low-water period – 1.8 to 3.2 particles/min/cm²; and during the spring flood period – 2.0 to 2.8 particles/min/cm². (Tables E.1–E.3, Annex E, in Book 2, Annexes (1st–3rd stages of 2024–2025) - previous reports in Ukrainian).

The results of radiometric analysis confirm the radiological safety of both soils and bottom sediments for residents of the area affected by the fuel depot explosion and fire.

5.1.5 Health Risks Associated with Soil Contamination by Petroleum Products and Heavy Metals

It is well established that hydrocarbons (components of petroleum) have the ability to dissolve certain heavy metals when they accumulate jointly in the upper soil layer, resulting in soil poisoning [6,7].

Hazards of soil contamination by petroleum products. Pollution with fuels and lubricants leads to a number of adverse effects: it reduces soil permeability, displaces oxygen, and disrupts biochemical and microbiological processes [6,7]. These changes degrade the soil's water and air regimes and impair nutrient migration, which in turn affects plant root nutrition and hinders growth and development, eventually resulting in vegetation die-off.

Hazards of soil contamination by heavy metals. Among metals that accumulate in contaminated soils and are readily absorbed by plants, the most dangerous are those with bioaffine properties – i.e., a strong affinity to biological tissues.

The transfer of metals into plants is quantitatively assessed by the biological absorption coefficient (A_x), which represents the ratio of an element's concentration in plant ash to its concentration in the soil. Estimates for the elements listed as "hazardous components" of Ukrainian waste range from 106 for sulfur to 0.001 for thallium [8].

The most intensively absorbed elements are compounds of sulfur and phosphorus (A_x = 106 - 75), followed by *silver, zinc, copper, barium, and tin* (A_x = 14–2).

The list of hazardous elements does not include key bioaffine elements such as *molybdenum* (Mo) and *manganese* (Mn), which are typically deficient in Ukrainian soils [9] and are therefore readily taken up by plants, contaminating both agricultural crops and the vegetation of meadows and pastures [10].

Another group of elements (*beryllium, vanadium, chromium, cadmium, mercury, thallium, molybdenum, cobalt, arsenic, and antimony*) exhibit biofobic properties – their concentrations in plants are typically lower than in soils. Hence, they pose the least threat to agricultural production and may not manifest as contamination in crops.

During the first stage of monitoring (July–August 2024), analysis was conducted to determine the total concentrations of *barium, boron, vanadium, cadmium, manganese, arsenic, mercury, lead, selenium, antimony, and iron, as well as the mobile forms of tungsten, cadmium, cobalt, manganese, copper, molybdenum, nickel, lead, chromium, zinc, and iron.*

Among these, the total forms of barium and boron and the mobile form of zinc exceeded the MAC.

In subsequent analyses, nearly all samples showed exceedances of total forms of *zinc, nickel, boron, and lead,* and mobile forms of *zinc* and, occasionally, *lead*.

Thus, the combined contamination of soils with bioaffine elements – *zinc, barium, boron, lead, and manganese* – and petroleum products represents a significant ecological and health hazard. Even at moderate concentrations, these contaminants pose a high risk to crop cultivation in both private household gardens and floodplain meadows along the Nemyshlya River, where vegetation is commonly used as animal feed.

As such, soils in the study area serve as a contamination source for vegetation, rendering them unsuitable for safe cultivation of food crops.

Summary of Section 5. Monitoring results indicate that the salinity levels in the aqueous extract of both soils and bottom sediments from the Nemyshlya River remained within regulatory limits.

However, the concentrations of heavy metals and petroleum products in bottom sediments exceeded MACs in nearly all sampling sites. Consequently, bottom sediments are considered a source of secondary water contamination, affecting the Nemyshlya River's aquatic biocenosis.

Soils from the upper horizon of private residential plots were found to be contaminated with *petroleum products, zinc, nickel, and,* in isolated samples, *lead and boron* (total forms). In many cases, concentrations of petroleum products in surface soils exceeded the MAC by 2 -14 times, while the mobile forms of zinc and lead also exceeded the MAC by 3.22 and 1.15 times, respectively. These soils pose a direct threat to vegetation, making them unsafe for growing edible crops.

No radioactive contamination of either soil or bottom sediments was detected in the Nemyshlya River area.

CONCLUSIONS TO PART 1

Based on the results of chemical and analytical studies conducted as part of environmental monitoring, the following conclusions can be drawn:

1. Groundwater contamination with petroleum products was recorded at two standpipes located on 1st Plidnyi Lane, 9 and Plidna Street, 28, with concentrations of 1.68 mg/dm³ (16.8 MAC) and 0.15 mg/dm³ (1.5 MAC), respectively.

In the well on Zapovidna Street, 54 and the spring at Zapovidna Street, 66, petroleum products were found at concentrations of 0.43 mg/dm³ (4.3 MAC) and 0.64 mg/dm³ (6.4 MAC), respectively. In the borehole on Tankova Street, 129, the

concentration in spring was 0.83 mg/dm³ (8.3 MAC). The water was classified as fresh based on salinity.

2. The ecological situation developing in the aquatic environment of the affected area is considered hazardous and requires continuous monitoring of petroleum product concentrations in drinking water, as well as surveillance for their occurrence in other water supply sources such as wells, boreholes, and standpipes.

3. In the Nemyshlya River, the water is classified as fresh based on mineralization (0.85–1.19 g/dm³), which remains within the permissible limits [5].

4. *Petroleum products* in surface waters of the Nemyshlya River were generally found in concentrations ranging from <0.05 mg/dm³ (absent) to 0.05–0.67 mg/dm³ (2.23 MAC). They were absent during the summer and spring seasons but present in the autumn – winter period at concentrations from 0.05 to 0.63–0.67 mg/dm³ (0.21–2.23 MAC).

5. Aqueous extracts of bottom sediments of the Nemyshlya River and soils were found to be fresh and low in salinity. Throughout the study period, mineralization ranged from 0.16 to 0.30 g/100 g in bottom sediments and from 0.16 to 0.37 g/100 g in soils.

6. Bottom sediments in the area impacted by the explosion and fire at the oil depot are intensively contaminated with *petroleum products* (from 64–492 mg/kg up to 3063–3564 mg/kg) and *heavy metals,* particularly *zinc* (1.48–8.48 MAC), *nickel* (1.45–6.75 MAC), *boron* (1.10–1.60 MAC), and *barium* (1.10–1.71 MAC). These sediments act as a source of secondary contamination of the river water and pose a threat to both the hydrobiocenosis and the ecosystem of the Nemyshlya River as a whole.

7. Soils in the upper horizon on private residential land parcels are severely contaminated with *petroleum products* and heavy metals – primarily *zinc and nickel*, and in some cases, *lead and boron* (total forms).

8. Petroleum product concentrations in surface soils ranged from 3912 to 12,582 mg/kg (7.82–25.16 MAC); at a depth of 0.15 m, concentrations ranged from 1073 to 6497 mg/kg (2.01–12.99 MAC). In particular, at sites on Tankova Street, 129; Kotelna Street, 30; Zapovidna Street, 54; and Yaseneva Street, 41/1, surface concentrations exceeded MAC values by a factor of 2 to 14.

9. The concentrations of mobile bioaffine metals in soils exceeded MACs and were recorded as follows: zinc – 1.09–3.22 MAC; lead – 1.12 - 1.15 MAC; manganese – 1.5 MAC. These metals exhibit relatively high biological absorption coefficients (A_x = 14 - 2), indicating their strong uptake by plants.

10. As of the monitoring period, soils on household plots in the private sector act as sources of contamination for vegetation, which makes safe cultivation of edible crops impossible. This situation poses a potential health risk to both adults

and children.

11. No radionuclide contamination was detected in soils or bottom sediments of the Nemyshlya River. Gamma and beta radiation doses did not exceed regulatory thresholds [4]. Over the study period, gamma radiation ranged from 5.7–14.0 μR/h in soils and from 4.8–11.0 μR/h in sediments. Beta radiation doses were 1.6–3.6 particles/min/cm² in soils and 1.8–3.2 particles/min/cm² in sediments. These values confirm the radiological safety of the investigated media.

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PART 2 SOCIO-ECONOMIC CONDITIONS

1 Background

According to a letter from the Head of the Nemyshlyanskyi District Administration (Annex A - previous reports in Ukrainian), the number of residents living in the area adjacent to the oil depot (LLC “KhNB - Reserve”) before the war (as of February 2024) was 202 people, including 21 children.

The number of residents who suffered as a result of the explosion amounted to 60 people (including 11 children). Among the victims were 7 fatalities, including 3 children.

In order to assess the damage caused to residents of the affected area, a questionnaire survey was conducted in 2024 among residents of the most heavily impacted territories. To ensure representative results, the study focused on individuals whose private households had been directly affected by the explosion and were located in the epicenter – on the following streets: Kotelna, Tankova, Plidna, Yaseneva, 1st Plidnyi Lane, Zapovidna, and Nemyshlyanska.

In the summer of 2024, this territory came under rocket fire again, which caused a fire in the floodplain and shallow areas of the Nemyshlya River (where residual petroleum products accumulated in the plant root zones and dried old stems ignited). As a result, some residents left the area. Many houses are now closed and uninhabited – the owners have fled due to the heavy contamination of soils with petroleum products. At the time of the study, the population had significantly declined. Most of those who remained were pensioners, who mainly became the respondents in the social research.

The primary objective of the study was to comprehensively examine the consequences of the rocket attack, explosions, and fire at the oil depot in the Nemyshlyanskyi District, as well as to understand residents’ perceptions of the changing living conditions in the affected area, given the catastrophic technogenic impact on the environment caused by the Russian Federation’s war of aggression against Ukraine – and specifically by the shelling of civilian infrastructure in the city of Kharkiv.

To obtain data suitable for statistical processing and use as a basis for assessing the impact of the explosion and fire at the oil depot on the social environment in Nemyshlyanskyi District, monitoring results from the area (conducted in 2024) were used. A survey was conducted among representatives of various segments of the population using specially developed questionnaires covering multiple problem groups:

- One group of questions concerned the general demographic structure;

- Another addressed residents' attitudes toward the consequences of the rocket attack and its environmental impact, as well as their perception of the relevance of conducting environmental studies to assess the current state of the environment.

In designing the survey questionnaires, it was essential to reflect a range of social issues that emerged after the explosion at the oil depot.

The *first issu*e was related to changes in the demographic structure of the community (due to the departure of a significant portion of the population), as well as to deteriorating material conditions resulting from the contamination of soil on household plots and the inability to grow vegetables (which had served as an additional source of income for most families), along with extremely limited financial support for families during the war. Additionally, the questionnaire included questions for respondents regarding the number of children in affected households, their age, and health status.

To address the *second issue*, the questionnaire included questions concerning the environmental consequences of the explosion and fire, and the resulting damage (losses) experienced by residents living in areas adjacent to the epicenter. It also contained questions exploring residents' perceptions of the relevance and necessity of conducting environmental research (particularly by scientists from USRIEP) to assess the current environmental situation.

The questionnaire survey enabled researchers to obtain answers to most of the critical questions and provided high-quality information for analysis.

For the study, the *general population* consisted of the most affected individuals – 60 residents in total. In order to adequately represent the situation, the required number of respondents (i.e., the sample size) for the survey was determined according to accepted methodological recommendations [1, 2, 3].

The number of respondents for the first group of questions – concerning the general demographic structure and material well-being – was 8 individuals who had experienced substantial material losses and emotional distress. For the second group of questions – focused on the environmental changes following the oil depot explosion – 10 individuals were surveyed.

The conclusions drawn from analyzing this sample allow for an assessment of the stated problems as being representative of the overall experiences of the most affected residents.

It should be noted that the environmental protection measures implemented during the critical period by the Kharkiv city administration, the Nemyshlyanskyi District Administration, Kharkiv-based scientific institutions, and others, helped shift the situation from a phase of acute environmental contamination to one of chronic pollution.

2 Analysis of the results of monitoring the social situation in the studied area and their visualization

2.1 Information highlighting the key aspects of socio-ecological problems

In order to identify the most pressing ecological and socio-economic issues that remain unresolved for the local population, the authors visualized the results of the respondents' answers to the questions included in the survey.

The identification of current problems was carried out by analyzing the percentage distribution of responses. Particular attention was given to the psychological and physical condition of children, with a focus on selecting questions related to the creation of environmentally acceptable living conditions and the justification for the need to address them.

The research consisted of a comparative analysis of the processed responses, which served as the basis for identifying the most critical aspects of the problems caused by the oil depot explosion. These included the impact on children's health, environmental conditions in the contaminated zone where they reside, and the material well-being of the local residents. The hope for assistance in resolving these issues directly affects the emotional and physical state of both children and adults. These concerns are the primary source of anxiety and psychological distress for most respondents.

To determine which issues are most urgent – those requiring further analysis, the development of recommendations for additional environmental protection measures, and prompt resolution and assistance – the following information was selected for analysis.

2.2 Analysis of the demographic structure characteristics of the affected population

In order to assess the socio-economic status of residents affected by the Russian missile strike, a study was conducted on the general characteristics of the demographic structure of the territorial community located in the zone of catastrophic environmental degradation.

The demographic characteristics, according to the responses gathered through the survey, include: distribution of households by total number of family members; by number of adult family members; by number of family members over 60 years and over 20 years of age; distribution of families by number of children aged under 1, 1 – 5, 5 –10, 10 – 15, and 15 – 20 years; and the distribution of respondents by

age and marital status. The collected data are presented in the diagrams (Figs. 2.2.1 – 2.2.6).

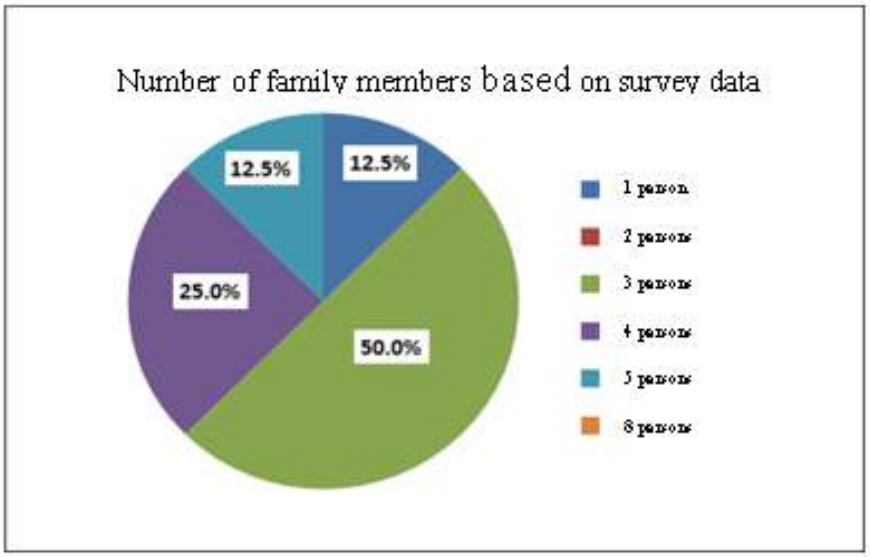


Figure 2.2.1. Number of family members based on survey data**

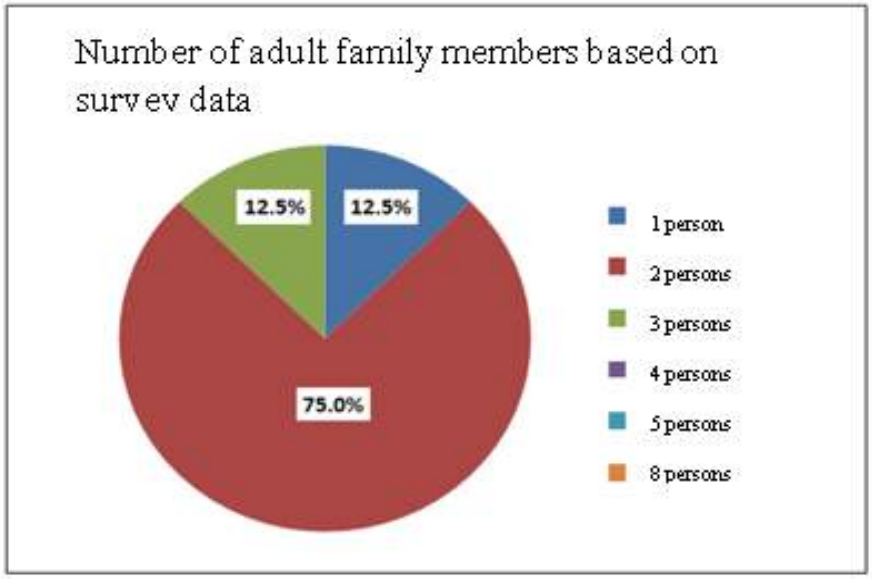


Figure 2.2.2. Number of adult family members based on survey data**

*Note**: Percentages indicating the absence of responses (0%) to the survey questions are not displayed on the charts presented in Figures 2.2.1, 2.2.2, and other figures throughout the text, although they are included in the legends of the diagrams.*

Based on the analysis of these diagrams, we can state that the average household in the studied area generally consists of 3 – 4 members, typically including 2 adults. One household had 3 adult members, and another had 4 adults.

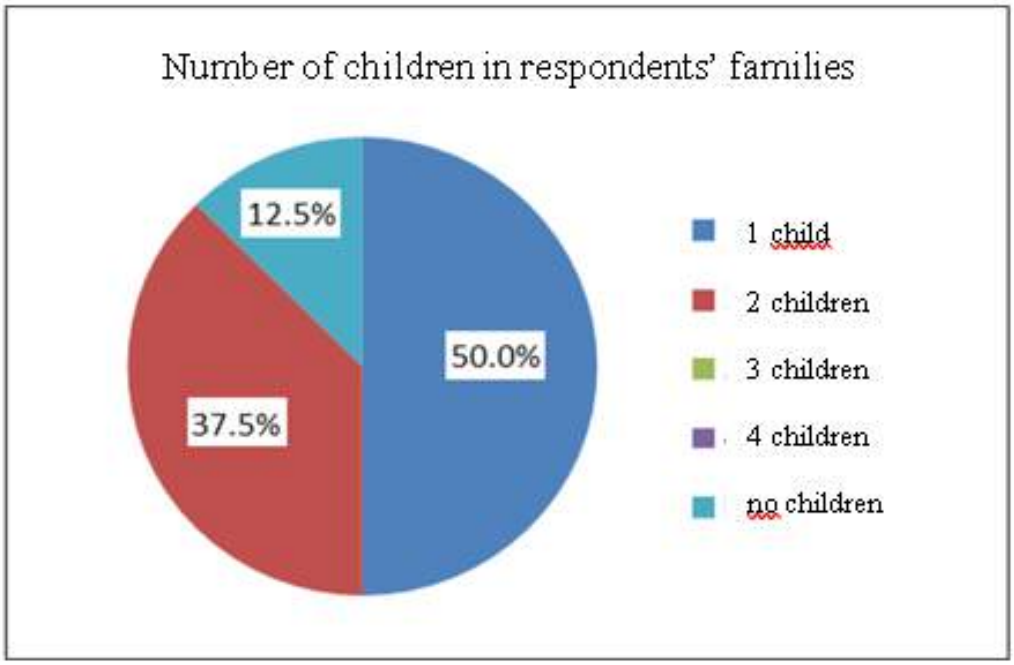


Figure 2.2.3. Number of children in respondents' families

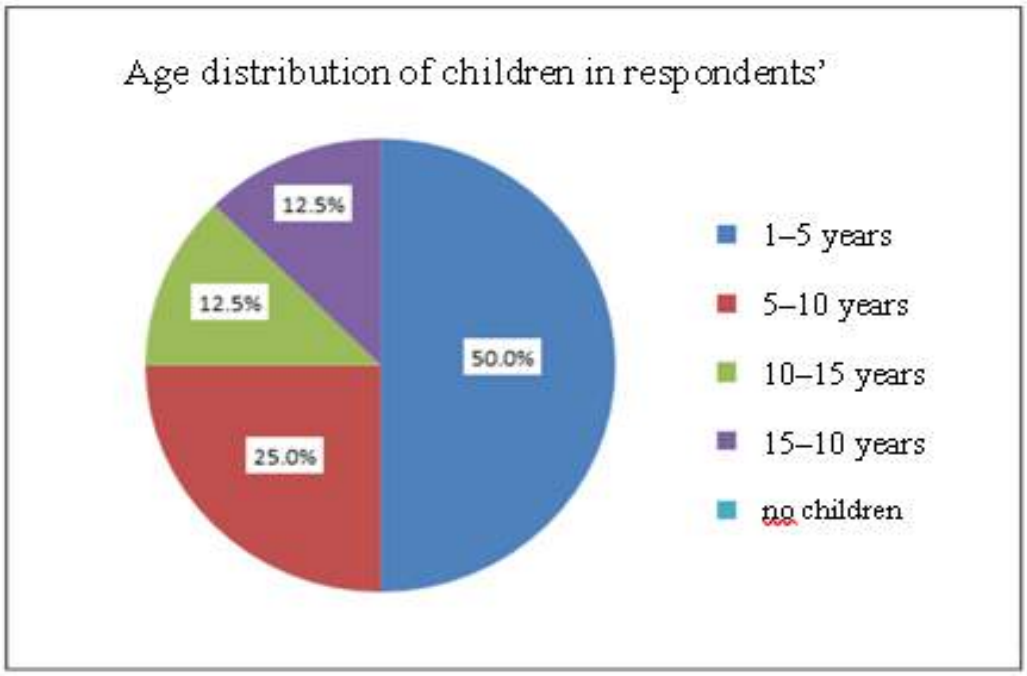


Figure 2.2.4. Age distribution of children in respondents' families

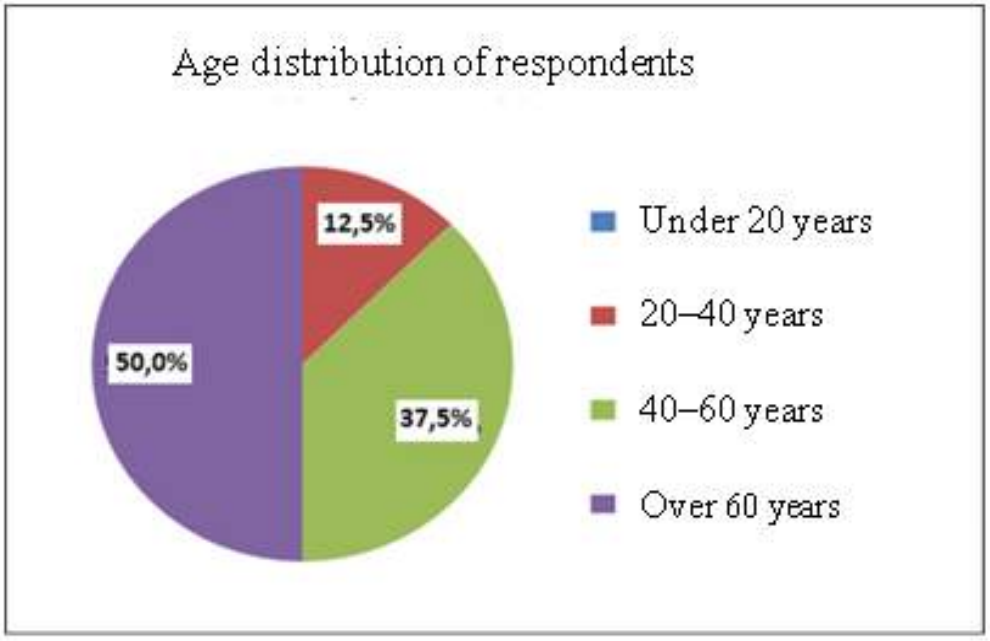


Figure 2.2.5. Age distribution of respondents

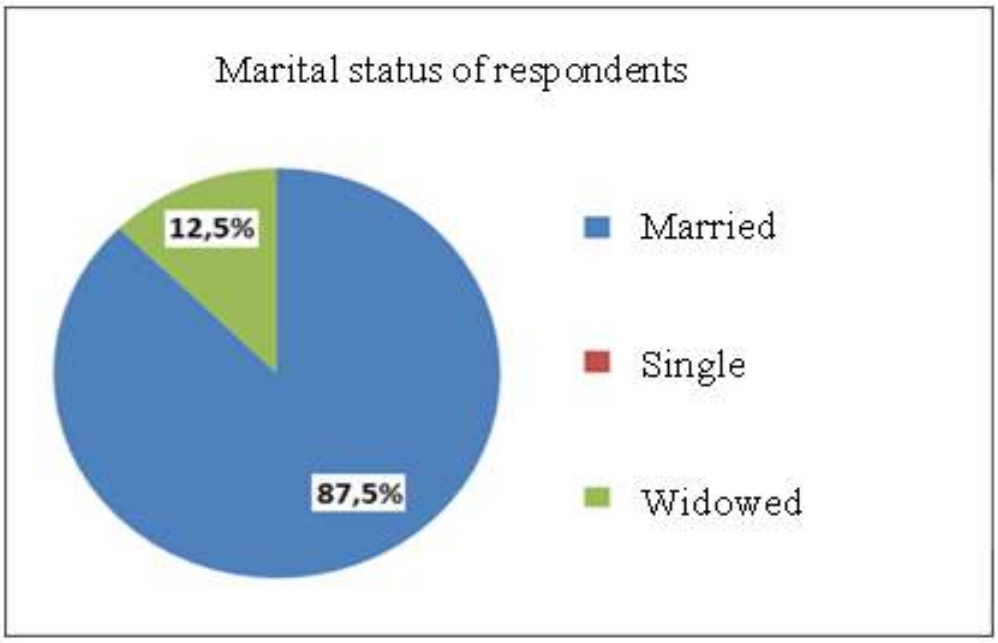


Figure 2.2.6. Marital status of respondents

According to the age distribution of respondents shown in Figs. 2.2.3 to 2.2.5, the age structure is characterized by a significant proportion (50%) of elderly individuals (aged over 60), which is a result of the war. Respondents aged 40–60 make up 37.5%, while those under 20 represent 12.5%. Among the families of the eight respondents, a total of 10 children were reported, aged between 1–5 and 15–

20 years. Specifically, 50% of these children are aged 1–5 years; 25% are 5–10 years old; 12.5% are 10–15 years old; and another 12.5% are aged 15–20 years.

Among the 14 respondents (100%), 35.7% (5 individuals) were women and 64.3% (9 individuals) were men. A total of 87.5% of the respondents were married (Fig. 2.2.6).

Analysis Results. According to the analysis, the demographic indicators – despite some specific issues – can be considered relatively favorable. There is no dominant trend toward population aging observed.

2.3 Analysis of the financial situation and needs of the affected population

Among the residents of the streets most severely affected by the explosion at the oil depot, a study was also conducted to assess the financial situation and needs of the local population. Respondents were asked questions regarding the total household income and per capita income, family budget conditions, general well-being, and more. The visualization of the results of the financial analysis is presented in diagrams 2.3.1 – 2.3.4.

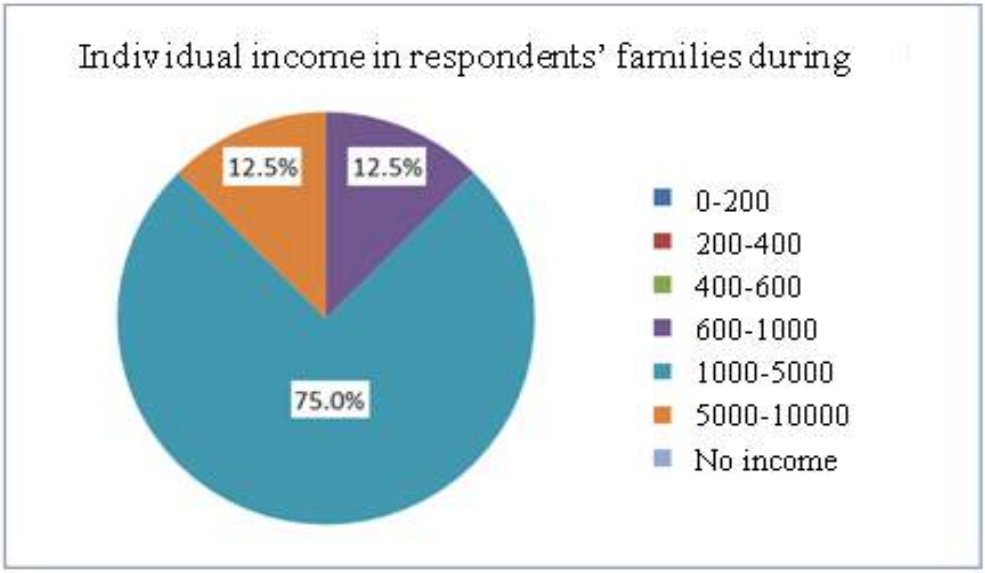


Figure 2.3.1. Individual income in respondents' families during the war

During the war, the average total household income per respondent ranged from 1,000 to 5,000 UAH (75.0%), with the highest income reaching 5,000–10,000 UAH (12.5%), and the lowest ranging between 600 – 1,000 UAH (12.5%). No respondents reported having less than 1,000 UAH in income or having no income at all (0.0%).

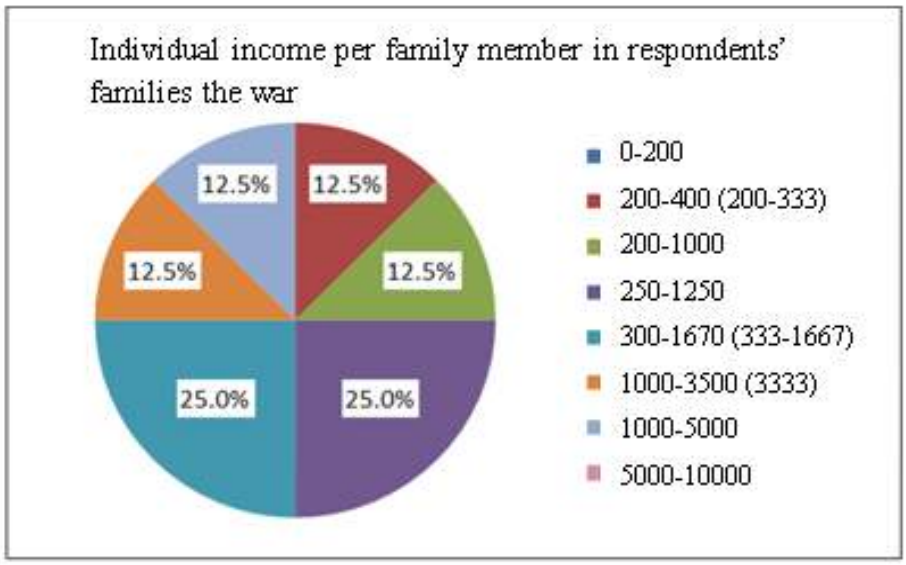


Figure 2.3.2. Individual income per family member

The average income per household member depended on the total household income and ranged from the minimum of 200 – 400 (200 – 333) UAH (12.5%) to the maximum of 1,000 – 3,500 (1,000 – 3,337) UAH (12.5%). On average, per capita income ranged between 250 –1,670 UAH (25%).

Let us now analyze the respondents' financial situation based on their subjective self-assessment regarding their ability to purchase new clothing, footwear, home appliances, a car, and real estate (Fig. 2.3.3).

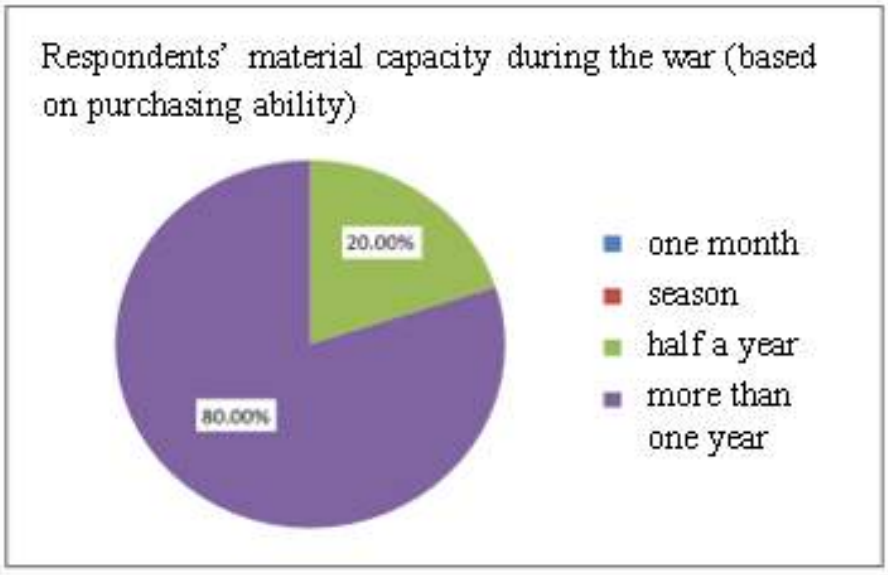


Figure 2.3.3. Material capabilities of respondents during the war (based on purchasing ability)

Most respondents noted that they are only able to buy necessary clothing and footwear once a year (80.0%), while 20% reported being able to afford such purchases once every six months. All respondents (100.0%) stated that the purchase of household appliances, property, or a vehicle was out of the question during wartime – especially since even before the war, it would have taken over 10 years to save up for such purchases. Some respondents also noted that they live without luxuries and only buy the most essential goods and necessities.

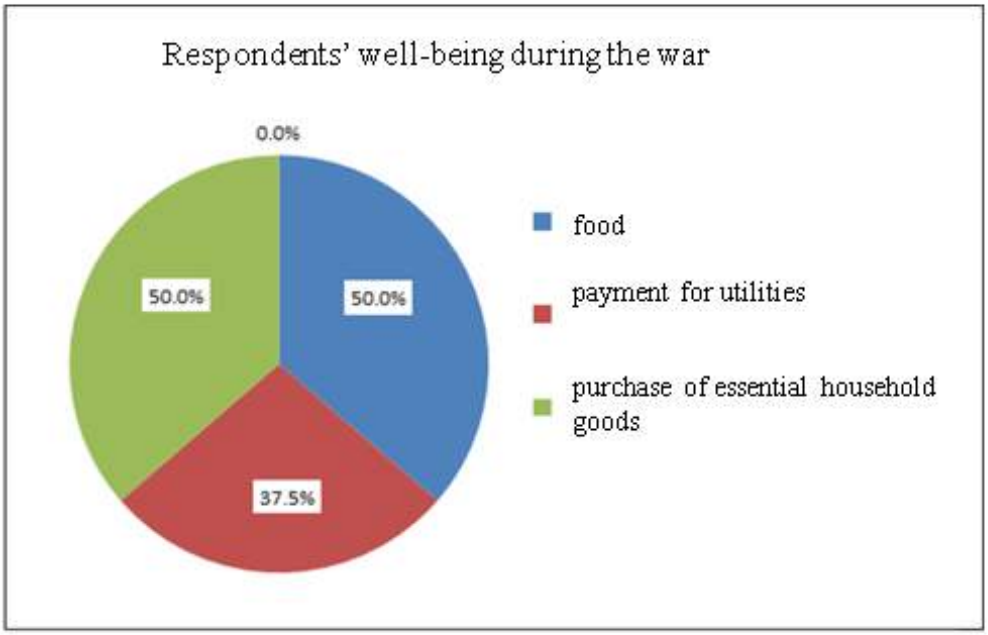


Figure 2.3.4. Well-being of respondents during the war

The financial well-being of respondents depends directly on the household's financial capacity. When asked, *"Is there enough money to pay for utilities, food, and essential goods?"*, the majority of respondents (62.5%) said their financial resources were insufficient to pay utility bills and buy household necessities, as these expenses consume most of the family's income (Fig. 2.3.4).

Additionally, 50% of respondents reported insufficient funds to adequately support their children.

Analysis Results. Based on the provided data, it can be concluded that the financial situation of most respondent households is quite poor.

*Conclusion***.** Families require financial assistance to support their children.

2.4. Analysis of employment structure and sources of income in the studied area

An important factor in assessing the socio-economic condition of residents affected by the oil depot explosion in the Nemyshlyanskyi district of Kharkiv is the evaluation of their employment status at state enterprises or in commercial structures that have survived during the war and continue to operate. Employment serves as a source and guarantee of income for the respondents. The visualization of data on respondents' sources of income is presented in the diagrams shown in Fig. 2.4.1.

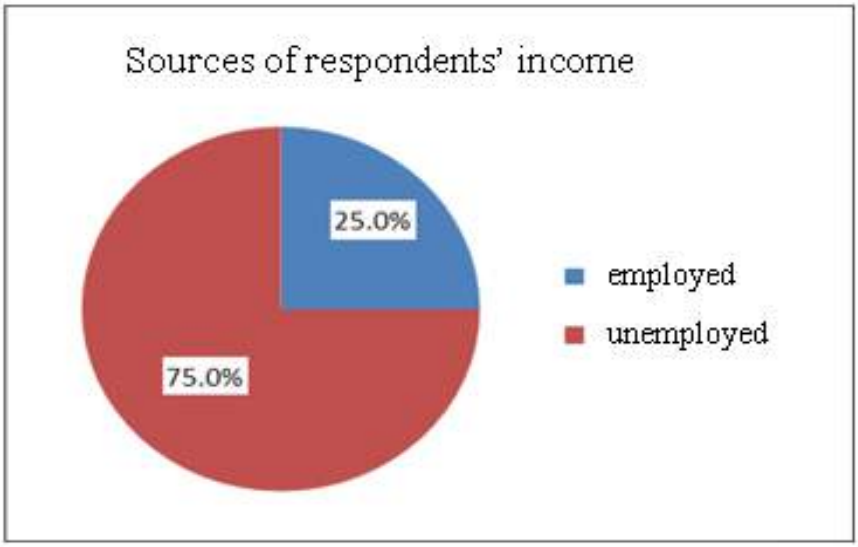


Figure 2.4.1. Respondents' sources of income

Analyzing the results of the survey, it can be stated that among the respondents, 25.0% are employed, while 75.0% are not. Among the unemployed, 50.0% are pensioners. Thus, the main source of income for the surveyed respondents is pension benefits: 50.0% of the respondents receive a pension. None of the respondents work at state enterprises (0.0%). A total of 25.0% are employed in commercial structures. At the time of the survey, 12.5% of respondents were not working due to caring for parents.

It should be noted that there are no enterprises available for employment during wartime in the studied area.

The standard of living in wartime conditions is very low. The majority of the population engages in activities on their private household plots. All respondents (100%) have their own land plots for personal use (Fig. 2.4.2). Before and at the beginning of the war, respondents received additional income from subsistence farming (Fig. 2.4.3).

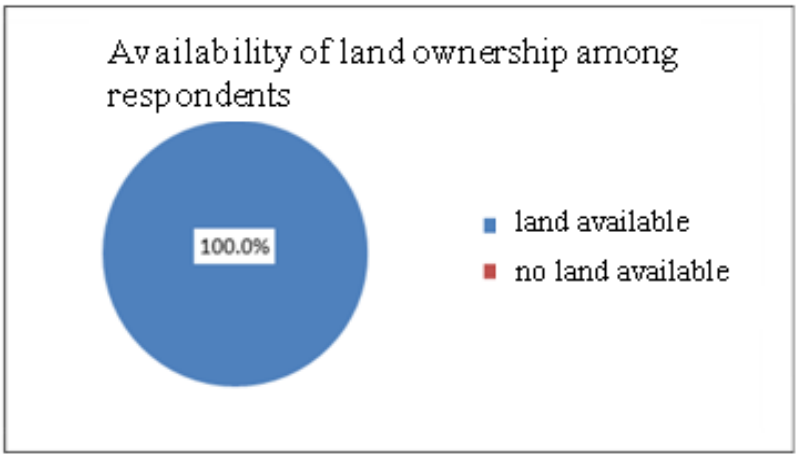


Figure 2.4.2. Ownership of land plots

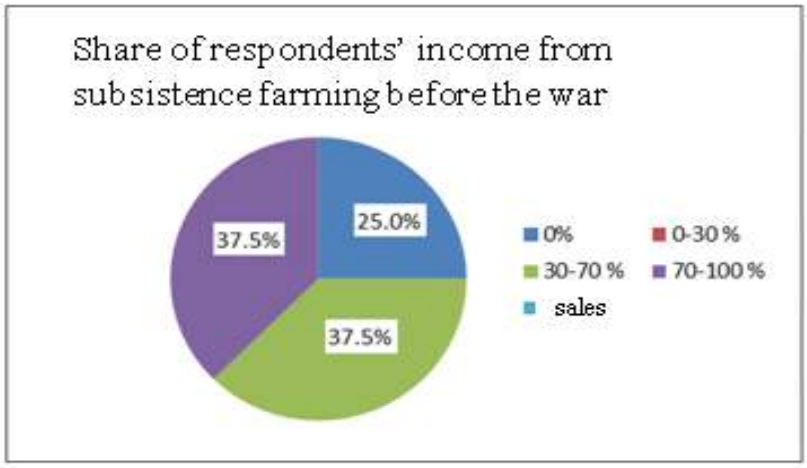


Figure 2.4.3. Share of income from subsistence farming before the war

In total, 75.0% of respondents who own land plots noted that before and during the war, agricultural produce played a significant role and was often a source of additional income, although it was not used for sale. This was reported by 37.5% of respondents from two households who received 30 – 70% and up to 70 – 100% of their income from cultivating agricultural products. At the same time, 25.0% of respondents did not use their plots (Fig. 2.4.3).

The majority of respondents (62.5%) who had a land plot and used it even during the war before the explosion at the oil depot noted that after the explosion and fire, the soil became significantly contaminated with petroleum products, making it impossible to grow agricultural produce (in particular, vegetables) (Fig. 2.4.4).

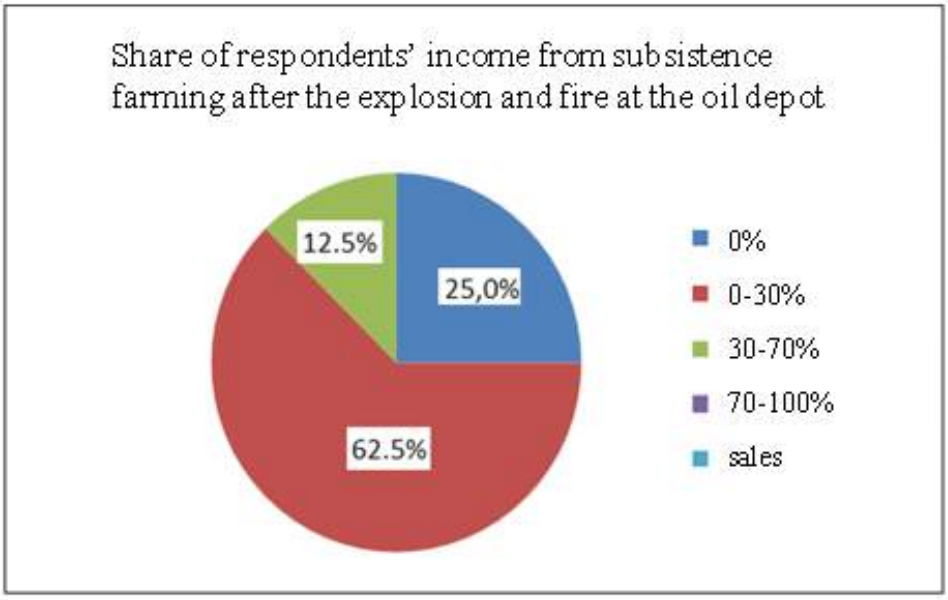


Figure 2.4.4. Share of income from subsistence farming after the oil depot explosion and fire

As a result, households lost sources of additional income from growing vegetables and fruits. Only 12.5% of respondents continue to harvest produce (within 30 – 70%) from their land plots.

Analysis of the respondents' answers regarding the receipt of financial assistance (Fig. 2.4.5) shows that the income of the majority of respondents depends on the state: 50.0% receive child benefits, 37.5% receive pensions. Income from work in commercial (non-state) enterprises accounts for 25.0%. All other sources of income have a very low share among respondents.

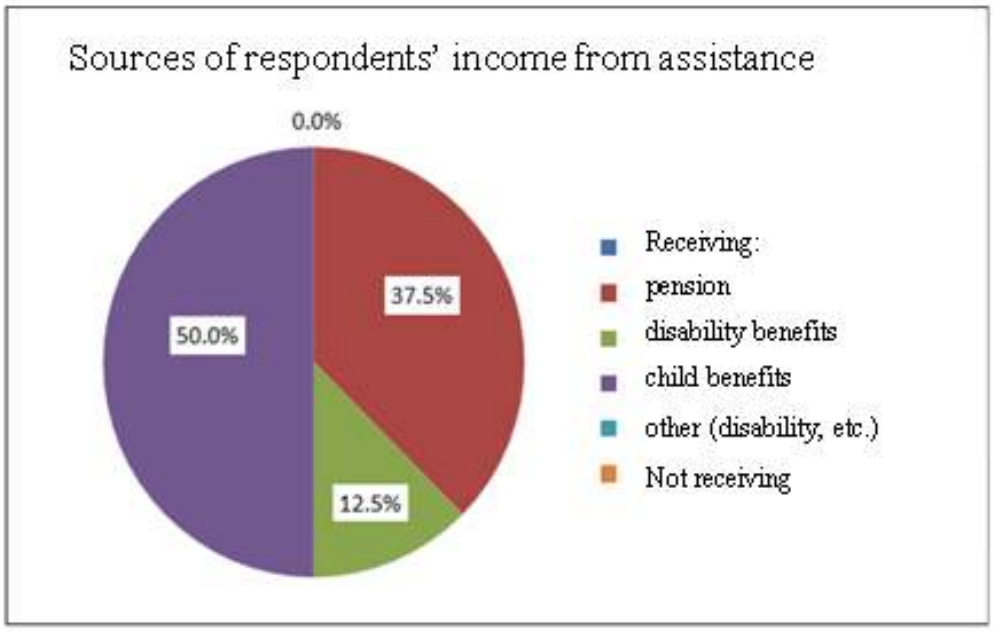


Figure 2.4.5. Income sources through aid

Analysis results. In the studied area, there are no enterprises providing employment during wartime. The standard of living of the population under war conditions is very low. The share of income sources is minimal, which generally indicates a rather weak position during the war of both the state and non-state (commercial) sectors of the economy in the employment structure of the residents of the studied part of the Nemyshlyanskyi district of Kharkiv.

After the explosion and fire at the oil depot, the soil became heavily contaminated with petroleum products, making it impossible to grow agricultural produce (particularly vegetables).

So, there is a need to implement additional measures for the decontamination of soil from petroleum products on private household plots.

Conclusion. The analysis of the material status and needs of the residents in the area that suffered catastrophic environmental degradation due to the oil depot explosion indicates that they are in a rather difficult financial situation, requiring assistance.

3. Analysis of the negative impacts of the explosion and fire at the oil depot (as well as Russian missile strikes in general) on social conditions, the natural environment, and living conditions

3.1 Analysis of environmental consequences in the epicenter of the explosion

An analysis of the respondents' answers to questions related to the assessment of the environmental condition in their area of residence reveals deep concern about the state of the environment. Among the respondents, 40% live in close proximity to the explosion site, including: 10% at a distance of 150 meters, 20% at 250 meters, 10% at 300 meters, and 40% at 500 meters. Another 20% reside approximately 2000 meters from the site (Fig. 3.1.1).

Considering that the locations of the respondents' private properties relative to the oil depot vary – with distances ranging from 150 meters to 2000 meters – the consequences also differ in terms of the intensity of soil, water, and air pollution, and destruction of crops (on some streets located within 150 – 300 meters, everything was destroyed: houses, gardens, vegetable plots, poultry, and livestock).

According to respondents living within 150 – 300 meters of the explosion, 40 – 60% to 100% of their household plot area was rendered unusable. For those living at distances of 500– 2000 meters, 10 – 15% of the land was affected. Prior to the explosion, household plots were actively used by respondents for gardening and fruit tree cultivation.

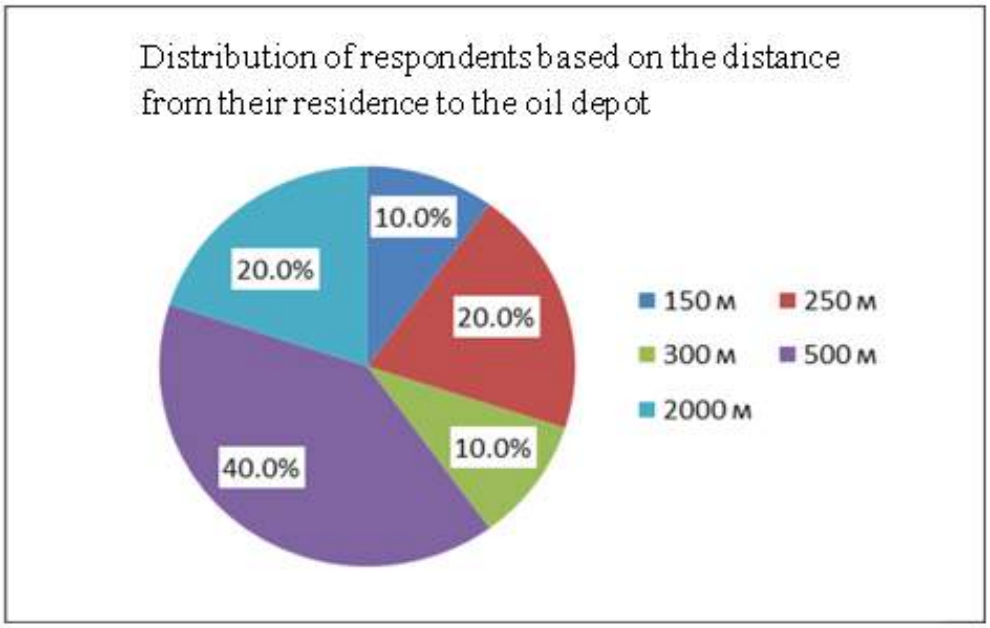


Figure 3.1.1. Distance of respondents' residences from the oil depot

The impact of the explosion and fire at the oil depot resulted in contamination of soils and water bodies with petroleum products and heavy metals, as well as destruction of the topsoil layer. Trees, including fruit-bearing species, were damaged. Conditions changed significantly, in some cases making household agricultural activities impossible.

Respondents perceive the broader environmental impact on the region as manifesting in the decline and destruction of trees, a decrease in bird populations and the destruction of nests during the fire, the die-off of meadow-steppe vegetation in the floodplain of the Nemyshlya River, and increased overgrowth of weeds on household plots abandoned by their owners.

The local population is widely experiencing the following consequences: the inability to use river water for irrigating vegetable gardens; the inability to mow grass in the river's floodplain; the loss of access to ponds on the Nemyshlya River as recreational areas; the inability for children to swim in the river during hot summer periods; and the inability to enjoy leisure fishing on weekends.

3.2 Generalized negative impacts of the oil depot explosion and fire, causing anxiety and hopelessness among residents

The explosion and fire at the oil depot, as well as Russia's missile strikes in general, have had a detrimental impact on the social conditions of life and the ability of the local population to meet their basic needs, including employment.

According to the respondents' perspectives, the following negative effects have already occurred:

- significant contamination of soils with liquid and dissolved petroleum products and toxic by-products of their combustion within the impact zone;
- exclusion of private land plots from agricultural use due to catastrophic soil contamination;
- alteration of the hydrological and hydrochemical regimes of surface water bodies, including the Nemyshlya River and recreational ponds along its course;
- changes in hydrogeological conditions – specifically, pollution of groundwater used for drinking and technical purposes via individual wells and dug wells, due to petroleum product infiltration;
- air pollution caused by combustion by-products from the oil depot fire;
- the emergence of health issues among both adults and children as a result of the above-mentioned environmental processes;
- death of animals and birds during the fire;
- the death of 7 people (including 3 children) and injury of 60 individuals.

To restore an ecologically viable environment in the region, to ensure livable conditions and protect children's health, to preserve the social, economic, and environmental quality of life for local residents, and to resume household-scale agricultural activity, 100% of respondents emphasized the urgent need for comprehensive *environmental assessments*. This includes monitoring the current condition of the most affected environmental components.

Analysis results. The implementation of certain mitigation measures during the peak of the ecological crisis – such as removal of contaminated soil layers and petroleum extraction from the Nemyshlya riverbed – has not fully resolved the problem.

Conclusion. The ecological situation requires the continuation of environmental monitoring to assess the current condition of soils, groundwater, and surface waters of the Nemyshlya River (including bottom sediments), and the implementation of additional remediation measures.

4 Analysis of the impact of the oil depot explosion, fire, and overall wartime actions on the physical and psychological health of children

4.1 Living conditions of children during the war and after the oil depot explosion

Following the explosion at the oil depot and the resulting large-scale fire, children have been living in conditions that pose a serious threat to their health.

In terms of both nature and intensity of impact on the environment – including the social environment – the explosion and fire at the oil depot are characterized by a high degree of ecological danger. As a result of the incident, there was extensive pollution of the environment by petroleum products and combustion by-products.

Petroleum products contain *heavy metals* in varying concentrations, depending on their origin and level of refinement. These may include *lead, cadmium, iron, nickel, vanadium, manganese, copper, and others.*

During the fire, hazardous substances were released into the atmosphere along with smoke and combustion gases, including: *benzo[a]pyrene, sulfur dioxide and sulfur trioxide, carbon dioxide (CO_2), nitrogen oxides, and various gaseous and particulate products of incomplete fuel combustion, along with vanadium compounds, sodium salts, and heavy metals*.

Benzo[a]pyrene, an aromatic hydrocarbon formed during the combustion of hydrocarbon fuels, is a highly potent carcinogen and mutagen. Therefore, the smoke from the fire at the oil depot was extremely toxic.

In this context, both gaseous and particulate substances emitted during the fire are considered dangerous to human health – especially for children as well as adults.

All of these compounds are by-products of *petroleum combustion*. At certain concentrations in air, soil, or water, they can significantly affect human health.

Specific Effects of Petroleum Products and Their Combustion By-Products on Children's Health

Specific effects of petroleum products and their combustion by-products on children's health

Contaminated soils are a direct source of contamination for vegetable crops grown on private household plots. Therefore, there is a potential risk to the health of both adults and children. Given the contamination of the soil cover, children's diseases may be associated with the consumption of low-quality vegetables and fruits grown on lands contaminated with petroleum products.

In addition, diseases may be the result of unregulated exposure to oil-contaminated surface waters of the Nemyshlya River, especially through swimming in the hot summer season.

The main types of diseases that can occur when the listed substances enter the body of a child (or adult) include: respiratory diseases; diseases associated with malignant neoplasms; cardiovascular diseases; disorders associated with *neurotoxicity; organ damage; carcinogenic risks; damage to genetic material*.

Heavy metals can negatively affect children's health due to their toxicity and ability to accumulate in body tissues.

In addition to somatic diseases caused by environmental pollution, children (and adults) can also suffer from mental and behavioral disorders due to prolonged stress from daily massive rocket attacks, the sounds of air raid sirens, explosions and fires at an oil depot, as well as emotional trauma from witnessing the irreversible loss of seven residents (including three children) and the injuries of sixty others on neighboring streets.

Research results. Undoubtedly, living in conditions of extreme environmental danger leaves lasting consequences for children's health.

4.2 Analysis of the conditions in which children live during the war

To clarify the circumstances in which children have been living during the war, the responses of survey participants were analyzed with regard to children's evacuation and intentions to leave Kharkiv. Among the respondents, in 60% of cases, children had been temporarily evacuated but later returned to their place of residence for various reasons (Fig. 4.2.1).

In 40% of cases, children have remained in Kharkiv the entire time and continue to live there under constant shelling and in a state of chronic stress. The adverse consequences of this are reflected in respondents' observations regarding children's health (Section 4.3 – Tables 4.3.1 – 4.3.3). Despite this, 20% of parents have no intention of leaving Kharkiv; 20% do have such intentions, and 60% said they would decide based on the intensity of hostilities in Kharkiv and the region (Fig. 4.2.2).

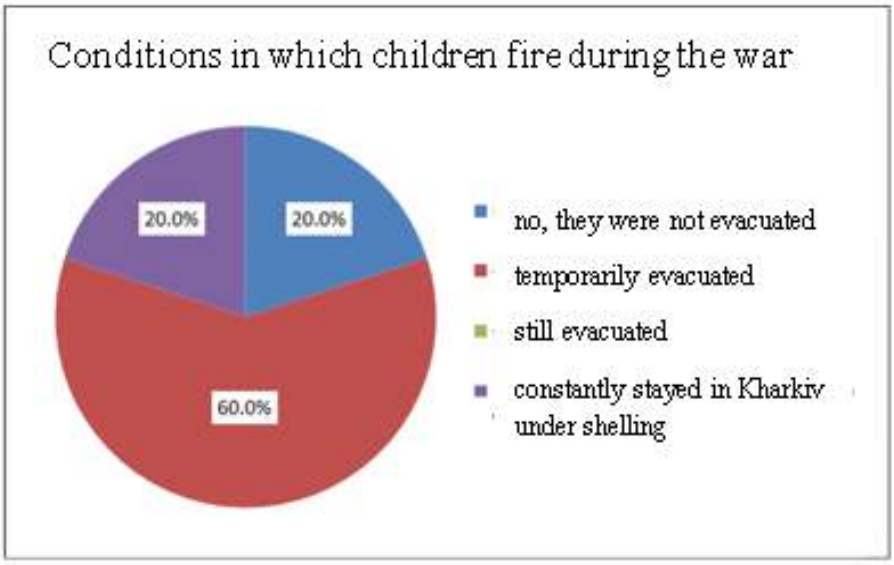


Figure 4.2.1. Conditions in which children stayed during the war

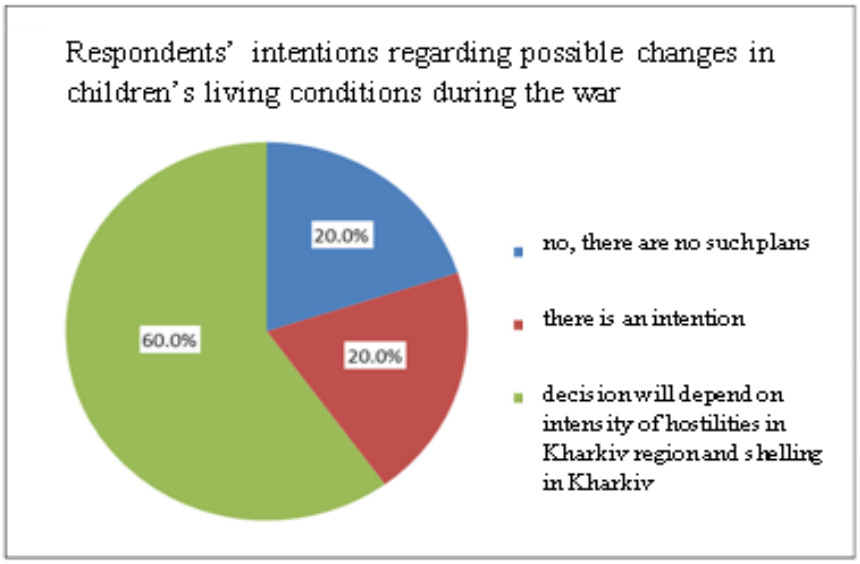


Figure 4.2.2. Respondents' intentions to change children's location during the war

4.3 Analysis of children's health before the war, during wartime, and after the oil depot explosion and environmental disaster (according to respondents)

Given the front-line wartime conditions in Kharkiv, obtaining objective medical information regarding children's health (such as hospital visit records or diagnoses) is extremely difficult. Therefore, children's health is assessed based on the respondents' personal observations and subjective perceptions.

Most respondents (60%) reported that children were healthy before the war, and in only one case (20%) did a child have a specific chronic condition (asthma) (Fig. 4.3.1).

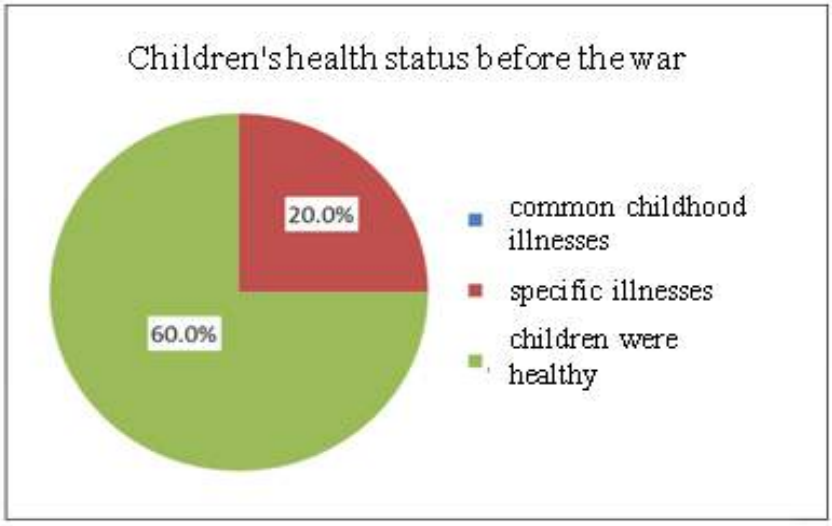


Figure 4.3.1. Children's health before the war

All respondents (100%) indicated that from the beginning of the war and throughout its three-year duration, there has been a noticeable change in children's psychological state, and 60% observed an increase in specific physical illnesses (Fig. 4.3.2).

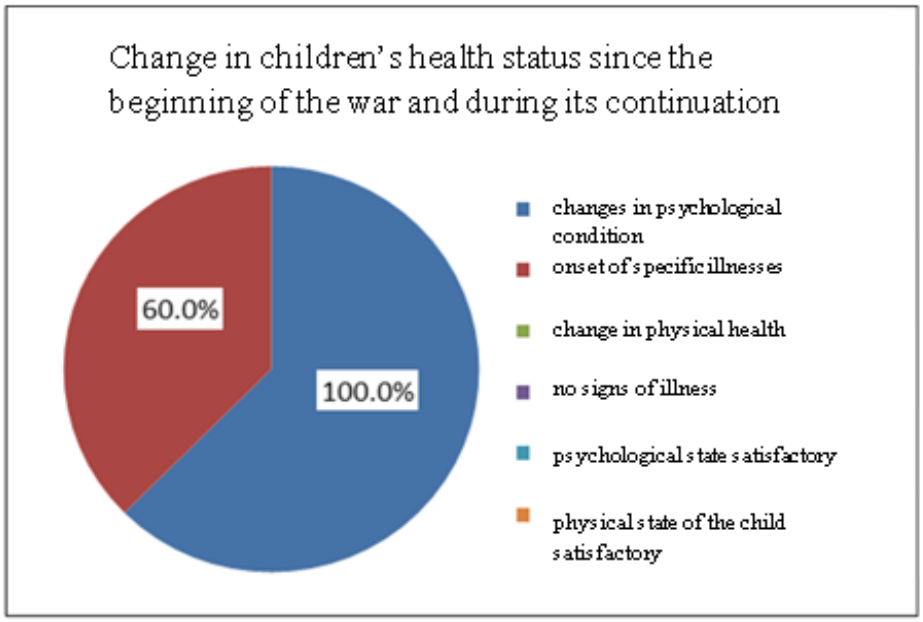


Figure 4.3.2. Changes in children's health since the beginning of the war

Following the explosion and fire at the oil depot, 60% of respondents observed children's emotional suppression caused by fear of explosions; 60% noted children's fear of daily and nightly shelling; 60% reported that the sound of air-raid sirens during alerts led to psychological distress (Fig. 4.3.3).

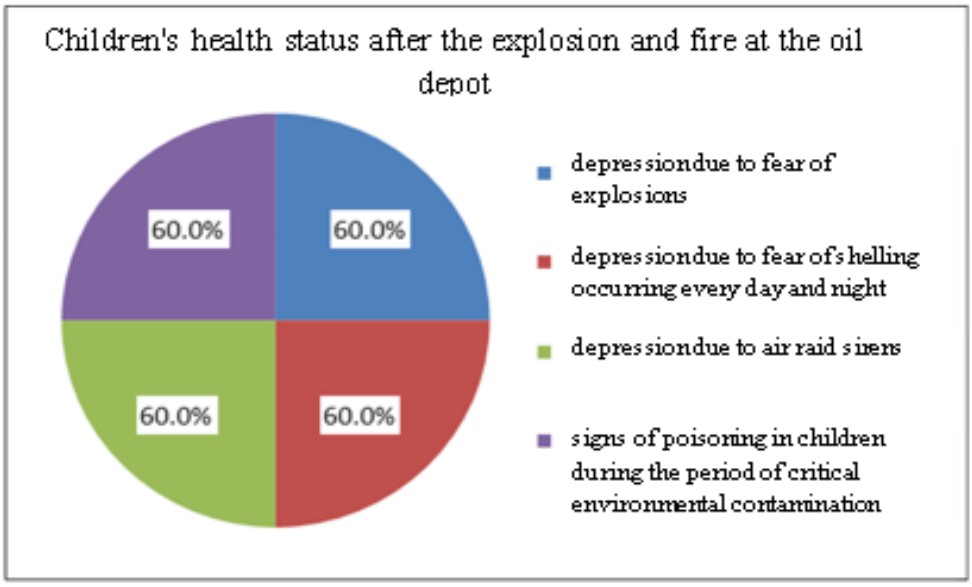


Figure 4.3.3. Children's health after the oil depot explosion

A majority (60%) of respondents observed signs of poisoning in children during the period of severe environmental contamination. Since respondents could select multiple answers, the cumulative percentage exceeds 100% (Fig. 4.3.3).

Result of the analysis. Under the conditions of ongoing missile strikes on Kharkiv and after the explosion at the oil depot and the resulting environmental disaster, children have been living in a state of chronic stress and somatic illnesses for the past three years.

Conclusion. It is necessary to ensure medical evaluation and psychological assessment of children and, where needed, provide access to psychological support services.

4.4 Analysis of respondents' attitudes toward environmental changes in the area

Given the significant contamination of soils and water bodies by petroleum products, all respondents (100%) expressed serious concern regarding the creation of acceptable living conditions for children and the preservation of their health (Fig. 4.4.1).

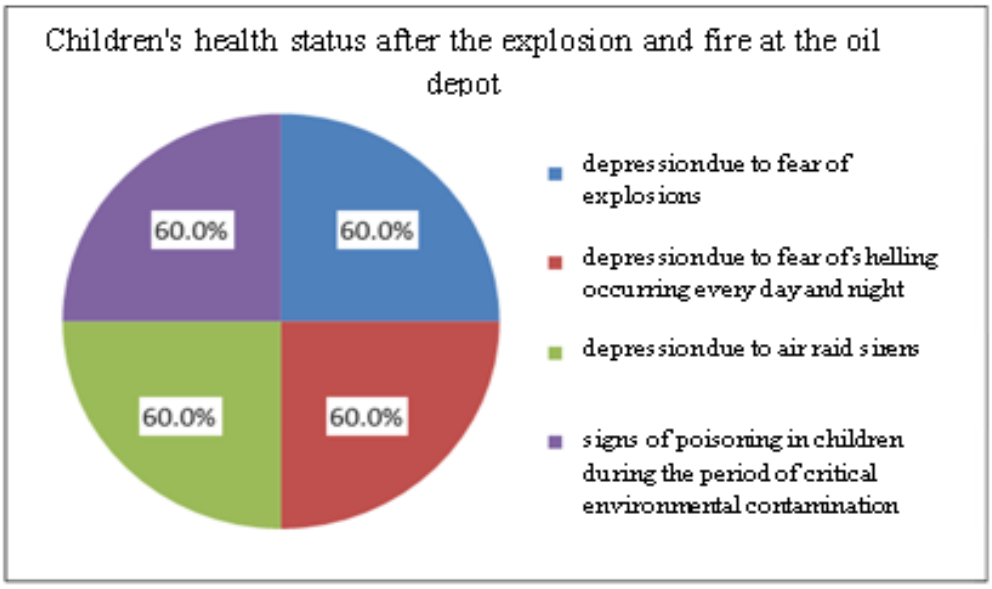


Figure 4.4.1. Environmental consequences of the oil depot explosion and fire that concern respondents regarding living conditions and children's health under significant environmental pollution

Since respondents were allowed to choose multiple answers, the cumulative percentage on the chart (Fig. 4.4.1) exceeds 100%.

Local residents are also concerned about the lack of awareness among children and adults regarding the dangers and behavioral precautions required in heavily polluted areas.

Only one respondent (12.5%) reported having observed any public announcements or official restrictions regarding the behavior of children and adults on the Nemyshlya River and within its floodplain (*including recreational fishing, children swimming, mowing grass in the floodplain, making campfires, etc.*), while 87.5% of respondents stated they had received no such information (Fig. 4.4.2).

Results of the analysis. Due to the high level of contamination of soils and aquatic environments with petroleum products, local residents are deeply concerned about ensuring safe living conditions for children and preserving their health. In this context, respondents consider it essential to continue environmental monitoring of the affected components.

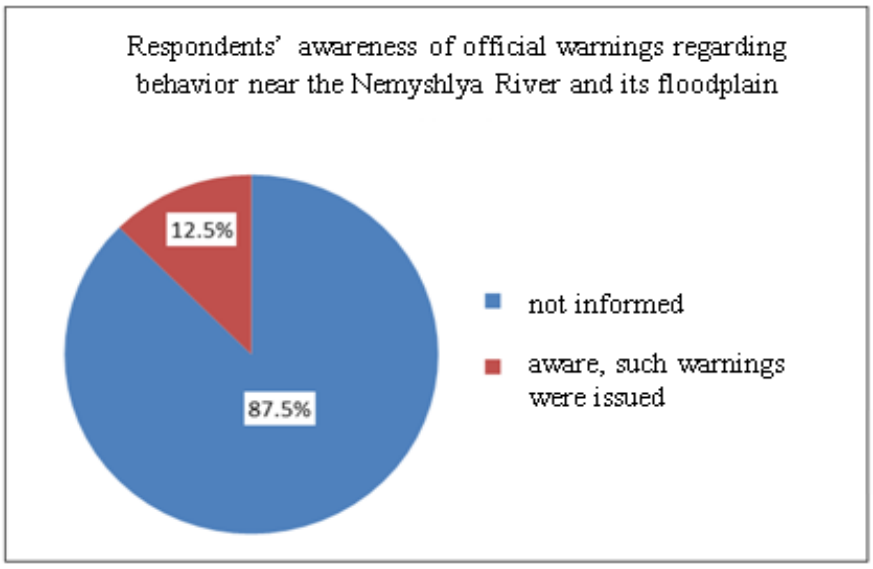


Figure 4.4.2. Respondents' awareness of official warnings on behavior near the Nemyshlya River and its floodplain

Conclusion. Local residents living in the contaminated area express a clear need for objective information regarding the level of soil contamination on their household plots, as well as for official conclusions on the feasibility of growing agricultural products on these plots, and on the quality of drinking water in wells and individual boreholes.

5. Analysis of local residents' attitudes toward the implementation of measures aimed at preventing further deterioration of socio-living conditions

The main components of the social environment affected by the oil depot explosion are private households located on the streets of Kotelna, Yaseneva, Nemyshlyanska, Tankova, Zapovidna, 1st Plidnyi Lane, and others situated in the epicenter of the explosion and fire.

A significant number of respondents (100%) expressed positive opinions regarding the activities of USRIEP in conducting studies on possible environmental changes over time and in developing scientifically grounded recommendations for the rehabilitation of the most polluted and vital components of the environment.

In terms of providing scientific support by USRIEP for assessing the current environmental condition in the area affected by the oil depot explosion, 100% of the surveyed residents positively evaluated the fact that research was conducted on the territory of their private property and throughout the neighborhood (Fig. 5.1.1). (Since respondents could select multiple answers, the cumulative percentage exceeds 100%.)

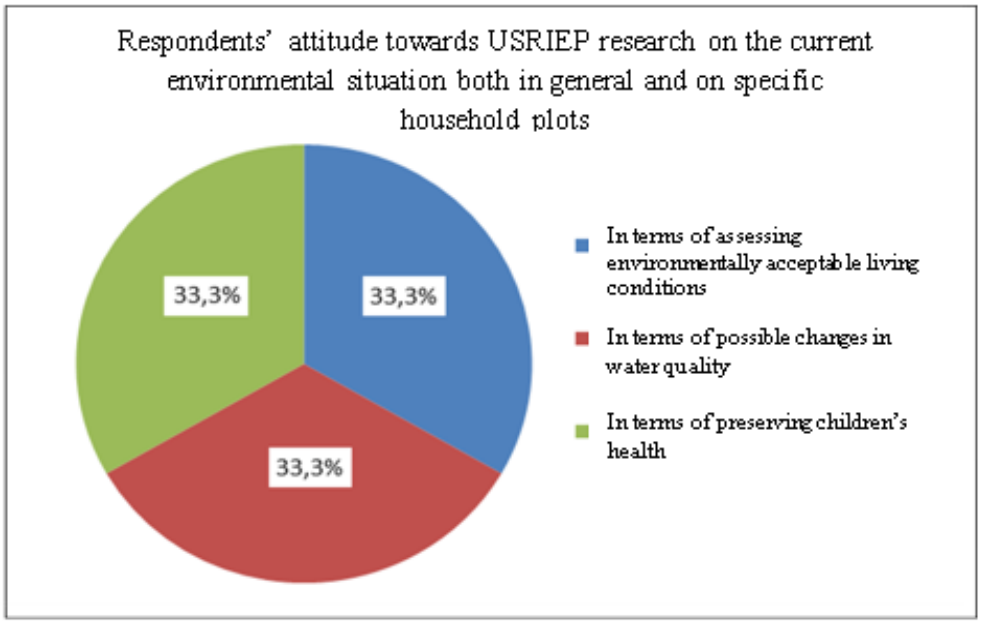


Figure 5.1.1. Respondents' attitude towards USRIEP research on the current environmental situation both in general and on specific household plots

Results of the analysis. From the perspective of scientific assistance provided by USRIEP in studying the current state of the environment in the area affected by the catastrophic explosion, residents of the impacted territory positively assess the

fact that environmental research was conducted both on their personal plots and across the entire neighborhood.

Conclusion. It is appropriate to ensure the continued implementation of monitoring studies regarding the contamination of soils and water bodies.

The processed responses of the surveyed residents serve as a foundation for identifying the most critical and hazardous aspects of the issue, specifically: the consequences of the oil depot explosion for children's health; the environmental conditions in which they live within the pollution hotspot; and the material well-being of the residents.

6 Analysis of the socio-economic conditions based on the survey results

An analysis of the gender and age structure of the permanent population revealed the following characteristics at the time of the study: among the respondents, 35.7% were women and 64.3% were men.

Among the adult population, the dominant age groups were between 40–60 years and over 60. Among children, 50% were aged 1–5 years; 25% were 5–10 years old; 12.5% were 10–15 years old; and 12.5% were aged 15–20 years. In total, 50% of the elderly population were over 60 years old; respondents aged 40–60 made up 37.5%, and 12.5% were under 20. Across the households of eight respondents, ten children aged 1–5 to 15–20 years were growing up.

According to the conducted analysis, the demographic indicators – despite certain nuances – remain relatively favorable. There is no clear trend toward population aging.

However, the demographic indicators suggest that, during wartime, ecological conditions have formed in the area affected by the oil depot explosion that make it extremely unsafe for habitation.

The demographic situation is also negatively impacted by the displacement of residents to other regions of Ukraine or abroad (in some cases, houses were destroyed by fire). According to the respondents, there has been a significant decrease in the number of residents in the area affected by the explosion and fire. *One reason* for this is the war and continued shelling; the *second* is the catastrophic contamination of the environment with petroleum products – both in general across the settlement and on individual homestead plots following the bombing and fire at the oil depot. The *third* is the issue of employment.

According to survey data, employment among the population is just 25%, with 75% unemployed. This distribution inevitably affects household income levels, which in the study area average between 1,000–5,000 UAH per household per month

and 250–1,250 UAH per family member monthly. Thus, many families in the area have become impoverished due to conditions caused by the Russian war.

Poor social and economic conditions are among the key factors negatively affecting public health. A sensitive indicator in this regard is the incidence of infectious diseases. However, given the constant bombardment of Kharkiv – and repeated missile, drone, and loitering munition strikes on the study area both day and night – psychological health has become the most pressing concern for both children and adults, due to prolonged stress and chronic sleep deprivation.

The health situation among children is also troubling. The trend over the past three years of war has been negative. Following the oil depot explosion and fire, 60% of respondents observed signs of emotional suppression in children due to fear of explosions; 60% due to fear of daily and nightly shelling; and 60% reported that the sound of air raid sirens during alerts caused additional distress.

Thus, against the backdrop of a relatively favorable demographic situation (despite certain aspects), the incidence of diseases among children—considered by respondents as indicators of social well-being during wartime—points to the existence of specific problems, even amid the broader context of a difficult socio-economic situation in the country (Ukraine) as a whole and in the frontline conditions of Kharkiv.

Conclusions To Part 2. Results of the study of the socio-economic situation of residents of the Nemyshlyanskyi district of Kharkiv living in the area adjacent to the oil depot of LLC "KhNB - Reserve", where an explosion occurred during a missile attack by the Russian Federation

1 Conclusions regarding the study of the general demographic structure

The main source of income for the surveyed respondents is pension benefits (50%). None of the respondents are employed by state enterprises. Only 25% of the respondents are employed in the commercial sector.

An analysis of the respondents' survey responses across a set of indicators, including their self-assessment of:

- *the level of material well-being and trends in its change during the war;*
- *the level of consumption of essential goods;*
- *the ability to pay utility bills;*
- *the main sources of income and the share of subsistence farming,*

reveals an objective level of material well-being, which is generally assessed as unsatisfactory at the time of the study.

2 Conclusions regarding living conditions and children's health

An analysis of the survey responses regarding:

- *the living conditions of children during the war;*
- *the health status of children before the war and changes in it after the war began and during its continuation;*
- *the health status of children after the oil depot explosion and fire, and under the conditions of catastrophic environmental degradation,*

demonstrates an objectively poor state of children's health, which has significantly deteriorated since the explosion and is assessed as extremely unsatisfactory during the study period. It also highlights the extremely dangerous ecological conditions in which children are living.

In the context of constant shelling of Kharkiv and repeated strikes on the study area by missiles, "Shaheds" and other UAVs (both at night and during the day), the psychological impact on children’s health comes to the forefront, with chronic stress and sleep deprivation being particularly critical factors.

3 Conclusions Regarding Respondents' Attitudes Towards the Need for Further Research on the Current Environmental Condition

The analysis of survey results based on a set of indicators, such as respondents’ personal assessment of:

- the hazardous environmental changes following the oil depot explosion;
- the necessity to ensure safe living conditions and protect children's health;
- the necessity to preserve the socio-economic and environmental living conditions of the local population;
- the necessity to restore household agricultural activities;

demonstrates the objective needs of residents for the restoration of an optimally required ecological state and well-being, which, overall, are evaluated as unsatisfactory during the period of the study.

From the Perspective of Providing Scientific Support by USRIEP in Studying the Current Environmental Condition in the Area Affected by the Catastrophic Impact of the Oil Depot Explosion

100% of respondents positively assess the continuation of research, including the development of scientifically grounded recommendations for the rehabilitation of the most polluted and vital components of the environment – both within their private households and throughout the affected area in general.

The analysis of socio-economic research results has made it possible to highlight the main material and demographic issues (including those related to children's health) that require urgent resolution. It also confirms the need to continue monitoring and researching the current environmental state in the affected territory.

References for Part 2

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PART 3 Highlighting socio-economic and environmental issues requiring timely resolution

1 Socio-economic issues and their resolution

The results of the socio-economic research have provided a basis for identifying the most critical aspects of the problem associated with the consequences of the oil depot explosion – specifically concerning children's health, the environmental conditions of their residence in the contaminated area, and the material well-being of residents. Hope for assistance in resolving this issue significantly affects the physical and psychological condition of both children and adults. These concerns provoke anxiety and psychological distress among the majority of respondents.

The analysis of socio-economic research results has made it possible to identify the main material and demographic issues (including those related to children's health) that require resolution, and confirms the necessity of continuing to study the current environmental conditions in the affected area.

The key issues requiring attention and resolution are as follows:

1. The analysis of the material conditions and needs of residents in the territory that suffered catastrophic environmental degradation due to the oil depot explosion indicates that many families are in a precarious financial situation.

Some families require financial assistance to support their children.

2. In the studied area, the standard of living during wartime is very low. Following the explosion and fire at the oil depot, significant soil contamination with petroleum products occurred, making it impossible to grow agricultural produce (particularly vegetables), which had previously provided supplementary income for households.

Under these circumstances, there is a need to implement additional measures to remediate the soil from petroleum contamination in order to restore household agricultural activity.

3. Since the implementation of measures to mitigate environmental impact during the period of critical ecological conditions – specifically, the removal of contaminated soil and petroleum extraction from the Nemyshlya River – did not fully resolve the problem, the environmental situation requires further remediation efforts.

4. Amid ongoing missile attacks on Kharkiv during wartime and the catastrophic environmental pollution following the oil depot explosion, children have experienced three consecutive years of chronic stress and somatic illnesses.

In this context, it is essential to provide conditions for the examination and assessment of children's physical and psychological health and, if necessary, to organize psychological assistance.

5. Given the substantial contamination of soils and water resources with petroleum products, local residents living in the pollution epicenter are deeply concerned about ensuring acceptable living conditions for children and preserving their health.

There is a need for objective information about the contamination levels in household garden plots, as well as official conclusions regarding the feasibility of growing agricultural products on these plots and the quality of drinking water in wells and private boreholes.

6. From the standpoint of scientific support for research on the current environmental state within the contamination zone, residents of the affected territory deem it necessary – and hope for – the continuation of monitoring studies of the current condition of underground and surface waters and soil contamination both within their private households and in the area as a whole.

It is necessary to continue monitoring the environmental condition of groundwater intended for drinking purposes and soils on land plots contaminated with petroleum products.

The listed issues requiring resolution reflect the objective needs of residents for the restoration of an optimally necessary ecological state and economic well-being, which, overall, are assessed as unsatisfactory at the time of the study.

2 Recommendations for the rehabilitation and remediation of soil on private household plots and for the purification of drinking water contaminated with petroleum products

The remediation of soil contaminated by petroleum products is a complex process that requires the use of modern technologies and methods. The main approaches include: mechanical cleaning, physicochemical treatment, and biological remediation of both soil and water.

An analysis of existing methods has identified the most suitable for use under martial law conditions – the biological remediation method (bioremediation technology). This method includes phytostimulation technology, which promotes the microbial biodegradation of hydrophobic substances (particularly petroleum products) in the rhizosphere.

2.1 Recommendations for soil remediation

Petroleum products cannot be absorbed by plants directly, but they can be degraded by microbes — a process known as phytodegradation. During phytodegradation, plant enzymes break down organic hydrophobic substances (petroleum products).

To clean contaminated soils on household plots where petroleum product concentrations in the upper soil layer exceed the maximum permissible levels, it is recommended to plant trees and grasses. Plants with extensive and dense root systems should be used. Grass roots typically penetrate to depths of up to 0.5 m, while tree roots can reach depths of up to 3.0 m. For decontamination of soils at depths between 0.15–0.50 m, the following grasses are recommended: ***fescue*** *(Festuca sp.),* ***ryegrass*** *(Lolium sp.)* For deeper soil layers (from 1.0 m and beyond), trees such as the ***mulberry tree*** *(Morus)* are recommended.

This phytoremediation method is highly effective, inexpensive, and feasible under current conditions. However, its primary drawback is that it requires a long-term timeframe to achieve full decontamination.

2.2 Recommendations for Drinking Water Purification

To remove petroleum products from drinking water sourced from public standpipes, wells, and boreholes, the water should be passed through activated carbon filters prior to use.

The activated carbon filtration method is characterized by high efficiency, strong filtering capacity, and cost-effectiveness in implementation.

3 Recommendations for Ongoing Monitoring of Drinking Groundwater and Soil

The frequency of repeated sampling of water and soil after the accident and following the annual monitoring is as follows.

Water monitoring frequency:

For **groundwater** (especially if there are risks of further contamination):

To monitor the temporal dynamics of established contamination of drinking water in a number of public standpipes, wells, and boreholes, and to detect the emergence of petroleum products in other water sources, it is recommended to:

- Continue monitoring once every 6 months if water quality remains stable and improves;
- In case of observed deviations, increase the frequency to once every 3 months.

Standards: DSanPiN 2.2.4-171-10 (Hygienic requirements for drinking water), DSTU ISO 5667-6:2001 (Water quality — Sampling — Part 6: Guidance on sampling of rivers and streams), Ministry of Health recommendations regarding drinking water.

For surface waters:

For the surface waters of the Nemyshlya River, it is recommended to collect samples quarterly (four times a year) in the event of increased contamination of the river water with petroleum products.

Standards: Sanitary Rules 4630-88, Orders of the Ministry of Environmental Protection and Natural Resources of Ukraine.

Soil monitoring frequency:

In areas with residential buildings, children's playgrounds, and recreational zones, soil should be monitored every 6 months.

It is specifically authors recommended to collect samples: after the autumn low-water period, after the spring flood period.

Standards: DSTU 4287:2004 (Soil quality – Sampling), Sanitary construction regulations, Law of Ukraine "On Land Protection".

Link to the regulatory framework

State Standard of Ukraine. (2001). DSTU ISO 5667-6:2001. Water quality. Sampling. Part 6: Guidance on sampling rivers and streams. Kyiv: State Committee for Technical Regulation and Consumer Policy of Ukraine.

State Standard of Ukraine. (2004). DSTU 4287:2004. Soil quality. Sampling. Kyiv: State Committee for Technical Regulation and Consumer Policy of Ukraine.

Ministry of Health of the Ukrainian SSR. (1988). Sanitary rules for planning and development of settlements (Sanitary Rules 4630-88). Kyiv: Ministry of Health of the USSR.

Ministry of Health of Ukraine. (2010). DSanPiN 2.2.4-171-10: Hygienic requirements for drinking water intended for human consumption. Kyiv: Ministry of Health of Ukraine.

Orders of the Ministry of Ecology Protection and Natural Resources of Ukraine;

Regulations on emergency response procedures. (SES of Ukraine, Ministry of Environmental Protection and Natural Resources of Ukraine)

Recommendations of the Ministry of Health of Ukraine regarding drinking water.