Summary of the report of the

GREAT NORILSK EXPEDITION

CONTENTS

CHARACTERISTICS OF THE RESEARCH OBJECT

The Norilsk industrial region is located north of the Arctic Circle, in the southern part of the Taimyr Peninsula.

The climate is subarctic, sharply continental, 2/3 of the year the average monthly air temperatures are negative, frost-free only in June, July and August.

The period of persistent frost lasts around 280 days a year, with more than 130 days with blizzards. A peculiarity of winter is a combination of low temperatures and strong squall wind (frost down to -53 °C and wind up to 24 m/s). Norilsk is one of the five windiest settlements on the planet.

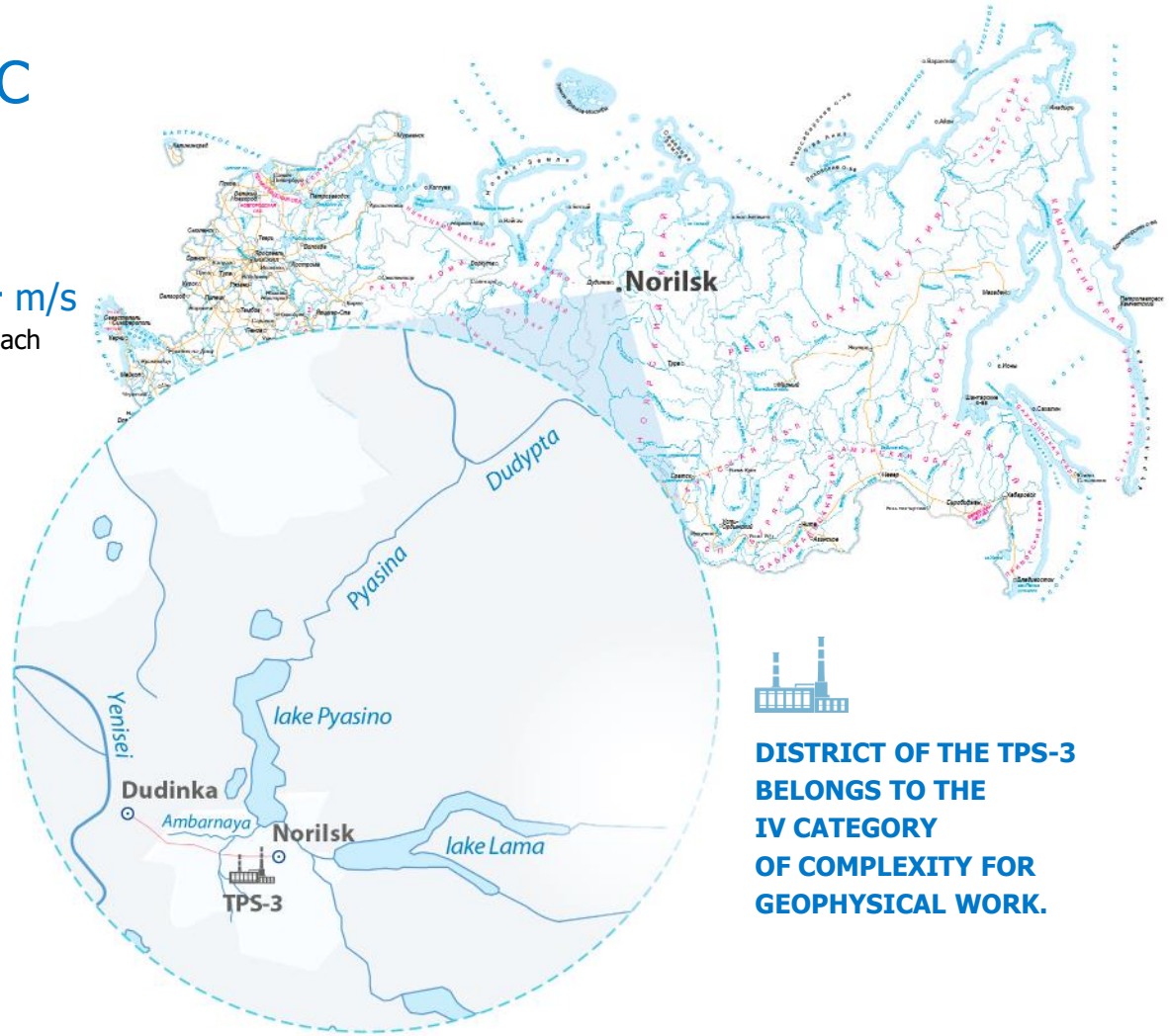
The annual cycle of absolute temperatures is 97 °C. The average annual air temperature is minus 9.6 °C. The absolute minimum air temperature is minus 53 ° C. The absolute maximum is 32 °C.

The polar day lasts from May 20 to July 24, and the polar night – from November 30 to January 13.

-53 °C
minimal temperature

+32 °C
maximal temperature

up to 24 m/s
wind gusts reach



DISTRICT OF THE TPS-3 BELONGS TO THE IV CATEGORY OF COMPLEXITY FOR GEOPHYSICAL WORK.

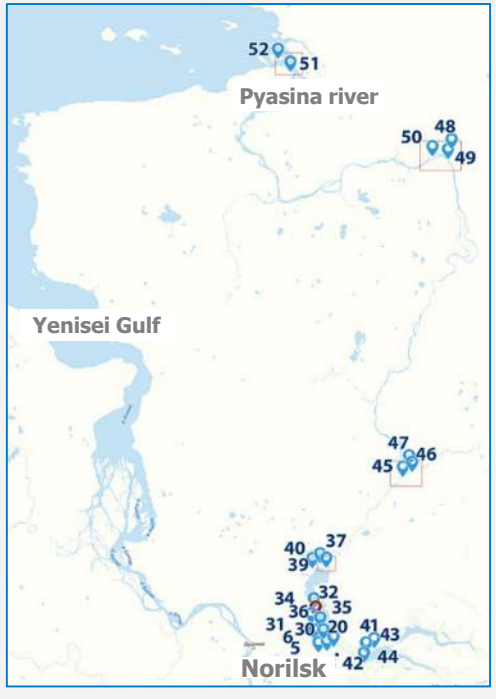
PARTICIPANTS OF THE EXPEDITION

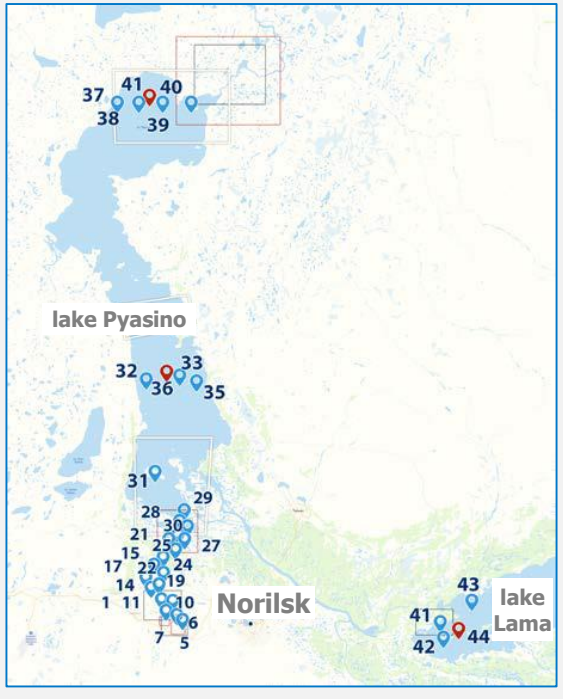
The development of the Arctic zone of the Russian Federation is one of the priority directions of the country's development, and in the context of global climatic changes and man-made impacts on all components of the environment, the issues of ecological safety of the region are most acute. In the summer of 2020, the Siberian Branch of the Russian Academy of Sciences conducted an expedition to comprehensively study the state of the environment of the Norilsk industrial region, as well as the impact on it of the oil spill at TPP-3 (Norilsk city), which took place in May 2020.

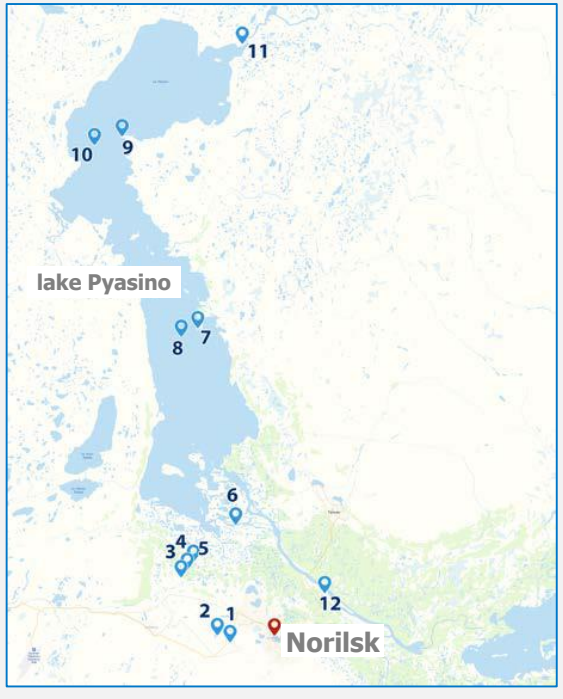
LIST OF INSTITUTIONS AND ORGANIZATIONS OF THE SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES (SB RAS), PARTICIPANTS OF THE GREAT NORILSK EXPEDITION:

- IBP – Institute of Biophysics SB RAS (Krasnoyarsk)
- ICM&MG – Institute of Computational Mathematics and Mathematical Geophysics SB RAS (Novosibirsk)
- IWEP – Institute for Water and Environmental Problems SB RAS (Barnaul)
- IGM – Sobolev Institute of Geology and Mineralogy SB RAS (Novosibirsk)
- IF – Sukachev Institute of Forest SB RAS (Krasnoyarsk)
- MPI – Melnikov Permafrost Institute SB RAS (Yakutsk)
- IPGG – Trofimuk of Petroleum Geology and Geophysics SB RAS (Novosibirsk)
- ISSA – Institute of Soil Science and Agrochemistry SB RAS (Novosibirsk)
- IPGP – Institute of Oil and Gas Problems SB RAS (Yakutsk)
- ICCT – Institute of Chemistry and Chemical Technology SB RAS (Krasnoyarsk)
- IPCh – Institute Petroleum Chemistry SB RAS (Tomsk)
- IEIE – Institute of Economics and Industrial Engineering SB RAS (Novosibirsk)
- SRI AEA – Scientific-Research Institute of Agriculture and Ecology of the Arctic (Norilsk)
- CSBG – Central Siberian Botanical Garden SB RAS (Novosibirsk)

SAMPLING MAP







General sampling map

Sampling map

A. hydrochemical and microbiological studies (yellow labels 1-54 in Figures 1-3 – IPGG, IPGP)

B. hydrobiological studies – (white rectangular areas in Figure 1 - IBP)

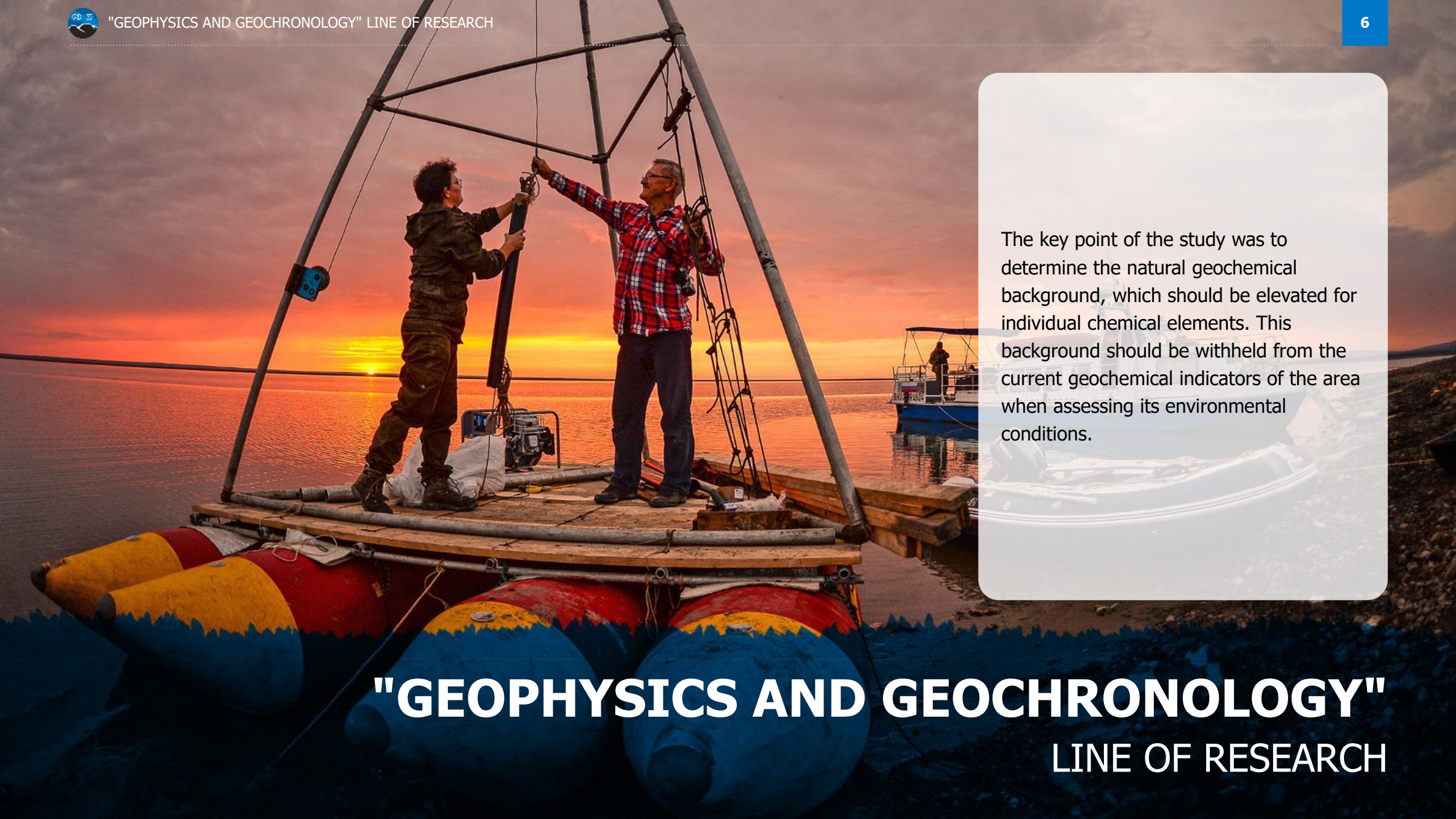
C. geochemical and geochronological studies of bottom sediments and soils – (yellow marks 31-44 and red marks in Figures 1-3. - IGM, IPGP (microbiology))

D. exploration of soils, vegetation cover and biological diversity – (red rectangular zones in Figures 1-3 – SRI AEA, CSBG, IF, IPGP (microbiology))

E. geophysical and geocryological investigations – (blue rectangular zones in Figures 1-3 - IPGG and MPI).

Sampling stations layout:

1 – Bezymyanny brook (Nadezhdinsky) in the area of TPP-3, **2** – Daldykan river (above the mouth of the Bezymyanny brook, background), **3** – Daldykan river (near the mouth), **4** – Ambarnaya river (above the mouth of the Daldykan river, background), **5** – Ambarnaya river (below the mouth of the Daldykan river), **6** – Ambarnaya river (near the mouth), **7** – lake Pyasino (in the area of Cape Tonky, near the coast), **8** – lake Pyasino (in the area of Cape Tonky, in the center), **9** – lake Pyasino (near Cape Goliy, near the coast), **10** – lake Pyasino (near Cape Goliy, in the center), **11** – Pyasina river (near the riverhead), **12** – Norilskaya river (background)



The key point of the study was to determine the natural geochemical background, which should be elevated for individual chemical elements. This background should be withheld from the current geochemical indicators of the area when assessing its environmental conditions.

"GEOPHYSICS AND GEOCHRONOLOGY"

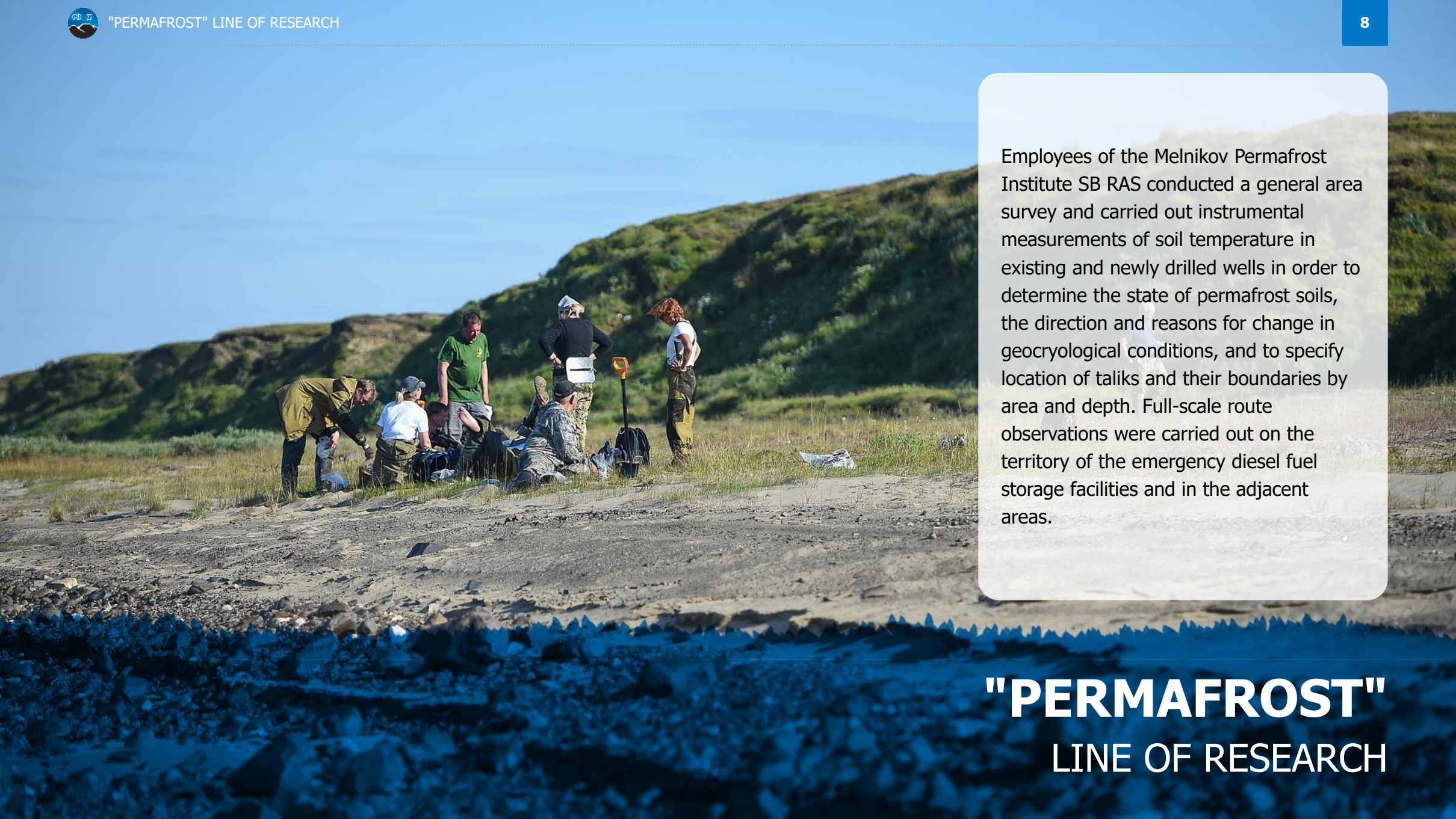
LINE OF RESEARCH

- **The Norilsk industrial region is a major geochemical anomaly.** Its ecosystems accumulate large amounts of chemicals and elements associated with ore occurrence and ore processing. The natural geochemical background is characteristic of all deposits that accumulated before the start of the economic development of the region. It is represented by the geochemical characteristics of bottom sediments of lakes Melkoye and Pyasino and is well recorded in the lower parts of the columns with data on terrestrial sediments. It is anomalous everywhere for nickel and copper.

- The content of potentially toxic elements in soils formed on natural geochemical anomalies of ore fields exceeds the average content in the earth's crust and maximum permissible concentrations. From the soils, these elements enter the vegetation and continue their path along the trophic chains.

- Comparing the natural geochemical background for the sediments of the Melkoye and Pyasino lakes, the natural uneven distribution of chemical elements was established. In the sediments of Lake Melkoye, the average content of Ni (90 ppm) is more than 4 times higher than the average content in the earth's crust (20 ppm), Cu (67 ppm) – more than 2 times higher (25 ppm). The lower part of the deposits of the Lake Pyasino is even more enriched with these elements, with average levels at 108 and 135 ppm, which is 6 and 10 times higher, respectively.

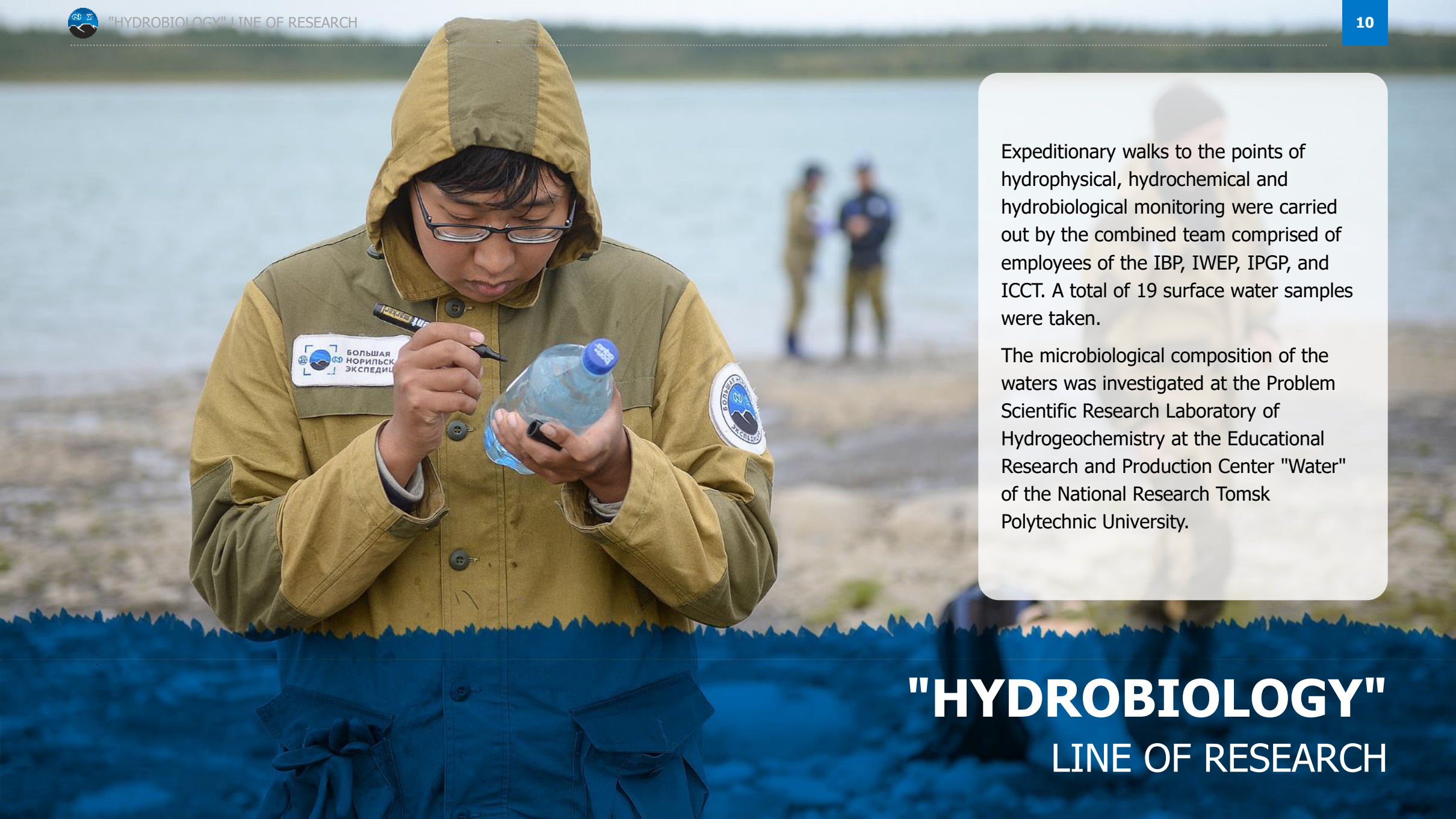
- According to the analysis of the results of remote sensing and GIS modeling, surface leak of a significant amount of oil products as a result of the accident into the Arctic Ocean, and even in the central and northern parts of the lake Pyasino, is practically impossible. In the first days after the accident, it was physically impossible due to the 'plug' made by residual ice cover in the northern basin of the lake Pyasino. Over the following days it was impossible due to the specifics of the mechanisms of surface distribution, including the effects of the wind load.



Employees of the Melnikov Permafrost Institute SB RAS conducted a general area survey and carried out instrumental measurements of soil temperature in existing and newly drilled wells in order to determine the state of permafrost soils, the direction and reasons for change in geocryological conditions, and to specify location of taliks and their boundaries by area and depth. Full-scale route observations were carried out on the territory of the emergency diesel fuel storage facilities and in the adjacent areas.

"PERMAFROST"
LINE OF RESEARCH

- Geophysical work was carried out at the site of the emergency diesel fuel storage facility of TPP-3 in the area of reservoirs No. 2-5 and outside the territory of the storage facility to the west in the area of a temporary seasonal watercourse before it flows into the Daldykan river, located at a distance of about 600 meters from the storage facility.
- Within the research area, a complex of geophysical methods was performed to determine the position of the boundaries of frozen and non-frozen terrain in plan and sectional views: electrical resistivity prospecting in electrical tomography modification and georadiolocation.
- The total volume of electrical tomography measurements amounts to 4885 linear meters. As a result, two-dimensional geoelectric models and a volumetric geoelectric model of a half-space were obtained, reflecting the distribution of the electrical resistivity of the terrain.
- Georadiolocation probing was carried out to study the upper part of the section, establish the thickness of the seasonal thawing layer, and identify channels for groundwater filtration. The volume of the georadiolocation probing amounts to 4346 linear meters.
- When identifying channels for groundwater filtration, a linear anomaly was identified. It is assumed that the groundwater source is a lake located 200 meters to the north of tank No. 5. It is likely that underground drainage caused the permafrost at the base of tank no. 5 to thaw, which led to subsidence of the pile foundation.
- Geothermal observations in wells were carried out in accordance with traditional methods used in geocryology. In each well, the temperature of the rocks was measured by a string of temperature sensors.
- The storage site, despite its small size, approximately 500 by 160 meters, is characterized by very diverse soil temperatures in the layer of annual heat turnover. The lowest temperatures (minus 4.2 °C) were recorded near reservoir No. 2 in well No. 18 drilled on July 3, 2020, to a depth of 9.0 meters. The area with low temperatures covers the base of reservoirs No. 2 and 3.
- In wells located near reservoir No. 4, higher temperatures are observed. The highest are in the suprapermafrost talik located in the western corner of the site near reservoir No. 5.



Expeditionary walks to the points of hydrophysical, hydrochemical and hydrobiological monitoring were carried out by the combined team comprised of employees of the IBP, IWEP, IPGP, and ICCT. A total of 19 surface water samples were taken.

The microbiological composition of the waters was investigated at the Problem Scientific Research Laboratory of Hydrogeochemistry at the Educational Research and Production Center "Water" of the National Research Tomsk Polytechnic University.

"HYDROBIOLOGY"
LINE OF RESEARCH

The high ability of the microbiological system for water self-purification from organic pollution was observed. It was determined that the microflora of the tested waters is adapted to oil products and is able to participate in their breakdown. However, in the waters of Ambarnaya river, due to the high content of oil products, there is a decrease not only in the number of oil-oxidizing bacteria, but also in their ability to oxidize volatile compounds of oil, benzene, toluene and naphthalene.

- The consistency of water quality assessments in terms of hydrophysical and biological indicators was observed between temperature, electrical conductivity and ORP data, on the one hand, and the number of bacterioplankton and the zooplankton saprobity index, on the other hand. According to these indicators, the water quality was low in the Bezymyanny brook, Daldykan river (below the inflow of the Bezymyanny brook) and Ambarnaya river (below the inflow of the Daldykan river), i.e. in watercourses close to the site of the accident. In the northern part of Lake Pyasino and in the Pyasina river, the waters were clear.
- The value of the saprobity index of Lake Pyasino, calculated by phytoplankton, ranged from 1.7 to 2.1 points, and by periphyton it was 2.3 points, which corresponds to the 2nd class of water quality 'Slightly polluted'. Nevertheless, it should be noted that the index value decreases in the lower part of the lake (stations 9, 10), which may indicate a decrease in organic pollution.

Thus, directly in areas below the emergency spill of oil products, in the Daldykan river and Ambarnaya river, classic signs of the effects of oil pollution on phytoplankton and phytoperiphyton were observed, namely, the dominance of flagellar algae, the death of phytoperiphyton in areas of heavy oil pollution and the massive development of green filamentous algae below the pollution zone. On the contrary, waters of the Norilsk river, Lake Pyasino and Pyasina river were dominated by diatoms, just like many years before the accidental spill, which indicates the absence of a negative impact of the accidental oil spill on the ecosystem of Lake Pyasino and Pyasina river.

- Evaluation of water quality by the concentration of chlorophyll a, as one of the environmental and sanitary indicators, showed that the waters at most of the examined stations correspond to class 1 ("extremely clean"). Only water from the Bezymyanny brook and Daldykan river, below its influx, was characterized by class 2 ("pure").
- Analysis of the pigment parameters of the examined water bodies showed significant deviations from the normal pigment composition of freshwater phytoplankton in the Bezymyanny brook and Daldykan river, below the brook's influx. Carotenoids predominate in the pigment pool, and additional chlorophylls b and c predominate among chlorophylls. The pigment composition of the phytoplankton of the Ambarnaya river is generally close to normal, with minor deviations. The amount and ratio of phytoplankton pigments in Lake Pyasino and the Pyasina river were characteristic of normally functioning freshwater plankton of oligotrophic waters. The same level and composition of pigments was noted in the background Norilskaya river.
- The average index weighted by the number of indicator species of zooplankton assigns the two lower stations (the outflow from the lake), to class 1 of water quality 'Conditionally clean'; all other stations of the lake and surveyed rivers – to class 2 'Slightly polluted'. However, within this class, the value of the index decreased (i.e. the water quality improved) from the sections of rivers exposed to fuel spills to lakes, namely, the ranked number of stations in decreasing order of the index in accordance with Table 10 is as follows: station 1 (Bezymyanny brook, subjected to the fuel spill), stations 5, 3, 6 (subjected to the fuel spill), station 4 (background Ambarnaya river), station 2 (background Daldykan river), stations 13 and 7 (the mouth of the Ambarnaya river below defense booms, and the southern part of Lake Pyasino), station 12 (Norilskaya river), stations 8 and 9 (Lake Pyasino, central and northern areas). A decrease in this index reflects a decrease in the organic load on water from the areas of fuel intake to the source of the Pyasina river as a result of physical, chemical and biological self-purification processes.

Within the examined water bodies on 4-11 August 2020, the Institute for Water and Environmental Problems SB RAS surveyed 12 areas.

The total content of petroleum products in the studied water bodies is **extremely heterogeneous**.

"SURFACE WATER"
LINE OF RESEARCH

- The content of oil products in the water of the most polluted parts of watercourses (Bezymyanny brook, Daldykan river, Ambarnaya river) is significantly higher than background levels (up to 0.41 mg/dm3).
- In Lake Pyasino, the concentrations of oil products are within the background levels (below the detection limits of the chemical analysis methods used) and below the maximum permissible concentration levels, which may indicate the effectiveness of the defense booms used to protect against the spread of oil products.
- Alkanes characteristic of petroleum products were observed only in the area of the inflow of the Daldykan river into the Ambarnaya river and in the floodplain of the Ambarnaya river. The level of C15-C20 alkanes in the Ambarnaya river is very insignificant, with the major ones being C27-C29, while composition of alkanes in the floodplain of the Ambarnaya river lacks homologues with the number of carbon atoms less than C21. This indicates a rapid evaporation of relatively light fractions of hydrocarbons (up to C15-C21) in the aquatic environment as they move away from the source of their entry.
- In the waters of the Lake Pyasino n-alkanes, identified in an amount of 131.4 μg/dm3, are represented by a set of C19-C34, and the bulk (C22-C34) is characterized by a predominance of "odd" homologues. This, as well as the presence of unsaturated structures of hopenes and oleanenes among hydrocarbons, indicates the predominant contribution of compounds produced by flowering aquatic plants or terrestrial plants to the composition of aqueous organic matter.
- To the north, in the area of the left bank of Lake Pyasino, there is a small amount of hydrocarbons in the water, represented by n-alkanes C15-C32 (1.8 μg / dm3) with a slight predominance of "odd" ones in the area of C22-C32. In the north of the lake near the source of the Pyasina river content of n-alkanes in water is even lower (0.5 μg / dm3). The characteristic compounds, on the basis of which conclusions could be drawn about the source of the oil (C15-C20) components, were not found, possibly due to the very low content of hydrocarbons in it.
- In Lake Pyasino, phenol concentrations are within the background levels (below the detection limits of the chemical analysis methods used), i.e. below maximum permissible concentration levels.

During the Great Norilsk Expedition from July 27 to August 21, 2020, employees of the Institute of Soil Science and Agrochemistry SB RAS (Novosibirsk) examined terrestrial floodplain ecosystems, studied and assessed changes in biodiversity and the state of the soil cover of the floodplains of Bezymyanny brook, Daldykan, Ambarnaya, Pyasina, Dudypta, and Tareya rivers, as well as the southern and northern shores of Lake Pyasino.

Specialists of the ISSA SB RAS analyzed soil and plant samples within area from the accident site to the Kara Sea.

"SOIL AND VEGETATIONAL COVER"
LINE OF RESEARCH

In the course of field research in technogenically contaminated and conditionally background areas, more than 60 key sites were selected with points for laying soil sections and by-pits, and for taking soil and plant samples. In total, 26 soil sections and 58 by-pits were made and described, 66 plant and 62 soil samples were taken for laboratory studies.

- Evaluation and assessment of the total content of oil products in the studied floodplain soils did not reveal ecologically dangerous high content even near the accident site.
- At the same time, the maximum concentrations of oil products were often found not in the surface, but in the underlying soil layer. The pollution of soil layers deeper than 30-40 cm was not recorded anywhere.
- The shallow depth of penetration of oil products into soils might be due to their frozen state, which prevented oil products from accumulating in soils and deeply penetrating into their depth.

According to the level of pollution and transformation of terrestrial ecosystems, preliminary zoning can be carried out and the surveyed territory can be divided into 4 zones:

1. Areas in the vicinity of Norilsk up to the Ambarnaya river delta (the most transformed territory), with unsatisfactory condition;
2. The area from the delta of Ambarnaya river to the source of Pyasina river (relatively average level of pollution), with satisfactory condition;
3. Mildly transformed area from the middle course of Pyasina (Kresty) river to the Tareya point, with good condition;
4. Areas not subjected to the technogenic impact of the Norilsk industrial region from Tareya to the Kara Sea, with excellent soil and ecological condition.

To determine the species composition of benthic bacteria by molecular genetic methods, bottom sediments were taken with a sterile plastic syringe at three different points of each predetermined site and combined into one sample. The soil was placed in plastic bags and stored in a freezer at -18 °C. Samples of zoobenthos in rivers and coastal areas of the lake were taken from a depth of 0.5–1.5 meters, and in the deep-water part of the lake – from a depth of 3–6 meters. The sampled soil was washed. In stationary conditions, invertebrates were taken from the sample and fixed in 80% ethanol.

"BOTTOM SEDIMENTS"
LINE OF RESEARCH

- In the studied water bodies, 36 species and taxa of a higher rank were found, widespread in the Palaearctic and Holarctic.
- Bell mosquitoes (chironomids) were found in all examined areas, but they reached mass development in the background area of the Daldykan river (station 2), and in the Pyasina river (station 11). Chironomid larvae are indicators of slightly polluted water. In Lake Pyasino, in silt sediments in the area of Cape Tonky, chironomids are represented singly. In the area of Cape Goliy, the species of chironomids recorded in the lake are indicators of mildly polluted water. In other water bodies, these insects are significantly scarcer both qualitatively and quantitatively.
- In the Ambarnaya river in the background area (station 4) and in the area below the mouth of the Daldykan river (station 5), pelophiles p. Chironomus (organisms living in the muddy substrate of the reservoir) were registered (indicator of polluted water), in the area above the booms (station 6) – pelophiles Cryptochironomus defectus (indicator of mildly polluted water), in the area below the booms (station 13) – pelophiles p. Procladius and psammo-pelophiles Psectrocladius delatoris (indicators of slightly polluted water).
- Gastropods Anisus acronicus, Valvata depressa were recorded singly and only in the area of Cape Tonky at Lake Pyasino. All these invertebrates are indicators of "slightly polluted" water. In earlier studies, molluscs were also noted as the dominant taxon of zoobenthos in the eastern part of the lake (Cape Elovy).
- Representatives of three types of aquatic invertebrates: Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddis flies) are widespread in shallow, fast-flowing watercourses with low water temperatures. These animals are highly sensitive to various kinds of pollution and anthropogenic pressure, which makes them satisfactory indicators in monitoring flowing water systems. Larvae of caddis flies and stoneflies were recorded singly in the Pyasina river (station 11), in the background area of Daldykan river (station 2), which indicates favorable conditions for the habitation of these rheophiles in these river areas. Their presence in Pyasina river indicates the absence of significant oil pollution in this river.

Field studies were carried out in the areas of the spill as a result of the accident at the TPP-3 in Norilsk. A total of 114 complete geobotanical descriptions were made both in areas polluted with oil products (55 descriptions) and areas not polluted (similar in the composition of the vegetation cover to polluted areas) – 59 descriptions.

"BIOLOGICAL AND ZOOLOGICAL DIVERSITY"
LINE OF RESEARCH

To clarify the species composition of plant communities, a herbarium of vascular plants was collected cosnsisting of 201 herbarium leaves, mosses and lichens, all in the amount of 65 herbarium packages (55 packages of mosses and 10 of lichens). The research was carried out in the following areas: the Bezymyanny and Daldykan brooks, the Ambarnaya river, the sources of the Pyasina river, the confluence of the Pyasina and Dudypta rivers (Kresty village), the Pyasina and Tareya rivers (Tareya village), the mouth of the Pyasina river (Kara Sea).

- The stages of disturbance are not long-term (formed as a result of the long-term effect of hydrocarbons). They arose simultaneously due to the impact of the spill and differ from natural communities in that some of the species in them died due to chemical burns caused by oil products. It is not yet clear how much the root systems of the burned plants suffered. Judging by the chemical burns left by diesel fuel on plants in the area of the lower Ambarnaya river the greatest impact of petroleum products was on plants and vegetation partially flooded with river waters. Aquatic plants and communities that were under water were not affected, or were affected to a lesser extent. A strong impact was exerted on floodplain communities – sparse willow stands, sedge-grass and sedge bogs.
- The number of disturbance stages is noticeably higher along the Ambarnaya river, which is associated with a much larger area of its flood plain and a wide variety of plant communities, which, to one degree or another, were affected by oil products.
- Only one stage of disturbance was noted on the Daldykan river, which may be due to the fact that at the time of the fuel spill the river was already full-flowing (due to the spring flood) and most of the plant communities were flooded. In the zone of contact with oil products, there were small and few areas of shallow waters and streams with sparse vegetation, which were poorly flooded by the spring waters of the brook.
- In the floodplain of the Bezymyanny brook, 3 stages of disturbance by oil products were observed. The Bezymyanny brook is shallower in comparison with the Daldykan river and, moreover, is located near the fuel tank of TPP-3. All this contributed to the larger number of plant communities getting into the zone of contact with diesel fuel.

PHYTO-DIVERSITY OF DISTURBED VEGETATION

In the direction from the Bezymyanny brook to the mouth of the Ambarnaya river a decrease in the phyto-diversity of disturbed vegetation is observed. The minimum decrease in diversity is in the areas of the source (1.0 times) and the middle reaches of the Pyasina river (Tareya – 1.1 times). We do not associate a slight decrease in diversity with the effect of oil products, since the latter were not visually detected in these regions. In areas of Kresty and the mouth of the Pyasina river, an increase in phytodiversity is observed in comparison with the background communities. As a reaction to pollution, dead plant species should be observed, which is not the case. Most likely, this is due to the effect of natural factors (soil characteristics, snow depth, flood duration, etc.).

ASSESSMENT OF THE DECLINE IN DIVERSITY AND PROJECTIVE COVER OF BRYOPHYTES

In the direction from the Bezymyanny brook to the mouth of the Ambarnaya river species diversity and projective cover of bryophytes in areas transformed by hydrocarbons decreases in comparison with the background levels. Nevertheless, on the Daldykan brook, these parameters are equal (2 species each in the background and disturbed communities and 5% and 6% of the projective cover, respectively). This is probably due to the fact that when the diesel fuel was moving along the Daldykan brook, mosses which prefer low parts of the floodplain with good moisture, mostly ended up at the bottom of by that time a full-flowing stream due to the spring floods. The diesel fuel layer was on the water surface and interacted weakly with mosses, which saved the mosses from degradation. The maximum number of mosses in the studied river valleys is noted in the source of the Pyasina river, and the indicator in the sections of this river is 2 times higher than the background values. This indirectly indicates the absence of oil pollution here.

- In general, the diversity of plant communities has not changed as a result of the oil spill. However, in 5 associations, a partial degradation of communities occurred, when, along with the background communities of lower-level syntaxa (associations and subassociations), their transformed analogs appear, characterized by a reduced species diversity and the presence of dead plants as a result of direct contact with hydrocarbons.
- Comparison of the species, sex and age composition of mammals in 2020 with the data from 2017 shows that their total number in 2020 has slightly decreased (by 9 individuals). The actual biodiversity of the entire research region is relatively low.
- For most areas of the shrub tundra and forest, the prevailing species has not changed – it is represented mostly by forest, granivorous rodents, the number of insectivores remains at a low level. During the examination of the internal organs of the common voles caught in the area of the diesel fuel spill, it was observed that they continued to feed on the green mass of sedge-cereal plants characteristic of the Ambarnaya river bed.
- When analyzing the internal organs of all captured individuals, no infectious or metabolic pathological processes were observed. The expected characteristic external changes in the form of chronic lesions of the internal organs as a result of technogenic burden, as well as the consequences of a fuel spill, were not found.
- 11 bird species were counted, and it is difficult to assess the background state of the avifauna. Potentially about 120 bird species were recorded during migration and nesting. In the flood plain of the Ambarnaya river along the coastline, only single individuals of the white wagtail were found, although at that time they should have maintained family groups. There were no behavioral differences for other species (mallard, hoary redpoll, little bunting). Most bird species are characterized by seasonal use of the tundra for reproduction, therefore, when arriving in spring, birds choose biotopes that meet their environmental requirements. In this regard, most species of migratory birds cannot be adversely affected.

SUMMER 2020