HYDROLOGICAL SITUATION OF THE UPPER DNIEPER

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ABSTRACT

This study aimed to assess the environmental conditions of the Upper Dnieper (the reach between the cities of Smolensk and Mogilev), based on the hydrological (depth, width and flow rate of the river), hydrochemical (water temperature, pH, conductivity, and dissolved oxygen), and meteorological (air temperature, atmospheric pressure, and wind speed) data obtained by the Complex Expedition to Explore Historical Waterways of Russia ("KEIWP"), conducted by S.I.Vavilov Institute for the History of Science and Technology of the Russian Academy of Sciences. All measurements were taken at measuring points located 3 to 5 km from each other, and a GPS was used to position each measuring point. The morphometric characteristics of the river were determined with the help of a Lowrance HDS-5x Gen2 echosounder and a Leica Geovid rangefinder binocular. The following portable analyzers were used for hydrochemical assessments: WTW MultiLine pH/Cond 340i for pH and conductivity measurements, WTW MultiLine oxi 340i for dissolved oxygen levels, and YSI 600QS sonde. The complementary meteorological data were obtained using a Kestrel 4500 NV Weather Meter. Based on the results of the study, three stretches were identified in this section of the Dnieper River that differ in the levels of water pollution: from the city of Smolensk to the village of Syrokorienie (class IV: polluted waters); from the village of Syrokorienie to the village of Beketovo (class III: moderately polluted waters); and from the mouth of the River Mereya to the city Mogilev (class II, moderately clean). The results demonstrate that the quality of water in the Dnieper from the city of Smolensk to the city Mogilev is satisfactory and this part of the river may be used for recreation and tourism purposes.

Keywords: water monitoring, water quality, hydrology, the Dnieper River

INTRODUCTION

With the length of 2,145 km and the catchment area of 504,000 km², the Dnieper is one of the biggest rivers of the European Plain as regards both the size and water content. The Dnieper has its source in the southern spurs of the Valdai Hills, originating from a small moor 1.5 km away from the village of Dudkino (Sychevskii Raion, Smolensk Oblast) and falls into the Dnieper-Bug Estuary in the Black Sea. The river runs across

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the Smolensk Oblast of Russia (503 km), Belarus (595 km), and Ukraine, changing the
direction of its course several times.

Hydrologically, the Dnieper is traditionally divided into two segments, the Upper
Dnieper that is 1,230 km long (from the source to the Pripyat estuary) and the Lower
Dnieper that has been turned into a reservoir cascade [3]. As regards the structure of the
river valley, channel, and flow conditions, the Upper Dnieper may be divided into three
segments: from the headwaters to the city of Smolensk (410 km); a stretch from the city
of Smolensk to the city of Mogilev (239 km); and a stretch from the city of Mogilev to
the Pripyat estuary (533 km) [5].

METHODS
The Complex Expedition to Explore Historical Waterways of Russia ('KEIVP'),
conducted by S.I.Vavilov Institute for the History of Science and Technology of the
Russian Academy of Sciences, has been exploring the Smolensk to Mogilev stretch of
the Dnieper River in July and August of 2012. The en-route field studies were carried
out while rafting in 2 motorized inflatable boats (rafts). The first boat was equipped
with the hydrological and meteorological laboratory facilities. The portable analyzers
(WTW MultiLine pH/Cond 340i pH-meter/conductometer, WTW MultiLine oxi 340i
oxygen, YSI 600QS sonde, and Kestrel 4500 NV weather meter) were used for
hydrological (depth, width and flow rate of the river), hydrochemical (water
temperature, pH, conductivity, and dissolved oxygen) and meteorological (air
temperature, atmospheric pressure, and wind speed) measurements.

The second boat was making descriptions of the landscapes.

All measurements were taken at measuring points located 3 to 5 km from each other.
Each measuring point was GPS-positioned while the morphometric characteristics of
the river (depth, width and flow rate) were determined with the help of Leica Geovid
rangefinder binoculars and Lowrance HDS-5x Gen2 echosounder.
The expedition traveled a total of 200 km and described 47 points that were mapped to
the landscape structure of the stretch of the River Dnieper under study.

RESULTS
The width of the Dnieper valley at the stretch between Smolensk and Mogilev varies
from 0.8 to 3 km, sometimes reaching up to 10 km. There are up to 4 or 5 mostly tilled
terraces visible on the slopes of the valley, with the height of the scarps reaching 12 to
30 meters. The scarps are steep and precipitous, incised with gullies, small flat-bottom
valleys and tributary valleys, the soils being loam and loamy sand. The groundwater
egresses can be seen [5].

The floodplain, comprising sand and loamy sand, rises 5-8 m above the low-water level.
Its width varies from 100 m near Smolensk to several kilometers near Mogilev. The
floodplain surface is mostly open and tilled, with occasional scrub-bushes and forests.
The floodplain is only flooded for 5 to 10 days during the high water periods [5].

The width of the Dnieper's channel varies from 60 to 120 m, reaching up to 1.3 km
between the village of Gat'kovshchina and the city of Orsha. The river's channel
distinguished for smooth meanders and long straight stretches with numerous shallows. Small flooded sandbars 15-170 m long and 7 to 80 m wide can be seen occasionally. The depth of the river is 2-4 m, down to 1 m at the shallows and up to 7 to 8 m in the wide parts of the river. The flow rate was found to be 0.2 – 1.3 m/s. The riverbed is smooth, comprising sands and sand-and-gravel material. The riparian zone is scattered with boulders. 9 km upstream from the city of Orsha, the river cuts through a Devonian limestone ridge, forming the Kobelyaki Rapids that are about 200 m long. In this segment, the banks become steep, reaching 2 to 10 m in height, and covered with shrubbery or meadows, with the soils being loamy sand, bouldery and nonbouldery loams [5].

The Dnieper’s catchment area comprises 65% of the basin’s total area. This is where 80% of the annual river flow is formed. The biggest water discharge (50 to 70% of the annual river flow) occurs in March and April during the high-water period when the water level rises by 5 to 7 m. The spring flood usually occurs as a single wave [1, 3, 5].

The lowest water level is observed in August during the low-water period. However, the summer/autumn low water levels are almost annually affected by the rainfall floods. The winter low water levels are more stable. The winter low-water period lasts 3 to 4 months, and in some winters they last up to 5.5 months. Winter floods do not occur every year. The river freezes in late November/early December, the ice breaks up in late March/early April. The ice is thickest in February and March [5].

Suspended-sediment concentration in the Upper Dnieper is elevated, with the average annual suspended-sediment concentration near Mogilev being 57 g/m³. The highest monthly suspended-sediment concentration (190 g/m³) is observed in April. The average annual suspended-sediment concentration in the Upper Dnieper drops downstream from 80 to 40 g/m³ due to low suspended-sediment concentration in the tributaries. The suspended matter mostly consists of mineral particles, with the organic matter comprising 15% [3, 5].

As regards its chemical composition, the water in the Upper Dnieper belongs to the calcium-bicarbonate type of freshwaters. In spring, the meltwater salinity is low (120 to 140 mg/l). The average water salinity during the summer low-water period comprises 200 to 300 mg/l [1].

In August 2012, the daytime water temperature was changing steadily, with an obvious tendency towards dropping from +24.5°C near the village of Syrokorenie, Smolensk Oblast (the first day of the route) to +21.1°C near the city of Mogilev. The water was cooling at nighttime. During the day, the Dnieper could not warm up to the previous day’s temperature. A rapid drop in water temperature (to +19.4°C) was observed downstream from the mouth of the Mereya river (the Dnieper’s left tributary), which was 3.6°C lower that the water temperature in the Dnieper upstream and downstream from that site.

Conductivity did not change much over the entire route, varying within the range from 350 to 360 μS/cm in the first two days. It was only at the mouth of the Mereya river that it reached 446 μS/cm. Some increase in conductivity was observed in the vicinity of Smolensk (367 μS/cm) and downstream from Orsha (380 μS/cm with the background conductivity of 365 to 375 μS/cm). Similar conductivity levels (375 to 378 μS/cm) were observed all the way to Mogilev. Thus, a downstream increase in conductivity is characteristic of the Dnieper.
The minimum pH value (7.14) was observed in Smolensk. The increase in pH was observed: downstream from Smolensk (8.1); near the village of Alekseyevka (8.6); at the border with Belarus: near the mouth of the Mereya river (8.4), in Orsha (8.5); several kilometers upstream from the city of Kopyys (8.5); and in Mogilev. In other stretches of the Dnieper, pH varied from 8 to 8.3. This is consistent with the average pH values for the Upper Dnieper (up to 8.4 in the summer low-water period [5]).

The dissolved oxygen level was changing unevenly. Near the city of Smolensk where the evidence of wastewater discharge was observed it reached 91.3% (7.8 mg/l), dropping to 65% (5.6 mg/l) downstream from the city and raising to 83.5% (6.9 mg/l) at the village of Tikili and to 114% (10.5 mg/l) at the mouth of the Mereya river. A noticeable rise in the dissolved oxygen level to 110% (9.9 mg/l) was observed near the village of Dubrovino. The highest level along the entire route – 123% (10.6 mg/l) – was found in Orsha near a wastewater discharge site. Downstream from Orsha, the dissolved oxygen level dropped to 103% (9.1 mg/l), to rise back to 112% (9.8 mg/l) in Mogilev. The dissolved oxygen saturation in the Upper Dnieper varies from 50 to 120% [5]. The values obtained by the Expedition along almost the entire route were below 120% except for Orsha and vicinity. It should be mentioned, however, that the values around 110% were in some cases observed at the sites of wastewater discharge. The fluvial waters with the dissolved oxygen level of 90% or higher are usually regarded as healthy in the absence of anthropogenic eutrophication. The waters with the dissolved oxygen level below 90% may contain high amounts of organic matter whose decomposition consumes oxygen.

The rivers in the Russian part of the Dnieper’s basin are relegated to class II fishery waters, which implies a special regime for their use and protection. This regime, however, is being violated: in the floodplains, there are cattle grazing and the discharge of wastewaters that do not meet fish protection norms [1]. The analysis of dissolved oxygen fluctuations in the Dnieper showed that, from the city Smolensk to the village of Syrokorene, the water was class IV (polluted), and from the village of Syrokorene to the village of Beketovo, it was class III (moderately polluted).

An abrupt rise in conductivity and dissolved oxygen, as well as elevated pH and temperature were observed in the Dnieper downstream from the Mereya river that forms the boundary between Russia and Belarus. Such changes are likely to be associated with the specifics of streamflow formation of the Mereya river that cuts through the Devonian carbonate deposits. Downstream from the mouth of the Mereya, the level of dissolved oxygen in the Dnieper increases to 10 mg/l. Therefore, in regard to this indicator, the Mereya’s waters may be relegated to class I (very clean). From the mouth of the Mereya to the city of Mogilev, the quality of water in the Dnieper remains stable and, in regard to the dissolved oxygen indicator, may be relegated to class II (moderately clean).

In the course of landscape observations, it was established that, due to the dry climate and low water content, the Dnieper’s floodplain almost had not been flooded in the 9th century, which could thus have been the factor limiting the development of settlements and the growth of population of the Gnezdovo (Gnyozdovo)-type sites of ancient settlements ("gorodishche"). In turn, at a certain point in history, this could have been conducive to the emergence of Smolensk in the area with large stretches of land located on the vast low valley sands suitable for agriculture.
Smolensk was founded on the high left bank of the Dnieper (with the relative elevation of up to 80 to 90 m), incised with numerous gullies and brook valleys. The tall hillocks between the gullies and brook valleys form the tongues where they protrude into the Dnieper’s valley. The local people call these tongues “gora (‘hill’)” (Sobornaya Gora, Pokrovskaya Gora, Kazanskaya Gora, Voskresenskaya Gora, Shklyanaya Gora, etc.) and it was on the most hard-to-reach of these “hills,” Sobornaya Gora, with its steep and precipitous slopes that the first Smolensk fortress was built [2].

On the left bank of the Dnieper near Smolensk, there are only the fragments of the low supra-floodplain terraces as well as a well-marked low valley sandr (the third supra-floodplain terrace) here and there [2]. Like in Gnezdovo (Gnyozdovo), there is a widespread system of low supra-floodplain terraces and floodplains there. Well-draining, nutrient-rich loams combined with the air and water regime conducive to agriculture created unlimited possibilities for agricultural exploration of this territory.

CONCLUSION

As regards its chemical composition, the water in the stretch of the Dnieper from Smolensk to Mogilev belongs to calcium-bicarbonate type of freshwaters, with predominant ions being HCO₃⁻ and Ca²⁺ ions. The average water salinity comprises 200 to 500 mg/l, which is well within maximum permissible concentration for fishery waters (1,000 mg/l). This type of waters is typical for forested areas of the European Russia’s moderate climate zone where sedimentary carbonate rocks (limestone, maraines, dolomites, marl, etc.) and the products of their weathering (soddy soils and rendzinas on the slopes of the valleys, and carbonate alluvial soils in the valleys) are widespread.

Regarding dissolved oxygen levels, this part of the Dnieper can be divided into three stretches: from the city of Smolensk to the village of Syrokorenie where the water is polluted (class IV); from the village of Syrokorenie to the village of Beketovo, with moderately polluted water (class III); and from the mouth of the River Mereya to the city Mogilev, with moderately clean water (class II). The deficit of dissolved oxygen is observed where the river is weedy and slow.

On the whole, the condition of surface streams in the area under study is satisfactory, with the concentrations of most analytes not exceeding maximum permissible concentrations for fishery waters (including the requirements of the sanitary regulations and standards SanPiN 2.1.5980-00, GN 2.1.5.689-98 with additions, and GOST 2761-84).

The detailed descriptions of the Dnieper valley were made, based on landscape observations, which allowed to extend the knowledge about the emergence of strongholds on the Dnieper. A unique combination of landscape conditions with high-nutrient soils facilitated the transformation of Smolensk into a major ancient settlement.

As regards recreation and tourism, the part of the Dnieper valley under study is deemed to be satisfactory for these purposes. A water route from Smolensk to Mogilev was elaborated.
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REFERENCES


