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Short Communication

Limnological characterization of the sources of Volga, Dnieper & Western Dvina (Daugava)

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Abstract

Springs are important habitats and determine the characteristics of headwater streams. However, they are rarely studied and usually not included in monitoring programs. Our study characterizes the sources of three large rivers and contributes to the knowledge about the biggest East European drainage divide. The catchment area is characterized by dense forests, which are rich in swamps and mires. The paludified catchment is typical for the rivers in this region and it is also determining the physicochemistry of the water. We provide a first dataset about the physicochemical conditions of the sources of Volga, Dnieper, and Western Dvina, which should build a basis for further analyses of the springs of these large rivers. We suggest that monitoring the sources of the large rivers in the Valdai hills should be considered as an extension of the existing monitoring programs.

Introduction

In general, springs are characterized by environmental stability with reduced seasonal fluctuations of physical and chemical parameters [1], thus they are even proposed as "natural laboratories" [2]. It is also known that a few square meters within spring habitats are characterized by multiple microhabitats or choriotopes [3]. However, systematic research about springs only started in the 1990s (Cantonati, et al. 2010 [4] and references therein). The source of a river and a small headwater stream provides important habitats and changes at the source can affect the river downstream [5].

In the Valdai hills, the sources of three large east European rivers are located close together, within a radius of 85 km [6]. The catchment area is characterized by dense forests, that are parts of the ancient "Okovsky Forest" and also rich in swamps and mires. The paludified catchment is typical for the rivers in this region and it also determines the physical chemistry of the water [7].

Already the Chronicle of Nestor or Kiev Chronicle (Russ. "Povest vremennykh let" – "Tale of bygone years") from the XII century [8] makes an account of this setting: "*The Dnieper flows out of the Okovsky forest and flows south* [... *to Pontus Euxinus* ... = the Black Sea], *and the Dvina flows from the same forest, but goes north and flows into the Varangian Sea* [= Baltic Sea]. *From the same forest, the Volga flows to the east and flows into the Khvalis Sea* [= Caspian Sea] *with seventy branches.*" [9]. Thus the "Okovsky forest", which included the forests in the Toropetsky, Ostashkovsky, and Kholmsky districts can be considered a geographical center, wherefrom the three large East European

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rivers emerge. In the 16th and 17th centuries, this forest was described as the "Volkovisky forest" (*Volkonsky* by Herberstein as well as Olearius and Meyerberg and *Volkovsky* by Gvanini) (https://ru.wikisource.org/wiki/ЭСБЕ/Волковиский_лес). In the west of the Tver region, the most preserved part of this ancient forest is protected by the Central Forest Nature Reserve (Tsentralno-Lesnoi Zapovednik), which was organized in 1931 [10].

Our short communication summarizes information about the sources of three large East European rivers and their role in the formation of those systems.

Materials and methods

Samples were collected during the summer low flow period in 2019 (Volga & Western Dvina) as well as in 2021 (Dnieper) (Figure 1). Air and water temperature, pH, and electrical conductivity were determined at the sampling site. The ionic composition of water was determined by capillary electrophoresis. With the hydro-chemical data, the ionic composition of the water from the three rivers was characterized according to Kurlov & Sobkevich [11].

Results and discussion

The source of Volga (228 m asl), Europe`s longest river (3551 km), is a limnokrene located near the village Volgoverkhovje. Several meters downstream of its source the Volga River forms a small runnel not wider than half a meter, but soon it is becoming a creek. Downstream of the Upper Volga Lakes the free-flowing section towards Tver evolves [12]. The Dnieper, which is Europe`s 4th longest river (2201 km), emerges at the village Bocharovo (220 m asl) near Smolensk, before flowing through Belarus and Ukraine to the Black Sea [13]. Daugava or Western Dvina (1020 km) emerges near the former village of Koriakino (221 m asl) and soon after enters Lake Okhvat, a humic lake, wherefrom the river emerges [14]. The Western Dvina flows through the territory of three countries (Russia, Belarus, and Latvia) and discharges into the Gulf of Riga (Baltic Sea).

The data from field measurements and laboratory analyses

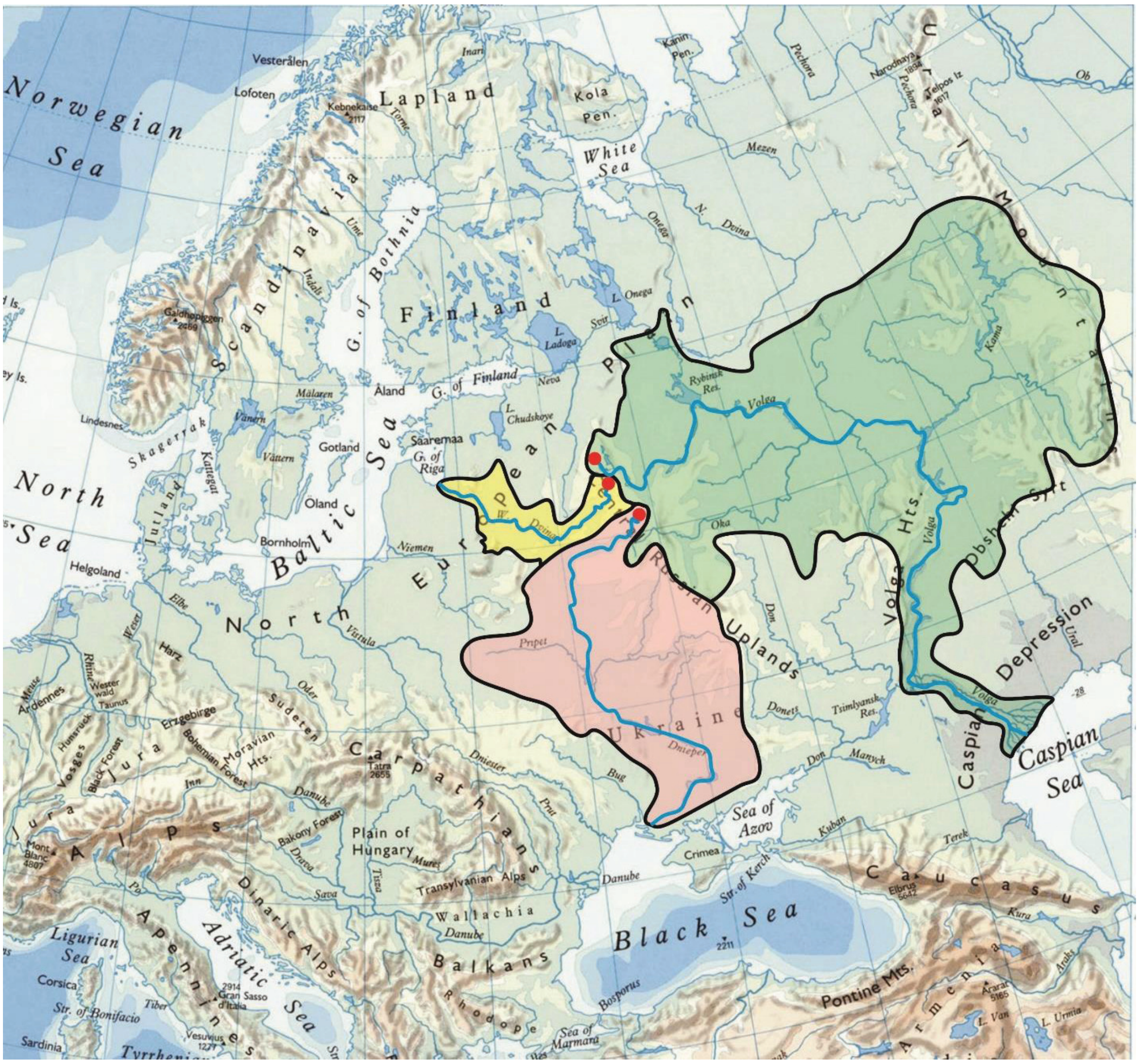

Figure 1: Sources and corresponding catchments of Volga (green), Dnieper (red), and Daugava (yellow), base map from https://www.mapsland.com/maps/europe/large-detailed-physical-map-of-europe.jpg

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of water samples from the sources of the three rivers are presented in Table 1. The water at the sources of all three rivers has low mineralization (less than 100 mg/l) with a predominance of bicarbonate and calcium ions. Due to more feeding, the water is highly saturated with organic substances and has high chromaticity and low pH. Official monitoring points along the three rivers indicate good quality in their headwater sections.

The Volga and the Western Dvina (Daugava) flow out of the mires (Figure 2). Due to mire feeding the water is highly saturated with organic substances and has high chromaticity (600-700°), low values of pH (3-5) and mineralization (50-60 mg/l). The source of the Dnieper is located on mineral soil (Figure 2). The water has a neutral pH, a chromaticity of 135°, and mineralization of 420 mg/l. The ionic composition in the sources of all three rivers is dominated by bicarbonate and calcium ions (Table 2).

In 2005, during an expedition along the Upper Volga, the Institute of Geography of the Russian Academy of Sciences determined the elemental composition of water taken at the source of the Volga [15]. Of the 61 elements determined by the

Table 1: Values of hydrochemical indicators of the sources of the Volga, Dnieper, and Western Dvina.

	Volga	Dnieper	Western Dvina
Sampling date	24.07.2019	26.07.2021	24.07.2019
Water temperature, °C	14.6	7.8	14.9
pH	5.40	7.29	3.28
Conductivity, μS/cm	53	490	58
Chromaticity, °	554	135	705
HCO_3^-, mg/l	35	315	32
SO_4^{2-}, mg/l	0.12	4.9	0.67
Cl^-, mg/l	0.21	1.51	1.21
NO_2^-, mg/l	0.017	0.026	0.023
NO_3^-, mg/l	0.057	0.146	0.363
PO_4^{3-}, mg/l	0.153	0.138	0.087
F^-, mg/l	0.005	0.323	0.005
Ca^{2+}, mg/l	10.6	75.7	9.08
Mg^{2+}, mg/l	2.3	18.3	0.94
Na^+, mg/l	0.89	5.7	0.68
K^+, mg/l	0.31	2.2	0.91
NH_4^+, mg/l	0.076	0.390	0.053
Sr^{2+}, mg/l	0.042	0.235	0.044
Water hardness, mg-eq/l	0.72	5.3	0.53
Sum of ions, mg/l	50	424	46

Figure 2: Source of the Volga River (a) 1910 (photo by Sergeĭ Mikhaĭlovich Prokudin-Gorskiĭ, permalink: https://lccn.loc.gov/2018680341) and (b) 2019 (photo: Martin Schletterer). Source of the Dnjepr in 2021 (c + d) (photo V.V. Kuzovlev). Source of the Western Dvina (e) 1910, near the village of Kariakino three versts from Lake Peno in Tver Province, Ostashkov District (photo by Sergeĭ Mikhaĭlovich Prokudin-Gorskiĭ, permalink: https://lccn.loc.gov/2018680337) and (f) 2019 (photo: Martin Schletterer).

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analysis (Table 3), the concentrations of aluminum, vanadium, manganese, iron, copper, and zinc at the source of the Volga exceeded the MPC for fish (highlighted in bold in Table 3). Of the 71 water samples taken in the Volga on a 450-kilometer section from the source to the city of Tver during the expedition of 2005, the maximum concentrations of such trace elements as silicon, cobalt, lead, and thorium is observed at the source of the river [15].

This underlines that trace elements can be used as an indicator of the extent of the krenal region [16]. For example, trace elements are also very useful indicators at geothermal springs [17] as well as for alpine springs [18].

Conclusions

Due to the stable characteristics of springs, they are valuable sites for long-term monitoring [19], both for Physico-chemical and biological parameters. Especially diatoms turned out to be a good indicator for spring ecosystems [3,20]. Thus, analyses of the sources of the large rivers in the Valdai hills, using the herein proposed physico-chemical as well as biological parameters (diatoms), should be considered as an extension of the existing monitoring programs. Besides, sampling should be carried out at additional locations along a longitudinal gradient from the source towards a few kilometers downstream. This would enable the characterization of the krenal region and its significance for the headwaters of the large rivers. Herein we provide a first dataset about the physico-chemical conditions of the sources of Volga, Western Dvina, and Dnjepr, which should build a basis for further analyses of the springs of these large rivers.

Table 2: Coordinates of the sources of the three large East European Rivers Volga, Dnieper, and Western Dvina as well as the corresponding Kurvol formulae in the summer low flow period (M - mineralization in *g/l*, the concentration of ions - in *%-equivalents*).

Volga 57°15'04.7"N 32°28'04.4"E	$M_{0,05}\frac{HCO_3 98Cl1NO_3 0,7SO_4 0,4}{Ca69Mg25Na5K1NH_4 0,7}t°_{15}pH5,4$
Dniepr 55°52'18.0"N 33°43'27.4"E	$M_{0,42}\frac{HCO_3 97SO_4 2Cl1}{Ca67Mg27Na4K1NH_4 0,4}t°_{8}pH7,3$
Western Dvina (Daugava) 56°52'13.9"N 32°31'54.8"E	$M_{0,05}\frac{HCO_3 91Cl6SO_4 2NO_3 1}{Ca77Mg13Na5K4NH_4 0,5}t°_{15}pH3,3$

Table 3: Concentrations of trace elements (µg/l) in the water of the source of the Volga, 07.08.2005 (data from [14]).

Li	0,62	Co	***0,61***	Cd	0,12	Ho	0,005
Be	0,011	Ni	1,16	In	0,00	Er	0,012
B	5,75	Cu	**1,03**	Sn	0,12	Tm	0,003
C	9018	Zn	**10,37**	Sb	0,50	Yb	0,013
Na	1006	Ga	0,29	I	1,77	Lu	0,002
Mg	4784	Ge	0,05	Cs	0,03	Hf	0,039
Al	**535,8**	As	1,40	Ba	21,93	Ta	0,001
Si	***4738***	Se	1,09	La	0,18	W	0,018
K	441	Br	49,81	Ce	0,461	Tl	0,016
Ca	10677	Rb	1,11	Pr	0,061	Pb	***0,978***
Sc	4,75	Sr	82,43	Nd	0,204	Bi	0,023
Ti	23,36	Y	0,26	Sm	0,036	Th	***0,063***
V	**1,18**	Zr	2,59	Eu	0,011	U	0,055
Cr	4,64	Nb	0,11	Gd	0,032		
Mn	**131,52**	Mo	0,06	Tb	0,005		
Fe	**898,6**	Ag	0,02	Dy	0,025		

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