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Dynamics of Water Quality Major Rivers in the Vologda Region

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Abstract—The state and trends of pollution of major surface water bodies in the Vologda region were analyzed on the basis of the generalized data collected by the state observation service in 1998–2011.

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The Vologda region comprises more than four thousand lakes (the largest being Kubenskoe, Onezhskoe, Beloe, Vozhe) and two thousand rivers and other surface water bodies which occupy 2.5% of the area. Among 13 rivers with an overall length of about 3000 km, the most practically important are Sukhona (with the tributary Vologda), Kubena, Malaya Severnaya Dvina, Yug, Vytegra, and Kovzha. The Sukhona and Severnaya Dvina rivers run directly to the White Sea, and through the Volga–Baltic Route, to the Baltic Sea and Caspian Sea. The least water streams with a length of up to 25 km constitute 98%, small rivers (up to 100 km), about 1.5%, and medium rivers (100 to 1000 km), less than 1%.

Rivers in the Vologda region flow to the Baltic, White, and Caspian Seas. The Baltic Sea basin covers Vytegra, Andoma, Megra, and Oshta with tributaries (8% of the area of the region), Sukhona, Kubena, Uftyuga, Eloma, and Porozovitsa with tributaries (70%) drain to White Sea, and Kovzha, Sheksna, Mologa, and Suda with tributaries, as well as other rivers (22%) belong to the Caspian Sea basin.

All surface water bodies are characterized by seasonal variations of water composition and such water parameters as chromaticity, alkalinity, and hardness. Surface waters in the Vologda region display increased concentration of organic materials of humic origin, which are produced as a result of plant decay. This is especially typical of turfary areas. High concentration of humic substances makes water yellow–brown. Surface waters also contain increased amounts of iron and copper.

The chemical composition of natural waters changes under anthropogenic impact. The largest pollution of water bodies is observed in summer and winter low-water periods and in spring high-water (snowmelt) period when pollutants run off from adjoining areas. The spring high-water maximum and drop periods and before freeze-up are characterized by improved water quality due to increased water flow. Pollution of surface water bodies is considerably contributed by nonpoint runoff from drainage areas.

The main sources of pollution of water bodies in the region are industrial enterprises, in particular *Sokolsky PPC* Joint Stock Company, *Sukhonsky PPC* Ltd., *Severstal'* Joint Stock Company, *Cherepovetsky Azot* Joint Stock Company, and *Ammofos* Joint Stock Company, housing and communal services, agricultural enterprises, and navigation.

Taking the above stated into account, the goal of the present study was to assess the dynamics of water pollution in major rivers in the Vologda region.

MATERIALS AND METHODS OF RESEARCH

Primary data of hydrochemical monitoring of nine rivers in the Vologda region (Table 1) over 1998–2011 performed by the Vologda Center for Hydrometeorology and Environmental Monitoring. The quality of water was estimated with comprehensive assessment

Table 1. Parameters of major rivers in the Vologda region

River, observation station	Length, km	Drainage area, km^2	Average high-water discharge, $m^3 s^{-1}$
Koshta, Cherepovets	19	106	–
Yagorba, Cherepovets	53	458	–
Yagorba, Mostovaya village	53	374	72.4
Sukhona, Velikii Ustyug	558	50300	3480
Sukhona, upstream of Sokol	558	15500	507
Sukhona, downstream of Sokol	558	15500	507
Pel'shma, Sokol	82	308	70.2
Vologda, upstream of the city	155	1510	204
Vologda, downstream of the city	155	2600	356
Malaya Severnaya Dvina, Velikii Ustyug	74	85900	5970
Kubena, Savinskaya village	368	4910	663
Kichmen'ga, Zakharovo village	208	2010	220
Vaga, Gluboretskaya village	575	1410	185

Table 2. Chaddock scale [3]

Correlation quality	Correlation coefficient	
	direct relation	reverse relation
Poor	0.1–0.3	(–0.1)–(–0.3)
Moderate	0.3–0.5	(–0.3)–(–0.5)
Salient	0.5–0.7	(–0.5)–(–0.7)
High	0.7–0.9	(–0.7)–(–0.9)
Very high	0.9–0.99	(–0.9)–(–0.99)

Table 3. Quality of correlation between SCWPI values and observation period for major rivers in the Vologda region

River, observation station	Determination coefficient r^2	Correlation coefficient, r	Correlation quality
Koshta, Cherepovets	0.45	0.67	Salient
Yagorba, Cherepovets	0.77	0.88	High
Yagorba, Mostovaya village	0.14	0.37	Moderate
Sukhona, Velikii Ustyug	0.21	0.46	Moderate
Sukhona, upstream of Sokol	0.13	0.36	Moderate
Sukhona, downstream of Sokol	0.03	0.17	Poor
Pel'shma, Sokol	0.43	0.66	Salient
Vologda, upstream of the city	0.08	0.28	Poor
Vologda, downstream of the city	0.63	0.79	High
Malaya Severnaya Dvina, Velikii Ustyug	0.17	0.41	Moderate
Kubena, Savinskaya village	0.01	0.10	Poor
Kichmen'ga, Zakharovo village	0.51	0.71	High
Vaga, Gluboretskaya village	0.05	0.22	Poor

Table 4. Dynamics of SCWPI for five rivers of Vologda region

Year	r. Yagorba, Cherepovets	r. Kichmen'ga, Zakharovo	r. Vologda, downstream of the city	r. Koshta, Cherepovets	r. Pel'shma, Sokol
	SCWPI values				
1998	5.61	5.21	6.51	7.31	8.19
1999	5.87	5.18	6.5	6.94	8.78
2000	5.23	4.18	7.17	7.19	8.84
2001	5.73	4.71	6.21	6.58	8.65
2002	5.59	4.7	6.71	7.01	9.25
2003	5.11	4.17	5.71	6.93	8.51
2004	5.02	4.25	5.76	6.62	8.65
2005	4.55	3.92	5.91	6.47	8.31
2006	4.22	3.07	5.16	6.55	7.75
2007	4.31	2.75	5.32	6.92	7.54
2008	3.91	3.47	5.03	6.45	7.63
2009	3.75	2.74	5.54	6.29	7.29
2010	4.41	3.61	6.02	6.11	7.86
2011	4.44	4.39	4.37	6.90	8.30

method of the degree of contamination of surface waters on the basis of hydrochemical parameters according to the Management Directive 52.24.643-2002 developed at the Hydrochemical Institute [1]. The following water quality grades were used: (I) arbitrarily pure; (II) weakly contaminated; (IIIa) contaminated, (IIIb) strongly contaminated; (IVa, IVb) dirty; (IVc, IVd) very dirty; (V, VI) extremely dirty.

The degree of pollution of surface waters was estimated according to "Standards of water quality of fishery purposes, including standards for maximum allowable concentrations of hazardous substances in the waters of fishery purposes," approved by order Federal Agency of Fishery no. 20 from 18.01.2010 [2]. The data was mathematically and statistically processed using MS Excel software, taking into

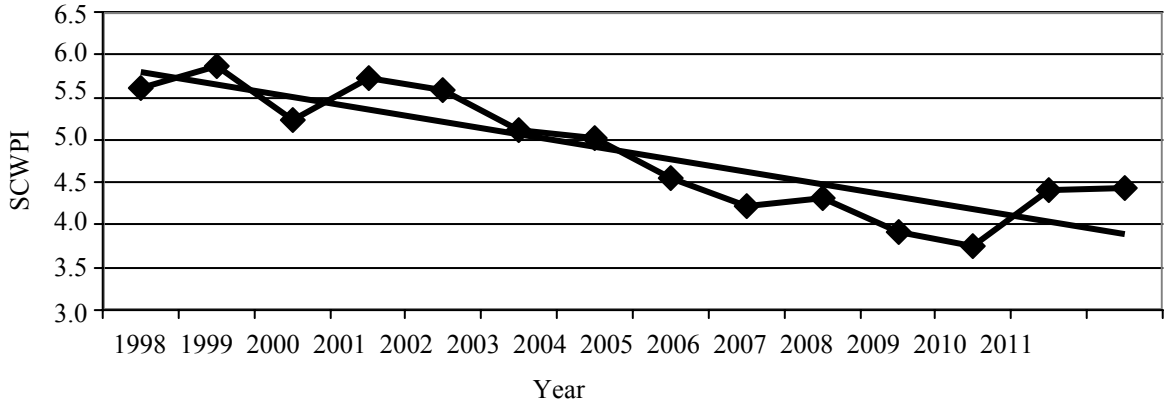

Fig. 1. Variation of the SCWPI values over 1998–2011 (observation station on the Yagorba river, Cherepovets).

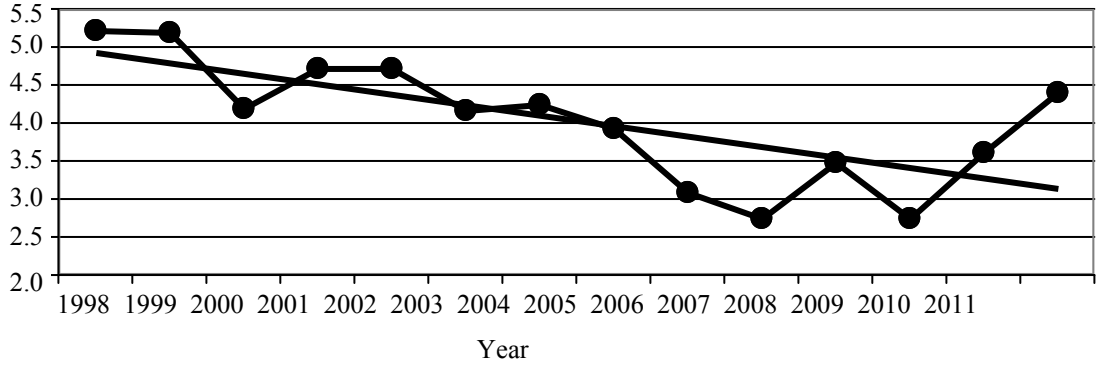

Fig. 2. Variation of the SCWPI values over 1998–2011 (observation station on the Kichmen'ga river, Zakharovo village).

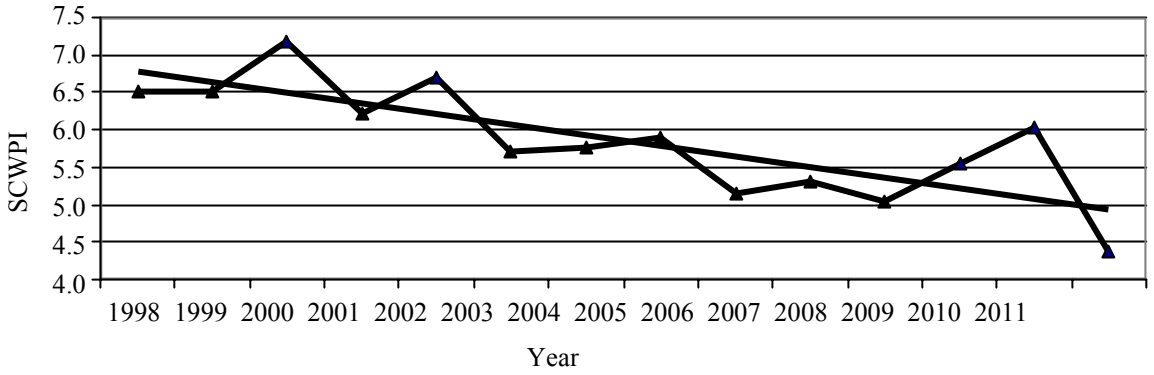

Fig. 3. Variation of the SCWPI values over 1998–2011 (observation station on the Vologda river, downstream of the city).

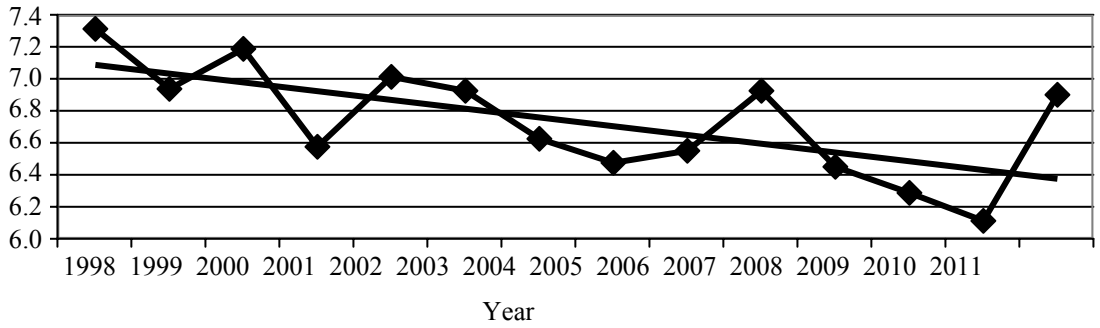

Fig. 4. Variation of the SCWPI values over 1998–2011 (observation station on the Koshta river, Cherepovets).

account that a linear probabilistic relation between random quantities (in our case, specific combinatorial water pollution index, SCWPI) implies a tendency of one random quantity to linearly increase (or decrease) upon increase of the other (observation year).

In the general case, when some quantities are related to each other through an arbitrary probabilistic relation, the linear correlation coefficient (r) ranges from –1 to 1. Then the closeness of relationship between variables may be qualitatively assessed using the Cheddock scale (Table 2).

RESULTS AND DISCUSSION

Mathematical and statistical analysis of the monitoring data (SCWPI values) for the major rivers in the Vologda region showed the following (Table 3).

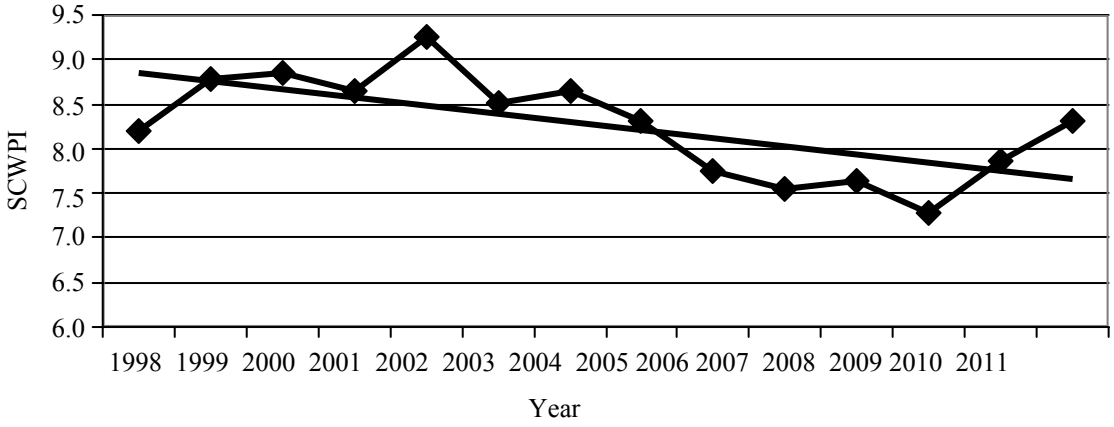

Fig. 5. Variation of the SCWPI values over 1998–2011 (observation station at the Pel'shma river, Sokol).

A high correlation quality between SCWPI and observation period (1998–2011) was found for three observation stations (Yagorba river, Cherepovets; Vologda river, down-stream of the city; Kich'menga river, Zakharovo village). A salient correlation quality was found for two observa-tion stations (Koshta river, Cherepovets; Pel'shma river, Sokol). The data collected from four observation stations (Yagorba river, Mostovaya village; Sukhona river, Velikii Ustyug; Sukhona river, upstream of Sokol; Malaya Severnaya Dvina river, Velikii Ustyug) displayed a moderate correlation quality, and poor correlation quality was revealed for four observation stations (Sukhona river, downstream of Sokol; Vologda river, upstream of the city; Kubena river, Savinskaya village; Vaga river, Gluboretskaya village).

The data from observation stations with high and salient correlation quality showed a trend to decrease of SCWPI (Table 4; Figs. 1–5). Despite the decreasing trend in values of SCWPI significant changes of water contamination of examined rivers has not occurred. For instance, water in the Yagorba river (Cherepovets) in 1998 and 2011 was assessed as dirty (quality grade IV). The situation with the Kich'menga river (Zakharovo) is analogous. The Vologda (downstream of the city) and Koshta rivers (Cherepovets) in both 1998 and 2011 were very dirty. In 1998 water in Pel'shma (Sokol) was extremely dirty (quality grade V), and its quality did not change till 2011.

CONCLUSIONS

(1) The chemical composition of water in rivers in the Vologda region is determined by natural and anthropogenic factors. Readily and difficultly oxidizable organic compounds, lignosulfonates, nitrite and ammonia nitrogen, and iron, copper, and zinc compounds constitute a considerable part of surface water pollution.

(2) Assessment of the state of major water bodies in the Vologda region indicated that surface waters therein are graded as contaminated (quality grade III), dirty (quality grade IV), and extremely dirty (quality grade V).

(3) Pel'shma, Koshta, and Vologda rivers are suffer from pollution maximally.

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