Factors leading to high concentrations of pollutants in surface waters

Vladimir I. Sturman*

The Bonch-Bruevich Saint-Petersburg State University of Telecommunications, 22 Prospekt Bolshevikov, St. Petersburg, 193232 Russia

Abstract. The dependence of the frequency of excess of hygienic standards in surface waters on individual substances and complex indexes is investigated. It was found that in some cases, there are significant dependencies on production-induced factors (water withdrawal, wastewater discharge, percentage of plowed lands), while in other cases natural factors (climatic humidity, geological structure of catchment areas) are the predominant ones. Technogenic factors are predominate in case of high values of biochemical oxygen consumption, concentrations of petroleum products and nitrogen compounds. Natural factors of high concentrations are more significant for metal ions, chlorides, sulphates and total salt concentrations. With regard to metals, especially copper and zinc, very strict standards have been adopted in Russia, which also contributes to a very high repeatability and multiplicity of their excess. As for phenols and chemical oxygen consumption, the role of natural or man-made factors is less unequivocal.

1 Introduction

Land surface waters have complex interdependencies with other components of the Environment, consequently they are characterized by a diverse and variable chemical composition. So, the common principle of watercourse monitoring is comparing water characteristics in the background and control points. The dependence of surface water chemical composition on natural conditions of catchment areas includes a number of patterns that can be revealed by summarizing and analysing the monitoring results. Objective of this research is search of criteria for differentiation of excesses of maximum permissible concentrations (MPC) owing to the natural and technogenic reasons. In the available publications it is consecrated insufficiently.

2 Materials and Methods

Within the framework of this study, the published water quality indicators according to state monitoring data were compared with the characteristics of natural conditions and water use in the respective areas. Tables 1-3 presents the summary data on recurrence of

* Corresponding author: st@izh.com

exceeded MPC for individual substances and indicators as well as the characteristics of water use and the conditions of runoff formation for river basins in the territory of Russia.

The data were obtained on the basis of officially published data for 2020 [1]. The data about relative indicators of water consumption and water disposal are taken for river basins according to the Water Cadastre [2]. Information about forested, swamped, and percentage of ploughed lands of river basins is systematized on the basis of a number of references: Schemes of Comprehensive Use and Protection of Water objects (SCUPWO) [3-10] developed in the recent years, the State Water Cadastre [11-16], regional reports [17, 19] and individual publications [19]. If the references contained no ready-made characteristics of large river basins, they were determined as weighted averages by the areas tributary basins.

3 Results and Discussion

The obtained correlation factors cover not so much direct effects as indirect ones, reflecting the influence of less quantifiable "third" factors, such as the degree of climate aridity (the decisive factor for sulphate ion and chloride ion), the content of the corresponding metals in the rocks of the catchment areas. The shares of water withdrawal and wastewater discharge in relation to river runoff also increase naturally in arid climate.

Table 1. The scale of water use for river basins in Russia

River basins	Natural resource management indicators, %%				
	Water with-drawal	Wastewater discharge	Amount of woodlands	Bogginess	Ploughness
Neva	0.8	0.2	55	13	12
Pregolya	4.2	2.8	18	3	27
Northern Dvina	0.4	0.4	84	8	2
Volga	4.2	4.1	35	1	30
Oka	9.2	15.0	22	2	38
Kama	1.6	1.4	70	2	15
Belaya	1.6	1.7	40	1	12
Don	25.8	28.7	5	<1	75
Kuban	41.7	17.7	50	<1	8
Terek	98.5	11.7	17	<1	5
Ural (in the RF territory)	16.9	16.6	17	n/a	34
Ob	1.2	1.2	58	18	7
Yenisei	0.2	0.2	65	n/a	1
Lena	0.02	0.02	80	10	2
Kolyma	0.2	0.1	21.6	10	0.05
Amur	0.1	0.1	84	10	n/a

Table 2. Data on recurrence of exceeded MPC for individual substances and indicators,

River basins	Recurrence of exceeded MPC, %% (2020)												
	Biochemical oxygen consumption	Chemical oxygen consumption	Phenols	Petroleum products	NH_4	NO_2	Fe	Mn	Cu	Zn	SO_4	Cl	Total salt contentrations
Neva	4.39	89.5	n/a	n/a	n/a	1.52	34.2	35.1	97.4	75.4	n/a	n/a	n/a
Pregolya	100	100	n/a	n/a	n/a	88.5	98.5	n/a	n/a	n/a	44.1	47.1	32.5
Northern Dvina	23.7	100	n/a	12.4	n/a	1.86	96.8	84.3	62.7	13.3	1.28	1.29	1.29
Volga	44.4	83.8	38.9	18.6	27.6	29.8	57.6	n/a	77.3	36.6	17.1	0.88	3.25
Oka	64.7	78.4	56.9	28.2	46.4	59.2	55.8	n/a	73.5	47.1	16.4	0.34	2.36
Kama	24.6	75.9	41.4	12.3	13.8	13.6	66.4	89.9	84.8	31.6	15.8	1.24	3.27
Belaya	38.0	64.4	5.94	23.4	6.8	7.84	65.9	96.9	99.6	57.9	17.4	2.17	4.34
Don	84.2	86.2	16.9	43.3	14.6	48.7	47.9	n/a	52.5	3.5	61.7	10.8	26.3
Kuban	21.7	58.5	41.7	37.4	2.04	16.3	64.6	n/a	79.9	6.32	41.0	n/a	n/a
Terek	31.5	63.1	8.33	7.64	24.3	20.3	25.0	70.8	10.4	3.5	48.1	n/a	n/a
Ural (in the RF territory)	58.7	90.0	2.1	16.1	15.7	25.4	27.5	75.6	100	40.4	50.4	8.78	4.74
Ob	43.9	64.8	31.2	33.9	19.9	21.6	58.3	81.1	84.7	39.3	13.4	2.85	5.48
Yenisei	13.3	46.2	37.8	17.9	3.48	5.08	47.4	32.2	28.7	16.3	2.05	0.85	0.81
Lena	11.4	65.7	69.8	6.91	2.89	9.9	51.3	55.6	72.4	23.5	1.44	0.41	0.21
Kolyma	14.8	23.5	82.0	36.8	37.8	12.2	44.3	89.6	76.4	14.6	3.82	n/a	n/a
Amur	26.5	61.6	8.27	19.3	16.8	5.49	81.8	67.6	59.2	22.6	2.87	n/a	0.2

Table 3. Correlation relationships between exceeded MPC and characteristics of water use (Pearson correlation indices)

	Biochemical oxygen consumption	Chemical oxygen consumption	Phenols	Petroleum products	NH_4	NO_2	Fe	Mn	Cu	Zn	SO_4	Cl	Total salt contentrations
On water withdrawal	0.07	-0.07	**-0.35**	-0.09	0.03	0.08	**-0.43**	0.02	**-0.58**	**-0.47**	**0.62**	0.16 (**0.90**)	**0.51**
On waste water discharge	**0.53**	0.22	-0.30	**0.47**	0.07	**0.42**	**-0.33**	0.13	-0.13	**-0.32**	**0.82**	0.08 (**0.82**)	**0.45**
On amount of woodland	**-0.66**	-0.08	0.16	**-0.44**	**-0.51**	**-0.65**	**0.40**	-0.24	0.05	0.05	**-0.74**	**-0.48 (-0.68)**	**-0.65**
On bogginess	**-0.44**	-0.27	0.124	0.30	-0.11	**-0.41**	-0.29	-**0.50**	-0.06	-0.06	**-0.47**	-0.15 (0.**48**)	-0.20
On ploughness	**0.77**	**0.49**	**-0.34**	**0.42**	0.21	**0.63**	-0.07	0.16	0.06	-0.01	**0.65**	0.26 (**0.74**)	**0.61**

Notes:
1. Statistically significant correlations are in bold.
2. Correlation values for chlorides are given in parentheses if the Pregolya River whose lower reaches are subject to salinization by waters of the Kaliningrad Bay is excluded from the sample [17].

The dominant impact of production-induced pollution factors is expressed by direct dependence of concentrations on water consumption and wastewater discharge, ploughness at inverse dependence on amount of woodland (biochemical oxygen consumption, petroleum products, nitrogen compounds). In other cases, natural factors such as climatic conditions (chlorides, sulphates, total salt content) and the geological structure of the catchment areas (metals) predominate.

High repeatability of exceeded fishery MPC of metals in the water of rivers with predominantly forested catchment areas (European North, Siberia, Far East) also reflects the features of the ecological standardization system adopted in the Russian Federation. As follows from the comparison given in Table 4, the standards being in force in Russia are much (up to tens of times) stricter than similar indicators adopted, in particular, in the European Union, moreover this concerns the water objects specifically designed for fish breeding [20].

Table 4. Maximum permissible concentrations of pollutants in water objects adopted in Russia and the European Union

Parameters	RF standards, mg/dm^2	EU standards, mg/dm^2
Chemical oxygen consumption	15	5 [21]
NH_4	0.5	1 [22]
NO_3	40	50 [21]
NO_2	0.08	0.5 [21]
Fe	0.1	0.2 [21]
Mn	0.01	0.05 [21]
Cu	0.001	0.04 [22], rough value for salmon and carp water objects)
Zn	0.01	0.3 [22], mandatory value for salmon water objects
SO_4	100	250 [21]
Cl	300	250 [21]

4 Conclusions

Since MPCs in river water are exceeded to the greatest extent for metals as published in the State Reports, this means that the predominant contribution to formation of generalized water quality indicators is made not so much by production-induced pollution as by natural factors along with strict standards adopted in Russia. Excesses of MPC caused by the natural reasons not only are widespread, but also can be divided into climatic caused increased concentration covering the whole natural zones, and the geologically caused increased concentration dated for elements of a geological structure.

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