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Study of the self-cleaning ability of a reservoir and watercourses by hydrochemical indicators of Akmola region for 2018

Abstract. *The article discusses the self-cleaning ability of lakes, rivers, and reservoirs of the Akmola region in terms of oxygen, as well as the influence of certain hydrochemical indicators such as (sulfates, chlorides, magnesium, salt ammonium, nitrite nitrogen, fluorides, total iron, zinc, manganese, copper, phenol). Among the chemical factors that inhibit the self-cleaning ability of reservoirs, one can note an increased content of salt sulfates, chlorides, calcium, magnesium, zinc, and copper phenol. ammonium, nitrite nitrogen, total iron, and copper. An assessment of the self-cleaning capacity of water bodies in the Akmola region was given based on oxygen indicators: the amount of dissolved oxygen in the water and the biological oxygen demand (BOD5). Rivers and lakes, based on the results obtained, were divided into six classes of self-cleaning ability, and a graph was also built from which among the studied water bodies, according to general annual indicators, lakes with low self-cleaning ability prevail. It has been established that the self-purification potential of waters can be influenced by both the excess of the content of individual hydrochemical components and the amount of the exceeded components, which can have a synergistic effect. Along with this, we studied which of the accompanying hydrochemical components affect the purification potential of water in lakes and rivers.*

Keywords: *reservoirs, watercourses, the self-cleaning ability of surface waters, biological capacity of oxygen, solubility of oxygen.*

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Introduction

Justification of the necessity and relevance of the study: In the introduction, the authors focused only on the area of their research, I would suggest for the next article briefly highlight the problem in other regions, to present the global significance and applicability of the study.

Among the challenges of our time, the issue of the loss of the quality of surface water resources is becoming more acute [1,2]. Pollution of rivers and lakes is a hot topic in many countries of the world. Of course, measures should be taken to prevent pollutants from entering surface waters, but do not lose sight of the fact of natural self-purification in them. The ability to self-purify in lakes and rivers is a multifactorial process that allows you to maintain chemical homeostasis in water and ensure the vital activity of all hydrobionts. However, the problem of reducing and even losing this ability of reservoirs due to the ingress of persistent toxicants or a combination of different pollutants that can act with different activities under different hydrological regimes is increasingly being raised [3,4]. Knowledge of the conditions of self-purification, and their peculiarities in different types of rivers and lakes can help preserve the quality of water resourcand es, the health of the entire aquatic ecosystem.

Natural waters differ from aqueous solutions of mineral and organic substances by the presence of complex communities of living organisms and a constant concentration of chemically active particles and compounds. With the participation of these organisms and particles, the synthesis and destruction of organic substances, the transformation of their forms, and, to a large extent, the migration of chemical elements are carried out.

The purpose of this work was: to carry out a comparative analysis of the self-cleaning ability of reservoirs and watercourses of the Akmola region in terms of oxygen indicators, as well as the influence of individual hydrochemical components [5,6,7,8,9].

In the Akmola region, the average results of hydrochemical studies for 2018 were taken in the following streams and reservoirs: river - Esil, Nura, Akbulak, Sarybulak, Zhabai, Bettybulak, Kypshakty, Shagalaly, lake - Sultangeldy, Zerendy, Kopa, Shabakty, Ulken, Kishi Shabakty, Sulukol, Karasye, Maybalyk, Tekekol, Katarkol, Lebyazhye. In total, 8 rivers, 13 lakes, one Nura-Esil canal, and the Vyacheslavskoe reservoir were considered.

Materials and research methods

We have studied such indicators as the amount of dissolved oxygen R and BOD_5 in the studied lakes and rivers. And calculated the ratio of these indicators as the ratio of photosynthetic activity in the reservoir to its destructive ability: R/BOD_5. The higher this ratio, the higher the potential for self-cleaning capacity in water bodies, and vice versa - the lower the ratio, the lower the self-cleaning capacity of the water body.

The content of the following components was studied in lakes and rivers: pH, sulfates, chlorides, calcium, magnesium, saline ammonium, nitrite nitrogen, fluorides, total iron, zinc, manganese, copper, phenol. Taking into account the concentration of substances in water (Ci) and their maximum permissible content (MPCi), several components (n) were used to calculate the hydrochemical index of water pollution (WPI) (table 3) [10,11,12].

$$ИЗВ = \frac{1}{n} * \sum_{i=1}^{n} \frac{Ci}{ПДКi} \qquad (1)$$

According to the results of the analyses of BOD_5 and the content of dissolved oxygen R, the R/ BOD_5 ratios were calculated (Table 1). The minimum value of 1,2 of the R/BOD_5 ratio was in Lake Maybalyk, the maximum value of 20,2 in the Bettybulak river (figure 1).

Table 1

Average annual oxygen indicators of surface waters of Akmola region for 2018

Name of reservoirs	BOD_5 mg / dm^3	The amount of dissolved oxygen R, mg / dm^3	R / BOD_5
reservoirs			
sil river	1,86±0,02	10,05±2,07	5,4
Akbulak river	3,21±0,008	8,18±1,25	2,5
Sarybulak river	3,34±0,08	7,69±2,14	2,3
Bettybulak river	0,51±0,05	10,30±3,04	20,2
Zhabay river	2,11±0,04	8,90±0,17	4,2
Kylshikty river	2,82±0,017	6,82±0,85	2,4
Chagalla river	1,69±0,03	8,87±1,54	5,2
Nura river	2,81±0,021	8,45±2,07	3
Nura-Esil Canal	2,32±0,07	7,20±1,22	3,1

reservoirs			
Sultankeldy lake	1,96±0,07	8,64±1,22	4,4
Reservoir-Vyacheslavskoe	1,30±0,36	11,60±3,21	8,9
Lake Kopa	1,68±0,09	9,64±2,11	5,7
Lake Zerenda	1,25±0,04	10,90±3,44	8,72
Burabay lake	1,22±0,07	8,59±2,37	7
Lake Ulken Shabakty	1,07±0,022	9,04±2,03	8,4
Lake Shchuchye	0,93±0,17	8,99±1,07	9,6
Lake Kishi Shabakty	1,25±0,034	9,02±1,11	7,2
lake Karasie	0,89±0,02	8,41±0,25	9,4
Sulukol lake	2.00±0,001	6.84±0,78	3,4
Lake Katarkol	2,98±0,01	7,88±0,54	2,6
Lake Tekekol	1,31±0,02	8,70±0,71	6,6
Lake Maybalyk	3,57±0,87	4,29±0,01	1,2
Lake Lebyazhye	1,44±0,021	7,25±1,13	5,0

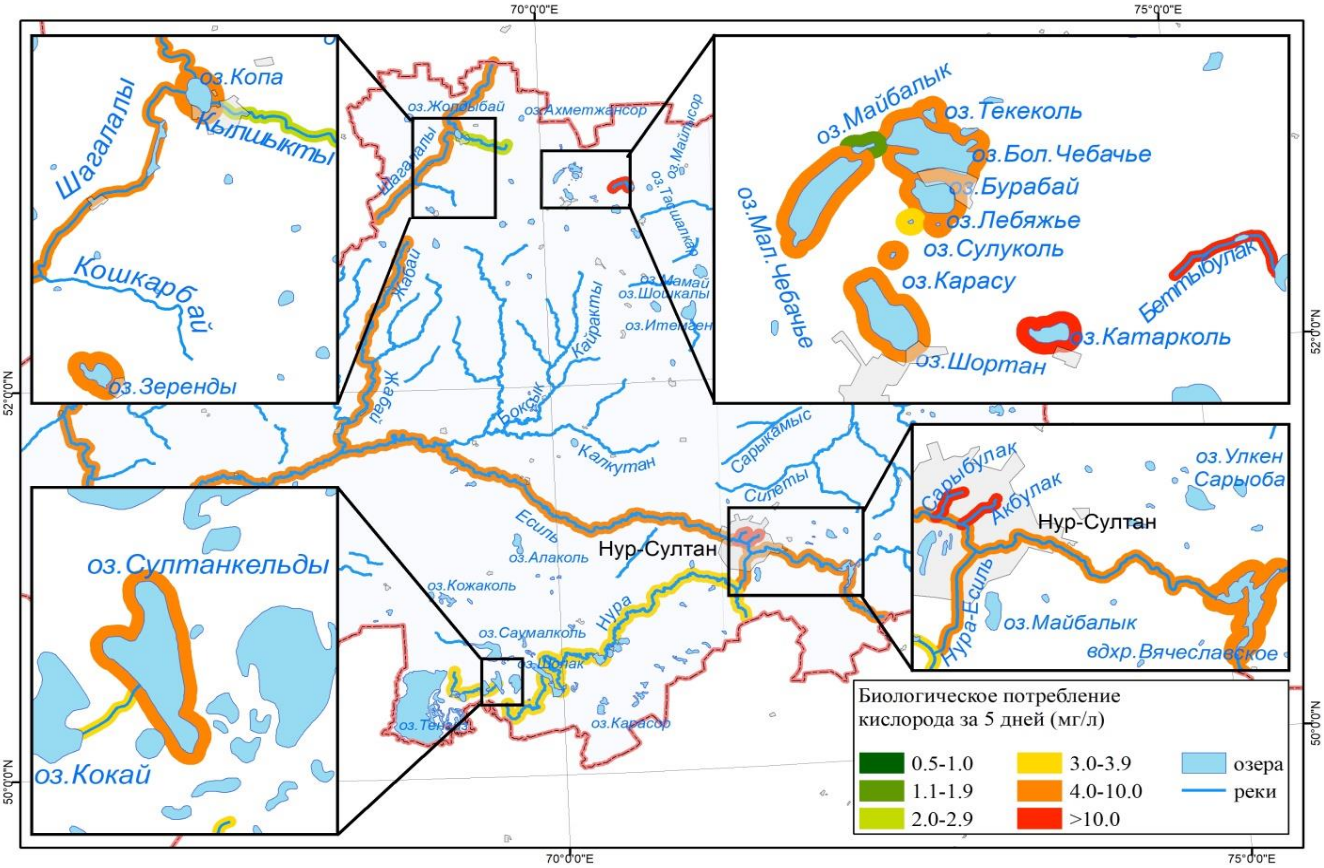

Figure 1. The mean annual oxygen indicators of surface waters on the map of the Akmola region

For the convenience of approximation, a variation series was compiled, divided into 6 classes, the size of the various class of streams is 3,1 (table 2) [13].

Table 2

Classes of watercourses by the self-cleaning ability

Class	R / BOD_5	f	Self-cleaning ability
I	1,2-4,3	9	very weak
II	4,4-7,5	7	weak
III	7,6-10,7	6	average
IV	10,8-13,9	-	average
V	17-17,1	-	good
VI	17,2-20,3	1	high

Results and discussions

As a result, the following graph was obtained (figure 2), from which it can be seen that among the studied rivers and lakes, according to annual indicators, rivers with a low self-cleaning ability prevail: Class I (R/BOD5 ratio 1,2-4,3), which is 39% of all bodies of water and watercourses. This class of watercourses includes Nura, Akbulak, Sarybulak, Zhabay, Kylshakty, Nura-Esil Canal, and reservoirs - Sulukol, Katarkol, Maybalyk.

To class II (R/BOD_5 4,4-7,5), the self-cleaning ability of the studied water bodies and watercourses was 30%. Rivers Esil and Shagalaly, lakes - Sultankeldy, Kopa, Burabay Kishi Shabakty, Tekekol.

III class 26% (R/BOD_5 7,6-10,7) is attributed to the Vyacheslavskoye Reservoir, reservoirs - Zerendy, Ulken Shabakty, Shchuchye, Karase.

IV classes (R/BOD_5 10,8-13,9) and V (R/BOD_5 17 – 17,1) in terms of the self-cleaning ability of water bodies and watercourses was - 0%.

in terms of self-cleaning ability VI class (R/BOD5 17,2 – 20,3), the Bettybulak river accounted for 4,3% of all streams and reservoirs.

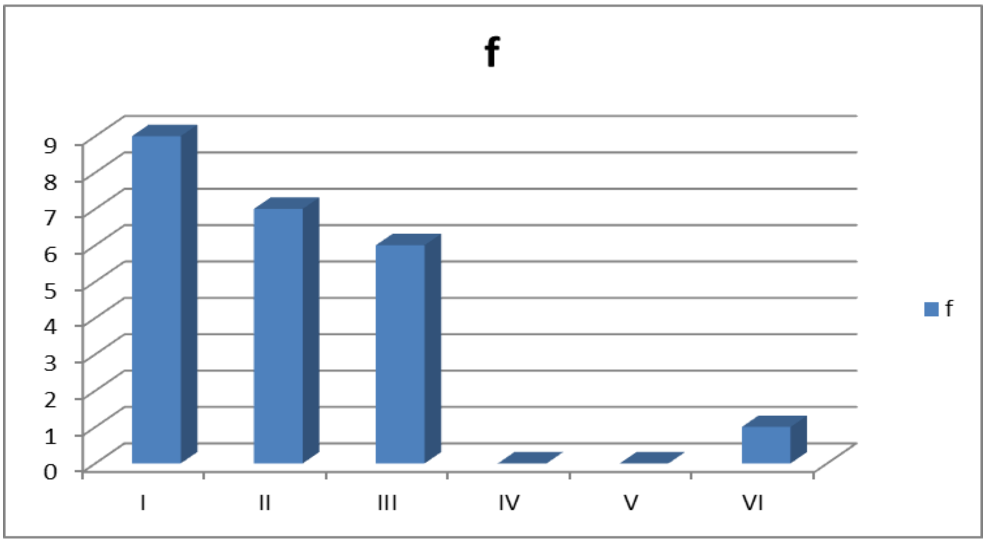

Figure 2. Numerical ratio of watercourses and reservoirs of Akmola region by class of ratio R/BOD_5

Hydrochemical components in the surface waters of the Akmola region for 2018 for the most priority pollutants are presented in (table 3).

Table 3

Hydrochemical components in surface waters of Akmola region for 2018

Name of reservoirs	pH	Class of reservoirs	The frequency rate of excess of MPC											
			Sulfates	Chlorides	Calcium	Magnesium	Ammonium Salt	Nitrite	Fluorides	Total iron	Zinc	Manganese	Copper	Phenol
MPC (mg / l)	-	-	100	300	-	-	0,5	0,02	0,75	0,1	0,01	0,01	0,001	0,001
Akbulak river	7,62	I	4,7±0,02	2,2±0,44	1,6±0,15	1,8±0,8	7,2±0,52	1,9±0,01	5,1±2,7	-	1,4±0,21	-	1,6±0,15	-
Sarybulak river	7,71	I	6,1±1,01	1,7±0,65	-	2,1±0,6	5.7±0,41	2,3±1,5	1,3±1,32	-	2,5±0,12	-	1,7±0,16	-
Zhabay river	8,08	I	1,5±0,18	-	-	-	1,5±0,74	2,3±0,4	-	3,4±0,32	-	14,1±8,07	-	-
Kylshikty river	7,83	I	-	-	-	-	2,8±0,32	-	1,9±0,78	5,3±2,1	-	209,5±48,21	-	-
Nura river	8,03	I	2,4±0,07	-	-	-	-	-	-	-	1,3±0,36	-	2,9±0,22	-
Nura Canal Esil	8,03	I	4,5±1,24	-	-	1,5±0,87	2,5±0,84	1,5±0,74	-	-	-	-	2,3±0,4	-
Sulukol lake	7,27	I	-	-	-	-	2,3±0,89	-	4.6±1,44	7,3±0,87	-	-	-	1,1±0,98
Lake Katarkol	9,04	I	1,3±0,24	-	-	1,8±0,15	-	-	11,0±0,5	-	-	-	-	-
Lake Maybalyk	8,72	I	45,2±6,12	43,1±5,16	-	40,5±3,7	2,8±0,21	2,2±0,95	6,7±2,2	1,5±0,14	-	-	1,7±0,16	1,1±0,77
Esil river	8,14	II	1,3±0,01	-	-	-	-	-	-	-	1,3±0,07	1,5±0,07	2,4±0,4	-
Chagalla river	7,95	II	-	-	-	-	-	-	-	1,5±0,02	-	63,4±11,78	-	-
Sultankeldy lake	8,33	II	1,5±0,04	1,2±0,20	-	1,5±0,14	-	-	-	-	-	-	1,4±0,21	-
Lake Kopa	8,25	II	1,6±0,96	-	-	-	-	-	-	-	-	5,9±2,27	-	-
Burabay lake	8,00	II	-	-	-	-	-	-	4,1±1,5	-	-	3,6±0,25	-	-
Lake Kishi Shabakty	8,76	II	12,4±1,22	6,1±2,04	-	10,0±1,12	1,6±0,44	-	16,1±1,8	-	-	5,0±1,65	1,2±1,2	-
Lake Tekekol	8,96	II	1,4±0,11	-	-	2,1±0,06	-	-	12,1±0,9	-	-	-	-	-
Reservoir-Vyacheslavskoe	8,16	III	-	-	-	-	-	-	-	-	1,1±0,87	-	2,3±0,4	-
Lake Zerenda	8,45	III	1,2±0,48	-	-	1,5±0,32	-	-	3,5±1,7	-	-	3,2±1,32	-	-
Lake Ulken Shabakty	8,76	III	2,8±0,27	-	-	2,2±0,87	-	-	1,75±2,4	-	-	1,6±0,48	-	-
Lake Shchuchye	8,30	III	-	-	-	-	-	-	8,0±2,97	-	-	2,0±0,24	-	-
lake Karasie	7,77	III	-	-	-	-	9,1±5,1	-	3,1±1,98	1,1±2,3	-	-	-	-
Lake Lebyazhye	7,17	III	-	-	-		-	1,4±0,41	4,7±0,7	3,9±1,4	-	-	-	1,2±0,24
Bettybulak river	7,54	V I	-	-	-	-	-	-	1,2±0,87	1,6±0,85	-	2,7±1,54	-	-

Excessive MPCs were recorded for substances from the groups sulfates, chlorides, calcium, magnesium, salt ammonium, nitrite nitrogen, fluorides, total iron, zinc, manganese, copper, and phenol.

In the Esil River, excess MPCs were recorded for substances sulfates – 1,3 MPC, heavy metals zinc (2+) – 1,3 MPC, manganese (2 +) – 1,5 MPC, copper (2 +) – 2,4 MPC.

In the Akbulak River, MPCs were exceeded for substances from the main ion groups: chlorides – 2,2 MPC, sulfates – 4,7 MPC, magnesium – 1,8 MPC, calcium – 1,6 MPC, nutrients: salt ammonium - 7, 2 MPC, fluorides – 5,1 MPC, nitrite nitrogen – 1,9 MPC, heavy metals: zinc (2+) – 1,4 MPC, copper (2 +) – 1,6 MPC.

In the Sarybulak River, excess MPCs were recorded for substances from the main ion groups: sulfates – 6,1 MPC, chlorides – 1,7 MPC, magnesium – 2,1 MPC, nutrients: salt ammonium – 5,7 MPC, nitrite nitrogen - 2 ,3 MPC, fluorides – 1,3 MPC, heavy metals: zinc (2+) – 2,5 MPC, copper (2 +) – 1,7 MPC.

In the Bettybulak River, MPCs were exceeded for substances from biogenic substances (fluorides – 1,2 MPC, total iron –1,6 MPC), heavy metals (manganese (2+) – 2,7 MPC).

In the Zhabai River, the excess was found for substances sulfates –1,5 MPC, nitrite nitrogen – 2,3 MPC, ammonium salt –1,5 MPC, total iron – 3,4 MPC, manganese (2+) – 14,1 MPC.

In the Kylshakty river, the excess of MPC was revealed for substances from the groups of biogenic substances: salt ammonium - 2.8 MPC, total iron - 5.3 MPC, fluorides - 1.9 MPC, heavy metals - manganese (2+) - 209.5 MPC.

In the Shagalaly River, excess MPCs were detected for substances from the groups of biogenic substances (total iron – 1,5 MPC), and heavy metals (manganese (2+) – 63,4 MPC).

In the Nura River, excess MPCs were recorded from sulfate ions – 2,4 MPC, heavy metals: copper (2 +) – 2,9 MPC, zinc (2+) -1,3 MPC.

In the Nura - Esil channel, the excess of MPC was recorded for ions: (sulfates -2,5 MPC, magnesium – 1,5 MPC), from biogenic substances (salt ammonium -2,5, nitrite nitrogen -1,6 MPC) and heavy metals (copper (2+) -2,3 MPC).

In Lake Sultankeldy, excess MPCs were recorded for substances from the main ion groups: sulfates – 3,2 MPC, magnesium – 1,5 MPC, chlorides – 1,2 MPC, heavy metals - (copper (2+) – 1,4 MPC.

In the Vyacheslavskoye reservoir - excess of MPC was recorded for heavy metals (copper (2+) -2,3 MPC, zinc (2+) -1,1 MPC).

In Lake Kopa, the water temperature exceeding the MPC was recorded for substances from the groups of the main ions (sulfates –1,6 MPC), heavy metals (manganese (2+) –5,9 MPC).

In Lake Zerendy, the excess was detected for substances from the groups of main ions (sulfates – 1,2 MPC, magnesium – 1,5 MPC), biogenic substances (fluorides –3,5 MPC), heavy metals (manganese (2+) –3, 2 MPC).

In Lake Burabay, MPCs were exceeded for substances from the groups of biogenic substances (fluorides – 4,1 MPC), and heavy metals (manganese (2+) – 3,6 MPC).

In Lake Ulken Shabakty, the excess of MPC was recorded for substances from the groups of main ions (sulfates – 2,8 MPC, magnesium – 2,2 MPC), biogenic substances (fluorides -17,5 MPC), heavy metals (manganese (2+) – 1,6 MPC).

In Lake Shchuchye, the excess of MPC was recorded for substances from the groups of biogenic substances (fluorides – 8,0 MPC), and heavy metals (manganese (2+) – 2,0 MPC).

In Lake Kishi Shabakty, excess MPCs were recorded for substances from the main ion groups (chlorides – 6,1 MPC, sulfates – 12,4 MPC, magnesium – 10,0 MPC), biogenic substances (fluorides – 16,1 MPC, ammonium salt – 1,6 MPC), heavy metals (manganese (2 +) – 5,0 MPC, copper (2+) – 1,2 MPC).

In Lake Karasye, the excess of MPC was recorded for substances from the groups of biogenic substances (salt ammonium – 9,1 MPC, total iron – 1,1 MPC, fluorides – 3,1 MPC).

In Lake Sulukol, the excess of MPC was recorded for substances from the groups of biogenic substances (fluorides – 4,6 MPC, ammonium salt – 2,3 MPC, total iron – 7,3 MPC), organic substances (phenols – 1,1 MPC).

In Lake Katarkol - excess of MPC was recorded for substances from the groups of main ions (magnesium – 1,8 MPC, sulfates – 1,3 MPC), biogenic substances (fluorides – 11,0 MPC).

In Lake Tekekol, the excess of MPC was recorded for substances from the groups of main ions (magnesium - 2.1 MPC, sulfates - 1.4 MPC), and biogenic substances (fluorides - 12.1 MPC).

In Lake Maibalyk, the excess of MPC was recorded for substances from the groups of main ions (magnesium – 40,5 MPC, sulfates – 45,2 MPC, chlorides – 43,1 MPC), biogenic substances (total iron – 1,5 MPC, ammonium salt -2,8 MPC, fluorides - 6.7 MPC, nitrite nitrogen – 2,2 MPC), heavy metals (copper (2+) – 1,7 MPC), organic substances (phenols – 1,1 MPC).

In Lake Lebyazhye, MPCs were exceeded for substances from the groups of biogenic substances (total iron – 3,9 MPC, fluorides – 4,7 MPC, nitrite nitrogen – 1,4 MPC), organic substances (phenols - 1.2 MPC).

Conclusion

Thus, summing up the results of this section of research for 2018 on watercourses and reservoirs of the Akmola region, it should be noted that:

- in surface waters, exceeding the maximum permissible concentration for substances from the groups sulfates, chlorides, calcium, magnesium, saline ammonium, nitrite nitrogen, fluorides, total iron, zinc, manganese, copper, phenol was recorded;

- among the studied rivers, according to annual indicators, rivers with a low self-cleaning ability prevail: from class I (ratio R/BOD_5 1,2-4,3), which is 30% of all watercourses. This class of watercourses includes the rivers Nura, Akbulak, Sarybulak, Zhabay, Kylshakty, the Nura-Esil Canal, and the reservoirs - Sulukol, Katarkol, Maybalyk;

- that the Bettybulak river prevails among the studied reservoirs in terms of annual indicators – 4,3% with a high self-cleaning ability - VI class.

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Ақмола облысының 2018 жылғы гидрохимиялық көрсеткіштері бойынша су қоймасы мен су ағындарының өзін-өзі тазарту қабілетін зерттеу

Аңдатпа. Мақалада Ақмола облысының көлдерінің, өзендерінің және су қоймаларының оттегі көрсеткіштері бойынша Өзін-өзі тазарту қабілеті, сондай-ақ жекелеген гидрохимиялық көрсеткіштердің әсері (сульфаттар, хлоридтер, магний, тұзды аммоний, нитритті азот, фторидтер, жалпы темір, мырыш, марганец, мыс, фенол) қарастырылады. Су объектілерінің өзін-өзі тазарту қабілетін тежейтін химиялық факторлардың ішінде тұзды аммонийдің, нитрит азотының, жалпы Темірдің, Мыстың жоғарылауын атап өтуге болады. Ақмола облысы су айдындарының өзін-өзі тазарту қабілетіне оттегі көрсеткіштері негізінде баға берілді: судағыерітілген оттегінің мөлшері және оттегінің биологиялық қажеттілігі (БПК5). Алынған нәтижелер негізінде өзендер мен көлдер өзін-өзі тазарту қабілетінің алты класына бөлінді, сонымен қатар график жасалды, зерттелген су қоймаларының арасында жалпы жылдық көрсеткіштер бойынша Өзін-өзі тазарту қабілеті төмен көлдер басым екендігі көрінеді. Судың өзін-өзі тазарту потенциалына жекелеген гидрохимиялық Компоненттердің мөлшері де, синергетикалық әсер етуі мүмкін Компоненттердің мөлшері де әсер етуі мүмкін екендігі анықталды. Сонымен қатар, олар гидрохимиялық компоненттердің қайсысы көлдер мен өзендердегі судың тазарту әлеуетіне әсер ететінін зерттеді.

Түйін сөздер: су қоймалары, су қоймаларының өзін-өзі тазарту қабілеті, фотосинтез, оттегі, гидрохимия, BPK_5.

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Изучение самоочищающей способности водоемов и водотоков по гидрохимическим показателям Акмолинской области за 2018 год

Аннотация. В статье рассматривается самоочищающая способность озер, рек и водохранилищ Акмолинской области по показателям кислорода, а также влияние отдельных гидрохимических показателей, таких как сульфаты, хлориды, магний, аммоний солевой, азот нитритный, фториды, железо общее, цинк, марганец, медь, фенол. Среди химических факторов, угнетающих самоочистительную способность водоемов, можно отметить повышенное содержание сульфатов, хлоридов, кальция, магния, аммония солевого, азота нитритного, фторидов, железа общего, цинка, марганца, меди, фенола.

Была дана оценка самоочищающей способности водоемов Акмолинской области на основании кислородных показателей: количество растворенного кислорода в воде и биологическая потребность кислорода ($БПК_5$). Реки и озера на основании полученных результатов были распределены по шести классам самоочищающей способности, а также построен график, из которого видно, что среди изученных водоемов по общегодовым показателям преобладают озера с низкой самоочищающей способностью. Установлено, что на самочистительный потенциал вод могут влиять как превышение содержание отдельных гидрохимических компонентов, так и количество превышаемых компонентов, которые могут дать синергетический эффект. Наряду с этим изучали, какие из сопутствующих гидрохимических компонентов оказывают влияние на очистительный потенциал воды в озерах и реках.

Ключевые слова: водоемы, водотоки, самоочищающая способность поверхностных вод, биологическая потребность кислорода, растворимость кислорода.

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