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STUDY OF ALGAE FROM WASTEWATER TREATMENT PLANTS IN ALMATY AND THEIR ROLE IN BIOMONITORING

This study focuses on investigating the algae of the wastewater treatment plants of Almaty City and its role in biomonitoring. Algae, including microalgae and cyanobacteria, performs self-purification functions, regulates biogeochemical cycles, and maintains the balance of substances in ecosystems. A comprehensive analysis of the composition of algal flora and the dynamics of microbial community abundance was conducted in the sedimentation tank after mechanical treatment, the wastewater channel after biological treatment, the wastewater divider, and the Sorbulak Storage Lake. A comprehensive analysis of the composition and dynamics of the algae was conducted in the sedimentation tank after mechanical treatment, the wastewater channel after biological treatment, the wastewater divider, and the Sorbulak Storage Lake. The key role of algae in biological treatment and biomonitoring processes was established. The variation in species composition aligns with pollution levels: cyanobacteria prevail in regions with elevated organic contamination, whereas green algae and diatoms become more prominent as pollution diminishes. Bacteriological indicators demonstrate the effectiveness of the treatment, showing a sequential reduction in the number of microorganisms at each stage of the process. Analysis of the saprobity index revealed a gradual decrease in organic pollution, transitioning from polysaprobic conditions in the sedimentation tank to significant water quality improvement in the Sorbulak Storage Lake. The results of the study confirm active processes of biological self-purification and stabilization of biological balance at the final stages of purification of the wastewater treatment plants of Almaty.

Key words: algae, biomonitoring, wastewater, bioindication, microalgae indicators of saprobity.

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Алматы тазарту қондырғыларының ағынды суларының альгофлорасын зерттеу және олардың биомониторингтегі рөлі

Бұл зерттеу Алматы қаласы тазарту қондырғыларының ағынды суларындағы альгофлораны және оның биомониторингтегі рөлін зерттеуге арналған. Альгофлора, соның ішінде микробалдырлар мен цианобактериялар, экожүйелерде өзін-өзі тазарту, биогеохимиялық циклдерді реттеу және заттардың тепе-теңдігін сақтау қызметтерін атқарады. Механикалық тазалаудан кейінгі тұндырғышта, биологиялық тазалаудан кейінгі ағынды суда, субөлгіште және Сорбұлақ су қоймасында альгофлора құрамының кешенді талдауы мен микробтық қауымдастық санының динамикасы зерттелді. Альгофлораның биологиялық тазарту және биомониторинг процестеріндегі негізгі рөлі анықталды. Түрлік құрамының динамикасы ластану деңгейімен тығыз байланысты: органикалық заттар жоғары аймақтарда цианобактериялар басым, ал ластану азайған сайын жасыл және диатомды балдырлар арта бастайды. *Тазарту кезеңдерінің өтуіне қарай микроорганизмдер саны біртіндеп азаятыны анықталды, бұл бактериологиялық тазарту процесінің тиімділігімен дәлелденеді.* Сапробтық индексін талдау барысында органикалық ластану деңгейінің төмендеуі анықталды, тұндырғышта полисапробтық жағдайлар басым болса, Сорбулак су қоймасында су сапасының айтарлықтай жақсаруы байқалды. Зерттеу нәтижелері Алматы қаласының тазарту қондырғыларының тазартудың соңғы кезеңдерінде биологиялық өзін-өзі тазартудың және биологиялық тепе-теңдікті тұрақтандырудың белсенді процестерін растайды.

Түйін сөздер: альгофлора, биомониторинг, ағынды сулар, биоиндикация, сапробтық индикатор-микробалдырлар.

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Изучение альгофлоры из сточных вод очистных сооружений Алматы и их роль в биомониторинге

Настоящее исследование посвящено изучению альгофлоры сточных вод очистных сооружений города Алматы и её роли в биомониторинге. Альгофлора, включая микроводоросли и цианобактерии, выполняет функции самоочищения, регуляции биогеохимических циклов и поддержания баланса веществ в экосистемах. Комплексный анализ состава альгофлоры и динамики численности микробного сообщества был проведён в отстойнике после механической очистки, в сточном канале после биологической очистки, в вододелителе сточных вод и в озере-накопителе Сорбулак. Установлена ключевая роль альгофлоры в процессах биологической очистки и биомониторинга. Динамика видового состава связана с уровнем загрязнения: в зонах высокой органической нагрузки преобладают цианобактерии, при снижении загрязнения возрастает доля зелёных и диатомовых водорослей. Бактериологические показатели свидетельствуют об эффективности очистки, демонстрируя последовательное снижение численности микроорганизмов на каждом этапе процесса. Анализ индекса сапробности показал последовательное снижение органического загрязнения, от полисапробных условий в отстойнике до значительного улучшения качества воды в озере-накопителе Сорбулак. Результаты исследования подтверждают активные процессы биологического самоочищения и стабилизацию биологического равновесия на последних этапах очистки очистных сооружений города Алматы.

Ключевые слова: альгофлора, биомониторинг, сточные воды, биоиндикация, микроводоросли-индикаторы сапробности.

Introduction

The quality of wastewater discharged into reservoirs is a key indicator of the state of ecosystems and water resources in urbanized areas. Wastewater treatment, especially from radioactive and organic pollutants, is a serious environmental problem requiring cost-effective and environmentally safe solutions. In this framework, utilizing microalgae for wastewater treatment and nutrient recovery aligns with the principles of circular bioeconomy, which focus on waste management and ecosystem preservation. Integrating microalgae cultivation with wastewater treatment not only enhances water quality but also generates valuable biomass for further applications. Due to their ability to bioaccumulate, biotransformation and adsorption, microalgae are considered as natural agents capable of reducing the level of various pollutants, including radioactive substances [1].

One of the largest artificial reservoirs in Kazakhstan and the world are wastewater storage facilities in Almaty and Almaty region, such as the Sorbulak Storage Lake and ponds of the Right-Bank Sorbulak Canal (RSC). Sorbulak Storage Lake, located northwest of Almaty, is a natural enclosed basin used for the collection, post-treatment and storage of wastewater. These reservoirs accumulate significant amounts of fresh, but not clean enough water, which can potentially be used for household needs. However, pollution of water bodies by wastewater from wastewater treatment plants requires systematic monitoring and assessment of their impact on aquatic ecosystems [2].

Phototrophic microorganisms grown on wastewater can serve as raw materials for the production of liquid fertilizers, biodiesel, glycerin and biogas. The main indicator of water quality is the specific and quantitative composition of the biocenosis. Even minor changes in the species composition of the biocenosis may indicate contamination of water bodies, which makes the analysis of aquatic biocenoses an important tool for assessing water quality. The predominance of organisms resistant to certain types of pollution indicates the presence of relevant pollutants. Thus, the composition of microalgae is a key indicator of the productivity of reservoirs and the state of aquatic ecosystems [3, 4, 5].

Under anthropogenic influence in Almaty, key indicators of the ecological state of water bodies include fluctuations in bacterial abundance and the saprobity index, which reflects the level of organic pollution. These parameters reflect the ability of aquatic ecosystems to self-purify. Microalgae and cyanobacteria, due to their ability to absorb nutrients and decompose organic compounds, are actively used in the biological purification of reservoirs. They help to reduce the level of microbiological contamination and improve water quality. However, the influence of these organisms on the dynamics of bacterial abundance and the saprobicity index in water bodies, such as Sorbulak Storage Lake and the Almaty sewage treatment plants, requires a more detailed study.

In this context, investigating the species diversity of algae in the reservoirs of wastewater treatment plants in Almaty and their role in biomonitoring is a relevant research priority. The scientific novelty of this study lies in the comprehensive assessment of wastewater quality at Almaty's treatment facilities and the Sorbulak Storage Lake, along with an in-depth analysis of algal species diversity and its significance in biomonitoring.

Materials and Methods

Location of the study and sampling. Water samples were collected from wastewater treatment plants in Almaty and the Sorbulak Storage Lake (43°41'8" N, 76°35'21" E). The pH of the analyzed samples ranged from neutral to mildly alkaline. Water temperature during the sampling period varied between 15 and 23°C, influenced by seasonal and climatic factors.

Sampling was conducted using pre-sterilized 1-liter plastic bottles. For microbiological and hydrochemical analysis, water samples were filtered through membrane filters with a pore size of 0.45 microns. The collected samples were transported to the laboratory and stored at 4°C until further processing [6, 7].

Biological mats, concretions, and sediments were collected using sterile forceps and spatulas, then transferred into sterile glass containers. For analyzing planktonic cyanobacteria strains, water samples were preserved in sterile glass vials and test tubes. Sampling took place during the spring and autumn seasons of 2023 and 2024.

Water temperature was measured on-site using a thermometer, while pH values were determined with a digital pH meter (HM Digital PH-80, USA) [8].

Species composition determination and bioindication methods. To study the algae, Premere and Betical light microscopes were used with magnification from ×40 to ×100, with the ability to display images on a monitor. In each sample, 30-40 visual fields were analyzed on five specimens. The number of detected cells was expressed in cells per 1 ml of water.

The identification of algae species was carried out both in the native and in the fixed state of cells. Solutions of formaldehyde (4%) and iodine (Lugol's solution) were used as fixatives. The species identification was carried out using modern determinants [9-18].

Indices of species richness and diversity were used to characterize the species structure of communities. The state of freshwater ecosystems was assessed by phytoplankton using the Pantle and Bukka method modified by Sladechka [19-23].

The physico-chemical composition of water, including the content of petroleum products, was determined in the Republican Scientific-Industrial and Informational Center "Kazecology" using the current regulatory documents [24-28].

Results and discussions

The wastewater treatment plants are situated southwest of the village of Japek-Batyr (December 12). Mechanical treatment facilities are positioned on the right bank, whereas biological treatment takes place on the left bank, beyond the coastal water protection zone. Following the complete cycle of mechanical and biological purification, the treated wastewater is discharged into the Sorbulak Storage Lake. In order to prevent possible emergencies, an emergency discharge system of treated wastewater into the Ili River is provided. Additionally, before being discharged into a water body, the water undergoes the final stage of post-treatment in biological ponds (Figure 1).

The results of the study of the physical and chemical composition of wastewater from the reservoir system of the Almaty wastewater treatment plants and the Sorbulak Storage Lake showed that the concentrations of a number of substances exceed the maximum permissible values (Table 1).

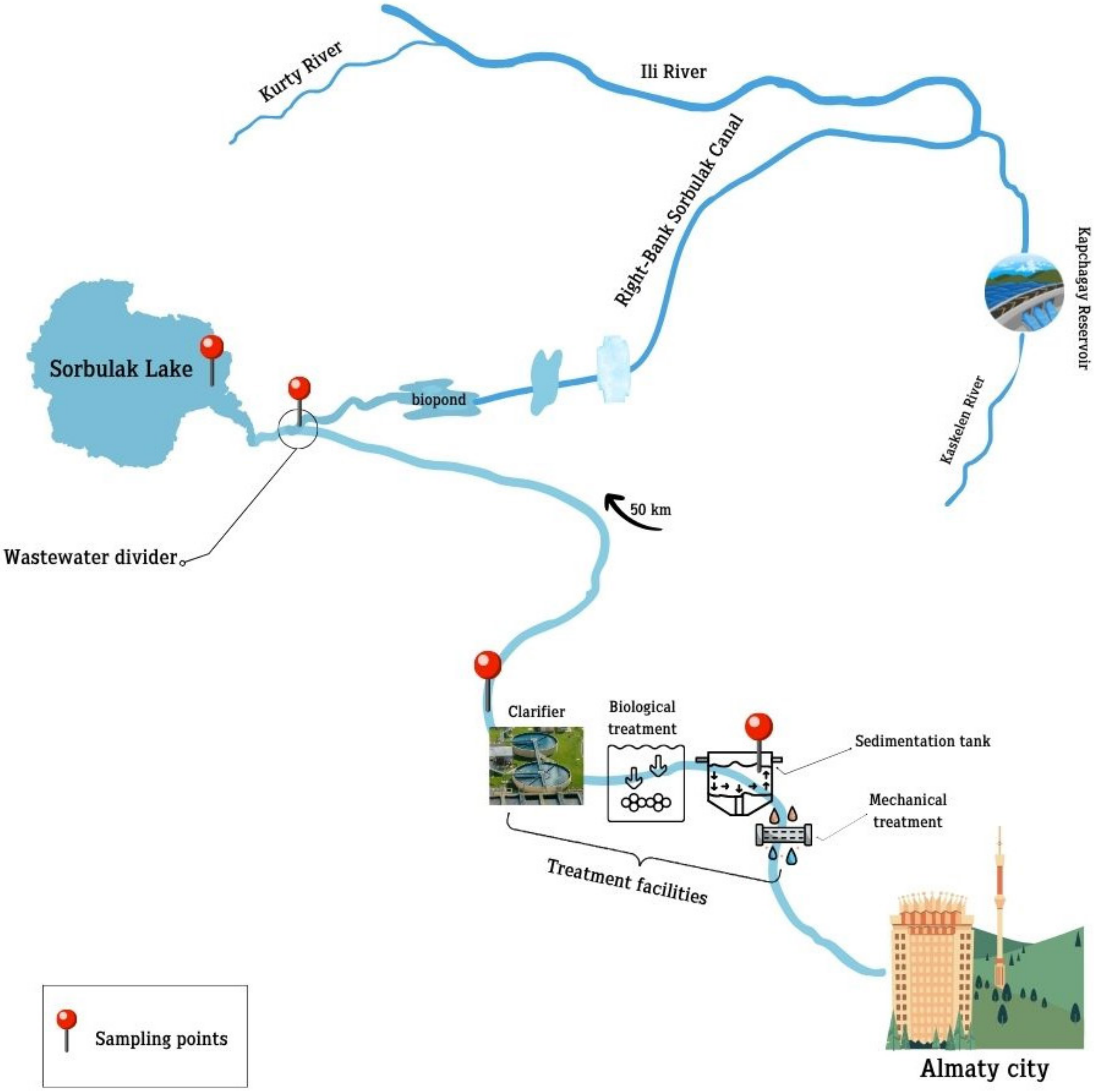

Figure 1 – Scheme of wastewater treatment plants in Almaty

Table 1 – Physical and chemical composition of wastewater treatment plants in Almaty

Indicators		Sedimentation tank after mechanical treatment	Wastewater channel after biological treatment	Wastewater divider	Sorbulak Storage Lake
1	Temperature (^{0}C)	16	18-20	18-23	18-23
2	pH	7,0	7,8	7,5	7,2
3	BOD_5, O_2 mg/dm³	83,4	55,4	38,9	27,1
4	Oxidation, O_2 mg/dm³	23,6	19,1	14,7	9,0
5	Chloride, mg/dm³	281,52	69,34	42,6	35,66
6	Sulfate, mg/dm³	86,6	59,6	43,6	18,1

Continuation of the table

Indicators		Sedimentation tank after mechanical treatment	Wastewater channel after biological treatment	Wastewater divider	Sorbulak Storage Lake
7	Ammonia, mg/dm³	29,0	13,6	4,6	1,4
8	Ammonium nitrogen, mg/dm³	35,2	28,1	12,3	5,0
9	Nitrite nitrogen, mg/dm³	7,7	1,4	0,3	0,001
10	Nitrate nitrogen, mg/dm³	13,2	7,8	3,0	2,1
11	Phosphate, mg/dm³	5,9	3,6	1,7	0,6
12	Phenol, mg/dm³	0,027	0,017	0,002	-
13	Iron, mg/dm³	1,32	0,29	0,14	0,11
14	Lead, mg/dm³	0,0038	0,0032	0,0017	-
15	Copper, mg/dm³	0,033	0,023	0,021	-
16	Zinc, mg/dm³	0,043	0,035	0,023	-
17	Cadmium, mg/dm³	0,00089	0,00074	0,0005	-
18	Calcium, mg/dm³	59,82	58,71	53,22	50,0
19	Petroleum products, mg/dm³	3,29	2,77	0,81	0,40

Comparative analysis of the algae from the reservoir system of the Almaty wastewater treatment plants. We have studied the species diversity of microalgae – inhabiting the reservoirs from wastewater treatment plants in Almaty. According to the results of an algological study, 22 types of microalgae were identified in the sedimentation tank after mechanical treatment.

All microalgae develop, forming films on the walls of the sump. Of the specific types of microalgae, 36% are green, 20% are diatoms, 40% are blue-green, and 4% are euglenic algae (Figure 2). Blue-green algae, such as *Phormidium foveolarum, Oscillatoria tenius, Oscillatoria irrigua,* and *Oscillatoria willei*, dominate among all microalgae. It is known that species of the *Oscillatoria* genera are found in large numbers at the initial stages of wastewater treatment plants.

56 species of microalgae were identified in samples of water from the wastewater channel after biological treatment. Of these, green and diatoms dominate in terms of species composition (Figure 2). Most often often found species: *Ankistrodesmus minutissimus*, *Chlorella vulgaris var. vulgaris*, *Coelastrum microporum*, *Closterium acerosum*, *Oocystis crassa*, *Pediastrum angulosum var. angulosum*, *Pediastrum simplex var. simplex*, *Scenedesmus obliquus var. obliquus*, *Scenedesmus granulatus*, *Scenedesmus quadricauda var. quadricauda*, *Cyclotella kuetzingiana*, *Cyclotella meneghiniana*, *Navicula cryptocephala*, *Navicula hasta*, *Nitzschia frustulum*, *Nitzschia hantzschiana*, *Stauroneis anceps*, *Stauroneis anceps f. gracilis*, *Synedra ulna*, *Synedra pulchella var. lanceolata*, *Stephanodiscus hantzschii*, *Anabaena variabilis*, *Anabaena constricta*, *Merismopedia punctata*, *Merismopedia glauca*, *Phormidium foveolarum*, *Phormidium ambiguum*, *Oscillatoria angustissima*, *Oscillatoria tenuis*, *Oscillatoria irrigua*, *Oscillatoria willei*, *Spirulina meneghiniana*, *Euglena viridis*, *Euglena caudata*, *Euglena satelles*, *Euglena acus*. The studied reservoirs differ in the species diversity of microalgae. Among certain species, diatoms play a leading role (36%).

A total of 62 species of microalgae have been identified in the wastewater divider of the Almaty city wastewater treatment plants, of which 36% are green, 33% are diatoms, 20% are blue-green, and 11% are euglenic algae (Figure 2). Among certain types of microalgae, green ones dominate, especially species of the order *Chlorococcales*, of which the most common are *Ankistrodesmus minutissimus, Chlorella vulgaris var. vulgaris, Coelastrum microporum, Pediastrum boryanum var. boryanum, Pediastrum duplex var. duplex, Scenedesmus obliquus var. obliquus*, as well as the types of genera *Volvocales, Desmidiales*. In the order or *Chlamydomonadales* most frequently found species are *Chlamydomonas rubrifila, Chlamydomonas monadina*, *Chlamydomonas reinhardtii* and from the order *Desmidiales – Closterium acerosum.* As can be seen from Figure 2, diatoms occupy the second place. Of the specific types of microalgae, 21 belong to diatoms. The following species have been identified from the order *Thalassiosirales*: *Cyclotella kuetzingiana, Cyclotella meneghiniana,* *Stephanodiscus hantzschii*; from the order *Araphidiales – Synedra ulna, Synedra acusfrom the order Bacillariales* and *Naviculales* – species *Achnanthes, Cymbella, Gomphonema, Hantzschia, Navicula, Nitzschia, Pinnularia, Stauroneis.*

Among the blue-green algae, 12 species have been identified, of which the dominant ones are *Anabaena flos-aquae f. minor, Anabaena constricta, Phormidium foveolarum*. Among the euglenovs most frequently meet species *Euglena satelles*. Of all the specific types of algae, 60% are indicators of water saprobicity.

At the last stage of the Almaty wastewater treatment plants, 98 species of microalgae were identified in the Sorbulak Storage Lake. The greatest diversity is observed among green algae (45%), which is typical for polluted aquatic ecosystems (Figure 2). The main representatives of this department were such species as: *Ankistrodesmus minutissimus, Ankistrodesmus longissimus var. longissimus, Ankistrodesmus arcuatus, Actinochloris sphaerica, Chlorella vulgaris var. vulgaris, Chlorella ellipsoidea, Chlamydomonas rubrifilum, Chlamydomonas elliptica, Chlamydomonas velata, Chlamydomonas floscularìae, Coelastrum microporum, Coelastrum sphaericum, Cosmarium connatum, Closterium acerosum, Closterium acutum, Closterium lanceolatum, Closterium reticulatum, Chaetopeltis orbicularis var. orbicularis, Didymocystis planctonica, Oocystis crassa, Oocystis marssonii, Oocystis solitoria, Pediastrum integrum, Pediastrum boryanum var. boryanum, Pediastrum duplex var. duplex, Pediastrum simplex var. simplex, Pediastrum boryanum var. longicorne, Palmellocystis planctonica, Pleodorina californica, Palmellopsis gelatinosa, Scenedesmus granulatus, Scenedesmus quadricauda var. quadricauda, Scenedesmus acuminatus var. bisseriatus, Scenedesmus obliquus var. obliquus, Scenedesmus platydiscus, Scourfieldia complanata, Trochiscia granulata, Volvox aureus, Zygnema sp.*

In terms of quantitative composition, diatoms occupy the second place (Figure 2). Among them, the leading role is played by species of the *Pennatophyceae* class, and there is also a large species diversity of the genera *Navicula*, *Nitzschia.* The species of *the Thalassiosirales* order developed in the greatest number: *Cyclotella kuetzingiana*, *Stephanodiscus hantzschii*.

Of the certain species in the ecosystem of the Sorbulak Storage Lake, 20% are blue-green algae. Representatives of the order *Chroococcales* are found among them: *Gloeocapsa minor*, *Microcystis aeruginosa*, *Microcystis aeruginosa f. sphaerodictycides*, *Microcystis aeruginosa f. flos-aquae*, *Microcystis aeruginosa f. aeruginosa*, *Merismopedia glauca*. From the order of *Nostocales* were found species of *Anabaena variabilis*, *Anabaena flos-aquae f. minor*, *Anabaena constricta*, as well as representatives of the order *Oscillatoriales*: *Oscillatoria irrigua*, *Oscillatoria brevis*, *Oscillatoria planctonica*, *Oscillatoria angustissima*, *Oscillatoria willei*, *Spirulina major*, *Spirulina laxissima*, *Spirulina meneghiniana*, *Spirulina minima*. In addition, euglenic algae (10 species) were found in the waters of Sorbulak Storage Lake, which played a secondary role in the formation of algocenosis. Among them there are representatives of the genus Euglena, as well as *Strombomonas urceolata* and *Phacus longicauda*. Among all the studied reservoirs of the Almaty wastewater treatment plants, the Sorbulak Storage Lake is distinguished by the greatest species diversity of algae. There are indicator species of microalgae of all saprobicity zones, dominated by β-mesosaprobic organisms such as *Scenedesmus quadricauda var. quadricauda*, *Scenedesmus obliquus var. obliquus*, *Pediastrum boryanum var. boryanum*, *Pediastrum duplex var. duplex*, *Microcystis aeruginosa*, *Merismopedia glauca*. Among α-mesosaprobic organisms, *Stephanodiscus hantzschii* and *Oscillatoria brevis* predominate in number and occurrence.

Thus, we have established that, according to the systematic position, algae from wastewater treatment plants belong to 112 species and subspecies.

The main part of the algae consists of green, blue-green, diatom and euglenic algae, while the species diversity is dominated by green algae (Figure 3). As shown in Figure 3, 45 species (40%) of microalgae of the *Chlorophyta* (green) division, 29 species (26%) of *Bacillariophyta* (diatoms), 25 species (22%) of Cyanophyta (blue-green), 13 species (12%) of *Euglenophyta* (euglenic).

Among green algae, the most common are *Ankistrodesmus minutissimus*, *Oocystis marssonii*, *Cosmarium connatum*, *Pediastrum boryanum var. boryanum*, *Scenedesmus obliquus var. obliquus*, *Chlorella vulgaris* var. *vulgaris*. Among diatoms (29 species) most frequently found species are *Gomphonema augur*, *Hantzschia amphioxys*, *Navicula cryptocephala*, *Stephanodiscus hantzschii*, *Stauroneis anceps*, *Cyclotella kuetzingiana*. Among the blue-green reservoirs, most commonly found species are *Oscillatoria willei*, *Anabaena flos-aquae f. minor*, *Anabaena constricta*, *Oscillatoria irrigua*, *Oscillatoria tenuis*, *Phormidium foveolarum*, *Spirulina meneghiniana*. Among euglenic algae, frequently meet species are *Euglena viridis*, *Euglena proxima*, *and Euglena acus.*

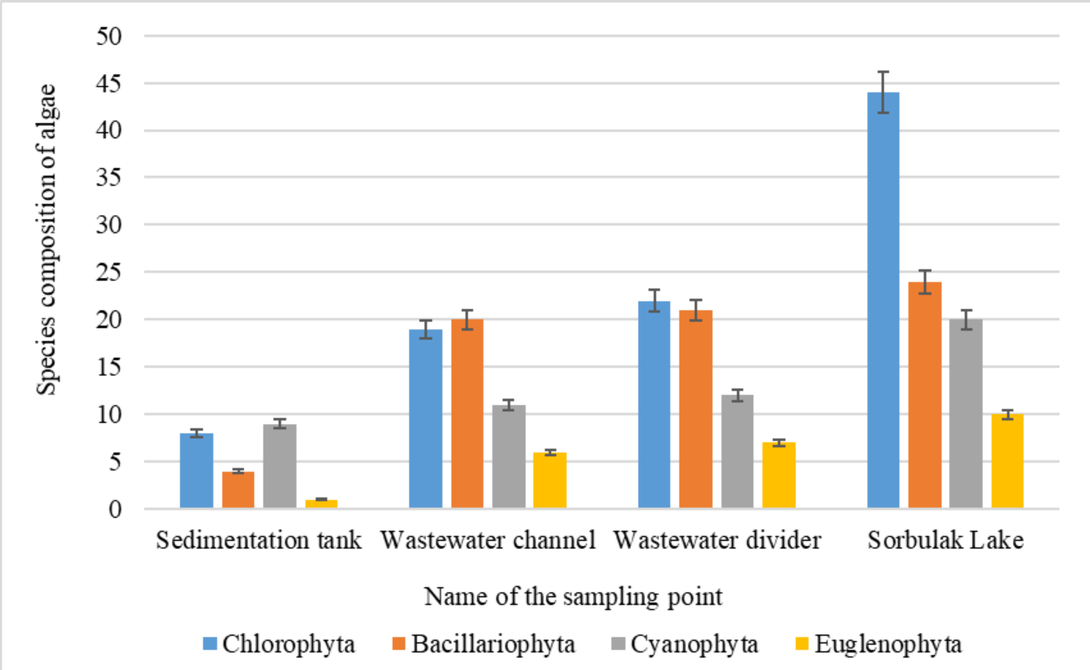

Figure 2 – Distribution of algae species in the wastewater treatment plants in Almaty

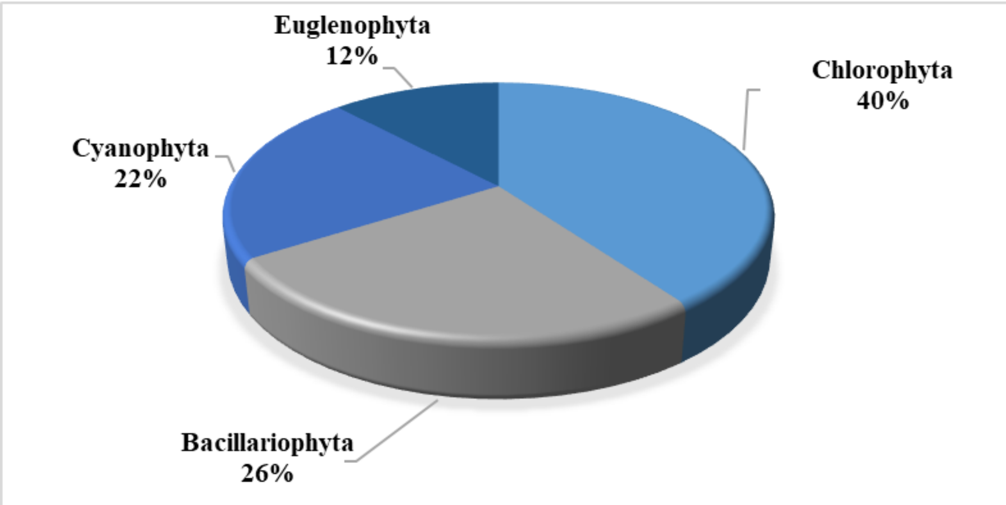

Figure 3 – Quantitative ratio of algae species in the wastewater treatment plants in Almaty

The biological balance of aquatic ecosystems is maintained by the connections between organisms and the environment. It is disrupted by harmful effects, which in turn affects the species composition of the biocenosis. In sanitary and biological analysis, the main indicator is the quantity and species composition of the biocenosis.

We conducted a comparative analysis of the occurrence of microalgae representatives in a sedimentation tank after mechanical treatment, the wastewater channel after biological treatment, the wastewater divider, and the Sorbulak Storage Lake. As can be seen from Figure 2, the species and quantitative composition of microalgae in Almaty wastewater treatment plants increases markedly as the degree of purification increases.

So, if in the sedimentation tank after mechanical treatment the main part of the algae is represented by blue-green species, then at the last stages of cleaning there is an increase in all types of microalgae. For example, the frequency of occurrence of microalgae, as well as the diversity of their species composition in the waters of Sorbulak Storage Lake, is much higher than in the initial purification sites.

Comparative analysis of the microflora from reservoirs of the Almaty wastewater treatment plants. One of the consequences of pollution of aquatic ecosystems is changes in microbial cenoses. The microflora of reservoirs, as the most significant and sensitive factor determining biological balance, reacts earlier than others to changes in environmental conditions. Timely and complete information about these phenomena helps to prevent the impact of water pollution on human health and the environment. Almost all representatives of the systematic and physiological groups of bacteria that occur in the biosphere are identified in reservoirs. However, the microflora of reservoirs is characterized by specificity, which significantly distinguishes it from those coming from outside. In clean water bodies, the incoming microflora makes up an insignificant part of its total amount. With an increase in the degree of contamination, the introduced microflora can change the quantitative ratio of microorganisms in the reservoir. In this regard, all aquatic microorganisms are divided into allochthonous, coming from outside, and autochthonous, or aquatic, adapted to the ecological conditions of the reservoir.

The allochthonous microflora of the reservoir is doomed to die off. However, with prolonged intake of pollutants that change the ecological balance, the species composition of the reservoir's own microflora changes. The autochthonous microflora is divided into 3 groups: strict autotrophs, mixotrophs and heterotrophs. Autotrophs include microorganisms capable of using carbon dioxide for their energy needs, heterotrophs need ready-made organic substances for these purposes, mixotrophs are able to switch from autotrophic nutrition to heterotrophic.

From a hygienic point of view, the allochthonous group of microorganisms is of the greatest importance, which may pose a potential epidemic danger due to the possible presence of pathogenic microorganisms in it. At the same time, the allochthonous saprophytic microflora consists of a complex of various physiological groups of bacteria that mineralize the organic matter of the reservoir. Depending on the degree of contamination of the reservoir, the number of allochthonous bacteria increases.

To identify the risk of epidemic danger in a polluted reservoir, both direct indicators of the presence of human infectious agents and indirect indicators of faecal contamination are used. Among the latter, representatives of the microflora of human intestinal diseases are more often used. Basically, these indicators are used in combination with indicators of the sanitary and hygienic condition of the facility – general microbial contamination, the presence of heterotrophs, nitrifiers [29].

L.A.Vinogradova emphasizes that the influence of pollution factors on the environment can be determined by the reaction of microorganisms to these pollutants [30]. The initial changes are in the ratio of microorganisms in the biocenosis. Thus, it has been established that in reservoirs with a predominance of organic pollutants, all representatives of the microbiocenosis, including pathogenic bacteria, are indicators. The number of non-fermenting bacteria often increases in these conditions. Wastewater rich in organic substances is a suitable environment for the development of water microflora. One of the most important features of natural reservoirs is the vital activity of aquatic organisms in them – microorganisms, algae, invertebrates and higher aquatic plants, which have a direct impact on water quality, and the development of pathogenic microorganisms in them leads to a sanitary and epidemiological risk. Among pathogenic microorganisms, salmonella, shigella, enterobacteria, enteroviruses, etc. are found more often than others.

Thus, from an ecological point of view, microorganisms in wastewater can be divided into two groups – saprophytic and pathogenic microorganisms.

Various bacteria develop in reservoirs from the Almaty wastewater treatment plants. In the sedimentation tank after mechanical treatment, the total number of microorganisms is 1200 thousand cells/ml, n the wastewater channel after biological treatment – 1000 thousand cells/ml, in the wastewater divider – 900 thousand cells/ml, in the Sorbulak Storage Lake – 700 thousand cells/ml. Our determination of the total number of bacteria revealed that in polluted aquatic ecosystems, changes in the number of bacterioplankton occur in parallel with an increase in the biomass and species composition of microalgae (Figure 4).

According to the values of the studied indicators, it can be seen that the number of bacterioplankton in the sump is higher compared to other stages of purification, i.e. a decrease in the number of bacterioplankton is accompanied by a gradual increase in algae biomass and an increase in their species diversity (Figure 3).

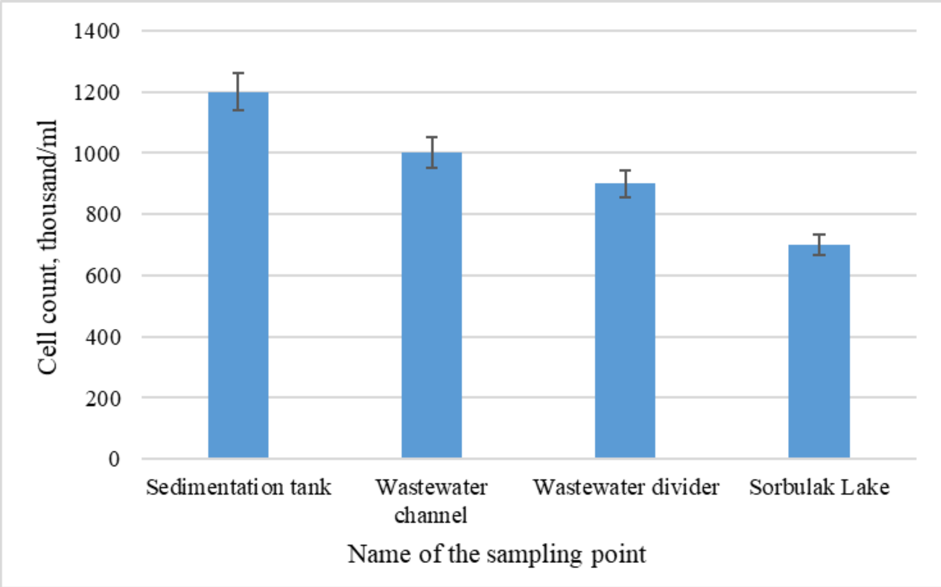

Figure 4 – Dynamics of total bacterial abundance in the wastewater treatment plants in Almaty

Thus, pollution of reservoirs is accompanied by drastic qualitative and quantitative changes in microbial cenoses of reservoirs, which are aimed at leveling and maintaining ecological balance in the reservoir.

Bioindication in reservoirs from the Almaty wastewater treatment plants using microalgae. As is well known, algae serve as the primary producers of organic matter and oxygen in aquatic ecosystems. In addition to their numerous ecological functions, microalgae play a crucial role in biological water analysis due to the stenotopic nature of many species and their high sensitivity to environmental conditions. The quantitative and qualitative composition of microalgae provides a reliable tool for accurately assessing the overall state of an aquatic ecosystem [31].

As can be seen from Figure 5, the qualitative and quantitative composition of microalgae, indeed, allows us to accurately assess the state of the aquatic ecosystem as a whole. When a reservoir is polluted, some forms of microalgae die, while others gain advantages for their development. As a result of these events, a change of biocenosis occurs in the contaminated area. Depending on the organic pollution of water bodies, the spectrum of indicator species of microalgae, which are indicators of water saprobicity, changes. This is due to the fact that the composition of microalgae depends on the class and amount of organic substances.

Thus, the sedimentation tank after mechanical treatment for organic contamination is characterized as a polysaprobe zone containing high concentrations of unstable organic substances and products of their anaerobic decomposition, very low concentrations of oxygen and high concentrations of dissolved carbon dioxide. The main part of microalgae species are polysaprobionts, of which *Chlorella vulgaris, Oscillatoria willei, Phormidium autumnale,* and *Oscillatoria brevis* are dominant [32]. The saprobic index according to the Pantle and Bucca method is 4.

According to organic pollution, the wastewater channel after biological treatment is characterized as a polysaprobic zone, with a saprobic index of 3.51.

As the purification process progresses, the saprobic index of polluted waters increases. Thus, the composition of the indicator species of microalgae in the wastewater divider characterizes the reservoir as an alpha-mesosaprobe zone of organic pollution, in which aerobic decomposition of organic substances begins, redox processes occur, resulting in intensive self-purification of water, and microalgae actively participate in it. The main representatives of indicator microalgae in the water separator are – *Closterium acutum, Cosmarium sublatereudatum, Navicula radiosa, Merismopedia tenussima, Oscillatoria angustissima, Euglena caudata, and Euglena viridis.* According to this, the saprobic index is 2.8. At the final stages of purification, representatives of β-mesosaprobic microalgae species are *Ankistrodesmus minutissimus, Oocystis crassa, Nitzschia Hantzschiana, Microcystis aeruginosa,* Indicator microalgae of oligosaprobic zones are found in smaller numbers. – *Synedra pulchela, Achnantes minutissima, Cyclotella Kuetzingiana, Scourfieldia complanata,* the saprobicity index is 2.5. According to this, the water of the reservoirs under consideration can be attributed to the β-mesosaprobic type of organic pollution.

The data obtained make it possible to classify the initial reservoirs from the Almaty wastewater treatment plants as a polysaprobic zone of organic pollution, the latter as 'moderately polluted' according to the αß-mesosaprobic type.

This means that the natural process of self-purification is actively underway in the last stages of purification.

Thus, as pollution levels decrease and water quality improves, there is a gradual decrease in saprobicity. The saprobic index in the studied samples varies from 4 to 2.5 (Figure 5).

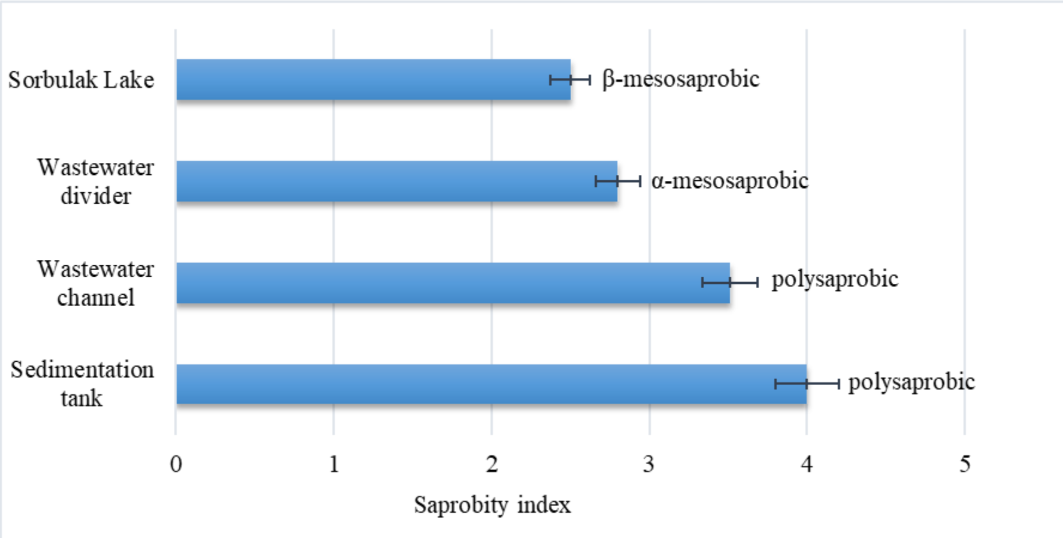

Figure 5 – Saprobity index of the wastewater treatment plants in Almaty

The results of our research indicate that as water is purified, the quantitative and qualitative composition of microalgae changes, and a parallel decrease in the values of key physical and chemical indicators of pollution is observed (Table 1). These data confirm the role of microalgae in the processes of natural self-purification of water. In addition, the massive development of algocenoses indicates the activity of biological purification, during which microalgae utilize organic pollutants and participate in the transformation of biogenic elements.

Conclusion

The study of algae from wastewater treatment plants revealed gradual changes in the species and quantitative composition of algae, which is an important indicator of the state of the aquatic environment. The sedimentation tank after mechanical treatment and the wastewater channel after biological treatment are dominated by diatoms and blue-green algae (*Bacillariophyta, Cyanophyta*), which indicates a high level of eutrophication. During the purification process, the proportion of green algae (*Chlorophyta*) increases, especially in the final Sorbulak Storage Lake, which indicates a stabilization of the ecological state and a decrease in the level of pollutants.

The study revealed the significant role of microalgae in the processes of biological wastewater treatment and biomonitoring from wastewater treatment plants in Almaty and the Sorbulak Storage Lake. A direct dependence of the dynamics of the species composition of microalgae and cyanobacteria on the level of anthropogenic load has been established: in conditions of high concentration of organic substances, cyanobacteria dominate, whereas with a decrease in pollution levels, the abundance of green and diatoms increases.

The analysis of bacteriological parameters confirmed the effectiveness of the purification processes: the number of microorganisms gradually decreases as the water passes through the purification stages. In the sedimentation tank after mechanical treatment, the total number of bacteria reaches 1200 thousand cells/ml, in the wastewater channel after biological treatment – 1000 thousand cells/ml, in the wastewater divider – 900 thousand cells/ml, and in the final reservoir (Sorbulak Storage Lake) – 700 thousand cells/ml. This confirms the reduction of sanitary and epidemiological risks and indicates the effectiveness of biological purification processes, as well as an improvement in the hygienic condition of water.

The analysis of the saprobic index showed that as the purification stages go through, the level of organic pollution decreases significantly, and the processes of natural self-purification become more active. In the sedimentation tank after mechanical treatment, the saprobicity level corresponds to the polysaprobic zone, and at the final stages there is a transition to α-mesosaprobic and β-mesosaprobic conditions, which indicates a significant reduction in organic pollution. This confirms the effectiveness of wastewater treatment plants and the use of microalgae as indicators of water quality. Based on the analysis of the saprobicity index, it was found that during water purification there is a consistent decrease in the level of organic pollution.

Thus, the conducted studies allowed us to establish the key role of algae in the processes of biological wastewater treatment and biomonitoring from wastewater treatment plants in Almaty and the Sorbulak Storage Lake. It has also been shown that wastewater treatment plants effectively reduce the level of pollutants and contribute to the restoration of the aquatic environment. The study found that changes in the species structure of algae are closely related to the level of pollution of aquatic ecosystems. In conditions of high organic load, blue-green algae (*Cyanophyta*) predominate, while with a decrease in pollution, an increase in the proportion of green (*Chlorophyta*) and diatoms (*Bacillariophyta*) is observed.

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Conflict of interest

All authors are familiar with the content of the article and have no conflict of interest.

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