This article provides information on the identification of micromycetes found in samples taken from areas of transboundary rivers of Azerbaijan with different levels of anthropogenic impact, and the study of their role in the removal of pollutants. Certain micromycetes were used as indicators of water quality. As a result of the studies, micromycetes belonging to 38 species from 16 genera were identified.

Directly at the sampling site, water temperature, pH, and the amount of dissolved oxygen in the water were measured, and biogenic elements were determined in laboratory conditions. The presence of nutrients in the studied river waters showed variable results. Thus, in the Astarachay River, nitrites range from 0.01–0.02 mg/l, nitrates 0.56–0.70 mg/l, ammonium 0.5–1.50 mg/l, phosphates 0.00–0.01 mg/l. In the Bolgarchay River, these indicators for nitrite range from 0.02–0.05 mg/l, for nitrates 0.20–0.50 mg/l, for ammonium 0.10–0.44 mg/l, for phosphates 0.01–0.05 mg/l. In the Arazchay River, nitrites range from 0.01–0.83 mg/l, nitrates 0.08–7.40 mg/l, ammonium 0.05–3.57 mg/l, phosphates 0.05–0.94 mg/l, and in Okhchuchay these indicators for nitrite range from 0.09 to 0.71 mg/l, nitrates 0.68–6.00 mg/l, ammonium 0.23–6.45 mg/l, phosphates 0.09–0.65 mg/l.

The results obtained showed that the identified microscopic fungi are involved in the formation of rich flora as an adaptation in river waters. The biomass and number of micromycetes significantly depend on hydrochemical conditions: parameters such as temperature, dissolved oxygen, pH, forms of nitrogen, phosphorus and organic carbon fractions. It can be recommended to use mushrooms for biological control of surface water purity and sanitary safety. It should be noted that environmental factors also influence the diversity of micromycetes

Keywords: aquatic ecosystem, identification of micromycetes, transboundary rivers, biogenic elements, physical and chemical indicators, dissolved oxygen

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THE ROLE OF MICROMYCETES OF TRANSBOUNDARY RIVER WATERS IN THE DECOMPOSITION OF ORGANIC SUBSTANCES

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1. Introduction

One of the global problems occurring in the world is the lack of fresh water and pollution of water bodies. Contamination of water sources by various pollutants makes water unfit for human consumption. About 2 billion tons of household waste are dumped into waterways every day. All this pollution has a significant impact on both the environment and human health. The discharge of untreated sewage, fertilizers and other chemicals into freshwater bodies can cause serious damage to aquatic ecosystems, which negatively affects the livelihoods of all organisms living in the aquatic ecosystem. And this, in turn, leads to a reduction in the biodiversity of the aquatic ecosystem, and sometimes to its complete destruction.

Water contamination also arises in drainage and sewer systems from pesticide applications in nonagricultural urban areas through increased runoff of pesticide-containing rainwater over sealed surfaces, such as roofs and roads. Water pollution by pesticide emissions is considered a key element in agricultural management practices to minimize ecological changes and to maintain biodiversity [1].

Pollution of water bodies with organic substances is an environmental problem caused by many industrial and agricultural activities, including oil exploitation and spraying of pesticides. In recent times, the pollution of water bodies with heavy metal-organic compounds has attracted more and more attention.

Transboundary water management cooperation is a critical element in all forms of sustainable development – from conquering water scarcity and protecting biodiversity to building stronger economies and ensuring peace and security – this was voiced at the 2023 UN Water Conference [2].

The world's transboundary river basins span 151 countries, include more than 2.8 billion people (around 42 % of the world's population), cover 62 million km^2 (42 % of the total land area of the Earth), and produce around 22,000 km^3 of river discharge each year (roughly 54 % of the global river discharge) [3].

The Republic of Azerbaijan is included in the list of countries with insufficient water resources, and about 70 % of water resources are formed in neighboring countries. their tributaries aggravate the water problems of our republic and make its water resources dependent on the level of use of the waters of these rivers in neighboring countries. The biggest problem of Azerbaijan's transit rivers is excessive pollution of river waters. The water quality of the Kura and Araz rivers, which are transit rivers flowing into our country, is mainly formed in the territory of Armenia and Georgia. One of the heavily polluted rivers on the territory of Armenia is Okhchuchay, the left tributary of the Araks. Okhchuchay is a source of wastewater from which more than one hundred thousand tons of solid acidic water, heavy metal salts and other waste from the Meghri, Gajaran, Gafan and Dastakert mining (metal processing) plants of Armenia are discharged. Transboundary rivers, which receive wastewater discharged from the territory of these countries, are subject to environmental aggression, as if performing a sanitary treatment function. As a result, the quality of their water does not meet the requirements of sanitary standards and ends up on the territory of Azerbaijan [4, 5] the use of a wide range of references [6] should be avoided, it is unacceptable.

Micromycetes are widespread (abundantly available) in the aquatic environment and can use any type of organic substance as a substrate. An aquatic environment containing nutrients creates potential conditions for the growth of micromycete spores. Thus, micromycetes are an important component of the aquatic ecosystem. Micromycetes are involved in various processes in the freshwater environment. Their main ecological role in the aquatic ecosystem is to break down plant and insect debris, purify water, and recycle organic matter used by other organisms. Thus, micromycetes play an important role in the decomposition of detritus with their enzymatic activity. In addition, micromycetes contribute to the mineralization of organic matter and the regulation of insect populations.

Water pollution affects the diversity and composition of aquatic micromycetes. Micromycetes are the primary decomposers of organic material and play important roles in nutrient cycling, bioremediation, and ecosystem functioning.

Aquatic fungi produce hydrolytic enzymes that degrade many compounds thus contributing to the purification of aquatic environments. Additionally, they have a high metabolic capacity for carbon capture, and are believed to be key elements in the carbon cycle and regulators of global climate.

The study of aquatic microbioflora will allow to identify micromycetes in these environments, determine their distribution and species composition. In water sources, micromycetes can survive if sufficient nutrients and oxygen are available. Micromycetes are practically not found in groundwater. Micromycetes are rare in mineral waters. In addition, these mushrooms are always found in open reservoirs and flowing rivers. Some prefer rivers with relatively low nutritional value, others prefer more or less eutrophic (rivers, seas and reservoirs are rich in nutrients) waters [7, 8].

As it is known, reservoirs have the ability to self-purify. The process of self-purification of water bodies is the ability, by physical, chemical and biological methods, to convert organic and partially inorganic substances found in a water body into harmless compounds. All hydrobionts participate in the self-purification of reservoirs, fungi also play an important role in this process. Therefore, studies devoted to the identification of micromycetes in transboundary river waters of Azerbaijan, subject to anthropogenic pollution and their role in the decomposition of organic substances are so important and relevant.

2. Literature review and problem statement

As already mentioned, cooperation on shared rivers between countries is very important. Transboundary water cooperation requires consideration of the impacts of climate change on aquatic ecosystems, the protection of ecosystems, the sustainable management of water and wastewater, and how countries manage the quantity and quality of water flowing from or into another country. In addition, information exchange can help ensure political stability and sustainable development at the regional level.

The article [9] presents the results of a study of transboundary river and lake basins, which account for about 60 % of the world's freshwater flow, and shows that an attempt was made to determine the importance of transboundary waters in water supply, briefly presenting the problem of water scarcity in the modern world and presenting statistical data on transboundary waters. Cooperation between countries, which became more intense especially in 2017, was analytically analyzed in two parts (good and bad cooperation). The reason for this may be the objective difficulties associated with cooperation carried out with good intentions. Externally, cooperation brings benefits to the parties, but if it occurs through the abuse of diplomatic pressure and other power tools of the parties, then cooperation is considered bad. Conflicts in the modern world over transboundary waters, which became so due to lack of cooperation, were also analyzed. An option to overcome the corresponding difficulties could be the concept of transboundary waters with the concept of water diplomacy and four forms of hydro-hegemony. This is the approach taken and the water-energy-food nexus considered. All this allows to say that cooperation in the field of transboundary waters should be in the interests of all countries, since it is tied to concepts that, like the SDGs, may not be directly visible, but affect the entire country. Sustainable Development Goals (SDGs) have been proposed depending on the regional and country contexts of each of these basins.

The article [10] presents the results of the study, showing that in the modern period almost all water bodies are subject to anthropogenic load. The main type of anthropogenic impact on them is pollution by a wide range of organic and inorganic substances coming from point and diffuse sources, but unresolved issues related to water purification remain. The reason for this may be objective difficulties associated with high costs, which makes relevant research impractical. A way to overcome these difficulties can be cleaning water bodies through the correct selection of strains of microorganisms.

The article [11] presents the results of a study in reservoirs with a large number of microorganisms, which is shown to depend on the time of year, the depth of the reservoir, the degree of its pollution, the degree of remoteness of the reservoir from populated areas and other factors. In this regard, river waters above cities are always poorer in bacteria than in the city itself and below. The reasons for the constant deterioration of surface water quality may be the growth of microorganisms. Monitoring may be a way to overcome these difficulties. This is exactly the approach used in [12]. All this suggests the feasibility of conducting research on the use of biodegradable microorganisms to clean the reservoir.

The article [13] shows that self-purification of the waters of the Caspian Sea from oil pollution occurred due to biodegradation microorganisms. But issues related to the change of seasons and natural temperature conditions remained unresolved. Due to the low water temperature in winter, the self-purification of the reservoir was extremely slow and, naturally, this was unprofitable from an economic point of view. An option to overcome these difficulties may be the preparation of biological products. This is exactly the approach used in [13].

The paper [14] presents the results of a study that focuses on contaminants found in water as they may pose a health risk to consumers. This may be due to daily contact with water through multiple exposure points such as drinking and showering. A way to overcome these difficulties would be to conduct regular monitoring in these waters. This approach was used in [15]. Monitoring of samples of water supply water was done. The average amount of micromycetes ranges from 8 to 18 CFU/100 cm^3, which indicates the need to develop normative documents on mycological control of water and technologies for removing micromycetes from it.

All of this is to say that the reports collected here on fungal contamination of drinking water, as well as many other possible contaminants and invasive activities, illustrate and justify the recommendation to consider fungi in risk assessment and risk management of drinking water, including monitoring in appropriate areas.

The article [16] presents the results of a study of water pollution. It has been shown that the reasons for this may be the presence of filamentous fungi in drinking water and the formation of biofilms. But there were unresolved issues related to the big problem associated with clogging of water pipes and, naturally, deterioration of the organoleptic properties of water. A way to overcome these difficulties may be standard methods equivalent to those available for bacterial contamination of drinking water. This is exactly the approach used in [16], but even greater progress will only be achieved if future research ensures the identification of strain species and the widespread use of standard methods.

All this suggests that it is advisable to conduct a study to study micromycetes found in transboundary waters of Azerbaijan subject to anthropogenic pollution. Therefore, our research is concentrated in this area.

3.The aim and objectives of the study.

The aim of the study is to identify the micromycetes found in the samples taken from some transboundary river waters of Azerbaijan with anthropogenic influence and to study their role in cleaning the generated pollutants.

To achieve this aim, the following objectives are accomplished:

– to study the physicochemical properties of water and their influence on the development of aquatic micromycetes in water samples taken from the transboundary river waters under study;

– to isolate and identify aquatic micromycetes from the samples taken;

– to study the role of identified aquatic micromycetes in the degradation of organic substances in the aquatic environment and determining the quality of river waters.

4. Materials and methods of research

The object of the study was the transboundary rivers Astarachay, Bolgarchay, Arazchay and Okhchuchay, the research was carried out taking into account seasonal dynamics. The research hypothesis assumes the possibility of monitoring to check the self-purification of water bodies from pollution through microorganisms.

The physicochemical properties of water in water samples collected at designated stations in the transboundary rivers under study were analyzed using modern methods.

Sampling stations were designated on the rivers; at designated stations, samples were taken from the coastal zone, and physicochemical measurements were carried out. Water temperature (°C) was measured on site with a mercury thermometer, pH and dissolved oxygen (mgL^{-1}) with an analyzer (pH 200, MW dissolved oxygen 600). In order to determine the content of nitrates, nitrites, ammonium and phosphates at sampling stations, water was taken and measured with a Polintest-Photometer 7100 device.

For mycological analysis, water samples were taken directly into sterile glass containers, and for collecting plant and insect remains – intosterile plastic bags and inoculated on SDA (Sabouraud dextrose agar), YEPD (yeast extract peptone dextrose) media in laboratory conditions and incubated for 3–7 days (28±2 °C). Colonies were counted per CFU/mL (colony forming unit). At the end of incubation, each colony was examined macroscopically for colony size (mm), shape, color of the upper and lower surfaces, presence of exudation and pigmentation. Colonies were also examined microscopically. Fungi isolated in a pure culture were identified using an MT 5200 L microscope. Light microscopy made it possible to determine such morphological parameters as the length and width of conidiophores, the length of phyllides, the shape and size of conidia [17–19].

5. Results of the role of microscopic fungi in determining the degree of pollution and treatment of transboundary river waters

5. 1. Determination of physico-chemical indicators of water

As a result of the research, the physical and chemical properties of water were studied for the first time. Water temperature, pH, and dissolved oxygen were measured in situ at sampling stations. Water samples were collected and measured to determine nitrates, nitrites, ammonium and phosphates in the water. The results obtained are shown below in Table 1.

Table 1

Data on changes in abiotic factors and average content of biogenic elements during collection of water samples of rivers by seasons of the year (maximum, minimum)

Parameter	Winter	Spring	Summer	Autumn
Temperature (°C)	6–8.1	15–19	24–27	12–18
pH	7.2–8.4	7.3–8.1	7.5–8.7	7.2–10.9
Dissolved oxygen (mg O_2/L^{-1})	7.5–9	5.9–7.8	4.5–6.3	5–8.1
Nitrite NO_2 mq/L	0.01–0.49	0.00–0.47	0.00–0.83	0.00–0.71
Nitrate NO_3 mq/L	0.70–6.80	0.46–7.40	0.48–4.40	0.70–7.5
Ammonium NH_4 mq/L	0.29–1.68	0.30–3.57	0.05–1.20	0.03–6.45
Ammonia NH_3 mq/L	0.252–1.368	0.3–3.42	0.024–1.44	0.024–6.00
Phosphate PO_4 mq/L	0.01–0.83	0.01–0.57	0.00–0.94	0.01–0.90
Phosphorus pentoxide P_2O_5 mq/L	0.0075–0.6225	0.0075–0.4275	0.00–0.705	0.0075–0.675

The presence of nutrients in the studied river waters showed variable results. Thus, in the Astarachay River, nitrite ranges from 0.01–0.02 mg/l, nitrate 0.56–0.70 mg/l, ammonium 0.5–1.50 mg/l, phosphate 0.00–0.01 mg/l. In the Bolgarchay River, these indicators for nitrite range from 0.02–0.05 mg/l, for nitrate 0.20–0.50 mg/l, for ammonium 0.10–0.44 mg/l, for phosphates 0.01–0.05 mg/l. In the Arazchay River, nitrites range from 0.01–0.83 mg/l, nitrates 0.08–7.40 mg/l, ammonium 0.05–3.57 mg/l, phosphates 0.05–0.94 mg/l, and in Okhchuchay these indicators for nitrite range from 0.09–0.71 mg/l, nitrates 0.68–6.00 mg/l, ammonium 0.23–6.45 mg/l, phosphates 0.09–0.65 mg/l.

5. 2. Isolation and isolation of micromycetes from the studied river waters

During the study, from 88 samples taken during the year from designated stations, 372 colonies of micromycetes were isolated and identified. Colony counts were performed on a CFU/mL (colony forming unit) basis.

The number of colonies identified by season is given in Table 2.

On the basis of the obtained results, it is possible to identify 38 species of micromycetes belonging to 16 genera isolated from the studied transboundary river waters.

Table 2

The colonial counts of isolated microscopic fungi accordingto sampling to the seasons of the year from transborder rivers, in terms of CFU/ml

Seasons	Astarachay	Bolgarchay	Arazschay	Okchuchay	Total
Winter	6	5	10	25	46
Spring	17	9	28	29	83
Summer	23	37	32	37	129
Autumn	32	26	23	33	114
Total	78	77	93	124	372

The number of micromycete species isolated during the study is given in Fig. 1, 2.

During the research, it became obvious that according to the types of micromycetes found in river water, *Aspergillus* 10, *Penicillium* 7, *Mucor* 4, *Fusarium* 3, *Trichoderma* 2, *Cladosporium* 2 and others represent 1 species. The genus *Aspergillus* was the most common at all designated stations.

The types of micromycetes isolated from transboundary river waters are given in the Table 3.

Table 3 shows that according to the frequency of occurrence of micromycete species, they are grouped into low, medium, high and rare. Yeasts were found in some of the rivers studied.

Table 3

Types of microscopic fungi isolated from transborder rivers by seasons

Species	Spring				Summer				Autumn				Winter			
	Astara-chay	Bolgar-chay	Ara-schay	Okchu-chay	Asta-rachay	Bolgar-chay	Ara-schay	Okchu-chay	Asta-rachay	Bolgar-chay	Ara-schay	Okchu-chay	Asta-rachay	Bolgar-chay	Ara-schay	Okchu-chay
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Aspergillus niger	×	–	×	×	×	×	×	×	×	×	×	×	–	–	×	–
A. flavus	–	–	×	×	–	–	×	×	×	–	×	×	–	–	–	–
A. nidulans	–	–	–	–	–	×	–	–	×	–	–	–	–	–	–	–
A. versicolor	–	–	–	×	–	×	×	–	–	–	–	×	–	×	–	×
A. fumigatus		–	–	×	–	–	×	×	×	×	–	×	×	–	×	×
A. candidus	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–
A. terreus	×	×	×	–	×	×	×	–	–	×	×	×	–	–	–	×
A. carneus	–	–	–	–	–	–	–	–	×	×	–	–	–	–	–	–
A. ochraceus	×	–	–	×	–	×	–	×	–	–	–	×	–	–	–	–
A. clavatus	×	×	–	×	–	–	–	×	–	–	–	×	–	–	–	×
Penicillium ochrochloron	–	–	×	–	×	×	–	×	×	×	×	×	–	–	–	–
P. cyclopium	–	–	–	–	×	–	–	–	×	×	–	–	–	–	–	–
P. notatun	–	–	–	×	×	–	×	–	×	×	×	×	–	–	–	–
P. brevicompactum	–	–	×	×	–	×	×	–	×	–	–	–	–	–	–	–
P. funiculosum	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–	×
P. arenarium	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–
P. frequentans	–	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–
Fusarium oxysporum	–	×	×	×	–	–	×	×	×	×	×	×	–	–	×	–
F. solani	–	–	×	×	–	×	×	×	×	×	–	–	–	–	–	×
F. culmorum	–	–	×	×	×	–	–	–	×	–	–	–	–	–	–	–
Trichoderma viride	×	×	×	×	×	×	×	×	×	×	×	×	–	–	–	×
T.harzianum	–	–	×	×	×	–	×	×	×	–	–	×	–	–	×	×
Alternaria alternata	–	×	×	×	×	×	×	×	–	×	–	×	–	–	–	×
Acremonium rutilum	–	–	–	×	–	×	×	×	×	×	–	×	–	–	–	–
Cladosporium Herbarum	×	–	×	–	×	×	–	×	×	×	–	–	–	–	–	×
C. cladosporioides	–	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–

Continuation of Table 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Candida albicans	×	–	×	×	–	×	×	×	–	–	×	×	–	–	–	×
Geotrichumcan-didum	–	–	–	×	–	–	–	×	–	–	×	×	–	–	–	×
Rhodotorula	–	–	×	×	–	–	×	×	–	–	×	×	–	–	×	×
Chaetomium globosum	–	–	–	–	×	–	–	–	×	×	–	–	–	–	–	–
Scopulariopsis Brevicaulis	×	–	×	×	–	×	×	×	×	–	×	×	–	–	–	×
Mucorracemosus	–	–	×	×	–	×	–	–	–	–	–	×	–	–	–	–
M. mucedo	–	–	–	–	–	–	–	×	–	–	–	–	–	–	–	–
M. hiemalis	–	–	–	–	–	–	×	–	–	–	–	–	–	–	–	–
M. corymbifer	×	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhizopus.sp	–	–	×	×	–	×	×	×	×	×	×	×	×	–	–	–
Bipolarissp	–	–	–	–	–	–	–	×	–	–	–	×	–	–	–	×
Mycelia sterilia	–	–	×	×	×	–	×	×	–	–	×	×	–	–	–	–

Note: (×) – occurring species; (–) non-occurring species

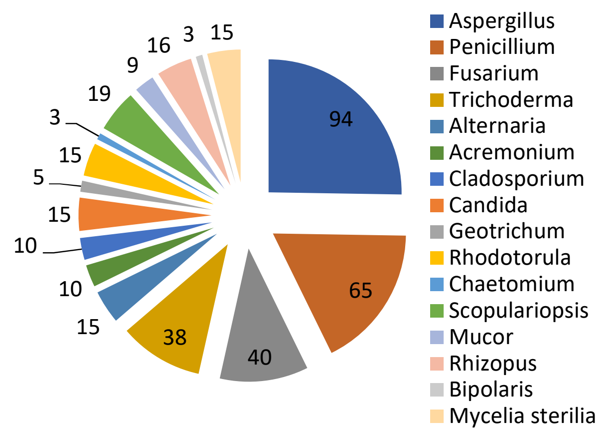

Fig. 1. The number of micromycetes species isolated during the study period from transboundary rivers (CFU/ml)

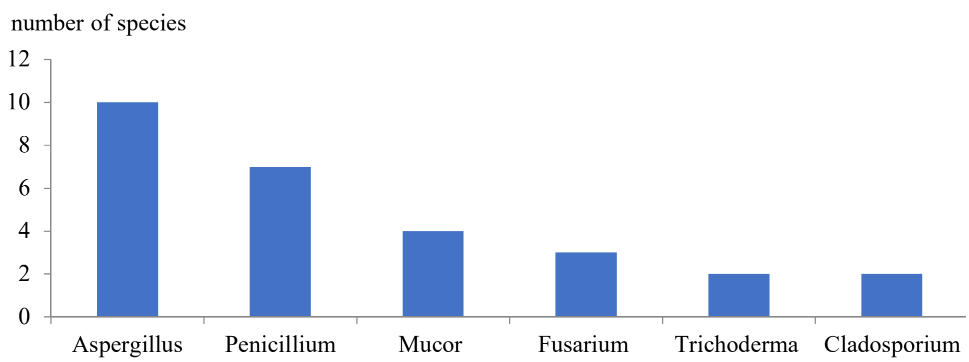

Fig. 2. The most common species of micromycetes isolated from transboundary rivers

Table 4

Kinetics of growth of micromycetes in cellulose

Species	Growth rate of micromycetes in cellulose			Weight of dry biomass, mg/l
	10 days	20 days	30 days	
Penicillium chrysogenum	++	+++	++++	29.46
Penicillum ochrochloron	++	+++	++++	32.93
Penicillium brevicompactum	++	+++	++++	35.95
Aspergillus flavus	++	++	++	0.986
Aspergillus niger	++	+++	++++	47.76
Trichoderma viride	++	+++	+++++	50.1

Note: +++ – active growth, ++ – average growth, + – weak growth

5. 3. Study of micromycetes in the degradation of organic substances in the aquatic environment and determination of water quality

Our studies examined micromycetes that play an important role in the decomposition of organic matter in the aquatic ecosystem and in the food chain. Micromycetes break down cellulose and use it as the sole carbon source. The results obtained were presented below in Table 4.

Table 4 shows cellulose activity, which was observed in all mushrooms used in the experiment.

6. Discussion of the results of the study of transboundary waters of Azerbaijan and the role of micromycetes

The obtained results revealed that the identified microscopic fungi participate in the formation of rich flora as an adaptation in river waters. Biomass and abundance of these fungi depend significantly on hydrochemical conditions with parameters such as temperature, dissolved oxygen, pH, nitrogen forms, phosphorus and organic carbon fractions (Table 1).

As can be seen from Table 1, the water temperature in the studied river waters was 6–8.1 °C degrees should be inserted by the symbol in winter, 15–19 °C in spring, 24–27 °C in summer, and 12–18 °C in autumn. Temperature also regulates the level of dissolved oxygen. Dissolved oxygen is an important parameter in water quality assessment because it affects the organisms living in the water body. Dissolved oxygen is the second most important factor after water itself.

The actual amount of dissolved oxygen varies with temperature, pressure, and salinity. As the temperature of water increases, the solubility of oxygen decreases. Dissolved oxygen is one of the most important parameters describing the environmental purity of the river system. Dissolved oxygen levels that are too high or too low can harm aquatic life of creatures in water and affect water quality.

Table 1 also shows the pH values. Anthropogenic causes of pH changes are usually related to pollution. The high pH level in the studied Okhchuchay is due to the direct discharge of hundred thousand tons of solid sour waters and other wastes of Megri, Gajaran, Gafan and Dastakert mining complexes of Armenia into the river. If the pH level of the water is too high or too low, it creates a great isolation for living organisms. Most aquatic organisms prefer a pH range of 6.5 to 9.0, but some can survive in water with pH levels outside this range. As can be seen from the Table 1, the pH is in the range of 7.2–10.9 pH levels vary with environmental influences, particularly alkalinity [20, 21].

As a result of the studies conducted in order to study micromycetes in the studied river waters (Table 2), it was found that in the studied river waters, the genus *Aspergillus* is represented by the most colonies with 94 CFU/ml, followed by *Penicillium* 65 CFU/ml, *Fusarium* 40 CFU/ml, *Trichoderma* 38 CFU/ml, *Scopulariopsis* 19 CFU/ml, genus is among the most common.The least frequent genera were *Geotrichum, Bipolaris and Chaetomium*.

As can be seen in Table 3, yeast fungi were more common in Araz and Okhchuchay, which are transboundary rivers under study, and it indicates that these rivers are more polluted. Some researchers have suggested using the presence of yeasts as an indicator of water quality. Yeast populations react quickly to organic pollution, and some species can be used as indicators of nutrient enrichment in the aquatic environment, and some of them are conditional pathogens (mainly those belonging to the *Candida* genus).

The studied rivers are constantly subjected to anthropogenic pollution due to the fact that they pass through densely populated residential areas.Discharge of residential and non-residential waste directly into rivers without treatment causes river water pollution and certain changes in river water quality. This process is more obvious mainly in the downstream of rivers. As a result of pollution, allochthonous organic matter of anthropogenic origin prevails in river waters. According to the studies of the above-mentioned authors [9, 13, 16], the biodegradation method can be preferred in the treatment of transboundary waters subjected to anthropogenic pollution. According to our research, in order to prevent pollution, the quality and number of water treatment plants should be increased, and at the same time, their work should be strictly monitored.

Thus, according to the conducted researches, it can be concluded that the pollution in Astarachay and Bolgarchay is less than that of Araz and Okhchuchay. One of the main characteristics of the low pollution of the Bolgarchay is that it has few water-collecting tributaries, as well as passing through mountainous areas from its source to the border of Azerbaijan, which is the main factor for the low pollution of the river.Araz River and Okhchuchay enter the territory of Azerbaijan in a state of both chemical and biological pollution. Okhchuchay is subjected to severe pollution in the territory of Armenia. Thus, hundred thousand tons of solid sour waters, heavy metal salts and other wastes of Megri, Gajaran, Gafan and Dastakert mining complexesare discharged directly into the river without passing through treatment facilities. As a result, the quality of their water does not meet the requirements of sanitary standards andenters the territory of Azerbaijan. Unfortunately, the Araz river continues to be polluted within the Republic. The main reason for this is the lack of modern garbage processing plants and a centralized sewage system in the regions across the country.

The rivers under study are constantly exposed to anthropogenic pollution due to the fact that they pass through densely populated residential areas. Discharge of household and non-residential waste directly into rivers without treatment leads to pollution of river water and some changes in the quality of river water. This process is more obvious mainly in the lower reaches of rivers. As a result of pollution, allochthonous organic matter of anthropogenic origin predominates in river waters. According to the studies of the above-mentioned authors [11, 14], the biodegradation method may be preferable for the purification of transboundary waters subject to anthropogenic pollution. It is necessary to increase the number of water treatment facilities, while at the same time strictly monitoring their operation.

Thus, according to the research conducted, it is possible to conclude that pollution in Astarachay and Bolgarchay is less than in Araz and Okhchuchaya. One of the main characteristics of the low pollution of the Bolgarchay River is that it has few drainage tributaries, and also passes through mountainous areas from the source to the border with Azerbaijan, which is the main factor for the low pollution of the river. The Araz and Okhchuchay rivers enter the territory of Azerbaijan in a state of both chemical and biological pollution. Okhchuchay on the territory of Armenia is subject to severe pollution. Thus, hundreds of thousands of tons of solid acidic water, salts of heavy metals and other waste from the Meghri, Gajaran, Gafan and Dastakert mining complexes are discharged directly into the river, bypassing treatment facilities. As a result, the quality of their water does not meet the requirements of sanitary standards and ends up on the territory of Azerbaijan. Unfortunately, the Araz River continues to be polluted in the republic. The main reason for this is the lack of modern waste treatment plants and a centralized sewerage system in the regions of the country.

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) was adopted in Helsinki, Finland in 1992 and entered into force in 1996. It serves as a mechanism for strengthening national measures and international cooperation for the environmentally sound management and protection of transboundary surface and groundwaters. If all countries join this convention and fulfill their obligations, this may include restrictions on the discharge of waste into transboundary rivers or after treatment of wastewater that ends up in water bodies.

Studying the micromycetes that are the object of research at the DNA level will make it possible to accurately diagnose fungal diseases caused and spread through water.

As can be seen from the Table 4, less results in cellulose degradation were observed in *Aspergillus flavus*, the weight of dry biomass is 0.986 mg/l. *Trichoderma viride* showed a higher result. Almost complete decomposition of the filter paper was observed and the weight of dry biomass was 50.1 mg/l. Thus, cellulose activity was observed in all mushrooms used in the experiment.

As a result of research, micromycetes isolated from samples taken from river waters were recognized as a new species for Azerbaijan. The results obtained showed that the identified microscopic fungi are involved in the formation of rich flora as an adaptation in river waters. The development and reproduction of these fungi significantly depend on hydrochemical conditions with parameters such as temperature, dissolved oxygen, pH, forms of nitrogen, phosphorus and organic carbon fractions. Based on the results obtained, it is possible to say that micromycetes play a key role in the decomposition of plant residues, the circulation of carbon and nitrogen, and the flow of energy to higher trophic levels. Micromycetes can also be used to determine the purity and sanitary safety of surface waters during biological monitoring of river waters.

The limitations of this study are:

– failure of some countries to join the International Convention on Transboundary Rivers and failure to conduct joint research;

– since the rivers under study are transboundary, research is carried out only within the territory of Republic of Azerbaijan.

Research work should develop primarily in the direction of joint development of measures and methods for preventing pollution of water bodies with the countries through which transboundary rivers pass.

7. Conclusions

1. It was determined that the amount of biogenic elements studied in the water samples taken from some transboundary river waters of Azerbaijan is variable. The amount of biogenic elements varies depending on the season of the year (the amount of rain, floods in river waters), the area it passes through, anthropogenic factors and the amount of substrate in the watercourse (inorganic nitrogen compounds in natural water – ammonium ions, nitrogen and nitric acids –mainly appears as a result of the final decomposition of protein-based substances). From the obtained results, it is obvious that Arazchay and Okhchuchay are more subjected to anthropogenic pollution. As a result of the research, data were obtained on the high pH level in the studied Okhchuchai, which is due to the direct discharge into the river of hundreds of thousands of tons of solid acidic waters and other waste from the Meghri, Hajaran, Gafan and Dastakert mining complexes of Armenia. The indicators of the amount of dissolved oxygen were also studied and measurements were carried out to determine nitrates, nitrites, ammonium and phosphates in water. Thus, the content of nitrites in the Astarachay River ranges from 0.01–0.02 mg/l, nitrates 0.56–0.70 mg/l, ammonium 0.5–1.50 mg/l, phosphates 0.00–0.01 mg/l. In the Bolgarchay River, these indicators for nitrites range from 0.02–0.05 mg/l, for nitrates 0.20–0.50 mg/l, for ammonium 0.10–0.44 mg/l, for phosphates 0.01–0.05 mg/l. In the Arazchay River, nitrites range from 0.01–0.83 mg/l, nitrates 0.08–7.40 mg/l, ammonium 0.05–3.57 mg/l, phosphates 0.05–0.94 mg/l, and in Okhchuchay these indicators for nitrites range from 0.09–0.71 mg/l, nitrates 0.68–6.00 mg/l, ammonium 0.23–6.45 mg/l, phosphates 0.09–0.65 mg/l.

2. It was determined that the micromycetes found in transboundary river waters belong to the genera *Aspergillus, Penicillium, Mucor, Fusarium, Trichoderma, Cladosporium, Alternaria, Acremonium, Chaetomium Scopulariopsis, Rhizopus, Rodoturula, Bipolaris, Candida, Geotrichum, Mycelia sterilia*. A comprehensive study of micromycetes in the studied transboundary river waters was carried out. Micromycetes were identified by season and the species composition was studied. It was established that in the studied river waters 38 species of micromycetes were identified, which belong to 3 divisions, 7 classes, 9 orders, 11 families and 16 genera.

3. According to the results of researches conducted in some transboundary river waters in Azerbaijan, it was found that micromycetes play a key role in the decomposition of plant residues, carbon and nitrogen circulation, as well as energy flow to higher trophic levels. It can be recommended to use fungi for biological monitoring of surface water purity and sanitary safety. It should be noted that ecological factors also affect the diversity of micromycetes.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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