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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

ECOBIOLOGY OF MICROMYCETES DISTRIBUTED IN FRESHWATER SOURCES IN THE SOUTHERN REGION OF AZERBAIJAN

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INTRODUCTION

The degree of actuality and study of the topic. One of the global problems in the world is the lack of fresh water and pollution of water bodies. Contamination of water sources with various pollutants makes water not suitable for human consumption. Freshwater pollution comes from many sources, including domestic waste, industrial and agricultural waste, power generation, heavy industry, automobiles, etc. "*About 2 billion tons of household waste are discharged into water bodies every day"*[1]. All this pollution has a significant impact on both the environment and human health. Discharge of untreated sewage, fertilizers and other chemicals into freshwater bodies can cause serious damage to aquatic ecosystems, which negatively affects the life of all organisms living in the aquatic ecosystem. Recently, global warming has also caused increased temperatures, floods and droughts. Recently, global warming has also caused increased temperature, floods and droughts. "*Although 70 percent of the planet is covered with water, there is a shortage of drinking water in more than 80 countries. Water scarcity is often divided into two categories: physical water scarcity, when there is a lack of water due to local environmental conditions; and economic water scarcity-when there is inadequate water infrastructure. The two frequently come together to cause water stress"*[2]. Stressed areas can be caused by lack of rainfall, lack of adequate water storage and sewage facilities. According to the information given, fresh water resources in the world constitute only one percent of all water resources. "*It is estimated that the demand for drinking water resources will increase by 30 percent in 2050. The number of people facing this problem will reach 3 billion"*[3]. Rivers, lakes and underground water sources are gradually drying up or becoming polluted.

[1] https://www.unesco.org/en/ihp

[2] https://www.cfr.org/backgrounder/water-stress-global-problem-thats-getting-worse.

[3] https://www.unwater.org/publications/un-world-water-development-report

Azerbaijan is among the countries with limited fresh water resources. Although the main cause of water shortage in Azerbaijan is considered to be climate change, water loss is also one of the main problems. Water is an urgent and global problem, it needs to be studied all the time. Considering all this, it is important to conduct research in river waters in Azerbaijan.

"*Lankaran natural region differs from other regions of the Republic of Azerbaijan in many physical-geographical, climatic, hydrobiological, fauna-flora, soil cover and a number of other characteristics, and also ranks first in the republic in terms of the density of rivers. Lankaran natural region is surrounded by Mughan plain of Kura-Araz lowland from the north, Salyan plain from the northeast, Caspian sea from the southeast, Talish mountains from the northwest and south. Natural province includes 6 administrative districts. Lankaran, Astara, Lerik, Masalli, Yardimli and Jalilabad"*[4].

As we know, water bodies have the ability to self-clean. The self-purification process of water bodies is the ability to transform organic and partially inorganic substances in the water body into harmless compounds by physical, chemical and biological methods. All hydrobionts participate in the self-purification of water bodies, and fungi also play an important role in this process. Fungi are recognized as a large and diverse group of microorganisms that play important functional roles in agriculture, ecology, and economy. As mentioned, fungi are an important component of the aquatic ecosystem, and their study is extremely important.

The aquatic ecosystem hosts many organisms, mainly plant and animal plankton, and microscopic organisms (bacteria and fungi). All these creatures form a link of the food chain in the aquatic ecosystem. As mentioned, fungi and fungus-like organisms are considered permanent and massive components of all types of aquatic ecosystems. Fungi are considered food for most aquatic

[4] https://az.wikipedia.org/wiki/L%C9%99nk%C9%99ran_fiziki-co%C4%9Frafi_rayonu

hydrobionts, including protozoa and fish, and they convert organic matter into simpler compounds that they can use.

Most aquatic fungi thrive on all kinds of living and dead organic substrates in water bodies. The occurrence, reproduction and development of fungi in different water bodies: temperature from -2^0C to $+50^0$C, halophyte with salinity up to 60 ‰, observed in oligotrophic, dystrophic, eutrophic, and even treatment facilities.

"According to on their degree of adaptation and dependence on the aquatic habitats, fungi are divided into three groups: indwellers, periodic immigrants and versatile immigrants. Aquatic fungi are actually considered immigrants"[5]. Water is important for their development and when they fall into water, they develop and reproduce in this environment. One of the important factors for the development of micromycetes is the pH of the water. While fungi thrive mainly in the pH range of 3-11, the optimum environment for aquatic fungi is considered to be 7-8. Some marine fungi are able to develop and multiply in high pressure at a depth of 2-3 km, and some fungi are able to grow and reproduce in dirty and even heavy metal-contaminated water bodies. Among the ecological groups of fungi, saprotrophs are the most widely studied, as they are easier to isolate and cultivate in the laboratory condition. Saprotrophic micromycetes participate in the biodegradation of organic substances of natural and anthropogenic origin in water, they mainly play an important role in the destruction of lignin, chitin and keratin. Fungi have important role the production of biologically active substances. Through decomposition, freshwater fungi can facilitate the transfer of nutrient and energy between trophic levels in the food web. The most important ecological function of freshwater fungi is the decomposition of allochthonous organic matter in aquatic systems.

It is important to note that the mycobiota of the Caspian Sea, Mingachevir reservoir, and some thermal waters have been studied in our republic, but the mycobiota of river waters has not been

[5] Hans-Peter Grossart & other. Fungi in aquatic ecosystems Nature Reviews Microbiology volume 17, pages339–354 (2019)

studied. For determine the ecological function of micromycetes in the river ecosystem, research was conducted in some river waters of Lankaran natural region.

Purpose and objectives of the research. The main goal of the research is to study the ecobiology of micromycetes distributed in some river waters (Astarachay, Lankaranchay, Vilashchay, Boladichay, Bolgarchay, Veravulchay) located in the Lankaran natural region.

To achieve this goal, the following tasks had been performed:

- Isolation of aquatic micromycetes from the samples taken from the studied river waters in the Lankaran natural region (Astaracay, Lankaranchay, Vilashchay, Boladychay, Bolgarchay, Veravulchay), their characterization according to their number and species composition, and compiling an annotated list;
- Comparison of species composition according to rivers of aquatic micromycetes separated from river waters in Lankaran natural province;
- Systematization of aquatic micromycetes according to frequency of occurrence and eco-trophic relationships and determination of substrate specificity;
- Determination of physico-chemical properties of water in river waters of Lankaran natural region and their effect on the diversity of water micromycetes in spatio-temporal dynamics.

Research methods. To achieve this goal, classical and modern methods widely used by microbiologists were used during the research. During sampling, the method of selecting permanent stations was used, sampling was carried out by seasons. The degree of purity of reagents used, for analyzes performed during the study the accuracy of the devices used the measurements have become the basis for obtaining honest data. The repeatability of the samples taken was at least 4 times, and the results obtained were processed statistically. For the degree of honesty of the experimental results, the formula $S/M=P\leq0.05$ was considered basic.

The main provisions of the dissertation presented for

defense:

- The investigated micromycetes are migrants in river waters, they develop and multiply when they fall into the water;
- Although the studied river waters are not suitable for micromycetes, special species are involved in the formation of mycobiota of river waters along with universal species;
- Micromycetes recorded as a result of research are active participants in the decomposition of organic and inorganic substances in the river ecosystem;
- The abundance of species and numbers of micromycetes in river waters depends on the areas the river passes through, environmental factors and anthropogenic pollution of river waters.

Scientific novelty of the research. As a result of the conducted research, for the first time, the mycobiota of some river waters located in the Lankaran natural region was comprehensively studied according to species composition, eco-trophic relationships, frequency of occurrence in river water and river waters were evaluated according to sanitary conditions. Micromycetes were determined according to the seasons of the year and species composition was studied. It was determined that 33 types of micromycetes participate in the formation of the microbiota of the river waters of the Lankaran natural region, which represent 2 division, 6 class, 8 order, 9 family, and 12 genus. Among them, six species of *Penicillium ochrochromon, Fusarium culmorum, Trichoderma harzianum, Cladosporium cladosporioides, Cladosporium herbarum, Mucor mucedo* were registered as new species for freshwater ecosystems of Azerbaijan.

The studies conducted it was determined that micromycetes differ from each other according to the frequency of occurrence in the ecosystem. At the end of the research, it was determined that 10 types of micromycetes are dominant and these fungi are characterized by the frequency of occurrence characteristic of dominants. The recorded dominant micromycetes have the following sequence: *Aspergillus niger, A. flavus, Aspergillus versicolor, Aspergillus terreus, Aspergillus ochraceus, Penicillium*

chrysogenum, P.brevi-compactum, Penicillium ochrochloron, Penicillium cyclopium, Trichoderma viride. It has been determined that the frequency and distribution of micromycetes in river water depends on the area where river water passes, climate, and anthropogenic factors. At the end of the results it was found that the development and reproduction of micromycetes involved in the formation of the mycobiota of the studied river waters depend significantly on parameters such as temperature, dissolved oxygen, pH, nitrogen forms, phosphorus and organic carbon fractions from hydrochemical conditions.

Theoretical and practical importance of the research. Micromycetes were studied for the first time in river waters of Lankaran natural region and the information collected about the identified micromycetes will serve to expand the information about fungi in Azerbaijan as well as in general. Also, it will be important as helpful for the study of fungus disease in fish, living in river waters. It can be recommended to use micromycetes to biological monitoring of surface water purity and sanitary safety.

Publication, approbation and implementation of the dissertation. 25 works related to the dissertation topic, including 8 articles and 17 theses, have been published. The materials of the dissertation were presented at the international scientific conference on "Innovation Problems of Modern Biology" IV International Scientific Conference" (Baku, 2014), at the Ith International Scientific Conference of Young Scientists (Ganja, 2016), at the International Scientific-Practical Conference on "Water resources, hydrotechnical facilities and environment" (Baku, 2017), at the international scientific conference on "Actual problems of modern natural and economic sciences" (Ganja, 2017), at the II International Scientific Conference of Young Scientists (Ganja, 2017), at the International scientific conference on "Actual problems of modern natural and economic sciences" (Ganja, 2018), at the "International Ankara Conference of Scientific Research" (Ankara, 2019), the International scientific conference on "Biotechnologies of microorganism" (Belarus, Minsk, 2019), at the International scientific and practical conference on “Medical

science of the XXI century-looking towards the future" (Dushanbe, 2019), at the "International Euroasia Congress on Scientific Researches and Recent Trends-V" (Baku, 2019), at the "1st International Scientific-Practical Conference" (Baku, 2019), at the international scientific conference on “The impact of climate change on biological diversity and the spread of viral infections in Eurasia” (Makhachkala, 2021), at the International scientific conference on "Achievements and problems of fundamental science and clinical medicine" (Tajikistan R., Dushanbe, 2021), at the International scientific conference on “Theoretical and applied aspects of natural science education” (Cheboksary, 2022), at the International scientific conference on “Biological diversity of the Caucasus and Southern Russia” (Magas, 2022), at hte “1st international conference: Conservation of Eurasian biodiversity: contemporary problems, solutions and perspectives” (Uzbekistan, Andijan, 2023), at the “6th international symposium on Euoasian Biodiversity SEAB-2023” (Baku, 2023), at the International scientific conference on “The Impact of Climate Change on Biological Diversity and the spread of viral infections in the Black Sea-Caspian region” (Makhachkala, 2023).

The organization in which the dissertation is performed. The dissertation work was carried out in the laboratories of Water microbiology of the Institute of Microbiology of Ministry of Science and Education of the Republic of Azerbaijan.

The structure and scope of the dissertation: The dissertation work is written on the basis of generally accepted principles and consists of sections such as introduction, summary of literature (Chapter I), materials and methods (Chapter II), experimental part (Chapters III and IV), final analysis of research, main conclusions, list of literature, tables, diagrams and pictures. The dissertation has a total of 216089 characters.

CHAPTER I.
MICROMYCETES COMMON IN FRESHWATER SOURCES: FRESHWATER MICROMYCETES AND THEIR STUDY, TAXONOMIC CLASSIFICATION, STUDY OF FUNGI IN AZERBAIJAN

In section 1.1 of the dissertation information about micromycetes common in fresh water sources and their study, in section 1.2 Taxonomy of freshwater micromycetes characterization and about new species of fungi identified in freshwater in the last decade, in section 1.3 Extensive information is provided on the history of the study of fungi in Azerbaijan.

CHAPTER II.
MATERIALS AND METHODS OF RESEARCH

2.1. Object of research and research methods

The object of the research was the micromycetes distributed in the waters of Astaracay, Lankaranchay, Vilashchay, Veravulchay, Boladichay and Bolgarchay located in the Lankaran natural region of Azerbaijan.

In order to carry out complex mycological researches in the natural region of Lankaran, were taken 6 rivers, which are widely used in the economic and agricultural development of the region, and most importantly, in meeting the population's demand for fresh water-Astaracay, Lankaranchay, Vilashchay, Boladichay, Veravulchay and Bolgarchay. In each of the rivers examined, research was carried out according to the seasons of the year in order to determine the effect of biotic, abiotic and anthropogenic factors affecting the natural state of water along the flow, as well as physico-chemical and mycological stability. For this purpose, the samples of the studied rivers were taken from stations designated according to the seasons of the year. Several ecological parameters of river water - "*temperature, transparency, pH, dissolved oxygen*

and biogenic elements were measured according to modern methods"[6]. To study the presence and distribution of micromycetes in river waters, were used water and organic waste materials (plant and insect remains) from the river waters and *"determined with appropriate determinants"*[7],[87,8]. To determine whether the growth of micromycetes differed from each other during the study Quantification of fungal growth (QG) was also used. The following formula was used to calculate the growth factor.

$$QG= DHd/T$$

In the formula shown: D – diameter of colonies (in mm);

H - colony height (mm); d - the density of the colony determined based on the visual image (1-5); T - is the duration of cultivation (days).

In addition, the frequency of occurrence of fungi was determined during the study. For this, the following formula was used.

$$FO(\%) = n/N \times 100$$

In the formula shown: FO-frequency of occurrence of fungi on samples; n- the number of detected fungi; N- total number of samples. All experiments were performed in at least 4 repetitions, and the results obtained were processed *"statistically"*[9].

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[6] American Public Health Association (APHA). Standard Methods for the Examination of Water and Wastewater; American Water Works Association and Water Pollution Control Federation: Washington, DC, USA, 1989. [Google Scholar]

[7] Identification of Common Aspergillus Species/ Maren A Klich, ASM Press, 2002, 116 p

[8] Food and Indoor Fung i/ Robert A Samson, Jos Houbraken, Ulf Thrane, Jens C Frisvad, Birgitte Andersen. Centraalbureau voor Schimmelcultures, 2010, 481 p.

[9] Кобзарь А.И. Прикладная математическая статистика. М.: ФИЗМАТЛИТ, 2006, 816 с.

CHAPTER III.
PHYSICO-CHEMICAL PROPERTIES OF SOME RIVER WATERS OF LANKARAN NATURAL PROVINCE AND THEIR INFLUENCE ON MICROMYCETES DIVERSITY IN SPATIOTEMPORAL DYNAMICS

3.1. The temperature of the studied river waters and its influence on water micromycetes in spatiotemporal dynamics

Both growth and sporulation of aquatic micromycetes depend on the substrate (plant residues) and physical-chemical properties of the environment (water). In river waters in temperate regions, micromycete species develop better between 15-25 ^{0}C, while sporulation occurs at slightly lower temperatures, and at higher temperatures, a decrease in the diversity of fungi is observed. Temperature plays an important role in water chemistry and influences the biological activity in surface waters, controlling the species of organisms that can live in the aquatic ecosystem. Increasing water temperatures determine the seasons and dictate which species can live in a given body of water. Therefore, measuring temperature is critical to the sustainability of any aquatic ecosystem. For this reason, we also studied the effect of temperature on micromycetes in spatio-temporal dynamics in the research conducted in Astaracay, Lankaranchay, Vilashchay, Bolgarchay, Boladichay and Veravulchay river waters in Lankaran natural province. For this purpose, we first measured the water temperature according to the seasons of the year at the stations determined on the planned route and the results are listed in the table below (tab. 3.1.).

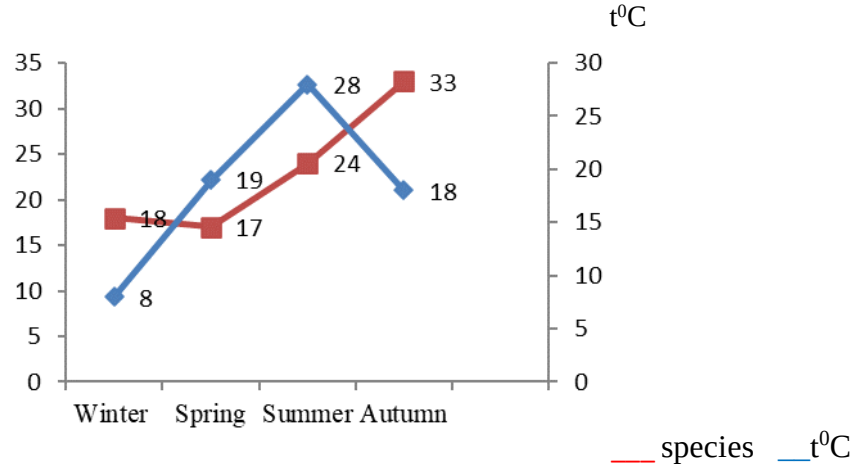
As can be seen from the table, the water temperature in the studied river waters (Astarachay, Lankaranchay, Vilashchay, Bolgarchay, Veravulchay and Boladichay) varies between 6-28 ^{0}C depending on the seasons.

Table 3.1.

Water temperature indicator (t^0C) in the studied river waters in the Lankaran natural region

Rivers	Winter	Spring	Summer	Autumn
Astarachay	6-6,5	15-17	27-28	15-16
Lankaranchay	6,5-7,2	16-16,5	25-27	13-14,3
Vilashchay	7-7,6	17-18	24,5-26	16-16,5
Veravulchay	7-8	17-19	24-27	11,7-12
Boladichay	7,9-8	16,5-18	25-26	15-17
Bolgarchay	6,5-6,8	16-17,5	22-24	15,5-18

When constructing a graph of the occurrence of water micromycetes, which is the object of research, in the studied river waters, depending on the temperature, it was found that the micromycetes showed variability depending on the temperature (gra.3.1).



Graph 3.1. Temperature (t^0C) dependence graph of freshwater micromycetes

Thus, water micromycetes are most often found in the autumn season, which is also related to the fact that there is enough substrate (the beginning of leaves shedding in the autumn season)

as another factor. The effect of temperature on the development of fresh water micromycetes significantly affected the radial growth rates and species identity of fresh water micromycete species. Aquatic micromycetes have the capacity to acquire nutrients from both organic substrate and the water column, and changes in dissolved nutrient concentrations are known to cause changes in the abundance of micromycete species.

3.2. Dissolved oxygen in the studied river waters and its effect on freshwater micromycetes in spatiotemporal dynamics

Another important factor affecting the development of micromycetes is dissolved oxygen in water. Dissolved oxygen in water is considered to be the main limiting factor for hydrobionts, although even under favorable conditions the amount of oxygen in water is lower than in air. During our research, it became clear that aeration affects the development of water micromycetes, primarily the intensive formation of conidia. Thus, the amount of dissolved oxygen in the river waters we studied in the Lankaran natural region is characterized by different indicators according to seasons throughout the year (tab.3.2). The results obtained are listed in the table below.

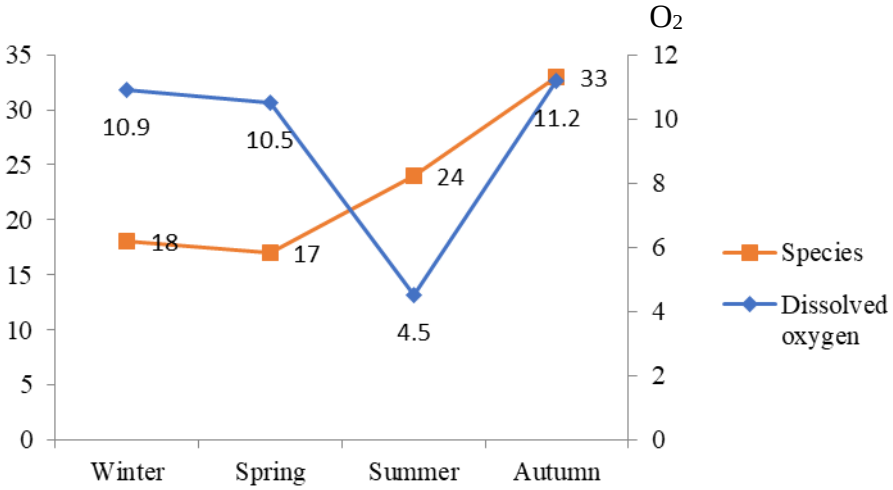
Table 3.2.

Dissolved oxygen indicator in river waters studied in Lankaran natural region (mg/L).

Rivers	Winter	Spring	Summer	Autumn
Astarachay	7,4-8	5,5-6,5	4,5-5	6,5-7
Lankaranchay	9,1-9,5	8-9,5	4,8-5,3	9,7-10,1
Vileshchay	8-8,5	8,5-9,0	7,8-8,5	9,9-11,2
Veravulchay	9-10,9	9,5-10,5	6,7-7	8-8,1
Boladichay	7,9-8,2	8,9-9,2	7,8-8,4	9,1-10,3
Bolgarchay	8-8,5	8-8,5	8-8,9	9,3-10,2

According to the obtained results, it is seen that the amount of dissolved oxygen in the river waters examined varies between 4.5-11.2 mg/l. The lowest amount of oxygen in river waters was observed in summer at 4.5-8.9 mg/l. The actual amount of dissolved oxygen varies with temperature, pressure and salinity. As the water temperature increases, the solubility of oxygen decreases. Dissolved oxygen is one of the most important parameters indicating the environmental cleanliness of the water ecosystem. We determined that the amount of dissolved oxygen in the river waters we studied was higher in spring and autumn season.

When we created the graph of the dependence of water micromycetes on dissolved oxygen, it was determined that the formation of micromycetes in the river waters we examined coincided with the autumn season (gra.3.2).



Graph 3.2. The dependency graph of water micromycetes on dissolved oxygen (mg\L).

This shows that the growth and reproduction of micromycetes in the water ecosystem depends not only on the abundance of oxygen, but also on the abundance of organic matter.

3.3. The pH of the studied river waters and its effect on freshwater micromycetes in spatiotemporal dynamics

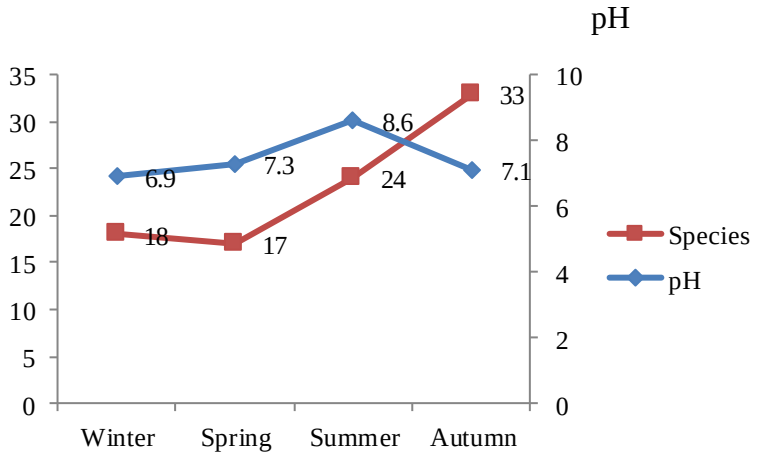
One of the basic physico-chemical parameters of water is pH. pH is an important indicator indicating the acidic and alkaline nature of water. Changes in the pH of river waters can be caused by precipitation and wastewater. As a rule, river waters are weakly alkaline and their pH varies between 7-8. During our research, we determined the pH of river water. The pH of the river waters we studied varies from 6.9 to 8.6. The lowest indicator was observed in the winter season in Lankaranchay, and the highest indicator was observed in the summer season in Boladichay. According to the results obtained, as can be seen from the table, the pH of the water in the river waters examined varies depending on the seasons (tab. 3.3.).

Table. 3.3.

pH indicator of water in river waters studied in Lankaran natural region

Rivers	Winter	Spring	Summer	Autumn
Astarachay	7,1-7,3	7,2-7,5	7,9-8,4	7-7,2
Lankaranchay	6,9-7,1	7-7,3	7,8-8,0	7,1-7,4
Vileshchay	7,5-8,2	7,2-8,1	8-8,3	7,5-7,9
Veravulchay	7,6-7,9	7,5-8.6	7,9-8,3	7-7,9
Boladichay	7,6-8	7,8-8,2	8,2-8,6	7,2-7,6
Bolgarchay	87,7-8	7,3-7,5	7,5-7,6	7-7,1

When we constructed a graph of dependence of water micromycetes on the hydrogen index (pH), it was determined that micromycetes are more dominant in the autumn season due to the diversity of the species composition and frequency of occurrence (gra 3.3).



Graph 3.3. The dependency graph of water micromycetes on pH

Hydrogen concentration not only has a complex effect on the growth, enzyme activity and reproductive activity of micromycetes, but also affects the availability of salts such as calcium, potassium, magnesium, iron and phosphorus and the available form of nitrogen. pH affects the growth of higher plants in the water, which in turn affects the available substrates. At low pH, the activity of micromycetes in competition with bacteria is higher, and at high pH, it is lower. It turned out that the species composition of micromycetes separated from river waters is strongly influenced by water pH. Thus, micromycete colonies found in stations with low pH are richer in species.

3.4. Biogenic elements identified in the studied river waters and their effect on freshwater micromycetes in spatiotemporal dynamics

Biogenic elements, which are considered among the physico-chemical parameters of water, also have a fundamental effect on micromycetes. Thus, the concentration of biogenic elements in water bodies and watercourses is the main ecological factor. Biogenic

elements refer to chemical elements essential for biological development as well as the base of the biological food chain. It is possible to assess the impact of human activity on river ecosystems based on biogenic factors. These elements, which are ubiquitous and critical to the cycling of materials in aquatic ecosystems, are directly affected by human activities.

Many aquatic ecosystems depend on allochthonous organic matter as a source of energy and nutrients. The waste produced when food and plant debris in water decays does not simply disappear. Waste in the form of nitrogen compounds is broken down by microorganisms into other compounds, and the final product, nitrate NO_3, is absorbed by plants. It is clear that different forms of nitrogen and phosphorus in water significantly influence the amount, types and diversity of speciation in different ecosystems. This reinforces the broad and comprehensive impact of biogenic elements on different biological populations in different river ecosystems. "*Consequently, when human activity affects the biogenic element in the river ecosystem, it can also affect the structure and diversity of species*"[10]. Biogenic element indicators total nitrogen, dissolved total nitrogen, nitrate nitrogen, ammonia nitrogen, nitrite nitrogen, total phosphorus, dissolved total phosphorus. Nitrogen enrichment of river ecosystems occurs as a result of leaching from soils and decomposition of organic matter. Also, the amount of biogenic elements increases as a result of the use of nitrogen and phosphorus-based fertilizers in agriculture, and the discharge of household detergents into rivers through household waste. As we mentioned, the amount of biogenic elements in water bodies mainly depends on the pollution of water sources with industrial and domestic waste water. The concentration of biogenic elements nitrite, nitrate, ammonium ions and phosphate was determined in the water samples taken from the river waters where we conducted research. As can be seen from Table 3.4, the ionic content of biogenic elements in the

[10] Y.L.Gao,T.Liang, S.H.Tian, L.Q.Wang, P.E.Holm, H.C.B.Hansen // High-resolution imaging of labile phosphorus and its relationship with iron redox state in lake sediments// Environ. Pollut., 219 (2016), pp. 466-474

studied river waters varies depending on the season (the amount of rain, floods in the river), the area it passes through (discharge of household waste directly into the rivers) and the amount of substrate in the water course. As can be seen from the table the concentration of these ions decreases in the summer months. The increase in these indicators in autumn is related to the breakdown of organic matter.

Table 3.4.

The result of chemical analysis of river waters studied in Lankaran natural region (mg/L)

Season	The name of the component	1	2	3	4	5	6
Spring	Nitrite	0,01	0,02	0,03	0,00	0,02	0,02
	Nitrate	0,56	0,76	0,36	0,40	0,40	0,30
	Ammonium	0,05	0,04	0,15	0,03	0,07	0,10
	Phosphate	0,01	0,06	0,01	0,01	0,02	0,02
Summer	Nitrite	0,00	0,00	0,01	0,00	0,00	0,01
	Nitrate	0,48	0,65	0,30	0,32	0,38	0,20
	Ammonium	0,20	0,08	0,25	0,06	0,12	0,40
	Phosphate	0,00	0,02	0,01	0,00	0,00	0,01
Autumn	Nitrite	0,02	0,03	0,06	0,01	0,04	0,02
	Nitrate	0,70	0,85	0,45	0,60	0,50	0,48
	Ammonium	1,50	0,10	0,40	0,10	0,18	0,35
	Phosphate	0,01	0,04	0,03	0,01	0,01	0,02
Winter	Nitrite	0,02	0,03	0,06	0,01	0,04	0,05
	Nitrate	0,40	0,65	0,40	0,40	0,35	0,30
	Ammonium	0,50	0,10	0,30	0,09	0,14	0,44
	Phosphate	0,01	0,03	0,03	0,01	0,01	0,05

Note: 1-Astarachay, 2-Lankaranchay, 3-Vileshchay,
4-Veravulchay, 5-Boladichay, 6-Bolgarchay.

Micromycetes that are the object of research participate in the main processes of nitrogen circulation in the aquatic ecosystem: depolymerization of nitrogen compounds, ammonification,

nitrification, reduction of oxidized forms. In the autumn season, when micromycetes were more common in the studied river waters, the amount of biogenic elements showed a relatively high result. The reason for this is that river waters are polluted with household waste, as well as abundant rains and rich in organic substances.

CHAPTER IV.
SPECIES COMPOSITION AND DISTRIBUTION CHARACTERISTICS OF MYCOBIOTA PRESENT IN SOME RIVER WATERS IN LANKARAN NATURAL PROVINCE

4.1 Characterization of micromycetes in the studied river waters according to their number and species composition

The species composition of micromycetes involved in the formation of the mycobiota of the studied river waters in the Lankaran natural region was determined, and based on the results, it was found that micromycetes are found in every river ecosystem, but the micromycetes involved in the formation of the mycobiota of this ecosystem differs from each other in terms of number and species composition (tab.4.1).

Table 4.1.

Characterization of the number and species composition of mycobiota of the studied river waters

Rivers	Number composition (CFU/ml)	Species composition, number
Astarachay	124	29
Lankaranchay	118	27
Vileshchay	107	26
Boladichay	94	28
Bolgarchay	77	24
Veravulchay	102	27

As a result of the research, it was found that the *Aspergillus* genus is represented by the most colonies of 94 CFU/ml in the studied river waters. *Penicillium* 65 CFU/ ml, *Fusarium* 40 CFU /ml, *Trichoderma* 38 CFU/ml, *Scopulariopsis* 19 CFU/ml, gender is among the more common ones.

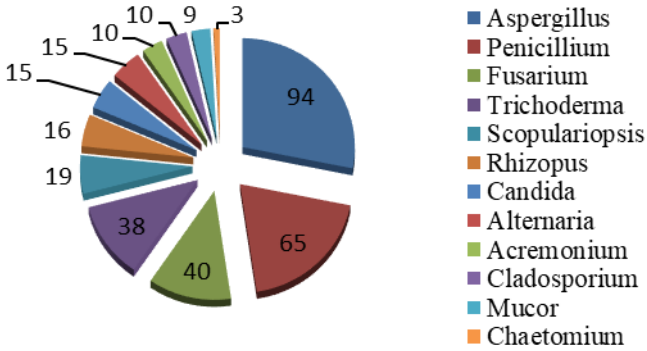


Figure 4.1. Number of genera of micromycetes found in the studied river waters CFU/ml

Based on literature data, we can say that the systematics of fungi has always been and continues to be a controversial issue. There is no unified system accepted by scientists. Taking all this into consideration, we compiled the taxonomic structure of fungi in our research, using the official number of IMA (International Mycological Association), which is accepted and applied by most scientists.

As a result of the conducted research, 33 types of micromycetes were identified, the information about them is listed in table 4.2. As can be seen from the table, 33 micromycete species represent 2 division, 6 class, 8 order, 9 family and 12 genus. 28 types of micromycetes recorded during the study belong to *Ascomycota*, and 5 types of fungi belong to *Zygomycota*. Identified of micromycetes to put it quantitatively the division *Ascomycota* is 84.8%, and the division *Zygomycota* is 15.2%.

Table 4.2.

Taxonomic structure of micromycetes recorded during research

Division	Class	Order	Family	Genus (number of species)
Zygomycota	*Mucoromycotina*	*Mucorales*	*Mucoraceae*	*Mucor(4)*
				Rhizopus(1)
Ascomycota	*Eurotiomcetes*	*Eurotiales*	*Trichocomaceae*	*Aspergillus(9)* *Penisillium (7)*
	Sordariomycetes	*Hypocreales*	*Nectriaceae*	*Fusarium (3)*
			Hypocreaceae	*Trichoderma (2)* *Acremonium (1)*
		Sphaeriales	*Chaetomiaceae*	*Chaetomium (1)*
	Dothideomycetes	*Capnodiales*	*Davidiellaceae*	*Cladosporium (2)*
		Pleosporales	*Pleosporaceae*	*Alternaria (1)*
	Saccharomycetes	*Saccharo-mycetales*	*Saccharo-mycetaceae*	*Candida (1)*
	Sordariomycetes	*Microascales*	*Microscaceae*	*Scopulariopsis (1)*

Although the micromycetes involved in the formation of the mycobiota of the studied river waters differ from each other according to species and gender composition, the genera of *Aspergillus* and *Penicillium* are dominant. As can be seen from Figure 4.2, although some species are rare, others are almost never found.

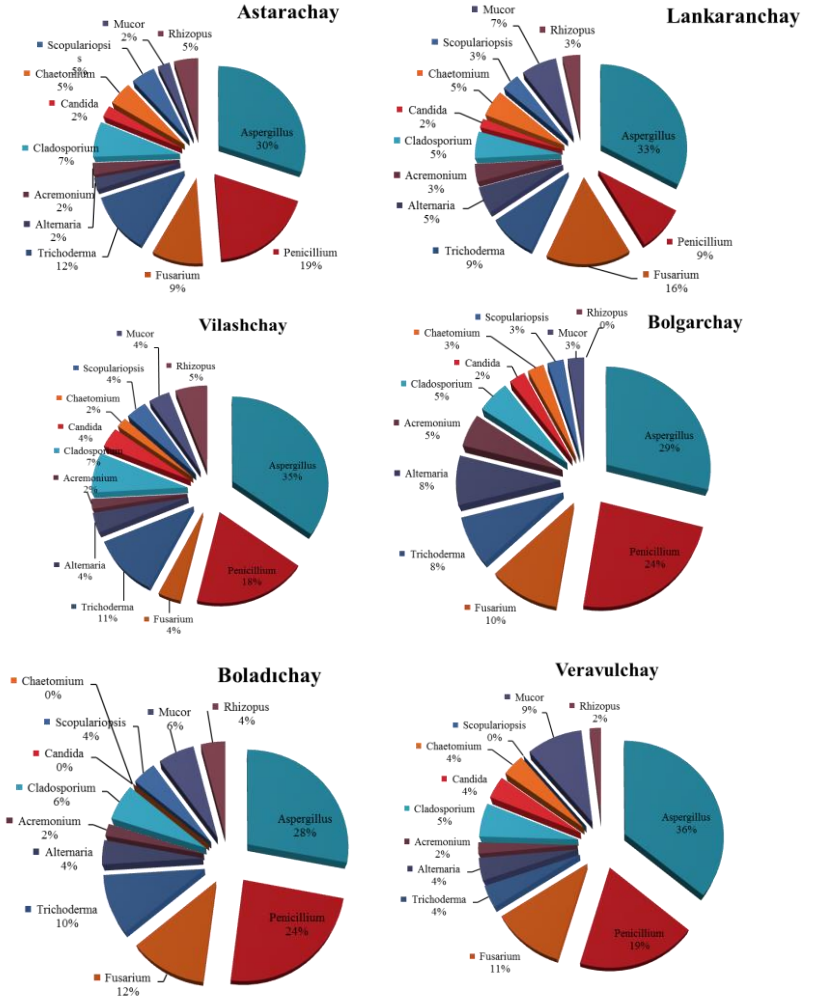


Figure 4.2. Micromycetes involved in the formation of the mycobiota of the studied river waters.

Micromycetes have been studied little in the water ecosystem in Azerbaijan (Caspian Sea, Mingachevir reservoir, Thermal waters), but micromycetes in river waters were studied for the first time in Lankaran natural region. Although the micromycetes recorded in the river ecosystem we studied are new for the river ecosystem of Azerbaijan, when compared with the research conducted in some water ecosystems of Azerbaijan although some separated species are found, but such micromycetes as *Aspergillus ochraceus, Penicillium ochrochloron, Fusarium culmorum, Trichoderma harzianum, Cladosporium herbarum, Mucor mucedo* are exceptions and it is the first time that they have been recorded in a freshwater ecosystem. Considering all this, it can be said that there is a need to conduct mycological studies of water ecosystems in Azerbaijan.

To fully characterize the fungi involved in the formation of the mycobiota of each ecosystem, the frequency of occurrence, eco-trophic relationship, role in the ecosystem and the functions they perform are the main factors.

It is known that if the frequency of occurrence fungi in any ecosystem is higher than 50%, it is dominant for that ecosystem, if the occurrence frequency is between 20-40%, it is often found, and if it is less than 10%, it is random or rare is characterized as a species. This approach was used to characterize the occurrence frequency of fungi recorded in some water ecosystems of the studied Lankaran natural region. Studies have shown that micromycetes differ from each other according to their frequency of occurrence in the ecosystem (tab. 4.3). 10 micromycetes species recorded during the study show dominance. The dominant micromycetes recorded have the following composition. *Aspergillus niger, A. flavus, Aspergillus versicolor, Aspergillus terreus, Aspergillus ochraceus, Penicillium chrysogenum, P. brevi-compactum, Penicillium ochrochloron, Penicillium cyclopium, Trichoderma viride*. 11 species are frequent and 12 species are occasional or rare species among the micromycetes identified in the studied river waters of the Lankaran natural region. The grouping of micromycetes according to their frequency of occurrence in the river ecosystem is reflected in the table below.

Table 4.3.

The frequency of occurrence micromycetes involved in the formation of mycobiota of river ecosystems of Lankaran natural region

Dominant species	Commonly encountered species	Rare or occasional species
Aspergillus niger	A. *fumigatus*	*Aspergillus candidus*
A. flavus	*A.nidulans*	*Aspergillus carneus*
A.versicolor	*P.frequentans*	*Acremonium rutilum*
Aspergillus terreus	*Fusarium oxysporum*	*P. funiculosum*
A.ochraceus	*F.solani*	*Penicillium arenarium*
Penicillium notatun	*Trichoderma harzianum*	*Fusarium culmorum*
P.brevi-compactum	*Alternaria alternata*	*Mucor racemosus*
Penicillium ochrochloron	*Scopulaiopsis sp*	*Mucor corymbifer*
Penicillium cyclopium	*Cladosporium herbarum*	*Mucor hiemalis*
Trichoderma viride	*Rhizopus sp*	*Mucor mucedo*
	Candida albicans	*Chaetomium globosum*
		Cladosporium cladosporioides

It became clear that from the studies conducted on the study of the mycobiota of the water ecosystem of the Lankaran natural region that the mycobiota of some river waters formed by both universal (i.e. without substrate specificity) and specific species (i.e. with substrate specificity).

Table 4.4.

Distribution of micromycete species in substrates in the river ecosystem of Lankaran natural region

Genus	Species	Substrates
1	2	3
Mucor	*M.racemosus*	Plant residues, water
	Mucor corymbifer	Plant residues, water
	Mucor hiemalis	Plant residues, water
	Mucor mucedo	water
Rhizopus	*Rhizopus .sp*	Plant residues, water
Aspergillus	*A.niger*	water
	A. flavus	water
	A. versicolor	Plant residues, water
	A. fumigatus	Plant residues, water
	A. candidus	Plant residues, water
	A. carneus	Plant residues, water
	A. terreus	Plant residues, water
	A.nidulans	Plant residues, water
Penicillium	*Penicillium chrysogenum*	Insects residues, water
	P. ochro-chloron	Plant residues, water
	P.cyclopium	Plant residues, water
	P. funiculosum	Plant residues, water
	P.brevicompactum	Plant residues, water
	P.arenarium	Plant residues, water
	P.frequentans	Plant residues, water
Trichoderma	*Trichoderma viride*	Plant residues, water
	T. harzianu	Plant residues, water
Fusarium	*Fusarium oxysporum*	Remains of plants and insects, water
	F.solani	Plant residues, water
	F.culmorum	water
Alternaria	*Aalternata*	Plant residues, water
Acremonium	*Acremonium rutilum*	Plant residues, water

Table 4.4. follows

1	2	3
Chaetomium	*Chaetomium globosum*	Plant residues, water
Cladosporium	*Cladosporium herbarum*	Plant residues, water
	Cladosporium cladosporioides	Plant residues, water
Candida	*Candida albicans*	water
Scopulariopsis	*Scopulariopsis. sp*	water

As can be seen from table. 4.4, micromycetes were found mainly in samples taken from water and plant residues.

FINAL ANALYSIS OF THE RESEARCH

As in most ecosystems, the decomposition of plant remains in the aquatic ecosystem is carried out by microorganisms. Bacteria and fungi are the main microorganisms that play a role in the decomposition of plant residues in the aquatic ecosystem. Fungi are ubiquitous parts of global microbial communities and ecosystems. For that they are cosmopolitan. As we mentioned, the main role of aquatic micromycetes is to participate in the decomposition of organic substances of natural and anthropogenic origin falling into the water, in particular the biological destruction of plant residues (leaves, tree branches). Most saprotrophic fungi participate in the decomposition of cellulose, hard-to-decompose organic matter such as lignin, as well as insect exoskeletons, fish scales, and other animal remains. Not all micromycetes are equally distributed in the aquatic ecosystem. Micromycetes in the aquatic ecosystem participate in the trophic relationship of the ecosystem. Thus, their easily assimilated zoospores are used as food by detritophagous. When studying the relationship between the physico-chemical properties of water and the richness of micromycete species, it was found that the species diversity of water micromycetes depends not

only on the physico-chemical properties of water, but also on the richness of organic substances. The dominant group in the early stages of plant residue degradation activity, diversity and productivity of aquatic micromycetes depends on the physico-chemical properties of leaves and the intra-species variation of leaf traits, as well as the influence of environmental factors. In unpolluted natural aquatic ecosystems, the concentration of inorganic forms of nitrogen (ammonia, ammonium, nitrites and nitrates) is very low. High concentration of nitrites in water bodies is usually shows pollution with domestic waste. Nitrate concentrations in unpolluted freshwater are usually low, averaging about 0.30 mg/L. The maximum concentration of nitrate in river waters is not constant, it mainly depends on the morphology, chemical properties and productivity of the river. Under normal conditions, the amount of nitrite in water is determined by biological processes: respiration, growth and photosynthesis. The nitrate content in the system increases as a result of bacterial nitrification and decreases when they are absorbed by green plants and during bacterial denitrification with the formation of free nitrogen. The chemical activity of phosphorus is very variable, which depends on the pH of the environment.

Characteristics of micromycetes contamination of studied river waters systematically analyzed and the source of micromycetes in river waters was determined. Species diversity, abundance and population characteristics of micromycetes were found in the studied river waters depending on the seasonal changes. It was determined that 33 types of micromycetes are involved in the formation of microbiota of river waters of Lankaran natural region. Six new species *Penicillium ochrochromon, Fusarium culmorum, Trichoderma harzianum, Cladosporium cladosporioides, Cladosporium herbarum, Mucor mucedo* were identified for freshwater ecosystems of Azerbaijan. Based on the obtained results, it was determined that the number of micromycetes in river waters is closely related to environmental variables, mainly when drastic changes in ecological conditions occur, such as floods, heavy rains, and pollution of river waters

with household waste. It was found that the number, growth rate and reproductive capacity of micromycetes can be affected by temperature, assimilable organic carbon, phosphorus, ammonium and nutrient concentrations. Most freshwater micromycetes can degrade cellulose, hemicellulose, xylan, and starch, which are important carbon compounds in plant wastes, depending on environmental climate, habitat, and substrate distribution.

MAIN RESULTS

1. For the first time, a complex study of micromycetes was conducted in some river waters located of in the Lankaran natural region. Micromycetes were determined according to the seasons of the year and species composition was studied. It was found that 33 types of micromycetes identified in the studied river waters represent 2 division, 6 classe, 8 order, 9 family and 12 genus.
2. It was determined that 33 types of micromycetes representing two divisions played a role in the formation of the mycobiota of the river waters examined. The division *Ascomycota* is 84.8%, and the division *Zygomycota* is 15.2%.
3. Six new species *Penicillium ochrochromon, Fusarium culmorum, Trichoderma harzianum, Cladosporium cladosporioides, Cladosporium herbarum, Mucor mucedo* were identified for freshwater ecosystems of Azerbaijan.
4. The micromycetes identified in the studied river ecosystem of Lankaran natural region 10 types are dominant, 11 types are frequent species, and 12 types belong to rare or occasional micromycetes.
5. It has been determined that the occurrence frequency and distribution of micromycetes in river waters vary according to climate and anthropogenic factors, depending on the spatialtemporal dynamics of the region through which the river water passes.
6. The obtained results showed that the development and

reproduction of the identified micromycetes depend significantly on parameters such as temperature, dissolved oxygen, pH, nitrogen forms, phosphorus and organic carbon fractions.

7. It was found that the identified micromycetes mainly participate in the biodestruction of plant remains (leaves, tree branches) in the decomposition of organic substances of anthropogenic origin, depending on the environmental climate, habitat, substrate abundance and their spatiotemporal dynamics.

PRACTICAL RECOMMENDATIONS

1. Fresh water shortage and pollution of water bodies is one of the main global problems of recent times. It is recommended to use fungi, along with other microorganisms, for biological monitoring of surface water purity and sanitary safety in determining the degree of pollution of water bodies.
2. It can be important as an auxiliary means in the study of mycosis diseases of fish living in river waters.

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