Georgian Scientists
ქართველი მეცნიერები
Vol. 8 Issue 2, 2026
https://doi.org/10.52340/gs.2026.08.02.46

Microbial Diversity and Biofouling Characteristics of Deposits Recovered from Membrane Filtration Systems in Wine and Water Treatment

George Bibileishvili[1], Manana Mamulashvili[2], Tinatin Butkhuzi Elene Kakabadze, Liana Ebanoidze, Ia Gogiberidze

Engineering Institute of Membrane technologies of Georgian Technical University

[1]Doctor of Chemical and Biological Engineering, Chief Scientist, email: 75bibileishvili@gmail.com ORCID ID: https://orcid.org/0009-0003-7712-2436

[2]Doctor of Chemical and Biological Engineering, Senior Research Scientist, email:mananamamula59@gmail.com ORCID ID: https://orcid.org/0009-0001-3982- 5515

Abstract

The research concerns the microbiological and morphological characteristics of deposits accumulated on membrane filters after the filtration of wine material, drinking water, and wastewater. The aim of the study was to evaluate signs of microbial contamination and biofouling associated with membrane filtration processes. Samples collected from membrane surfaces were examined using the crushed drop ("hanging drop") microscopic method combined with optical microscopy at ×400 magnification.

The results of the study showed significant differences in the microbial composition of the filtered samples. The wine material was dominated by yeast cells, primarily oval-shaped Saccharomyces cerevisiae, which frequently formed aggregates and were associated with the fermentation process. No biological contamination was observed in the drinking water samples, indicating effective water purification and microbiological safety. Wastewater samples showed high microbial load, diverse bacterial morphology, activated sludge flocs, and biofilm-associated aggregates, indicating degree of membrane biofouling.

The study confirmed that the sediments accumulated on the membranes contain a variety of microbial organisms that may negatively affect the filtration efficiency and operational stability of the system. The results obtained emphasize the importance of microbiological monitoring in membrane filtration systems for optimizing the filtration process, reducing biofouling, and ensuring the long-term effective functioning of wine and water treatment technologies.

Keywords: microbiological analysis, membrane filtration, optical microscopy, wine materials, drinking and wastewater

Introduction

Membrane technologies are widely used in water and wine processing, but one of the main problems is the accumulation of microorganisms on the filters and the development of biofouling. This process leads to a decrease in filtration efficiency, increased energy costs, and deterioration of product quality.

Identification of microorganisms and their morphological study are important stages in managing this process. The “smashed drop” method is a simple and effective way to observe living microorganisms, which allows assessing their shape, movement, and aggregation ability. Filtration plays a crucial role in the wine industry. The final filtration of wine must ensure its crystal clarity, 100% denaturation, stability, and storage stability [1,2].

This leads to the production of ecologically clean, crystal clear, high-quality wine with extended shelf life. During wine production, microorganisms are introduced from the surface of grapes, fruits and berries. The wine material is infected with microorganisms of the genera Rhizopus, Mucor, Penicillium, Aspergillus, Pullularia, Botrytis and yeasts of the genera Zygosaccharomyces, Hansenula, Pichia, Schizosaccharomyces, Asatanomyces, Saccharomycodes, Candida, Toruloptersis. Wine microorganisms include wild yeast and mold bacteria. Bacterial contaminants are: acetic acid bacteria (Acetobacter), lactic acid bacilli (Lactobacillus) and micrococci [5]. E. coli, common coliform and mesophilic aerobes and facultative anaerobes are mainly found in drinking and wastewater [3].

Filtration of wine, drinking water, and wastewater was performed on a microfiltration device developed at the Membrane Technologies Engineering Institute, using membranes with 0.2 - 0.45 μm pore size [4].

Materials and methods

The object of the study was: the sediment remaining on the membrane surface after filtration of wine material, drinking water and wastewater. The sediment was collected from the surface of the filters using a sterile loop. The samples were placed in sterile containers and immediately examined using the “smashed drop” method. The preparation of the preparation was carried out in the following stages: a small part of the sediment was placed on a glass slide, 1 drop of sterile distillate was added and covered with glass again, after drying, the smear was stained. The observation included morphological analysis, assessment of movement, signs of aggregation and biofilm, for which an optical microscope with ×400 magnification was used.

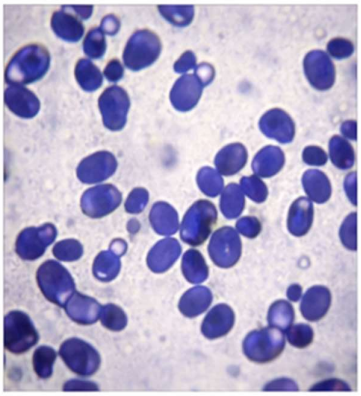

Fig. 1

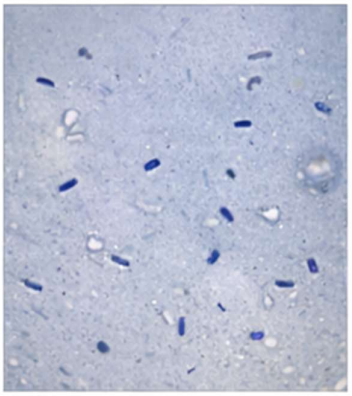

Fig. 2

Fig. 3

Fig. 1. Yeast cells in grape juice – oval-shaped Saccharomyces cerevisiae (×400)

Fig. 2. Bacteria found in wine lees – elongated (bacillary)-shaped Lactobacillus spp. (×400)

Fig. 3. Filtered wine lees – crystalline (tartrates) and mechanical impurities (×400)

Wastewate

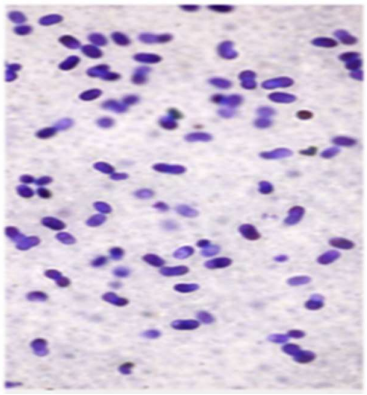

Fig. 1

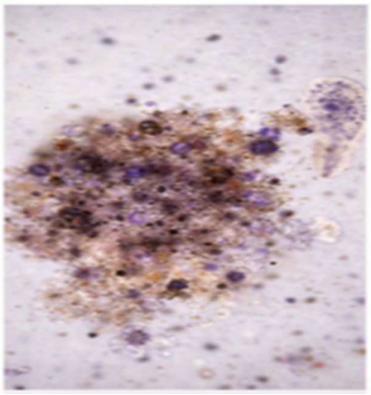

Fig. 2

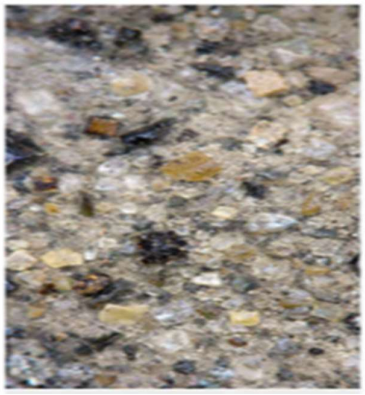

Fig. 3

Figure 1. Microflora of wastewater – bacterial cells (×400) – bacteria of different morphology are shown (cocci, rods);

Figure 2. Activated sludge of wastewater – aggregates of microorganisms (×400) – bioflocs are visible, consisting of bacteria, protozoa and organic particles;

Figure 3. Filtered wastewater sediment – mechanical and mineral impurities (×400) – inorganic particles, crystals and the remaining solid fraction after filtration are presented.

Results

Wine samples were dominated by yeast, mainly oval-shaped cells that often formed aggregates. No biological contamination was observed in drinking water. High microbial load, diverse microflora, and biofilm structures were observed in wastewater. Microbial contamination levels were assessed qualitatively based on the observed abundance of microorganisms in microscopic fields. Comparative analysis was performed between wine, drinking water, and wastewater samples to assess differences in microbial load and biofouling characteristics.

Table 1. Number and characteristics of microorganisms in the test samples

Sample	Microorganisms	Quantity	Peculiarity
Wine ingredients	Yeast	High	Aggregation
Drinking water	Bacteria	wasn't	--
Wastewater	Mixed	Very high	Biofilm

The results obtained indicate that the type and quantity of microorganisms significantly depend on the water source. The dominance of yeast in wine is due to the fermentation process. No microbial content was confirmed in drinking water. The presence of biofilm observed in wastewater is a serious problem for membrane systems. The accumulation of contaminants on membranes can significantly reduce the efficiency of the system, increase energy consumption, and ultimately lead to deterioration of functioning and membrane replacement.

Conclusions

The study showed that the sediments accumulated on the filters after the membrane filtration process contain various types of microorganisms, the composition of which significantly depends on the nature of the filtered liquid. Yeast cells, which are associated with fermentation processes, dominated in the wine material, while high microbial load, diverse microflora and signs of biofilm formation were detected in the wastewater. No microbial contamination was observed in the drinking water samples, which indicates the effectiveness of water treatment.

The study confirmed that the “smashed drop” method and optical microscopy are effective and rapid methods for the initial identification and morphological assessment of microorganisms accumulated on membrane surfaces. The results obtained are important for a better understanding of the biofouling processes of membrane systems and for assessing the efficiency of filtration.

Biofilms and microbial aggregates detected in wastewater indicate that biofouling is one of the main problems in membrane filtration systems, as it leads to a decrease in membrane permeability, increased energy consumption, and a deterioration in the efficiency of system operation.

The results of the study provide opportunities for microbiological monitoring, optimization of the filtration process, and improvement of membrane operation in wine and water treatment technologies.

References

1. Manana Mamulashvili[1], Giorgi Bibileishvili[2], Zaza Javashvili[3], Tinatin Butkhuzi[4], Elene Kakabadze[5] Determination of morphological and tinctorial characteristics of microorganisms in wine and water. Georgian Scientists Vol. 7 №2, 2025 https://doi.org/10.52340/gs.2025.07.02.59 pp. 647-651
2. [1]George Bibileishvili, [2]Manana Mamulashvili, [3]Elene Kakabadze, [4]Liana Ebanoidze, [5]Nona Butkhuzi, [6]Ia Gogiberidze Microbiological analysis of wastewater, fruit juices, determination of microbial sizes, diagnostics and filtration of microorganisms. Georgian Scientists Vol. 7 №4 2025. Pp 440-443 https://doi.org/10.52340/gs.2025.07.04.
3. Bibileishvili G.V., Mamulashvili M.A., Javashvili Z.D., Kakabadze E.G. Microbiological study of natural fresh waters treated with ultrafiltration membranes. Georgian Engineering News, Vol. 93 ф2, 2021, pp. 113-114
4. G. Bibileishvili, N. Gogesashvili, M. Kezherashvili, L. Kuparadze, M. Mamulashvili, L. Ebanoidze Micro- and ultrafiltration treatment of water and fruit juices. Collection of abstracts of the international conference “Chemistry - Achievements and Prospects” dedicated to the 90th anniversary of the birth of Academician Givi Tsintsadze. GTU 2023
5. Fleet G. Yeasts in Wine Production Book. Chapter 1 - Yeast Ecology in Winemaking 2022
6. Mamulashvili M., Gogiberidze I. RESEARCH ON THE HYDROBIOCHEMICAL STATE OF LAKE LISI WATER. Slovak international scientifik journal №105 2026. pp. 4-7

ღვინისა და წყლის დამუშავების მემბრანული ფილტრაციის სისტემებიდან ამოღებული ნალექების მიკრობული ორგანიზმები და ბიოდაბინძურების მახასიათებლები

გიორგი ბიბილეიშვილი[1], მანანა მამულაშვილი[2],თინათინ ბუთხუზი., ელენე კაკაბაძე., ლიანა ებანოიძე., ია გოგიბერიძე

საქართველოს ტექნიკური უნივერსიტეტის მემბრანული ტექნოლოგიების საინჟინრო ინსტიტუტი

[1]ქიმიური და ბიოლოგიური ინჟინერიის დოქტორი, მთავარი მეცნიერი თანამშრომელი email: 75bibileishvili@gmail.com ORCID ID: https://orcid.org/0009-0003-7712-2436; [2]ქიმიური და ბიოლოგიური ინჟინერიის დოქტორი, უფროსი მეცნიერი თანამშრომელი email:mananamamula59@gmail.com ORCID ID: https://orcid.org/0009-0001-3982- 5515

რეზიუმე

კვლევა ეხება ღვინომასალის, სასმელი და ჩამდინარე წყლების მემბრანული ფილტრაციის შემდეგ ფილტრებზე დაგროვილი ნალექების მიკრობიოლოგიურ და მორფოლოგიურ შესწავლას. კვლევის მიზანს წარმოადგენდა მემბრანული ფილტრაციის პროცესებთან დაკავშირებული მიკრობული დაბინძურებისა და ბიოდაბინძურების (biofouling) ნიშნების შეფასება. მემბრანის ზედაპირიდან აღებული ნიმუშები შესწავლილ იქნა „გაჭყლეტილი წვეთის“ მეთოდისა და ×400 გადიდების ოპტიკური მიკროსკოპიის გამოყენებით.

კვლევის შედეგებმა აჩვენა განსხვავებები გაფილტრული სინჯებს მიკრობულ შემადგენლობაში. ღვინომასალაში დომინირებდა საფუარის უჯრედები, ძირითადად ოვალური ფორმის *Saccharomyces cerevisiae*, რომლებიც ხშირად ქმნიდნენ აგრეგატებს და დაკავშირებული არიან ფერმენტაციის პროცესთან. სასმელი წყლის ნიმუშებში ბიოლოგიური დაბინძურება არ დაფიქსირდა, რაც წყლის ეფექტურ გაწმენდასა და მიკრობიოლოგიურ უსაფრთხოებაზე მიუთითებს. ჩამდინარე წყლების ნიმუშებში გამოვლინდა მაღალი მიკრობული დატვირთვა, მრავალფეროვანი ბაქტერიული მორფოლოგია, აქტიური ლამის ფლოკები და ბიოფილმთან ასოცირებული აგრეგატები, რაც მემბრანული ბიოდაბინძურების ხარისხზე მიუთითებს.

კვლევამ დაადასტურა, რომ მემბრანებზე დაგროვილი ნალექები შეიცავს მრავალფეროვან მიკრობულ ორგანიზმებს, რომლებიც შესაძლოა უარყოფითად მოქმედებდნენ ფილტრაციის ეფექტურობასა და სისტემის ოპერაციულ სტაბილურობაზე. მიღებული შედეგები ხაზს უსვამს მემბრანული ფილტრაციის სისტემებში მიკრობიოლოგიური მონიტორინგის მნიშვნელობას ფილტრაციის პროცესის ოპტიმიზაციის, ბიოდაბინძურების შემცირებისა და ღვინისა და წყლის დამუშავების ტექნოლოგიების გრძელვადიანი ეფექტური ფუნქციონირებისათვის.

საკვანძო სიტყვები მიკრობიოლოგიური ანალიზი, მემბრანული ფილტრაცია, ოპტიკური მიკროსკოპია, ღვინომასალა, სასმელი და ჩამდინარე წყალი;