Georgian Scientists
ქართველი მეცნიერები
Vol. 7 Issue 4, 2025
https://doi.org/10.52340/gs.2025.07.04.24

Colloidal-chemical study of sediment formed natural water on a microfiltration membrane

[1]George Bibileishvili, [2]Liana Ebanoidze , [3]Mzia Kezherashvili, [4]Manana Mamulashvili, [5]Liana Kuparadze, [6]Nona Butkhuzi, [7]Ia Gogiberidze

[1]Academic Doctor of Chemical and Biological Engineering - e-mail 75bibileishvili@mail.com

ORCID https://orcid.org/0009-0003-7712-2436

Engineering Institute of Membrane Technologies Georgian Technical University

Abstract

The paper presents a colloidal-chemical research of the precipitate formed natural water on a membrane with during microfiltration. Particle sizes in natural water formed on the membrane, the magnitude and sign of the electrokinetic potential were determined by the dynamic light scattering method, and the sedimentation velocity was determined by sedimentation analysis. The coagulating and adsorbing ability of particles suspended in water was identified, which affects the structure of the resulting sediment.

Keywords: Microfiltration, Membrane, Sedimentation, Coagulation, Adsorption

Sediment formed on the membrane during filtration natural water is considered as membrane surface fouling, which is formed during the intensive operation of the membrane apparatus.

To determine the optimal hydrodynamic parameters, regeneration process, and maximum service life of microfiltration membrane devices, it is necessary to study the mechanism of membrane fouling.

The aim of the study was to conduct a colloidal-chemical study of sediment formed natural water on a microfiltration membrane [1-3].

For particle size, electrophoretic and sedimentation analysis, suspension analysis samples were prepared from the sediment removed from the membranes using the international standard method ISO 5667-10 [4].

The particle size, charge magnitude, and sign of the suspension samples were determined by Dynamic Light Scattering (DLS) on a Zetasizer Nano 3690 nanoparticle analyzer (With a scattering angle of -173^0 and a wavelength of 633 nm).

The determination of the particle size of the dispersed phase and their percentage distribution in the range of 0.3 nm to 10000 nm was carried out using the M3-PALS method using the patented Zetasizer Software 6.1 program, and measurement of the ξ-potential and its percentage distribution in the range from -200 mV to +200 mV - according to the Zetasizer Software 6.2 program [5-6]. To maintain the stability of the system, the suspension samples were processed in a water bath of an ultrasonic device (Unitra-Unima, UM-4, Olsztyn, Poland). Particle sedimentation analysis was performed using a VT-500 torsion balance [7-8]. The processes of coagulation and adsorption of suspended particles in water, which have a significant impact on sediment formation, have been studied [9-11]. The results obtained from theoretical and experimental research are given in Figures 1., 2. and 3.

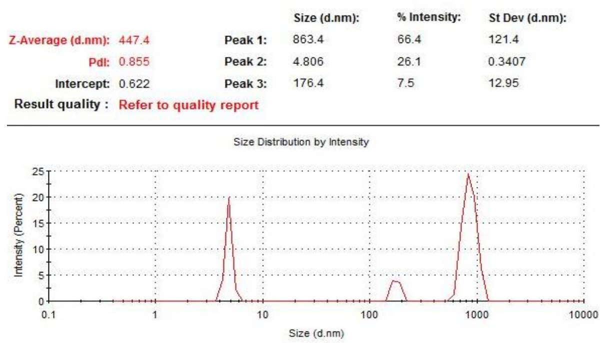

Figure 1. Particle size distribution curves by intensity

From the granulometric analysis (Figure 1) it can be seen that the average hydrodynamic size of particles present in natural water (447.4 nm) exceeds the pore size of the microfiltration membrane used, i.e., a layer of sediment forms on the membrane surface.

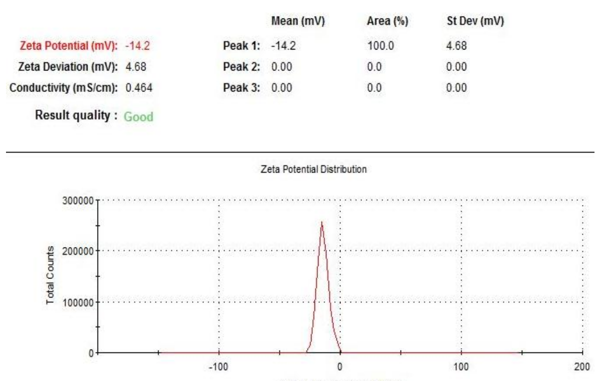

Figure 2. Particle ξ-potential distribution curve

Electrophoretic analysis (Figure 2) showed that at pH=6-8, the magnitude and sign of the electrokinetic potential of natural water particles is ξ=-14.2 mV. This means that the particles have the same charge as the membrane surface. The presence of surface charge in the dispersed phase particles is one of the factors causing membrane fouling and sediment formation.

The results of sedimentation analysis indicate a decrease in the sedimentation rate of particles with increasing concentration. According to the results, the concentration increased so much that liquid became difficult between to penetrate the particles and eventually the precipitate hardened. The results calculated using the Stokes equation showed that the sedimentation rate of particles is very small and does not exceed 2·10-4 mm/s, and it takes at least 24 hours for its formation.

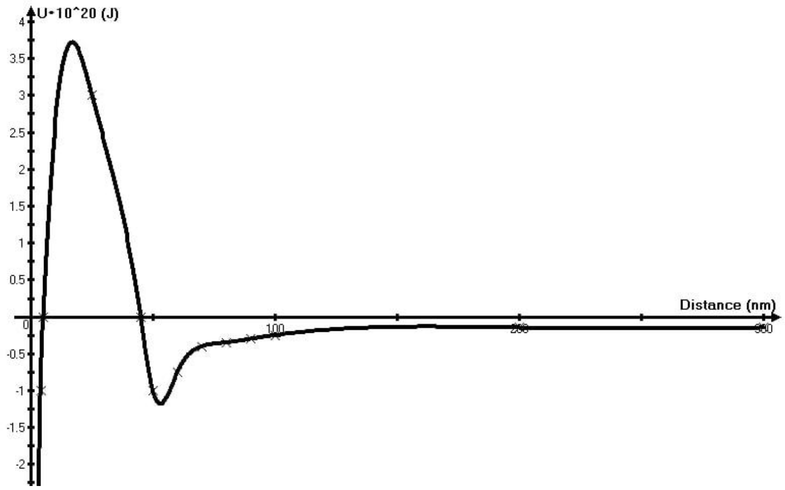

Figure 3. Two particles energies of attraction (Um) and repulsive (Ue) dependency curves in the distance between the particles

Observations of particle sedimentation showed that sedimentation occurred earlier than 24 hours, indicating the coagulation ability of suspended particles present in natural water. In the study, the stability and coagulation of the system are considered as the result of the combined action of intermolecular attraction (Um) and electrostatic repulsion (Ue) forces between particles, according to which it can be argued that, based on which, one can discuss in which cases particle aggregation occurs and what coagulation is like. In the study, the stability and coagulation of the system are considered as the result of the combined action of the intermolecular attraction (Um) and electrostatic repulsion (Ue) forces between the particles, according to which it is possible to discuss in which cases particle aggregation occurs and what coagulation is like. The analysis of the comparison of the attraction-repulsion energy curves revealed that at an average distance (maximum of the potential barrier), where the repulsion energy (Ue) between the particles prevails and the potential barrier is high - particle aggregation does not occur. At short and long distances (two minima of the potential barrier), where the energy of attraction (Um) between particles prevails and the potential barrier is low - the particles stick together, harden and precipitate (coagulate). At long and short distances, where the particles approach each other, reversible coagulation is observed (at one minimum of the potential barrier), and at the other - irreversible coagulation (at the second minimum of the potential barrier), which leads to the formation of a dense precipitate.

Adsorption studies have revealed the ability to adsorb silica, aluminosilicates, polysilicon, and humic substances present in natural water. Even in low concentrations, molecules of these substances are adsorbed onto the surface of impurity particles and affect the structure of the sediment that forms on the membranes.

Thus, the research conducted revealed that microfiltration membranes retain impurities in water whose particle sizes exceed their pore size. As a result of water filtration, the concentration of impurity particles on the membranes and their aggregation produces a sediment with a sediment formed is quite loose, easily breaks down, and detaches from the membrane surface. Therefore, structured sediment formed can be an additional filter for water purification of membrane.

References

1. Bibileishvili G.V., Kezherashvili M.G., Kuparadze L.P., Mamulashvili M.A., Ebanoidze L.O. Studying the Optimal Mode Parameters of the Microfiltration Separation Process and the Mechanism of Sediment Formation on the Membrane Surface Under Hybrid Flow Conditions. Georgian Engineering News, V.99, №3, 2023. pp.69-72. ISSN: 1512-0287. https://doi.org/10.36073/1512-0287;
2. Bibileishvili G.V., Kezherashvili M.G., Gogesashvili N.N., Javashvili Z.D. Research of Microfiltration Process Under Conditions of Sedimentation on Membrane Surface. Georgian Engineering News, V.95, №1, 2022. pp.132-134. ISSN: 1512-0287. https://doi.org/10.36073/1512-0287;
3. Bibileishvili G.V., Ebanoidze L.O., Kuparadze L.P., Kezherashvili M.G., Butkhuzi, T.G. Study of the Mechanism of Precipitation Formation on the Membrane Surface Under Laminar Flow Conditions of the Ultrafiltration Process. Georgian Engineering News, V.100, №1, 2024. pp.85-91. ISSN: 1512-0287. https://doi.org/10.36073/1512-0287;
4. International Standard ISO 5667-10. Water quality - Sampling - Part 10: Guidance on sampling of waste water, Second edition, 2020;
5. R. Pecora. Dynamic light scattering measurement of nanometer particles in liquids. Journal of Nanoparticle Research 2, 2000. pp.123–131;
6. S. Chakraborty., P.K. Panigrahi. Stability of nanofluid: A review. Applied Thermal Engineering. V.174, №25, 2020. pp.115259. https://doi.org/10.1016/j.applthermaleng.2020.115259;
7. R. Vie., N. Azema., Jean-Christophe Quantin., E. Touraud., M. Fouletier. Study of suspension settling: An approach to determine suspension classification and particle interactions. Colloids and Surfaces A: Physicochemical and Engineering Aspects V.298, №3, 2007. pp.192-200. 10.1016/j.colsurfa.2006.10.074ff. ffhal-03181072f;

8. D. Narsia., M. Razmadze. Experimental description of sedimentary events and their potential development. International Journal of Progressive Sciences and Technologies (IJPSAT), V.43, №1, 2024. pp.84-91. ISSN: 2509-0119;
9. M. Razmadze., N. Abuladze. Colloidal chemistry. Textbook GTU, 2017. pp.22-142.
10. Nägele G., Dhont J.K.G., Voigtmann T. Theory of colloidal suspension structure, dynamics, and rheology. In Theory and Applications of Colloidal Suspension Rheology; Cambridge University Press: Cambridge, UK, 2021. pp. 44–119;
11. Antonenkov, D. A. Specifics of application of various methods for studying the size composition and concentration of a substance suspended in water. Vestnik SevNTU, Issue 97: Mechanics, Energetics, Ecology, (2009). pp.181–187.

მიკროფლტრაციულ მემბრანაზე წარმოქმნილი ბუნებრივი წყლის დანალექის კოლოიდურ-ქიმიური კვლევა

[1]გიორგი ბიბილეიშვილი, [2]ლიანა ებანოიძე, [3]მზია კეჟერაშვილი, [4]მანანა მამულაშვილი, [5]ლიანა ყუფარაძე, [6]ნონა ბუთხუზი, [7]ია გოგიბერიძე

[1]ქიმური და ბიოლოგიური ინჟინერიის აკადემიური დოქტორი, მთავარი მეცნიერი - e-mail 75bibileishvili@mail.com ORCID https://orcid.org/0009-0003-7712-2436

საქართველოს ტექნიკური უნივერსიტეტის მემბრანული ტექნოლოგიების საინჟინრო ინსტიტუტი

აბსტრაქტი

ნაშრომში წამოდგენილია ბუნებრივი წყლის მიკროფილტრაციისას მემბრანაზე ფორმირებული დანალექის კოლოიდურ-ქიმიური კვლევა. ბუნებრივ წყალში არსებული ნაწილაკების ზომები, ელექტროკინეტიკური პოტენციალის სიდიდე და ნიშანი განსაზღვრულია სინათლის გაბნევის დინამიკური მეთოდით, ხოლო დანალექის სიჩქარე - სედიმენტაციული ანალიზის საშუალებით. გამოვლენილია წყალში არსებული შეწონილი ნაწილაკების კოაგულაციის და ადსორბციის უნარი, რაც გავლენას ახდენს ფორმირებული დანალექის სტრუქტურაზე.

საკვანძო სიტყვები: მიკროფილტრაცია, მემბრანა, სედიმენტაცია, კოაგულაცია, ადსორბცია