Reusable Microfiltration Apparatus in Mineral Water Production

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Currently, Mineral Water Bottling Enterprises use disposable paper filters containing asbestos for the filtration of mineral waters, which is medically unacceptable.

The aim of this study was to examine the filtration quality, the performance of a membrane apparatus developed by us, and the regularities of filtrate volume reduction during the filtration of mineral waters (Borjomi, Nabeghlavi, Kokotauri).

In our filtration apparatus, a fluoroplastic membrane was used, which is approved for use in food technology and medicine. Through modification, a membrane with pore sizes ensuring the disinfection of mineral waters during filtration was obtained.

The composition, concentrations, and technological regimes of regeneration solutions for the membranes were determined, making it possible to reuse the microfiltration apparatus multiple times, thereby reducing the cost of mineral water filtration.

Analysis results confirmed that the filtrate does not contain suspended or undissolved substances and is characterized by clarity and transparency. The initial ion composition of the mineral waters is fully preserved after filtration.

Keywords: mineral waters, microfiltration, regeneration, disinfection, fluoroplastic membrane.

INTRODUCTION

Georgia's mineral waters are renowned worldwide, yet the bottling technology remains underdeveloped, which hinders their market potential. In addition to design and marketing, emphasis is placed on the filtration of mineral waters.

As is commonly known, manufacturers use disposable paper filters containing asbestos—an approach that is medically unacceptable.

The implementation of membrane-based equipment in mineral water bottling plants presents several challenges: during filtration, membrane pore plugging occurs, which leads to a decline in the system's performance. In order to ensure the repeated use of membranes in membrane-based filtration processes at mineral water bottling plants, it is essential to select appropriate regeneration agents and optimize the regeneration processes for fouled membranes.

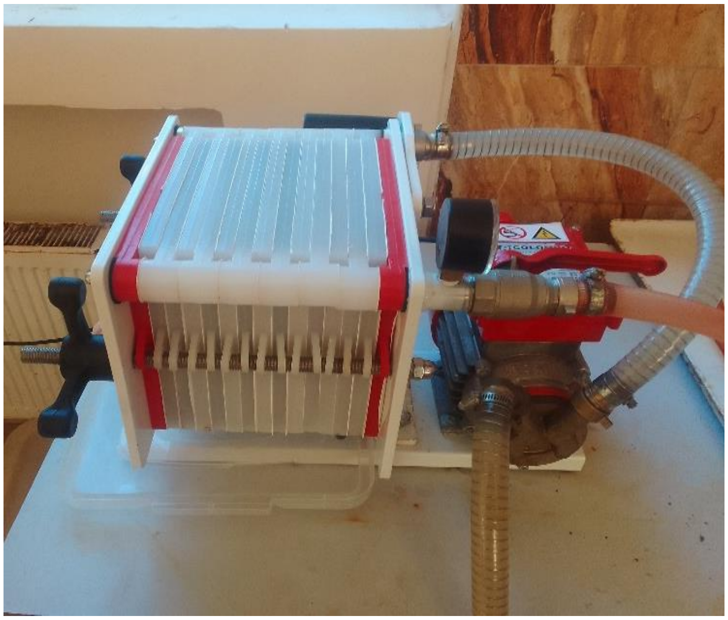
In our study, we selected mineral waters from Nabeghlavi, Kokotauri, and Borjomi for filtration. The primary objective was to select and develop membranes that ensure no alteration in the organoleptic and physicochemical properties of the mineral waters before and after filtration.

1. MATERIALS AND METHODS

To fabricate the microfiltration membrane, we selected a thermally and chemically resistant polymer—fluoroplastic, specifically polytetrafluoroethylene (PTFE). The use of fluoroplastics is permitted in both food production and the pharmaceutical industry [1–3]. Using a modification method developed by us [4], we produced an asymmetric membrane from PTFE.

The average pore size of the resulting membrane was determined by the capillary porometry method [5] using a POROLUX 500 porometer (POROMETER NV, Belgium). Based on the pore size distribution, the membrane exhibited the following characteristics: minimum pore size – 0.3265 μm; average pore size – 0.9966 μm; maximum pore size – 2.285 μm. It is noteworthy that the formation of membrane pores below 2000 nm is critical for the removal of microorganisms from water [6].

A microfiltration apparatus of the filter press type was constructed in the institute's workshop. The design of the filter press apparatus allows for easy disassembly and enables backwashing for cleaning (see photo).



Microfiltration apparatus

2. EXPERIMENTAL PART

The aim of this study was to investigate the filtration quality, productivity, and filtrate volume reduction trends when using membranes synthesized by us and membrane apparatuses developed on their basis for mineral water treatment. Additionally, the study focused on the selection of appropriate regeneration solutions and the determination of technological parameters for the full regeneration of fouled membranes, with the goal of enabling their repeated use.

During the experiment, filtration of mineral waters was carried out directly from the raw source, without any preliminary filtration.

The initial filtration was performed at the mineral water bottling facility in the village of Kokotauri, Keda District. Filtration was conducted by directly connecting the microfiltration unit to the pipeline delivering the raw mineral water.

Analysis of the filtered water showed that the concentration of all salts present in the original mineral water remained unchanged in the filtrate, while the water quality corresponded to that of the final product. The mineral content of the waters was confirmed before and after filtration to ensure no significant loss of essential mineral ions.

During the filtration process, membrane regeneration was performed using a regeneration solution consisting of 1–3% hydrochloric acid. The productivity of the apparatus was fully restored to its initial level (Productivity (Flux) Measurement: Water flux through the membrane was measured in liters per square meter per hour (L/m²·h) using volumetric collection over a defined period). The results are presented in **Table**.

Table: Regeneration Efficiency of Fouled Microfiltration Membranes after Filtration of "Kokotauri" Mineral Water.

№	Reagents Used	Reagent Concentration, %	Initial Productivity, L/m²·h	Productivity After Fouling, L/m²·h	Regeneration Time, min	Productivity After Regeneration L/m²·h
1.	Drinking wate	_	480	100	30	110
2.	Hydrochloric acid (HCl)	3	480	110	30	540
3.	Drinking wate	_	540		30	480

After completing three filtration/regeneration cycles with Kokotauri water, we performed filtration of Nabeghlavi mineral water.

Following the filtration of Nabeghlavi water, membrane fouling became significantly more difficult to clean. Both traditional reagents and various chemical compounds in different combinations were applied. After disassembling the filtration unit, a sticky yellow clay deposit was observed on the membrane surface. Clay particles that had penetrated into the membrane pores could not be removed either by mechanical brushing or by back-flushing within the membrane apparatus. Satisfactory results were achieved only after immersing the microfiltration membranes in a 2% hydrofluoric acid solution (HF). The results are presented in **Figure 1.**

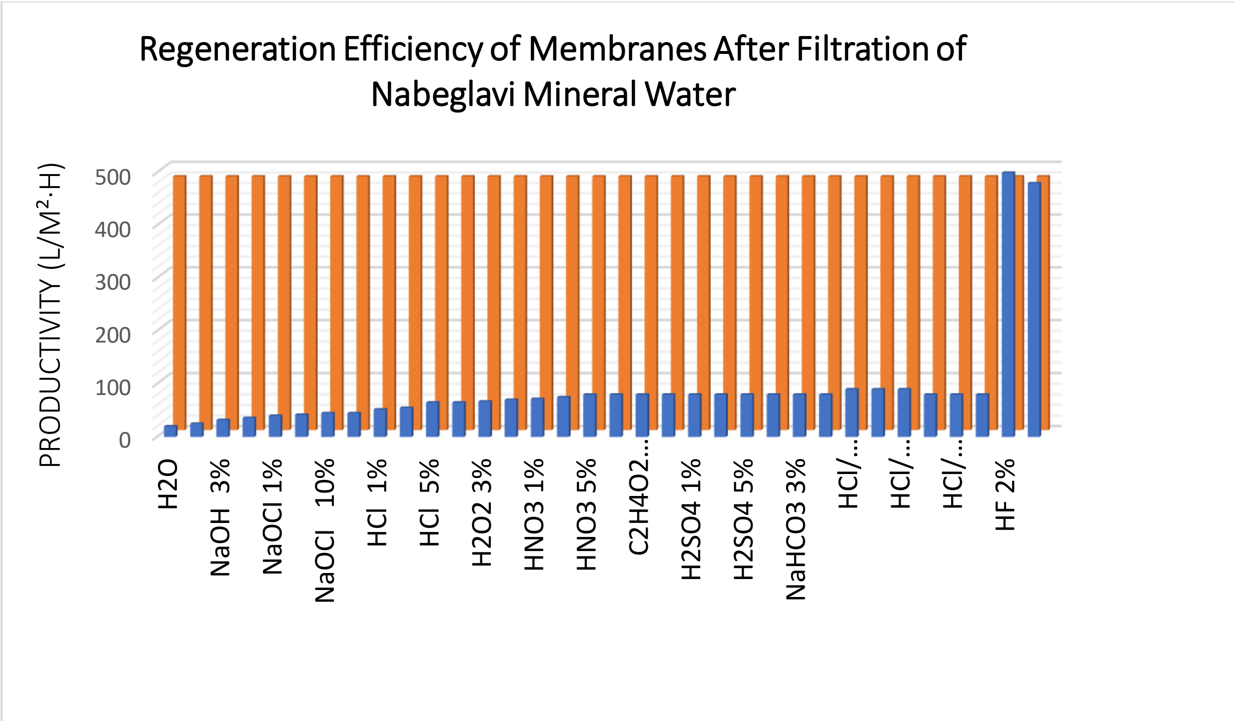


Figure 1: Regeneration Efficiency of Membranes After Filtration of Nabeghlavi Mineral Water

Finally, filtration of Borjomi mineral water was conducted. To restore the membranes fouled after Borjomi water filtration, a 5% hydrochloric acid (HCl) solution and a 5% sodium hydroxide (NaOH) solution were used. The obtained results are presented in **Figure 2**.

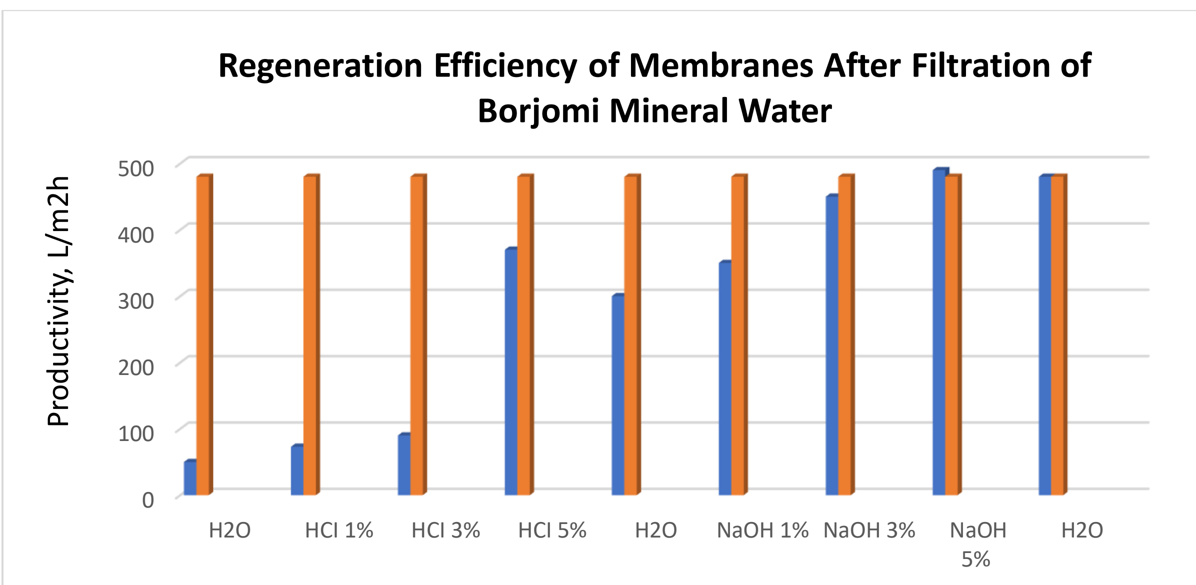


Figure 2. Regeneration Efficiency of Membranes After Filtration of Borjomi Mineral Water.

The full restoration of membrane performance allows us to conclude that with the microfiltration membranes we developed, the flat-sheet fluoroplastic microfiltration units, designed with this structure and technology, can be implemented in mineral water bottling plants for the polishing and commercialization of the product.

RESULT

Technological regimes for filtration and regeneration were successfully developed, along with the optimal compositions and concentrations of regeneration solutions, enabling the repeated use of microfiltration units for mineral water filtration.

During the experiments:

- Filtration of Kokotauri mineral water was conducted over three filtration/regeneration cycles. After fouling, complete recovery of membrane productivity was achieved using 3% hydrochloric acid, with initial productivity restored from 100 $L/m^2 \cdot h$ to 540 $L/m^2 \cdot h$ after regeneration.
- Filtration of Nabeghlavi mineral water presented significantly greater challenges. Severe membrane fouling occurred, characterized by sticky yellow clay deposits that were not removable by conventional methods such as brushing or back-flushing. Full membrane recovery was only achieved after immersion in a 2% hydrofluoric acid (HF) solution.
- Filtration of Borjomi mineral water showed moderate fouling. Regeneration was effectively achieved using sequential treatments with 5% hydrochloric acid (HCl) and 5% sodium hydroxide (NaOH) solutions. Membrane productivity was fully restored to nearly original levels (480–490 $L/m^2 \cdot h$).

Analysis of the filtrates confirmed that:

- The final filtered waters did not contain any suspended or undissolved solids.
- The filtrates were characterized by high clarity and transparency.
- The original ionic and mineral compositions of Kokotauri, Nabeghlavi, and Borjomi waters were fully preserved after microfiltration, thus maintaining their commercial quality.

The full restoration of membrane performance, even after multiple filtration cycles, demonstrates the high potential of the developed flat-sheet fluoroplastic (PTFE) microfiltration membranes and apparatuses for industrial mineral water bottling applications.

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მრავალჯერადი გამოყენების მიკროფილტრაციული აპარატი მინერალური წყლების წარმოებაში

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დღეისათვის საწარმოები გამოიყენებენ მინერალური წყლების ფილტრაციის დროს ერთჯერად ქაღალდის ფილტრებს, რომლის შემადგენლობაშიც შედის აზბესტი, რაც სამედიცინო თვალსაზრისით მიუღებელია.

კვლევის მიზანს წარმოადგენდა მინერალური წყლების (ბორჯომი, ნაბეღლავი, კოკოტაური) ფილტრაციისას ფილტრაციის ხარისხის, ჩვენ მიერ დამზადებული მემბრანული აპარატის წარმადობისა და ფილტრატის რაოდენობის შემცირების კანონზომიერების შესწავლა.

ჩვენ მიერ ფილტრაციულ აპარატში გამოყენებულია ფთოროპლასტური მემბრანა, რომელიც ნებადართულია კვების ტექნოლოგიებსა და მედიცინაში. მოდიფიცირების გზით მიღებულია ისეთი ზომების ფორებიანი მემბრანა, რომელიც უზრუნველყოფს ფილტრაციისას მინერალური წყლების გაუსნებოვნებას.

დადგენილია მემბრანების სარეგენერაციო ხსნარების შემადგენლობა, კონცენტრაციები და რეგენერაციის ტექნოლოგიური რეჟიმები, რომლებიც შესაძლებელს გახდის მიკროფილტრაციული აპარატის მრავალჯერადად გამოყენებას, რაც, თავის მხრივ, შეამცირებს მინერალური წყლების ფილტრაციის ხარჯებს.

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საკვანძო სიტყვები: მინერალური წყლები, მიკროფილტრაცია, რეგენერაცია, გაუსნებოვნება, ფთოროპლასტური მემბრანა.