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TECHNOLOGIES OF PACKAGED WATER FOR HOSPITALITY INSTITUTIONS

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Abstract. .Prospects for the development of packaged water technologies include their use in various industries. An important problem of the development of society is the need to provide consumers with high-quality drinking water. The state of the environment shows that the supply of quality drinking water to the population is an urgent issue of the present and the future. Therefore, the selection of innovative methods of water treatment is an urgent task today. Establishments of the hospitality industry must use high-quality drinking water both for direct consumption and as a component of food dishes. In recent years, the packaged drinking water market has been developing rapidly in Ukraine, which is a promising solution to the problem of supplying consumers with quality water. The article presents the results of theoretical and experimental research on the improvement of water treatment technology in the production of bottled water. The results of theoretical studies for correcting water parameters from various sources to meet consumer requirements and ensure compliance of its composition with the needs of the human body are presented. Changes in salt content, electrical conductivity, and pH depending on pressure and water consumption are given. The performance of the installation and the mineral composition of the permeate of membrane water filtration were studied depending on the number of membranes. The use of recirculate in specified quantities at the recommended pressure made it possible to obtain a permeate with a given composition of salt ions. Their content in water with the use of 25% recirculate ensured pressure in the system and allowed to reduce the amount of concentrate obtained. The article describes the technological parameters of water treatment and provides prospects for the use of reverse osmosis installations for the production of packaged water. The obtained results regarding the use of reverse osmosis installations in water treatment with the use of recirculate make it possible to prepare bottled water of a specified mineral composition in accordance with the needs of consumers and institutions of the hospitality industry.

Keywords: words: water, permeate, concentrate, recirculate, hospitality industry establishments, polyphenolic substances.

Introduction. Formulation of the problem

In recent years, Ukrainian consumers have increasingly focused on food products that contribute to overall health improvement. High-quality packaged drinking water (PDW) is an essential component of a healthy diet. Market trends indicate a growing share of still water, which is considered more beneficial compared to carbonated water.

The rapid development of the bottled water market in Ukraine is driven by the large number of consumers and the availability of natural resources within the country. However, the low purchasing power of the population and specific consumption habits limit market growth compared to highly developed countries [1, 2].

One of the most significant global environmental challenges is ensuring the proper quality of drinking water, which is directly related to population health, the ecological safety of food products, and various medical and social factors [3]. According to the World Health Organization, nearly 80% of all diseases worldwide are transmitted through water, causing up to 25 million deaths annually. Another pressing issue is that despite increasing water consumption, natural freshwater reserves continue to decline [3, 4].

Analysis of recent research and publications

The main sources of drinking water are rivers, freshwater lakes, and groundwater. However, their distribution across continents is uneven. In Eurasia, where approximately 70% of the world's population resides, only about 39% of global river water resources are concentrated. In Europe, which is home to nearly 20% of the global population, freshwater availability amounts to only about 7% [5].

Although most of our planet is covered with water, freshwater remains a scarce resource. According to the World Wildlife Fund, 1.1 billion people lack access to drinking water, and 2.7 billion experience water shortages. By 2025, two-thirds of the world's population may face insufficient access to drinking water [1, 4].

By the volume of water resources available for use, Ukraine belongs to water-poor countries. In low-water years, only 52.4 km³ of water is formed within the territory of Ukraine, which amounts to about 1,000 m³ per person annually [6]. According to the United Nations Economic Commission for Europe, a country with water resources below 1.7 thousand m³ per person per year is considered water-deficient. For comparison, water availability (thousand m³ per year per person) is as follows: Canada – 94.3; Sweden – 19.7; USA – 7.4; France – 3.4; England – 2.5; Germany – 1.9; Poland – 1.6 [1, 3, 7]. Among 152 countries, Ukraine ranks 111th in water availability. Total water withdrawal comprises 11.3 billion m³ from rivers, lakes, and reservoirs; 2.5 billion m³ from groundwater sources; and 0.9 billion m³ from seas [3, 5]. Industrial use exceeds 9 billion m³. The main consumers are municipal services (28%), industry (49%), and agriculture (21%). The regions with the highest water consumption include Dnipropetrovsk, Donetsk, Zaporizhzhia, Kyiv, Vinnytsia regions, and the Autonomous Republic of Crimea, which together account for around 70% of total water use in Ukraine [2, 6, 8].

Ukraine shows significant regional disparities in drinking water distribution. For example, in Donetsk, Zaporizhzhia, Dnipropetrovsk, Mykolaiv, Kherson, and Odesa regions, between 5–10 to 40 thousand m³ of water per 1 km² is available, amounting to only 120–400 m³ per person annually—15–20 times less than in western regions of Ukraine (Lviv, Rivne, Ivano-Frankivsk, Zakarpattia, Ternopil) [1, 3, 5].

The chemical composition of groundwater is influenced by numerous natural and anthropogenic factors, including temperature, oxygen and carbon dioxide content, pH, redox potential, groundwater flow, extraction intensity, microorganisms, and technogenic impacts. As a result, groundwater differs significantly in composition and represents complex multicomponent systems containing inorganic and organic compounds, dissolved gases, and microflora [2, 8, 9].

Hospitality industry establishments primarily rely on centralized water supply networks. The water from most municipal systems in Ukraine meets the requirements of the national sanitary regulations (DSanPiN 2.2.4-171-10 «Hygienic requirements for drinking water intended for human consumption»). However, the hardness of tap water often exceeds recommended levels due to high calcium and magnesium concentrations.

The use of packaged drinking water with a defined mineral composition, including controlled hardness, is a promising direction for the effective development of foodservice establishments within the hospitality industry. Producers of packaged drinking water can, upon request, ensure the required mineralization of their products according to consumer needs, which supports the efficient operation of restaurants, cafes, and similar establishments.

The packaged drinking water market in Ukraine is characterized by rapid development despite the economic challenges faced by the country. This market remains highly attractive to investors, although competition is exceptionally strong. The Ukrainian bottled water market also has its own specific features. Therefore, the search for innovative water treatment methods—particularly the use of reverse osmosis systems in the production of packaged water as a primary source of drinking water in restaurant technologies –is both timely and relevant.

The increasing contamination of water supply sources necessitates improvements in water purification systems. Using municipal tap water without prior treatment is unacceptable due to the potentially high content of residual chlorine. For this reason, consumers frequently rely on household carbon filters or purchase bottled water, which typically retains the natural macro- and microelement composition of the source water. Consequently, consumer demand for bottled water continues to grow [9, 10].

The use of water with high hardness levels negatively affects the operation of beverage-preparation equipment that involves heating. Scale formation in technological equipment results in the need for regular cleaning of working surfaces, prolonged maintenance, and, in many cases, complete equipment replacement.

Producers of packaged drinking water must consider not only the economic feasibility of production but also the health benefits of the final product. Enterprises engaged in PDW production apply various water treatment methods in their technological processes. Most commonly, they use artesian wells and, after mechanical filtration, bottle the water directly. This approach offers advantages (such as preserving the natural mineral composition and removing mechanical impurities) but cannot fully meet the physiological needs of people of different ages and demographic groups [6, 11].

An effective direction in PDW technology is the application of innovative water treatment methods, particularly membrane technologies. The key element of a membrane system is a barrier that divides the feed solution into two streams: permeate (the fraction that passes through the membrane) and concentrate (the retained fraction). The most widely applied are pressure-driven membrane processes. Depending on particle size retention, these include reverse osmosis, ultrafiltration, and microfiltration, which differ in operating pressure, membrane pore size, and specific productivity [12, 13].

Pressure-driven membrane processes can be used for various purposes. In some cases, they provide deep purification of contaminated water. In others, they enable the concentration of dissolved substances—where multistage processing using different types of membranes allows maximizing the concentration of selected components at relatively low pressures. In a third application, a single process can combine purification, concentration, and fractionation of substances [11, 14]. Consequently, the need for membrane materials with diverse properties—combining high selectivity, high throughput, and stability in solutions with a wide pH range and in aggressive environments—continues to grow, and the assortment of membranes must steadily expand [15].

Among membrane technologies used in water treatment, reverse osmosis is the most widespread. This method involves separating water constituents through semipermeable membranes that allow water molecules to pass while retaining ions and dissolved substances with particle sizes of 0.0001–0.001 μm under pressures of 3.0–10 MPa. Additionally, reverse osmosis removes radioactive isotopes, nitrates, organic compounds, pesticides, bacteria, and viruses [7, 10, 16].

Membrane technologies in PDW production have significant potential, but their implementation progresses slowly due to various factors, particularly high equipment costs and operational expenses [12, 15].

Therefore, studying the effects of different water treatment methods, including reverse osmosis, is a promising direction in PDW technology. This approach not only ensures the supply of high-quality drinking water but also allows adjustment of the mineral composition according to the needs of different population groups. The use of PDW enhances the quality of restaurant products and ensures consistency of their characteristics.

Purpose and Objectives of the Study.

The aim of this research was to investigate changes in the mineral composition of artesian water obtained from a Jurassic geological aquifer at a depth of 291 m when processed using a reverse osmosis system with recirculation.

Research materials and methods

The study utilized artesian water from a Jurassic geological aquifer at a depth of 291 m, supplied by LLC «Rosyana». The reverse osmosis system employed TMH20A-400 membranes with various elements. The influence of water treatment modes was evaluated according to the reports provided by LLC «LVT Engineering».

The research applied methods commonly used in the food industry. Total dissolved solids (TDS) were measured using a TM720D400 TDS meter. The pH of the water was determined potentiometrically using an ion-selective electrode in accordance with DSTU 4077-2001. Ammonium content was determined according to DSTU ISO 5664:2007 using distillation and titration. Calcium content was measured titrimetrically with ethylenediaminetetraacetic acid (EDTA), following DSTU ISO 6058:2003. Magnesium was determined in accordance with DSTU ISO 6059:2003, while potassium and sodium were measured according to DSTU ISO 11885:2019. Nitrite levels were determined by molecular absorption spectrometry following DSTU ISO 6777:2003.

Chlorides were measured by silver nitrate titration using chromate as an indicator (Mohr method), in accordance with DSTU ISO 9297:2007. Total iron was determined using a photometric method based on the reaction of ferrous iron with 2,2-bipyridyl to form a colored complex (DSTU ISO 6332-2003). Electrical conductivity was evaluated using a conductometer, based on the direct correlation between conductivity and dissolved ions (DSTU 7525:2014).

To determine the total polyphenol content in tea, a colorimetric method was used according to ISO 14502:2005. Quantification of phenolic compounds was based on the Folin–Ciocalteu method, which involves electron transfer in an alkaline medium from phenolic compounds to form an intensely colored blue complex, whose maximum absorbance depends on the concentration of phenolics. The reduced Folin–Ciocalteu reagent was detected spectrophotometrically at 650–750 nm. The reaction temperature was maintained at 37 °C to reduce the time needed to reach maximum absorbance. Gallic acid was used as a standard, and results were expressed as gallic acid equivalents (μg/mL).

Water treatment was performed using a reverse osmosis system that produced the following semi-products:

- permeate – demineralized water
- concentrate – an aqueous solution containing removed macro- and microelements
- recirculate – a portion of the concentrate reused by adding it to the feed water before treatment.

Feed water was subjected to mechanical filtration. The recirculate and feed water were mixed in predetermined proportions depending on the processing objectives.

The pretreated water was then supplied to the reverse osmosis unit to obtain permeate and concentrate. A specified portion of the concentrate, used as recirculate, was added to the feed water before treatment. Various processing modes and system inlet pressures were investigated. Total dissolved solids, individual ion concentrations, electrical conductivity, and pH of the feed water and semi-products were determined. For the final product, ion content and pH were measured.

Results of the research and their discussion

The shortage of drinking water and the search for renewable resources represent some of the most critical challenges in the modern world, requiring substantial intellectual and financial efforts to address. Reverse osmosis is one of the most widespread technologies for producing high-quality drinking water [17, 18].

The study examined the effect of inlet water pressure on the total salt content, the number of membrane elements (with a total surface area of 37.3 m²), changes in the performance of the system, and permeate characteristics, as well as the ionic composition of water when 25% recirculation was applied.

To determine the optimal operating pressure, the first stage of research employed untreated feed water. The effect of inlet pressure on the salt content in the permeate is presented in Fig. 1

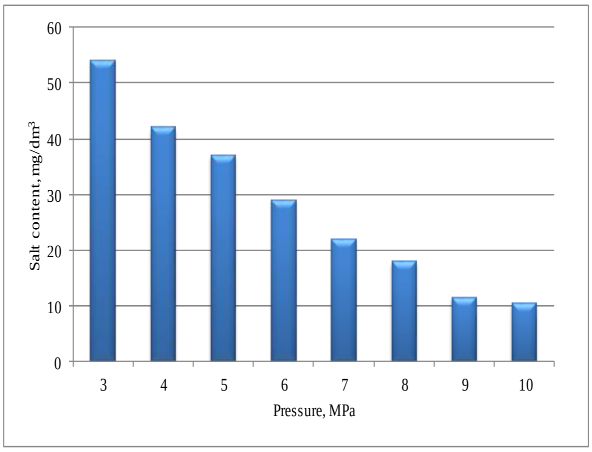


Fig. 1 – Effect of inlet water pressure on the salt content in the permeate

It was established that when the pressure increased from 3 to 10 MPa, the salt content decreased by a factor of 4.3. The recommended inlet water pressure for the system is 9 MPa, which ensures a salt concentration in the permeate of 13.57 mg/dm³.

Changes in salt content, electrical conductivity, and pH depending on pressure and water flow rate are presented in Table 1.

It was found that when recirculate was used under a defined inlet pressure, the salt content in the permeate decreased by a factor of 57.8 compared with the feed water, while system pressure stabilized and membrane load was reduced. The salt content in the recirculate decreased by 1.7 times compared with the feed water, whereas in the concentrate it increased by 2.3 times. It was also established that the pH value of the water decreased by 22% compared with the original feed water.

The reverse osmosis system consists of five membranes, each with a capacity of 1 m³/h. Table 2 presents the effect of the number of membrane elements on changes in system performance and permeate characteristics.

It was established that increasing the number of membrane elements improves their recovery rate by 7.4% and reduces water consumption by 54%, including a 15% reduction in allowable losses.

The content of salt ions in the water and the pH values obtained when using 25% recirculation—which helps maintain system pressure and reduces the amount of concentrate produced—are presented in Table 3.

It was found that the concentrations of Ca^{2+} and Mg^{2+} ions in the permeate, which determine water hardness, decrease by a factor of 44; chloride ions (Cl^{-}) decrease by a factor of 68; and iron is completely removed. At the same time, the concentrations of Ca^{2+}, Mg^{2+}, Cl^{-}, and Fe^{3+} ions in the concentrate increase by a factor of 3.9, and the pH decreases by 20%.

Foodservice establishments offer consumers a wide range of tea beverages, which are typically evaluated based on organoleptic properties; however, the content of polyphenolic compounds is of particular nutritional interest.

Table 1 – The effect of water pressure and vorticity on water parameters

The name of the semi-finished product	Flow rate, m³/h.	Pressure, MPa	Salt content, mg/dm³	Electrical conductivity, µS	pH
Incoming water	6.667	-	458.2	706.9	7.700
Recirculate	8.866	9.000	786.9	962.3	7.904
Part of the recycled material*	2.200	8.235	1784.60	1938.8	7.700
Part of the concentrate*	3.867	8.235	1784.60	1939.8	8.183
Concentrate	1.667	8.235	1784.60	1939.8	8.183
Permeate	5.000	-	13.575	21.2	6.132

* – determined by the research conditions.

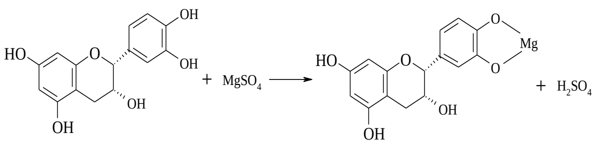
Table 2 – Change in the performance of a membrane water filtration plant depending on the number of membrane elements and the mineral composition of the permeate

Indicators	The number of membrane elements				
	1	2	3	4	5
Water consumption, m^3/h.	8.867	7.801	6.768	5.765	4.797
Permissible water flow rate, m^3/h.	1.065	1.034	1.002	0.969	0.930
Permeate parameters, mg/dm^3					
Name	5	4	3	2	1
Ca^{2+}	0.719	0.937	1.228	1.667	2.371
Mg^{2+}	0.216	0.281	0.368	0.500	0.711
Na^{+}	0.470	0.612	0.802	1.088	1.547
K^{+}	0.515	0.670	0.876	1.184	1.676
Ba^{2+}	0.0011	0.0014	0.0018	0.0025	0.0036
NH_4^{+}	0.019	0.0247	0.0323	0.0437	0.0619
HCO_3^{-}	4.964	6.411	8.405	11.360	16.073
Cl^{-}	0.186	0.242	0.317	0.431	0.613
NO_3^{-}	0.112	0.146	0.191	0.259	0.368
F^{-}	0.0174	0.0227	0.0297	0.0403	0.0572
SiO_2	0.0464	0.0545	0.0657	0.0813	0.105
CO_3^{2-}	0.0001	0.0002	0.0004	0.0007	0.0014
Total salt content	7.265	9.403	12.317	16.658	23.59
pH	5.933	6.060	6.168	6.285	6.413

Table 3 – Comparative characteristics of the tested water samples

Indicators	**Units of measurement**	**Water from a well**	**Recirculate**	**Concentrate**	**Permeate**
Ca^{2+}	mg/dm^3	60.00	103.5	235.6	1.357
Mg^{2+}	mg/dm^3	18.000	31.05	70.67	0.407
Na^{+}	mg/dm^3	30.00	51.60	117.2	0.886
K^{+}	mg/dm^3	13.000	21.93	49.05	0.965
Ba^{2+}	mg/dm^3	0.09	0.155	0.353	0.002
NH_4^{-}	mg/dm^3	0.480	0.810	1811	0.0356
Fe^{3+}	mg/dm^3	0.200	0.348	0.799	0.0
HCO_3^{-}	mg/dm^3	305.0	521.5	1.179	9.258
CO_3^{2-}	mg/dm^3	0.707	2.878	9.466	0.0006
CI^{-}	mg/dm^3	24.00	41.54	94.80	0.351
$N0_3^{-}$	mg/dm^3	4.000	6.812	15.347	0.211
F^{-}	mg/dm^3	0.760	1.300	2.938	0.0328
SiO_2	mg/dm^3	2.000	3.432	7.780	0.0695
Total salt content	mg/dm^3	458.2	786.9	1785	13.575
pH	unit pH	7.700	7.904	8,183	6.132

The influence of total water hardness on the polyphenol content in tea is determined by the formation of coordination bonds with calcium and magnesium salts. For magnesium sulfate, the reaction proceeds as follows:



The main extractive substances in tea beverages are polyphenolic compounds, represented primarily by catechins and theaflavins. Catechins are found predominantly in green tea and include: epicatechin, (−)-epicatechin-3-gallate, (−)-epigallocatechin, (−)-epigallocatechin-3-gallate, (+)-catechin, and (+)-gallocatechin. Theaflavins occur in high concentrations in black tea and are formed during fermentation, during which catechins undergo oxidation and polymerization. Theaflavins in black tea include theogallin, theaflavin-3-gallate, and thearubigins [19]. The effect of the studied water samples on the content of polyphenolic compounds extracted into tea was investigated (Fig. 2).

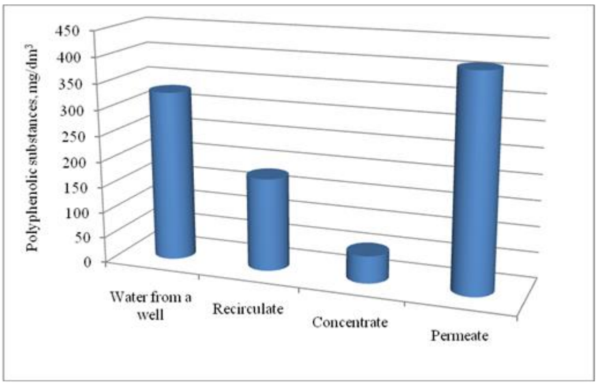


Fig. 2 – Content of polyphenolic compounds in tea

It was established that the physicochemical properties of water significantly affected the polyphenol content in tea. A decrease in water hardness led to an increase in the amount of polyphenolic compounds in the beverage. To preserve a high content of polyphenols in tea–and thus increase the biological value of the drink–the total water hardness used for infusion preparation should not exceed 2.0 mmol/dm³ [20, 21].

The use of water with high hardness also negatively affects technological equipment involving heating. Scale formation results in the need for regular cleaning of working surfaces, longer maintenance periods, and, in many cases, equipment replacement.

The use of packaged drinking water with a defined mineral composition, including controlled hardness, is a promising direction for the efficient development of foodservice establishments within the hospitality industry. Producers of packaged drinking water can supply products with customized mineral content based on customer requirements, ensuring efficient operation of restaurants, cafés, and similar establishments.

Conclusion

1. Treatment of water using a reverse osmosis system equipped with TMH20A-400 membranes and a defined amount of recirculate allows the production of permeate with a specified ionic composition. The recommended inlet water pressure for the system, with a total membrane area of 37.3 m², is 9 MPa, which ensures a total salt content in the permeate of 13.57 mg/dm³.

2. When recirculate is used, the salt content in the permeate decreases 57.8-fold compared with the feed water, system pressure stabilizes, and membrane load decreases. The salt content in the recirculate is 1.7 times lower than in the feed water, whereas in the concentrate it increases 2.3-fold. At the same time, the pH of the permeate decreases by 22% compared with the original water.

3. Increasing the number of membrane elements improves membrane recovery by 7.4% and reduces water consumption by 54%, including a 15% reduction in allowable losses.

4. Using 25% recirculate stabilizes system pressure, reduces the amount of concentrate produced, and decreases the concentrations of Ca^{2+} and Mg^{2+} ions in the permeate 44-fold, Cl^{-} 68-fold, while iron is completely removed.

5. To maintain a high content of polyphenolic compounds in tea—and therefore enhance the biological value of the beverage—the total hardness of the water used for infusion should not exceed 2.0 mmol/dm³.

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ТЕХНОЛОГІЇ ФАСОВАНОЇ ВОДИ ДЛЯ ЗАКЛАДІВ ІНДУСТРІЇ ГОСТИННОСТІ

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Анотація. Перспективність розвитку технологій фасованої води передбачають їх використання у різних галузях. Важливою проблемою розвитку суспільства є необхідність забезпечення споживачів якісною питною водою. Стан довкілля свідчить, що постачання населення якісною питною водою є актуальним питанням сьогодення і майбутнього. Тому підбір інноваційних способів водопідготовки є актуальним завданням сьогодення. Заклади індустрії гостинності повинні використовувати питну воду високої якості як для споживання безпосередньо, так і як складову харчових страв. Останніми роками в Україні стрімко розвивається ринок фасованої питної води, що є перспективним вирішенням проблеми постачання споживачів якісною водою. У статті наведено результати теоретичних та експериментальних досліджень з удосконалення технології водопідготовки у виробництві бутильованих вод. Наведено результати теоретичних досліджень для корегування показників води із різних джерел для задоволення вимог споживачів та забезпечення відповідності її складу потребам організму людини. Наведено зміну вмісту солей, електропровідності та pH залежно від тиску та витрат води. Досліджено продуктивність установки та мінерального складу пермеату мембранної фільтрації води залежно від кількості мембран. Використання рециркуляту у визначених кількостях за рекомендованого тиску дозволило отримати пермеат із заданим складом іонів солей. Їх вміст у воді із використанням 25 % рециркуляту забезпечувало підтримання тиску в системі та дозволило зменшити кількість отриманого концентрату. У статті наведено технологічні параметри водопідготовки та наведено перспективи використання установок зворотнього осмосу для виробництва фасованої води. Отримані результати щодо використання установок зворотнього осмосу у водопідготовці із застосуванням рециркуляту дозволяють готувати фасовані води визначеного мінерального складу відповідно потребам споживачів та закладів індустрії гостинності.

Ключові слова: вода, пермеат, концентрат, рециркулят, заклади індустрії гостинності, поліфенольні речовини

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