SHARED AUTOMATIC DRINKING WATER TREATMENT AND DISPENSING SYSTEMS AND METHODS OF THEIR OPTIMIZATION

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Access to clean and safe drinking water is a fundamental human right. However, in many parts of the world, water scarcity and contamination pose significant challenges. To address these issues, shared automatic drinking water treatment and dispensing systems have emerged as innovative solutions. The article is devoted to the problem of access to safe, physiologically complete drinking water in collective systems of water preparation and sale, namely in water vending machines. Since such machines are a relatively new solution, the search for rational ways of adapting existing technologies is relevant and necessary for their widespread implementation. The article discusses the peculiarities of preparation and sale of water in the network of existing vending machines. It was established that automatic machines are autonomous multifunctional systems, the effectiveness of which depends on the balanced operation of all elements. Formulated requirements for the operation of automatic machines in autonomous conditions, namely, regarding water quality, automatic machine productivity, and the duration of its operation without operator intervention. A comparison of the requirements with operational data showed a discrepancy in water quality (in terms of hardness, pH, dry residue), productivity (10 times higher than required), duration of operation without an operator (4 times shorter than specified in the requirements). Factors influencing the operation of vending machines are formulated, namely: water preparation technology, number of stages, resource of filter elements, volume of water for own needs, combination of payment methods, time or volume logic of service. To achieve the proposed requirements, solutions have been developed, the effectiveness of which will be investigated in the course of further work. It was noted that a mandatory condition for the successful solution of the tasks set is digital control of the operation of the machine.

Keywords: *digitalization, payment systems, plastic-free water, reverse osmosis, safe physiologically complete drinking water, water vending machine*

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1. Introduction

Access to safe drinking water is one of the main problems of humanity. Nowadays, the water sector is negatively affected by three global factors: the reduction of freshwater reserves on the planet; decrease of water quality due to climate change, anthropogenic influence, detection of new pollutants; aging of the centralized water supply infrastructure. As a result, the quality of tap water increasingly does not meet the established requirements. This, in turn, contributes to the development of tap water purification technologies up to the level of existing requirements and methods of its delivery to consumers.

Common methods of water purification are adsorption, ion exchange, reverse osmosis, mechanical filtration, and ultraviolet disinfection. The technology based on the use of reverse osmosis in combination with other methods is the best for obtaining safe drinking water.

Regarding the delivery routes, drinking water can be bottled, in which case the purification process takes place at the factory, or it can be purified directly at the point of consumption by installing a purification system at home or at collective water filling points.

Collective water dispensing systems, namely vending water machines (WVM), are currently a relatively new and promising direction. The main feature of these machines is the autonomous operation of the system, that is, uninterrupted cleaning and filling of water for a long time without constant supervision of the operator. Ensuring the stability and autonomy of automatic machines opens the possibility of their larger implementation.

Scientific research on this topic is necessary to find rational ways of adapting existing technologies for obtaining safe, physiologically complete drinking water specifically for collective purification and pouring systems. The results of scientific research can be used in practice to improve collective water purification systems and their distribution on a national and global scale.

Purpose and tasks

The purpose of this work is to formulate the criteria for evaluating the work of WVM and to determine the factors influencing the autonomy of its work.

To achieve the goal, the following tasks must be solved:

- formulate the requirements for the work of the WVM in the autonomous mode;
- compare performance indicators of existing WVM with formulated requirements.

Establish the factors affecting the efficiency of the work of the WVM in the autonomous mode and propose solutions to optimize their work.

2. Materials and Methods

Safe drinking water and methods of obtaining it

Today, there are several ways to provide people with high-quality drinking water: water in a plastic bottle, water filters for home use, water purification systems for collective use.

Many people choose bottled water for their daily consumption. According to the data of the European Bottled Water Federation, the volume of the world bottled water market is 437.3 billion liters (Mitchenko & Bolshak, 2020). The growth in demand for bottled water is determined, in addition to the deterioration of the quality of tap water, by the increase in the population's ability to pay and the change in lifestyle. At the same time, it should be noted that most people prefer water in plastic containers, which is easily explained by the availability, cheapness, lightness and strength of the latter (Consumer Reports, 2023).

However, there are several reasons why bottled water may not be the best choice. First, it is an unknown source of water origin. So, for example, water, allegedly from mountain springs or streams, may turn out to be purified tap water. This is possible because information about the quality of bottled water is much more difficult to find than that of tap water, which is constantly monitored by various special services and is public. Therefore, we can say that bottled water can be even less safe than tap water (Bobrytskyi, 2023).

The second is the use of plastic containers. According to recent studies, water from plastic bottles contains microplastics, which are a source of such toxic chemicals as bisphenol A, polychlorinated biphenyls, aromatic polycyclic hydrocarbons, and others (Zare Jeddi et al., 2015). There is also a significant problem with the formation of biofilms on plastic surfaces, which contributes to the transfer of bacteria and viruses over long distances (Lights, 2023).

The third is the problem of plastic waste. Perhaps the biggest problem caused by the use of bottled water is environmental pollution with plastic. It has been established that plastic bottles are the main source of pollution (Mitchenko & Bolshak, 2020). A very small number of bottles are disposed, and an even smaller number are recycled into new ones. Because of this, most plastic bottles end up in landfills and in the ocean (Parker, 2023). The trend of plastic recycling, although actively gaining momentum, is not enough to ensure at least half of the existing plastic waste is recycled (Laville & Taylor, 2017). The most effective way out of the current situation is to reduce the consumption of bottled water by switching to purified water provided by alternative methods.

According to statistics, home filters for water purification in Ukraine are used by about 20% of people. In this case, further purification of tap water to the established norms takes place directly at the place of its consumption, which eliminates the need to use disposable plastic containers. Water of the highest quality is provided by filters based on reverse osmosis (RO) technology (Mitchenko, 2017). They are quite widespread, both in the world and in Ukraine, and their popularity is growing (see Figure 1).

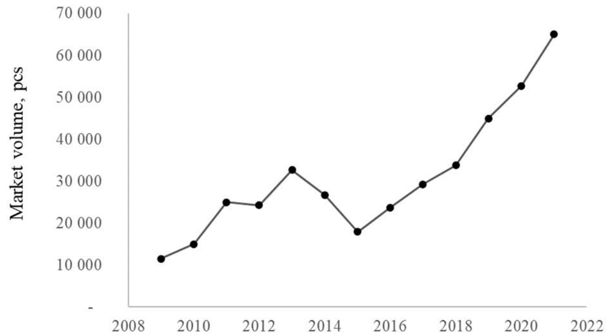

Fig. 1. *Market volume of home reverse osmosis filters in Ukraine*

However, not always and not everyone has the opportunity to install such filters due to the rather high cost. In addition, these filters are stationary, it is difficult to move them to another residence, which becomes a significant disadvantage when regularly changing the place of residence (Ecosoft, 2023).

Collective water purification and pouring systems are devices or kiosks installed near places where a large number of people live: in grocery stores, in residential areas, in shopping centers, etc. Such systems are connected to municipal water supply sources and provide additional purification of tap water and its filling into consumer containers.

The cost of water in a water vending machine is the lowest, which is a significant advantage for users, which contributes to the spread of vending machines. However, the cost of purified water in the machine is quite high, and the profitability does not exceed 15%. Such a low level of profitability reduces the interest of potential investors in WVM, which does not contribute to their spread. Since the price of water in WVM is limited by market conditions, the increase in profitability is possible only at the expense of reducing the cost of purified water. The cost of water is affected by the following factors: the number and cost of consumables and the frequency of their replacement, water consumption for own needs, frequency of service and encashment. Simultaneous adjustment of these factors can significantly reduce the cost.

Among the collective systems, it is WVM that is developing the fastest both in the world and in Ukraine. Figure 2 shows a device that is popular in Ukraine.

Table 1 shows the advantages, disadvantages, and cost of drinking water from different sources.

Table 1. *Comparison of properties of drinking water from different sources*

Source	**Advantages**	**Disadvantages**	**Price, UAH/dm^3**
Bottled water	- always available in any store; - convenient to use.	- water pollution with microplastics and microorganic compounds; - contributes to the formation of a large amount of plastic waste; - high price.	8-15
Water after home filtering	- absolutely clean drinking water; - always available.	- is not always physiologically complete; - high cost of the filter (from UAH 5,000); - the filter requires systematic maintenance and replacement of consumables.	3-5
Water after vending machines	- absolutely clean drinking water; - available if machines are available; - the machine can provide water needs in conditions of a large crowd of people; - the cheapest.	- not always available; - is not always physiologically complete; - machines are not autonomous enough - they require systematic maintenance and replacement of consumables.	1.5

Fig. 2. *Appearance and internal layout of the water vending machine*

WVM is a mini-plant for the production of high-quality fresh drinking water. Such devices are connected to the water supply, the water undergoes 7 stages of purification: mechanical filtration, dechlorination on activated carbon, dosing of antiscalant, reverse osmosis, adsorption on activated carbon, enrichment with mineral compounds, in particular magnesium and calcium, and ultraviolet disinfection. Users buy water through built-in payment systems and pour into their reusable bottles from 1 to 19 liters. Figure 3 shows a block diagram of the process of further purification of tap water and its sale using a water vending machine (BTWaqua, 2023).

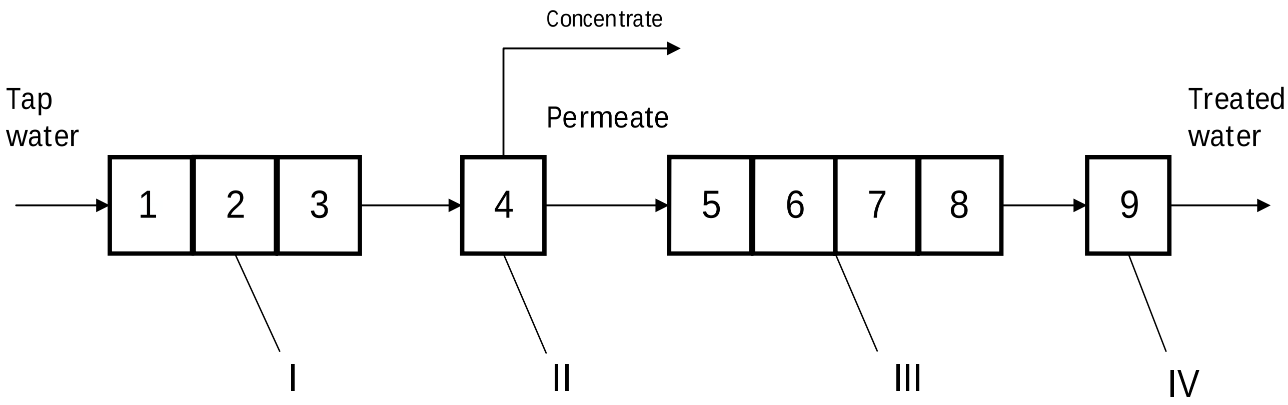

Fig. 2. *Block diagram of the process of preparing and selling water in a vending machine: I – preliminary preparation of water; II – reverse osmosis; III – post-treatment of water; IV – payment system; 1 – mechanical filtration; 2 – dechlorination on activated carbon; 3 – dosage of antiscalant; 4 – reverse osmosis; 5 – permeate capacity; 6 – adsorption on activated carbon; 7 – mineralization; 8 – disinfection; 9 – payment system.*

Let's consider the main stages of the process:

Preliminary preparation of water (I)

The main element of the technological scheme of water purification is the reverse osmosis module. Before it, mechanical impurities, organic compounds, and residual chlorine are removed from the water to exclude the possibility of damage to the membrane fabric (Technical Manual, 2023).

At the stage of preliminary water preparation, as a rule, polypropylene filters are installed for mechanical cleaning (1) and filled cartridges with activated carbon for adsorptive cleaning of organic impurities and residual chlorine (2). Recently, carbon block filters have become increasingly popular, the use of which allows combining these two stages into one (Braslavska et al., 2022). At the next stage (3), an antiscalant is added to the water to prevent the formation of insoluble compounds on the surface of the membrane and decrease its productivity (Orestov, 2012).

Reverse osmosis (II)

The prepared water enters the membrane module (4), where it is divided into deeply purified, desalinated permeate and concentrate. The salt content of the permeate is about 5 mg/dm^3. The concentrate contains only components that were in the source water, but in a higher concentration, which allows it to be discharged into the sewer without additional treatment (Mitchenko, 2021, Haflich et al., 2021).

Post-treatment of water (III)

The reverse osmosis permeate is collected in the tank (5), that ensures a sufficient speed of water filling. After contact with the reverse osmosis element and the tank, the water sometimes acquires a "synthetic" taste. To correct this phenomenon, water is passed through a filter with granular activated carbon (6) to improve the taste (Lamma & Outhman, 2015).

To ensure the physiological quality of water, reverse osmosis permeate in machines is subject to mineralization (7). To do this, it is passed through a special cartridge filled with minerals, or a ready-made saline solution is dosed into it (Mitchenko et al., 2017). However, as we have shown in (Tyvonenko et al., 2023), these methods are not perfect. In the same paper, a scheme for obtaining safe and physiologically complete water by using modified membrane elements in the reverse osmosis module with selectivity set considering the salinity of the source water is proposed.

The final stage of water purification in the machine is the disinfection module (8). It is designed to neutralize microorganisms immediately before pouring water into the user's container. Since the water can be used immediately after pouring, it is necessary to use exclusively reagent-free disinfection methods. It is most rational to apply the method of ultraviolet irradiation with a wavelength of 200-300 nm for water disinfection (Mitchenko, 2019). There are two types of disinfection modules: based on mercury-incandescent lamps and based on LED lamps. Mercury lamps begin to emit ultraviolet waves of the required intensity and disinfect after a few minutes of heating, LED lamps - immediately after switching on. Mercury lamps lose their resource every time they are turned on and off, LED lamps do not have such a limitation (UV Lamps, 2023). LED lamps can be turned on only when needed, which significantly extends their service life and reduces electricity consumption (State of the Art LED, 2023).

Table 2 shows a comparison of the operational characteristics and areas of application of ultraviolet disinfectants of various types.

Table 2. *Comparison of operational characteristics and areas of application of ultraviolet disinfectants of different types*

Type of UV disinfectant	Mercury incandescent lamp	LED lamp
Operation mode	continuous	alternate
Productivity	over 20 dm^3/min	less than 20 dm^3/min
Service life	1 year	5–10 years
Size	large-format	compact
Area of use	water supply systems	water pouring systems home water filters

Payment system (IV)

WVMs are equipped with a payment module for making payments for drinking water in automatic mode. The payment module can include several payment methods (Payment Options, 2023; Bezghotivkovi rozrakhunky, 2023):

- cash - coins, bills;
- non-cash - bank card, application, quick code (QR-code).

The payment module must meet the following requirements:

- be convenient for most users;
- meet the trends in the development of payment methods;
- comply with current legislation;
- reliably function without frequent maintenance;
- have an acceptable cost.

Considering the peculiarities of each of the methods, their combination is most often used in WVM. The optimal combination ensures comfortable use for consumers, and for the owners of WVM - cost savings on its equipment and maintenance. For example, a payment system can include payment with coins, a QR code, and an app. Coins and QR code are convenient payment methods for new users, the app is for regular users. Such a combination requires small capital expenditures and infrequent collection. When a certain number of regular users of the application is reached, it is rational to remove payment in coins. This reduces the frequency of maintenance and the amount of equipment, which means it increases the reliability of the WVM.

Thus, the above information indicates that WVMs are multifunctional systems, the effectiveness of which directly depends on the balanced action of all components. Digitalization is the most rational and modern way to solve this problem.

The spread of the Internet, the increase in the speed of data transmission and processing, the availability of sensors and microcontrollers gave an impetus to the digitization of various devices (Grievson et al., 2022). The essence of digitalization consists in equipping engineering systems with sensors and microcontrollers for collecting and transmitting technological parameters for the purpose of their further processing and analysis. Thanks to digitalization, operators receive much more information about the operation of equipment.

The analysis of technological parameters opens opportunities to optimize processes thanks to a better understanding of their functioning over time. In addition, the measurement of parameters at a distance and their analysis makes it possible to predict and prevent possible accidents (Porter & Heppelmann, 2014). Digitization of WVM consists in equipping them with water quality sensors, flow meters, state sensors of technological equipment and a payment module.

This will make it possible to obtain information about the actual performance of each device and determine the frequency of maintenance based on the volume of bottled water, and not based on time as is the case today.

New opportunities provided by digitalization are necessary on the way to a larger implementation of WVM.

Table 3 shows the features of existing payment methods.

Table 3. *Comparison of payment methods*

Payment method	Advantages	Specifications of use
Coins and bills	The most popular and the simplest method - Common for a lot of users	It is necessary to have small cash Frequent visits are required for encashment and maintenance Acceptors of bills and coins increase the value of WVM It is necessary to issue a fiscal check
Bank card	Fast payment method No need to look for cash No need to encashment	WVM must have an Internet connection - Payment bank terminal increases the cost of WVM Each terminal requires bank registration It is necessary to issue a fiscal check
Application in a smartphone	Fast and convenient for regular purchases No need to look for cash Does not require encashment Provides an opportunity to receive an individual purchase price No need to issue a fiscal check	The user need to have a smartphone The user needs to install the application on a phone WVM must have an Internet connection Not used for one-time purchases
QR-code	Quick payment method for one-time payments Does not require installation of a payment terminal No need to issue a fiscal check No need to look for cash Does not require encashment	The user need to have a smartphone The user need to enter bank card data into the smartphone WVM must have an Internet connection

For example, as of 2023, approximately 1,000 WVMs have been established in Ukraine, which serve about 100,000 families, approximately 1-2 % of the total population. The world's largest network of vending machines is located in the USA and has 20,000 units, covering the drinking water needs of only 1-2 % of households. Considering their advantages, WVM can become one of the main ways of obtaining drinking water, providing the water needs of up to 25 % of people. This means that in Ukraine, with a developing economy, and in the USA, a country with a developed economy, there is a potential to increase the number of machines in 10–20 times.

Such an increase in the number of WVM without digitalization can lead to the decrease of water quality or mass shutdown of devices due to untimely maintenance and elimination of accidents. As a result, large-scale implementation of WVM will not be possible.

As noted above, the main feature of WVM is the autonomy of its work, namely, uninterrupted cleaning and filling of water for a long time without constant supervision of the operator or user. Criteria for evaluating the work of WVM in the autonomous mode are not formulated in literary sources. That is why it is advisable to formulate these criteria and check the operation of existing devices for compliance with them, as well as to determine the factors affecting the autonomy of the WVM.

3. Results and Discussion

Requirements for the work of WVM in conditions of autonomy

The autonomy of WVM is their ability to continuously purify and dispense water for a long time without constant supervision of service personnel.

When the WVM works in the autonomous mode, the requirements for water quality, productivity and duration of operation without supervision must be met.

The water quality in the vending machine must meet the requirements established by the state. In Ukraine, these requirements are formulated in document (Pro zatverdzhennia, 2023). This document regulates the content of 86 substances in water, 11 of which are sanitary-bacteriological and 75 are sanitary-chemical. Permanent quality control is carried out not on the entire list of indicators, but only on indicators that most often do not meet the established requirements in a certain region.

In the Dnipro river basin, there are the following indicators: turbidity, smell, color, hardness, iron, manganese, dry residue, pH, oxygen demand, total microbial count. The requirements for these indicators are listed in Table 3.

Productivity is an important characteristic when ensuring the autonomous operation of the WVM, because its value determines the choice of equipment and the frequency of its maintenance. To determine the rational productivity, the existing experience of the machines in the Kyiv network, consisting of 183 units, was considered.

Figures 4 and 5 show data on the distribution of the number of machines according to the daily capacity of bottled water.

Data analysis shows that the daily productivity of machines, depending on their location, varies in a wide range of 50–1000 dm^3/day, but 90 % of machines are limited to filling 50–350 dm^3/day. This accounts for 76 % of water from the network's total sales.

Figure 6 shows hourly water sales statistics during the day. Data analysis shows that the main amount of water (97 %) is poured by the machine in 14 hours, and during peak hours (from 19:00 to 21:00) the filling is 10 % of the daily amount.

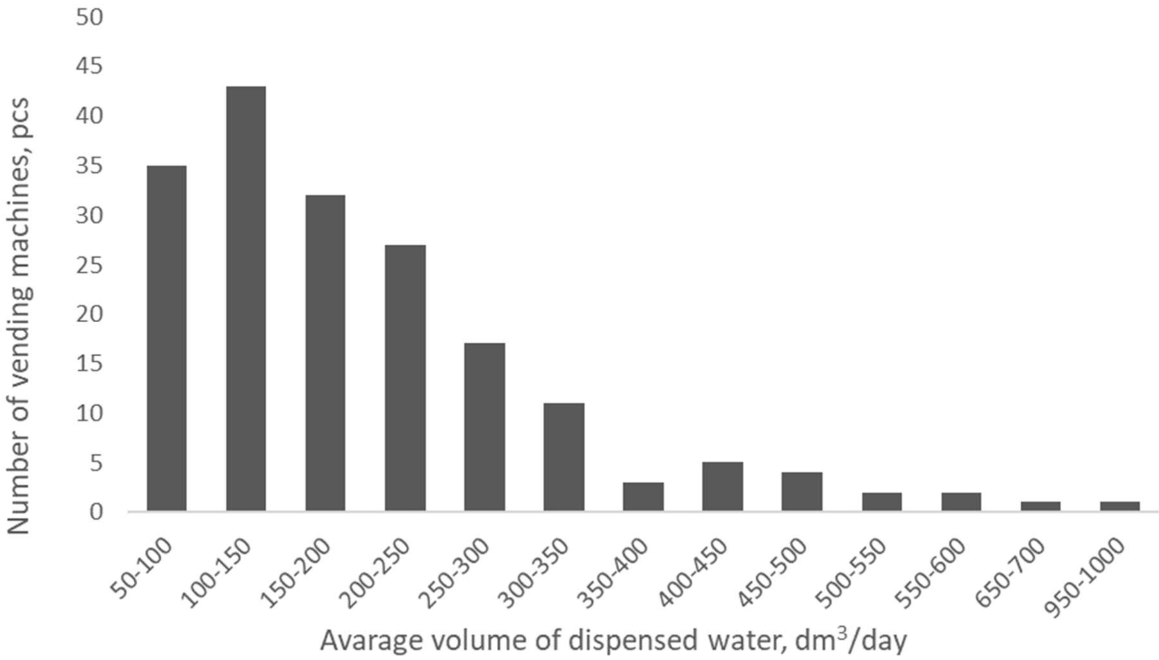

Fig. 4. *Distribution of network machines by volume of bottled water*

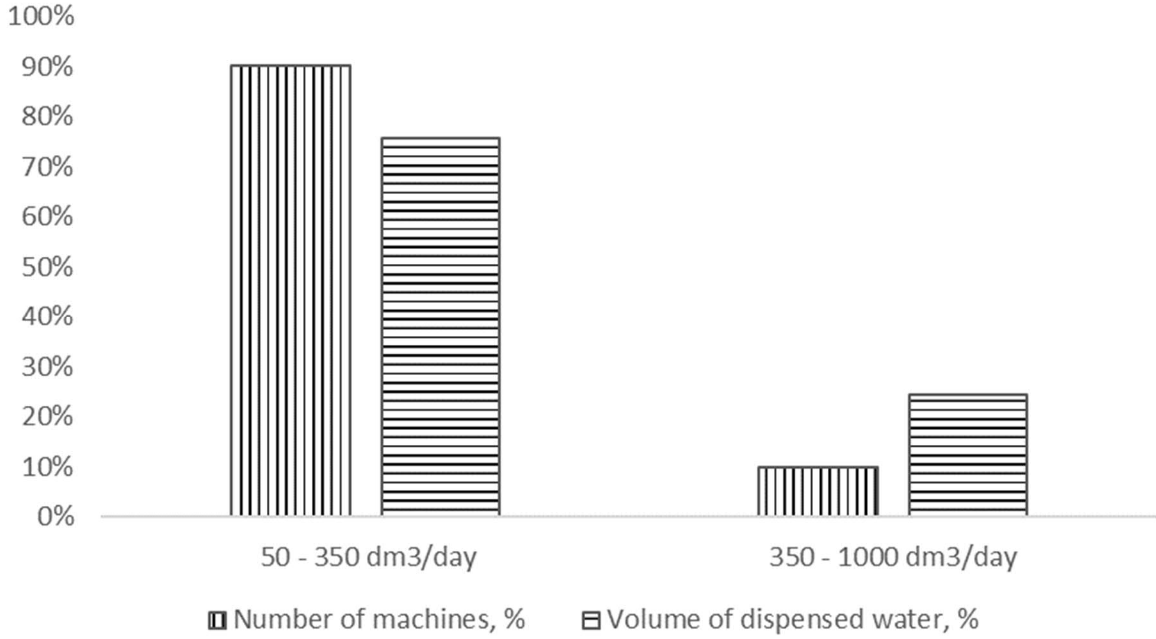

Fig. 5. *Shares of vending machines with average daily water pouring of 50–350 dm*^{3}*/day and 350–1000 dm*^{3}*/day and the volume of water bottled from the total indicators of the network*

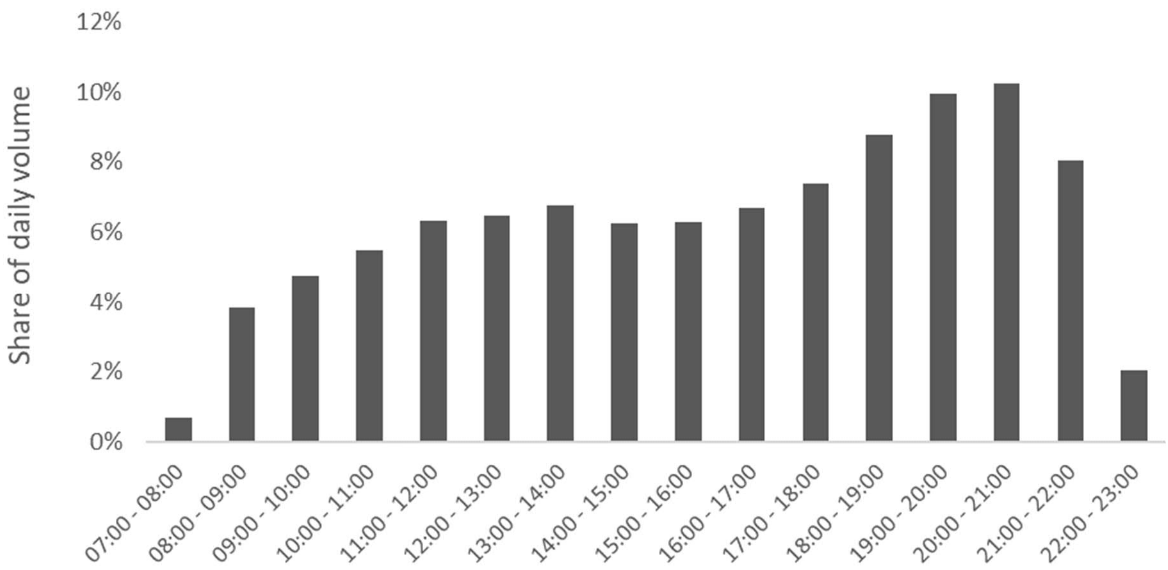

Fig. 6. *Dynamics of hourly sales of water in vending machines in fractions of the average daily volume*

The analysis of the operation of the Kyiv vending machine network allows us to offer the following:

- the daily productivity of the machine should be 350 dm^3. If the need for water at a specific location is higher, then another machine is to be installed;
- hourly productivity should be at least 35 dm^3, taking into account the 14-hour period of water pouring per day and the increase in use during peak hours.

The duration of WVM operation without technical maintenance depends on the frequency of performance of individual routine works, namely replacement of consumables, maintenance of technological equipment and payment system, encashment. In addition, emergency situations can significantly affect the uninterrupted operation of the equipment, reducing its autonomy. In our opinion, the machine can be considered autonomous if the duration of its operation without operator intervention is 12 months.

Comparison of performance indicators of existing WVM with the proposed requirements

A network of vending machines in Kyiv was chosen to compare the performance of existing ATMs with the proposed requirements. Two types of devices operate in the network, which are built according to similar technological schemes and differ in performance, methods of mineralization, as well as the volume and type of container for purified water. All machines of the network are equipped with the same payment modules with the cash payment method using coins and bills.

Schemes of machines are shown in Figures 7 and 8.

Performance indicators of both types of WVM are shown in Table 4.

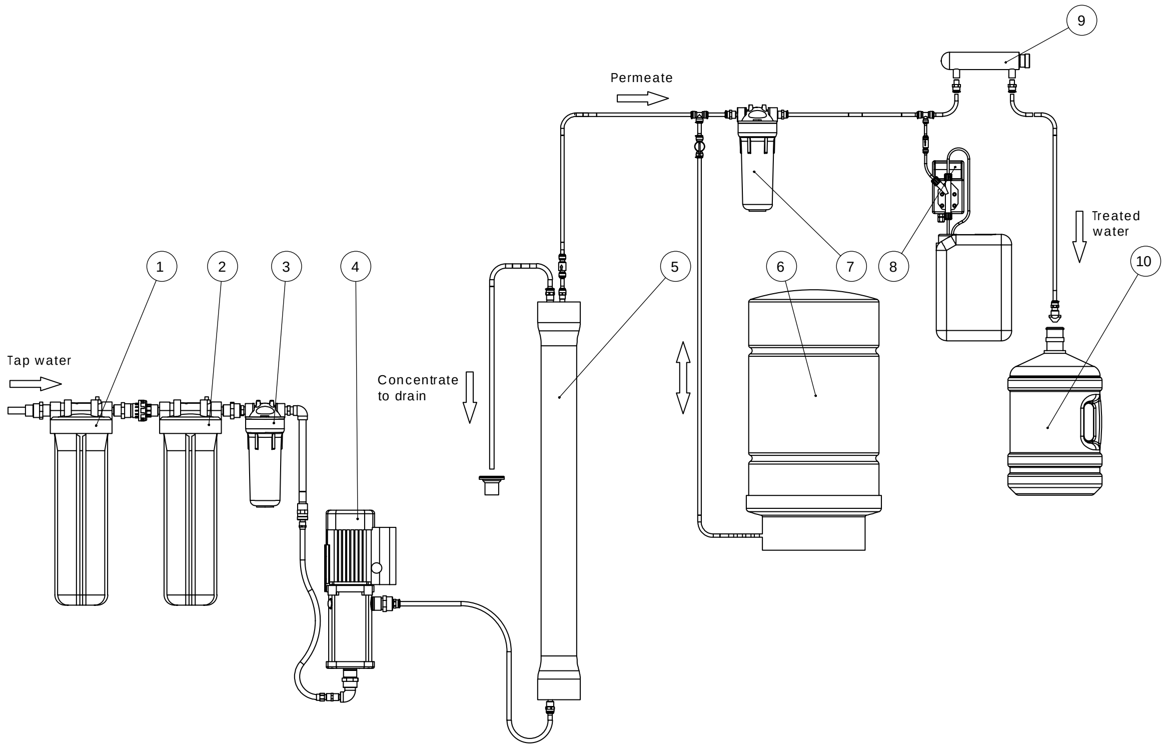

Fig. 7. *Schematic diagram of water vending machine Type 1:*
1 – mechanical cleaning filter; 2 – carbon filter for chlorine removal; 3 – cartridge - antiscalant dispenser; 4 – high pressure pump; 5 – reverse osmosis module; 6 – closed type clean water tank; 7 – carbon filter to improve organoleptic indicators of water quality; 8 – salt solution dosing module; 9 – ultraviolet disinfectant with an incandescent lamp; 10 - user's bot

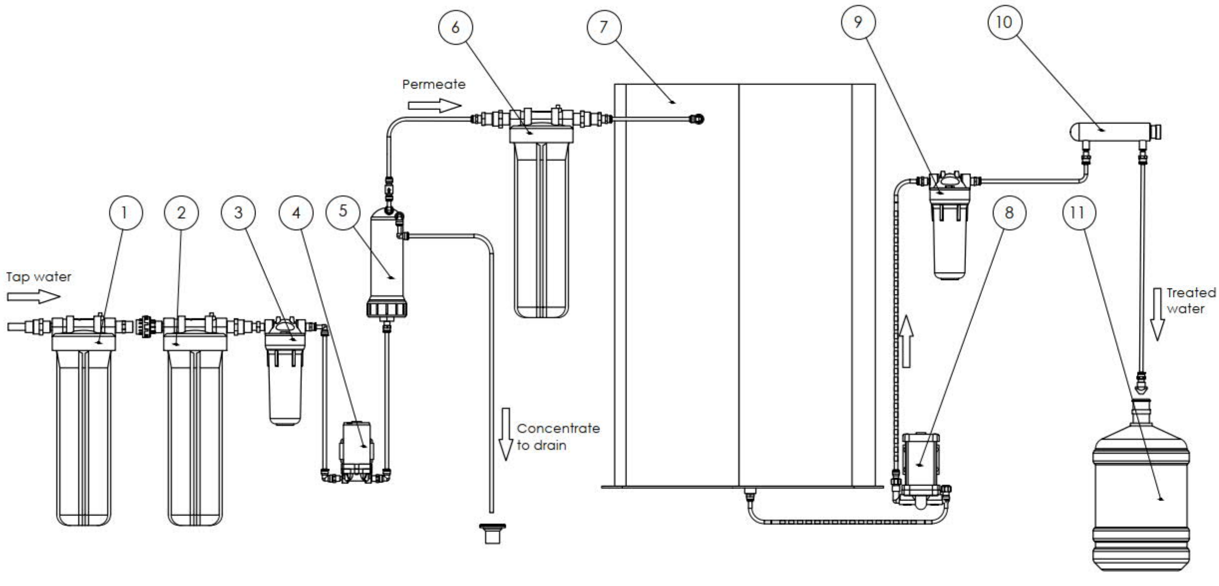

Fig. 8. *Basic technological scheme of the water vending machine Type 2:*
1 – mechanical cleaning filter; 2 – carbon filter for chlorine removal; 3- antiscalant dispenser cartridge; 4 – high pressure pump; 5 - reverse osmosis module; 6 – filter with minerals; 7 – open-type clean water tank; 8 – water filling pump; 9 – carbon filter to improve organoleptic indicators of water quality; 10 – ultraviolet disinfectant with an incandescent lamp; 11 –user's bottle

Table 4. *Average performance indicators of various types of machines and requirements for their functioning in autonomous mode*

Indicator	RO	WVM Type 1	WVM Type 2	Requirements
	Water quality indicators			
Turbidity, mg/dm^3	≤ 0,58	≤ 0,58	≤ 0,58	≤ 0,58
Odor, points	≤ 2	≤ 2	≤ 2	≤ 2
Color, deg	≤ 20	≤ 20	≤ 20	≤ 20
Iron, mg/dm^3	≤ 0.2	≤ 0,2	≤ 0.2	≤ 0,2
Manganese, mg/dm^3	≤ 0.05	≤ 0,05	≤ 0,05	≤ 0,05
Hardness, mmol/dm^3	≤ 0.1	0.2–0.8	0.1–0.8	1–7
Dry residue, mg/dm^3	< 5	10–80	10–40	100–1000
pH	5.5–6.0	6.3–9.0	6.3–9.8	6.5–8.5
TMC, CFU/cm^3	≤ 3	3–10	10–40	≤ 50
	Specifications of the method			
Type of mineralisation	-	Dosage of salt solution	Filtration through the mineral cartridge	
Type of purified water tank	-	closed	open	closed
Volume of water tank, дм^3	-	60	180	
	Productivity			
Productivity by initial water, dm^3/h	-	360	180	45–50
Productivity by purified water, dm^3/h	-	250	90	≥ 35
	Frequency of maintenance, times per year			
Change of expendable supplies	-	4	4	1
Technical maintenance	-	2	2	1
Encashment	-	12	6	-

From the data in Table 4, the following conclusions can be made: the results of analyzes of purified water indicate that both methods of demineralization used in existing machines do not meet the requirements for water quality in terms of pH, hardness, and dry residue. As for productivity, both types of machines do not meet the proposed requirements, neither on an hourly basis, nor on a daily basis. The same can be said about the frequency of maintenance and replacement of consumables.

Suggestions for optimizing operation of the WVM

In order to achieve the requirements proposed in Table 4, it is necessary to improve the technological and operational characteristics of the existing machines. To do this, the factors affecting their work parameters should be adjusted:

- to develop a single technological scheme of water purification to replace the two that are used today;
- the number of stages of both pre- and post-membrane water preparation should be minimized;
- the volume of water for own needs should be reduced, which is possible by increasing the efficiency of the membrane module;
- the resource of the selected filter elements must be balanced and sufficient for their

simultaneous replacement in accordance with the requirements;
- replacing the cash payment method with a non-cash or combined method will reduce the frequency of encashments;
- the logic of maintenance of automatic machines should be changed from time to volume, which will allow to determine the degree of exhaustion and, therefore, the frequency of replacement of filter elements more accurately;
- to introduce digitalization of automatic control.

Changing the cleaning technology, reducing the number of stages of water preparation, choosing materials with a greater resource and switching to cashless forms of payment are necessary conditions for meeting the requirements for the frequency of WVM service. However, they are not sufficient. During the operation of the WVM network, a deviation of the water discharge volume of each device from the normative value is observed. Therefore, to meet the requirements for water quality, productivity and service frequency, it is necessary to change the maintenance logic from time to volume. To do this, it is necessary to set the resources of each filter in the digital device management system, and to predict the date of their replacement based on the actual water consumption. In this way, the maintenance of each unit will be carried out as planned, exactly when the resource of the filters is almost exhausted, but the device still pours water with the specified parameters in terms of quality and performance. Therefore, it is digitization that will achieve the maximum long-term operation of the device without constant supervision of personnel, which is a necessary condition for autonomy.

4. Conclusions

Requirements for the operation of water vending machines in autonomous mode are stated, namely:
- the quality of purified water must be monitored according to the quality indicators of hardness, dry residue, pH, total microbial count and meet the established requirements for safety and physiological integrity;
- the productivity of purified water should be at least 35 dm^3/hour;
- the duration of operation of the machine in normal mode without operator intervention should be 12 months.

The operation of 183 vending machines in the Kyiv network was analyzed and the obtained indicators were compared with the formulated requirements. It was established that the existing machines do not meet the requirements for water quality in terms of pH, hardness and dry residue, productivity, as well as the frequency of maintenance and replacement of consumables.

A set of solutions for optimizing the operation of water vending machines in offline mode is proposed, which includes:
- meeting water quality requirements through the use of the latest methods and materials;
- reducing the volume of water for own needs by increasing the efficiency of the reverse osmosis module;
- transition to non-cash forms of payment;
- digitalization of automatic control;
- changing the logic of maintenance of machines from time to volume, which will allow to more accurately determine the degree of exhaustion of filter elements, which means reducing the frequency of their replacement.

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References

1. Mitchenko, T.; Bolshak, A. Ekolohiia chystoi vody. *Water and Water purification technologies,* **2020**, *95-96*, 18-26.

2. Should we break our bottled water habit? Consumer Reports. https://www.consumerreports.org/epa/should-we-break-our-bottled-water-habit-a5667672175 (accessed May 20, 2023).

3. Bobrytskyi, D. Yakist i tsina: yaku pytnu vodu my kupuiemo i chym vona vidrizniaietsia. Porivniannia. https://www.epravda.com.ua/publications/2021/01/13/669917 (accessed May 21, 2023) [in Ukrainian].

4. Zare Jeddi, M.; Rastkari, N.; Ahmadkhaniha, R.; Yunesian, M. Concentrations of phthalates in bottled water under common storage conditions: Do they pose a health risk to children? *Food Research International,* **2015**, *69*, 256-265. https://doi.org/10.1016/j.foodres.2014.11.057.

5. Lights, Z. What's the Problem with Plastic Bottles? One Green Planet. https://www.onegreenplanet.org/animalsandnature/whats-the-problem-with-plastic-bottles/ (accessed May 21, 2023).

6. Parker, L. How the plastic bottle went from miracle container to hated garbage. National Geographic. https://www.nationalgeographic.com/environment/article/plastic-bottles (accessed May 20, 2023).

7. Laville, S.; Taylor, M. A million bottles a minute: world's plastic binge 'as dangerous as climate change. https://www.theguardian.com/environment/2017/jun/28/a-million-a-minute-worlds-plastic-bottle-binge-as-dangerous-as-climate-change (accessed June 28, 2017).

8. Mitchenko, T.Y. Evoliutsiia zvorotnoho osmosu. *Water and Water purification technologies,* **2017**, *84*, 4-12 [in Ukrainian].

9. Filtry dlia pytnoi vody. https://ecosoft.ua/ua/filtry-obratnogo-osmosa-prod/ (accessed May 10, 2023) [in Ukrainian].

10. Vseredyni akvaboksu chystoi vody | BWT Aqua. https://bwtaqua.com.ua/inside-bwt/ (accessed May 6, 2023) [in Ukrainian].

11. FilmTec™ Reverse Osmosis Membranes Technical Manual Water Solutions. https://www.dupont.com/content/dam/dupont/amer/us/en/water-solutions/public/documents/en/RO-NF-FilmTec-Manual-45-D01504-en.pdf (accessed May 19, 2023).

12. Braslavska, Y.; Mitchenko, T.; Ponomarov, V.; Maletskyi, Z.; Kosogina, I. Production technology and filtering properties of carbon block cartridges *Water and water purification technologies. Scientific and technical news,* **2022**, *33* (2), 32-42. https://doi.org/10.20535/2218-930022022255835.

13. Orestov, Y. Reahenty dlia bezreahentnoi vodopidhotovky. *Water and Water purification technologies*, **2012**, *63*, 4-10. [in Ukrainian].

14. Mitchenko, T.Y. (Ed.) *Seriia vydan Svit suchasnoi vodopidhotovky. Tekhnolohichni rishennia*; VUVT WATERNET: Kyiv, 2021, 80 p. [in Ukrainian].

15. Haflich, H.M.; Membreno, M.A.R.; Job, H.; Huang, K.; Toomey, M.; Howarter, J.A.; Shah, A.D. Effect of halides on polyamide-based membrane flux and monomer degradation during chloramination *Journal of Membrane Science* **2021**, *639*, 119717. https://doi.org/10.1016/j.memsci.2021.119717.

16. Lamma, O.A.; Outhman, A. Impact of reverse osmosis on purification of water. *Journal of Pharmaceutical Biology*, **2015**, *5* (2), 108-112.

17. Mitchenko, T.Y.; Orestov, Y.; Vasilyuk, S. Ot demyneralyzatsyy k domyneralyzatsyy. *Water and Water purification technologies*, **2017**, *83*, 4-7.

18. Tyvonenko, A.; Mitchenko, T.; Homaniuk, O.; Vasilyuk, S.; Kosogina, I.; Mudryk, R. Production of physiologically complete drinking water using modified reverse osmosis membrane elements Eastern-European Journal of Enterprise Technologies 2023, 2/10 (122), 6-13. https://doi.org/10.15587/1729-4061.2023.277491.

19. Mitchenko, T.Y. (Ed.) *Seriia vydan Svit suchasnoi vodopidhotovky. Metody i materialy*; VUVT WATERNET: Kyiv, 2019, 132 p. [in Ukrainian].

20. UV Lamps vs UVC LEDs: Which is best for your water disinfection needs? https://klaran.com/uv-lamps-vs-uvc-leds-which-is-best-for-your-water-disinfection-needs (accessed May 2, 2023).

21. State of the Art LED Ultra-Violet Disinfection Systems. https://www.leduv-c.co.uk (accessed May 2, 2023).

22. Payment Options. https://www.practicalbusinessskills.com/managing-a-business/financial-management/payment-options (accessed May 3, 2023).
23. Bezghotivkovi rozrakhunky. https://bank.gov.ua/ua/payments/nocash (accessed May 3, 2023).
24. Grievson, O.; Holloway, A.; Johnson, B. *Strategic Digital Transformation for the Water Industry;* IWA Publishing: London, 2022, 102 p.
25. Porter, M. E.; Heppelmann, J. E. How Smart, Connected Products Are Transforming Competition. *Harvard Business Review* **2014**, *92,* 64-88.
26. Pro zatverdzhennia Derzhavnykh sanit... | vid 12.05.2010 № 400. https://zakon.rada.gov.ua/laws/show/z0452-10#Text (accessed February 8, 2023).

АВТОМАТИЗОВАНІ СИСТЕМИ КОЛЕКТИВНОГО КОРИСТУВАННЯ ПІДГОТОВКИ І РОЗЛИВУ ПИТНОЇ ВОДИ ТА МЕТОДИ ЇХ ОПТИМІЗАЦІЇ

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Стаття присвячена проблемі доступу до безпечної фізіологічно повноцінної питної води в колективних системах підготовки і продажу води, а саме у водних вендингових автоматах. Оскільки такі автомати є відносно новим рішенням, то пошук раціональних шляхів адаптації існуючих технологій є актуальним і необхідним для їх широкого впровадження. В статті розглянуті особливості підготовки та продажу води в мережі існуючих автоматів. Встановлено, що автомати є автономними поліфункціональними системами, ефективність яких залежить від збалансованості роботи всіх елементів. Сформульовані вимоги щодо роботи автоматів в умовах автономності, а саме щодо якості води, продуктивності автомату та тривалості його роботи без втручання оператора. Порівняння вимог з експлуатаційними даними показало невідповідність за якістю води (за показниками твердість, pH, сухий залишок), продуктивністю, (в 10 разів перевищує необхідну), тривалістю роботи без оператора (в 4 рази коротша ніж зазначено у вимогах). Сформульовані фактори впливу на роботу автоматів, а саме: технологія підготовки води, кількість стадій, ресурс фільтруючих елементів, об'єм води на власні потреби, комбінація платіжних методів, часова чи об'ємна логіка обслуговування. Для досягнення запропонованих вимог сформовані рішення, ефективність яких буде досліджена в ході подальших робіт. Відзначено, що обов'язковою умовою успішного вирішення поставлених задач є цифровізація управління роботою автомату.

Ключові слова: *безпечна фізіологічно повноцінна питна вода, вода без пластику, водний вендинговий автомат, зворотний осмос, платіжні системи, цифровізація*