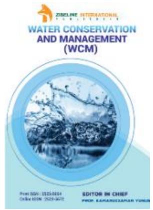
ZIBELINE INTERNATIONAL™ PUBLISHING

**Water Conservation & Management (WCM)**

*DOI: http://doi.org/10.26480/wcm.02.2024.133.139*

***ISSN: 2523-5664 (Print)***
***ISSN: 2523-5672 (Online)***
***CODEN: WCMABD***

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***RESEARCH ARTICLE***

# METHODS OF DISPOSAL OF BRINES AND REGENERATION SOLUTIONS IN THE DESALINATION OF MINERALISED WATERS

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**ARTICLE DETAILS**

***Article History:***

Received 23 September 2023
Revised 26 October 2023
Accepted 12 November 2023
Available online 16 November 2023

**ABSTRACT**

The relevance of the study is due to the fact that the presented object, namely mineral waters in the modern world have a huge potential and play an important role in farming, the coal industry, and in many other fields of life. Mineral water desalination technologies also affect the environment, so there are requirements for improving the methods of recycling brines and regenerative solutions in the desalination of water, due to which it is possible to make a substantial contribution to meeting the requirements of a number of consumers. The purpose of the study is to conduct an experiment, as a result of which recommendations will be made to eliminate errors and improve the quality of various methods of desalination of mineral waters and prevent the problem of disposal of brine, which, when discharged into reservoirs or evaporative sites, substantially worsen the ecological situation. Among the methods used are analytical, experimental, functional, statistical, classification, synthesis. In the course of the study, the features of mineral waters were noted, errors that were made during treatment, and the causes of their occurrence were analysed, and difficulties in the field of coal industry enterprises were analysed: the formation of water, its composition, properties, and degree of impact on the environment. It is important to understand the possibilities of various methods that allow choosing the best technological modes of operation of water treatment processes and successfully solving environmental problems with minimal consumption of reagents, water, and its discharge to the external environment. The practical value lies in the fact that the results obtained can be useful for the industry where mineral resources are extracted and processed, for researchers engaged in the development of new desalination methods, and can substantially reduce production costs and ensure the ecology of the process.

**KEYWORDS**

Coal Industry, Pollutants, Filtration, Cleaning Structures, Water Treatment

## 1. INTRODUCTION

The intensive development of technologies over the past decades in many structures, such as energy, light, and heavy industry, rural and municipal economy, has created a substantial demand for the development of water supply. Water quality requirements have increased, which has contributed to the construction of new structures for water supply systems, and the expansion and innovation of old ones. Unfortunately, most of these systems have a negative impact on the environment, both direct and indirect. Therefore, the use must be conducted strictly in accordance with the regulations on environmental protection.

Important problems in the desalination of mineral waters are some errors and shortcomings in techniques, as a result of which environmental problems have substantially increased. The continuous growth of production leads to contamination of the environment. Water treatment systems that have serious waste, such as sludge from erdlators, waste mineralised regenerative solutions after ion exchange installations, have a large negative impact on the environmental background (Kyrychuk and Muzyka, 2017). The purpose of this study is to perform an objective analysis to identify problems and errors in the methods of desalination of mineral waters. Completing this task will allow desalinating mineral waters using improved methods and minimising problems.

A group researchers argued that as a result of industrial processes using radionuclides, waste is generated, which is released, which leads to pollution of the environment and depletion of natural resources (Boncz et al., 2022). An example of such waste is brine – a concentrated salt stream formed in water treatment processes, which is currently regularly discharged into reservoirs. However, brine is a recyclable material, and it must be restored (Koibakov and Umirkhanov, 2013b). The joint project "zero brine" is aimed at developing the process for this purpose. As stated by the technical progress of any modern society is inextricably linked with the development of production capacities, increased industrial production and constant growth and large-scale consumption of material resources, including water resources (Abu Sharkh et al., 2022).

According to when desalinating mineral waters to provide the population and animals with high-quality water, brine of the maximum concentration is obtained and discharged into the gorge, a natural water source that is harmful to the environment (Ahmad et al., 2019). Therewith, Kazakhstan lacks food-grade table salt that meets the requirements of the standard. In many regions and districts, low-quality artisanal salt is used. Such salts have a high content of insoluble impurities (granite, marble), their composition contains salts of calcium, magnesium, iron, copper, and lead in quantities exceeding the maximum permissible concentrations (Subhoni et al., 2018). In this regard, it is possible to modify the technical base for the desalination of mineral waters in a versatile direction. That is,

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| | **Website:** www.watconman.org | **DOI:** 10.26480/wcm.01.2024.133.139 |

Cite The Article: Timur Ustabayev, Yerkin Tazhgaliyev, Nurlan Balgabayev, Mirobit Mirdadayev, Gylnaz Telgarayeva (2024). Methods of Disposal of Brines and Regeneration Solutions in The Desalination of Mineralised Waters. *Water Conservation & Management, 8(2): 133-139*.

it takes drinking water, uses the resulting brine and makes table salt and some types of fertilisers from it. According to a study, maintaining the quality of water in recirculating systems is an important factor in the optimal operating mode of production, which mainly affects the efficiency of heat exchange devices (Ergozhin et al., 2021). Deterioration of water quality leads to a decrease in the efficiency and productivity of the oil processing plant (Martynovskii et al., 1990).

According to the role of desalination at the current stage is not limited only to the problem of eliminating water scarcity in a number of low-water and anhydrous regions of the world (Burdo et al., 2022). The principle of desalination is increasingly accompanied by the concentration of solutions to obtain commercial mineral products from them. In this regard, the demand for desalination plants with high economic indicators is growing in the global market. According to a study, ion exchange can effectively remove natural organic substances from surface waters during drinking water treatment (Caltran et al., 2020). The main disadvantage of removing substances by ion exchange is the production of processed recirculating brine, which is polluted waste, the removal of which is expensive (Kyrychuk, 2010).

The aim of this study is to assess the environmental and economic feasibility of implementing reverse osmosis and vacuum evaporation technologies for water desalination and waste management. The study also aims to explore the applicability of vacuum evaporators in diverse industrial sectors, including fertilizer production, the oil industry, and food processing, for waste processing, concentration of desired solutions, and water purification for reuse. The study's problematics encompass a multifaceted exploration of the potential benefits and challenges associated with the widespread adoption of mobile reverse osmosis and vacuum evaporation technologies.

## 2. Materials and Methods

A study in the field of investigating the problems of desalination of mineral waters was conducted using methods that cover the essence of modelling in the laboratory conditions of the desalination process, and the theoretical and practical content of the object. Using the analytical method, it was possible to identify the main problems in the desalination of mineral waters, namely the disposal of brines obtained during desalination of water, and the washing solution for recirculation (washing) of reverse osmosis devices. Using the statistical method, indicators that help analyse the number and causes of errors in the development of a mobile reverse osmosis unit, the potential for using this mechanism on open evaporation sites were considered. Using a functional method, the role of brine disposal and regeneration solutions in the desalination of mineralised waters at a mobile reverse osmosis plant was analysed, namely, the role of mechanism in the modern world, its efficiency, advantages and disadvantages, and the impact of the plant's functioning on the environment in general. Experimental testing of this mobile installation was conducted, the purpose of which was to assess the indicators of the evaporation process. A statistical analysis of the data was also conducted, namely the ratio of solution volumes and vaporised liquid at a vacuum value of up to 0.7 bar – 1 and heating of the solution to 60°C. Chemical and physical research methods were no less effective and used for the comparative analysis of the indicators of this study. Laboratory study was conducted using an installation, all equipment of which was installed in the car body in separate blocks (Figure 1).

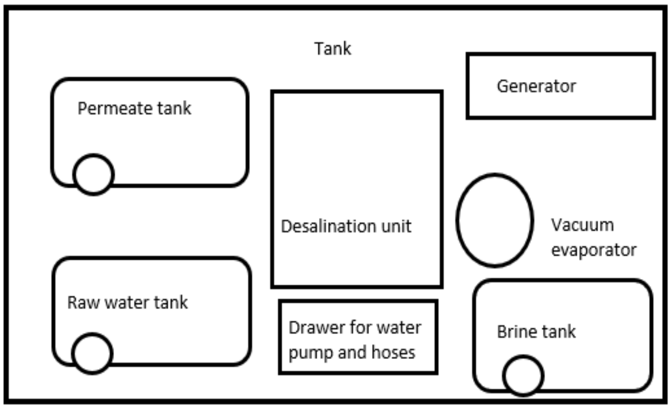



**Figure 1:** Placement of technological equipment on a mobile installation

In the rear part of the trailer, tanks are installed: exhaust water and permeate with supply pipes and drain pipes with valves. In the centre there is a reverse osmosis unit (factory version) with a high-pressure pump, pre-cleaning filters and two ESPA -4040 type devices. In the same zone is a vacuum evaporation unit (author's development, patent), which is currently in the stage of refinement and testing. LKS-250PW circulation pumps are installed on the exhaust water supply lines and in the recirculation circuit. A vacuum evaporation unit was installed to dispose of the washing solution, and a patent from the Republic of Kazakhstan was obtained for its design. The membranes were washed with an acidic or alkaline 10% solution of technical citric acid or sodium tripolyphosphate. The frequency of flushing depends on the type of water, the amount of mineralisation, and is conducted after 300-500 hours of operation. A brine tank is used to prepare the washing solution. The proposed technological scheme received a patent from the Republic of Kazakhstan No. 6827. Figure 2 shows a hydraulic diagram of the installation.

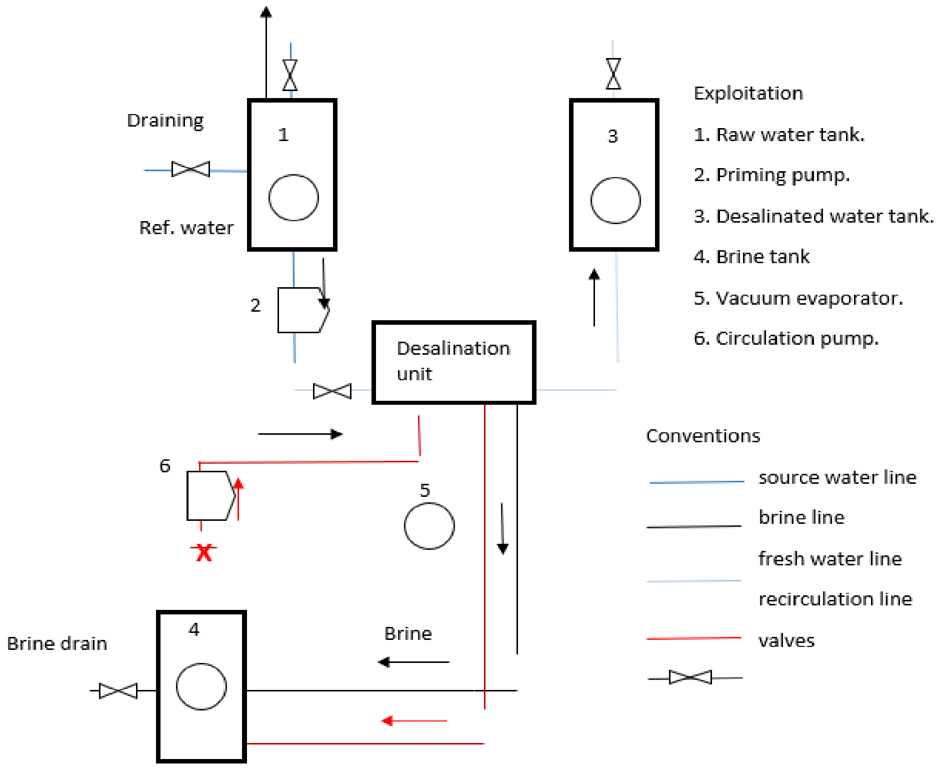



**Figure 2:** Technological scheme

Figure 2 shows how the source water is fed by a pump from the water source at the water pump point to the source water tank (1). After that, the source water is supplied from the tank by a boosting pump (2) to the filters of the desalination unit and the high-pressure pump. During desalination, the permeate is fed into the freshwater tank (3), and the brine is drained into the brine tank (4). After that, expenses along the paths are registered with rotameters. The resulting desalinated water is drained to the consumer, and the brine is poured onto the evaporation site or a vacuum evaporator (with small volumes of brine and its high concentration) (5). A circulation pump (6) is provided for membrane regeneration. In this case, an additional container for the washing solution is not provided, but a brine tank is used (4). After regeneration, the washing solution is fed into a vacuum evaporator, because it contains alkalis or technical citric acid. The discharge of the washing solution to the evaporation site of the brine (conditionally clean) is not desirable. Notably, the main goal is to conduct a laboratory study of the disposal of brine and regeneration solutions in the desalination of mineralised water at a mobile reverse osmosis plant.

## 3. Results

### 3.1 Preparation for Desalination of Mineralised Water on a Mobile Reverse Osmosis Plant

Today's demand for fresh water is a huge economical problem, so there are many different methods of desalination of mineral water, which are used in various installations, mechanisms, and stations to provide consumers with the necessary amount of water. It is necessary to pay attention to the fact that during the desalination process, there are various waste products that give negative attention to the environment. Brines, in turn, represent a special problem associated with their disposal, which makes the issue of brine disposal urgent and requiring attention (Garipov et al., 2020). Notably, an important aspect in providing clean fresh water is also the effective use of resources such as water, energy, and other resources used in the desalination process. Therefore, it is necessary to look for methods of desalination of water that are most effective in the use of resources and have the smallest negative effect on the environment (Backer et al., 2020).

This experimental study, which is described in this text, can be an important step towards solving problems related to the desalination of mineralisation waters at a mobile reverse osmosis plant, and can also help correct the issue of brine disposal and reduce the problem of freshwater shortage. This will be an important contribution to the mobility of desalination of mineralised water and will help solve the problem of using this type of plant. In turn, a successful solution to this problem can become the basis for the development of an ecologically clean and efficient process of desalination of mineralisation waters, which in turn will help to solve current environmental problems and the problem of freshwater availability (Novikova and Ratnikova, 2021).

The experiment described in this text is aimed at solving problems related to the desalination of mineralisation waters at a mobile reverse osmosis plant, namely the problem of brine disposal. The first task in conducting this experiment was to determine its importance and universality of using this mobile installation. Analysis of the situation showed that the cost of delivery by car carriers is 5 to 8 times more expensive than desalination on the spot, and the quality of water delivered is low and has a risk of secondary infection with bacteria. Therewith, the efficiency of using desalinated water using a mobile installation lies not only in the quality of water but also in the convenience of its use (Karimov and Baygazy kyzy, 2019; Jawecji and Kowalczyk, 2023).

The second task was to prepare all the necessary materials for conducting the experiment. Among such materials were: a vacuum evaporation unit, for its design received a patent of the Republic of Kazakhstan; an acidic or alkaline 10% solution of technical citric acid or sodium tripolyphosphate; a brine tank, for the technological scheme proposed above, which received a patent of the Republic of Kazakhstan No. 6827 (Figure 3).

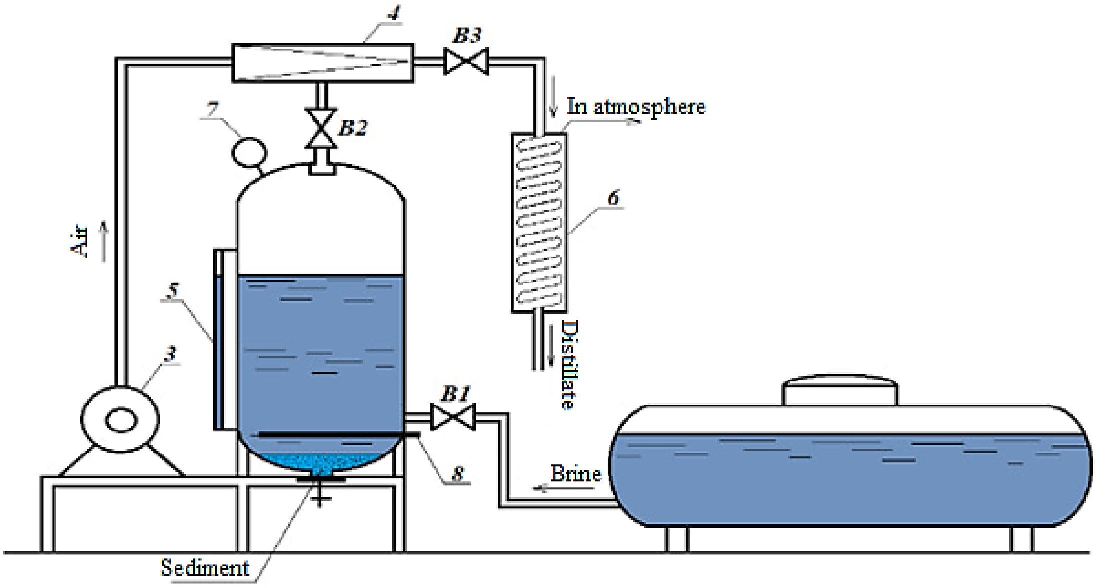
**Figure 3:** General type of vacuum evaporator unit

The description of the technological scheme allows for presenting in more detail the process of conducting the experiment. The brine tank is a container for storing and processing brines and regeneration solutions, which are formed during the desalination of mineralisation waters. Then the brines are sent to the vacuum evaporation unit, where water is separated from the salts. This process is based on the use of the difference in partial pressures of water in the gaseous and liquid states. Water evaporation occurs at a pressure below atmospheric, which allows getting clean water of high quality. The third and most important task was to conduct the experiment itself on a mobile reverse osmosis plant, which was improved to solve the problems of brine discharge, which negatively affect the environmental situation, describe the processes that took place, study the results, and draw conclusions.

Cite The Article: Timur Ustabayev, Yerkin Tazhgaliyev, Nurlan Balgabayev, Mirobit Mirdadayev, Gylnaz Telgarayeva (2024). Methods of Disposal of Brines and Regeneration Solutions in The Desalination of Mineralised Waters. *Water Conservation & Management, 8(2): 133-139.*

### 3.2 Process of Technical and Experimental Desalination of Water by the Vacuum Evaporator

Due to the fact that during the evaporation of mineralised waters of the sodium chloride and calcium chloride types, brine is drained to the evaporation site, during a water puncture, and the salt obtained after evaporation is consumed by animals, with high concentrations of other types of brine and a regenerative (washing) solution of reverse osmosis a vacuum evaporator is used for their disposal. This design of the vacuum evaporator did not require the installation of a vacuum pump but used an injection method, which is also known as a Venturi tube. During the operation of this mechanism, it was assumed to use exhaust gases from an autonomous electric generator to create a high-speed air flow. During the bench test, indicators were known that indicated an evident problem, namely the inability to obtain the necessary air flow, which will be sufficient to create the required vacuum of 0.6-0.8 bar. Thus, it was necessary to conduct additional research to eliminate this problem and optimise the operation of the vacuum evaporator. The operation diagram of the vacuum evaporator is shown in Figure 4.




1- Brine tank
2- Vacuum evaporator capacity
3- Compressor
4- Injector (Venturi tube)
5- Water tube
6- Capacitor
7- Vacuum gauge
8- TPH (thermal power heater)

**Figure 4:** Operation diagram of the vacuum evaporator

In the process of desalination of water or regeneration solution, namely technical citric acid or sodium tripolyphosphate, brine was poured into the brine tank (1), as a result of which the compressor was turned on (3). After that, valves B3 and B2 opened, resulting in a vacuum in the vacuum evaporator tank (2). As a result, after opening the B1 valve, the tank indicated in diagram number 2 was filled to the desired level. The fill level was monitored using a water-measuring tube (5). Due to the fact that the evaporator tank is full, valves B1, B2, and B3 are closed and the heating element (heat generator) is turned on to increase the liquid temperature to 50-60°C. Heating was monitored using an electronic thermometer from the condenser sensor (6). After the brine was heated to the required temperature, the evaporation process was started in the order indicated above. The vacuum value was monitored using a pressure gauge (7), in some cases it reached 0.6-0.7 bar. After that, the steam-air mixture was discharged into a condenser, where it was distilled after cooling. The condenser is made of a horizontal plastic pipe in a cylindrical (plastic) casing, which is supplied with air from the compressor by a wind flow in relation to the movement of the steam-air mixture and removed to the atmosphere.

Subsequently, after opening the B1 valve, the liquid was supplied to the vacuum evaporator, which occurred as it evaporated. Due to the completion of evaporation of the entire volume of brine, the evaporator turned off, and the sediment that appeared during the process described above was discharged through the hatch at the bottom of the tank (2). Thus, a technological scheme was adopted that allows the disposal of brines obtained during the desalination of water, and washing regeneration solutions to restore the selectivity of the membranes of reverse osmosis devices. This means that brines and solutions that were previously discarded as waste can now be processed and reused in the production process. It is important to note that membrane regeneration should preferably be conducted connected to stationary power grids. This allows for providing stable conditions for the regeneration process and reducing the possibility of unforeseen failures. Since the rate of brine evaporation depends on many factors, namely gas temperatures, vacuum depth, brine mineralisation, it will be determined during production tests of a mobile installation. This will allow for determining the most effective conditions for the installation operation and achieving maximum performance.

Ultimately, preliminary bench tests of the vacuum evaporator circuit and its connection to the brine tank showed the possibility of creating a vacuum up to 0.7 bar$^{-1}$. At this vacuum value and heating of the solution up to 60°C occurs in two processes: boiling and steaming. Table 1 shows the evaporation process indicators, namely the solution volume, temperature, vacuum value, liquid volume to be evaporated, electricity consumption, and evaporation time.

**Table 1:** Indicators of the evaporation process

| No. | Volume of solution, L | Temperature, °C | Vacuum value, bar$^{-1}$ |
|---|---|---|---|
| 1 | 50 | 60-80 | -0.7 |
| 2 | 40 | 60-80 | -0.7 |
| 3 | 30 | 60-80 | -0.7 |
| 4 | 20 | 60-80 | -0.7 |
| 5 | 10 | 60-80 | -0.7 |

From the Table 1, it can be seen that the volume of the solution varies depending on the initial concentration of the solution and the power of the equipment used, but the time remains unchanged, that is, fixed. As the solution volume increases, the volume of vaporised liquid also increases, which can be useful for increasing the productivity of the process. An important indicator is the use of electricity, which also depends on the power of the equipment used and the evaporation time. These indicators can be optimised to improve process efficiency and reduce operating costs. Thus, the results of bench tests allow evaluating the efficiency of the solution evaporation process using a vacuum evaporator and determine the optimal parameters for maximum productivity and minimum costs.

When considering the design of a vacuum evaporator unit, namely what components it consists of, what they are necessary for, and what functions they perform, it is possible to improve its performance and durability. The vacuum evaporator unit consists of several components, including a water-measuring glass, a vacuum pressure gauge, an electronic sensor for measuring the temperature of the solution, an ejector for creating a vacuum, a compressor and a condenser for cooling the steam mixture. Water-measuring glass is used to measure the volume of the solution, and a vacuum pressure gauge is used to measure the vacuum in the system. An electronic sensor measures the temperature of the solution, which must be determined for effective evaporation.

With a more detailed analysis of the technical processes that occur when using a mobile reverse osmosis unit, weak points can be identified and the operation of the installation can be optimised. The compressor is used to maintain pressure in the system while the condenser cools the steam mixture and allows the vapours to condense into distilled water. The vacuum evaporation unit is designed for cleaning and concentrating solutions of various chemical compounds, including salts, acids, alkalis, organic substances. When using a vacuum evaporator, the solution is evaporated at low pressure, which allows getting a concentrated product with minimal energy and raw materials costs (Doroshkevich et al., 2019). Water-measuring glass and a vacuum pressure gauge were necessary to monitor the water level and pressure in the system. An electronic sensor for measuring the temperature of the solution allowed monitoring changes in temperature and controlling the evaporation process. The ejector, which operates based on the law of energy conservation and allows creating a low pressure in the system, was used to create a vacuum in the system by ejecting a jet of steam from the capacitor.

Distilled water after the condenser was poured into the tank and was ready to be used for the preparation of a battery electrolyte or fed into a desalination water (permeate) tank. In addition, the sediment after evaporation of the washing solution or brine (insubstantial volumes) was discharged and stored for subsequent processing (chemical production) or burning in special furnaces. Regeneration of reverse osmosis membranes is preferably conducted connected to permanent power grids, which would substantially reduce the cost of the recycling process. The technical and economic performance of a vacuum evaporator is determined by many factors, such as efficiency, productivity, energy costs, raw materials, maintenance, and repair of equipment. Field tests of the mobile installation will allow evaluating the actual performance and efficiency of the vacuum evaporator in various conditions and determine the optimal parameters for economically profitable operation.

## 4. Discussion

The quality of studies to identify errors and problems related to the use and efficiency of brine for various mineral water desalination plants and reclamation solutions is one of the most pressing issues of our time, and these and some other problems require immediate solutions. For example, the discharge of household wastewater is determined by the need for water for household needs and accounts for an average of 85% of water consumption (Dolina and Reshetnyak, 2018).

All these mineral waters require careful treatment and disinfection. During the experiment described above, some difficulties with the implementation of theoretical tasks in practice were identified, such as using exhaust gases from an autonomous electric generator to create a high-speed air flow, energy costs when using this installation, maintenance, and repair of equipment. Considering the above problem, it may be necessary to review and refine the design of the vacuum evaporator to increase the efficiency of its operation and solve problems that arise during operation. However, in general, the use of a vacuum evaporator for the disposal of various types of brine is an important process for protecting the environment and economic efficiency in production. Vacuum evaporators, and the presented mobile installations, are effective tools for cleaning and disposing of brine, which can be used in various fields of industry. Due to the lack of water, desalination activities are expanding all over the world. Brine discharges during the desalination process pose a substantial threat to the environment. A large amount of water, energy, and minerals is lost in the form of brine in desalination plants. Due to the tightening of environmental standards and the need for more economical desalination processes, sustainable brine management is important for the use of these unused brine resources (Ogunbiyi et al., 2021; Koibakov et al., 2015).

According to the data provided in the study by the principle of electrodialysis (ED) desalination was first introduced by Megro and Sabat in 1890, and its industrial development began more than 50 years ago due to the development of exchange membranes (Al-Amshawee et al., 2020). This advantage provides environmental benefits since it does not require the use of fossil fuels or chemical detergents. Despite the fact that many reviews have been conducted to optimise the operation of electrodialysis desalination for various applications, ED technology still has limitations in terms of salt formation, membrane regrowth, and permeability selectivity. The similarity of the study with this one is largely due to the fact that they both provide an advantage in the ecological field of using methods of desalination of mineralised waters. Their main distinguishing feature is mobility, which is, was, and will be one of the main problems associated with the desalination process.

According to the latest study by the main efficiency of the method of desalination of mineral waters presented by the author lies in the effectiveness of the technology of combined ionisation of mineralised waters (Djavadova, 2018). Namely, among the examined range for mixtures of anionite $AN_{31}$ and cationite $CU_2$. Regeneration conditions were identified that exclude the loss of salt deposition in the filter load. In the field of mineralised waters with a content of 3-12 g/l, regression equations were obtained to determine the exchange capacity of the specified mixture of HCO ions, depending on the conditions of sorption and regeneration, and the loading rate of CU. The main advantage of this study is the method of regeneration of solutions, excluding the deposition of brines, which has a positive effect on the environment and solves one of the important problems.

In their paper, a report that during the ion exchange softening of water, excess sodium chloride is released into the aqueous medium during the regeneration cycle (Vassallo et al., 2021). It is necessary either to regenerate the brine or to reduce the amount of salt used during regeneration to reduce the amount of sodium chloride used and removed in the ion exchange process. Both options lead to a compromise associated with loss of coating production per cycle and increased hardness leakage. The experimentally confirmed model was used to compare the typical treatment of tap water in the Midwest states with and without direct repeated use of the processed brine, with different amounts of salt used and simultaneous softening treatment. Both approaches have reduced the use of salt and related discharges. Reducing the use of salt and discharge by reducing the rate of regeneration during salt use leads to an increase in the hardness leak and a decrease in the efficiency of cleaning; salt recirculation systems with one or two tanks can reduce the use of salt and discharge without increasing the hardness leak, although the efficiency of cleaning will be reduced easily.

Research conducted by made a substantial contribution to the methodology of ion desalination (Liu et al., 2021). According to them, ion exchange (IE) using synthetic resins is an economically effective technology for combating a wide range of pollutants in water treatment. However, the implementation of the IE process was difficult because the regeneration of resins produces highly concentrated brine (i.e., ion-exchange brine), the disposal of which is expensive and environmentally harmful (Ye Kyrychuk and Muzyka, 2016). Substantial research has been conducted to optimise resin performance and control brine to make the use of resins in water treatment more stable. This study critically evaluates the literature on operational strategies and brine management that can be used to reduce the negative impact of brine. The physico-chemical properties of the brine regenerated by resin were analysed to achieve this goal. They the operational strategies that facilitate brine management, including resin selection, contactor selection, operating mode, and regeneration strategy were critically evaluated. Besides, the researchers analysed brine management strategies, including re-use and processing of brine (untreated or purified). Finally, a new workflow for the design of water treatment plants using ion exchange is proposed, which combines operational strategies and brine management to identify areas where ion exchange technology can become more stable in water treatment.

At the moment, the ecological and economic components of various methods of desalination of mineral waters need to be considered. The similarity of this study with the one presented in this paper is mainly to improve the components mentioned above. A group researchers state that the treatment of industrial wastewater is a serious ecological problem (Micari et al., 2019). The study is devoted to the purification of waste brine formed as a result of the regeneration of ion-exchange resins used to soften water. For the first time in their study, a comprehensive technical and economic assessment of the cleaning chain and analysis of energy needs was conducted by modelling a specific implementation model. The purification chain consists of such elements of action as nanofiltration, two-stage crystallisation, and multi-stage distillation (Koibakov and Umirkhanov, 2013a). A valuable product is a brine after multi-stage distillation, which can be reused for regeneration. Therefore, the economy of the cleaning chain is evaluated based on the current cost of brine, which includes the costs and revenues of each division in the chain.

Thus, costs can be substantially reduced if the industrial site has waste heat. In general, the treatment chain is economically justified and allows reducing the impact of production on the environment due to the disposal of wastewater and waste heat (Lyubchyk et al., 2015). A study is dedicated to the examination of the stability of salt water treatment technologies (Mahmud et al., 2022). When desalination by reverse osmosis (RO), the technology should be aimed at achieving maximum recovery of fresh water on a global scale, along with the restoration of valuable compounds. In this study, an integrated process of conversion of NaCl into chemical substances using bipolar membrane electrodialysis was developed and described. The effectiveness of the membrane regeneration stage depends, in particular, on the concentration and purity of the source salt solution, which makes it necessary to use various stages of pre-treatment (Asgerov et al., 2022). The purpose of this study was to evaluate the possibility of removing calcium, magnesium, and sulphates from reverse osmosis brine to obtain a purified solution rich in NaCl.

The absence of fresh water is a serious problem in many parts of the world, according to a recent study by population growth and uncontrolled expansion of industrial and agricultural activities exacerbate the fresh water issue (Luo et al., 2022). Therefore, the search for new water sources to satisfy the expected demand growth of 100 million m3/day by 2015 has become one of the main tasks of research-development work. It is necessary to consider all the current problems of methods and installations for the desalination of mineral waters. Perform diagnostics of all methods and create optimal solutions to problems that have arisen with the disposal of brines.

## 5. Conclusions

In conclusion, the experimental study detailed in this text stands as a significant stride towards addressing the pressing challenges surrounding the desalination of mineralized waters using a mobile reverse osmosis plant. At its core, this study underscores the paramount importance of finding sustainable solutions to the desalination process, with a specific emphasis on mitigating the environmental impact of brine disposal and preserving our increasingly scarce freshwater resources.

One of the standout features of this research is the innovative vacuum evaporation unit, which has the potential to revolutionize the desalination process. While it has shown promise, further refinement is needed to consistently achieve the desired vacuum levels, a crucial factor in optimizing the efficiency and effectiveness of the desalination process. Moreover, the study provides a clear and comprehensive understanding of the functions of the various components within the vacuum evaporation unit. This insight is invaluable in ensuring that these components work in harmony to maintain efficiency and effectiveness, ultimately contributing to the success of the entire desalination process.

Additionally, the versatility of applications for the distilled water generated through this method cannot be understated. Whether utilized for battery electrolyte preparation or other purposes, this by-product represents an opportunity to optimize resource usage and reduce waste. Of course, economic considerations play a pivotal role in the practicality of implementing such technology. Factors like energy costs, raw materials, and maintenance must be thoroughly analysed to gauge the economic viability of the vacuum evaporator unit. Real-world field tests will be instrumental in providing insights into its feasibility under diverse conditions and scenarios.

Looking forward, this research opens up exciting possibilities for future developments in desalination technology. Future efforts should concentrate on refining and optimizing the vacuum evaporation process, evaluating its scalability to meet increasing demands, and enhancing its economic sustainability. In sum, this study's findings hold great promise for addressing critical environmental concerns and ensuring a more sustainable approach to desalination in the years to come. It represents a significant step towards securing our access to freshwater resources while minimizing the ecological footprint of desalination processes.

## Acknowledgements

This article was prepared as part of the Scientific and Technical Program "Technologies and technical means of irrigation when introducing new irrigated lands, reconstructing and modernizing existing irrigation systems" for 2021-2023 (BR10764920).

## References

Abu, S.B., Al-Amoudi, A.A., Farooque, M., Fellows, C.M., Ihm, S., Lee, S., Li, S., Voutchkov, N., 2022. Seawater desalination concentrate – A new frontier for sustainable mining of valuable minerals. Clean Water, 5, Pp. 9. https://doi.org/10.1038/s41545-022-00153-6

Ahmad, M., Garudachari, B., Al-Wazzan, Y., Jumar, R., Thomas, J.P., 2019. Mineral extraction from seawater reverse osmosis brine of Gulf seawater. Desalination and Water Treatment, 144, Pp. 45-56. https://doi.org/10.5004/dwt.2019.23679

Al-Amshawee, S., Bin Mohd Yunus, M.Y., Aziz Mohd Azoddein, A., Hassell, D.G., Dakhil, I.H., Hasan, H.A., 2020. Electrodialysis desalination for water and wastewater: A review. Chemical Engineering Journal, 380, Pp. 122231. https://doi.org/10.1016/j.cej.2019.122231

Asgerov, E.B., Beskrovnyy, A.I., Doroshkevich, N.V., Mita, C., Mardare, D.M., Chicea, D., Lazar, M.D., Tatarinova, A.A., Lyubchyk, S.I., Lyubchyk, A.I., Doroshkevich, A.S., 2022. Reversible Martensitic Phase Transition in Yttrium-Stabilized ZrO2 Nanopowders by Adsorption of Water. Nanomaterials, 12 (3), Pp. 435. https://doi.org/10.3390/nano12030435

Backer, S.N., Bouaziz, I., Kallayi, N., Thomas, R.T., Preethikumar, G., Takriff, M.S., Laoui, T., Atieh, M.A., 2020. Review: Brine solution: Current status, future management and technology development. Sustainability, 14 (11), Pp. 6752. https://doi.org/10.3390/su14116752

Boncz, M.A., van Linden, N., Haidari, A., Wang, Y., Spanjers, H., 2022. Physicochemical model for simulating the chemical processes during the crystallization of minerals from spent ion exchange regenerant. Water Resources and Industry, 28, Pp. 100185. https://doi.org/10.1016/j.wri.2022.100185

Burdo, O.G., Terziev, S.G., Mordynsky, V.P., Sirotyuk, I.V., Fateeva, Ya. A., Molchanov, M.Yu., 2022. Development of a low-temperature installation of block type for sea water demineralization. Problems of Regional Energy, 2 (54), Pp. 13-24. https://doi.org/10.52254/1857-0070.2022.2-54.02

Caltran, I., Rietveld, L.C., Shorney-Darby, H.L., Heijman, S.G.J., 2020. Separating NOM from salts in ion exchange brine with ceramic nanofiltration. Water Research, 179, Pp. 115894. https://doi.org/10.1016/j.watres.2020.115894

Djavadova, H.A., 2018. Investigation of NaCl ionization processes of mineralized waters on a mixture of $CU_2$ and $AN_{31}$ ionites. Integration of Sciences, 4 (19), Pp. 423-425. (In Russian)

Dolina, L.F., Reshetnyak, T.P., 2018. Wastewater treatment of industrial enterprises with natural metals. Bulletin of the Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, 2 (74), Pp. 7-17. https://doi.org/10.15802/stp2018/129531 (In Russian)

Doroshkevich, A.S., Asgerov, E.B., Shylo, A.V., Lyubchyk, A.I., Logunov, A.I., Glazunova, V.A., Islamov, A.Kh., Turchenko, V.A., Almasan, V., Lazar, D., Balasoiu, M., Doroshkevich, V.S., Madadzada, A.I., Kholmurodov, Kh.T., Bodnarchuk, V.I., Oksengendler, B.L., 2019. Direct conversion of the water adsorption energy to electricity on the surface of zirconia nanoparticles. Applied Nanoscience (Switzerland), 9 (8), Pp. 1603-1609. https://doi.org/10.1007/s13204-019-00979-6

Ergozhin, E.E., Chalov, T.K., Kovrigina, T.V., Melnikov, Ye.A., Khakimbolatova, K.Kh., 2021. Improving the quality of recycled water by pulsed electromagnetic treatment. Bulletin of the Oil and Gas Industry of Kazakhstan, 3 (2), Pp. 76-83. https://doi.org/10.54859/kjogi89500

Garipov, I.T., Yuldashev, A.B., Gapurova, O.U., Abdukhakimov, M.K., Khaydarov, R.R., Sadikov, I.I., 2020. New import-substituting antiscalant for membrane desalination system. Science and Innovative Development, 3 (6), Pp. 103-114.

Jawecji, B., Kowalczyk, T., 2023. The assessment of the quality and quantity of water retained in closed granite quarries with the view to mitigate the effects of droughts in agriculture. Water, 15 (4), Pp. 782. https://doi.org/10.3390/w15040782

Karimov, T.Kh., Baygazy kyzy, N., 2019. Technology of collector-drainage water desalination in the conditions of the Kyrgyz Republic. Eurasian Union of Scientists, 3 (60), Pp. 11-14. https://doi.org/10.54647/dee47296

Koibakov, S., Meldebekova, G., Maliktaiuly, M. 2015. Warning hydraulic facilities from the ground in drifts deflation soils. In: 15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, ARC 2015: New Innovations and Sustainability (pp. 382–385). Fukuoka, Kyushu: Asian Regional Conference on Soil Mechanics and Geotechnical Engineering. https://doi.org/10.3208/jgssp.KAZ-19

Koibakov, S.M., Umirkhanov, M.G. 2013a. Icebreaker unit. World Applied Sciences Journal, 25 (8), Pp. 1251–1254. https://doi.org/10.5829/idosi.wasj.2013.25.08.13423

Koibakov, S.M., Umirkhanov, M.G., 2013b. Model research of ice jams. World Applied Sciences Journal, 25 (8), Pp. 1158–1160. https://doi.org/10.5829/idosi.wasj.2013.25.08.13382

Kyrychuk, G.Y., 2010. Peculiarities of cabohydrate metabolism in Planorbarius purpura under the effect of cadmium and zinc ions. Hydrobiological Journal, 46 (2), Pp. 64-74.

Kyrychuk, G.Ye., Muzyka, L.V., 2017. Peculiarities of carotenoid pigments' distribution in organism of the freshwater mollusks. Hydrobiological Journal, 53 (5), Pp. 85-93.

Liu, Z., Haddad, M., Sauvé, S., Barbeau, B., 2021. Alleviating the burden of ion exchange brine in water treatment: From operational strategies to brine management. Water Research, 205, Pp. 117728. https://doi.org/10.1016/j.watres.2021.117728

Luo, Y., Liu, Y., Shen, J., van der Bruggen, B., 2022. Application of bipolar membrane electrodialysis in environmental protection and resource recovery: A review. Membranes (Basel), 12 (9), Pp. 829. https://doi.org/10.3390%2Fmembranes12090829

Lyubchyk, A., Lygina, O., Lyubchyk, S., Fonseca, I., Tulepov, M., Mansurov, Z., Lyubchik, S. 2015. Activated carbons from co-mingled liquid and solid organic wastes. Eurasian Chemico-Technological Journal, 17, Pp. 47-65. https://doi.org/10.18321/ectj339

Mahmud, N., Fraga Alvarez, D.V., Ibrahim, M.H., El-Naas, M.H., Esoisito, D.V., 2022. Magnesium recovery from desalination reject brine as pretreatment for membraneless electrolysis. Desalination, 525, Pp. 115489. https://doi.org/10.1016/j.desal.2021.115489

Martynovskii, A.A., Samura, B.A., Omelyanchik, V.N., Panasenko, A.I., Omelyanchik, L.A., Panasenko, T.V. 1990. Synthesis, physicochemical properties, and biological activity of (acridinyl-9-thio) acetic acid hydrazides. Pharmaceutical Chemistry Journal, 24 (7), Pp. 470–472. https://doi.org/10.1007/BF00764993

Micari, M., Cipollina, A., Tamburini, A., Moser, M., Bertsch, V., Micale, G., 2019. Combined membrane and thermal desalination processes for the treatment of ion exchange resins spent brine. Applied Energy, 254, Pp. 113699. https://doi.org/10.1016/j.apenergy.2019.113699

Novikova, O.K., Ratnikova, A.M., 2021. Water supply industrial enterprises, BelNUT. (In Belarusian)

Ogunbiyi, O., Saththasivam, J., Al-Masri, D., Manawi, Y., Lawler, J., Zhang, X., Liu, Zh., 2021. Sustainable brine management from the perspectives of water, energy and mineral recovery: A comprehensive review. Desalination, 513, Pp. 115055. https://doi.org/10.1016/j.desal.2021.115055

Subhoni, M., Kholmurodov, K., Doroshkevich, A., Asgerov, E., Yamamoto, T., Lyubchyk, A., Almasan, V., Madadzada, A., 2018. Density functional theory calculations of the water interactions with ZrO2 nanoparticles Y2O3 doped. Journal of Physics: Conference Series, 994 (1), Pp. 012013.

Vassallo, F., La Corte, D., Cancilla, N., Tamburini, A., Bevacqua, M., Cipollina, A., Micale, G., 2021. A pilot-plant for the selective recovery of magnesium and calcium from waste brines. Desalination, 517, Pp. 115231. https://doi.org/10.1016/j.desal.2021.115231

Ye Kyrychuk, G., Muzyka, L.V., 2016. Peculiarities of the Distribution of β-carotene in the Organism of Lymnaea stagnalis under the Influence of the Ions of Heavy Metals. Hydrobiological Journal, 52 (5), Pp. 63-72.