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Assessing Water Quality for Human Consumption in the Shardara Reservoir Using Nanofiltration Methods

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ABSTRACT

Reservoir water is an important source of drinking water in an increasingly scarce world. An adequate integrated assessment of water quality from the point of view of its suitability for human use therefore remains a pressing issue. The purpose of this work is to assess water quality using nano-filtration methods, using the example of the Shardara reservoir, their suitability for human consumption. The main advantage of nano-filtration methods is the production of better-quality water without harmful bacteriological and microbial contamination. In 2022 and 2023, the territory of Shardara (Turkestan Oblast, Kazakhstan) conducted a detailed complex analysis of water quality, 6,000 samples, 3,000 each in 2022 and 2023. The following methods were used: measurement of potential salinity, Determination of the water permeability index, sodium, magnesium adsorption coefficients, and microelement content, cation and anionic composition. The results showed that the main pollutants of the Shardara reservoir in the studied region were sulphates, nitrites, copper and magnesium. Sulphate content 548 mg/l (5.5 MPC), nitrite 0.028 mg/l (1.4 MPC), copper 0.003 mg/l (3.0 MPC) and magnesium 71.5 mg/l (1.8 MPC). The water pollution index was 1.97. The data obtained were compared with the register of cardiovascular morbidity and oncology cases, and a positive correlation (0.75) was obtained between the location of the reservoir and the registration of diseases. A comprehensive analysis of the indicators of the complex composition of the water and the disease (oncology, cardiovascular system, digestive organs) in the population is proposed.

1. INTRODUCTION

One of the goals of sustainable development is to ensure the availability and rational use of water resources and sanitation for all. Important indicators for this goal of sustainable are the percentages of the population that uses safely managed drinking water, and has access to safely managed sanitation, improve water quality, increase water-use efficiency and ensure freshwater supplies. Central Asia has huge freshwater resources, however, they are unevenly distributed throughout country, as a result of which many areas of Kazakhstan and Central Asia lack water suitable for water supply to the population, irrigation and irrigation of agricultural land [1-3]. While membrane treatment offers significant advantages over traditional methods, such as higher efficiency in removing contaminants and reducing energy consumption, it also has potential limitations, including high operational costs and membrane fouling, which need to be carefully managed to ensure long-term sustainability.

The Shardara Reservoir holds significant importance as a vital water source for agriculture and local communities, but it faces severe challenges due to increasing water pollution. Employing nanofiltration techniques is essential for improving water quality, as they offer an effective solution to remove contaminants and ensure the sustainable use of this critical resource.

The intensification of agriculture implies the increasing use of various insecticides and herbicides that enter surface waters and make them unsuitable not only for drinking, but also for irrigation of agricultural crops. In the conditions of industrial areas, water pollution with heavy metals prevails, in megacities, household waste plays an important role among the factors of deterioration in the quality of drinking water [3].

The human right to use high-quality drinking water was recognized in 2010 at the UN General Assembly. Every second person from the entire population of the planet uses water from a water pipe [4].

The health of the population largely depends on the quality of drinking water, since water is the main medium and reagent of vital metabolic processes in the human body – respiration, etc. In addition, water is the main component of the human body: from 70 to 85% of the weight. Electrolytic dissociation reactions occur in the aqueous medium, and colloid solutions are dispersed here. In case of deviations of water quality from the generally accepted standards of norms, the development of endemic diseases among the population is possible [5]. In the case of a lack of fluoride, the incidence of caries among the population can be up to 70% of all cases of dental treatment, if fluoride is present in excess, on the contrary, cases of fluorosis are noted. The hardness of water in case of exceeding the permissible values may be the main factor causing massive cases of kidney stones among the population. In the case of a reduced concentration of iodine, cases of hypothyroidism are noted. An important role is played by the presence of pathogenic microorganisms, as well as parasites that can cause various diseases [6].

Recently, cases of man-made disasters have become more frequent, when wastewater and industrial water emissions occur. Further, these waters penetrate into aquifers underground [7].

For the Republic of Kazakhstan, as in many other countries of the world, there is an increasing shortage of fresh water volumes. According to the ecologist, measures are being taken by the state, and considerable. Of particular relevance are studies devoted to the consideration of this issue within individual territories, model regions. This is due to the fact that it is quite difficult to make a forecast for a large territory based on the prevailing trends in the quality of drinking water, since the situation may be diametrically opposite in different regions. At the same time, the results of data analysis on the state of groundwater in the model region can be used for territories with similar geological, climatic and hydrological characteristics.

The city of Shardara (Turkestan region, Republic of Kazakhstan is proposed as a model region in this work. About 30 thousand inhabitants live in Shardara. The length of the Shardara reservoir is 80 km, the width is 25 kilometers. The reservoir is located in the south of Kazakhstan, on the border with Uzbekistan. Due to the southern position, it is non-freezing. Area - 783 km^2, total volume - 5.7 km^3, useful - 4.2 km^3 [8]. In 2008, it was reported that the critical maximum is 5.5 km^3 [4]. In low-water years, it can be triggered below the "dead volume", but when the volume decreases to 0.5 km^3, "dirty sludge" remains [5]. Water consumption: average annual - 626 m^3/s; summer minimum - 56.3 m^3/s; winter minimum - 137 m^3/s; through all 4 turbines at design head - 780 m^3/s. Flowing watercourses: Syrdarya, the Kyzylkum Canal, the channel to the Arnasai lakes, the supply channel to the Dostyk canal [9].

Thus, a large reservoir is concentrated on the territory of the model region (Shardara), which is combined with a high level of pollution, mainly due to motor transport and sedimentation, as well as effluents from the eastern part of the city are diverted into the Syrdarya River channel without purification.

The authors suggest determining the water quality class of the Shardara reservoir depending on the value of the water pollution index, as well as the purification of drinking water when using the membrane method.

The purpose of this work is to conduct a comparative analysis of the state of the water basin of the Shardara reservoir and their suitability for use by the population.

The objectives of this work are study of the effect of sedimentation and pollution on the effectiveness of membrane water treatment; compare the number of cases of diseases of the digestive system and the level of water pollution in samples taken from wells of various locations.

2. MATERIALS AND METHODS

2.1 Fabrication and characterization of membranes

For desalination of underground waters was used a membrane made as aromatic polyamide MGA-90.

Technological and physico-chemical characteristics of semi-permeable membranes are described in Tables 1 and 2.

Table 1. Technological characteristics of semi-permeable membranes

Membrane Brand	Selectivity for NaCl, 5 g/dm^3, %	Permeability at p = 5 MPa, $dm^3/(m^2$ day)
MGA-90	90	350

Mass transfer at the surface of an ultrafiltration membrane is usually considered from the standpoint of the film theory, according to which laminar boundary layers appear at the phase interface, within which concentration gradients exist. The main resistance to mass transfer is concentrated in these layers. During the ultrafiltration process, solvent and low molecular weight solutes predominantly pass through the membrane. An increase in the concentration of retained substances in the boundary layer near the surface5X3membrane properties is known as concentration polarization.

The selection of membrane materials is critical for optimizing nanofiltration performance, as it influences permeability, selectivity, and resistance to fouling. Apparatus design should ensure efficient flow dynamics, minimizing concentration polarization by reducing the buildup of retained substances near the membrane surface. Additionally, operational parameters such as pressure, flow rate, and temperature must be optimized to enhance mass transfer and overall filtration efficiency while controlling the adverse effects of concentration polarization.

Tables 2-4 present the main characteristics of membrane desalination, energy consumption, overall dimensions of the device, requirements for the quality of water supplied to the reverse osmosis plant.

Table 2. Main characteristics of membrane water purification

Productivity, m^3/hour	Working Pressure, MPa	Filtrate-Concentrate Ratio in %
50	3	80/20

Table 3. Main characteristics of energy consumption

Power Supply	Consumption Power, kWt	Pump Power Maprotec, Grundfos, kW
380V/50Hz	3.0	20.0

Table 4. Main overall dimensions of the device

Diameter, m	Height, m	Membrane Type	Porosity, %	Pore Diameter, μm
0.4	0.6	Osmonics	80	0.001

2.2 Filtration experiments

In order to obtain optimal quality of drinking water with optimal salinity and minimum content of undesirable contaminants, was developed a membrane apparatus for cleaning liquids [10-12].

The essence of the invention membrane apparatus is explained in Figures 1 and 2.

The membrane apparatus contains a cylindrical housing (1), membrane modules (9) are installed, consisting of a cylindrical frame (2) with drainage holes (3) for the passage of the cleaned liquid, where semi-permeable membranes (4) are located from the outer surface, the cylindrical frames has a nozzle (5) for the output. The housing (1) is equipped with a nozzle (6) for the input of the liquid to be cleaned, located tangentially to the forming body, thereby creating turbulence of the liquid flow, and a coarse filter (FGO) (7).

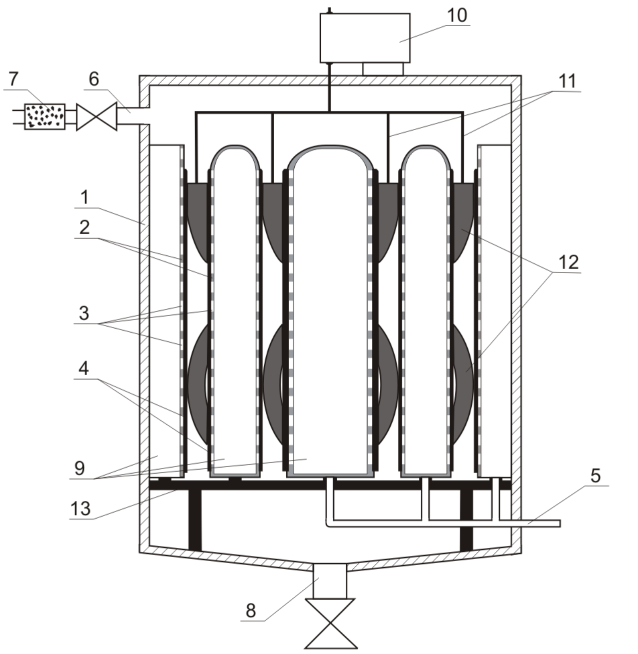


Figure 1. Membrane apparatus for cleaning liquids (side view)

1- cylindrical body, 2 - cylindrical frame, 3 - drainage holes, 4 - semipermeable membranes, 5 - outlet for the output of purified liquid, 6 - outlet for the input of purified liquid, 7 - coarse filter (FGO), 8 - outlet for the output of untreated liquid, 9 - membrane modules, 10 – electric motor, 11 - metal drive, 12 - elastic elements.

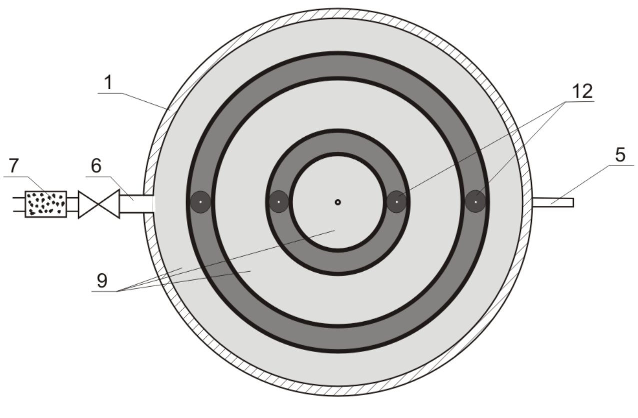


Figure 2. Top view

The membrane unit works with the following principle: water for desalination is filtered through a filter (9) with large holes, passing through a pipe (8) located tangentially in the membrane housing. Salt water is purified from impurities and salts by passing through semi-permeable membranes, and through special drainage holes (3), penetrating inside the membrane module, special desalinated water is discharged through the outlet pipe (6). When the membrane unit is operated in filtration mode, the pipe (10) for the discharge of uncleaned liquid is closed. When the magnitude of the pressure difference reaches the given one, the elastic roller element (12) is automatically activated by means of an electric motor (13). When the elastic roller-shaped element (12) is activated, it comes into contact with the surface of the membrane (4) and removes contaminants with a tangential water jet by washing, resulting in the membrane (4) being cleaned and washed, and the unrefined liquid is discharged through 10 pipes. In this way, the membrane (4) cleaning i.e. regeneration frequency, prevents its wear. The elastic element is made of porous elastic material, which does not damage the surface of the membrane and cleans mechanically. After the membrane unit for water desalination has been operating for up to 2.5-3 years, the membranes inside it are replaced with new ones [13].

In some situation, filtration methods energy consumption in the process is relatively low: the design of the device is simple and compact, does not require a qualified specialist to work on the device, work equipment can be easily automated; Since the filter is very clean, it can be connected to the water supply system. Thus, the use of an elastic element reduces the wear of the membrane and increases the efficiency of cleaning the surface and pores of the membrane [8]. The parameters of devices that can be used in the creation of new and modernization of existing equipment for deep water purification.

2.3 Characterization of the water sample

The permeate conductivity was measured with a MeterLab (CDM210). The measurements of the permeate mass and conductivity were automatically registered via a MATLAB 9.7 (MathWorks, Natick, MA, USA). Another important issue in the design of membrane installations is the accuracy and reliability of the method of measuring the salinity of the water flow. For continuous monitoring of the quality of the water flow, a conductometric method based on the measurement of its conductivity is used. Conductivity is a quantitative characteristic of dissolved components and can be determined by direct measurement in the flow of a water stream. The standard unit of conductivity in water treatment is micro-Siemens (mS or mmho). The conductivity of natural waters can range from 20 mS for meltwater and up to 70,000 mS for seawater. The concentration of relevant cations was measured by inductively coupled plasma spectroscopy (ICP) (PerkinElmer® Optima 8000 Optical Emission Spectrometer, Waltham, MA, USA) after calibration with standards from PlasmaCAL Q.C. No 4 (SCP Science, Clark, QC, Canada) [13-16].

3. RESULTS OF THE RESEARCH

In accordance with sanitary rules and regulations SanPiN 2.1.4.1074-01 "Drinking water, hygienic requirements for the quality of water of centralised drinking water supply systems, quality control" from 26 September 2001 N 24, the maximum permissible concentrations of the content of the main substances in the water of the Shardara reservoir were determined (Table 5). The table shows that the main pollutants of the Shardara reservoir exceed MAC norms several times over [17, 18].

For the Shardara reservoir the parameters of ecological condition are defined and in Tables 6 and 7 the identified zones of ecological emergency and ecological disaster are presented taking into account changes in the natural environment of the

Shardara reservoir by chemical and biological indicators.

The main task of both sanitary-hygienic and ecological standardisation of the Shardara reservoir is to assess the quality class of the reservoir according to the whole set of informative indicators. The importance of this problem is especially manifested under conditions of sharply increased multicomponent environmental pollution, when the main harmful factor is not the excessive concentration of traditional pollutants, but a complex "bouquet" of synthesised in recent decades household products - detergents, additives, etc.

Table 5. Maximum permissible concentrations (mg/l) of the content of main substances in water of the Shardara reservoir

Chemicals and Water Quality Indicators	WHO	EU	Russia		Shardara Reservoir
			Source	Normative	
BODpoln			VNIRO	3	17
Hydrogen index pH		6.5–8.5	SanPiN VNIRO	6.5 – 9 6.5 – 8.5	7
Total iron	0.3	0.2	SanPiN VNIRO	0.3 0.1	0.5
Total rigidity		1.2	SanPiN	7	16
Mineralisation total	1000	1500	SanPiN VNIRO	1000 1000	1060
Nitrates	50	50	SanPiN VNIRO	45 40	10.34
Nitrites	3	0.5	SanPiN VNIRO	3 0.08	0.08
Permanganate oxidisation		5	SanPiN	5	1.,5
Sulphates	250	250	SanPiN VNIRO	500 100	564
Fluorides	1.5	1.5	SanPiN VNIRO	1.5 0.05	0.75

Table 6. Sanitary and hygienic assessment of the danger of contamination of drinking water and sources of drinking water supply with chemical substances of the Shardara reservoir

No.	Indicators	Parameters	
		Before cleaning	After cleaning
		Environmental emergency	Relatively satisfactory situation
1	Content of toxic substances of the third and fourth hazard classes (in fractions of MPC)	10-15	Within hygienic standards (MAC)
2	pH	5.6	7
3	BOD full, mg/litre	12	0.9
4	COD, mg/litre	60-80	-"-
5	Dissolved oxygen, mg/l	1-2	> 4
6	Odour and flavour, points	3-4	no more than 1 - 2

Table 7. Assessment of the degree of chemical pollution of the Shardara reservoir

No.	Indicators	Parameters	
		Before cleaning	After cleaning
		Environmental emergency	Relatively satisfactory situation
1	Odour, flavour in points	4	0
2	Medium reaction, pH	7	7
3	Chemical oxygen demand COD (anthropogenic component to background), mg/l	15	20
4	Dissolved oxygen, % saturation	30	80
5	Nitrites (NO_2), fractions of MAC	3.1	0.5
6	Nitrates (NO_3), fractions of MAC	0.1	0.085
7	Sulphates (SO_4), fractions of MAC	5.6	0.9
8	Mineralisation, (excess level)	1.06	0.05

Further, the water quality of Shardara reservoir was assessed by hydrochemical water pollution index (WPI) and the results are presented in Table 8.

Table 8. Water quality class depending on water pollution index value

Waters	WPI Values	Water Quality Classes
Contaminated	3.5	IV

For the combined assessment of water quality of the Shardara reservoir, hydrochemical and hydrobiological indicators were used, i.e. assessment of the state and rules of taxation of fishery water bodies according to GOST 17.1.2.04-77 (Table 9).

It is the only document that defines a system of detailed assessment of water bodies according to the following indicators at the standard level:

- water and bottom sediment quality;

- hydrological regime;
- flora and fauna, with identification of groups of commercial organisms.

Water quality in accordance with GOST is characterised by the following indicators:

- salinity, hardness and hydrogen index (pH);
- tropho-saprobability;
- content of harmful substances.

The document regulates the classification by ion-salt composition (halobicity zones), hardness and hydrogen index in sufficient detail.

Table 9. Classification of the Shardara reservoir according to GOST 17.1.2.04-77

Name of Indicators	Clean Water (After Treatment)	Dirty Water (Before Treatment)
	Saprobic classes	
	Xenosaprobia (xs)	Hypersalinity (HS)
Tropho-saprobic indicators		
Dissolved oxygen, % saturation	80	30
Water transparency along Secchi disc, m, not less than	3.0	Less than 0.1
BOD5, mg/litre	0.4	10
BOD20, mg/litre	1.0	11
Permanganate oxidisation according to Kubel, mg/litre	5	82
Nitrates, mg/litre	10.34	8.5
Nitrites, mg/litre	0.08	0.01
Bacteriological indicators		
Total microbial count, million cells/ml	0.1	11
Index: (Total count / saprophytes)	More than 103	Less than 102

The main problems of filtration technology of drinking water production can be considered: 1) assessment of selective properties and membrane selection; 2) study of sedimentation and selection of methods of sediment control. In this connection, we have carried out the following studies: study of sedimentation, and criteria for the quality of water supplied to membrane plants; influence of sedimentation and prediction of water quality during the operation of the plant; methods of sedimentation control.

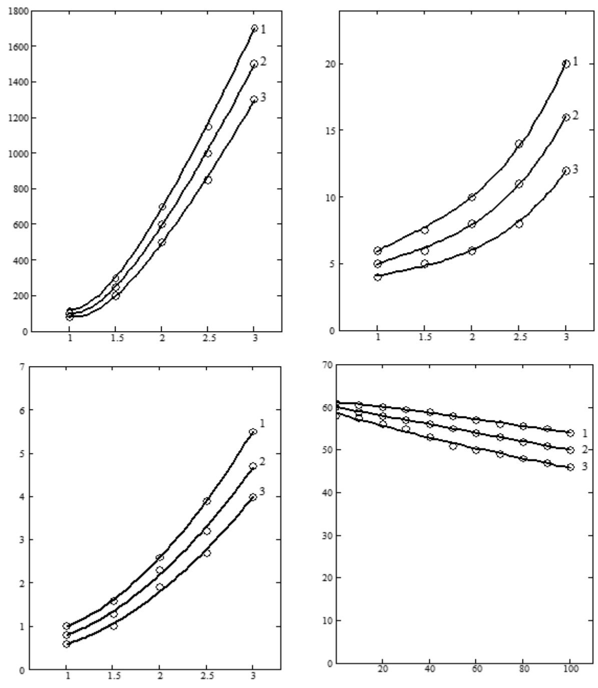
Various types of precipitates, especially crystalline precipitates of poorly soluble substances, have been considered in solving the problem of precipitation. In most cases of low-pressure reverse osmosis, calcium carbonate is the main type of precipitate. In some cases, precipitation of silicates and calcium sulphate occurs. Figure 3 shows the growth of calcium carbonate sludge directly in the membrane apparatus.

The figure shows that crystalline precipitates are formed in membrane apparatuses due to design features. Increasing the concentration ratio and pressure leads to an increase in sludge formation. We further propose a methodology for predicting the decrease in performance and selectivity, as well as the rate of $CaCO_3$ precipitate accumulation. The prevention of precipitation formation comes in combination with membrane regeneration and flushes that remove precipitation from the membrane surface. Depending on the amount of water in the filtrate tank, the filtrate yield (ratio between filtrate and concentrate flow rate) or the volume concentration ratio is set. The higher the filtrate yield value, the higher the value of salt concentration in the filtrate. This method simulates the operation of the filtration plant and allows to determine the parameters of treated water depending on the set filtrate yield value.

Figure 4 shows the dependence of sedimentation rate on the concentration ratio. The figure shows that the rate of sedimentation is higher the higher the value of membrane selectivity. Experiments were carried out with NaCl solutions added to tap water (Figure 3). Here, the increase in total salt content is due to the increase in NaCl concentration.

Figure 5 shows the dependence of Ca concentration on the multiplicity of concentrating the initial water, where the increase in salt content is due to an increase in the concentration of SO_4. Figure 6 shows the dependence of productivity on the duration of operation in the developed membrane unit. The graph shows that the use of elastic elements for regeneration allows to significantly increase the average specific productivity of the membrane in the filtration mode and extend the filter cycle until the chemical regeneration from one month to two months and more.

In our proposed membrane device, there are pores in the membrane that freely pass water molecules and do not pass hydrated ions of dissolved salts due to their size. It is assumed that water and part of salts penetrate through the membrane by two parallel processes: diffusion and permeation through the pores under the action of applied pressure



Source water concentration ratio

Figure 3. Dependence of Ca concentration on concentration ratio with Na_2SO_4 solution

Figure 4 shows the dependence of filtrate yield on the filtrate velocity, i.e. the capacity of the plant for filtrate of desalinated mineralised water. At a velocity of 2 m/s the productivity of 50 m^3/hour of desalinated water is registered.

As initial (desalinated) water at Shardara reservoir water with total salt content - 1060 mg/l and total hardness - 16 mg-eq/l is used (Table 10). According to its salt composition this water belongs to brackish water according to I.E. Apeltsin and V.A. Klyachko classification or slightly brackish according to I.L. Mongait classification. According to the number of E. coli bacteria in 1 litre of water, as it can be seen from the results of sanitary and bacteriological analysis, this indicator exceeds the norm for drinking water by 13 times, and according to the number of bacterial colonies in 1 ml of water by 2.4 times (Table 11).

Phosphates in water are not dangerous for the membrane apparatus; on the contrary, a dose of up to 20 mg RO-34/l reduces sedimentation on membranes. It is also known that the presence of sodium hexametaphosphate (HMFN) in water inhibits the deposition of gypsum $CaSO_4$-$2H_2O$ on the membrane surface. The presence of silicates in water can adversely affect the operation of the membrane apparatus, since the influence of not only iron but also aluminium hydroxides on the formation of silicate deposits is known. Petroleum products present in water negatively affect the membrane desalination process. At their concentration above 10 mg/l during 50 hours the membrane performance decreases 1.5 times, and salt content decreases from 91-94% to 55-60% [19, 20].

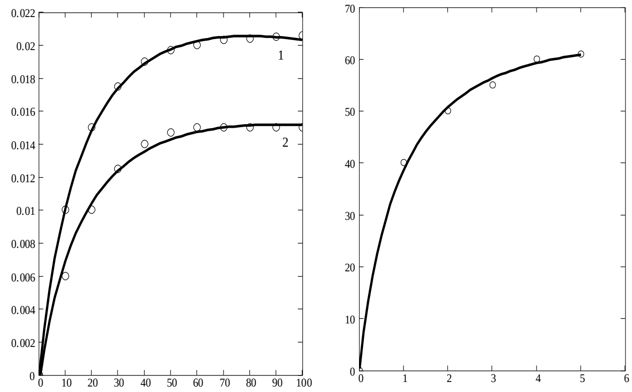


Figure 4. Petroleum products membrane desalination process

Table 10. As initial (desalinated) water at Shardara reservoir water with total salt content

No.	Name of Indicators, Unit Well	Shardara Reservoir		Drinking Water, Norms (CIS Standards)
		Before cleaning	After cleaning	
1	Hydrogen index (pH)	7	7	6.0-9.0
2	Dry residue (total salt content), mg/l	1060,0	250	1000,0
3	Sulphates (SO_4^{2-}), mg/l	564,0	90	500,0
		16.8	1.7	7.0
	Total hardness $Zh_{ob}(Ca^{2}++Mg^{2}+)$, mg-eq/l	5.2		
4	Calcium (Ca^{2+}), mg-eq/L	11.6		
	Magnesium (Mg^{2+}), mg-eq/L	4.25	0.1	
		0	0	
5	Total iron Fe_{ob} (Fe^{2+}+Fe^{3+}), mg/l	0.5	0.1	0.3
6	Nitrates ($NO\text{-}_3$), mg/l	10.34	8.5	45.0
7	Nitrites ($NO\text{-}_2$), mg/l	0.08	0.01	3.0

Table 11. Sanitary and bacteriological composition of the Shardara reservoir

No.	Name Indicators	Unit of Measurement	Drinking Water (CIS Standards)	Content	
				Before purification	After purification
1	COU (chemical oxygen uptake)	mg O_2/l	not > 15.0	16.0	0.1
2	BODpoln (biochemical oxygen demand)	mg/l	not > 3.0	4.5	0.9
3	Coli-index	Number of Escherichia coli bacteria (E. coli) in 1 litre of water	not > 3.0	39.0	1
4	Total microbial number, t 37℃	Number of bacterial colonies in 1 ml of water	not > 100.0	240.0	<50

Membrane desalination of water treatment has a wide spread and is the undisputed leader where the temperature of water for desalination does not exceed 32-33℃ with salinity level of about 35-38 g/l. As a rule, sea water with such parameters already one passage through the membrane reduces salinity to 300-450 mg/l. In order to obtain not just desalinated but fresh drinking water, several types of additional treatment are required.

The advantage of a membrane desalination system is the possibility to build a mixed type plant to optimise performance in case of significant fluctuations in the daily or seasonal ratio between water and electricity production. In terms of typical capacity, a single module system can produce in the order of 4000-7000 m^3 or more of fresh water per day. Most of the membranes of these plants are very sensitive to the presence of various bacteria in the water, as well as chlorine, which is used to combat the formation of scale and deposits of animal and vegetable origin, without which virtually no system can do without. It is therefore essential that the source water is pre-treated to avoid clogging of the operating membranes.

The operating pressure required for membrane separation systems varies depending on the salinity of the source water. For example, the conversion ratio can be 50% for water from open and relatively cold seas (up to 26℃) and drop to 35% for saltier seawater, provided that the water temperature does not exceed the membrane limit. The pressure of the source water for desalination depends on its salinity (Figure 5).

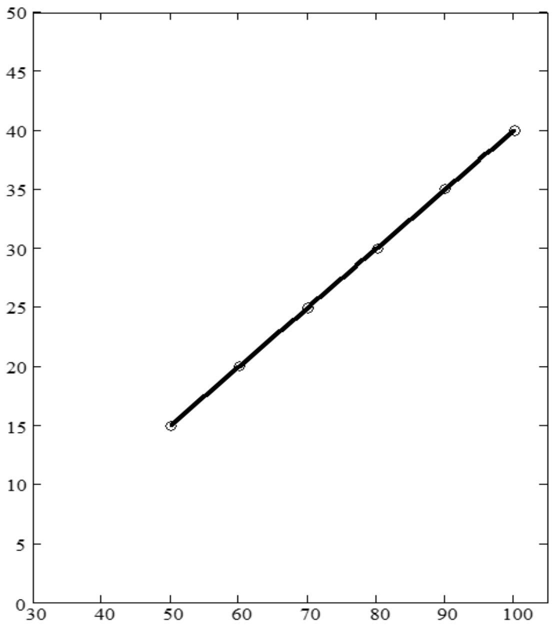


Figure 5. Dependence of operating pressure on water salinity

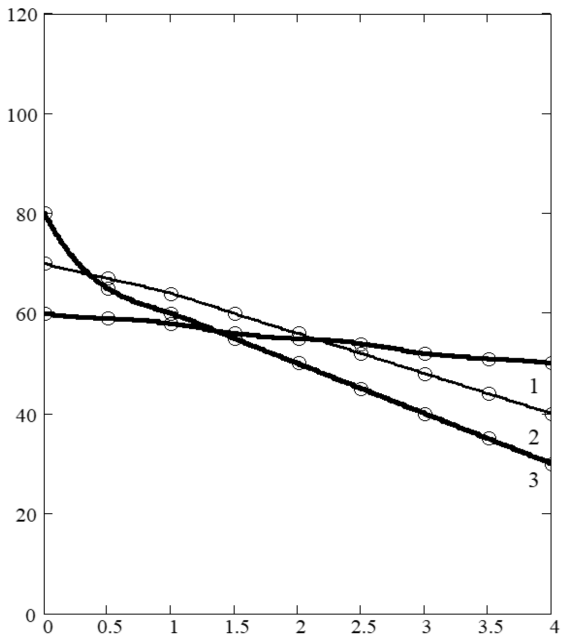


Figure 6. Water flow rate dependence on temperature
1 - water temperature 20℃; 2 - water temperature 25℃; 3 - water temperature 300℃.

Due to flow acceleration, desalination performance increases with increasing water temperature, but the efficiency of operating membranes is limited by the salinity of the water. In very hot climates (38 to 44℃), the rooms where membrane desalination plants are installed must be air-conditioned, which inevitably leads to an overall increase in energy consumption.

The main disadvantage of membrane desalination methods is membrane fouling. In order for membrane apparatuses to maintain long-term performance, it is necessary to choose the right technological scheme of water treatment regimens before desalination and to carry out periodic measures to restore the characteristics of semipermeable membranes that have changed as a result of the operation of the apparatuses.

One of such methods is hydraulic flushing of membrane units. To achieve a turbulent regime, which corresponds to effective flushing of the membrane surface, it is necessary to create velocities of liquid flow in the membrane channel tens and hundreds of times higher than the velocity of liquid flow in the operating mode. But such speed increase is not possible.

Figure 6 shows the dynamics of membrane permeability as a function of time (in years) and source water temperature at an operating pressure of 3 MPa. Water condition, its temperature, as well as pre-treatment have a significant influence on membrane service life.

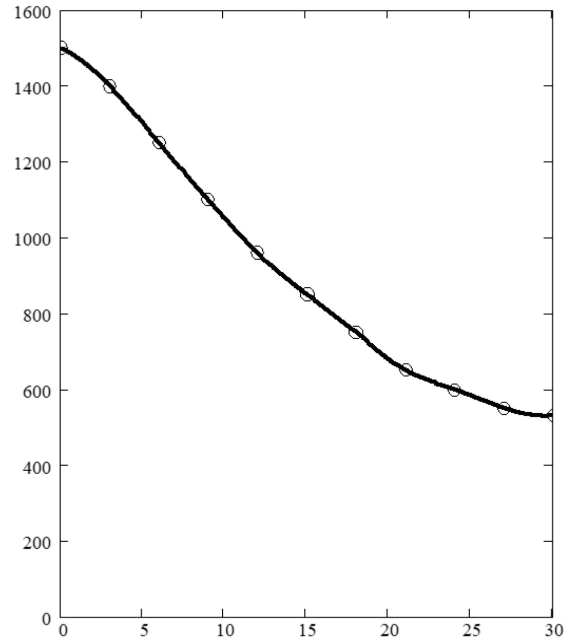


Figure 7. Dependence of permeate consumption on the operating time of the plant without pre-treatment

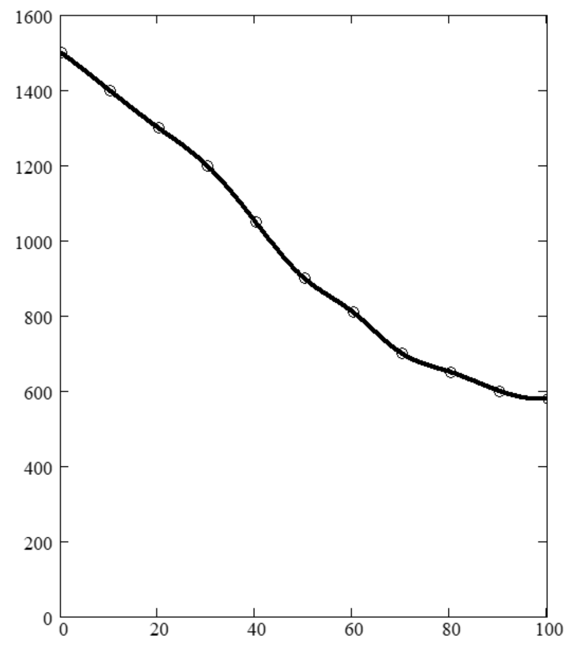


Figure 8. Dependence of permeate flow rate on the operating time of the plant using membrane system cleaning control

Comparison of systems operation with and without hydraulic washing is shown in Figures 7-8.

The graphs show that when the hydraulic washing mode is realised by increasing the flow rate of the initial solution by 2-3 times and simultaneous pressure reduction, the filter cycle of the membrane unit increases by more than 3 times. On the basis of the complex of conducted researches and obtained results the algorithm of control of membrane systems, which is based on the application of periodic hydraulic washing, is developed.

For some open water reservoirs, the SDI-index value is up to 500. By the value of the permissible critical SDI value, it is possible to judge about the class of the membrane water treatment system. Systems of leading manufacturers successfully operate at SDI of source water: for artesian water - up to 5; for surface water - up to 18. Pre-treatment of source water is used to reduce SDI value. Calculations of SDI-index value for desalination of Shardara reservoir water are presented in Table 12.

Table 12. SDI-index values for desalination of Shardara reservoir water Reservoir

No.	Type of Source Water	SDI Values
1	Surface	20

For membrane elements it is experimentally established that LSI - index should be less than 0.5. LSI is a logarithmic function, so the tendency for sedimentation in the LSI range from 0.5 to 2.0 can be 10 to 20 times the calculated value. The LSI-index methodology is applicable up to a TDS (total dissolved solids) value of 10 g/litre of concentrate. In practice, the LSI index in the concentrate stream is defined as a function of TDS, calcium ion concentration, total alkalinity, pH, temperature and conversion parameter. A decrease in LSI index is favoured by a decrease in conversion, a decrease in calcium ion concentration or total alkalinity in the source water. Table 13 shows LSI-index values for desalination of Shardara reservoir water

Table 13. Maximum permissible LSI-index value

No.	Conditions of Use	LSI Value
1	Without anti-skeylant	< 0.4

Membrane water treatment plant is one of the main components of the water treatment system and is designed to carry out deep water purification on composite membranes. The system guarantees removal of up to 99% and above of inorganic salts, up to 99.5% of organics, 100% removal of bacteria and viruses. The system has a return line of treated water (permeate) back into the cycle (to the high-pressure pump inlet line) to reduce the concentration of salts in the source water. This results in purified water (permeate) with a total salt content of 3 mg/l or less.

Thus, the use of this membrane apparatus design allows to reduce membrane wear and increases the efficiency of membrane surface cleaning. Increase of membrane surface and decrease of concentration polarisation allows to increase productivity of the apparatus, avoid premature fouling of membranes and their failure, high degree of demineralisation and decrease of total salt content of water [21].

4. CONCLUSION

The research revealed that the concentration of substances in water does not reflect the toxicological load on the ecosystem, as it does not take into account the processes of accumulation of substances in biological objects and bottom sediments, i.e. the prehistory associated with the accumulation of pollutants in the aquatic environment is not taken into account.

The research findings highlight the effectiveness of nanofiltration technology in significantly reducing pollutants such as sulphates, nitrites, copper, and magnesium from the Shardara Reservoir, while also improving water quality by eliminating harmful bacteriological and microbiological contamination. By reducing biological oxygen demand by 92.5% and chemical oxygen demand by 100%, the process ensures the treated water meets sanitary and hygienic standards, making it suitable for sustainable public use in Turkestan province. To further improve water treatment, future studies could explore optimizing membrane materials and refining operational parameters to enhance pollutant removal efficiency and long-term performance.

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