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Analysis of the limits in the application of membrane technologies in Polish water supply systems using the reverse osmosis process as an example

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ABSTRACT

This article presents a theoretical analysis of the feasibility to use membrane technologies, based on the example of the reverse osmosis process in Poland's public water supply system. Barriers to the potential implementation of the reverse osmosis process into the national public water supply system were defined according to the characteristics of the systems currently in operation, as process pressure, percentage of wastewater and physico-chemical parameters of the feed water. For the purposes of the analysis, water quality data were used from the central Hydrogeological database, for underground intakes in central Poland where higher chloride concentrations were diagnosed. To analyse process pressure, recovery rate and process efficiency, a calculation programme from a membrane module manufacturer was used. A comparative study of the amount of water generated as a reject from the reverse osmosis process in relation to classical filtration processes was also carried out. The results showed a classification system for water types with elevated chloride concentrations according to values limiting the use of dedicated membrane processes in Polish drinking water supply systems.

Keywords: Water treatment; Membrane technologies; Application restrictions; Groundwater; Brackish water

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1. Introduction

Access to freshwater in many regions of the world is negligible or completely limited. In many parts of the world, even if freshwater sources are available, their reserves are not sufficient to supply the region's inhabitants as well as local industry, agriculture and crop irrigation [1,2]. On the other hand, regions of water scarcity are often areas of interest for completely different values, resulting in territorial expansion of the population. Hence, the progress of civilisation in various branches of the economy and the migration of populations has been followed by galloping advances in the technology of producing water from "new" sources. Many authors identify the use of brackish water as an interesting direction for the extraction of significant amounts of resources for freshwater production [3–5]. The search for innovative methods of obtaining water of a quality suitable for public supply or agricultural purposes, including irrigation of crops, is carried out in parallel with the optimisation of process parameters of existing technologies. Hence, the use of membrane technologies, with proven effectiveness in removing contaminants, in the extraction of fresh water from technologically unfavourable resources, including seawater, is of unflagging interest worldwide [6,7]. In water treatment processes, membrane technologies are used for the removal of water salinity, but also for the reduction of water hardness or the removal of sulphates and, in certain cases, for the removal

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of the microorganisms and organic pollutants from the water environment [8–10]. Their use in the energy sector, food, pharmaceuticals, cosmetology and many other industries is gaining popularity at the present time [11–13].

As a desalination process for brackish groundwater, according to literature data, the reverse osmosis (RO) process is considered the most optimal [14,15]. Improvements in RO systems, according to the literature, have been made in several aspects, including the modification of membranes - their structure and materials aimed at improving their separation properties, as well as extending service life, improving mechanical resistance, and reducing fouling by lowering the susceptibility of the material to overgrowth [16,17]. Among the critical elements in the use of membrane technologies, particularly the reverse osmosis process, factors relating to energy requirements are indicated in the literature [18]. Therefore, the unit cost of water production is also optimised, including the reduction of the specific energy consumption (SEC) factor. In addition, modifications are also being made to RO system configurations in order to achieve higher efficiency and better quality of produced water. As part of the reduction in energy requirements, several products are already offered on the commercial market with proven reductions in the required process pressure [19,20]. In addition, feed water quality is indicated as a limiting element for the use of membrane technologies. In specific cases, the use of different membrane technologies is analysed depending on the amount of salinity and other contaminants in the deep water [16]. In Poland, there is a growing interest in local (domestic, homestead, factory) water production systems based on membrane treatment technologies. This interest is related to the technological development of equipment and modules, including easier availability of products and reduction of investment costs. In contrast, the situation is different in Polish collective water supply systems for human consumption. In collective water supply systems, desalination processes are not required in most cases [21]. Most of the country's regional water supply systems are supplied from underground intakes, with relatively good quality of intake water, requiring only basic filtration processes. The use of membrane technologies in domestic municipal systems is therefore not widespread [22]. However, there are areas of the country where the quality of groundwater shows exceeded chloride limits [23]. The demand for the use of water treatment systems based on membrane processes is therefore beginning to occur in domestic systems and, in the authors' opinion, will grow. Within the scope of this article, the limitations that exist in the case of a task of adapting membrane systems for use in water treatment plants operating in a public water supply system fed from a underground intake are analysed. An analysis of the literature revealed work on process optimisation of reverse osmosis systems fed by raw water, including seawater, and fed by brackish groundwater. The identified research gap concerns the adaptation of existing technologies to water supply systems characterised by specific boundary conditions. The rationale arising from the operating conditions of existing water treatment plant facilities was identified as barriers to the application of technologies different from classical filtration, which is currently the backbone of the groundwater treatment process. Firstly, process pressure was identified as a determinant of the introduction of new elements into the system, limiting both the cost of operation of the facility and the technical aspects related to the operational safety of water supply systems. Another barrier limiting the use of membrane technologies is the quality of feed water, which in the case of this analysis was captured by determining the correlation of parameters related to the characteristics of groundwater and the salinity present. In addition, the feasibility of using the technology in existing systems is determined by the ability to manage the waste stream generated during the process.

In order to obtain the conditions underpinning the design of a system dedicated to operating in a real water supply system, a programme made available by a leading manufacturer of membrane modules on the commercial market was used. The programme, called Lewa Plus, is available under the Lanxess brand. The programme is built from different modules and allows the selection of available commercial components dedicated to water treatment processes. The programme allows the configuration of a system based on FilmTec™ membranes.

The reverse osmosis module allows the calculation of RO plant performance for both brackish and seawater feed water. It helps to simulate the impact on system performance and quality using various parameters such as chemical composition, pH and water temperature. The programme allows calculation of system performance, including feed pressure and permeate quality. The programme also gives support for hybrid pressure equipment configurations to achieve reduced feed pressure or to equalise the permeate flux distribution along the membrane unit.

In the context of this article and the expected quality of the treated water, an important element of the programme is the support for the design of two-pass systems with partial distribution and various options for concentrate recirculation and feed stream mixing. The programme is used in scientific and scientific-technical projects worldwide. For example, the programme was used in the analysis of a case study of the selection of a technological system responding to changes in the quality of groundwater in the city of Kabala [3].

Similar software is provided by manufacturers (i.e., DuPont de Nemours Inc., and Toray Industries, Inc.) of membrane technology components to facilitate their selection and parameterisation [24,25].

The motivation for choosing the topic of this article was the fact of the increasing popularity and availability of membrane technologies in recent years and the simultaneous definitive elimination of intakes with elevated chloride concentrations from domestic water supply systems. Analysing the theoretical limits of the use of membrane technologies for use in the treatment of water from groundwater intakes, a study was undertaken to determine the actual values limiting the use of membrane processes in water supply systems. Intakes located in an area where, according to the Polish hydrogeological database [26], elevated chloride concentrations have been recorded were selected for the study. The selection of the study sites was aimed at covering a wide spectrum of chloride contents in groundwater in the context of the possibility of obtaining such waters as a source for the production of water intended for human consumption.

The aim of this study is to define a correlation matrix of chlorides and iron and manganese in water abstracted from a groundwater intake, enabling the use of a membrane process, particularly reverse osmosis, to treat this water, within a national water supply system. The determinant of the behaviour of the boundary conditions is the maintenance of the prior value of the process reject flow and the process pressure range typical of existing systems.

2. Materials and methods

The analytical work was carried out in three stages:

- Stage I: Within the framework of Stage I, groundwater intakes were selected on the basis of the hydrogeological database [26]. The database was narrowed down to the area of occurrence of chloride anomalies in groundwaters [23] in the region of four voivodships of central Poland, that is, Wielkopolskie, Kujawsko-Pomorskie, Mazowieckie and Lodzkie voivodships (Fig. 1).

The intakes were then classified from the point of view of other groundwater contaminants such as iron and manganese affecting the water treatment process. The quality of the feed water was identified as the first limiting criterion for the use of a specific water treatment technology.

A water matrix was developed to characterize the quality of the waters subjected to process analysis. The classification of waters was developed according to the parameters included in the provisions of Polish law regarding the requirements for the quality of water intended for human consumption [27]. Concentrations of iron and manganese as typical contaminants of groundwater were adopted as the dividing line in each of the chloride concentration ranges according to Table 1.

- Stage II: In the second stage, additional criteria (in addition to feed water quality) affecting the feasibility of using membrane technology in a water supply system were determined, which included: process pressure and concentrate volume. Subsequently, limit values were set

Table 1
Classification of water matrix according to iron and manganese concentration

Concentration (mg/L)	A	B	C	D
Fe	>0.2	>0.2	<0.2	<0.2
Mn	>0.05	<0.05	>0.05	<0.05

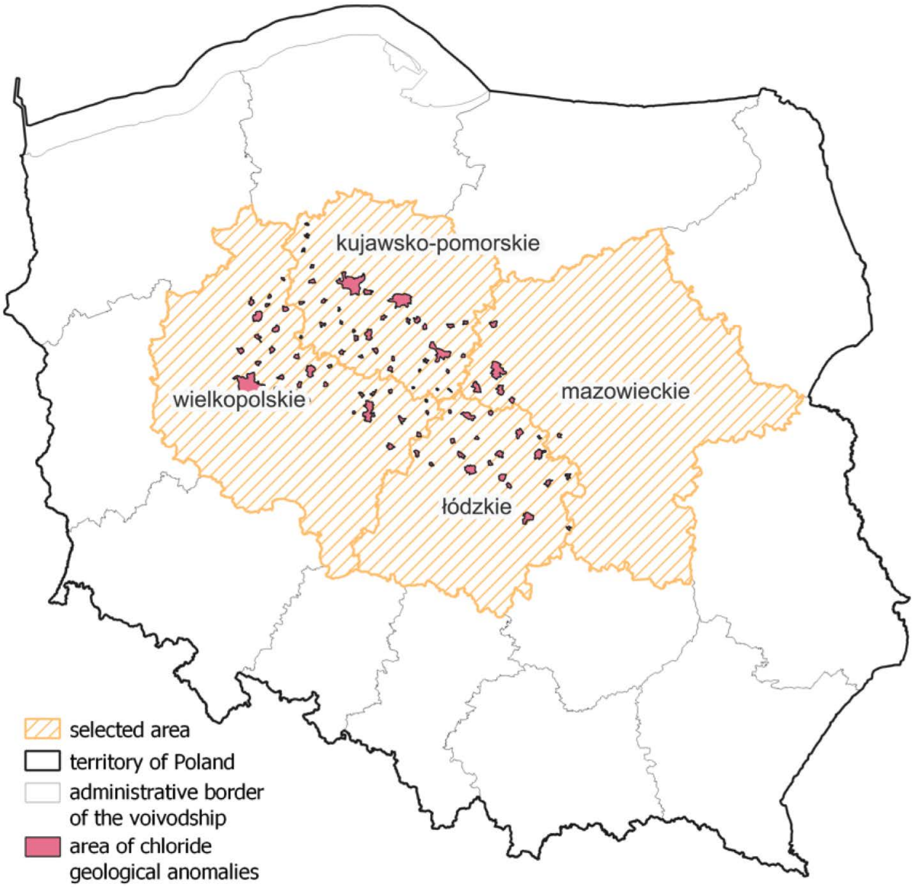


Fig. 1. Map of selected voivodships of central Poland (source: author's study).

for each criterion, that is, for the system operating pressure, values from 6 to 12 bar were adopted as typical values for water supply systems. The optimisation of the concentrate volume was carried out by comparing it to the backwash water stream of a classic groundwater filtration process.

- Stage III: The third stage involved optimising the process scheme, including optimising the number of process stages used, mixing streams and changing the membrane type. The three parameters identified in the previous stages were used as an evaluation criterion; that is, process efficiency, process pressure and concentrate volume. For each class, a treatment system scheme was developed that met the value assumptions limiting the use of the indicated technology.

2.1. Water matrix

Four groups of groundwaters were selected for the study, classified according to the concentration of contaminants present. The concentrations of iron and manganese typically found in groundwater in correlation with the occurring chloride concentration were selected as technological determinants of water use as a medium in the water supply system. Table 2 illustrates the characteristics of the water matrix.

Due to the fact that a hydrogeological database was used, without the possibility of supplementing the study with possibly unavailable parameters, the water samples were selected in the context of the availability in the database of parameters relevant to the effectiveness of the membrane processes, that is, the chemical composition, including sodium, calcium and magnesium cations and anions of sulphate, nitrate, carbonate.

2.2. Analysis software

For the theoretical analysis, commercial software was used to accurately diagnose both the permeate and concentrate ratios in each of the systems analysed, as well as to assess the quality of the treated water when mixing the permeate stream with the feed and the process pressure. The programme used was The LewaPlus TM design software, Version 2.2.6 Copyright © 2012–2023 Lanxess Deutschland GmbH, This software is provided by LANXESS Deutschland GmbH, Leverkusen, Germany.

The LewaPlus software is a comprehensive tool for designing demineralisation systems based on ion exchange and membrane technologies including RO processes. The software allows the programming of the plant system in various system configurations using products implemented into the software. According to the authors, the software has a user-friendly operator interface and offers more flexibility regarding the programming of process stages, mixing streams and circulation stages than other software available on the domestic market.

2.3. Technological schemes

Three variants of the process diagrams shown in Figs. 2–4 were analysed as part of this study.

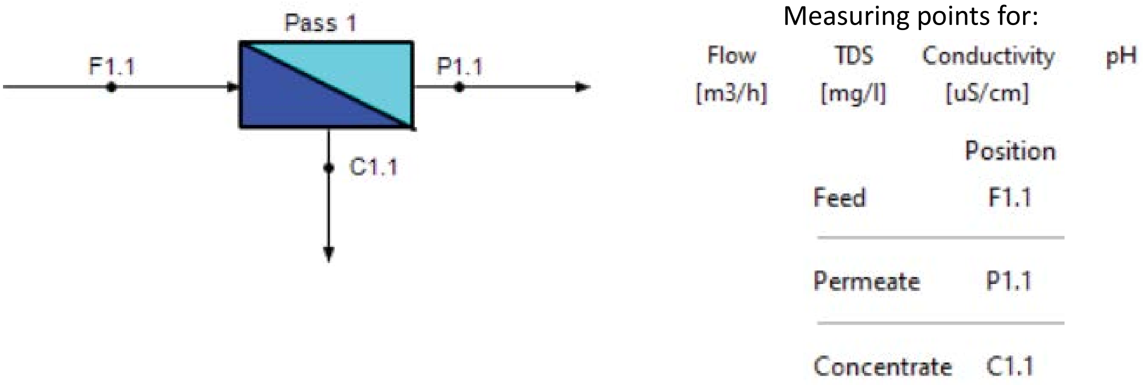
In addition, each option was considered in a graded configuration. The configuration of the options analysed (Figs. 5 and 6):

2.3.1. Membrane parameters

To characterise the current state of the membranes, the membrane age, flux decline factor and annual increase in salt permeation can be entered into the programme. Based on the

Table 2
Water matrix by chloride concentration in groundwater

Range classification by primary identification	Chloride concentration	Range classification by specific identification (Fe, Mn) according to Table 1			
	(mg/L)	A (Fe, Mn)	B (Fe, Mn)	C (Fe, Mn)	D (Fe, Mn)
I	251–500	IA	IB	IC	ID
II	501–1,000	IIA	IIB	IIC	IID

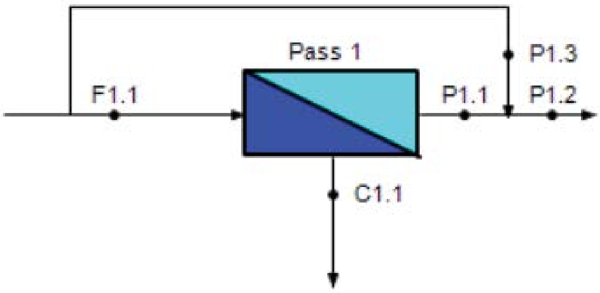


Measuring points for:

Flow [m3/h] TDS [mg/l] Conductivity [uS/cm] pH

	Position
Feed	F1.1
Permeate	P1.1
Concentrate	C1.1

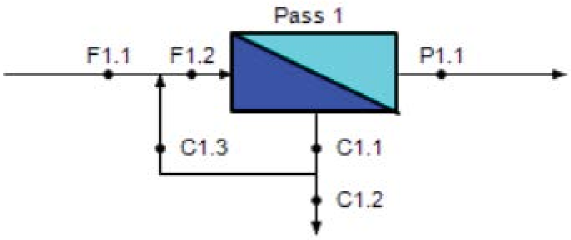
Fig. 2. Basic system.



Measuring points for:

	Position
Feed	F1.1
Permeate	P1.1
	P1.2
	P1.3
Concentrate	C1.1

Fig. 3. System configuration with permeate blending.



Measuring points for:

	Position
Feed	F1.1
	F1.2
Permeate	P1.1
Concentrate	C1.1
	C1.2
	C1.3

Fig. 4. System configuration with concentrate recirculation.

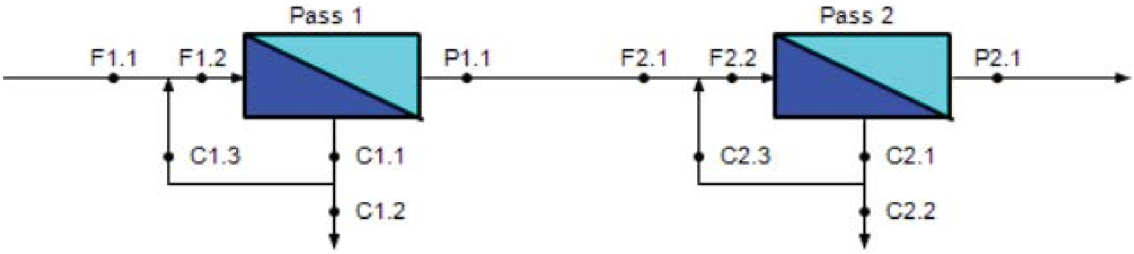


Fig. 5. Two - pass unit.

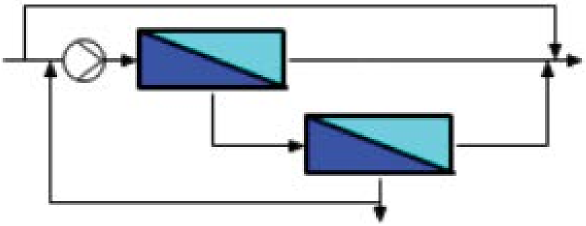


Fig. 6. Two - stage unit.

membrane age and flux decline factor, a fouling factor is determined to predict the decrease in water permeability through the membrane over time. The following section provides more information on the modelling built into the software.

The programme assumptions are based on a conservative design approach, using source type, pre-treatment type and methodology as the basis for operational parameters. For this study, groundwater was identified as the source but brackish water was specified as the water type, pre-treatment was omitted and actual water analysis data for each class of separately developed matrix was used.

2.4. Comparative analysis

One of the parameters identified as a potential barrier to the application of membrane technology in water treatment is the need for concentrate management. The premise of this paper revolves around the analysis of barriers in the potential implementation of membrane technology using the example of RO to an actual water treatment plant. The value of the concentrate was therefore related to the washings of a classical filtration process.

Literature data indicate a concentrate flux for water filtration that ranges from 5 to as much as 47%. [28,29]. Therefore, in order to determine the amount of concentrate flux that could be a barrier to the use of membrane technology, a calculation was made of the amount of wash produced, based on data from a database where information on national public investment, including the water supply sector, are published [30]. An instantaneous water production capacity of 100 m^3/h, a filtration rate of no more than 12m/h and a backwash capacity of 60 m/h were assumed. If identical quality of water subjected to the filtration process is assumed (compatible process speeds, identical mixture of filter beds), the amount of backwash water generated depends on the number of units operating in the filtration system. The calculated values are shown in Fig. 7.

In the case of classical processes used in groundwater treatment systems, the calculated values for the amount of wash water as process rejection are 21% on average. Value maximum 32% was taken as a reference for comparing the concentrate flux from the RO process.

3. Results and discussion

On the basis of a structured set of data from each voivodeship of central Poland, included in the selected area, intakes were selected for which boundary assumptions for the study in question were fulfilled (classified according to positions IA to IID according to the water matrix presented in Table 2).

In the next stage, the selected intakes were subjected to an attempt to optimise the process of reducing chloride concentration in groundwater to the level of 250 mg/dm^3 resulting from the regulations of the Polish law [27]. Using the diagrams (Figs. 2–6), threshold values for the effectiveness of the adopted technology were then determined for the groundwater intakes of the selected area. Each time, for the feed water quality introduced into the scheme (for each class from IA to ID and IIA,B and D), a system was selected that would enable reduction of chloride, iron and manganese concentrations to the applicable provisions of Polish law. In order to verify the effectiveness of the adopted scheme in relation to the type of module selected, the number of process stages and the degree of mixing of the raw water stream, the value of the pressure required for the process and the concentrate stream were studied.

Table 4 shows the results of the selected configurations for each of the water matrix classes except for the group labelled IIC due to the lack of detailed data to enable simulations. The study carried out for class IID allows the results to be used for class IIC water.

In each case, the condition for using the reverse osmosis process to produce water was to assume a maximum allowable process pressure and an impassable separation ratio on the membrane (hydraulic recovery). The factors that had the greatest influence on the feasibility of using the proposed technology, in addition to the water matrix as a boundary condition, was the degree of mixing between the feed stream and the treated water. In each case, the possibility of introducing additional process stages and increasing

Table 3
Current design guidelines in a typical reverse osmosis installation project

Feed water type	Brackish wells (SDI* < 5)
Average permeate flux (range), L/m^2·h	23 (2026)
Lead element permeate flux, L/m^2·h	<34
Concentrate flow rate per vessel, m^3/h	>3.6, >0.7
Feed flow rate per vessel, m^3/h	<15, <2.8
Pressure drop per vessel, kPa	<200.0
Element recovery rate, %	<17
Beta value	<1.2
Flux decline ratio, %	13
Salt passage increase, %/a	>10

*SDI - silt density index

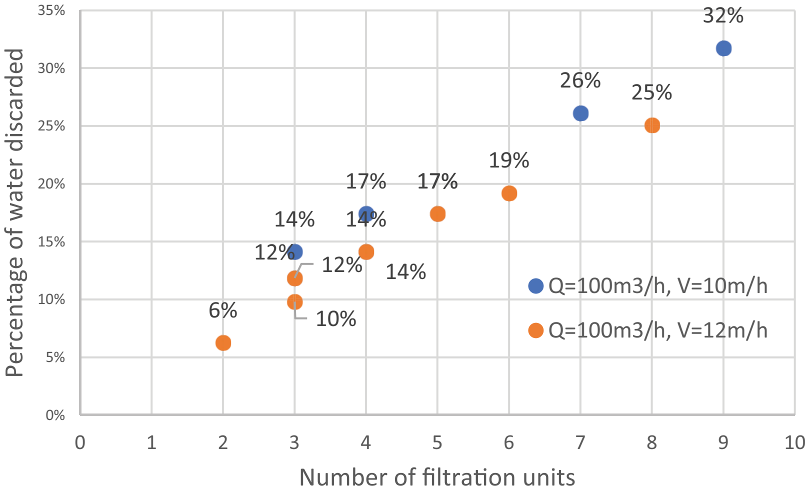


Fig. 7. Hydraulic recovery.

Table 4
Summary of simulation results by feed water quality class

Parameter	IA	IB	IC	ID
System permeate flow (expected) (m^3/h)	30	30	30	30
Feed flow (m^3/h)	31.25	18.75	13.75	6.25
Feed flow to stage 1 (m^3/h)	34.25	22.25	14.75	8.75
Permeate flow (m^3/h)	25.00	15.00	11.00	5.00
Permeate blending (m^3/h)	5.00	15.00	19.00	25.00
Recovery (%)	80	80	80	80
Hydraulic recovery (%)	72.99	67.42	74.58	57.14
Pump discharge pressure (kPa)	954.8	616.92	1,043.43	1,085.3
Pass	1/1	1/1	1/1	1/1
No of stages/elements	2/35	2/35	2/14	1/7
Concentrate recirculation (m^3/h)	3.0	3.5	1.0	2.5
Power consumption (kWh/m^3)	0.39	0.16	0.19	0.12
Total electric power (kW)	11.56	4.9	5.67	3.49
	IIA	IIB	IID	
System permeate flow (expected) (m^3/h)	30	30	30	
Feed flow (m^3/h)	18.75	22.50	25.00	
Feed flow to stage 1 (m^3/h)	25.75	24.50	28.00	
Permeate flow (m^3/h)	15.00	18.00	10.00	
Permeate blending (m^3/h)	15.00	12.00	20.00	
Recovery (%)	80	80	80	
Hydraulic recovery (%)	58.25	73.47	71.43	
Pump discharge pressure (kPa)	1,221.98	1,132.17	1,261.69	
Pass	1/1	1/1	1/1	
No of stages/elements	2/21	3/28	2/18	
Concentrate recirculation (m^3/h)	7.0	2.0	3.0	
Power consumption (kWh/m^3)	0.36	0.31	0.4	
Total electric power (kW)	10.62	9.33	11.94	

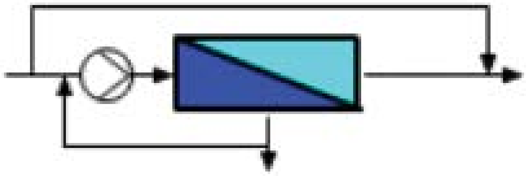


Fig. 8. Technological scheme of water treatment process (1 stage).

the recirculation ratio was analysed, but such measures were irrelevant from a process pressure point of view and generated negligible impacts on water quality.

The most optimal scheme was a system involving mixing of treated water (permeate) and raw water, as illustrated in Fig. 8.

For parameters in the ID group (Table 2), a system based on a single stage was optimal. For feed water parameters from group IA to IC and IIA, IIC (Table 2), a system based on two stages, with mixing of the feed stream at the beginning of the system, was the optimal choice (Fig. 9).

A schema based on 3 steps was adopted for group IIB parameters (Fig. 10).

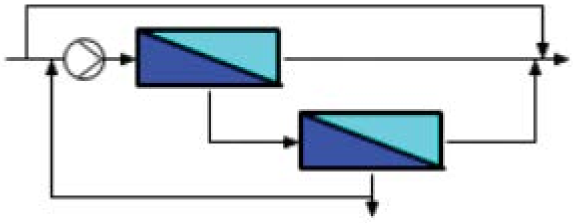


Fig. 9. Technological scheme of water treatment process, dedicated to group IA to IIC, without IIB (2 stages).

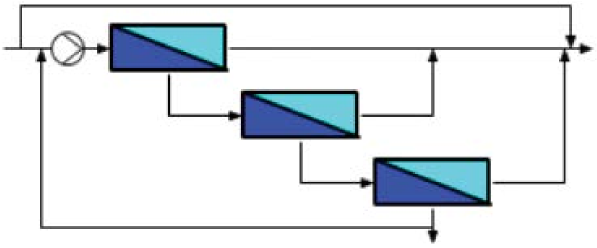


Fig. 10. Technological scheme of water treatment process, dedicated to group IIB (3 stages).

Table 5
Results of obtained parameters in measuring point for each analyzed causes (IA, IB, IC, ID, IIA, IIB and IID)

	Position	Flow	TDS	Conductivity	pH
		(m^3/h)	(mg/L)	(µS/cm)	(–)
IA					
Feed	F1.1	31.25	515.44	725.44	7.3
	F1.2	34.25	694.22	966.06	7.3
Permeate	P1.1	25	5.26	8.63	7.3
	P1.2	30	90.29	135.42	7.3
	P1.3	5	515.44	725.44	7.3
Concentrate	C1.1	9.25	2,555.79	3,379.06	7.3
	C1.2	6.25	2,555.79	3,379.06	7.3
	C1.3	3	2,555.79	3,379.06	7.3
IB					
Feed	F1.1	18.75	531.1	769.87	7.7
	F1.2	22.25	859.62	1,223.36	7.7
Permeate	P1.1	15	10.28	16.73	7.7
	P1.2	30	270.69	402.24	7.7
	P1.3	15	531.1	769.87	7.7
Concentrate	C1.1	7.25	2,615.66	3,563.26	7.7
	C1.2	3.75	2,615.66	3,563.26	7.7
	C1.3	3.5	2,615.66	3,563.26	7.7
IC					
Feed	F1.1	13.75	424.1	571.89	7.4
	F1.2	14.75	537.76	718.68	7.4
Permeate	P1.1	11	5.13	8.08	7.4
	P1.2	30	270.48	370.89	7.4
	P1.3	19	424.1	571.89	7.4
Concentrate	C1.1	3.75	2,100.16	2,661.69	7.4
	C1.2	2.75	2,100.16	2,661.69	7.4
	C1.3	1	2,100.16	2,661.69	7.4
ID					
Feed	F1.1	6.25	799.42	987.19	7.3
	F1.2	8.75	1,703.35	2,041.93	7.3
Permeate	P1.1	5	11.03	16.3	7.3
	P1.2	30	668.01	830.74	6.47
	P1.3	25	799.41	987.26	6.3
Concentrate	C1.1	3.75	3,960.41	4,588.67	7.3
	C1.2	1.25	3,960.41	4,588.67	7.3
	C1.3	2.5	3,960.41	4,588.67	7.3
IIA					
Feed	F1.1	18.75	1,033.38	1,330.86	7.8
	F1.2	25.75	2,138.42	2,675.72	7.8
Permeate	P1.1	15	22.75	34.23	7.8
	P1.2	30	528.07	698.06	7.8
	P1.3	15	1,033.38	1,330.86	7.8
Concentrate	C1.1	10.75	5,090.83	6,148.43	7.8
	C1.2	3.75	5,090.83	6,148.43	7.8
	C1.3	7	5,090.83	6,148.43	7.8
IIB					
Feed	F1.1	22.5	961.08	1,323.99	7.2
	F1.2	24.5	1,269.06	1,729.57	7.2
Permeate	P1.1	18	18.53	28.77	7.2
	P1.2	30	395.55	563.34	7.2
	P1.3	12	961.08	1,323.99	7.2
Concentrate	C1.1	6.5	4,731.09	6,116.4	7.2
	C1.2	4.5	4,731.09	6,116.4	7.2
	C1.3	2	4,731.09	6,116.4	7.2
IID					
Feed	F1.1	25	1,031.79	1,307.32	7.4
	F1.2	28	1,468.76	1,835.32	7.4
Permeate	P1.1	20	13.35	20.16	7.4
	P1.2	30	352.83	465.9	7.4
	P1.3	10	1,031.79	1,307.32	7.4
Concentrate	C1.1	8	5,107.7	6,068.5	7.4
	C1.2	5	5,107.7	6,068.5	7.4
	C1.3	3	5,107.7	6,068.5	7.4

The lack of a certain degree of mixing of the raw water to reduce the amount of concentrate each time disturbed the quality of the treated water or the required process pressure.

Each time a parameterization of the mixing degree was carried out, varying by 1 m^3/h. Reducing the raw water flux in relation to the flux fed to the membranes resulted in inadequate water treatment (Cl > 250 mg/L). In the case of an increase in the value of the treatment water flux, the modules had to be increased due to too high a hydraulic load or the process pressure increased and its limit value was a condition for the effectiveness of the task.

If the number of stages was changed, the parameters of the treated water deteriorated each time or the per-vessel load was inadequate.

A summary of the treated water quality results for each group, obtained for the assumed boundary conditions (pressure not exceeding 12 bar and reject flux not exceeding 20%–30%), is shown in Table 5.

4. Conclusions

In the selected area there is an increasing demand for water produced by water supply systems fed mainly from groundwater intakes. The potential possibility of using water with increased salinity in times of diagnosed shortages of water resources used for supplying the population is an important factor related to water supply security.

This study is mainly based on a reference to the limits encountered when trying to adapt membrane technologies to classical water treatment systems supplied from groundwater intakes. Barriers to the application of membrane technologies are process pressure and the need to manage the concentrate in collective water supply units. The results obtained illustrate the theoretical lack of need for process pressure in excess of the adaptive capacity of water supply systems when using RO stations for water treatment for chloride concentrations not exceeding 1,000 mg/L (assumptions for Class II tested). For waters occurring in the selected area, it is possible to design a membrane process at a pressure not exceeding the values dedicated to the water treatment plant equipment (10–12 bar). The use of reverse osmosis technology for water production in water supply systems, with the assumed system, does not generate a higher waste water stream than classical filtration systems (20%–30%).

The detailed selection of the optimum technological scheme for a specific medium to be exploited in selected areas of Poland requires a thorough analysis of all the physic-chemical parameters and should not be based solely on chloride concentration. As has been shown, the mutual correlation of selected parameters - assignment to defined groups is an important determinant of the reduction of barriers identified as determinants of the use of membrane technology for water supply systems.

The simulation method used allows a preliminary diagnosis of the potential of any groundwater intake for which elevated salinity was identified at the well construction stage. The analysis indicates that it is possible to include water from all the categories studied in the water supply systems, assuming a water treatment scheme based on RO using a FilmTec for Breakisch Water membrane and mixing the feed and permeate streams in a proportion of no more than 50%.

Currently, in national water supply systems, a chloride concentration exceeding the requirements of the Regulation for drinking water is diagnosed in water intended for supply to the system. The studies carried out indicate the possibility of using membrane processes, particularly on the example of the reverse osmosis process for the production of drinking water for defined groups of quality parameters of the feed medium. As the results illustrate, such a solution does not result in an increase in effluent flow compared to current technologies and does not require higher process pressures than those currently used in treatment processes. The availability of such solutions from a formal adaptability point of view remains a separate issue, but from a technical point of view, it is possible to design optimal systems based on the RO process.

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