

Alexei Pervov, Alexei Andrianov, Tamara Gorbunova

## APPLICATION OF MEMBRANES TO TREAT NATURAL AND WASTE WATERS: NEW CONSIDERATIONS TO REDUCE FOULING AND INCREASE RECOVERY UP TO 99%

**Abstract.** Survey shows that high operational costs of membrane facilities and large amounts of effluents are mainly attributed to fouling and scaling. Research of scaling and fouling mechanisms showed that these processes depend not only on hydraulic and hydrodynamic factors, but on membrane type, material and channel configuration as well. Operational parameters of different membrane configurations show that spiral wound modules demonstrate best hydraulic and hydrodynamic characteristics combined with lowest price.

Main ways to develop new fouling-free techniques are outlined that require modified «open-channel» spiral wound membranes. Elimination of «deadlocks» as a main cause of scaling and fouling provide new technological approach to develop water treatment techniques without pretreatment facilities and chemicals. Modification of channel provides possibility to reach high recoveries and high supersaturation values due to strong stability of calcium carbonate solutions.

Membrane transport is not only purification instrument it is also a reactor to coagulate, concentrate and precipitate water constituents on membrane surface. Several examples of water treatment flow diagrams are presented to demonstrate principles of zero concentrate flow discharge. Coagulated suspended matter after membrane flushes is collected, sedimented and finally dewatered. The dewatered sludge contains averagely 0,8 per cent of initial water. Due to the use of an «open-channel» modules membrane brine flow could be concentrated by many times without a fear of scaling and added to the sludge. Thus the excessive salts and impurities could be withdrawn from water systems together with partially dewatered sludge. Similarly excessive calcium carbonate could be also concentrated in membrane modules and subsequently precipitated, sedimented and dewatered. Solution of fouling problems thus provides a new approach to save operational costs and to increase ecological efficiency of membrane water treatment tools.

**Keywords:** domestic waste water; fouling-free technologies; membrane fouling; nanofiltration; natural water treatment; open-channel module; reclamation; recovery; reverse osmosis; scaling; spiral wound module; urban surface water; zero discharge.

## INTRODUCTION

Modern membrane techniques (UF, NF, RO) have demonstrated high efficiency in removal of suspended matter, bacterial, as well as organic and mineral ingredients from natural and waste waters. Meanwhile, certain problems of membrane fouling

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Alexei PERVOV, Alexei ANDRIANOV, Tamara GORBUNOVA – Moscow State University of Civil Engineering, Department of Water supply

arise, resulting in shortening of membrane life and product flow decrease. To prevent formation of fouling layers on membrane surface and cake resistance increase, a number of measures are applied, such as backflushes, chemical cleanings, pretreatment. Despite these measures applied, fouling remains a major factor that determines operational costs.

Long operational experience of membrane units to treat natural water as well as theoretical and experimental investigation results enable us to draw to a conclusion that hydraulic, hydrodynamic and chemical processes that occur during membrane separation are closely connected. Many researchers approve of this concept in a number of reports [1] but nevertheless many state-of-the-art reviews demonstrate conventional limited description of these processes without relationship. Meanwhile, critical and detailed assessment of different processes separately shows the importance and significance of each process in formation of the whole overview of membrane fouling and deterioration of membrane performance characteristics.

Natural surface water contains high concentrations of suspended and colloidal matter with different particle size distribution, as well as dissolved organics (mainly humus substances) with various molecular weights. Membrane fouling mechanisms caused by various foulants (sparingly soluble compounds, bacterial, organic and colloidal matter) are different. Suspended and colloidal particles deposit and adhere on membrane surface thus building fouling layer that create hydraulic resistance and reduce membrane product flow. Organic compounds adsorb on membrane surface and on particles of deposit.

Formation of colloidal fouling layers can be attributed to hydrodynamic flow characteristics (such as cross-flow velocities, concentration polarization level, product flow etc.) as well as membrane surface characteristics (surface charge, hydrophilic properties that are depended on polymer composition). Configuration of membrane channel and module also should be considered as decisive factor that influence fouling [1, 2]. Spiral wound configuration is widely applied at more than 90 % of all water installations but nevertheless is considered as useless to treat surface water that contain suspended and organic matter due to fouling hazard. At present time hollow fiber ultrafiltration is considered as the best pretreatment tool for RO facilities where tubular and capillary UF membranes are utilized. These membrane configurations are supposed to demonstrate better reliability than spiral wound flat sheet channel due to lower delta pressure values, better conditions for hydraulic flushing and backwashing performance. Besides, tubular and capillary membrane channels, as well as plate and frame and flat sheet elements channels are still very expensive that makes RO pretreatment costs higher than RO itself.

At the early stages of UF applications to treat surface water cross-flow operational mode was applied with tubular membrane channel whereby high velocity values provide efficient shear force to reduce particulate and organic fouling [3]. High cross-flow values require high energy costs that combined with costly membrane

equipment exceeds reasonable price level for water treatment. Dead-end filtration mode combined with timely backflushing has replaced cross-flow operation at surface water treatment UF techniques due to more economical and operational costs and more membrane surface in capillary modules. Backflushing also could not be considered as efficient measure to control fouling due to plugging factors and the use of product water. Cross-flow operation of ultrafiltration and nanofiltration [4] is recognized as efficient fouling-free process that could be implemented in tubular modules that is not widely applied in water supply practice due to high membrane costs and power consumption.

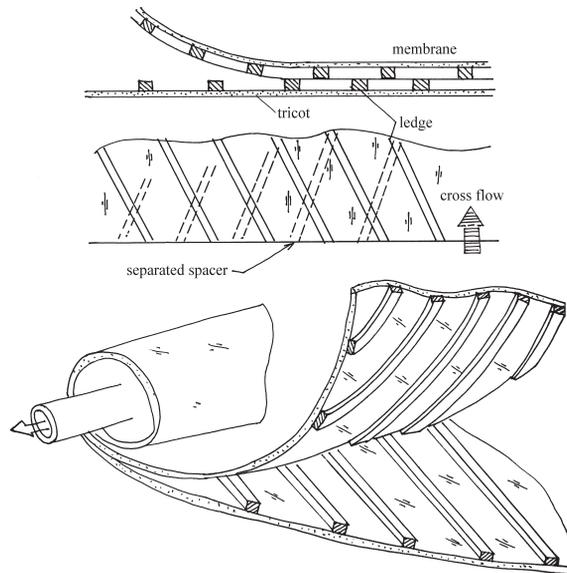
## **RO AND NF WATER TREATMENT TECHNIQUES**

This report presents results of research that was conducted to improve conventional spiral wound configuration to treat directly natural and waste water. The idea of possible channel modification and safe operation of RO/NF module without pre-treatment was already proposed and discussed earlier. It is based on results of different fouling mechanisms investigations. The conclusion that membrane fouling is dependent not only on hydraulic factors but on channel configuration as well was claimed in publications in 1991 [2, 5].

Spiral wound configuration is recognized as optimum both economically and technically, as it use flat sheet membranes and provides high membrane square / module volume ratio at significantly low costs. However the existing spiral wound module configuration used for RO, NF and UF applications is very susceptible to fouling that makes it useless to treat wastewater containing high organics, bacteria and suspended matter. Main disadvantages of spiral wound modules are attributed to presence of separation spacer mesh in the channel that traps fouling particles and increase delta pressure. Mechanism of mesh performance and its influence on scaling/fouling process initiation is proposed in [2, 6]. The places (spots) where mesh contacts membrane surface provide dead lock areas without cross-flow, thus resulting in high concentration increase at membrane surface within this area. Concentration polarization increase initiates formation of crystals and coagulation of colloids inside the deadlocks. Membrane autopsies performed at different stages of fouling formation enabled us to trace crystals trajectories withdrawn from the deadlocks and subsequently sedimented on membrane surface. Organics and colloidal matter coagulate and sediment within deadlock area providing further conditions for particle coagulation and adhesion to the formed layer promoting expansion of foulant layer around deadlock area [2]. The accumulation of foulant around mesh bungles provides increase of delta pressure following filtration theory mechanisms.

Elimination of the mesh could help to develop new type of modules with decreased fouling potential and suggest new reliable and efficient techniques for surface water treatment. This idea was discussed by Richard Riddles in report [1]

devoted to development of an open-channel spiral wound module. Modification of spiral wound module is shown on figure 1 where mesh is withdrawn from the channel by dividing it by ledges and thus providing higher cross-flow velocities. Introduction of new RO open channel modules offers certain perspectives for direct treatment of municipal effluents without a fear to suffer fouling problems during long period of stable operation.



**Fig. 1.** Spiral wound module with open-channel configuration

Nanofiltration process has some advantages over ultrafiltration, such as high membrane resistance, small pore size that exclude plugging and cake resistance increase. NF membranes efficiently remove colour (by 70-95%), oxidability (by 50-80%) and hardness (by 50-80%). Nanofiltration units are used at number of large municipal water treatment facilities (up to 10000 cubic meters per hour capacity) in Paris, Amsterdam, USA, Australia etc. to remove trihalomethans and other low-molecular organics to meet WHO standards [7]. Despite high efficiency in drinking water production strong skeptics exists towards perspectives of using NF method in municipal water treatment. Such an attitude is attributed to existing NF spiral wound modules operation that requires adequate pretreatment, high chemical consumption and thus high operational costs.

Meanwhile, during last years a number of surface water treatment applications use nanofiltration techniques whereby surface water is directly fed to membrane modules without pretreatment [8 – 11]. The efficiency of such fouling-free operation is attributed to hydrodynamic conditions in tubular and capillary membrane channels that prevent deposition of suspended particles. Fouling control is also reached

through application of flushing (including air scouring), timely chemical cleanings and high cross-flow velocities. But these systems are still not widely used due to high capital and operational costs.

Present work is aimed at development of a new modified spiral wound configuration and performance of research program to evaluate optimum operational characteristics (recoveries, cross-flow velocities, flushing cycle durations, cleaning schedules) to ensure long and reliable operation of membrane systems with minimum of operational costs.

## **DEVELOPMENT OF AN “OPEN-CHANNEL” MODULE DESIGN**

A number of companies (PCI, Norit and others) apply tubular/capillar NF membrane module design that enables to treat surface water with high colour and turbidity without pretreatment but using flushing techniques. A possible solution to reduce fouling is improvement of conventional spiral wound configuration to develop an open-channel modules and therefore achieve stable and reliable operation of desalination facilities.

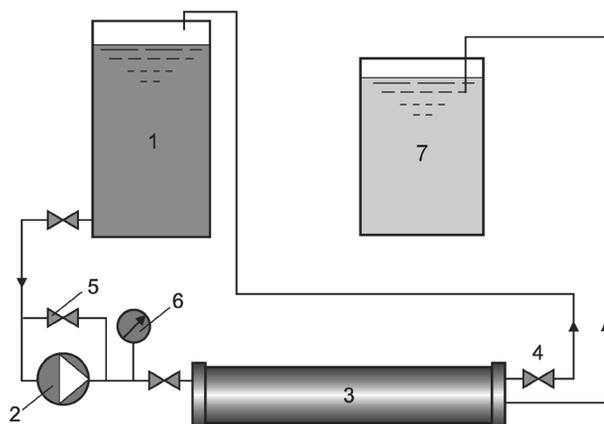
Authors have undertaken various steps to improve channel configuration and eliminate influence of spacer mesh on delta pressure increase during operation and fouling. Different innovations were implemented and tested throughout the research program performed. Various types of spacers, as well of double spacers were tried and tested. To eliminate deadlocks and provide low flow resistance, a spacer should not touch membrane surface. One of the best solutions was the idea of “separate” spacer where mesh fibers are glued to membrane surface. RO module spacer is a platted mesh where parallel groups of fibers are crossed and welded forming a rhombic structure (Fig. 1). In our construction parallel groups of fibers (ledges) are glued to membrane surface whereby ledges on opposite sides are oriented in different directions. The glued fibers form a rhombus having 1.2 mm width and 0.35 mm thickness. When a module is rolled, opposite membrane sides are pressed to each other but ledges separate membrane surfaces providing enough space for flow with very low resistance. The idea of a channel configuration was already patented and some innovations are being continuously introduced. Several modules of 1812 standard were rolled using various types of NF and low pressure RO membranes (cellulose acetate, TFC based on polyvinyl alcohol and polyamide). Cellulose acetate asymmetric NF membranes were provided by Vladipore Co (Vladimir, Russia) and TFC RO membranes were ESPA samples (Hydranautics).

## **EXPERIMENTAL PROCEDURE AND TEST PROGRAM**

The test program included determination of fouling rates, flushing efficiencies and delta pressure values in the modules according to a test procedure described in earlier publications [5].

The research program was aimed at:

- investigation of fouling rate dependencies on hydrodynamic flow characteristics;
- determination of delta pressure increase depending on amount of accumulated foulant;
- investigation of chemical cleaning efficiencies;
- membrane performance (flow decrease) prognosis;
- determination of fouling rates depending on membrane material.



**Fig. 2.** Schematic diagram for NF test unit: 1 – feedwater tank, 2 – high pressure pump, 3 – NF module, 4 – concentrate line valve; 5 – by-pass valve for adjusting operational pressure; 6 – pressure gauge; 7 – product tank

Experimental program was performed using membrane laboratory test unit shown on figure 2. Feedwater is pumped from the tank (1) to a spiral module (3) by the pump (2). The working pressure value is controlled by a valve (5) and pressure gauge (6). Cross-flow velocity is controlled using by-pass valve (4). The test procedure is conducted in circulation mode whereby reject flow (concentrate) is returned to the tank (1) and product is collected in separate tank (7). Determination of concentration values in brine tank and in product tank enables us to calculate amount of foulant accumulated in membrane module and fouling rate values. Delta pressure values could be determined using pressure gauge (6) and cross flow is adjusted by valves (4) and (5).

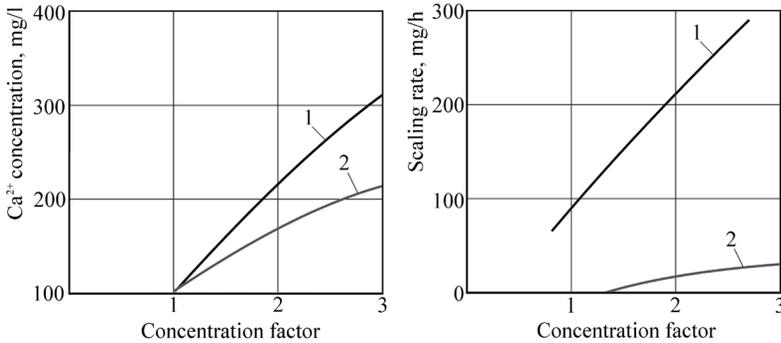
Natural river water was tested that had turbidity of 40 NTU, colour of 40...45 degrees, oxidability of 20...24 ppm.

Elimination of mesh eliminates reasons for crystal formation that provides scale control tools. Also application of described ledges decrease turbulence effect compared to conventionally used spacers.

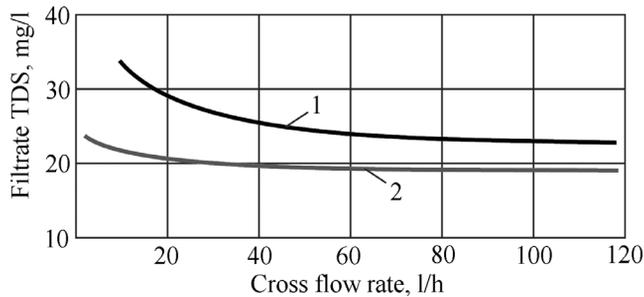
Figures 3 and 4 show results of scaling rates determination and membrane rejection characteristics versus cross-flow rate values.

The experimentally obtained relationships are shown on figures 5 and 6. Figures show the results of particulate (figure 5) and organic (figure 6) fouling rate

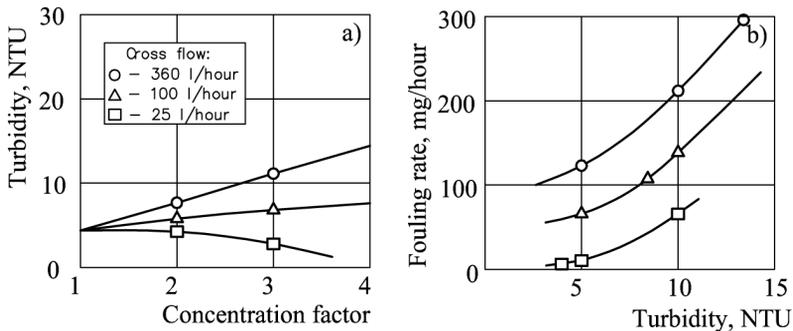
determination depending on cross-flow velocities in membrane module. The higher velocity is the less particulate matter is accumulated on membrane surface. Vice versa, organic material is adsorbed on membrane surface more intensively when cross-flow is higher.



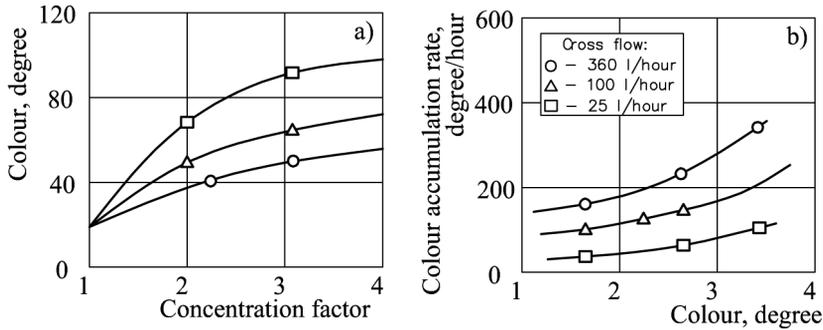
**Fig. 3.** The results of scaling rate determination for different module configuration: 1 – conventional module (1812, BLN, “CSM”); 2 – open channel module (1812, BLN)



**Fig. 4.** The influence of cross-flow rate on filtrate TDS: 1 – conventional module; 2 – open channel module

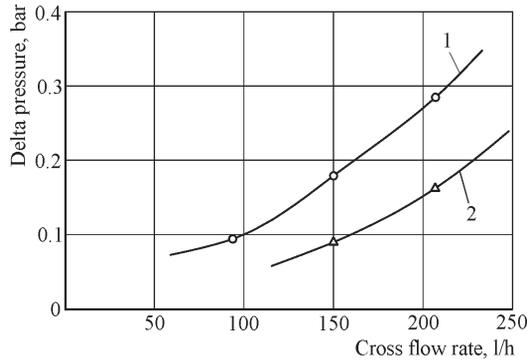


**Fig. 5.** Determination of particulate fouling rates: a) turbidity versus concentration ratio, b) fouling rate versus turbidity



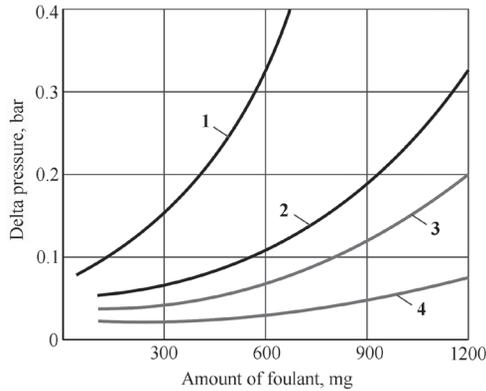
**Fig. 6.** Dependencies of circulated water colour on concentration ratio (a) and organic fouling rate on feedwater colour (b)

Comparison of delta pressure values versus flow rates for conventional spiral wound and an open-channel module is shown on figure 7. During accumulation of foulant, delta pressure increase and product flow decrease. The amount of accumulated foulant could be detected throughout circulation experiments. Figure 8 shows the delta pressure values versus flow graphs for different amounts of particulate foulants in the module. To predict product flow decrease with time, module permeate flow could be presented as a function of foulant amount and mass of accumulated foulant could be calculated using previously determined fouling rate values.

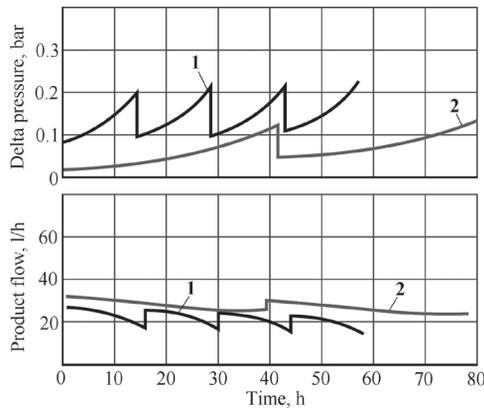


**Fig. 7.** Delta pressure increase versus cross-flow values: 1 – conventional module (1812, BLN, “CSM”); 2 – open channel module (1812, BLN)

Application of hydraulic flushings destroys fouling layers and withdraw foulants from membrane surface due to cross-flow velocity increase and water hammer initiation through rapid pressure drop. Figure 9 shows the product flow values versus time and delta-pressure versus time relationships where flushings are constantly applied after certain time periods. Flushing modes (time between flushes and flush duration) are very important to maintain fouling control and product flow on the desired level. Suspended solids concentration, colour, recovery, pressure, cross-flow velocities as well as membrane type and module design are factors that influence operational and flushing modes.

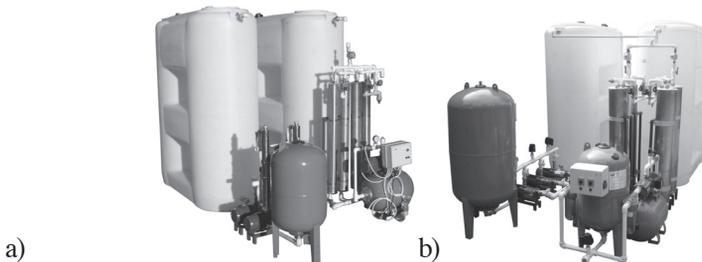


**Fig. 8.** Determination of delta pressure increase during foulant accumulation: 1, 2 – conventional module (1812, BLN, “CSM”); 3, 4 – open channel module (1812, BLN); cross-flow: 1, 3 – 100 l/h; 2, 4 – 50 l/h



**Fig. 9.** Comparison of “standard” (1) and “open-channel” (2) modules performance

Operational costs depend on the pump characteristics and energy consumption, reject effluent flow, chemical cleaning schedules (to reduce fouling) and could be minimized by selection of optimum operation conditions. Typical NF units to treat surface water are shown on figure 10.



**Fig. 10.** Nanofiltration units for surface water treatment: a) production of 10 – 15 cubic meter per day of quality drinking water; b) production of 50 cubic meter per day

## DISCUSSION OF THE RESULTS

Suspended and colloidal fouling rates are successfully determined in circulation mode. Deposition rates depend on cross-flow velocities that provide shear-force of the particles. Mechanism of deposition is obviously attributed to particle adhesion to membrane surface. Depending on membrane surface properties (hydrophilicity, surface charge) rates of colloidal and organic matter deposition could vary. Research is being conducted to modify membrane surface with a purpose to protect it from bacteria and particulate adhesion [12, 13]. Acetate membranes are less susceptible to organic and colloidal fouling. Mechanism of organic fouling is widely investigated. It is based on adsorption of organic molecules from water solution. It is also important to reveal properties of organic substances that are better adsorbed by membrane surface. To determine most likely foulants molecular mass distribution techniques are successfully applied. Molecular mass of main potential foulants could be detected and their sorption rates determined [5].

Suspended and colloidal particulate fouling is dependent on cross-flow velocities and is rising with flow decrease. Organic sorption provides opposite relationship: the higher velocity is the more is adsorption rate. This fact could have two explanations: colloidal fouling layer blocks the active surface and reduce sorption rate and sorption process occurs according to diffusion mechanism and is going on more intensively with higher flow velocities.

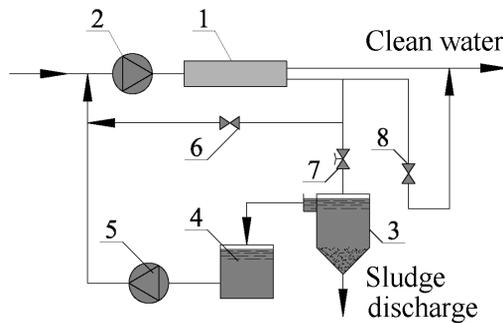
Hydraulic flushing provides efficient measure to control fouling. Large amount of colloidal and organic material accumulated during hours of operation is efficiently flushed-off membrane surface in a few seconds. Meanwhile, analysis of flush water shows that the colour of it is different and depends on operation conditions. This fact prompted that foulant and water colour could interact. Colloidal foulant (mainly surface water humic acids) sorbs organics (fulvic acids) due to amide and peptic ties. The more foulant is deposited on membrane surface, the higher is flushing water colour and vice versa: small particulate and colloidal foulant amounts correspond to lower colour values in flushing water effluents. It was concluded that organics adsorbed by the foulant is successfully flushed off membrane surface and organics is more intensively adsorbed by membrane surface than by fouling layer.

Channel geometry is a strong factor that influences on membrane performance if fouling occurs. During foulant accumulation delta-pressure is growing. Product flow decrease during fouling is mainly attributed to increase of hydraulic resistance and loss of applied working pressure. When open-channel modules were tested the observed rates of delta pressure increase and product flow decrease was significantly lower.

## INDUSTRIAL APPLICATION OF THE RESULTS. WAYS TO REDUCE CONCENTRATE FLOW AND INCREASE RECOVERIES

RO and NF techniques are successfully applied to treat natural water and produce quality drinking water.

Fig. 11 shows flow diagram of surface water treatment system to remove colloidal and suspended particles, colour and organics. Flush water effluents are collected in sedimentation tank. Membrane unit is operated in circulation mode and recovery could reach 90-95 per cent. After sedimentation of suspended particles and adsorbed organics this water could be mixed with product water. Thus, sedimented sludge contains all removed impurities. Concentrate after sedimentation does not contain these impurities and could be mixed with product water. Product water after mixing contains all ingredients in conformity with WHO standards.



**Fig. 11.** A flow diagram of surface water treatment with reverse osmosis membranes: 1 – membrane module, 2 – high pressure pump; 3 – flush water sedimentation tank; 4 – clean water collection tank; 5 – pump; 6 – pressure valve; 7 – solenoid valve; 8 – pressure regulation gauge

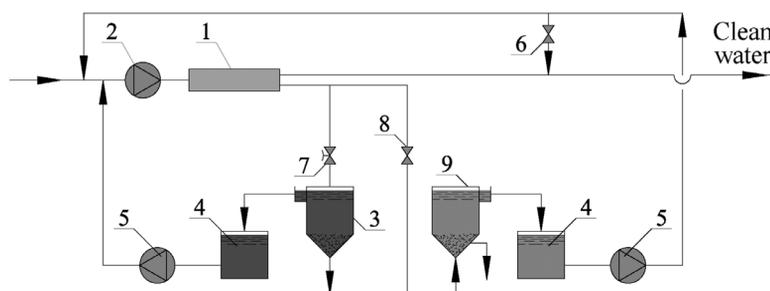
Table 1 presents results of chemical analysis of surface water, RO concentrates and product water (membrane permeate).

**Table 1.** Water quality characteristics

№	Parameters	Surface water from Desna river	Filtrate	Concentrate
1	Calcium, meq/l	3.8	0.5	9.5
2	Magnesium, meq/l	2.3	0.4	6.5
3	Chlorides, mg/l	72.4	53.3	364.0
4	Sulfates, mg/l	39.7	10.2	208.0
5	Alkalinity (hydrocarbonates), meq/l	5.9	2.2	20.5
6	pH	6.75	6.84	7.6
7	Permanganate oxidability, mg/l	6.48	9.52	108.0
8	Colour, degree	42.0	17.5	368.0
9	Turbidity, mg/l	12.1	1.1	145.0

The described membrane techniques could be applied only for the cases when feedwater contains colloidal matter, iron, colour etc. For other complicated cases when water contains excessive hardness, fluorides, ammonia etc. special membrane tools are applied. In these cases product flow is mixed with a part of concentrate (reject) flow that ensure final concentration of each ingredient corresponding to drinking quality standards. Other part of reject flow could be discharged in the drain or further concentrated and withdrawn together with sedimented sludge. Water in sludge (sludge humidity) averagely constitutes 0.8-1.0% of initial water volume. Thus membrane reject stream could be concentrated by 50-100 times by volume through the use of additional RO membrane unit and all excessive salts and impurities could be withdrawn from the system together with sludge as sludge humidity. Membrane (RO and NF) techniques are very efficient when are used to remove fluoride, strontium, nitrates, ammonia, arsenic from well water. The main problem that arise when membrane is applied – utilization of reject streams.

Concentrate volume could be dramatically decreased by its multiplied concentration by RO with increased recoveries. A flow diagram of membrane process used to remove iron, hardness and other dissolved impurities is shown on Fig. 12.



**Fig. 12.** Well water treatment flow diagram: removal of iron, hardness, fluoride, ammonia etc. with RO membranes without concentrate discharge: 1 – membrane module, 2 – high pressure pump; 3 – flush water sedimentation tank; 4 – clean water collection tank; 5 – pump; 6 – pressure valve; 7 – solenoid valve; 8 – pressure regulation gauge; 9 – calcium carbonate precipitation reactor

Calcium carbonate formation on membrane surface is a main factor that resists multiplied concentration of the feedwater. It was already reported that the use of an “open channel” membrane modules enables us to concentrate calcium carbonate and calcium sulphate solutions that become supersaturated without a risk to scale-up membrane. The use of such a reliable modules could also suggest a new reagent-free techniques to remove calcium carbonate from the feedwater.

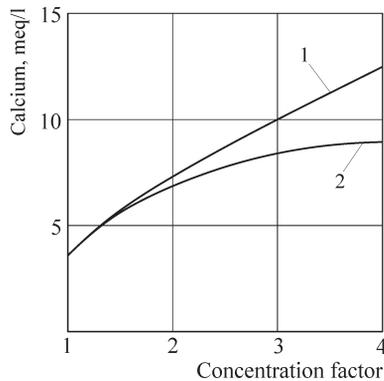
The flow diagram showing principles of calcium carbonate precipitation from the RO concentrate is shown on Fig 11. Concentrate is added to reactor where seed crystals are. The RO unit is operated in constant concentration mode, concentrate enters reactor and after precipitation of supersaturated excessive calcium carbonate on a seed mass is withdrawn from reactor and forwarded to the inlet of the

membrane unit. Thus, concentrate always enter reactor having increased concentration values of calcium and carbonate ions as well as values of Langelier index.

Table 2 offers concentration values of calcium, carbonate, chloride ions and pH. While concentrate passes through reactor calcium carbonate is precipitated on the seed mass and calcium concentration does not increase, as it is shown on Fig. 13. The described calcium carbonate removal procedure offers efficient water softening tools that do not require chemicals and do not increase water TDS value.

**Table 2.** Concentrate composition transformation after contact with seed mass

Parameters	Feedwater	Concentrate	Concentrate after contact with seed mass
Calcium, meq/l	3.75	8.2	7.4
Alkalinity ( $\text{HCO}_3^-$ ), meq/l	3.4	8.4	4.8
Chlorides, mg/l	9.23	17.8	17.8
pH	6.8	7.11	7.0

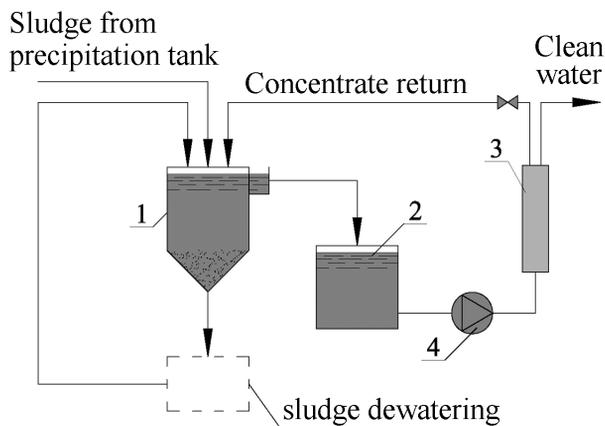


**Fig. 13.** Dependence of calcium ion concentration value on the feed water concentration ratio: 1 – concentrate of membrane unit; 2 – water at the exit from precipitation reactor (after contact with seed mass)

For majority of well water treatment cases to meet drinking water standards partial removal of hardness, iron, fluoride, nitrates, ammonia, strontium etc. In these cases major part of concentrate flow could be mixed with membrane product water to reach drinking quality. The described technical approach enables us to completely utilize concentrate flow by producing drinking quality water and sludge (iron hydroxide and calcium carbonate). For some cases, depending on TDS and ionic species concentration values concentrate could not be mixed with product water. To utilize concentrate, the described above procedure could be applied to concentrate feed water by 100-200 times by volume so concentrate flow constitutes about 0.5% of initial feed flow. If initial feed TDS is 300-500 ppm, concentrated by 100 times feed flow TDS would be 20000-30000 ppm assuming that calcium carbonate is withdrawn. The sludge after dewatering contains about 0.4-0.5% of initial water. The

described concentrate utilization procedure provides all excessive rejected by membrane salts and components disposal together with sludge with concentrate flow does not exceeding 0.4% of product water flow.

The described above techniques could be successfully applied to solve a problem of sludge dewatering – utilization of filtrate after sludge vacuum filtration. Such effluents often contain aluminum, flocculation chemicals and organics that provide colour. These effluents could not be discharged in surface water sources. According to developed and presented above procedure sludge dewatering filtrate could be concentrated by 10-15 times using RO unit (Fig. 14). The RO reject stream (concentrate) is discharged together with dewatered sludge as it volume corresponds to sludge humidity. The total amount of salts in the sludge withdrawn from water treatment facilities is equal to amount of salts containing in the dewatered sludge. RO permeate could be mixed with treated drinking water.



**Fig. 14.** The use of RO techniques to concentrate and utilise water filtrate after sludge dewatering at municipal water plants (process flow diagram): 1 – sludge thickening tank; 2 – concentrate collection tank; 3 – reverse osmosis module; 4 – pump

## CONCLUSIONS

Long research devoted to membrane fouling has revealed that fouling mechanisms depend not only on hydrodynamic conditions in membrane channel, but on membrane material sorption characteristics and channel configuration as well. The existing spiral wound modules used in RO, NF and UF facilities are very susceptible to fouling that makes them useless for water treatment containing high organics, bacteria and suspended matter.

Main disadvantages of spiral wound modules are attributed to presence of spacer mesh in the channel that trap fouling particles and increase delta-pressure of the module.

Introduction of new open-channel modules suggests a new approach to treat wastewater with high fouling potential without a fear to suffer fouling problems throughout a long period of stable operation.

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## ZASTOSOWANIE MEMBRAN DO OCZYSZCZANIA WODY I ŚCIEKÓW: NOWE ASPEKTY ZMNIEJSZENIA ZANIECZYSZCZENIA I ZWIĘKSZENIA ODZYSKU DO 99%

**Streszczenie.** Badania wykazują, iż wysokie koszty eksploatacji urządzeń z zastosowaniem membran i duże ilości odcieków są przypisywane zanieczyszczeniom i odkładaniu się kamienia. Procesy te zależą nie tylko od czynników hydraulicznych i hydrodynamicznych, ale także od rodzaju membran i materiałów użytych do ich budowy. Parametry pracy różnych membran wykazały najlepsze właściwości modułów spiralnych przy najniższej cenie. Przepływ przez membrany nie ogranicza się jedynie do oczyszczania, jest to także reaktor do koagulacji, zążęzania i strącania. Zawiesina po procesie koagulacji z procesu czyszczenia membran jest poddana sedymentacji i odwadnianiu. Osad z odwadniania zawiera około 8% wody. Zastosowanie modułów o "otwartych kanałach" powoduje zmniejszenie zagrożenia zanieczyszczenia i odkładania się kamienia. Rozwiązanie problemu zmniejszenia zanieczyszczenia membran pozwoli zmniejszyć koszty pracy instalacji i spowoduje wyższy poziom ekologicznej efektywności narzędzi wykorzystujących technikę membranową.

**Słowa kluczowe:** ścieki bytowe, nanofiltracja, odwrócona osmoza, odzysk, regeneracja.