

ROADMAP "APPLYING NANOTECHNOLOGIES TO WATER TREATMENT"

TECHNOLOGICAL TASKS

Reduction of the price per 1 L of purified water

CWP	SU	DF	GIU	SIU	MS	IW
1*	3	4	4	6	4	2

Nanoproducts performance improvement

CWP	SU	DF	GIU	SIU	MS	IW
3	4	5	2	3	5	1

Reduction of the price of nanoproducts

CWP	SU	DF	GIU	SIU	MS	IW
4	2	1	7	1	2	5

Extension of the life cycle of nanoproducts

CWP	SU	DF	GIU	SIU	MS	IW
5	5	2	6	4	3	6

Reduction of the power consumption in purification processes

CWP	SU	DF	GIU	SIU	MS	IW
6	6	-	3	7	6	7

Improvement of the chemical and thermal resistance of nanoproducts

CWP	SU	DF	GIU	SIU	MS	IW
7	7	-	5	5	7	4

Reduction of the ownership and maintenance costs of water treatment systems

CWP	SU	DF	GIU	SIU	MS	IW
2	1	3	1	2	1	3

Improvement of the automation of purification processes

CWP	SU	DF	GIU	SIU	MS	IW
8	8	-	8	8	8	8

* the level of importance of technological problem in the given market segment (1 = highest importance, 8 = lowest importance).

PROCESSES AND TECHNOLOGIES

Membrane-based processes and technologies

BMP		Baromembrane processes	
+	removal of fine pollutants and organic impurities impurities helps to avoid chlorine organic compounds in the water	-	cannot inhibit all types of microbiological contamination and substitute chlorination
UF		Ultrafiltration	
+	effective in the pretreatment of water resistant to chlorine and membrane fouling	-	does not remove dissolved inorganic compounds and some microorganisms
NF		Nanofiltration	
+	effective in the removal of organic low molecular compounds and microorganisms	-	high exposure to biocorrosion does not remove all salts removes only multiply charged ions
MF		Microfiltration	
+	removes suspended particles effective in pretreatment of water	-	does not remove dissolved organic and colloidal matter and many microorganisms
RO		Reverse osmosis	
+	high quality elimination of inorganic compounds and microorganisms desalting	-	purified water is not suitable for drinking high power consumption low specific production capacity

EMP		Electromembrane processes	
+	can remove traces of ions from solution	-	unable to remove uncharged components from the wastewater
ED		Electrodialysis	
+	deep demineralization and softening of water production of saturated solutions	-	corrosion of the elements frequent regeneration required low performance
EDI		Electrodeionization	
+	used at the final stage of deep demineralization low power consumption	-	high consumption of aggressive chemicals contamination of wastewater

MD		Membrane degassing	
+	high efficiency of removal of gases dissolved in the water (oxygen, carbon dioxide, etc.)	-	relevant active application is limited to the treatment of desalinated water for power production, microelectronics, and medicine

MBR		Membrane bioreactors	
+	high efficiency of wastewater purification prevention of secondary contamination of wastewater sewage treatment downsizing of the water treatment facilities	-	relevant active application is limited to wastewater purification

Prospective supporting technologies

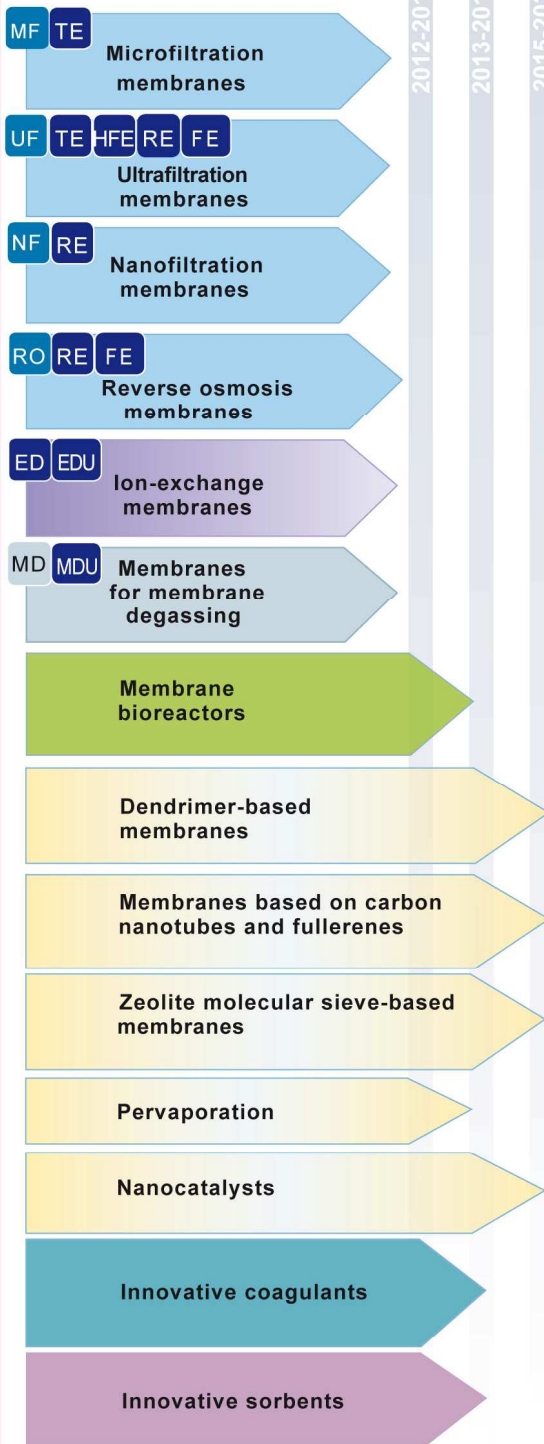
Incorporation of the dendrimers			
+	<ul style="list-style-type: none">• removal of organic contaminants• antimicrobial action• improved absorption capacity of membranes• do not clog the membrane; this reduces power consumption	-	<ul style="list-style-type: none">• unstable structure• further studies are needed
Incorporation of carbon nanotubes and fullerenes			
+	<ul style="list-style-type: none">• high reaction activity• high oxidizing ability, and, as a consequence, efficiency of disinfection• prevent accumulation of bacteria and microorganisms in membranes, this lowers membranes and tubes replacement frequency	-	<ul style="list-style-type: none">• potentially toxic• high costs• difficult to remove from the water• further studies are needed
Incorporation of zeolites			
+	<ul style="list-style-type: none">• increased membrane performance• lower clogging• removal of many types of contaminations• good adsorption capacity for bacteria and viruses	-	<ul style="list-style-type: none">• potentially toxic• high costs• further studies are needed
Catalysis			
+	<ul style="list-style-type: none">• increases efficiency of membrane purification and ozone treatment	-	<ul style="list-style-type: none">• after using the catalyst additional water treatment is required

Traditional + potential application of nanotechnology

C		Coagulation	
+	widely used relatively cost-efficient wide range of applications	-	some coagulant impurities may remain after the treatment water temperature limitations requires large tanks
A		Absorption	
+	relatively cost-efficient suitable for individual use	-	replacement of sorbents is required effective against contaminants present in low concentrations bacterial, fungal and mold growth may occur

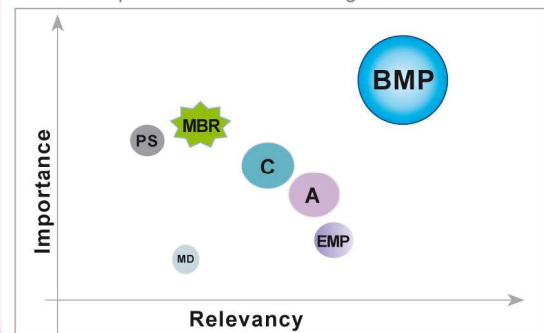
PRODUCTS Y

Year of commercialization:



- TE Unit based on tubular elements
- HFE Unit based on hollow fiber elements
- FE Unit based on flat elements
- RE Unit based on roll-fed elements
- EDU Electrodialysis unit
- MDU Membrane degassing unit

Evaluation of prospects of processes and technologies




MARKETS

Purification of water for public use

Centralized		C		A	
+	can be integrated into existing water treatment system	-	high costs and large scale modernization	Strategy: extensive state financial support of modernization	Market size, \$mln:
		2010	2015	2020	
		70	60	110	200
		1075	1690	1750	1800
				2500	2900
					3500
Decentralized		A		PB	
+	direct consumer satisfaction	-	high costs cooperation is needed for the system to function	Strategy: introduction of decentralized water supply in areas without centralized systems	Market size, \$mln:
		2010	2015	2020	
		25	30	45	60
		440	690	750	800
				1050	1300
					1600
Domestic filters		A		PB	
+	compact and affordable	-	high barriers to market entry	Strategy: R&D investment	Market size, \$mln:
		2010	2015	2020	
		34	45	90	180
		690	1000	1150	1300
				1450	1500
					2000

Industrial water treatment

General industrial use				ED	EDI	MD	C	A	PB									
	UF	NF	MF	RO														
 provides required water treatment quality	 high costs		Strategy: investments into available R&D projects for future commercialization		Market size, \$mln:													
 lower operating costs																		
					2010					2015		2020						
					70		90		140		170		100		220		350	
					3430		4100		4500		4900		4500		5100		6000	
																		

Special industrial use				C	A	PB												
	NF	RO																
 high efficiency purification	 high costs		Strategy: development of new markets (e.g. hemodialysis in medicine)		Market size, \$mln:													
					2010		2015		2020									
					13		20		30		40		20		40		70	
					235		600		650		700		750		850		950	
																		

Sewage treatment

Industrial wastewater		MBR		C		A		PB	
+	effectively purifies multicomponent wastewater	-	lack of standard solutions high costs	Strategy: promotion of MBR introduction	Market size, \$mln:				
		2010	2015	2020					
		21	30	35	40	20	50	90	
		710	1420	1500	1650	1700	2650	3000	
Municipal wastewater		MBR		C		A		PB	
+	direct satisfaction of consumer needs	-	high costs	Strategy: promotion of MBR introduction	Market size, \$mln:				
		2010	2015	2020					
		35	45	50	60	30	60	100	
		510	750	850	870	1000	1500	1700	

+	contributing factors	-	inhibiting factors	Low	Moderate	High	Market potential	0 inertial scenario	0 moderate scenario	0 active scenario
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Barriers and limitations

Lack of state financial support	Water purification services are conservative	Lack of human resources and certified specialists	Lack of research centers
Shortage of equipment in laboratories	Heavy wear of water supply systems	Poor management and public culture of water use	Inadequate protection of intellectual property
Inadequate water quality control	Lack of integrated approach to the monitoring of water supply	Lack of a harmonized legal and regulatory framework in the field of water and industrial wastewater treatment	No programs for the development of innovative approaches to water purification

ALTERNATIVE AND SUPPORTIVE PROCESSES AND TECHNOLOGIES

Common traditional methods

Electrochemical activation and pulsed power treatment

- + economic efficiency
- harmful compounds may form during the treatment

Ion exchange

- +
- ultra-pure water can be obtained
- well-tested and reliable process
- minimum power consumption
- minimum amount of secondary waste
- high consumption of aggressive chemicals
- high operating costs
- reclaim treatment is necessary

Filtration

- +
- wide range of applications
- can be used in different stages of water purification
- particle removal efficiency can be varied
- filter regeneration problems
- microbial growth may occur

Ozonation

- +
- strong disinfectant
- effective against viruses
- eliminates off-taste and off-odor
- harmful byproducts
- no residual effect
- high operating costs

Chlorination

- +
- has residual effect
- effective decontaminating agent
- decomposes organic compounds
- harmful byproducts (improved in the version which uses hypochlorite sodium)
- strict requirements for transportation and storage

Flotation

- +
- handles large volumes of water
- relatively cheap
- purification efficiency is lower than in membrane-based methods

Thermal method

- +
- minimum amounts of chemicals required
- high quality purification of suspensions
- elimination of dissolved gases
- pretreatment is required
- high power consumption
- high capital costs

Distillation

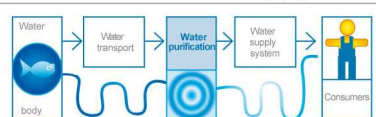
- +
- high efficiency of the purification
- reliability
- hot purified water can be obtained (important for manufacturing of drug products)
- high costs
- high-power consumption
- water pretreatment is required

Ultraviolet

- +
- does not require storage and transportation of chemicals
- does not generate byproducts
- effective against microorganisms
- no residual effect
- high operating costs and power consumption
- operation monitoring is unavailable

- CWP centralized water purification
- SU shared facilities
- DF domestic filters
- GIU general industrial use
- SIU special industrial use
- MS municipal sewage
- IW industrial wastewater

Scheme of water supply



Scheme of wastewater disposal

