CHAPTER 5.
PUBLICATIONS AND THEIR FRAGMENTS OF THE PERIOD WHEN FEM AND MB ELEMENTS WERE WIDELY USED IN ELECTROCHEMICAL SYSTEMS FOR VARIOUS APPLICATIONS

At present, several hundred thousand papers have been published all over the world devoted to electrochemically activated water and solutions. The process of wide dissemination of information on the unusual properties of water and solutions subjected to unipolar electrochemical treatment began with articles in popular science journals at the end of the seventies. The simplicity and accessibility of the process of obtaining electrochemically activated anolyte and catholyte made it possible to discover and describe thousands of most interesting applications of activated liquids and the very processes of electrochemical treatment of liquids. However, a large number of studies and results remained unclaimed or inaccessible for reproduction by other people due to inaccuracies in the description of electrochemical systems that were used to obtain electrochemically activated solutions, as well as inaccuracies in the description of the mode parameters of their operation. Certain difficulties for an adequate perception of the research results were also created by errors in the design of electrochemical devices and equipment. The emergence of flow-through electrochemical modular FEM elements, subsequently replaced by flow-through electrochemical modular MB elements, made it possible to standardize the conditions of electrochemical treatment and provide the possibility of creating both laboratory and industrial electrochemical systems of varying degrees of complexity, for various applications and productivity. Hundreds of thousands of FEM and MB cells operate in various electrochemical devices around the world. Some models have become standard products and are included in the supply range for the manufacture or repair of electrochemical systems. Tenders are announced for the supply of FEM and MB electrochemical cells. It is safe to say that FEM — MB elements have become part of the range of electrochemical technology. Therefore, the results obtained with the use of electrochemical devices for various applications with reactors made of FEM-MB elements are universal, reproducible and are of interest for researchers and workers in the practical sphere, **regardless of the time and place of research**. This chapter provides information in the form of publications and individual fragments of publications on the work performed with the use of the main tool for obtaining electrochemically activated solutions and water — FEM and MB elements as part of various electrochemical systems.

5.1. THE RESULTS OF WATER PURIFICATION EFFICIENCY IN EMERALD DEVICES

There is a well-known everyday idea that the consumer qualities of drinking water are the better, the less it contains dissolved chemicals and other "foreign" impurities. However, in nature there is a significant amount of trace elements necessary for the body, which enter the body mainly with water. For example, many metals are part of active enzyme groups, and therefore excessive desalination of water leads to neuro-endocrine disorders.

A purely mechanistic urge to remove from drinking water all that it contains is essentially tantamount to turning it into a distillate that is not suitable for constant drinking. In a number of localities where the population constantly

V.M. Bakhir, Yu.G. Zadorozhny, B. I. Leonov, S. A. Panicheva, V. I. Prilutsky. ***Electrochemical activation: water purification and obtaining functional solutions****. — M.: VNIIMT, 2001. — 176 p.; — ill.*

drinks ultra-fresh water, endemic foci of pathology associated with water factors tend to develop.

At the same time, there is no exact recipe for "perfect" drinking water. Therefore, in the process of purification or additional purification of water, the following tasks should be solved:

- removal of pathogenic and excess microflora;
- elimination of colloidal suspensions;
- elimination of excess chemical impurities (inorganic and organic) to a level corresponding to hygienic standards;
- removal of toxic impurities from water, their neutralization either by complete destruction or transformation into chemical forms that are safe for the body;
- preservation of trace elements useful for the body in water;
- preservation of normal organoleptic properties of water or improvement of its organoleptic characteristics;
- improvement and normalization of the redox properties of water.

Under natural conditions, self-purification of water is carried out on the basis of the processes of oxidation, reduction, catalysis, sorption, filtration, ion exchange, structuring of water in contact with soils and rocks.

EMERALD-type devices of all varieties — from the simplest to the most advanced ones — carry out almost all of the above processes of water purification in a short time frame in extreme physicochemical conditions. At the same time, the results of processing different water samples in the same device can differ significantly. However, the experience accumulated in years of testing EMERALD devices allows us to identify a number of certain patterns presented in Tables 5.1.1—5.1.17. The tables take into account the data of the research of the EMERALD systems with various technological processes of water purification — Emerald, Crystal, Sapphire, Rubin, Aquamarine, Topaz — for the period of 1991 to1999. From January 2000 to June 2011, NPO EKRAN produced EMERALD devices with improved and new technological processes for water purification: Sapphire-M, Agat-M, Topaz-M, Quartz and Diamond.* Below is a list of sources of information on the test results of EMERALD devices. Evaluation of efficiency of the devices was carried out by various companies and laboratories at different times, either according to generally accepted protocols and methods, which are intended for studying other types of systems for water purification (non-electrochemical), or according to specially developed methods that are not standard. At present, standard protocols and test methods for three types of systems are generally accepted in the world: filtration, reverse osmosis, and systems for ultraviolet water treatment. Each type of standard method has been specifically designed for a specific type of system and cannot be used for systems of another class. Each test standard for a water purification system includes special test reports drawn up taking into account the physicochemical characteristics of the purification process itself. Therefore, for example, protocols and test procedures for reverse osmosis systems do not correspond to the documents for systems with conventional micro and ultrafiltrations or sorbents. The lack of a standard for methods of testing electrochemical systems today is the main obstacle to their wide use in the world.

* *Note: Since 2018 the authorized manufacturer of Emerald-type devices along with the Vitold Bakhir Institute is EMERALD ECOTECHNOLOGIES LLC (www.emerald.eco).*

However, the data of experimental studies obtained by methods that do not correspond to the standard ones for this type of systems are especially valuable, since they characterize a high level of product performance.

In Tables 5.1.1–5.1.17 the numbers in the entries *Sources of information* coincide with the numbers of the list of sources of information on the results of experimental studies of EMERALD devices of various models.

List of sources of information on the test results of EMERALD devices of various models

1. Results of research of the analytical laboratory of military unit 44881, Rostov-on-Don, 1994.
2. Results of research of the analytical laboratory of of Samsung Co., South Corea, 1995.
3. Results of research of the Aquita Medical-Ingeneering Center, Moscow,1997.
4. Report of the St. Petersburg State Medical Academy named after I.I. Mechnikov, Department of Communal Hygiene, St. Petersburg, 1996.
5. Results of the research of the Aquapure engineers laboratory, New Delhi, India, 1994 (starting water obtained from an open reservoir).
6. Quality Analysis Lab. Protocol, Malta, 1998.
7. Report on the microbiological assessment of household water purifiers of the EMERALD system, Izhevsk State Medical Academy, Department of Microbiology, Izhevsk, 1997.
8. Test report of the Izumrud-M water purification device for water disinfection, Scientific Research Institute of Preventive Toxicology and Disinfection (NIIPTiD), Moscow, 1995, as well as other reports of NIIPTiD.
9. Oaklend Calvert Consultants Ltd. Analytical Report, England, 1994.
10. Test results of the Northern County SES analytical Laboratory, Moscow, 1991 (testing water samples brought from the island of Cyprus).
11. Report of Research Institute of Human and Environment Ecology named after A. N. Sysin, Moscow, 1994.
12. The Conclusion of the StatniZdravotniUstavnaronnirefe rencnicentrumpropitnouvodu Analytical Service, Praha, 1994.
13. Results of the research of Moscow Timiryazevsky District SES Analytical Laboratory, 1991 (water samples from an open reservoir were under study).
14. Results of the research of the Jordan Antiseptic Company Analytical Service, Amman, 1993.
15. Scientific report on the results of sanitary-hygienic and sanitary-microbiological research of filters for additional purification of drinking water of various modifications, Samara Military Medical Institute, Samara, 1999.
16. Berkshire Microbiological Service Certificate — UK, 1991.
17. Report on testing the efficiency of drinking water purification using the EMERALD-C and EMERALD-K systems, Kyrgyz Research Institute of Preventive Care and Medical Ecology, Bishkek, 1996.
18. Sanitary and hygienic conclusion on approbation of Emerald water disinfection and purification system. Sanitary and hygienic laboratory of the Republican SES of the Ministry of Health of the Republic of Uzbekistan, 1993.
19. Report on testing the efficiency of drinking water purification using the "EMERALD-M" system. Academy of Postgraduate Education, St. Petersburg, Department of Medical Ecology, St. Petersburg, 1999.
20. Results of research of SES Analytical Service, Kirov, 1999.
21. Conclusion on experimental assessment of ecological and hygienic safety and efficiency of EMERALD household devices intended for tap water purification. St. Petersburg State Medical Academy. Department of Ecology and Environmental Hygiene. St. Petersburg, 1995.
22. Report of the All-Russian Scientific Research Institute of Medical Technology (VNIIIMT), Ministry of Health of the Russian Federation, Moscow, 1999.
23. Laboratory of the Center for Sanitary and Epidemiological Supervision, Yegoryevsk, Moscow Region, 1996.
24. Report of the All-Russian Scientific Research Institute of Medical Technology (VNIIIMT), Ministry of Health of the Russian Federation, Moscow, 1998.
25. Report of the St. Petersburg State Medical Academy named after I.I. Mechnikov, Department of Communal Hygiene, 1996; Hygienic assessment of the efficiency of drinking water purification using Aquamarine system.
26. Official report on heavy metal and pesticide residues of water to prove the effectiveness of Crystal. Lao People s Democraatic Republic, Ministry of Public Health of Hygiene and Epidemiology. № 836/NIHE, 1995.
27. Test report of the AQUEL-05 analyzer on the quality of water purification in EMERALD systems. Institute Biosensors, Moscow, 1993.
28. Test report of the EMERALD K potable water tertiary treatment device for some pollutants. St. Petersburg Medical Academy of Postgraduate Education. Department of Medical Ecology, St. Petersburg, 1996.

Table 5.1.1

Results of microbiological studies of water treated in EMERALD devices*

Indicators	Starting water	Treated water	Disinfection efficiency, %	Sources of information
Total microbial count (TMC), CFU/ml **MPC = 50 CFU/ml** (SanPiN 2.1.4.559–96)	10^2 $>10^2$ 10^2–10^3 10^2–10^3 10^3 10^3–10^4 10^5–10^6	0–10^0 10^0 0–10^0 10^0 10^0 10^0 10^1	> 99 > 99.9 > 99.9 > 99.9 > 99.9 > 99.9 > 99.99	1. 4 2 3 4 5.6 7 9
Coli-index, CFU/l **MPC = 3 CFU/l (GOST 2874–82)**	10^2 10^2 10^2–10^3 10^3 $8.6{\cdot}10^2$** $1.6{\cdot}10^2$** 10^5 10^5–10^6 10^7 $6{\cdot}10^7$	10^0 0 0–10^2 0 $2.5{\cdot}10^1$ < 3 10^2 10^3 10^0 10^2–10^3	>99 > 99 > 99 > 99.9 >97 > 98 >99.9 >99.9 > 99.9 > 99.99	10 11 7 12 4 4 8 14 15 16
Salmonella, u/ml	$4{\cdot}10^6$	10^2	> 99.99	16
Enterobact. fecalis, u/ml	10^3	0	> 99.9	12
Pseudomonas, u/ml – `` –	$4{\cdot}10^6$ $7{\cdot}10^5$	10^2 10^3	> 99.99 > 99	16 14
Micrococci, u/ml	10^3–10^4	0	> 99.9	7
Legionella, u/ml	$8{\cdot}10^6$	10^0	> 99.99	16
B. Subtilis, u/ml	10^4	10^3	>90	14
Anthracoids, u/ml	10^3–10^4	0	> 99.9	7
Bifidobacteria, u/ml Lactobacillus, u/ml	10^1–10^{11} 10^1–10^{11}	0 0	> 99.99 > 99.99	7 7
Polio virus, u/ml – `` – Hepatitis A virus antigen, conv. units.	10^7 $7{\cdot}10^8$ Test (+)	10^1–10^2 10^3 Test (–)	>99.99 >99.99 Qualitative effect	17 16 17
Causative agents of typhoid, paratyphoid fever, Staphylococcus aureus, Escherichia coli (st. 11303), u/ml	$7.5{\cdot}10^3$	No growth	>99.9	18

Note:

* *Data obtained from testing of EMERALD-type devices for water treatment in accordance with technological processes "EMERALD", "Crystal", "Sapphire", "Rubin", "Topaz" and others. The studies were carried out in a wide range of conditions on samples of ordinary drinking water and on model aqueous solutions seeded with microorganisms. According to the requirements of GOST and SanPiN, pathogenic microorganisms in drinking water must be completely absent. CFU stands for colony-forming units.*

*** The indicators of water from an open reservoir were investigated, bypassing the pre-treatment phase.*

Comment to Table. 5.1.1. In all samples, taking into account a wide variety of test conditions, the TMC indicator is guaranteed to meet the hygienic standard with the initial TMC values no more than 10,000 CFU/ml, inclusive. Guaranteed water disinfection in an electrochemical reactor is 4 log reduction (not less). With the initial values of TMC 100,000-1,000,000 CFU/l, disinfection is achieved by 3-5 log reduction. In all samples of treated water, regardless of the degree of contamination of the source water, the TMC does not exceed the standard in accordance with GOST 2874–82 (100 CFU/l).

Table 5.1.2

Organoleptic characteristics, pH and redox values (ORP) of water treated in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Color, grades **Standard = 20 (GOST 2874–82)**	10 16 20 25 27 30 35	10 < 7 20 20 10 15–20 15–20	0 > 50 0 20 63 33–50 43–57	20 2 19 19 15 19 19
Turbidity on a standard scale, mg/l **Standard is 1.5 mg/l (GOST 2874–82)**	0.5 0.7 0.73 1.0 1.4 1.9 2.0 2.0 2.3 6	0.5 0.5 0.32 0.5 1.1 0.9 1.4 1.2 1.0 < 4	0 29 56 50 21 53 30 40 57 > 33	19 19 23 19 15 20 18 19 19 2
Smell at 20°C, points **Standard = 2 (GOST 2874–82)**	1 1–2 2 2 2–3 3 3–4 4	0 1–2 2 1 2 2 2 2	100 0 0 50 33 33 25–50 50	17 20 19 18 15 19 15 19
pH, **Standard pH 6.0–9.0 (GOST 2874–82)**	5.8–7.2 6.8 6.65 6.7 7.9 8.0 6.8–7.2 8.0	6.8–7.5 6.8 6.45 7.35 7.65 8.1 7.0–7.4 8.2	– – – – – – – –	19 20 4 21 17 18 22 23
Oxidation-reduction potential (ORP), mV, SCE* (not standardized)	240 415 ± 7 320 ± 80	0 ± 35 73 ± 3 0 ± 75	– – –	4 21 22

Note:
** Measured by platinum electrode with a silver chloride reference electrode (SCE).*

Comments to Table 5.1.2. According to the test data treted water by EMERALD devices with technological processes of water purification EMERALD, Crystal, Sapphire, Rubin comply with the following standards:

- by color — with the color of the starting water up to 35 grades;
- by turbidity — with the turbidity of the starting water about 3 mg/l;
- by smell — with the starting water smell 4 points at 20°C;
- compliance with the pH of the treated water with GOST requirements is fully guaranteed;
- in treated water, ORP offset is guaranteed by 240–340 mV in the direction of biologically favorable reduction (lower) values, providing a protective antioxidant background in water.

Table 5.1.3

Solids content, total hardness indicators, chloride and sulfate content in water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Dry residue, mg/l **MPC = 1000 (GOST 2874–82)**	319 320 476 1118	313 305 310 698	- 5 35 38	17 23 18 2
Total hardness, mg-eq/l **MPC = 7.0 (GOST 2874–82)**	2,8 3,7 4,2 4,3	2,8 3,7 4,1 3,9	0 0 2 9	20 20 17 21
Permanganate oxidizability, mg/l **MPC = 5.0 (SanPiN 2.1.4.559–96)**	2,8 5,5 5,6 9,7	2,4 2,4 4,8 2,1	14 56 14 78	20 19 20 19
Chlorides, mg/l **MPC = 350 (GOST 2874–82)**	13 25 24 57 180 431	13 25 22 57 158 356	0 0 8 0 12 17	17 20 20 18 21 2
Sulfates, mg/l **MPC = 500 (GOST 2874–82)**	1,5 28 29,8 130 130 131 560	1,5 28 29,6 98 103 109 594	0 0 0 25 11 17 -	18 21 17 21 21 21 2

Comments to Tables 5.1.3 and 5.1.4.

The treatment of water in the EMERALD devices leads to a decrease in the dry residue by approximately 40%, with an initial value of over 300 mg/l. The total hardness is reduced by approximately 50% at the initial values of 6.0–25.0 mEq/l. The values of the permanganate oxidizability of the treated water samples decreased by 56–78% with the initial values exceeding the requirements of GOST. The indicators of the total hardness and permanganate oxidizability of water that meet the requirements of GOST do not change significantly after treatment.

Table 5.1.4

Concentration of chlorides, sulfates, as well as dry residue and water hardness after treatmentin EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Water sampling point
Dry residue, mg/l **MPC = 1000 (GOST 2874–82)**	2808	1598	43	Rostov region
	1308	784	40	Rostov region
	1284	896	30	Rostov on Don
	590	257	56	Izhevsk
	510	352	31	St. Petersburg
	480	320	37	Tashkent
	330	215	35	Vladimir
	250	230	8	Moscow
	140	135	4	Cyprus island
Total hardness, mg-eq/l **MPC = 7.0 (GOST 2874–82)**	25.0	12.8	49	Rostov region
	17.1	9.8	43	Rostov region
	17.1	8.5	50	Rostov on Don
	6.0	3.1	48	Izhevsk
	4.4	3.8	14	St. Petersburg
	2.6	2.35	10	Tashkent
	1.9	1.9	0	Vladimir
	4.1	3.4	17	Moscow
	2.5	2.3	8	Cyprus island
Chlorides, mg/l **MPC = 350 (GOST 2874–82)**	655	164	75	Rostov region
	438	270	38	Rostov region
	143	71	50	Rostov on Don
	224	102	54	Izhevsk
	185	172	7	St. Petersburg
	57	56	2	Tashkent
	13	12	8	Vladimir
	184	164	11	Moscow
	49	47	4	Cyprus island
Sulfates, mg/l **MPC = 500 (GOST 2874–82)**	1.05	0.98	7	Rostov region
	146	148	- 47	Rostov region
	617	329	40	Rostov on Don
	545	236	5	Izhevsk
	130	123	6	St. Petersburg
	1.6	1.5	5	Tashkent
	42	40	16	Vladimir
	137	115	3	Moscow
	89	86		Cyprus island

Indicators of dry residue in starting water, mg/l	Average values of dry residue reduction in treated water, %
< 300	4.5 ± 1.4
300–600	43 ± 4.9
1200–2000	38 ± 2.8

Table 5.1.5

Efficiency of removing aluminum ions from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Residual aluminum, mg/l **Assessment according to GOST 18165-81, as well as: methods of plasma photometry, atomic absorption spectrometry** **MPC = 0.5 (GOST 2874-82, SanPiN 2.1.4.559–96)**	0.16 0.16 0.41 0.41 0.95 0.95 1.1 2.0 2.0 2.15 2.35 6.25 6.25 6.30 6.30	0.05 0.09 0.06 0.07 0.31 0.40 0.24 0.135 0.82 0.32 0.4 0.15 0.26 0.19 0.23	69 44 85 83 67 58 88 93 59 85 83 98 96 97 96	17 17 21 21 17 17 18 16 9 4 25 21 21 21 21

Range of initial values of the indicator, mg/l	Average values of the indicator decrease after treatment in the device, %
< 0.5	70 ± 9.4
0.95	62.5 ± 4.5
0.9–2	73.0 ± 7.3
2.15–2.35	83–85
> 6	97 ± 0.5

Table 5.1.6

Efficiency of removing chromium ions from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Chromium ions, mg/l **Assessment by ISO 9174-90 (atomic absorption spectrometry)** **MPC = 0.05 (SanPiN 2.1.4.559–96)**	0.03 0.067 0.078 0.44 0.52 0.55 0.60 0.61 0.66 10.0	0.01 0.025 0.025 0.03 0.03 0.03 0.02 0.03 0.03 0.001	77 63 68 93 94 95 97 95 95 > 99	21 4 25 19 19 21 21 21 19 16

Range of initial values of the indicator, mg/l	Indicator decrease values after treatment in the device, %
0.03–0.078	63–77
0.44–0.66	93–97
10.0	> 99

Table 5.1.7

Efficiency of removing iron ions from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Iron ions, mg/l **Assessment according to GOST 4011-72 or ISO 6332 — atomic absorption spectrometry MPC = 0.3 (GOST 2874-82, SanPiN 2.1.4.559–96))**	0.5	0.15	70	23
	0.52	0.13	75	19
	0.42	0.08	81	19
	2.84	0.22	92	19
	3.05	0.17	94	19
	0.36	0.08	78	19
	2.54	0.18	93	19
	0.44	0.08	82	19
	3.05	0.18	94	19
	0.47	0.09	81	21
	5.38	0.11	98	21
	5.44	0.19	97	21
	0.49	0.07	86	21
	0.08	0.06	25	20
	0.04	0.03	25	20
	3.0	0.21	93	18
	0.1	0.03	70	15
	2.0	0.5	75	15
	2.0	0.1	95	16
	0.5	0.2	60	24
	0.28	0.23	18	24

Range of initial values of the indicator, mg/l	Average values of the indicator decrease after treatment in the device, %
<0.3	35 ± 12
0.3–1.0	78 ± 3
1.0–2.0	85 ± 6
2.0–5.5	95 ± 1

Table 5.1.8

Efficiency of removing copper ions from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Copper ions, mg/l **Assessment according to ISO 8288 MPC = 1.0 (GOST 2874-82, SanPiN 2.1.4.559–96))**	0.06	0.01	83	19
	0.06	0.01	83	19
	0.08	0.01	87	19
	0.315	0.225	29	17
	0.55	0.26	53	15
	0.55	0.30	45	15
	2.17	0.52	76	19
	2.51	0.35	86	19
	3.14	0.38	88	21
	3.14	0.75	76	21
	3.24	0.32	90	21
	3.24	0.71	78	21
	5.05	0.38	92	18
	19.5	4.1	79	9
	30.0	0.13	> 99	16

Range of initial values of the indicator, mg/l	Indicator decrease values after treatment in the device, %
0.06–0.55	29–87
2.17–5.05	76–92
19.5–30.0	79 — (> 99)

Table 5.1.9

Efficiency of removing zink ions from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Zinc ions, mg/l **Assessment: Plasma Spectrometry, Atomic Absorption Spectroscopy** **MPC = 5.0 (GOST 2874-82, SanPiN 2.1.4. 559–96)**	3.1 25.0 50.0	0.94 0.70 0.2	70 97 >99	4 18 16

Table 5.1.10

Efficiency of removing arsenic and selenium from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Arsenic, mg/l **Assessment by ISO 11969** **MPC = 0.05 (GOST 2874–82, SanPiN 2.1.4. 559–96)**	0.01 0.15 0.15 0.18 0.18	0.0082 0.002 0.005 0.03 0.04	18 99 97 83 78	17 21 21 21 21
Selenium, mg/l **Assessment by ISO 9965** **MPC_1 = 0.001 (GOST 2874–82);** **MPC_2 = 0.01 (SanPiN 2.1.4.559–96))**	0.08 0.08 0.09 0.09	0.003 0.004 0.002 0.003	96 95 98 97	21 21 21 21

Table 5.1.11

Efficiency of removing cadmium, barium, nickel from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Cadmium, mg/l * **MPC = 0.001 (SanPiN 2.1.4.559–96)**	0.004 0.0055	0.0012 0.001	70 82	4 25
Barium, mg/l * **MPC = 0.1 (SanPiN 2.1.4.559–96)**	0.48	0.095	80	4
Nickel, mg/l * **MPC = 0.1 (SanPiN 2.1.4.559–96)**	0.45	0.003	> 99	4

Notes:
** testing by atomic absorption spectroscopy*

Table 5.1.12

Efficiency of removing mercury from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Mercury, mg/l **Assessment by ISO 5666** **MPC = 0.00005 (SanPiN 2.1.4.559–96)**	0.011 0.013 0.013 0.5	0.003 0.002 0.003 0.002	73 85 77 > 99	21 21 21 16

Table 5.1.13

Efficiency of removing lead from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Lead, mg/l **Assessment by ISO 8288** **MPC = 0.03 mg/l** **(SanPiN 2.1.4.559–96, GOST 2874–82)**	0.0005	0.00002	96	26
	0.01	0.00	≈ 100	19
	0.01	0.00	≈ 100	19
	0.01	0.00	≈ 100	19
	0.01	0.00	≈ 100	21
	0.01	0.00	≈ 100	21
	0.02	0.00	≈ 100	19
	0.072	0.025	65	4
	0.11	0.024	78	18
	0.32	0.01	97	21
	0.32	0.01	97	21
	0.33	0.02	94	21
	0.33	0.02	94	21
	0.45	0.02	96	19
	0.50	0.02	96	16
	0.55	0.01	98	19
	0.58	0.02	97	19

Table 5.1.14

Efficiency of removing phenol from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Phenol, mg/l **Assessment by ISO 6439–90** **MPC = 0.001** **(SanPiN 2.1.4.559–96)**	0.0007	0.0001	86	21
	0.0058	0.00087	85	4
	0.01	0.003	70	16
	0.01	0.004–0.007	60–30	21
	0.02	0.01	50	2
	0.15	0.01	93	19
	0.21	0.01	95	19
	0.24	0.01	96	19
	0.26	0.01	96	19
	1.0	0.1–0.2*	80–90	27
	1.0	0.3–0.4**	60–70	27

Notes:
** — when testing the model solution on the EMERALD-M device.*
** * — when testing the model solution on the EMERALD-K device.*

Table 5.1.15.

Efficiency of removing mineral nitrogen-containing substances from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency, %	Sources of information
Ammonium ions. mg/l **Assessment by GOST 4192–82** **MPC = 0.5–2.0** **(standards of Sumsung and other sources)**	0.44	0.44	0	20
	1.9	1.7	11	2
	4.0	0.51	87	15
	4.0	0.75	81	15
Nitrates, mg/l **Assessment by ISO 7890–3 MPC = 45** **(GOST 2874–82)** **MPC = 10 (USEPA)**	1.15	1.15	0	18
	4.0	1.0	75	15
	4.0	1.05	74	15
	21	12.0	43	21
	21	17.0	19	21
	23.4	23.4	0	17
	25.4	23.0	9	12
	29.9	26.6	11	2
	34.0	33.0	3	9
Bitrates, mg/l **Assessment by ISO 6777** **MPC_1 = 3 (SanPiN 2.1.4.559–96)** **MPC = 1 (USEPA)**	0.01	0.002	80	20
	0.018	<0.008	> 56	9
	1.0	0.01	99	21
	1.0	0.01	99	21

Table 5.1.16

Efficiency of removing benzene. chloroform. trichlorethylene. tetrachlorethylene from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency. %	Sources of information
Benzene. mg/l **Assessment: liquid chromatography** **MPC = 0.01 (SanPiN 2.1.4.559–96)**	1.95	0.5	74	4
Cloroform, mg/l **Assessment: liquid chromatography** **MPC = 0.2 (SanPiN 2.1.4.559–96)**	0.105 0.17	0.029 0.06	72 65	28 4
Trichlorethylene, mg/l **Assessment: liquid chromatography** **MPC = 0.005 (USEPA)**	0.09	0.02	78	2
Tetrachlorethylene, mg/l **Assessment: liquid chromatography** **MPC = 0.005 (USEPA)**	0.0003 0.0003 0.03 0.085	0.0001 0.0001 0 0.001	67 67 100 98	21 21 2 16

Table 5.1.17

Efficiency of removing organic pollutants (surfactants. insecticides. pesticides. trihalomethanes) from water after treatment in EMERALD devices

Indicators	Starting water	Treated water	Removal efficiency. %	Sources of information
Surfactants. mg/l **Assessment by ISO 7875/2–90** **MPC = 0.5 (SanPiN 2.1.4.559–96)**	3.64	0.21	94	19
Carbon tetrachloride, mg/l **Assessment: gas chromatography** **MPC = 0.006 (SanPiN 2.1.4.559–96)**	18.6	5.6	70	28
2.4 — dibromomethane, mg/l **Assessment: gas chromatography** **MPC — no data**	81.3	24.6	70	28
DDT, mg/l Assessment: gas chromatography	9.21	1.07	88	28
DDT-RR, DDT-OR, DDE-RR, mg/l, repectively **Assessment: gas chromatography** **MPC — DDT by total fractions 0.002 (SanPiN 2.1.4.559–96)**	0.000353 0.000277 0.000159	0.000011 0.000045 0.000008	97 84 95	26 26 26
Dichlorvos, mg/l **Assessment: gas chromatography** **MPC = 1.0 (SanPiN 2.1.4.559–96)**	0.001060	0.000010	91	26
Carbaryl, mg/l, MPC = 0.7** Diazinon, mg/l, MPC = 0.003** Trihalomethanes total, mg/l, MPC = 0.1* **Assessment: gas chromatography**	0.22 0.07 0.03	0.01 0 0	95 100 100	2 2 2

* *maximum permissible level by standards of USEPA — National Primary Drinking Water Regulations;*

* *level of compliance with the permitted degree of pollution of drinking water according to standards USEPA (DWEL — drinking water equivalent level)*

УДК 544.6+625.35
ББК 24.57
Э45

Bakhir V. M., Panicheva S. A., Prilutsky V. I., Panichev V. G.

Э45 ELECTROCHEMICAL ACTIVATION:
INVENTIONS, SYSTEMS, TECHNOLOGY

The book considers theoretical concepts and hypotheses about the nature of the phenomenon of electrochemical activation of substances discovered by Vitold M. Bakhir in the seventies of the last century. It provides information on the most significant inventions in the field of electrochemical activation and the results of the practical implementation of inventions in various fields of science, engineering and technology. It describes various electrochemical systems for producing liquids with an abnormally high activity in oxidation-reduction, catalytic and biocatalytic processes.

Based on the experience of engineering and practical use of electrochemical systems for production environmentally friendly, safe for humans and animals electrochemically activated detergents, disinfectants and for production of the environmentally friendly sterilizing solutions, the authors predict further development of electrochemical activation technology. Various examples show that the role of electrochemical activation in the near future will steadily increase not only in the field of drinking water disinfection and purification, wastewater and swimming pool water treatment, food industry and agriculture, but also in chemical, petrochemical and mining industries to save raw materials, time and energy, while improving environmental safety and efficiency of the processes.

The book is intended for a wide range of specialists and students interested in the application of electrochemical technologies in various fields of human activity.

ISBN 978-5-6047707-0-2

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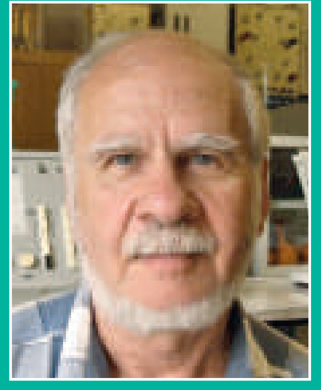

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ISBN 978-5-6047707-0-2
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