

**BAKHIR V. M.
PANICHEVA S. A.
PRILUTSKY V. I.
PANICHEV V. G.**

ELECTROCHEMICAL ACTIVATION

**INVENTIONS
SYSTEMS
TECHNOLOGY**

**Moscow
2021**

LIST OF FREQUENTLY USED ACRONYMS

Acronym	Full name
AS	Active substances
CCH	City Clinical Hospital
CFU	Colony-forming units
CSAA	Cationic surface active agents
DDW	Double-distilled water
DEL	Double electric layer
ECA	Electrochemical activation
ECF	Extracellular fluid
EMF	Electromotive force
FEM	Flown-through electrochemical module
GOST	Russian Government Technical Requirements
GPP	Gaz Processing Plant
ICF	Intracellular fluid
IED	Interelectrode distance
ISED	Ion-selective electrolysis with diaphragm
ISO	International Standardization Organization
MB	Bakhir Module
MPO	Myeloperoxidase
NHE	Normal Hydrogen Electrode
NPO	Research and Production Association
ORP (REDOX)	Oxidation-reduction potential
PCB	Printed Curcuit Board
pH	Potential of hydrogen
PO	Production Association
RF	The Russian Federation
RHE	Reversible Hydrogen Electrode
RPA	Rotary pulsation apparatus
RPE	Flow-through electrochemical reactor
SanPiN	Russian Sanitary Regulations and Standards
SCE	Silver Chloride Electrode
SHE	Standard Hydrogen Electrode
TBW	Total body water (ECF + ICF)

6.5. ELECTROCHEMICALLY ACTIVATED WATER: THE MECHANISM OF BIOLOGICAL ACTION AND MODERN DEVICES FOR ITS PRODUCTION

Prilutsky V.I., Gnatyuk P.V.

Electrochemically activated (ECA) water from the standpoint of physical chemistry is a thermodynamically nonequilibrium (metastable) state of a dilute aqueous solution of inorganic electrolytes after unipolar (anode or cathode) electrochemical exposure in a high-intensity electric field in a double electric layer (DEL) at the electrode surface in diaphragm type electrolyzers. The separation of the electrode chambers by an ultrafiltration membrane prevents mixing of the anode and cathode products of electrochemical synthesis. Accordingly, anolyte is synthesized in the anode chamber, and catholyte in the cathode chamber. Electrochemical activation (ECA) is most efficiently carried out in electrochemical reactors with a small distance between the electrodes with intensive stirring of the solution or water in the interelectrode space. Such conditions are fulfilled in flow-through electrochemical modules of the FEM and MB types, including new generation modules MB-11 and MB-26 [RF patent No. 2350692]. In Russia, on the basis of FEM and MB elements, electrochemical devices of STEL and EMERALD type have been developed and serially produced since 1991. STEL devices are designed for the synthesis of washing, disinfecting and sterilizing solutions. EMERALD devices are used for high-quality water disinfection, purification and conditioning.

The most accessible and at the same time very meaningful for assessing the physicochemical properties of water are the values of hydrogen index (pH) and redox potential (ORP). The pH characterizes the activity of hydrogen ions (H^+) in comparison with the activity of hydroxyl ions (OH^-). The ORP value is a summary characteristic of the activity of electrons in a liquid medium, since the measuring platinum electrode of an ORP meter exchanges only electrons with the liquid medium.

Under real conditions, the forms of oxidized and reduced substances (atoms, molecules) coexist and form redox pairs — [Ox]: [Red], where the designations [Ox] and [Red] refer to the concentrations of oxidized and reduced components of the solution, respectively, in mol/liter. The ratio [OX]: [Red] is not static. A redox-pair is a two-component reaction system (medium) with constant multidirec-

Activated water

*journal № 1 (27), 2020,
p. 4 – 26.*



tional transitions of electrons between oxidized and reduced forms going on in it: $[Ox] \leftrightarrow [Red]$.

In a redox system, there is a constant multidirectional transfer of electrons, which exert an electronic pressure on the measuring electrode (in the classical version it is a platinum electrode) and on the reference electrode. In the classical version, the so-called Normal Hydrogen Electrode (NHE) or Standard Hydrogen Electrode (SHE) are used as reference electrodes, but in practical redoxmetry, the most widespread is the Silver Chloride Electrode (SCE) of reference, whose potential is about 200 millivolts higher than that of the hydrogen reference electrode and depends on the temperature of the solution. In our experiments, redox measurements were carried out with a platinum electrode relative to a silver chloride reference electrode (SCE).

The redox potential for specific redox pairs is determined by the Nernst equation [1], which connects the ORP of the system with the activities of the substances included in the electrochemical equation and the standard electrode potentials of redox pairs:

$$E = E_0 + [RT/nF] \cdot [\ln (Ox/Red)], \quad (1)$$

where E is the electrode potential (ORP), V; E_0 is the standard electrode potential of a redox pair, V; R is Boltzmann's absolute gas constant equal to $8.314 \text{ J}/(\text{mol} \cdot \text{K})$; T is the absolute temperature, K; F is Faraday constant equal to $6485.33 \text{ C} \cdot \text{mol}^{-1}$; n is the number of electrons partici-

pating in the redox reaction; $RT/F = 0.0267$ (for $n = 1$); $(Ox):(Red)$ is the ratio of the concentrations of the oxidized and reduced forms of chemical compounds forming the redox pair.

According to the Nernst equation, the value of the ratio $(\Delta ORP):(\Delta pH) = -59.1$ mV/pH unit. That is, the ORP index decreases, on average, by 59 mV in the case of an increase in pH by 1 unit. It should be emphasized that this relationship is characteristic only of electrolyte solutions in the state of thermodynamic equilibrium.

There are many redox systems in the human body with a wide range of values. The standard redox potentials of the participants in the main biochemical reactions in the body are located in a fairly wide range from (−420 mV) in the reaction $(2H^+/H_2)$ to (+820) mV (O_2/H_2O) [2]. However, the integral value of the ORP of the internal environment of a healthy body is in the range (−100)÷(−200) mV [3].

Dissolution of inorganic acids, alkalis and other inorganic compounds in ordinary (non-activated) water changes the pH of solutions in a wide range. For the vast majority of inorganic substances, the correlation between static pH and ORP is described by the linear regression equation:

$$ORP = (770 - 59 \cdot pH) \pm 110 \text{ mV, SCE} \quad (2)$$

Among the investigated substances, the ORP range described by equation (2) does not include the ORP of sodium, potassium and calcium hypochlorite solutions (the ORP values are above the upper border of the range) and sodium hyposulfite (the ORP values are below the lower border of the range).

At the same time, for almost all of the studied organic compounds and organic media in the pH range from 2.4 to 8.5, the covariant ORP values are lower than the minimum calculated ORP for these pH values according to equation (2). For example, a 10% acetic acid solution has a pH of 2.9. In a solution of inorganic acid with the same pH, the minimum expected ORP value is $770 - 59 \cdot 2.9 - 110 = 489$ mV. However, the real value of the ORP of the studied sample of a 10% acetic acid solution is +300 mV, that is, 186 mV below the minimum calculated value. In this case, the regression of the ORP of the organic solution relative to inorganic solutions with the same pH was 186 mV.

According to our estimates, the average regression of all investigated organic solutions relative to the ORP of inorganic solutions and biological fluids (including donor blood) with initial ORP values in the range of 5 mV÷446 mV at $pH = \text{const}$ is, on average, 192 ± 24 mV. Liquid media with a relatively low ORP are electron-donor relative to media with higher ORP. Thus, electron donation is a common

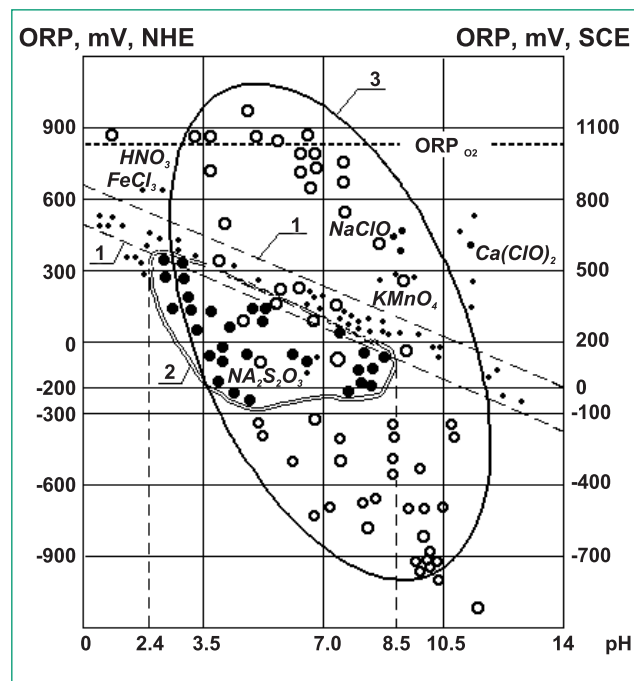


Fig. 6.5.1. Distribution of pH and ORP covariates in non-activated solutions of inorganic electrolytes, in organic media, as well as in activated liquid media.

distinctive prevailing property of organic, including biological, matter in comparison with the class of inorganic liquids and substrates. Fig. 6.5.1 in a rectangular coordinate system pH — ORP gives the following parameters:

- Area 1–1, limited by parallel straight lines, shows the correlation corridor of static pH and ORP values of non-activated inorganic solutions;
- Area 2, bounded by the contour, shows the distributions of the pH and ORP covariates in organic media;
- Area 3, in the form of a regular ellipsis, shows the distributions of the statistical values of pH and ORP in electrochemically activated media based on water and salt solutions with total dissolved solids (TDS) value of no more than 3 gram/liter. Area 3 completely takes up the zone of distribution of pH and ORP in organic media and includes about 45% of all theoretically possible pH and ORP combinations.

1. BIOLOGICAL SIGNIFICANCE OF THE ORP VALUES

The ORP of liquid media characterizes their electron-donor or electron-acceptor properties relative to individual redox chemical (including biochemical) redox pairs. If in any aqueous solution a substance in oxidized [Ox] and (or) reduced [Red] forms is present in excess, then the ORP of such a solution when measured relative to a normal hydrogen electrode (NHE) is determined by the following expression:

$$E = E_o + 0.42 + \frac{RT}{nF} \ln \frac{[Ox]}{[Red]} - 2.3 \frac{RT}{F} pH \quad (3)$$

where E is the stationary ORP of the solution containing the components of the system $[Ox]: [Red]$; E_o is the standard ORP of a given redox pair under normal conditions; R is Boltzmann's gas constant; T is the absolute temperature, K; n is the number of transported electrons; F — Faraday number.

The numerical values of ORP on the NHE scale are approximately 200 mV lower than the ORP values on the SCE scale.

Equation (3) is valid only for idealized conditions, when the components of one redox pair dominate in the solution. If the solution contains other redox vapors or factors affecting the ORP, then the integral value of the ORP of such a solution is determined by the ratio of all electron-acceptor and electron-donor components, and in this case, the special ratios of the oxidized and reduced forms will adjust to the general ORP value. When homogenates of living tissues were placed into media with different predetermined ORP = E , the parameters $[Ox]$ and $[Red]$ were equal precisely for those redox pairs that had $E_o = E$ [2]. In the general case:

$$\frac{[Ox]}{[Red]} i \rightarrow \frac{[Ox]}{[Red]}, \text{ where } \frac{[Ox]}{[Red]} = f_{(E-E_o^i)} \quad (4)$$

That is, it is assumed that at a given ORP value, the ratio of the concentrations of the oxidized and reduced forms of the substance (i), characterized by the standard ORP = E_o^i , becomes a function of E . This regularity creates the prerequisites for the electrochemical control of biochemical processes. If a biological object, for example, an isolated cell, is placed in an environment with an ORP value obtained during electrochemical treatment equal to E_j , then in redox systems characterized by $E_o > E_j$, reduction processes will prevail, and with $E_o < E_j$, oxidation processes will prevail.

Thus, ECA solutions create a given electron-donor or electron-acceptor background relative to a biological object (or in the internal environment of a biological object).

2. ABNORMAL ABILITY OF ECA SOLUTIONS TO MAINTAIN ELECTRON-NONEQUILIBRIUM PROPERTIES RELATIVELY INDEPENDENT OF PH

Ordinary (non-activated) chemicals (acids and alkalis) of exogenous and endogenous origin can change the pH and ORP of biological fluids inside the body, but the ORP regres-

sion coefficient remains equal to (-59) mV with an increase in pH by one unit, all other things being equal. Biological fluids inside the body, also called the total body water (TBW), consisting of extracellular fluid (ECF) and intracellular fluid (ICF) [4], provides a substantial buffer reserve. Therefore, significant changes in the values of acid-base balance in the body (acidosis or alkalosis) are achieved only under extreme physiological conditions. However, even in these cases, pH deviations from the norm rarely go beyond ± 0.1 units, so the contribution of pH to changes in the ORP of the individual TBW is relatively small. A decrease in pO₂ in TBW in itself creates a tendency towards a decrease in ORP. However, tissue hypoxia is accompanied by a decrease in pH, which contributes to an increase in ORP. Thus, the electron-donor effect of hypoxia is superimposed on the electron-acceptor effect of acidosis. In this case, the final, total shift of the ORP turns out to be undefined. Therefore, directed changes in the ORP in the body by means of non-activated chemicals (acids and alkalis), in general, are difficult for a number of pharmacological and physiological reasons.

A bench in vitro experiment has shown that the electron-acceptor and electron-donor properties obtained by ECA are retained when strong oxidants and reducing agents are added to the anolyte or catholyte. The ORP displacements were analyzed in solutions of anolyte A (pH less than 5) and catholyte K (pH more than 10), synthesized on a STEL type device, after adding hydrochloric acid and potassium oxide hydrate. The experiment was set up as follows. Electrochemically activated solutions A and K were obtained by treating drinking tap water in the STEL-UNIVERSAL device. Non-activated tap water with pH = 6.9 and ORP = +210 mV was used as a control. Potassium hydroxide was added to the control water sample and to the solution A with initial pH = 2.3 until the level of pH = 12.6÷12.8 was reached. Hydrochloric acid was added to the solution K with initial pH = 11.4÷11.8 until the level of pH = 1.7÷1.9 was reached. Then ORP was measured in media with modified pH. After that, hydrochloric acid was added to alkalized solutions (water and A) to pH = 1.5 in water and pH = 2.2 in A. Potassium hydroxide was added to the acidified K solution to pH = 12.8. Then ORP of the resulting mixtures was measured again. The following technique enabled to obtain in the investigated aqueous solutions the dynamic pH drops of approximately 10 units from extreme alkaline to extreme acidic values.

The experiment has shown that abrupt changes in pH during sequential alkalization and acidification of non-activated water are accompanied by shifts in ORP, respectively, towards decreasing and increasing. The vectors of the ORP displacement in a non-activated medium generally coincide with the correlation corridor of the static values of these parameters in

Table 6.5.1

Results of an experiment indicating the preservation of the electron-donor properties of activated catholyte in buffer media with constant pH values

Catholyte dilution	Cattle serum		Radelkis buffer	
	pH	ORP, mV	pH	ORP, mV
0	7.80	60	7.09	140
1:100	7.80	(-30)	7.09	120
1:50	7.80	(-70)	7.09	100
1:20	7.80	(-140)	7.09	80
1:10	7.82	(-175)	7.09	35

non-activated inorganic solutions (area 1–1, bounded by parallel straight lines, in Fig. 6.5.1).

At the same time, the ORP displacement vectors at imposed pH drops in anolyte A and in catholyte K deviate significantly from the correlation corridor in inorganic media. At equal pH values, the ORP values in anolyte-based solutions are by 200÷300 mV higher than the upper border of the correlation corridor and in catholyte-based solutions it is by 800÷900 mV lower than the lower border of the correlation corridor. In all cases, the ratios of the ORP and pH increments are relatively constant and with average number of $(-60) \pm 7$ mV/pH unit (with limiting fluctuations from (-85) mV/pH unit to (-48) mV/pH unit).

Thus, alkalization and acidification of electrochemically activated media using chemical reagents does not affect the electron-acceptor and electron-donor background obtained during unipolar electrochemical processing.

An experiment with the addition of electrochemically activated catholyte to buffer media has shown that the addition of ECA solutions to biological fluids with a high buffer capacity and to buffer inorganic solutions in proportions of 1:100÷1:10 does not affect the pH of the buffer media, but causes noticeable ORP shifts in them, corresponding to the ORP sign of the electrochemically activated solution. Table 6.5.1 shows the results of measuring the pH and ORP of canned blood serum of cattle (cattle serum) and a buffer solution from Radelkis Company (Hungary) after adding catholyte with initial pH = 10.7 and ORP = (-770) mV (electrical conductivity 2.0 mS/cm) to these media in various proportions.

3. POSSIBLE CHANGES IN THE ORP OF THE INTERNAL ENVIRONMENT OF THE BODY AFTER THE INTAKE OF ELECTROCHEMICALLY ACTIVATED CATHOLYTE OBTAINED FROM FRESH WATER

The activated solution (for example, catholyte), after ingestion, is in the stomach cavity. Physicochemical conditions in the environment of the stomach contents are modeled by diluting the enzyme medicine acidin-pepsin in water. Aqueous 0.5% solution of acidin-pepsin is characterized by pH = 2.15, ORP = +500 mV, SCE. The values of pH and ORP of acidin-pepsin solution mixed with an activated catholyte (TDS of 1 g/l) are presented in Table 6.5.2.

As it follows from the data in Table 6.5.2, an electrochemically activated catholyte based on fresh water with a high pH and low ORP practically does not affect the pH of a medium simulating the gastric contents, but causes a considerable shift in the ORP towards electron-donor values.

The data in Tables 6.5.1 and 6.5.2 proves that the electrochemically activated catholyte retains electron-donating properties when diluted in non-activated media characterized by significant pH drops. Thus, a portion of catholyte passing through the gastrointestinal tract and along the pathways of physiological absorption of water causes a regression of the ORP of the food chyme and biological fluids of the body. During the process of catholyte dilution

Table 6.5.2

pH and ORP values of the acidin-pepsin solution mixed with electrochemically activated catholyte

Media under testing	pH, units	ORP, mV
Acidin-pepsin 0.5%	2.15	+500
Initial catholyte	10.5	(-540)
Catholyte + acidin-pepsin 1: 100	2.16	+445
Catholyte + acidin-pepsin 1:15	2.17	+100
Catholyte + acidin-pepsin 1:10	2.18	+75
Catholyte + acidin-pepsin 1: 5	2.18	(-50)

Table 6.5.3

Probable regression of the ORP of the contents of the stomach and the internal media of the body after drinking catholyte with pH = 10.5÷10.7 and ORP = (–540)÷(–770) mV at a dose of 0.4 liters during the day

Medium in which the drinking dose of the catholyte is mixed	Estimated regression of the ORP of the medium in which the drinking dose of catholyte is mixed, mV
Stomach chyme	400÷550
CBV	105÷235
Total body water (ICF and ECF)	20÷90

in the TBW, including the circulating blood volume (CBV) which is a part of extracellular fluid, the ORP regression will decrease. An average adult person has the volume of the stomach about 1–2 liters and the volume of the CBV about 4–6 liters. The volume of the TBW in an average adult person of 70 kg is about 40 liters, where extracellular fluid is about 15 liters (1/3 of the total body water) and intracellular fluid is about 25 liters (2/3 of the total body water) [4]. Consequently, a daily dose of the catholyte in a volume of 400 ml (two glasses), taken orally, is subjected to successive dilutions in the following proportions: in the stomach — 1:5÷1:15 (when drinking in doses of 2/3÷1 glass, 3–2 times a day respectively); in the CBV — 1:10÷1:15; in the total body water — 1:100 (taking into account the uniform dilution of the entire dose during the day). Table 6.5.3 shows the estimated regression of the ORP of the contents of the stomach and internal media of the body after drinking catholyte, taking into account its dilution according to the data from tables 6.5.1 and 6.5.2.

The electrochemically activated catholyte after ingestion in a volume of about one glass (with a total daily dose of 2 glasses) reduces the redox potential of the stomach chyme, is absorbed into the blood and is diluted in the cell fluid enhancing its electron-donor background by several tens of millivolts.

In the tissues of the body, in the process of biological oxidation of energy substrates, certain ratios of oxidized and reduced forms of specific redox pairs are established. For example, lactate, the reduced form of pyruvic acid, in the normal condition, accumulates in tissues at a concentration of 0.0020 mol/l, pyruvate, an oxidized form of lactic acid, is present in normal tissues at a concentration of 0.0001 mol/l. Thus, the normal ratio [pyruvate]: [lactate] = 1: 20. The E_o value for the redox pair lactate-pyruvate is (– 0.18) V, (NHE). The redox reaction «lactate ↔ pyruvate» is two-electron ($n = 2$). For practical calculations at pH = 7.0 and the temperature of 37°C (310 K) formula (3) can be rewritten in the following form:

$$E = E_o + 0.42 + \frac{0.0626}{n} \lg \frac{[Ox]}{[Red]} - 0.0626 \cdot 7.0 \quad (5)$$

After substitution in the formula (5) $E_o = (-0.18)$ V, (NHE), $n = 2$ and $[Ox]:[Red] = 1:20$ we have $E = (-0.240)$ V, (NHE). On the scale of the measuring platinum electrode and

the silver chloride reference electrode (SCE), the obtained E value is approximately equal to (–0.040) V, that is, minus 40 mV, (SCE). So, in the tissue environment of a warm-blooded organism at pH = 7.0, a twenty-fold predominance of lactate over pyruvate is achieved at ORP = (–40) mV, (SCE). If the ORP of the tissue medium after the ingestion of catholyte decreases by at least 20 mV, reaching (–0.06) V, (SCE) or, which is the same, (–26) V, (NHE), then the lactate: pyruvate ratio must satisfy the equality:

$$(-0.26) = (-0.18) + 0.42 + 0.0313 \lg Y - 0.0626 \cdot 7.0 \quad (6)$$

where Y is [pyruvate]:[lactate].

The solution of equation (6) with respect to Y gives the value of the ratio [pyruvate]:[lactate] = 0.0106. That is, with the regression of tissue ORP by 20 mV, the concentration of lactic acid relative to pyruvate increases 5 times. A similar calculation for the regression of tissue ORP by 50 mV yields the value of the ratio [pyruvate]:[lactate] = 0.00117, which is equivalent to a relative increase in the concentration of lactate by 50 times. Regression of tissue ORP by 90 mV is equivalent to the ratio [pyruvate]:[lactate] = 0.00006, which is equivalent to a relative increase in lactate concentration by 800 times.

Thus, the hypothetical biochemical consequence of electrochemically activated catholyte drinking is the accumulation of reduced forms of tissue metabolites in the body, a decrease in the ORP of the internal media of the body and the creation of thermodynamic advantages for reducing biochemical processes. Accordingly, the water activated at the anode should stimulate biological oxidation if its effect does not cause damage to respiratory enzymes.

4. ELECTROCHEMICALLY ACTIVATED CATHOLYTE EFFECT ON THE BIOCHEMICAL SYSTEM OF ANTIRADICAL DEFENSE

Ingestion of electroactivated water with an ORP < 0 mV is a recognized type of antioxidant therapy for correcting the redox status (peroxides homeostasis) of the internal en-

vironment of the body. The principle of action of electrochemically cathode-activated water is as follows:

Violation of the redox status of the body due to oxidative stress is an obvious consequence of the depletion of the electron-donor properties of the internal environment of the body. Catholyte is a means of correcting and stabilizing the electronic status of the internal environment of the body. Cathode water penetrates into the biological fluids of the body and imposes the ORP value necessary to normalize the disturbed equilibrium of the reduced and oxidized forms *in loco* (at the site of the redox pair localization). In complex multicomponent chemical systems, including biochemical systems, redox pairs are present in complex combinations and constantly changing ratios. Strong reducing agents in biochemical chains are capable of donating electrons to several oxidants with higher ORP values. Further on, acceptors that have received electrons reduce other oxidants with even higher potentials.

An excess of the reduction (electron-donor) energy of a redox pair with larger absolute values of the negative standard ORP (E_0) creates an electron pressure on other «oxidized» redox pairs with lower negative ORP (E_0) in absolute values [2]. A «reverse» situation is also possible, when a redox pair with predominance of oxidized forms has an electron-acceptor effect on the reduced redox pair. So, if a single reducing or oxidizing agent (or a group of them) prevails in a complex redox system, then the electron-donor or electron-acceptor properties of the entire system ultimately change. Therefore, there is an effect of imposing of the aggregated (background) ORP values on chemical systems and even on the entire set of biological media of the body. This is the way of correcting the redox status of the body by means of electrochemically cathode-activated (antioxidant) water.

The antioxidant (antiradical) system of the body plays an important role in protection of the body from strong oxidants, free radicals and radiolysis factors, using a number of biochemical systems, including the antiradical chain of substances that transfer electrons and protons from the products of enzymatic oxidation to free radicals and other electron-acceptor compounds [5].

An electrochemically activated catholyte with a negative ORP and neutral pH based on fresh drinking water makes it possible to correct the redox status of the body and restore the proper functioning of the endogenous antioxidant systems (antiradical chain) by reducing the ORP of the internal environment of the body to reduction values less than < 0 mV in the zone of action of endogenous antioxidants. It is the prerequisite for the effective restoration of normal enzymatic antiradical chain reactions, which is blocked under

oxidative stress, and for recovering the transfer of electrons and protons along the entire antiradical chain.

The shift of ORP towards reduction values ($\Delta \text{ORP} < 0$) promotes the transfer of electrons and protons along the links of the antiradical chain ($\text{H-NADP} \rightarrow \text{H-glutathione} \rightarrow \text{H-ascorbate} \rightarrow \text{H-tocopherol}$) from metabolites of enzymatic oxidation to free radical agents in the internal media of the body, which leads to inactivation of free radicals.

In such a case, the electron-donor effect, primarily associated with the factors of the ORP reduction, indirectly affects the components of the antioxidant (antiradical) system [5].

According to Water Institute of Tokyo [6], cathode-activated drinking water donates electrons to active oxygen radicals ($\text{AO}^\bullet$) and blocks their interaction with normal biological molecules (BM). As a result, electron-donor biological molecules remain intact and undamaged. The mechanism of the direct antiradical action of electrochemically cathode-activated water is outlined in Fig. 6.5.2.

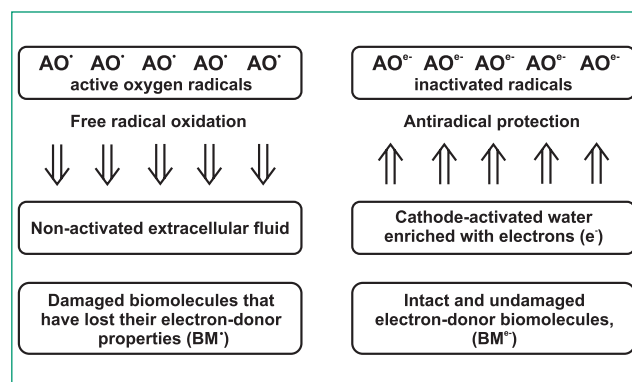


Fig. 6.5.2. Diagram illustrating the principle of direct antiradical action of cathode-activated water (catholyte).

Oral intake of traditional antioxidant agents does not provide significant ORP shifts in internal biological fluids. At the same time, cathode-activated drinking water can be used in relatively large doses (1–2 glasses per day or more), providing the enrichment of the total body water with free electrons. The small size of the clusters and the high liophilicity of electrochemically cathode-activated water contribute to its rapid penetration into biological fluids of the body, where it shows antioxidant and draining effect, accelerates water exchange and flushes out metabolic wastes and toxins.

As a hypothesis explaining the effect of cathode-activated water enriched with electrons on mitochondria, one can say that electrons from reduced forms of nicotinamide adenine dinucleotides (NAD) enter the mitochondria through the outer membrane using specialized biochemical mechanisms. In particular, one of the electron carriers is glycerol-3-phosphate, which easily passes through the outer mitochondrial membrane. Then electrons are transferred

through the interstitial (intramembrane) layer of the double-circuit mitochondrial membrane, penetrate through the inner mitochondrial membrane and are accumulated on its inner surface on the matrix side.

Pyruvate inside the mitochondrion interacts with matrix enzymes and is oxidized in the Krebs cycle (tricarboxylic acid cycle) with the release of four pairs of hydrogen atoms, which, as part of the reduced form of NAD (NAD-H_2), are transferred to the inner mitochondrial membrane. Then these hydrogen atoms are «pushed out» in the form of H^+ ions into the transmembrane space along a chain of enzyme proteins built into the membrane, transforming it into an H^+ — reservoir. The surface of the inner mitochondrial membrane on the side of the H^+ reservoir is positively charged and on the side of the matrix is negatively charged. The pH values of the matrix significantly exceed the pH inside the intramembrane space.

The usual (stationary) values of the pH difference (ΔpH) on the inner mitochondrial membrane are $1.0 \div 1.4$ units, which corresponds to a transmembrane potential of about $60 \div 80$ mV. The inner mitochondrial membrane offers resistance to the transfer of protons towards the matrix. To overcome this resistance a transmembrane gradient (ΔE) not less than 200 mV is required. If, with the accumulation of protons in the medium of the H^+ reservoir and (or) with an increase in the electron density on the surface of the mitochondrial membrane on the matrix side, the ΔE value exceeds the specified critical value, then H^+ ions are transported towards the matrix along the ion channels of ATP synthase built into the inner mitochondrial membrane. The energy of proton transfer across the inner mitochondrial membrane is consumed for phosphorylation of the ADP (adenosine diphosphoric acid) molecule according to the reaction $\text{ADP} + \text{P} \rightarrow \text{ATP}$ (adenosine triphosphoric acid), where P is the phosphorus residue.

Catholyte dilution in the total body water, including the cytoplasmic fluid surrounding the mitochondria, creates additional electron pressure on the outer shell of the mitochondria and stimulates the transport of electrons towards the matrix. This fact creates the prerequisites for an increase in ΔE and for «pushing» of protons to the inner side of the mitochondrial membrane, followed by an increase in ATP resynthesis. In this case, the matrix surface of the mitochondrial membrane partially loses its electron-donating properties. When the ORP inside the mitochondria acquires values corresponding to the reactions of oxidative phosphorylation, glucose is converted to pyruvic acid and further oxidation of pyruvate along the tricarboxylic acid cycle to CO_2 and H_2O takes place.

A shift in electronic equilibrium in biological fluids surrounding mitochondria can enhance the processes of energy

generation, regardless of the sign of the ORP change. However, the consequences of electron-donor and electron-acceptor effects are different. The shift in ORP towards reduction (negative) values creates conditions for the activation of tissue respiration and energy expenditure, compensated by the accumulation of reduced chemical forms and, finally, results in the anabolic effect. The shift of ORP towards electron-acceptance (positive) values is accompanied by the intensification of general catabolism without subsequent compensation. In the case of excessive electron-acceptor (oxidative) effects on mitochondria, there is a risk of toxic inhibition of respiratory enzymes (by analogy with oxygen intoxication). So, the oral intake of electrochemically anode-activated water (anolyte) will be accompanied by suppression of tissue respiration. In such a metabolic situation, the formation and accumulation of reduced biochemical components is unlikely. Therefore, anolyte intoxication is accompanied by depletion of the energy reserve of a living cell.

In any case, one should take into account that the exorbitant ORP shifts are capable of imposing an almost complete thermodynamic ban on biological reduction or oxidation processes. Inhibition of tissue respiration occurs if the ORP shifts in biological fluids of the body exceed ± 350 mV relative to the optimal level. Therefore, an overdose of anolyte ingestion, as well as an excessive catholyte oral intake, can lead to undesirable consequences in the form of suppression of tissue respiration and the development of oxidative stress (acidosis) or reductive stress (alkalosis) in the body.

5. EXPERIMENTAL DATA CONFIRMING THE POSSIBILITY OF CONTROLLING REDOX REACTIONS IN LIQUID BIOLOGICAL MEDIA AND IN THE INTERNAL ENVIRONMENT OF THE BODY USING ELECTROCHEMICALLY ACTIVATED WATER

In the following experiment, the enhancement of the electron-donor properties of antioxidant drugs under the action of cathode-activated water was studied. By means of Emerald K device for electrochemical water purification a purified drinking water was obtained with the following parameters: $\text{pH} = 7.0 \div 7.2$; $\text{ORP} = (-200) \div (-150)$ mV, SCE. The characteristics of the initial (control) drinking water are the following: $\text{pH} = 6.8 \div 7.1$; $\text{ORP} = (+200) \div (+350)$ mV, SCE. Based on the samples of the initial non-activated water and electrochemically activated water, the following solutions were made:

1. 2% solution of the multivitamin product *Dekamevit* with a flavoring addition of 10% sucrose;

Table 6.5.4

Comparative characteristics of pH and ORP of multivitamin drugs solutions based on the initial non-activated and electrochemically cathode-activated water

Investigated solution	Control		Catholyte	
	pH	ORP	pH	ORP
Decamevit 2% with 10% sucrose	6.9 ± 0.1	200 ± 15	6.7 ± 0.2	(-230 ± 20)
Pangexavit 1%	7.1 ± 0.15	280 ± 25	7.3 ± 0.2	70 ± 18

2. 1% solution of the multivitamin product *Pangexavit*.

Both drugs contain vitamins with antioxidant activity and are used in the treatment and prevention of vitamin deficiencies, senile metabolic disorders and asthenic conditions. The pH and ORP values were measured in the resulting solutions. The measurement results are shown in Table 6.5.4.

As follows from the data in Table 6.5.4, mixing electrochemically cathode-activated water with medicinal components related to antioxidants (including B vitamin class, ascorbic acid, α -tocopherol and others) does not influence the pH values which remain mostly unchanged in neutral range, but significantly lowers the ORP of vitamin solutions by about 210–430 mV compared to that of control samples prepared on non-activated water. The reduction ORP values of multivitamin drug solutions prepared on electrochemically cathode-activated water are metastable and relax to stable values within 1–3 days, depending on storage conditions.

This *in vitro* experiment shows the way cathode activation enhances the electron-donor activity of exogenous antioxidants. A similar effect is achieved in the processes of catholyte interaction with endogenous antioxidants.

In the case of catholyte oral intake, the shift of ORP in the total body water is assumed to be within several tens of millivolts (see Table 6.5.3), which in itself is not enough for an absolute thermodynamic prohibition of redox biochemical reactions. However, the data from Table 6.5.4 show that a relatively small shift in the ORP of the aqueous medium leads to a significant increase in the electron-donor activity of endogenous antioxidants, which is associated with their transformation into the forms of reduced electron-enriched compounds. As a result, a reserve of reduced antioxidants is formed in the body, with a targeted electron-donor effect on those components of antiradical chains that are electron-acceptor toward these specific antioxidants.

The consumption of the reducing agent for the reduction of the substance, which is the subsequent (and irreplaceable) component of the antiradical chain, is strictly equimolar. At the same time, the reducing agent (antioxidant) is in an electron-exchange relationship with the solvent (with water) or, more precisely with the components of the solvation-hydration shells formed around the antioxi-

dant molecule in an aqueous colloidal solution. If particles of cathode-activated water with electron-donating factors take part in the formation of solvation-hydration shells around the organic molecule, then the probability of electron transfer from the reducing agent to the oxidizing agent increases. Therefore, the number of electron-donor particles of catholyte dissolved in the total body water should be equivalent to those electron-acceptors that impose a thermodynamic limitation on reductive biochemical processes.

As shown in Fig. 6.5.2, active oxygen acts as an electron-acceptor factor in the intracellular and extracellular fluids relative to electron-donor biomolecules and makes up about 2% of all oxygen absorbed by the body in normal conditions and about 20% during intense physical work. Moreover, toxic lipoperoxides are formed as a result of the direct action of active oxygen on the bio-substrate. Calculations show that the total free radical background of the internal biological fluids under normal conditions is about 10^{-6} mol/l. Under extreme conditions, the concentration of free radicals in biological fluids of the body can increase by two orders of magnitude (by 100 times).

The effectiveness of antiradical protection in the body depends on the absolute number of antioxidants and on the entire balance of antioxidant system transporting electrons and protons to radical acceptors.

The final component of the antioxidant chain is H-tocopherol which is a reduced form of vitamin E (also called a «radical trap») and has a molecular weight of 153 atomic mass units (a. m. u.). H-tocopherol is contained in body tissues with high water volume in concentrations of 6–10 mg/l [$(4 \div 7) \cdot 10^{-5}$ mol/l]. The body's daily vitamin E requirement is approximately 12–15 mg [$9 \cdot 10^{-5}$ mol per day]. The daily therapeutic dose of vitamin E is from 50 to 200 mg [$(3 \div 13) \cdot 10^{-4}$ mol per day] [7].

Thus, the role of vitamin E in the formation of antiradical protection in biological fluids of the body corresponds to its concentrations of about $10^{-5} \div 10^{-6}$ mol/l. At the same time, the physiological or therapeutic need of vitamin E is approximately $10^{-6} \div 10^{-3}$ mol per day.

To compare the number of electron-donor particles in the electrochemically activated catholyte with some traditional antioxidant vitamins, the following calculation

Table 6.5.5

Comparison of the daily (therapeutic) antioxidants dose for the body of an adult in electrochemically activated catholyte and in some traditional antioxidants

substance (antioxidant)	Molecular weight	Daily requirement	
	a.m.u.*	mg	mol
Catholyte (therapeutic dose of activated reducing agents)	10 ¹	—	1·10 ⁻³
β — carotene (vit. A, physiological need)	150	1.5	1·10 ⁻⁵
α- tocopherol (vit. E, physiological need)	153	12–15	9·10 ⁻⁵
α- tocopherol (vit. E, therapeutic dose)	153	50–200	(3÷13)·10 ⁻⁵
Vitamin C (therapeutic dose)	176	50–100	(3÷6)·10 ⁻⁴

* Note: a.m.u — in atomic mass units.

was carried out. By means of STEL-UNIVERSAL device an electrochemically activated catholyte ($\text{pH} = 9.0 \div 9.5$; $\text{ORP} = (-600) \div (-400)$ mV) was produced from fresh water at a current of 3A with a water consumption of 0.008 l/s (specific electricity consumption 375 C/l). The calculated concentration of the sum of active reducing agents in a given catholyte ($C_{\text{Red}} = (375 \text{ C/l}) : (96500 \text{ C/mol}) \approx 4 \cdot 10^{-3} \text{ mol/l}$ (where 96500 C/mol = F or Faraday number). In real conditions C_{Red} in the catholyte with such parameters is about $2 \cdot 10^{-3} \text{ mol/l}$. Consequently, a person who drinks 0.5 liters per day of such electrochemically activated catholyte receives a dose of antioxidants (electron-donor particles) equivalent to $1 \cdot 10^{-3} \text{ mol/l}$.

Table 6.5.5 shows that the sum of active electron-donor particles in a daily dose of electrochemically activated catholyte made on fresh drinking water exceeds by 1–2 orders of magnitude (by 10–100 times) the molar equivalents of the daily physiological need for β-carotene (vitamin A), α- tocopherol (vitamin E) and is equivalent to therapeutic doses of α- tocopherol and vitamin C.

The small size of clusters in electrochemically cathode-activated water and the high lyophilic activity promote its rapid diffusion through biological barriers. Moderate shifts in the ORP in biological fluids of the body towards reduction values do not disrupt the functions of respiratory enzymes, but are sufficient to increase the activity of endogenous and exogenous antioxidants.

6. EVALUATION OF THE BODY REDOX STATUS ACCORDING TO THE pH AND ORP OF URINE AFTER ORAL INTAKE OF ELECTROCHEMICALLY CATHODE-ACTIVATED WATER

Direct monitoring of antioxidant water (with ORP values < 0 mV) effect on the redox status of the body is carried out by indirect methods. There are no non-invasive methods

for direct monitoring of ORP in the body due to the impossibility of frequent sampling of internal biological fluids.

From the point of view of systems theory, the internal environment of a person with many dependent and independent variable characteristics is a «black box». The research method of the «black box» is based on studying the response of the system as a whole by comparing the characteristics of the impact «at the input» of the system with the characteristics of the response «at the output» of the system. Oral intake of catholyte with specified parameters by a living organism can be considered as a signal «at the input» of the «black box». At the exit from the system of the internal environment of the body, one may analyze indicators that are available for objective measurement by non-invasive means. One of such indicators can be the pH and ORP values of urine, since this liquid reflects the properties of the blood filtrate in the Bowman's capsule of the kidneys and is most suitable for such measurements. Urine pH and ORP values make it possible to obtain an indirect assessment of the blood acid-base balance and of the redox status (peroxides homeostasis) of the internal environment of the body.

It may be added that in parallel with urine pH and ORP measurements, it is also necessary to calculate the ratio of changes in the ORP relative to pH ($\Delta \text{ORP} / (\Delta \text{pH})$). Calculation and studying of this ratio have a diagnostic significance in cases of prevention and treatment of various diseases for monitoring the redox status of the body, as well as for assessing the effectiveness of antioxidant water therapy. It should be noted that during antioxidant water therapies using electrochemically activated catholyte the measurement results of the ratio ($\Delta \text{ORP} / (\Delta \text{pH})$) approaches the mathematical expectation, when the concentration of reduced and oxidized forms in the internal environment of the body returns to normal and becomes controllable. The mathematical expectation of this ratio, according to the Nernst equation, is ($\Delta \text{ORP} / (\Delta \text{pH}) = (-59.1) \text{ mV/pH unit}$.

Table 6.5.6

Urine pH and ORP values among individuals before and an hour and a half after oral intake of electrochemically activated catholyte [8]

Indicator	Initial values	Values after 1.5 hours	Δ Changes
pH, pH units	5.8 ± 0.2	6.5 ± 0.4	+ 0.7
ORP, mV	165 ± 26	123 ± 27.5	– 42

In paper [8] it was shown that the oral intake of electrochemically activated catholyte with negative ORP values definitely reduces the urine ORP, which indicates a decrease in the ORP of the biological fluids in the body. The article describes studies carried out on three groups of volunteers:

- 1 — the control group, who took ordinary non-activated drinking water;
- 2 — a group of volunteers who took catholyte orally (ORP = –550 mV, pH = 9);
- 3 — a group of volunteers who took anolyte orally (ORP = +750 mV, pH = 6.8).

In all cases, the volume of ingested water, catholyte and anolyte was at the rate of 2 ml/kg ($\approx$ 150 ml). An hour and a half after oral intake of the liquids, the pH and ORP parameters of the participants' urine were measured.

In the control group, who drank ordinary water, the initial values of urine pH were $5.9 \pm 0.4 \rightarrow$ final pH values after 1.5 hours were 6.2 ± 0.6 (an increase of 0.3 units). Baseline urine ORP values were 132 ± 25 mV $\rightarrow$ final ORP values were 115 ± 27 mV (minor changes).

In the group who drank anolyte, the initial urine pH values were $5.9 \pm 0.4 \rightarrow$ final pH values were 6.2 ± 0.6 . Initial ORP values were 126 ± 17 mV $\rightarrow$ final ORP values were 120 ± 40 mV. The differences are not statistically significant. Ratio of (Δ ORP): (Δ pH) = $(126 - 120) : (5.9 - 6.2) = (-20)$ mV/pH unit. The nature of values shifts is uncertain.

In the group who drank catholyte the initial values of urine pH were $5.8 \pm 0.2 \rightarrow$ final pH values were 6.5 ± 0.4 . An average increase in urine pH was (Δ pH) = (+0.7 units). Initial ORP values were 165 ± 26 mV $\rightarrow$ final ORP values were 123 ± 27.5 mV. An average urine ORP regression was (Δ ORP) = (–42 mV).

In this case, the ratio (Δ ORP): (Δ pH) according to Table 6.5.6 is $(-42) : (+0.7) = (-60)$ mV/pH unit, which means almost complete coincidence with the mathematical expectation.

An oral intake of catholyte with low ORP values within a short time interval (1.5 hours) caused a decrease of the ORP in the circulating blood volume, which led to a significant regression of the ORP in the blood filtrate excreted by the kidneys.

In cooperation with the medical staff of the balneological hospital, the authors carried out similar studies, the re-

sults of which, with slight deviations, correspond to the data presented in paper [8].

Based on the comparison of the research results, it was concluded that there are no qualitative or statistical discrepancies in the dynamics of changes in the ORP of urine of healthy people after oral intake of catholyte. It is confirmed that the injections of electrochemically activated catholyte with negative ORP values (< 0 mV) cause a sustained decrease in urine ORP over several hours.

7. PHENOMENON OF MOMENTARY ACTIVATION OF INTERNAL BIOLOGICAL FLUIDS OF THE BODY UPON CONTACT WITH ELECTROCHEMICALLY ACTIVATED CATHOLYTE

In the process of our research, the following phenomenon was recorded: an instant change in urine ORP parameters upon momentary contact of the body with electrochemically activated catholyte under the influence of unknown and hidden factors of electrochemical effect on the internal biological fluids.

The experiment was carried out according to the following procedure. Tap water (ORP +220 mV, pH 6.1, TDS 110 mg/l) was purified and activated using an EMERALD HOME 60 device (see Fig. 6.5.3). The purified antioxidant drinking water (electrochemically activated catholyte) obtained from the device had the following parameters: ORP — 410 mV, pH 6.2, TDS 100 mg/l). The water treatment scheme in EMERALD HOME 60 device makes it possible to produce an electrochemically activated catholyte with pronounced antioxidant (electron-donor) properties while maintaining a neutral pH level.

The procedure of urine samples acquisition for pH and ORP measurements during the same urination process was as follows:

- **sample 1** is taken at the beginning of urination to determine the initial values. In this case, the very first portion of urine is drained into the toilet, while the next portion of urine is sampled. After taking sample 1, the urination process is suspended;
- **sample 2** is taken immediately after touching the catholyte with the lips. Specifically, the glass with the catholyte is brought to the lips, for 2 or 3 seconds the

Table 6.5.7

**Urine pH and ORP values before contact with electrochemically activated catholyte
and immediately after the contact during one urination process**

Indicator	sample 1	sample 2	Sample 3	Δ Change in sample 2 relative to sample 1	Δ Change in sample 3 relative to sample 1
Morning					
pH, pH units	5.4	5.4	5.4	0	0
ORP, mV	−47	−88	−110	−41	−63
Midday					
pH, pH units	5.8	5.8	5.7	0	−0.1
ORP, mV	−27	−70	−90	−43	−63
Evening					
pH, pH units	5.6	5.6	5.6	0	0
ORP, mV	−32	−74	−92	−42	−60

person touches the catholyte with his lips and then immediately continues the process of urination, taking urine for sample 2. After taking sample 2, the urination process is suspended again;

■ **Sample 3** is taken immediately after taking one sip of catholyte. Specifically, the glass with catholyte is brought to the lips, the person during 3–5 seconds takes one slow sip of catholyte and then immediately continues the urination process taking urine for sample 3. After taking sample 3, the process of urination continues until the end.

The urine ORP and pH values were measured immediately within no more than 5 minutes from the moment of samples acquisition. Table 6.5.7 shows the average obtained values based on the measurements of two participants of the experiment.

Despite the natural individual differences in the physiological state of the participants of the experiment (differences in age, nature of work, health status, diet), there are no qualitative or statistical differences in the dynamics of changes in the ORP of urine taken by the above procedure. The results presented in Table 6.5.7 confirm the possibility of momentary urine ORP adjustment due to the short-term impulse contact of electrochemically activated catholyte based on fresh drinking water with the human body. Despite a neutral pH of the catholyte, just one touch of it with the lips of a person, as well as one sip, causes an instant and sustained decrease in the ORP of urine. In this case, presumably, not only urine ORP is subjected to momentary shifts followed by impulse activation, but also the ORP of other biological fluids comprising the total body water. At the same time, urine pH values in all samples remain unchanged.

It is worth mentioning, that the described effect is not observed in case of the contact of a human body with non-activated alkali solutions or water. The use of alkaline solutions in a similar experiment, for example, based on water and baking soda, just like the usage of ordinary tap drinking

water, does not provide similar results of an instant decrease in the ORP of urine. Summing up, only electrochemically activated metastable solutions have the necessary properties for active biostimulation of vital processes in living organisms (in metastable systems).

8. MODERN ELECTROCHEMICAL DEVICES FOR PRODUCING PURIFIED ANTIOXIDANT DRINKING WATER

The technology of electrochemical water treatment is the best available technique (BAT) in the sphere of directed reagent-free regulation of the physicochemical properties of water.

For more than 30 years (since 1990) household and industrial EMERALD devices have been produced for effective purification of fresh water and correction of its redox potential. Water treatment processes in EMERALD devices



Fig. 6.5.3. EMERALD HOME 60 device for purification and activation of water in flats, offices and country houses.

Productivity — 60 l/h;
power consumption —
no more than 90 W;
year 2020.



Fig. 6.5.4. MB-11 electrochemical module of the new generation, general view

are based on the electrochemical activation technology and flow-through electrochemical modules of FEM and MB type. During this period more than 300.000 original EMERALD devices have been produced, which with various technological schemes and productivity successfully operate both in Russia and abroad [9].

Today, the most up-to-date equipment is EMERALD devices (Fig. 6.5.3, 6.5.5) manufactured by EMERALD ECOTECHNOLOGIES LLC and equipped with the new flow-through electrochemical MB-11 modules (Fig. 6.5.4).

EMERALD devices, depending on the modification, have a productivity from 50 to 1000 liters per hour and are used for purification of tap water, as well as of water from underground and surface water sources (incl. water from wells and boreholes).

EMERALD devices for purification and activation of water are used in city flats, country houses and cottages, as well as in office buildings, fitness and spa centers, kindergartens, schools, universities, medical centers, resort hotels, cafes and restaurants.

All the processes of water treatment in EMERALD devices are as close as possible to what happens with water in living nature since the mechanism of fresh water purification processes in nature is basically represented by the two main processes: oxidation-reduction (redox) reactions and filtration.

That is why the combination of electrochemical anode and cathode water treatment in line with ecological filtration modules in EMERALD devices provides effective water purification from microbes, microbial toxins, biofilms, heavy metals, iron, manganese, hydrogen sulfide and harmful organic compounds (including herbicides, pesticides, surfactants, phenols, oil products, antibiotics, antidepressants, hormones and other technogenic pollution factors, appearing in growing rates in fresh water).

Moreover, EMERALD devices purify water from free chlorine and organochlorine compounds, improve the taste of water and eliminate unpleasant odors, also due to the anode removal of phenols and hydrogen sulfide, and ensure guaranteed water transparency, removing turbidity and impurities. At the same time, the water treatment method in EMERALD devices preserves all useful and necessary microelements in purified water: calcium, magnesium, sodium, potassium, iodine, etc.

The water purified in EMERALD devices acquires increased biological activity due to the acquisition of antioxidant (electron-donor) properties and enrichment with molec-

ular hydrogen. Average ORP and pH parameters of purified antioxidant drinking water from the EMERALD devices of HOME series are in the range of ORP = $(-150) \div (-400)$ mV, pH = 7.0÷8.5 units.

It is worth mentioning that electrochemically activated water from EMERALD devices has pronounced antioxidant properties and maintains a neutral pH level, which makes it safe and suitable either for regular usage as part of a daily diet, or for antioxidant water drinking courses for restoring the optimal redox status of the internal environment of the body due to oxidative stress neutralization.

Purified antioxidant water from EMERALD devices is also used for watering indoor plants and seedlings, watering pets, preparing food and drinks, brewing herbal teas, washing food from films of herbicides and pesticides, making cosmetic applications and humidifying the air.

The efficiency and safety of EMERALD type devices has been studied in Russia, Japan, Germany, USA, Great Britain, Czech Republic, India, Mexico, Malta, Cyprus and other countries. The research results are positive and are confirmed by appropriate certificates [9].



Fig. 6.5.5. EMERALD HOME 60 OFFICE device in the form a point-of-use water dispenser for purification and activation of tap water in public places like fitness and spa centers, kindergartens, schools, universities, medical centers, resort hotels, cafes and restaurants.
Productivity — 60 l / h;
power consumption — no more than 156 W;
year 2020.

Purified antioxidant drinking water from EMERALD devices fully complies with the Russian sanitary standards of *SanPiN 2.1.4.1074–01 «Drinking water: Hygienic requirements for water quality from centralized drinking water supply systems»* and with international quality standards for drinking water, including the WHO recommendation [10].

9. DEVICES FOR ANTIOXIDANT (ELECTRON-DONOR) WATER THERAPY IN THE FORM OF BATHS AND SHOWERS

An advanced direction in the field of balneotherapy is antioxidant (electron-donor) water therapy in the form of baths and showers using electrochemically activated catholyte produced from fresh drinking water.

Antioxidant water therapy in the form of baths or showers based on purified electrochemically activated catholyte produced from fresh water is an effective and safe method for regulating the redox status of the internal environment of the body. Antioxidant water therapies enable to restore the body at the cellular level, normalizing the balance of oxidative and reduced chemical compounds in the extracellular and intracellular fluids, which is a prerequisite for the correct functioning of all fundamental vital processes of the body.

The effectiveness of this procedure is due to the fact that when a person is immersed in a bath with catholyte, about 67% of the skin gets into direct contact with the electron-donor liquid medium and the negative electrostatic charge of activated water is transferred into the blood through the skin. Taking into account that the blood flow through the skin areas which are in contact with the catholyte is approximately 0.3 l/min and the total blood flow in the body is about 5.5 l/min, one will obtain the following result: during a 7 minute antioxidant bath therapy, approximately 33 % (about 1.5–2 liters) of the total circulating blood volume in the body is subjected to percutaneous electrochemically activated catholyte treatment. Moreover, one could achieve even better results by means of combining courses of antioxidant baths or showers with courses of antioxidant water drinking which will result in synergistic effect.

It is important to note that only electrochemically activated water or aqueous solutions have the necessary properties for carrying out effective antioxidant water therapies. The following experiments [11] have shown that the ORP value of physiological solution in sealed containers made of glass and fluoroplastic (dielectrics), after immersing the ampoules in the cathode chamber of a working diaphragm electrolyzer with exposure for 30 minutes, significantly changed into the negative values zone (< 0 mV). That is, the phenomenon of a contactless electrochemical activation of the solu-

tions inside the sealed ampoules that do not conduct electric current was detected. The relaxation of negative ORP values in the ampoules to an equilibrium state took around 2 hours. However, in the case of immersion of the same sealed glass and fluoroplastic ampoules with physiological solution in non-activated strong alkali solutions, the ORP inside the ampoules did not change. Thus, non-activated alkaline solutions do not transfer reducing properties through non-conductive materials. Accordingly, simple water alkalization for sanitary bath therapies, for example with baking soda, does not give the desired effect.

Effective electron-donor water therapy in the form of baths or showers directly depends not only on the methodology of carrying out this procedure, but also on the quality of the equipment used for producing electrochemically activated catholyte. EMERALD ECOTECHNOLOGIES LLC in R&D partnership with the Vitold Bakhir Electrochemical Systems and Technologies Institute have engineered and brought into serial production new devices for antioxidant water therapy in the form of baths or showers called EMERALD HOME SPA devices (Fig. 6.5.6).

EMERALD HOME SPA devices are used for conducting antioxidant balneotherapy procedures for treatment, prevention and restoration of impaired body functions by neutralizing



Fig. 6.5.6. EMERALD HOME 200 SPA device for antioxidant water therapy in the form of baths and showers.

Productivity — 200 l/h;

power consumption — no more than 350 W; year 2020.

oxidative stress and restoring the optimal redox status of the biological fluids of the body. The devices can be used in resorts and sanatoriums, medical and rehabilitation centers, fitness and spa centers, massage centers, as well as for personal purposes in private flats, country houses and cottages.

The water treatment scheme in EMERALD HOME SPA devices is based on authentic MB-11 electrochemical modules and allows for producing from 200 to 900 l/h of warm electrochemically activated catholyte from ordinary tap water in a flow-through mode with ORP value in the range of $(-150) \div (-450)$ mV, while maintaining a neutral pH level in the range of 7.0–8.5 units. Preservation of the neutral acid-base balance of the catholyte in line with notable ORP shift towards reduction values is an important factor for producing antioxidant water similar in ORP and pH values to biological fluids of the body, making antioxidant water therapies in the form of baths and showers safe and effective.

At the same time, the electrochemically activated catholyte in EMERALD HOME SPA devices undergoes a complex

scheme of water purification from microbes, microbial toxins, biofilms, heavy metals, iron, manganese, hydrogen sulfide, harmful organic compounds, free chlorine and organochlorine compounds, turbidity and impurities, while preserving all the necessary useful microelements in the purified water.

Summing up, the water treatment method in EMERALD devices is environmentally friendly and safe, since the electrochemical modules exchange only electrons with water, taking them away from the water in the anode chamber, where oxidation reactions take place and the water is enriched with oxygen, and loading electrons into the water in the cathode chamber, where reduction reactions take place and the water is enriched with hydrogen. Therefore, the catholyte from EMERALD devices for water purification and conditioning or for antioxidant water therapies is in fact pure drinking water with pronounced electron-donor (antioxidant) properties which meets all the main Russian and international requirements for drinking water, including the international WHO recommendation «Guidelines for drinking-water quality» [10].

REFERENCES

1. Wahl. *A Short History of Electrochemistry//Galvanotechnik*. — 2005. — T. 96, № 8. — P. 1820–1828.
2. Straub F. B. *Biochemistry. Academy of Sciences of Hungary. Budapest*. 1985. P. 181.
3. Prilutsky V. I., Bakhir V. M. *Electrochemically activated water: abnormal properties, mechanism of biological action*: — М.: VNIIMT NPO Ekran OJSC, 1995; В. И. Прилуцкий, В. М. Бахир. *Электрохимически активированная вода: аномальные свойства, механизм биологического действия*: — М.: ВНИИИМТ АО НПО «Экран», 1995.
4. John T. Hansen; Bruce M. Koeppen (2002). *Netter's Atlas of Human Physiology*. Teterboro, N. J: Icon Learning Systems. ISBN 1-929007-01-9.
5. Voskresensky O. N. *Significance of the systemic nature of biological inhibition of lipid peroxidation in atherogenesis. In the book: Bioantioxidants*. Nauka, Moscow. 1975. P. 121–125; О. Н. Воскресенский. *Значение системности биологического ингибирования перекисления липидов в атерогенезе*. В кн. *Биоантиокислители*. «Наука», Москва. 1975. С. 121–125.
6. Hidemitsu Hayashi. *Welcome to microwater*. Water Institute, Tokyo, 1996.
7. Mashkovsky M. D. *Medicine remedies. Part 2*. «Belarus», Minsk, 1988. p. 34. М. Д. Машковский. *Лекарственные средства*. Ч. 2. «Беларусь», Минск, 1988. С. 34.
8. Brezdynyuk A. D., Selyavin S. S., Trofimova T. G. *Change the redox potential of body fluids. The journal of scientific articles «Health & education millennium» (series Medicine)*, 2012, T. 14 (1)
9. Bakhir V. M. *Electrochemical activation: inventions, systems, technology*. — М., Viva-Star, 2014. — 514 p. with ill. Бахир В. М. *Электрохимическая активация: изобретения, техника, технология*. — М., Вива-Стар, 2014., — 514 с., ил.
10. World Health Organization, [Electronic resource]/*Guidelines for drinking-water quality, 4th edition, 2017*. Access mode : <https://www.who.int/teams/environment-climate-change-and-health/water-sanitation-and-health/water-safety-and-quality/drinking-water-quality-guidelines>
11. V. M. Bakhir. *Electrochemical activation. Part 1*. Ed. VNIIMT. Moscow. 1992. P. 197–204. В. М. Бахир. *Электрохимическая активация*. Ч. 1. Изд. ВНИИИМТ. Москва. 1992. С. 197–204.

EMERALD HOME DEVICES

LIVING WATER FOR YOUR HEALTH

**THE UNIQUE DEVICES WHICH COMBINE
AND ACCELERATE THE NATURAL WATER
PURIFICATION AND ACTIVATION PROCESSES**



**ENGINEERED
IN COOPERATION WITH
VITOLD BAKHIR
INSTITUTE**

Disinfection, purification and conditioning of fresh water

EMERALD HOME devices manufactured by EMERALD ECOTECHNOLOGIES LLC represent the most up-to-date electrochemical water treatment equipment for disinfection, purification and conditioning of fresh water by means of ECA technology and flow-through electrochemical MB-11 modules.

EMERALD HOME devices, depending on the modification, have a productivity from 50 to 1000 liters per hour and are used for purification of tap water, as well as of water from underground and surface water sources (incl. water from wells and boreholes). The devices are used in city flats, country houses and cottages, as well as in office buildings, fitness and spa centers, kindergartens, schools, universities, medical centers, resort hotels, cafes and restaurants.

EMERALD HOME devices provide a complex scheme of water purification from microbes, microbial toxins, biofilms (microbial colonies), heavy metals, iron, manganese, hydrogen sulfide, harmful organic compounds, free chlorine and organochlorine compounds, turbidity and impurities, while preserving all the necessary useful microelements in the purified water.

Moreover, the purified water acquires increased biological activity due to the acquisition of antioxidant (electron-donor) properties and enrichment with molecular hydrogen. Antioxidant water from EMERALD device has a beneficial effect on the whole body, normalizes metabolism and the functioning of internal organs, reduces oxidative stress, cleanses from toxins and wastes, strengthens the immune system, improves memory and increases the physical vigor.

It is worth mentioning, that EMERALD HOME devices produce antioxidant water with pronounced electron-donor properties while maintaining a neutral pH level which makes the purified water similar in ORP and pH values to the biological fluids of the body, making it safe and suitable for regular usage.

Purified antioxidant water from EMERALD HOME devices is used for drinking as a part of a regular diet, for watering plants and seedlings, pets drinking, preparing food and drinks, brewing herbal teas, washing food from films of herbicides and pesticides, making cosmetic applications, humidifying the air and for many other applications where pure and safe water is needed.

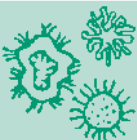
Antioxidant water from EMERALD devices is also used for electron-donor water procedures in the form of baths or shower.

The efficiency and safety of EMERALD type devices has been studied in Russia, Japan, Germany, USA, Great Britain, Czech Republic, India, Mexico, Malta, Cyprus and other countries. The research results are positive and are confirmed by appropriate certificates.

Purified antioxidant drinking water from EMERALD devices fully complies with international quality standards for drinking water, including the World Health Organization's recommendations in guidelines for drinking water quality.



EMERALD HOME devices are based on the new generation of MB-11 electrochemical modules

PURIFICATION METHOD	CRUTIAL WATER TREATMENT CRITERIA						
	 Destruction of microbes	 Elimination of microbial toxins and biofilms	 Purification from organic substances and heavy metal ions	 Purification from iron, manganese and hydrogen sulfide	 Improving taste and smell	 Preservation of beneficial trace elements	 Enrichment of water with molecular hydrogen
 Mechanical and carbon filters	—	—	—	—	+	+	—
 Reverse osmosis	—	—	+	+	+	—	—
 Traditional filters plus UV lamp	+	—	—	—	+	+	—
 Reverse osmosis plus UV lamp	+	—	+	+	+	—	—
 Electrochemical activation	+	+	+	+	+	+	+

ECA technology used for water treatment in EMERALD device is a nature-like and reagent-free technique of regulating the physicochemical properties of water

All the processes of water purification and activation in EMERALD devices are as close as possible to what happens with water in living nature since the mechanism of fresh water purification in nature is basically represented by the two main processes: oxidation-reduction (redox) reactions and filtration.

That is why the combination of electrochemical anode and cathode water treatment in line with ecological filtration modules in EMERALD devices provides a deep water purification from microbes, microbial toxins, biofilms, heavy metals, iron, manganese, hydrogen sulfide and harmful organic compounds (including herbicides, pesticides, surfactants, phenols, oil products, antibiotics, antidepressants, hormones and other technogenic pollution factors, appearing in growing rates in fresh water).

Moreover, EMERALD devices purify water from free chlorine and organochlorine compounds, improve the taste of water and eliminate unpleasant odors, also due to the anode removal of phenols and hydrogen sulfide, and ensure guaranteed water transparency, removing turbidity and impurities. At the same time, the water treatment method in EMERALD devices preserves all useful and necessary microelements in purified water: calcium, magnesium, sodium, potassium, iodine, etc.

ECA water treatment method is environmentally friendly and safe, since the electrochemical modules exchange only electrons with water, taking them away from the water in the anode chamber, where oxidation reactions take place and the water is enriched with oxygen, and loading electrons into the water in the cathode chamber, where reduction reactions take place and the water is enriched with hydrogen.

Basic water treatment scheme in EMERALD HOME devices



STAGE 1. ANODE CHAMBER OF MB-11 ELECTROCHEMICAL MODULE

In the anode chamber of the MB-11 module oxidation reactions take place, providing:

- Full elimination of microorganisms, microbial toxins and biofilms of all species and forms;
- Oxidative destruction of organic compounds: herbicides, pesticides, surfactants, antibiotics, hormones, antidepressants, phenols, oil products;
- Iron removal with the conversion of iron ions into a 3-valent form easy for further mechanical filtering;
- Purification from manganese and hydrogen sulfide;
- Enrichment of water with oxygen.



STAGE 3. THE CATHODE CHAMBER OF MB-11 ELECTROCHEMICAL MODULE

In the cathode chamber of the MB-11 module reduction reactions take place, providing:

- Restoration of antioxidant properties of water with simultaneous maintaining of neutral pH level;
- Purification from heavy metal ions which are converted into insoluble hydroxides and subsequently removed on the electrokinetic filter;
- Preservation of all trace elements in the purified water: calcium, magnesium, sodium, potassium, lithium, fluorine, iodine;
- Enrichment of water with hydrogen.



STAGE 2. CATALYTIC FILTER

- Water purification from a wide range of organic and inorganic dissolved impurities that undergo oxidative degradation in the anode chamber of MB-11 module;
- Free chlorine and organochlorine compounds removal;
- Water taste improvement and unpleasant odor elimination (also due to the anode removal of phenols and hydrogen sulfide).



STAGE 4. ELECTROKINETIC FILTER

- Final purification from mechanical impurities after anodic and cathodic water treatment, including hydroxides of heavy metals and oxidized organic compounds, iron, manganese and hydrogen sulfide;
- Removal of turbidity and impurities for guaranteed water transparency.

Consolidated results of water purification and conditioning efficiency in EMERALD devices*

Disinfection of water with 300 colony-forming units (CFU) per 1 ml in source water, %	99.9999
Odor elimination at 20°, %	95–99
Anodic oxidation of divalent iron ions with concentration in source water of 5 mg/l, %	90–99
Surface active substances (surfactants) elimination with concentration in source water of 3 mg/l, %	90–99
Permanganate index decrease with concentration in source water of 10 mg/l, %	80–85
Heavy metals, iron hydroxides, manganese and hydrogen sulfide removal, %	80–95
Catalytic conversion of chlorine-oxygen oxidants to hydroperoxide in the catalytic filter, %	60–70
ORP reduction relative to the source water ORP level, mV	(-200)÷(-700)
pH changes relative to the source water pH level, units	±1

*Source: Consolidated results of water purification and conditioning efficiency by Emerald devices of various modifications conducted by authorized laboratories in Russia (Moscow, St. Petersburg, Izhevsk, Samara, Sergiev-Posad) and abroad (USA, Great Britain, Czech Republic, India, Mexico, Lithuania, Latvia, Kazakhstan, Uzbekistan, Malta, Cyprus).

EMERALD HOME DEVICES PRODUCT LINE

EMERALD HOME 60 DEVICE

EMERALD HOME 60 is a compact device for producing pure drinking water with antioxidant properties from ordinary tap water in a flow-through mode. Due to the compact size the EMERALD HOME 60 device can be installed either under or above the sink.



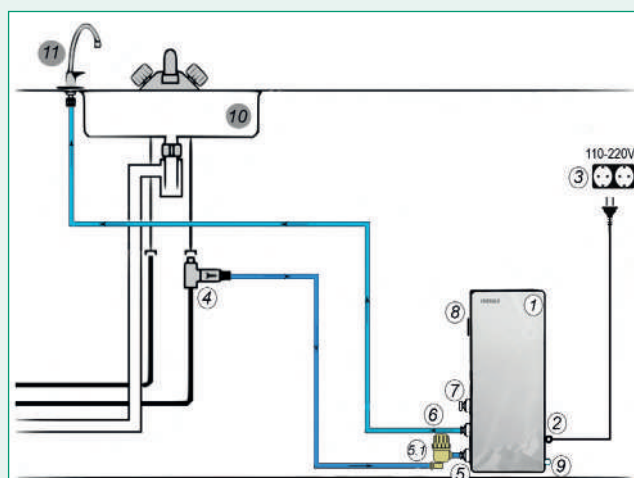
TECHNICAL FEATURES

Performance in pure antioxidant water, liters per hour	60
Power consumption, no more than, W	90
Supply voltage (standard socket with grounding), V	110÷220
Overall dimensions, WxHxD, mm	140x353x121
Net weight, kg	3
The number of electrochemical modules of MB-11 type, pieces	2
The number of water treatment stages, pieces	6
Purification costs for 1000 liters of water, \$	3

WATER CONDITIONING PARAMETERS

ORP of purified water, mV	–300
pH of purified water, pH units	7.5

* Aggregated indicators obtained on tap water with the following parameters: Total dissolved solids (TDS) 250 mg / l, ORP +300 mV, pH 7.0 units.



EMERALD HOME 60 DEVICE, UNDER THE SINK CONNECTION DIAGRAM

The list of main elements:

1. EMERALD HOME 60 device;
2. Plug for connecting the power supply (adapter) to the device;
3. Power supply (adapter), connected to the electric network;
4. T-bend with a ball valve, for supplying cold tap water to the device;
5. INLET fitting for tap water;
- 5.1. Mud filter for mechanical pretreatment of water;
6. CLEAN WATER fitting for the outlet of purified antioxidant water (catholyte);
7. FLUSHING fitting for the inlet of flushing solution (used only in Flushing mode);
8. Electronic display with ammeter / voltmeter;
9. PUMP on/off button for Flushing mode activation;
10. Sink/worktop;
11. Tap for purified antioxidant water (catholyte) outlet.

EMERALD HOME 60 LUX DEVICE



EMERALD HOME 60 LUX is a compact device for producing from tap water in a flow-through not only pure drinking water with antioxidant properties (catholyte), but also antimicrobial water with disinfecting properties (anolyte).

Anolyte is an environmentally friendly and harmless to humans and animals disinfectant with a wide spectrum of action (against bacteria, mycobacteria, viruses, fungi and spores of any species and forms), to which microflora is not able to develop resistance.

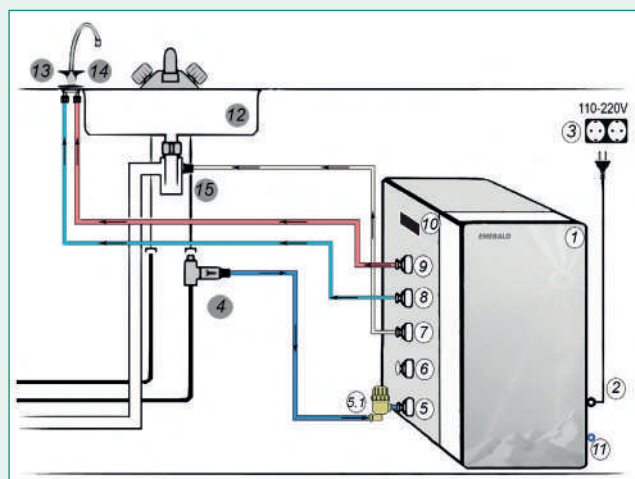
TECHNICAL FEATURES

Performance in pure antioxidant water (catholyte), liters per hour	60
Performance in pure antimicrobial water (anolyte), liters per hour	60
Power consumption, no more than, W	156
Supply voltage (standard socket with grounding), V	110÷220
Overall dimensions, WxHxD, mm	200x360x150
Net weight, kg	4.5
The number of electrochemical modules of MB-11 type, pieces	2
The number of water treatment stages, pieces	10
Purification costs for 1000 liters of water, \$	3

WATER CONDITIONING EFFICIENCY

ORP of antioxidant water (catholyte), mV	-400
pH of antioxidant water (catholyte), units	8.0
ORP of antimicrobial water (anolyte), mV	+800
pH of antimicrobial water (anolyte), units	5.5
Oxidants concentration in anolyte (in terms of active chlorine), mg/l	5–10

* Aggregated indicators obtained on tap water with the following parameters: Total dissolved solids (TDS) 250 mg / l, ORP +300 mV, pH 7.0 units.



EMERALD HOME 60 LUX DEVICE, UNDER THE SINK CONNECTION DIAGRAM

The list of main elements:

1. EMERALD HOME 60 LUX device;
2. Plug for connecting the network cable to the device;
3. Power plug for connecting to the electric network;
4. T-bend with a ball valve, for supplying tap water to the device;
5. INLET fitting for tap water;
- 5.1. Mud filter for mechanical pretreatment of water;
6. FLUSHING fitting for the inlet of flushing solution (used only in Flushing mode);
7. DRAINAGE fitting for drainage water outlet;
8. CATHOLYTE fitting for purified antioxidant water outlet;
9. ANOLYTE fitting for purified antimicrobial water outlet;
10. Electronic display with ammeter / voltmeter;
11. PUMP on/off button for Flushing mode activation;
12. Sink/worktop;
13. Catholyte shut-off valve on a double water tap for purified antioxidant water outlet;
14. Anolyte shut-off valve on a double water tap for purified antimicrobial water outlet;
15. Drain clamp connected to the trap of the kitchen sink for the drainage outlet.

EMERALD HOME 60 OFFICE DEVICE

EMERALD HOME 60 OFFICE is a professional device for producing hot and cold pure drinking water with antioxidant properties in a flow-through mode. The device is made in a form of a point-of-use water dispenser and is connected to the cold tap water supply line.

EMERALD HOME 60 OFFICE devices are especially useful in public places with high drinking water consumption enabling to substantially save money on regular bottled water purchases. EMERALD HOME 60 OFFICE devices can be used at fitness and spa centers, kindergartens, schools, universities, medical centers, resort hotels, cafes and restaurants.

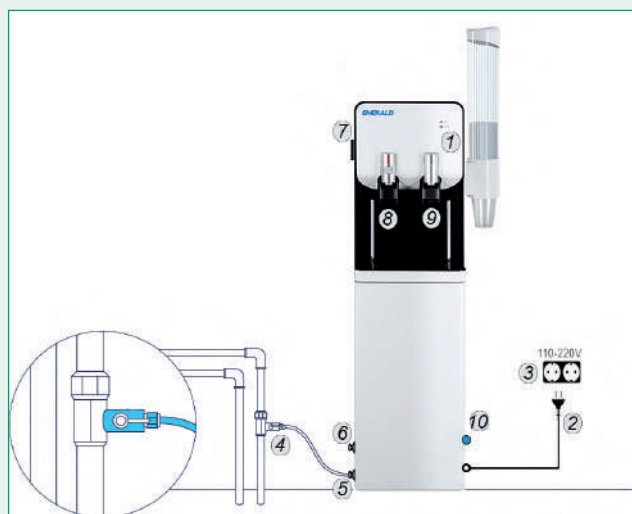
TECHNICAL FEATURES

Performance in pure antioxidant water (catholyte), without heating and cooling, l / h	60
Performance in cold antioxidant water (5–10 C°), l / h	3
Performance in hot antioxidant water (85–95 C°), l / h	5
Power consumption during water purification and activation, no more than, W	156
Power consumption during water cooling, W	100
Power consumption during water heating, W	500
Supply voltage (standard socket with grounding), V	110÷220
Overall dimensions, WxHxD, mm	260x995x325
Net weight, kg	19
The number of electrochemical modules of MB-11 type, pieces	2
The number of water treatment stages, pieces	10
Purification costs for 1000 liters of water, \$	4

WATER CONDITIONING EFFICIENCY

ORP of purified water (without heating and cooling), mV	-300
pH of purified water (without heating and cooling), pH units	7.5

* Aggregated indicators obtained on tap water with the following parameters: Total dissolved solids (TDS) 250 mg / l, ORP +300 mV, pH 7.0 units.



EMERALD HOME 60 OFFICE DEVICE, ON FLOOR CONNECTION DIAGRAM

The list of main elements:

1. EMERALD HOME 60 OFFICE device;
2. Network cable for connecting the device to the electric network;
3. Electrical socket with ground contact;
4. T-bend with a ball valve, for supplying tap water to the device;
5. INLET fitting for tap water;
6. FLUSHING fitting for the inlet of flushing solution (used only in Flushing mode);
7. Electronic display with ammeter/voltmeter;
8. Hot purified antioxidant water outlet;
9. Cold purified antioxidant water outlet;
10. PUMP on/off button for Flushing mode activation.

EMERALD HOME 200 SPA DEVICE



TECHNICAL FEATURES

Performance in pure antioxidant water, liters per hour	200
Power consumption, no more than, W	350
Supply voltage (standard socket with grounding), V	110÷220
Overall dimensions, WxHxD, mm	400x600x200
Net weight, kg	11.5
The number of electrochemical modules of MB-11 type, pieces	6
The number of water treatment stages, pieces	6
Purification costs for 1000 liters of water, \$	4

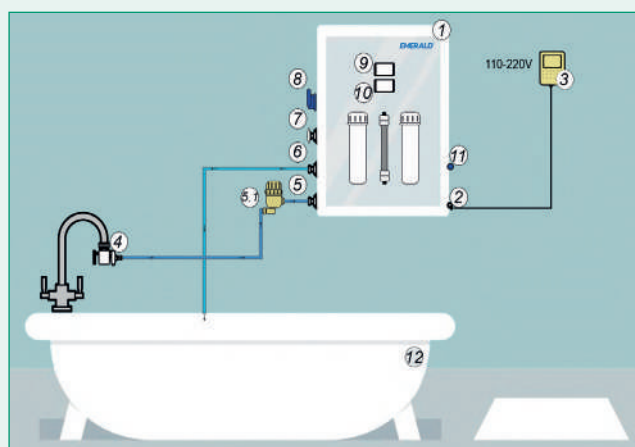
WATER CONDITIONING EFFICIENCY

ORP of purified water, mV	-350
pH of purified water, pH units	7.5

* Aggregated indicators obtained on tap water with the following parameters: Total dissolved solids (TDS) 250 mg / l, ORP +300 mV, pH 7.0 units.

EMERALD HOME 200 SPA devices are used for carrying out antioxidant balneotherapy water procedures in the form of baths or shower using purified electrochemically activated catholyte produced from fresh water. Antioxidant water therapies are used for treatment, prevention and restoration of impaired body functions by neutralizing oxidative stress and restoring the optimal redox status of the internal biological fluids of the body. Antioxidant water therapies enable to restore the body at the cellular level, normalizing the balance of oxidative and reduced chemical compounds in the extracellular and intracellular fluids, which is a prerequisite for the correct functioning of all fundamental vital processes of the body.

EMERALD HOME 200 SPA device produces 200 l/h of warm electrochemically activated catholyte from ordinary tap water in a flow-through mode and can be used in resorts and sanatoriums, medical and rehabilitation centers as well as in fitness, spa and massage centres for providing safe and effective antioxidant water therapies in the form of baths and showers.



EMERALD HOME 200 SPA DEVICE, CONNECTION DIAGRAM IN THE BATHROOM

The list of main elements:

1. EMERALD HOME 200 SPA device;
2. Plug for connecting the network cable to the device;
3. Power plug for connecting to the electric network (with integrated 30 mA GFCI);
4. Diverter connected to the bathroom faucet spout for supplying tap water to the device;
5. INLET fitting for tap water;
- 5.1. Mud filter for mechanical pretreatment of water;
6. CLEAN WATER fitting for the outlet of purified antioxidant water (catholyte);
7. FLUSHING fitting for the inlet of flushing solution (used only in Flushing mode);
8. Catholyte outlet flow control valve;
9. Electronic display with ammeter/voltmeter;
10. Electronic display with water temperature indicator;
11. PUMP on/off button for Flushing mode activation
12. Bath or shower.