6.3. ANOLYTE ANK SUPER: PATH OF IMPROVEMENT

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If you type in any search engine the words «Anolyte», «Catholyte» in any language, you will find an overwhelming number, hundreds of thousands of links devoted to disinfectants, electrochemically activated «live» and «dead» water, as well as various derivatives of these words and concepts. Yet, the original meaning of the terms anolyte and catholyte will take a very modest place in this array of information. In fact, these terms are borrowed from the applied electrochemistry in the early seventies of the last century by one of the authors of this paper to indicate fresh or brackish water subjected to electrochemical treatment in the anode or cathode chambers of the laboratory diaphragm electrolyzer for further use of the obtained solutions in the process of preparation of drilling muds. By the late seventies the laboratory experiments were transformed into industrial electrochemical systems and technologies of electrochemical conditioning and purification of drilling muds saving tens of metric tons of chemical reagents during oil and gas production in Uzbekistan, Turkmenistan, and Azerbaijan. Publications in newspapers and popular science journals on the new scientific and technical trend attracted the attention of specialists in various industries. They were looking for the best way of obtaining and using electrochemically activated solutions and water in their respective areas of activity and willingly shared the peculiarities with the newly-appeared specialists — electrochemists. It gave rise to a creative cooperation based on scientific interest and mutual learning, which has remained active until now with a constant expansion of the spectrum of new technical and engineering solutions. Physicians were among the first to show interest in electrochemically activated water and solutions. It is thanks to their work that the terms Anolyte and Catholyte years later became familiar to healthcare providers. The collaboration of inventors, physicians and chemists from the late seventies to the present has made possible an application of electrochemically activated water and solutions in healthcare. This biomedical layer of work carried out by a group of specialists, scientists and inventors of technical electrochemical systems in conjunction with specialists and scientists in the field of healthcare, biology, biophysics, chemical and food industries are partially presented in references on drilling muds [1–42], arranged approximately in chronological order, starting with the first significant publication of 1975.

Vitold Bakhir. Electrochemical Systems and Technologies Institute.
2020, 32 p. with ill.

The history of the appearance of anolyte as a disinfectant began in 1978 with studies of the Tashkent branch of the All-Union Research Center of Surgery (ARCS) under the leadership of academician Vazid Vakhidovich Vakhidov [5–7]. It was then that the unsurpassed antimicrobial activity of anolyte and its ability to prevent resistance development by microflora was indisputably proven, which fundamentally distinguished anolyte from other disinfectants. But the acidic brackish anolyte the first researchers worked with, had a very high corrosivity and a pungent smell of chlorine. This drawback had to be tolerated, since at that time the methods of obtaining anolyte and catholyte in laboratory were quite simple: the starting fresh or slightly salted water was poured into the interelectrode space of the diaphragm electrolyzer divided into the cathode and anode chambers by a porous diaphragm.

The porous diaphragm soaked in water conducted current due to the electromigration movement of ions in the pores, but prevented the mixing of water volumes in the chambers. With the electric current running, the products of electrochemical reactions from the surface of the cathode and anode entered the water, thus forming an alkaline catholyte in the cathode chamber and an acidic anolyte in the anode chamber. Such an electrolyzer was called static, as opposed to a flow-through one, in which water was continuously running at different set rates through the electrode chambers (Fig. 6.3.1).

Laboratory static electrolyzers had many fundamental drawbacks. The main ones were as follows: high specific

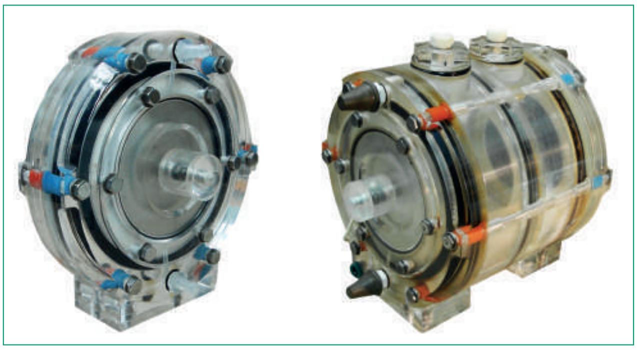

***Fig. 6.3.1.** Laboratory flow-through (left) and static diaphragm electrolyzers.*

power consumption and, accordingly, significant heat release in the interelectrode space. In the treatment of slightly salted water, there was a large useless loss of chlorine. The fact is that the chlorine released at the anode during the electrolysis of brackish water first dissolves to form equal amounts of hypochlorous and hydrochloric acids. With a decrease in the pH of the water in the anode chamber due to the accumulation of hydrochloric acid, chlorine is released into the atmosphere. The use of a tubular ceramic alundum microfiltration diaphragm 80 mm in diameter with the wall thickness of 5 mm, with coaxially placed glass-graphite electrodes, made it possible to create a sealed flow-through electrolyzer and significantly improve the technology for the synthesis of electrochemically activated solutions and water. During this period (1982–1983) the baton of medical and biological research was picked up by doctors from medical institutions in Kazan, headed by Professor G. M. Nikolaev and academician P. A. Kirpichnikov [9]. As a result, methods were developed for the treatment of purulent wounds and burns with electrochemically activated solutions of potassium chloride and permission was obtained from the USSR Pharmacological Committee for the use of an electrochemically activated potassium chloride solution for external application to treat burns, purulent wounds and bedsores.

Continuous improvement of the designs of compact electrolyzers led in 1989 to the creation of a flow-through electrochemical modular cell (FEM), equipped with a porous ceramic diaphragm, capable of operating at absolute pressure up to 4 bar, liquid flow rate in the electrode chambers up to 100 l/h and differential pressure on the diaphragm up to 1 bar, and also suitable for use in industrial electrochemical systems [20]. The study of technological schemes with a new electrochemical FEM element was started in 1989 by a team of researchers and developers based on VNIIIMT M3 RF [21–40].

Authors of this article being part of that team, have devoted many years to the study of the properties of oxidant solutions (anolytes) obtained in electrochemical systems using various technological schemes. Some important aspects of this work are highlighted in this overview, which can be used as a quick reference for electrochemically activated detergents and chlorine-oxygen disinfectants.

The first medical device with a number of FEM elements was REDOX (Fig. 6.3.2, 6.3.3) for disinfection, presterilization cleaning and sterilization of artificial kidney dialyzers, with the purpose of their reuse [15–19]. The work was carried out under a business agreement between NPO KHIMAVTOMATIKA (Customer) and VNIIIMT (All-Union Scientific Research and Testing Institute of Medical Technology).

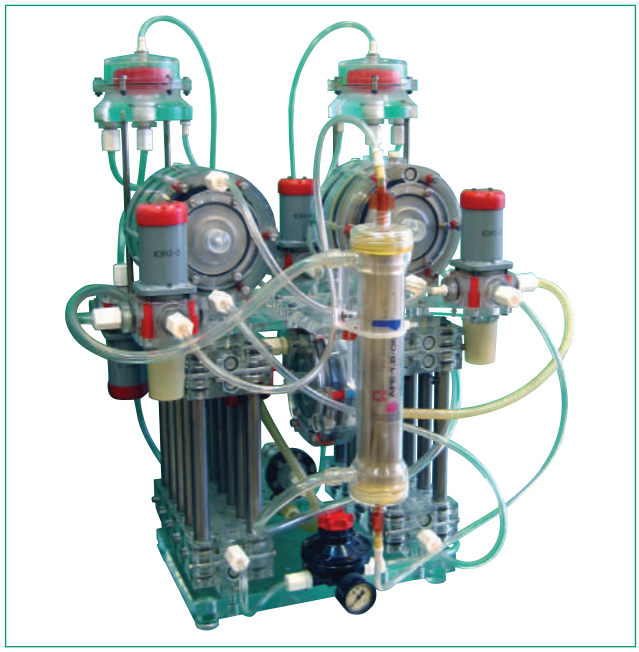

***Fig.6.3.2.** REDOX device prototype for the regeneration of hemodialyzers, created at VNIIIMT of the USSR by order of NPO KHIMAVTOMATIKA, 1989.*

***Fig.6.3.3.** REDOX Device. NPO KHIMAVTOMATIKA, Moscow, 1990.*

Early versions of this device used an alkaline catholyte as a detergent, named Catholyte K, with a pH of more than 12 and an oxidation-reduction potential (ORP) of minus 800mV. The need to assign special designations to electrochemically activated solutions and water arose due to the fact that, thanks to the use of FEM elements, technologies were developed for producing catholyte and anolyte with neutral pH values (close to 7), but with practically the same ORP as for alkaline catholyte and acidic anolyte. Such products were named, respectively, catholyte KN and Anolyte AN. Catholyte KN was used for treatment plate hemodialyzers DIP-02 with cuprophan membranes sensitive to alkaline media. The neutral pH of the catholyte was achieved by organizing the process of ion-selective electrolysis of an aqueous solution of sodium chloride with a concentration of 1.3–1.5 g/l at a pressure drop across the diaphragm, providing the set intensity of energy-mass transfer from the anode chamber to the cathode chamber by hydroxonium ions.

Hemodialyzers with capillary polysulfone hollow fiber membranes were treated in REDOX devices with a washing solution represented by an alkaline catholyte K. The electrochemical reactors of all REDOX devices synthesized a unitary disinfecting and sterilizing solution — Anolyte A, which, with a total mineralization of 1.3–1.5 g/l, had an oxidant concentration in the range of 250–300 mg/l, pH in the range 3.5 to 4.0 and ORP from plus 1000 mV to plus 1100 mV. The main advantage of REDOX devices against other types of systems for the regeneration of hemodialyzers was the complete extraction of blood proteins from the dialyzer membranes based on their electroosmotic and electrophoretic removal, due to the difference in electrical potentials on the dialyzer membranes, induced by the ORP difference of the solutions run.

These devices have passed all tests stipulated by the standards at VNIIDiS (All-Union Scientific Research Institute of Disinfection and Sterilization). Dialyzers, regenerated using the REDOX device, formally had the product status with the label «Sterile, non-pyrogenic, non-toxic», but for ethical reasons, regenerated dialyzers have only been used for the same patient. At the same time, pyrogenic reactions have never occurred on the same dialyzer, for patients with repeated procedures, the number of which reached 25. In total, in various hemodialysis centers (in Pskov, Vologda, Moscow and other cities) more than one million artificial kidney dialyzers were cleaned in the years 1989–1993.

Almost simultaneously (1989) with the development of the REDOX system, work was organized at VNIIIMT to create devices for the synthesis of electrochemically activated disinfecting, washing and sterilizing solutions. The collective name for this kind of systems was chosen from the first letters of the words Electrochemical Sterilization, arranged in the order of euphony. This is how the STEL class of devices appeared (Fig. 6.3.4). STEL-10AK devices with an electrochemical reactor of ten FEM elements synthesized acidic anolyte A and alkaline catholyte K at 100 liters per hour production capacity. Those solutions were used for disinfection, pre-sterilization cleaning and sterilization of medical instruments. Despite the higher quality of anolyte A, due to its lower mineralization (1.3 g/l versus 5–6 g/l in anolyte produced in early laboratory diaphragm reactors of the 1970s), the smell of chlorine was one of the drawbacks. Another disadvantage of anolyte was its high corrosiveness. However, Catholyte K as a cleaning solution was flawless and demonstrated a cleaning ability exceeding standard cleaning methods.

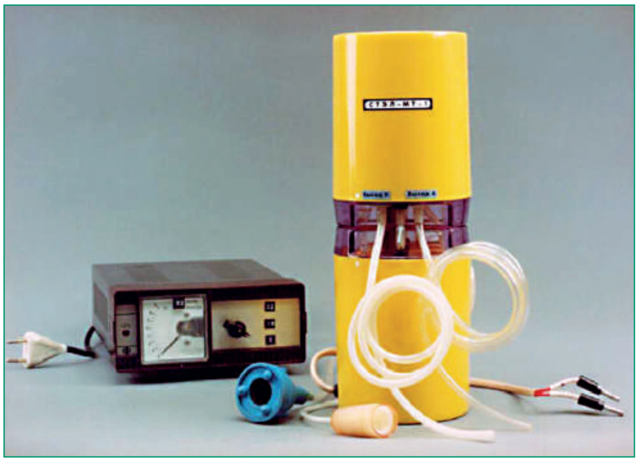

Fig.6.3.4. *STEL-MT-1 Device, VNIIIMT Min. of Health RF, 1992.*

As an example, photographs of medical instruments that had undergone standard disinfection, pre-sterilization cleaning and sterilization procedures were demonstrated. The instruments were immersed in two basins — with clean water and Catholyte K. In the first basin, the water remained perfectly transparent, in the second, after 10 or 15 minutes it acquired a pronounced pink color. This meant that the catholyte was extracting the remains of clotted blood from the joints and other hard-to-reach places of medical instruments. An explanation for this fact was found by chemists [12–14]: the critical concentration of micelle formation (CMC) of surfactants in catholyte is thousands of times less than in ordinary water. This means that the electrochemically activated catholyte, due to a very low ORP value (minus 700 to minus 800 mV) and a high pH value that does not correspond to the real concentration of alkaline components, can saponify organic compounds, in particular fats, converting them into surface-active substances. This effect was immediately used practically when washing clothes and allowed to reduce the consumption of detergents by 70–80% [16].

The disadvantages of acidic anolyte were eliminated in 1991 by creating an anolyte with a pH value close to neutral. This anolyte was named Anolyte AN. It had a very faint smell of chlorine mixed with a faint smell of hydrogen peroxide and ozone. The corrosive activity of the anolyte was significantly reduced, and the biocidal activity underwent minor changes, depending on the material of the treated objects (glass, ceramics, rubber, etc.). In addition, it was discovered that Anolyte AN had a detergentability, which was an advantage over Anolyte A. The most important role in the emergence of Anolyte AN belongs to Nina Vasilievna Ramkova, at the time head of the Sterilization Department of VNIIDiS.

The neutral pH of the anolyte AN were achieved by the migration of free hydroxyl groups through the diaphragm into the anode space from concentrated catholyte generated during the flow of the initial brine solution through the anode chamber of the FEM element.

In 1991 Academy of Sciences at the All-Union Scientific Research Institute of Preventive Toxicology and Disinfection (VNIID, former VNIIPTID) published a report named «Some aspects of the antimicrobial activity and toxicity of electrochemically activated solutions obtained by STEL and STEL-MT-1 devices [20–23], using sodium chloride». The report on 58 pages also contained data on acidic anolyte and alkaline catholyte produced by REDOX devices, which were previously tested at the same institute. The STEL devices referred to in the report were actually an electrochemical system for generating acidic anolyte and alkaline catholyte, which was used in REDOX devices.

It seems appropriate to cite separate fragments of that report, illustrating the description of the physicochemical synthesis processes in STEL devices and the design features of electrochemical cells.

Fragments of the 1991 VNIIPTID report.

1. The research results indicate a wide spectrum of anolyte antimicrobial activity. At a concentration of active chlorine from 42 to 100 mg/l and treatment time from 1 to 60 minutes anolyte kills vegetative and spore forms of bacteria, mycobacteria, pathogenic fungi and viruses.
2. Acute toxicity test on animals showed low toxicity of anolyte.
3. Catholyte is a low-toxic and low-hazard agent. It is safe for medical devices to have a residue of catholyte after pre-sterilization cleaning.
4. One of the methods of disinfection, pre-sterilization cleaning and sterilization in a medical facility is the treatment with solutions of appropriate agents, which ensures these processes. The range of such agents is limited, and the need to expand it is urgent.
5. Based on experimental study of anolyte and catholyte, the Commission of the USSR Ministry of Health for the regulation of the use of disinfectants (Protocol No. 13 of December 21, 1989) allowed carrying out clinical trials.

Tests took place on 4 bases (medical facilities in Moscow, Kazan and Ufa). Anolyte was used for disinfection of premises and objects in them and sterilization of medical products; catholyte was used for pre-sterilization cleaning of medical devices made of metal, glass, rubber and PVC.

27 people participated in tests of anolyte and catholyte as a disinfectant, sterilizing agent, as well as for pre-sterilization cleaning.

The tests revealed 100% efficiency of electrochemically activated solutions and their safety in accordance with the developed guidelines.

Evaluation of the antimicrobial activity of the anolyte was tested using the suspension method and the method of test objects. Test objects were made of materials used in the DIP dialyzer (separating plates, membranes made of cuprophane), as well as from metal, plastic, rubber.

To assess the disinfecting and sterilizing efficiency, we used medical devices (scalpels, tweezers, drains, probes, syringes, test tubes, micropipettes). Test cultures were represented by vegetative microorganisms: intestinal bacteria, Pseudomonas aeruginosa, Staphylococcus aureus, poliomyelitis virus, spores of bacillus cereus.

It was found that when using the suspension method, the kill of vegetative forms of microorganisms was achieved in less than 0.5 minutes, kill of spores — in 1 minute, the time of virus inactivation was 5 to 30 minutes.

On test objects, the kill of vegetative forms of bacteria occurred within 1 to 30 minutes, that of bacterial spores — within 1 to 360 minutes, of virus 5 to 90 minutes. It was noted that the efficiency of anolyte solutions clearly depended on the material of the test object and the concentration of active chlorine in the anolyte.

Disinfection of products seeded with vegetative forms of bacteria is provided by immersing them in anolyte solutions with an active chlorine concentration of 200–400 mg/l for 5–20 minutes, respectively; contaminated with a virus — in solutions containing 210–400 mg/l of active chlorine, for 5–60 minutes. Sterilization of a number of medical devices is achieved by immersion in anolyte solutions with an active chlorine concentration of 210–360 mg/l for 1 to 240 minutes.

Products made of metal (scalpels, tweezers, etc.), rubbers, glass (syringes, test tubes, micropipettes) and PVC were washed from blood at the appropriate stages of treatment with catholyte solutions with pH 10.9 to 12.1 and redox potential of minus 900 to minus 985 mV.

Together with NPO EKRAN, work is being carried out on the topic «Study of electrochemically activated solutions obtained at STEL and STEL-MT-1 devices using sodium chloride, and medical research of these devices».

The present work is carried out on the basis of the data obtained in the above studies and serves as their development. Its purpose is to identify some regularities linking the washing and antimicrobial activity of solutions with their physicochemical parameters, conditions of use, in particular, the material of test objects, products, processing method.

Note to the 1991 VNIIPTID report: this report is the most complete and detailed document of this organization on the functional properties of the first samples of anolytes.

STEL-MT-1 devices for production of Anolyte AN and Catholyte K, manufactured at the pilot plant VNIIIMT under the supervision of employees of the department of electrochemical medical equipment of VNIIIMT, began to be supplied to healthcare institutions in Moscow and a number of other cities. In total for the period 1991–1992 there were about 100 STEL devices and about 400 STEL-MT-1, STEL-4N-60-01, STEL-4N-60-02 devices were manufactured, with production capacity by anolyte AN from 10 to 60 liters per hour. An analysis of the reviews of the personnel of hospitals operating the devices, along with positive reviews about the unique properties of anolyte AN as a washing and sterilizing agent, has revealed a number of disadvantages. In particular, it takes from 10 to 15 minutes for a STEL device to reach the operation regime. This time is necessary to reach the optimal concentration of catholyte, while devices producing acidic anolyte with the smell of chlorine. For this reason, the devices had to be placed under fume hoods.

It was found that the retention time of functional properties for all types of anolytes should be assessed only by sporicidal activity, but not by the retention of active chlorine compounds. For Anolyte AN, the time turned out to be 1 to 2 days less in comparison with the shelf life of Anolyte A (5 days).

Scientific research work carried out by the team of VNIIIMT during 1992–1993 made it possible to explain the results of observations and find appropriate solutions. It was found that ions of polyvalent metals at pH values of the solution close to neutral played the role of active catalysts for the destruction of hypochlorous acid in AN Anolyte. It was also noted that the washing ability of AN Anolyte was due to an increase in the proportion of peroxide compounds in the composition of active substances, represented by a mixture of oxidants.

The key point in improving the technology of anolyte synthesis was in removing polyvalent metal ions and saturating the initial solution with electrochemically synthesized hydrogen before injecting oxidants [22]. So, in 1993 Anolyte ANK appeared [24–27]. The letter K, added to the designation, meant the use of cathode products in the synthesis process, however, the methods for realizing this possibility are mainly technological secrets.

Fig.6.3.5. STEL-10N-120–01 Device (Mod. 60) at CCH (City Clinical Hospital) No. 52, Moscow, 1995.

All the various names later invented by authorized and unauthorized manufacturers of electrochemical equipment both in Russia and abroad refer just to this type of anolyte. In order not to upset people on Easter days, when this text is being written, only authorized manufacturers of equipment for the synthesis of Anolyte ANK are mentioned. This has made the text shorter, since there are many times less authorized manufacturers than unauthorized ones.

The essence of the Anolyte ANK production technology is quite simple: first, the starting aqueous solution of sodium chloride with a concentration of 2 to 5 g/l is fed into the cathode chamber of a flow-through electrochemical cell (RPE) made of FEM elements — one or several, connected hydraulically in parallel. After leaving the cathode chamber, the solution enters a flotation reactor, in which a certain amount of the liquid (in the range from 5 to 10%) is discharged from the main flow through the branch pipe for the removal of flotation sludge together with excess gaseous hydrogen. The main part of the solution from the flotation reactor is directed to the inlet of the anode chamber of the same RPE cell, at the outlet of which the solution converts into Anolyte ANK. The original technology for the synthesis of Anolyte ANK, among others, has a secret that is not disclosed in the descriptions of inventions. In view of the fact that the Anolyte ANK became an obsolete disinfectant with the appearance on the market of Anolyte ANK SUPER (2013), it makes sense to partially reveal this secret, indicating that the pressure in the anode chamber of the RPE cell during the synthesis of Anolyte ANK should be 0.2 to 0.3 bar higher than in the cathode chamber. In this case, the current running through the diaphragm is mainly

Fig. 6.3.6. *STEL-10N-120–01 device, (Mod. STEL-40) with a productivity of 40 l/h. NPO EKRAN, 1995.*

due to the electromigration of cations from the anode chamber to the cathode one.

This also ensures a more complete conversion of polyvalent metal ions into insoluble hydroxides, which are removed from the flow of electrolyte solution in the flotation reactor due to adhesion to hydrogen bubbles. The total mineralization of Anolyte ANK also decreases. Since all physicochemical and electrophysical processes of the synthesis of electrochemically activated solutions occur during a very short residence time of the initial components in the interelectrode space of the reactor, functional properties and parameters of the product, as well as technical and economic indicators of the entire technical electrochemical system are highly sensitive to the design features of the electrochemical reactor: materials, shape and size ratio of electrodes, diaphragm characteristics, as well as to direct and indirect relationship of these design features with current density, pressure, chemical composition, flow rate, energy and mass transfer through the diaphragm, microcirculation of electrolytes and other parameters of the system as a whole.

The first samples of STEL-10N-120–01 devices for the synthesis of Anolyte ANK were developed and manufactured at NPO EKRAN, the former All-Union Scientific Research and Testing Institute of Medical Technology (VNIIIMT), where one of the authors of the article for many years headed the department of electrochemical medical technology. Serial production of those devices was also organized there (Fig. 6.3.6, 6.3.7).

Below are excerpts from a six-page 1996 report of the All-Russian Research Institute of Disinfectology (VNIID) on the efficiency of an electrochemically activated solution — neutral Anolyte ANK produced by the STEL-10N-120–01 device.

1. Implementation of electrochemically activated (ECA) solutions produced by devices like STEL, ECA-30, UMEM in healthcare practice, has facilitated the position of medical institutions in terms of purchasing disinfectants, detergents and sterilizing agents. At the same time, the use of ECA solutions does not eliminate all problems due to some undesirable properties of these agents: for example, the significant corrosive activity of «acidic» anolytes, the ability to irritate the respiratory organs and mucous membranes of the eyes when using anolytes with an active chlorine content of 0.05 % and higher. The mildest in action and at the same time universal means are the so-called «neutral» anolytes, which have a broad spectrum of antimicrobial activity, as well as detergent properties. In recent years, the search for ways to obtain ECA solutions even more functionally active and sparing for materials of processed objects has been going on. This search is associated with the development of new device models. The new STEL-10N-120-01 device, due to the changes in technological scheme, allows producing a new type of neutral anolyte (ANK). This anolyte has the following characteristics: active chlorine content from 0.01 % to 0.05 %; hydrogen index value pH = 7.8 ± 0.6; redox potential from +750 mV to + 810 mV.

   In order to study the antimicrobial and detergent properties of this ECA solution and develop effective modes of its use, studies of the disinfecting, washing and sterilizing activity of the agent were undertaken in laboratory conditions.
2. The study of the disinfecting efficiency of neutral anolyte (ANK) for various objects was carried out according to the protocol set forth in the «Instructions for the study of the bactericidal properties of new disinfectants» No. 739–68 and in the «Methodological recommendations for the determination of virucidal activity of drugs» No. 1119–73.

   Museum strains of Staphylococcus aureus (strain 906), Candida albicans (strain 15), Mycobacterium B 5 and polio virus type I (vaccine strain ZSc 2av) were used as test microorganisms.
3. The results of changing the physicochemical parameters of the neutral anolyte during its storage are given in the stability certificate. As a result of checking the efficiency of the neutral anolyte with an active chlorine concentration of 0.02 % on medical devices contaminated with S aureus (strain 906) and B. cereus (strain 96) within 1 and 5 days after production, it was found that the disinfecting and sterilizing properties of the agent remain practically at the initial level.
4. Conclusion. The results of laboratory studies of the effectiveness of the electrochemically activated solution — neutral Anolyte ANK produced by the STEL-10N-120–01 device have shown that antimicrobial and detergent

Fig. 6.3.7. *STEL devices (NPO EKRAN) for the production of Anolyte ANK (500 l/h) in the «Anolyte» room Moscow City Hospital №915, Moscow, 1999.*

properties of this agent are more than not inferior to previously approved neutral anolytes (STEL-MT-1, STEL-4N-60-01, steel-4N-60-02): it even surpasses them, since it provides disinfection of objects for a number of infections, as well as pre-sterilization cleaning and sterilization of medical products at lower concentration of active chlorine (0.01–0.02 %).

Note to the text of the above fragments of the VNIID report: the UMEM device mentioned in the report was made by KRONT enterprise at NPO LAVOCHKIN and was actually an automated version of the ECA-30 device.

NPO KHIMAVTOMATIKA company, thanks to business relationships with NPO EKRAN and the technology of production of electrochemical systems licensed by the authors, produced more than 20.000 STEL-60-03-ANK devices in the period from 1995 to 2008, as well as, together with NPO EKRAN, about four hundred ENDOSTERIL devices (Fig. 6.3.8) in 1998–2002 for sterilization of endoscopes, winning an international tender of the European Bank for Reconstruction and Development for several million Euro.

The authorized manufacturers of equipment for the production of Anolyte ANK in Russia were the Izhevsk plant KUPOL (1997–2007), Vitold Bakhir Electrochemical Systems and Technologies Institute LLC (from 2005 to the present), as well as Laboratory of Electrotechnology LLC (LET LLC) from 1991 to the moment of the raider takeover in 2011 and transformation into a bogus company that has a similar name to the point of confusion and has appropriated the twenty-year history of the original company.

Abroad, on the basis of licenses, as well as agreements on cooperation and development, the production of electrochemical systems for the synthesis of Anolyte ANK was organized in companies RSCECAT, MONSANTO, ECT, STERILOX, BATTELLE, PURICORE, BLUE SAFETY, REALM THERAPEUTICS. Companies CHEMSTAR, ECOLAB and URGO are using electrochemical systems for supplying Anolyte to the Food and Medical Device markets.

Summing up, from 1994 to 2014 about 60.000 STEL devices were produced in Russia, basing on the modifications of two models STEL-10N-120-01 and STEL-60-03-ANK.

After several months of devices operation in various healthcare facilities, among which some of the first were CCH (City Clinical Hospital) No. 15, CCH No. 50 and CCH No. 52 of the city of Moscow, it was confirmed that Anolyte ANK had the lowest corrosive activity in comparison with other solutions obtained by the unipolar electrochemical treatment, and also had the properties of a washing solution. Devices for the synthesis of Anolyte ANK became much more convenient in operation: the time to reach the production mode was no more than 1 or 2 minutes, chlorine off-gassing during start-up and shutdown were completely eliminated.

The experience of using STEL electrochemical devices for the synthesis of Anolyte ANK in healthcare facilities in Russia was discussed in specialized journals, at conferences and scientific symposia. On the way of improving the properties of Anolyte ANK and electrochemical systems for its synthesis, the authors used the advice of such outstanding specialists as T.I. Noskova, S.M. Savenko, V.M. Melnikova, N.V. Loktionova, V.B. Rovinskaya, V.V. Toropkov, V.I. Pokrovsky, G.P. Belikov, A.A. Podkolzin, O.A. Zarezaev, V.P. Dymkovets, B.I. Leonov, V.G. Vedenkov,

Fig.6.3.8. *ENDOSTERIL device for disinfection, cleaning and sterilization of flexible endoscopes.*

V.I. Toloknov, V.V. Kolkutin, V.P. Baldin, O.A. Mashkov, V.Yu. Ryzhnev, A.M. Pulavsky, R.Sh. Perlovsky, A.N. Mankin, M.V. Byalko and many others. As a result of numerous conversations and discussions, the requirements for Anolyte ANK were formulated, for it to be considered a perfect antimicrobial and antiviral agent:

- an antimicrobial agent must have a wide spectrum of action, i.e. effectively destroy bacteria, mycobacteria, viruses, fungi and spores, regardless of the duration and frequency of use, which implies the presence of properties that prevent microorganisms from developing resistance;
- an antimicrobial agent must be safe for humans and animals, both during its preparation and use, and after the end of its intended use, that is, during the period of degradation and destructive changes under the influence of environmental factors or as a result of biodegradation processes in the human body, in other words, the antimicrobial agent and products of its natural or artificial degradation should not contain xenobiotic substances;
- an antimicrobial agent must be versatile, i. e. have not only antimicrobial and antiviral properties, but also have a cleaning ability with minimal damaging and corrosive activity in relation to various materials, must not leave deposits after drying on smooth surfaces, and must also be as easy to use as possible and at the same time relatively inexpensive.

It should be noted that as early as in 1995 it became obvious that Anolyte ANK should be improved in decreasing its total mineralization while maintaining the concentration of active substances with a simultaneous increase in the proportion of hydroperoxide oxidants. Experimental laboratory systems in 1995–2000 for obtaining such a solution with a concentration of oxidants of 500 mg/l with a total mineralization of 0.6 g/l consisted of up to 40 FEM-3 elements, but their productivity was only 15–20 liters per hour. Conventional serial original STEL devices had an electrochemical cell with each of the FEM elements, depending on the degree of perfection, producing from 10 to 15 l/h of Anolyte ANK. Thus, the cell of the STEL-10N-120–01 device with a capacity of 120 l/h consisted of 12 FEM elements, the cell of the STEL-60–03-ANK device with a capacity of 60 l/h first consisted of six, then, after improvements — of four elements.

Non-original devices with the same names, which by 2002 began to be produced much more than the original ones, as a rule, had cells with fake FEM elements in an amount from two to three times less than in devices manufactured under the authors' licenses. The result was a high mineralization of anolytes, usually in the range from 8 to 20 g/l with a standard initial concentration of oxidants of 500 mg/l, which at that time and to this day is the main indicator of the quality of Anolyte for most doctors and employees of Rospotrebnadzor. In the original STEL devices, the mineralization of Anolyte ANK does not exceed 5 g/l at a concentration of oxidants of 500 mg/l and not more than 2 g/l at a concentration of oxidants of 200 mg/l. With a high mineralization of the initial saline solution, the anolyte obtained from it contains little hydroperoxide oxidants, quickly (within one day) loses its sporicidal activity and, degrading at a rate usual for active chlorine solutions, turns into a saline solution leaving traces on drying on smooth surfaces, initiating corrosion of metals, provoking the absorption of moisture by porous materials, including walls, as a result of salt accumulation, which, due to the effect of «wet walls», can lead to mold formation.

It was considered unreasonable to reduce the mineralization of the anolyte by increasing the number of FEM elements in the cell, due to the difficulty of providing identical flows distribution through the electrode chambers of the elements in conditions of active pulsed gas release and differences in the intensity of energy-mass transfer processes in the diaphragms, which are due to the peculiarities of the porous structure of oxide-zirconium ceramic diaphragms manufactured by slip casting.

In order to choose the optimal way of improving Anolyte ANK, it was necessary to accurately determine the composition and properties of active substances, depending on the various synthesis conditions.

On this path in Russia, the authors faced considerable difficulties in the process of certification tests of Anolyte A, Anolyte AN and Anolyte ANK. It was required to indicate precisely the composition and percentage of active substances. However, methods for the determination of such compounds in aqueous solutions did not yet exist at that time. The authors' requests to analyze similar situations associated with the actual uncertainty of the chemical composition and the mechanism of antimicrobial action of such metastable, but very effective antimicrobial substances as the flame of boric acid ester (about 40 degrees Celsius), ultraviolet and X-rays, products of corona electric discharge used in particular in officially approved devices for sterilizing dental instruments, at best were reduced to an explanation that the antimicrobial activity of those substances was evaluated by the effect, but not by the chemical composition of the substance. It was this decision that was proposed to apply in the years 1991–1995. It was accepted, but forgotten years later.

Based on the regularities of the course of electrochemical processes in the FEM elements, as well as on a number of results of direct and indirect studies of the products of chemical, biological, including catalytic and ion-catalytic reactions, by 1995 the authors arrived at the conclusion that the active substances in the Anolyte ANK were a mixture of peroxide compounds ($HO^{\bullet}$ — hydroxyl radical; HO_2^- — peroxide anion; $^1O_2$ — singlet molecular oxygen; O_2^- — superoxide anion; O_3 — ozone; $O^{\bullet}$ — atomic oxygen) and chlorine-oxygen compounds (HClO — hypochlorous acid; ClO^- — hypochlorite ion; $ClO^{\bullet}$ — hypochlorite radical; ClO_2 — chlorine dioxide, Cl_2O — chlorine monoxide).

Such a combination of active substances ensures the absence of adaptation of microorganisms to the biocidal action of Anolyte ANK, and the low total concentration of active oxygen and chlorine compounds guarantees complete safety for humans and the environment during prolonged use. The loss of antimicrobial properties of Anolyte ANK during storage is due to the reactions of mutual neutralization of the majority of metastable chlorine-oxygen and hydroperoxide oxidants, which have the higher rate, the higher the total mineralization of Anolyte ANK. Reactions of this type, in particular, include the processes of interaction of hypochlorous acid with hydrogen peroxide ($HClO + +H_2O2 \rightarrow O2\uparrow + + H2O + HCl$), hydrogen peroxide with ozone ($H_2O_2 + O_3 = = 2O_2\uparrow + H_2O$) and a number of others.

Scientific and technical cooperation within the framework of licensing agreements with MONSANTO, BATTELLE MEMORIAL INSTITUTE and PURICORE, which began in 1995, has helped to understand the issues of the chemical composition and functional properties of Anolyte ANK. The main participants in this cooperation and its ideological core are the authors of this article, chemists-technologists Svetlana Panicheva and Vadim Panichev.

After the laboratories of the MONSANTO company had confirmed the presence of hypochlorous acid, hydrogen peroxide, ozone, chlorine dioxide and some accompanying compounds, as well as the absence of hypochlorite ions in the Anolyte ANK, the question arose about the mechanism of the coexistence of antagonist compounds in Anolyte ANK. The experiments have shown that with various options for mixing solutions of hypochlorous acid and hydrogen peroxide, mutual neutralization occurs, in accordance with the above reactions. It was suggested that in the initial period of the anolyte existence (from several minutes to several tens of minutes) gaseous products of electrochemical reactions dissolved in it, due to the interaction with which and under the electrostatic protection of which the antagonist compounds could form around themselves protective structures of electrically oriented water molecules. Calculations have shown that such dissolved gas «bubbles» should have dimensions from 15–20 to 30–50 angstroms. The search for these hypothetical bubbles by various methods (EPR, X-ray and ultraviolet spectroscopy, nephelometry, capillary zone electrophoresis) lasted almost two years and, finally, was crowned with success.

Fig. 6.3.9. *Treatment with Anolyte ANK of troops who have been in microbiological or chemical contaminated zone, as well as of all their equipment and clothing. The specialists of the Battelle Memorial Institute (USA) have found that it takes 30 minutes to kill anthrax spores by 0.5% sodium hypochlorite solution, and a few seconds by 0.035% Anolyte ANK (with 14 times less active substances concentration). Marine Corps Base Camp Lejeune, USA.*

The funny thing about this search story was that the secret of the bubbles lay on the surface. Two of the authors of the article in Moscow, at VNIIIMT, a week before the confirmation of the hypothesis in the laboratory of MONSANTO, USA, Saint-Louis, decided to vacuumize the anolyte and see if there was a difference in the «boiling» pressure with ordinary water. It turned out that the difference was huge — more than 0.25 kgf/cm2. At the same time, unlike water, where the centers of gas release (embryos) were located on the walls of the vessel, gas release in the anolyte began uniformly throughout the volume with the amount of released gas greater than that assumed by calculation, referring to the tabular data on solubility.

During 1998–2002, in cooperation with the BATTELLE Memorial Institute, Anolyte ANK generator was designed to meet requirements of the US Marines to the field equipment (Fig. 6.3.9) used for chemical and biological decontamination of troops and equipment. After assembly and successful testing of Anolyte ANK generator, US Marines have been trained installing and operating it in the field. Also, the result of cooperation with the BATTELLE Institute was the confirmation of superiority of the biocidal efficiency of Anolyte ANK (trademark ECASOL) in comparison with sodium hypochlorite solution with a concentration of hypochlorite ions fourteen times exceeding the concentration of active substances in Anolyte ANK.

In 1999, the department of electrochemical medical equipment of NPO EKRAN began preparation of the documentation required to obtain a pharmacopoeial monograph for Anolyte ANK as a remedy. The primary document for the beginning of the works was the report of the All-Russian Research Institute of Disinfectology (VNIID) on the results of laboratory studies of the effectiveness of electrochemically activated solution — neutral anolyte (ANK), produced by STEL-10N-120–01 device.

In 2000, studies on the ability of the Anolyte neutral ANK drug with an oxidants content of 0.05 % to induce chromosomal aberrations in the bone marrow cells of mice were carried out at the Russian Cancer Center of the RF Academy of Medical Sciences under the general supervision of Professor D. E. Zaridze, the Director of the Research Institute of Carcinogenesis, Corresponding Member of the Russian Academy of Medical Sciences. The potential mutagenicity of the Anolyte neutral ANK drug was also experimentally studied. The general conclusion based on the results of the studies performed was as follows: The Anolyte neutral ANK solution studied in accordance with the Methodological Recommendations of 1998 does not possess cytogenetic toxicity.

In 2002, a study of the allergenic properties of the Anolyte neutral ANK solution was carried out under the leadership of Ph. D.V. E. Lappo at the All-Russian Scientific Research and Testing Institute of Medical Technology of the RF Ministry of Health, in the Department of Toxicological Testing and Research of Materials and Medical Products.

Investigations of the effectiveness of the therapeutic action of Anolyte neutral ANK in infected burns of rats were carried out at the Research Institute of Experimental Cardiology of the Russian Cardiological Research and Production Complex of the RF Ministry of Health in the laboratory of drug toxicology under the leadership of Professor E. V. Arzamastsev. In the same laboratory, the effect of the Anolyte neutral ANK drug on the DNA repair system in the SOS chromotest was studied, as well as the embryotoxic and teratogenic properties of the Anolyte neutral ANK drug and its effect on reproductive function.

In 2001, investigations of the immunotoxic properties of the Anolyte neutral ANK electrochemically activated solution were carried out at the Medical Radiological Scientific Center of the Russian Academy of Medical Sciences under the general guidance of Professor A. F. Tsyba, the Director of the MRRC RAMS.

At the Research Institute of Experimental Cardiology of the Russian Cardiological Research and Production Complex of the Ministry of Health of the Russian Federation in the laboratory of drug toxicology under the leadership of Professor E. V. Arzamastsev investigations of the effectiveness of the therapeutic action of Anolyte neutral ANK in infected burns of rats were carried out.

In the same laboratory, the effect of the Anolyte neutral ANK drug on the DNA repair system in the SOS chromotest was studied, as well as the embryotoxic and teratogenic properties of the Anolyte neutral ANK drug and its effect on reproductive function.

The result of all successfully completed scientific and experimental studies was the pharmacological monography of the enterprise (NPO EKRAN) FSP 42–0664792406 dated 27.10.2006. This pharmaceutical monography was approved by registration certificate No. LS-002150 of the Federal Service for Surveillance in Healthcare and Social Development of the Russian Federation for neutral Anolyte ANK, used as a drug in the form of a solution for local and external use.

See below **a fragment from the Instructions for medical use of the ANOLYTE NEUTRAL ANK drug (ANOLYTUM NEUTRALIUM ANK).**

1. **Pharmacotherapeutic group:** antiseptic. Code ATX D08AX.
2. **Pharmachologic effect:** Anolyte neutral ANK is an aqueous solution of a diluted sodium chloride solution passed through an electrochemical reactor producing chlorine-oxygen and hydroperoxide oxidants (hypochlorous acid, hypochlorite ion, active oxygen compounds). Anolyte neutral ANK is non-toxic, has a high reaction and catalytic activity at a low concentration of active substances, disinfecting effect, washing and anti-inflammatory properties. Anolyte neutral ANK accelerates the healing of infected purulent wounds.
3. **Pharmacokinetics:** active substances of Anolyte neutral ANK when applied topically, do not have a resorptive effect on the body.
4. **Indications:** Treatment of the skin, skin folds, mucous membranes in order to disinfect and remove organic impurities (sweat, sebaceous matter, other impurities). Treatment of infected wounds, prevention of wound infection.

Data obtained by the BATTELLE Memorial Institute (USA) regarding the sporicidal activity of Anolyte ANK were tested on anthrax strains and fully confirmed at the Scientific Research Institute of Microbiology MORF (Kirov, E. V. Pimenov, 2002). As a result, the use of Anolyte ANK is recommended for processing the premises of the Institute. At the Virology Center of the Research Institute of the RF Ministry of Defense (Sergiev Posad, V. Bondarev, V. Maksimov, Yu. Semin,2001) high virucidal activity of Anolyte ANK was ascertained. In the Central Forensic Medical Laboratory of the Ministry of Defense of the Russian Federation (Moscow, V. V. Kolkutin, 1999), studies were carried out and recommendations were developed for the use of Anolyte ANK for the purpose of express preservation (embalming) of corpses and remnants for subsequent genetic examination, as well as for disinfection of sectional halls of forensic and pathological and anatomical laboratories. The first practical experience of using Anolyte ANK for these purposes was acquired almost immediately after the end of the research: STEL-10N-120–01 devices worked at Regalia, in Roslyakovo and produced Anolyte ANK, which compared favorably with formalin in that it did not destroy the DNA structure, simultaneously stopping the action of enzymes and destroying microflora of all types and forms.

Summarizing the laboratory research data accumulated over almost a decade and a half, confirmed by information on the practical use of Anolyte ANK in medical and prophylactic institutions in Russia, Academician of the Russian Academy of Medical Sciences, Director of VNIID Professor M.G. Shandala expressed his opinion in a letter addressed to B.I. Leonov, Director General of NPO EKRAN, No. 1–01/167 dated March 3, 2006: «Dear Boris Ivanovich! We hereby inform you that the virucidal activity of electrochemically activated agents (anolytes produced by STEL-type devices) confirmed by the state registration in the Russian Federation indicates their disinfecting activity against all known viruses — human pathogens, including viruses of enteral and parenteral hepatitis, HIV, poliomyelitis, adenoviruses, atypical pneumonia viruses (SARS), human and H5N1 avian influenza, herpes and others».

In the course of work on the improvement of the Anolyte ANK [28–30], the scientific results of studies of the antibacterial defense mechanism created by Nature and functioning in the internal environment of humans and animals for millions of years were analyzed.

It is known [43–49] that the leading role in the bactericidal action of neutrophils belongs to hypochlorous acid (HClO), produced by phagocytic cells. During a respiratory explosion, up to 28 % of the total amount of oxygen consumed by neutrophils is spent on the formation of HClO. The formation of HClO in neutrophils occurs from hydrogen peroxide and chloride ions. The catalyst in this reaction is myeloperoxidase (MPO) $H_20_2 + Cl^- \rightarrow [Cat(MPO)] \rightarrow \rightarrow HClO + OH^-$ [43,44].

Hypochlorous acid dissociates in an aqueous medium to form hypochlorite anion and hydrogen ion: $HClO \leftrightarrow H^+ + ClO^-$.

At pH values close to neutral, the concentrations of HClO and hypochlorite anions ClO^- are approximately equal. A decrease in pH leads to a shift in the equilibrium of this reaction towards an increase in the concentration of HClO, an increase in pH — towards an increase in the concentration of hypochlorite anions.

The formation of H_2O_2 and HClO in a short period of time (fractions of a second) in a small volume of an aqueous medium (fractions of a microliter), i. e., in the volume of the active zone of phagocytosis, is inevitably accompanied by reactions of spontaneous decay and interaction of transformation products of these compounds with the formation of active particles, similar to those which are formed during radiolysis or electrolysis of water.

The spontaneous decomposition of hydrogen peroxide in an aqueous medium produces compounds with very high antimicrobial activity (the corresponding chemical reactions are given in parentheses): HO_2^- — hydroperoxide anion ($H_2O_2 + OH^- \rightarrow HO_2^- + H_2O$); O_2^{2-} — peroxide anion ($OH^- + HO_2^- \rightarrow O_2^{2-} + H_2O$); O_2^- — superoxide anion ($O_2^{2-} + H_2O_2 \rightarrow O_2^- + OH^- + OH^\bullet$); $HO_2^\bullet$ — hydrogen peroxide radical ($HO^\bullet + H_2O_2 \rightarrow H_2O + HO_2^\bullet$); HO_2 — hydrogen superoxide ($O_2^- + H_2O \rightarrow HO_2 + OH^-$). At the same time, the formation of an extremely reactive singlet oxygen $^1O_2$ is possible: ($ClO^- + H_2O_2 \rightarrow {}^1O_2 + H_2O + Cl^-$). It has been experimentally confirmed [43, 44] that the molecular oxygen radical ion O_2^- participates in phagocytosis reactions, one of the ways of formation of which may be as described above.

It is known [43–49] that in an aqueous medium in the presence of HClO and ClO^- the formation of active free radicals is possible: $ClO^\bullet$, $Cl^\bullet$, $HO^\bullet$: ($HClO + ClO^- \rightarrow ClO^\bullet + Cl^- + HO^\bullet$). Moreover, from the standpoint of the modern theory of catalytic processes, the formation of an intermediate activated complex with the participation of myeloperoxidase as a catalyst is also possible. The decomposition of this complex is accompanied by the formation of $O^\bullet$, the return of the catalyst to its original state, and the acidification of the medium: $HClO + ClO^- \rightarrow [HClO \leftrightarrow Cat(MPO) \leftrightarrow \leftrightarrow ClO^-]2Cl^- + 2O^\bullet + H^+$.

Active hypochlorite radicals $ClO^\bullet$ can take part in the reactions of formation of atomic oxygen ($O^\bullet$) and hydroxyl radical ($HO^\bullet$): $ClO^\bullet + ClO^- + OH^- \rightarrow Cl^- + 2O^\bullet + OH^\bullet$. Further development of the chain occurs during the formation of atomic chlorine: $OH^\bullet + Cl^- \rightarrow C1^\bullet + OH^-$.

The resulting radicals, atomic oxygen take part in the destruction of microorganisms, interacting with biopolymers capable of oxidation, for example, in accordance with the reactions: $RH_2 + OH^\bullet \rightarrow RH^\bullet + H_2O$; $RH_2 + Cl^\bullet \rightarrow RH^\bullet + HCl$; $RH_2 + O^\bullet \rightarrow RH^\bullet + OH^\bullet$.

The metastable mixture of compounds formed in the process of phagocytosis is a very effective means of killing microorganisms, since it has many spontaneously realized opportunities for irreversible disruption of the vital functions of biopolymers of microorganisms at the level of electron transfer reactions. Metastable particles with different values of the electrochemical potential have a universal spectrum of action, that is, they can have a damaging effect on all large systematic groups of microorganisms (bacteria, mycobacteria, viruses, fungi, spores) without harming the cells of human tissues or those of other higher organisms, i. e. somatic animal cells in the multicellular system.

It is the fundamental difference in the structure and living conditions of the cells of these life forms. The cells of higher organisms in the process of vital activity, for example, in oxygenase reactions of the functioning of cytochrome P-450, during phagocytosis during adhesion and immobilization of microbial cells, produce and use a number of highly active oxidants. These cells have a powerful chemical antioxidant defense system that prevents the toxic effects of such substances on vital cellular structures.

The antioxidant properties of somatic cells are associated with the presence of a powerful three-layer lipoprotein shell (peplos), which contains diene conjugates (─C=C─) and sulfhydryl groups (SH─) with electron donor properties. Microorganisms do not have powerful antioxidant defense systems with the participation of these chemical groups.

All somatic cells of animal organisms are heterotrophs: their trophism depends on the presence of nutrient components in the extracellular environment: glucose, amino acids, fatty acids. The biological well-being of a somatic cell depends on the place it occupies in the process of distributing the trophic functions of all elements of the multicellular system (a cell supports another cell). The trophism functions of animal cells are subject to the law of interchangeability. If the trophism of one single cell is disturbed, then this disturbance can be corrected by neurotrophic regulation, endocrine regulation, the function of neighboring cells, reparative processes, the nutritional function of the blood, etc.

All microbial cells are autotrophs, and their nutrition depends on their own energetic activity, that is, if enzymatic processes inside a microbial cell are suppressed, this entails its death, since there are no compensatory mechanisms. A microbial cell provides all its trophic functions only through enzymatic reactions. The interaction between microbial cells in their habitat is not compensatory, that is, the vulnerability of a microbial cell is its autonomy. Comparison of the known scientific data [43–49] with the chemical composition of active substances of electrochemically activated Anolyte ANK has made it possible for the first time to formulate a conclusion about the identity of active substances of Anolyte ANK and those of a metastable substance formed during phagocytosis [50].

Thus, in 2003 it was shown [50] that the effectiveness of metastable electrochemically activated solutions, which manifests itself, among other things, in their ability to prevent the appearance of resistant microflora, is due to fundamental differences between representatives of the micro- and macrobiological world. It became clear that the use of chemically stable disinfectants to combat representatives of the microworld is a road to nowhere. One can endlessly compose new (increasingly expensive) combinations of reagents from the same classes of stable xenobiotic chemicals that persist in warehouses and do not deteriorate during transport, but it should be understood that THE DEAD WILL NEVER WIN THE LIVING. The rate of chemical interconversion of active particles in inorganic metastable systems is orders of magnitude higher than the rate of any, including adaptive, biochemical reactions in microorganisms. This is the reason for the absence of resistant microflora to metastable anolytes.

Studies of the relationship between the total mineralization of anolyte and its physicochemical properties have been conducted for several years.

Fig. 6.3.10 shows the general dependence of the electrical conductivity of aqueous solutions of various inorganic electrolytes — chlorides, sulfates, carbonates, nitrates of alkali and alkaline earth metals, corresponding acids and bases, on their concentration in an aqueous solution (shaded area 1). In dilute electrolyte solutions (less than 1 g/l), small changes in the concentration of dissolved substances lead to significant shifts in the specific conductivity of the solution, which indicates the presence of a large number of water molecules that do not participate in the formation of hydration shells around charged particles (ions). For more

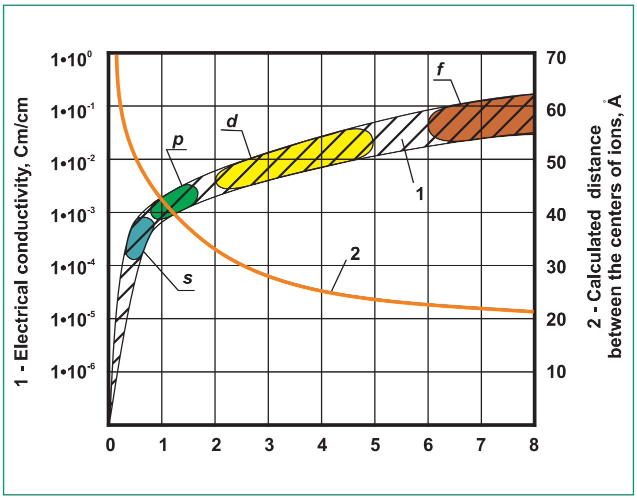

Fig. 6.3.10. *The dependence of specific conductivity (1) and average distances between ions (2) from the total mineralization of electrolyte solutions.*

Legend:

areas s; p; d; f — highlighted with colors correspond to anolytes of different mineralization, with the same concentration of oxidants (500 mg/l).

Parameter variation: «>» — more, «<» — less.

Antimicrobial and antiviral activity: s > p > d> f.

Corrosion activity: s <p <d <f.

Time of maintenance of sporicidal activity: s > p> d > f.

Sediment after drying: s <p <d <f/

Smell: s <p <d <f.

concentrated electrolyte solutions (at concentrations above 1 g/l), on the contrary, a relatively small change in electrical conductivity is observed with a significant change in concentration. This indicates that the hydration shells surrounding charged particles in solution are in close interaction with each other and the degree of their interpenetration increases with an increase in the concentration of electrolyte ions. These representations are illustrated by curve 2 in Fig. 6.3.10, which characterizes the theoretically calculated distances between the centers of electrolyte ions in solution, depending on their concentration.

Curve 2 is a kind of indicator of the structural properties of solutions.

The structure of a solution is understood as a relatively stable in space and time order in the arrangement of dissolved particles and water molecules interacting with each other, relative to an arbitrarily chosen particle, corresponding to their most probable distribution. There is a well-known postulate about the electroneutrality of a hydrated ion, put forward by L. Pauling, one of the leading specialists in the theory of chemical bonding. According to this postulate, the charge of an ion is redistributed over the hydrogen atoms of the water molecules surrounding the ion. The concept of the donor-acceptor nature of the interaction between an ion and water molecules is generally accepted. When an ion is hydrated, a kind of neutralization and redistribution of its charge occurs over the water molecules surrounding the ion. The most important consequence of this is the ability to represent an ion as a kind of neutral particle or as a complex atom with filled electron orbitals.

Thus, an ion in solution can be likened to an atom of a noble gas with the same number of electrons and the same mass. The theoretical concept developed by G.A. Krestov [51] has made it possible to explain the various features of the processes of transformation of substances during their transition into a solution.

The redistribution of the ion charge also affects water molecules in the region of distant hydration. It is quite obvious that the displacement of a part of the electron density from the water molecules closest to the cation creates a deficit of it on these molecules, which will be partially covered by the displacement of the other part of the electron density from the next water molecules, etc. Near anions, the displacement of a part of the electron density is in the opposite direction.

The reason for these displacements is the same: the tendency to achieve a state of equilibrium corresponding to a minimum of energy. The defining elements of the structure of a solution are the coordination of water molecules around a dissolved particle, as well as all types of interactions.

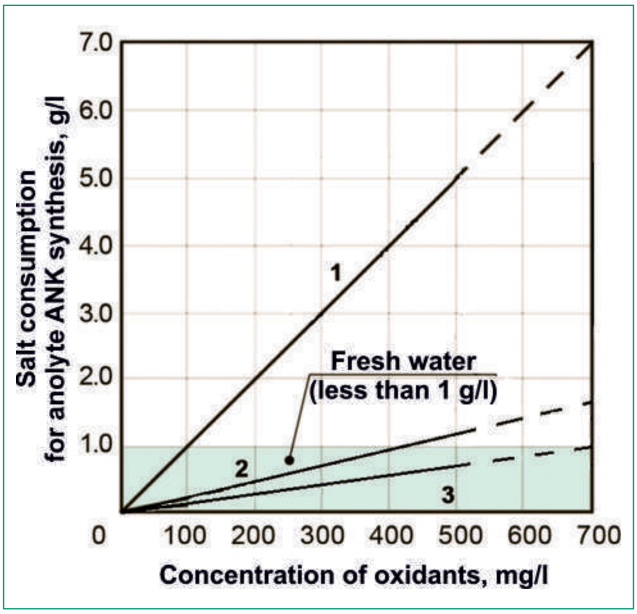

Fig. 6.3.11. *The ratio of the amount of salt consumed for the synthesis of 1 liter of Anolyte ANK and the concentration of oxidants in Anolyte ANK obtained in STEL devices.*

1 — Anolyte ANK of the first generation, obtained in STEL-YUN-120–01 devices. Salt consumption to oxidant concentration ratio: 5.0:0.5 = 10. There are approximately 10 times more ballast substances than active substances.

2 — Anolyte ANK of the second generation, obtained in STEL-ANK-PRO type devices. Salt consumption to oxidant concentration ratio: 1.0:0.5 = 2. Ballast substances are present in approximately the same quantity as active substances.

3 — Anolyte ANK of the third generation, obtained in the STEL-ANK-SUPER type devices. Salt consumption to oxidant concentration ratio: 0.6: 0.5–1.

There are no ballast substances.

The hydration of charged particles in solutions is also subject to the same factors. The structure of the solution and the hydration of particles in it turn out to be closely related to each other. During the hydration of monatomic uncharged particles weakly interacting with water molecules, the destruction of old water is additionally changed due to the rotational degrees of freedom of charged particles. And when charged particles are hydrated, new structures of bound water are also formed. Thus, during hydration, both the structure of water and that of the reagents themselves change. In essence, the change in the properties of particles during the formation of a solution is determined by their structural changes, and therefore the structure determines the energy of the system, steric factors, the rates of processes and the state of equilibrium.

In the process of obtaining an electrochemically activated solution, it is important to ensure the hydration of the newly formed associates of highly charged reagents (compounds) directly in the diffuse part of the double electric layer of the electrode, i. e., in the zone where the electric field strength reaches several million volts per centimeter. At the same time, the greatest directional change in the structure of the solution is provided.

As a result of the research, it was found that the lower the total mineralization of the solution of oxidants, the more clearly manifests itself the metastability factor, the factor of the electrochemically activated medium, which determines the success and safety of using the electrochemically activated solution.

STEL devices of the first generation (STEL-1 ON-120–01 type) provide Anolyte ANK with the total mineralization in the range from 2 to 5 g/l with an oxidant content of 500 mg/l. This area on curve 1 (Fig. 6.3.10) is marked with the letter d and highlighted in yellow. Almost all solutions of disinfectants including hypochlorite, as well as solutions from devices simulating STEL systems and called by their authors electrochemically activated are on curve 1 in the f area marked in red, that is, they are not actually activated.

Even if they are produced according to the Anolyte ANK synthesis technology described above, they lose their anomalous activity in a fairly short time, turning into a solution of hypochlorite and hypochlorous acid. Of course, such a solution is antimicrobial, but unlike electrochemically activated one, it does not have sporicidal activity, has a characteristic chlorine smell and, when used for water disinfection, forms chlorination by-products, in particular, chloroform.

Anolyte ANK from STEL-ANK-PRO devices on curve 1 conductivity — concentration is located in the area p marked in green and occupies the space above line 2. The low total mineralization of this anolyte with a high specific content of oxidants determines the high stability of existing in the solution molecular complexes with a hydrogen bond, the components of which can be not only molecules in the ground state, but also ions, free radicals, molecules in an excited state (exciplexes), which in turn are hydrated (the phenomenon of distant hydration), turning into electrically neutral aqua complexes [51, 52].

An increase in the stability of aqua complexes and a decrease in the charge density of metastable particles are the more noticeable, the lower the concentration of ions in the solution.

When disinfecting solid porous surfaces with electrochemically activated solutions with a salt content even at the level acceptable in Anolyte ANK, the salt contained in the solutions remains on the treated surfaces after they dry and accumulates over time. The salt layer on the surface, being hygroscopic, absorbs moisture from the air. Such a surface becomes wet, «sweats», and wet surfaces are known to be a favorable environment for the growth of microorganisms. To a greater extent, the above applies to solutions of hypochlorites, since they are usually used in concentrations ten times higher than electrochemically activated solutions. The presence of chlorides increases the chemical corrosion of metals, in particular, metal equipment in the medical and food industries, as well as metal pipelines used to transport water to the consumer. An increase in the salt concentration in the electrochemically activated anolyte contributes to equilibrium displacement towards the formation of molecular chlorine, thereby increasing the corrosive activity of the solution, its destructive effect on polymeric materials, metals, and gives the solution a characteristic chlorine smell.

On the contrary, a decrease in the salt content in the electrochemically activated anolyte leads to an increase in the proportion of reactions of the formation of active oxygen in the process of electrochemical synthesis, a significant decrease in the corrosivity of the solution, and a decrease, up to complete disappearance, of the chlorine odor. Comparison of the results of studying Anolytes ANK of different mineralization shows the advantage of low-mineralized solutions in preventing biochemical corrosion. This is primarily due to the synergistic activity of the antimicrobial effect of hypochlorous acid against the background of the oxidative activity of dissolved oxygen and leads to the removal of old bio-deposits, as well as to the prevention of the growth of new biofilms while reducing corrosion and biocorrosion.

On the way of improving Anolyte ANK, the tasks were solved of enhancing antimicrobial activity while reducing corrosiveness, reducing the content of ballast substances (sodium chloride), reducing the smell of chlorine-oxygen compounds from weak to vanishingly weak, increasing the storage time of Anolyte ANK without losing the properties. To solve these problems, original theoretical and experimental studies were used, based on the fundamental principles of the theory of solutions, nonequilibrium thermodynamics, chemistry of peroxide compounds, kinetics of electrochemical reactions.

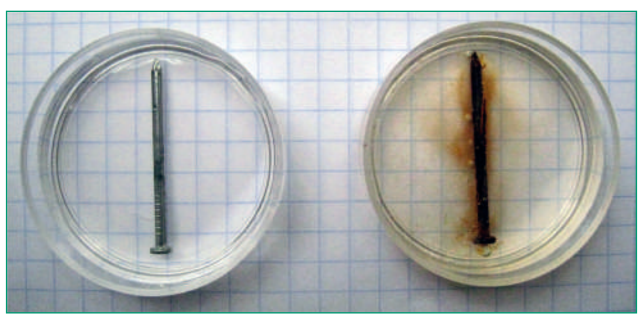

Fig. 6.3.12. *Comparison of the corrosiveness of Anolyte ANK produced in a STEL-10N-120–01 device with an oxidant concentration of 500 mg/l and a total mineralization of 5 g/l (photo on the right) and Anolyte ANK produced in a STEL-ANK-PRO device with an oxidant concentration 500 mg/l and total mineralization 1.2 g/l (left photo) after 25 hours.*

By 2011, as a result of two years of experiments with newly designed electrochemical MB elements incorporated diaphragms made of extruded ultrafiltration ceramics, electrochemical systems of varying degrees of complexity have been built. Those systems made it possible to achieve the targeted parameters of the Anolyte ANK bringing it significantly closer to the concept of «Perfect Disinfectant». The completion of these works took place in the premises of Delfin Aqua LLC, with which employees of the Vitold Bakhir Electrochemical Systems and Technologies Institute worked under license agreements for four years (from September 2011 to November 2015). As a result of those works, the pilot models of STEL-ANK-SUPER systems were created, and Anolyte ANK SUPER of various concentrations was granted the RF Registration certificates.

This type of Anolyte ANK, called Anolyte ANK SUPER and produced by the first generation of STEL-ANK-SUPER devices, occupies space in the p area in Fig. 6.3.10 below line 2.

After the termination of cooperation with Delfin Aqua LLC and designing in 2016 of the new types of MB electrochemical cells, with the performance approximately ten times higher than that of previously existing analogues, the only manufacturer of original STEL-ANK-SUPER devices (Fig. 6.3.13–6.3.15) with new generation of the MB elements in Russia is the Vitold Bakhir Electrochemical Systems and Technologies Institute and abroad is the Blue Safely company, which produces unique automated small-sized electrochemical systems that provide the highest level of microbiological protection of dental offices with complete safety of patients, staff and the environment.

A gradual approach to the «perfect» anolyte took place along the way of reducing its total mineralization while maintaining a constant concentration of oxidants, including by increasing the proportion of hydroperoxide oxidants in the solution.

STEL-ANK-SUPER, mass production of which started in 2016, produce Anolyte ANK SUPER with properties that are as close to perfect as possible, and further improvement of which is not currently possible due to limitations caused by the physical nature of metastable compounds (active substances). Anolyte ANK, for which the authors have retained the name «ANOLYTE ANK SUPER» (area s in Fig. 6.3.10) is the most perfect product of this type, since the content of ballast ions of sodium chloride is vanishingly small. But the differences in the basic properties and parameters of Anolyte ANK SUPER from areas s and p (Fig. 6.3.10) are much smaller than between Anolyte ANK SUPER and Anolyte ANK.

The corrosive ability of Anolyte ANK SUPER from the s and p areas is less pronounced than that of Anolyte ANK of the second generation (p) obtained in the STEL-ANK-PRO device, not to mention the first generation of Anolyte ANK (d) obtained in the STEL- 10N-120–01, which is clearly shown in Fig. 6.3.12. Close functional and physicochemical parameters of Anolyte ANK SUPER from the s and p areas allow us to speak of it as one and the same solution. Anolyte ANK SUPER has a good cleaning ability, has a very weak odor of chlorine-oxygen oxidants, actively reacts with ethyl alcohol, converting it into peracetic acid, leaves no residue on a smooth surface after drying when spraying, the smell of chlorine is completely absent, off-flavors practically disappear instantly, the air feels fresh, like after rain. The retention time of the sporicidal activity of Anolyte ANK SUPER from the s and p areas is higher than that of Anolyte ANK from the p area. The main achievement on improving Anolyte ANK SUPER is the creation in 2017 of electrochemical systems, which rationally combine the advantages of MB elements of the 2016 standard with fundamentally new technological solutions that allow for providing high-quality physical and chemical preparation of source water, saline solution and produce a solution of oxidants with minimal energy and time consumption. New technological solutions have made it possible to significantly unify the electrochemical systems of STEL, AQUACHLOR, ECOCHLOR and EMERALD [52], multiply the productivity of each of the electrochemical systems in terms of the final product, while improving its quality.

Fig. 6.3.13. *STEL-ANK-SUPER-100 Device. The Vitold Bakhir Electrochemical Systems and Technologies Institute, Moscow, 2019.*

Fig. 6.3.14. *STEL-ANK-SUPER-100 Device. The Vitold Bakhir Electrochemical Systems and Technologies Institute. Moscow, 2018.*

The above mentioned information about anolytes to a large extent describes the solutions with chlorine-oxygen and hydroperoxide oxidants mixture concentration in the range from 100 to 500 mg/l, which is standard for medical personnel, although similar solutions with oxidants concentrations from 10 to 8000 mg/l obtained using various technological schemes are equally widely used in various fields, including healthcare.

However, based on the test results obtained by the Institute of Theoretical and Experimental Biophysics from Pushchino on Oka in the framework of grants from the Russian Science Foundation (RSF) [52–56], below the s area in Fig. 6.3.10 there is an even more mysterious and full of surprises area of electrochemically activated water and solutions of ultra-low mineralization. The electrical conductivity of the studied aqueous solutions is in the range from 3 to 5 µS/cm, i. e., the concentration of dissolved electrolyte ions does not exceed 5 mg/l.

In this case, the ORP of Anolyte A is close to the corresponding parameter of hydrochloric acid with a concentration of 36 g/l, and that of Catholyte K is close to the value of the ORP of a sodium hydroxide solution with a concentration of 40 g/l. That is, if the activity of electrons is equal, measured by the value of the redox potential on the platinum electrode relative to the reference electrode [57–59], in a one-molar solution of acid and Anolyte A of distilled water, as well as in a one-molar solution of alkali and Catholyte K of distilled water, the difference in concentration between chemically stable and electrochemically activated solutions is approximately ten thousand times. It is on this phenomenon that the technological scheme for the use of electrochemically activated dilute aqueous solutions and a number of other fluids is based.

In conclusion, it makes sense to briefly characterize Anolyte ANK SUPER, as well as to outline express ways to control its authenticity.

Anolyte ANK SUPER is a broad-spectrum disinfectant (against bacteria, mycobacteria, viruses, fungi, spores), to which microflora is not able to develop resistance, harmless to humans and animals, environmentally friendly, universal and safe in any application (irrigation, immersion, wiping, soaking, aerosol, foam and ice). Active substances of Anolyte ANK SUPER are a mixture of oxidants, equivalent in composition to those formed in the organisms of living beings during phagocytosis (destruction of foreign substances by phagocytes). It is approved for the use in healthcare, food industry, veterinary, agriculture and other areas in Russia and foreign countries (USA, Germany, Italy, Bulgaria, UAE, Vi-

Fig. 6.3.15. *STEL-ANK-SUPER-1000 (AQUACHLOR-600) Device. Vitold Bakhir Electrochemical Systems and Technologies Institute. Moscow, 2019.*

etnam) where Anolyte ANK SUPER is known under other trade names.

Anolyte ANK SUPER is produced by STEL-ANK-SUPER electrochemical devices, developed in 2012 under the leadership of V. M. Bakhir, Doctor of Engineering, Professor (the author of all known STEL-type devices) at the Electrochemical Systems and Technologies Institute.

The starting components of Anolyte ANK SUPER are sodium chloride salt, purified water and electricity.

Active substances of Anolyte ANK SUPER are represented by chlorine-oxygen and hydroperoxide oxidants: hypochlorous acid, hydrogen peroxide, ozone, and singlet oxygen. Anolyte ANK SUPER, when dry, does not leave a residue on smooth surfaces, does not initiate corrosion of metals, is practically odorless.

Long-term (more than 25 years) use of Anolyte ANK, the predecessor of Anolyte ANK SUPER, in healthcare facilities without switching to other disinfectants, has demonstrated the complete absence of resistivity in microorganisms to this agent, due to its metastability properties.

Unlike Anolyte ANK with the total concentration of dissolved substances up to 5 g/l and the shelf life with sporicidal activity not exceeding five days, Anolyte ANK SUPER has a mineralization corresponding to fresh drinking water and a shelf life with sporicidal activity up to 6 months, which has been tested in Russian and foreign credible organizations. After use, Anolyte ANK SUPER turns into ordinary fresh water, which eliminates the need for its neutralization or disposal.

One of the main secrets of Anolyte ANK SUPER is the technology of its synthesis in STEL-ANK-SUPER devices, manufactured by the Vitold Bakhir Electrochemical Systems and Technologies Institute according to TU 3614–017–77350578–2016.

The unique technology of electrochemical synthesis enables the long-term preservation of antagonist substances in the solution: hypochlorous acid with accompanying chlorine-oxygen compounds and hydrogen peroxide with accompanying hydroperoxide compounds. It is this mixture of oxidants that is produced by phagocytes in living Nature, existing for only a few milliseconds, while in Anolyte ANK SUPER these compounds do not «see» each other under long-term storage due to powerful ion-hydrate shells surrounding active charged molecular structures acting together only when Anolyte ANK SUPER comes into contact with the processed objects of animate and inanimate nature.

It is quite easy to verify the authenticity of Anolyte ANK SUPER-500 with an oxidant concentration of 500 mg/l in field conditions.

1. It is necessary to measure the concentration of dissolved substances using the simplest device — a conductometer or TDS-meter (from the English «Total Dissolved Solids»). If the concentration of dissolved substances — electrolytes is more than 0.9 g/l (900 ppm), then this solution is not Anolyte ANK SUPER.

If the concentration of solutes is equal to or less than 0.9 g/l, then the concentration of oxidants should be measured.

2. The exact method for measuring the concentration of oxidants is the iodometric titration method, which requires special laboratory equipment and chemical reagents. However, for a rough estimate, it is sufficient to use test strips (for example made by HACH Company) to measure the concentration of oxidants in terms of active chlorine from 0 to 800 mg/l.

Moreover, one can estimate the concentration of oxidants using a simple reagent — potassium iodide. A small amount of potassium iodide powder with a spatula or at the tip of a penknife is introduced into a glass with 100–150 ml of the test solution. The behavior of the powder granules is observed through the walls of the glass. If after some time they settle and form a colored dark brown layer at the bottom of the glass, then the concentration of oxidants is equal to or more than 500 mg/l. If the entire volume of liquid in the glass acquires a less intense color, then the concentration of oxidants in the solution is less than 500 mg/l.

So, if it turns out that the concentration of oxidants is below 500 mg/l, then this solution is not Anolyte ANK SUPER. If the concentration of oxidants in the solution is equal to or greater than 500 mg/l, then another test should be performed: the pH level measurement of the solution.

3. One can measure pH which shows the activity index of hydrogen ions using a portable or laboratory pH meter.

If the pH of the solution is below 5.0 or above 6.5, then one can be sure that this solution does not contain a mixture of chlorine-oxygen and hydroperoxide oxidants and contains active substances represented only by chlorine-oxygen compounds, which does not allow it to be considered Anolyte ANK SUPER. At the same time, it should be borne in mind that with an increase in pH above 6.5, the concentration of the least active form of chlorine-oxygen compounds represented by sodium hypochlorite proportionally increases in the solution.

The scope of application of electrochemically activated solutions is constantly expanding. In particular, it is evidenced by the constantly growing number of links in any search engine by the words «electrochemical activation», which has far exceeded 20 million. In this regard, the authors will gratefully receive information on new areas of application of electrochemically activated solutions and will also try to answer questions from interested people and companies.

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A very short list of official documents regulating the use of STEL electrochemical devices of all types with MB (FEM) elements and their products.

1. *Certificate of state registration No. RU. 77.99.88.002. E. 006350.08.13 of the Customs Union of the Republic of Belarus, the Republic of Kazakhstan and the Russian Federation dated 01.08.2013 for the disinfectant agent Anolyte ANK SUPER produced by STEL-ANK-SUPER type devices manufactured by Delfin Aqua LLC. Свидетельство о государственной регистрации № RU. 77.99.88.002. E. 006350.08.13 Таможенного Союза Республики Беларусь, Республики Казахстан и Российской Федерации от 01.08.2013 г. на средство дезинфицирующее «Анолит АНК СУПЕР», вырабатываемое установками типа «СТЭЛ-АНК-СУПЕР», изготовителя ООО «Делфин Аква».*
2. *Registration certificate of the Russian Federation No. 77.99.1.2. U. 12139.12.09 dated 30.12.2009 for ANOLYTE ANK disinfectant produced in the STEL-ANK-PRO device (TU 9392–042–44464870–2008 ANOLYTE ANK Disinfectant produced by STEL-ANK-PRO devices manufactured by Electrotechnology Laboratory LLC, Moscow. Регистрационное свидетельство РФ № 77.99.1.2. У. 12139.12.09 от 30.12.2009 на средство дезинфицирующее «АНОЛИТ АНК», вырабатываемое в установке «СТЭЛ-АНК-ПРО» (ТУ 9392–042–44464870–2008 «Дезинфицирующее средство «АНОЛИТ АНК», вырабатываемый установками типа «СТЭЛ-АНК-ПРО», производитель ООО «Лаборатория электротехнологии», Москва.*
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4. *Sanitary and Epidemiological Conclusion No. 77.99.15.945. Clause 000088.01.03 for neutral anolyte ANK, obtained at the STEL-YUN-120–01 device manufactured by NPO Ekran OJSC, valid from 01/27/2003 to 01/27/2008 (scope: as a product for water disinfection of centralized and decentralized drinking water supply systems). Санитарно-эпидемиологическое заключение № 77.99.15.945. П. 000088.01.03 на анолит нейтральный АНК, получаемый на установке СТЭЛ-ЮН-120–01, производитель ОАО «НПО «Экран», срок действия с 27.01.2003 г. по 27.01.2008 г. (область применения: в качестве средства для дезинфекции воды централизованной и децентрализованной систем питьевого водоснабжения).*
5. *Certificate of state registration No. 77.99.28.2. U. 5222.5.05 of 17.05.2005 for anolyte aerosol produced by mobile aerosol generators MAE (TU 5156–024–54368736–05), issued by CJSC ECA-MAE, St. Petersburg. Свидетельство о государственной регистрации № 77.99.28.2. У. 5222.5.05 от 17.05.2005 г. на аэрозоль анолита, вырабатываемого мобильными аэрозольными генераторами МАЕ (ТУ 5156–024–54368736–05), выданное ЗАО «ЭХА-МАЕ», Санкт-Петербург.*
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ВНИИИМТ МЗ РФ, Москва, срок действия с 04.05.2000 г. по 04.05.2001 г. (область применения: в качестве препарата для подщелачивания воды при водоподготовке на водопроводных станциях для хозпитьевого водоснабжения и дезинфекции объектов окружающей среды).

8. *Hygienic conclusion No. 78.1.3.515. Cl. 17678.9.99 for Anolytes AN and ANK agents produced on STEL devices, manufacturer VNIIIMT, Moscow, valid from 09/13/1999 to 09/13/2002 (scope: as disinfectants of waste water and pool water). Гигиеническое заключение № 78.1.3.515. П. 17678.9.99 на продукцию «Анолиты АН и АНК производящиеся на установках СТЭЛ», производитель ВНИИИМТ МЗ РФ, Москва, срок действия с 13.09.1999 г. по 13.09.2002 г. (область применения: в качестве дезинфектантов сточных вод, воды бассейнов).*
9. *Registration certificate No. 2919020298/0324–00 for the Automated complex for disinfection, pre-sterilization cleaning, sterilization of fully and incompletely immersed flexible endoscopes KADS-80–01- ENDOSTERIL manufactured by Laboratory of Electrotechnology, Moscow, valid from 26.06.2000. to 03.02. 2008Регистрационное удостоверение № 2919020298/0324–00 на Комплекс автоматизированный для дезинфекции, предстерилизационной очистки, стерилизации полностью и не полностью погружаемых гибких эндоскопов КАДС-80–01-«ЭНДОСТЕРИЛ», производитель ООО «Лаборатория электротехнологии», Москва, срок действия с 26.06.2000 г. по 03.02.2008 г.*
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12. *Registration certificate of the Committee for New Medical Equipment MH of Ukraine on permission to use in medical practice of Ukraine devices for electrochemical synthesis of washing, disinfecting and sterilizing solution of neutral anolyte (ANK) STEL-1 ON-120–01 (mod. 40–01, 80–01, 120–01,250–01, 1000–01), approved by the Deputy Minister of Health Moskalenko V. F., Eos. register MH No. 973/98 dated 02.12.98. Регистрационное удостоверение Комитета по новой медицинской технике МЗ Украины о разрешении применения в медицинской практике Украины установок для электрохимического синтеза моющего, дезинфицирующего и стерилизующего раствора нейтрального анолита (АНК) СТЭЛ-1 ОН-120–01 (мод. 40–01, 80–01, 120–01,250–01, 1000–01), утвержденное заместителем министра здравоохранения Москаленко В. Ф., Еос. реестр МЗ № 973/98 от 02.12.98.*
13. *Hygienic certificate MH of the Republic of Lithuania for neutral anolyte ANK, manufactured in STEL-1 ON-120–01 and STEL-60–03-ANK devices for disinfection of surfaces, tableware, linen, toys, items for patient care in healthcare institutions and for final disinfection in foci of bacteriological, viral infections, fungal infectious diseases No. 2–2-1–10118 dated 01/12/1999. Гигиеническое свидетельство МЗ Литовской Республики на нейтральный анолит АНК, изготовленный в установках СТЭЛ-1 ОН-120–01 и СТЭЛ-60–03-АНК для дезинфекции поверхностей, столовой посуды, белья, игрушек, предметов для ухода за больными в учреждениях здравоохранения и для окончательной дезинфекции в очагах бактериологических, вирусных инфекций, грибковых инфекционных заболеваний № 2–2-1–10118 от 12.01.1999.*
14. *Sanitary and Epidemiological Conclusion No. 78. DC. 05.515. P. 000003.07.01 for Anolytes A, AN, ANK, produced on STEL, AQUACHLOR devices, manufactured in accordance with MU No. 01-19-48–11, for*

use as a disinfectant for treating natural and waste water, water supply systems and pool water. Issued by OJSC NPO Ekran, valid from 20.07.2001 to 20.07.2004. Санитарно-эпидемиологическое заключение №78. ДЦ. 05.515. П. 000003.07.01 на Анолиты А, АН, АНК, производящиеся на установках СТЭЛ, АКВАХЛОР, изготовленные в соответствии с МУ №01-19-48–11, для применения в качестве дезинфицирующего средства для обеззараживания природных и сточных вод, систем водоснабжения и воды бассейнов. Выдан ОАО «НПО «Экран», срок действия с 20.07.2001 г. по 20.07.2004 г.

15. *List No. 0034–97 of domestic and foreign disinfectants approved for use on the territory of the Russian Federation dated 04.21. Перечень №0034–97 отечественных и зарубежных дезинфекционных средств, разрешенных к применению на территории Российской Федерации от 21.04.1997 г.*
16. *Resolution of the Chief Sanitary Doctor for St. Petersburg of 23.11.98 N 16 on the introduction of «Sanitary rules for the sale in the distribution network and the use of detergents and disinfectants at food industry and public catering enterprises» SP 2.3.3.006–98. Постановление Главного санитарного врача по Санкт-Петербургу от 23.11.98 N 16 о введении «Санитарных правил по реализации в торговой сети и использованию на предприятиях пищевой промышленности и общественного питания моющих и дезинфицирующих средств» СП 2.3.3.006–98.*
17. *Registration certificate No. 77.99.1.2. U. 5720.6.09 dated 09.06.2009 for the disinfectant agent «Neutral anolyte ANK», produced on the STEL-YUN-120–01 device. Manufacturer — Electrotechnology Laboratory LLC. The products are manufactured by EKOMED LLC. The certificate was issued on the basis of an expert opinion based on the results of a disinfectological examination of 02.04.2009 No. 3–05/192 FEUN NIID Rospotrebnadzor. Регистрационное свидетельство №77.99.1.2. У. 5720.6.09 от 09.06.2009 на средство дезинфицирующее «Нейтральный анолит АНК», вырабатываемый на установке СТЭЛ-ЮН-120–01. Изготовитель — ООО «Лаборатория электротехнологии». Продукция изготовлена ООО «ЭКОМЕД». Свидетельство выдано на основании экспертного заключения по результатам дезинфектологической экспертизы от 02.04.2009 г. №3–05/192 ФЕУН НИИД Роспотребнадзора.*
18. *Registration certificate No. RU. 77.99.01.002. E. 031063.08.11 dated 08.08.2011 for the disinfectant «Neutral anolyte ANK», produced by the STEL-YUN-120–01 device. Manufacturer (producer) — OJSC NPO Ekran. Research protocols — expert opinion dated June 24, 2011 No. 3–05/448-a FEUN NIID Rospotrebnadzor. Регистрационное свидетельство № RU. 77.99.01.002. Е. 031063.08.11 от 08.08.2011 на средство дезинфицирующее «Нейтральный анолит АНК», вырабатываемый установкой СТЭЛ-ЮН-120–01. Изготовитель (производитель) — ОАО НПО «Экран». Протоколы исследований — экспертного заключения от 24.06.2011 г. №3–05/448-а ФЕУН НИИД Роспотребнадзора.*
19. *Certificate of Conformity No. ROSS RU. HP09. B1641 for the disinfectant agent «Neutral anolyte ANK», produced at the «STEL-YUN-120–01» device, issued by ECOMED LLC, valid from 07/13/2011 to 07/13/2011. Сертификат соответствия № РОСС RU. ХП09. В1641 на средство дезинфицирующее «Нейтральный анолит АНК», вырабатываемый на установке «СТЭЛ-ЮН-120–01», выданный ООО «ЭКОМЕД», срок действия с 13.07.2011 г. по 13.07.2011 г.*
20. *Registration certificate in Ukraine No. AA-00736–03–09 for Anolyte neutral ANK agent for disinfection purposes from STEL-YUN-120–01 devices, manufactured by Laboratory of Electrotechnology, Moscow, valid from 29.12.2009 to 28.12.2014. Регистрационное свидетельство на Украине № АА-00736–03–09 на препарат Анолит нейтральный АНК для целей дезинфекции из установок «СТЭЛ-ЮН-120-01», изготовитель ООО «Лаборатория электротехнологии», Москва, срок действия с 29.12.2009 г. по 28.12.2014 г.*
21. *Instruction No. DA 005–13 on the use of the Anolyte ANK SUPER disinfectant manufactured by Delfin Aqua LLC (Russia), obtained from STEL-ANK-SUPER devices for disinfection and sterilization purposes, Moscow. 2013. Инструкция № ДА 005–13 по применению дезинфицирующего средства «Анолит АНК СУПЕР» фирмы ООО «Делфин Аква» (Россия), полученного из установок СТЭЛ-АНК-СУПЕР для целей дезинфекции и стерилизации, Москва. 2013.*

22. *Instruction No. IB-17 on the use of Anolyte ANK SUPER disinfectant from the Vitold Bakhir Electrochemical Systems and Technologies Institute (Russia), obtained from STEL-ANK-SUPER devices for disinfection and sterilization purposes, Moscow. 2017. Инструкция № ИБ-17 по применению дезинфицирующего средства «Анолит АНК СУПЕР» фирмы ООО «Институт Электрохимических Систем и Технологий Витольда Бахира» (Россия), полученного из установок СТЭЛ-АНК-СУПЕР для целей дезинфекции и стерилизации, Москва. 2017.*
23. *Methodical instructions for the use of ANK neutral Anolyte, produced in STEL-YUN-120–01M devices for the purpose of disinfection in the workshops for ambulance vehicles (ASMP), Moscow: VNIIIMT, 2003. Методические указания по применению Анолита АНК нейтрального, вырабатываемого в установках СТЭЛ- ЮН-120–01М для целей обеззараживания в салонах автомобилей скорой медицинской помощи (АСМП), Москва: ВНИИИМТ, 2003.*
24. *Methodical instructions No. 11–3/206–09 of June 17, 2002 on the use of neutral anolyte ANK produced in the STEL-YUN-120–01 device for the purposes of disinfection, pre-sterilization cleaning and sterilization, approved by the Head of the Department of State Sanitary and Epidemiological Supervision MH of the Russian Federation. Методические указания № 11–3/206–09 от 17.06.2002 г. по применению «Нейтрального анолита АНК», вырабатываемого в установке СТЭЛ-ЮН-120–01, для целей дезинфекции, предстерилизационной очистки и стерилизации, утвержденные Руководителем Департамента госсанэпиднадзора МЗ РФ.*
25. *Methodical instructions No. MU-17–12 dated 02.14.1997 on the use of neutral anolyte ANK produced in the STEL-YUN-120–01 device for the purposes of disinfection, pre-sterilization cleaning and sterilization, approved by the Head of the Department of State Sanitary and Epidemiological Supervision MH of the Russian Federation. Методические указания № МУ-17–12 от 14.02.1997 г. по применению нейтрального анолита АНК, вырабатываемого в установке СТЭЛ-ЮН-120–01, для целей дезинфекции, предстерилизационной очистки и стерилизации, утвержденные Начальником Департамента госсанэпиднадзора МЗ РФ.*
26. *Methodical instructions No. MU-169–113 dated 08/10/1998 on the use of neutral anolyte ANK produced in the STEL-60–03-ANK device for disinfection, pre-sterilization cleaning and sterilization, approved by the Head of the Department of State Sanitary and Epidemiological Supervision MH of the Russian Federation. Методические указания № МУ-169–113 от 10.08.1998 г. по применению нейтрального анолита АНК, вырабатываемого в установке СТЭЛ-60–03-АНК, для дезинфекции, предстерилизационной очистки и стерилизации, утвержденные Начальником Департамента госсанэпиднадзора МЗ РФ.*
27. *Methodical instructions No. 01–19/49–11 dated 08/10/1993 on the use of an electrochemically activated solution of sodium chloride (neutral anolyte) produced in the STEL-4N-60–01 device for disinfection, pre-sterilization cleaning and sterilization, approved by the Deputy Chairman of the State Committee for Sanitary and Epidemiological Surveillance of the Russian Federation, VNIIIMT MH RF and NIIPTiD, Moscow. Методические указания № 01–19/49–11 от 10.08.1993 г. по применению электрохимически активированного раствора натрия хлорида (нейтральный анолит), вырабатываемого в установке СТЭЛ-4Н-60–01 для целей дезинфекции, предстерилизационной очистки и стерилизации, утвержденные Заместителем председателя Еосударственного Комитета санитарно-эпидемиологического надзора РФ, ВНИИИМТ МЗ РФ и НИИПТиД, Москва.*
28. *Methodical instructions for the use of electrochemically activated sodium chloride solution (neutral anolyte), produced in the STEL-MT-1 device, for the purposes of disinfection, pre-sterilization cleaning and sterilization. Registration certificate number of the State Committee for Sanitary and Epidemiological Supervision of the Russian Federation 01–19/15–11 dated 16.09.1992, — 27 p.. Методические указания по применению электрохимически активированного раствора хлорида натрия (нейтральный анолит), вырабатываемого в установке СТЭЛ-МТ-1, для целей дезинфекции, предстерилизационной очистки и стерилизации. Номер регистрационного свидетельства Госкомсанэпиднадзора РФ 01–19/15–11 от 16.09.1992, — 27 с.*

29. *Methodical instructions No. 11–3/197–03 dated 08.16.2000 of the company NPO Khimavtomatika on the use and quality control methods of the Neutral Anolyte ANK agent produced by the STEL-60–03-ANK devices in the automated KADS complex -80–01 Endosteril for disinfection, pre-sterilization cleaning and sterilization of fully and incompletely immersed flexible endoscopes, approved by the Head of the Department of State Sanitary and Epidemiological Surveillance MH RF. Методические указания № 11–3/197–03 от 16.08.2000 г. компании ОАО НПО «Химавтоматика» по применению и методам контроля качества средства «Нейтральный анолит АНК», вырабатываемого установкой «СТЭЛ-60–03-АНК» в автоматизированном комплексе КАДС-80–01 «Эндостерил» для дезинфекции, предстерилизационной очистки и стерилизации полностью и не полностью погружаемых гибких эндоскопов, утвержденные Руководителем Департамента Госсанэпиднадзора МЗ РФ.*
30. *Sanitary Rules for the Safety of Work with Microorganisms of I — II Pathogenicity Groups approved by the Chief Sanitary Doctor of the Russian Federation No. SP1. 2. 011–94 dated 4.05.1994, in which Anolyte ANK is indicated as a means of destroying the causative agents of cholera, plague, anthrax, tularemia. Утвержденные Главным санитарным врачом РФ Санитарные Правила Безопасности работы с микроорганизмами I — II групп патогенности № СП1. 2. 011–94 от 4.05.1994., в которых Анолит АНК указан в качестве средства уничтожения возбудителей холеры, чумы, сибирской язвы, туляремии.*
31. *Instruction No. IPAU. 001.09 dated 23.06.2009 by the company Laboratory of Electrotechnology on the use of the disinfectant ANOLYTE ANK, produced in the STEL-ANK-PRO device for disinfection, pre-sterilization cleaning and sterilization. Инструкция № ИПАУ. 001.09 от 23.06.2009 г. компании ООО «Лаборатория электротехнологии» по применению дезинфицирующего средства «АНОЛИТ АНК», вырабатываемого в установке «СТЭЛ-АНК-ПРО» для дезинфекции, предстерилизационной очистки и стерилизации.*
32. *Instruction No. 24 on the use of anolyte aerosol generated by mobile aerosol generators MAG (TU-5156–024–54368736–05) dated 15.04.2005, issued by CJSC ECA-MAG by the Federal Agency for Healthcare and Social Development, St. Petersburg, 2005. Инструкция № 24 по применению аэрозоля анолита, вырабатываемого мобильными аэрозольными генераторами МАГ (ТУ-5156–024–54368736–05) от 15.04.2005 г., выданная ЗАО «ЭХА-МАГ» Федеральным Агентством по здравоохранению и социальному развитию, Санкт-Петербург, 2005*
33. *Instruction issued by ECA-MAG CJSC on the use of anolyte aerosol produced by MAG aerosol generators (TU-5156–024–54368736–05) for disinfection of water supply networks and structures, at housing and communal facilities, industrial and food enterprises, catering facilities, in agriculture, in medical institutions, in crowded places, infectious foci, to eliminate the consequences of chemical and bacteriological contamination). Инструкция выданная ЗАО «ЭХА-МАГ» по применению аэрозоля анолита, вырабатываемого аэрозольными генераторами МАГ (ТУ-5156–024–54368736–05) для дезинфекции водопроводных сетей и сооружений, на жилищно-коммунальных объектах, промышленных и пищевых предприятиях, предприятиях общественного питания, в сельском хозяйстве, в лечебно-профилактических учреждениях, в местах массового скопления людей, инфекционных очагах, для устранения последствий химического и бактериологического заражения).*
34. *Methodical recommendations on the use of the aerosol complex STEL-TUMAN for disinfection of premises, Military Medical Academy, St. Petersburg, 2001. Методические рекомендации по применению аэрозольного комплекса «СТЭЛ-ТУМАН» для дезинфекции помещения, Военно-медицинская академия, Санкт-Петербург, 2001 г.*
35. *Regulations for disinfecting the premises of sectional rooms of forensic and pathological laboratories using washing and antimicrobial electrochemically activated solutions synthesized on STEL devices dated June 21, 1999. Central Forensic Laboratory of the Ministry of Defense of the Russian Federation. Регламент обеззараживания помещения секционных залов судебно-медицинских и патологоанатомических лабораторий с помощью моющих и антимикробных электрохимически активированных растворов, синтезированных на установках СТЭЛ от 21.06.1999 г. Центральная судебно-медицинская лаборатория Министерства обороны РФ.*

36. *Methodological recommendations for the practical application of neutral anolyte in emergency situations, Academy of Civil Protection, Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of Natural Disasters, Novogorsk, 2002. Методические рекомендации по практическому применению анолита нейтрального в условиях чрезвычайных ситуаций, Академия гражданской защиты, Министерство РФ по делам гражданской обороны, чрезвычайным ситуациям и ликвидации стихийных бедствий, Новогорск, 2002.*
37. *Methodological recommendations for application of Neutral anolyte produced by STEL-Medicom-YUN -120–01 for the purpose of disinfection, pre-sterilization cleaning and sterilization. Регламент із застосування «Нейтрального аноліту, що виробляется установкою СТЭЛ-Медиком ЮН-120–01» з метою дезінфекції, передстерилізаціонного очищения і стерилізації.*
38. *Registration certificate No. LS-002150 dated 10/27/2006, issued by OJSC NPO EKRAN by the Federal Service for Surveillance in Healthcare and Social Development of the Ministry of Health and Social Development of the Russian Federation for neutral anolyte ANK agent — a solution for local and external use. Регистрационное удостоверение № ЛС-002150 от 27.10.2006, выданное ОАО НПО ЭКРАН Федеральной службой по надзору в сфере здравоохранения и социального развития Минздравсоцразвития РФ на лекарственное средство — анолит нейтральный АНК — раствор для местного и наружного применения.*
39. *Certified pharmacopoeial description of the enterprise (NPO EKRAN OJSC) FSP 42–0664792406 dated October 27, 2006, registered by the Federal Service for Surveillance in Healthcare and Social Development of the Ministry of Health and Social Development of the Russian Federation for neutral anolyte ANK — a solution for local and external use. Фармакопейная статья предприятия (ОАО «НПО «ЭКРАН») ФСП 42–0664792406 от 27.10.2006, зарегистрированная Федеральной службой по надзору в сфере здравоохранения и социального развития Минздравсоцразвития РФ на анолит нейтральный АНК — раствор для местного и наружного применения.*
40. *Hygienic conclusion of the Center for State Sanitary and Epidemiological Supervision M3 RF No. 78.1.3.515. Clause 5039.6.0 dated 06.16.2000 on the use of ANK anolyte for the purposes of water disinfection at utility and drinking water supply stations, as well as for decentralized water supply to the population. Гигиеническое заключение Центра госсанэпиднадзора МЗ РФ № 78.1.3.515. П. 5039.6.0 от 16.06.2000 на использование анолита АНК для целей дезинфекции воды на станциях хозяйственно-питьевого водоснабжения, а также для децентрализованного водоснабжения населения.*
41. *Methodological recommendations on the use of anolyte obtained at STEL-type devices for disinfection of water in swimming pools (disinfection of water in swimming pools, baths and saunas), approved by the Chief State Sanitary Doctor of the City Center of the State Sanitary and Epidemiological Supervision of St. Petersburg on July 21, 1995, No. 1305. Методические рекомендации по использованию анолита, получаемого на установках типа СТЭЛ, для дезинфекции воды в плавательных бассейнах (дезинфекция воды в плавательных бассейнах, банях и саунах), утвержденные Главным Государственным санитарным врачом городского центра Госсанэпиднадзора г. Санкт-Петербурга 21.07.1995, № 1305.*
42. *Methodical recommendations dated December 27, 1994 on the use of neutral anolyte produced in the STEL-4N-60–01 device for disinfection purposes at public utilities and hotels, approved by the State Sanitary Doctor of Moscow. Методические рекомендации от 27.12.1994 г. по применению нейтрального анолита, вырабатываемого в установке СТЭЛ-4Н-60–01 для целей дезинфекции на объектах коммунального хозяйства и гостиницах, утвержденные Государственным санитарным врачом г. Москвы.*
43. *Recommendations of the deputy Chief State Sanitary Doctor of the Republic of Kazakhstan on the wide use of STEL-type devices in medical institutions, preschool institutions, at trade and communal facilities No. 7–2-3/3874 dated July 8, 1995. Рекомендации зам. Главного Государственного санитарного врача Республики Казахстан по широкому использованию установок типа СТЭЛ в медицинских учреждениях, детских дошкольных учреждениях, на объектах торговли и коммунального хозяйства № 7–2-3/3874 от 8 июля 1995 г.*

44. *Order of the Government of Moscow on the introduction of automated electrochemical devices STEL at municipal facilities dated February 23, 1995, No. 169-RP. Hygienic conclusion No. 78.1.3.515. P. 17678.9.99 dated 09/13/1999. Sanitary and Epidemiological Conclusion of the Department of the State Sanitary and Epidemiological Service of the Russian Federation No. 77.99.04.945. D005022.07.02 of 25.07.2002. Распоряжение Правительства Москвы о внедрении автоматизированных электрохимических установок СТЭЛ на объектах городского хозяйства от 23 февраля 1995 г., № 169-РП. Гигиеническое заключение № 78.1.3.515. П. 17678.9.99 от 13.09.1999. Санитарно-эпидемиологическое заключение Департамента ГСЭН РФ № 77.99.04.945. Д005022.07.02 от 25.07.2002.*
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46. *Methodical instructions: disinfection of pipelines and tank structures on water supply networks and facilities of the State Unitary Enterprise Vodokanal of St. Petersburg, enterprise standard STP 10.002.0–05, St. Petersburg, valid from 01.09.2005 to 01.09.200846. Instruction No. 24 on the use of anolyte aerosol generated by mobile aerosol generators MAG (TU-5156–024–54368736–05) dated 15.04.2005, issued by ECA-MAG CJSC by the Federal Agency for Health and Social Development, St. Petersburg, 2005. Инструкция № 24 по применению аэрозоля анолита, вырабатываемого мобильными аэрозольными генераторами МАГ (ТУ-5156–024–54368736–05) от 15.04.2005 г., выданное ЗАО «ЭХА-МАГ» Федеральным Агентством по здравоохранению и социальному развитию, Санкт-Петербург, 2005*
47. *Instructions for the use of anolyte aerosol generated by MAG aerosol generators (TU-5156–024–54368736–05) for disinfection of water supply networks and structures, at housing and communal facilities, industrial and food companies, catering facilities, in agriculture, in medical preventive institutions, in crowded places, infectious foci, to eliminate the consequences of chemical and bacteriological contamination). Инструкция по применению аэрозоля анолита, вырабатываемого аэрозольными генераторами МАГ (ТУ-5156–024–54368736–05) для дезинфекции водопроводных сетей и сооружений, на жилищно-коммунальных объектах, промышленных и пищевых предприятиях, предприятиях общественного питания, в сельском хозяйстве, в лечебно-профилактических учреждениях, в местах массового скопления людей, инфекционных очагах, для устранения последствий химического и бактериологического заражения).*
48. *Disinfection of premises with anolyte ANK aerosol: Permission from the State Committee for Sanitary and Epidemiological Supervision of the Russian Federation for the use of anolyte ANK in the form of fog, obtained using an aerosol centrifugal generator KGA-1 for use in medical institutions. Hygienic certificate No. 78. SP. 09.331. Cl. 06016K98 dated 04/30/1998. Обеззараживание помещений аэрозолем анолита АНК: Разрешение Госкомсанэпиднадзора РФ на применение анолита АНК в виде тумана, полученного с помощью генератора аэрозольного центробежного КГА-1 для применения в лечебно-профилактических учреждениях. Гигиенический сертификат № 78. СП. 09.331. П. 06016К98 от 30.04.1998.*
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УДК 544.6+625.35
ББК 24.57
Э45

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

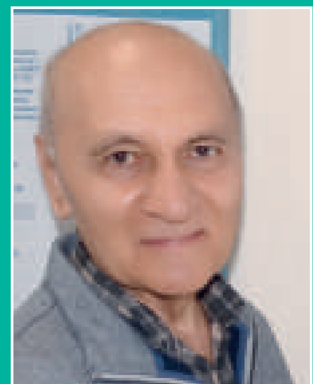
Э45 ELECTROCHEMICAL ACTIVATION:
INVENTIONS, SYSTEMS, TECHNOLOGY

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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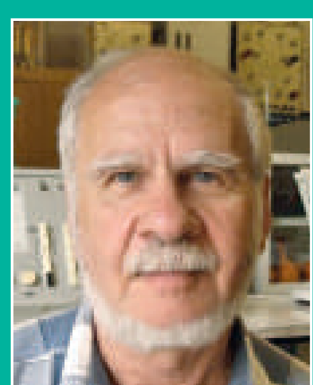

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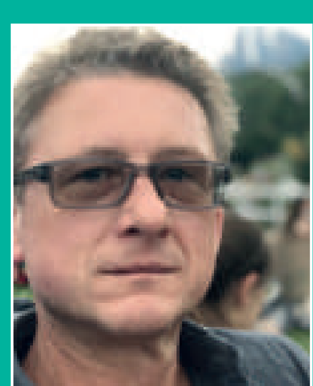

VADIM PANICHEV — expert in Electrochemical Technology Applications for Regulated Industries (Pharma, Medical Devices, Biotech, etc.), working over the past 25 years in Electrochemical Equipment Design and Development, Product Development and process validation for DOD, Agricultural, Medical Devices and Pharma Industries. The author of international patents for methods of manufacturing and application of electrochemically activated solutions and stabilized hypochlorous acid formulations.

ISBN 978-5-6047707-0-2
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