5.3. IN SEARCH FOR THE PERFECT ANTIMICROBIAL AGENT

When wondering what a perfect liquid germ-fighting agent should be, it's easy to formulate the following:

- a germ-fighting agent must have a wide spectrum of antimicrobial action, i. e. effectively destroy bacteria, mycobacteria, viruses, fungi and spores, regardless of the duration and frequency of use, which suggests the presence of properties that prevent microorganisms from developing resistance;
- the germ-fighting agent must be safe for humans and animals both during its preparation and application, 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, i. e., in other words, the antimicrobial agent and products of its natural or artificial degradation should not contain xenobiotic substances;
- the germ-fighting agent must have versatility of action, that is, have not only antimicrobial properties, but also have a detergency with minimal damaging and corrosive activity in relation to various materials, and also be as simple as possible to use and at the same time relatively inexpensive.

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The most distant position from the above characteristics is occupied by preparations based on stable organic compounds, which currently dominate the market of disinfectants.

Often, the absence of odor (as opposed to chlorine-containing drugs) or, on the contrary, the presence of a pleasant smell of fragrance substances is often indicated as a positive property of agents based on stable, i. e., difficult to transform under the influence of environmental factors. In fact, these "benefits" should be treated with great caution. Most organic compounds used as disinfectants or products of their transformations during natural or artificial decay processes are no less and often much more toxic than, for example, chlorine gas at the same concentrations. The smell for most multicellular complex organisms in the usual conditions of the environment is a source of information. The absence of a smell, signaling danger, does not allow a person to evade harmful effects, which as a result leads to functional and organic disorders in the body. These violations are usually observed later more or less long time after direct contact with a harmful substance, so their reasons can very rarely be adequately identified.

Until recently, the general public could become aware of the harmful effects of chemicals only in the case of catastrophic side effects of their use, which could not be hidden or explained in any other way. Such disasters include, for example, the consequences of the use in the republics of Central Asia of the former Soviet Union of a stable organic chemical — defoliant butifos with a rather pleasant smell of freshly cut grass.

It should be noted that this drug once passed all the strict official licensing procedures and received a positive conclusion from several toxicological examinations. And it was completely justified, since in the process of this kind of research it is fundamentally impossible to adequately model the factors of the real conditions of the practical use of the drug.

It is advisable to take this kind of experience into account when creating new means for disinfection, giving preference to those of them, the mechanism of antimicrobial action of which, in principle, cannot have a harmful effect on the human body.

It can be concluded that disinfecting solutions of stable organic compounds when treating surfaces with them always form a film invisible to the eye on the surface of the processed products, and the molecules of the active substance evaporating from it harm a warm-blooded organism, since organic compounds — disinfectants are xenobiotic substances, i. e. substances alien to life in any of its manifestations, be it the life of microbes or the life of a human being.

Are there environmentally friendly disinfectants? This issue is attracting public attention today. Progress in the development of society is accompanied by more and more frequent direct human contacts with bactericidal, virucidal, fungicidal drugs — from the purchase of fruits, the safety of which is ensured with the help of biocidal chemical compounds, to staying in premises (hospitals, clinics, dentist offices), vehicles (trains, airplanes, more recently — in buses, trams), regularly treated with disinfectants. Faced with a choice, a human consumer gives preference to an environmentally friendly product or technology, as opposed to a human seller (producer). For example, an apple with a worm, which testifies to its development in natural conditions, is valued more today than a similar fruit with a perfect surface texture and a long fresh shelf life. Products without preservatives are more valuable for the Consumer, although the Seller (Manufacturer) cannot but use them, since he cannot suppress the growth of microorganisms and ensure the long-term preservation of products in any other way.

Flame should be recognized as the oldest of the environmentally friendly disinfectants. Being a metastable substance, flame plasma does not have a toxic aftereffect and, unlike most solutions of organic chemical disinfectants, does not leave a fundamental possibility for microorganisms to develop resistance. Another environmentally friendly agent is hydrogen peroxide, which is used in the latest sterilization systems in a metastable state, converting it into plasma

Studies of recent decades have shown that all higher multicellular organisms, including humans, synthesize hypochlorous acid and highly active metastable chlorine-oxygen and hydroperoxide compounds (metastable mixture of oxidants) in special cellular structures to fight microorganisms and foreign substances [5]. Hypochlorous acid dissociates in an aqueous medium with the formation of hypochlorite anion and hydrogen ion: $HClO \leftrightarrow ClO^- + H^+$. 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 — towards a higher concentration of hypochlorite anions. Sodium hypochlorite has an incomparably less bactericidal activity than hypochlorous acid. For example, if spores of anthrax B. anthracis in an aqueous solution of active chlorine compounds with a concentration of 50 mg/l at pH = 8.6 die within 40 minutes, then in a solution with a concentration of active chlorine compounds of only 5 mg/l at pH = 7.2 the same result is achieved in 20 minutes [6]. This is explained by just a small change in the pH of the medium causing huge differences in the antimicrobial activity of the same solution. The highest bactericidal activity of oxygenated chlorine compounds is manifested in the pH range from 7.0 to 7.6, where the concentrations of hypochlorite ions and hypochlorous acid are comparable. This is explained by the fact that these compounds, being conjugated acid and base ($HClO + H_2O \rightarrow H_3O^+ + ClO^-$; $ClO^- + H_2O \rightarrow HClO + OH^-$), in the specified pH range form a metastable system capable of generating a number of compounds and particles with a much greater antimicrobial effect than hypochlorous acid: $^1O_2$ — singlet molecular oxygen; $ClO^\bullet$ — hypochlorite radical; $Cl^\bullet$ — chlorine — radical (atomic chlorine); $O^\bullet$ — atomic oxygen; $OH^\bullet$ — hydroxyl radical. The catalysts of reactions involving chlorine-oxygen compounds are H^+ and OH^- ions, which also exist in water in approximately equal amounts at pH values close to neutral [7].

There is an important conclusion following from the above: **to exclude the development of resistance of microorganisms to a liquid antimicrobial agent is only possible by using solutions with metastable** active substances, their spontaneous disintegration during the treatment providing a multiplicity and unpredictability (for microorganisms) of ways of the development of reactions disrupting the processes of their vital activity.

The unique ability of hypochlorous acid to form metastable mixtures of oxidants universal in the spectrum of antimicrobial action is widely used in many disinfectants based on cyanuric acid salts (Aquatabs, Deochlor, Chlorsept, Precept, Javelion, Chlor-Clean, Sanival and others), which makes it possible to reduce the concentration of active chlorine in working solutions of disinfectants by at least 10 times in comparison with solutions of sodium hypochlorite while achieving a higher antimicrobial activity. As an example, consider the mechanism of action of the Precept tablets manufactured by Johnson & Johnson. It is believed that the main active ingredient in these tablets is sodium dichloroisocyanurate. In fact, the active ingredient is hypochlorous acid, which is formed by the interaction of sodium dichloroisocyanurate with water and exists in the working solution at pH = 6.2, which is maintained by adipic acid in the tablet formulation. All drugs of this type work in approximately the same way.

However, their use is unsafe for humans and other warm-blooded creatures, since they contain an organic chlorine compound, in particular sodium dichloroisocyanurate, which, unlike inorganic chlorine-oxygen compounds, does not disappear without a trace when dry, but accumulates in the environment and in the human body.

The highest antimicrobial activity among all known liquid sterilizing and disinfecting agents with the least toxicity or no toxicity for warm-blooded organisms is characteristic of electrochemically activated solutions, in particular, neutral Anolyte ANK, which is produced in STEL-type devices from a diluted aqueous solution of sodium chloride. Quite often these solutions are identified with hypochlorite solutions. This is explained by the lack of awareness of people and their natural desire to simplify perception by classifying electrochemically activated solutions as well-studied hypochlorite solutions based on external similar features.

Anolyte ANK, in contrast to 0.5–5.0% hypochlorite solutions, which have only a disinfecting effect, is a sterilizing solution with a concentration of oxidants in the range 0.005–0.05%.

The main principle of the technology for obtaining activated solutions is the use of a unipolar combined electrophysical and electrochemical effect on the treated medium, in the process of which either the withdrawal or inlet of electrons is carried out, resulting in a directed change in the physicochemical, including the structural-energetic and catalytic properties of the medium.

The active ingredients in Anolyte ANK are 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).

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.

Anolyte ANK is a universal solution, therefore it is used both for disinfection, pre-sterilization cleaning and sterilization, and for general cleaning of premises, disinfection of equipment in hospitals, clothes, surgeon's hands, etc.

The sum of active oxygen and chlorine compounds in Anolyte ANK (total concentration of oxidants) is in the range from 100 to 500 mg/l, which is ten times less than in most working solutions of modern disinfectants. Anolyte ANK does not cause coagulation of the protein that protects microorganisms and, due to its loosened structure, easily penetrates the microchannels of living and inanimate matter. Anolyte ANK is non-toxic due to the low concentration of active ingredients, therefore it does not require removal from the treated surfaces after the end of treatment.

Summing up the above, we can conclude that **the most effective in terms of functional properties with a simultaneous low toxicity or its complete absence are metastable low-mineralized chlorine-oxygen antimicrobial solutions (electrochemically activated solutions)**, which have no alternative, while life on Earth is represented by various forms of existence of protein bodies in the electrolyte of aqueous solutions of ions, mainly of sodium and chlorine.

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Э45

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

Э45 ELECTROCHEMICAL ACTIVATION:
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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.

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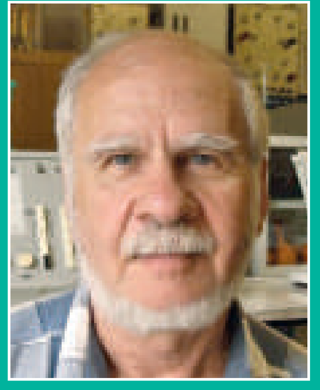

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