

# Chapter 1

## Introduction

**Abstract** This book is based on papers, which present the application of the pulsed electrical discharges in water and water dispersions of metal and oxide nanoparticles in surgery, dentistry, oncology, biology, and ecology. Initially, the researches were focused on the physical processes and parameters of the pulsed discharges in water to prove their possibility for bacterial purification of water and sewage from almost all known bacteria and spores of fungi. It was founded for the first time that the so called prolonged microbial resistance of water treated by the pulsed electric discharges due to the nanoparticles and positive ions emitting by them. It has been shown that the nanoparticles are not genotoxic and mutagenic. The intensive shock waves generated by the pulsed discharges represent a novel technique of “soft” destroying of viruses’ membranes and this way to prepare anti-virus vaccines. This book is useful for researchers and graduate students in the field.

Disinfecting effect of electric current in water is known for a long time and the first attempt of its usage in 1871 had been undertaken. In 1898 Bredig and then Svedberg in 1909 have applied an electric arc for the first time [1] and pulsed electric discharges (PED) [2] to produce water dispersions of metal and organic sol-gels. During last century, PED in water were applied, basically, to destruct microbes, spores, protozoa, etc., and to transform organic and inorganic compounds.

The medical investigations for the last decades have shown that the sharp rise of oncological and cardiovascular diseases is a result of a chlorine disinfection of the tap water [3, 4]. It was revealed that chlorinated potable water contains steady macroradicals, which provoke occurrence and development of various serious diseases [5].

It is well known that distinctive feature of electrophysical techniques such as electronic beams, ozonation, PED, etc. is that they do not use harmful and dangerous substances containing dioxins of chlorine and fluorine. At the same time a PED equipment is much easier and cheaper, than, for example, electronic beams one.

This determines an importance and urgency of works, which are addressed to search of alternative and safe ways of water disinfection. Moreover, studies of pulsed electric fields influence on man’s cells and organic tissue (including the cancer tissue) are implementing now [6].

There are some methods for water and air purification from microbic and other pollutions, which use the electric energy. Most effective methods are pulsed electric fields [7, 8], glow discharges [9, 10], streamer/corona discharges [11, 12], gliding discharges [13], barrier discharges [14], and PED [15–18].

The methods mentioned above are of approximately equal efficiency for destruction of microbes, because of in all of them, the acting factors are the same ones: UV-irradiation, OH radicals,  $H_2O_2$ ,  $O_3$ , etc. However, the PED methods have essential advantages in comparison with others: first, intensive shock waves; second, the effect of prolonged microbial resistance of water (PMRW), i.e., the property of treated water to destroy the bacteria for a long time (several months) after treatment by the PED [19–21]. Due to this property, water treated by the PED is the bactericidal agent.

When the absence of negative action of the electric methods on human beings has been confirmed, their application in medicine, pharmaceuticals, food industry, and other areas is widely expected [22, 23]. Nowadays, the electric methods for disinfecting the drains of hospitals and industrial enterprises can be used.

Last years, the powerful PED were applied for water purification from chemical pollutions, including salts of heavy metals [24–29].

Besides this area of researches of the PED in water, it is necessary to mention the WDN, which have now found wide applications in medicine and biology.

The progress in contemporary studies in experimental and clinical oncology is largely determined by intensive introduction of achievements of fundamental physics and chemistry [30, 31]. Nanoparticles, nanotubes, nanocapsules, dendrimers, and nanoconductors comprise incomplete list of high-tech developments used for studying targeted delivery of anticancer drugs and radioactive labels to cancer cells as well as for designing new methods of precise detection of transformed cells, proteins, DNA, and individual genes [32, 33].

In particular, promising nanotechnological approaches in oncological studies are based on the use of nanoparticles those exhibit new physicochemical and biological properties [34]. It is known that silver nanoparticles and ions possess an intrinsic cytotoxic activity [35, 36] and have a prolonged antimicrobial effect when applied to silicon structures [37].

Results of microbiological studies indicate that the interaction of silver ions with molecules of extracellular lipoprotein matrix increases permeability of the plasma membrane of microbial cells and eventually causes their death [38]. The result of our study demonstrated that the WDN of silver nanoparticles exhibit antitumor properties *in vivo*. The observed cytostatic effect was confirmed by significant growth suppression, cytodystrophic changes, and fibrosis of transplanted the Pliss lymphosarcoma in the rats that received regular intravenous injections of the silver WDN. Impact of silver atoms on stabilization of molecular structure of the DNA, inhibition of tumor growth and/or reversion of the malignant phenotype requires further study on tissue, cellular, and molecular levers. Further studies of mechanisms of the discovered biological effect may become the basis for development of nanoparticles based preparations for treating malignant neoplasms in clinical practice [39].

Bactericidal properties of the silver WDN can use in surgery for treatment of upper purulent wounds with a chronic component [19, 40, 41]. The patients with such wounds are of large number and differ on etiology of diseases but the common feature of these diseases is long treatment without marked positive changes [42]. Therefore, long application of antibiotics leads to abnormality of immune processes and antibacterial resistance to microbial flora [43]. Moreover, local antiseptics are frequently toxic and one can oppress processes of repairing the wounds [44]. However, under usage of water dispersions of silver nanostructures, there were no cellular atypia and preternatural exhibitions of inflammatory reactions. It is possible to assume that, in prospect, this method will allow one to correct the practice of outpatient therapy of chronic and slow pyoinflammatory diseases.

Other area of application of the WDN is stomatology. Generalized periodontitis is systemic disease with progressive destruction of periodontal tissues and first symptoms presentation in young age. The incidence of periodontitis in 35–44 years old population is 98 %. The WDN of silver for clinical research had been used. As our researches have shown, periodontal pocket depth is decreased in average on 2.2 mm, bleeding index was of 1 point, and the RT-PCR data appeared within normal values in 3 weeks that coincided with absence exudates from periodontal pockets.

Distinctive property of magnetic nanoparticles (that explains interest to them) is their mobility under action of a magnetic field, which can be used for their directed transportation, sedimentation and concentration in the required area. Our researches have shown that nanoparticles, consisting of iron oxides, can be used as magneto-active agents for transformation of cells of microorganisms into microaggregates for their directed transport or concentration under action of a magnetic field [45].

We investigated connection between the properties of the metal oxide nanostructures produced by the PED in water and peculiarities of their interaction with the human blood serum, lysozyme, and albumin solutions under various conditions.

By means of dynamic light scattering technique, atomic force, and transmissive electronic microscopes, it was found that the albumins and lipoproteins of blood serum are aggregated on the surface of the nanostructures and form the supramolecular complexes.

In single protein system, it was shown that aggregation ability strongly depends on folding state of lysozyme and loading state of albumin. Since the nanostructures have specific effect and different absorptive abilities to the biological objects, possibility appears for developing new tools for diagnosis of some conformational diseases. Potential diagnostic is proposed estimation of new integral characteristics of patient state and characteristic radii of nanostructures-serum components complex [46–48].

Thus, the PED applications are prospective to water purification from microbic and chemical pollutions and producing (by the PED) water dispersions of metal and oxide nanoparticles. It is promising in ecological, biological, and medical problems.

The investigations were carried out for more than 20 years at the Institute for Electrophysics and Electric Power of the Russian Academy of Sciences (IEE RAS) in collaboration with the following institutes and universities:

- A.F. Ioffe Physical-Technical Institute of the Russian Academy of Science, St.-Petersburg, Russia (developing of pulsed electric high-voltage generators)
- Pasteur Institute, St.-Petersburg, Russia (bactericidity of WDN)
- Institute for Toxicology, St.-Petersburg, Russia (impact of the WDN on laboratory animals)
- A.A. Uhtomsky Physiology Research Institute of St.-Petersburg State University, St.-Petersburg, Russia (fungicide activity of the WDN)
- Institute of Analytical Instruments of the Russian Academy of Sciences, St.-Petersburg, Russia (chemical and physical properties of the WDN)
- N.N. Petrov Institute for Oncology, St.-Petersburg, Russia (impact of the silver WDN on tumor growth in vivo)
- Institute for Nuclear Physics of the Russian Academy of Sciences, Gatchina, Russia (interaction of the WDN and biological objects)
- Institute for Influenza of the Russian Academy of Medicine Sciences, St.-Petersburg, Russia (impact of electric pulses and shock waves on viruses)
- Oryol State University, Medical Institute, Oryol, Russia (treatment of pyoinflammatory diseases with a chronic component by means of the WDN)
- Dental Center “PetroDent”, Russia (treatment of periodontal diseases by means of the WDN)
- St.-Petersburg State Technological Institute, St.-Petersburg, Russia (chemical properties of the WDN)
- Moscow State University, Moscow, Russia (chemical properties of the WDN)

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