Published in the Slovak Republic
European Journal of Molecular Biotechnology
Has been issued since 2013.
ISSN: 2310-6255
E-ISSN: 2409-1332
2017, 5(1): 23-29

DOI: 10.13187/ejmb.2017.1.23
www.ejournal8.com

Processes in Catholyte and Anolyte as Result of Water Electrolysis

Dimitar Mehandjiev [a], Ignat Ignatov [b, *], Stoil Karadzhov [c], Georgi Gluhchev [d], Atanas Atanasov [e]

[a] Institute of General and Inorganic Chemistry, Bulgarian Academy of Science (BAS), Acad. G. Bonchev Street, Sofia, Bulgaria
[b] Scientific Research Center of Medical Biophysics (SRCMB), Bulgaria
[c] Bulgarian Association of Activated Water, Sofia, Bulgaria
[d]. Institute of Information and Communication Technologies (BAS), Sofia, Bulgaria
[e] Bulgarian Association of Activated Water, Sofia, Bulgaria

Abstract

A two stage model of the physicochemical processes at the electrolysis of pure water is proposed. The presence of nascent hydrogen in the catholyte and nascent oxygen in the anolyte during the first stage explains the antioxidant properties of the catholyte and the strong biocidal action of the anolyte. In the second stage the nascent hydrogen and oxygen are combined into hydrogen and oxygen molecules, respectively. The comparison between their average energies with the average energy of the control sample of water shows an increase in the average energy of the catholyte and decrease in the average energy of the anolyte. This indicates that some changes in the structure of the activated water have occurred.

Keywords: Electrochemically activated water (ECAW), catholyte, anolyte, nascent hydrogen, nascent oxygen, energetic spectrum, energy of hydrogen bonds.

2. Introduction

Water is the main factor of the life on our planet. Even more, according to one of the co-authors of this paper the life has started in the warm thermal springs on the earth (Ignatov, Mosin, 2015). Water regulates the vital processes in the living things actively participating in the metabolism and their adaptation to the environment. That's why every change of its composition and structure influences the live matter either aiding its development and stability or on contrary provoking its destruction. It seems strange that despite such enormous importance scientists from different countries have seriously started paying attention and investigating the unusual properties of the water put to different kind of influence only in the last decades. In this direction a great attention was paid to its electrochemical activation (Bakhir, 1999; Kloss, 1988; Petrushenko, Lobyshev, 2004; Prilutsky, Bakhir, 1997; Zenin, 1999). Notwithstanding the easy description of the chemical processes the explanation of the obtained properties of the alkaline (catholyte) and acidic (anolyte) water solutions are still not fully convincing (Ball, 2008). Even more, in the majority of the existing descriptions and experiments NaCl has been used which gives a satisfactory explanation of the biocidal properties of the anolyte but does not work in case of pure water which obtains same properties. The explanation probably relates not only to the chemical changes in the water composition but also to the changes of its structure.

* Corresponding author
E-mail addresses: mbioph@dir.bg (I. Ignatov)

The main questions that researchers have to answer are as follows.

1. What physical and chemical changes occur in the water during its electrolysis?

This question should be investigated in two aspects:

а) pure water is processed;

б) NaCl or other minerals are added to the water solution.

2. What parameters of the activated water play a major role for the explanation of its unusual properties?

3. What the mechanism of the action of the activated water on the living things is?

In this paper attention is paid to the question 1a), i.e. the activation of water without additional mineralization, free of ions of other elements. A model of the corresponding physicochemical processes is proposed.

Every model has to describe satisfactory the observed effects of the modeled process. In our case the known effects of the activated water (catholyte and anolyte) reported by different investigators concern especially its influence on the living things. An explanation for the described effects could be the increased presence of both molecular hydrogen (H_2) in the catholyte solution and molecular oxygen (O_2) in the anolyte solution. But such an increase can be achieved through saturation of the water solution with these gases as well. It is true that in this case the water properties will be changed but without same effects. It is reasonable to assume that the increased concentration of OH^- ions in the catholyte as well as H^+ ions in the anolyte cause such an action. Therefore, one may conclude **that the action of the direct current on distilled or de-ionized water leads to changes in its chemical composition and structure different for the catholyte and anolyte.**

Electrolysis of pure water.

According to the modern notion the following reaction takes place at the cathode :

$$2H^+ + 2e^- \rightarrow H_2\uparrow \quad (1)$$

The analogous reaction at the anode is as follows:

$$2O^{2-} - 2e^- \rightarrow O_2\uparrow \quad (2)$$

Actually, the above reactions run in two stages.

At the cathode:

First stage $H^+ + e^- \rightarrow H^*$ (3)

Second stage $H^* + H^* \rightarrow H_2$ (4)

At the anode:

First stage $OH \rightarrow O^* + 2e^- + H^+$ (5)

Second stage $O^* + O^* \rightarrow O_2$ (6)

Therefore, according to formula (3) H^* - atomic hydrogen is produced at the cathode during the first stage. It is called also nascent hydrogen and possesses high reactivity. Atomic oxygen O^* called also nascent oxygen is produced at the anode, and it is highly reactive as well. These atoms can react between them according to formulae (4) and (6), and the obtained hydrogen and oxygen molecules can be either separated from the solution and go to the air or remain dissolved in the water. If there are molecules of hydrogen and oxygen at the cathode and the anode obtained according to formulae (4) и (6) they can react with the nascent hydrogen and oxygen respectively as follows:

$$4H^* + O_2 \rightarrow 2H_2O \quad (7)$$

$$O^* + H_2 \rightarrow H_2O \quad (8)$$

and water molecules will be produced.

2. Results and Discussion

It is supposed in the proposed model that nascent hydrogen and nascent oxygen are produced in the catholyte and anolyte respectively. Their presence is substantial for the processes that may occur in the above solutions. The most probable assumption is that they will take part in reactions (4) and (6) or for example (7) and (8). Another possibility for them is to be stabilized in small quantity. It has to be underlined that the stabilization possibility depends on the probability to encounter corresponding re-agents from the above mentioned reactions. If this probability is small there is a possibility other molecules that can not react with them to play the role of

stabilizers. For example, the water molecules due to their dipole character allowing for the formation of dimmers, thrimmers and larger structures could play such a role. In that case stabilized atoms of nascent hydrogen will remain in the catholyte, and stabilized atoms of nascent oxygen will remain in the anolyte. Since the nascent hydrogen is an active reducer it will attack admixtures that could be reduced when the catholyte is blended with another medium. This could explain the catholyte action as a strong antioxidant (Hanaoka, 2001; Kokichi et al., 2004). Probably, this could explain its healthy influence in case of different stress-related or due to the action of free radicals deceases. Such influence has been observed by many researchers (Hayashi, Kawamura, 2002; Komatsu et al., 2001; Lee et al., 2006; Sanetaka Shirahata et al., 2012; Yahagi,et al., 2000; Ye et al., 2008; Ye, Jun et al., 2004).

In a similar way the anolyte put in another medium will demonstrate its strong oxidative property and will oxidize all present organic admixtures and will destroy microorganisms, bacteria and viruses (Gluhchev et al., 2015; Karadzov et al., 2014; Kirkpatrick, 2009; Kumar et al., 1999; Miroshnikov, 2002; Suzuki et al., 2002; Tanaka et al., 1996; Zinkevich et al., 2000), which makes it an excellent biocidal, disinfection and harmless for the people and the environment mean.

The presence of nascent hydrogen and nascent oxygen in the hydrolyzed water could produce changes in its state. Indeed, using the method NES (Antonov, 1995; Ignatov, Mosin, 2014) as a measure of the energy spectrum of the water stage a useful information could be obtained about the structural changes in water and the average energy of hydrogen bonds among individual H_2O molecules in samples. It was experimentally established (Ignatov, Mosin, 2014) that the surface pressure was increased in the catholyte and more molecules were included in a unit volume. The average energy E of the hydrogen bonds H...O between water molecules H_2O, measured for the catholyte and anolyte, accordingly when a de-ionized water is used is E = -0.1293 eV for the catholyte and E = -1221 eV for the anolyte. The difference $\Delta E_{H...O}$ between the average energy of the control sample of water E = -0.1251 eV, evaluated by the method DNES (Ignatov, Mosin, 2014) and the average energy of the catholyte and anolyte is respectively ΔE= -0.0042 ± 0.0011 eV and ΔE= 0.003 ± 0.0011 eV.

4. Discussion and Conclusions

A two-stage model describing physicochemical processes stemming from the electrolysis of pure water is suggested in the paper. The production of nascent hydrogen and nascent oxygen during the first stage is used as a basic assumption. The enriched concentration of these components in the solutions explains the antioxidant action of the catholyte the strong biocidal effect of the anolyte. The observed difference in the average energy and hydrogen bonds between catholyte and anolyte is an indication of structural changes that have taken place in the activated water. The development of more general model describing the physicochemical processes and analysis of the content and structure of activated water in case of electrolysis of weak water mineralization is a subject of future work.

References

Antonov, 1995 – *Antonov, A.* (1995). Research of the Nonequilibrium Processes in the Area in Allocated Systems. *Diss. Thesis Doctor of Physical Sciences. Sofia*: *Blagoevgrad*: pp. 1–255.

Bakhir, 1999 – *Bakhir, V.M.* (1999). Theoretical Aspects of Electrochemical Activation. *2nd Int. Conf. Electrochemical Actvation in Medicine, Agriculture and Industry*. [in Russian]

Ball, 2008 – *Ball, P.* (2008). Water – an Enduring Mystery. *Nature,* Vol. 452*:* 20 p.

Dimitrova et al., 2015 – *Dimitrova, L., Kussovski, V., Tsvetkova, I., Mihaylova, S., Ivanov, N., Gluhchev, G., Najdenski, H.* (2015). Bacterial Effect of Electrochemically Activated Water on the Aerobic Bacterial Population on Digestate. *Ecological Engineering and Environment Protection*, Vol. 4, 23-32 [in Bulgarian]

Gluhchev et al., 2015a – *Gnluhchev, G., Ignatov, I., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O.V.* (2015). Biocidal Effects of Electrochemically Activated Water. *Journal of Health, Medicine and Nursing*, V. 11: pp. 67-83.

Gluhchev et al., 2015b – *Gluhchev, G., Ignatov, I., Karadzhov, S., Miloshev, G., Ivanov, N., Mosin, O.V.* (2015). Electrochemically Activited Water: Biophysical and Biological Effects of Anolyte and Catholyte Types of Water. *European Journal of Molecular Biotechnology*, V.1, pp. 12-26.

Gluhchev et al., 2015c – *Gluhchev, G., Ignatov, I., Karadzhov, S., Miloshev, G., Ivanov, N.,*

Mosin, O.V. (2015). Studying the Antimicrobial and Antiviral Effects of Electrochemically Activated Nacl Solutions of Anolyte and Catholyte on a Strain of E. Coli DH5 and Classical Swine Fever (CSF) Virus. *European Journal of Medicine*, 9 (3): pp. 124-138.

Gluhchev et al., 2015d – *Gluhchev, G., Ignatov, I., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O.V.* (2015). Electrochemically Activated Water. Biophysical and Biological Effects of Anolyte and Catholyte as Types of Water. *Journal of Medicine, Physiology and Biophysics*, Vol. 10: pp. 1-17.

Gluhchev et al., 2015e – *Gluhchev, G., Ignatov, I., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O. V.* (2015). Studying of Virucidal and Biocidal Effects of Electrochemically Activated Anolyte and Catholyte Types of Water on Classical Swine Fever Virus (CSF) and Bacterium E. coli DH5. *Journal of Medicine, Physiology and Biophysics*, Vol. 13: pp. 1-17.

Hanaoka, 2001 – *Hanaoka, K.* (2001). Antioxidant Effects of Reduced Water Produced by Electrolysis of Sodium Chloride solutions. *Journal of Applied Electrochemistry*, Vol. 31: pp. 1307–1313.

Hayashi, Kawamura, 2002 – *Hayashi, H., Kawamura, M.* (2002). Clinical Application of Electrolyzed-reduced Water. In S. Shirahata et al. (Eds). *Animal cell technology: Basic and applied aspects,* Vol. 12: pp. 31-36.

Ignatov et al., 2015 – *Ignatov, I., Mosin, O.V., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, N.* (2015). The Evaluation of Mathematical Model of Interaction of Electrochemically Activated Water Solutions (Anolyte and Catholyte) with Water. *European Reviews of Chemical Research*, Vol. 2 (4): pp. 72-86.

Ignatov, 2005 – *Ignatov, I.* (2005). Energy Biomedicine. *Gea-Libris, Sofia*, pp. 1–88.

Ignatov, 2010 – Ignatov, I. (2010). Which Water is Optimal for the Origin (Generation) of Life? *Euromedica*, Hanover: 34-35.

Ignatov, 2011 – *Ignatov, I.* (2011). Entropy and Time in Living Matter. *Euromedica:* 74 p.

Ignatov, 2012 – *Ignatov, I.* (2012). Origin of Life and Living Matter in Hot Mineral Water, Conference on the Physics, Chemistry and Biology of Water. *Vermont Photonics*, USA.

Ignatov, Mosin, 2013 – *Ignatov I., Mosin O.V.* (2013). Possible Processes for Origin of Life and Living Matter with Modeling of Physiological Processes of Bacterium *Bacillus Subtilis* in Heavy Water as Model System. *Journal of Natural Sciences Research*, Vol. 3 (9): pp. 65-76.

Ignatov, Mosin, 2013 – *Ignatov, I., Mosin, O. V.* (2013). Modeling of Possible Processes for Origin of Life and Living Matter in Hot Mineral and Seawater with Deuterium. *Journal of Environment and Earth Science*, Vol. 3(14): pp. 103-118.

Ignatov, Mosin, 2013 – *Ignatov, I., Mosin, O. V.* (2013). Structural Mathematical Models Describing Water Clusters. *Journal of Mathematical Theory and Modeling*, Vol.3 (11): pp. 72-87.

Ignatov, Mosin, 2014a – *Ignatov, I., Mosin, O. V.* (2014). Nature of Haydrogen Bonds in Liquids and Crystals. Ice Crystal Modifications and Their Physical Characteristics. *Journal of Medicine, Physiology and Biophysics*, Vol. 4: pp. 58-80.

Ignatov, Mosin, 2014b – *Ignatov, I., Mosin, O. V.* (2014). The Structure and Composition of Carbonaceous Fullerene Containing Mineral Shungite and Microporous Crystalline Aluminosilicate Mineral Zeolite. Mathematical Model of Interaction of Shungite and Zeolite with Water Molecules. *Advances in Physics Theories and Applications*, Vol.28: pp. 10-21.

Ignatov, Mosin, 2014c – *Ignatov, I., Mosin, O.V.* (2014). The Structure and Composition of Shungite and Zeolite. Mathematical Model of Distribution of Hydrogen Bonds of Water Molecules in Solution of Shungite and Zeolite. *Journal of Medicine, Physiology and Biophysics*, Vol. 2: pp. 20-36.

Ignatov, Mosin, 2014d – *Ignatov, I., Mosin, O.V.* (2014). Mathematical Models of Distribution of Water Molecules Regarding Energies of Hydrogen Bonds, *Journal of Medicine, Physiology and Biophysics*, Vol. 2: pp. 71-94.

Ignatov, Mosin, 2014e – *Ignatov, I., Mosin,O.V.* (2014). Mathematical Model of Interaction of Carbonaceous Fullerene Containing Mineral Shungite and Aluminosilicate Mineral Zeolite with Water. *Journal of Medicine, Physiology and Biophysics*, Vol. 3: pp. 15-29.

Ignatov et al., 2014 – *Ignatov, I., Mosin, O. V., Bauer, E.* (2014). Carbonaceous Fullerene Mineral Shungite and Aluminosilicate Mineral Zeolite. Mathematical Model ans Practical Application of Water Solution of Water Shungite and Zeolite. *Journal of Medicine, Physiology and Biophysics*, Vol. 4: pp. 27-44.

Ignatov, Mosin, 2016a – *Ignatov, I., Mosin, O.V.* (2016). Water for Origin of Life. *Altaspera Publishing & Literary Agency Inc.* pp. 1-616. [in Russian]

Ignatov, Mosin, 2016b – Ignatov, I., Mosin, O.V. (2016). Deuterium, Heavy Water and Origin of Life. *LAP LAMBERT Academic Publishing*, pp. 1-500.

Ignatov et al., 2016 – *Ignatov, I. et al.* (2016). Results of Biophysical and Nano Technological Research of ZEOLITH Detox of LavaVitae Company. *Journal of Health, Medicine and Nursing*, Vol. 30, pp. 44-49.

Ignatov, 2006 – *Ignatov, I.* (2016). Product of LavaVitae BOOST is Increasing of Energy of Hydrogen Bonds among Water Molecules in Human Body. *Journal of Medicine, Physiology and Biophysics*, Vol. 27., pp. 30-42.

Ignatov, 2016 – *Ignatov, I.* (2016). VITA intense – Proofs for Anti-inflammatory, Antioxidant and Inhibition Growth of Tumor Cells Effects. Relaxing Effect of Nervous System. Anti Aging Influence. *Journal of Medicine, Physiology and Biophysics*, Vol. 27, pp. 43-61.

Ignatov et al., 2014 – *Ignatov, I., Karadzhov, S., Atanasov, A., Ivanova, E., Mosin, O. V.* (2014). Electrochemical Aqueous Sodium Chloride Solution (Anolyte and Catholyte) as Types of Water. Mathematical Models. Study of Effects of Anolyte on the Virus of Classical Swine Fever Virus. *Journal of Health, Medicine and Nursing*, Vol. 8: pp. 1-28.

Ignatov et al., 2015a – *Ignatov, I., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O.V.* (2015). Preparation of Electrochemically Activated Water Solutions (Catholyte/Anolyte) and Studying Their Physical-Chemical Properties. *Journal of Medicine, Physiology and Biophysics*, Vol. 11: pp. 1-21.

Ignatov et al., 2015b – *Ignatov, I., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O. V.* (2015). Preparation of Electrochemically Activated Water Solutions (Catholyte/Anolyte) and Studying of their Physical-Chemical Properties. *Journal of Medicine, Physiology and Biophysics*, Vol. 13, pp. 18-38.

Ignatov et al., 2015c – *Ignatov, I., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, I., Mosin, O. V.* (2015). Preparation of Electrochemically Activated Water Solutions (Catholyte/Anolyte) and Studying of their Physical-Chemical Properties. *Journal of Health, Medicine and Nursing*, Vol. 13: pp. 64-78.

Ignatov et al., 2015d – *Ignatov, I., Mosin, O. V., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, I.* (2015). Studying Electrochemically Activated NaCl Solutions of Anolyte and Catholyte by Methods of Non-Equilibrium Energy Spectrum (NES) and Differential Non-Equilibrium Energy Spectrum (DNES). *Journal of Medicine, Physiology and Biophysics*, Vol. 14: pp. 6-18.

Ignatov et al., 2015e – Ignatov, I, Gluhchev, G., Karadzhov, S., Ivanov, N., Mosin, O.V. (2015). Preparation of Electrochemically Activated Water Solutions (Catholyte/Anolyte) and Studying Their Physical-Chemical Properties. *Journal of Medicine, Physiology and Biophysics*, Vol. 16: pp. 1-14.

Ignatov et al., 2016 – *Ignatov, I., Mosin, O.V., Gluhchev, G., Karadzhov, S., Miloshev, G., Ivanov, I.* (2016). Studying Electrochemically Activated NaCl Solutions of Anolyte and Catholyte by Methods of Non-Equilibrium Energy Spectrum (NES) and Differential Non-Equilibrium Energy Spectrum (DNES). *Journal of Medicine, Physiology and Biophysics*, Vol. 20: pp. 13-23.

Ignatov, 2017 – *Ignatov, I.* (2017). Aluminosilicate Mineral Zeolite. Interaction of Water Molecules in Zeolite Table and Mountain Water Sevtopolis from Bulgaria. *Journal of Medicine, Physiology and Biophysics*, Vol. 31, pp. 41-45.

Ignatov, Mosin, 2015 – *Ignatov, I., Mosin O.V.* (2015). Origin of Life and Living Matter in Hot Mineral Water. *Advances in Physics Theories and Applications*, Vol. 39: 1-22.

Ignatov, 2017 – *Ignatov, I.* (2017). VITA intense and Boost – Products with Natural Vitamins and Minerals for Health. *Journal of Medicine, Physiology and Biophysics*, Vol. 31, pp. 58-78.

Ignatov, 2017 – *Ignatov, I.* (2017). ZEOLITH detox for Detoxification and ZELOLITH Creme for Skin Effects as Products of LavaVitaae Company. *Journal of Medicine, Physiology and Biophysics,* Vol. 31, pp. 79-86.

Ignatov, Mosin, 2014a – *Ignatov, I., Mosin, O.V.* (2014). Methods for Measurements of Water Spectrum. Differential Non-equilibrium Energy Spectrum Method (DNES). *Journal of Health, Medicine and Nursing,* Vol. 6, pp. 50-72.

Ignatov, Mosin, 2014b – *Ignatov, I., Mosin, O.V.* (2014). Mathematical Models of Distribution of Water Molecules Regarding Energies of Hydrogen Bonds. *Journal of Medicine,*

Physiology and Biophysics, Vol. 6, pp. 50-72.

Ignatov, Mosin, 2014c – *Ignatov, I., Mosin, O.V.* (2014). Structural Models of Water and Ice Regarding the Energy of Hydrogen Bonding. *Nanotechnology Research and Practice*, Vol. 7 (3): pp. 96-117.

Ignatov, Mosin, 2014d – *Ignatov, I., Mosin, O.V.* (2014). Nano Mix of Shungite and Zeolite for Cleaning of Toxins and Increasing of Energy of Hydrogen Bonds among Water Molecules in Human Body. *Journal of Medicine, Physiology and Biophysics,* Vol. 27, pp. 1-10.

Luck et al., 1980 – *Luck, W., Schiöberg, D., Ulrich, S.* (1980). Infared Investigation of Water Structure in Desalination Membranes. *J. Chem. Soc. Faraday Trans.*, Vol. 2(76), pp. 136–147.

Kirkpatrick, 2009 – *Kirkpatrick, R. D.* (2009). The Mechanism of Antimicrobial Action of Electro-chemically Activated (ECA) Water and its Healthcare Applications", *Doctoral Thesis, University of Pretoria.*

Kloss, 1988 – *Kloss, A.I.* (1988). Electron-radical Dissociation and Mechanism of Water Activation. *Trans. Acad. Sc. USSR,* Vol. 303: pp. 1403-1406. [in Russian]

Kokichi et al., 2004 – *Kokichi H., Dongxu S., R., Lawrence, Y. Kamitani, Fernandes G.* (2004). The Mechanism of the Enhanced Antioxidant Effects Against Superoxide Anion Radicals of Reduced Water Produced by Electrolysis. *Biophisical Chemistry,* Vol. 107: pp. 71-82.

Komatsu et al., 2001 – *Komatsu, T., Kabayama, S., Hayashida, A et al.* (2001). Suppressive Effect of Electrolyzed Reduced Water on the Growth of Cancer Cells and Microorganisms. *In E. Lindner-Olsson, N.* Chatzissavidou, L. Elke (Eds). Animal cell technology: From target to market. Dordrecht://*Kluwer Academic Publishers*. pp. 220-223

Kumar et al., 1999 – *Kumar, S. V., Ezeike, G. O., Hung, Y-C., Doyle, M. P.* (1999). Efficacy of Electrolyzed Oxidizing Water for Inactivating Escherhia coli O157:H7, Salmonela enteritidis, and Lusteria monocytogenes. *Applied and Evironmental Microbiology*: 4276-4279.

Lee et al., 2004 – Kyu-Jae Lee, Seung-Kyu, Jae-Won, Gwang-Young et al. (2004). Anticancer Effect of Alkaline Water, Korea.

Lee et al., 2006 – *Lee, M-Y., Kim.-K., Ryoo, K.-K et al.* (2006). Electrolyzed-reduced water protects against oxidative damage to DNA, RNA and protein. *Applied Biochemistry and Biotechnology* Vol. 135, pp. 133-144.

Miroshnikov, 2002 – *Miroshnikov, A.I.* (2002). Stimulation and Inhibition of Escherichia coli Cell Growth During Cultivation in the Catholyte and Anolyte of Culture Medium. **Biofizika.** Mar-Apr; Vol. 47(2):pp.304-308. [in Russian]

Mehandjiev et al., 2017 – *Mehandjiev, D., Ignatov, I., Karadzhov, I., Gluhchev, G., Atanasov, A.* (2017). On the Mechanism of Water Electrolysis. *Journal of Medicine, Physiology and Biophysics,* Vol. 31, pp. 23-26.

Mosin, Ignatov, 2013 – *Mosin, O.V., Ignatov, I.* (2013). The Structure and Composition of Natural Carbonaceous Fullerene Containing Mineral Shungite. *International Journal of Advanced Scientific and Technical Research*, Vol. 6(11–12), pp. 9–21.

Mosin, Ignatov, 2012a – *Mosin, O.V., Ignatov, I.* (2012). The Composition and Structural Properties of Fullerene Natural Mineral Shungite. *Nanoengineering*, Vol. 18 (12), pp. 17–24 [in Russian]

Mosin, Ignatov, 2012b – *Mosin, O.V., Ignatov, I.* (2012). Composition and Structural Properties of Fullerene Natural Mineral Shungite. *Nanomaterials and Nanotechnologies,* 2: pp. 25-36.

Mosin, Ignatov, 2015 – *Mosin, O.V., Ignatov, I.* (2015). An Overview of Methods and Approaches for Magnetic Treatment of Water. *Water: Hygiene and Ecology*, Vol. 3-4 (4): pp. 113-130.

Panayotova, Velikov, 2002 – *Panayotova, M., Velikov, B.* (2002). Kinetics of heavy metal ions removal by use of natural zeolite. *Journal of Environmental Science and Health*, *Vol.* 37(2): pp. 139–147.

Parfen'eva, 1994 – *Parfen'eva, L.S.* (1994). Electrical Conductivity of Shungite Carbon. *Solid State Physics*, *Vol.* 36(1), pp. 234–236.

Podchaynov, 2007 – *Podchaynov, S.F.* (2007). Mineral zeolite – a multiplier of useful properties shungite. Shungites and human safety. *Proceedings of the First All-Russian scientific-practical conference* (3–5 October 2006), ed. J.K Kalinin (Petrozavodsk: Karelian Research Centre of Russian Academy of Sciences), pp/ 6–74 [in Russian]

Petrushenko, Lobyshev, 2004 – *Petrushenko I., Lobyshev V.I.* (2004). Physico-chemical

Properties of Aqueous Solutions, Prepared in a Membrane Electrilyzer. *Biofizika, Vol.*49(1): pp. 22-31.

Prilutsky, Bakhir, 1997 – *Prilutsky, V. I., Bakhir V. M.* (1997). Electrochemically Activated Water: Anomalous Properties, Mechanism of Biological Action. *All Russian Scientific Research and Experimental Institude of Medical Engineering* (VNIIIMT), 1: 124. [in Russian]

Shirahata et al., 2012 – *Sanetaka Shirahata, Takeki Hamasaki, Kiishiro Teruya* (2012). Advanced Research on the Health Benefit of Reduced Water. *Trends in Food Science & Technology Vol.* 23: pp. 124-131.

Suzuki et al., 2002 – *Suzuki, T., Itakura, J., Watanabe, M., Ohta, M., Sato, Y., Yamata, Y.* (2002). Inactivation of Staphylococcal Enterotoxin-A with an Electrolyzed Anodic Solution. *Journal of Agricultural and Food Chemistry,* Vol. 50: pp. 230-234.

Tanaka et al., 1996 – *Tanaka, H., Hirakata, Y., Kaku, M., Yoshida, R., Takemura, H,. Mizukane, R.* (1996). Antimicrobial Activity of Superoxidized Water. *Journal of Hospital Infection,* Vol. 34(1): pp. 43-49.

Yahagi et al., 2000 – *Yahagi N., Kono M., Kitahara M., Ohmura A., Sumita O., Hashimoto T.* (2000). Effect of Electrolyzed Water on Wound Healing. *Artificial Organs,* Vol. 24(12): pp. 984-987.

Ye et al., 2008 – *Ye, J., Li, Y., Hamasaki, T., N., Komatsu, E. et al.* (2008). Inhibitory Effect of Electrolyzed Reduced Water on Tumor Angiogenesis. *Biological and Pharmaceutical Bulletin,* Vol. 31: pp. 19-26.

Ye et al., 2004 – *Ye, Jun, K. Teruya, Y. Katakura et al.* (2004). Suppression of Invasion of Cancer Cells and Angiogenesis by Electrolyzed Reduced Water. *World Congress on in Vitro Biology*.

Zenin, 1999 – *Zenin, S. V.* (1999). On the Mechanism of Water Activation, Second Int. Symposium. *Electrochemical Activation in Medicine, Agriculture and Industry*, pp. 155-156 [in Russian]

Zinkevich et al., 2000 – *Zinkevich, V., Beech, I.B., Tapper, R.C., Bogdarina, I.* (2000). The Effect of Super-oxidized Water on Escherichia Coli. *Journal of Hospital Infection*. Vol. 46(2): pp. 153-156.