Electrochemically Activated Water – Anolyte. Nascent Oxygen

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Authors’ contributions

This work was carried out in collaboration among all authors. Author GG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DM and PV managed the analyses of the study. Author II managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Chemical processes that could occur in the anode chamber of an electrolytic cell divided by a semi-permeable membrane when direct current passes through a water solution of weak mineralization are described. The interest concerns the possibility of a formation of chemical substances with strong oxidative action as \( \text{O}_2 \) and \( \text{H}_2\text{O}_2 \), due to nascent oxygen. These substances can destroy the structure of pathogenic bacteria and viruses. The preservation of these properties for a long period of time without specific storage requirements makes the anolyte cheap and effective disinfection and therapeutic means.

Keywords: Electrochemical Activation (ECA); catholyte; anolyte; nascent hydrogen; nascent oxygen.
1. INTRODUCTION

Interest in the unusual properties and bio effects of electrochemically activated water has been steadily increasing since the middle of the last century when the first investigations have been carried out. It was observed that the anolyte and catholyte fractions obtained as a result of the application of direct current to water solution of weak mineralization, divided by a semipermeable membrane, possessed specific properties that could not be obtained under another physicochemical action [1,2,3,4]. The water solution around the cathode (catholyte) is characterized with values of pH higher than 8.5 and negative oxidation reduction potential (ORP), while the solution in the anode chamber (anolyte) has pH smaller than 3.5 and positive ORP in mV. These differences determine their different actions on living things. A number of investigations carried out by scientists all over the world have demonstrated strong biocide action of the anolyte, and suppression of different bacterial and viral development [2,5,6,7,8]. This characterizes the anolyte as an effective disinfection and therapeutic means.

Catholyte on its part possess stimulating tissue development properties that allow fast wound healing [4,9,10], prevention of DNA, RNA and proteins from oxidative damage [11] and tumor development suppression [12,13,14].

The change in the physicochemical composition of catholyte and anolyte related to the above-mentioned effects and obtained as a result of the changes in hydrogen bonds energy, structure of the water clusters, water molecules, and formation of new active substances, is a question of major importance [1,4,15].

There are effects of Catholyte and Anolyte against Virus of Classical Swine Fever Virus [16], Bacterium E. coli DH5 [17], Staphylococcus aereus, Erscherithia coli [18,19,20], Candida albicans, Psuedomonas aeruginosa [21,22] and SARS-CoV-2 [23]. There were effects on the dissection of plants [24]. There are anti-cancer effects of Catholyte [25]. The parameters of the effect of different water according to the local extremums in the water spectrum were described [26].

It is supposed that the formation of nascent hydrogen is responsible for the catholyte changes. The authors in [27] prove theoretically and experimentally verify its present and stabilization for a given time using potassium permanganate.

However, some questions about the anolyte have not yet been strictly explained. For example, what are the active components that determine its strong oxidation and biocide action and make it an effective means of disinfection?

Thus, the goal of the current investigation is to analyze the mechanism of the reactions taking place at the anode during electrochemical activation, and to elucidate the most significant component that determines the strong oxidation and antitoxic ability of the anolyte.

2. METHODS AND MATERIALS

The electrochemical treatment of water occurs in the electrolysis’ cell, consisting of a glass jar and two platinum electrodes cathode and anode separated by a special semipermeable membrane (diaphragm). Ecologically clean white clay is used as a membrane. To avoid the influence of external ions, deionized water is used. Direct current of 90 V is applied to the electrodes for 6 min. When the electric current passes through the water, the flow of electrons from the cathode as well as the removal of electrons from water molecules at the anode is accompanied by a series of reduction-oxidation reactions. As a result, the water is divided into an alkaline fraction (catholyte) and an acidic fraction (anolyte) possessing quite different physicochemical parameters. While catholyte pH and ORP values can remain unchanged or change slightly for twenty-four h, in the anolyte they remain stable for more than half a year.

3. RESULTS

Detailed analysis of the processes at the cathode [27] proved that nascent hydrogen H* obtained according to reaction (1) was the basic active antioxidant component in the catholyte.

\[
H^* + e \rightarrow H^* \quad (1)
\]

H* is stabilized and determines catholyte properties for a couple of days.

Similar reactions can take place at the anode. Their mechanism follows the next scheme.

First stage \( \text{OH}^- \rightarrow \text{O}^* + 2e + \text{H}^* \quad (2) \)

Second stage \( \text{O}^* + \text{O}^* \rightarrow \text{O}_2 \quad (3) \)
The first stage can be presented in two consecutive steps, as follows.

First step \( \text{OH}^- \rightarrow \text{OH}^* + e \) \quad (4)

Second step \( \text{OH}^* \rightarrow \text{O}^* + e + \text{H}^* \) \quad (5)

However, it is possible a new highly active component to be obtained according to the formula.

\[ 2 \text{OH}^* \rightarrow \text{H}_2\text{O}_2 \text{O} \] \quad (6)

i.e. hydrogen peroxyde, which is responsible for the strong oxidative ability of the anolyte.

4. DISCUSSION

The above examinations show that processes of highly active component formation take place during the ECA of water. They determine its specific properties and the possibility for different applications. It has to be noted that these processes are possible when a direct current is applied to water, but the separation of the active substances is only possible when a specific equipment and semipermeable membrane are used [1,2,3,4,15]. As a result, the hydrogen ions form nascent hydrogen at the cathode according to (1), which stabilizes by itself and gives specific antioxidant properties of the catholyte.

At the anode reactions (4) and (5) are possible, as it was demonstrated. Also, it is possible that reaction (6) flows before reaction (5), where nascent oxygen is produced, generating in such a way the well-known strong oxidizer oxygen peroxyde, which remains stable for a long time.

Due reactions (3) and (6) the anolyte obtains the property of strong oxidizing solution and can be used as an effective disinfectant without adding of other elements and compositions. This assertion is in accordance with the investigations proving that the anolyte preserves its properties for a few months if put in a firmly closed container. Anolyte has effects against viruses, which are speeding by water [28].

Finally, the catholyte can be used for drinking and wound healing. In the anolyte nascent oxygen and hydrogen peroxyde are present and stabilized, which make it an antibacterial and antiviral substance. It is most likely that the formation of these new substances provokes changes in the physicochemical characteristics of the ECA water.

5. CONCLUSION

The above considerations of the electrochemical processes at the anode and anolyte formation show that, by analogy to the catholyte, nascent OH* is formed, which is stabilized and determines strong oxidative activity. This nascent OH* can interact and create new components of highly oxidative activity, as well. Because of this, the anolyte obtains strong oxidative potential and highly expressed biocide effect, conformed in many investigations. It’s very stable composition, strong antimicrobial and antiviral action, and harmlessness make it a perfect disinfection and tool.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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