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STUDY OF CHANGES IN WATER INDICATORS DURING PROCESSING ON A TWO-CHAMBER MEMBRANE ELECTROLYSER

The modern science of nutrition hygiene increasingly pays attention to the quality of drinking and process water for the food industry, since water is an important component of food products and makes up a significant portion of their mass. Currently, Ukraine is faced with anthropogenic destruction of the hydrosphere, which worsens the quality of natural sources of water supply and makes it difficult to maintain adequate drinking water and water, which is an important component of the food industry. Traditional methods of water treatment do not ensure the safety of drinking water supply and do not meet the new requirements for maintaining the biological value of water. Sorption and baromembrane treatment methods, such as ion exchange softening and reverse osmosis, are widely used for the purposeful preparation of water before its use. However, recent studies show that contact with the surface of ion-exchange materials causes secondary contamination of water with organic products of ion-exchange resin degradation. One of the promising directions of research is the creation of fundamentally new possibilities for changing the physico-chemical and medical-biological properties of water without changing its chemical composition, with the help of various physical reagentless factors. This can be achieved by electrolysis of water in a diaphragm electrolyzer with separation of the products of electrochemical reactions in the cathode (catholyte) and anode (anolyte) zones. As a result of such electrochemical treatment, water acquires abnormal physicochemical and biological properties, its chemical and biochemical activity increases. The water that was subjected to such treatment was called electrochemically activated water (ECAW) and represents a new class of substances that requires further research.

1. Electrochemical activation of drinking water

Water is extremely sensitive to external physical influences, which it perceives and stores in the form of structural-energy and informational factors. These factors can be transferred to systems designed by nature for their perception and applied in various fields, in particular in food technology.

A number of researchers[1] have proven the effectiveness and prospects of electrochemical treatment of water to improve the quality of products based on it, in particular for the production of beer, milk, whey, dough kneading, modification of brines, etc.

To obtain water with reductive electron-donating properties, the electrochemical method is widely used, with the separation of the cathode and anode zones by an electrically conductive membrane, which prevents the mixing of electrolysis products. Catholyte contains a weakly alkaline solution with reducing electron-donating properties that provide an excellent electron-donating antioxidant effect. However, electrochemical water ionizers are not widely available and have some medical limitations. The mechanism of their action is associated with the processes: the probable dissociation of water molecules in the gradient of the electrostatic field of the electric double layer of the cathode, or with the enrichment of water with hydrogen, which is electrochemically generated at the cathode. We experimentally confirmed the hypothesis that connects the catholyte's acquisition of a reduced state with the manifestation of the electron-donating

1 Filhol, J. S., & Neurock, M. (2006). Elucidation of the electrochemical activation of water over Pd by first principles. *Angewandte Chemie*, *118*(3), 416-420. URL: https://doi.org/10.1002/ange.200502540; Shang, X., Dong, B., Chai, Y. M., & Liu, C. G. (2018). In-situ electrochemical activation designed hybrid electrocatalysts for water electrolysis. Science Bulletin, 63(13), 853-876. URL:https://doi.org/10.1016/j.scib.2018.05.014; Svyatnenko, R., Marynin, A., Kochubej-Litvinenko, O., & Zakharevych, V. (2016). ВПЛИВ ІМПУЛЬСНОГО ЕЛЕКТРОМАГНІТНОГО ПОЛЯ НА ЖИТТЄЗДАТНІСТЬ ESCHERICHIA COLI В МОДЕЛЬНОМУ РОЗЧИНІ МОЛОЧНОЇ СИРОВАТКИ. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies, 18(2), 92-94. URL:https://doi.org/10.15421/nvlvet6818; Kozodaev, A., Andrushko, A., & Firsova, A. (2019, March). Research of reagent-free waste water treatment methods of the chrome plating line for mineralizing the rod of hydraulic cylinders. In IOP Conference Series: Materials Science and Engineering (Vol. 492, No. 1, p. 012021). IOP Publishing. URL:https://doi.org /10.1088/1757-899X/492/1/012021; Alkhadra, M. A., Su, X., Suss, M. E., Tian, H., Guyes, E. N., Shocron, A. N., ... & Bazant, M. Z. (2022). Electrochemical methods for water purification, ion separations, and energy conversion. Chemical reviews, 122(16), 13547-13635. URL: https://doi.org/10.1021/acs.chemrev.1c00396.

properties of chlorine anions under the action of the energizing electropolarizing effect of the gradient of the electrostatic field strength on the chlorine anion in the zone of the electric double layer of the cathode. This contributes to the separation of an electron from an anion of chlorine and its transition to a hydrated free state in water, which enriches water with electrons without competitive enrichment with protons, as occurs in the electrolysis of water[2].

Water is extremely sensitive to external physical influences, which it perceives and stores in the form of structural-energy and informational factors. These factors can be transferred to systems intended by nature for their perception and applied in various fields, in particular in food technology.

One of the most well-founded methods of water treatment is the use of an electrochemical two-chamber membrane electrolyzer (Fig. 1), which can provide the necessary level of purification and saturation of water with oxygen.

Various microorganisms, toxic organic compounds, and heavy metal ions that exceed sanitary standards can be removed in the process of water purification with the help of an electroactivator. At the same time, calcium ions, magnesium, potassium, sodium and trace elements, which are important for ensuring normal vital activity, are stored.

This treatment of water can accelerate the elimination of metabolic waste and ensure a more complete absorption of nutrients.

2. Physico-chemical foundations of the process of electrolysis of aqueous solutions in an electrochemical two-chamber membrane electrolyzer.

Electrochemical activation technology is one of the most accessible methods of converting water into a metastable excited state using a unipolar electrochemical effect. The main processes that take place in an electrolyzer can be simplified and described as follows[3]:

1) oxidation of water at the anode:

$$2H_2O - 4e^- \rightarrow 4H^+ + O_2 \tag{1}$$

2) recovery of water at the cathode:

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \tag{2}$$

2 Jirotková, D., & EidelpesovÃ, L. (2012). Use of electrolyzed water in animal production. *Journal of microbiology, biotechnology and food sciences*, *2*(2), 477–483. URL:doi:https://www.jmbfs.org/jirotkova_jmbfs_rf/?issue_id=1498&article_id=6; Ma, Q., Li, B., Wang, C., Ji, Y., Wang, S., & Cao, W. (2009). Efficiency of electrolyzed oxidizing water for inactivation of salmonella spp. and inoculated shell eggs. International journal of food engineering, 5(3). URL:https://doi.org/10.2202/1556-3758.1651.

3 Danylkovych, A. G., Lishchuk, V. I., & Romaniuk, O. O. (2016). Use of electrochemically activated aqueous solutions in the manufacture of fur materials. *SpringerPlus*, *5*, 1–11. URL:10.1186/s40064-016-1784-6; Українець, А. І., Большак, Ю. В., Святненко, Р. С., & Прохоренко, Ж. І. (2018). Застосування фізично зміненої (активованої) води для підвищення ефективності технологій харчового виробництва та поліпшення якості продукції. Наукові праці Національного університету харчових технологій, (24,№ 5), 218–224. 10.24263/2225-2924-2018-24-5-27

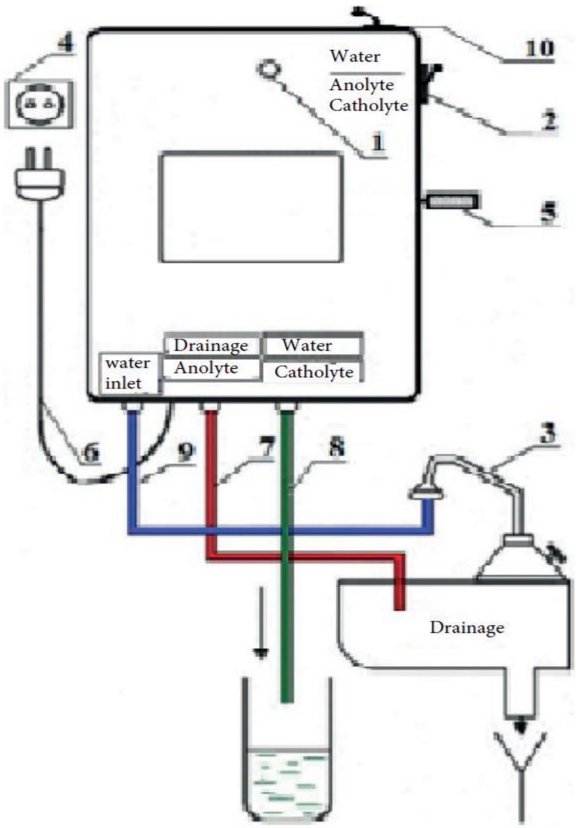

Fig. 1. – Electrochemical two-chamber membrane electrolyzer
1 – a signal about the presence of water flow through the electrochemical cleaning system.
2 – switch «Purified water» / «Activated water» catholyte – anolyte, which serves to select the necessary sub-mode of operation of the installation,
10 – switch for selecting the operation mode of the installation hard/soft water,
5 – faucet «Catholyte». In the lower part of the installation there are:
6 – an electrical cord for connecting the device to the electrical network,
7 – «Anolyte» outlet hose and drainage, 8 – hose for the outlet of purified water and «Catholyte», 9 – hose with nozzle, necessary for connecting the unit to the tap. Devices necessary for the operation of the installation:
3 – faucet for supplying water to the installation, 4 – electrical rosette.

2) formation of gaseous chlorine at the anode in solutions of hydrochloric acid salts: $2Cl^- - 2e^- \rightarrow Cl_2$ (3)

3) formation of highly active oxidants in the anode chamber:

$$Cl_2O, ClO_2, ClO^-, HClO, Cl^{\cdot}, O_2^-, O_3, HO_2, OH^- \quad (4)$$

4) formation of highly active reducing agents in the cathode chamber:

$$OH^-, H_3^-O_2^-, H_2, HO_2^-, HO_2^-, O_2^- \quad (5)$$

In an aqueous environment, the presence of a sufficient amount of strong oxidants and free radicals in the anolyte turns it into a solution with pronounced biocidal properties. Catholyte, saturated with reductants, exhibits high chemical activity in adsorption processes and has strong cleaning properties. Samples of aqueous environments of anolyte and catholyte with different levels of mineralization are characterized by sharp changes in pH and oxidation-reduction potential (ORP) relative to the initial values: in the anolyte, pH is reduced, ORP is increased toward positive (oxidizing) values, in the catholyte, pH is increased, and ORP is decreased toward negative (reducing) values.

3. Dependence of the change in ORP of anolyte and catholyte on time after treatment on an electrochemical two-chamber membrane electrolyzer.

Artesian water was used for this experiment. The water was treated on a laboratory diaphragm electrolyser to obtain two water samples with different ORP parameters: catholyte and anolyte. To study the parameters of the ORP, water was processed at different speeds and duration of water contact with the selective membrane in the contact chamber. This was achieved due to the availability of a modular complex water treatment laboratory, which was created in the Problem Research Laboratory of the National University of Food Technologies and contained an electrochemical diaphragm electrolyzer module. Ezodo PCT-407 ORP meter and I-160M pH meter were used to measure changes in water parameters. The research was conducted at a temperature of t=19±1 oC, and the parameters of the treated water were determined by taking a water sample after 3 minutes of operation of the electrolyzer at different water flow rates (ml/min: 200, 300, 350, 500, 600, 700, 750, 800, 900, 1000).

The results of measurements of water ORP (catholyte, anolyte.) processed on a diaphragm electrolyzer are presented in Table. 1 and Fig. 1.

Table 1

Dependence of the ORP change of anolyte and catholyte on time after processing on the diaphragm electrolyzer «Izumrud»

№	ORP, mV		Time, min
	Catholyte	Anolyte	
1	2	3	4
1	0	+384	0,5
2	-49	+420	1
3	-100	+448	1,5
4	-178	+518	2,0
5	-190	+535	2,5
6	-230	+612	3
7	-229	+626	4
8	-420	+638	5

Continuation of table 1

1	2	3	4
9	-418	+651	6
10	-598	+657	7
11	-603	+650	8
12	-754	+623	9
13	-690	+451	10

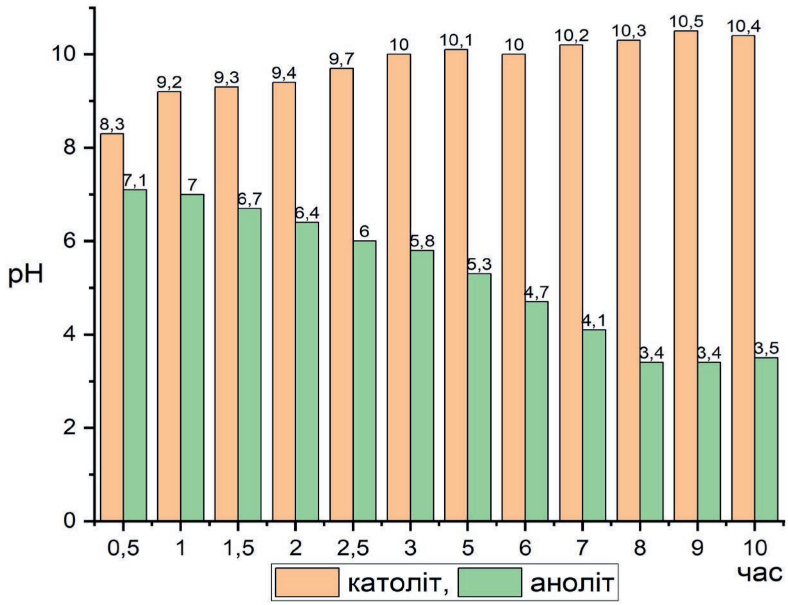

Fig. 2. – Dependence of the pH change of the anolyte and catholyte on the treatment time

The obtained dependencies reflect the process of formation of electrochemically activated water with oxidizing and reducing properties. The change in catholyte and anolyte parameters is expected from the point of view of theoretical ideas about the mechanisms of formation of activated aqueous solutions. Values of critical parameters are reached at certain values of ORP and pH. For catholyte, ORP = -690 mV at pH = 10.4, and for anolyte, ORP = +451 mV at pH = 3.5. It should be noted that the parameters of water that characterize its acid-alkaline and redox balance are interdependent: a change in water pH by one unit is accompanied by a change in ORP by about 60 mV. A change in pH to the acidic side increases the ORP value, and to the alkaline side – decreases it.

The dependence of the ORP of the treated water on the rate of water consumption in the electrolyzer was also investigated, Table 2.

Table 2

Dependence of ORP of treated water on the speed of water in the electrolyzer

№	V (H_2O), mg/min	ORP, mV
1	200	-160
2	300	-130
3	350	-135
4	500	-135
5	600	-110
6	700	-100
7	750	-80
8	800	-60
9	900	-50
10	1000	-55

The analysis of the results showed that an increase in the working flow of water in the electrolyzer leads to a decrease in the rate at which water acquires a reducing electron-donating state (a proportional decrease in ORP from -160 mV to -55 mV). This indicates the need for purposeful regulation of the speed of water in the electrolyzer depending on the task: the higher the level of the catholyte, the lower the speed of water treatment in the electrolyzer should be, and vice versa.

Quantitative laws governing the formation of products of electrochemical reactions on the cathode and anode of the electrolyzer in the reaction space have been established. It was found that the rate of mass transfer of incoming water in the reaction zone affects the level of activation of the solutions and the redox state of the products. Theoretical ideas about the kinetic features of the electrochemical activation of water have been experimentally confirmed, which can improve the quality of water treatment and the effectiveness of further research and their practical use. The obtained results indicate the expediency of continuing work in this direction, especially in the study of dilute solutions of hydrochloric acid salts, taking into account previously obtained data on the electron-donating properties of energized chlorine anions.

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