

Optimization of the process of electrochemical wastewater treatment of yeast production

Anna Poshtarenko^{1,*}

¹National Aviation University, Department of Biotechnology, 1 Liubomyra Huzara ave., 03058, Kyiv, Ukraine

Abstract. The process of purification and disinfection of yeast production sewage under the action of electro dialysis has been studied. As a result of research to determine the physicochemical and microbiological sewage composition, it was found that in sewage of the 1st degree of yeast separation has the highest excess content of organic and mineral substances in terms of: Chemical oxygen consumption (COC) - 31096/500 mg O₂ / dm³, suspended solids - 6800 / 300 mg / dm³, chlorides - 2147/350 mg / dm³ and sulfates - 6089/400 mg / dm³. The content of organic substances, which is characterized by the Chemical oxygen consumption (COC) indicator, in sewage of general discharge, 2nd and 3rd degree of yeast separation is 41%, 50% and 74% and that is lower than in sewage of the 1st degree of yeast separation. The number of microorganisms in terms of Total microbial count (TMC) in sewage of the 1st stage of yeast separation is the largest and is 12·10⁷ colony-forming units CFU / cm³. It is determined that the process of sewage treatment and disinfection from minerals occurs more efficiently in the cathode zone, and from organic substances and microorganisms - in the anode zone of the electro dialyzer at a water temperature of 293 K, current of 0.1 A and duration of exposure 20 min.

1 Introduction

Water as the main or auxiliary raw material is used in the vast majority of food production technological processes. Almost all food production is associated with the consumption of tap water and groundwater aquifers [1].

The development of industrial production, in particular the food industry, increases the amount of waste that has a detrimental effect on the environment.

Food industry wastes are mainly disposed by technologies inherent in the utilization of solid household waste of the country housing and communal services.

Today, most municipal biological sewage treatment plants work extremely inefficiently, resulting in pollution of natural reservoirs, the processes of their flowering and overgrowth, etc. [2].

Industrial enterprises poison ponds with sewage, which contains a large amount of heavy metals, cyanides, etc. Domestic effluents and wastes of the food industry are

* corresponding author: strutinskaya@ukr.net

especially harmful due to the fact that the oxidation of these substances in water bodies takes a lot of oxygen [3].

Modern water purification technologies (membrane, sorption, catalytic, etc.) allow to purify water from any pollution. However, the application of these methods increases the cost of purified water and does not always unambiguous consequences of its use. One of the areas that allow more rational organization of purification processes is the implementation of synthesis modern concepts of chemical-technological systems (CTS). Typical sewage treatment schemes include pre-treatment by physical (settling, filtration, flotation), physicochemical (coagulation) and biological (mostly aerobic) methods. [4].

A typical method of treatment of such sewage is biological. However, very often the limited area and location of enterprises near the estates do not allow from both technical and sanitary points of view to arrange biological sewage treatment. [5].

Therefore, the search for alternative means of disposal and effective wastewater treatment is relevant for the entire processing industry. Important arguments to solve these problems are increasing the requirements for the environmental condition of enterprises and the need to pay for waste disposal in accordance with current legislation of Ukraine [6].

The yeast industry, as well as other enterprises of the food industry, is tasked with developing rational methods of process water preparation and reducing the amount of industrial effluents. One of the promising ways to treat natural waters and industrial effluents is the method of electrodialysis.

There are many reports in the literature [7, 8, 9, 10, 11, 12, 13] on similar experimental work on the treatment of natural and sewerage using electric current, but the influence of a number of factors on the process of electrolytic treatment has not been studied enough. Preparation of water for the nutrient medium in accordance with the requirements of yeast production technology and a number treatment of specific industrial effluents of yeast plants (industrial waters of baker's yeast separation shops) has not been studied at all by this method.

Traditional water treatment technologies based on coagulation and settling, as well as oxidation or ion exchange are ineffective in the conditions of modern anthropogenic loads and new more stringent requirements for drinking and industrial water quality. The use of membrane technologies in industry opens wide prospects for the possibility of creating fundamentally new energy-saving, environmentally friendly technological schemes. [14]

Analysis of the literature has shown that among the many known electrochemical methods of sewage treatment are electrolysis in a diaphragm-free electrolyzer of a solution containing sodium chloride, which is added to sewage to oxidize bacterial contaminants [15]. The disadvantage of this method is that for electrolysis uses a solution of sodium chloride with a concentration of at least 150 - 200 mg / dm³, from which is formed and used about 10 - 15% of sodium hypochlorite. Another amount of salt is introduced into the water in the form of ballast ions, thereby increasing the overall mineralization of the aqueous phase, which is unfavorable for the environment and increases the cost of disinfection.

There is a method of electrochemical treatment of water with disinfectants by direct electrolysis, which consists in its flow through a diaphragmless cell with insoluble anodes, in which under the action of a direct electric current on the anodes flows chlorine ions with the release of chlorine gases and oxygen dissolving in water [16]. The disadvantage of this method is the significant energy consumption of the oxidation process. This is due to the fact that during the electrochemical treatment of water at the cathode hydrogen gas is released, which is a reducing agent and neutralizes part of the gaseous chlorine and oxygen as bacterial contaminants oxidants. In addition, this method requires the presence in the water of a certain minimum concentration of chlorides, below which the process of electrochemical disinfection becomes inefficient.

There is a method of water purification, including the introduction of a coagulant containing aluminum hydroxide and treatment of water in a diaphragm-free cell using insoluble electrodes [17]. Electro-treatment of water with the use of insoluble electrodes, in which aluminum hydroxide is introduced as a coagulant, allows to improve its coagulating qualities, reduce the processing time and simplify the method of water purification. The disadvantage of this method is its low performance, as when using this method does not disinfect the water and requires further treatment with a disinfectant.

There is a method of electrochemical treatment of water with disinfectants by direct electrolysis, which consists in its flow through a diaphragmless cell with insoluble anodes, in which under the action of a direct electric current on the anodes flows chlorine ions with the release of chlorine gases and oxygen dissolving in water [18]. The disadvantage of this method is the significant energy consumption of the oxidation process. This is due to the fact that during the electrochemical treatment of water at the cathode, hydrogen gas is released, which is a reducing agent and neutralizes part of the gaseous chlorine and oxygen as oxidants of bacterial contaminants. In addition, this method requires the presence in the water of a certain minimum concentration of chlorides, below which the process of electrochemical disinfection becomes inefficient.

The disadvantage of electro dialysis is the inability to clean uncharged substances. However, for water treatment purposes in the yeast industry, this problem is less important because the incoming water usually contains a minimum amount of such substances, and the main problem is the presence of microorganisms, organic acids and various salts. This means that electro dialysis can be used for water treatment purposes in the yeast industry.

The use of electro dialysis is attractive because it requires minimal equipment. In addition, the proposed method has a number of technological advantages over known methods of electrochemical water disinfection, as there is no need for transportation and storage of hazardous reagents for oxidation of contaminants and pH adjustment of treated water, and simplifies maintenance of equipment and control of electrochemical water treatment. Changing the current to obtain the desired effect of disinfection. [19].

The purpose of the work is to determine the optimal parameters of the process of purification and disinfection of sewage of yeast production under the action of electro dialysis.

The task of the work is to build a mathematical model to obtain the optimal parameters of the process of sewage treatment and disinfection to minimize the amount of pollutants and microorganisms.

2 Materials and methods

2.1 Preparation of sewage samples

The sewage was poured under sterile conditions into pre-sterilized 200 ml glass bottles.

2.2 Conditions of sewage treatment in an electric dialyzer

Sewage treatment and disinfection were performed in a laboratory electro dialyzer (Figure 1).

The electrolytic cell is a rectangular cuvette 60 mm wide, 250 mm high and long, which is made of plexiglass. In the middle part of the device the membrane (1) from fabric “belting” is established. The working surface makes 6,25 m². In lateral parts of the device insoluble electrodes are established. The cathode (2) is made of a non-continuous titanium plate with a thickness of 1 mm. The anode (3) is made of a solid plate with a thickness of 1

mm and a working surface of 6.25 m². of stainless steel. The distance between the cathode and the anode is 48 mm. The usable volume of the device is 0.003 m³.

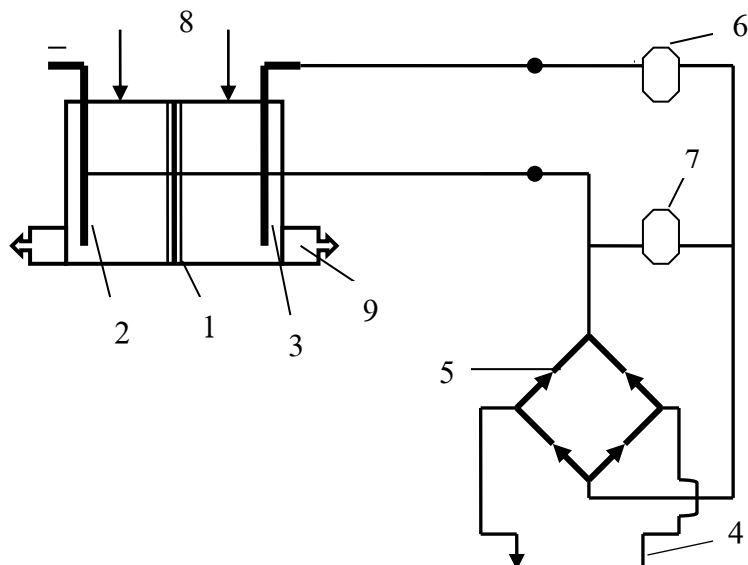


Fig. 1. Scheme of the laboratory installation of the electro dializer: 1 - membrane; 2 - cathode; 3 - anode; 4 - rectifier; 5 - LATR-1M; 6 - ammeter; 7 - voltmeter; 8 - sewage; 9 - outlet pipes.

The electrodes were supplied with direct current from a rectifier (4) mounted on a bridge circuit made of diodes and connected to the AC network via LATR-1M (5). Current and voltage were measured using an ammeter (6) and a voltmeter (7) of class 0.5. Wastewater (8) was fed in equal amounts to the cathode and anode zones of the electro dializer and electro dialysis was performed. At the end of the electrochemical process through the outlet pipes (9) purified water was simultaneously and in equal amounts drained from the cathode and anode zone of the installation.

Electro dialysis took place at an initial current of 0.2 A, water temperature 293 K, duration of action 5, 10, 15 and 20 minutes.

After electro dialysis, the composition of wastewater was studied by physicochemical and microbiological parameters.

2.3 Determination of physicochemical and microbiological parameters

The chloride content was determined by the method of [State Standard of Ukraine. DSTU ISO 9297: 2007 Water quality. Determination of chloride. Silver nitrate titration with chromate indicator (Mohr's method)], total nitrogen content [State Standard of Ukraine. DSTU ISO 5663: 2007 Water quality.

Determination of kjeldahl nitrogen. Method after mineralization with selenium (ISO 5663: 1984, IDT)], weighted substances [State Standard of Ukraine. DSTU EN 872: 2013 Water quality.

Determination of suspended solids method by filtration through glass fiber filters (EN 872: 2005, IDT)], calcined residue [State Standard. GOST18164-72 Drinking water. Method for determination of total solids content], sulfates [State Standard of Ukraine. GOST 31940-2012. Drinking water. Methods for determination of sulfate content (ISO 787-13-73 General methods of test for pigments and extenders. Determination of water-

soluble sulphates, chlorides and nitrates)], chemical consumption of oxygen [State Standard of Ukraine. DSTU ISO 6060: 2003. Water quality. Determination of the chemical oxygen demand (ISO 6060: 1989, IDT)]. Water pH values were measured by potentiometric method [State Standard of Ukraine. DSTU 4077-2001. Water quality. Determination of pH (ISO10523: 1994, MOD)]. The total microbial count was determined by the method [ISO 6222: 1999 Water quality. Enumeration of culturable micro-organisms. Colony count by inoculation in a nutrient agar culture medium (ISO 6222: 1999)]

Laboratory tests were performed in triplicate. Statistical processing of the obtained results was performed using the MS Excel software package. The error of experimental researches was within the limits provided by research methods.

Mathematical models of optimization of parameters of process of clearing and disinfection of sewage by electro dialysis constructed by means of a package were used in work.

3 Results

As a result of the study, some conclusions were made regarding significant contamination of wastewater with organic and mineral substances. These findings were confirmed by laboratory studies (table 1 - 2).

Table 1. The composition of sewage 3 stages of yeast separation.

Indicators	1st degree Sewage	2nd degree Sewage	3rd degree Sewage
pH	4.80	4.9	5.2
Chlorides, mg/dm ³	2147	1093	814
Nitrogen total, mg/dm ³	10.8	8.9	6.2
Suspended substances, mg/dm ³	6800	2000	800
Calcined residue, mg/dm ³	3600	800	400
Sulfates, mg/dm ³	6089	2798	1481
COC, mg O ₂ /dm ³	31096	15 504	8120
TMC, CFU cm ³	12 · 10 ⁷	21 · 10 ⁶	12 · 10 ⁶

From the above results it is seen that the pH value in all studied samples of sewerage indicates an acidic reaction of the environment, chlorides exceed the norm by 2.3-6.1%, suspended solids - by 2.7-22.7%, sulfates - by 3,7 - 15.2%, COC - at 16.2– 62.2%. The total microbial count is thousands of times higher than the norm for discharge into sewage treatment plants (STP). The total nitrogen is within normal limits.

Table 2. The composition of the total sewage discharge.

Indicators	Actual value	Norm for reset in STP
pH	4.7	6.5-9.0
Chlorides, mg/dm ³	1351	350
Nitrogen total, mg/dm ³	11.8	50
Suspended substances, mg/dm ³	3200	300
Calcined residue, mg/dm ³	1600	it isn't determined
Sulfates, mg/dm ³	3457	400
COC, mg O ₂ /dm ³	18240	500
TMC, CFU cm ³	12 · 10 ⁶	100

It was found that the content of chlorides in sewage of the total discharge exceeds the norm by 3.9 times, sulfates - by 8.6 times, COC - by 36.5 times, it is characterized by a high level of color, low pH, a significant amount of suspended solids and microorganisms. Total nitrogen is within normal limits.

The indicators of the investigated wastewater in most parameters exceed the discharge rates in the STP, and their discharge is possible only if treated to the normative values.

The work is based on the task of creating an improved method of sewage treatment and disinfection, which would increase its efficiency and performance that includes water treatment in the anode and cathode chamber of the diaphragm electro dialyzer, anode and cathode chambers operate in non-flow mode.

Under the action of a direct electric current on the insoluble anode, the discharge of chlorine ions and water molecules takes place with the release of gaseous chlorine and oxygen, which, dissolving in water, oxidize bacterial contaminants. Due to the release of oxygen in the anolyte, hydrogen ions are formed. During the presence of water in the cathode chamber at the cathode, a discharge of water molecules takes place with the formation of hydrogen gas and hydroxyl ions, which accumulate in the catholyte.

The process of electro dialysis is influenced by such indicators as current, voltage, ambient temperature. The interelectrode distance is determined depending on the composition and velocity of the electrolyte. The concentration of hydrogen ions does not significantly affect the electro dialysis process. The output of chlorine in the current remains at the same level in the pH range from 5 to 10. The speed of water at constant operating parameters of the cell (voltage, interelectrode distance, NaCl concentration, strength and current density) varies depending on the speed of the electrolyte.

The study results of 3 stages sewage composition of yeast separation after electro dialysis are shown in table 3.

Table 3. The study results of 3 stages sewage composition of yeast separation after electro dialysis.

Indicators		Processing time, min											
		1st degree Sewage				2nd degree Sewage				3rd degree Sewage			
		5	10	15	20	5	10	15	20	5	10	15	20
pH	Anode	4.7	4.66	4.6	4.57	4.8	4.75	4.7	4.62	5.0	4,9	4.7	4.65
	Cathode	5.0	5.25	5,45	5.7	5.2	5.5	5.9	6.29	5.5	6,0	7.0	7.7
Chlorides, mg/dm ³	Anode	2522	2897	3272	3650	3878	6663	9448	12233	3357	5902	8447	10992
	Cathode	3810	5473	7136	8800	2105	3117	4129	5141	1496	2179	2862	3546
Nitrogen total, mg/dm ³	Anode	10.5	10.3	9.9	9,7	8.5	8.1	7.8	7.4	5.9	5.6	5.2	4.9
	Cathode	9.4	8.0	6.6	5.2	7.7	6.4	5.2	3.9	5.3	4.4	3.5	2.6
Suspended substances, mg/dm ³	Anode	5780	4760	3740	2720	1700	1400	1100	800	650	500	350	200
	Cathode	5610	4420	3230	2040	1650	1300	950	600	630	520	300	200
Calcined residue, mg/dm ³	Anode	3150	2700	2250	1800	700	600	500	400	300	200	100	0
	Cathode	2925	2250	1575	900	650	500	350	200	330	180	120	0
Sulfates, mg/dm ³	Anode	5099	4109	3119	2131	2345	1892	1439	987	1275	1069	863	658
	Cathode	5541	4993	4445	3896	2551	2304	2057	1810	1276	1071	866	660
COC, mg O ₂ /dm ³	Anode	26976	22856	18736	14615	13466	11428	9390	7352	6360	4600	2840	1080
	Cathode	27520	23944	20368	16791	13741	11978	10215	8451	6404	4688	2972	1254

The duration of electro dialysis on the process of sewage treatment and disinfection at which the best results are achieved - 20 minutes.

For sewage of the 1st stage of yeast separation, such indicators as nitrogen, suspended solids, calcined residue, sulfates and COC are lower than the initial values by 10, 60, 50, 65 and 53%, respectively, for the anode zone, and 52, 70, 75, 36 and 46% respectively for the cathode zone.

For sewage of the 2nd stage of yeast separation, such indicators as nitrogen, suspended solids, calcined residue, sulfates and COC are lower than the initial values by 17, 60, 50, 65 and 53%, respectively, for the anode zone, and 56, 70, 75, 35 and 46% respectively for the cathode zone.

For sewage of the 3rd stage of yeast separation, such indicators as nitrogen, suspended solids, calcined residue, sulfates and COC are lower than the initial values by 21, 75, 100, 56 and 87%, respectively, for the anode zone, and 58, 75, 100, 55 and 85% respectively for the cathode zone.

The study results of sewage composition of the total discharge after the action of electro dialysis are presented in table 4.

Table 4. Sewage physico-chemical composition of total discharge after electro dialysis.

Indicators		Processing time, min			
		5	10	15	20
pH	Anode	4.65	4.6	4.55	4.5
	Cathode	4.8	4.95	5.1	5.2
Chlorides, mg/dm ³	Anode	2786	4221	5656	7092
	Cathode	1457	1563	1669	1773
Nitrogen total, mg dm ³	Anode	9.2	6.5	3,9	1,3
	Cathode	9.3	6.7	4.2	1.6
Suspended substances, mg/dm ³	Anode	2700	2200	1700	1200
	Cathode	2750	2300	1850	1400
Calcined residue, mg dm ³	Anode	1402	1204	1006	810
	Cathode	1296	992	688	385
Sulfates, mg/dm ³	Anode	3127	2798	2469	2139
	Cathode	3086	2716	2346	1975
COC, mg O ₂ /dm ³	Anode	15966	13692	11418	9145
	Cathode	16094	13948	11802	9654

For general sewage, suspended solids, sulphates and COC are lower than similar control samples for the anode zone by 89, 63, 38 and 50%, respectively, and for the cathode zone by 86, 56, 43 and 47%, respectively.

In the anode chamber we obtain a new type of antimicrobial solution - electrochemically activated anolyte. During the treatment of water in electroactivators (electric current), all molecular structures break down into ions. Water is saturated with highly active substances - oxidants and reducing agents. Under the action of electric current, as well as highly active oxidants and reducing agents, the destruction of microorganisms of all kinds and forms. The result is the death and decomposition of bacteria, spores, fungi, microorganisms into simple substances (namely water, carbon dioxide) [20].

Water disinfection is achieved through the following physicochemical processes:
 - strong disinfecting action of a direct electric current.

- chemical action on bacteria, viruses, zoo- and phytoplankton of strong oxidants, such as hydrogen peroxide, ozone, atomic oxygen, etc. Increasing the degree of disinfection is achieved by introducing metal chlorides (KCl, NaCl) into the water [21].

The process of sewage disinfection during electro dialysis depends on the content of Cl⁻ and SO₄²⁻ ions. With increasing concentrations of chlorides in the treated water from 20 to 300 mg / dm³, the yield of chlorine in the current increases from 5 to 25%. The presence of sulfates reduces the current output of chlorine by 4-5 times. This is due to the fact that SO₄²⁻ ions, increasing the total electrical conductivity of the solution, do not participate in the formation of active chlorine [22].

The required dose of active chlorine is maintained by adjusting the amount of reagent supplied. During electro dialysis of treated water, the dose of chlorine can be regulated only electrically, for example by changing the amount of electricity consumed per 1 m³ of treated water. The output of chlorine in the current remains almost constant. Only the total amount of chlorine produced changes. The amount of chlorine in water increases in direct proportion to the energy expended. At chlorides concentration of 20-50 mg / dm³ it is economically expedient to use the method of direct electro dialysis at stations with a capacity of up to 800-1000 m³ / day. At a higher content of chlorides in the water, electro dialysis disinfection can be used at water supply stations with a capacity of up to 3.5-5.0 thousand m³ / day. Disinfection of sewage by electro dialysis should be carried out on facilities with a capacity of up to 500-1000 m³ / day [23].

The microbiological composition of sewage after electro dialysis is demonstrated in table 5.

Table 5. The microbiological studies results of sewage before and after disinfection by electro dialysis.

Indicators		Disinfection time, min.											
		1st degree Sewage				2nd degree Sewage				3rd degree Sewage			
		5	10	15	20	5	10	15	20	5	10	15	20
TMC final, CFU/cm ³	Anode	42·10 ⁵	22·10 ⁵	10.8·10 ⁵	36.3·10 ⁴	32·10 ⁴	11.5·10 ⁵	52.2·10 ⁴	61.9·10 ⁴	6·10 ⁵	6·10 ⁵	5.4·10 ⁵	17.1·10 ⁴
	Cathode	26·10 ⁶	4.8·10 ⁶	18.6·10 ⁵	11.5·10 ⁵	171·10 ⁴	363·10 ⁴	20·10 ⁴	68·10 ⁴	1.3·10 ⁶	1.2·10 ⁶	9.3·10 ⁵	32·10 ⁴
TMC initial CFU/cm ³		12·10 ⁷				21·10 ⁶				12·10 ⁶			

The table figure out that the total number of microorganisms after treatment of sewage by electro dialysis has decreased significantly compared to the initial values. The best process of sewage disinfection of yeast separation 3rd degree is observed in the anode zone, as evidenced by the degree of disinfection of 97.3 - 98.57%. In sewage of the 1st and 2nd degree of separation, the reduction of TMC also occurs in the anode zone by 99.04 - 99.69% and 96.76 - 97.05%, respectively.

The study results of sewage microbiological composition of the total discharge after the action of electro dialysis are shown in table 6.

Table 6. Sewage microbiological composition of total discharge after electro dialysis.

Indicators		Disinfection time, min.			
		5	10	15	20
TMC final, CFU/cm ³	Anode	6.1·10 ⁵	5,9·10 ⁵	5·10 ⁵	82·10 ⁴
	Cathode	1.4·10 ⁶	1.3·10 ⁶	8.9·10 ⁵	88·10 ⁴
TMC initial, CFU/cm ³		12·10 ⁶			

It was found that the best process of sewage disinfection took place in the anode zone with a duration of 20 minutes The degree of disinfection is 92.6-93.16%.

Listed in table. 5, 6 numerical results demonstrate how the value of TMC varies depending on the time of electro dialysis τ . We have assumed that this dependence is generally described by law

$$TVC(\tau) = TVC_0 \cdot \exp (\alpha + \beta\tau) \tag{1}$$

where TVC_0 is the value of the TMC at the initial time, and the change dynamics of the TMC does not depend on the type of wastewater studied, but depends only on where exactly - near the anode or cathode - the treatment took place. In other words, we assume that there are certain coefficients $\alpha^{(a)}, \beta^{(a)}$, which determine the dependence of $TVC(\tau)$ in the anode zone, and the coefficients $\alpha^{(c)}, \beta^{(c)}$ respectively, for the cathode zone.

From the model we have chosen, it follows that

$$\ln \left(\frac{TVC(\tau)}{TVC_0} \right) = \alpha + \beta\tau \tag{2}$$

For each type of sewage, the value of the $\frac{TVC(\tau_i)}{TVC_0}$ ratio was calculated for individual moments of time on the basis of known TMC; they are shown in Fig. 2 on a logarithmic scale along the y-axis.

In order to find the coefficients $\alpha^{(a)}, \beta^{(a)}, \alpha^{(c)}, \beta^{(c)}$, two regression lines were constructed - the first approximates $n = 16$ calculated for the anode zone values of $\ln \left(\frac{TVC(\tau_i)}{TVC_0} \right)$ and the second also approximates $n = 16$ values, but calculated for the cathode zone. Measurement results were used for time points $\tau_i = 5, 10, 15, 20$ min, because during the first 5 minutes of the electro dialysis process the decrease in the value of SMC in both the anode and cathode zone is quite fast, and the time dependence deviates from the line constructed for $\tau > 5$ min

For the coefficient $\alpha^{(c)}$ of the regression line, which corresponds to the data measured in the cathode zone, the values of $\alpha^{(c)} = -1.5$ and 95% confidence interval $[-2.5; -0.5]$, and for the coefficient $\beta^{(c)}$ the value of $\beta^{(c)} = -0.111$ and 95% confidence interval $[-0.183; -0.039]$.

For the regression line constructed from the results of measurements in the anode zone, it turned out that the hypothesis of the difference between the coefficient $\beta^{(a)}$ (zero) can not be accepted with a confidence level of 95%, because the value found $\beta^{(a)} = -0,0496$ satisfies the inequalities $|\beta^{(a)}|/\sqrt{D[\beta^{(a)}]} < t_{0,95;14} = 2.1452$, where $t_{0,95;14}$ - a quantile of the level of 0.95 Studentas distribution with $n-2 = 14$ degrees of freedom. Therefore, the coefficient $\beta^{(c)}$, which characterizes the slope of the regression line, is not significant, and therefore for the approximation will have to be satisfied only with the coefficient $\alpha^{(a)}$,

which is now calculated as the average of 16 measurement results in the anode zone. For the specified coefficient, the values of $\alpha^{(a)} = -3,6$ and 95% confidence interval were found $[-4.05; -3.13]$.

From the obtained numerical results we conclude that in the process of electro dialysis the index of the TMC near the cathode during the first 5 minutes decreases to the level $\frac{TVC(\tau=5)}{TVC_0} = \exp(\alpha^{(c)} + \beta^{(c)} \cdot 5) = 0.13$, and during the next 15 minutes decreases in $\frac{TVC(\tau=5)}{TVC(\tau=15)} = \frac{\exp(\alpha^{(c)} + \beta^{(c)} \cdot 5)}{\exp(\alpha^{(c)} + \beta^{(c)} \cdot 15)} \approx 3$ times. On the other hand, near the anode, the TMC for the first 5 minutes falls to the level $\frac{TVC(\tau=5)}{TVC_0} = \exp(\alpha^{(a)}) = 0.028$ from the initial value. Further changes in the TMC in the anode zone are not observed to the accuracy of the errors in the measurement of the TMC (Figure 2).

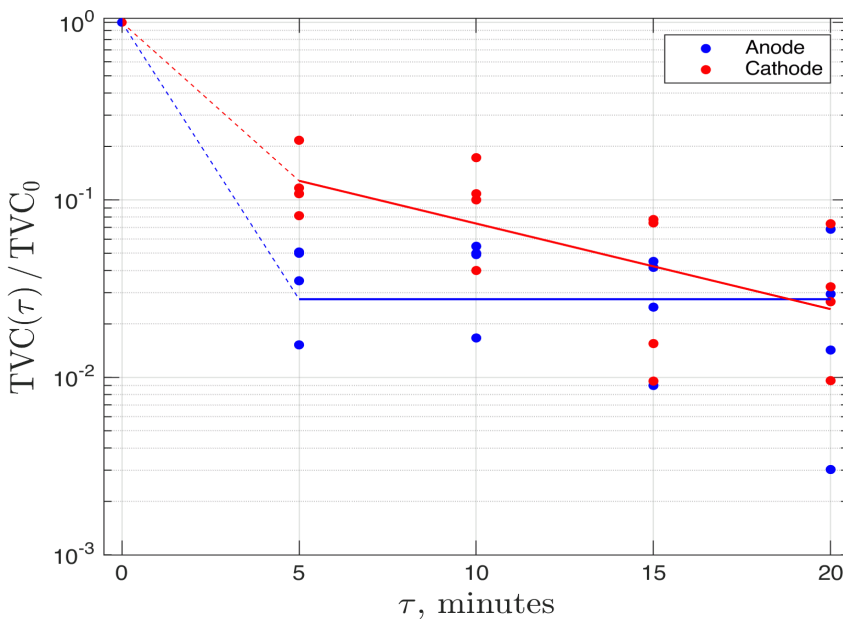


Fig. 2. Approximation of the duration effect dependence of electro dialysis treatment (τ) on the TMC of total discharge and sewage of 1-st, 2-nd, 3rd stages of yeast separation.

4 Discussion

In the interval of processing duration of 15 - 20 min. the lowest indicator of TMC is reached. The highest degree of sewage disinfection is observed in the anode zone due to the accumulation during electro dialysis in the anode zone of chloride ions and atomic oxygen, which contribute to the oxidation of organic matter and the death of microorganisms.

As the duration of electro dialysis increased, as expected, the TMC of all investigated sewage decreased. The decrease was quite large: with a duration of exposure of 20 min. TMC decreased by 92 - 99%. The decrease was almost linear with the duration of action in the considered range. This dependence suggests that the limit of reducing the content of microorganisms has not yet been exhausted, and perhaps even more reduction in the number of microorganisms, which can be provided by a longer exposure to the electric field. [24]

The effect of disinfection during electro dialysis of water depends on the amount of electricity consumed, the residence time of water in the installation.

With increasing amount of electricity per 1 dm³ of treated water, the degree of water purification increases. However, in all cases with any minimal infection, the desired effect of disinfection is observed only at a certain amount of residual chlorine. With increasing water pollution, the concentration of chlorine required for its complete disinfection increases. If this condition is not met, then regardless of the amount of electricity applied, complete disinfection of water is not achieved.

The state of the aqueous medium (temperature, pH, turbidity and color) significantly affects the efficiency of the disinfection process in the electro dialyzer.

With increasing concentration of chlorine in water, increasing its temperature, the speed of the disinfection process increases. The adverse effects of low temperatures can be offset by increasing the dose of chlorine and prolonging the time of its contact with the treated water.

The bactericidal effect of chlorine is enhanced by lowering the pH of the medium. As the pH decreases, the dissociation degree of hydrochloric acid formed during the hydrolysis of chlorine in water decreases, and, consequently, a large concentration of more active substance (HOCl) remains in the water and the concentration of less active hypochlorite ion OCl⁻ decreases accordingly.

Hypochlorites, hypochlorous acid and molecular chlorine readily react with ammonia present in water, ammonium or organic salts containing amino groups, forming mono- and dichloramines, nitrogen chloride. During the hydrolysis of the obtained compounds, active chlorine is released, so they also have a bactericidal effect [25].

5 Conclusions

Physicochemical and microbiological indicators of sewage composition after 1, 2 and 3 stages of yeast separation and total discharge, which contain a large number of organic substances and microorganisms, have been experimentally determined.

The parameters of electro dialysis action on sewage treatment and disinfection are optimized. For sewage of the 1st stage of yeast separation, the treatment duration is 20 minutes, the current value is 0.4 - 0.2 A, the voltage is 19 - 20 V, the ambient temperature is 293 K, with nitrogen, suspended solids, calcined residue, sulfates and COCs are lower than the initial values by 10, 60, 50, 65 and 53%, respectively, for the anode zone, and 52, 70, 75, 36 and 46%, respectively, for the cathode zone. The degree of disinfection is 99.04 - 99.69%.

For wastewater of the 2nd stage of yeast separation, the treatment duration is 20 minutes, the current value is 0.5 - 0.2 A, the voltage is 18 - 19 V, the medium temperature is 293 K, with nitrogen, suspended solids, calcined residue, sulfates and COCs are lower than the initial values by 17, 60, 50, 65 and 53%, respectively, for the anode zone, and 56, 70, 75, 35 and 46%, respectively, for the cathode zone. The degree of disinfection is 96.76 - 97.05%.

For wastewater of the 3rd stage of yeast separation, the treatment duration is 20 minutes, the current value is 0.5 - 0.2 A, the voltage is 15 - 16 V, the medium temperature is 293 K, with nitrogen, suspended solids, calcined residue, sulfates and COCs are lower than the initial values by 21, 75, 100, 56 and 87%, respectively, for the anode zone, and 58, 75, 100, 55 and 85%, respectively, for the cathode zone. The degree of disinfection is 97.3 - 98.57%.

For sewage of total discharge, the treatment duration is 20 minutes, current value 0.5 - 0.2 A, voltage 18 - 19 V, ambient temperature 293 K, with suspended solids, sulfates and COC below similar indicators of control samples for the anode zone by 89, 63, 38 and 50%

respectively, and for the cathode zone by 86, 56, 43 and 47% respectively. The degree of disinfection is 92.6 - 93.16%.

References

1. N.V. Mailunets, M.M. Zatserklyanny, *Water consumption and promising equipment for wastewater treatment. Collection of abstracts of the X All-Ukrainian scientific-practical conference of young scientists, graduate students and student (Odessa)* (2019)
2. O.O. Emonakova, *Improvement of wastewater treatment technologies after grain soaking Collection of abstracts of the X All-Ukrainian scientific-practical conference of young scientists, graduate students and student (Odessa)* (2019)
3. A.T. Bezusov, N.V. Dotsenko, *Biotechnological processing of industrial effluents Collection of abstracts of the X All-Ukrainian scientific-practical conference of young scientists, graduate students and student (Odessa)* (2019)
4. V.P. Kovalsky, V.P. Ocheretny, M.O. Postolatiy, *Promising technologies, modern reagents and materials for wastewater treatment Collection of abstracts of the X All-Ukrainian scientific-practical conference of young scientists, graduate students and student (Odessa)* (2019)
5. R.V. Mnykh, Y.V. Sukhatsky, O.I. Zin, *Cavitation wastewater treatment of meat processing enterprises Collection of abstracts of the X All-Ukrainian scientific-practical conference of young scientists, graduate students and students (Odessa)* (2019)
6. G.O. Bilyavsky, L.I. Butchenko, *Fundamentals of ecology Textbook* (2002)
7. D.I. Kibirev, K.S. Pozhivilko, G.I. Nikiforov, *A method of treating water with sodium hypochlorite and a flow cell to obtain sodium hypochlorite RF patent 2100483* (1997)
8. B.C. Brazhkin, N.P. Kuprikov O.A. Zhuravkov, *Method of electrochemical treatment of water with disinfectants RF patent 2500625* (2013)
9. V.V. Kunizhenkov, M.S. Yaroshinskiy, Y.P. Struk, L.Z. Boguslavskiy Y.G. Kazaryan, *Installation for water contamination Patent of Ukraine 99276 Bull 3* (1997)
10. L.Z. Boguslavsky, Y.G. Ghazaryan, J.P. Struk, V.V. Kunizhenkov, M.S. Yaroshinsky, *Installation for water disinfection Patent of Ukraine 99276 Bull 10* (2015)
11. D.I. Kibirev, K.S. Pozhivilko, G.I. Nikiforov, *A method of treating water with sodium hypochlorite and a flow cell to obtain sodium hypochlorite RF patent 2100483* (1997)
12. B.C. Brazhkin, N.P. Kuprikov, O.A. Zhuravkov, *Method of electrochemical treatment of water with disinfectants RF patent 2500625* (2013)
13. L.V. Filipchuk, V.L. Filipchuk, *Method of electrochemical disinfection of water Patent of Ukraine 111278 Bull 21* (2016)
14. I.A. Burtna, D.V. Litvinenko, *Review of membrane technologies of water purification in water supply and water treatment*, East European Journal of Advanced Technologies **6/10** (60), 4-6, 1729-3774 (2012)
15. D.I. Kibirev, K.S. Pozhivilko, G.I. Nikiforov, *Published A method of treating water with sodium hypochlorite and a flow cell to obtain sodium hypochlorite RF patent 2100483* (1997)
16. B.C. Brazhkin, N.P. Kuprikov, O.A. Zhuravkov, *Method of electrochemical treatment of water with disinfectants RF patent 2500625* (2013)

17. S.G. Chulkov, A.O. Mokin, P.S. Latukhin, G.V. Styr, O.M. Plitkin, L.D. Barkov, *Method of water purification and disinfection Patent of Ukraine 106611 Bull 8* (2016)
18. B.C. Brazhkin, N.P. Kuprikov, O.A. Zhuravkov, *Method of electrochemical treatment of water with disinfectants RF patent 2500625* (2013)
19. A.A. Kulakov, Features of purification of tap water by means of electro dialysis (2019) (Electronic Materials) URL <https://watermagazine.ru/nauchnye-stati2/novye-stati/23021-osobennosti-ochistki-vodoprovodnoj-vody-s-pomoshchyu-elektrodializa.html>
20. V.D. Kurtov, *On the amazing properties of electroactivated water* (2007)
21. N.M. Romanchenko, V.B. Kostin, *Reagent-free method of water disinfection by electroactivation Prospects for the future and realities of the present in water treatment technologies: Proceedings of the III International Scientific and Practical Conference (Kyiv)* (2019)
22. O.V. Goltvyanytska, T.O. Shabliy, M.D. Gomel, S.S. Stavska, *Removal and separation of chlorides and sulfates during ion exchange desalination of water*, Eastern European Journal of Advanced Technologies **1/6** (55), 40-44 (2012)
23. A.A. Kulakov, *Peculiarities of tap water purification by means of electro dialysis Journal "Water Magazine" was published by LLC "ID" EcoMedia* (2018) URL: <https://watermagazine.ru/zhurnal/informatsiya.html>
24. A.A. Kulakov, *Features of purification of tap water by means of electro dialysis* (2019) URL: <https://watermagazine.ru/nauchnye-stati2/novye-stati/23021-osobennosti-ochistki-vodoprovodnoj-vody-s-pomoshchyu-elektrodializa.html>
25. O.A. Squeezed, V.G. Petruk, *Analysis of factors of ecological danger of chlorinated drinking water*, Bulletin of Vinnytsia Polytechnic Institute **5**, 69-75, 1997-9266 (2014)