

RESEARCH ARTICLE

STUDY OF THE PROCESS OF NEUTRALIZING AND OXIDIZING HARMFUL PHENOL COMPOUNDS IN WASTEWATER USING OZONE TECHNOLOGY

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ABSTRACT

In the scientific research work, the process of neutralization and cleaning of microorganisms harmful to human health found in surface water with an ozonator device based on a pilot electric discharge is considered. A pilot ozonator based on a special high-frequency electric discharge has been developed for disinfection and cleaning of harmful microorganisms found in surface water. In order to conduct practical tests on scientific research work, special water was taken from the Ili floodplain and an examination of the water composition was carried out. According to the results of the examination, various painful microorganisms were found in the composition of the source water that do not meet the maximum permissible concentration (MPC). Effective economic indicators of ozone content (mg/l), contact time (t, minutes) and the like were determined for disinfection and removal of microorganisms from the water composition. In addition, an algorithm for theoretical calculations for the destruction of harmful microorganisms in 1m³ surface water was compiled and a mathematical model was given.

KEYWORDS

Ozonator; ozone; surface water; water field; primary water; ozonated water; ozone content; decontamination process

1. INTRODUCTION

The most effective and appropriate is the use of ozone for water purification and disinfection when using water sources that are heavily contaminated with microbiological indicators (Orlov, V.A., 1996). Ozone is used not only to destroy natural and anthropogenic organic pollutants, but also to neutralize the necessary harmful bactericidal microorganisms that chlorine-based reagents cannot remove (Alekseev et al., 2001; Draginsky et al., 2007).

Ozonation has the following advantages over decontamination of water by chlorine, namely:

- high oxidizing potential of ozone, as a result of which the bactericidal effect of ozone in water is stronger than that of other chemical reagents;

- ozone affects not only the redox system of bacteria, but also directly on the protoplasm;
- ozone acts 15 - 20 times faster than chlorine. For example, while ozone at a dose of 0.45 mg/l kills the polio virus in 2 minutes, chlorine at a dose of 2 mg/l kills after 3 hours.
- the required amount of ozone is about 2.5 times less than chlorine.

The bactericidal effect of ozone is less dependent on the value of the pH = 6 - 10 range at a water temperature of 0 - 37°C. The effectiveness of the bactericidal effect of ozone is influenced by the presence in the composition of floating and dissolved organic substances, non-ferrous and chemical pollutants (Draginsky et al., 2007).

Improvement of surface water disinfection methods is currently being developed in the following main areas (Figure 1):

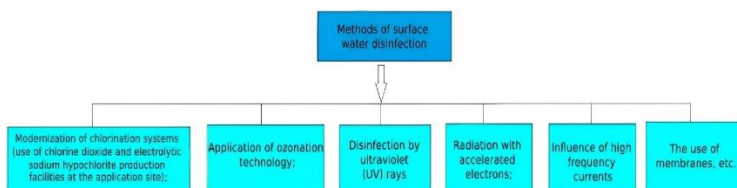


Figure 1: Water disinfection processes

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Currently, methods of water disinfection using ozone and UV radiation are quite common in Europe and America (Percival, 1991; Smith and Clark, 1995). For this purpose, a pilot ozonator device was developed in the laboratory, based on a high-frequency electric discharge.

2.MATERIALS AND METHODS.

Disinfection methods are used to remove microorganisms and viruses from the water composition during the process. If the content of viruses and microorganisms is higher than the maximum permissible concentration (MPC), the water will be unsuitable for drinking, domestic

use or industrial purposes. Therefore, it is imperative to disinfect the waters that carry out such infectious diseases (WHO, 1994; Alekseeva, 1986).

Currently, tactics there are the most common methods of disinfection and disinfection using strong oxidants such as chlorine, sodium and calcium hypochlorite, ozone. Also in practice, a physical method is widely used - disinfection with ultraviolet rays. Table 1 below presents the results of the analysis of the use of various methods of water disinfection processes in foreign countries (Sehested et al., 1991; Leszczynski, 2013).

Table 1: Comparative analysis of decontamination methods in use in different states (Leszczynski, 2013).					
Country	Cl ₂	ClO ₂	NH ₂ Cl	O ₃	UV
Australia	+++	+	++	-	+
Austria	+++	+	-	+	+
Belgium	+++	+	-	+	-
Belarus	+++	-	-	+	+
Bulgaria	+++	-	-	-	+
Hungary	+++	-	+	+	-
UK	+++	+	+	-	+
Germany	+++	+++	-	++	+
Spain	+++	+	-	++	-
Ireland	+++	-	-	+	-
Italy	+++	+++	-	-	-
China	+++	-	-	+	-
Norway	++	-	+	-	++
Poland	+++	+	+	+	-
Russia	+++	-	-	+	+
USA	+++	+	+	+	+
Finland	+++	+	+	+	-
France	++	++	-	++	-
Czech Republic	+++	-	-	+	-
Sweden	+	++	-	++	++
Sweden	+++	+	++	-	-
South Africa	+++	-	+	+	-
Japan	+++	-	-	+	-

Warning. "+++" - in priority use; "++" – meet; "+" – in very little use "-" not in use at all.

Ozone has a high redox potential - 2.07 V (for comparison: Cl₂ -1.36 V, O₂ – 1.23 V), which is the main reason for its activity in relation to various types of water pollution, including microorganisms (Orlov and Stroyzdat, 1984). In the absence of bromides, by-products are not formed in distilled water (Battino, 1981). In addition, ozone is a toxic and corrosive substance, so the exposure time for disinfection is very fast.

Among the methods of water disinfection, according to foreign experience, the use of ozonator installations as one of the stages of water purification is increasing from year to year. For example, there are more than 1,200 ozonator plants in Europe and the United States, which use ozonation technology as one of the steps in water purification and decontamination processes (Sedlak David, 2011; Von Sonntag and Von Gunten, 2012).

When using chlorine-containing substances and ozone in water treatment processes, you need to pay attention to the following important points:

- water solubility of ozone;
- corrosive activity of disinfectant solutions on materials of water

treatment stations;

- efficiency of inactivation of microorganisms when using various disinfectant solutions in working conditions;
- processing parameters of networks and water supply facilities;
- environmental impact;
- feasibility study of the application of the proposed substances and technology.

The advantages of different disinfectants and chemical oxidizers to compare the efficiency of killing bacteria and different viruses contained in water are as follows:

- Chlorine and chlorine dioxide;
- Ozone;

The properties and effectiveness of disinfection using UV light can be observed in Figure 2 below (Abdykadyrov et al., 2023).

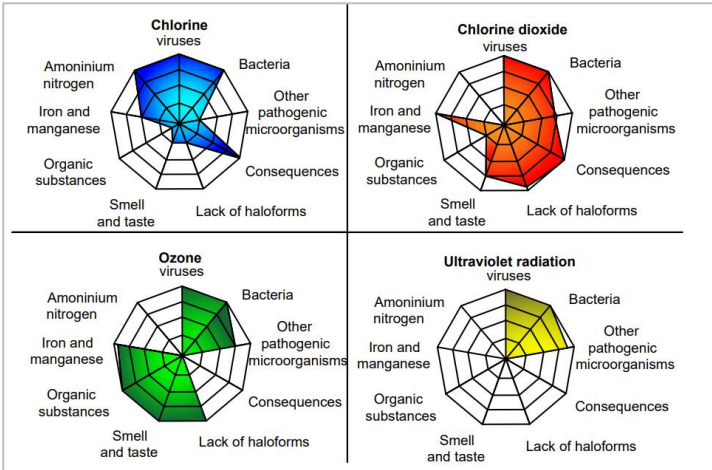


Figure 2: Efficiency of surface water disinfection methods (Abdykadyrov et al., 2023).

During the process of decontamination and purification of water, ozone dissolves relatively more slowly than chlorine. To increase the solubility of ozone in water, the contact time and contact surface area must be increased. Or it is necessary to use special devices that ensure the intensive mixing of ozone with water. As a rule, the ozone-air mixture is dispersed and given in the form of small bubbles (0.1-1 mm). In scientific research works, some literature (Punmia, 1995) provides data on the solubility of ozone in water depending on temperature, as well as in the W. B. Kogan's (Kogan, 1961) solubility handbook using the Bunsen coefficient. The conditions given in the definitions make it possible to theoretically predict the equilibrium concentration of ozone. However, the dissolution of ozone in natural water is influenced by many factors, such as the presence of oxidizing agents, the concentration of ozone in the gas mixture, pressure, the size of the gas bubbles created by the aerator, and a number of other factors are not taken into account in the basic formulas.

Thus, (Romanovskii, 2015) experimental research work related to processing parameters such as processing time, gas mixture flow rate, ozone concentration in gas mixture, and liquid layer are considered in the following sections.

3. RESULTS AND DISCUSSIONS.

To assess the necessary parameters of the ozonator, an approach based on the assessment of the effect of a disinfectant in a water treatment reactor is often used – the Ct factor. Where C is the concentration of the disinfectant, t is the contact time (reduced microorganisms in order of their number). During the process of ozone disinfection of drinking water, it is usually taken 1.6 mg/l (taking into account the maintenance of a residual concentration of 0.4 mg/l for 4 minutes). Table 2 shows ozone disinfection values of various microorganisms up to 99% percent at pH = 6 – 7 (Draginsky, 2007).

Table 2: Results of the process of ozone disinfection of water

Microorganism	Ct, mg/(l.min)	T (°C)
E.coli	0,02	20
B. subtilis spores	-	20
Rotavirus	0,006-0,06	20
Giardia lamblia cysts	0,5-0,6	25
Giardia muris cysts	1,8-2	25
Cryptosporidium parvum oocysts	2,5-18,4	20

As can be seen from the table, during the process of ozonation of water, it reacts to various mechanisms in the composition of water, including microorganisms, as well as processes of oxidation of heavy and light metals in the chemical composition of water, decomposition of organic compounds, i.e. fats. Water destroys microbacteria, oxidizing the chemical elements it contains. Ozonation of water has the following advantages over chlorination:

- as a result of the high oxidizing potential of ozone, the bactericidal effect in water is stronger than that of other chemical reagents;
- ozone affects not only the redox system of bacteria, but also directly on the protoplasm;
- ozone acts 15 - 20 times faster than chlorine. For example, if ozone kills the Rotavirus in 2 minutes (ozone content 0.45 mg/l), chlorine kills after 3 hours at a dose of 2 mg/l;
- the required amount of ozone is about 2.5 times less than chlorine (Abdykadyrov et al., 2023).

3.1 Dissolution of Ozone in Water During the Technological Process.

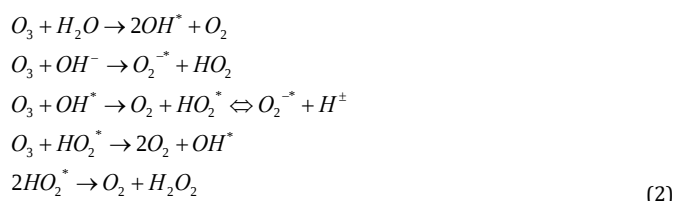
During the dissolution of ozone in water, there is not only a tendency to react with chemicals present in the water, but also its own distribution. These two processes occur simultaneously and depend on the temperature of the water, in the pH environment, and the types of ions dissolved by the Ionic force.

In general, the rate of ozone propagation in water can be written as (Draginsky et al., 2007).

$$\frac{-d[O_3]}{dt} = K_p \cdot [O_3] \quad (1)$$

where, K_p is the constant of the rate at which ozone is dissipated in water.

A quantitative description and an important feature of the process of dissolving ozone in water is shown as follows (Orlov, 1996; Draginsky et al., 2007).



This can be traced to the formation of the OH^* radical and hydrogen oxide from the above expressions.

The decomposition of ozone occurs faster in an alkaline medium than in

an acidic one, in such conditions the rate of its dissolution is expressed as follows:

$$\frac{-d[O_3]}{dt} = K_p [O_3] = K_a [OH^-]^{1/2} \cdot [O_3]^{3/2} \quad (3)$$

where, K_p and K_a are stability at a wide interval of pH in water. The ionic strength of the stabilized phosphate buffer is 0.15 (Mole/m³).

$$K_p = 5.43 \cdot 10^3 \exp\left(\frac{-4964}{T}\right) \text{sec}^{-1}; \quad (4)$$

$$K_a = 9.5 \cdot 10^{16} \exp\left(\frac{-10,1}{T}\right) \text{l/mole} \cdot \text{sec} \quad (5)$$

The presence and tendency to decay of OH^- ions at a pH equal to or lower does not matter. OH^- ions have a faster tendency to dissolve in self - water in the region of a value up to $pH = 7 \div 10$. Most often, at such pH values, the time of ozone propagation in water is taken into account as about 10 - 25 minutes (Orlov, 1996; Draginsky et al., 2007 (Orlov, 1996; Draginsky et al., 2007)).

The solubility and decay rate of ozone in water depends on temperature, the active reaction of the medium and the salt content. With a decrease in temperature and an increase in PH, the solubility of ozone increases, while base salts reduce its solubility, while neutral salts increase the solubility of ozone (EPA, 1999). The rate of decay of ozone increases with increasing temperature, pH and oxidizing substances. It should be noted that the dissolution of ozone in water at different pH values has been cited in many studies (Gurol, and Singer, 1982; Olah, 1976), although the results of the kinetics of ozone decay are different their value under experimental conditions is completely different.

Thus, it was found that the buffer additives used (phosphates, boric acid, etc.) are not indifferent to ozone and its decay products (Yoneda and Olah, 1977). They can also react with hydroxyl radicals, which are formed during the decomposition of ozone in water. In some scientific research papers, the mechanism of the chain reaction of ozone interaction with impurities in water is given (Yoneda et al., 1984). As for the dissolution of ozone in an acidic environment, research on this topic adequately demonstrates the increase in the reactivity of ozone in these scientific works (Jacquesy et al., 1997). The mechanism by which ozone interacts with organic compounds leads to the formation of protonated ozone, an intermediate product with very strong electrophilic properties in the presence of peroxide acids (Hoigne, 1983; Razumovsky, 1974). It is known that the O_3 molecule in aqueous solutions interacts much more slowly with protonated types of compounds (Hoffman et al., 1995). Therefore, the specific acid catalysis of reactions with ozone is higher than with conventional ozone (Hoigne, 1983).

As shown by studies to determine the kinetics of ozone decay by the height of the liquid column (Romanovskii et al., 2015). (in the experiment, water was used directly from the Ili Water Valley), about 96% percent of it decomposes in 20 minutes (Figure 3).

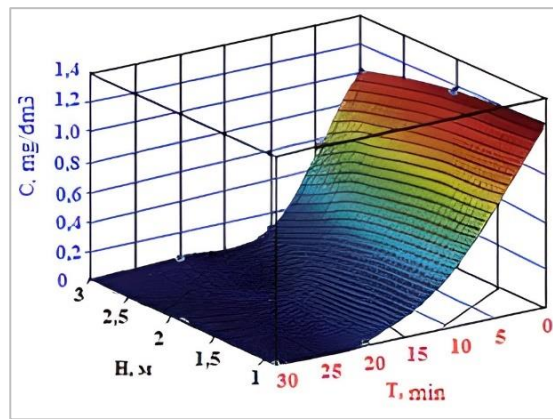


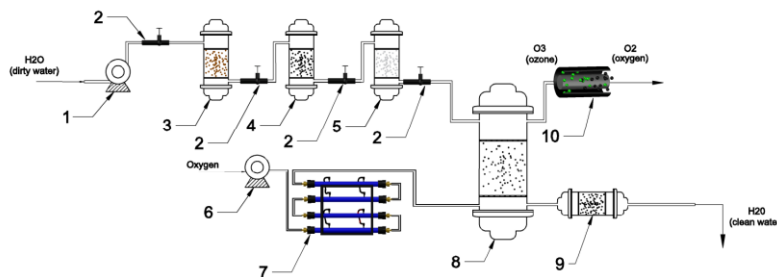
Figure 3: Decomposition of dissolved ozone in water at the top of the column

One of the most important practical problems with the use of ozone in water disinfection and purification processes is the comparison of its corrosive activity with solutions of chlorine-containing substances.

3.2 Practical Testing of The Device.

For practical study and analysis of the process of disinfection and

purification of surface water from harmful micro-organisms, a pilot ozonator based on an electric discharge was specially developed at the Department of Electronics, Telecommunications and space technologies of the Kazakh National Research Technical University named after K. I. Satpayev. The technological scheme of the unit is presented in Figure 4 below.



Where: 1-pump, capacity 10m³; 2-valve, d = 36x40 mm; 3-zeolite sand filter; 4 - activated carbon filter; 5-quartz sand filter; 6-air compressor; 7-electric Crown discharge-based ozonator; 8-Tank (H₂O+O₃); 9 - membrane filter; 10 - waste ozone decompressor

Figure 2:Technological scheme of the process of neutralization of surface water using ozone technology

The characteristics of the operation of the technological scheme are as follows: the initial water from which the surface water does not come through the pump (1) comes to the load of sand from the first zeolite (3). Water in the load made of this zeolite is cleaned mechanically in advance. The purified water passes through the activated carbon, adsorbed from toxic substances (4), and through a quartz filter, the color of the water is reduced, and it comes into contact with Ozone (8). Ozone is supplied to the tank (8) through the ozonator (7) using a compressor (6). After 30 minutes, ozonated water is filtered through a membrane filter (9) and sent to consumers. The residual ozone deposited on the surface of the tank is decomposed using a destructor (10) and released into the atmosphere. The general image of the upper-frequency corona discharge-based ozonator (7) can be seen in the figure below (Figure 5).

Based on the results of Experimental Studies, a regression equation describing the concentration of ozone in water (G_v mg/dm³) was obtained from the studied parameters:

$$G_v = 3,9436 - 27,2356 \cdot D + 0,0339 \cdot G_g + 0,0286 \cdot T - 0,0456 \cdot H + 0,0247 \cdot Q - 155,3858 \cdot D^2 - 0,0003 \cdot T^2 + 0,0522 \cdot eH \quad (6)$$

Where G_v is the ozone concentration in water, mg/dm³; D is the column diameter, m ($D = 0,1 - 0,3$ m); G_g is the ozone concentration in the gas mixture, dm³/minute ($G_g = 4 - 13$ dm³/minute); T is the water saturation time, min ($t = 0,5 - 10$ minutes); H is the sampling height, M ($H = 0 - 4$ m); Q is the ozone - air mixture flow rate, dm³/min ($Q = 3,3 - 700$ dm³/min).

Ozone has a higher efficiency compared to the chlorine-containing method of calcium hypochlorite and sodium hypochlorite. In the same way, during the research work, various disinfection methods were used from Table 3 below (temperature 20 °C. pH = 7) when used against indicator bacteria you can see the effectiveness of cleaning up to 99% percent from (E.coli) and viruses.

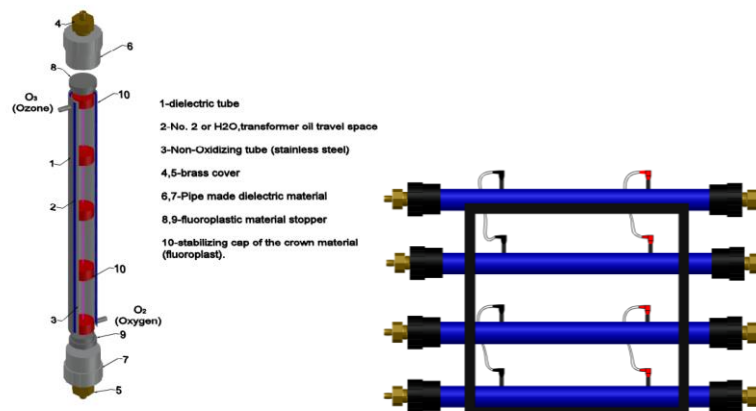


Figure 5: High frequency electric Crown discharge-based pyolot ozonator unit

Table 3: Activity of the most common disinfectants [26]

Disinfectant methods	Bacteria (<i>Escherichia coli</i>)	Poliovirus 1	Cyst (<i>entameba histolytica</i>)
Ozone, O ₃	1950	840	2,7
Calcium hypochlorite Ca(ClO) ₂	110	1,7	-
Sodium hypochlorite NaClO	10	1,21	-
Chloric acid (HOCl)	110	1,7	0,12
Chlorine dioxide (ClO ₂)	10	1,21	-
Hypochlorite ions OCl ⁻	3,5	0,12	-
Dichloramine (NHCl ₂)	0,52	0,0011	-
Chloramine (NH ₂ Cl)	0,013	0,0012	-

To determine the effectiveness of disinfectant oxidants in water supply systems, it was necessary to develop a sanitary reliability criterion, taking into account the types and doses of various reagents, the length of the water supply network, quality indicators. The introduction of such a criterion into practice was included in the basic drinking water supply law in the United States in 1986 (Karaffa-Korbut, 1912).

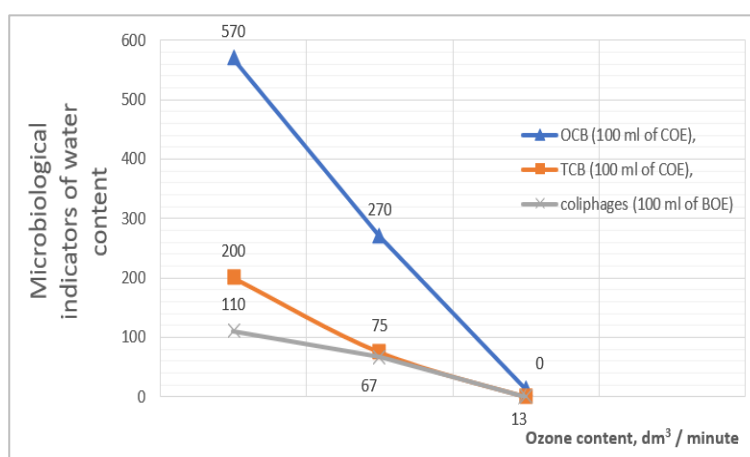
In order to carry out scientific research work on testing the ozonator plant, water was taken from the Ili floodplain and research work was carried out. The total number of microbes in water is 1 ml of Koe, CCB (100 ml of KOE), OCB (100 ml of KOE), coliphages (100 ml of BOE), *Escherichia coli*,

slostridium sp., it was found that microbiological indicators such as *pseudomonas fluorescens* do not come to the size of the MPC. The results of the study of the effectiveness of the process of destruction of bacteria in water by ozone are presented in Tables 4 and 5 below.

As can be seen in the table, it was found that as the amount of ozone increased by 4 - 13 DM³/minute, the content of TCB (100 ml of COE), OCB (100 ml of COE) and coliphages (100 ml of BOE) in water decreased. With an ozone content of about 13 DM³/minute, it can be seen that the water content of TKB, OCD and coliphages is destroyed by 100% percent (Figure 5).

Table 4: Microbiological indicators of water content in the Ili floodplain

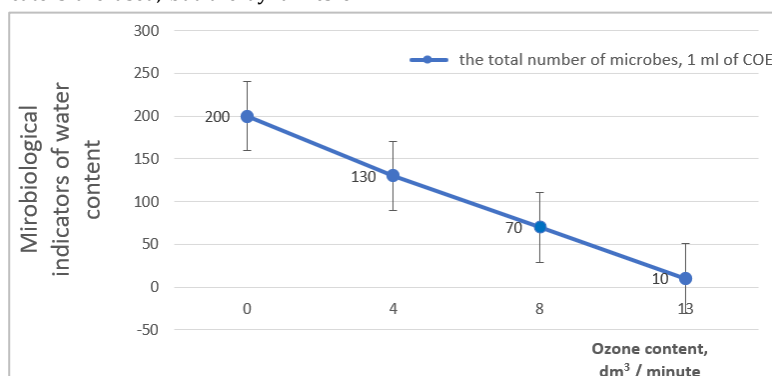
№	Microbiological indicators of water content	Regulations not more (MPC)	Number of microbiological indicators in the composition of primary water	Ozone content dm ³ /minute		
				4	8	13
1	Total number of microbes, 1 ml COE	<50	200	130	75	10
2	TCB (100 ml COE)	0	450	200	75	0
3	OKB (100 ml COE)	0	850	520	270	0
4	Coliphages (100 ml BOE)	0	170	110	67	0

**Figure 6: The relationship between microbiological indicators and ozone content in water**

In practice, the total number of microbes is one of the main indicators indicating the degree of water pollution. To quickly check the sanitary condition of Water Treatment Systems, a Bacteriological Analysis of water is carried out, in which dynamic values are taken into account in the first place.

Also, the analysis is often used when it is necessary to quickly check the operation of disinfection and water treatment systems. To carry out this procedure, not their absolute indicators are used, but the dynamics of

values at certain points of the selected water samples. Comparison of the total number of microbes installed at a temperature of 22 and 37 degrees allows you to determine the state of the processes of self - purification of natural reservoirs. In the course of scientific research, according to the results of laboratory examination, the total number of microbes in the surface water of the Ili floodplain – 200 (1 ml of Koe 200mg/l) was met (Table 4). The process of ozonation was carried out to reduce the total microbial content in the water (Figure 7).

**Figure 7: The relationship between the total number of microbes in water and the amount of ozone**

As can be seen in Figure 7, it can be seen that as the amount of ozone increases, the total number of microbes in the water decreases. In the case of the total number of microbes, the unit of measurement is COE/ml - this value indicates the total value of heterotrophic bacteria that grow during the day at a temperature of about 37 degrees. If the temperature is 22 degrees, it increases to 72 hours in the water content. According to the norm of drinking water, the maximum permissible concentration should

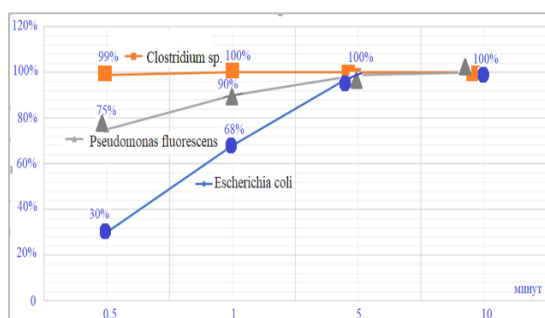
not exceed 50 COE/ml. During the research work, it was found that the total number of microbes decreases by 10 COE/ml in a time of 13 dm³/minute of ozone content.

Escherichia coli, *slostridium sp* in primary water content, the effectiveness of ozone disinfection of microorganisms such as *rseudomonas fluorescens* can be observed in Table 5 and figure 8 below.

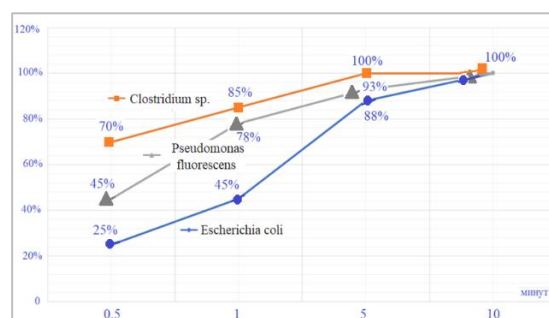
Table 5: Efficiency of ozone disinfection of water, % (percentage)				
Ozone concentration loss, dm ³ /minute	Decontamination time, minute			
	0,5 minute	1 minute	5 minute	10 minute
Escherichia coli				
13 dm ³ /minute	30 %	68 %	100 %	100 %
8 dm ³ /minute	25 %	45 %	88 %	100 %
4 dm ³ /minute	4 %	25 %	50 %	100 %
Clostridium sp.				
13 dm ³ /minute	99 %	100 %	100 %	100 %
8 dm ³ /minute	70 %	85 %	100 %	100 %
4 dm ³ /minute	50 %	65 %	98 %	100 %
Pseudomonas fluorescens				
13 dm ³ /minute	75 %	90 %	99 %	100 %
8 dm ³ /minute	45 %	78 %	93 %	100 %
4 dm ³ /minute	25 %	63 %	75 %	100 %

As can be seen from Table 5, according to the results of the study, 100% percent water content is harmful *Escherichia coli*, *slostridium sp.*, *rseudomonas fluorescens* it can be seen that it takes at least 10 minutes to

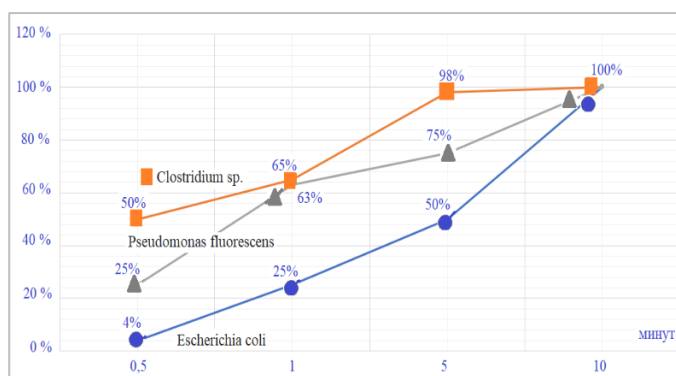
remove microorganisms with ozone and an ozone content of 13 dm³/minute (Figure 8)



a) Ozone concentration 13 dm³/minute



b) Ozone concentration 8 dm³/minute



d) Ozone concentration 4 dm³/minute

Figure 3: Destruction of bacteria in water due to time (a-ozone concentration 13 dm³/minute; b-ozone concentration 8 dm³/minute; d - ozone concentration 4 dm³/minute)

For disinfection of microorganisms contained in such water by chlorine, an active chlorine concentration of more than 100 dm³/minute is required with a period of more than 12 hours (Romanovskii et al., 2015). If the concentration of ozone in water is higher than 100 mg/dm³, the recommended treatment time of at least 5-10 minutes is sufficient. In experimental conditions, it can be seen that the CT criterion for active chlorine is several times less than for ozone.

However, in water that has passed the entire complex of classical treatment plants, including water disinfection, after the decomposition of ozone, there is an increase in the activity of bacteria and an increase in their number. It has been observed that under the influence of ozone, the amount of biodegradable compounds increases as a result of the destruction of organic matter in the water. For the same reason, it

promotes the re-growth of microorganisms in the water supply network. Therefore, when transporting water over long distances, it is correct to disinfect with reagents containing ozone and additional chlorine (chlorine, chloramines, chlorine dioxide) (Abdykadyrov et al., 2023).

In order to evaluate and compare the use of chlorine-containing substances and ozone in water treatment processes, it is necessary to first analyze and consider methods for assessing their costs and negative impact on the environment. For example, it is necessary to conduct an analysis on disinfection technologies at water supply facilities.

Mathematical model of the technological process. The total number of harmful microbes in water is 1 ml of Koe, CCB (100 ml of COE), OCB (100 ml of COE), coliphages (100 ml of BOE), *Escherichia coli*, *slostridium sp.*

special programs Mathcad and SMATH Solver were used to create a mathematical model of the process of destruction of microbiological bacteria and microorganisms, such as *Pseudomonas fluorescens* [28,29]. According to scientific research work, the water disinfection algorithm is presented in Figure 9 below. According to the technological process, the water content of highly hazardous TKB (100 ml of COE), OCD (100 ml of COE) and coliphages (100 ml of BOE) *Escherichia coli*, *Slostridium* sp., an algorithm for reducing and eliminating the amount of *Pseudomonas fluorescens* was compiled and theoretical calculations were carried out. Theoretical calculations were considered according to two options:

3.3 Mathematical Model Of The Technological Process.

The total number of harmful microbes in water is 1 ml of Koe, CCB (100 ml of COE), OCB (100 ml of COE), coliphages (100 ml of BOE), *Escherichia coli*, *Slostridium* sp. special programs Mathcad and SMATH Solver were used to create a mathematical model of the process of destruction of microbiological bacteria and microorganisms, such as *Pseudomonas fluorescens* (Benker, 1999). According to scientific research work, the water disinfection algorithm is presented in Figure 9 below. According to the technological process, the water content of highly hazardous TKB (100 ml of COE), OCD (100 ml of COE) and coliphages (100 ml of BOE) *Escherichia coli*, *Slostridium* sp., an algorithm for reducing and eliminating

the amount of *Pseudomonas fluorescens* was compiled and theoretical calculations were carried out. Theoretical calculations were considered according to two options:

Version A. During the process, the concentration of ozone was changed, keeping the decontamination time ($t = 5$ minutes) constant. The N - maximum allowable concentration (MPC) can be calculated as follows.

$$N = \frac{1}{\sum_{n=1}^m K \cdot G \cdot t}, (100 \text{ ml COE}) \quad (7)$$

Where $\sum_{n=1}^m K$ - algebraic sum of harmful bacteria in water; G - ozone content ($\text{dm}^3/\text{minute}$); t - decontamination time (minutes).

By changing the concentration of ozone (G_{ozone} , $\text{dm}^3/\text{minute}$) using the expression (7), the value of the N - maximum allowable concentration (MPC) can be calculated as follows:

$$N_1 = \frac{1}{\sum_{n=1}^m K \cdot G_1 \cdot t}, \text{ there } G_1 = 4 \text{ dm}^3/\text{minute} \quad (8)$$

$$N_2 = \frac{1}{\sum_{n=1}^m K \cdot G_2 \cdot t}, \text{ there } G_2 = 8 \text{ dm}^3/\text{minute} \quad (9)$$

$$N_3 = \frac{1}{\sum_{n=1}^m K \cdot G_3 \cdot t}, \text{ there } G_3 = 13 \text{ dm}^3/\text{minute} \quad (10)$$

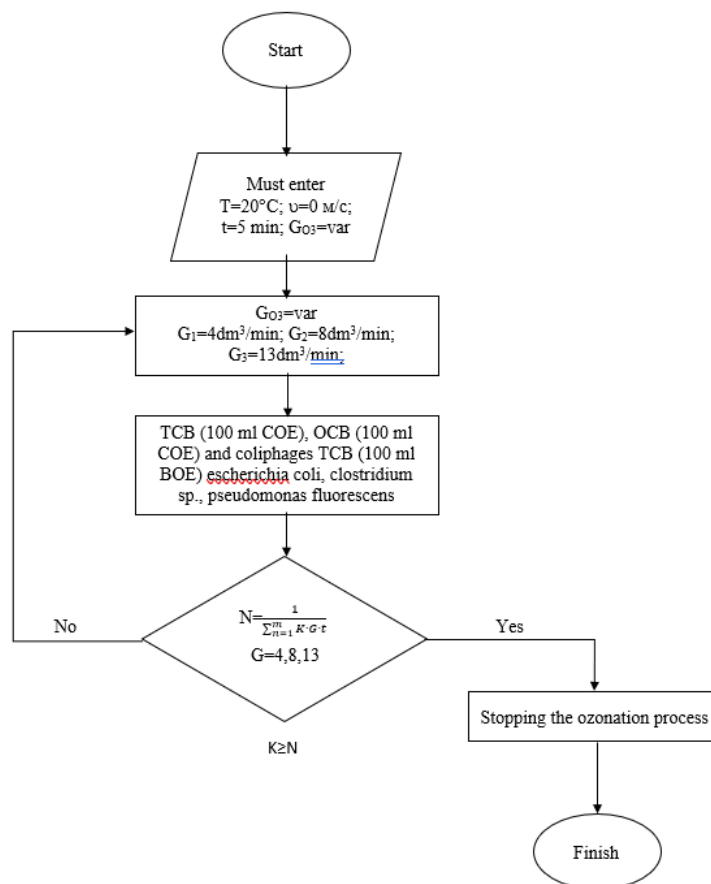


Figure 9: Algorithm of the process of destruction of harmful microorganisms in water ($t = \text{const}$)

Figure 9 of the above expression (7) shows that the process of destroying harmful microorganisms in water by the algorithm is the effective amount of ozone $G_{\text{ozone}} = 13 \text{ dm}^3/\text{minute}$. At this point, it can be seen that the microorganisms contained in the water are destroyed by 100% percent. During the technological process, it is possible to neutralize the composition of water from harmful compounds by changing the time constant at some point. If we keep the amount of ozone in the water constant ($G_{\text{ozone}} = \text{const}$) and change the decontamination time, then we can determine the effective time constant.

Version B. Keeping the ozone concentration ($G_{\text{ozone}} = \text{const}$) constant and changing the time, it can be seen that the harmful microbiological indicators in the water have decreased.

In Figure 10, it can be seen that the decontamination i.e. the longer the contact time, the greater the quality of the water. The experimental data presented in Figure 10 can theoretically be calculated as follows. Where $T = 15 - 20^\circ\text{C}$; $v = 0 \text{ m/c}$; $G = 8 \text{ dm}^3/\text{minute}$; $t = \text{var}$. That is, $t_1 = 0.5 \text{ min}$; $t_2 = 1 \text{ min}$; $t_3 = 5 \text{ min}$; $t_4 = 10 \text{ min}$. Depending on the time elapsed during the

decontamination process, the N - maximum allowable concentration (MPC) can be calculated as follows.

$$N_1 = \frac{1}{\sum_{n=1}^m K \cdot G \cdot t_1}, \text{ there } t_1 = 0.5 \text{ minute} \quad (11)$$

$$N_2 = \frac{1}{\sum_{n=1}^m K \cdot G \cdot t_2}, \text{ there } t_2 = 1 \text{ minute} \quad (12)$$

$$N_3 = \frac{1}{\sum_{n=1}^m K \cdot G \cdot t_3}, \text{ there } t_3 = 5 \text{ minute} \quad (13)$$

$$N_4 = \frac{1}{\sum_{n=1}^m K \cdot G \cdot t_4}, \text{ there } t_4 = 10 \text{ minute} \quad (14)$$

If the algebraic sum of harmful microorganisms in water is $K \geq N$, then the decontamination process will have to be extended. During the research work, it was theoretically and experimentally established that the nominal value of ozone is $G_{\text{ozone}} = 8 - 13 \text{ dm}^3/\text{minute}$, and the neutralization time is 10 minutes, harmful microorganisms contained in water are destroyed by 99 - 100% percent.

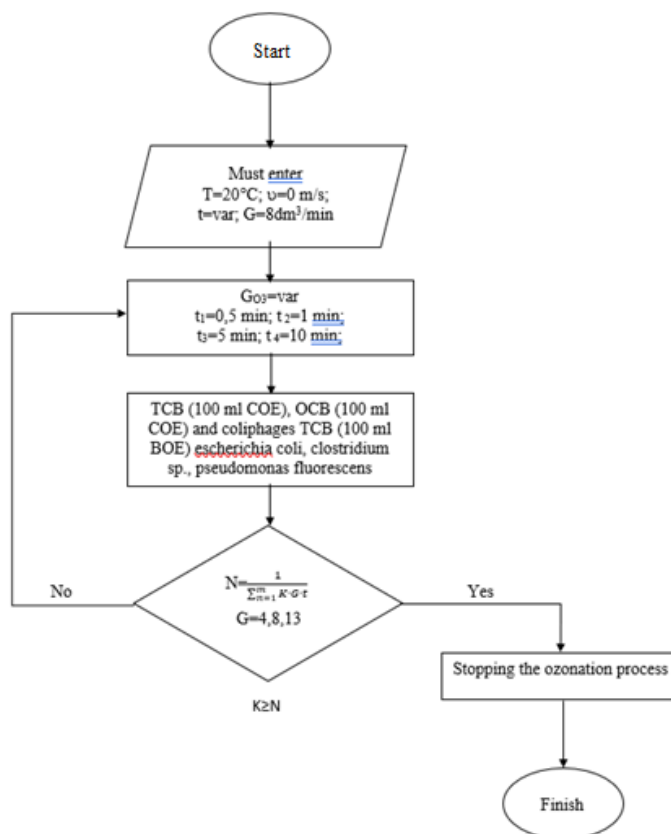


Figure 10: Algorithm of the process of destruction of harmful microorganisms in water

4. DISCUSSION OF RESEARCH WORK IN TECHNICAL AND ECONOMIC CONTEXT.

A comparative analysis of the properties of the main oxidants, which are often used in production, was carried out on the process of decontamination and purification of surface water from harmful microorganisms. A comparative analysis of the corrosive activity of chlorine-containing disinfectant solutions, such as sodium hypochlorite, calcium hypochlorite, chloramine with an active chlorine concentration of 50, 100 and 150 mg/dm³, as well as a saturated solution of ozone in water, was carried out.

The research was carried out by gravimetric and indirect electrochemical

methods. In the above scientific works, it was found that sodium hypochlorite has the highest oxidative activity of a saturated solution of ozone in water compared to chlorine-containing disinfectant solutions. Therefore, it is noted that, for example, in the processes of disinfection of water supply facilities, there is a significant reduction in ozone treatment time and a significantly lower corrosion mass index compared to chlorine-containing reagents.

According to the scientific research work, the categories of ozone effects on the environment (carcinogenic, effects on the respiratory organs, ozone depletion, ecotoxicity to water and land resources, etc.) were identified. The comparative results of various disinfectants in the category of exposure, except ozone, which are currently used in water management, were discussed (Figure 11).

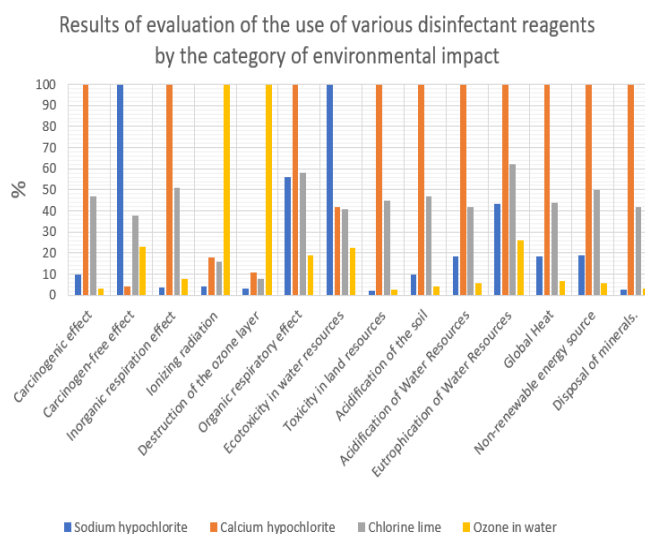


Figure 11: Comparative results of various disinfectant oxidants by category of action

On the graph, it can be observed that the most dangerous for the environment and humanity is calcium hypochlorite, a disinfectant with chlorine.

The research paper also presents the results of a comparison of three strong decontamination methods such as calcium hypochlorite, sodium hypochlorite and ozone in terms of capital and current costs between 2013 and 2023 (figure 12,13).

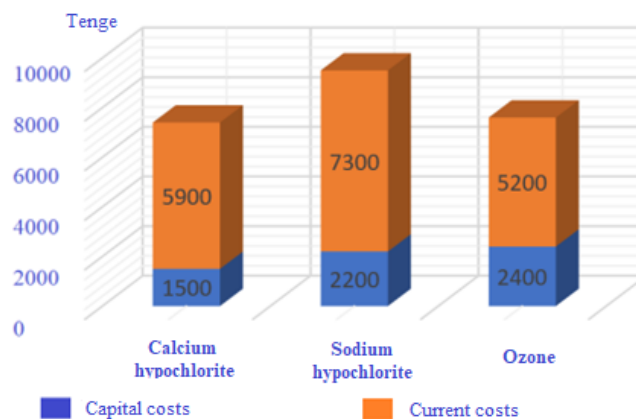


Figure 12: Comparison of the three selected methods of disinfection by Capital and current costs without taking into account the time factor

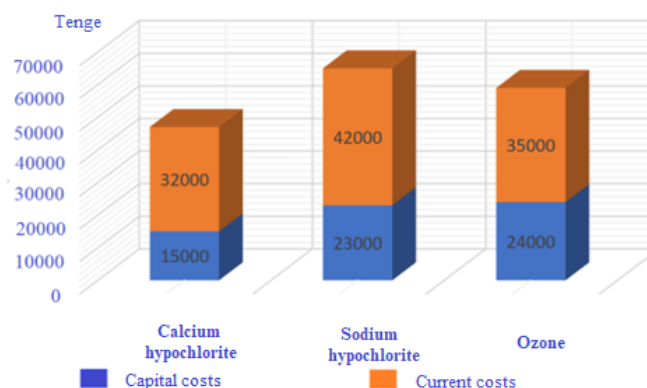


Figure 13: Installation costs between 2013 and 2023

When calculating the sum of costs during the general technological process, the following values should be taken into account:

- cost of raw materials and materials;
- salary expenses;
- depreciation charges;
- cost of technological energy;
- equipment maintenance cost;
- costs of current equipment repairs;
- costs for maintaining the working area;
- the cost of moving the unit to the processing site.

Taking into account these issues, a comparison of current cost items for each version of the disinfectant was considered.



Figure 14: Comparison of three selected disinfection methods by current costs

According to the results of the calculation of technical and economic indicators, disinfection technology using ozone is more economical than using disinfectant solutions containing chlorine. In general, ozone technology has a lot of capital costs, and current costs are very small. At the same time, the largest share of current costs when using chlorine – containing reagents is the cost of raw materials and materials, and when using ozone-depreciation costs.

Among the considered options, the most effective chlorine-containing reagents are sodium hypochlorite. However, if we compare chlorine-containing reagents with ozone, ozone technology is the most effective. It can be noted that the use of ozone facilitates the process, improves the

efficiency of disinfection, reduces the processing time, reduces the corrosive effect on metal parts of water pipes and is environmentally safe. Another feature of ozone is that water does not contain residual ozone, such as chlorine ozone, which decomposes into oxygen in water for a short time.

5. CONCLUSIONS

In order to study the process of disinfection and purification of surface water from harmful micro-organisms, the Department of Electronics, Telecommunications and space technologies of the Kazakh National Research Technical University named after K. I. Satpayev developed a pilot

ozonator installation based on a special electric discharge. For practical testing of the plant, the main advantages of ozone in comparison with other oxidizing agents were revealed when performing ozonation work with the removal of water from the Ili floodplain:

- During the decontamination process, it was found to be a stronger oxidizing agent than chlorine. For example, water has been found to oxidize and clean chemical pollutants in addition to micro-organisms. In particular, the effectiveness of color, smell, taste, removal of iron, manganese, phenols, petroleum products, surfactants was noted;
- High biocidal activity, including the effect against viruses and cysts, and microbiological indicators found in water, including the complete disappearance of thermotolerant coliform bacteria, in general coliform bacteria, were found;
- It has been found to improve the efficiency of filter and coagulation work during water treatment work;
- The proposed design simplicity of the ozonator installation based on a pilot electric discharge and an automation system for the process of water disinfection have been created;
- The main feature of the device was found to reduce the harmful effect of drinking water on human health in sanitary and hygienic conditions;
- It was found that the process of ozone purification and disinfection of water in surface reservoirs and water areas, which are subject to environmental problems, does not have a negative impact on the environment;
- It was found that there are no compounds such as indirectly toxic organochlorine reaction products.
- Scientific results on research work were made on a pilot ozonator installation based on an electric discharge. Scientific and practical research work was carried out in 2018-2023 at the training and drilling training ground of the Kazakh National Research Technical University named after K. I. Satpayev.

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