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RESEARCH ARTICLE

STUDY OF THE PROCESS OF NEUTRALIZATION OF MICROORGANISMS IN DRINKING WATER EXPOSED TO ENVIRONMENTAL PROBLEMS

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ABSTRACT

The scientific research investigates the neutralization and purification process of harmful microorganisms present in surface water using an ozonator device, which operates based on a pilot electric discharge method. 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. The examination results revealed the presence of several harmful microorganisms in the source water, surpassing the maximum allowable 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 1m^3 surface water was compiled and a mathematical model was given.

KEYWORDS

Ozonator, ozone, ozone content, primary water, water field, ozonated water, surface water, 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, 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 offers several advantages compared to water decontamination with chlorine:

- Ozone boasts a high oxidizing potential, resulting in a stronger bactericidal effect in water compared to other chemical agents.
- Ozone not only impacts the redox system of bacteria but also directly affects their protoplasm.
- Ozone works 15 to 20 times faster than chlorine. For instance, while ozone at a dosage of 0.45 mg/l eliminates the polio virus in 2 minutes, chlorine, at a dosage of 2 mg/l, achieves the same result after 3 hours.
- The required quantity of ozone is approximately 2.5 times less than that of chlorine (Draginsky et al., 2007).

Moreover, the bactericidal efficacy of ozone is less influenced by pH levels within the range of 6 to 10 and water temperatures between 0 to 37°C. However, the effectiveness of ozone's bactericidal impact can be affected by the presence of floating and dissolved organic substances, as well as non-ferrous and chemical pollutants in the water composition.

The enhancement of surface water disinfection methods is currently progressing across several key areas. (Figure 1):

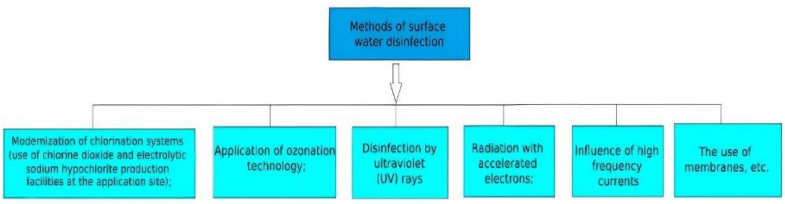

Figure 1:Water disinfection processes

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Currently, methods of water disinfection using ozone and UV radiation are quite common in Europe and America (U.S.Environmental Protection Agency, 1989; 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_2Cl	O_3	UV
Australia	+++	+	++	-	+
Austria	+++	+	-	+	+
Belgium	+++	+	-	+	-
Belarus	+++	-	-	+	+
Bulgaria	+++	-	-	-	+
Hungary	+++	-	+	+	-
UK	+++	+	+	-	+
Germany	+++	+++	-	++	+
Spain	+++	+	-	++	-
Ireland	+++	-	-	+	-
Italy	+++	+++	-	-	-
China	+++	-	-	+	-
Norway	++	-	+	-	++
Poland	+++	+	+	+	-
Finland	+++	+	+	+	-
USA	+++	+	+	+	+
Russia	+++	-	-	+	+
France	++	++	-	++	-
Czech Republic	+++	-	-	+	-
Sweden	+	++	-	++	++
Sweden	+++	+	++	-	-
Japan	+++	-	-	+	-
South Africa	+++	-	+	+	-

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: Cl_2 -1.36 V, O_2 – 1.23 V), which is the main reason for its activity in relation to various types of water pollution, including microorganisms (Orlov, 1984). In the absence of bromides, by-products are not formed in distilled water (Battino, R., 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 (Sonntag, 2012).Which use ozonation technology as one of the steps in water purification and decontamination processes (Sedlak David, 2011).

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., 2003).

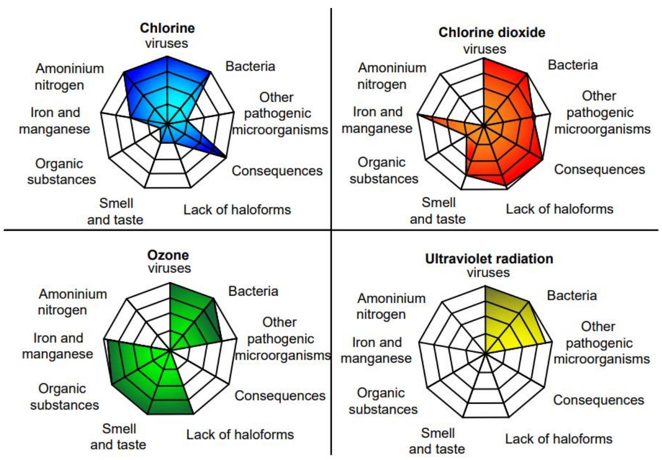


Figure 2: Efficiency of surface water disinfection methods (Abdykadyrov, et al., 2003).

In the decontamination and purification process of water, ozone dissolves at a slower rate compared to chlorine. To enhance ozone solubility in water, it's necessary to increase both the contact time and the surface area of contact. 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 et al., 1995) provides data on the solubility of ozone in water depending on temperature, as well as in the W. B. Kogan's solubility handbook using the Bunsen coefficient (Punmia, et al., 1995). The conditions given in the definitions make it possible to theoretically predict the equilibrium concentration of ozone (Kogan et al., 1996; Punmia, et al., 1995). Nevertheless, the process of ozone dissolution in natural water is subject to numerous factors, including the presence of oxidizing agents, the ozone concentration in the gas mixture, pressure, the size of gas bubbles produced by the aerator, and various other factors that are not accounted for in the fundamental formulas. Thus, 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 (Romanovsky et al., 2015).

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 et al., 2007).

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

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

The table illustrates that during the ozonation process of water, it engages with various mechanisms within the water composition, targeting microorganisms, and facilitating the oxidation of heavy and light metals present, as well as the decomposition of organic compounds like fats. Water undergoes microbacteria destruction while oxidizing its chemical elements. Ozonation offers several advantages over chlorination:

- Due to ozone's high oxidizing potential, its bactericidal effect in water surpasses that of other chemical reagents.
- Ozone not only affects the redox system of bacteria but also directly impacts their protoplasm.
- Ozone operates 15 to 20 times faster than chlorine. For instance, while ozone eradicates the Rotavirus in 2 minutes (with an ozone content of 0.45 mg/l), chlorine achieves the same effect after 3 hours at a dosage of 2 mg/l.

- The required quantity of ozone is approximately 2.5 times less than chlorine.

3.1 The Process of Ozone Dissolving in Water During The Technological Procedure.

During the dissolution of ozone in water, two simultaneous processes occur: its tendency to react with chemicals in the water and its own distribution. These processes are influenced by factors such as water temperature, pH level, and the types of ions dissolved, which determine the ionic strength. In general, the rate of ozone propagation in water can be expressed as: (Draginsky et al., 2007).

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

where, $К_p$ 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 V.A., 1996; Draginsky et al., 2007):

$$\begin{aligned} &O_3 + H_2O \rightarrow 2OH^* + O_2 \\ &O_3 + OH^- \rightarrow O_2{}^{-*} + HO_2 \\ &O_3 + OH^* \rightarrow O_2 + HO_2{}^* \Leftrightarrow O_2{}^{-*} + H^{\pm} \\ &O_3 + HO_2{}^* \rightarrow 2O_2 + OH^* \\ &2HO_2{}^* \rightarrow O_2 + H_2O_2 \end{aligned} \quad (2)$$

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).

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

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

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).

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, although the results of the kinetics of ozone decay are different their value under experimental conditions is completely different (Gurol and Singer, 1982; Olah et al., 1976).

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, 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, 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 et al., 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, and Bader,1983).

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

One of the key practical challenges in utilizing ozone for water disinfection and purification processes is assessing its corrosive potential when compared to chlorine-based solutions.

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 Satpayev University. The technological scheme of the unit is presented in Figure 4 below.

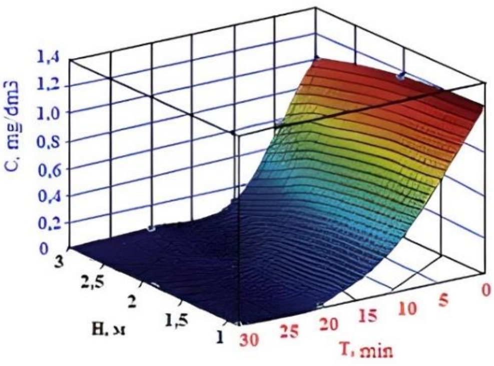
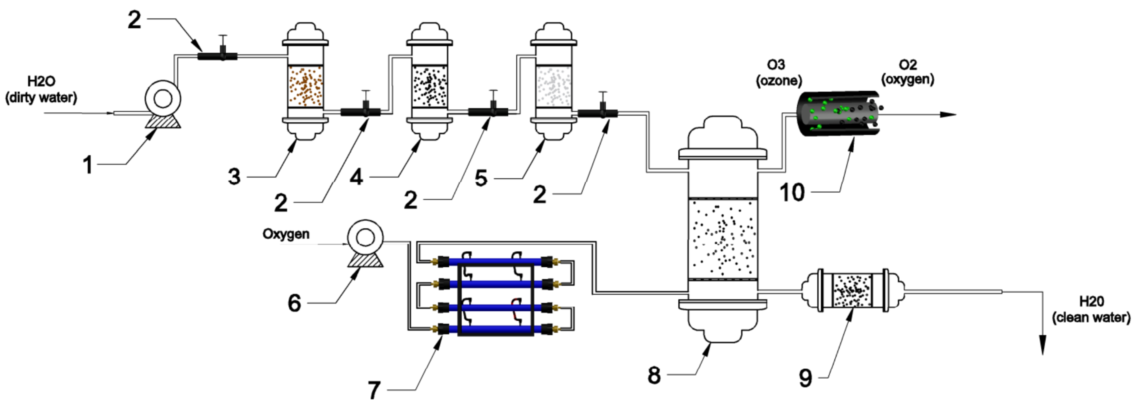


Figure 3: Decomposition of dissolved ozone in water at the top of the column



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

The operational characteristics of the technological scheme are outlined as follows: The initial water, bypassing the pump (1) and sourced from the surface, enters the sand bed of the first zeolite (3). This zeolite bed mechanically cleans the water beforehand. The purified water then traverses through activated carbon (4) to eliminate toxic substances, and a quartz filter to diminish water coloration. Subsequently, the water encounters ozone (8), introduced into the tank (8) through the ozonator (7) powered by a compressor (6). After a 30-minute duration, the ozonated water undergoes filtration via a membrane filter (9) before distribution to consumers. Any residual ozone present on the tank's surface is decomposed utilizing a destructor (10) and released into the atmosphere. The general structure of the upper-frequency corona discharge-based ozonator (7) is illustrated in Figure 5.

Based on the results of Experimental Studies, a regression equation describing the concentration of ozone in water (G_v mg/dm^3) was obtained from the studied parameters:

$$G_v = 3{,}9436 - 27{,}2356 \cdot D + 0{,}0339 \cdot G_г + 0{,}0286 \cdot T - 0{,}0456 \cdot H + 0{,}0247 \cdot Q - 155.3858 \cdot D_2 - - 0.0003 \cdot T_2 + 0.0522 \cdot e_н \quad (6)$$

Where G_v is the ozone concentration in water, mg/dm^3; D is the column diameter, m (D = 0,1 - 0,3 m); G_G is the ozone concentration in the gas mixture, dm^3/minute (Gg = 4 - 13 dm^3/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, dm^3/min (Q = 3.3 - 700 dm^3/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 ^{0}C. pH = 7) when used against indicator bacteria you can see the effectiveness of cleaning up to 99% percent from (E.coli) and viruses.

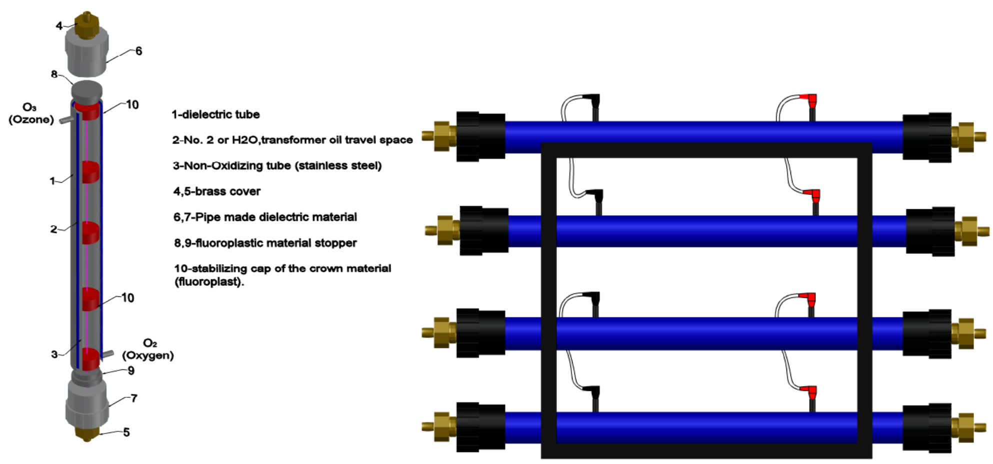


Figure 5: High frequency electric Crown discharge-based pyolot ozonator unit

In order to evaluate the efficiency of disinfectant oxidants in water supply systems, it was essential to establish a sanitary reliability standard. This standard needed to consider factors such as the types and quantities of different reagents used, the length of the water supply network, and quality parameters. The implementation of such a criterion became part of the foundational drinking water supply legislation in the United States in 1986 (Karaffa-Korbut et al., 1912) [27].

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 rseudomonas 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).

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).

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

№	Microbiological markers reflecting water quality	Regulations not more (MPC)	Number of microbiological indicators in the composition of primary water	Ozone content dm³/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

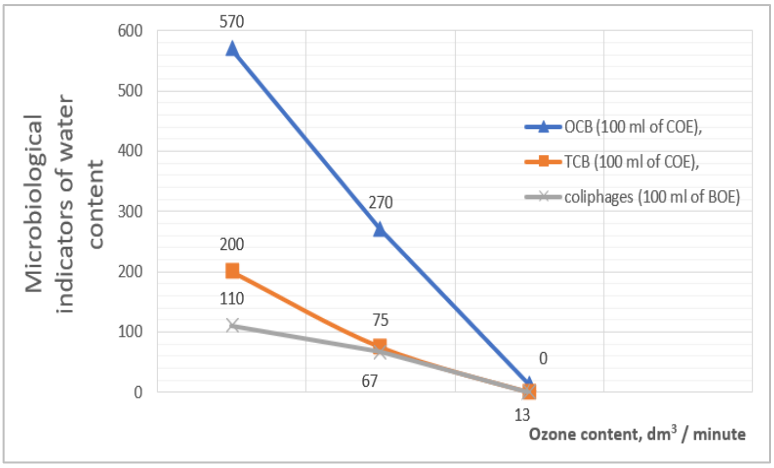


Figure 6: The relationship between microbiological indicators and ozone content in water

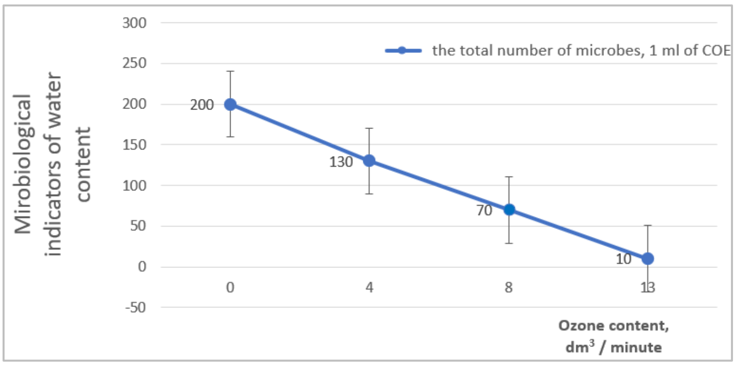


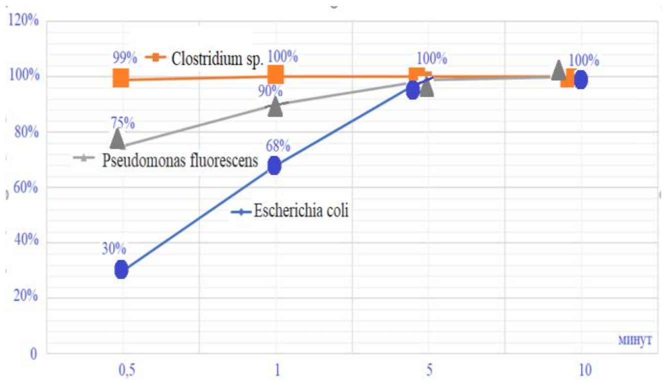
Figure 7: The correlation between the total microbial count in water and the concentration of ozone

As depicted in Figure 7, there is a clear trend showcasing a decrease in the total microbial count in water as the ozone concentration increases. 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.

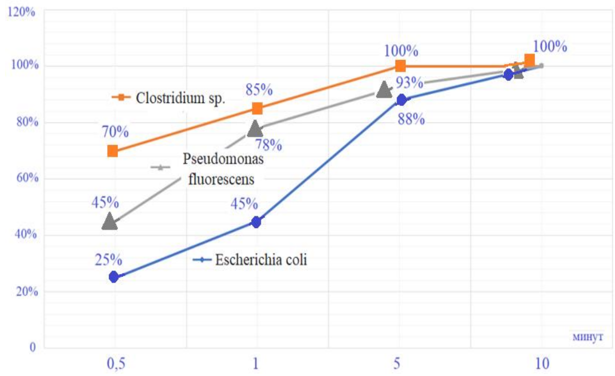
Escherichia coli, slostridium sp in primary water content., the effectiveness of ozone disinfection of microorganisms such as rseudomonas fluorescens can be observed in Table 5 and figure 8 below.

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).

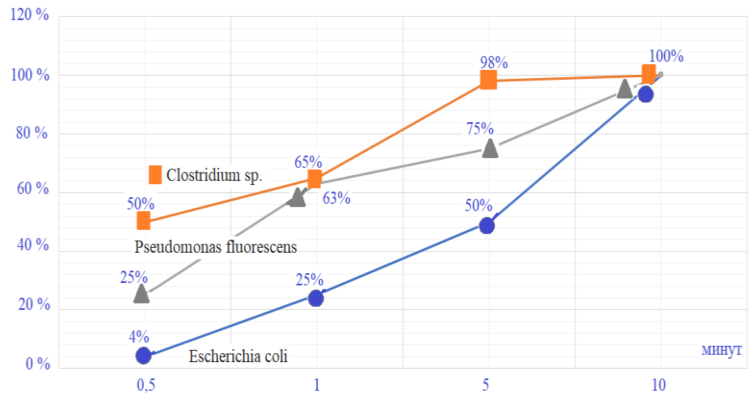
Table 5: Efficiency of ozone disinfection of water, % (percentage)				
Ozone concentration loss, dm³/minute	Decontamination time, minute			
	0,5 minute	1 minute	5 minute	10 minute
	Escherichia coli			
13 dm³/minute	30 %	68 %	100 %	100 %
8 dm³/minute	25 %	45 %	88 %	100 %
4 dm³/minute	4 %	25 %	50 %	100 %
	Clostridium sp.			
13 dm³/minute	99 %	100 %	100 %	100 %
8 dm³/minute	70 %	85 %	100 %	100 %
4 dm³/minute	50 %	65 %	98 %	100 %
	Pseudomonas fluorescens			
13 dm³/minute	75 %	90 %	99 %	100 %
8 dm³/minute	45 %	78 %	93 %	100 %
4 dm³/minute	25 %	63 %	75 %	100 %



a) Ozone concentration 13 dm³/minute



b) Ozone concentration 8 dm³/minute



d) Ozone concentration 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 (Romanovsky 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 undergone comprehensive treatment in conventional treatment plants, including disinfection, there is a subsequent rise in bacterial activity and population after ozone decomposition. This phenomenon is attributed to the increase in biodegradable compounds resulting from organic matter breakdown in water due to ozone treatment. Consequently, it fosters the regrowth of microorganisms within the water distribution system. Hence, it is advisable to disinfect water during long-distance transportation using reagents containing both ozone and additional chlorine (such as chlorine, chloramines, or chlorine dioxide) (Abdykadyrov et al., 2003).

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.

A mathematical model representing the technological process. The mathematical model of the process involves determining the destruction of microbiological bacteria and microorganisms, including Pseudomonas fluorescens, based on the initial concentrations of harmful microbes in water. Specialized software programs like Mathcad and SMath Solver were utilized for this purpose (SMathStudio. 2010; Mathcad mathematical system. 2024). Based on scientific research, the water disinfection algorithm outlined in Figure 9 addresses the presence of highly hazardous components such as TKB (100 ml of COE), OCD (100 ml of COE), coliphages (100 ml of BOE), Escherichia coli, and Clostridium sp. Additionally, an algorithm was devised for reducing and eliminating Pseudomonas fluorescens. Theoretical calculations were conducted based on two alternative approaches:

3.3 A Mathematical Representation 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 rseudomonas fluorescens (SMathStudio. 2010 ; Mathcad mathematical system. 2024). 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 rseudomonas fluorescens was compiled and theoretical calculations were carried out. Theoretical calculations were conducted based on two options:

Option A: In this version, the concentration of ozone was varied while keeping the decontamination time constant at 5 minutes. The maximum allowable concentration (MPC) can be calculated as follows.

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

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

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

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

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

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

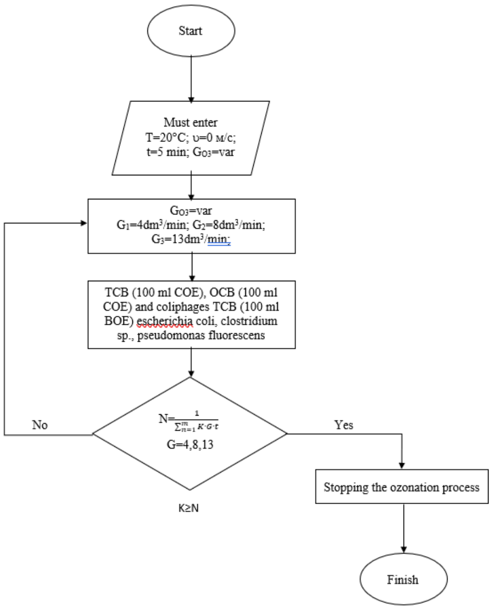


Figure 9: Algorithm of the process of destruction of harmful microorganisms in water *(t=const)*

Figure 9 illustrates that the effectiveness of destroying harmful microorganisms in water is dependent on the appropriate concentration of ozone G_{ozon} = 13 dm^3/minute. At this point, it can be seen that the microorganisms contained in the water are destroyed by 100% percent. In the technological process, it is feasible to neutralize the composition of water from harmful compounds by adjusting the time constant at a certain juncture. By maintaining a constant ozone concentration in the water (G_{ozon} = const) and altering the decontamination time, we can ascertain the effective time constant.

Option B. Keeping the ozone concentration (G_{ozon} = 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 ^{0}C; υ = 0 m/c; G = 8 dm^3/minute; t = var. That is, t_1 = 0.5 min; t_2 = 1 min; t_3 = 5 min; t_4 = 10 min. Depending on the time elapsed during the decontamination process, the N - maximum allowable concentration (MPC) can be calculated as follows.

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

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

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

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

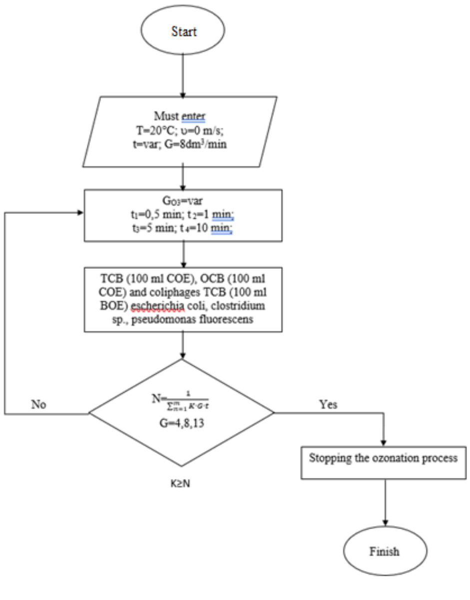


Figure 10: Process algorithm for eliminating harmful microorganisms in water

If the algebraic sum of harmful microorganisms in water is K ≥ 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 Gozon = 8 - 13 dm^3/minute, and the neutralization time is 10 minutes, harmful microorganisms contained in water are destroyed by 99 - 100% percent.

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 micro-organisms. 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/dm^3, 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).

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).

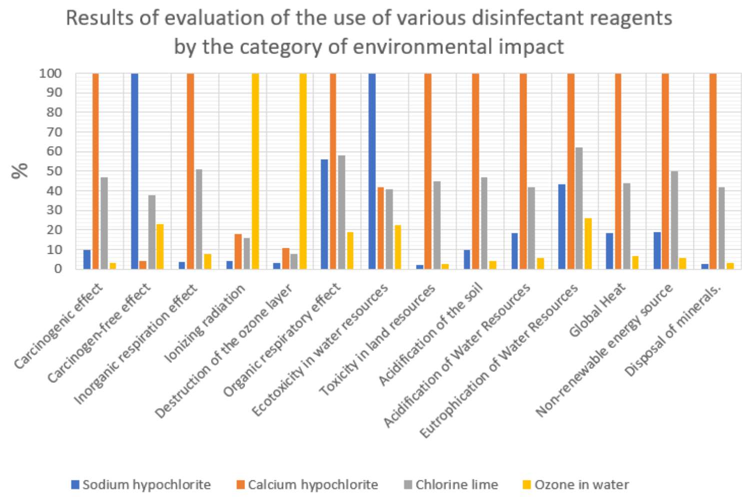


Figure 11: Comparative results of various disinfectant oxidants by category of action

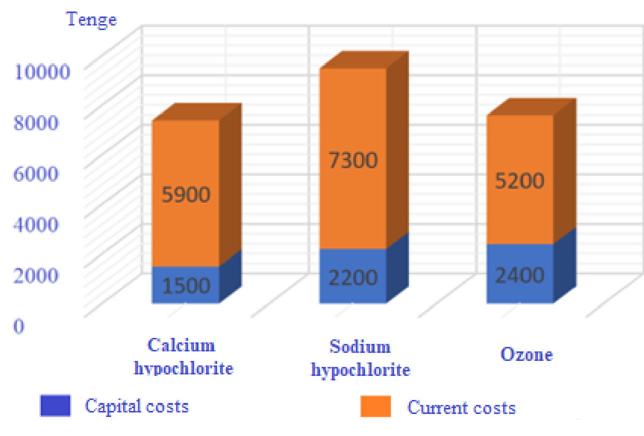


Figure 12: Comparison of the three selected methods of disinfection by Capital and current costs without taking into account the time factor

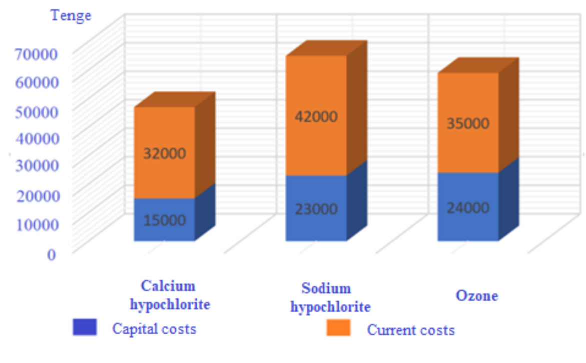


Figure 13: Installation costs between 2013 and 2023

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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.

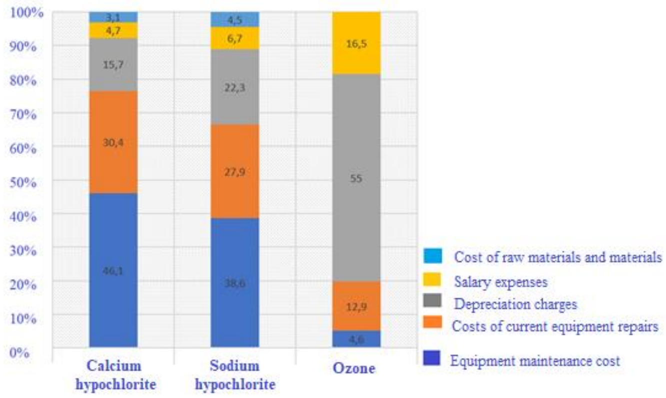

Figure 14: Comparison of three selected disinfection methods by current costs

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

- To investigate the disinfection and purification process of surface water from harmful microorganisms, Satpayev University designed a pilot ozonator installation utilizing a unique electric discharge method. During practical testing of the facility, the primary benefits of ozone over other oxidizing agents were demonstrated, particularly during ozonation operations targeting 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 Satbayev University.

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