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RESEARCH OF METHODS FOR WATER DISINFECTION

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ABSTRACT *Access to safe water remains a challenge in conflict-affected areas. Irregular water supply, which is becoming a common phenomenon, is caused by numerous factors, in particular: 1) wear and tear of water mains that need repair and were damaged as a result of hostilities; 2) reduction in the efficiency of important pumps due to power outages, shelling of power lines that supply energy to the pumps; 3) access problems due to the presence of armed groups, the presence of mines or unexploded shells, as well as the poor condition of roads, which prevent local residents from reaching wells or obtaining water delivered by tankers; 4) problems with access, due to which workers cannot perform repair work or obtain spare parts necessary for repairing water pipes; 5) normative legal acts that limit the freedom of movement and/or supply of goods or water across the contact line, affecting the supply of water from settlements controlled by Ukraine to settlements not controlled by Ukraine; as well as 6) frequent water supply interruptions, which contributed to the deterioration of the situation. In most cases, the use of a combined system can be optimal for high-quality water disinfection. Combined water disinfection is carried out by physical and chemical methods at the same time. Water pollution is determined by its bacteriological examination, which shows the total number of bacteria and the number of indicator bacteria of the coliform group (E. coli) in 1 milligram of water. The main type of bacteria of the Escherichia coli group is E.coli bacteria, which in practice are the easiest to determine and have a high level of resistance coefficient. Traditional methods of water disinfection, namely chlorination and ozonation, are harmful byproducts of disinfection. Ultraviolet radiation is a safe alternative, but quite energy-consuming. The paper analyzes existing methods of decontamination of drinking water, examines the state of the issue, and analyzes alternative methods of decontamination of drinking water.*
Keywords*: ozonation; water disinfection; ultraviolet; water purification*

ДОСЛІДЖЕНЯ МЕТОДІВ ЗНЕЗАРАЖЕННЯ ВОДИ

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АНОТАЦІЯ *Доступ до безпечної води залишається проблемою в районах, уражених конфліктом. Нерегулярне водопостачання, яке стає звичним явищем, зумовлене численними факторами, зокрема: 1) зношеністю водогонів, які потребують ремонту та були пошкоджені внаслідок бойових дій; 2) зниження працездатності важливих насосів через перебої з електропостачанням, обстріли електромереж, що постачають енергію насосам; 3) проблеми з доступом через присутність озброєних груп, наявність мін або снарядів, що не розірвалися, а також поганий стан доріг, що не дозволяє місцевим мешканцям дістатися до колодязів або отримати воду, що доставляється автоцистернами; 4) проблеми з доступом, через які працівники не можуть виконувати ремонтні роботи або отримати запчастини, необхідні для ремонту водопроводів; 5) нормативно-правові акти, які обмежують свободу переміщення та/або постачання товарів чи води через лінію зіткнення, що впливає на постачання води з підконтрольних Україні населених пунктів до непідконтрольних їй населених пунктів; а також 6) часті перебої з водопостачанням, що сприяло погіршенню ситуації. У більшості випадків оптимальним для якісного знезараження води може бути використання комбінованої системи. Комбіноване знезараження води здійснюється фізичним і хімічним методами одночасно. Забрудненість води визначається за допомогою її бактеріологічного дослідження, яке показує загальну кількість бактерій та кількість бактерій-індикаторів групи кишкової палички (E. coli) в 1 міліграмі води. Основним видом бактерій групи кишкової палички є бактерії E.coli, які на практиці найлегше визначаються та мають високий рівень коефіцієнта резистентності. Традиційні методи знезараження води, а саме хлорування та озонування, утворюють шкідливі побічні продукти дезінфекції. Ультрафіолетове випромінювання є безпечною альтернативою, проте досить енергозатратною. В роботі проаналізовано існуючі методи знезараження питної води, розглянуто стан питання та проаналізовано альтернативні методи знезараження питної води.*
Ключові слова: *озонування; знезараження води; ультрафіолет; очищення води*

Introduction

Today in Ukraine, the level of water purification is very low, as a result of which there is insufficient disinfection of water, which may contain various industrial and infectious pollutants that can cause various diseases, both among humans and animals.

The problem of water purification and disinfection is one of the most pressing issues of today's science and technology. The reason is the excessive pollution of the entire water basin of the Earth, connected with the economic activities of people. The growth of cities, industrial and rural production, as well as in as a result of the military offensive launched by the Russian Federation on February 24th, 2022, and drastic climate change, Ukraine's environmental security, especially water is under threat.

According to UNICEF, more than 6 million Ukrainians have faced the problem of unhindered access to drinking water, which is an essential vital resource without which people are unable to live for more than a

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few days. In general, 13.6 million residents of Ukraine in 20 regions suffer from a lack of water for sanitary and hygienic needs. Most of the supply water pipes are damaged, leaving urban inhabitants without a reliable source of drinking water and creating catastrophic environmental threats (especially in frontline cities).

Purpose of work

The purpose of the work is the technical and ecological substantiation of water disinfection for drinking purposes.

Presenting main material

Considerable scientific interest is caused by the possibility of using potentially dangerous natural water from surface sources, meltwater, and rainwater as drinking water sources. Unfortunately, such water may contain chemical pollutants of organic and inorganic origin and pathogenic microorganisms, such as bacteria and viruses, which are more dangerous to human health. In particular, contaminated drinking water threatens the development of infectious diseases, such as viral hepatitis A, typhoid, dysentery, cholera, rotavirus infections, etc.

Modern technologies make it possible to purify water from foreign impurities: in particular, special tablets, chemical disinfectants, the reverse osmosis method, and the use of filters. However, access to reagents is not always possible.

In recent years, scientists worldwide have paid attention to reagent-free water purification and disinfection methods that require electrical energy: ultraviolet (UV) water disinfection, ozonation, cavitation, silver treatment, the use of photo-catalysts, membrane filter methods, etc. One of the topical directions of the developed technology is the use of combined methods, for example, UV radiation with other physical and chemical effects, enhancing the disinfecting one.

However, none of these methods is universal and requires additional research. The lack of data on the effectiveness of each method, its combination, and science-based water disinfection technology that can be used for domestic needs remains an unresolved issue. Consequently, research and development of effective methods of obtaining drinking water in the extreme conditions in which Ukraine is today should become one of the main tasks on the way to ensuring environmental security. The results of such studies will have practical value and contribute to the determination of an effective method of disinfection and the intensity of the impact on microorganisms. Disinfection and purification methods can be applied to research in other areas, e.i. the food industry, water treatment, wastewater disinfection, etc. As a result, it is envisaged to create an easy-to-use portable water purification and disinfection device that will not require electricity and use effective methods of impacting pathogenic microorganisms.

The results of the research of real samples of rain and river waters of the regions in Ukraine and methods for their disinfection by reagentless methods in the form of scientific publications will create a scientific base and enable the scientific community to get acquainted with the results of the research. In turn, the studies of methods alternative to water chlorination are especially relevant in the context of the concept of sustainable development not only in Ukraine but in the world as a whole.

The problem of contamination of drinking water in Ukraine is now felt by millions of people living in the front-line territory, which is why the research and the development of a new method of purification can save millions of lives. Consumption of clean water in the absence of access to a central water supply will prevent poisoning with low-quality water, eliminate human intestinal infections (cholera, diphtheria, typhoid fever, etc.), and reduce the risk of epidemics.

1. Methods of water disinfection

Nowadays, the disinfection methods used in the practice of water supply and drainage can be divided into three groups: -chemical; - physical; - physico-chemical.

Recently, various modern methods of disinfection have been used to disinfect drinking water and reduce the risk. Developed countries are increasingly using ozonation (disinfection, deodorization, and discoloration are achieved by oxidizing organic compounds with ozone), the disadvantage of which is, first of all, the cost and complexity of the technology.

Another modern alternative method is the use of mixed oxidants, which, thanks to their stronger disinfecting characteristics, make it possible to reduce the dosage of active chlorine. In recent years, scientists from various countries have paid attention to UV disinfection of water, improving technology and technological equipment to solve complex problems. One of these directions is the use of combined methods that combine UV radiation with other physical and chemical technologies. Ozonation of water, first of all, solves the task of physical and chemical purification, allows reducing reagent costs, and provides a primary barrier against microbial contamination. This process before UV disinfection has been used for many years at two large stations in Finland (Pitkakoski and Vanhakaupunki), which supply drinking water to the city of Helsinki, as well as at the Canadian station Coquitlam, which is part of the water supply system.

Correctly selected disinfectants during complex water treatment lead to the emergence of synergistic effects (when the effect of a complex of disinfectants exceeds the sum of the effects of individual disinfectants). This provides a higher antimicrobial effect while maintaining or even reducing the doses of administered reagents. Work in this direction is widely carried out all over the world.

The methodological basis of theoretical research is based on the use of systematic scientific analysis of processes and methods of cleaning and reagent-free disinfection of polluted waters.

The urgency of the work is due to the need to research and find alternative methods of water disinfection to ensure its bactericidal safety. The combined use of oxidizing agents, as well as compatible with physical methods of water disinfection and purification, is currently quite promising. Correctly and rationally selected disinfectants during complex water treatment lead to the emergence of synergistic effects that provide more high antimicrobial effect while maintaining or even reducing the doses of reagents administered. In this connection, the use of ultraviolet - ozone technology for oxidation and disinfection of water is promising, which is determined by the unique properties of the excited ozone-oxygen mixture as a medium for the flow of chemical reactions. Cavitation. The process of formation and subsequent collapse of air bubbles (steam) in a liquid stream, accompanied by noise and hydraulic shocks, the formation of cavities in the liquid (cavitation bubbles, or cavities), which may contain rarefied steam.

UV disinfection of water. Today, one of the most common methods of water disinfection is UV water disinfection. UV filter systems affect pathogens with radiation in the 250-270 nm range. Scientific studies confirm that this interval of electromagnetic waves provides the most effective disinfection. Affected cells lose their ability to reproduce. In this state, they are safe for UV disinfection of water. Today, one of the most common methods of water disinfection is UV water disinfection. UV filter systems affect pathogens Ozonation. The analysis of literary sources showed that one of the effective and most used methods is the ozonation method. At present, more than 1,000 water stations in Europe, mainly in France, Germany and Switzerland, use ozonation as an integral part of the overall technological process. Recently, ozonation began to be used in Japan and the USA [1]. Ozone has a high electrode potential, that is, it is an active compound and oxidizes organic and inorganic water pollutants, microorganisms which are no exception. Dissolving ozone in water contributes to two main processes - oxidation and disinfection. As a result of the process, a significant increase in dissolved oxygen is observed. The widespread use of ozone is due to its feature of rapid decomposition in water. In the process of treating water with ozone, organic substances are decomposed and water is disinfected, while bacteria die several thousand times faster than when treating water by the chlorination method, which in turn is the main disadvantage of this chlorination method, is the formation of organochlorine compounds that have a high toxicity Compared to other oxidizing agents, ozone has such advantages as the possibility of obtaining it directly at treatment plants, and the raw material can be technical oxygen or atmospheric air [2].

The ozone molecule is unstable and has a single connected system of bonds. In air, the molecule disintegrates into diatomic and atomic oxygen. Ozone has a bactericidal effect on water, deodorizes, cleans it of nitro compounds, carcinogens. Ozonation can be distinguished: destruction of all known viruses, bacteria and other microorganisms; removal of unpleasant odors and flavors; high speed of action; exposure to ozone does not affect the acidity of water, nor does it change it [3,4]. Ozone improves the organoleptic properties of water; removes color and extraneous odors that are not removed by chlorination, in particular, the odors of oil and oil products; inactivates some pesticides and carcinogenic hydrocarbons. An excessive amount of ozone does not accumulate in water, so it quickly disintegrates with the formation of molecular oxygen. The dose of ozone required for water disinfection is 0.8-4 mg/l, depending on the water quality, its temperature, the degree of mineralization, and the content of humic substances [5,6].

Based on all advantages, the method is one of the most promising methods of decontamination of impurities that are even contained in wastewater.

Based on the research presented in the article [7], we can see the results of the study of biological oxygen consumption (BOD), chemical oxygen consumption (COD) and total microbial number (TMC) in Table 1.

Table 1 – Results of the study of the effect of ozone on BOD, COD and TMC

Time, min	The influence of the intensity of treatment of samples with ozone on indicators								
	BOD, mg/l			COD, mg/l			TMC, CFO^2 thousands/cm^2		
	1 mg O_3/l	2,2 mg O_3/l	3,4 mg O_3/l	1 mg O_3/l	2,2 mg O_3/l	3,4 mg O_3/l	1 mg O_3/l	2,2 mg O_3/l	3,4 mg O_3/l
0	3250	3250	3250	8100	8100	8100	156	156	156
5	2900	2650	2300	6730	6000	5940	24,8	17,4	12,95
10	1740	1370	1220	3700	3060	2110	22,1	16,5	12,87
15	1120	950	860	1980	1920	1890	18,7	15,3	12,8
20	980	870	810	1940	1870	1780	17,9	14,4	12,7
25	870	840	790	1890	1810	1730	15,8	13,2	12,65
30	830	810	780	1840	1770	1710	14,1	13,6	12,6

Studies of wastewater, which contained a mixture of soil and potato juice, made it possible to determine the dependence of the reduction of COD, BOD and TMC on the amount of ozone and the time of wastewater treatment. The processed samples are shown in Fig. 1.

Fig. 1 – Model samples of waste water

Discussion of results

From the obtained results of the experiment, which are graphically presented in Fig. 2, it follows the fact that the ozone concentration has a much stronger effect than the processing time. This is explained by the fact that with an increase in the concentration of ozone to 3.4 mgO3/l, more effective dissolution and oxidation of organic substances and the death of bacteria in water occur. For lower concentrations of ozone, after 5 minutes of treatment, a sharp decrease in the indicators of the TMC begins, which reaches a maximum during the entire time of the study. For low concentrations of ozone, the liquid treatment time is

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decisive, the value of the reduction of the TMC is already after 30 minutes. for an ozone concentration of 1 mgO3/l and 2.2 mgO3/l are close to the values obtained at an ozone concentration of 3.4 mgO3/l.

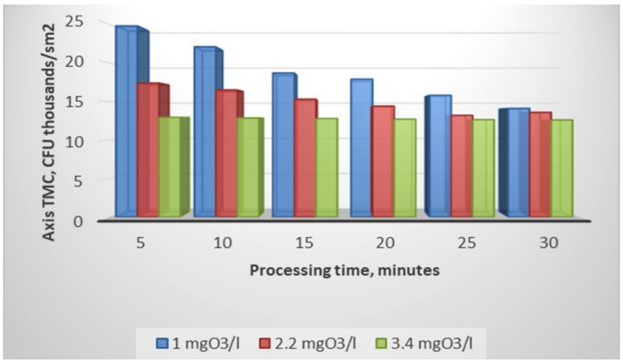

Fig. 2 – Dependence of the total microbial number on treatment time and ozone concentration

At the next stage, the change in indicators of COD during the treatment of samples with ozone was investigated and presented graphically in Fig. 3. From the obtained diagrams, it can be concluded that the change in the indicator of COD has a greater influence on the value of the treatment time. At different concentrations of ozone, a sharp decrease in COD is observed during the first 15 minutes of treatment, after which the value becomes unchanged during further ozone treatment.

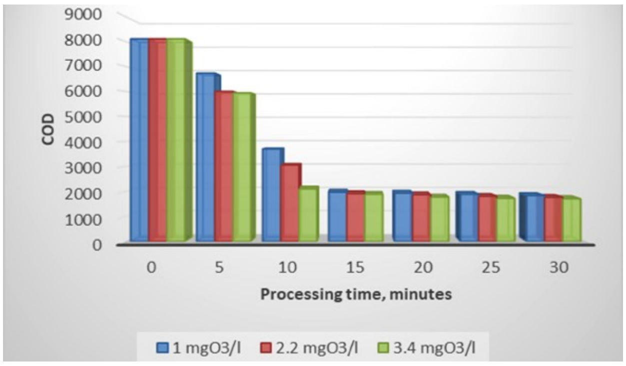

Fig. 3 – Dependence of the indicator of chemical oxygen consumption on the treatment time and ozone concentration

Fig. 4 shows the change in the indicator of BOD. It can be seen from the obtained figure that the dynamics of the indicator repeats the dynamics of the indicator of COD.

Conclusions

Ozonation of polluted water significantly reduces the number of total microbial numbers, biological and chemical oxygen consumption, but does not allow to purify the wastewater to standards for drainage or secondary use. However, ozonation can be used for the final disinfection of previously purified wastewater from bacteria and additional purification from organic impurities by oxidizing them with ozone. Thus, all disinfection methods, even alternative ones, also have certain disadvantages. All this indicates the insufficiency of studying and researching this

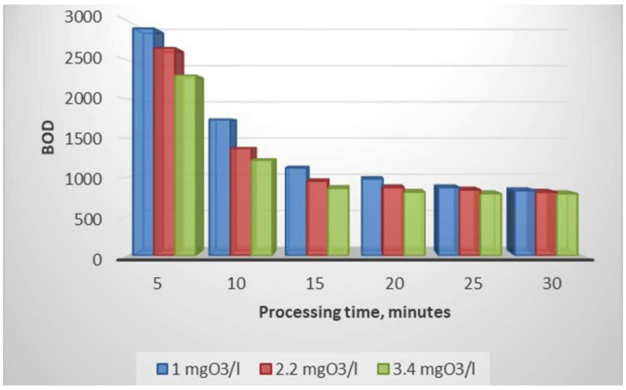

Fig. 4 – Dependence of the indicator of biological oxygen consumption on the treatment time at a specific ozone concentration

problem. Therefore, the problem of high-quality disinfection of drinking water remains extremely urgent and needs to be solved as soon as possible.

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