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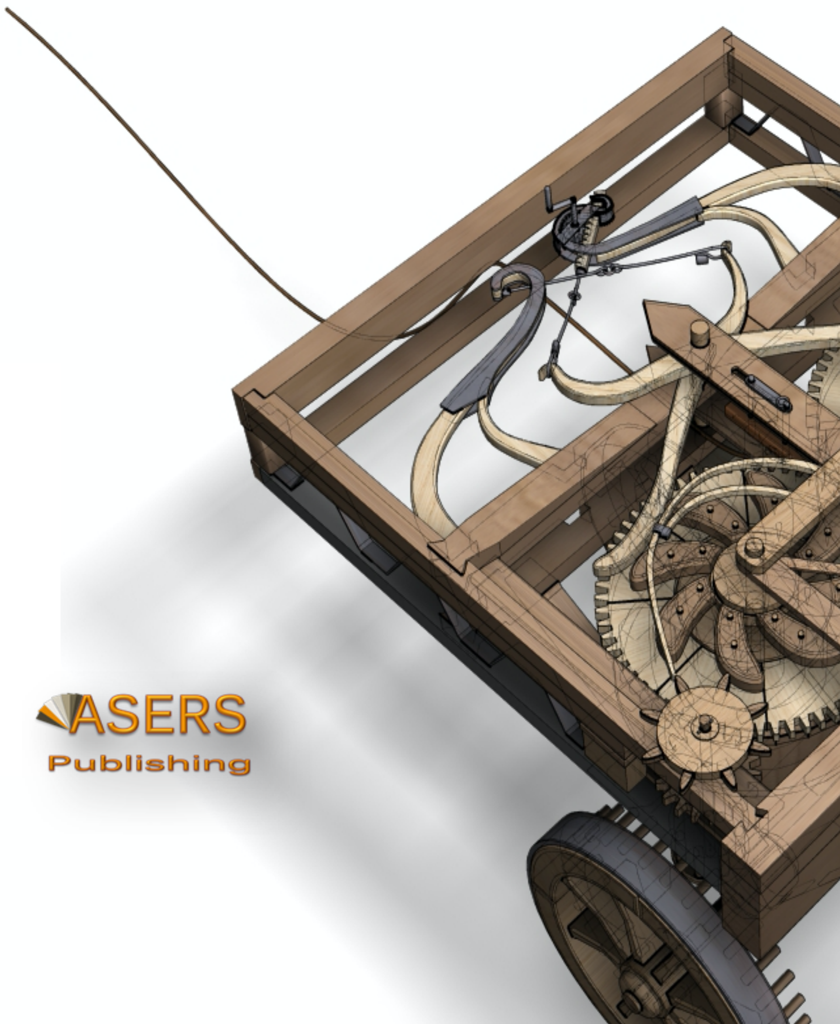

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Research of the Process of Ozonation and Sorption Filtration of Natural and Anthropogenicly Pollated Waters

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Abstract:

This scientific research work is written based on the problem of studying the process of ozonation and sorption filtration of natural and anthropogenically polluted waters. Scientific research work of our country is diverse It was prepared in the laboratory of water ozonation, and purification technology and equipment of Kazakh National Research Technical University named after K. I. Satbayev based on long-term research conducted in cities and regions. The current state of ozonation equipment and active carbon production is considered in the research work. The scientific research work is intended to solve problems and tasks related to the use of ozonation and sorption water purification methods for employees of the sector of quality water supply and water treatment. In addition, the research work is devoted to the problems of water purification using ozone. Provides general information about the properties of ozone, its interaction with inorganic and organic compounds. The main methods of obtaining ozone, the effect of design parameters on the efficiency of ozonators are shown. The main domestic and foreign manufacturers of ozonation equipment are presented. In the research paper, considering the effectiveness of removing various organic and inorganic pollutants of natural and anthropogenic origin, microbiological pollutants, the authors' long-term research on purification and disinfection of natural waters are systematized. Production experience of using ozone in foreign and Kazakh water facilities, as well as in local water treatment plants is presented.

Keywords: ozonator; activated carbon; quality water; natural water; polluted water; ozonized water; amount of ozone; decontamination.

JEL Classification: Q23; Q53; Z10.

Introduction

Due to the increase in pollution of water bodies used as sources of water supply to the population, the use of ozone for the preparation of drinking water is expanding in the world practice. Currently, more than 1,000 water utilities in Europe, especially in France, Germany, and Switzerland, use ozonized water as an integral step in the technological process of purification.

The discharge of untreated or insufficiently treated domestic and industrial wastewater, as well as the discharge of water containing pesticides and other toxic substances into agricultural areas, leads to the deterioration of water supplies. The composition of surface water bodies near large cities includes phenols, oil products, organochlorine compounds, ammonium, nitrite nitrogen, etc. characterized by increased concentration (Hlatky M.A. *et al.*, 2002). The number of chemical compounds in such water bodies is sometimes tens and hundreds of times higher. It is higher than the permissible limit concentration (MPC) according to sanitary hygiene indicators.

The sanitary condition of most of the Ile, Karatal, Lepsi rivers, as well as Kapshagai and Balkash lakes in Almaty and Zhetysu regions in the Far Eastern region of the country is unsatisfactory. As a result, there is a tension in the supply of drinking water to the people in the cities that use these water bodies as a source of water supply.country, one of the ecologically unfavorable areas is the Kapshagai reservoir, where the water of the Ile River is polluted by the wastes of chemical, metallurgical, mining, pharmaceutical and other industries because it originates from China. River water has anthropogenic pollution in a concentration that significantly exceeds the standard values used as the main source of water supply for the population. Toxic and carcinogenic pollutants such as phenol are constantly found in river waters - at the level of 2 to 10 SHR; chloroform - from 2 to 20 MPC; amines - 2 - 5 MPC and others.

Widely used technologies and installations for water purification from surface sources are known. The barrier role of such structures in relation to anthropogenic chemical pollution is very low. Many existing water treatment plants designed according to traditional technology (coagulation, chlorination, sedimentation and filtration) cannot ensure the removal of chemical pollutants, but, on the contrary, in some cases contribute to an increase in the concentration of certain compounds. For example, pre-chlorination of water from surface sources usually results in the formation of high concentrations of chloroform and other organochlorine compounds in treated water.

Country 's state sanitary-epidemiological supervision committee, about 50% of the country's population is forced to use drinking water that does not meet the requirements for a number of indicators to a certain extent. Thus, at present, every eighth sample of tap water does not meet the hygienic requirements according to bacteriological indicators, 45% of it is dangerous in terms of epidemics. Every fifth sample studied does not meet the standard in terms of chemical parameters. Among them, 10% of the samples contained chemicals that are hazardous to health (Mathon B. *et al.*, 2017).

In some regions, water in centralized water supply systems does not always meet a number of requirements of MEST 2874 - 82 "Drinking water". As a result, people are forced to use water, which, according to medical organizations, has a negative effect on the blood circulation system, organs of the gastrointestinal tract, the immune system, and leads to cancer.

Due to the current situation, many companies and organizations have appeared in recent years that produce tap water purification devices of various designs for private and local purposes, children's institutions, schools, hospitals, outpatient clinics, canteens and other institutions. For this purpose, we carried out water purification with a corona discharge ozonator based on a new type of ozone technology. Research work was carried out on the process of ozonation and sorption filtration of natural and anthropogenically polluted waters.

1. Materials and Methods

Studies on controlling the potential of trihalomethane formation in the process of ozone and biofiltration are considered. If ion-exchange materials are present in such filters, elements necessary for the body - calcium, magnesium and fluorine - are removed from the water. In the case of using sorbent materials, the growth of different groups of microorganisms occurs in purified water. In addition, desorption of pollutants from the filter material and entry of all previously stored pollutants into one glass of water cannot be ruled out in many designs.

Due to the high oxidizing and disinfecting ability of ozone, it is widely used in the purification of drinking water. A 3-section ozone contactor structure was used to ensure ozone oxidation. By changing the operating conditions of the contactor, attention was paid to the effect of ozone transport. The results showed that the best operating condition of ozone transport was in the downstream section in the first section, and an ozone dosage ratio of 3:3:1 was acceptable among the three sections (Withanachchi S.S. *et.al.*, 2018).

In one of the foreign research projects, the process of catalytic ozonation and biologically activated carbon was used to improve the quality of drinking water. The results showed that CODMn, TOC and UV 254 removal in the catalytic ozonation unit at 2.0 mg/L of ozone was 24.6% to 59.8% percent and increased to 40% to 68% percent, respectively. The catalytic ozonation unit contributed to more than 50% of total bacteria removal. It was also found that ozone and catalyst (activated carbon) act in a synergistic effect rather than a pure mixture.

This study, based on a pilot-scale experiment at a water treatment plant in southern China and combined with molecular weight (MW) separation of organic matter, mainly evaluated the removal effect of organic matter of different molecular weights using assimilable organic carbon. Ozonation is combined with biologically activated carbon. Research work has shown that it is effective during the technological process and has a great advantage in the advanced treatment of drinking water in China (Normatov I.S. *et al.*, 2021).

The growing demand for fresh water is partially met by desalination plants that often use membrane technologies and advanced oxidation processes that generate ozone to produce purified water. In this study, a water purification technology was developed using advanced oxidation processes that generate ozone, which allows to destroy the content of humus acids and organic compounds. It can be concluded that the proposed method still requires extensive treatment to produce potable water. In some foreign research works, it can be seen that the removal of organic pollutants from urban waste water for artificial recharge of underground water has given positive results. In the research works, first ozonation and then filtration with pebbles were carried out.

Many Chinese electroplastic enterprises usually discharge wastewater containing CN-, Cu2+, Zn2+ and other toxic heavy metals to the surface. This mixed wastewater is difficult to treat effectively. Currently, conventional chemical treatment methods can bring the quality of the treated water into compliance with the standard system, but do not meet the need for recycling. In this work, the integrated treatment process was investigated by O3 oxidation, FeSO4 reduction, precipitation of heavy metal ions, nanofiltration and reverse osmosis experiments. The results showed that at pH = 9, O3: CN- 5:1 (mass ratio) and oxidation time of about 45 minutes, the total cyanide removal rate was higher than 99% percent. At pH = 9 ÷ 10, with FeSO4: Cr 10:1 (mass ratio) and a recovery time of about 15 minutes, the reduction rate of Cr was higher than 99% percent and the main pollutants such as Cr, Cu, Zn were finally removed by nanofiltration and reverse osmosis. purified water reached zero. Ozone also destroys harmful substances in the surrounding air during the water disinfection process (Abdullayev S. *et al.* 2017).

In this scientific study, the work of ozone and air and wastewater disinfection was studied. During the research work, a small-scale laboratory model of HVAC was developed, and a dielectric resistance discharge plasma source was used for air treatment. This PDRF (pathogen detection and recovery facility) consisted of a circulating air flow system, a plasma chamber and a sampling system. Air disinfection experiments were carried out and the inactivation of Escherichia coli was studied. Traditional methods of water disinfection, such as chlorination, ozonation, filtration, ultraviolet radiation, etc. have a number of disadvantages. Pulsed plasma discharge is a recently developed cost-effective method for the destruction of microorganisms in wastewater and drinking water. The energy efficiency of different types of plasma discharges in water contaminated with Escherichia coli was studied. The effect of the initial concentration of the bacterial solution on the inactivation efficiency was also studied (Takuya Kuwahara, 2018).

In the research work, environmental pollution and industrialization on a global scale focused on the important need to develop new hygienic cleaning technologies. Ozonation, chlorination, filtration, etc. The most common methods of indoor and outdoor cleaning, such as electricity and other energy sources, have corresponding limitations. However, heterogeneous photocatalysis using photocatalysts operating at room temperature is a strong competitor as an environmentally friendly decontamination process and a unique source of the most powerful oxidizing agent (hydroxyl radical). Such a safe, low energy consumption, efficient generator of hydroxyl radical and bactericidal competent photocatalytic systems is urgently needed for the purification of natural or anthropogenically polluted water, degradation of atmospheric odors, and large-scale decomposition of NO_x compounds. To solve such enormous challenges, it is necessary to create heterogeneous photocatalytic systems using metal oxide semiconductors such as ZnO, which can work efficiently under UV light. Metal oxide semiconductors with optical absorption characteristics, namely ZnO nanoparticles capable of detoxifying water from organic compounds, were developed in the research work. This paper describes the results of experiments with ZnO nanoparticles for photocatalytic degradation of organic compounds.

Plasma disinfection technologies have been the subject of several studies and remarkable discoveries over the past few years. Ozone (O_3) is an effective sterilizer, and its applications include water purification. Ozone is usually formed from oxygen (O_2) in non-thermal plasma (NTP). However, this process requires the use of an additional gas cylinder or O_2 supply device, thus increasing operating costs and energy consumption.

Alternatively, O_2 can be used as a source gas for obtaining O_3 from air. However, this results in the formation of nitrogen oxide (NO_x), an air pollutant, during the plasma discharge. Therefore, it is very important to develop a method of O_3 generation that solves the problems of energy costs and air pollutant emissions. Therefore, this study proposes an energy efficient NTP decontamination system. The system is based on the electrolysis of water to produce O_2 and hydrogen (H_2). The produced O_2 is used to neutralize O_3 and H_2 used in fuel cells to generate electricity. This study describes in detail the efficiency characteristics in energy consumption and O3 production and explains the proposed NTP decontamination system (Mai Kai Suan Tial and Fumiaki Mitsugi, 2018).

Many research papers describe different methods of treating highly colored wastewater using UV radiation, ozonation, and chlorination. However, the costs of these methods require the use of plasma. This study examines the treatment of highly colored wastewater using a dielectric barrier discharge based (DBD) ozonator. The underwater DBD plasma system is designed to interact directly with water, thereby producing reactive oxygen species (ROS) and acting as a powerful oxidizer. In addition, UV, O3 and H2O2 are generated by a plasma system developed without the use of other additives to obtain OH radicals for the purification of organic pollutants. Therefore, this system bypasses the use of complex and advanced oxidation processes. A simulation test was performed, which showed that methylene blue and rhodamine B were completely removed within 7 and 3 minutes, respectively. Therefore, the developed plasma system can be successfully used for the treatment of highly colored wastewater.

The system of spraying ozonated water for disinfection and cleaning of agricultural buildings was developed in scientific research work. Because ozone effectively neutralizes viruses, bacteria and pests. Dielectric barrier discharge (DBD) ozonizers were used in previous works, while in this research work, a spray system was developed. In addition, the specific charge of the ozonator was investigated by placing an induction ring electrode. It has been found that the addition of induction charging to the ozonator can increase the effective coupling of the ozone layer to the target by applying a DC voltage to the ring electrode.

According to the research, if ion-exchange materials are present in the filters, elements necessary for the body - calcium, magnesium and fluorine - will be removed from the water. In the case of using sorbent materials, the growth of different groups of microorganisms occurs in purified water. Finally, desorption of contaminants from the filter material and entry of all previously stored contaminants into a glass of water cannot be ruled out in most designs. In general, the spread of such individual installations is suitable as a temporary measure until the provision of quality drinking water by centralized water supply systems (Abdullayeva A. *et al.*, 2022).

For this purpose, it is necessary to reconstruct the facilities that allow water purification using new technology. The possibility of using efficient and ecologically clean technology of water purification has increased in the country. In the CIS countries, due to a number of reasons, ozonation is mainly used in Russia in some water facilities in large cities (Moscow, Nizhny Novgorod, Kyiv, Minsk) using foreign equipment (French company Treiligaz). Individual small facilities where household equipment is used (mainly for industrial wastewater treatment), swimming pools, etc.

Over the last ten years, the Laboratory of Natural Water Purification Technology and Equipment of the KVOV Research Institute has conducted extensive research to determine the effectiveness of water ozonation (with and without sorption methods) in various regions of Russia (Vladimir, Taganrog, Ryazan, Kemerovo, Novokuznetsk, Yaroslavl, Orinbor etc.). It has been convincingly shown that without using these methods, it is practically impossible to obtain water of the required quality from the water of polluted water bodies used as a source (Riza M. and Hoque S., 2022).

The issue of deep-water purification is particularly relevant at the moment, as new regulatory documents are being prepared to introduce more stringent requirements for some water quality indicators. In the neighboring country of Russia, the development and adoption of the law "On the provision of drinking water to the population" raises the task of water purification to a new level, which also requires a radical improvement of water purification equipment. This explains the increasing interest in water ozonization and the desire of water supply and water supply enterprises to implement the ozonation method in water treatment plants. However, when choosing schemes and modes of water ozonation, sometimes they make wrong decisions due to wrong ideas.

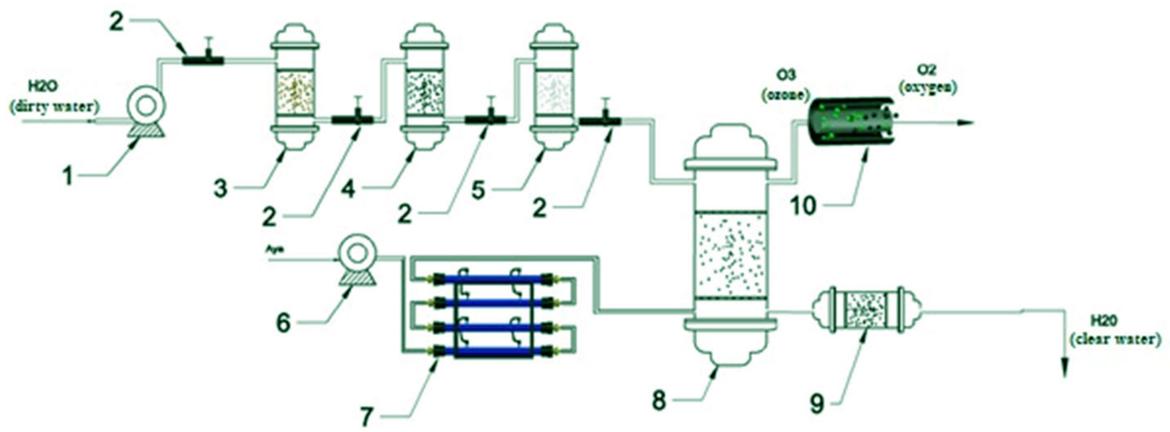
Modes of water treatment with ozone and the adopted ozonation scheme are usually selected on the basis of physical and chemical analysis data of natural water. In addition, it is known that the quality of water in the water source undergoes significant changes during its movement, therefore, both reagent treatment and ozonation regimes are different for each case. Often, arbitrarily, the amount of ozone is chosen without any justification, according to which the productivity of ozone equipment is calculated, and the production is ordered at the plant. Obviously, in this case, the technological scheme of using ozone will not be completed. The possible disadvantages of this approach are detected only at startup when errors cannot be corrected. Even if in some cases technological studies are carried out during the production process of the equipment, the latter is actually carried out for the ordered equipment, and this prevents the full use of ozone's potential (Ustaoğlu F. and Tepe Y., 2019).

If the mode of water ozonization and the amount of ozone are not selected correctly, oxidation by-products can be formed, which are poorly removed in the treatment process and can be more toxic than the original pollution. In some cases, ozonation of water can cause deterioration of coagulation processes, and can also introduce high concentrations of chemical pollutants, such as phenols, into treated water. Many plumbing and sewage companies expect to be able to completely abandon chlorination and eliminate chlorine from the water treatment process by introducing ozonation. In addition, in the course of such studies and only according to their results, it is possible to determine the optimal amounts of ozone in specific periods of the year, to determine the design and design parameters of the oxidation-sorption water purification method. In particular: the ozone utilization rate, the contact time of the ozone-air mixture with purified water, the options for using sorption filters by selecting the most effective types of activated carbon, the reactivation mode, determining the filtration speed, the time of reactivation of the carbon load and its monitoring and measuring devices, and clarification of other technological and technical-economic issues of using ozone and activated carbon in water treatment plants was considered.

2. Results and Discussion

Kapshagai reservoir is located in Konaev city, Almaty region, Central Asian Republic of Kazakhstan. 70-80% of the reservoir is filled by the Ile River. The Ile River originates from the neighboring country of China. The warehouse was built in 1970 for the purpose of a hydroelectric power station. The area is 1847 km², the length is 187 km, the width is 23 km, the average depth is 15 m, the deepest part is 46 m. The planned capacity of the facility is 28 km³. The catchment area is 113 thousand km², the length of the coast is 430 km. The northern shore of Bogen is sandy and stony, a significant part is high and steep, the southern shore is low, flat, sandy and clayey. More than 450,000 hectares of land are irrigated with water from the reservoir. Rice and garden crops are planted there. At the same time, meadows and pastures are irrigated, as well as used by enterprises of the city of Konaev. The idea of using the water in the warehouse for drinking water was started in 2010. This is because there is a training and drilling site at the Kazakh National Technical Research University near the warehouse. In order to supply the landfill with drinking water, it is planned to carry out scientific research on cleaning and disinfecting the water in the warehouse. In order to study the process of ozonation and sorption filtration of water in the warehouse, which is naturally and anthropogenically polluted, according to the research work, a technological scheme was first prepared (Fig. 1).

Figure 1. Technological outline of the process of ozonation and sorption filtration of natural and anthropogenically polluted waters



The technological scheme of one-stage ozonation process is provided in the figure. Ozone (7) can be used in the water pre-oxidation stage or before or after a zeolite sand filter (3), activated carbon filter (4) or quartz sand filter (5).

Ozonation of purified, *i.e.,* filtered water provides complete disinfection and improves the organoleptic properties of water (Bushra H. *et al.*, 2019).

According to the number of places of ozone application, communication chambers where the ozone-air mixture is mixed with water are installed (reservoir (8) H2 O+O3). Bubbling basins are commonly used for municipal wastewater treatment plants. As dispersants, metal-ceramic pipes (or plates) or special valves made of stainless steel installed in pipes (2) can be used. Contact chambers can work both in countercurrent and direct flow mode, and with the countercurrent mixing method, the ozone utilization factor increases to 0.93 - 0.97. The set of equipment of the ozonation station includes: pumps with a capacity of 10 m3 per hour (1), air compressors (6), air cleaning and drying units, ozone generators (7), power plants, monitoring and measuring devices and devices for catalytic decomposition of ozone (10), membrane filter (9) is included.

Justification of the size range of ozonation equipment. Calculations were carried out in the entire range from 1 to 10 m3/hour to determine the approximate required amount of ozone for typical capacities of water treatment plants, as well as to justify the standard size range of ozonators. The required amount of ozone was taken as an average value based on many studies on water treatment with ozone under real conditions. For example, the following options were considered:

- moderately polluted water sources - ozone content - 4 mg/l;
- heavily polluted water sources - ozone content - 7 mg/l;
- underground and surface water sources characterized by high color (up to 150 - 200 degrees) - the amount of ozone varies up to 15 - 20 mg/l.

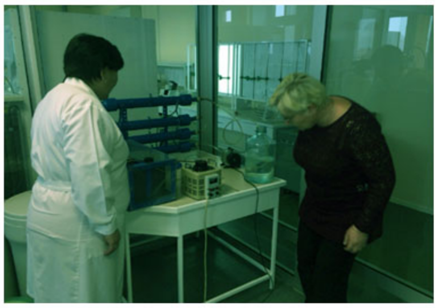
3. Technological Efficiency of Combined Use of Ozone and Activated Carbon

Any technology has its own efficiency. In the process of water purification, the technology of sorption water purification with ozone has its own characteristics. In each case, for this specific object, the water of natural water sources is characterized by different concentrations of harmful substances due to different physical and chemical indicators. Therefore, the effectiveness of these methods can be evaluated only for specific situations, each of which has its own scheme of water purification (Dar S.A. *et al.,* 2020).

Therefore, in the research work, scientific research was conducted at the training ground of KazNRTU (Fig. 2). The research paper provides general information on the effectiveness of ozone and activated carbon for specific conditions and types of storage water pollution. This research work should be considered as informative material showing the capabilities of the method.

Figure 2. Testing of the "ETRO - 02" ozonator unit based on electric corona discharge the timing

a) Kapshagai reservoir



b) Color control of water in the reservoir

c) Disinfection of water using an ozonator unit of a small laboratory type

If the water is pre-oxidized with ozone, it is possible to reduce the concentration of organochlorine compounds (Fig. 3). The results of studies to determine the efficiency of water pre-ozonation can be seen in Table 1 below.

Chlorine is oxidizes very easily with ozone, resulting in the formation of hydrochloric acid (reaction rate constant ($k = 3 \cdot 10^{-3} l/mole^{-1} sec^{-1}$). This acid is then acidified to chlorate by individual transformation of chlorine. Chlorine can be considered stable in solution.

Chlorite is an ion. The general scheme of this reaction can be written as follows (Abdullayeva A. et al., 2022):

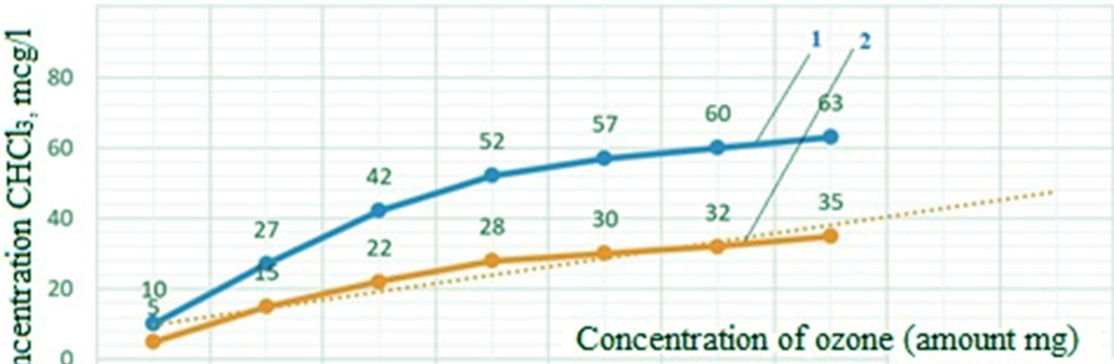
$$ClO_2^- + O_3 \Leftrightarrow ClO_3^- + O_2 \tag{3.1}$$

In addition, chlorite ion can react with ozone as follows:

$$\begin{aligned} & ClO_2^- + O_3 \rightarrow ClO_2^{\bullet} + O_3^{\bullet} \\ & ClO_2^{\bullet} + O_{3\,3}^{\bullet} \rightarrow ClO_3^- + O_2 \\ & \kappa = 10^5\, l/mole.\sec \\ & \kappa = 10^3\, l/mole.\sec \end{aligned} \tag{3.2}$$

The second of these equations is much simpler than the first, so we can assume the existence of an intermediate connection.

Figure 3. To organochlorine compounds in case of pre-oxidation of water with ozone effect



300	350	400	450	500	550	600
10	27	42	52	57	60	63
5	15	22	28	30	32	35

Here 1- not ozonized; 2 - ozonized.

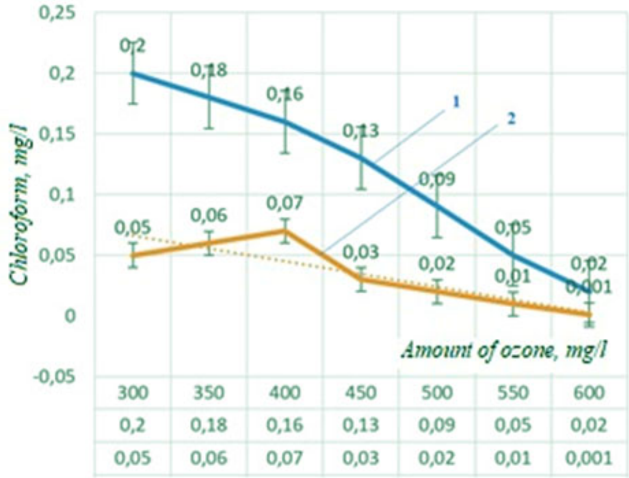
As can be seen from the research results, as a result of preliminary water treatment with ozone (ozone content 600 mg/l), oxidation (destruction) of some organic compounds occurs. Chlorination of purified water is significantly less expensive than chlorination of non-ozonated water (. Satya K. and Narayan C., 2018).

Thus, the concentration of chloroform decreases by an average of 30-35%, dichlorobromomethane and carbon tetrachloride - by 80 and 50%, respectively. In addition, chlorine absorption of ozonized water decreases, so the amount of chlorine needed for water disinfection is reduced (about 15-20% percent).

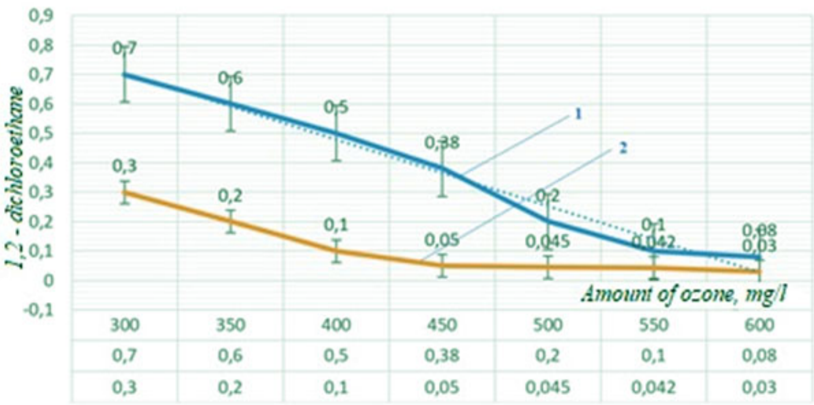
The results of the study are shown in Figure 4 below (after cleaning the water in the warehouse). In the research work, it can be observed that when there is chloroform at a concentration of 0.13 mg/l after filtration, its concentration increases or decreases depending on the amount of ozone, and it decreases sharply after carbon loading.

As a result of studying the effect of pre-ozonation on the process of coagulation treatment, we observed in the research work that it reduces the color, turbidity and oxidation capacity of water (Fig.5). The process of ozonization, sedimentation, and disinfection of water immediately increased the quality of water in the warehouse. In all studied cases, after preliminary ozonation, a significant reduction in the amount of coagulant required for its purification (by 20-30%) is observed.

Figure 4. Changes in the concentration of organochlorine compounds after filtration of storage water with ozone and activated carbon



a) Dependence between ozone and chloroform



c) Dependence between ozone and dichloroethane

Here. 1 – ozonized water; 2 - water composition after activated carbon

It was found that the technological schemes with one-stage water ozonation are the most effective in terms of indicators such as turbidity, color, nitrates and nitrites, total hardness, sulfates, dry residue, fluoride and microbacteria. In such a technological scheme, organic pollution was removed by 80-85% by oxidization, 95-99% by UV index, 90-95% by oil products and 100% by microbacteria (Hosam M. S. et al., 2022).

Table 1 below shows information on ozone removal of fluorine concentration in storage water. And sorption treatment shows that the concentration of fluorine decreased to 0.02 - 0.15 mg/dm3.

Since all halogens are very reactive, they are not found in nature, i.e., in natural water. Fluorine is found in various rocks and salts. Soluble compounds of fluorine in water contain 0.00002% in river water and 0.0001% in ocean water. Fluorine readily reacts with almost all metals and most non-metals in water at any temperature. Most chemical compounds are separated and decomposed by the action of fluorine. For example, the reaction of fluorine with water is different from that of other halogens.

$$F_2 + H_2O \Leftrightarrow 2HF + O \qquad 3.3$$

The liberated atomized oxygen on the right side of the equation causes several additional, simultaneous reactions:

$$O + O = O_2 \qquad 3.4$$

$$H_2O + O = H_2O_2 \quad 3.5$$
$$F_2 + O = F_2O \quad 3.6$$
$$O_2 + O = O_3 \quad 3.7$$

F_2O - fluorine oxide is a colorless gas with an ozone-like odor. Only recently has free fluorine been substituted for hydrogen in organic matter to obtain several valuable compounds. In addition, there are no reliable data in the research works on the possibilities of ozone and acidification of fluorine ions in water. Also, one of the organic compounds in water is nitrides **(NO_2).** The properties of nitrides vary depending on the position of their constituent elements in the periodic system, for example, in small periods: s of groups I and II - nitrides of elements (Na_3N, Mg_3N_2) - crystalline substances are destroyed at 300^0C, chemically active substances, For example, water reacts with ozone in the following way (Takuya Kuwahara, 2018):

$$Na_3N + 3H_2O = 3NaOH + NH_3 \quad 3.8$$
$$NO_2^- + O_3 = NO_3^- + O_2 \quad 3.9$$

nitrite (NO_2) in water reacts with ozone NO_3, it becomes oxidized (nitrate). That is why the amount of nitrite **(**NO_2**)** in the water content decreases, and on the contrary, the amount of nitrates (NO_2) increases.

Pre-ozonation of water in the amount of 300 - 600 mg/l, followed by filtration with activated carbon ensured the complete destruction of fluorine, nitrates and nitrites, total hardness, sulfates, dry residue, fluorine and microbacteria. In recent years, scientific and research work at the department has studied the technology of medium and high-color water purification using the combined use of ozonation and activated carbon filtration as an independent method of water purification. Ozonation of water can significantly reduce the color of natural water. The results of the research can be seen in tables 1 and 2 below. The amount of ozone needed for water purification is 300 - 600 mg/l. In this case, the color of water after ozonation decreases to 25 - 13 degrees, and sorption treatment reduces the color to normal values (Nkansah M.A. et al., 2019).

The obtained data made it possible to give a positive technological and sanitary-hygienic assessment to this method. This technological scheme and the ETRO-02 ozonator device are protected by the copyright of the Republic of Kazakhstan.

Table 1. Results of chemical and bacteriological analysis of water taken from Kapshagai reservoir on 18.03.2018

Indicators	Regulations not more (MPC, no more)	Ozone size 300 mg/l	Ozone size 400 mg/l	Ozone size 500 mg/l	Ozone size 600 mg/l
Opacity, mg/dm^3	2.0	3.49	2.35	2.30	1.81
Color, degrees	20.0	25	20	15	13
Odor 20^0C (points)	2	no	no	no	no
Hydrogen index, pH	6.0-9.0	8.23	8.25	8.22	8,10
Perman. oxidation, mgO_2 / dm^3	5.0	2	2.5	2.6	3.0
Ammonium salt, mg/dm^3	2.0(po N)	0.81	0.85	0.96	1.19
Copper, mg/dm^3	1.0	0.05	0.04	0.04	0.04
Nitrates, mg/dm^3	45.0	3.0	3.0	3.2	3.6
Nitrites, mg/dm^3	3.0	0.02	0.01	0.01	0.01
Total hardness, mol/m^3	7.0	3.7	3.7	3.6	3.6
Total iron, mg/dm^3	0.3	0.03	0.03	0.03	0.03
Sulfates, mg/dm^3	500.0	46.4	44.4	40.2	38.7
Dry residue, mg/dm^3	1000.0	311.4	309.8	305.1	300.3
Fluorine, mg/dm^3	1,2	0.3	0.3	0.27	0.25
Chlorides, mg/dm^3	350.0	24.5	24.5	24.8	46.4
Koli - index in 1dm^{3,} more not	10000	200	50	20	0
General microbial number, 1 cm^3	< 50	47	27	14	0
General coliform bacteria, 100ml	It shouldn't be	10	7	5	0

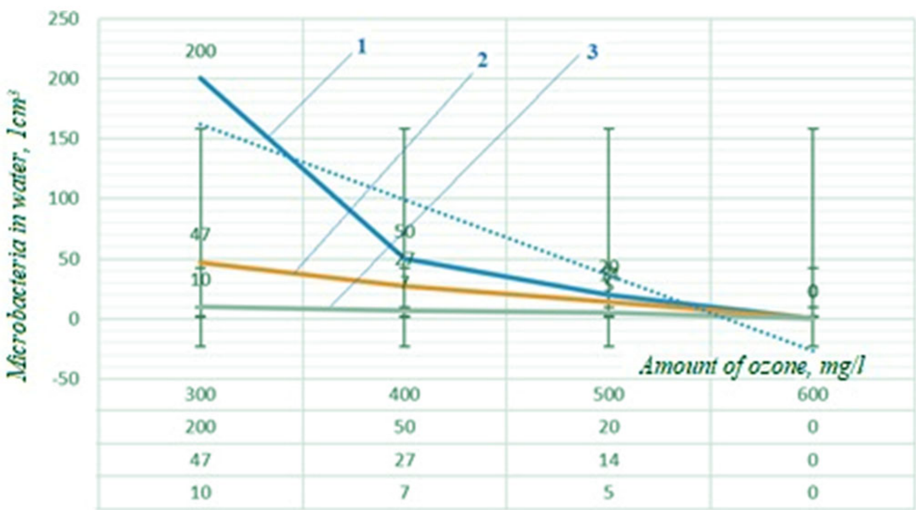
❖ *Warning.* Indicators of non-compliance with the amount of MPC written in red in the table

Table 2. Results of chemical and bacteriological analysis of water taken from Kapshagai reservoir on 18.03.2018

Indicators	Regulations (No more than MPC)	Ozonated water (of ozone size 600mg/l)	Water after activated carbon	Water quality after passing through quartz and zeolite filters
Opacity, mg/dm^3	2.0	1.81	1.57	1.08
Color, degrees	20.0	2	2	2
Odor 20^{0}C (points)	2	no	0	0
Hydrogen indicator, pH	6.0-9.0	8,10	6.02	2.78
Permanganate oxidation, mgO_2 / dm^3	5.0	3.0	2.5	1.7
Ammonium salt, mg/dm^3	2.0(po N)	1.19	1.14	1.07
Copper, mg/dm^3	1.0	0.04	0.03	0.02
Nitrates, mg/dm^3	45.0	3.6	3,4	2.9
Nitrites, mg/dm^3	3.0	0.01	0.01	0.01
General hardness, mol/m^3	7.0	3.6	3.6	2.6
General iron. mg/dm^3	0.3	0.03	0.03	0.02
Sulfates, mg/dm^3	500.0	38.7	37.2	35.1
Dry residue, mg/dm^3	1000.0	300.3	209.0	181.4
Fluorine, mg/dm^3	1,2	0.25	0.20	0.15
Chlorides, mg/dm^3	350.0	46.4	17.9	17.4
Koli - index in 1dm^{3,} more not	10000	0	0	0
General microbial number, 1 cm^3	< 50	0	0	0
General coliform bacteria, 100 ml	It shouldn't be	0	0	0

During ozonization of water, the effectiveness of its disinfection was constantly checked. In particular, bacteriological observations conducted in special laboratories in the cities of Kapshagai and Almaty confirmed the high bactericidal capacity of ozone: the coli index in ozonized water at the amount of 300-600 mg/l of ozone decreased to 0 (the coli index in storage water was 100,000-300,000), and the average number of total microbes decreased to 0 (found in river water up to 55 - 47 cm^3).

Figure 5. Effect of ozone on microorganisms in water



Here: 1 - column - index ; 2 - total number of microbes; 3 - y giant coliform bacteria

Thus, the above examples show the most typical cases of using ozone and activated carbon in water purification technology, which, of course, does not include all options for using the oxidation-sorption method of purification and does not purify all pollutants. During ozonation of some waters, the amount of ozone significantly affects the subsequent treatment processes. That is, they have a rather small range of optimal values, below which ozonation is ineffective, and in high amounts, a suspension appears in filtered water and the concentration of residual aluminum and some chemical compounds increases. Therefore, it is better to carry out the research work carefully depending on the quality of the water. That is, it is necessary to thoroughly analyze the processes of ozonation and sorption filtration of natural and anthropogenically polluted waters.

Conclusion

In the scientific research work, the main rules for using special methods of water purification from anthropogenic pollution are established, and general data on the efficiency and design parameters of water ozonation and sorption purification methods are given, which were obtained on the basis of many years of research. Natural water purification technology and equipment were developed in the research laboratory of KazNRTU named after K. I. Satbaev. In addition, in addition to ozone equipment and tested tasks in industrial and experimental conditions, there are also a number of scientific and experimental problems that allow to further increase the efficiency of ozone use and its reliability. Similarly, there are technical issues related to ozonator design, namely:

- organization of the production of a new high-performance ozonator industry in the country;
- development of new designs of oil-free compressors;
- development of special types of turbochargers;
- creation of new means of air preparation;
- mastering the production of glass pipes of appropriate quality (precise or special glass);

The main technological issues that need to be investigated and verified are:

- introduction of the technology of biological purification of natural waters using ozone, according to foreign experiences and researches of KazNRTU, the destruction of microorganisms by ozone and activated carbon filters is shown, as a result of which the efficiency of water purification from organic pollutants and the duration of the intermediate period of active reactivation increases (carbon performance increases significantly);
- determining the efficiency and design parameters, to determine the use of ozone in combination with UV radiation by the so-called "catalytic oxidation" method, which is more effective than using these processes separately. This method, known from foreign experience, allows to remove from water difficult oxidizing pollutants (for example, cyanides) and high-molecular organic compounds, in particular, organic dyes;
- determining the conditions of formation of by-products of water chlorination and ozone depletion, developing measures to reduce their concentration in drinking water;
- improving the system of mixing the ozone-air mixture with purified water and creating new more efficient devices and facilities;
- creation of treatment plants using ozone and activated carbon based on small water treatment plants such as "Struya" and "Vlaga" with a capacity of 100-10,000 m3/day produced by the neighboring Russian industry for heavily polluted water sources.

These tasks are to a certain extent fundamental issues that are important for the operation of water purification processes by ozonation and sorption methods and, ultimately, for obtaining high-quality drinking water. Funds allocated from the special budget are required for the implementation of these works. Ultimately, since ozone has not yet been widely used, it is relevant to develop additional technological schemes for the use of ozone in water purification at plants of any capacity in different regions, under industrial conditions. In addition, there is no experience of using sorption water purification in public water pipes of third-stage facilities in the country, as well as experience of using activated carbon reactivation units. All of this requires real-time verification in the form in question and is one of the important tasks facing water channel specialists, design and research institutes in the field of water supply and drainage.

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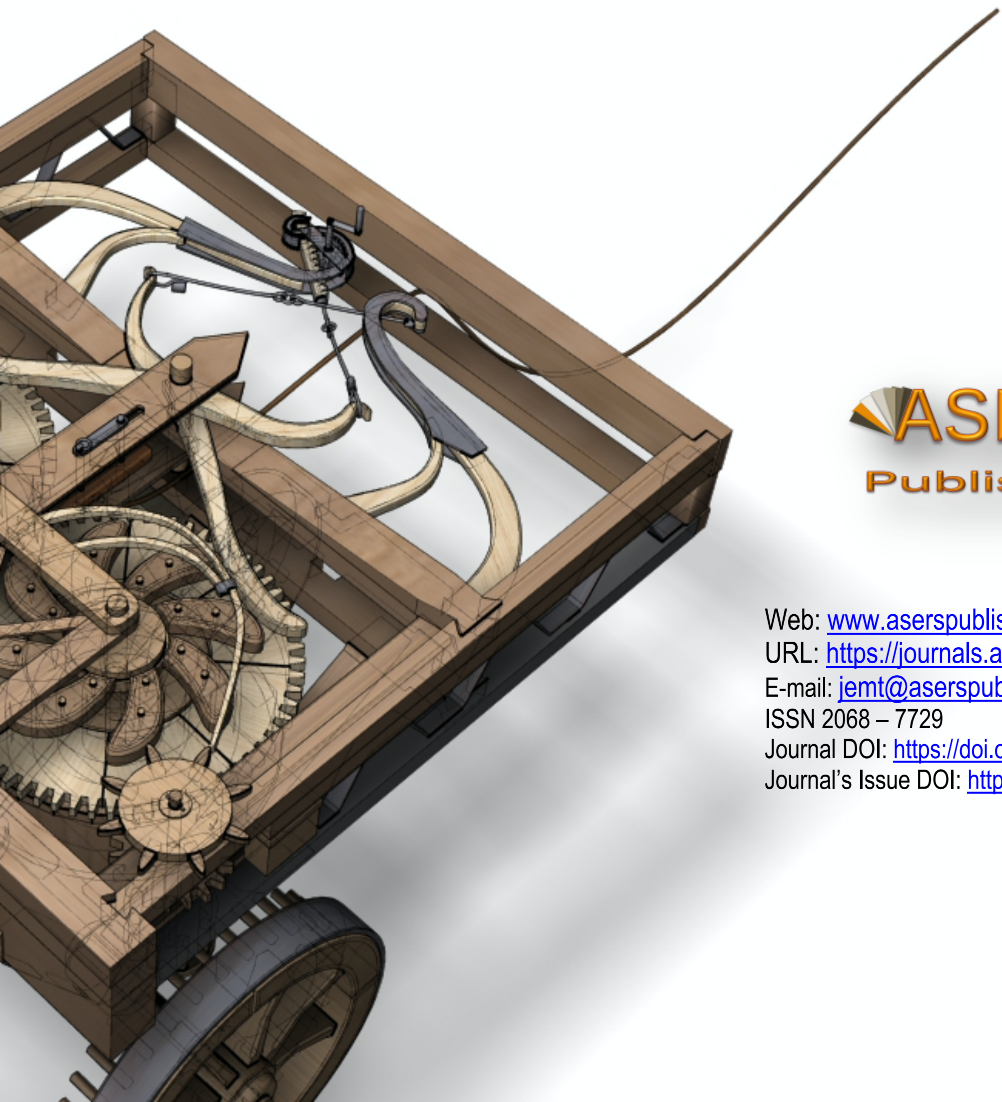

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