# Application of ozone electrodispersion technology for disinfection of water

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# Application of ozone electrodispersion technology for disinfection of water

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**Abstract.** This article provides definitions of the positive and negative effects of the use of chlorine and ozone in water disinfection and presents the methodology and results of experimental studies of the parameters of water treatment with ozone, the electrodispersion method, as well as the electrode system "potential plane with corona needles - grounded plane". The parameters of water treatment modes were determined by the method of three variants of aerosol charge, negative, positive and bipolar. The parameters of water treatment with ozone determined on the basis of these studies were verified on the basis of experimental studies of the process of ozone effects on aerosol particles in the contact chamber. The methodology and analysis of the results of these studies are given. Based on these studies, the best ratios of the parameters of water flow, air velocity and electrical voltage were determined. The best disinfection result was determined by the charge polarities of the water aerosol.

## 1. Introduction

Billions of people around the world continue to suffer from poor access to water, sanitation and hygiene, according to a new report from UNICEF and the World Health Organization. Around 2.2 billion people worldwide lack safe drinking water services, 4.2 billion people lack safe sanitation services, and 3 billion lack basic handwashing facilities [1].

Only 0.3-0.4% of the world's water is drinkable due to its natural quality, which would be enough for just under 1 minute. It is obvious that water is consumed during the day in a specially prepared way, and the role of water supply in life is invaluable.

As a result of studies carried out by European scientists, it became known that the main factors of environmental impact are point (38%) and diffuse pollution of sources (18%), and about 25% of groundwater throughout Europe is in poor chemical condition. Agriculture accounts for 30% to 60% of the local water used throughout Europe and contributes to water pollution from emissions of nutrients, pesticides and other pollutants (eg tractor oils). Due to nitrate pollution and plant protection products (PPP), agriculture is a major source of environmental pressure leading to an inability to achieve good groundwater chemistry status [3].

Uzbekistan ranked 25th out of 164 in the ranking of countries suffering from withdrawal stress, published by the World Resources Institute [16].

For Uzbekistan, the lack of water is a very urgent problem, given that its shortage in a number of regions of Uzbekistan, in particular in Karakalpakstan, can lead to a social and environmental crisis. Already today there is a shortage of water not only for agricultural purposes, but also for the domestic needs of the population. In this regard, reasonable questions arise about how much water shortage affects the economic and political life in Uzbekistan?

During water scarcity or the dry season, water scarcity can adversely affect health due to unsanitary conditions, insufficient water availability for consumption and hygiene, and dependence on alternative water sources. Alternative water sources may increase the risk of water related diseases if they are of poorer water quality. Disinfection is the last and most important step in drinking water purification.

Water chlorination is the most common method of drinking water disinfection using gaseous chlorine or chlorine-containing compounds. As a result of the interaction of chlorine with proteins and amino compounds contained in the shell of bacteria and their intracellular substance, oxidative processes, chemical changes in the intracellular substance, disintegration of the cell structure and death of bacteria and microorganisms occur.

Disinfection (disinfection) of drinking water is carried out by dosing chlorine, chlorine dioxide, chloramine or sodium hypochlorite. However, the process of disinfecting water with chlorine-containing reagents, as a result of which humanity got rid of the risk of infectious diseases and epidemics, has a downside.

Preventing some diseases, it is the cause of other, more serious diseases.

Scientists in the 70-80s of the last century found that chlorinated water contributes to the accumulation of carcinogens in the water. Among the population consuming chlorinated drinking water, cases of cancer of the esophagus, rectum, breast, larynx, and liver disease have been identified. Because when chlorine interacts with organic substances in water, chemicals are formed. These substances - trichlomethanes - are carcinogenic, which has been proven by scientists empirically. That is, the presence of side compounds in water is one of the disadvantages of using gaseous and liquid chlorine as a disinfectant. Therefore, in world practice, alternative methods of water treatment have begun to be used in water purification technology.

One of the effective methods that is used in Europe and in some countries of the CIS and Central Asia is water ozonation.

Currently, more than 1000 waterworks in Europe, mainly in France, Germany and Switzerland, use ozonation as part of the overall process. Recently, ozonation has been used in Japan and the United States. In the CIS countries, ozonation is used at waterworks in such large cities as Moscow, Kyiv, Minsk, Nizhny Novgorod and others. Water ozonation can significantly improve the quality of drinking water and solve many problems that arise during its chlorination [2].

Due to its high oxidizing potential, ozone interacts with many mineral organic substances, including the protoplasm of bacterial cells, destroying them. When comparing the disinfecting effect of ozone and chlorine at 0.1 mg / dm3 each, it was found that 60,000 seconds for complete destruction. New methods and equipment for the disinfection of waste and natural waters 25 Escherichia coli in 1 liter of water takes 5 seconds for ozone and 15,000 seconds for chlorine. The parameters of effective regimes depend on the quality of the treated water, the technology used, the design of the facility at specific facilities, and in each specific case should be specified on the ground [4].

## 2. Materials and Methods

### *2.1 Purification and disinfection of drinking water*

The quality of water used for drinking, household and technical purposes depends on the content of various soluble and insoluble minerals and organic substances in water and is determined by an indicator (set) of the physical, chemical, bacteriological and biological properties of water.

Requirements for the quality of drinking water. State standard of Uzbekistan “Drinking water. Hygienic requirements and quality control” is based on the requirements of GOSTRUZ 950: 2000 [5].

Clean drinking water should be clear, colorless, odorless, tasteless and free of pathogenic bacteria. The water temperature should be as even as possible throughout the year. In particular, the optimal temperature for increasing the productivity of animal husbandry is in the range of 7-120C.

Although the clarity of water depends on the floating substances it contains, its color depends on the amount of various soluble and insoluble substances. The unit of measure for color is the degree, which is determined by comparing a standard with colored water using an instrument called the platinum-cobalt scale. The color of drinking water should not exceed 20 degrees. The smell of water depends on the amount of various gases and organic substances in it. The unpleasant smell of water indicates that it contains salts and humus, characteristic of plant residues. According to GOSTRUZ 950: 2000, smell and taste should not exceed 2 (two) points (<2 points) even when drinking water is heated at a temperature of 20 degrees Celsius to 60 degrees.

The presence of minerals in the water - calcium and magnesium salts - gives it hardness. hardness is measured in "mg-eq/l" or degrees. A hardness of 1 degree corresponds to 10 mg of calcium oxide (SaO) or 14 mg of magnesium oxide (MgO) in water. to convert the hardness from degrees to "mEq/L" it is sufficient to divide the amount in degrees by 2.804.

*2.2 Properties of ozone*

Over the past fifteen years, there has been a significant expansion of the scope of ozone, as well as an intensive development of ozone technology and research. This development of ozone technology is facilitated by the environmental friendliness of ozone, since its use does not form harmful by-products. The formation of saturated oxides during reactions distinguishes it from other known oxidizing agents [6].

In addition to the bactericidal action, the process of ozonation of water has the ability to eliminate odors and tastes, as well as discolor water. Discoloration occurs due to the oxidation of compounds, which cause this color. Thus, the oxidized molecules decompose into simpler ones that are colorless.

At the same time, the residual concentration of ozone decomposes into atomic and molecular oxygen, as a rule, these products are considered not to pollute the environment and do not lead to the formation of carcinogenic substances, for example, as in the case of oxidation with chlorine or fluorine.

To date, the preference for the use of ozone in the processes of purification and disinfection of water is generally recognized.

Ozonation is an effective alternative to the treatment of wastewater containing metals in organic complexes. Ozone is an unstable gas; therefore, its generation must be done locally. Commercially available ozone generation technology is based on the corona discharge process, which involves the application of a high-voltage discharge in a cooled, dried gas phase containing oxygen ($O_2$ or air) [12, 15].

*2.3 Existing technology for the treatment of drinking water with ozone*

The existing technology for the treatment of drinking water with ozone includes the following elements (Figure 1): filter for air purification 1; a compressor for supplying air to the ozone generator 2; The process of electrosynthesis of ozone significantly depends on the air temperature, therefore, before air is supplied to OG 5, it is cooled in a refrigerator 3. Due to the fact that air cooling leads to the condensation of water vapor, it is necessary to dry it in a dryer 4.

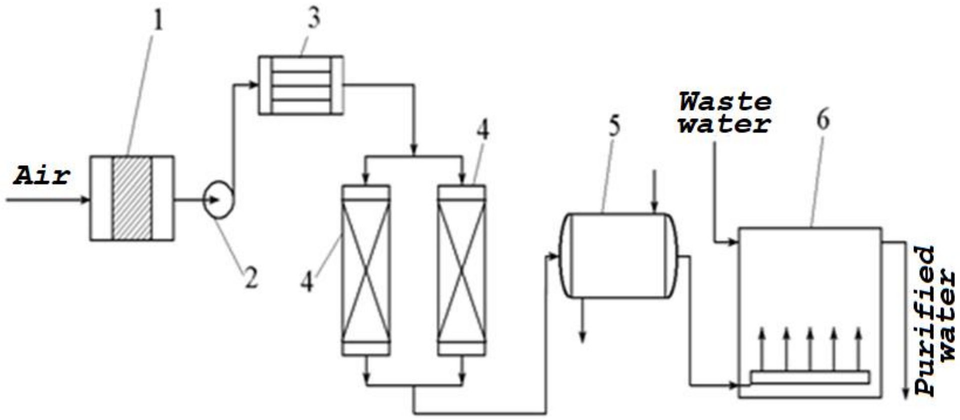


**Figure 1.** Technological scheme of drinking water treatment with ozone using the developed method of ozone electrosynthesis: 1 - air filter; 2 - compressor for the blower; 3 - cooling device; 4 - device for drying air; 5 - ozonizer; 6 – bubbling chamber (contact).

The prepared air is supplied to the ozone generator 5. Ozone-containing air is supplied to the contact chamber 6 filled with water to be processed, where it is bubbling. The ozone generator is powered by a

sinusoidal voltage from the GI step-up transformer, in view of the fact that when using sinusoidal voltages, the dielectric barriers of the OG are heated, then cooling water is supplied to the OG to cool them.
The existing technology of periodic action, the water in the contact chamber after treatment is removed, then filled with a new portion of the water to be treated.
Studies conducted in 2015 and 2016 found that when using periodic voltage pulses with a duty cycle of more than 5, the process of ozone electrosynthesis is practically not affected by the temperature of the treated air, and there is no heating of the dielectric barrier. Therefore, the cooler and dryer can be excluded from the technological scheme of the existing method of water treatment with ozone (Figure 1).
Instead of the listed elements, a generator of periodic voltage pulses is added to the technological circuit [9]. In addition, there is no need to cool the dielectric barrier. Taking into account the higher ozone yield, the conclusion follows that the planned tasks for the solution are fulfilled.

*2.4 Development of a flow technology for the treatment of drinking water with ozone*
The use of flow technology is of scientific and practical interest. To do this, it is proposed to use electrostatic water spraying (Figure 2) to obtain an aqueous aerosol with a uniform dispersion. Water atomization is performed by supplying ozone-containing air to the atomizer, which is the first stage of processing. Aerosol particles of water mixed with ozone-containing air are fed into the contact chamber of the CC, where the second stage of disinfection is performed. Due to the fact that the density of ozone exceeds the density of nitrogen and oxygen, naturally ozone will be located in the lower part of the CC. Excess gas will be removed through the top hole in the CC cover. A corona aerosol separator was installed at the exit of the contact chamber.

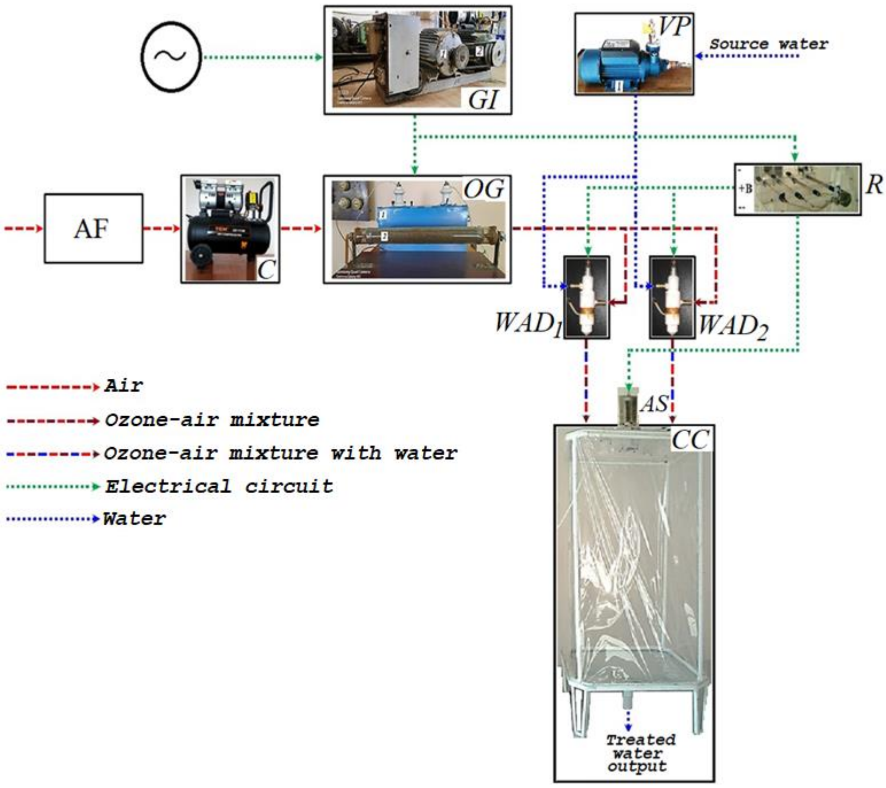


**Figure 2.** Technological scheme of flow-through water treatment with ozone: AF - air filter; C - compressor; VP-water pump; GI - generator of periodic voltage pulses; OG – ozone generator; R - rectifier; AS - aerosol separator; CC - contact chamber; WAD - water aerosol dispenser

The cross section of the aerosol separator is 100x100 mm. A potential electrode with corona needles is installed in the center of the ozone separator. The parameters of the electrode system were determined experimentally. The length of the needles is 15 mm, the distance between the needles in a row located across the gas flow is 30 mm, the distance between the rows of needles is 60 mm [10].

The height of the CC is 1.5 m. Three variants of spraying were tested in the experiment: spraying with a negatively charged water aerosol; spraying with a positively charged aqueous aerosol; spraying with negatively and positively charged water aerosol using two nebulizers. WAD.

*2.5 Flow treatment of drinking water with ozone*

Ozone generator device. The ozone generator for the experimental sample, due to the ease of manufacture, was made of a single glass tube with a diameter of 40 mm$^2$ and a length of 400 mm, which is hermetically sealed on both sides with plexiglass, in which openings were made for the outlets of the air inlet tubes and the outlet of the ozone-air mixture. The glass tube is wrapped in a metal mesh that acts as a potential electrode. The active zone of the tubular ozone generator is 360mm. Side covers - Plexiglas 10 mm thick. The ozone generator is housed in a metal casing.

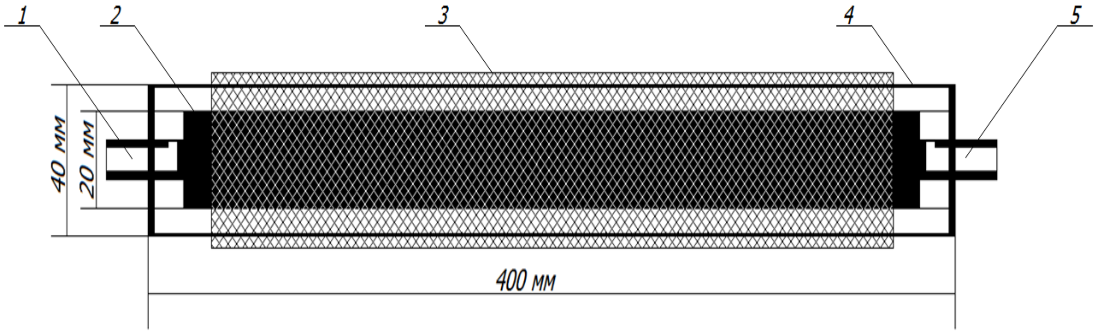


**Figure 3.** Sketch of a tubular ozone generator: 1 - air inlet; 2–grounded electrode; 3 - grid-potential electrode, 4-dielectric barrier; 5-output of ozone-air mixture.

*Water spray dispenser.* Working drawings of the elements of the atomizer are shown in Figure 4. The inner and outer clips of the atomizer are made of fluoroplastic. The bushing of the contact rod is made of stainless steel. The bushing of the contact rod is made of stainless steel. To create an electric field, an electrode made of copper foil is installed in the recess of the outer casing.

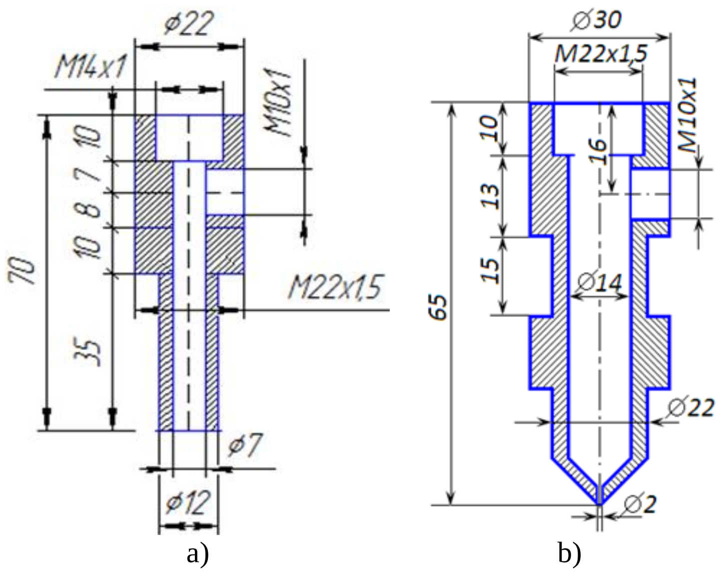


**Figure 4.** Parts of the water mist sprayer: a - inner clip, fluoroplast; b - outer clip

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*2.6 The installation for the flow treatment of drinking water with ozone*

An experimental sample of a plant for the flow treatment of drinking water with ozone (Figure 5) consists of a contact chamber 1.5 m high and a base 0.7x0.7 m. Two pneumoelectrostatic atomizers, an aerosol separator and a rectifier unit are installed on the top cover (Figure 6).

**Figure 5.** General view of the experimental setup for flow-through water treatment with ozone


**Figure 6.** Equipment installed on the cover of the contact chamber: 1-pneumoelectrostatic atomizer; 2-aerosol separator; 3 - block of rectifiers

Separately from the contact chamber, on a rack, a compressor driven by a universal collector motor, a water pump with a regulator-distributor (Figure 7), a rotometer, an ozone generator with a step-up transformer (Figure 8) are installed. Air and water wires are made of PVC pipes with a diameter of 9 and 10 mm.

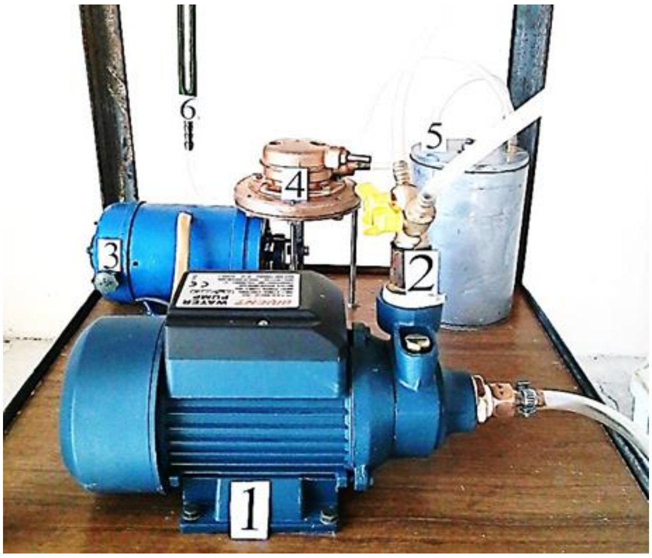


**Figure 7.** Equipment of the lower shelf of the rack: 1 - pump; 2- distributor water flow regulator; 3- universal commutator drive motor of the compressor; 4-compressor; 5-receiver; 6 - rotometer for measuring air supply

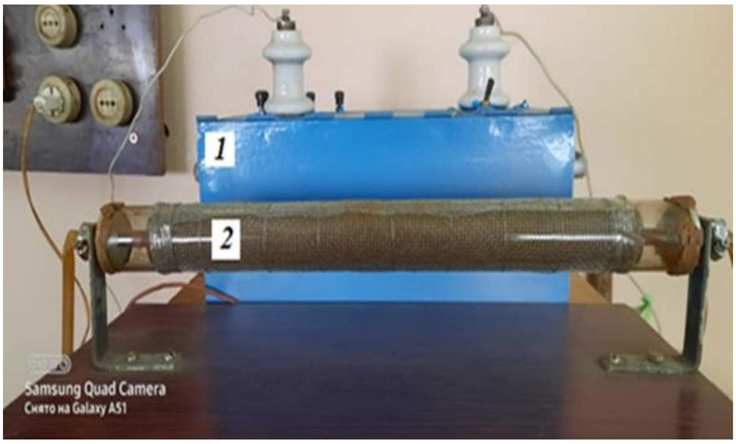


**Figure 8.** Top shelf equipment: step-up transformer; 2-ozone generator

*2.7 Production tests of an experimental plant for the treatment of drinking water with ozone*

Production tests of the experimental plant for the flow treatment of drinking water were carried out at the pumping station of drinking water LLC “Toshkent suv taminoti” of the Kibrai district, on open source water (Bozsu canal) and on the water of an artesian well. Research was carried out for three options:

- on negatively charged aerosols;
- on a positively charged aerosol;
- on bipolar charged aerosols.

Before the research, the air flow rate was selected. The best atomization of water occurred at an air flow rate of 0.027 m3/s and a water flow rate of 0.1 kg/s.

When applied to the atomizers, a half-wave operating voltage is equal to 2.5 kV, the voltage amplitude is 12.5 kV. At a higher voltage, spark breakdowns were observed on the inducing grounded rod. At these values of the impulse voltage, studies were carried out. At this voltage, the ozone concentration at the generator output was measured with a GOz-150 ozonometer and was equal to 73 $mg/m^3$.

Dispersion of sprayed water was determined using glass slides coated with a mixture of spindle oil 3 parts and one part of vaseline. When water particles hit the surface of the treated glass slides, the drops do not blur, but have the shape of an almost perfect ball. When spraying without applying voltage, the dispersion of droplets measured by microscopes lies in the range of 50-800 microns. When a voltage of negative polarity is applied, the dispersity of the droplets lies in the range of 30–50 µm. When a voltage of positive polarity is applied, the dispersion of drops is 40–60 µm. The droplet sizes were determined using a microscope.

## 3. Results and Discussion

*3.1 production tests of the pilot plant for the flow treatment of drinking water with ozone*

Production tests were carried out from September 6 to September 10, 2017 at the drinking water pumping station of the Botanika sanatorium. Analysis of the results of studies of the process of water disinfection in open reservoirs and artesian wells (Table 1) shows that the best disinfection process is observed with bipolar charging of water aerosols.

**Table 1.** Results of bacteriological analysis of water treated with ozone

| s/n | water consumption, 0.1 kg/s | Air flow, 0.027 $m^3/s$ | Type of processing | Ozone concentration, $mg/m^3$ | Total microbial count in 1 liter |
|---|---|---|---|---|---|
| Water from an open reservoir | | | | | |
| 1 | 0.1 | 0.027 | Control | 73 | 2014 |
| 2 | 0.1 | 0.027 | (+)spray can | 73 | 124 |
| 3 | 0.1 | 0.027 | (- ) spray can | 83 | 107 |
| 4 | 0.1 | 0.027 | (-,+)spray can | 73 | 41 |
| Water from an artesian well | | | | | |
| 5 | 0.1 | 0.027 | Control | 73 | 1230 |
| 6 | 0.1 | 0.027 | (+)spray can | 73 | 90 |
| 7 | 0.1 | 0.027 | (- ) spray can | 73 | 74 |
| 8 | 0.1 | 0.027 | (-,+)spray can | 73 | 31 |

At the maximum allowable concentration (MPC) of the total microbial number (TMC) equal to 100 l-1, when treated with a bipolar charged aerosol, the TMC for water in open reservoirs decreased from 2014 to 41, and for water from artesian wells - from 1230 to 31.

Chemical analysis of water treated with ozone showed a slight decrease in the concentration of some impurities and salts in the water. The chemical analysis was carried out only for the bipolar charged aerosol.

Before carrying out the research, the selection of air flow was carried out. The best atomization of water occurred at an air flow rate of 0.027 $m^3/s$ and a water flow rate of 4 l/min.

When applied to the atomizers, a half-wave operating voltage is equal to 2.5 kV, the voltage amplitude is 12.5 kV. At a higher voltage, spark breakdowns were observed on the inducing grounded rod. At these values of the impulse voltage, studies were carried out. The voltage parameters supplied to the ozone generator are the same. At this voltage, the ozone concentration at the generator output was measured with a GOz-150 ozonometer and was equal to 73 $mg/m^3$.

The supply voltage of the aerosol separator, rectified according to the multiplication circuit, is as follows: the constant component of the voltage is 12.5 kV; operating voltage - 15 kV; amplitude – 25 kV [11].

The dispersity of the sprayed water (Figure 9) was determined using glass slides coated with a mixture of 3 parts of spindle oil and one part of vaseline.

When water particles hit the surface of the treated glass slides, the drops did not blur, but had the shape of an almost perfect hemisphere. When spraying without applying voltage, the dispersion of droplets measured by microscopes lies in the range of 50-800 μm. When a voltage of negative polarity is applied, the dispersity of the droplets lies in the range of 30–50 μm. When a voltage of positive polarity is applied, the dispersion of drops is 40–60 μm.

During the tests, the process of heating the surface of the ozone generator was monitored. During the entire test period, the barrier temperature increased by 1 $^{0}$C. The temperature was measured during the operation of the ozone generator, remotely using an infrared thermometer type G-300.

Bacteriological and chemical analyzes were carried out by employees of the Tashkent regional CSEC.

a) b) c)

**Figure 9.** Photomicrographs of a sprayed water aerosol: a – aerosol after electrostatic spraying; b - aerosol after spraying with air blowing; c - aerosol without air blowing (One division of the sight line corresponds to 15 μm)

*3.2. Production tests of an experimental installation for the flow treatment of drinking water with ozone*

Production tests were carried out on September 22 and 23, 2020 at the drinking water pumping station of Toshkent suv taminoti LLC, Kibray district. Analysis of the results of studies of the process of water disinfection in open water bodies (Table 2) and artesian wells (Table 3) shows that the best disinfection process is observed with bipolar charging of water aerosols.

**Table 2.** The results of bacteriological analysis of open reservoir water treated with ozone

| № s/n | Sample name | Type of processing | TCB, CFU in 100 ml | CCB, CFU in 100 ml | Pathogenic microbes, including salmonella |
|---|---|---|---|---|---|
| 1. | Kurgazma street Water of the Boz-su canal before treatment | Control | 585 | 8955 | Not detected |
| 2 | Kurgazma Street Boz-su canal water after treatment | Conventional spray | 370 | 7982 | Not detected |
| 3 | Kurgazma Street Boz-su canal water after treatment | (+) spray can | 207 | 575 | Not detected |
| 4 | Kurgazma Street Boz-su canal water after treatment | (-,+)spray can | 117 | 275 | Not detected |
| 5 | Kurgazma Street Boz-su canal water after treatment | (- ) spray can | 153 | 252 | Not detected |

Conclusions of the head of the department of the Tashkent regional CSEC G. Musabekov: The tested samples of water from an open reservoir after bacteriological treatment meet the requirements of San KMI 0318 - 15 [14, 13, 7]. And the drinking water of an artesian well meets the requirements of GosStru -950/2011 [8].

**Table 3.** The results of bacteriological analysis of artesian well water treated with ozone

| № s/n | Sample name | Type of processing | Total microbial count in 1.0 | ITBG (residues) | Pathogenic microbes, including salmonella |
|---|---|---|---|---|---|
| 1. | Water taken from plot 29 before treatment | Control | T.M.L = no growth | c/i=7 | Not detected |
| 2 | Water taken from 29 plots after treatment | Conventional spray | T.M.L = no growth | c/i =4 | Not detected |
| 3 | Water taken from plot 29 before treatment | Control | T.M.L = no growth | c/i = less 3 | Not detected |
| 4 | Water taken from 29 plots after treatment | (-,+) spray can | T.M.L = no growth | c/i = less 3 | Not detected |
| 5 | Water taken from plot 29 before treatment | Control | T.M.L = 100 | c/i =9 | Not detected |
| 6 | Water taken from 29 plots after treatment | (- ) spray can | T.M.L = no growth | c/i = less 3 | Not detected |
| 7 | Water taken from plot 29 before treatment | Control | T.M.L = no growth | c/i =4 | Not detected |
| 8 | Water taken from plot 29 after treatment | (+) spray can | T.M.L = no growth | c/i = less 3 | Not detected |

When an uncharged aerosol is fed into the contact chamber, disinfection is weak, due to the fact that aerosol particles have different dispersion. The best performance was obtained with a bipolar charged aerosol, which is due to the fact that already in the contact chamber there is an interaction of a bipolar charged aerosol. These are visually observed foggy formations in the lower part of the contact chamber.

## 4. Conclusions

a) The existing technology of drinking water treatment with ozone provides for cooling and drying of the air supplied to the ozone generator. It is also envisaged to cool the electrodes of the ozone generator with running water. Water treatment with ozone is periodic. The contact container is filled with water, and the treatment is carried out by dispersing ozone-containing air in water.
b) When using periodic high-duty voltage pulses, the existing technology for treating drinking water with ozone eliminates the operations of cooling and drying the air supplied to the ozone generator, as well as cooling the electrodes of the ozone generator with running water. At the same time, the treatment process will be significantly reduced, due to the higher concentration of ozone at the output of the ozone generator.
c) The technology of spraying water into an ozone-containing environment is of scientific and practical interest. In this case, spraying is carried out by a pneumoelectrostatic sprayer. The atomizer is supplied with ozone-containing air from an ozone generator. Further processing of aerosol particles is carried out in a contact chamber.
d) To capture aerosols by the wave in the place where air is removed from the contact chamber, an aerosol separator is installed, the parameters of which are determined on the basis of experimental studies.
e) The technology of spraying water into an ozone-containing environment is of scientific and practical interest. In this case, spraying is carried out by a pneumoelectrostatic sprayer. The atomizer is supplied with ozone-containing air from an ozone generator. Further processing of aerosol particles is carried out in a contact chamber.
f) To capture aerosols by the wave in the place where air is removed from the contact chamber, an aerosol separator is installed, the parameters of which are determined on the basis of experimental studies.
g) Further research should be carried out in the direction of increasing the productivity of the plant.

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