Development of the design and manufacturing technology of a bactericidal ionizer

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Abstract. The design and manufacturing technology of a bactericidal ionizer with electrolytic coatings of copper and silver forming a galvanic cell are described. The ionizer is capable of creating solutions containing silver and copper ions. Using an ionizer, one can get preventive solutions that strengthen the immune system; medical preparations; cosmetic compositions; receive disinfectant solutions that can destroy a number of pathogenic bacteria and viruses. The ionizer has a low cost; it is easy to use and surpasses analogues in performance. A manufacturing technology for such an ionizer has been developed.

1. Introduction

At present, in connection with the spread of coronavirus infection worldwide, it is very important to increase immunity, use effective disinfecting solutions at home, drink disinfected water and drinks, and be able to prepare some medications at home. An ionizer allows creating solutions containing copper and silver ions. Copper, being a completely irreplaceable microelement, in addition to antimicrobial action, has immunostimulating, antioxidant and anti-inflammatory properties. Thus, a 99% reduction in the number of initial bacteria occurred in 10 hours at a concentration of copper ions of 0.01 mg/l, in three hours at a concentration of copper ions of 0.1 mg/l, and after one hour at a copper ion content of 1 mg / l [1, 2]. Silver in ionic form has an immunomodulating, bactericidal, bacteriostatic, antiviral, antifungal and antiseptic effect against more than 500 pathogenic microorganisms. One milligram of silver ions in one liter of water for half an hour causes inactivation of the influenza viruses A, B, Miter and Sendai, has a therapeutic effect in the treatment of viral enteritis, and also inhibits the initial development of the AIDS virus. The effect of silver killing bacteria is 1.500 times higher than the action of the same phenol concentration and 3.5 times higher than the action of mercuric chloride [3–5]. In this regard, the authors of the utility model [6] developed plastic utensils with bactericidal properties containing silver nanopowder. When using this glassware, liquids poured into it are saturated with silver ions. However, the concentration of silver may not always be sufficient for a full disinfecting effect. Since the area of contact of silver and the liquid used in the proposed bactericidal dishes is insignificant, even the presence of silver in the form of nanopowder does not completely solve the problem. A significantly higher concentration of silver and copper ions can be obtained using electrochemical ionizers. In particular, the utility model “Ionizer for disinfecting drinking water with silver or copper ions and preparing silver or copper aqueous solutions of a given concentration” is known [7]. The ionizer contains a grid electrometering device, where a current isolation is provided, ensuring the safety of the ionizer, stabilizing the current and...
reversing the polarity. The ionizer has a timer, a stabilizer of the concentration of ions in a given volume of drinking water and electrodes made of chemically pure silver or copper, made identical in shape and size, parallel to each other. The electrodes are predominantly triangular in shape and perforated with round holes, enclosed in a dielectric cassette of a similar shape and perforation, while the cassette is equipped with a handle made in one piece with the cassette, and has the shape of a “spoon” for the forced separation of silver or copper ions from the electrodes by stirring water throughout the electrolytic process. The ionizer is equipped with an autonomous power source, and an electronic device (tester) is nested in a “spoon” to visually monitor the amount of dissolved silver or copper. Using this ionizer, you can get solutions containing copper and silver ions of any desired concentration. Simpler in design are such ionizers as antimicrobial ionizer [8] and copper-silver ionizer [9]. These ionizers contain a spiral anode and a cathode which are short-circuited to each other by direct electrical contact, made of metals with various electrochemical potentials. They are installed in a vessel of limited capacity. The following electrochemical metal pairs are used as electrodes: copper (anode) and silver or silver-plated copper (cathode), and in the second version, silver (anode) and gold or gilded silver (cathode). The formation of copper and silver ions occurs due to the galvanic cell operation. In this case, electrodes with surface areas of 10.5 cm² each are used in a copper-silver ionizer. Tests have shown an increase in resistance to colds and a decrease in the frequency of exacerbation of chronic otolaryngological diseases if using an ionic solution. Herewith, they have no inhibitory effect on the ciliary epithelium. No side effects from the use of the solution were noted [9]. However, this ionizer also has disadvantages. It has low productivity, because small area electrodes are used. In this ionizer it is impossible to obtain solutions with different ratios of copper and silver ions, as well as solutions containing only copper ions or only silver ions. The ionizer is not very convenient to use, since it takes a relatively long time to clean and service it. Thus, the problem of creating an inexpensive, productive, universal, convenient ionizer for home use is quite relevant. In this regard, the goal of this work is to develop the design and manufacturing technology of such an ionizer.

2. Experiment: materials and methodic
The samples had dimensions of 30x20x0.5mm; they were made of low-carbon steel 10kp containing 0.1% carbon. For the preparation of electrolytes, distilled water and chemically pure chemicals were used. The electrodeposition of the coatings was carried out using an AC rectifier with current stabilization and short circuit protection. The setup graph is shown in the experimental part. Electrodeposition of coatings was performed in laboratory galvanic baths with a volume of electrolytes of one liter. The electrolyte was stirred with a magnetic stirrer at a speed of 60 - 80 r/min. The thickness of the coatings and the deposition rate were determined by the weight method (by weight gain) on an analytical balance with an accuracy of 0.1 mg. The wear resistance of the coatings was determined at the stand of the reciprocating motion of the LTI structure. The porosity of the coatings was determined by applying a filter paper impregnated with a solution containing 10 g/l of potassium iron-hydrogen sulfide and 20 g/l of sodium chloride, after 20 minutes exposure. The adhesion strength of coatings was tested by such methods as applying a grid of scratches and brushing with a brass brush.

3. Results and discussion
The proposed ionizer consists of containers of various capacities from 25 ml to several tens of liters and a spoon. Tanks can have a different cylindrical shape with either the same diameters at the top and bottom or expanding up. These containers can be made of high purity copper; silver can be coated on the lower inner part of the container so that the ratio of the internal surfaces of copper and silver coating is from 0.8:1 to 1:1. The second, more economical option, presents the tank made of low-carbon steel 05kp, 08kp or 10kp, and then its entire surface is coated with copper. In the third variant, the container is made of plastic. Then the entire surface of the tank is covered with copper. After that, a silver coating is on the lower inner part of the vessel, so that the ratio of the inner surfaces of copper and silver coating is from 0.8:1 to 1:1. In this case, it must be borne in mind that the liquid is not poured into the tank to the very top. The ionizer is a galvanic cell consisting of copper and silver coatings in contact with each
other wetted by an electrolyte. As an electrolyte, a low concentrated solution of citric acid (100 mg/l is enough) in distilled water, mineral or drinking water, physiological saline with citric acid, milk whey, tomato juice containing sodium chloride and other electrolytes depending on the purpose of the solution can be used. In this pair of coatings, a silver coating having a standard potential of + 0.8V is cathodic, and a copper coating having a standard potential of + 0.3V is anodic. In actually used solutions, the coating potentials, of course, will differ from the standard ones. However, in any of the prepared solutions, the potential of copper will be more negative compared to the potential of silver. Accordingly, the copper coating will be the anode and will dissolve faster than the silver coating due to the reaction (1):

$$\text{Cu}^0 - 2e = \text{Cu}^{2+}$$ (1)

In this case, silver oxide is formed on the surface of the silver coating, which, slowly dissolving, also passes into the solution. The set of processes can be expressed with formulas:

$$\text{Cu} + 2\text{Ag} + \text{H}_2\text{O} + 2\text{H}^+ \rightarrow \text{Cu}^{2+} + \text{Ag}_2\text{O} + 2\text{H}_2$$ (2)

$$\text{Ag}_2\text{O} + \text{H}_2\text{O} = 2\text{Ag}^+ + 2\text{OH}^-$$ (3)

To make a therapeutic and preventive solutions using copper ions in combination with silver ions and cosmetics with the participation of copper and silver, which can stimulate the processes of generating biological tissue without side effects, one can use the recommendations set forth in the patent [9]. In the ionizer with the ratio of the areas of their electrodes Cu/Ag: 1/0.7; 1/0.8; 1/0.9; 1/1 the following ratios of concentrations of Ag/Cu in drinking water were obtained: 1/6500, 1/4900, 1/4800, 1/4500. The authors of this patent found that the ionizer with the above parameters in 400 ml of physiological solution with the addition of citric acid at a liquid temperature of 18-20°C releases 0.4 mg of copper and 0.00008 mg of silver within an hour. The amount of emitted ions is directly proportional to the exposure time. So, when installing the ionizer in a standard container with physiological saline (400 ml) with the addition of citric acid 100 mg/l, at an exposure of 6, 12 and 24 hours, respectively, the following silver concentrations were obtained: 0.0012; 0.002; 0.0048 mg/l and for copper: 6.0; 12.0; 24.0 mg/l.

When using the proposed bactericidal dishes, the exposure time should be significantly reduced, since the anode surface area in the proposed bactericidal dishes (the same volume of 400 ml) is an order of magnitude higher than the anode area (10.5 cm²) of the ionizer proposed in the patent [9]. For the preparation of preventive solutions simultaneously containing both copper and silver ions, it is sufficient to keep the fluid used for 5-10 minutes in the ionizer. To prepare preventive solutions containing only silver ions, one should pour liquid inside the ionizer so that its upper level does not touch the copper coating. To prepare preventive solutions containing only copper ions, it is necessary to place the bactericidal container inside another non-metallic (glass, ceramic) container with a larger diameter and pour liquid between the outer copper surface of the ionizer and the inner surface of another non-metallic container, as shown in figure 1.

When preparing preventive solutions containing only copper or only silver, the exposure time should be significantly increased to several hours (2-24 hours), since in these cases the dissolution of copper or silver is much slower, not due to the work of the galvanic cell, but due to contact discharge. The reason is that the solubility of copper and silver is very low. Since the solubility of silver in water is 0.04 μg/l, Ag + silver ions form hydrated ions that maintain stability for a long time:

$$\text{Ag}(\text{H}_2\text{O})^+ \rightarrow \text{H}^+ + (\text{Ag}^+ + \text{OH}^-)$$ (4)
Another element of the ionizer is a bactericidal spoon. A bactericidal spoon, as well as a bactericidal container, can be made of copper and coated with half of the copper area (taking into account the liquid level) with silver. A bactericidal spoon, as well as a bactericidal container, can be made of low-carbon steel and first totally covered with copper, and then half (taking into account the liquid level) coated with silver, observing the ratio of the surfaces of copper and silver coating from 0.8:1 to 1:1. A spoon can also be used to prepare solutions. A solution simultaneously containing copper and silver ions is prepared if the spoon is immersed in the liquid almost completely, so that both the silver and copper coatings are wetted by the liquid. To prepare a solution containing only copper ions, only part of the copper-coated spoon is immersed in the liquid. To prepare a solution containing only silver ions, only part of a spoon with silver coatings is immersed in a liquid. A bactericidal spoon is easier to make, but it can mainly be used to prepare bactericidal prophylactic solutions, and it is better to use bactericidal dishes for the preparation of therapeutic and cosmetic solutions, since it usually has a larger surface of the coating electrodes. The content of silver and copper in drinking water is regulated by the norms of Sanitary Rules and Norms (hereinafter – SanPiN) 2.1.4.1074-01 “Drinking water. Hygienic requirements for water quality of centralized drinking water supply systems. Quality control”. The copper content should not exceed 1 mg/l, silver should not be more than 0.05 mg/l. For packaged water, the content of silver ions should not exceed 0.025 mg/l in accordance with SanPiN 2.1.4.1116-02 “Drinking water. Hygienic requirements for the quality of water packaged in containers. Quality control”. Concentrations of silver and copper close to the maximum permissible concentrations do not adversely affect the human body. If the solution is prepared on the basis of drinking water, it is necessary to consider the concentration of these ions in the water of particular region. Prolonged use of solutions with silver and copper ions in amounts significantly exceeding the maximum permissible concentration can have a negative effect, in particular, lead to argyria.

For the manufacture of an ionizer, shaping and coating technologies are used. The most productive methods of forming from copper and steel belong to the field of pressure treatment. To make a spoon, molding is used. Tanks can be made by hood. In small-scale production, for example, for the manufacture of a pilot batch, the shaping of metal containers for the ionizer can be performed by the end rolling process. Forming of spoons and containers made of plastic, most often, is carried out by injection molding with injection molding machines. Next, it is necessary to apply copper and silver coatings. On plastic products, the first layer of copper coating can be applied by vacuum condensation, and then the local silver coating is applied galvanically, because it is the easier way. The second variant of metallization is the deposition of copper and silver plating. This option is more multi-operational, but it allows getting an ionizer with higher performance due to the creation of coatings with large actual areas. First, we consider the technology of metallization of steel products in a galvanic mode. To prepare the surface, degreasing and etching solutions were used; they are presented in table 1.
Table 1. Solutions for preparing the surface of low carbon steel.

| Components, g/l and modes | Solution 1 | Solution 2 |
|---------------------------|------------|------------|
| Sodium hydroxide          | 15–25      |            |
| Sulphuric acid            |            | 120–150    |
| Sodium carbonate          | 30–50      |            |
| Trisodium phosphate       | 30–50      |            |
| Sodium liquid glass       | 10–20      |            |
| Inhibitor KPI             | -1–1.0     | 0.5–1.0    |
| Preparation OS-20         | 0.1–0.5    |            |
| Temperature, °C           | 60–80      | 18–30      |
| Density of alternating current, A/dm² | 3–8       |            |
| Time, min                 | 4–5        | 3–4        |

Electrochemical degreasing on alternating current was used. It made possible to use cheaper electrical equipment and increase the load of the degreasing bath, since in this case it is not necessary to use additional electrodes. The etching time may vary depending on the amount of oxides on the surface of the steel. After etching, the operation of decapitation in a solution of sulfuric acid 50–70g/l was performed for 0.5–1 minutes. Then washing was performed in tap and distilled water. After that, galvanic coatings were applied. For electrodeposition of coatings, the installation shown in Figure 1 and electrolytes, the compositions of which are given in tables 2, 4, 5, were used.

Figure 2. Installation for applying electrolytic coatings. 1 – ACRG (AC rectifier designed by V.M. Goreev); 2 – current regulator; 3 - tumbler switch on of electricity grid; 4 – tumbler switch on of current supply; 5 – digital milliamperemeter; 6 – tumbler switch on of ACRG; 7 – anode terminal “+”; 8 – cathode terminal “−”; 9 – mixing element of the stirrer; 10 – magnetic stirrer; 11 – mixing speed controller; 12 – heating switch on button; 13 – power switch on button; 14 – anodes; 15 – bath with electrolyte; 16 – metallized product.

The thickness of the coatings was determined by the gravimetric method using formula 5.

\[
h = \frac{(m_2-m_1) \times 10000}{\rho \cdot S} \tag{5}
\]
where $h$ is the coating thickness, microns; $m_2$ is the mass of the coated sample, g; $m_1$ is the mass of the sample without coating, g; $\rho_1$ is the density of the coating metal, g/cm³; $S$ is the area of the covered area, cm².

The most common copper plating electrolytes are sulfate electrolytes. However, acidic copper plating electrolytes do not allow obtaining sufficient, necessary adhesion of the copper coating on steel due to contact release of copper. Contact release of copper is not completely suppressed in the presence of special additives introduced into acidic electrolytes. A number of copper plating alkaline electrolytes are devoid of this disadvantage. Pyrophosphate electrolytes are the simplest in composition, stable and harmless compared to other copper plating alkaline electrolytes. For copper plating, two pyrophosphate electrolytes were proposed; their operating modes and compositions are given in tables 2 and 4, preliminary copper plating electrolyte 3 and electrolyte 6 of the main, more high-speed copper plating. To suppress the contact release of copper in the preliminary copper plating electrolyte, the copper concentration was reduced and citric acid, trioxyglutaric acid and sodium sulfosalicylate were introduced. To increase the adhesion of the copper coating to steel, the samples were loaded under current and a current boost was performed for 30–45 seconds with a current density of 1.5–2 times higher than the working cathode current density. Then the coating was applied to the required thickness at the working current density. Table 2 also shows the compositions of electrolytes and modes of preliminary nickel plating and tinning.

Table 2. Compositions and modes of electrolytes of preliminary copper plating, nickel plating and tinning.

| Components, g/l and modes | 3       | 4       | 5       |
|---------------------------|---------|---------|---------|
| Copper sulfate            | 3–8     |         |         |
| Potassium pyrophosphate   | 100–150 |         |         |
| Nickel fluoroborate       |         | 300–400 |         |
| Tin sulfate               |         | 40–60   |         |
| Nickel chloride           |         | 10–15   |         |
| Sulphuric acid            |         | 80–100  |         |
| Citric acid               |         | 15–25   |         |
| Boric acid                |         | 10–15   |         |
| Trioxylglutaric acid      |         | 5–7     |         |
| Preparation OS-20        |         | 2–5     |         |
| Sodium sulfosalicylate    | 20–30   |         |         |
| Temperature, °C           | 18–25   | 18–50   | 18–25   |
| pH                        | 8.3–8.7 | 3–3.5   |         |
| $D_c$, A/dm² without stirring | 0.2–0.5 | 5–20    |         |
| $D_c$, A/dm² with stirring |         |         | 1–2     |
| Process duration, min     | 15–38   | 1–3     | 4–8     |

To prevent contact release of copper on carbon steel, electrolytic tin plating and nickel plating can be used. For these purposes, nickel sulfate electrolyte (Watts electrolyte) is most often used. However, this electrolyte does not have high nickel rate and dissipation ability, and in these parameters it is inferior to a hydrofluoric nickel plating electrolyte. In addition, the fluoroborate nickel plating electrolyte is stable in operation, it allows obtaining light, not hard, elastic coatings; therefore, the nickel fluoroborate electrolyte was used (electrolyte 4 in table 2). The use of this electrolyte significantly reduced the time of preliminary nickel plating. However, the fluoroborate nickel plating electrolyte is inferior in its scattering power to tin plating electrolyte and copper plating pyrophosphate electrolyte. For preliminary metallization of steel, tin sulfate electrolyte 5 was also used (table 2). Tin electrolytes are prone to delamination and suspension, so they are not mixed, which is usually done to increase the deposition rate of coatings. To determine the required thickness of coatings deposited using pre-metallization...
electrolytes, we determined the effect of coating thicknesses on adhesion. Coating of pre-metallization electrolytes with a thickness of 1.5 and 3 μm was applied. Then, all samples were coated with copper with a thickness of 6 μm using pyrophosphate electrolyte of the main copper plating 6. The results are shown in table 3.

**Table 3.** The effect of thickness and composition of coatings and preliminary metallization on adhesion.

| Coatings | Thickness 1.5 μm | Thickness 3 μm |
|----------|------------------|----------------|
| Copper   | +/-              | +/-            |
| Nickel   | +/-              | +/-            |
| Tin      | +/-              | +/-            |

Table 3 shows the method of measuring adhesion: in the numerator – brushing with a brass brush, in the denominator – scratching (drawing marks). As can be seen, from the data given in table 3, in order to ensure sufficient adhesion, the thickness of the copper coating electrodeposited in the electrolyte prior to copper plating should be 1.5 μm. Nickel and tin coatings should have a thickness of 3 μm. The duration of electrolysis to obtain such thicknesses is given in table 2, depending on the current density used. Covered containers can have a complex shape for coating, for example, a large ratio of the height of the container to the diameter, etc. Electrolytes may not have enough opacity and dispersion for high-quality metallization of such containers. In these cases, it is advisable to carry out the coating with an additional anode, which is installed inside the covered tank, both during preliminary metallization and during the main build-up of the required coating thickness.

After preliminary coating the operation of copper coating extension to the required thickness can be performed in copper plating electrolytes 6 and 7, which is presented in table 4.

**Table 4.** Electrolytes of the main copper plating.

| Electrolyte Components (g/l) and Modes | 6    | 7    |
|---------------------------------------|------|------|
| Copper sulfate                        | 80–100|      |
| Copper Fluoroborate                   |      | 200–250|
| Potassium pyrophosphate               | 300–350| 2–3  |
| Hydrofluoric acid (free)              |      |      |
| Citric acid                           | 15–25 |      |
| Boric acid                            | 15–16 |      |
| Boron nitride                         | 5–10  | 5–10 |
| Temperature,°C                        | 40–60 | 40–60|
| pH                                    | 8.3–8.7| 1.2–1.7|
| Dc, A/dm2 with stirring               | 1.5–2.5| 5–20 |
| Process duration, min                 | 36–60 | 6–18 |

As can be seen from table 4, pyrophosphate and hydrogen fluoride electrolytes were used for the main copper plating. Pyrophosphate has a significantly higher scattering power. In addition, the use of pyrophosphate electrolytes of preliminary and main copper plating allows abandoning the washing operation in purified water. Products, after preliminary copper plating, can be transferred without washing to the main pyrophosphate copper plating electrolyte. However, pyrophosphate electrolytes, by almost an order of magnitude, have a lower copper plating rate compared with hydrogen fluoride. On the other hand, a hydrogen fluoride electrolyte is more toxic. When choosing the electrolyte of the main copper plating, first of all, it is necessary to take into account the configuration of the bactericidal dishes. Copper electrolytes 6 and 7 contain cubic boron nitride (elbor) MRTU 2-036-1-68 brand LM 1/0. The grain size of the main fraction (95%) is 1 μm and smaller, i.e., the main fraction contains boron nitride...
nanopowder BN. Cubic BN in hardness is second only to diamond and penetrating into coatings significantly increases their wear resistance [10]. It is known that nanopowders can adsorb metal cations and improve their delivery to the cathode. Nanopowders, as a rule, increase the adhesion of coatings and reduce their porosity [11]. Thus, the introduction of boron nitride into the electrolyte made it possible to reduce the required thickness of the copper coating. Since the copper coating should be continuous without through pores reaching the base metal of the steel, so that iron ions do not fall into the solutions created with the help of bactericidal dishes. In this regard, the porosity of the coatings was determined, the results are given in table 5.

Table 5. The effect of pre-coating type and the thickness of the main copper coating on the number of through pores, pieces/cm².

| Pre-coating type | Main copper 6 μm | Main copper 12 μm | Main copper 18 μm |
|------------------|------------------|------------------|------------------|
| Copper 1.5 μm    | 19               | 8                | 0                |
| Nickel 3 μm      | 12               | 5                | 0                |
| Tin 3 μm         | 26               | 14               | 2                |

As can be seen from the results obtained with a thickness of 18 μm, almost all coatings become non-porous. The maximum permissible concentration (MPC) of iron in drinking water: from artesian wells, 0.5-30 mg/l, and for schools, hospitals and other similar institutions – 0.3 mg/l. Given that the MPC of iron in drinking water is relatively large, the thickness of the main copper coating of 18 μm will be enough for safe operation of the ionizer. Table 4 gives the time of electrolysis to obtain a coating of this thickness depending on the cathode current density.

After applying the copper coating, a silvering operation was performed. The greatest cathodic polarization during the electrodeposition of silver is possessed by cyanide electrolytes, which so far remain the best in terms of the quality of the coatings obtained, in the stability of the electrolyte, in scattering power, and other parameters. However, cyanide electrolytes are highly toxic due to the presence of free potassium or sodium cyanide in their composition. Among non-cyanide electrolytes, the most close in its characteristics to cyanide electrolytes is ferruginous-heterodistor (hexacyanoferrate II) electrolyte. This is due to the fact that silver is present as a cyanide complex in ferruginous-ferroelectric electrolytes, but the electrolyte does not contain free cyanide. To dissolve the anodes, potassium thiocyanate is introduced into the electrolyte. The compositions of the ferruginous-hydrodynamic electrolyte and the modes of their operation are given in table 6.

Table 6. Ferruginous-heterodistor electrolytes of silver plating.

| Electrolyte components (g/l) and electrolysis mode | 8   | 9   |
|---------------------------------------------------|-----|-----|
| Silver (in terms of metal)                        | 1–2 | 25–30|
| Potassium ferruginous (free)                      | 40–60 | 40–80 |
| Potassium rhodonite                               | 80–100 | 80–100 |
| Potassium carbonate                               | 35–40 |
| Boron nitride                                     | 5–10 | 5–10 |
| Temperature, °C                                   | 18–25 | 18–25 |
| D₀, A/dm² without stirring                         | 0.1–0.2 |
| D₀, A/dm² with stirring                            | 0.6–1.2 |

Electrolyte 8 is a pre-silvering electrolyte. To prevent contact emission of silver on the copper coating, the silver concentration is reduced to 1–2 g/l. To apply a silver coating only on the inner lower surface of bactericidal dishes, one should pour silver electrolyte to the required level, install a silver anode in the cover in the electrolyte, connect the container to the negative pole of the rectifier and conduct electrolysis. The electrolysis time in the pre-silvering bath is 5 minutes. The recommended
thickness of the silver coating on the dishes (spoons, forks, etc.) is 24 microns. However, taking into account the fact that the wear resistance of the silver composite coating, determined on the wear stand of the reciprocating movement, increased by 8.6 times, it is possible to reduce the thickness of the coating. Of course, the wear stand does not reproduce the real conditions of the abrasion of the silver coating on the dishes; however, the coating thickness can be reduced at least by half. In the main silver plating electrolyte 9, a coating thickness of 12 μm was electrodeposited at Dk = 1 A/dm² in 24 minutes. Silver composite coatings were matte, light, even without visible defects and passed the test for adhesion strength.

4. Conclusion
As a result of this work, an ionizer has been developed that surpasses analogues without a current source in the rate of saturation of liquid media with copper and silver ions. A technology has been developed for the manufacture of bactericidal dishes using copper, silver, nickel and tin plating. The influence of the composition and thickness of coatings, preliminary metallization, on the adhesion and porosity of multilayer coatings is established. Two technological schemes for the metallization of bactericidal dishes have been created. The first scheme is using pyrophosphate electrolytes of preliminary and main copper plating, which allows applying copper coatings to containers of a relatively complex shape. The second, more productive, technological scheme with the use of preliminary nickel plating or tinning can be applied for the manufacture of ionization spoons and ionization tanks. At the same time, electrolytic coating of containers with complex configurations using hydrofluoric nickel plating and copper plating electrolytes, as well as tinning, should be carried out using additional anodes. A technology has been developed for producing a composite, wear-resistant electrochemical coating consisting of silver and boron nitride.

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