Researches Regarding the Use of Silver and Screen Printed Electrodes to the Improvement of the Drinking Water Quality from Rural Areas

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Abstract. Based on the antibacterial properties of the silver, some pieces of water drinking installation could be covered by thin layer of silver to enhance the drinking water quality. In the water tanks could be introduces activated pieces coverer by layers of silver such as: screens, grids, adjustable cylindrical rings, taps etc. The obtained waters were characterized by detecting by electrochemical way the heavy metals content and the total content of the microbial charge.

Keywords: Silver, water quality, rural area, electrodes

INTRODUCTION

Silver is a strong bactericide. It is one of the strongest natural bactericides, effective against over 650 pathogen organisms, germs, viruses and fungi [1, 2]. Silver is a strong disinfectant used in preparing drinking water. Water stored in silver containers is sterilized and keeps for a long time without becoming infected, due to the Ag⁺ silver ions resulting from the water coming into contact with the silver in the container wall. AgCl₂ silver chloride, a bactericide substance, is obtained in contact with the residual chlorine in drinking water [1].

Legal norms – Law no. 311/28.06.2004 supplementing Law no. 458/2002 regarding the quality of drinking water – do not stipulate anything on the content of precious metals (gold, silver, platinum, rhodium) in drinking water, and do not restrict their use [3].

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Metallic silver has a cubic crystalline structure with centered surfaces, a density of 10.5 g/cm³ at 20°C and it melts at 950.5°C. It is a good conductor of heat and electricity; it is moldable and soft, with hardness of 2.5-3 on the Mohs scale [3, 4]. It has good thermal stability. In order to increase the low mechanic resistance of silver, it is alloyed with copper, thus resulting in an alloy with eutectic solidification. With a content of 3% Cu silver becomes harder, and the alloy is called "hard silver". Table 1 shows the characteristics of Ag-Cu alloys [3].

<table>
<thead>
<tr>
<th>ALLOY</th>
<th>HV HARDNESS</th>
<th>RESISTANCE TO TRACTION</th>
<th>ELASTICITY MODULE</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Soft</td>
<td>Hard</td>
<td>daN/mm²</td>
</tr>
<tr>
<td>Ag-Cu 97/3</td>
<td>45</td>
<td>140</td>
<td>24</td>
</tr>
<tr>
<td>Ag-Cu 90/10</td>
<td>60</td>
<td>140</td>
<td>30</td>
</tr>
<tr>
<td>Ag-Cu 80/20</td>
<td>80</td>
<td>160</td>
<td>32</td>
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Tab. 1 The characteristics of Ag-Cu alloys
The drinking water supply from rural area (from fountain and water well) for domestic use, ranches must arrived at the consumer tap’s with the microbial and chemical parameters of quality which must fit in the values and concentrations mentioned in the Tables 1A, 1B, 2 and 3 of Romanian law 311/28.05.2004.

The water from the installation could be unpurified with sands, microbes, bacteria if the pipes are cracked, from the exchange parts of taps, filters or by direct contact of water at the exit of the plumbing.

The water contamination could occur due to the contact with the dirty hands of the consumers or other dirty parts of the installation.

The water in the distribution network may accidentally become infected with viruses or bacteria, e.g. *Legionella Pheremophila* [5], which can cause disease in the people who use the water in that particular network.

The present paper deals with the development of silver coated devices with antimicrobial properties. The resulted water was analyzed by electrochemical sensors for the detection of heavy metals [6] and also the total content of the microbial charge was detected.

**MATERIALS AND METHODS**

It has been projected and executed a complex experimental installation presented in figure 1.

![Fig. 1 The design of the experimental installation: A. 1-basin, 2-screen, 3-cock, 4-recycling pump, 5-gauge water, 6-silver cock, 7-agitator; B. picture of the installation.](image)

The installation is compounded of:
- a basin made of stainless steel with the capacity of 0.05 m³
- active pieces of silver alloy AgCu 97/3; screen made of wire of AgCu 97/3 with a diameter of 0.5 mm and 8 meshes on a square centimeter; a grid realized by a hard soldering of 8 pieces of pipe with an exterior diameter of 5 mm and the thickness wall S=0.5 mm, length 300mm; an adjustable cylindrical ring with 60mm width, 0.5 mm breadth and with the maximum diameter of 500 mm;
- silver cock 3/8 on both interior and exterior;
- recycling pump, with the following characteristics: power 250 W, the maximum capacity 600l/h, the discharge pressure 6 bar;
- gauge water;
- stirrer
The silver alloy AgCu 97/3 pieces presented in figure 2: the grid, the screen and the cylindrical ring.

Fig. 2 Active pieces: 1 - screen, 2 - grid, 3 - adjustable cylindrical ring, 4. the silver coated 3/8” tap coated on the inside and outside, general view. The silver layer is 3-5 µm thick.

RESULTS AND DISCUSSIONS

The water collected from the individual sources of water supply (fountain, drain) is being introduced in the basin (1) after it was microbiologically analyzed. Inside the basin (1) one of the 3 active pieces of silver alloy AgCu 97/3 is installed. The pump (4) recycles the water from the basin. The experimental rig offers the opportunity of making a research on the following characters of service:
- laminar flow;
- turbulent flow (the agitator is being started);
- steady flow, when water is kept in the basin (1) without any recycling, but still in contact with one of the 3 active pieces of silver alloy AgCu 97/3.

The determination of the disappearance time of the total content of microbial

In the experimental installation showed in figure 3 it have being introduced a quantity of 40 l water taken off from a fountain which probably presents the number of total coliforms bacteria 250 – 300 / 100 ml. The active component was the cylindrical ring which has the water contact surface of 760 cm, respectively a specific contact surface of 19 square cm AgCu 97/3 / l water. The sterilization of the active piece was realized by heating it at 200º C. the experiments were made in a steady regime. There were performed 7 experiments on the same work conditions: the water temperature 18º-19º C. The variation of the total content of coliforms in time is presented in figure 3. The experiment carried on with smaller quantities of water, so with a higher specific contact surface: 38 cm² AgCu 97/3 / l water. It is to be
mentioned that by increasing the specific surface of the active component made of silver alloy AgCu 97/3 the probable number of the total microbial content decreases rapidly.

![Graph](image)

Fig. 3. The variation of the probable number of the total germs in time

The detection of heavy metal traces with screen printed electrodes (SPE) modified with mercury film

Printed electrodes have more advantages than classical methods for the detection of heavy metals [6]:
- they are easy to make, at a low cost;
- they can be produced in large quantities in a short time;
- their sensitivity (ppb) is very high when stripping methods are used;
- they can be coupled to portable potentiostats, which makes them extremely interesting for the detection of pollutants in situ.

The SPE is mass production procedure. The printing is performed on polyester-type surfaces. Three layers of polymer thermosensitive inks are printed. The first layer consists of Ag ink for tracing metallic contacts, the second is the graphite ink for covering the silver (it prevents it from rusting, which leads to lower conductivity) and tracing the working electrode and the counter-electrode, and the third layer is the insulating ink, over the electrical contacts (fig 4).

![Diagram](image)

Figure 4. SPE used for the detection of heavy metals
A thin layer (a few microns) of Hg film is deposited electrochemically on the working electrode using a diluted Hg(NO$_3$)$_2$ 10$^{-3}$ M solution. The electrode thus prepared is stabilized by approximately 20 cycles (cyclical voltammetry in the -0.5 - +0.5 V/Ag/AgCl potential range)

Determinations on synthetic solutions are shown in Fig. 5.

It can be noted that these electrodes are capable of simultaneously detecting three potentially toxic cations (Cu (II), Pb (II), Cd (II)).

The presence of 20 µg/L Cu (II) and 2 µg/L Pb (II) was detected in the drinking water samples delivered, and Cd (II) was below the detection limit. The maximum concentrations allowed by Laws no. 458/2002 and 311/2004 are the following: Cd (II) 5 µg/L, Cu (II) 0.1 mg/L and Pb (II) 10 µg/L. It can be noted that the drinking water in the analyzed rural area water supply network contains hard metals in quantities which do not contravene the current legislation, but are below the limits imposed by Laws no. 458/2002 and 311/2004.

CONCLUSIONS

After the accomplishment of this research we can withdraw some conclusions:
- the silver cocks have a nice aspect and can also be used in the installation of the drinking water supply;
- taking into consideration that at the potable water supply installation the number of the germs and the probable number of the total germs/100 ml water are 0 after the classic processing with chlorine, ozone and ultraviolet radiation, the silver cock would have a cosmetic role and also a protection one against the infiltration from the exterior side of some germs brought by the taker’s hand, through the pearl spout;
- the use of some active pieces of alloy AgCu 97/3 is beneficial at the individual water supply installation (fountain, drain) from the rural zones; they must be set up in the water storage tank and the silver cocks will also accomplish the role of antibacterial component;

- the detection of heavy metals is a very versatile and decentralized analysis due to the use of screen printed electrodes covered with thin layers of mercury (to enhance the sensitivity and the limit of detection) and to portable potentiostats.

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