Single-cell biofuel element of simple construction from sanitary parts and testing of its work

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Abstract. A model of single-chamber biofuel cell from easily accessible sanitary components (sanitary tees for Sinikon internal sewage pipes and plugs to them) was developed and tested. It is characterized by low cost and easy assembly. As the bioagents the authors used, in particular, the individual strain Micrococcus luteus 1-I, isolated from the active sludge of the petrochemical plant. The proposed single-chamber biofuel cells, based on this strain for 96 hours of the experiment generated an open circuit voltage of up to 480 mV, the current strength was up to 1 mA. Promising bioagents for the developed design were commercial microbiological preparations for cesspools and septic tanks and for composting: biofertilizer “EM-Bio” (LLC “Primorsky EM-Center”, Vladivostok); means for cesspools and septic tanks “Doctor Robik” (LLC VIPEKO, Moscow); microbiological fertilizer "Baikal-EM" (OOO “EM-Kooperatsiya”, Moscow); microbiological preparation for eliminating odors and recycling “Won!” (IP Dugarova, D.C., Ulan-Ude). The voltage of the open circuit, which was generated in single-chamber biofuel cells’ commercial microbiological preparations, increased to 357 – 546 mV for 96 hours of the experiment. The short-circuit current was increased to 597 – 843 μA. The specific power of the single-chamber biofuel cells on the basis of all the bioagents, tested in the paper, was quite close and varied in the range 10.2 – 12.7 μW / cm^2.

1. Introduction

The volume of waste, the number and diversity of pollutants is continuously increasing. At the same time, natural resources are depleted. Therefore, technologies for waste disposal are now relevant in order to obtain products with added value. Such a direction is also the production of an electric current in the processes of oxidation of various pollutants and wastes in biofuel elements of BFC [1-7]. This relatively young area of alternative energy is actively developing in the US, China, and Japan. In Russia, the level of development of BFC is much lower. This, in particular, is associated with the high cost of BFC [8]. Expensiveness constrains the output of BFC beyond the scope of laboratory research. The proton exchange membrane is the most expensive element in BFC. Studies are under way to reduce the cost of BFC [9-13]. Ion-selective membranes are replaced by materials, films, compounds that perform functions analogous to membranes: 1) separation of the cathode and anode BFC cells with the creation of anaerobic conditions in the latter; 2) preventing the entry of microorganisms into the cathode chamber and oxygen molecules into the anode chamber; 3) providing permeability for hydrogen protons. At the same time, the designs of such BFCs are simplified by using only one chamber-the anode chamber [14-18]. The purpose of this work was the development and approbation of single-chamber BFC operation of a simple design from cheap and easily accessible elements.

2. Materials and methods of research

Polypropylene plumbing parts were used for manufacturing single-chamber BFC. The main elements were tees for internal sewerage of T-shaped type (Sinikon, Russia, article 508011R, D40 × 40 × 87) and plugs to them (Sinikon, Russia, article 524001R, D40). The bioagents used in the testing of the developed BFC design were commercial microbiological preparations: bio-fertilizer "EM-Bio" (LLC "Primorsky EM-Center", Vladivostok); means for cesspools and septic tanks "Doctor Robik" (LLC VIPEKO, Moscow); microbiological fertilizer "Baikal-EM" (OOO "EM-Kooperatsiya", Moscow); microbiological preparation for eliminating odors and recycling "Won!" (IP Dugarova, D.C., Ulan-Ude). The strain Micrococcus luteus 1-I was also used. It is isolated from the active sludge of treatment facilities of the petrochemical combine of Angarsk (Russia) E. Yu. Konovalova. Earlier we showed the high electrogenic activity of *Micrococcus luteus* 1-I in two-chamber BFCs [19]. This strain was deposited with the All-Russian Collection of Microorganisms G.K. Scriabin RAS (registration number assigned to VKM – As-2637D, certificate of deposit No. 12310 / 02-1-4-11-49 dated June 20, 2014). Based on this strain, we proposed a bioelectrochemical fuel cell [20].

The working environment in the BFC was model wastewater. Its composition (mg / l): Na_2CO_3 – 50; KH_2PO_4 – 25; $CaCl_2$ – 7.5; $MgSO_4 \times 7H_2O$ – 5, peptone – 500 [GOST R 50595-93]. The model wastewater was autoclaved immediately before the experiments. For the control, BFC was taken without the addition of microorganisms. Carbon fabric was used as electrodes (OJSC "SvetlogorskKhimvolokno", Republic of Belarus). It is a viscose coated with carbon. The thickness of the fabric used was 0.36 mm, the specific density of the fiber was 1.43 g / m2. The specific surface electrical resistance of the fabric was 0.4 ohms.

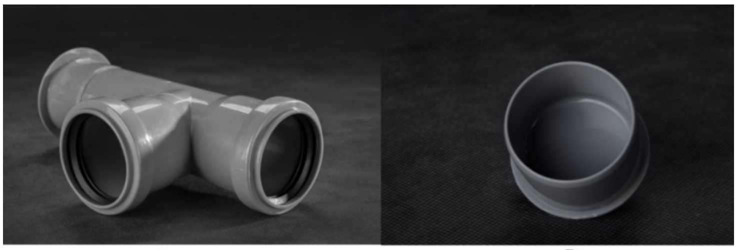
The measurement of the generated BFC voltage was carried out continuously in an automatic mode. The current was recorded using a "DT32 DIDGITAL" multimeter. Measuring the voltage and current in the experiments, we found the power of the BFC (W):

$$P = U \times I \quad (1)$$

For the comparative analysis of the operation of the BFC, the power per unit area of the anode (μW / cm^2) was calculated. All experiments were carried out in at least 5 independent experiments with 3 parallel measurements in each. Statistical processing of the experimental data was carried out using the Excel software package. The tables show the average values for the sample and their standard deviations. The conclusions are made with the probability of an error-free forecast $P \geq 0.95$.

3. Results and discussion

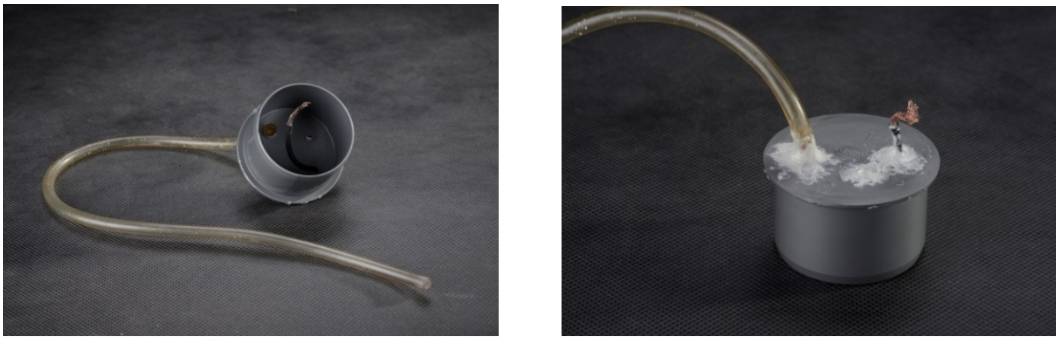
The upper and lower parts of the BFC chamber were the sanitary fittings for the Sinikon internal sewer pipes (Russia, article 508011R). The diameter of the inlet holes was 40 mm. A suitable sewer plug (diameter 40 mm) was attached to the bottom of the tee with a cyanoacrylate adhesive. The place of gluing after drying was treated with the sealant "Moment" (silicone sanitary sealant for the bathroom and kitchen) to prevent leakage. The volume of the resulting chamber was 400 ml (figure1).



A B

Figure 1. Parts for assembling single-chamber BFC. A - tee for internal sewerage of polypropylene T-shaped, serving as working chamber for BFC, B - cap for upper part of BFC

The plug for internal sewerage served as a cover for the upper part of the chambers. Two holes with a diameter of 2 and 5 mm were made in the plug. Through one of them, a copper wire 11 cm long was passed through. Another passed a silicone tube with a water seal. The tube drained off the gases formed in the processes of the life of microorganisms. To maintain anaerobic conditions inside the chamber, the slots between the lid and the chamber were treated with a sealant (figure 2).



A B

Figure 2. The cover of a single chamber BFC chamber with a gas discharge tube and a copper wire of 20 AWG OD (1.8 mm) for fixing the anode electrode. A - a view from the inside, B – a view from the outside

In the strip of carbon cloth (12 × 3 cm), the stripped end of the copper wire was woven from the inside of the lid. Preliminarily, the edges of the carbon cloth were glued along the perimeter with a thin band of thermoplastic glue (ProfKley-8372) using an adhesive gun. This was necessary to prevent the exfoliation of the tissue fibers and preserve the integrity of the electrodes.

On the outer side of the lateral branch of the sewer tee, a piece of carbon cloth 7 × 7 cm was simultaneously attached and molten 2% bacteriological agar was poured (State Research Center for Applied Microbiology and Biotechnology, Obolensk). This led to the formation of a "plug" in the tube lumen 1-1.5 cm thick. Thus, when frozen, the "stopper" from bacteriological agar adhered to the carbon cloth. The scheme of the developed BFC and its cathode is presented in figure 3.

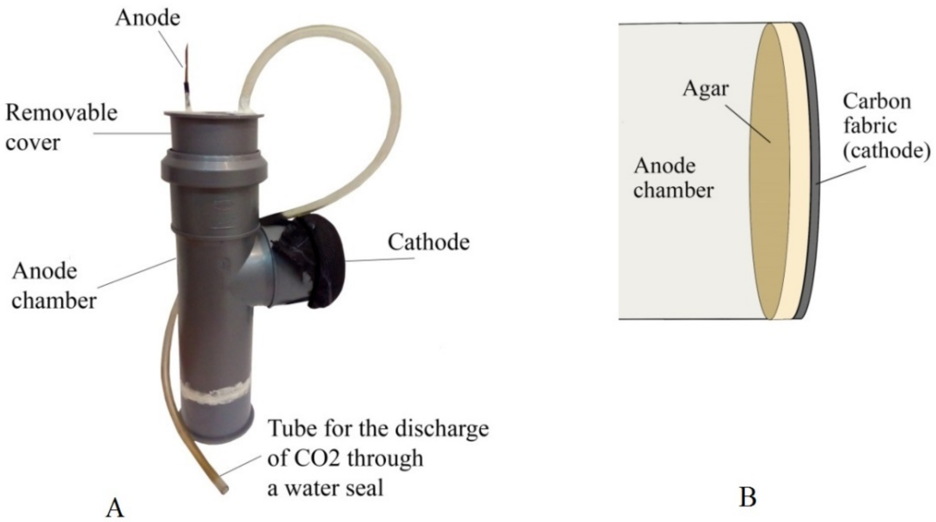


Figure 3. Single-chamber BFC. A – Scheme of single-chamber BFC, B – cathode diagram of single-chamber BFC

The testing of the developed design of the BFC has shown the following. The proposed single-chamber BFC based on the *Micrococcus luteus* 1-I strain generated a voltage of up to 480 mV for a 96 hour experiment, and a current strength of up to 1 mA (figure 4).

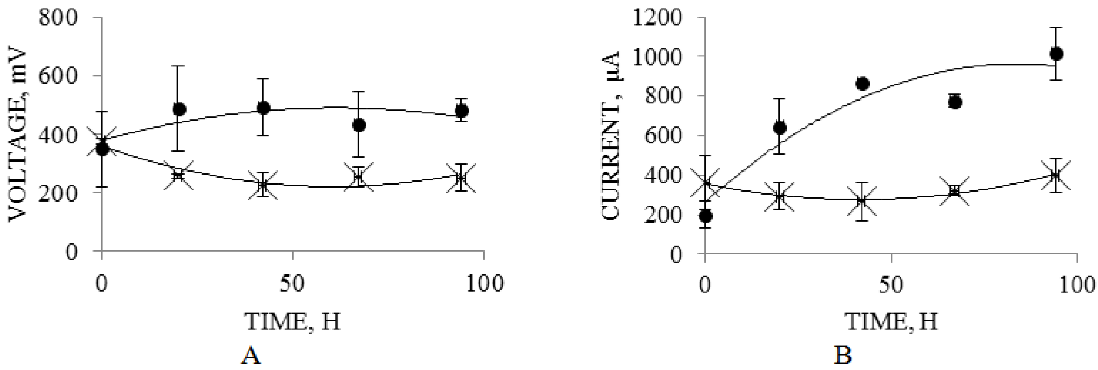


Figure 4. Dynamics of voltage (A) and current intensity (V) generated by the strain *Micrococcus luteus* 1-I in the developed single-chamber BFC (medium - model wastewater, substrate - peptone 0.15 g / l, electrodes – carbon cloth). ● – BFC with model wastewater with peptone; × – BFC with model wastewater, peptone and *Micrococcus luteus* 1-I

Positive results were obtained when using commercial microbiological preparations "VON!", "Doctor Robik 109", "Baikal-EM1", "EM-Bio" as bioagents in the developed single-chamber BFC. The voltage generated by them during the 96 hours of the experiment increased to 357-546 mV, the current strength was up to 597 - 843 μA (Figure 5).

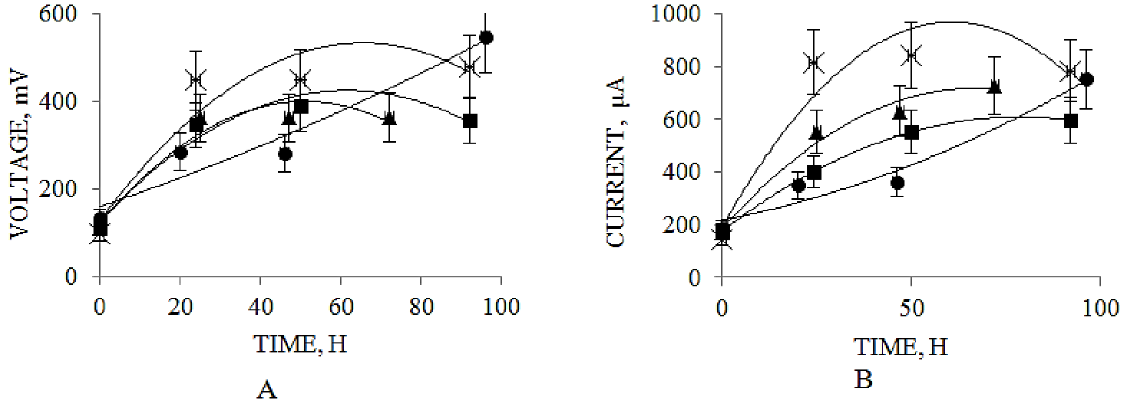


Figure 5. Dynamics of voltage (A) and current intensity (V) generated by commercial microbiological preparations in the developed single-chamber BFC (environment - model sewage, substrate - peptone 0.15 g / l, electrodes - carbon cloth). ● - "WON!"; × – "Doctor Robik 109"; ▲ – "Baikal-EM1"; ■ – "EM-Bio".

The specific power of the BFC on the basis of all the bioagents tested in the work was quite close, and varied in the range 10.2-12.7 μW / cm^2 (Figure 6).

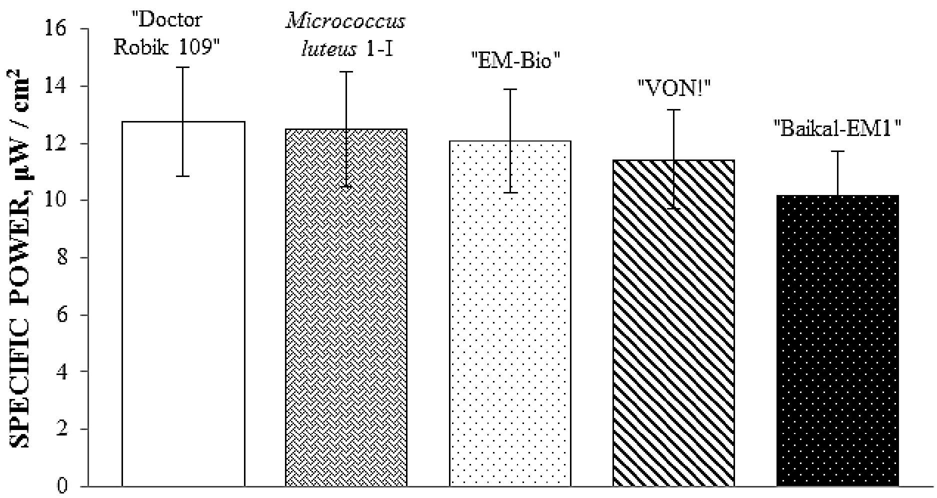


Figure 6. Specific power of the developed single-chamber BFC with the use of *Micrococcus luteus* strain 1-I and commercial microbiological preparations "VON!", "Doctor Robik 109", "Baikal-EM1", "EM-Bio" (environment – model wastewater, substrate – peptone 0.15 g / l, electrodes – carbon cloth, duration of the experiment – 96 h).

4. Conclusion

Thus, the design of a single-cell biofuel element has been proposed and tested. Structurally developed BFC is a single chamber cell without a proton exchange membrane. This significantly lowers the cost of technology, since the membrane is the most expensive component of classical BFC. The developed BFC consists of inexpensive parts for sanitary purposes. It features simple assembly and reliability. All these factors cause the low cost of development, its availability and ease of assembly. As bio-agents in such BFC, commercially available commercial microbiological preparations for composting, cesspools and septic tanks, biofertilizers and individual strains of microorganisms can be used.

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