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DISCUSSIONS

The Peculiarities of Heating Water by a Biological Object

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Abstract—The reasons for differences in the temperature coefficients of the electrical conductivity of water during its heating by a biological object (e.g., an operator's hand) in comparison with an electric heater of the same temperature were investigated. Two possible explanations for the observed effects, viz., the difference in the spectral composition of radiation generated by an operator's hand in comparison with an electrical source of heat and the dissolution of carbon dioxide released by human skin in water, are discussed.

Keywords: emission, radiation, electrical conductivity, absorbance, dissociation

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INTRODUCTION

Water is a highly sensitive compound, whose physical parameters change during almost any type of external exposure. A substantial volume of published literature exists that is related to this problem, which is mainly focused on studying the effects of electromagnetic radiation and fields of various frequencies and intensities on water (see [1, 2] as an example). We previously demonstrated a correlation between the electrophysical properties of water and the parameters of solar activity. In addition, the effect of weak magnetic fields that are comparable with the geomagnetic field on water has been described [3–5]. We demonstrated that the measured relative temperature coefficient of electrical conductivity is higher when heating water using a hand in comparison with a physical source of energy [5].

These data point to the existence of chemical or physical factors that impact water during measurements. Each living organism forms a complex physicochemical environment in its vicinity that includes a number of gaseous chemical compounds, as well as physical fields of different natures [6]. The complex impacts of such an environment on water may cause the effects that have been described. However, questions about the components that display the strongest effect on water remain unanswered. It is quite clear that electromagnetic radiation that is emitted by a hand in the infrared range and the carbon dioxide that is released by the skin of a hand [7] should be considered as the most significant physical and chemical components, respectively. This is due to the fact that the intensity and the concentration of these components are the highest among other physicochemical emission components. Carbon dioxide dissolves in distilled water with the formation of hydrogen ions and a carbonic acid residue; substantial changes in the electrical conductivity of water with the dissolution of low doses of carbon dioxide have been investigated in detail [8].

A large quantity of experimental data demonstrate the dependence of various physical properties of water, such as the absorbance spectrum or specific electrical conductivity, not just on its temperature but also on the material of the heat source [9, 10]. It was shown that the transparency coefficient and electrical conductivity of water during its heating using various energy sources varies within the 5–8% range [9]. These values could be higher, reaching tens of percent, during the heating of water by a hand [10, 11].

In this work, anomalous changes in the electrical conductivity of water during its heating by a biological object (an operator's hand) were investigated. The results were compared to those that were obtained during the heating of water using an electric source of heat and the results of similar experiments using ethanol. The comparison allowed us to determine the contributions of the physical (radiation) and chemical (CO_2) components emitted by the skin of a hand. A mechanism of action for the physical component related to certain features of the emission spectrum of a hand was proposed.

MATERIALS AND METHODS

The sensor for measuring the electrical conductivity of water was a conductometric cell made of a dielectric material and in the form of flat parallelepipeds with two built-in stainless steel or platinum electrodes (dimensions 40 × 20 × 10 mm, the volume of water was approximately 1 cm^3). Flat or cylinder-shaped electrodes were installed in close proximity to the narrow vertical wall of the sensor. To measure the temperature of water, a thermoresistor was located in the center of the lower part of the sensor. Polystyrene, polypropylene, and polyethylene were used to build the body of the sensor. Several modifications of the sensor were tested in our experiments; however, the version that is described above displayed the best electrophysical and operational characteristics. The sensor components and the experimental device have been described in detail [5, 10, 11].

The surface area of water in the sensor approximately coincided with a central inner part of an operator's palm, which showed the highest level of radiation emission. The choice of a palm as a biological object was related to the relatively easy creation of the experimental device as well as the fact that a palm has the highest emission of physicochemical components among human body parts. Prior to conducting the experiments the operator's hands were thoroughly cleaned from contaminants and further wiped with surgical spirits.

A sinusoidal alternating voltage at a frequency of 200–300 Hz and an amplitude of 0.5 V provided by a digital power supply was applied to the electrodes. The current that passed through the sensor was recorded using an analog-digital converter. Bi-distilled water with a specific conductivity of 2 μS/cm was used.

The measurements were performed in parallel using two identical sensors, one of which was affected, whereas the other one served a control.

The procedures that were used in our experiments are described below. Sensors were initially filled with water and allowed to equilibrate for a few minutes to reach similar temperatures across the volume and within the walls of the sensor. The water was then heated by 1–2 degrees by a radiation from an electric heater, which was a copper plate with carbonized dielectric coating. The heater and the operator's hand were located at a distance of 3–5 mm above an open water surface. The desired distance was achieved by placing a dielectrical layer of different thickness on top of the sensor.

It was shown that heating the water using an electric heater led to an increase in its specific electrical conductivity by a value that is close to the reference data (2–2.5% during heating by 1°C). The electric heater was then removed and the procedure was repeated by heating the water using an operator's hand. The current of the electric heater was chosen so that similar increments in the temperature of the water were observed during its heating by an operator's hand and an electric heater. The typical duration of the impact was 1 min.

To estimate the effect quantitatively, the temperature coefficient of electrical conductivity, which reflects the relative change in conductivity as a percentage associated with a change in temperature of 1 deg, was used.

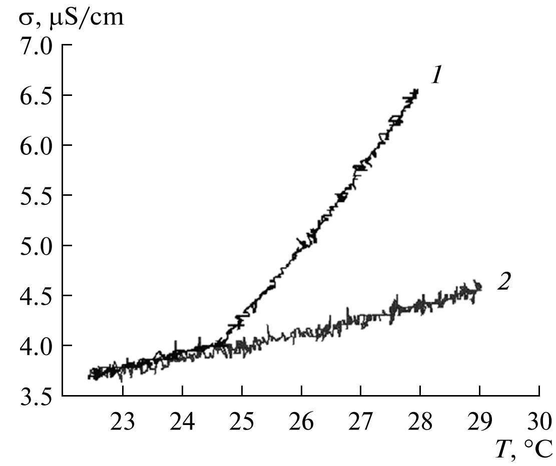

Fig. 1. The dependences of the specific conductivity of water on temperature during heating by a physical source of radiation (curves *2* and *1* at temperatures below 24.5°C) and an operator's hand (curve *1* at temperatures above 24.5°C).

The relative accuracies of the measurements of the specific electrical conductivity and the temperature of water were at least 0.01 μS/cm and 0.01°C, respectively.

RESULTS

It was shown that changes in the temperature coefficient of the electrical conductivity of water during its heating with radiation that is emitted by an operator's hand are significantly different from those that are induced by heating water using an electric heater [5, 10–12]. A typical curve that reflects changes in the electrical conductivity of water during its simultaneous heating in two identical sensors is shown in Fig. 1. The electrical heater in one of the sensors (see curve *1*) was replaced by the operator's hand at a temperature of approximately 24.5°C. As observed, heating by the hand was characterized by a significantly higher temperature coefficient.

To determine the causes behind this effect, similar measurements were performed using various materials as a source of heat. The dependences of the specific electrical conductivity of water on temperature during the heating of water using sources made of different materials are shown in Fig. 2. The numbers next to the curves denote the following: *1*, the reference value of the temperature coefficient of the electrical conductivity of water, viz., 2.5%/°C; *2*, copper; *3*, lavsan; *4*, glass; *5*, cellulose triacetate; *6*, lead; *7*, cellophane; *8*, magnesium; and *9*, the operator's hand. It is clear that the temperature coefficient values were close to 2.5%/°C when heated copper, lavsan, glass, and cellulose triacetate were used. At the same time, the temperature coefficient of electrical conductivity was significantly higher when the water was heated using

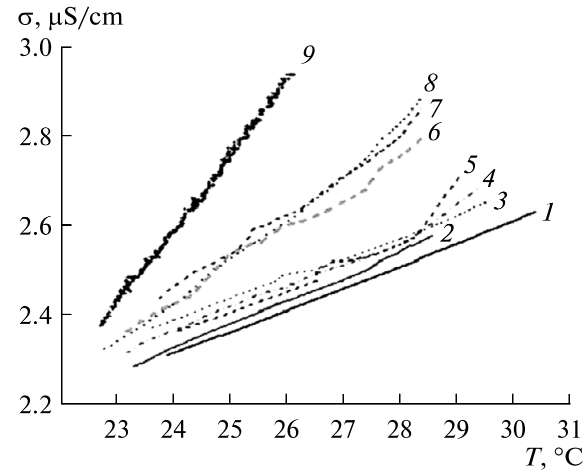

Fig. 2. The dependences of the specific conductivity of water on temperature during heating by sources of radiation that were made from different materials: *1*, the reference value of 2.5%/°C; *2*, copper; *3*, lavsan; *4*, glass; *5*, cellulose triacetate; *6*, lead; *7*, cellophane; *8*, magnesium; and *9*, an operator's hand.

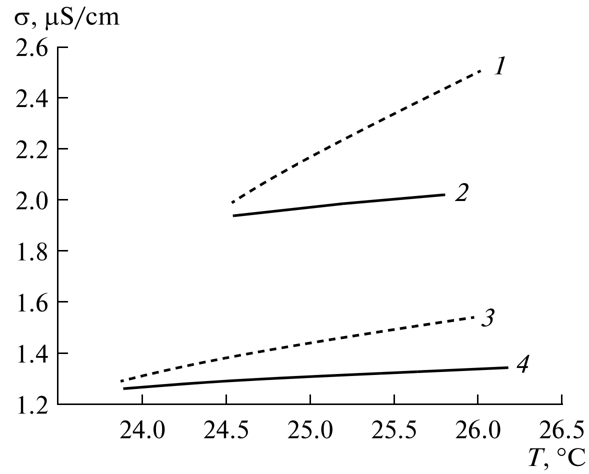

Fig. 3. The dependences of the specific conductivity of water (curves *1*, *2*) and ethanol (curves *3*, *4*) on temperature during heating by an electrical source (dashed line, curves *2* and *4*) and an operator's hand (solid line, curves *1* and *3*).

lead, cellophane, and magnesium, for which the spectral composition of the emitted radiation differs from the emission spectrum of a black body to a higher extent. It should be noted, however, that even in the latter case the observed effect was weaker than when water was heated by an operator's hand.

To determine the role for the chemical factor (CO_2 emission), which, together with the physical factor (the radiation of an operator's hand), might contribute to the observed effect, a series of experiments using ethanol instead of water (96% alcohol by volume) was carried out. The results are shown in Fig. 3. Curves *1* and *2* indicate the heating of water by an operator's hand and an electrical heater at a temperature of approximately 40°C, whereas curves *3* and *4* correspond to the heating of ethanol by hand and by an electric heater, respectively. As seen in Fig. 3, the changes in the electrical conductivity of both water and ethanol were significantly higher for the radiation that was emitted by an operator's hand as compared with an electrical heater. The observed temperature coefficients of the electrical conductivity of water were 20.6%/°C during heating by hand and 2.5%/°C using the electrical heater. In the case of ethanol, the temperature coefficients were 12%/°C and 3.2%/°C during heating by hand or using an electric heater, respectively. Thus, the effect of an anomalous increase in the temperature coefficient of electrical conductivity was observed in the case of water as well as ethanol, although to a lesser extent.

In the next series of experiments, whose results are shown in Figs. 4 and 5, both water and ethanol were treated by using a flow of air that contained an increased content (up to 4%) of carbon dioxide for 10 s. The beginning and the end of the airflow impact are shown by arrows (between 20 and 30 s). A decrease in the temperature of liquid was observed in both sensors following application of the airflow; this effect is related to an intensification of liquid evaporation, as shown in Figs. 4a and 5a (ethanol and water, respectively). In the case of ethanol, however, the decrease in temperature corresponded to a reduction in conductivity, as expected (Fig. 4b), whereas the opposite situation was observed with water. In this case, we observed an increase in conductivity despite a decrease in temperature (Fig. 5b). To present the data more clearly, the same effects are shown in Figs. 6 and 7, where the data from Figs. 4 and 5 are presented as the dependences of the conductivity on temperature during a 10-s timespan that corresponded to the action of an airflow with an increased content of CO_2. Since the temperature of both liquids decreased, the time scale of the measurements in Figs. 6 and 7 is directed from right to left, as denoted by arrows. It was demonstrated that carbon dioxide had little, if any, effect on ethanol, whereas its effect of water was substantial, leading to an increase in conductivity.

DISCUSSION

Our results support the existence of two main issues behind the increase in the temperature coefficient of electrical conductivity of water as it is heated by human contact. The chemical nature of the observed increase in conductivity has been relatively well studied and is related to the dissolution of carbon dioxide in distilled water with the formation of hydrogen ions and a carbonic acid residue [8].

At the same time, the physical component of the effect, that is, the increase in the conductivity of water

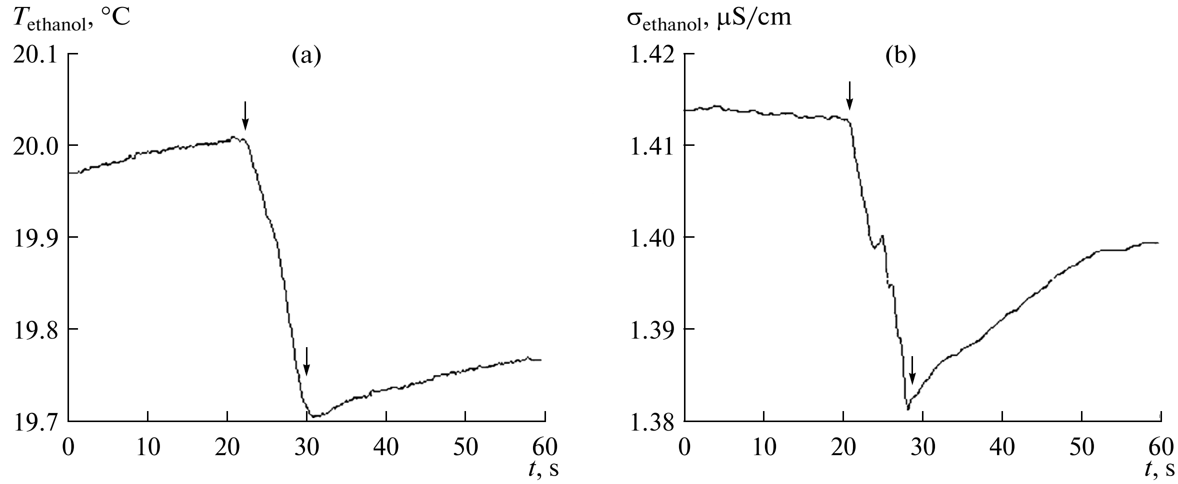

Fig. 4. Changes in the temperature (a) and the sxpecific electrical conductivity (b) of ethanol during cooling with the flow of air that contains an increased concentration of carbon dioxide. The beginning and the end of the airflow impact are shown by arrows.

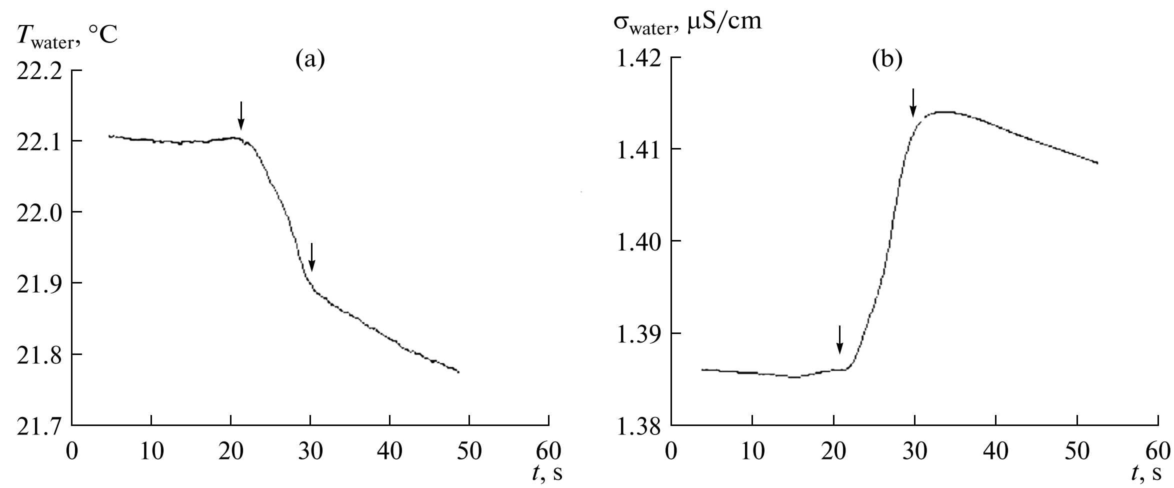

Fig. 5. Changes in the temperature (a) and specific electrical conductivity (b) of water during cooling with the flow of air that contains an increased concentration of carbon dioxide. The beginning and the end of the impact of the airflow are shown by arrows.

due to differences in the radiation spectra of an operator's hand and a black body, requires additional study, such as detailed high-resolution measurements of the radiation spectrum that is emitted by a human hand. There are published data on the radiation spectrum of human skin that indicate its differences from a black-body radiation spectrum. However, the frequency of the recorded spectra were of low resolution and an integral character. We suggest that the physical mechanism that underlies the observed effect is related to the resonance absorption of radiation by water in some relatively narrow areas, leading to excitation of the rotation–vibration levels of the water. This excitation of rotational and vibrational degrees of freedom of a water molecule results in changes in shape and size, further leading to an increase in the molecule's potential energy. The consequences include the dissociation of water molecules at a temperature that is lower than when heating is carried out in conditions of thermodynamic equilibrium, that is, during heating by a black body at a temperature that is similar to that of an operator's hand or during heating via thermal conductivity.

The effect was more pronounced following the contact with an operator's hand compared with sources of heat that are based on various materials. This phenomenon can be explained by the intensive resonance absorption of radiation when the spectrum of an "emitter," viz., the water within an organism, coincides well with the frequency of a "collector" that consists of the water within a sensor.

The absorption spectra of water and ethanol are distinct, although there is a partial overlap in some

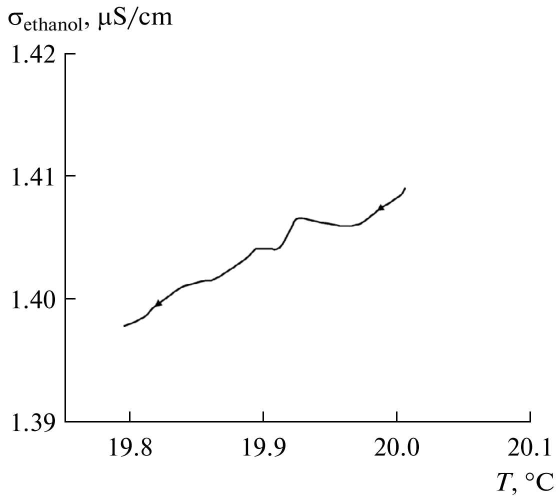

Fig. 6. Dependence of the specific conductivity of ethanol on temperature upon cooling with the flow of air containing increased concentration of carbon dioxide. The direction of time is shown by arrows.

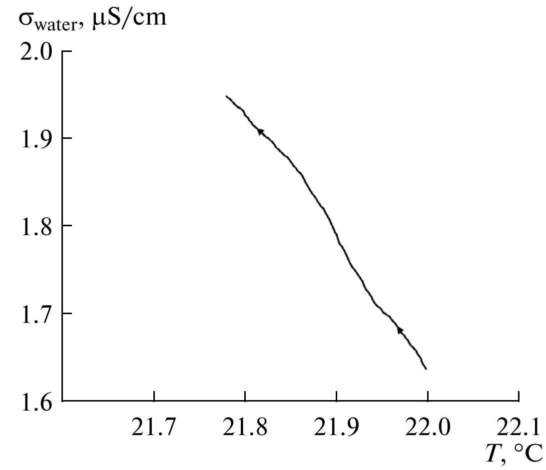

Fig. 7. Dependence of the specific conductivity of water on temperature upon cooling with the flow of air with an increased concentration of carbon dioxide. The direction of time is shown by arrows.

spectral areas [14]. It is likely that the absorption of the radiation that is emitted by water in the human body by ethanol in these particular spectral areas also contributes to the observed effect, although to a significantly lesser extent when compared with water.

The changes in the temperature coefficient depending on the distance between the operator's hand and the water surface, which were observed previously, also point to the electromagnetic nature of the radiation. This dependence fits well with the theoretical intensity dependence of electromagnetic radiation that reaches the water at the distance between the emitting surface and the surface of the water, which were separated by a waveguide with absorbing walls. The results in these measurements have been described in detail [12, 15].

To summarize our experimental results, the anomalously sharp increase in the specific conductivity of water during its heating by an operator's hand is related to the two following factors: (1) the resonance absorption of non-equilibrium radiation that is emitted by an operator's hand by water molecules and (2) the dissolution of carbon dioxide that diffused through the skin of the hand in water.

During the contact of ethanol with the operator's hand, as observed for water that was heated by various materials, the anomalous increase in conductivity was related to factor (1); this leads to similar, although less pronounced, effects.

Our previous studies [11, 12] demonstrated significant changes in the temperature coefficient of the electrical conductivity of water for different psychoemotional and physiological states of an experimenter. Therefore, the development of equipment and techniques for quantitative assessment of emission components and the links between the components and the psychoemotional and physiological state of an operator is of great importance for improving the capabilities of medical diagnostic equipment.

CONCLUSIONS

An anomalous increase in the conductivity of water due to the actions of physical and chemical components that are emitted by an operator's hand was demonstrated.

The observed effects are thought to be related to the resonance absorption of the non-equilibrium radiation that is emitted by an operator's hand by water molecules, as well as the dissolution of carbon dioxide that is diffused through the skin of the hand in water.

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