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RESEARCH ARTICLE

Post-vibration activity of electrochemically activated water

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Abstract

Objectives. It was recently discovered that water samples with modified physicochemical properties can be obtained by successive vibration treatment of intact water together with a solution of a substance located in separate closely spaced vials. We refer to such samples as iterations. By adding the vibrational iterations into the initial substance, the physicochemical properties of the latter are changed, i.e., they demonstrate post-vibration activity. In addition, it has been shown that vibrational iterations can be obtained using water treated with a magnetic field as the initial substance. On this basis, we may hypothesize that the phenomenon of post-vibration activity is universal. To confirm this hypothesis, water treated with an electric signal having various parameters (electrochemically activated water) was used as the initial substance for the preparation of vibrational iterations.

Methods. The physicochemical properties of vibrational iterations, which were obtained from electrochemically activated water, were studied by conductometry, terahertz spectroscopy, and radiometry. The effect of the initial substance or its vibrational iterations on intact water (a neutral carrier) was evaluated by dynamic light scattering. For this purpose, the intensity of light scattering by the sample and the hydrodynamic diameter of optical heterogeneities were measured. The attenuation coefficient of an additional electric signal applied to the samples was determined.

Results. The obtained vibrational iterations differ from intact water and their mixtures with intact water in terms of specific electrical conductivity, power flux density of microwave radiation, as well as in the contribution of the main (Debye) relaxation process to the overall dielectric response. Mixtures of vibrational iterations with water also differ from intact water in terms of the size of optical heterogeneities. By analogy with the vibrational iterations for which solutions of high- and low-molecular-weight substances were used as the initial substance, vibrational iterations obtained using electrochemically activated water can be classified into different groups (fractions) according to their physicochemical characteristics. Different degrees of changes in the physicochemical characteristics are observed depending on the parameters of the electric signal used to obtain the initial substance. The efficiency of electrical signal propagation in these mixtures, as estimated by the signal strength attenuation coefficient, is additionally changed. The addition of the initial substance (electrochemically activated water) to intact water also leads to changes in the physicochemical properties of the resulting mixture compared to the control. Depending on the parameters of the electric signal used to obtain the initial substance, the magnitude of changes in the physicochemical characteristics of these mixtures similarly varies.

Conclusions. The fundamental possibility of obtaining vibrational iterations from electrochemically activated water similarly to vibrational iterations prepared in other studies, was demonstrated. This confirms the universality of the phenomenon of post-vibration activity.

Keywords

vibrational iterations, post-vibration activity, electrochemical activation, aqueous solutions, conductometry, THz spectroscopy, dynamic light scattering, optical heterogeneities

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НАУЧНАЯ СТАТЬЯ

Поствибрационная активность электрохимически активированной воды

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Аннотация

Цели. Недавно открыто, что при последовательной вибрационной обработке интактной воды совместно с раствором вещества, находящихся в разных, вплотную расположенных пробирках, можно получить образцы воды, обладающие измененными физико-химическими свойствами. Такие образцы названы нами «вибрационными итерациями». При добавлении вибрационных итераций в исходную субстанцию, они способны изменять ее физико-химические свойства, т.е. вибрационные итерации обладают поствибрационной активностью. Кроме того, было показано, что вибрационные итерации можно получить при использовании в качестве исходной субстанции воды, обработанной магнитным полем. Это позволило предположить, что феномен поствибрационной активности имеет универсальный характер. Для подтверждения этой гипотезы в настоящем исследовании в качестве исходной субстанции для приготовления вибрационных итераций использовали воду, обработанную электрическим сигналом с различными параметрами (электрохимически активированная вода).

Методы. Изучение физико-химических свойств полученных вибрационных итераций, которые являются производными от электрохимически активированной воды, проводили методами кондуктометрии, терагерцовой спектроскопии, радиометрии. Воздействие исходной субстанции или ее вибрационных итераций на интактную воду (нейтральный носитель) оценивали методом динамического рассеяния света. Для этого измеряли интенсивность рассеяния света образцом и гидродинамический диаметр оптических гетерогенностей. Кроме этого, пропускали через образцы электрический сигнал для определения коэффициента его ослабления.

Результаты. Показано, что полученные вибрационные итерации и их смеси с водой отличаются от интактной воды по значениям удельной электропроводности, потока мощности микроволнового излучения, а также по вкладу основного (Дебаевского) релаксационного процесса в общий диэлектрический отклик. Смеси вибрационных итераций с водой также отличаются от интактной воды по размеру оптических гетерогенностей. Аналогично вибрационным итерациям, для которых в качестве исходной субстанции использовали растворы высоко- и низкомолекулярных веществ, вибрационные итерации, полученные с использованием электрохимически активированной воды, в соответствии с физико-химическими свойствами могут быть классифицированы на различные группы (фракции). Показано, что физико-химические характеристики таких групп изменяются в различной степени в зависимости от показателей электрического сигнала, использованного для получения исходной субстанции. Кроме того, в данных смесях меняется эффективность распространения электрического сигнала, оцениваемая по коэффициенту его ослабления. Внесение исходной субстанции (электрохимически активированной воды) в интактную воду также приводит к изменениям физико-химических свойств полученной смеси по сравнению с контролем. Аналогично, в зависимости от показателей электрического сигнала, использованного для получения исходной субстанции, выраженность изменений физико-химических характеристик смеси различается.

Выводы. Показана принципиальная возможность получения вибрационных итераций из электрохимически активированной воды, аналогично вибрационным итерациям растворов, использованных в других исследованиях, что является подтверждением универсальности феномена поствибрационной активности.

Ключевые слова

вибрационные итерации, поствибрационная активность, электрохимическая активация, водные растворы, кондуктометрия, ТГц-спектроскопия, динамическое рассеяние света, оптические гетерогенности

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1. INTRODUCTION

Vibrational treatment of various substances (low- and high-molecular-weight) changes their properties and imparts the ability to participate in distant interactions [1, 2–4]. It has recently been discovered that sequential vibrational treatment (crossing) of two solutions, one of which is a solution of the initial substance and the other is a neutral carrier (intact water), which are located in separate closely spaced vials, can produce water samples having different physicochemical properties from those of the neutral carrier. Such samples are called *vibrational iterations* [1]. Unlike a neutral carrier, the addition of vibrational iterations into the initial substance is capable of changing the physicochemical properties of the initial substance, i.e., vibrational iterations demonstrate post-vibration activity. Vibrational iterations differ from intact water in terms of their physicochemical properties, allowing them to be classified into groups (fractions).

It has been shown that vibrational iterations can be obtained not only from high- and low-molecular-weight substances used as the initial substance, but also from water treated with an external physical factor such as a magnetic field [5]. An earlier study of vibrational iterations prepared from magnetized water demonstrated that they differ from each other in terms of their physicochemical properties [5]. It is likely that various physical factors can be used to obtain samples demonstrating post-vibration activity. One of the types of treatment that can influence the physicochemical properties of water is electrochemical activation (ECA) [6–8]. ECA is carried out by passing through water an electric signal with defined parameters [9–17]. Thus, we assume that ECA water can be used to prepare vibration iterations.

The present study sets out to confirm the universal character of the post-vibration activity phenomenon. For this purpose, vibrational iterations were obtained from water previously subjected to electrical treatment at different signal parameters to study the possibility of their classification according to physicochemical properties into fractions demonstrating post-vibration activity. Then, the effect of different fractions of vibrational iterations on the physicochemical properties of intact water was studied by comparing the samples with the initial substance (ECA water) from which the vibrational iterations were prepared.

2. MATERIALS AND METHODS

Ultrapure water obtained using a Milli-Q Integral 5 water purification system (*Millipore*, France) was used in the study. Freshly produced purified water having specific conductivity ~0.06 μS/cm was kept for at least 1 h at ambient conditions (temperature 24.5°C, humidity 45–50%, and normal atmospheric pressure). After this period, the specific conductivity of the water was 0.731 ± 0.011 μS/cm. Purified water was also present among experimental samples, where it is labeled as "intact water."

2.1. Samples

In accordance with the purpose of the work, vibrational iterations of ECA water, their mixtures with intact water (to assess their post-vibration activity on intact water), and mixtures of ECA water with intact water (to assess its effect on intact water) were studied. To perform ECA of water, voltages less 0.8 V and more 8 V (that is more than the threshold of water electrolysis (~1.5–2.0 V [18])) were selected. Electrical treatment was carried out using both a constant and a sinusoidal signal. The frequency of the sinusoidal signal was 12.6 Hz, which corresponds to the frequency of the ion cyclotron resonance of water (12.6 Hz) [6].

Thus, three groups of samples were prepared.

Group 1. Vibrational iterations of ECA water:

- vibrational iterations of water to which a constant electric signal with a voltage of 0.8 V was applied (hereinafter referred to as vibrational iterations of "ECA water 0.8 V");
- vibrational iterations of water to which a sinusoidal electric signal with an amplitude of 0.8 V and a frequency of 12.6 Hz was applied (hereinafter referred to as vibrational iterations of "ECA water 0.8 V, 12.6 Hz");
- vibrational iterations of water to which a constant electric signal with a voltage of 8 V was applied (hereinafter referred to as vibrational iterations of "ECA water 8 V");
- vibrational iterations of water to which a sinusoidal electric signal with an amplitude of 8 V and a frequency of 12.6 Hz was applied (hereinafter referred to as vibrational iterations of "ECA water 8 V, 12.6 Hz");
- vibrational iterations of water placed in a cuvette for electric treatment, but in the absence of voltage applied to the electrodes (hereinafter referred to as vibrational iterations of "ECA water 0 V").

Group 2. Mixtures of vibrational iterations of ECA water with intact water in a volume ratio of 1 : 9 and control:

- vibrational iterations of ECA water (group 1) + intact water;
- control (mixture of "intact water + intact water").

Group 3. Mixtures of ECA water with intact water in a volume ratio of 1 : 9 and control:

- Water to which an electrical signal with different parameters was applied (ECA water) + intact water;
- Control (mixture of "intact water + intact water").

2.2. Obtaining electrochemically activated water: treating water with an electric signal

To obtain ECA water, we used an electric signal treatment device (*Vitek-Avtomatika*, Russia), a hardware and software complex consisting of an arbitrary waveform signal generator (NI 9263, *National Instruments*, USA) and a measuring module (NI 9215, *National Instruments*, USA) installed in a chassis (cDAQ-9185, *National Instruments*, USA). The device is operated under the control of LabView software (*National Instruments*, USA). The water incubation period was controlled using a laboratory timer (*VWR® Traceable®*, Germany). Figure 1 demonstrates the appearance and diagram of an electric signal treatment device.

An optical glass cuvette (704-001-30-10, *Hellma Analitycs*, Germany) was filled with 18 mL of ultrapure water. Two plate electrodes made of AISI 304 stainless steel were placed inside the cuvette along two opposite walls. The electrode area completely covered the corresponding wall of the cuvette. Then, for 60 min, a potential difference with the following parameters was applied to the plate electrodes:

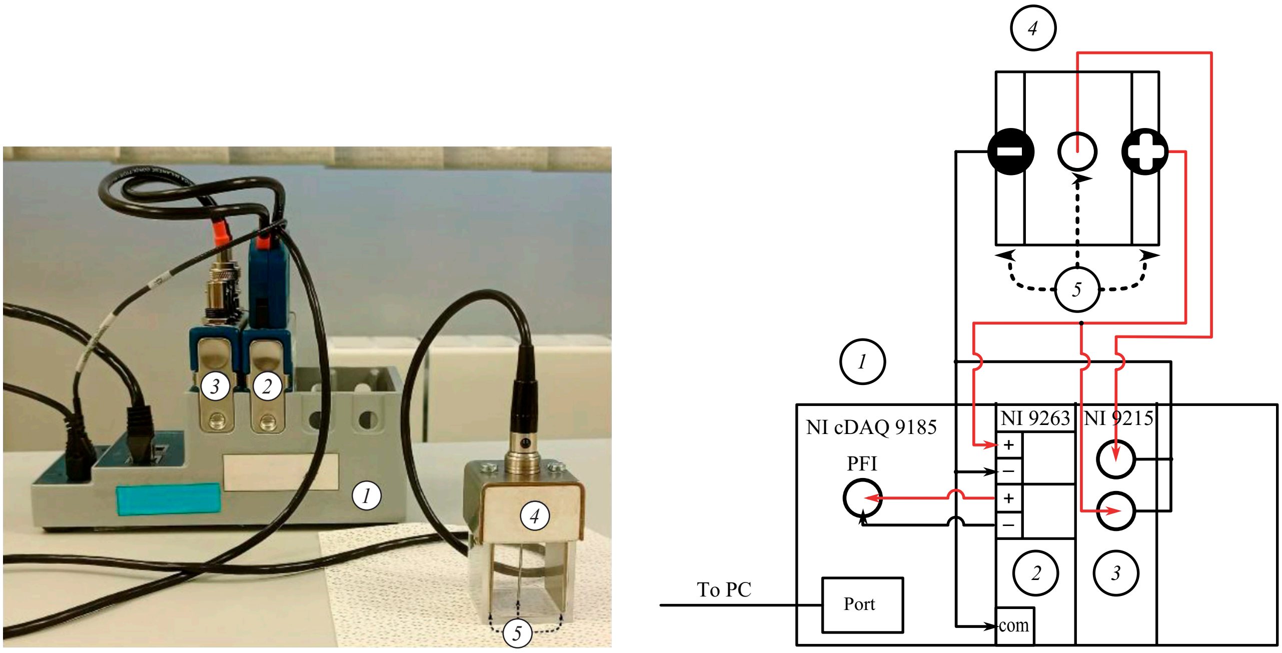
- constant electrical signal with a voltage of 0.8 V;
- electrical sinusoidal signal with an amplitude of 0.8 V and a frequency of 12.6 Hz;
- constant electrical signal with a voltage of 8 V;
- electrical sinusoidal signal with an amplitude of 8 V and a frequency of 12.6 Hz;
- electrical signal with a voltage of 0 V (i.e., the electrical signal generator was turned off).

In this way, 5 types of ECA water samples were obtained.

2.3. Preparation of vibrational iterations from ECA water

A row of vibrational iterations was prepared from each type of ECA water obtained in accordance with the parameters of the electrical signals applied to the electrodes (i.e., 5 different rows of vibrational iterations were obtained). Transparent borosilicate glass vials (250 mL, *Simax*, Czech Republic) were used to prepare vibrational iterations. Schematic representation of the method for preparing vibration iterations is presented in Fig. 2.

ECA water (18 mL) obtained after electric treatment was placed in a borosilicate glass vial (Fig. 2). Next, 180 mL of intact water (neutral carrier) were added to another vial. The filled vials were placed close to each other and subjected to joint vibration (MS 3 basic vortex with MS 1.21 platform, *IKA-Werke*, Germany) for 10 s at 3000 rpm, after which they were incubated for 1 min at room temperature of 24.5°C (during such process, crossing of water with the initial substance occurred). As a result, 180 mL of the zero vibrational iteration (hereinafter, I0) was obtained in the vial with intact water.



(a)

(b)

Fig. 1. (a) Photo and (b) schematic diagram of the electric signal treatment device.
(*1*) NI cDAQ-9185 chassis; (*2*) NI 9263 module (arbitrary waveform generator); (*3*) NI 9215 module (analog-to-digital signal meter); (*4*) optical glass cuvette; (*5*) stainless steel immersed plate electrodes located along the walls of the cuvette, and a needle electrode, which is located in the center of the cuvette

To obtain vibrational iteration No. 1 (I1), a vial with 180 mL of vibrational iteration I0 was placed close to another borosilicate glass vial with intact water (neutral carrier) in a volume of 180 mL and subjected to joint (with close contact) vibration on a vortex for 10 s at 3000 rpm, after which they were incubated for 1 min at room temperature. As a result, 180 mL of vibrational iteration I1 was obtained in the vial with intact water.

The above steps were repeated to obtain vibrational iterations, up to I7 (Step 2, Fig. 2). Samples from I0 to I7 constituted a row of iterations.

Vibrational iterations of ECA water were prepared on the same day at room temperature. If the study of the properties of vibrational iterations or mixtures containing them was not conducted on the day of preparation, then on the day of analysis of vibrational iterations, they were once processed on a vortex for 10 s at 3000 rpm. Before preparing mixtures with ECA water, for 1 h it was subjected to repeated treatment with electric signal with the same parameters that were used in the primary treatment.

2.4. Preparation of mixtures with intact water

To study the ability of ECA water (substance) and vibrational iterations to change the physicochemical properties of intact water, mixtures of vibrational iterations (or ECA water, or intact water as a control) with intact water were prepared in a volume ratio of 1 : 9. The mixtures were prepared immediately before carrying out measurements. Depending on the final volume required for measurements, the mixtures were prepared in 20 or 40 mL borosilicate glass vials (*Glastechnik Grafenroda*, Germany) for radiometry or conductometry, respectively, or in 2 mL plastic test tubes (*Eppendorf*, Germany) for THz spectroscopy.

3. METHODS OF ANALYSIS

3.2. Conductometry, radiometry, and THz spectroscopy

The properties of the samples were studied by conductometry (specific electrical conductivity) and radiometry (power flux density), as described in [1] (Table 1). The study using the THz spectroscopy (determining dielectric constant $d\varepsilon_1$, i.e., contribution of the main (Debye) relaxation process to the overall dielectric response) was conducted in two versions:

(1) mixing 1 part of the test sample (control or vibrational iterations of ECA water) with 99 parts of intact water as described in [1];

(2) mixing 1 part of the test sample (control, ECA water or vibrational iterations of ECA water) with 9 parts of intact water.

The samples were subjected to the following numbers of measurements: conductometry—9; radiometry—not less than 6; THz spectroscopy—not less than 10.

In the present work, the analysis of vibrational iterations classified into fractions in accordance with [1] was carried out. Vibrational iterations can be classified into four types of fractions as compared to intact water in terms of their unique physicochemical properties, as well as according to their ability to influence the physicochemical properties of intact water and aqueous solutions (the so-called *modifying effect*). These four types of fractions were named Active, Native, Semi-Active, and Semi-Native. In the work [1], it was demonstrated that the number of Active fractions increases at the end of the iteration rows and over time during their storage, while the Active fraction exhibits stability in its physicochemical properties when mixed with other types of fractions. In the present work, only the Active and Native or Semi-Native fractions were used to study the modifying effect of vibrational iterations on intact water.

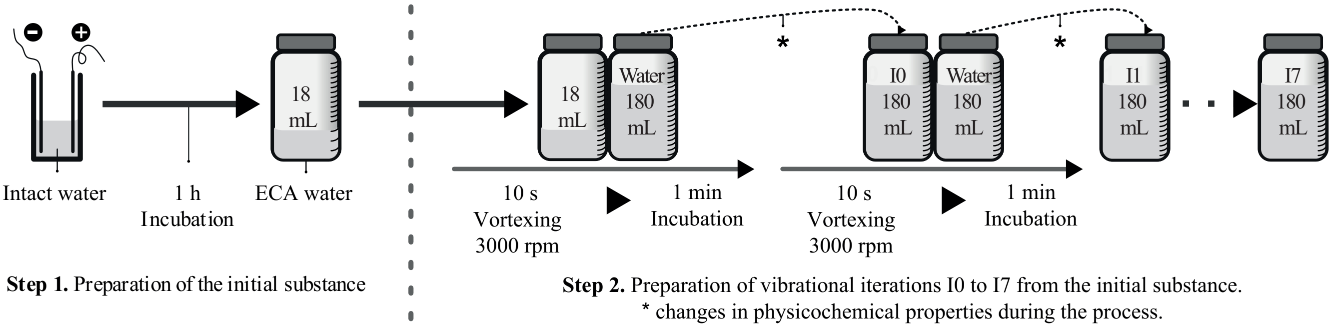


Fig. 2. Preparation of vibrational iterations of electrochemically activated water. Designations: Water is intact water (neutral carrier); ECA water is electrochemically activated water; I0 is the zero vibrational iteration of ECA water; I1 is the vibrational iteration No. 1 of ECA water, ..., I7 is the vibrational iteration No. 7 of ECA water

In addition to conductometry, radiometry, and THz spectroscopy, we used the following methods for sample analysis: dynamic light scattering and oscillography (determination of the attenuation coefficient of the signal passed through the studied sample).

3.3. Dynamic light scattering

The scattering intensity of solutions and the distribution of hydrodynamic diameters of optical heterogeneities in the range of 50–200 nm were determined on a Photocor Compact-Z analyzer (*Photocor*, Russia). The analyzer was equipped with a temperature stabilized continuous-wave semiconductor laser (80 mW of maximum output power at 638 nm wavelength) with a thermostated cell compartment (25 ± 0.1°C). The signal was recorded for 20 s; the number of signal accumulations was 10. The number of measurements of each sample was at least 10. To establish the particle diameter according to the Stokes–Einstein equation, the viscosity of water was taken as 0.89 mPa·s. Size distributions were calculated using the DynaLS software (version 2.8.3) supplied with the device (*Alango*, Israel).

3.4. Determination of the attenuation coefficient of the signal passed through the studied sample (oscillography)

18 mL of the mixture “ECA water + intact water” (group 3) or “vibrational iteration + intact water” (group 2) in a volume ratio of 1 : 9 were added into a clean cuvette of the electric treatment device, and electrodes were immersed in the mixture. An electric signal (of the type used to prepare ECA water) was applied for 3 min. The procedure was repeated five times. In all cases (both for supplying constant and alternating sinusoidal signals), an arbitrary waveform generator NI 9263 (*National Instruments*, USA) was connected to the plate electrodes (“–” electrode and “+” electrode) of the cuvette (Fig. 1). The signal was recorded using the NI 9215 module (*National Instruments*, USA). Two oscillograms were synchronously recorded: one between the plate electrodes, the second between one plate electrode, and an additional needle electrode located in the center of the cuvette. Then, the attenuation coefficient was calculated.

- The attenuation coefficient for constant signals was calculated as the ratio of the average potential difference measured between the central and “–” plate electrodes to the average potential difference between the “–” and “+” plate electrodes (Fig. 1b).
- The attenuation coefficient for alternating (sinusoidal) signals was calculated as the ratio of the average amplitude of the potential difference measured between the central and plate electrodes to the average amplitude of the potential difference between the plate electrodes (Fig. 1b).

3.4. Statistical analysis

Statistical data processing was performed in RStudio 2023.09.1+494 (© 2009–2023 *R Foundation for Statistical Computing*, Vienna, Austria) using the R package version 4.2.2. The normality of distribution was assessed by the Shapiro–Wilk test, the homogeneity of variances was assessed by the Bartlett test. Groups were compared using the Student–Welch t-test and the Kruskal–Wallis test followed by Dunn’s test. Differences between groups were considered statistically significant at $p < 0.05$.

4. RESULTS AND DISCUSSION

4.1. Physicochemical properties and modifying effect of vibrational iterations of ECA water. Classification of iterations into fractions

The physicochemical properties and modifying effect of vibrational iterations I0–I7 obtained using five different types of ECA water as the initial substance were assessed. Crossing water with the initial substance (Fig. 2), five rows of vibrational iterations were obtained. For each iteration, the physicochemical properties and the effect on intact water (modifying effect) were analyzed. The results are presented in Table 2.

Based on the differences of vibrational iterations from intact water in physicochemical properties and the modifying

Table 1. Classification of vibrational iterations into fractions according to changes in physicochemical characteristics relative to intact water [1]

Parameter (method of analysis)	Presence of differences from intact water			
	Native	Semi-Native	Semi-Active	Active
Physicochemical properties (conductometry and radiometry)	–	+	–	+
Modifying effect (THz spectroscopy)	–	–	+	+

Note: the test result was considered positive (“+”) if it met the acceptance criteria. Otherwise, the result was taken as negative (“–”). The acceptance criteria: the values obtained for vibrational iterations should statistically significantly ($p < 0.05$) differ from those of intact water by ±5% or more (by conductometry and THz spectroscopy) and by +10% or more (by radiometry). The values obtained for intact water were taken as 100%.

Table 2. Physicochemical properties and modifying effect of vibrational iterations

Initial substance	Iteration number							
	I0	I1	I2	I3	I4	I5	I6	I7
Specific electrical conductivity, %								
ECA water 0.8 V	99.9 ± 2.2	107.2 ± 1.1*	103.0 ± 3.0	100.9 ± 1.6	106.5 ± 1.2*	119.2 ± 1.1*	102.9 ± 0.8	103.4 ± 0.8
ECA water 0.8 V, 12.6 Hz	143.1 ± 15.4*	140.3 ± 8.2*	139.3 ± 4.5*	143.9 ± 11.2*	146.7 ± 5.6*	133.7 ± 5.5*	147.6 ± 13.5*	142.2 ± 9.9*
ECA water 8 V	121.0 ± 1.8*	113.8 ± 1.6*	112.6 ± 4.4*	112.4 ± 4.7*	112.0 ± 0.3*	112.9 ± 1.3*	119.5 ± 0.1*	121.7 ± 0.6*
ECA water 8 V, 12.6 Hz	108.8 ± 3.4	114.7 ± 6.3*	118.8 ± 7.1*	112.1 ± 4.4	112.0 ± 0.8	119.6 ± 5.5*	112.2 ± 4.1	112.0 ± 0.8
ECA water 0 V	126.7 ± 0.2*	111.0 ± 0.2*	111.2 ± 0.4*	112.2 ± 2.0*	112.2 ± 0.9*	112.1 ± 2.0*	121.3 ± 4.1*	119.2 ± 3.2*
Power flux density across GHz range, %								
ECA water 0.8 V	94.0 ± 3.1#	103.7 ± 3.4	113.4 ± 4.5*	110.8 ± 3.6#	109.4 ± 6.5#	87.0 ± 10.2#	125.4 ± 10.4*	102.9 ± 11.0
ECA water 0.8 V, 12.6 Hz	116.4 ± 5.8*	135.8 ± 12.2*	128.4 ± 10.2*	141.0 ± 18.5*	70.9 ± 1.7#	185.6 ± 6.6*	84.5 ± 2.8#	182.2 ± 5.6*
ECA water 8 V	167.5 ± 8.3*	165.4 ± 14.3*	128.1 ± 20.7*	117.5 ± 16.6	96.1 ± 4.5	87.1 ± 5.2*#	81.8 ± 3.3#	107.5 ± 5.8#
ECA water 8 V, 12.6 Hz	111.7 ± 14.3*	108.2 ± 4.2*	140.3 ± 14.5*	119.8 ± 9.2*	150.7 ± 24.8*	90.4 ± 7.5#	119.1 ± 11.3*	88.5 ± 5.5#
ECA water 0 V	100.0 ± 20.9	108.1 ± 16.3#	95.6 ± 6.3	107.3 ± 16.0	117.6 ± 21.8*	117.5 ± 12.5*	210.1 ± 8.9 #	107.2 ± 7.3#
Dielectric constant $d\varepsilon_1$ (modifying effect) ^{1}, %								
ECA water 0.8 V	103.8 ± 5.3	99.9 ± 8.5*	102.8 ± 9.7	95.2 ± 4.9	97.1 ± 3.1*	102.5 ± 6.9	100.0 ± 6.7	102.9 ± 4.3
ECA water 0.8 V, 12.6 Hz	104.2 ± 5.8*	105.4 ± 3.3*	103.0 ± 3.7*	101.3 ± 3.8	95.0 ± 5.8*	106.0 ± 5.1*	101.9 ± 4.2	107.2 ± 3.1*
ECA water 8 V	99.7 ± 4.6	103.8 ± 7.7	101.3 ± 2.5	97.8 ± 4.4	99.9 ± 6.7	100.5 ± 4.5	98.5 ± 2.7	108.2 ± 5.2*
ECA water 8 V, 12.6 Hz	98.3 ± 4.0	95.2 ± 6.2*	97.5 ± 3.4	97.4 ± 5.1	99.2 ± 3.7	98.3 ± 4.2	102.6 ± 6.4	100.4 ± 4.1
ECA water 0 V	103.9 ± 3.7	105.2 ± 3.2*	103.1 ± 7.6*	103.2 ± 2.3	98.1 ± 4.3	101.4 ± 1.7*	94.4 ± 7.5	96.8 ± 4.5

Table 2. Continued

Initial substance	Iteration number							
	I0	I1	I2	I3	I4	I5	I6	I7
	Fraction							
ECA water 0.8 V	Native	Active	Semi-Native	Semi-Native	Active	Semi-Native	Semi-Native	Native
ECA water 0.8 V, 12.6 Hz	Active	Active	Active	Semi-Native	Active	Active	Semi-Native	Active
ECA water 8 V	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Active
ECA water 8 V, 12.6 Hz	Semi-Native	Active	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Semi-Native	Semi-Native
ECA water 0 V	Semi-Native	Active	Active	Semi-Native	Semi-Native	Active	Semi-Native	Semi-Native

Note:
* meet the acceptance criteria (statistical significance $p < 0.05$) compared to intact water (see MATERIALS AND METHODS);
# do not meet the acceptance criteria ($p < 0.05$; mean values differ less than ±5% according to conductometry and THz spectroscopy and less than ±10% according to radiometry compared to intact water);
unlabeled values: $p > 0.05$ compared to intact water.

Data are normalized to the corresponding values obtained for intact water according to the formula: $\frac{\text{Value measured for the sample}}{\text{Value measured for intact water}} \times 100\%$ and presented as Mean ± Standard Deviation (SD).

[1] In order to obtain the parameter Dielectric constant $d\varepsilon_1$, 99 parts of water were added to 1 part of each sample.

effect on intact water, all iterations were assigned to one or another fraction in accordance with [1]. Depending on the type of ECA water, which was used as initial substance to prepare vibrational iterations, the number of iterations classified into each of the fractions varied (Table 3).

Thus, among all the studied rows of vibrational iterations, the Semi-Active fraction is absent, while the Native fraction is detected only among vibrational iterations for which "ECA water 0.8 V" was used as the initial substance. In addition, vibrational iterations of "ECA water 0.8 V" show the smallest number of differences relative to the control for the studied physicochemical parameters and the greatest diversity of fractions. In the row of vibrational iterations of "ECA water 0.8 V, 12.6 Hz," the Active fraction prevails. An increase in the intensity of the electrical signal to 8 V (for both constant and alternating signals) was shown to lead to an increase in the number of Semi-Native fractions. At the same time, for the row of vibrational iterations "ECA water 0.8 V, 12.6 Hz" and "ECA water 8 V, 12.6 Hz," an increase in the differences in the radiation power flux density was noted.

Thus, depending on the parameters of the electrical signal for obtaining ECA water used as the initial substance in the preparation of vibrational iterations, the properties of the iterations differ. This fact indicates the fundamental similarity of vibrational iterations obtained from water treated with an external physical factor with vibrational iterations of a substance of natural origin, whose properties also specifically depend on the particular substance [1].

4.2. The influence of vibration iterations of ECA water on intact water

In order to study the influence of vibration iterations of ECA water on intact water, the following vibration iterations were selected:

- among the row of vibrational iterations of "ECA water 0 V": I5 (Active), I3 (Semi-Native);
- among the row of vibrational iterations of "ECA water 0.8 V": I4 (Active), I0 (Native);
- among the row of vibrational iterations of "ECA water 0.8 V, 12.6 Hz": I1 (Active), I6 (Semi-Native);
- among the row of vibrational iterations of "ECA water 8 V": I7 (Active), I4 (Semi-Native);
- among the row of vibrational iterations of "ECA water 8 V, 12.6 Hz": I1 (Active), I7 (Semi-Native).

After adding the above samples to intact water in a volume ratio of 1 : 9, the resulting mixtures were analyzed using conductometry, radiometry, THz spectroscopy, dynamic light scattering, and oscillography. The measurement results were compared with the control, to which the corresponding amount of intact water had been added instead of vibrational iterations. Different vibrational iterations were shown to have different effects on intact water (Table 4).

The magnitude and direction of the changes depend on the characteristics of the electrical signal used to prepare the initial substance of vibrational iterations. Thus, each studied vibrational iteration caused changes in the radiation power of the resulting mixtures: both studied fractions of iterations obtained from "ECA water 0.8 V" decreased the radiation power, while vibrational iterations obtained from other substances increased this parameter.

It is also evident from Table 4 that the mixtures of intact water with both fractions of the rows of vibrational iterations "ECA water 0.8 V," vibrational iterations "ECA water 0.8 V, 12.6 Hz" and vibrational iterations "ECA water 8 V" have lower light scattering intensity than the corresponding control mixture, whereas the mixture of intact water with the Semi-Native fraction of vibrational iterations "ECA water 0 V" has higher scattering intensity. The introduction of other vibrational iterations did not affect the scattering intensity of the obtained mixtures. A similar (but not entirely corresponding) situation is observed with the size of optical heterogeneities:

Table 3. Distribution by fractions in the rows of vibrational iterations prepared from each type of ECA water

Electric signal parameters	Fraction, number			
	Native	Semi-Native	Active	Semi-Active
0 V	–	6	2	–
0.8 V	2	4	2	–
0.8 V, 12.6 Hz	–	2	6	–
8 V	–	7	1	–
8 V, 12.6 Hz	–	7	1	–

Table 4. Changes in the physicochemical properties of intact water after addition of vibrational iterations of ECA water in 1 : 9 ratio

Parameter	Parameters of the electric signal for processing the initial substance for vibration iterations					
	0 V		0.8 V		0.8 V, 12.6 Hz	
	Semi-Native + ECA water	Active + ECA water	Native + ECA water	Active + ECA water	Semi-Native + ECA water	Active + ECA water
Specific electrical conductivity, %	105.2 ± 3.6	94.9 ± 0.1	97.6 ± 2.9	91.6 ± 0.5*	103.5 ± 0.8	96.7 ± 0.5
Power flux density across GHz range, %	115.4 ± 7.7*	143.3 ± 10.9*	86.8 ± 3.1*	77.7 ± 1.4*	187.8 ± 21.4*	142.7 ± 6.1*
Dielectric constant $d\varepsilon_1$, %	111.3 ± 3.9*	109.3 ± 4.2*	102.3 ± 10.8	97.2 ± 20.7	93.0 ± 8.0	96.1 ± 12.7
Hydrodynamic diameter of optical heterogeneities, %	87.8 ± 7.4*	161.3 ± 20.7	42.9 ± 2.8*	41.9 ± 7.1*	38.2 ± 5.7*	91.2 ± 5.9*
Scattering intensity, %	107.1 ± 14.8*	125.8 ± 17.6	61.2 ± 5.3*	42.6 ± 1.8*	46.6 ± 1.7*	42.8 ± 7.0*
Signal intensity attenuation coefficient (sample), rel. units	Not applicable		0.269 ± 0.044	0.234 ± 0.038	0.493 ± 0.005	0.494 ± 0.005*
Signal intensity attenuation coefficient (control)$^{\$}$, rel. units	Not applicable		0.253 ± 0.008		0.483 ± 0.001	

Table 4. Continued

Parameter	Parameters of the electric signal for processing the initial substance for vibration iterations			
	8 V		8 V, 12.6 Hz	
	Semi-Native + ECA water	Active + ECA water	Semi-Native + ECA water	Active + ECA water
Specific electrical conductivity, %	88.5 ± 4.8*	90.2 ± 5.3*	100.1 ± 3.2	101.3 ± 1.6
Power flux density across GHz range, %	113.7 ± 6.0*	139.7 ± 13.9*	148.4 ± 6.4*	187.1 ± 4.1*
Dielectric constant $d\varepsilon_1$, %	97.4 ± 8.1	97.3 ± 9.8	103.0 ± 13.2	104.8 ± 6.3
Hydrodynamic diameter of optical heterogeneities, %	117.9 ± 28.5*	134.6 ± 17.3	147.3 ± 12.0*	28.1 ± 8.9*
Scattering intensity, %	50.7 ± 4.1*	40.1 ± 3.2*	97.0 ± 16.4	85.7 ± 5.2
Signal intensity attenuation coefficient (sample), rel. units	0.482 ± 0.002	0.478 ± 0.012	0.502 ± 0.001*	0.502 ± 0.001*
Signal intensity attenuation coefficient (control)$^{\$}$, rel. units	0.485 ± 0.014		0.511 ± 0.002	

Note:
* statistically significant differences from intact water, $p < 0.05$);
$^{\$}$ control measurements (intact water + intact water) were carried out on the day of the study of the corresponding iteration (vibrational iterations of ECA water + intact water). Data are normalized to the corresponding values obtained for intact water according to the formula: $\frac{\text{Value measured for the sample}}{\text{Value measured for intact water}} \times 100\%$. This normalization was applied to all parameters except the signal intensity attenuation coefficient. Data are presented as Mean ± SD.

mixtures of intact water with both fractions of vibrational iterations "ECA water 0.8 V" and "ECA water 0.8 V, 12.6 Hz," as well as the Active fractions of vibrational iterations "ECA water 8 V, 12.6 Hz" and the Semi-Native fraction of vibrational iterations "ECA water 0 V" contain optical heterogeneities of a smaller size than the control. Mixtures of intact water with the Semi-Native fraction of vibrational iterations "ECA water 8 V" and "ECA water 8 V, 12.6 Hz" contain optical heterogeneities of a larger size than the control. The resulting mixture is not affected by the addition of the remaining iterations. The specific electrical conductivity of the mixture, which decreases with the addition of both fractions from the rows of vibrational iterations "ECA water 0.8 V" and "ECA water 8 V," does not change with the addition of the rest of the studied iterations.

The signal attenuation coefficient (according to oscillography data) decreases with the action of both fractions from the row of vibrational iterations "ECA water 8 V, 12.6 Hz" on water and increases with the action of the Active fraction of vibrational iterations "ECA water 8 V, 12.6 Hz" (Table 4). In the overwhelming majority of cases, different fractions of vibrational iterations prepared using the same electrical signal change the physicochemical properties of the resulting mixture in the same direction (compared to intact water).

In this experimental setup (a 1 : 9 mixture with intact water), it is important to note that neither the Active nor the Native/Semi-Native fractions of ECA water obtained by applying an electrical signal affect the value of the dielectric constant $d\varepsilon_1$ (obtained using THz spectroscopy) of the resulting mixture as compared to the control (Table 4). However, the value of $d\varepsilon_1$ of the mixture of intact water with both the Active and Semi-Native fractions of vibrational iterations of "ECA water 0 V" increases. Comparing the results obtained by THz spectroscopy (Table 2 and Table 4), it becomes clear that the degree of influence of vibrational iterations on intact water depends on the volume ratio of the mixture components. This conclusion is in agreement with the conclusion made in [19] that the reaction of the Nafion polymer depends on the method of obtaining a salt solution of a certain final concentration, including the number of cycles of mechanical action on water used. This fact indicates the regularity of the dependence of the measurement result on the method of obtaining the mixtures that we have discovered.

The established changes in the physicochemical parameters in the mixtures of vibrational iterations of ECA water relative to intact water demonstrate that intact water (neutral carrier) after the crossing procedure acquires physicochemical properties that are different from intact water, i.e., crossing leads to the formation of a new substance. However, it is also important to understand whether the effect on intact water of the samples of the Active or Native/Semi-Native fractions is similar to that of the initial substance (i.e., the corresponding ECA water). In order to clarify this, experiments described in the next section were conducted.

4.3. Influence of ECA water on the physicochemical properties of intact water

In order to test the effect of ECA water on the physicochemical properties of intact water, one volume part of ECA water was added to nine volume parts of intact water, then the resulting mixture was analyzed using conductometry, radiometry, THz spectroscopy, dynamic light scattering, and oscillography. The results were compared with the control (for the control, the corresponding amount of intact water was added instead of ECA water). The results are presented in Table 5.

All mixtures of intact water and ECA water demonstrate differences from the control in terms of certain physical and chemical characteristics. The magnitude and direction of these differences depend on the voltage applied during the preparation of ECA water. "ECA water 0.8 V" (compared to the control—intact water) causes an increase in the specific electrical conductivity of the mixture by 22% and a decrease in the value of the signal attenuation coefficient (according to the results of oscillography), in contrast to "ECA water 8 V", which has no effect on this indicator.

Increases in radiation power flux density (by 22% for "ECA water 0.8 V + intact water"; 63% for "ECA water 8 V + intact water") and in diameters of optical heterogeneities (51% for "ECA water 0.8 V + intact water," 191% for "ECA water 8 V + intact water") are observed. At the same time, a stronger and oppositely directed effect is observed in the dynamic scattering intensity of the resulting mixture ("ECA water 0.8 V" increases this parameter in the mixture by 177%, and "ECA water 8 V" reduces by 16%).

The effect of ECA water on intact water (compared with effect of the control—intact water) differs depending on whether constant or alternating electrical treatment was used to obtain it. The addition of "ECA water 0.8 V" leading to an increase in the specific electrical conductivity, radiation power, scattering intensity and diameter of optical heterogeneities is accompanied by a decrease in the signal attenuation coefficient (according to the results of oscillography). However, the addition of "ECA water 0.8 V, 12.6 Hz" leads only to a decrease in specific electrical conductivity, which is accompanied by an increase in the signal attenuation coefficient (according to the results of oscillography). The addition of "ECA water 8 V" leading to an increase in the scattering intensity

Table 5. Effect of ECA water on the physicochemical properties of intact water (mixture in 1 : 9 ratio)

Parameter	Parameters of the electric signal used to prepare ECA water (in ECA water + intact water mixtures)				
	0 V	0.8 V	0.8 V, 12.6 Hz	8 V	8 V, 12.6 Hz
Specific electrical conductivity, %	106.2 ± 0.8*	122.4 ± 0.3*	93.1 ± 3.9*	101.4 ± 3.8#	99.5 ± 2.3
Power flux density across GHz range, %	121.2 ± 9.6*	122.3 ± 7.9*	121.5 ± 18.7	163.3 ± 8.5*#	142.7 ± 13.8*
Dielectric constant $d\varepsilon_1$, %	97.3 ± 4.5	106.0 ± 11.9	104.9 ± 12.3	106.1 ± 4.4#	104.1 ± 13.5
Hydrodynamic diameter of optical heterogeneities, %	81.7 ± 21.9	150.8 ± 19.4*	100.2 ± 8.2	291.2 ± 18.8*#	37.6 ± 10.5*
Scattering intensity), %	186.5 ± 18.7*	277.4 ± 26.5*	122.7 ± 23.4	84.2 ± 3.5*	300.7 ± 42.6*
Signal intensity attenuation coefficient (sample), rel. units	Not applicable	0.216 ± 0.016*	0.506 ± 0.001*	0.496 ± 0.012	0.507 ± 0.001*
Signal intensity attenuation coefficient (control), rel. units	Not applicable	0.253 ± 0.008	0.483 ± 0.001	0.485 ± 0.014	0.511 ± 0.002

Note:

* statistically significant differences from the control, $p < 0.05$;

statistically significant differences from the ECA water 0 V and intact water mixture, $p < 0.05$. Data are normalized to the corresponding values obtained for intact water according to the formula: $\frac{\text{Value measured for the sample}}{\text{Value measured for intact water}} \times 100\%$. This normalization was applied to all parameters except the signal intensity attenuation coefficient. Data are presented as Mean ± SD.

and a decrease in the diameter of optical heterogeneities in intact water is accompanied by an increase in the radiation power. Conversely, the addition of "ECA water 8 V, 12.6 Hz" leads to a decrease in the scattering intensity and an increase in the diameter of optical heterogeneities, which is also accompanied by an increase in the radiation power. While the signal attenuation coefficient is not changed by the addition of "ECA water 8 V" (according to the oscillography results) in water, the addition of "ECA water 8 V, 12.6 Hz" causes its decrease.

Thus, similar to the effect of vibrational iterations of ECA water on water, the effect of ECA water itself on intact water depends on the parameters of the electrical signal that was used to prepare ECA water.

4.4. Comparison of the addition of ECA water on the physicochemical properties of intact water

In order to understand whether the samples of the Active or Native/Semi-Native fractions have the same effect on the properties of intact water as that of the substance itself (corresponding ECA water), a comparison of their effects on water was carried out (Table 6). However, in order to study the contribution of only the applied electric signal rather than the presence of contact of water with the measuring cell (and, accordingly, the immersion electrodes) in the absence of a signal, the comparison was carried out using only those indicators that did not differ between the "ECA water 0 V + intact water" sample and the control (intact water). Such characteristics were the dielectric constant $d\varepsilon_1$ and the hydrodynamic diameter of optical heterogeneities (Table 6).

A higher value of dielectric constant is found in both the mixtures of water with Active and Semi-Native fractions compared to the control; moreover, in the mixture of water with the Semi-Native fraction, smaller optical heterogeneities are found as compared to the control. Nevertheless, treatment of water with an electric signal did not affect its ability or that of its vibrational iterations to change the dielectric constant of intact water. At the same time, the ability of both ECA water and its iterations to affect the size of optical heterogeneities in water is demonstrated. A pattern is observed when ECA is carried out with a constant voltage: in a mixture with intact water, the size of the optical heterogeneities increases; however, when an alternating electric signal (8 V, 12.6 Hz) is used, it decreases.

Table 6. Direction of the effect of adding ECA water and vibrational iterations prepared from it to intact water in a volume ratio of 1 : 9

Parameter	Parameters of the electric signal for processing the initial substance for vibration iterations														
	0 V			0.8 V			0.8 V, 12.6 Hz			8 V			8 V, 12.6 Hz		
	ECA water	Semi-Native	Active	ECA water	Native	Active	ECA water	Semi-Native	Active	ECA water	Semi-Native	Active	ECA water	Semi-Native	Active
Dielectric constant $d\varepsilon_1$, %	—	↑	↑	—	—	—	—	—	—	—	—	—	—	—	—
Hydrodynamic diameter of optical heterogeneities, %	—	↓	—	↑	↓	↓	—	↓	↓	↑	↓	—	↓	↑	↓

Note: "↑" indicates an increase, "↓" indicates a decrease, and "—" indicates no change in the recorded characteristics compared to the control ($p < 0.05$).

Vibrational iterations (both the Active and Native/Semi-Native fractions) obtained from "ECA water 0.8 V" and "ECA water 0.8 V, 12.6 Hz" reduce the size of optical heterogeneities observed in the resulting mixture when mixed with water. The same effect is produced by the Semi-Native fractions of vibrational iteration "ECA water 8 V" and the Active fraction of vibrational iteration "ECA water 8 V, 12.6 Hz". However, adding the Active fraction of vibrational iteration "ECA water 8 V" to water does not affect the resulting mixture, while adding the Semi-Native fraction of vibrational iteration "ECA water 8 V, 12.6 Hz" to water leads to an increase in the optical heterogeneities in the mixture.

Thus, in the overwhelming majority of the studied sample types, the effect exerted by vibrational iterations of ECA water on the size of optical heterogeneities in water differs from the effect exerted by the substance used to prepare vibrational iteration. However, the result of the effect of vibrational iterations of ECA water on the size of optical heterogeneities in water weakly depends on the parameters of the electrical signal used to prepare the substance, as well as on the fraction of vibrational iteration. Vibrational iterations predominantly cause a decrease in the size of optical heterogeneities.

5. CONCLUSIONS

1. The study of vibrational iterations of ECA water demonstrated that they follow general patterns of post-vibration activity and can be classified into fractions that differ from each other in physicochemical properties. The obtained result indicates the universality of the mechanisms of vibration treatment, i.e., the possibility of their implementation regardless of the nature of the initial substance.
2. The use of an electric signal with a constant voltage of 0.8 V for the preparation of the initial substance allows us to obtain a greater variety of fractions of vibrational iterations. The use of an electric signal with a constant voltage of 8 V or alternating voltage of 8 V, 12.6 Hz allows us to obtain a greater number of vibrational iterations of the Semi-Native fraction. This result emphasizes that the mechanisms of formation of the post-vibration activity are sensitive to the degree and nature of external influences, which may indicate their plasticity.
3. The addition of ECA water or its vibration iterations in a volume ratio of 1 : 9 to intact water leads to a change in the physicochemical parameters of intact water. The degree of difference depends on the parameters of the electrical signal used to obtain ECA water. The degree of influence of vibration iterations on intact water depends on the volume ratio of the mixture components.
4. In the overwhelming majority of the studied types of electrical signal, the effect of vibration iterations of ECA water on the size of optical heterogeneities of water differs from the effect of the substance used to prepare the vibration iteration. However, in most cases, vibration iterations cause a decrease in the size of optical heterogeneities (regardless of the electrical signal used to obtain the sample).

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Authors' contributions

O.V. Slatinskaia—analyzed the data and wrote the original draft of the manuscript.

G.O. Stepanov—planned the experiments, analyzed the data, and contributed to the final version of the manuscript.

O.V. Fartushnaya—planned the experiments and contributed to the final version of the manuscript.

E.V. Zubkov—planned the experiments and contributed to the final version of the manuscript.

A.D. Zatykina—carried out the experiments (THz spectroscopy).

O.M. Gizitdinova—carried out the experiments (THz spectroscopy).

N.S. Karpov—carried out the experiments (sample preparation, conductometry, oscillography).

A.V. Smirnov—carried out the experiments (radiometry, dynamic light scattering).

V.S. Boriskin—carried out the experiments (radiometry).

N.N. Rodionova—analyzed the data and contributed to the final version of the manuscript.

A.O. Petrova—planned the experiments and analyzed the data.

Conflict of interest

O.V. Slatinskaia, G.O. Stepanov, O.V. Fartushnaya, E.V. Zubkov, A.D. Zatykina, O.M. Gizitdinova, N.S. Karpov, A.V. Smirnov, V.S. Boriskin, N.N. Rodionova, and A.O. Petrova are employees of NPF "Materia Medica Holding," Moscow, Russia (full or part-time employment).

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