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Change in the volume of water crystallization as a result of exposure to a high-frequency electromagnetic field

The influence of a high-frequency electromagnetic field on the process of water crystallization has been studied. Water irradiated by a field at 30–200 MHz was kept from 0 to 21 days, then it was frozen. Volumes of ice at crystallization were compared for water irradiated and unirradiated by the field. Values located more or less symmetrically near zero; 2) values with a predominantly positive shift, and 3) values for which the shift is mostly negative. Positive shift was noted when combining 200 MHz and the exposure time up to 11 days. The maximum effect of relative volume increase almost two times was observed at 200 MHz and one day exposure time. The maximum compression of ice approximately three times compared to the unirradiated sample occurred twice: after field effect at 90 MHz and exposure time of 11 days, and at 140 MHz and exposure time of 21 days. The similarity of time dependence at 170 MHz with the dependence of thermal effect of glucose dissolution found in early works was noted. The data obtained confirm that field effect results in both strengthening and loosening of water structure.

Keywords: electromagnetic field, water structure, ice structure, defects in ice structure, frequency of field effect, post-effect changes in water structure, loosening of water structure, strengthening of water structure.

Introduction

The effect of physical fields on water and water-containing systems is of interest not only from an academic standpoint, but also from a practical point of view, since water is one of the most common substances on the earth's surface and is a part of living objects. Interest in liquid water, to which the presence of internal structure is attributed, is due not only to the presence of physical anomalies, but also to a crucial role in biological processes. Magnetic field as well as mechanical (ultrasonic), electrical and electromagnetic ones prevail among the factors of influence. There is a wide variability of influencing factors taking into account the diverse frequency range and field strength. The effect of magnetic field on water and aqueous solution properties are most often presented in literature [1–4]. One of the important issues is to explain the nature of changes in structural organization of water and water solutions due to field effect. Some models assume the presence of monomolecular water and polymolecular formations, which was expressed many years ago by Samoilov, and then by other researchers [5]. We studied crystallization processes when a magnetic field is applied to answer the question about the strengthening or loosening of the structural organization of water [6, 7]. O.M. Rosenthal and his team investigated the kinetics of ice crystal nucleation and growth. It was found that the share of fine-crystalline ice increases, while the dispersion of their size distribution decreases simultaneously in the 3 kE constant magnetic field [6]. O.M. Rosenthal as well as V.S. Dukhanin [3] believed, that the effect of magnetic field loosens the structure of water and promotes the formation of a skeletal rather than a close-packed ice structure. It was shown in [8], that the volume of ice increases by about 1.4 % under the influence of magnetic field.

In turn, electromagnetic fields have a very significant effect on the properties of water and aqueous solutions, which is manifested in changes of pH, electrical conductivity, redox potential, oxygen solubility [9], as well as in changes of the substances reactivity and of the crystalline hydrates thermodynamics [10, 11].

Although the term «water structure» is criticized and perhaps deservedly is applied to liquids, many properties of liquid water can be explained only by the presence of internal structural organization. D. Eisenberg and V. Kautsmann did not find the term «water structure» controversial, including it in the title of their monograph [12]. Zatsepina [13] agrees with them, using the term «structure» as well. However, this term is hardly applicable to dynamic systems, to which liquid water should be attributed. The majority of authors, describing the structural organization of liquid water, refer to the structure of ice, as noted in later reviews [14].

All models mention the nonideal structure of both ice and water to one degree or another. In this regard, it can be expected that structural defects of liquid water will influence the process of its crystallization and affect the properties of ice. There are many methods to study the structural organization of liquid water, such as IR, UV, NMR spectroscopy, dielcometry, etc. However, it is the structure that can be reliably studied directly or indirectly by transferring water to a crystalline state.

Naturally, the question of how the electromagnetic high-frequency field affects the process of water crystallization and the volume of ice was of great interest in order to find out if the water structure is strengthened or loosened due to the field effect.

Experimental

Water preparation. The field impact did not fundamentally differ from the methods used in earlier works. The cell is described in [15]. The experiment was conducted at 30–200 MHz frequency; the exposure time was 90 minutes. A G4–119A generator was used as the source of high-frequency signal. The difference was that the water after field exposure was kept in a closed container for a certain time (from 0 to 21 days), and then it was used in the experiment. This was due to the fact that a complex relationship between frequency and exposure time was found after the field effect [11]. Since we used common equipment, the main attention was paid to the crystallization process which allowed us to obtain the primary experimental data. To increase the reliability of the estimation parameter, it was necessary to determine the ice core size as accurately as possible. For this purpose, the crystallization was implemented in a narrow polypropylene tube with an inner diameter of 5 mm and a length of 125 mm. The tubes were precisely measured in length using a micrometer, sealed on the burner, checked for tightness, and calibrated in length again. The main problem was to organize the process of ice crystal growth so that it starts from the top of the tube, not from the bottom. Since we used a freezing chamber of the refrigerator as a cryochamber, we measured the temperature of mixture of water and glycerin in glasses and studied the temperature field; afterwards we chose a homogeneous area of 10×15 cm^2, where the temperature differed by no more than 1 K. The cassette for tubes was made of PVC foam. It was 10×15 cm^2 in area and 3 cm thick, in which holes were made equal to the diameter of the tubes. The selection of conditions involved changing the distance between the lower edge of the tube and the cooling surface.

If the distance was not optimal, either swelling occurred in the lower part of the tube followed by its destruction, or water was squeezed out and flowed downward with a distortion of the cylindrical shape, or the shape of the ice core deviated from the cylindrical one. The temperature during the experiment was –2 ºC. The choice of temperature was based on preliminary experiments to obtain the correct core. This was also an important parameter, since the crystallization temperature determined the cooling rate and, consequently, the rate of crystal growth. Each tube was marked individually, and the dimensions were taken into account when calculating the relative change in the core length. Water was poured into the tubes with a thin needle. The control of homogeneity and volume (including the absence of bubbles) was monitored visually in front of the window. The tubes were filled on a level with the upper edge, placed in the cassette holder and put into a cryochamber. The core was measured every other day. Ordinary distilled water was frozen concurrently with the field-exposed water. Each tube was measured exactly before the experiment. After crystallization, we measured its length with a protruding core and determined how much the core was above the edge of the tube, or below it. The measurement was more complicated when the core was below the edge of the tube. In this case, the tube was shone through and the length of the ice column was determined by the shadow contour.

The mean and the confidence interval were determined using five parallel measurements. To quantify the effect of field and time exposure, we determined $\Delta l = l - l_0$, where l is the core above the edge of the tube for the affected sample and $\boldsymbol{l_0}$ is the same for the unaffected water. To reduce the effect of error mean square, we estimated the relative effect $\delta l = \Delta l/l_0$. The exposure time was chosen using the data obtained in [11], which indicated that the most significant changes took place within about 20 days. The scale of exposure time after the field effect was as follows: 0 (immediately after the field), 1, 3, 6, 9, 11, and 21 days. Compared with work [11], we increased the number of frequencies of the field effect, making a series of 30, 60, 90, 110, 140, 170, and 200 MHz.

Based on measurements and calculation of the relative change in the core length, the dependences of the relative size of the ice core on the frequency and exposure time of water after the field effect were constructed.

Results and Discussion

Figures 1 and 2 show the dependences of the relative change in the length of the ice core at different exposure time for all frequencies used in the experiment. To simplify the analysis, we present the dependences in two figures.

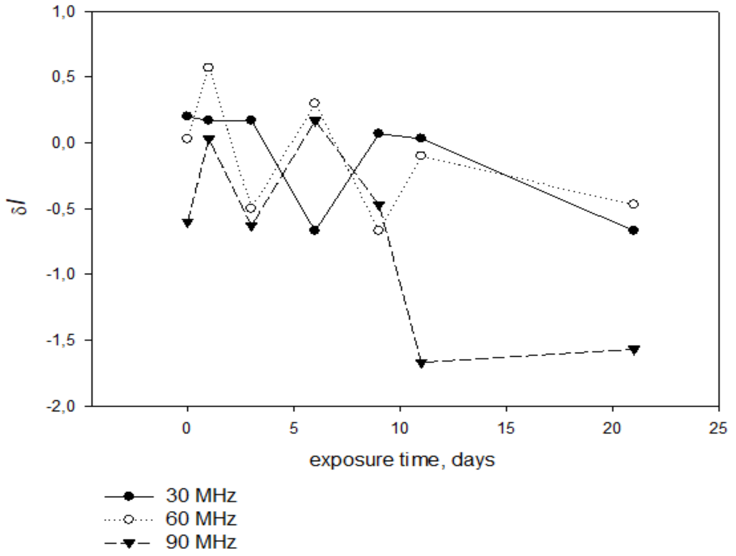

Figure 1. Dependence of the relative change in the length of the ice core on the exposure time after the field effect at given frequencies

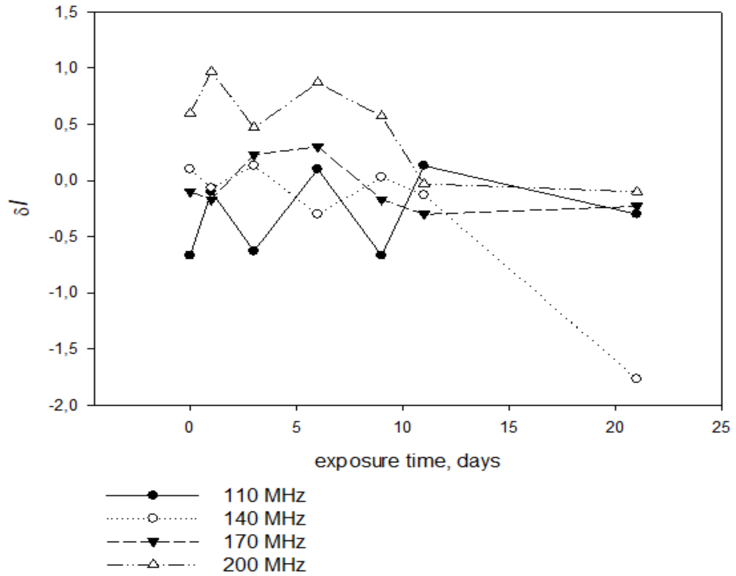

Figure 2. Dependence of the relative change in the length of the ice core on the exposure time after the field effect at given frequencies

As can be seen from the data presented in Figures 1 and 2, there are three groups of frequencies can be distinguished: 1) values located more or less symmetrically near zero; 2) values with a predominantly positive shift, and 3) values for which the shift is mostly negative. Frequencies 30, 60 and 140 MHz are included in the first group, frequencies 170 and 200 MHz are included in the second group, the remaining frequencies are included in the third group. Although this is not a completely deterministic feature, the individuality of the frequency factor is clearly visible. The specific nature of time dependence can also be noted. For example, the dependences on the exposure time are antiphase both for absolute values and ***δl*** in the frequency range of 30 and 60 MHz. At the same time, beats are observed for up to nine days at 90 MHz, and then a sharp shift to the negative region with a large ***δl*** takes place. The higher frequencies show a significant difference of ***δl*** dependence on the exposure time after the field effect. High positive values are observed at 200 MHz and noticeable negative ones at 110 MHz; beats close to zero are found at 170 MHz, and all curves are close to zero on the 21st day.

The frequency of 140 MHz stands apart; it showed an abnormally negative ***δl*** after 21 days of exposure.

Figure 3 shows the time dependence of the core length at 170 MHz.

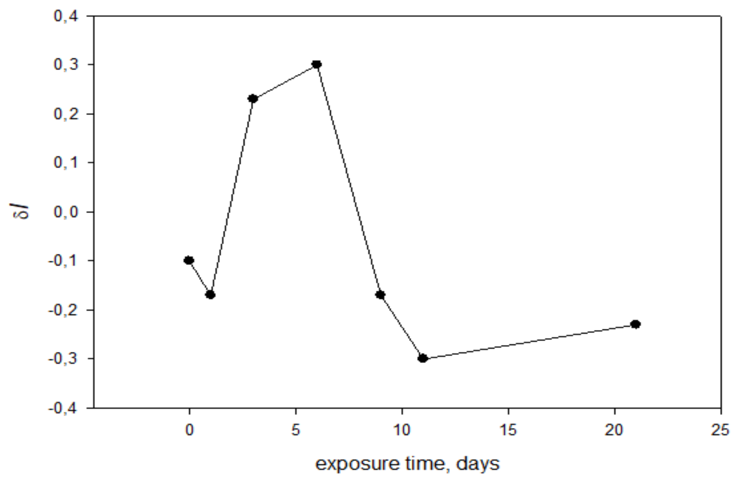

Figure 3. Dependence of the relative change in the length of the ice core on the exposure time after the field effect at 170 MHz

Comparison of the dependence form with the data given in [11] shows a sufficiently clear coincidence of the curve up to 21 days. It shows that certain changes in the structural organization of the water network are manifested in the same way in different processes. In this case, these are the hydration processes during the dissolution of glucose and the process of solvent crystallization (water).

When analyzing the exposure time for different frequencies presented in Figures 4 and 5, it should be noted the multidirectional influence of the frequency factor at short exposure time, which was observed in Figures 1 and 2. Nevertheless, an unidirectional effect of the 200 MHz field is clearly visible: an exposure from 0 to 6 days leads to close values of the relative core size. There is a similarity of dependences for 0 and 3-day exposure for all frequencies. If the exposure time is longer (9–21 days), the frequency dependence is more individual, though the location relative to the zero line is similar: most values are located in the negative area.

The models, detailed in [13], can be used to explain. First of all, it should be noted that water molecules in a liquid state have several types of motion: vibrational, rotational and translational. In addition, proton transfer along structural defects also occurs. These motions have significantly different transformation time. Taking this into account, it is possible to exclude fast processes and leave only slow ones, coincident or close to the frequencies of external influence. These include the rotation of a water molecule in the surrounding field of other molecules, which may coincide with the frequency of the field effect. Consideration of rotational processes and their peculiarity is associated with the fact that usually the ice I is not an ideal structure. It has D and L defects, the relaxation of which is caused by the rotation of individual molecules. The structural organization of water at 300 K is polymorphic according to modern models, i.e. consists of domains of $(H_2O)_n$ type.

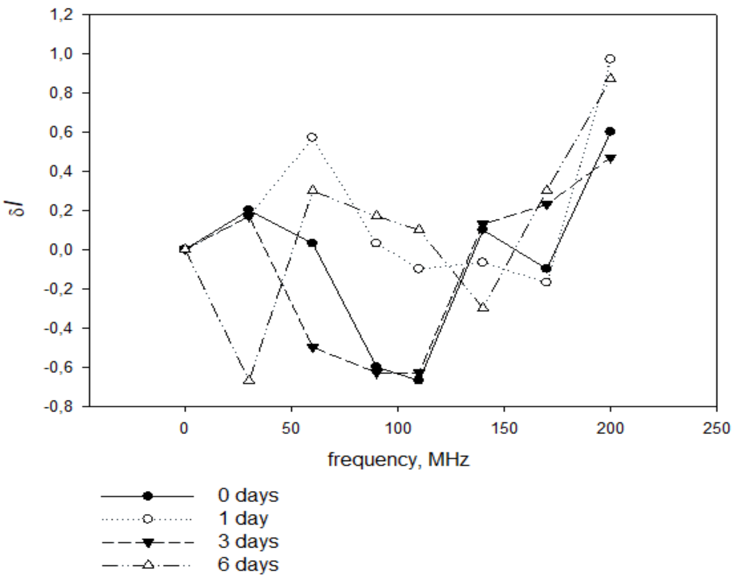

Figure 4. Dependence of the relative change in the length of ice core on the frequency of field effect for different exposure times

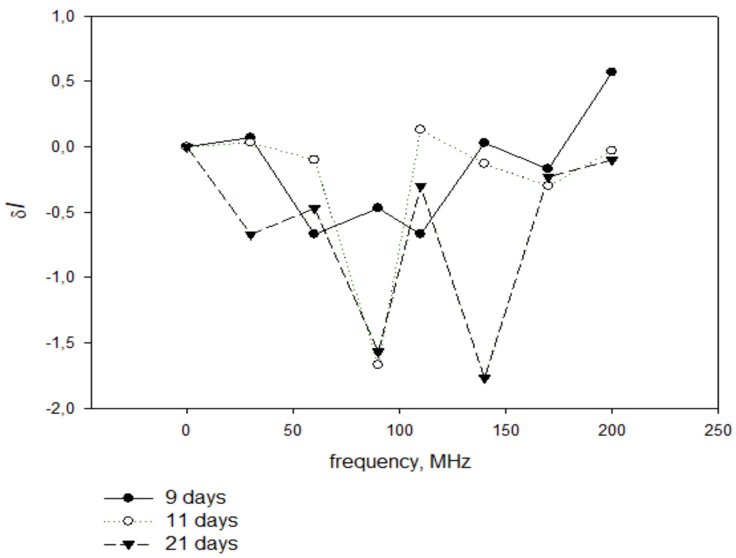

Figure 5. Dependence of the relative change in the length of the ice core on the frequency of the field effect for different exposure times

Taking into account this fact that, it can be assumed that for each domain group there is the resonance frequency of oscillation under the effect of an external electromagnetic field. This may lead to a redistribution of the ratio of the amount of monomolecular water (or the corresponding structural domain) and the polymolecular domain with a certain *n*. In turn, such a reconstruction either promotes the «healing» of defects in the ice structure, or stimulates their generation. Oscillation of the field effect in time can be associated with the fact that crystallization does not occur instantaneously, but takes a certain period of time, including the metastable state of supercooling. During this time, the relaxation of water structure to the closest energy state can occur either with a large or smaller number of defects. Thus, it follows that when the defects are «healed» and water does not tend to include single molecules in the cluster cavities, the volume of ice increases in comparison with uneffected water. If the number of defects increases, the structure becomes denser and shrinks.

Conclusion

It is shown that the effect of an electromagnetic field of 30–200 MHz on water subsequently causes a change in the crystallization volume of ice. The effect of changing the crystallization volume depends both on the frequency of field action and the time of water exposition after the field action before crystallization. Both increase and decrease in the ice volume as compared to the uneffected sample were found. The maximum effect of volume increase was observed for the frequency of 200 MHz and exposure time of 1 day. The maximum ice compression occurred after the field effect at a frequency of 90 MHz and exposure time of 11 days as well as, at 140 MHz and exposure time of 21 days. It is considered as both loosening and strengthening of water net structure.

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Б.П. Шипунов, М.В. Захарова

Жоғарыжиілікті электромагниттік өрістің әсерінен судың кристалдану көлемінің өзгеруі

Судың кристалдану процесіне жоғарыжиілікті электромагниттік өрістің әсері зерттелді. 30-дан 200 МГц дейінгі жиіліктегі далалық өңдеуде ұшыраған су жабық ыдыста 0-ден 21 күнге дейін сақталды, содан кейін мұздатылды. Далалық өңделмеген судың кристалдануы кезіндегі мұздың көлемі далалық өңдеуден кейін судың кристалдануы кезіндегі мұздың көлемімен салыстырылды. Жиіліктердің 3 тобы бар: олар үшін шамалар сәулеленбеген судан алынған мұздың мәндеріне қатысты симметриялы түрде азды-көпті нөлге жақын орналасқан, олар үшін оң ауысу басым және ауысым негізінен теріс. Оң жақтылық 200 МГц жиілігінде және экспозиция уақыты 11 күнге дейін байқалды. Көлемнің салыстырмалы ұлғаюының максималды әсері шамамен 2 есе, 200 МГц жиілікте байқалды, 1 тәулікке экспозициямен, мұздың максималды сығылуы, сәулеленбеген сынамамен салыстырғанда шамамен

3 есе, 90 МГц жиіліктеге өріс әсерінен кейін 11 тәулік ұстау уақыты кезінде және 140 МГц жиілігі үшін 21 тәулік ұстау уақыты кезінде далалық әсер ету орын алды. 170 МГц жиіліктегі экспозиция уақытына тәуелділіктің ерте жұмыстарда алынған глюкозаның еруі жылулық әсеріне тәуелділігі ұқсастығы атап өтілді. Алынған мәліметтер далалық әрекеттің нәтижесінде су құрылымының күшеюі де, қопсытуы да болатынын растайды.

Кілт сөздер: электромагниттік өріс, су құрылымы, мұз құрылымы, мұз құрылымындағы ақаулар, өрістің әсер ету жиілігі, сәулеленуден кейінгі су құрылымындағы өзгерістер, су құрылымын босату, су құрылымын нығайту.

Б.П. Шипунов, М.В. Захарова

Изменение объёма кристаллизации воды в результате воздействия высокочастотного электромагнитного поля

Изучено влияние высокочастотного электромагнитного поля на процесс кристаллизации воды. Вода, подвергшаяся полевой обработке частотой в диапазоне от 30 до 200 МГц, выдерживалась от 0 до 21 дня, затем замораживалась. Объём льда при кристаллизации необработанной полем воды сравнивался с объёмом льда при кристаллизации воды после полевой обработки. Выделено 3 группы частот полевого воздействия: 1) те, для которых значения располагаются вблизи нулевого значения; 2) те, у которых превалирует положительный сдвиг и 3) те, у которых смещение, в основном, имеет знак минус. Положительное смещение отмечено при сочетании 200 МГц, и время выдержки — до 11 суток. Максимальный эффект относительного увеличения объёма, почти в 2 раза, наблюдался для частоты 200 МГц, при выдержке 1 сутки, максимальное сжатие льда, примерно в 3 раза, по сравнению с необлучённым образцом, происходило после полевого воздействия на частоте 90 МГц при времени выдержки 11 суток, и для частоты 140 МГц при времени выдержки — 21 сутки. Отмечено сходство зависимости от времени выдержки для частоты 170 МГц с зависимостью теплового эффекта растворения глюкозы, полученное в ранних работах. Результаты подтверждают, что при полевом воздействии происходит как упрочнение, так и разрыхление структуры воды.

Ключевые слова: электромагнитное поле, структура воды, структура льда, дефекты в структуре льда, частота полевого воздействия, изменения в структуре воды после облучения, разрыхление структуры воды, укрепление структуры воды.

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