

Effect of Magnetic Fields on UV Absorption and Evaporation of Water

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Research Article

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Abstract

We investigated the effects of unipolar magnetic fields (N or S polarity) on the physical properties of deionized water. Long-term experiments revealed significant pole-dependent changes in water absorption in the UV range (180 – 350 nm). In the case of water in open vessels, the order of absorption values was C-N-S. That is, control (C) water absorbed the most, N-pole-influenced water absorbed less, and S pole the least. The differences in absorption between N and S waters were substantial. In the case of closed vessels, the differences in absorption spectra substantially diminished, and the arrangement of the absorption values became C-S-N (highest to lowest). A correlation between UV absorption values and evaporation rates was also found. The relative order of evaporation rates, C-N-S (highest to lowest), was the same as the order of the absorption values, also C-N-S. The differences in UV absorption spectra of the N- and S-treated waters persisted for several months after removing the magnets. Hence, the effects of magnetic fields were long term. The interaction of magnetic fields with water is of interest not only from a physical sciences perspective, but also in the context of the significant applications in medicine and biology.

Introduction

Throughout evolution, the Earth's magnetic field (MF) has been a feature present in the environment of living organisms. Nowadays, those fields are augmented by many artificial MFs – from various electronic devices, electrical power lines, electric transport systems (trams, trolleys, trains), and so on. Studies have revealed a wide variety of biological effects in living organisms exposed to MFs^{1,2,3,4}. Nevertheless, despite abundant, and diverse, experimental data, the mechanisms underlying magneto-reception have yet to be identified.

Since water is the predominant component of most biological tissues, the biological effects of MF may conceivably lie in water, particularly if water has diamagnetic properties^{5,6,7}. It follows that any changes in the physical and chemical properties of magnetized water could affect the biology of living organisms. Therefore, the interaction of MF with water is of interest, not only from a fundamental science perspective, but also in the context of applications in biology and medicine.

The properties of MF-influenced water have been widely investigated. However, many questions remain controversial and poorly understood. The molecular dynamics simulation revealed that the structure of the water gets more stable and the ability of the water molecules to form hydrogen bonds is enhanced when a magnetic field is applied⁸. Some results imply that the average size of water clusters increased in response to magnetic treatment⁹. It was found experimentally that the externally applied magnetic fields cause displacements and polarization of molecules and atoms and result in changes of dipole moment in the transition and vibrational states of molecules¹⁰. No generally accepted physical mechanism of MF influence on water has been demonstrated up to now.

Multiple experimental studies have shown an increase in water evaporation and a small decrease in the surface tension of air/water interface during magnetic treatment^{11,12,13,14,15}, although contrary results can also be found for the surface tension. The evaporated amounts depended on which pole of the ring magnet was directed up¹³.

Deformation of the air/water interface by magnetic fields and dissolved gases plays an important role in many phenomena related to the water 's magnetic treatment^{15,16}. It has been shown^{17,18} that the magnetization of pure water required dissolved gas (oxygen or air). In magnetically treated oxygenated water, infrared and Raman spectroscopic evidence indicated the formation of quasi-stable oxygen clathrate-like hydrates¹⁸. No change in properties of pure water distilled from ultrapure water in vacuum was observed by magnetic treatment¹⁷.

Most researchers pay no special attention to MF polarity, i.e., to whether the surface of the magnet nearest the object of interest was the north (N) or south (S) pole. Nevertheless, fundamental differences have been identified in the biophysical effects of the respective poles¹⁹. Since the appearance of the latter work, many studies have investigated the effect of a MF on water, but the results have often proved contradictory. Some studies showed that each pole produced effects that were quite different from the other.

For example, the differing properties of opposite polarity magnetic fields were demonstrated in long-term experiments connected with the biological treatment of organic wastes in water²⁰. In that study, the N and S poles of a magnet were applied, respectively, to a bioreactor for more than 10 days. The MF of the S pole increased biological oxidation activity by a factor of two relative to the N pole. However, the increase occurred only after four days of exposure.

It has been shown²¹ that magnetically generated water structures produced by different polarities of a magnet produce differential effects on oestrous cycles and body weight of mice. In the catfish *Clarias batrachus*, different water structures produced by S or N poles induced different and significant changes of liver (hepatic cell density, size, and nuclear diameter)²². Male 9- to 10-week-old mice were exposed to different polarities MF of 128 mT for 1 h/day during a 5-day period. It was found that MF affected various organs and these effects were dependent on MF polarity²³. A recent study²⁴ showed a different impact of opposite polarity magnetic fields on hematological parameters of spontaneously hypertensive rats. Another recent study²⁵ found that long-term exposure (88 h) of a MF of 9.4 T (Tesla) strength (planned for use in magnetic resonance imaging) significantly inhibited tumor growth (up to 41%) in mice with lung cancer. This effect was observed only with exposure to the magnetic north pole. These results are in accordance with the earlier study²⁶ results where a MF of 0.2–1 T was used for treatment of different cell lines. It was found that the north magnetic field could effectively reduce the cell numbers of all human tumor cell lines, but a south magnetic field did not produce significant effect. In contrast, most non-cancer cells were not affected by N or S magnetic fields.

The obtained results have revealed the high sensitivity of some bacteria and seeds to permanent magnetic fields¹. A study²⁷ has revealed that the only north pole MF of a magnet (0.1 T) inhibited the growth of *E. coli* and *Staphylococcus epidermidis* bacteria. The effect of a magnetic field (62 mT) on chilli seed germination, growth and development has been investigated²⁸. It was found there that the seeds treated with south pole were showing maximum growth status as compared to north pole and untreated control.

Perhaps the most impressive polarity-dependent effect is related to the human perception of the geomagnetic field. Biophysical tests²⁹ showed that the people's neural response was sensitive to static components of the magnetic field. Moreover, the neural response was also sensitive to the polarity of the magnetic field. It is interesting that the human cardiovascular system did not react to the polarity of a MF^{30,31}.

The present study focused on the effects of unipolar magnetic fields (N or S) on the physical properties of water. We supposed that any changes in physicochemical characteristics might be reflected in the spectral content of light absorption. Especially over the long term, we found significant pole-dependent changes in water absorption in the UV range (185 – 300 nm) and, also, in evaporation rates. We also noted a definite correlation between differences in UV absorption levels and differences in evaporation rates of the control (C) water and waters treated with magnetic fields of N and S polarity (N and S water). The differences in water-absorption spectra remained measurable up to and beyond six months post-exposure.

Methods

Experiments were performed under laboratory conditions, at a room temperature of $21 \pm 1^\circ\text{C}$. The MF was produced by disc-shaped neodymium magnets, 45 mm in diameter and 3 mm thick. Magnetic field strength at the flat surface was 0.4 – 0.5 T. We used de-ionized (DI) water, obtained from a Barnstead D3750 Nanopure Diamond purification system. The purity of water from this system was certified by a resistivity value up to 18.2 M Ω cm. For the magnetic treatment, glass Petri dishes, diameter 50 mm, height 14 mm, containing DI water (5 ml) were positioned on the surface of each of two magnets (N or S pole facing up) for a fixed duration. To avoid cross-interference, the dishes were kept 1.5 m apart from each other. An additional Petri dish with control water was placed also at 1.5 m from the other two, under the same lighting conditions. We carried out two series of experiments: short-term (20 minutes)

and long-term (20 – 28 days). For short-term experiments, the above-mentioned covered and open Petri dishes were used. For long-term experiments with open vessels 50-ml glass beakers (diameter 40 mm, height 55 mm) were used. Conical glass flasks (diameter 42 mm, height 70 mm, capacity 25 ml) plugged by rubber stoppers were used for long-term experiments with closed vessels. To determine the differences between the treated and untreated water, control DI water was contained in the same type of vessel as water for treatment by N and S magnetic field, but with no magnetic field applied.

For water-absorption spectral measurements, a Cary 5000 UV-Vis-NIR Spectrophotometer (175 – 3300 nm) was used. A series of scans (N-treated, S-treated, and control water) from 180 nm to 350 nm took less than 10 min to complete for 0.4 nm wavelength intervals. Spectrosil® Quartz 1.4-mL cuvettes with 10 mm path length were used (Starna Cells, Inc. Catalog Number: 9-Q-10, Useable range: 170 to 2700 nm). Absorbance does not have special units and was measured in dimensionless absorbance units, or a.u. The latter is a logarithmic ratio between the light intensity before and after the beam of light passes through the sample.

To measure the weights of N, S and C waters remaining in the beakers during evaporation, an Acculab VIC-123 digital scale with repeatability ± 0.001 g and capacity 120 g was used. At the beginning of each experiment the water weight of each beaker was 40.00 g. Weight measurements were carried out one time per day in the morning (approximately 10 AM). On weekends, the measurements mostly were not carried out, with several exceptions.

Results

Spectral range of measurement. Preliminary, short-term measurements of treated (N and S) and control (C) waters revealed distinct differences in UV absorption spectra, while the IR spectra showed no immediately obvious changes. Hence, we focused on UV absorption spectra, in the range between 180 and 350 nm. We first determined consistent features of water absorption in that wavelength range, by examining three types of water: DI, ultrapure distilled, and tap water. Fig. 1 shows that all three spectra had a consistent absorption peak (185.5–186.0 nm), with similar falloff at longer wavelengths. Hence, the particular type of water had little impact on the shape of the spectrum. As will be shown later, the characteristic spectral shape, including the peak, continues to exist for treated N and S waters.

- It should be noted that this absorption peak has been observed earlier in water and water solutions^{32,33,34}. UV radiation at $\lambda \sim 185$ nm is the effective method of water purification³⁵. Our experiments show that the magnetically sensitive spectral region lies beyond that peak, to longer wavelengths, where N- and S-treated waters show the largest changes.
- **Short-term experiments.**
- DI water was used for all experiments. A series of experiments was carried out to clarify the influence of unipolar MF on DI water's absorption spectrum. After the water (5 mL in every PD) had been exposed ($t = 20$ min) to the MF, we immediately measured the spectra. We studied three types of exposure: control water (C), water exposed to N pole (N) and water exposed to S pole (S). Typical results showed differences of absorption that depended on polarity (Fig. 2).

It is seen that the absorption of S water was the highest. (For brevity's sake, the order is written as S-N-C.) Differences were not large (0.01 – 0.02 AU), which translated to differences of transmittance of only 4 - 5%. We found that these differences were inconsistent: the order of absorption of N, S and C waters could change from experiment to experiment. Therefore, it was not possible to conclude that the results

reflected any real physical phenomenon. The same experiments carried out with the covered PDs gave no visible differences in the UV spectra of N, S, and control water.

Long-term exposure.

The results above implied that longer-term exposure to magnetic fields might possibly increase the spectral differences between N and S waters and the repeatability of the results. The experimental conditions remained the same except that the duration of continuous MF exposure was increased significantly, to nearly four weeks. Two types of experiment were conducted: with open and closed vessels (beakers and flasks, respectively).

Experiments with open beakers. During experiments with long-term MF exposure, absorption spectra were measured every 2 – 3 days. For the first several days the differences between N, S, and C waters remained small, and the order of absorption magnitude remained inconsistent. After approximately 18 – 20 days, however, the differences between N and S water grew larger, and the order of the absorption-spectra amplitudes remained stable. During the subsequent period, the differences in absorption of N and S water increased further and reached values up to 0.1 – 0.3 a. u. near the peak wavelength. The absolute values of absorption also increased – i.e., the waters became more absorptive.

Figure 3. Representative UV absorption spectra of the N, S and C waters measured on 18th day of magnetic field treatment. DI water samples were contained in open beakers (40 mL in every beaker), as shown in the photo.

As indicated above, the absorption curves for experiments conducted in open beakers were consistently ordered C-N-S, from highest to lowest, with one exception that showed N-C-S order ($n = 5$). After 18-20 days of the magnetic treatment, the repeatable result was that S water always showed less absorption than N water, while C water had the largest absorption. These differences persisted for some time, even after the end of MF exposure. A representative example is shown in Fig. 5. The figure demonstrates that even at 70 days following the end of MF exposure, some differences in the absorption between S and N waters remained.

Experiments with closed flasks. In theory, the absorption spectra could be impacted by physical and/or chemical processes occurring during evaporation. To determine if such processes influence the phenomena under study, particularly in long-term experiments with open beakers, we substituted closed flasks. Conical flasks were filled with water up to approximately 2/3 of their volume and closed with rubber stoppers. This minimized any impact of the evaporation during the experiment. We conducted five experiments. Representative results are shown in Fig. 6.

The figure shows that the absorption of C water was the highest, followed by S and then N. The differences were relatively small, and the results differed from those obtained using the open beakers (Fig. 4). On the other hand, the ordering, C-S-N, did not change from experiment to experiment ($n = 5$). C showed the highest absorption, while N showed the lowest. This ordering differs from that obtained in the

experiments with the open beakers, which showed mostly C-N-S ordering. Thus, exposure to the open environment apparently plays a role in the way MFs impact water.

Evaporation of N, S, and C waters. The principal difference between experiments conducted with open vs. closed vessels is the presence, or absence, of evaporation. Since magnetic fields are known to influence the evaporation rate^{12,13,14}, we explored whether the evaporation rate might show MF polarity dependence, an issue not yet explored in earlier experiments. Therefore, long-term evaporation experiments were carried out with S, N and C waters.

In addition to measuring the absorption spectra, each type of water (N, S and C) contained in the open beakers was weighed daily to determine the amount of water that had evaporated. Fig. 7 shows representative amounts of evaporated water as a function of MF-exposure duration (in days).

The level of evaporation differed for C, N, and S waters. The highest level was for C water. N and S waters showed lower and lowest evaporation levels, respectively. That distribution (C-N-S) was observed in four out of five experiments. In those experiments, the evaporation order was the same as that for the absorption spectra. In other words, the C water showed the highest absorption and the highest rate of evaporation. S water showed the least absorption and the least rate of evaporation. One experiment gave the N-C-S distribution in UV absorption and the same order (N-C-S) in evaporation. An interesting feature was observed during the experiments: the rate of evaporation gradually decreased for N and S waters in comparison with C water. This decrease was not uniform: the gradual decrease was the biggest for S water (Fig. 7). Therefore, by 25th day in vessels with C, N, and S waters remained respectively 10.0, 12.5, and 17.5% of water (Fig. 7). These values are close to their averaged values over the results of all experiments, i.e., 11, 13, and 21%.

A similar diagram constructed using the results of another experiment is shown in Figure 8. Here, we plotted the weight of the evaporated water component that was caused solely by N and S magnetic fields (δW_N , δW_S) relative to the same initial weight of each water (W_I):

$\delta W_N (\%) = 100 (W_N - W_C)/W_I$ and $\delta W_S (\%) = 100 (W_S - W_C)/W_I$ respectively, for N and S waters. Having thus eliminated the changes in weight caused by the usual evaporation process, we can more easily see the differences in the long-term impact of N and S magnetic fields. They agree with our previous conclusions, namely the rate of evaporation gradually and differently decreased for N and S waters in comparison with C water.

All experiments indicate a relationship between the evaporation of water and the corresponding UV spectra. Moreover, they show a direct proportionality between the differences in water absorption and the differences in their evaporation.

The findings also have good correlation with transient alterations in growth and size of GH3 cells, which were cultured during long-term (up to 5 weeks) continuous exposure to a 0.5 T magnetic field³⁶. MF strength was the same as used in our experiments. Following one-week exposure, cell growth reversibly

declined by 22%, returning to control levels in one week. This agrees with our results, as we could observe that the one-week exposure was still insufficient to create the stable changes in water structure. But with a four-week exposure, a decline in growth of 51% was observed, and return to control levels did not occur until four weeks' time. This observation resembles those obtained in our long-term experiments, where we observed large, stable changes in the UV absorption after 25-28 days of magnetic exposure (Fig. 4 and Fig. 5).

Discussion

The experimental results reveal three principal findings. First, the influence of north and south poles on water are not the same. In terms of the UV absorption spectra, the impact of N and S poles differ in magnitude. This finding supports the notion that the impacts of the two poles may not be the same, a result supported by other studies.

The second finding is that exposure to the environment matters. The impact of magnetic field differed in situations in which the experimental chamber remained open to the environment compared to situations in which the chamber was cut off from the environment. Results obtained with closed chambers differed from those obtained with open chambers.

The third finding of significance is that evaporation rate is sensitive to various aspects of magnetic fields. First, the very presence of the magnetic field impacted the rate of evaporation; and second, that rate depended on whether the exposure arose from the north pole or south pole.

The question is how to these observations may be interpreted in terms of what we know about magnetic fields and about water.

Recently, we identified the presence of exclusion zones (EZs) in water exposed to magnetic fields. When magnets were inserted into aqueous suspensions of microspheres, the microspheres moved dynamically from regions adjacent to each pole, leaving sizable zones free of microspheres. These zones, on the order of 0.5 to 1 mm wide, closely resemble those found next to many hydrophilic surfaces³⁷. The water in these EZs differs substantially from ordinary liquid water and has been termed water's fourth phase⁶.

If magnetic fields create these aqueous zones, then taking them into account would seem necessary when considering the impacts of magnetic fields on water. At present, the long-term behaviours of these zones have not yet been studied in detail, but one may extrapolate from shorter-term behaviours in seeking a rationale for the effects observed here.

One such impact is on the UV-Vis absorption spectrum. In the UV region, the spectrum is profoundly impacted by the presence of EZ, especially in the wavelength region near 270 nm³⁸. If the aqueous solutions in question here contain EZ, then we anticipate changes in the spectrum, which are observed. We cannot be certain of the presence of EZ over the long term. On the other hand, EZs are routinely

observed over days, and hence there is reason to suspect that they might persist over times considerably longer than that.

As for the second point, the impact of environment, several possibilities exist. The first is the availability of oxygen supply in one case but not the other. That could play a role. The reason is that EZ water, as H_3O_2 , contains a higher oxygen to hydrogen ratio than ordinary water⁶. Over the long term, it is possible that even modest oxygen diffusion through an opening in the flask might produce relatively more EZ water.

Another possibility to explain the difference between open and closed flasks is the presence/absence of infrared energy. Infrared (IR) energy is necessary for EZ build-up and sustenance³⁹. Open flasks, even modestly open, can pass IR, while closed flasks cannot, as glass does not ordinarily pass IR. Consequently, the amounts of EZ may well differ in open vs. closed flasks, especially over substantial periods of time.

As for the third aspect, evaporation rate, one may expect differences in evaporation between EZ and bulk water. Multiple factors enter consideration here, as the two structures differ qualitatively. EZ water evaporates in large macromolecular clusters, especially at elevated temperatures⁴⁰, whereas bulk water, consisting of individual water molecules acting more-or-less independently^{41,42}, can be expected to evaporate under different regimes^{43,44,45,46}. Hence, the relative presence/absence of EZ water can be expected to have substantial impact on evaporation rate, as observed.

The interaction of magnetic fields with water is of interest not only from a physical sciences perspective, but also in biology and medicine, especially in cancer therapy^{2,3,4}. Our findings imply that different poles of a permanent magnet may create different effects in both realms. This conclusion has been supported by the results of multiple independent medical and biological studies.

In sum, magnetized water undergoes substantial structural change when exposed to magnetic fields. These structural changes may be responsible for the effects noted here, both the spectral changes and the changes of evaporation rates. Further studies are planned to explore these features in more detail.

Declarations

Data availability

All data are available within the text of the article. The raw/processed data required to reproduce these findings are available from the corresponding author upon reasonable request.

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Author contributions

Conceptualization and methodology: GHP, VS; Experiments: VS; Data curation: VS, GHP; Writing – original draft: VS; Writing – review & editing: GHP.

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Additional Information

Competing interests

The authors declare no competing interests.

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Figures

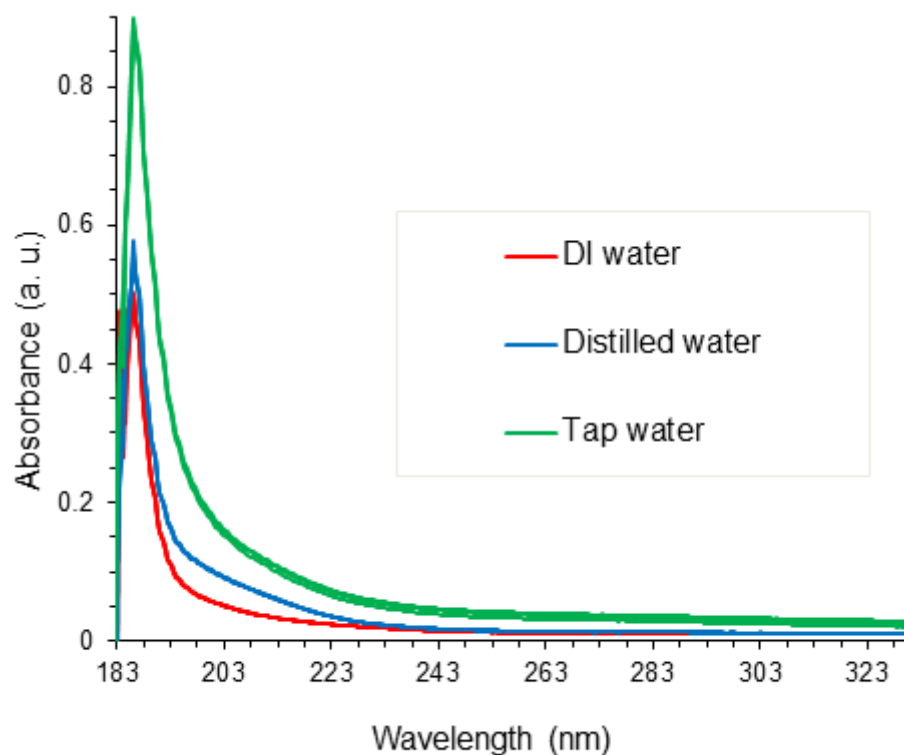


Figure 1

UV absorption spectra of the three types of water: 1 – DI water; 2 – distilled water; 3 – tap water. Measurements for each type of water were made three times (at 1-minute intervals). The resulting curves (three superimposed curves for each type of water) are practically indistinguishable.

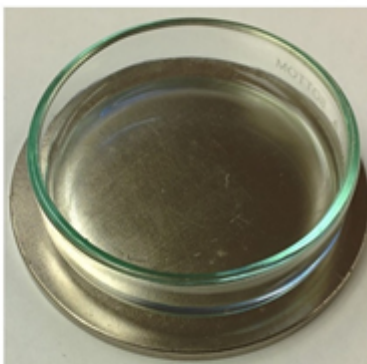
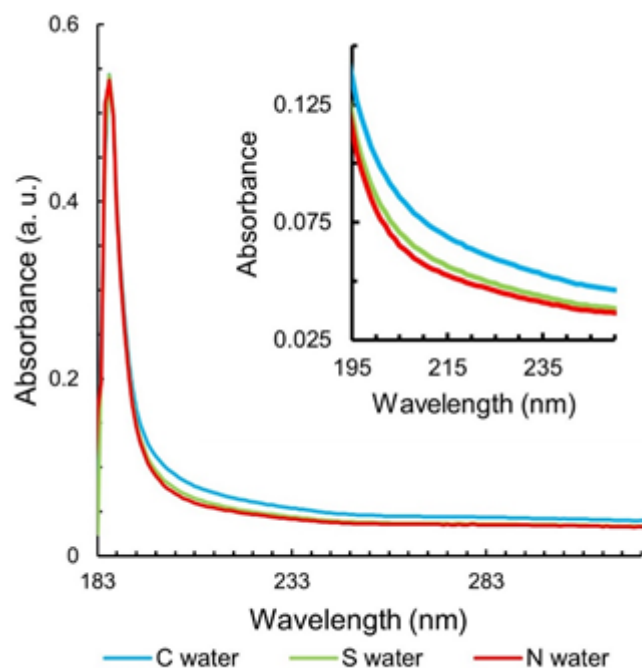


Figure 2

Representative UV absorption spectra of C water and water exposed to the north (N) and south (S) poles of the magnet for 20 min. DI water samples (V = 5 mL) were contained in covered Petri dishes, as shown in the photo.

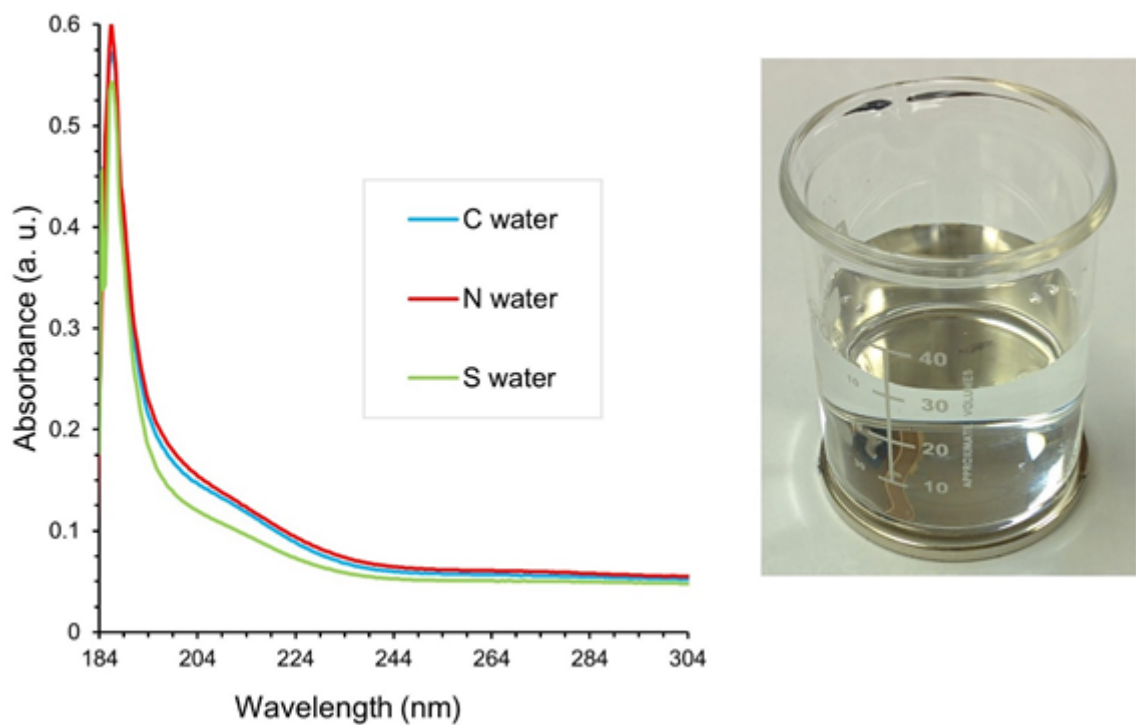


Figure 3

Representative UV absorption spectra of the N, S and C waters measured on 18th day of magnetic field treatment. DI water samples were contained in open beakers (40 mL in every beaker), as shown in the photo.

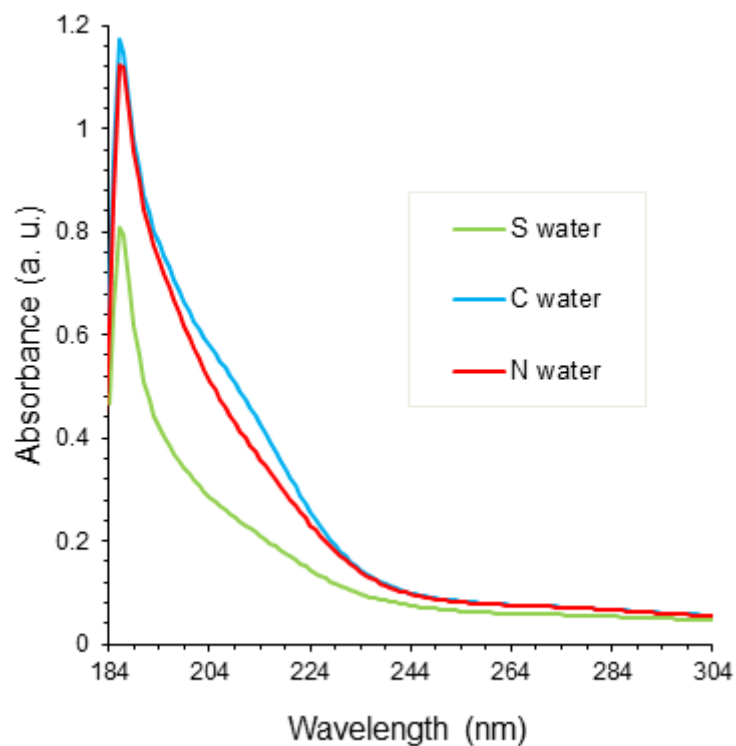


Figure 4

Representative UV absorption spectra of the N, S and C waters measured on the 25th (final) day of magnetic field treatment.

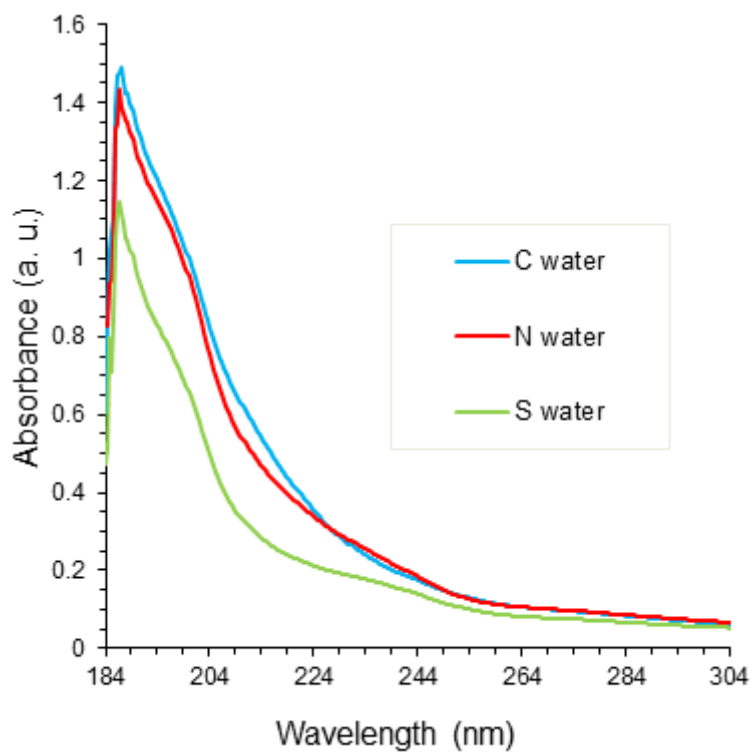


Figure 5

Representative UV absorption spectra of N, S and C waters, measured 70 days after MF exposure had ended. The MF-treated water had been saved in plastic tubes sealed with plastic stoppers until the time of measurement.

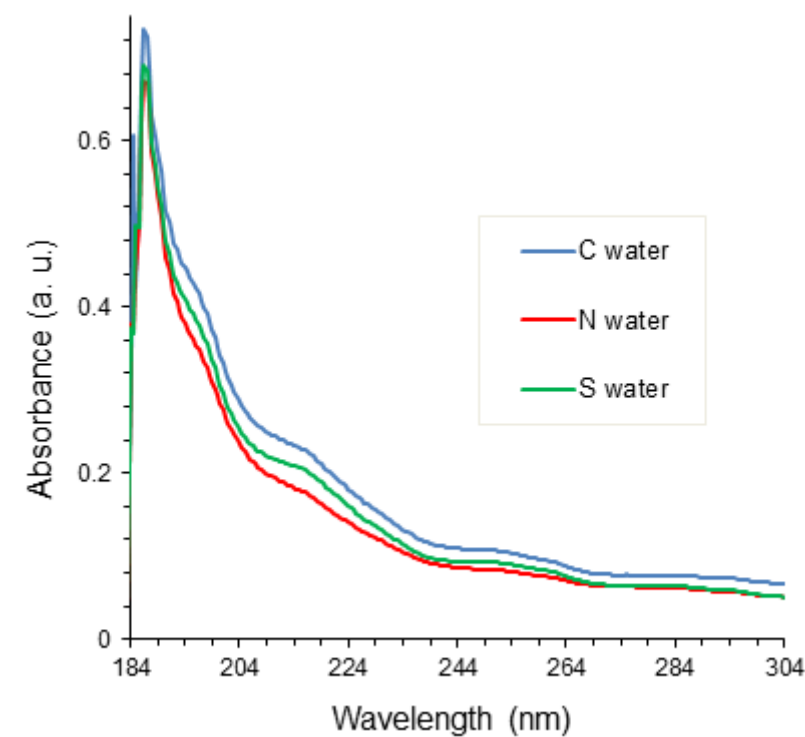


Figure 6

UV absorption spectra of the N, S and C water, measured on the 26th day of magnetic field treatment.

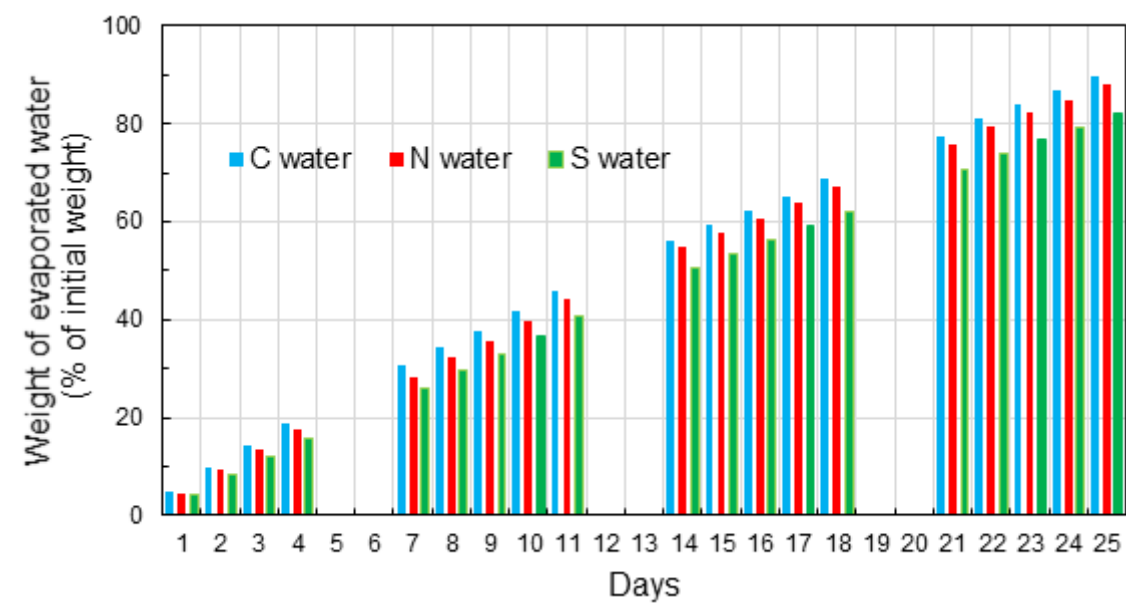


Figure 7

Amount of evaporated water as a function of MF-exposure duration. The vertical axis label shows the ratio of the evaporated water weight (WN, WS, and WC) to the weight (WI) of water that had been in the

vessel just before the beginning of an experiment (in percent).

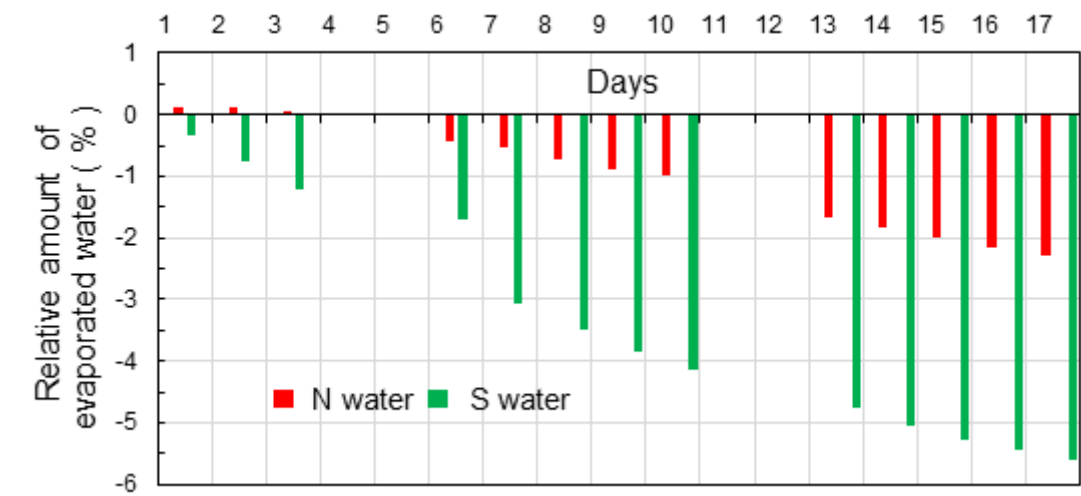


Figure 8

Amount of evaporated N and S water in comparison with C water.