

Delayed Shifts in pH Responses to Weak Acids in Spring Water Exposed to Circular Rotating Magnetic Fields: A Narrow Band Intensity-Dependence

ABSTRACT

The time required for the shift in pH after addition of small quantities of a weak acid into fixed volumes of spring water was measured once per minute while the sample was exposed to magnetic field configurations that have been shown to influence photon emissions and to produce non-local effects in other experiments. The rotating magnetic fields were generated through a circular array of eight solenoids first with an accelerating angular group and decelerating phase velocity followed by a decelerating angular group and accelerating phase velocity for a total of 18 min. There was an intensity dependent increase in the latency (from 185 s to 886 s) required for the pH to decrease (towards acidity) between ~ 0.13 and ~ 0.33 μT (microTesla) where an asymptote was evident. The duration was systematically related to the magnetic energy within the volumes of spring water associated with various intensities. Quantitative analyses indicated that the most likely mechanism involved the energy per molecule associated with the numbers of HCO_3^- and H^+ ions in the fixed volumes. These results suggest that weak magnetic fields with specific rotational configurations within physiologically relevant volumes of water containing several ion species can delay the onset of acid-base responses in buffered systems.

Keywords: pH; weak magnetic fields; changing angular velocity; response latency; 10^{-20} J.

1. Introduction

The effects of weak physiologically-patterned magnetic fields upon aqueous systems such as those containing concentrations of ions similar to those found in cells have implications for theoretical and applied chemistry. Toledo et al [1] measured the enthalpies, viscosity and surface tension of water exposed to 45 to 65 mT static magnetic fields. Their data indicated the exposure disrupted intra-cluster hydrogen bonds. Gang et al [2] found that stronger (0.16 T) static magnetic fields affected the diffusivity of solutes. We reasoned that appropriately-patterned and much weaker magnetic fields at specific intensities could facilitate cohesion between intermolecular networks of hydrogen bonds that would be reflected in increased response latencies to shifts in pH following addition of small quantities of proton donors to liquid water.

Persinger [3] has suggested that the mobile protons associated with H_3O^+ ions could mediate many of the subtle changes in the properties of water following exposures to magnetic flux. The product of the average viscosity of water and the ratio of the magnetic moment of a proton and unit charge produces a force that when applied across the distance of two hydrogen bonds is $\sim 1.7 \cdot 10^{-20}$ J. This is remarkably similar to the energy associated with second shell hydrogen bonds and is consistent with proton mobility [4].

That strong static magnetic fields affect aqueous systems has been shown by multiple experiments. Oshitani et al [5], who reviewed this area of research, showed that “residual” changes in different physical properties of water, a type of “memory effect,” were frequent but inconsistent phenomena. Measurements by atomic force microscopes indicated that the effects of uniform magnetic fields applied to aqueous samples slowly became evident and approached an asymptote after 10 to 20 min. Oshitani et al [5] found that the thickness of the layer of water molecules and ions absorbed on a surface (as well as the surface potential of an electrolyte solution) responded differentially to either pulsed, alternating or static magnetic fields.

With a flux density of 0.4 T which is within the range known to produce a maximum magnetic effect on selected aqueous properties, they found that the time required for the maximum effects upon layer thickness by the pulsed, alternating and static fields were 6, 10, and 20 min respectively. The latency of the appearance of the effect decreased with increasing frequency up to 90 Hz which was the limit of their equipment. The residual effect upon layer thickness after 30 min exposure was at least 5 days for the pulsed and alternating fields and about 3 days for the static field. The static field effect was no longer measureable after 5 days.

Gang et al [2] measured diffusion velocity of a solute (ink) in different aliquots of spring water after 1 hr exposures to a 0.16 T static (horseshoe) magnetic field every 15 min for several hours. They found sudden and protracted increases in diffusion velocity that were a function of the volume of the initially exposed water. The sudden increases for the successive 80 μL aliquots from the original 25 cc, 50 cc, and 100 cc volumes were 5.9 hr, 7.4 hr, and 8.6 hr, respectively. The effect was not measured in similar volumes of water exposed to a 7 Hz, 140 to 400 nT field generated by a Helmholtz coil. Gang et al [2] suggested that the energy stored within the water as a function of volume was maintained with increased viscosity at the boundary of interfacial and bulk water as described by Del Giudice and Preparata [6]. The dissipation of this “intrinsic organization” induced by the magnetic field within the water was presumed to be mediated by hydronium ions.

Murugan and her colleagues, as reported by Persinger [3], found that exposure of spring water in the dark to a physiologically patterned, weak (0.3 to 0.6 μT) magnetic field that had also been shown to slow the growth of different types of cancer cells in culture but not normal cells [7], resulted in an increase

and shift in the peak of photon counts as measured by fluorescence spectrophotometer. The shift within the 1 cc samples was about 10 nm (to a longer wavelength) within the range of 350 to 466 nm. It involved an increase of about 100 photon counts over the reference value and was equivalent to a net energy change of about 10^{-20} J.

We [8] have observed that the nature of the temporal-spatial application of the magnetic field is a major factor that determines the range of the intensity that most effectively influences the target material, in these instance aqueous mixtures. One particular pattern involves rotating magnetic fields produced by the serial activation of a ring of solenoids. If the phase velocity of the pattern that is being constantly applied is opposite to the changing angular velocity of the rotating field (group velocity) conspicuous changes in the duration of a constant pH value (despite addition of protons) occur as a function of the intensity of the magnetic field. Here we show the threshold for this effect involves intensities within the microTesla range.

2. Materials and Methods

There were a total of 61 experiments completed over separate days (not more than one per day) over several weeks. For each experiment a 125 cc beaker containing 25 cc of spring water (4 mM of HCO_3 ; 1.77 mM Ca; 76 μM of Cl; 1.3 mM of Mg, 41.9 μM of NO_3 , 61 μM of SO_4 , 17.9 μM of K and 43.5 μM of Na) was placed in the center of a circular array of pairs of solenoids as described by Dotta and Persinger [9]. The equipment is also described in U.S. Patent 6,312,376: b1; November 6, 2001 and Canadian Patent No. 2214296.

Each pair of solenoids was composed of reed relays (Radio Shack, 275-0232). They exhibited a coil resistance of 250 ohms and a potential of 5 V DC (nominal current, 20 mA). Each pair was arranged in plastic film canisters and connected such they were pairs of north and south poles. The circumference of the equally spaced solenoids that were separated by 45 degrees from each other was about 60 cm.

The magnetic fields were generated from custom-constructed equipment such that columns of numbers each between 0 and 255 were converted to between -5 and +5 V (127=0 V) by a digital-to-analogue converter (DAC). The first field exhibited a decelerating phase (frequency) modulation while the second field exhibited an accelerating phase (frequency) modulation. Figures of their shapes in real time have been published elsewhere [10]. The spectral analyses of the two patterns are shown here in Figures 1 and 2.

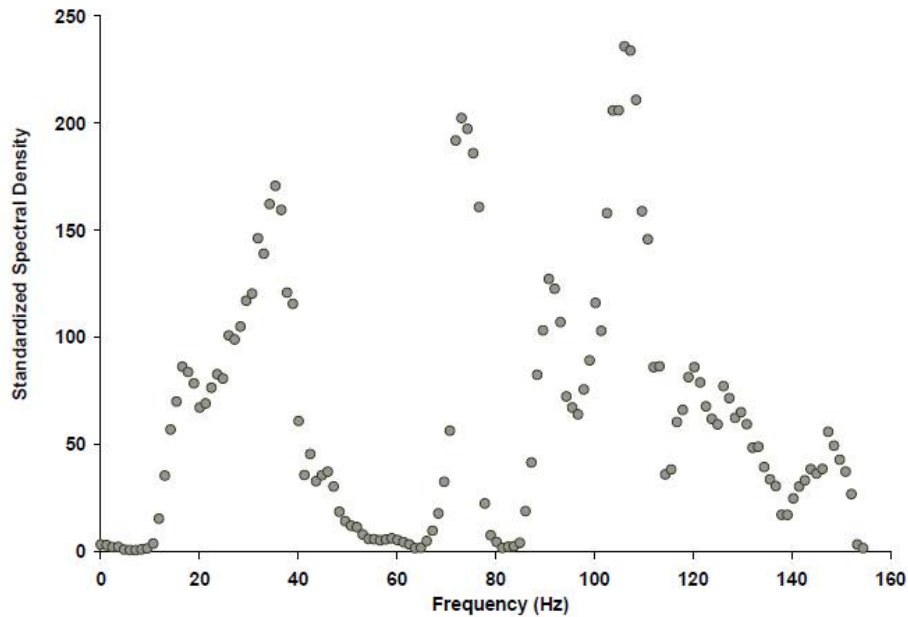


Figure 1. Standardized spectral density of the decelerating phase modulated pattern generated with an accelerating angular velocity of the rotating magnetic field within which the water samples were placed.

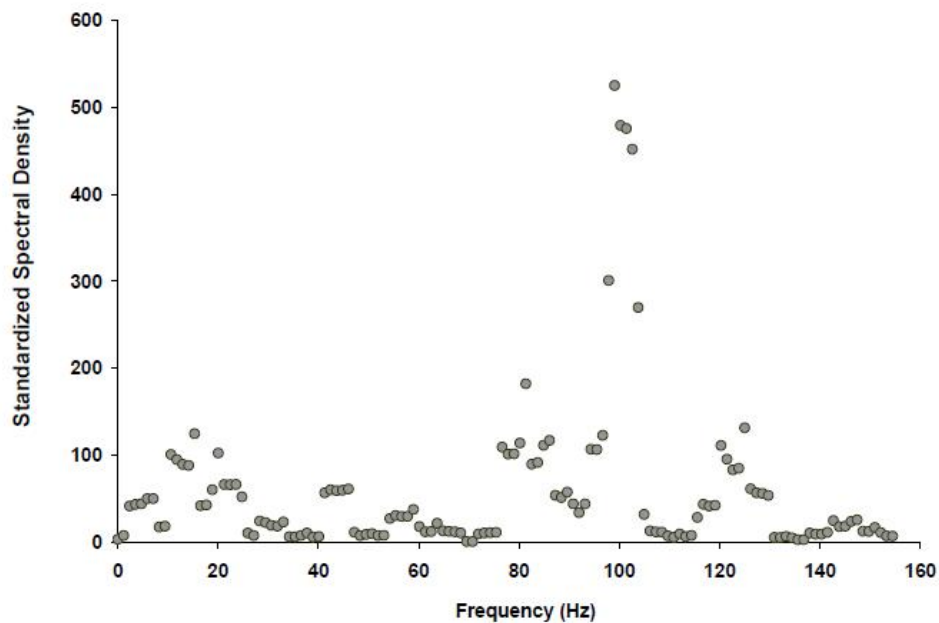


Figure 2. Standardized spectral density of the accelerating phase modulated pattern generated within a decelerating angular velocity of the rotating magnetic fields within which the water samples were placed.

The protocol was identical to the procedure by which excess correlation has been demonstrated over a distance of 10 m for both photon emissions and shifts in pH in non-local settings. The first field (decelerating phase) was

generated around the circular array of solenoids with an accelerating velocity. This was completed by adding 2 ms to the duration the field was presented to each solenoid beginning with 20 ms. Consequently the time required to complete one rotation was 104 ms or 9.6 Hz. The second field (accelerating phase velocity) was presented with decelerating group velocity. This was completed by subtracting 2 ms from the duration of the field presentation at each solenoid. Consequently the time required for one completion was 216 ms or 4.6 Hz.

The first field configuration was presented for 6 minutes. After 4 min of exposure 50 μ L of 0.83 M acetic acid was injected into the 25 cc of spring water with a microLiter syringe. The initial pH of the spring water was 7.4 ± 0.1 . Immediately after the onset of the second field which was activated for an additional 12 min, 50 μ L of acetic acid were injected every min for 16 min. There were a total of 9 injections. The pH values were recorded once per second by Dr. Daq systems (Pico Technology, United Kingdom) and were sensitive to 0.01 pH unit.

Over the 61 experiments different intensities of magnetic fields were applied. They were controlled by the software from the computer by which the fields were generated. In addition to the no field condition there were 10 different intensity settings. There were between 3 and 9 experiments per intensity condition. Direct measurement in the middle of the ring of solenoids with a power meter allowed average measurements of the strength in mG which ranged from 0.35 to 5.5 mG.

The time elapsed (“holding time”) after the first injection before the shift in pH occurred from the injections of the acetic acid as well as the shift in pH between the end and beginning of the experiment were obtained from the data files and loaded into SPSS-16. Analyses of variance as a function of intensity were completed. *Post hoc* analyses (Tukey’s $p < .05$) were completed to discern group differences; polynomial analyses revealed the linearity of the curve.

3. Results

Figure 3 shows the average “holding” duration in seconds after the repeated injections of the same small quantities of acetic acid before the decrease in pH began to occur as a function of the intensity of the field. Oneway analyses of variance as a function of intensity indicated a significant difference [$F(11,49)=24.95$, $p < .001$] between the intensities. The intensities explained about 85% of the variance (effect size) in the holding durations. *Post hoc* analyses indicated the major source of the difference was between the holding durations below 1.3 mG, which did not differ significantly from each other, and the holding durations for intensities above 3.3 mG, that did not differ significantly from each other. Polynomial analyses indicated that the first order best fit curve was linear and there was no significant deviation from this term.

Figure 4 shows the average net change in pH for each of the intensity conditions. The maximum decrease in pH was about 3.0, that is a change from 7.4 to 3.4 for the control (no field conditions). There was no significant shift in pH within the more intense magnetic field conditions until the “holding” duration was exceeded. When that occurred, the pH in all conditions decreased to 3.4 which was the same value displayed by the control (no field) conditions.

The 11 points shown in Figure 3 were analyzed separately. Correlation (Pearson) analyses indicated a strong positive relationship between the intensity of the applied magnetic field and the “holding” duration ($r=0.96$) and the total net shift in pH ($r=-0.98$). The inverse correlation coefficient between holding duration and net shift in pH was -0.91 . Partial correlation analyses holding each of the dependent variables constant did not appreciably diminish the correlation between field strength and holding duration (partial $r=0.77$, $p < .001$) or between field strength and net shift in pH (partial $r=-0.88$, $p < .001$). Direct analyses of the total data (excluding the no-field controls) set revealed similar effects. The correlation between field strength and hold time decreased from 0.88 to 0.72 after covarying for the change (decrease) in pH and the correlation between field strength and change in pH decreased from -0.86 to -0.62 after covarying for holding duration.

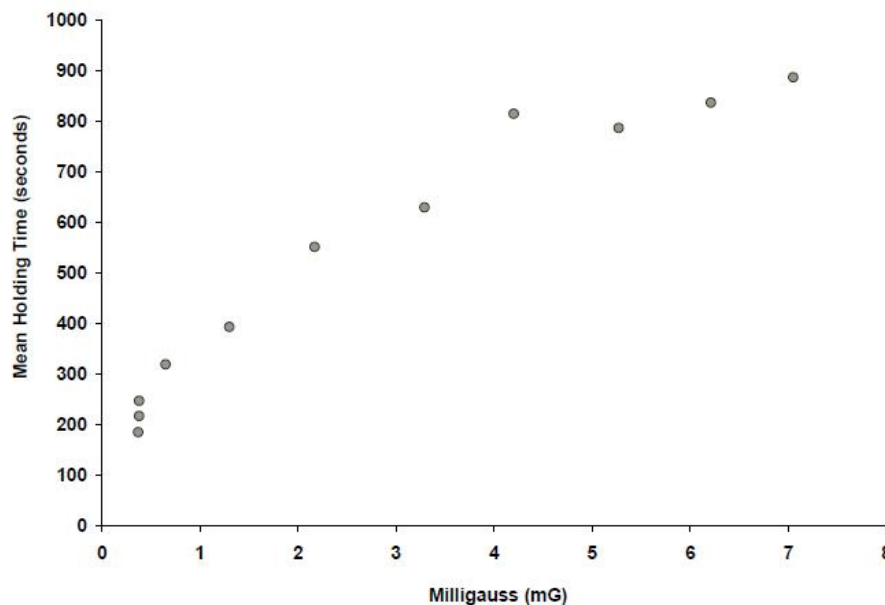


Figure 3. Mean holding time (in seconds), or the latency before the sudden decrease in pH in response to additions of a weak acid to the spring water as a function of the intensity of the rotating magnetic accelerating-decelerating angular velocity magnetic field.

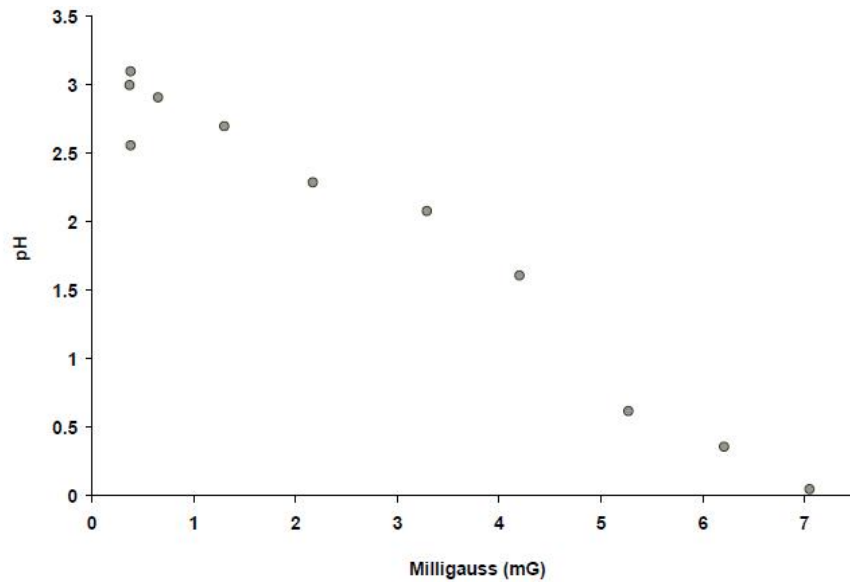


Figure 4. Mean values for change (decrease) in pH as a function of magnetic field intensity to which the spring water was exposed following additions of a weak acid.

Figure 5 shows the inverse release between the holding duration and the net shift in pH as a function of magnetic field intensities. The data were standardized (z-scored) in order to allow direct comparison. The interface for the inflection of both curves occurred around 2 mG or $2 \cdot 10^{-7}$ T.

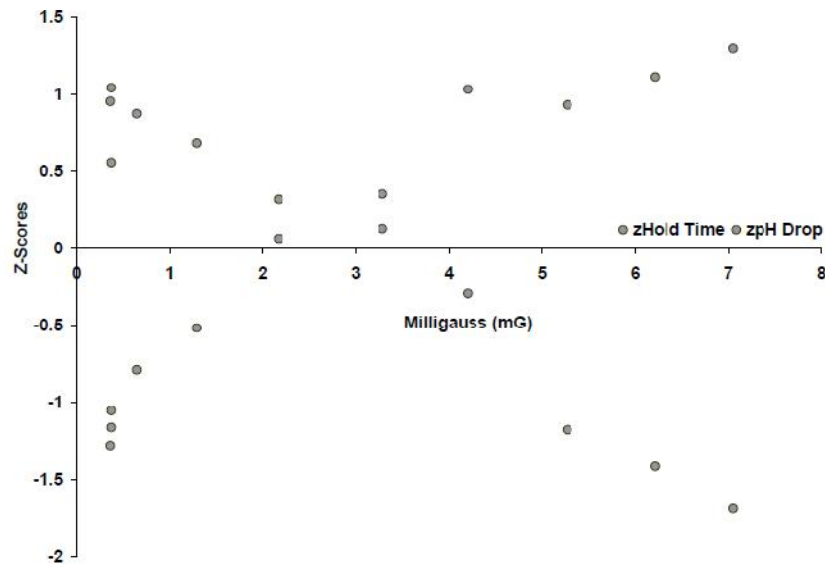


Figure 5. Standardized scores for the increase in latency to display a shift towards acidity and the total decrease in pH as a function of field intensity (horizontal axis).

4. Discussion

The results of these experiments demonstrated that the intrinsic rates of the responses (shift to acidity) of a fixed volume of spring water to successive injections of a proton donor were delayed by a factor of approximately 5 when the water was exposed to a specific spatial and temporal configuration of weak circularly rotating magnetic fields. The maximum mean shift from 185 s to 885 s (~factor of 5) occurred within field intensities whose statistically significant discrepancies ranged by a factor of ~2.5 or approximately 1.3 mG to 3.3 mG. The correlation coefficient between the mean values of the delay in shift in pH as a function of intensity was remarkably strong.

Because the cumulative consequence of the serial injections produced a net shift of ~3 pH units, from the beginning near-neutral values of the water (7.4) to 3.4, the results indicate that the presence of the magnetic field prevented the protons injected with each aliquot to contribute to the volume acidity for several hundreds of seconds compared to no field conditions. The strong inverse correlation between the duration of stability of pH and the net drop in pH when it occurred indicates the two processes were strongly interconnected.

The partial correlation analyses were completed to discern which phenomena, the protracted prevention of the shift in pH (the “holding effect”) or the magnitude of the net increase in acidity were driving the reaction. Covarying for the other variable did not eliminate the correlation between the holding time and field intensity or the net decrease in pH and field intensity. This would suggest the field affected different processes that independently controlled the net change in pH and the holding effect.

If the sample size had been larger so that statistical significance had emerged, the smaller size of the partial correlation for the pH shift after the shared variance with holding time had been removed would be consistent with an interpretation that the duration of the protracted original pH (holding time) was the driving stimulus for the ultimate value of the net change in pH. This interpretation would consistent with a model where the magnetic field facilitated maintenance of the additional H^+ within some of the other solutes until some threshold was exceeded and the protons were released to contribute to the decreased pH.

The magnetic energy from the exposure of the 25 cc of water to the magnetic field can be estimated by:

$$E=(B^2 \cdot 2\mu^{-1}) \cdot m^3 \text{ (1),}$$

where B is the field strength in Tesla, μ is magnetic permeability ($4\pi \cdot 10^{-7} \text{ N} \cdot \text{A}^{-2}$) and m^3 is volume. Within a 25 cc volume ($2.5 \cdot 10^{-5} \text{ m}^3$) of spring water the energy from a ~1 mG to 3.3 mG (10^{-7} T) magnetic field would be between $1 \cdot 10^{-13} \text{ J}$ and

10.9·10⁻¹³ J. In other words the increased would be about a factor of 10. If the intercept between the holding time and net change in pH is considered (Figure 5), the difference is a factor 5 and well within the range of the increase in “holding” time between the no field and maximum field conditions.

The quantitative evidence indicates that the most likely candidate of the many ions within the spring water that sequestered the additional protons would have been the HCO₃⁻ molecules. For 4 mM per L (the concentration within the spring water source containers) the number of ions within 2.5·10⁻² L (multiplied by Avogadro 's number) would be 6.0·10¹⁹ molecules. The numbers of H⁺ (protons) within the original near-neutral solution (accommodating for the fact that 1 M of water is 18 cc), would have been 3.3·10¹⁶.

For the ultimate pH of 4.4, which was the final net shift of the solutions after various durations of magnetic field-dependent protraction of the original pH, the total numbers of H⁺ would have been 2.4·10¹⁹ which is within error range of the total concentration of bicarbonate ions. Thus when the cumulative concentration of H⁺ approached the numbers of HCO₃⁻ ions the contributory effect of the magnetic energy from this particular configuration of changing angular velocity field was no longer maintained.

The energy from the most effective range for the intensity of the applied magnetic field per molecule would be 10.9·10⁻¹³ J divided by 6.0·10¹⁹ molecules or 1.8·10⁻³² J per molecule. We think it is relevant that when this is divided by the average life time of each hydronium ion, about ~10⁻¹² s [3], the energy available per interaction for each H₃O⁺ would be about 1.8·10⁻²⁰ J. This value is within the range of energy (1.9·10⁻²⁰ J) associated with second shell hydrogen bonds and is consistent with measurements of the mobility of protons [3]. This “quantum” of energy is associated with a variety of important biological functions including the resting plasma membrane potential, the neuronal action potential, and the sequestering values for many ligand-receptor systems [11].

The contribution from the changing angular velocity of the circulating magnetic fields to the phenomena may be important from a quantum perspective. The intrinsic frequency for the energies between 0.2·10⁻³² J and 1.8·10⁻³² J of magnetic energy per molecule in the band of intensities producing the “holding” effect is obtained by dividing by Planck's constant (6.626·10⁻³⁴ J·s). The frequency is between 2.5 and 25 Hz. This would be within the range of the completion of one average rotation for the accelerating and decelerating velocities.

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