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Magnetic Field Effect on Physicochemical Properties of Water

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Abstract

Water is a vital component of almost every organism. Magnetic fields effecting on physical properties of water are reported in this work. In order to obtain the magnetized water, magnetic fields were applied and subsequently passed through water. The chemical properties of magnetized water were also studied such as pH, dissolved oxygen gas, spectroscopic data of UV-, X-ray and IR-spectrum, calcium carbonate crystallization, concrete strength, levitation, refractive index, melting point, contact angle, electrolytic potential value, hydrogen bonding, vaporization, conductivity, flow rate, dielectric constant, viscosity, surface tension, total hardness, convection, Ac magnetic susceptibility and diffusion. In addition, the magnetized water affecting the growth of some plants and mice with antineoplastic drugs were also studied.

Keywords : Magnetized Water; Magnetic Field

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1. Introduction

The argument of magnetized water (MW) is still doubtful among the scientific community. Many scientific literatures have reported an effect of magnetic fields on water. However, inconsistent experimental findings and unreproducible results are observed. The use of magnetic or electromagnetic treatment has provided different results. Therefore, many factors affecting experimental results must be controlled, for instance, magnetic flux density, saturation effect time, memory effect time, temperature and flow rate of water. Some people believe that the properties of pure water could not be changed by magnetic treatment (MT).

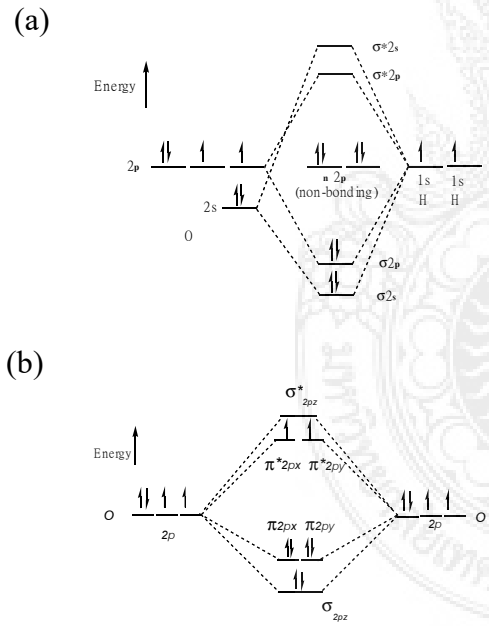

Fig. 1 Schematic view molecular orbital of water molecule (a) and oxygen gas molecule (b)

Nevertheless, there are a few studies which claim the existence of magnetized water. Thus, this work reviews the properties of magnetized water, which had been revealed in the literature and its purposing possible mechanisms. A water molecule is diamagnetic, explained by molecular orbital theory because of the absence of an unpaired electron in the molecule (**Fig. 1a**), therefore, it is weakly repelled by a magnet. On the other hand, an oxygen molecule is paramagnetic, containing two unpaired electrons (**Fig. 1b**), and is attracted by a magnet. Gutierrez-Mejia, F. and Ruiz-Suarez, J.C. [1] studied on the topic of an inter-conversion between diamagnetic and paramagnetic properties of water molecules under a magnetic field, and the change of its physicochemical properties.

Even though many scientists have said that magnetized water is a pseudoscience, a few people still believe that water properties could be changed after treatment with magnetic field. Therefore, the effect of magnetic fields onto the change of water properties is reviewed in this article. Both supporting and opposing experimental results are reported and discussed in this work. However, the other detail of experiment has been reported in references [1]-[56]. Moreover, the physical and biological properties are also reviewed in this article.

2. Results and Discussion

2.1 Physical properties' aspect

2.1.1 pH effect

Zamora, L.L. *et al*. [2] determined the effect of a magnetic field (50 mT) which was applied onto drinking water under a flow rate of 65.5 mL/s for 5 times of circulation, at 27-30 ºC. The results showed that the a change of pH was not observed. Similarly, the finding of Quickenden, T.I. *et al.* [3] supported no change in pH (2.7 T magnetic field,

water flow rate of 1.08-200 ml min^{-1}, at 27-30 ^{o}C).

2.1.2 Dissolved oxygen gas effect

Ueno, S. and Harada, K. [4] applied a dc magnetic field (1 T magnetic field intensity, gradient 10 T m^{-1}, 30-60 min) onto the water surface in an oxygen atmosphere, effecting an increase in the degree of the oxygen redistribution, which depended on the initial concentration of oxygen gas. Redistribution of dissolved oxygen was not observed in an equilibrium state of oxygen pressure in the air atmosphere.

Obviously, this magnetically induced response controlled the diffusion of dissolved oxygen in the bulk water. The results showed that an increase of 5% of dissolved oxygen concentration in water occurred after the applied ac magnetic field ranging from 1-8 T, which depended on an initial concentration of oxygen gas [5]. The maximum of dissolved oxygen was found with the maximum magnetic field flux density (B) which was independent on the maximum magnetic force, wherein B (dB/dz) was the largest in a magnetic field (wherein z = a position along the z-axis). Notice that the increasing or decreasing dissolved oxygen content in the duration before and after exposure with magnetic field showed an exponential change. Furthermore, Hirota, N. *et al.* [6] reported on the magnetic field (4 T) accelerated with oxygen gas dissolving into water. An increase of 37% oxygen concentration was observed (1 h, at 15 ^{o}C) compared with controls. The mechanism could be explained by magnetically induced convection in the water due to the non-uniformity of magnetic susceptibility created by the dissolution of oxygen in the water phase. While Nakagawa, J. *et al.* [7] reported that the water surface (13 ^{o}C) was suppressed around 28.2 mm from the surface region which was exposed with 8 T of magnetic field intensity (Moses effect) by using an oxygen gas atmosphere (11 ^{o}C). The pressure of oxygen gas was increased to 47 Pa. They summarized that the water surface was dependent on magnetic field and oxygen gas pressure. However, the dissolution of carbon dioxide gas was not affected by the magnetic field. On the other hand, in the presence of oxygen gas, the dissolution of carbon dioxide gas has become significantly faster (137.2 ± 5.27 g m^{-3} → 177.1 ± 6.76 g m^{-3}). They proposed that a difference of magnetic susceptibility ($\Delta\chi$) between degassed water and saturated oxygen gas in water ($+3.3\times10^{-8}$, $P[O_2] = 5\times10^{4}$ Pa, 15 ^{o}C) was larger than that of degassed water and saturated carbon dioxide gas in water (-0.2×10^{-8}, $P[CO_2] = 2\times10^{4}$ Pa, 25 ^{o}C). The larger difference of magnetic susceptibility was extended, the more force has influenced on a water surface, which is given by equation (1).

$$F = \frac{\Delta\chi}{\mu_o} B\left(\frac{dB}{dz}\right) \quad (1)$$

When

F is force

$\Delta\chi$ is a volume magnetic susceptibility difference

μ_o is vacuum magnetic permeability

Therefore, the surface water molecules showed more effectively by the magnetic field than the inner ones. The magnetic susceptibility difference around surface water was much more than that of inner ones (**Fig. 2**).

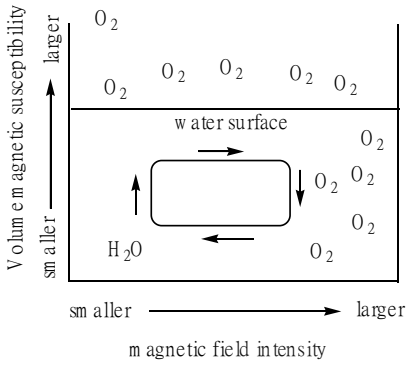

Fig. 2 Showing the difference of volume magnetic susceptibility of oxygen gas and water regions and magnetic field intensity into water [7]

2.1.3 Optical properties effect

2.1.3.1 UV-spectra

Rai, S. *et al*. [8] studied UV- and fluorescence spectra by using a static magnet (0.3 T, 25 ºC) applied onto distillated deionized water. It was found that the N (north), S (south) and N+S poles produced the differences result of the spectrum. They proposed that the magnetic field effected on the restructuring of water ranging from distorted tetrahedral through a clathrate hydrate framework. The South pole of a magnet raised the water structures to higher energy states and the North pole to the lower energy states than normal. On the other hand, Colic, M. and Morse, D. [9] attributed differences in UV- and fluorescence spectra to the water being magnetically induced into gas/liquid interface perturbation and resulting in the generation of ozone gas and hydrogen peroxide. In addition, they proposed the idea of "magnetic memory of water" that the water could retain the properties for a while after treatment. Moreover, Bo, D. and Pang, X.F. [10] investigated the UV-spectra of magnetized water (0.44 T magnetic field; 5 h; 25 ºC). The changing of UV-spectra was observed at the wavelength of 191 nm. The absorbance of normal water and magnetized water were ~0.4 and ~2.94, respectively. They proposed that the magnetic field induced the polarization and distribution of electrons. Ding, Z.-R. *et al.* [11] has ascribed the breaking of a large number of hydrogen bonds which was due to the electron states being affected by magnetic field or perturbation, and this phenomena was influenced by magnetic field over 200 mT.

2.1.3.2 IR-spectra

Bo, D. and Pang, X.F. [10] and X.F. Pang, *et al*. [12] reported that the IR-spectra of magnetized water (0.6-0.44 T, 5 h, 20 ºC) was changed in the region of 400 - 4,000 cm^{-1}. A higher intensity of peaks under magnetic flux density was observed at a longer duration time. Saturation effect time was also studied for 110, 100, 90 and 60 min which were influenced from external magnetic field *via* a magnetic flux density of 0.06, 0.20, 0.30 and 0.40 T, respectively. In conclusion, the magnetic flux density increased while a saturation effect time decreased. Moreover, a memory effect time, which is a time for recovery of the ordinary state, was also introduced which was 35, 45, 58 and 60 min, respectively (**Table 1**).

Table 1 Showing a saturation effect time and memory effect time at various magnetic flux density (Pang, X.F. and Bo, D. [13]

Magnetic flux Density (T)	Saturation effect time (min)	Memory effect time (min)
0.06	110	35
0.20	100	45
0.30	90	58
0.44	60	60

Additionally, the effect of temperature ranging from 25-85 ºC was investigated [13]. The different IR-spectra of magnetized water was recorded compared with controls. Magnetized water showed its anomaly properties. They proposed that bulk water did not exist as free molecules, but was more complicated than ordinary substances.

2.1.3.3 X-ray-spectra

Bo, D. and Pang, X.F. [10] demonstrated the X-ray diffraction result of magnetized water (0.44 T magnetic field intensity for 5 h, at 25 ºC) by shifting from 39,417 count/s to 42,872 count/s. A diffraction angle (2θ) was slightly decreased. Water could be magnetized by mixing the magnetized water with Fe_2O_3. The diffraction angle was decreased by 2º compared with the mixture Fe_2O_3 and ordinary water.

As the results mentioned above, they proposed a theory of "Molecular Current" or "Small Magnet" that bulk water existed as closed loops. The magnetic field induced a current in the closed loops as well as the proton responded for a conductive carrier (instead of the electron). Therefore, water could be magnetized in this process. Due to the fact that proton is larger than electron. Thus, the mobility of proton is slower than that of electron. However, this effect is very small and it is enough to increase the intensity peaks of Raman- and IR-spectrum in the experiments.

2.1.4 Calcium carbonate crystallization effect

Coey, J.M.D. and Cass, S. [14] applied a magnetic field (10 mT) into a solution of 120 mg, Ca/L. It was found that a ratio of aragonite/calcite changed and the memory of magnetic treatment was extended over 200 h.

In accordance with Kobe, S. *et al*. [15] reported later; the aragonite/calcite ratio decreased from 2.43 to 0.32. Goncharuk, V.V. *et al*. [16]-[17] concluded that the crystallization forms of calcium carbonate were influenced by paramagnetic substances, nitrogen oxide, oxygen of the air, and TEMPON (2,2,6,6-tetramethylpipyridine-on-*N*-oxyl radical). As mentioned above results, they refused a contribution of oxygen gas microbubbles.

2.1.5 Concrete strength effect

Engineering paper reported by Su, N. *et al.* [18], the tap water was irradiated *via* the magnetic field and used as a solvent in concrete mixing. An increasing of mortar's compressive strength in the range of 9-23% was dependent on the magnitude of the applied magnetic field. Clearly, enhancement of the combined force among the molecules, corpuscles and components in the concrete, lifted its mass density [19], workability and some of durability [20]-[21]. The proposed mechanism was due to an increase in the degree of concrete's hydration.

2.1.6 Levitation effect

Ikezoe, Y. *et al.* [22] has succeeded in levitating a droplet of water by the superconducting magnet (10 T) in accord to "magneto-Archimedes levitation" which was illustrated by equation (2).

$$-(\rho_w - \rho_a)g + \left(\frac{\chi_w - \chi_a}{\mu_o}\right)B\left(\frac{dB}{dz}\right) = 0 \quad (2)$$

where ρ_w was density of water (1.0 kg/m^3), and ρ_a was density of internal atmosphere system (for air and oxygen

gas was 1.21 and 1.31 kg m^{-3}, respectively). χ_w was a volume magnetic susceptibility of water (-9.03×10^{-6}), χ_a was volume magnetic susceptibility for air (0.379×10^{-6}), and oxygen gas (1.80×0^{-6}) at 20 °C, and *g* was a gravitational force.

Researchers found that replacing the internal atmosphere with air (60 atm) affecting the gravitational force (first-term in eq. 2) was balanced with the Buoyancy force (second-term in eq. 2), a droplet of water levitated. However, if the air replaced by oxygen gas (paramagnetic substance), its internal pressure could be reduced to 12 atm; giving the same result. It was found that the different degree of levitation depended on density and volume magnetic susceptibility of each substance.

This technique has been used to separate any compounds such as potassium chloride and sodium chloride crystals, which were levitated at different positions in the air under applied magnetic field [23]-[26].

2.1.7 Refractive index effect

Refractive index of magnetized water was increased by 0.1 % which reported by Hosoda, H. *et al.* [27]. The value increased from 1.333 to 1.335 under magnetic field (10 T at 25 °C). Not only magnetized water, but also the diluted electrolyte solutions (0.40 M, $NiCl_2$ and 0.5 M, NaCl) gave the same results. Due to a higher hydrogen bond of ordinary water formed under the applied magnetic field. In contrast, the opposite result has been found with the concentrated electrolyte solutions (2.5 M, $NiCl_2$ and 5.0 M, NaCl).

Four years later, Pang, X.F. [28] has confirmed that the 0.7% of refractive index was slightly increased (1.336 to 1.3345) under a lower magnetic field intensity (0.44 T, 25 °C). It was probably due to the strengthening of intermolecular hydrogen bonds of magnetized water [29].

2.1.8 Meting point effect

Regarding the melting point, an effect has been shown by Inaba, H. *et al.* [30], who applied a 6 T magnetic field intensity on the water. A slightly increasing melting point of water (H_2O) was 5.6 mK. With heavy water (D_2O), a larger effect was observed, increased by 21.8 mK. They explained this by Lorentz force suppressing the thermal motion of the partially charged atoms, strengthening the hydrogen bonding and increased the dynamic magnetic susceptibility (the term “dynamic” means the movement of atoms due to the thermal motions such as vibrating and rotating motions at high frequencies). The suppression of the thermal motions by the magnetic field makes the solid phase more stable and makes the dynamic magnetic susceptibility larger. They interpreted the larger experimental values that the dynamic magnetic susceptibility rather than the static magnetic susceptibility was assumed, and the larger ones were considered to be due to the larger dynamic magnetic susceptibility.

Osuga, T. and Tatsuoka, H. [31] has concluded that the magnetic field effect on water was one of the factors affecting the increase of melting point for H_2O and D_2O. Magnetic field provided a suitable position for the liquid water molecules to freeze; subsequently the enhancement of nucleation rate in liquid phase near the melting point has taken place.

2.1.9 Contact angle effect

Otsuka, I. and Ozeki, S. [32] have observed the un-changing of contact angle ($\theta = 65^{o}$) in ultrapure water (Milli-Q water; 18 MΩ) as an ordinary and magnetized water in a vacuum. On the other hand, during the irradiation with oxygen gas present (140-760 mmHg), the contact angle was sharply changed during ~ 30-100 min at ~ 57.5°. This value existed for ~ 70 min and it subsequently sharply increased to the reference water at 210 min. In conclusion, the contact angle of magnetized water was not affected by magnetic fields if it did not coexist with oxygen gas.

2.1.10 Electrolytic potential effect

Otsuka, I. and Ozeki, S. [32] have investigated the effect of magnetic field on the diluted electrolyte solution (10 mM of NaCl, KCl, or $CaCl_2$). Furthermore, it was found that the magnetized water was more difficult oxidize than the ordinary water, it is likely due to a higher electrolytic potential ($E^{o} = 2.35$ to 2.63 V; $H_2O \rightarrow 0.5\ H_2 + O_2$), the magnetic field induced transient oxygen clathrate-like hydrate, $(O_2)_m(H_2O)_n$, and including the developing water networks [33].

2.1.11 Hydrogen bonding effect

Chang, K.T. and Weng, C.I. [34] have calculated the forming of a new hydrogen bond, by varying the applied magnetic field intensity. The 10 T applied magnetic field increased the number of hydrogen bond's by 0.34%.

2.1.12 Vaporization effect

Increasing rate of evaporated water under magnetic field has been found, and compared with ordinary water [35]-[36]. These parameters [37] were the product of magnetic flux density (B) with its gradient (dB/dz). The possibility of creation for the magnetic wind was driven by the gradient susceptibility distribution caused by water content distribution in the atmosphere. Toledo, E.J.L. *et al.* [29] has also reported the increase of magnetized water's vaporization enthalpy ranging from 58.86 kJ/mol to 68.86 kJ/mol, and was compared to an ordinary water (45-65 mT magnetic field at 22 °C).

2.1.13 Conductivity effect

The conductivity of magnetized water depended directly on applied magnetic field intensity (0.144-0.5 T). Reported [38] the saturation effect time was 5 min after the irradiation. It was explained in a way that the conductivity in water, causing of proton conductivity (instead of the electron) and they calculated the mobility and conductivity of protons as 6.5 -6.9x10^{-6} m^2 V^{-1} and 7.6-8.1x10^{-3} $\Omega^{-1}m^{-1}$, respectively [39].

In contrast, Zamora, L.L. *et al.* [2] and Shen, X. [40] did not observe the change of conductivity of magnetized water in comparison with the ordinary water. The conductivity of ordinary water result was 2.00 ± 0.07 mS cm^{-1}, while the ones of magnetized water under magnetic field were 1.99 ± 0.07 mS cm^{-1} and 2.06 ± 0.06 mS cm^{-1}, at 4 and 16 h, respectively.

Nevertheless, the opposite results have been reported by Szczes, A. *et al.* [36]. The magnetic field reduced the conductivity of magnetized water which was inversely proportional to the flow rate of water. Furthermore, a bulk of water could be kept hold a memory effect up to 24 h. They proposed that the applied magnetic field increased a number of hydrogen bonds network

strengthening, and the perturbation of gas/liquid interface from the air nanobubbles in the water.

2.1.14 Flow rate effect

Applied magnetic field (0.2-0.5 T, unspecified temperature), in perpendicular to burette, reduced the flow rate of distillate water. The 0.5 T of magnetic field intensity can reduce droplets of magnetized water to 2 mL min^{-1}, which was comparable with an ordinary water of 19.5 mL min^{-1} [38]. It was due to the increase of the magnetized water's viscosity [41]-[42].

2.1.15 Dielectric constant effect

The dependence of magnetic field intensity (0.02-0.05 T) and dielectric constant were observed by Ibrahim, H.I. [38]. Shen, X. [40] also indicated that the increase of 3.7% in dielectric constant of deionized water under applied magnetic intensity of 0.15 T, was due to more polarized water molecules under a higher magnetic field intensity.

2.1.16 Viscosity effect

Cai, R. *et al.* [41] has indicated that magnetic field (1 T, treatment time 13 min, 25 ºC) can increase a high-level of purified water's viscosity (18.2 MΩ, 298 K) up to 11%, ranging from ~1.066 mPa s to ~ 1.18 mPa s. The result showed that the longer the time of magnetic field treatment was, a higher viscosity extended. According to the previous work of Ghauri, S. A. and Ansari, M. S. [42], they have reported the changing of relative viscosity which slightly increased by 0.12%, ranging from 0.8904 mPa s to 0.8915 ± $3x10^{-5}$ mPa (under 0.75 T transverse magnetic field at 25 ºC). Similarly, Toledo, E.J.L. *et al.* [29] has reported a 3.34% higher viscosity, from 964.42 ± 1.19 μPa s to 996.63 ± 4.42 μPa s, in comparison with the ordinary water (22 ºC under 45-65 mT).

Ghauri, S. A. *et al.* [42] has also reported the variation of viscosity ($\Delta\eta$) with temperature (T) that it could be well explained by the following second order equation (3) which contained a regression value of 0.9916. The proposed mechanism was on the basis of the stronger hydrogen bonds forming.

$$\Delta\eta = (1.0x10^{-6})\ T^2 + (8.0x10^{-4})\ T - 0.133 \quad (3)$$

Cai, R. *et al.* [41] also attributed that rotational motion of magnetized water was slower than ordinary water, because of an increase of 'correlation time' (τ_c, the average time for one molecule rotating per radian) from 65 ps to 140 ps. The slower rotational motion indicated that the strengthening of hydrogen bonds was reflected by a larger of water clusters formed. As above results which were refused by Pang, X.F. and Bo, D. [43] who revealed that the water viscosity decreased by 17% (0.3-0.4 T magnetic field and the temperature of 37.5 ºC). Saturation effect time was 68 min, ranging nearly from 6 mPa s to 5.5 mPa, while the viscosity of ordinary water was 1.002 mPa. Notice that the viscosity of magnetized water by Pang, X.F. and Bo, D. was highly prone when compared to the ordinary water.

2.1.17 Surface tension effect

The surface tension of magnetized water decreased by 8% of 72.44 mN/m to 62.5 mN/m (1 T intensity field with treatment time for 13 min at 25 ºC). In summary, as exposure time increases, the surface tension decreases [41]. Cai, R. *et al.* also attributed surface tension

descended with the cohesive inner molecular energy $E^{inner}{}_{A.}$ As the cohesive inner molecular energy decreased, new hydrogen bonds formed. In previous work, Pang, X.F. and Bo, D. [28] reported similar results, the viscosity was reported in terms of contact angle. These values of magnetized water onto copper and graphite surface were reduced by 2º and 1.4º, respectively. They proposed the polarization of water by applying the magnetic field and effecting a change in water clusters.

Fujimura, Y. and Iino, M. [44]-[45] disagreed with the preceding results. Theirs result displayed surface tension of magnetized water (10 T, duration treatment time 20-40 min, 25 ºC) that increased by 1.83 ± 0.18%, ranging from 71.96 ± 0.14 mN/m to 73.31 ± 0.16 mN/m. The other has reported [29] a smaller effect by 0.04% of surface tension (from 72.27 ± 0.37 mN m^{-1} to 75.50 ± 0.23 mN m^{-1}, at 22 ºC with 45-65 mT of magnetic field intensity). Note that after removal from the magnetic field, the surface tension exponentially decreased to the control value.

They proposed hydrogen bonds were more stabilized during magnetic field treatment. In addition, Toledo, E.J.L. *et al.* [29] proposed that the magnetic field effect broke an intra hydrogen bond of larger water clusters; therefore, the smaller water clusters with stronger inter cluster hydrogen bonds were formed. The water clusters sizes were explained by 4, 8 and 12. Later, Lee, C. *et al.* [46] calculated the most stable water cluster was sizes of 4. However, Zamora, L.L. *et al.* [2] refused any changing of the surface tension of water after magnetic field treatment. The observed surface tension of ordinary water and magnetized water of 4 h and 16 h for treatment time was 75.4, 75.2 and 75.6 mN m^{-1}, respectively.

According to Amiri, M.C. and Dadkhah, A.A. [47] 's work, the authors suggested that the soluble/insoluble impurity materials were responsible for changing of surface tension water instead of magnetic field effect.

2.1.18 Total hardness effect

Zamora, L.L. *et al.* [2] has not observed the changing total hardness of magnetized water. The value of ordinary water was 0.873 g, $CaCO_3$ L^{-1}, while the magnetized water's values (4 and 16 h treatment time) depending on the treatment time were 0.877 and 0.879 g, $CaCO_3$ L^{-1}, respectively.

2.1.19 Convection effect

The convection of water was either suppressed/enhanced by downward/ upward magnetic field, depending on the direction of magnetic force [48]. The results indicated that the convection in a diamagnetic fluid of water could be controlled by using the magnetic field of 10 T. Additionally, Zhou, *et al.* [49] proposed that water molecule clusters have a district anisotropy and it was explained in terms of magnetic moment interaction. The magnetic moment will be negative if most of the nearest water molecules form long chains that run nearly parallel to magnetic field strength B. This configuration has a higher stability. Furthermore, if most water molecules become form chains which were vertical to B, the magnetic moment interaction energy will be positive, and that is less stable. This may explain a directional effect of magnetic force.

2.1.20 Ac magnetic susceptibility effect

Gutierrez-Mejia, F. and Ruiz-Suarez, J.C. [1] has investigated the ac

magnetic susceptibility of water in the frequency range of 1 kHz – 1 MHz at a low magnetic field. The results showed a paramagnetic behavior between 500 kHz and 1 MHz of samples (at 37 ºC and 25 ºC) which was surprising as water was believed to be a diamagnetic. The transition from diamagnetism to paramagnetism was observed in pure water and diluted salt solution (1 mM, NaCl) but the concentrated salt solution (0.1 M and 0.25 M) was not chance. They proposed that while the magnetic field was applied, the perturbation of such molecules would be increased. It may be due to the excitation produced by the magnetic field. However, this effect was not observed at a constant magnetic field because under this condition the magnetization had been seen as an average. In case of ice, water acquired a rigid conformation. The perturbation was small due to the small magnetic field and it only detected the diamagnetic contribution.

2.1.21. Diffusive effect

Chang, K.T. and Weng, C.-I. [34] have calculated the diffusion coefficients of liquid water and that it decreased by approximately 14% (changing from 2.14x10 m^2 s^{-1} to 1.87x10^{-9} m^2 s^{-1}, at 27 ºC). It could be assumed that a static magnetic field has restricted the movement of water molecules.

2.2 Magnetized water affecting biological system

Yi-long, M.A. *et al.* [50] irradiated 80 mT magnetic field intensity onto water (preparing by doubly distilled deionized water and it was kept at 4 ºC overnight before used). Magnetized water could accelerate the activity of the glutamate decarboxylase; increased by 30%. They proposed the magnetization of ordinary water, and it was rearranged in order, subsequently with a weak magnetic field was formed. The active site of enzyme conformation was activated by this field. Hence, the enhanced activity of enzyme could be observed.

On the other hand, Ueno, S. and Iwasaka, M. [51], reported hydrogen peroxide's decomposed by catalase to give water and oxygen gas as products. They indicate that magnetic fields affect the dynamic movement of oxygen bubbles which are produced in the reaction mixture by the decomposition of hydrogen peroxide. A 20-25% oxygen gas increased during monitoring the reaction. However, the mechanism proposed by the dynamic movement of oxygen bubbles and the magnetic field did not affect the activity of catalase.

Johnson, K.E. *et al.* [52] used magnetized water oral irrigator with 29 patients. The treatment with magnetized water yielded a significant lower calculus index (64%). Gingival and plaque indexes were reduced by 27.5% and 2.2%, respectively. There were not statistically significant, however, a strong positive correlation between the plaque index and the Watt accretion index was observed.

They proposed that the magnetized water oral irrigator could be a useful adjunct in the prevention of calculus accumulation in periodontal patients. As mentioned, it could be due to the changing formation of calcium carbonate crystallization in magnetic fields from calcite to aragonite forms. Aragonite had higher density than calcite form, and it is less prone to form hard scale (Coey, J.M.D. and Cass, S. [14].

Dayong, L. *et al.* [53] studied the effect of magnetized water (distillate water, 0.25 T magnetic field intensity,

flow rate water was 20 mL/mL, 50 times of circulation) on mice given high doses of antineoplastic drugs; CTX (cyclophosphamide), MMC (mitomycin C), Lyc (lycobetaine), DDP (cisplatin) and HA (harringtonine).

Table 2 The %ILS of mice after being given magnetized water daily for a week[d]

Drug	Dosage (mg/kg)	Mean survival days			
		No. of mice	(1)[a]	(2)[b]	%ILS
CTX	500	8	0.5	4.0	700
MMC	8	8	4.8	7.2	50
Lyc	200	8	0.6	1.8	200
DDP	40	8	1.5	3.0	100
HA	20	8	2.0	4.5	125

[a]With magnetized water, [b]Without magnetized water, [c]The increase of life span (ILS), [d]Experimental term was 7 days, $p < 0.01$

The positive effect of magnetized water among various anticancer drugs on life span was different (**Table 2**). Increased in %ILS of all drugs was observed. They proposed that magnetized water could remarkably extend the life span of mice and attenuated the leukopenia by mitigating the toxicity of anticancer drugs *in vivo*. They believed that magnetic field strengthened the immune functions of the body.

Maheshwari, B.L. and Grewal, H.S. [54] used magnetic field treatment of tap water, recycled water, 1500 ppm NaCl water and 3000 ppm NaCl water as irrigation water of celery, snow peas and peas, all samples were conducted in glasshouse under controlled environmental conditions. Mostly, magnetized water showed a higher % increase in fresh weight as seen in **Table 3**. Except for celery which was not changed, but the water productivity increased.

Table 3 Showing the fresh weight without MF (1), with MF (2) and % increase of fresh weight with MF was comparable without MF and water productivity (4) of celery, snow peas, and peas.

Celery

	(1)	(2)	(3)	(4)
- tap water	414.3	414.5	0	4
- recycled water[a]	377.3	424.0	12	12
- 1500 ppm NaCl water	181.0	198.3	9	11
- 3000 ppm NaCl water	108.5	133.3	25	23

Snow peas pod

	(1)	(2)	(3)	(4)
- tap water	216	233	8	12
- recycled water[a]	198	210	6	7.5
- 1500 ppm NaCl water	186	188	1	0
- 3000 ppm NaCl water	164	174	6	13

Peas

	(1)	(2)	(3)	(4)
- tap water	1.6	1.62	8	5
- recycled water[a]	1.23	1.33	6	7
- 1500 ppm NaCl water	1.05	1.03	1	0
- 3000 ppm NaCl water	0.88	0.93	6	4

(1) Mean yield of fresh weight(g) without MF (2) Mean yield of fresh weight(g) with MF, (3) % Increase of fresh weight with MF is comparable without MF and (4) Water productivity (kg/1000 L water), [a]Treated water from Richmond Sewage Treatment Plant) [54]

Selim, A-F.H. and El-Nady, M.F. [55] showed the result of irrigated tomato seeds by magnetized water. This treatment revealed the best for overcoming the bad effects of water deficit on tomato plant growth characteristics, water relations, proline concentration and photosynthetic pigments, as well as anatomical structure of some organs of tomato plants, in which was comparable to that seed with tap water as a control group. They suggested that the effect of magnetic

treatments act as a protective factor against water deficit. A 13.3% increase in germination of wheat seeds was observed when compared to a control using the magnetized water, whereas the increase in germination was insignificant with the seed magnetization [56].

3. Conclusion

So far, magnetic field slightly effects the properties of water. It is believed that this phenomenon did not influence the pH of water, but it was dependent on the diffusion/dissolution of oxygen, UV-spectra absorption, IR-spectra intensity, x-ray count of its properties. Crystallization of calcium carbonate changed a calcite/aragonite ratio. Engineering reported a compressive strength of mortar increased *e.g.* an increase of the degree of hydration.

Sodium chloride and potassium chloride crystals were differently levitated in the air under the magnetic field. An increase by 0.1% of refractive index and a slight increase of the melting point by 5.6 mK was observed for an ordinary water and also showed more effect on heavy water (21.8 mK). The contact angle was decreased for a while and upward to the ordinary state after an hour. Magnetized water was harder to oxidize due to an increase in electrolytic potential. A 0.34% increase of hydrogen bonds was gained after magnetic treatment. The rate of evaporated water and dielectric constant increased, but the viscosity incline decreased due to reducing by the flow rate. Regarding a number of different results in surface tension, this property is still unconcluded. Conductivity presumably inverted on magnetic flux. The water flow rate decreased under the magnetic field, but the total hardness was not changed.

The AC magnetic susceptibility of water transformed from diamagnetism to paramagnetism, it was observed for pure water and diluted salt solution, only at room temperature but not for concentrated salt solutions. In the biological aspect, magnetized water accelerates 30% glutamate decarboxylase activity. In the other hands, the decomposition activity of hydrogen peroxide by catalase was unaffected. It was employed as an oral irrigator and yielded a significant lower calculus index (64%). Gingival and plaque indexes were reduced by 27.5% and 2.2%, respectively.

Furthermore, it increased in %ILS of drugs; antineoplastic drugs; CTX, MMC, Lyc, DDP and HA, which were taken at high doses on mice. Magnetized water showed positive results as an irrigator of celery, snow peas and peas. A higher growth in fresh weight in comparison to tap water except for celery, where although % increase in fresh weight did not change, the water productivity increased. Magnetized water could overcome the negative effects of water deficit on tomato plant growth characteristics, water relations, proline concentration, and photosynthetic pigments, as well as the anatomical structure of some organs of tomato plants which was comparable to that seed with tap water as a control group. Furthermore, increasing in wheat seeds' germination was also observed.

Many theories of magnetized water were proposed, including the molecular current or small magnets, dissolved oxygen, water cluster forming, hydrogen bond formed changing, oxygen nanobubbles forming, liquid/gas interface perturbation, and oxygen clathrate-like hydrate, $(O_2)_m(H_2O)_n$ + water network). Nevertheless, all those just have ascribed

by limitations. Many works' claims have been made that the magnetic field changed the physicochemical property of water which depended on many factors in experiments *e.g.* magnetic flux density, saturation effect time, memory effect time, temperature, flow rate of water, etc. It can be assumed that the water molecules after magnetic treatment could be kept "memory effect" for a while whether its significantly changed physicochemical properties on biological systems. Although, all proposed theories would seem to be reasonable, but clearer accountability is needed for further studies.

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5. References

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