Electrochemical Effects of Magnetic Field and Potassium Carbonate in Water

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Abstract
Due to the polarity and restructuring of hydrogen bonds, investigations have been conducted into the effects of permanent magnetic field (MF) on water. The water molecule is polar, with a bond angle of approximately 104.5°. Electrical charges at O and H atoms were unevenly distributed. The negative charge was drawn toward O atom, and positive charges were redistributed toward H atoms. Water is a polar solvent. The applied MF influenced the orientation of dynamics of H bonds between water molecules, of which process depended on MF parameters. Fourier Transform Infrared (FT-IR) spectroscopy was applied to research potassium carbonate (K_2CO_3). One indicator of magnets' properties is magnetic induction. It was shown that MF and strength were essential for this effect, which was on a limescale, in a reversed scheme of arranging magnets. In a non-reversed scheme, the effects manifested in water. The authors researched the effects of a permanent MF on water with and without dissolved K_2CO_3. The potential application was for animal husbandry.

Keywords: animal husbandry; FT-IR; K_2CO_3; magnetic field; water.

Introduction•

Magnetic fields (MF) can influence various physical and chemical properties of aqueous solutions. These effects are particularly noticeable in solutions containing dissolved ion mobility and local water structure. As water is a polar solvent, changes in ion hydration inevitably affect the orientation and dynamics of surrounding water molecules and hydrogen bonds.

MF influences hydrogen bonds and orientation of water molecules, and this effect is connected with its parameters [1]. A key parameter is the change in electrical conductivity (EC) [1]. Significant effects are achieved with anisotropic magnets [2].

• The abbreviations list is in page 416.

MF is applied to water before saturation with H_2 [3-5].
In water, there are effects of MF on hydrogen bonds. When magnetic poles are arranged in a non-reverse manner, water becomes activated by the permanent MF. In a non-reversed scheme, where permanent magnets' N and S poles are arranged sequentially, stronger effects on pH, oxidation-reduction potential (ORP) and dissolved oxygen (DO) are known and proven [6]. Effects of MF on pH and EC have also been demonstrated by [7]. Studies of magnetic water treatment, when that applied MF can influence water's EC, pH and DO, were performed by [8]. According to [6, 8], MF can alter orientation of water molecules and hydration shells around ions, leading to ion mobility and some degree of ion dissociation. In the reverse ordering of the magnetic poles, effects are anti-scaling [9, 10].
Herein, potassium carbonate (K_2CO_3) was employed for greater ion dissociation with a chemical reaction:

$$K_2CO_3 \rightarrow 2K^+ + CO_3^{2-} \quad (1)$$

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^- \quad (2)$$

The reaction originated K^+, HCO_3^- (hydrogen carbonate) and OH^- ions. The dissociation of K_2CO_3 increased pH, ORP and EC.
Waters influenced by MF [10] and electro MF [11, 12] show changes in physicochemical parameters.
Strong gradients in weak MF may induce the formation of DOLLOP in tap water containing Ca^{2+} and HCO_3^- ions [13]. It was shown that the gradient of MF is more essential for that effect than magnetic strength. Results were obtained using magnetically activated water for crops [14, 15]. Electromagnetically activated water improves the osmosis process [16] for plants, growth and antimicrobial activity [17]. The results on sheep have demonstrated changes in daily and total production of milk, of which composition was improved. Ewes and lambs have shown improved hematological and biochemical parameters [18]. MF exposure has increased shelf life of goat milk [19]. Scientific studies have shown that adding K_2CO_3 to the diet increases the synthesis of milk fats in cows [20]. Provided carbohydrates can lead to fermentation, acidification, and a decrease in pH in the digestive system of domestic animals [21, 22]. An alkaline environment improves alkaline balance in digestive system and reduces inflammatory diseases [23].
The possibility of combining water with K_2CO_3 was indicated by [24]. The study was performed to determine the influence of the MF, where B was or 0.3 T, on water and on a water solution with K_2CO_3 [25].
In the present work, studies and analyses have aimed to demonstrate the effects of MF activation on a K_2CO_3 water solution.

Materials and methods

Water samples for studies

For the influence with permanent MF, control samples containing low mineralized water, with pH of 7.94 and EC of 56.19 µS/cm^{-1}, were employed. The samples were influenced with a permanent MF, where B was 3000 G. The second investigation examined a water solution with 13.8 mg/L^{-1} K_2CO_3 as control samples, which were influenced with a permanent MF, where B was 3000 G.

Permanent magnets

Permanent magnets complying with Standard: ISO 9001: 2008, for design, development, production and trade of oxide magnets, were herein utilized. The magnet type was ferrimagnet and non-isotropic, catalog No. 598470, with a size of 51/110/20 mm (Fig. 1 a, b). The producer was Ferromagnet PLC, Pernik, Bulgaria.

(a) **(b)**

Figure 1: Permanent magnets.

Fig. 2 is a scheme for 1000 L water, containing dissolved K_2CO_3, influenced by a permanent MF, where B was 3000 G.

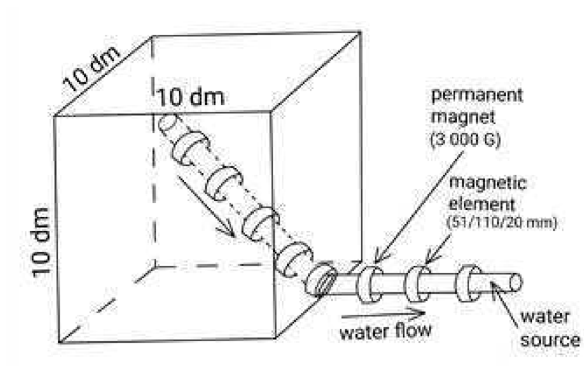

Figure 2: Scheme for 1000 L water, containing dissolved K_2CO_3, influenced by a permanent MF, where B was 3000 G

Drinking water came from a water source where sheep and goats' flocks were raised. The water pipe was placed in permanent magnets, with 20 cm long. The magnetically activated water flowed through the source, with a diameter of 5 cm, into the troughs, for sheep and goats to drink about 7-8 L per day.
Containers with 1000, 2000 and 3000 L daily provided fresh water for up to 100, 200 and 300 animals, respectively. They were constantly replenished, allowing the water to be influenced by the MF.

FT-IR spectroscopy

FT-IR spectrometer Brucker Vertex was employed to research IR spectra of K_2CO_3. Thermo Nicolet Avatar 360 IR source had the following parameters: average spectral range from 370 to 7800 cm^{-1}; visible spectral range from 2500 to 8000 cm^{-1}; permission of 0.5 cm^{-1}; and accuracy of wave number in the range from 0.1 to 2000 cm^{-1}.

Results and discussion

Results for the water solution containing K_2CO_3

The pH of the K_2CO_3 solution with different molar concentrations was converted. For 0.1, 0.01, 0.001 and 0.0001 M, pH values were 11.5, 10.5, 9.5 and 8.5, respectively. Herein, the application for 1000 L had 13.8 g and pH of 8.5 [8, 23]. K_2CO_3 dissociates into K^+ and CO_3^{2-} ions in the solution.

$$K_2CO_3 \rightarrow 2K^+ + CO_3^{2-} \tag{3}$$

CO_3^{2-} reacts with water (H_2O), to form carbonic acid (H_2CO_3)

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^- \tag{4}$$

HCO_3^- can react again with water:

$$HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^- \tag{5}$$

A quality analysis of the dissolving K_2CO_3 was performed. 1 L distilled water contained 25 mg K_2CO_3. Laboratory investigations showed that K ions were 14.16 mg/L^{-1} and HCO_3^- ions were 11.04 mg/L^{-1}. The analysis illustrates that 21.7 mg K_2CO_3 was dissolved. The pH increased from 6.60 to 7.10.

FT-IR spectrum of K_2CO_3

Fig. 3 and Table 1 show results for FT-IR analysis of K_2CO_3.

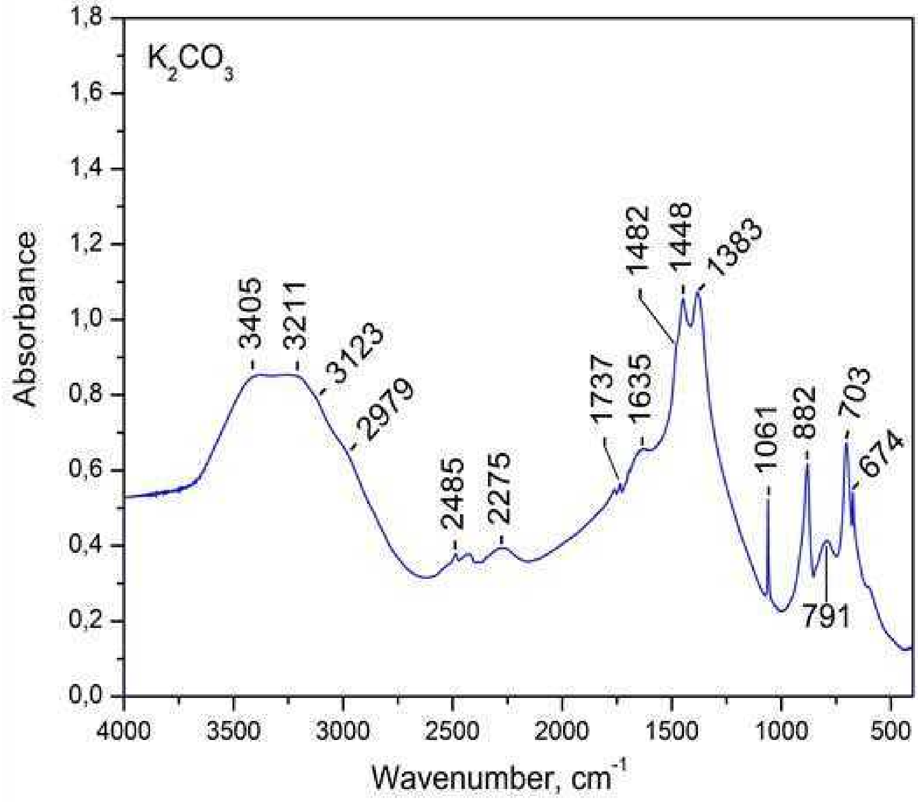

Figure 3: Results with FT-IR spectroscopy of K_2CO_3.

Table 1: Absorption bands in a FT-IR spectrum.

Absorption bands		
Wave number (cm^{-1})	**Wavelength (µm)**	**Type**
3405	2.94	medium
3211	3.11	medium
3123	3.20	medium
2979	3.36	medium
2485	4.02	weak
2275	4.40	weak
1737	5.76	medium
1635	6.12	medium
1482	6.75	strong
1448	6.75	strong
1383	7.23	strong
1061	9.43	medium
882	11.34	medium
791	12.64	weak
703	14.23	medium
674	14.84	weak

CO_3^{2-}, C and O atoms showed symmetric stretching at 1061 cm^{-1}, and asymmetric stretching was around 1400 cm^{-1}.

Fig. 4 illustrates the chemical structure of K_2CO_3

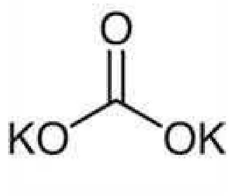

Figure 4: Chemical structure of K_2CO_3.

An MF influenced the parameters of water with K_2CO_3.

The experiments were performed in an open vessel with a controlled temperature of 293.15 K (20 ºC). Before adding K_2CO_3, low mineralized water had pH of 7.94 and electrical conductivity of 56.19 µS/cm^{-1}.

The investigation studied 10 water control samples with 13.8 mg/L^{-1} K_2CO_3. The following results were achieved: average EC was 93.4 µS/cm^{-1} and pH was 8.49.

This solution was influenced by a permanent MF, where B was 3000 G or 0.3 T. The EC for the 10 samples was 97.5 µS/cm^{-1}, and the pH was 8.73.

Table 2 illustrates the parameters of EC, for each hour, during 24 h, with the influence of a K_2CO_3 solution with a MF of 0.3 T.

Table 2: Parameters of K_2CO_3 electric conductivity for 24 h.

	Time (h)	**EC (µS/c**
K_2CO_3 solution with MF of 0.3 T	1	97.5
	2	97.5
	3	97.6
	4	97.7
	5	97.9
	6	97.6
	7	97.4
	8	97.3
	9	93.1
	10	97.7
	11	97.8
	12	96.7
	13	96.0
	14	92.0
	15	95.6
	16	94.8
	17	95.1
	18	95.7
	19	95.0
	20	95.9
	21	95.7
	22	95.7
	23	95.6
	24	95.4

The Student t-test, with results of $p<0.001$, where r was 2.56, demonstrated a very strong effect of the applied MF, with 0.3 T, on the EC of the samples (Table 2), compared to the control specimens. The results illustrate the influence of MF on the K_2CO_3 solution.

MF can influence the orientation of water molecules in water and in solutions, by interacting with dissolved ions and on the hydrogen bond network [1]. Water molecules, being polar, can reorganize their hydrogen bonds and positions. This restructuring can modify the physical properties of the solution, such as viscosity, surface tension and ionic mobility.

MF influence hydration shells and mobility of ions in aqueous solutions. These effects depend on the strength and orientation of the MF and the nature of the dissolved substance and solvent itself. In this study, the solvent was low-mineralized water with added K_2CO_3. The interaction between MF and hydration structures around potassium and carbonate ions contributes to their effective radius and mobility changes, indirectly affecting dissolution dynamics and their ionic equilibrium in the solution.

Conclusions

The studies were performed to determine the influence of MF, where B was 3000 G or 0.3 T, on a solution with K_2CO_3, at a concentration of 13.8 mg/L^{-1}. EC (μS/cm^{-1}) and pH were measured.

EC parameters were measured each hour, during 24 h, for a solution of K_2CO_3 with a MF of 0.3 T.

In the investigation, for 13.8 mg/L^{-1} K_2CO_3, the following results were achieved: EC was 93.5 μS/cm^{-1} and pH was 8.49.

A permanent MF influenced this solution, where B was 3000 G or 0.3 T. The pH result was 8.73, and EC was 97.5 μS/cm^{-1}.

The investigations demonstrated that a permanent MF, with induction of 0.3 T, significantly influenced EC and pH in aqueous solutions. Following exposure to the magnetic field, both distilled water and K_2CO_3 solutions showed increased EC and changes in pH. Stable changes in EC and pH parameters persisted over a 24-h period, suggesting that the MF can affect physicochemical properties of aqueous solutions.

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Authors' contributions

Ignat Ignatov: analyzed data obtained by experiments. **Ignat Ignatov and Ivan K. Stankov**: conceived the original idea of the analysis and research paper; collected data; performed experimental work; inserted data or analysis tools; wrote the paper.

Abbreviations:
B: magnetic flux density
DO: dissolved oxygen
DOLLOP: dynamically ordered liquid like oxyanion polymers
EC: electrical conductivity
FTIR: Fourier Transform Infrared Method
G: Gauss
H: hydrogen atom
HCO_3: hydrogen carbonate
K_2CO_3: potassium carbonate
O: oxygen atom
ORP: oxidation-reduction potential
T: Tesla

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