Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 13, No. 1, 2024

Application of Magnetized Water in Agricultural Irrigation

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Abstract: Magnetized water has attracted considerable attention due to its unique physicochemical properties and memory effect. Research has primarily focused on property regulation, magnetization mechanisms, and agricultural applications. The influence of magnetic fields on the structure of water molecules and their clustering patterns is significant, leading to noticeable changes in macroscopic properties such as water magnetism, surface tension, and conductivity after magnetization treatment. The magnetization mechanisms mainly involve the role of hydrogen bonds between water molecules and the impact on dissolved ions. This paper reviews the research progress in magnetized water and summarizes its application in the agricultural field as well as future development prospects.

Keywords: Magnetized water; magnetization mechanism; agricultural application.

1. Introduction

Magnetism, a common physical phenomenon, is ubiquitous in all objects and closely related to their chemical composition and structure. Magnetic fields exert varying degrees of influence on substances within the field, altering their physical and chemical properties. With the continuous advancement of science and technology, our understanding of magnetic phenomena has deepened, leading to an increase in related research and applications. Many scholars have conducted in-depth studies on magnetization. Magnetized water refers to water in which the water molecules align along the direction of magnetic force lines under the action of a magnetic field, thereby forming an ordered molecular structure and altering its physical and chemical properties. Due to its simple operation and low cost, this magnetization device is widely used in multiple industries. This paper will review the current research status of magnetized water, as well as its application progress and future development prospects in the agricultural field.

2. Research on the Physicochemical Properties and Mechanism of Action of Magnetized Water

2.1. Study on the Mechanism of Action of Magnetized Water

Regarding the mechanism of action of magnetized water, the prevailing view is that magnetization affects the hydrogen bonds between water molecules, leading to changes in related properties of water. Yang Xiaohong[1] pointed out through theoretical analysis that the change in physicochemical properties of water after magnetization treatment is mainly due to the disruption of hydrogen bonds, which in turn disrupts the original structure of water. Normally, water molecules do not exist in isolation but rather form larger aggregates through hydrogen bonding, and the formation and breaking of hydrogen bonds are a dynamic equilibrium process. However, under the action of a magnetic field, this equilibrium is broken, with a large number of hydrogen bonds being destroyed, causing the originally tightly bound water molecules to become dispersed and form smaller aggregates, thereby inducing changes in physicochemical properties. Research by Zhu Yuanbao and others[2] also supports this view, as they believe that after hydrogen bonds are broken, individual water molecules are released from larger polymers, losing their constraints and potentially accelerating evaporation while increasing solubility. The principle of dynamic equilibrium can also be used to explain the phenomenon of hysteresis in magnetization effects. Ding Zhenrui and others[3] found through research on the physical properties of different magnetized waters under stirring conditions that the physicochemical characteristics are not simply an increasing or decreasing relationship with magnetic induction intensity and magnetization time, but rather exhibit a multi-extremum change relationship. This phenomenon can be attributed to the influence of the Lorentz force on charged particles during magnetization, which on the one hand leads to the destruction of some hydrogen bonds but also facilitates the formation of new hydrogen bonds, thereby weakening the damaging effects. Liu Guanglei and others[4] believe that magnetization treatment may be related to energy changes. Under the action of a magnetic field, the internal energy of water is affected, and they emphasize that the mechanism is related to hydrogen bonds in the microstructure. Cai Hang'an[5] proposed that an electromotive force is generated internally after magnetization, and under the action of an electric field, macromolecular polymers are subdivided into smaller particles, thereby effectively preventing and removing water scale due to the detailed dispersion of large scale deposits.

2.2. Characteristics of Physicochemical Property Changes in Magnetized Water

Yan Haike and others[6] studied the changes in surface tension of distilled water under different magnetic field intensities. The results showed that the surface tension varied with increasing magnetic field intensity, and the magnetization effect could last for 7 to 14 days. They also pointed out that the degree of change in surface tension was related to water flow rate. Zhu Yuanbao and others[2] found through research on the properties of water under different magnetization conditions that magnetization treatment could increase the dissolved oxygen content and solubility of insoluble salts in water, and increase the pH value, but had no significant effect on infrared spectroscopy and nuclear magnetic resonance spectra. They also noted that changes in electrical conductivity were related to magnetization time and magnetic induction intensity. Wang Kaihua[7] showed through experiments that water treated with magnetization had higher viscosity than untreated water and significantly reduced the formation of water scale. Theoretical analysis suggested that this effect may be related to changes in water molecule energy. Literature indicates that magnetization can lead to a decrease in the bond angle of water molecules, thereby increasing osmotic pressure and solubility, while also increasing dissolved oxygen content, with decreases in viscosity coefficient and surface tension[8]. Yang Ming and others[9] studied the physicochemical properties of pure water, tap water, and wastewater after magnetization. The results showed that the pH value, surface tension, and electrical conductivity of the three water bodies exhibited periodic fluctuations with changes in magnetic field intensity, but the fluctuation range differed depending on the water type. Zhao Ximei and others[10] found that static magnetization had no significant effect, while multiple dynamic magnetizations increased the surface tension coefficient of water and maintained it at a relatively stable level. Yao Qingzhao and others [11] explored the influence of magnetization treatment on resistivity under different conditions through orthogonal experiments. The results showed that this treatment could reduce resistivity, with an effect that exhibited hysteresis. M.C. Amiri and others [12] pointed out that as the number of magnetizations increased, the surface tension of the water gradually decreased and eventually stabilized at a certain value. They believed that this change was related to soluble and insoluble impurities in the water. He Jinsong and others[13] observed that liquid water exhibited decreased surface tension and increased viscosity with prolonged magnetization time at a magnetic induction intensity of 0.5 T, and believed that this phenomenon contributed to the formation of associative structures in liquid water. Otsuka and others[14] proposed that the contact angle was an important physical quantity for assessing the degree of magnetization. Zhou and others[15] found that the contact angle of water decreased when the magnetic field intensity was 0.5 T, and continued to decrease gradually as the intensity increased. Jing Dalei and others[16] used an adjustable electromagnet to statically treat deionized water and found that the viscosity of the deionized water and the charge density at its interface with high-borosilicate glass changed. They believed that this was due to the increase in internal energy of the deionized water after magnetization treatment, which reduced the degree of association, while hydrogen-oxygen bonds broke. Zhang Jun and others[17] used physical simulation methods to study the influence of magnetization treatment on water. The simulation results showed that under certain magnetic induction intensities, this treatment increased the internal energy of the water and decreased its specific heat, with the most significant effect occurring at a magnetic field intensity of 0.25 T.

3. Application of Magnetized Water in Agriculture

3.1. Effects of Magnetized Water on Soil Water-Salt Transport and Nutrient Transformation

Based on the characteristic that magnetized irrigation water can alter its physicochemical properties, numerous scholars have conducted extensive research on the effects of magnetized water irrigation on soil physical structure, solute transport such as salinity, and soil nutrient changes[18]-[19]. These studies provide a theoretical foundation for further understanding the physiological and ecological effects of magnetized water in agricultural production and its underlying mechanisms.

Soil moisture is essential for crop growth and development. To improve soil moisture conditions, it is necessary to optimize soil structure, enhance its water-holding capacity, and boost the crop's water absorption capacity. Magnetized water irrigation can effectively promote the absorption and utilization of soil moisture by crops. Studies have found that magnetized water irrigation can increase the content of aggregates smaller than 0.053 mm and larger than 0.250 mm in saline-alkali soil in Xinjiang and sandy loam soil in Shaanxi, while reducing the content of aggregates between 0.053 and 0.250 mm, thereby improving soil structure. Compared with conventional water irrigation, soil moisture content within a depth of 45 cm is more conducive to better absorption of water and nutrients by crops[20]. The increased moisture content ensures an adequate water supply. More importantly, it improves the transport of water in the soil, which can be characterized by parameters such as wetting front movement depth and cumulative infiltration. Research shows that magnetized water enhances its transport capacity in the soil during irrigation. Li Xia[21] and Zheng Deming et al.[22] concluded through related experiments that soil salinity significantly decreased after magnetized water irrigation in cotton fields, and the reduction in salinity was proportional to the number of times the irrigation water passed through the magnetizer. Peng Yao et al.[23] found that magnetized water could effectively increase soil moisture content in cotton fields, thereby promoting cotton growth. Wang Quanjiu et al.[24] pointed out that magnetization reduced the infiltration rate, favoring horizontal movement within the root zone and increasing soil moisture. Zlotopolski[25] also observed an increase in the mobility of magnetized irrigation water. In addition, Li Zongyu et al.[26] found through one-dimensional vertical infiltration experiments that when magnetized water was used, the soil cumulative infiltration reached its maximum value with the shortest infiltration time, and the soil moisture content also significantly increased, with all relevant parameters increased.

3.2. Reducing Soil Surface Salinity

Due to the natural conditions in Xinjiang, water scarcity and a large area of saline-alkali soil have always been significant issues. Therefore, the scientific and rational development and utilization of groundwater with low salinity for agricultural irrigation is particularly important. Currently, magnetized brackish water irrigation has been verified through numerous scientific research experiments and practical experiences. Relevant studies show[27]-[28] that magnetized irrigation water is more easily adsorbed by soil particles, thereby increasing soil volumetric water content. Compared with non-magnetized water, magnetized water irrigation significantly increases soil moisture content. Mostafazadeh et al.[29] found that magnetized water irrigation could alter soil chemical properties and effectively reduce the concentrations of cations and anions in the soil. Wang Hongbo et al.[30] demonstrated through experiments that treating irrigation water with a magnetizer before field irrigation could effectively reduce soil salinity, creating a favorable environment for crop growth. Furthermore, Xu Li et al.[31] pointed out that magnetized water irrigation significantly improved soil salinization problems in Xinjiang.

3.3. Promoting Soil Nutrient Transformation

The nutrient status in soil is quite complex. Relying on natural conditions and human factors to regulate soil nutrient composition and supply capacity is an important way to improve crop quality and yield. However, crops still face issues of insufficient nutrient absorption and low utilization rates. Since water is the medium for crop nutrient absorption, its activity, i.e., the ability of water to interact with other substances, is crucial for nutrient migration and transport. Preliminary studies have shown that magnetized water treatment technology can promote nutrient transformation. Wang Lu et al.[32] found that after magnetized water irrigation, soil enzyme activity increased, contributing to the continuous transformation and accumulation of nutrient substances in the soil, thereby significantly enhancing soil nutrient availability and providing a good nutritional environment for crop growth. Xie Jiangbo[33] discovered through soil culture experiments that after magnetized water irrigation, the soil cation exchange capacity (CEC) and total exchangeable bases increased, with the CEC of salt-affected soil increasing by 1.65% to 5.13% and the total exchangeable bases increasing by 1.18% to 3.54%. At the same time, the contents of available phosphorus and available potassium in the soil also increased significantly, with available phosphorus increasing by 6.38% to 17.76% and available potassium increasing by 1.51% to 5.31%. However, the study also found that soil colloid electrophoretic potential and alkaline nitrogen content decreased, with the electrophoretic potential decreasing by 3.23% to 9.92% and alkaline nitrogen content decreasing by 10.32% to 28.30%. In addition, when comparing the activation effects of magnetized water, de-electronized water, and magnetoelectric water, the results showed that magnetized water treatment was the most effective.

4. Conclusion and Outlook

Applying a specific intensity of magnetic field to water can alter the number and state of hydrogen bonds between water molecules, thereby affecting the association structure of water molecules and their macroscopic physicochemical properties. The magnetic field also influences the motion state of charged ions in aqueous solutions, changing the magneto-electric properties and chemical activity of water. These microscopic effects can be explained by the DOLLOP theoretical model. Furthermore, magnetized water has a memory effect and has been widely used in agricultural production, bringing significant economic and environmental benefits.

However, there are many factors that affect the properties of magnetized water, and the changes in its microstructure are difficult to directly characterize, posing challenges in experimental design and research methods. In the future, research means need to be continuously improved, especially through specific methods to amplify and display changes in the properties of magnetized water, while using precise and reliable equipment for quantitative analysis. On this basis, theoretical research on molecular simulation should also be strengthened, combining theory with experimentation to reveal the mechanism of water magnetization at the microscopic level.

In terms of application, magnetized water is expected to achieve wider application in various fields such as new material synthesis, bioengineering, clean production, and environmental protection.

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