

Advanced Technologies of Magnetic Water

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ABSTRACT

Electronic plus Magnetic water conditioner (EMWC) techniques (also known as physical water treatment) have various applications in various fields such as construction ,agriculture safety, compatibility and simplicity, environmentally friendliness, cheaper cost and do not harm environment. Magnetic water is having unique properties physically and chemically which is making it a multi-purpose compound with heavy benefits in medical treatment, industrial as well as environmental applications.Improvement in the field of irrigation water quality and quantity, crop yields, soil improvement and water saving are some of the best advantages in agriculture. It also effects on germination of seeds, plant growth and development, the ripening and yield of field crops. The main hurdle while using magnetic water agriculture in is efficient integrating of irrigation components, designing suitable pumps compatible with technical and field requirements of magnetic EMWT systems. This study summarizes the uses of magnetic water(MW)in agricultures. The practical challenges for using magnetic water(EMWC) in future is discussed in this paper.

Key words: Agriculture; Construction;; Magnetized water; Crop yield; Irrigation water treatment ,physical water conditioner.

What is hard water problem?

Initially rain water is not a hard water, Its TDS is less than 60ppm. But when it comes in contact with carbon dioxide(CO₂) it forms carbonic acid which makes it acidic. Now this rain water travel through various minerals and salts. This salt and minerals get dissolved into the water and makes it hard. TDS more than 200ppm.

Hard water issues :

Hard water is very difficult to use as compare to soft water in every use it creates problem.

Hard water do not make good lather and foam. After taking bath skin itching and irritation happens. White clothes will be yellowish and color clothes will lose its shining.

During shower bath hairs will be sticky and rough dry very difficult to manage .

Use of physical electromagnetic water conditioning technology in all concrete and cement allied products.

Present problem : In all concrete and cements products, cement is the most expensive ingredient but quality of water can affect concrete or cement particle to great extent as per it harms water used for any concrete application (Concrete application means any product which uses cement and water). As per standards Water used in concrete industry Should be potable means TDS below 500 ppm, it should be odorless, colorless should be chemical free. But in the real world the situation is different. In all over India water quality is different. In same area it is as per norms but almost 80% area the water is very hard above 500 ppm and polluted. As the good water is even not available for drinking purpose so potable water for construction industry is almost difficult thing to get as per is norms water for construction activity.

Due to this problem the available non suitable water is used for construction activity, example non potable water with TDS more than 500 ppm.

The issue with this water is content of dissolved salts particles, example calcium and magnesium salts. In any concrete application the role of water is to provide a solvent for cement dissolve process. Now when water is already hard due high TDS. The solubility of this water is low as compared to water below 500ppm water

Information about physical water conditioner technology and why no chemical testing possible .

1. Pl note our physical water conditioner is not a chemical softener or a device to reduce TDS or remove salts in any type of water . We all need to understand difference between chemical softeners , RO purification systems and physical water conditioner technology .

A.RO purification systems

A. Chemical softener or RO purification systems or machines which actually remove all salts (each and every salt) from your water using reverse osmosis technology . In output there two pipes one good water and other is bad water(drain water) using high pressure pump and hi tech membrane,water is forced to get separate into pure low TDS water and high TDS drain water . The ratio is around 50:50 initially but over the period of time drain water flow increases and vice versa. The best part here is it is your own drinking water plant with little investment and compact size . Bad part is it can give you only very little qnty and can be used only for 6 hrs a day

. Example domestic household RO units are used to give little qnty 50 liter per day only . Industrial RO units required big investment and still per hour output is not very high hardly 3000 to 4000 lph etc offcourse you can increase this flow rate but then it increases huge cost . This technology requires continuous maintenance and recurring cost . Because of this all reasons use of this technology is limited to drinking water area only. IN THIS TECHNOLOGY OUTPUT WATER IS COMPLETELY PURE AND LOW TDS AROUND 60 PPM ONLY . IT CAN BE PROVE IN ANY LAB OR EVEN SIMPLE TDS METER WILL SHOW DIFFERENCE immediately.

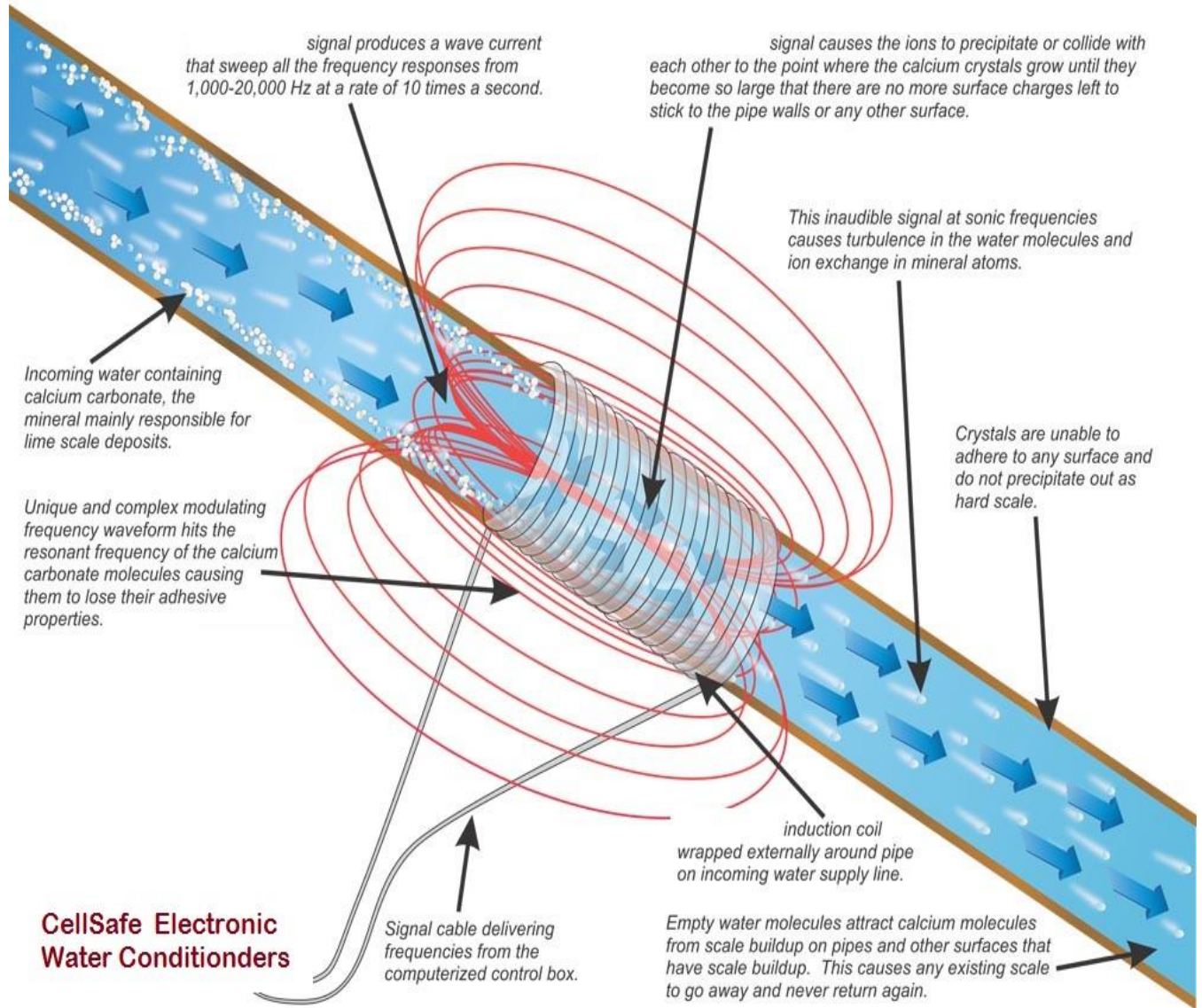
B. Salt based water softener .

In this technology resins were used to replace calcium and magnesium salts dissolved in water with sodium salts . This technique is more practical and economical compared to RO system and water waste is low. The bad part is output water contain more sodium and not suitable for low sodium diet people or patients. Also frequent regeneration is again a very big issue. Most user as mostly people are not doing on there own . Outside people are not that honest to carry salt and do regeneration timely. Due to all this salt based softener are.not very popular at least in India .

IN THIS TECHNOLOGY OUTPUT WATER TDS INCREASES BUT CALCIUM HARDNESS DECREASES . IT CAN BE PROVED IN ANY LAB TEST .

3. Physical water conditioner softener .

In this technology very novel concept is used to treat water . First of all there is no physical contact in between water and device used for this application. The pipe which carries water is fully empty and Hollow. All coils magnets and special transformer used is mounted on outer side of pipe not inside pl see attached drawing . Magnet ,coils and transformer creates a strong special sweeping frequency electromagnetic waves which acts on water irrespective of pipe wall thickness (1.5 mm to 6.0 mm) . These waves are responsible for a change in physical properties of water not chemical properties . The dissolved slats in water gets de bonded and its size decreases from 40 micron to 4 micron . Also there ability to stick to any surface or to each other is completely zero now . The output result is change in molecular structure of water and low surface tension of output water and very important 100% increase in solubility of water . The output is more soluble as compared to input water . This water will able to make more lather and more foam compared to input water . Best part is no chemicals or salts or filters are used to do this. Only little power around 25 to 50 watts watts per water cylinder and some electronic instrument to create high frequency electronic waves.



CellSafe Electronic Water Conditioners

Question .

There is no lab test report means input and output water shows same result .

Answer . In any physical water conditioner let it be ours or any other mfr all over world TDS or EC of output water never change . Reason is very simple logic . *We are not adding and removing anything from water under treatment* . Both these parameter change is possible in only RO because water is actually divided into good low TDS and bad high TDS drain water . In physical water conditioner even there is no physical contact in between water and conditioner instrument. What exactly gets changed is physical properties of water that is taste , turbidity , solubility (ability to dissolve more salts ,molecular structure of water and very important sticking ability of dissolved salts .

How we can test the water then ?

Answer . You can do soap test (use same soap for before and after water then you will get more foam in treated water and less in non treated . Also stickiness will be less in treated water .)

You may also dissolve some water soluble fertilizer or micro nutrient . They will get dissolved in treated water fast as compared to non treated .

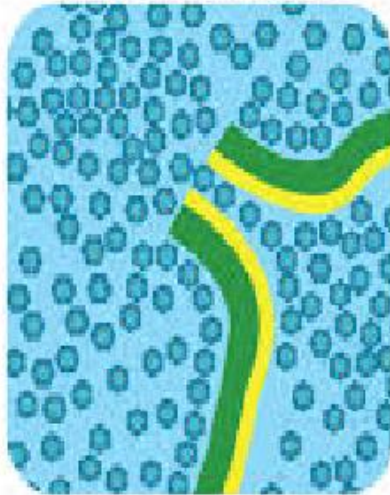
PL NOTE NO CHEMICAL TEST IS AVIALABLE OR POSSIBLE BECAUSE THIS TECHNOLOGY DO NOT CHANGE ANY CHEMICAL PROPERTIES OF WATER . IT ONLY CHNAGE PHYSICAL PROPERTIES OF WATER .

How it is beneficial for agriculture application then ?

When we give hard water to any plant them due to low absolute pressure(high surface tension water) it is very difficult for water molecules to get entry into cell membranes .

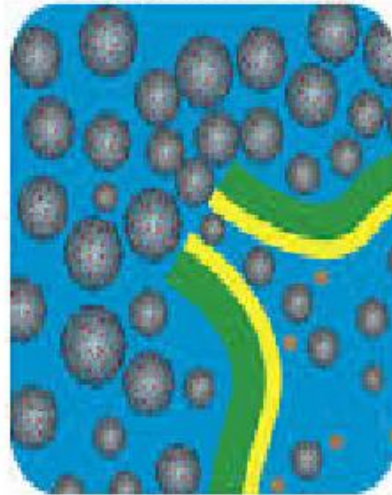
Now lot of molecules are not able to enter cell membranes. Because of this, plant mechanism gets a bad signal and cannot produce more new white sub roots which are very much essential for further plant growth . In treated water these molecules are now in small hexagonal size and easily able to enter cell membranes. As absolute pressure of water is more (low surface tension water) then uptake lifting towards leaves is very easy compared to non treated water . This all results to give a good signal to plant mechanism and now it can produce more new white sub roots .

Treated Water



Full Hydration

Untreated Water



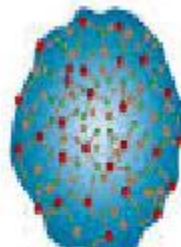
Partial Hydration



Water molecules



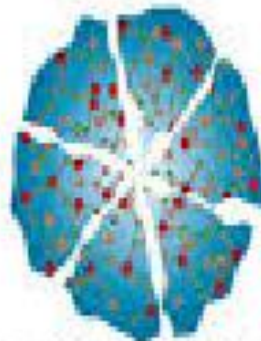
bond together



to form water molecule clusters.

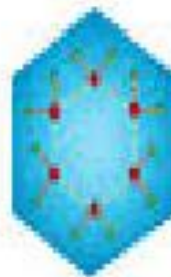


Many are too large to enter the cell.

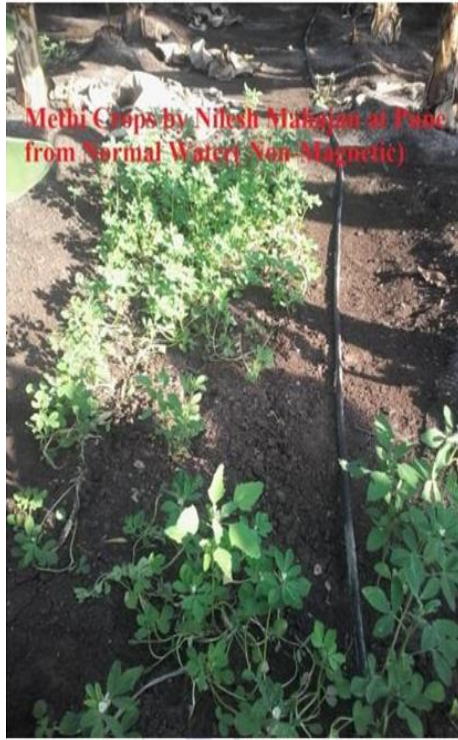


breaks apart clusters

the clusters are broken



into smaller hexagonal clusters.

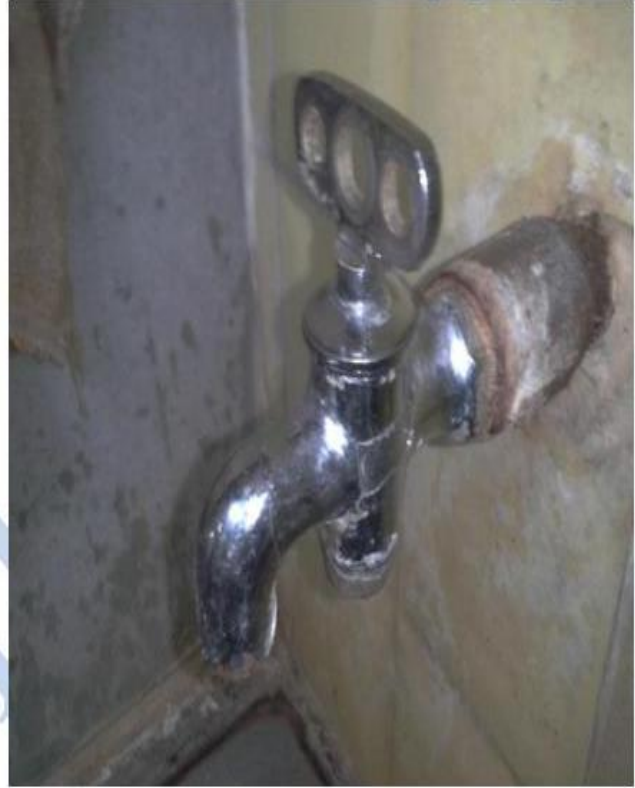


THERE ARE ALMOST 300% MORE WHITE SUB-ROOTS AS COMPARED TO NON-MAGNETIC WATER



Non Magnetic Water of Mumbai (600 PM) is having less white roots as compared with magnetic water





Due to hard water often these scaling happened (1st Image) in bathroom or home appliances. 2nd image is the result from water conditioner without using any chemicals.

PL NOTE NO CHEMICAL CHANGE IS NOT A DRAWBACK OR LIMITATION OF THIS TECHNOLOGY. BUT IT IS PART AND PARCEL OF THIS TECHNOLOGY . IT IS NOT DRAWBACK OR LIMITATION IT IS STRENGTH OF IT. BECAUSE OF THIS ONLY WITHOUT ANY PHYSICAL CONTACT AND USING VERY LITTLE ENERGY WE CAN TREAT LARGE NO.OF WATER. EXAMPLE A FOUR INCH WATER CONDITIONER GIVE 100,000 LITER PER HOUR without any recurring cost and maintainance . If you requirement and water resource then you can treat and supply 24,00,000 liter water per day using this four inch size machine. It can do this job years after years .

What is main issue today for this wonderful technology .

Awareness is the key issue . People's imagination level is not going beyond RO filters or uv based filters . We need understand working principal of microwave and induction plate . In microwave electrical energy is used to create microwaves in such a way that it will only heat up those food items which has water not anything else. If you place a samosa to heatup then you will notice outer part is not that hot but inner potato is too hot. Inner potato has more water content compared to outer side of samosa.

But in Induction Plate it completely different . Here electrical energy is used to produce induction waves which will heat up only those items which has metal . Example plate bottom metal utensils . If you place you hand on induction plate then nothing will happen but if have a spoon in hand it will get heat up.

Our point is in both instrument electrical energy is converted into invisible waves which causes heating of metal or water content items without any physical contact . In the same way using electronic circuit, coils and Permanent magnets, we are producing electronic plus magnetic high frequency waves which causes change in physical properties of water without changing chemical properties (chemical properties of water remains unchanged). All this done without any physical contact with water . As there is no physical contact so no moving parts or recurring or maintenance part .

In all other treatments physical contact is must so again regular periodic maintenance is must and consumables required .

Question . What about suspended particles example iron particles or dust particles etc etc .

This technology works for dissolved salts only so no bad or good effect on suspended particles . Lot of filters like sand filter or disk filter or screen filters cyclone filters are there in market to do this job.

Introduction

Electronic plus magnetic water technologies have shown great potentials in medical, agriculture, construction industrial and environmental applications¹⁻⁷. Because of the electrical origin of the life and existence of all cells and living creatures, electromagnet can interact with all living cells so that can modulate their functions. These modulations in appropriate conditions can have useful outcomes such as treatment or inducing the desire characteristics in different compounds. Water is a crucial source for life on the earth. Any living creature needs water to hydrate every cell. Long term and frequent droughts and competing water demands in most parts of the world have caused severe pressure on water

METHODOLOGY

this technology works, Magnetic fields are produced by the motion of charged particles. For example, electrons flowing in a wire will produce a magnetic field surrounding the wire. The magnetic fields generated by moving electrons are used in many household appliances, automobiles, and industrial machines. One basic example is the electromagnet, which is constructed from many coils of wire wrapped around a central iron core. The magnetic field is present only when electrical current is passed through the wire coils. Permanent magnets do not use an applied electrical current. Instead, the magnetic field of a permanent magnet results from the mutual alignment of the very small magnetic fields produced by each of the atoms in the magnet. These atomic-level magnetic fields result mostly from the spin and orbital movements of electrons. While many substances undergo alignment of the atomic-level fields in response to an applied magnetic field, only ferromagnetic materials retain the atomic-level alignment when the applied field is removed. Thus, all permanent magnets are composed of ferromagnetic materials. The most commonly used ferromagnetic elements are iron, cobalt, and nickel. The strength of a magnet is given by its magnetic flux density, which is measured in units of Gauss. The earth's magnetic field is on the order of 0.5 Gauss [10]. Typical household refrigerator magnets have field strengths of about 1,000 Gauss. According to the distributors, the magnets sold for water treatment have magnetic flux densities in the 2,000 to 4,000 Gauss range, which is not unusually strong. Permanent magnets with flux densities in the 8,000 Gauss range are readily available.

The strongest magnets avail in world are known RARE EARTH MAGNETS ALSO KNOWN AS NEUBIDIUM IRON BORON MAGNETS .

Case study on RO plant .

it proves EMWC will help to keep expensive RO membranes scale free and avoid /minimise anti scaling usage (In 2015 BARC claim that 27 percent

One of the site near Trichy.e at Pudukottai, the capacity of the RO Plant is 500 Litres per Hour. It's an 4 Years Old RO plant. The Total Membranes Got Choked & the customer replaced the RO Membrane & the membrane details are given below

Make	:	Hi-Tech, India
Model	:	Brackish Water (BW Model)
Model Number	:	4040
Total No of Membranes	:	2 Nos
No of RO Housing	:	2 Nos

Even though the membrane replaced, gradually flow rate reduced & TDS increased.

Operating Pressure	:	10 Kg/cm ²
RO Product Water Flow	:	320 LPH
RO Product Water TDS	:	60 PPM
Raw water TDS	:	900 PPM
RO Feed water Flow	:	1350 LPH
RO Reject Water Flow	:	1030 LPH

Finally customer approached us, we visited the plant & taken the service of the plant. During our service we did the following things

- Cleaning of Multigrade Filter of Size Diameter 250mm & Height 1350mm – 1 No
- Replacement of Micron Filter of Size 2.5" Dia x 20" Length – 2 Nos
- Chemical Cleaning of RO membrane using
 - ❖ High pH Chemical
 - ❖ Low pH Chemical

After our service we taken the RO Plant in to service & found the below results

Operating Pressure	:	8 Kg/cm ²
RO Product Water Flow	:	400 LPH
RO Product Water TDS	:	60 PPM
Raw water TDS	:	900 PPM

RO Feed water Flow	:	1350 LPH
RO Reject Water Flow	:	900 LPH
% of Product Recovery	:	29.63%
% of Salt Passage	:	6.67%
% of Salt Rejection	:	93.33%

After that we installed our “Cell Safe Electronic Magnetic Water Conditioner” before the RO Plant & We found gradually the Product water TDS reduced & it is given below

TDS on First 3 days	:	No Chances
TDS on 4 th Day	:	56 PPM
TDS on 5 th Day	:	48 PPM
TDS on 6 th Day	:	48 PPM
TDS on 7 th Day	:	30 PPM
TDS on 8 th Day	:	28 PPM

SO after installed our “Cell Safe Electronic Magnetic Water Conditioner”, we found improvement in the quality of the RO Product water i.e reduction in Product TDS & Improvement in the Product Flow rate. All the details are mentioned below

Operating Pressure	:	8 Kg/cm ²
RO Product Water Flow	:	450 LPH
RO Product Water TDS	:	28 PPM
Raw water TDS	:	900 PPM
RO Feed water Flow	:	1350 LPH
RO Reject Water Flow	:	850 LPH
% of Product Recovery	:	33.33%
% of Salt Passage	:	3.11%
% of Salt Rejection	:	96.89%

Parameters	Before installing EMWC	After Installed EMWC
% of Product Recovery	29.63%	33.33%
% of Salt Passage	6.67%	3.11%
% of Salt Rejection	93.33%	96.89%



CALCITE

Chemical Formula: CaCO_3
Molecular Weight: 100.09g
Calcium: 40.04% Ca
Carbon: 12.00% C
Oxygen: 47.96% O

ARAGONITE

Chemical Formula: CaCO_3
Molecular Weight: 100.09g
Calcium: 40.04% Ca
Carbon: 12.00% C
Oxygen: 47.96% O



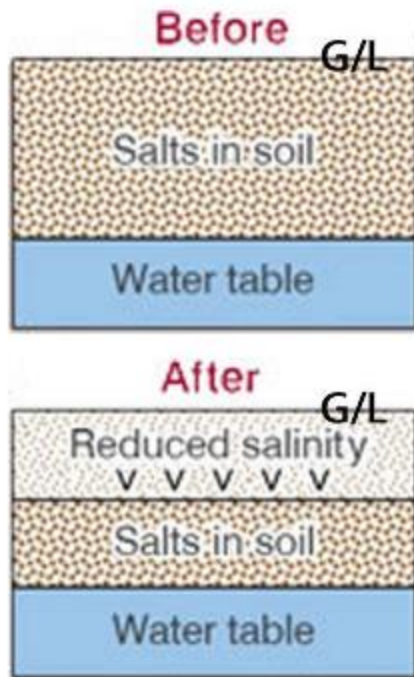
There are three common forms of calcium carbonate, aragonite, calcite and vaterite. These materials are composed of the same chemicals and for all purposes have the same compositions, i.e the chemical formula is CaCO₃). However the atoms of the minerals are arranged differently in space – this is called polymorphism.

Because these minerals are arranged differently in space, they have different properties. As you can imagine, some of these structures are stronger than others. For example, the solubility product of calcite is roughly a half of the solubility product of aragonite. Calcite is more insoluble in hot water (about 4 times for a 50 degree celcius temperature range) and thus is liable to drop out and form on hot surfaces. Aragonite forms at higher temperatures and tends to stay in solution longer. Thus it is likely to be present but still in solution.

We have conducted preliminary tests to show that aragonite forms at higher temperatures than calcite and that aragonite is preferentially formed when the Care-Free Conditioner was used. Techniques used were XRD, particle size measurements, and SEM."

Dr Gary Lee BSc (Hons) PhD, Aqueous Geochemist, ANSTO

Courtesy care free water conditioner

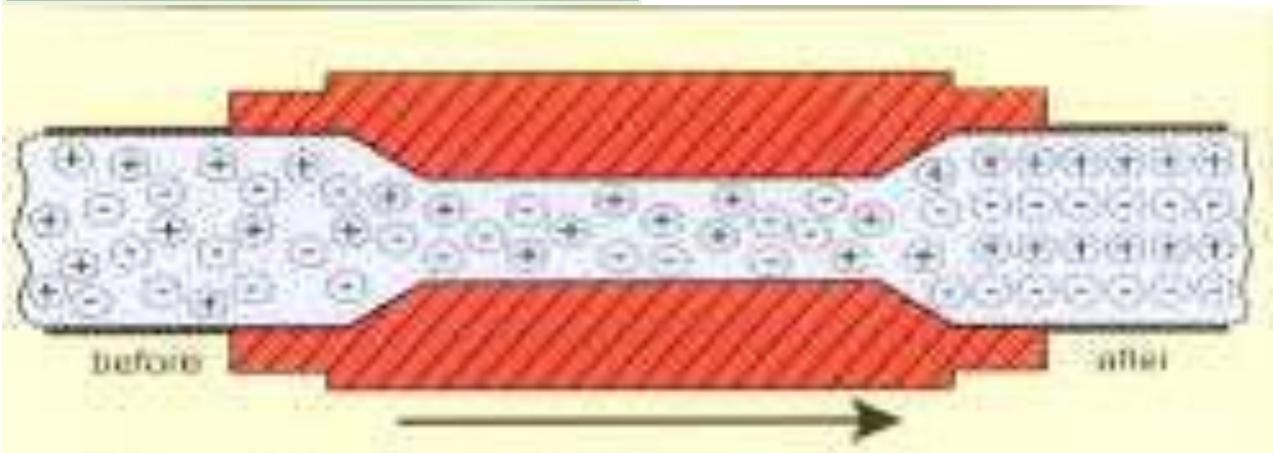
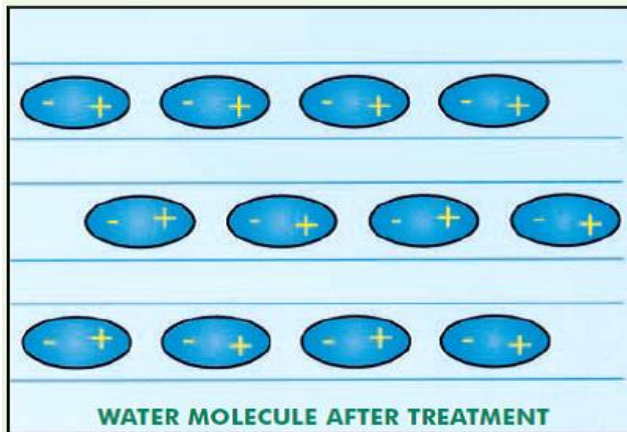
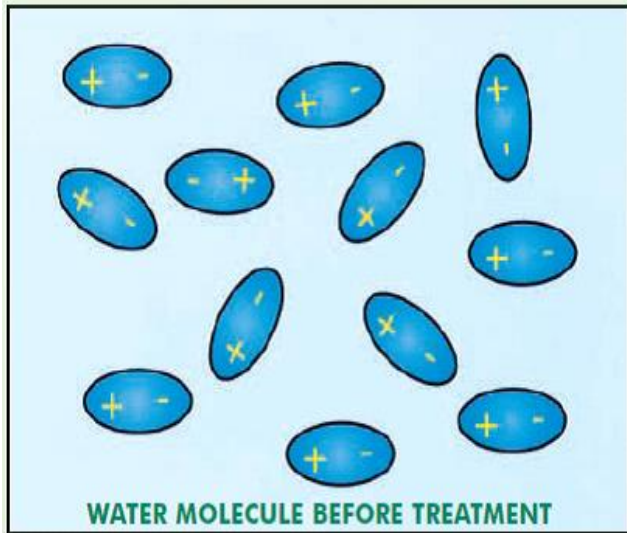


There are observed salinity reductions in the soils where trials have taken place...”
 “I will emphasise that there is no difference in EC from input water to output water from a Care-Free Water Conditioner. What we have found out at ANSTO by undertaking a range of tests on the device, in relation to particle size analysis, in the colloidal fraction, is that the distribution of the particle size of colloids is reduced significantly. That is, there is an increase in the portion of particles at the lower colloidal size once saline water has passed through the device.

By reducing the size of particles, the device influences the impact of the saline water, which has stayed in the same EC, and allows the salts, or should I say the ions which also vary in ionic radii, to pass downward through the soils below the root zone. Hence, why there are observed salinity reductions in the soils where trials have taken place. The irrigated water has had particle size reduction take place allowing the ions to pass quicker through the soils and not get caught up in the root zone for plants.”

Dr John Bradd Hydrogeologist
 ANSTO ASAN – National Coordinator

Courtesy care free water conditioner



The magnets sold for magnetic water treatment are nothing special; they are just ordinary magnets. Magnetic water treatment is based on magnets are placed inside or to the exterior surface of the incoming water pipe. The water is exposed

to the magnetic field as it flows through the pipe between the magnets. An alternative approach is to use electrical current flowing through coils of wire wrapped around the water pipe to generate the magnetic field.

There is apparently no consensus among magnet vendors regarding the mechanisms by which magnetic water treatment occurs. A variety of explanations is offered, most of which involve plenty of jargon but little substance. Few vendors, if any, offer reasonable technical explanations of how magnetic water treatment is supposed to work.

ANNALS OF FACULTY ENGINEERING HUNEDOARA – International Journal Of Engineering

Tome XI (Year 2013). 148 Fascicule 4. ISSN 1584 – 2673

Vendors explain the principle of magnetic water treatment using the magnetic resonance that is the physical effect applied to the atoms of water as it passes from one magnetic field into the reverse

magnetic field of the opposite polarity. This produces a resonating, polarizing effect on the atoms of hydrogen, oxygen and mineral in water as illustrated in Figure 1.

a)

b)

Figure 1. (a) Water Molecules Before and After Magnetic Treatment

(b) Configuration of Ionic Particles in Magnetic Field

According to some vendors, magnetically softened water is healthier than water softened by ion exchange. Ion-exchange softeners increase the water's sodium concentration, and this, they claim, is

unhealthy for people with high blood pressure. While it is true that ion-exchange softening increases

the sodium concentration, the amount of sodium typically found even in softened water is too low to

be of significance for the majority of people with high blood pressure. Only those who are on a severely sodium-restricted diet should be concerned about the amount of sodium in water, regardless

of whether it is softened [14]. Such individuals are often advised to consume demineralized water

along with low-salt foods.

Purveyors of magnetic water treatment devices claim that exposing water to a magnetic field will decrease the water's "effective" hardness. Typical claims include the elimination of scale deposits,

lower water-heating bills, extended life of water heaters and household appliances, and more efficient use of soaps and detergents. Thus, it is claimed, magnetic water treatment gives all the benefits of water softened by ion-exchange without the expense and hassle of rock-salt additions. Note that only the "effective" or "subjective" hardness is claimed to be reduced through magnetic treatment. No magnesium or calcium is removed from the water by magnetic treatment. Instead, the

claim is that the magnetic field decreases the tendency of the dissolved minerals to form scale.

Even

though the dissolved mineral concentration indicates the water is still hard, magnetically treated water supposedly behaves like soft water.

The important question here, though, is whether magnetic water treatment works. In an effort to find the answer, we conducted a search for relevant scientific and engineering journal articles.

I

describe the results of this search below.

More than one hundred relevant articles and reports are available in the open literature, so clearly magnetic water treatment has received attention from the scientific community (e.g., see reference list in [3]), in nearly all cases researchers report finding no significant magnetic treatment

effect. On the other hand, many researchers have evaluated Magnetic Water Treatment Devices (MWTD) worldwide for scale control in various industrial processes, including desalination, and also

for desorption of scales and corrosion products [4]. Rameen et. al. [12] reported the effect of commercial magnetic water conditioners on the total dissolved salts and pH on different solutions, the

work includes laboratory evidence of water quality modifications which supplies different purposes

using magnetic means. PANG et. al. [11] investigated the properties of water and their changes under

the action of a magnetic field were gathered by the spectrum techniques. It was found that some properties of water were changed, and a lot of new and strange phenomena were discovered after magnetization. Magnetized water really has magnetism. These results show that the molecular structure of water is very complicated, which needs studying deeply. Dave[2] found in the personal

test runs, the magnetic “water softener” did exactly nothing. H. Banejad et. al. [6] found that changing magnetic field intensity, amounts of water influent, and also together influence there factors, have significant effects at level of 99 percent on reducing of water hardness. In the other way, for finding their mechanisms, analyzes done by X ray. Calcium carbonate exists in two forms,

calcite and aragonite. But the main form of sediment is calcite. One of the new strategies is magnetic water technology. Regarding to the chemical analysis to determine the hardness of samples, titration procedures

provide relatively inexpensive means for the analysis of different substances. These titrations are based on chemical reactions with completion points that can be monitored by some visible change in

the reaction systems.

The most common system involves acids and bases with the use of an indicator that changes color as the system moves from an acidic to basic composition. Calcium and magnesium ions can be

measured through reaction with a chelating agent EDTA (ethylenediaminetetraacetic acid). This molecule has four carboxylic acid ($\sim\text{COOH}$) group sites and two nitrogens, all of which have lone pairs

Some of these applications are therapeutic effects of MW, preventing scale deposition, improving irrigation

water quality and crop yield, scale elimination, soil improvement, corrosion control and wastewater treatment¹¹⁻¹³.

FINDING

Magnetic Water Treatment in Agriculture

In normal or non-MW, the water molecule clusters comprising of many water molecules are loosely attracted. This loose and chaotic form of attraction predisposes the water to toxins and pollutants to travel inside the water molecule cluster. The large structure of these water molecule clusters or presence of toxins blocks large portions of these clusters when they pass through the cell membrane. The smaller size of these chaotic clusters, some of them carrying toxins, can enter the cell with consequent harmful effects¹¹⁻¹³. Therefore, to hydrate a plant a great deal of normal water is required. Magnetic treatment of water restructures the water molecules into very small clusters, each made up of six symmetrically organized molecules. This tiny and uniform cluster has hexagonal structure thus it can easily enter the passageways in plant and animal cell membranes. In addition, toxic agents cannot enter the MW structure. These features make MW a bio-friendly compound for plant and animal cells. MW can be used to increase crop yield, induce seed germination and benefit the health of livestock. Studies have demonstrated that MW for irrigation can improve water productivity; thus, conserving water supplies for the expected future global water scarcity¹⁴. In addition, MW is reportedly effective at preventing and removing scale deposits in pipes and water containing structures.

Magnetic Treatment of Irrigation Water

Previous studies have shown several beneficial effects of MF treatment on the growth of plants. It was demonstrated that an optimal external EMF can increase the rate of the plant growth, especially the percentage of seed germination^{11, 12}. Podleony *et al.* (2004) reported that exposing the broad bean seeds to variable magnetic strengths during before sowing imposes significant effects on seed germination and seed yield¹². In addition, they showed that applying MF to broad bean during the growing season can increase the number of pods per plant and reduce the plant losses per unit area. Several studies have demonstrated the effectiveness of MFs on the root growth of various plants¹⁴⁻¹⁸. Similarly, Muraji *et al.* (1992) observed that MF treatment increases the root growth of maize¹⁸. Turker *et al.* (2007) reported that static MF has an inhibitory effect on the root dry weight of maize plants, but had a beneficial effect on root dry weight of sunflower plants [19]. Different studies have shown the inhibitory effect of weak MF on the growth rate of primary roots during early growth^{16, 19}. It was demonstrated that MF can decrease the proliferative activity and cell reproduction in meristem cells in plant roots¹⁶.

Magnetic treated water undergoes several changes in its physical properties. It also exerts several effects on the soil-water-plant system. Leaching the soil with MW significantly increases available soil phosphorus content compared with the leaching with normal water at all soil depths. Behavior of nutrients under an MF is a function of their magnetic susceptibility.

The previous studies have shown that the effects of magnetic treatment varied with plant type and the type of irrigation water used, and there were statistically significant increases in plant yield and water productivity (kg of fresh or dry produce per kL of water used). In particular, the magnetic treatment of recycled water and 3000 ppm saline water respectively increased celery yield by 12% and 23% and water productivity by 12% and 24%. For snow peas, there were 7.8%, 5.9% and

6.0% increases in pod yield with magnetically treated potable water, recycled water and 1000 ppm saline water, respectively.

Effects on Quality of Water

Several studies demonstrated that MWT influences molecular and physicochemical properties of water that alter the quality of water²⁰. The origin of physical and chemical modulations of water molecules under magnetic treatment is the alteration of water nucleus²⁰⁻²³. The effects of magnetic treatment on irrigation water include increasing the number of crystallization centers and the altering the free gas content²⁴. Both effects improve the quality of irrigation water. The important components for effective magnetic treatment are flow rate through the apparatus and certain chemical parameters of water, namely, carbonate water hardness of more than 50 mg/L and concentration of hydrogenous ions in water at $\text{pH} > 7.2$. Irrigation with magnetically

Aliet et al., Curr. World Environ., Vol. 9(3), 695-703 (2014)

treated water is the most effective for soils with high soda content²⁴.

Effects of low level magnetic and EMFs, below 100 mG for AC MF, and below 1000 G for static MF, on purified water include modulating pH and oxidation/reduction potential (ORP) values²⁵. To accurately evaluate the effects of weak MFs on water, subtle experimental conditions such as differential field conditions produced by common lab devices and procedures, and background lab fields, cannot be ignored. Moreover, extending measurements beyond several hours may be essential to reliably observe the presence or absence of these effects²⁵.

Experimental studies have shown that magnetic treatment can increase the number of crystallization and modulates the free gas content of the solution²⁵. Magnetic treatment on water plays important roles in different procedures influencing a crystallization process such as association, dissociation and nucleation rates^{26, 24, 27}.

Effects on Crop Yield

In the field of crop yield, researchers have focused on using of physical growth stimulation approach because of no known adverse effect on the environment. MW technology is a promising physical growth stimulation approach. The characteristics of water treated by the magnetic field can be altered to cause changes in plant properties, growth and production^{28, 29}. MW can be used for saving irrigation water³⁰.

MWT can increase the seed germination³¹. Irrigation with MW modulates several parameters that are associated with the crop yield: growth characteristics, potassium, GA₃, kinetin, nucleic acids (RNA and DNA), photosynthetic pigments (chlorophyll a & b and carotenoids), photosynthetic activity and translocation efficiency of photo-assimilates³²⁻³⁶. Several studies have shown the enhancement of water productivity in both crop and livestock production, number of flowers and total yield of fruits for different crops including strawberry and tomatoes^{28, 29}.

In addition, weak MF decreases the speed of cell cycle in meristem cells in plant roots due to the expansion of G₁ phase and sometimes G₂ phase. Therefore, the functional activity of genome before replication phase is decreased. Under these mechanisms, weak MF treatments result in the intensification of protein synthesis and disintegration in plant roots¹⁶. Irrigation with MW can improve the quality of crops including tomato, broad bean, cress and potato^{14, 35}

Weak MF can increase the size and volume of mitochondria, calcium over-saturation in cytoplasm and disruptions in different metabolic systems including Ca²⁺ homeostasis in root cells^{15, 16}. One of the important function of MF treatment is reducing the heat stress effects in different seedlings including cress³⁷.

Benefits to Plants

Several studies have revealed beneficial effects of MF treatment in fruit yield and plant growth. Lin and Yotvat (1990) explained that applying magnetically treated water increases productivity of water in both crop and livestock production³⁸. Similarly, several studies have shown that MF treatments enhance the flowers and total fruit yield of strawberry and tomatoes^{28, 29}. Duarte Diaz *et al* (1997) observed that magnetic treatment increases the nutrients absorption in tomato¹⁰. Some of the main effects of magnetic treatment of seeds or irrigation with MW in plants include plant growth rate, transplant dry weight, transplant leaf area, and seed germination.

Effects on Plant Growth

Using MW for irrigation of squash increases the weight of squash. Bio-magnetic water is more solvent and has a lower surface tension; therefore, nutrients are absorbed greater in the water^{28, 39, 40}. MW is the water which are treated with magnetic field or pass through a magnetic device.

When water is magnetized, some properties changed which can alter the characteristics of plant, growth and production. It was suggested that MW irrigation could increase the germination of seed⁴¹. Similarly, other field studies have indicated a significant role of MW irrigation of seeds in improving the growth of seedling^{35, 39}. Furthermore, MW improves quantity and quality of bean crop and germination, fresh weight, and shoot length of maize⁴². In addition, magnetic treatment before sowing increases the number of pods per plant and decreased plant losses ⁶⁹⁸ Ali *et al.*, *Curr. World Environ.*, Vol. **9**(3), 695-703 (2014)

per unit area¹². The root growth of various plant species can be enhanced using MWT technique¹⁵⁻¹⁹. Muraji *et al* reported that the roots of maize plants have the highest growth rate under an MF of 5 mT at 10 Hz¹⁷. Moreover, MFs have an important influence on root dry weight of sunflower plants^{16, 19}.

Effects on Transplant Dry Weight

The results of a study conducted by El-Yazied *et al* (2011) revealed that applying magnetic seed treatment and/or irrigated with MW in different seasons significantly increases the transplant dry weight compared with the non-treated treatment⁴³. In consistent with these results, Gurusamy and Kalavathi (1998) demonstrated that the dry weight of seedling grown from magnetically treated seeds is significantly higher than the untreated cowpea⁴⁴. Ozdemir *et al.* (2005) reported that electromagnetic treated water enhances the root dry weight by 11% compared with the control group⁴⁵. Furthermore, Fernandez *et al* (1996) revealed that the MW irrigation significantly increases the weight of seedling⁴⁶.

Effects on Transplant Leaf Area

El-Yazied *et al* (2011) showed that irrigation with MW enhances the leaf area in the grown seedling⁴³. Similarly, several other studies have reported improvements of the leaf size of different seedlings grown by magnetically treated seeds^{47, 48, 49}.

In this regard, it was found that magnetically water irrigation is an ecological and harmless technology. Therefore, it must be recommended for agriculture applications⁴³. Carbonell *et al* (2004) revealed that the MW increases the contents of various minerals compounds of soil such as nitrogen, phosphorus and potassium and improved the fertilizers dissolve in the soil irrigated with MW⁵⁰. Various studies have demonstrated higher absorption of nutrients was greater increased if irrigation with magnetically treated water was used^{10, 49}. Although it was proved that MF could improve the water attributes but its mechanisms are not well known yet⁴³.

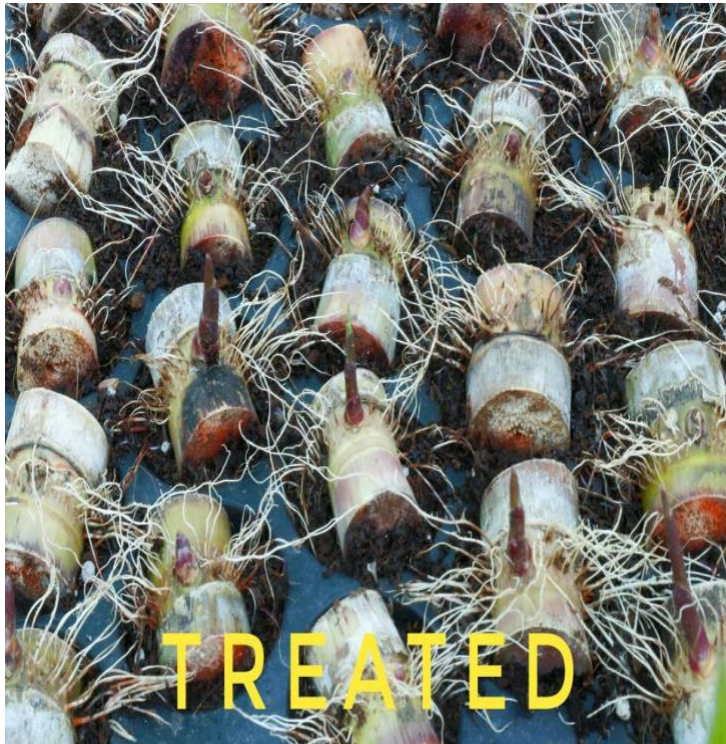
In addition, Selim (2002-2005) showed that irrigation of lentil plant with magnetic treated water enhances various crop yields such as number of brunches and pods per plant and weight of pods, etc. Furthermore, they reported improvements of other characteristics such as the height of plant, fresh and dry weight of MW irrigation compared with the tap water irrigation⁵¹.



Effects on Seed Germination

An optimal external EMF can influence the speed and percentage of germination^{11, 12}. The strength of MF and exposure time are among the most significant factors influencing the seed germination, emergence rate and seed yield. Magnetic treatment can accelerate the plant emergence to 2–3 days, compared with the control plants. El-Yazied *et al* (2011) and Aladjadjiyan (2002) showed that the MF dose and the duration of exposure can affect the germination traits of different seeds including tomato and broad bean. They demonstrated that strength of MF plays a significant role on germination percentage^{42, 43}. In agreement with these results, Souza *et al* (1999) concluded that best germination percentage of tomato seeds is obtained under the MF strength of 0.1 Tesla with exposure time of 10 minute^{43, 52}. Several studies have shown that MF strength has significant effects on germination percentage through reducing water salinity⁵¹. Rochalska (2001) revealed that MF treatment improved the germination process under stress conditions⁵³. El-Yazied *et al* (2011) demonstrated that MF exposure time can significantly influence germination percentage through modulating water salinity. They also concluded that increasing the MF strength significantly reduces the number of days needed for germination as compared with untreated seeds⁴³. In line with these findings, Pietruszewski (1999) revealed that wheat seeds treated by MF can speed up germination compared with the untreated samples⁵⁴. Furthermore, exposure time to MF plays a significant





role on the germination rate where different exposure periods result in different minimum time required for germination. However, Florez *et al* (2007) showed that the time needed for germination in each magnetic treatment of various strengths and periods are lower than values recorded by control¹³.

Increasing the salinity level increases the time required for germination. Some studies have reported that increasing the salt concentration delays the tomato seeds germination^{14, 40, 55, 699} Aliet *al.*, *Curr. World Environ.*, Vol. **9**(3), 695-703 (2014)

Effects on Soil

Magnetic treatment has reportedly shown various benefits to soil which can improve the water consumption, crop yields and plant growth. The three main functions of magnetic treated water in soil are removal of excess soluble salts, lowering pH values of soil layers, and dissolving slightly soluble components such as phosphates carbonates and sulfates^{28, 40, 56}. Furthermore, magnetic treated water increases nutrient mobility in soil and enhances extraction and uptake of P, K, N and Fe by plants. Magnetic treated water increases the efficiency of added fertilizers⁵⁷. Magnetic treatment of water increases the water absorption in soil. Furthermore, magnetic treatment of saline irrigation water is reportedly an effective method for soil desalinization. Water treatment by MF decreases the hydration of salt ions and colloids that increases the salt solubility, accelerated coagulation and salt crystallization⁵⁶. The study showed that MW increased leaching of excess soluble salts, lowered soil alkalinity and dissolved slightly soluble salts ⁵⁶. Leaching the soil with MW significantly increases available soil phosphorus content compared with the leaching with normal water at all soil depths. Behavior of nutrients under an MF is a function of their magnetic susceptibility.

The increase in salt concentrations reduces final germination percentage. The reduction is significant particularly for high levels of salt concentration (higher than 5000 ppm). Similar results were found by other research groups who found that increasing salt concentration up to 2500 ppm significantly reduced tomato seed germination^{55, 57}.



Scale Prevention and Elimination

Suspended particles or solids in water can cause serious problems in irrigation distribution systems and also drink water networks. The deposition of scale can even completely block an irrigation system. Deposition of scale due to entrapped oxygen increases corrosion. When the surface of any pipeline or water-using systems becomes scaled, this insulating scale reduces the efficiency of the system, increases fuel requirements and maintenance⁵⁸⁻⁶¹.

Therefore, there is an ever increasing demand for effectively scale prevention/elimination technique, not only economically, but to insure the minimum environmental pollution attainable. One of the most important applications of MW is scale prevention and elimination⁶². An effective water treatment program can provide substantial savings in both production time and costs^{61, 26}. MWT directly affects the equilibrium of carbonate in water where induces formation of calcium carbonate particles within a solution. These particles cannot precipitate on pipe walls and other equipment and are transferred to the downstream of pipe flow which can be removed by filtration^{24, 27}. It was found that using MW can reduce the mineralized coatings inside pipes³⁸. Barrett and Parsons (1998) investigated the effect of MW on calcium carbonate (CaCO_3) by suppressing nucleation and increasing the rate of crystal growth, and they observed scale reduction⁶³. The hexagonally structured of MW molecule cluster won't allow the bonding of minerals to it and removes scaling from pipes and won't allow new scaling to take effect^{23, 27, 59, 61, 64, 65}.

Gehr *et al.* (1995) reported that magnetic treatment induces precipitation of gypsum crystals ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) in the solution²². They also reported that magnetic treatment may be a useful treatment for scale prevention so that it can decrease the precipitation on solid surfaces and facilitate crystallization²². Furthermore, it was demonstrated that applying MF can decrease the pH of solution and that this change in pH directly affects the scale growth^{61, 26, 24, 27, 65}.

To applying MWT for prevention of scale, water must pass through a strong magnet installed on or in a feed line. Afterward, when the water is heated, it has lost its tendency to precipitate scale onto the hot surfaces and the built deposits gain a looser texture that is easily removable^{66, 26, 24, 26, 27}. . In this regard, Parsons *et al.* (1997) reported that using MWT decreases scale by 48% and Busch (1997) proposed a 22% reduction^{61, 65}. The magnetic device can inhibit the scales growth and remove them at the water line in the pool by 50%⁶⁷. Reducing and preventing the scale from irrigation water systems can reduce the water consumption up to 30%.

Although MWT is very useful for scale reduction, the exact mechanics of interaction⁷⁰⁰ Aliet *al.*, *Curr. World Environ.*, Vol. **9**(3), 695-703 (2014)

between magnetic treatments and calcium carbonate in solution is still unknown. To shed light on the exact mechanism of actions of MWT in exerting physical and electrochemical effects conducting further controlled laboratory and field studies are necessary. In this regard, few studies have been conducted on the effects of magnetic treatment of irrigation water on plant growth and crop and water productivity.

Technical considerations

A typical MWT system is a simple flange installed on the main pipeline and contains powerful, specific magnetic inductions that restructure the water and minerals passing through them. Most of the devices are in-line invasive and non-invasive as opposed to side-stream. The invasive devices require a section of pipe to be removed and replaced with the device. Most of the invasive devices are larger in diameter than the section of pipe they replace. The increased diameter is partially a function of the magnetic or electromagnetic elements, and also a function of the cross sectional flow area. The flow area through the devices is generally equivalent to the flow area of the section of pipe removed.

The non-invasive in-line devices are designed to be wrapped around the pipe. Therefore, downtime, or line out-of-service time, is minimized or eliminated. In MWT, when irrigation water passes under an MF, it gains a magnetic moment that persists for 24 to 48 hrs. Magnetic treatment of irrigation water depends on MF intensity, composition of dissolved salts and velocity of crossing a magnetron of 0.5 inch diameter [61] [26] [24, 27].

Conclusion

MWT has opened new research avenues in agriculture., compatibility and simplicity, environmentally friendliness, low operating cost and not proven harmful effects are the main advantages of this technique. Improvements of irrigation water quality and quantity, crop yields and quality, soil improvement, scale prevention/elimination in water-using systems, and water saving are some of the reported benefits of MWT in agriculture. In addition, MF treatments have shown beneficial effects on the germination of seeds, plant growth and development, the ripening and yield of field crops. The main challenge in applications of MW in agriculture is efficient integrating of irrigation components, designing suitable pumps compatible with technical and field requirements of magnetic MWT systems. To shed light on the exact mechanism of actions of MWT in exerting physical and electrochemical effects conducting further controlled laboratory and field studies are necessary. In this regard, few studies have been conducted on the effects of magnetic treatment of irrigation water on plant growth and crop and water productivity. In addition, further field and laboratory experiments are needed to overcome the field challenges and to gain knowledge about the mechanism of action of the MWT.

Acknowledgments

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