

Water Purification Under the Magnetization Method: A Review

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Abstract:

Water is an essential element for living organisms. The availability of fresh drinking water is getting lower day by day with the increasing pollution. Water contamination is a major cause of concern all around the world. There are many methods through which the water is treated among which the Magnetic water treatment method is one method. Which has shown its potential in treating the water. The electromagnetic water treatment classified and extended method of magnetic water treatment has shown its potential in the Reduction of the formation of scales and treating industrial wastewater has been its most covered area when it comes to treating water. It is a simple technique and has shown its potential in different fields. This review aims to magnetic water treatment techniques. The efficiency, working mechanism, and classification of the magnetic water treatment technique are highlighted.

Keywords: Magnetic water treatment, Electromagnetic water treatment, Scaling, Industrial wastewater, Water treatment methods.

Nomenclature:

MWT	Magnetic Water Treatment
EMT	Electromagnetic water treatment
MF	Magnetic Field
WHO	World Health Organization
MHD	Magneto Hydrodynamics
ELF-EMF	Electro Magnetic Field
LF-EMF	Low-Frequency Electro Magnetic Field

Greek Symbol:

σ	Cell wall conductivity
β_0	Magnetic field amplitude value
\vec{F}_A	Lorentz Force
q	Charge
\vec{u}	Velocity
\vec{B}	Magnetic Field

Introduction

Water is an essential need and abundantly available resource in the world (Umar DA, 2017). As per the reports submitted by the WHO, about 780 million people have faced the inadequacy of drinking water (WHO, 2011). The increase in population and prosperity has led to an increase in demand for quality water supply (Richardson SD, 2020). About one-sixth of the world’s populace is suffering from the unavailability of fresh water (Elimelech 2006). Contagion of water is a serious problem facing across the world (Fawell, 2003). The drastic increase in the world population and increased modernization results in an increase in water pollutants ultimately resulting in making water pollution one of the primary causes of concern for human beings Burke (2005). Developed countries suffer from chemical discharge and developing countries with agricultural sources. Leading to the contamination of the water resulting water born disease. Making it difficult to provide safe drinking water (Shannon et al. 2008). As per the reports submitted by the UN, it is noted that sewage, industrial, and agricultural wastes are discharged in water all around the world every day (UN WWAP 2003). Inorganic, organic, and radiological are three classifications of contaminants. When water consists of hardness in the range of 300-400mg/L is termed a feasible drinking water level (EPA US 2006; Nriagu 1988). The water containing the carbonate ions CO_3^{-2} termed as carbonate hardness. Combination other than carbonate ions comes under non-carbonate hardness. MWT has been regarded as showing potential results in treating water (Reimers, 1989). The MWT has been potentially used in treating wastewater in many industries even the nuclear industries are using the EMF in

filtering the nuclear reactor coolant (Bitton, 1974). The EMF technique is a recent trending technique that has shown its potential in treating wastewater (Francis Hartmann, 1972), (Kai-Tai Chang and Cheng-I. Weng, 2006). Scale deposits are a common problem resulting in the blocking of the water flow in pipes (Legrand, 1990). The MWT supports human health due to the exposure of the water to the magnetic field results in changes in the molecular structure of the water (Abdulmane, 2001.). The light electric charge of MWT with much more content of OH- causes an increase in the water alkalinity, enhancing all other properties of the water, making it much more suitable for human consumption and human health (Tischler, 2006), (Lam, 2001). The MWT is an anti-scale magnetic technique resulting in preventing and eliminating the scale formation on the water-carrying equipment (Bolto, 1990), (Yavuz, 2000), (Yadollahpour, 2014). The use of EM apparatus results in up to 70% reduction of the scale formation. There is not only a reduction in calcium carbonate deposits it is also observed that there is an alteration in bacterial growth, and adsorption of nutrients of crops by eh water that has been treated by the EMF process. Giving us clear-cut examples that the EMF treatment is beneficial in many different fields (Sergio Martínez Moya, 2021). The wastewater resulting from the mining contains large amounts of heavy metals which do not match the drinking water standards. Techniques such as ozonation and electromagnetic resonance help in removing heavy metals from the water (Veny Luvita, 2021). The treated water from the magnetic method when later boiled or heated it loses its tendency to form deposits of scales on the walls of the apparatus, pipes, etc. even if there is a formation of deposits they don’t stick to walls (Epuo, 2000).

Common Constituents are Found in Water and are Needed to Be Removed to Make the Water Feasible for Drinking.

Table. No.1: The water is only said to be feasible to drink when water is free from the constituents which are mentioned in the below figure (John C, 2021).

Typical constituents found in various waters that may need to be removed to meet specific water quality objectives ^a		
Type	Typical Constituents Found In	
	Ground Water	Surface Water
Colloidal Constituents	Microorganisms, trace organic & inorganic constituents	Clay, Silt, Organic materials, Pathogenic organisms, algae, other micro-organisms
Dissolved Constituents	Iron and Manganese, hardness ions, inorganic salts, trace organic compounds, radionuclides	Organic compounds, tannic acids, hardness ions, inorganic salts radionuclides
Dissolved Gasses	Carbon dioxide, Hydrogen Sulfide	c
Floating & Suspended materials	None	Branches, Leaves, Algal mats, soil particles
Immiscible liquids	d	Oils & greases

a – Specific water quality objectives may be related to drinking water standards, industrial use requirements, and effluent.
 b- Typically of anthropogenic origin
 d- Unusual in natural groundwater aquifers

Magnetic Water Treatment (MWT):

The water consists of atoms of hydrogen and oxygen and their molecules and an intermolecular force interlinks the molecules of hydrogen and oxygen which is reported to be the hydrogen bond. When the magnetic field is applied to treat the water, some research states that the magnetic field influences the hydrogen bond. As the magnetic field increases the weaker the hydrogen bond becomes. Whereas some other research states that the magnetization of water makes the hydrogen bond stronger. And some other researchers state that with the magnetic water treatment, the hydrogen bond becomes more stable. It is seen that properties such as the intensity of the MF, time period of process, temperature, and flow rate affects the structure of the water. These characteristics influence the water structure in making the hydrogen bond weaker or stronger or more stable. The basic principle that lies behind the magnetic water treatment method is the water is passed through the magnetic field. When the water is passed through the magnetic field the change takes place in the behavior of water molecules and salts resulting in a change of the substantial and element properties of the water (R. Cal, 2009). With the effect of the depolarization of water molecules, the magnetic field shows a direct impact on the structure of the water. Theoretically, each water molecule is contemplated to be charged dipole. When the water is made to flow through the magnetic field. The water molecules flow perpendicular to the direction of the MF. A Lorentz force is produced in the vertical direction and it tries to deploy the water molecule which is in the x-axis. Now after escaping from the X-axis when the water molecule moves to the Y-axis then the Lorentz force deploys the water molecule from the perpendicular direction. In the same way, the water molecule is arrested from all three directions X, Y, and Z. resulting in the inhibition of the moment of the water molecule perpendicular to the magnetic field. There the whole process results in making the water molecule move only along one direction that is along with the direction of the magnetic field. The process we stated before the process makes the water molecule sandwiched between the magnetic poles. The MWT method is best suited for flowing waters. (Oleg Mosin, 2013).

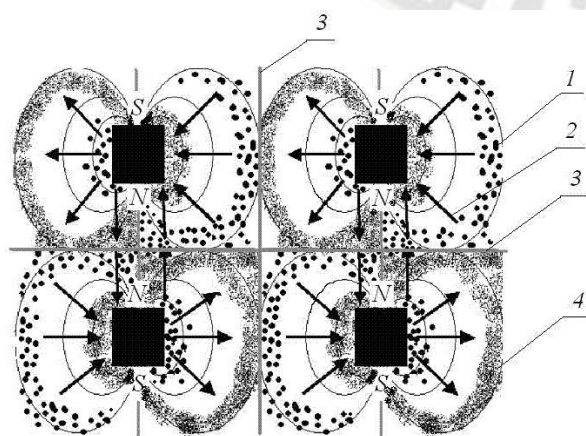


Figure.No.1: Showing the layout of the magnets in MHD-cell (Oleg Mosin ,2015)

1 – anions, 2- Induced current direction

3- Zero induction zone, 4 -Cations

It is advised while designing the magnetic devices the specification for device performance, amplitude, the strength of the magnetic field, speed and passage time of the water, etc are needed to be considered (Mosin, 2012).

Classification of MWT:

- Direct Purification
- Magnetic Flocculant

In the direct purification method, the anti-scaling technique is used in most cases. In the magnetic flocculant, MF is applied to form an insoluble sudden rush resulting in reducing the oil and suspended solids in water (Nishijima and Takeda 2007). Sorbent magnets are used in treating wastewater consisting of ions that are difficult to coagulate (Kakihara et al. 2004).

Mechanism of Magnetic Field Action on Water:

Magnetization is a unique somatic property that helps water which has the capability to influence the physical properties of the impurities of the water. This technology is been there around the world for 100 years. The magnetic field is generated and exposed to the fluids which contain the cations such as Ca^{2+} , Mg^{2+} , Fe^{2+} , Fe^{3+} . The MF is produced using permanent magnets or electromagnets. When the magnetic field is applied to the water there occurs a change in the structure and its components of the water. The dissolved salt nucleation is increased and dispersion of ferro particles into the local volume of water is seen. There is a change that is seen in the congealing and deposit rates of the scattered particles under the treatment of MWT method. This change results in losing the ability of calcium and magnesium salts to form dense deposits and adhere to the walls of the equipment. The whole process of the magnetic water treatment method when it comes to its usage in industries is done to reduce the formation of scaling while it depends on the strength of the magnetic field, the composition of treated water, fluid rate, and duration of fluid under the magnetic field (Oleg Mosin, 2014).

Configuration Of Magnetic Assemblies:

For permanent magnets, there are different alignments of MF referring to them as class I, II, III, and IV for both intrusive and non-intrusive systems. With the application of a MF parallel to the fluid flow in classes I and IV the application of a MF is orthogonal to the fluid flow as shown in the below figure (Sergio Martínez Moya, 2021).

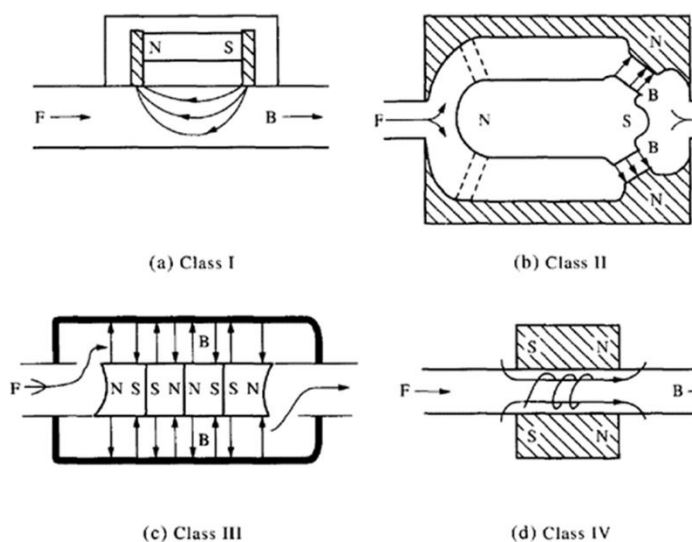


Figure. No.2: Magnetic field alignment (Gruber,1981).

Design of MWT System:

There are two types of magnetic water treatment devices. In these devices, permanent magnets are used operation is carried out using the alternating current solenoid electromagnets. Furthermore, hydromagnetic systems and transducers come under the subdivision of these devices apart from this water series activators are used for both industrial and domestic usage. Most of them are analogous in design and working principles. The devices are mounted on the walls of the pipeline where the fluid flows.

Permanent and superconducting magnets are the two types of magnets that are used in the MWT. The permanent magnets are made up of iron, nickel, and cobalt having the ability to produce an MF of less than 1T with increasing technology the MF capacity of magnets is being improved (Zhu and Halbach 2001); (Iwashita et al. 2008). The superconducting magnets highest MF between 5T – 10T more than the EMT (Selvaggi et al. 1998; Yan et al. 1996). There is a little aggregation effect seen in the static flow under the influence of the MF. Whereas the aggregation effect was seen in the flowing fluid (Tombacz, 1991).

Electromagnetic Techniques (EMT):

The EMT for treating the water is an extended technique of the MWT technique. The EMT of water is another way of MWT technique for treating the water. The setup consists of a nickel-galvanized iron casing with a steel plate inside. The pulsating field is produced by the solenoid which is an electromagnetic coil. The efficiency of the electromagnetism apparatus is verified by the computer-aided simulation process. The electromagnetism apparatus reduces the carbonate deposits. The below figure shows the most common design that is in use for electromagnetic field generation (Sergio Martínez Moya, 2021).

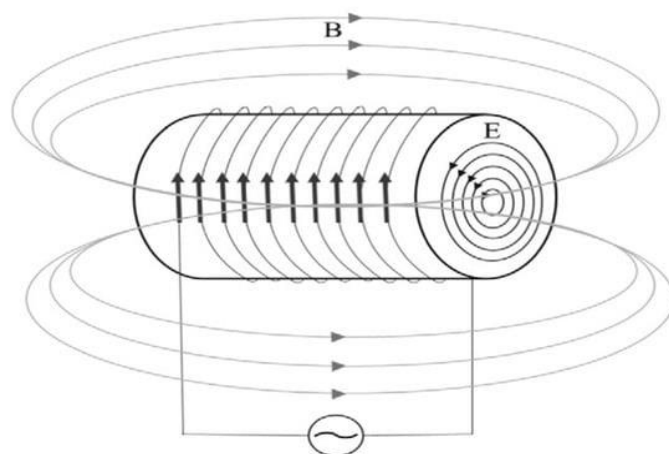


Figure. No.3: Showing EMF field generator (Sergio Martínez Moya, 2021).

All the apparatus that has been used are mainly solenoid-based apparatus for which the electricity is passed. Though the apparatus is solenoid base apparatus the fluids that have been used differ from water to seawater (Sergio Martínez Moya, 2021).

Mechanism Behind the EMF:

The EMT technique of treating the water is a resonance-based technology. The behavior of protons and molecular bonds of water is exploited. The behavior of the proton is usually gets influenced by some amount of frequency when it is disturbed by another magnetic field which also possesses some amount of frequency with a rule that both the frequencies are in opposite directions rather than being parallel to each other. This is the basic formula that is adopted in the EMF water treatment technique. This process results in the clustering of the water molecules and this process continues until the pure water gets higher and is not obstructed by integration materials (Francis Hartmann, 1972), (Kai-Tai Chang and Cheng-I. Weng, 2006). The electricity generated by the solenoid cell can generate MF ranging between 2-4T (Li et al. 2007) (Timoshenko and Ugarov 1994).

The moving water possesses the electro conductivity resulting in the generation of small electric currents by the MF compared to the water which is fixed, making the moving water more suitable for EWT (Shchelokov, 2002). Commonly the EWT apparatus consists of a magneto cell in the hollow cylindrical format manufactured from a ferromagnetic material consisting of magnets within it Koshoridze & Levin, (2009). When electrically conductive water is made to flow in the Magento dynamic cell results in producing the Lorentz force whose value is dependent on the charge (q), velocity (u), and magnetic field (B) whose expression is given below

$$\vec{F}_A = q \cdot \{\vec{u} \times \vec{B}\}$$

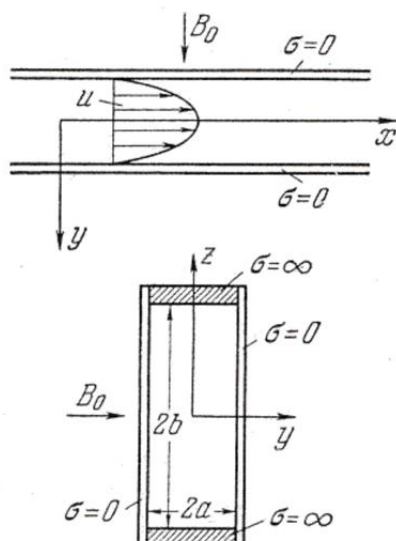


Figure. No.4: Showing the water flow – MHD- cell (Oleg Mosin ,2015)

β_0 – Magnetic field amplitude value
 σ – Cell wall conductivity

Electromagnetic Device:

There are many EMT devices available in the market that are showing good results for example let's take the EM device Aqua – 4D, 60E. The Aqua 4D follows the technology of quantum physics and electrodynamics. This EMT device is introduced by the Swiss company Aqua-4D water solutions. The device consists of an electronic box which already programmed to produce the EM waves. Another part of this device is the treatment unit which is designed with the purpose to transmit electromagnetic waves into the water. Every treatment unit consists of 2 separate coils which dispersed the electromagnetic waves in the water. The device works on low EM fields of about 10V and low frequencies ranging between 0kHz to 10kHz. Two harmonic frequency waves are enforced simultaneously (G. Merlin, 2015). The below table shows the different EM apparatuses that have been used in the different research studies with the ranging frequencies between 0.05 to 400kHz.

Low-Frequency EMF for E. Coli Removal:

The low magnetic frequency of about 50 – 60Hz has been in use in killing the bacteria in the water. This is the process where the EMF is introduced to treat the water rather than adopting the chemical process to treat the water. A non-chemical method using a magnetic field to treat the water has been a positive effect on removing the number of bacteria from the water.

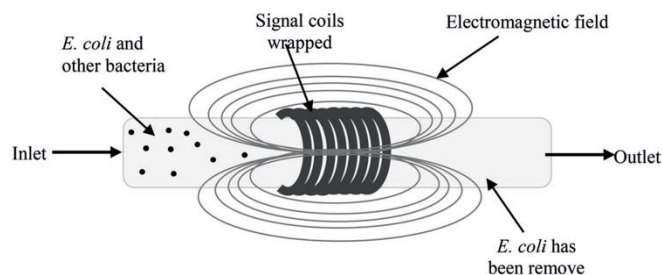
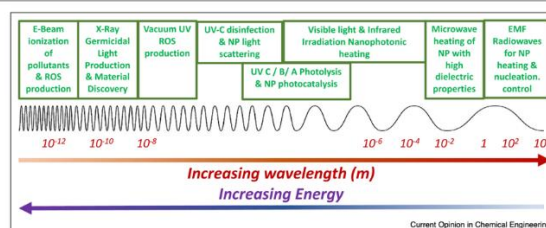


Figure. No.5: Showing Electro Magnetic system for water treatment consists of a magnetic field of coils wrapped around a pipe (Rossitah Selamat, 2019)

Here, E.coli is a type is bacteria. It is believed that the ELF-EMF wave can kill the bacteria such as E.coli and others with varying frequencies. The effects of the EMF depend upon the type of bacteria, intensity, etc. Treating water through a magnetic field is a non-chemical method and has been showing good results in treating the water by removing the bacteria present in it (Torgomyan H, 2011).

Use Of Nanotechnology in Producing Energy Around the Electromagnetic Water Treatment Method:

The cost of the EMT technique still remains a cause of concern. To overcome this nanotechnology has been tested and the procedure is as follows. Nanomaterials are made to interact with the higher-value energy-efficient ranges of the electromagnetic spectrum ranging from 250nm. This process is taken place through radio waves ranging in value in order to target water pollutants. The physical and chemical properties of the nanomaterials are highly tunable properties that can capture the energy, redirect the energy and utilize the energy around the electromagnetic spectrum (Paul Westerhoff, 2021). It is a fact that the bacteria such as DNA and RNA absorb light ranging from 230nm to 280nm (Beck SE, 2018), (Beck SE, 2017). The ability of light to spread to larger areas using the optical fibers the same principle is taken into use and is coated with the nanoparticle SiO₂ resulting in the formation of the blazing stick when the bacteria try to absorb the light then it also absorbs the nanoparticle which is coated on the optical fiber and gets destroyed hence the growth of the bacteria is stopped (Lanzarini-Lopes M, 2002).



Electromagnetic spectrum ranges that can be used in conjunction with nanotechnology to enable disinfection, pollutant oxidation or reduction, and localized thermal driven desalination (frequency $f, Hz = C/\lambda$, where the C is speed of light $(3 \times 10^8 \text{ m/s})$ and λ is wavelength of energy (m); Hertz (Hz) have units of sec^{-1}).

Figure. No.6: Showing Use Of Nanotechnology in Producing Energy Around the Electromagnetic Energy (Paul Westerhoff, 2021).

Relationship Between Magnetic and Electromagnetic Field Treatment Methods:

The main difference between MWT and EMT is that in the EMT method, electricity is used in producing the magnetic field. Producing the electromagnetic field is common in both methods. Magnetization is common in both methods. Permanent magnets or electromagnets are used in producing electricity (J. F. Grutsch, 1977), (J. F. Grutsch, 1984). In the below figure, we can see the two devices through which the magnetic field is produced that are either by an electromagnetic method which is coil based device or the other is a permanent magnet-based device.

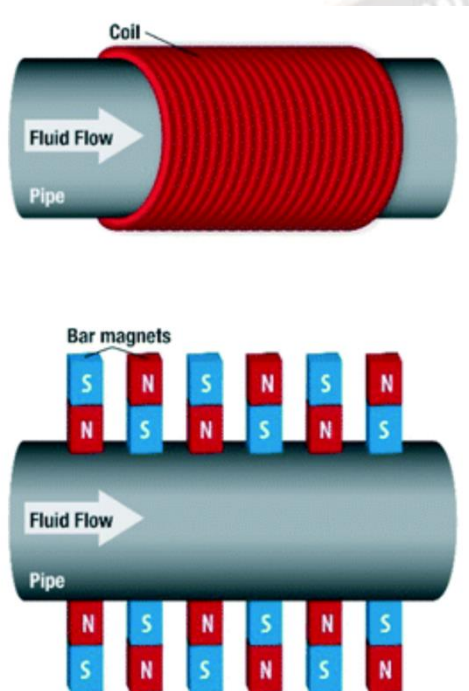


Figure. No. 7: Showing the devices used for producing the magnetic field (Adetunji Alabi, 2015).

When it comes to the electromagnetic method the magnet field produced depends upon the number of coils that have been placed in the device. So basically, the number of turns of the coils makes a huge difference in producing the magnetic field but when to the magnetic method of treating the water the magnet field strength depends on the arrangement of the magnets. The placement of magnets with alternating poles and some are not placed without alternating poles. The number of magnets may also make a difference in producing the magnetic field strength. The necessary setup is set up with one goal in common in both methods is to produce the magnetic field. Apart from the basic principle which lies behind these methods when it comes to the devices which are helping to achieve the process then the devices are sometimes designed customized or prepared by the manufacturer. Again, it is a notable point when a device is available in the market it means that the device is capable of conducting the particular

task for which it has been manufactured for. If the apparatus for the methods is from the manufacturer's side, then the manufacturer provides the essential data regarding the placement of the apparatus, duration, etc., Now when it comes to the magnetic field that is produced by the devices it may be static or pulsating. The direction of application would be in the same direction as the flow or it may also be in the opposite direction flow of water depending upon the type which has been adopted in the apparatus (Adetunji Alabi, 2015).

Benefits Of Magnetic Water Treatment:

The MWT/EMT is mainly used in treating wastewater treatment as it has shown potential results in treating industrial wastewater. The particles which are in the suspension with higher receptiveness are made to flocculate along with the weak magnetic and non-magnetic filters resulting in the formation of the magnetic filter (Ying, 2000). The process is common in treating industrial waste water as it is capable of removing chemicals and ultrafine minerals such as phosphate (Shaik, A.M, 1992), Hematite, chromite (Wang, Y., 1994), and heavy metals (Terashima, 1986), etc. But they have their own disadvantages such as setting up the process in practice is difficult, High cost, and the high amount of sludge mass (Cooper, 1993). The MWT/EMT has shown its potential in steel packing systems in removing the organic compound and phosphorous from domestic wastewater resulting in a potential water treatment technique for treating the wastewater (Ali Yadollahpour, 2014). Chemical reagents are a common method that has been used the wastewater and it has shown potential results in delivering accurate results. Precipitation of phosphate ion is initiated by the reactive chemical reagents from the fluids in the form of soluble salts sometimes absorption components when they combine with the phosphate ion. Aluminum (Al), Iron (Fe), and calcium (Ca) salts are commonly used compounds. Commonly known as the activated sludge methods which are complicated but are suitable for the microorganisms (Fuskase. T, 1985), (Clark, 1997). The water is stated to show improvements in the physical properties of the soil (K.A. Al Mosawi, 2019). Magnetic water has shown better results in seedling growth (X.Liu, 2019). Apart from showing many positive effects. The magnetic water treatment influences the soil properties and has also shown a reduction in the salinity and pH values of irrigated soil (M. Khoshrbesh, 2011), (A.A.M. Al-Ogaidi, 2017), (M. Hachicha, 2018). The magnetized water has helped in improving the soil moisture up to 7.5% compare to the soil which is subjected to untreated water (B. Mostafazadeh-Fard, 2011). Better leaching effects and better retention of water are seen with the adoption of magnetic water treatment (M. Moussa, 2020). MWT/EMT results reduction in the hydration of salt and salt solubility is enhanced along with coagulation and crystallization (Abedinpour, 20117). MWT/EMT water treatment has shown potential results in removing of the scale (Adetunji Alabi, 2015).

Factors Affecting the Magnetic Water Treatment Methods:

Scaling:

When there is a change in pH, temperature, change of pressure which affects the solubility of water results in the formation of the scale commonly referred to as fouling. The most common constituent which is formed in the scaling process is calcium carbonate (J. S. Baker, 1996), (M. Crabtree,1999) Other than magnesium carbonate, calcium sulfate, strontium sulfate, barium, and iron sulfate, including the silicates and phosphates of oxides. Formation of the scaling happens when the water comes in contact with the rocks and other sediments which are present in the surrounding environment resulting in the hardness of the water below-given figure shows a sample of the formation of the scaling (Adetunji Alabi, 2015).



Figure. No. 8: Showing the formation of scale on pipe (Adetunji Alabi, 2015)

Industries such as desalination, oil and gas, petrochemical, etc. are facing the problem of scaling. The formation of scales creates problems by blocking the pipes and interrupting the flow of fluids. The formation of scales reduces the life span of the boilers resulting in an increase in the cost of maintenance sometimes failure of the apparatus is also seen (A. Antony, 2011).

Table. No. 2: Showing costs bearing by a few countries due to fouling (J. MacAdam, 2004)

Nation	Cost caused due to Fouling (Million US \$)
UK	700-930
USA	8000-10000
Japan	3062
Total Industrialized world	26,850

Water Hardness Level:

Figure. No.3: Showing the hardness level of water (N. F. Gray, 2008)

Concentration of CaCO ₃ per ppm	Hardness Level
0-75	Soft
75-150	Moderately Hard
150-300	Hard
350>	Extremely Hard

Magnetic Field Treatment on Scale Removal:

Magnetic field treatment has been there for around a century in treating scale scaling in industries. Seeing the potential of magnetic water treatment methods there are magnetic water treatment devices launched in the market to treat the water.

Surface Tension:

When the surface tension was observed using both the solenoid cell and permanent magnetic method. It is observed that there is a reduction in the surface tension of the hard water when the electromagnetic method is used. The hardness of the water seems to be affecting the efficiency of the solenoid cell. The possible reason that has come forward is an increase in the collision number of ions leading to bulk precipitation. As per the dye injection test results, it is evaluated. The faster fall of dye drop samples of the MWT shows that there is a reduction in the surface tension of the hard water when it is passed through the electromagnetic water treatment device for a longer period (Y. I. Cho, 2009). The treated water samples have shown unstable surface tension whereas the untreated water samples have shown stable surface tension with respect to time (M. C. Amiri, 2006). There was no difference in physical and chemical properties of the water which is treated through the magnetic water treatment method the reason for which remains unexplainable (E. Gruber,1981). The MWT helps in reducing surface tension (Forsythe J, 2023).

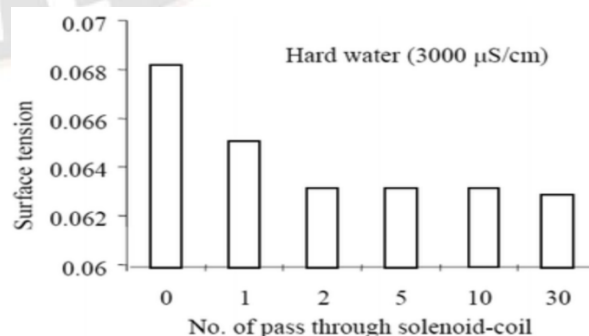


Figure. No.9: Showing the reduction in the surface tension with the electromagnetic water treatment (Y. I. Cho, 2009).

Zeta Potential:

The parameter which shows the characterization of the electrochemical equilibrium on borders is called zeta potential (Adetunji Alabi, 2015). The research suggests that there is no influence of zeta potential on the water samples which have undergone the magnetic water treatment (S. Knez, 2005).

Conductivity:

When it comes to the conductivity of the water which has been treated by the magnetic water treatment methods. The research outputs on the conductivity vary some researchers have stated that there has been a reduction in the conductivity in the hard water which has been treated through the magnetic water treatment methods (X. Pang, 2008). Whereas some researchers have stated that the conductivity has increased with the use of MWT methods (79,81 X. Pang, 2008, S. I. Jeon, 2001).

Bulk Precipitation and Coagulation:

Many research reports suggest that the MWT shows an effect on the bulk precipitation and coagulation of the hard water. The MWT reduces the calcium carbonate solubility and increases the bulk precipitation. The EMF method increases the number of collisions between the calcium and bicarbonate ions resulting in the occurrence of precipitation in bulk solutions instead of adhering to the device walls (F. Alimi, 2009). The bulk precipitation and coagulation also depend on factors such as duration, pH, the Flow rate of fluid, etc. (J. S. Baker, 1996). The effect of MWT is unnoticeable below the 25^o C between the temperature 30^o C to 50^o C a wane in MWT is seen and when the temperature is above 50^o C the change that has been seen at the temperature between 30^o C to 50^o C will disappear (K. Higashitani, 1998).

Temperature Effect: Rotational motion is seen in the positive and negative charges due to the thermal tension leading to the formation of the Lorentz force due to the formation of the electric current for a short period of time due to which change in the chemical and physical characteristics of the water (H.B. Amor, 2018). It is seen that when the temperature of the water is increased the magnetization period on the water is reduced. Resulting in the temperature increase results in a reduction in the MF intensity (Redouane Mghaiouini, 2020).

Supersaturation:

The concentration of the calcium carbonate when the MWT is performed were ranging from 250 – 400ppm. 350ppm is the maximum amount that has been reported. When there is a high amount of calcium ions in the solution results in an increase in the number and size of the crystals (S. A. Parsons, 1997). When there are high levels of supersaturation then the MWT becomes unproductive (J. D. Donaldson, 1988). There

are many factors such as magnetic field strength, Duration on the nucleation and crystallization of CaCO₃(S. Kobe, 1993).

Magnetic Field Duration:

The time the water is exposed to the MWT plays a vital role in achieving the desired results. It is reported that with the increased duration of the treatment, there is an increase in the efficiency of the MWT (S. Knez, 2005). The MF effects in changing the properties of water such as boiling point, and specific heat (Youkai, 2018). MF shows no effect on altering the chemical characteristics of treated water (M. Gryta, 2011).

Nucleation Rate:

The research has reported that there is an increase in the rate of nucleation and formation of the crystals with a reduction in the mean size of the crystals (H. E. L. Madsen, 1995). The application of the MWT method increases the particle size along with the number of particles in the solutions (S. A. Parsons, 1997). Larger the amount size of particle lesser the surface charge they possess which in turn results in a lesser tendency to stick to the walls resulting in the reduction of the scaling (J. D. Donaldson, 1994).

Effect pH:

The reduction in pH values results in a reduction in the scaling and when the pH value increases then the scaling also results in the increment (D. M. Dawson, 1990).

Flow Rate of Water:

When the MWT is applied the rate of scaling is dependent on the flood frequency of the water (S. A. Parsons, 1997). When magnetic water treatment has been applied it is observed that there is an increase in the rate of flow of the fluid along with the duration of magnetic water treatment (A. Fathi, 2006). When the flow rate is about 1.3ms⁻¹ results in the reduction of scaling up to such level where the water is clearly said to be scale-free water (A. Shahryari, 2008). It is seen that the MF decreases with the decrease in the flood of water. The velocity of the water and the MF are directly proportional to each other (Redouane Mghaiouini, 2020).

Effect of Water: The water naturally possesses a magnetic charge in it but as the water passes through different environmental conditions water loses its magnetic charge. Treating the water under the MWT method the water regains the magnetic charge that it naturally possesses. The increased percent of (OH)⁻ ions result in the reduction of the acidity in the water which is treated under the MWT (Forsythe J, 2023).

Polymorphism Of Calcium Carbonate:

The behavior of calcium carbonate crystalline does affect the magnetic water treatment method. Magnetic water treatment helps in the consistent precipitation of calcium carbonate when they are in the crystalline state (87 A. Fathi, 2006). There are two types of calcium carbonate that are formed one is calcite crystals and the other is spherical shape calcite. Crystalline types of calcites are found in most of the deposits. The scales which are formed on the surface of the heat exchanger are determined to be spherical-shaped calcite which is formed at temperatures $60^{\circ}C$ (37 S. A. Parsons, 1997). $CaCO_3$ is the most common mineral that forms in the form of scale. The formation of calcite is in the crystal form whereas the formation form of aragonite forms in the form of loose bundles of crystals in the shape of a needle (Rudert, 1982). When static solutions of Sodium carbonate and calcium chloride are under the MWT in the range of 2700G then reduction of mean crystal size of $CaCO_3$ is observed (Wang et al. (1997). Under 8000G MF even smaller $CaCO_3$ crystals are detected. The nuclei formation is the cause for the formation of a smaller $CaCO_3$ crystals which are caused due to the faster transformation of proton ion from the bicarbonate ion water under the effect of the MF on the rotation of the proton (Madsen, 1995).

The Magnetic Method In Comparison With Other Methods:

The magnetic water treatment method compared to other methods is simple along with being economical and ecologically safe. In countries such as Russia and Bulgaria about 80% of water concerns are related to calcium carbonate and magnetic water treatment is proven to be the most efficient technique in treating such water. The formation of different chemicals in the water in the industrial secretions deteriorates the thermal apparatus. The magnetic water treatment method has shown its potential in reducing the corrosion of steel pipe systems and other thermal power apparatus (11 J. MacAdam, 2004).

Draw Backs of Magnetic Water Treatment:

There are some cases where the MWT have not shown better results when they are installed in real-time. Though the purposes for their inefficiency are still unknown (J.S. Baker, 1996). Drawing conclusions based on the tests carried out on laboratory or industrial-based trials has been opposed at some times (Busch et al., 1986).

Conclusion:

The MWT is a potential water treatment method. The MWT is there around for a long time but with increasing technology, the advancement in MWT has also taken place in the form of EMT. The EMT is an improvised method of MWT. The Mean difference between the EMT and MWT is in the EMT method

the magnetic field is produced electrically. Both the MWT and EMT work on the common ground that is treating the water by producing a magnetic field. No matter whatever the advancements that take place in the MWT method the core principle that is treating the wastewater using the magnetic field remains the same. The advancements will continue to take place in MWT mainly focusing on improving the intensity of the magnetic field. There are some debates that show that the MWT has not shown the proper results in regard to treating wastewater. It is believed that the MWT changes the quality of water without affecting the chemical and physical characteristics of water but it is also a fact that when the temperature of water is raised then there could be a change in the chemical properties of the water. in spite of all this the MWT has shown its potential in different fields such as agriculture, Industrial, Medical, Mining, etc., Seeing the potential of MWT there are a number of MWT devices available in the market. The MWT device should be taken considering the required MF intensity for treating the water and also by considering the factors which influence the functioning of the MWT which are mentioned in the paper. Seeing the potential of MWT which it has shown in many different fields it is highly recommended that MWT is a potential method for treating the water.

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