EXPERIMENTAL ANALYSIS OF THE MAGNETIC FIELD ON CALCIUM CARBONATE SCALES IN RUNNING WATER

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By

Rishabh Singh

Roll no-1180456003

Under the Supervision of

Amrit Anand Dosar

BBD UNIVERSITY

School of Engineering

BABU BANARASI DAS UNIVERSITY LUCKNOW

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CERTIFICATE

It is certified that the work contained in this thesis entitled **"Experimental Analysis of the Magnetic Field on Calcium Carbonate Scales in Running Water"**, by Rishabh Singh (Roll No. 1180456003), for the award of Master of Technology from Babu Banarasi Das University has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

Signature

Amrit Anand Dosar

Assistant Professor

BBDU, Lucknow

Date:

ABSTRACT

This paper focus to show that the circulation of water in a permanent magnetic field having flux density of 0.57 Tesla reduces the nucleation induction time and extent of decline of total alkalinity, inhibits reducing of electrical conductivity, TDS removal efficiency and increment of the pH level. Magnetic treatment increases the nucleation rate of calcium carbonate, and inhibits crystal particle growth. The effect is more pronounced for homogeneous nucleation. The effect of water velocity at 7l/min showed higher concentration of Ca^{+2} and Mg^{+2} in effluent of water sample compared with 5l/min. The magnetic field inhibits bicarbonate content to decrease, and thus inhibits formation of calcium carbonate. Magnetic field significantly reduces turbidity. The circulation of water in a stationary MF enhances the removal of scale in water pipeline. With higher magnetic field intensity and higher water flow velocity, the rate of scale removal from the water pipeline is higher.

ACKNOWLEDGEMENT

Firstly I bow my head in the name of **"God"** the most beneficent and merciful. With respect. "What is important is to keep learning, to enjoy challenge, and to tolerate ambiguity. In the end there are no certain answers." Above all, I owe my deep sense of gratitude to **"Lord shiva"** the omnipotent, omnipresent and omniscient for showering His blessings, mercy, guidance without which this task would have remain a mere dream. All is possible for him that believeth, who has a definite goal backed by the determination to achieve it, no matter what the odds or obstacles.

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CHAPTER- 1
INTRODUCTION

INTRODUCTION

The expectation, observing, and outcomes of $CaCO_3$ arrangement have for quite some time been a key issue in consumable water treatment. An early concern was that waters exceptionally under soaked with $CaCO_3$ would be destructive to metallic and solid funnel foundation (Baylis, 1935), and for waters profoundly supersaturated with $CaCO_3$, issues identified with scaling (i.e., pipe stopping up, head misfortune, higher warming expenses) are the essential concerns (Garrett-Price et al., 1985). In the 80+ years since the milestone contemplates looking at these issues were distributed, numerous progressions have happened that can significantly modify the probability of $CaCO_3$ scaling in consumable water frameworks including compound consumption control, changing water radiator set-point temperatures, autogenous fix, a dangerous atmospheric devation, biofilm development, and disintegration erosion. This audit is planned for summing up these progressions and featuring their reasonable ramifications for water utilities, controllers, building administrators and buyers.

As indicated by (Magnetic Water clarified, 2007) a great deal of the doubtful examinations are done in the premiums, or under the weight of large substance organizations who remain to lose a huge number of dollars if new options are produced for the treatment of hard water, green growth and microscopic organisms related conditions. While most science researchers (who have insignificant involvement with attraction) appear to accept that polarizing water will have no impact and is a "quack remedy" trick, the victories can't be not entirely obvious. The cases, whenever demonstrated right, offer immense advantages for significant businesses around the globe. It ought not be an instance of "once demonstrated right then we will examine it", yet an instance of "we should consider this till we demonstrate it doesn't work".

Attractive fields can change the physicochemical properties of water atoms when the water test went through an attractive field. Hence, it will assist with forestalling the crystallization of calcium carbonate in water test and this prompts forestall the development of in water pipeline

The development of scales inside cooling water channels and evaporator dividers is a typical and expensive issue for some modern procedures. Albeit a few strategies have been utilized for scale counteraction, they for the most part causes some different issues, for example, significant expense of included synthetics, process water being contaminated by added substances, misuse of water by cleansing, and low effectiveness. Among these techniques, a progressively affordable and helpful strategy is the attractive treatment. Be that as it may, the counter scale attractive treatment has had along and questionable history **(Al-Malack *et al.,* 2001).**

Analyses were additionally acted in the lab to examine the attractive consequences for $CaCO_3$ nucleation and precious stone development through an increasingly precise methodology; in any case, clashing outcomes likewise exist in the writing.

Attractive water treatment doesn't change the science of water anyway it adjusts the structure of water as it were. Lorentz power is applied on water particles the redirection of particles will expand the recurrence of crash between particles to make a mineral accelerate or in dissolvable compound scale stores by regular waters for the most part bring about different specialized and efficient issues in modern plants and household instrumentality by obstacle the progression of water in channels or constraining warmth move in heat exchangers **(X. Zhu *et al.,* 1997).**

From the beginning of the century, differed synthetic or physical medications are anticipated to diminish scaling. Since the utilization of scaling inhibitors changes the water organization, they have to maintain a strategic distance from for drink conveyance. Determinate of water hardness is basic investigation for survey water quality on modern and local components.

Albeit numerous agents have demonstrated that the attractive impact is reliant on the nature and state of arrangement, for example, super immersion, pH, and ionic quality, a large portion of them have not controlled the arrangement properties in their investigations, aside from a couple of cases utilizing a pH-detail strategy.

MWT has been used in water treatment for different utilizations to found that mineral particles were seen as bigger and a great deal of much of the time disapproved in attractive water contrasted with typical water. Furthermore, MWT moreover extensively decreased assortment of unhealthful microorganism like E.coli, destructive infections, and alga found that field with productivity diminished shading content, absolute suspended strong (TSS), substance O request (COD) and torridness in biodegradable contamination.

Water used in exchange originates from waterways, lakes, wells and seas; it perpetually contains broke down and suspended solids. These solids add to water hardness that is evaluated as transitory and perpetual. Brief hardness is inferable from broken down bicarbonates in the water, chiefly calcium and magnesium, that can without much of a stretch be expelled by warming to separate them into carbonates which are insoluble and accelerate out. Changeless hardness, which is because of the nearness of solvent sulfates and chlorides of calcium and magnesium, can't be made insoluble by warming.

Scale stores can likewise build consumption, due to captured oxygen, and in light of the fact that the scale itself is in some cases destructive to the surface with which it is in contact. Likewise, scale will meddle with the activity of inhibitors in the framework, shielding them from responding with the surface beneath the scale. On the off chance that the scale is inconsistent, the differential air circulation between the perfect surface and the scale surface may make an erosion cell set up.

1.1Scaling

Scaling is the most evident appearance of $CaCO_3$ precipitation in consumable water frameworks, bringing about stream limitations in the framework by stopping up plumbing gadgets and making head misfortune **(Krappe, 1940; Crabtree et al., 1999).** $CaCO_3$ scaling is an issue in granular media channels, where its development can "concrete" together the channel bed making it hard to recover the media **(Logsdon et al., 2002).** Scaling is additionally a significant issue in present day channels, for example, turn around assimilation (RO) or ultrafiltration layers as it adds to film fouling (**Gwon et al., 2003).** The grouping of Ca^{2+} and inorganic carbon in the reject stream can prompt $CaCO_3$ encouraging on the layer surface **(Bremere et al., 1999)** and it is suggested that feed water pH is brought down to forestall scaling on the film and salt water release framework **(Seneviratne, 2007).** The expanded inclination of $CaCO_3$ to accelerate at higher temperatures makes scaling an inconvenient issue in boiling water frameworks, particularly in water warmer or water cooling applications in which scale layers meddle with heat move and framework effectiveness.

Water warming is very vitality escalated, and the complete vitality interest for building water warming frameworks surpasses the vitality interest for the whole water and wastewater utility segment **(Brazeau and Edwards, 2011).** It is evaluated that a hard water can bring down the warmth move productivity of gas stockpiling water radiators by 8.5%, and of immediate gas water warmers by 30%, over a multi year lifecycle if no conditioning or de-liming is rehearsed **(WQRF, 2011).** Mellowing hard water can decrease the existence cycle cost of quick gas water radiators by 22.5% and gas stockpiling water warmers by 6.6% over a multi year lifecycle (WQRF, 2011). The yearly expense of fouling for modern tasks in the U.S. alone was assessed in 1982 to be around $3-10 billion **(Garrett-Price et al., 1985),** including the expense of hostile to scaling programs, personal time for upkeep, lost creation, cleaning, higher vitality costs because of marked down warmth move, and over-measuring hardware where fouling is normal. The overall expense in 2000 was evaluated at generally $26 billion and $8-10 billion in the U.S. alone **(Müller Steinhagen, 2000).**

1.2 Benefits of Magnetic water treatment

The following are the most recognized benefits of magnetic water treatment for various water-using equipments **(Gabrielli *et al.,* 2001):**

- Prevents pollution
- Reduces energy
- Conserves water
- Saves time and money
- Lengthens service life of existing fluid movement equipment
- Eliminates existing chemical cost to inhibit scale
- Reduce the need for periodic acid cleaning
- Increasing protection against corrosion within the system
- Eliminates continual operating cost as compared to chemical system

Using magnetic water treatment, industrial and agriculture processing will change, and foods, cosmetics and sanitation, etc. might be improved. Different nonchemical methods of water treatment have been introduced to prevent scale formation. Examples of these technologies are those that are based on permanent magnetic, electromagnetic, electric, electrostatic, ultrasonic, radiation, etc.

1.3 Recent Trends Affecting CaCO3 Formation

In the last 50 years, the science and practice of consumable water treatment and circulation has changed notably in manners that can significantly adjust the degree of $CaCO_3$ arrangement and scaling in central pipes and reason plumbing pipe frameworks. Inorganic carbon breaks up into normal water frameworks from CO_2 in the air, and Ca^{2+} is discharged in characteristic waters through disintegration of minerals, for example, portlandite, gypsum, and dolomite that come into contact with the water (Table 1-1). De-icing salt can likewise contribute a huge number of huge amounts of Ca^{2+} to groundwater in areas where calcium chloride is utilized **(Houska, 2007).**

Table 1.1: Solubility of calcium containing minerals found in natural waters.

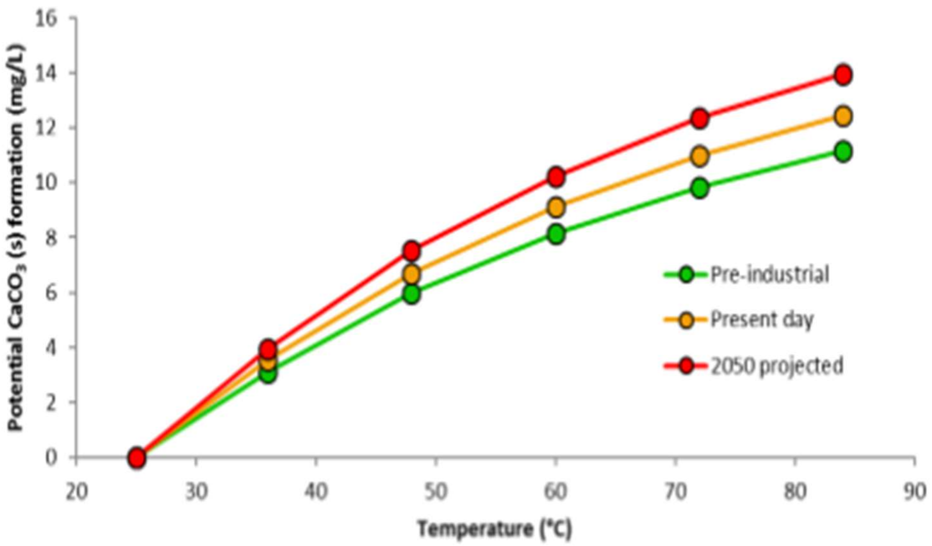
Minerals	pKsp (25 °C)	Reactions	References
Limestone (calcite + aragonite)	8.34 - 8.48	$CaCO_3(s) \rightleftharpoons Ca^{2+} + CO_3^{2-}$	Plummer and Busenberg, 1982
Portlandite	22.8	$Ca(OH)_2(s) \rightleftharpoons Ca^{2+} + 2OH-$	Brezonik and Arnold, 2011
Dolomite	17.2	$CaMg(CO_3)_2(s) + H+ \rightleftharpoons MgCO_3(s) + Ca^{2+} + HCO_3^-$	Sherman and Barak, 2000
Gypsum	4.16	$CaSO_4 \cdot 2H_2O(s) \rightleftharpoons Ca^{2+} + SO_4^{2-} + 2H_2O$	Brezonik and Arnold, 2011

$CaCO_3$ formation as a corrosion control method has fallen out of favor- Corrosion has taken a heavy toll on plumbing and distribution systems throughout the U.S. The cost of maintaining the aging drinking water infrastructure in the U.S. alone will exceed $1 trillion over the next 25 years (AWWA, 2012). The original basis for controlling or reducing corrosion in potable water distribution systems was based on the premise that a layer of $CaCO_3$ formed on pipe surfaces could almost completely protect all pipe materials from corrosive reactants in the water supply including oxygen and free chlorine. Numerous corrosion indices based on this hypothesis were formulated to monitor and control the supposedly protective carbonate scales including: Langelier saturation index (LSI), Ryznar stability index (RSI), Puckorius scaling index (PSI), Larson-Skold index (LI), and measurement of temporary hardness **(Langelier, 1936; Ryznar and Langelier, 1944; Puckorius and Brooke, 1991; Larson and Skold, 1958).**

Early on some of these indices were criticized because they oversimplified the process of scaling **(Wiggin *et al.*, 1938; Schneider and Stumm, 1964)**. Such views dominated potable water treatment until about the mid-1980s, when researchers studying corrosion began to notice that iron, lead, and copper corrosion had little to do with $CaCO_3$ precipitation, and a consensus emerged that the overall approach was without basis and should be abandoned **(Stumm, 1956; Larson and Skold, 1957; Schock, 1989; AWWARF, 1996).** However, that consensus neglected to consider the possible benefits of the approach in reducing pipeline leaks and extending lifetime of assets through autogenous repair processes or clogging (**Tang *et al.,***

2013). In practice, many water utilities continue to calculate and target specific levels of $CaCO_3$ saturation (or under saturation) for corrosion control.

Climate change may play a role in CaCO3 formation- Rising CO_2 levels in the atmosphere and more frequent and longer droughts caused by global warming can increase calcium levels in natural waters **(Anderson and Faust, 1972; Mosley, 2015).** Consequently, the $CaCO_3$ saturation index in potable water systems may also be rising. The net effect of these changes is as yet unclear. Some types of dissolved organic carbon (DOC) are known to be a $CaCO_3$ precipitation inhibitor **(Lebron and Suarez, 1996).** Although the major cause of increased DOC levels in natural waters is attributed to a decrease in acid rain deposition **(Evans *et al.*, 2006),** there is evidence that higher CO_2 levels leading to increases in primary productivity **(Freeman *et al.*, 2004)** and rising temperatures (**Freeman *et al.*, 2001**) also contribute to DOC release.



Impact of rising atmospheric CO_2 levels on $CaCO_3$ formation: Calcite at equilibrium with atmospheric CO_2 levels in the pre-industrial era, present day, and those projected for 2050. Higher atmospheric CO_2 can increase the precipitation potential. Using Mineql+, waters were equilibrated at $[Ca^{2+}]$ = 40 mg/L and $PCO_2 = 280x10^{-6}$, $390x10^{-6}$, and $550x10^{-6}$, atm. Using the equilibrium CaT, Alk, and pH from the open systems as starting conditions for the closed systems, the potential $CaCO_3$ formation at equilibrium was calculated for the closed systems.

Table 1.2: Recent phenomena and its effect on $CaCO_3$ formation

Phenomenon	**Effects on $CaCO_3$ formation**	**Research priorities**
Global warming	□ Greater CO_2 in atmosphere can raise or lower amount of $CaCO_3$ that could form. □ More severe droughts could raise Ca^{2+} in natural waters	□Experimentally alter $CaCO_3$ formation potential at varying PCO_2
Corrosion and scaling inhibitors	□ Phosphates added to drinking water reduce $CaCO_3$ formation □ Use increased in last 25 years, but pressure on industry to lower the dosage for cost and environmental reasons □ NOM is a scaling inhibitor, utilities are targeting it for removal because it is a precursor to DBPs	□ Find out how $CaCO_3$ precipitation is affected by higher and lower phosphate concentrations □ Effect of non-phosphate inhibitors on $CaCO_3$ precipitation
Raising water heater temperature	□ Home and building owners are raising water heater temperatures to control opportunistic pathogens. Higher temperatures increase $CaCO_3$ scaling potential	□ Improve water heater design to reach higher temperatures but reduce scaling potential
Autogenous repair	□ $CaCO_3$ formation could beneficially be used to seal leaks in plumbing and distribution systems □ Alter chemistry of drinking water to promote leak repair via $CaCO_3$	□ Examine the impact inhibitors have on ability to repair
Biofilm growth	□ $CaCO_3$ provides a surface for biofilm to grow on. Shields biofilm from antimicrobial plumbing materials	□ Determine health implications of $CaCO_3$ induced biofilm growth in domestic plumbing
Erosion corrosion	□ Small (< 2 mm) $CaCO_3$ particles and $CaCO_3$ scale released from pipe surface can cause erosion corrosion	□ Analyze flow patterns and plumbing design to mitigate erosion corrosion from $CaCO_3$

1.4 Controlling $CaCO_3$ precipitation through water chemistry parameters

Temperature- Reducing water temperature is very effective in reducing $CaCO_3$ scaling potential in potable water systems. First, the solubility of all $CaCO_3$ polymorphs (calcite, vaterite, aragonite, and amorphous $CaCO_3$) increase with decreasing temperature **(Clarkson *et al.,* 1992; Plummer and Busenberg, 1982),** causing less $CaCO_3$ to precipitate at lower temperature. Second, the reaction kinetics for $CaCO_3$ formation is much slower at lower temperatures **(Morse *et al.,* 2007),** thereby forming less $CaCO_3$ precipitates. Finally, polyphosphates, which are widely present in potable water systems and are stronger inhibitors for $CaCO3_3$ precipitation than orthophosphate **(Lin and Singer, 2005),** are converted into orthophosphate much faster at higher temperature through hydrolysis reactions (**Holm and Edwards, 2003).**

Water pH- Reducing water pH and removing dissolved Ca content can reduce scaling potential by decreasing the ion activity product ($Q = \{Ca_2^{+}\}\{CO_3^{2-}\}$). However, engineers should be careful when considering reducing water pH in drinking water systems, because the decrease in water pH might cause corrosion of metallic pipelines.

CHAPTER- 2
LITERATURE REVIEW

LITERATURE REVIEW

2.1 History of magnetised water

As indicated by **Brower (2005),** case narratives of the achievement of attractively treated water go back to 1803. The attractive impact was first recorded when there was an outstanding contrast in the surface of the mineral gathering within soup and clothing pots. These pots were set over flames and huge stones were set in the base to shield them from swinging in the blustery climate.

Allegedly, two of the five pots, which were totally produced using a similar cast iron metal, didn't have hard scale development. Rather, they had a delicate, fine substance which was forgotten about without any problem. It was later discovered that the two of the five rocks used to balance out the pots in the breeze were lodestones which are normal attractive rocks.

As indicated by the **Marshutz et al (1996**) Michael Faraday was the primary scientist who truly delved into magneto science starting in 1863. From 1890 and onwards, the subject of attractively treating water had gotten very disputable, and was marked "gadgetry" and "not supportable under logical examination". An organization called Solavite, situated in France, started to advertise a MTD in 1936. In the Eastern Bloc Countries, especially Russia, expanded research and uses of MTDs started after the Second World War. This was to a great extent because of the way that the U.S.S.R didn't have the synthetic skill or subsidizing to treat their water synthetically like that in the U.S.A. **(Lobley, 1990).**

Marshutz(1996) reports that in 1954 the Federal Trade Commission documented a grumbling against the Evis Manufacturing Company, which produced an early attractive water conditioner. They accused the organization of uncalled for rivalry and bogus publicizing by its rivals. Following broad hearings, the grievance was excused two years after the fact. Analyses and studies in the west expanded after various effective uses of MTDs came out of the U.S.S.R. By the 1990's, numerous believable establishments were exploring the subject with blended outcomes.

Today, there are various assortments of MTDs available to be purchased, extending from $100 up to $10000. The questionable discussion over the adequacy of polarized water is as yet unsure. There have been numerous effective mechanical uses of MTDs in the west, including frameworks for NASA, yet the treatment has not been discharged standard or acknowledged by the Water Quality Association **(Federal Technology Alert, 1996).**

2.2 Past analyses of charged water

2.2.1 Property Changes from MTD

1-pH change

Changes in the pH of refined water of up to 0.4 pH units have been accounted for by **Joshi and Kamat (1966).** Anyway **Quickenden (2002)** found no pH change in twofold refined water exposed to an extremely solid attractive field of 24 000 Gauss.

Tai et al (2008) refered to that Ellingsen and Kristiansen indicated that their water test's pH diminished from pH 9.2 to 8.5 after attractive treatment. (**Busche et al, 1985)** indicated an underlying diminishing in pH of 0.5pH units from 7.0 to 6.5, trailed by a steady increment for the duration of the hour of the examination to pH 7.5 – 8.0. Parsons et al (1996) likewise recorded a lessening of 0.5 pH units in the wake of going water through a MTD.

Yamashita et al. (2003) saw, what he considered, slow and huge pH vacillations (0.05 - 0.1) during the initial a few hours of attractively treating refined water. His outcomes demonstrated that to precisely assess the impacts of attractive fields on water, inconspicuous exploratory conditions, for example, field conditions delivered by normal lab gadgets and methods can't be disregarded. He likewise expresses that expanding estimations past a few hours might be fundamental to watch precisely the impacts of charging water.

From these analyses, it shows up the vacillations in pH change from trial to test propose that unanticipated cooperations are adding to pH change. While pH change might be a pointer for attractively treated water in certain circumstances, it can't be exclusively depended upon.

2-Physical Properties

It has been indicated that the water vaporization rate, a fundamental procedure for every organic procedure, is altogether influenced by the utilization of a static attractive as per **Nakagawa et al (1999).**

Studies by Lee et al (2003) and Iwasaka and Ueno (1998) have discovered that the size of the water bunches, changes when presented to an attractive field.

It has been accounted for by **Nakagawa et al (1999)** that the disintegration rate into water of oxygen is essentially quickened by the nearness of an attractive field.

Applying an expanding attractive field to water can likewise decrease basic super cooling and brief balance cementing when the quality of the attractive field is higher than 0.5 T as indicated by **Aleksandrov (2000).**

2.2.2 Scale Reduction

Scaling issues from hard water in warming or cooling frameworks can vigorously diminish the proficiency of the framework in two different ways. First it can diminish the warmth move rate with the development of a protecting store on a warmth move surface fundamentally decreasing the cooling or warming productivity of the hardware. Also it can square channels, condenser tubes or different openings diminishing stream rate and siphoning proficiency.

As indicated by **Smith (2003)** the cost required because of warmth move wastefulness and the evacuation of scale in Britain alone was assessed at £1 billion for every annum in the mid 90's. A 25mm thick $CaCO_3$ scale layer can diminish the warmth move by 95%,

Appropriately introduced and designed MTDs have had numerous achievements in diminishing the measure of scale develop in pipes. In an examination performed by **Smith (2003),** changeless magnets diminished the development of scale in 6 out of 6 high temp water stockpiling tanks with a normal of 34%. The most extreme decrease was 70% and the base decrease was 17%.

Lipusa and Dobersekb, (2007) accomplished victories, with the scale on a warming copperpipe winding being 2.5 occasions more slender because of Magnetic Water Treatment (MWT) contrasted and untreated water. Another significant contrast was found inside the outlet steel channeling where just a limited quantity of powder-like covering was found in the attractively treated line. This sum was irrelevant in contrast with the bottomless scale from the untreated water. Figure 2.5 looks at comparable steel pipes. Picture D shows diminished measures of scale develop due to MWT.

Kobe et al (2001) deduced in his examination that the synthetic treatment of scale was just partially better than the treatment with MTDs. **Busch (1997)** achieved a 22% decrease in scale utilizing falsely arranged hard water. **Parsons et al (1996)** recorded a 48% decrease in scale in his analysis.

An article by **Quinn et al (1997)** in the Iron and Steel designing diary expresses that at a steel plant, a 60-inch hot strip factory was tormented with long electrical postponements in light of lacking engine room cooling because of lime scale develop on the warmth exchangers. A warmth exchanger before the establishment of MTDs is appeared in Figure 2.6a. A half year subsequent to introducing the MTDs, no plant delays were credited to engine room cooling disappointment because of scale develop.

Krauter et al (1996) introduced a MTD Lawrence Livermore National Laboratory Treatment Facility D. At this office, unstable natural contaminants (VOCs) were expelled via air stripping, which raised the water pH, causing the statement of calcium carbonate as calcite scale downstream. The MTD was introduced before the air stripping unit and no gainful scale decrease was recorded by the examination.

Tai (2008) found in their examination that the precious stone development paces of calcite were stifled totally within the sight of the attractive field under low pH and supersaturating conditions. Paradoxically, the development rate appeared to increment at high pH and relative supersaturating.

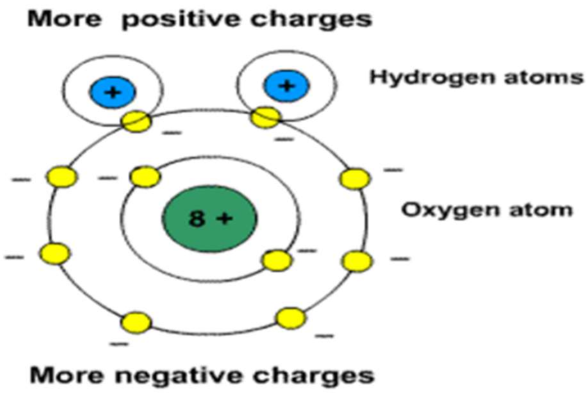
2.3 Current hypotheses of polarized water

The rule of this marvel is as yet not surely knew and different opposing theories have been proposed.

Brower (2005) clarifies that attractive frameworks treat water by going it through a multi-post, multi-turning around extremity attractive field. The dipolar developments of the particles of broke down solids and water atoms are influenced so that at the moment of precious stone arrangement, the gem structure is separated into flimsy layers and the particles adjust as indicated by a solitary attractive pivot. The attractive field at that point impacts the creation of an a lot more prominent number of cores. Henceforth, the solids encourage as a lot better precious stones, which will in general stay isolated due to the overabundance comparative charge. The calcium carbonate powder is presently in a slop shape and can be handily kept up as it won't adhere to components and channeling.

As indicated by The Department of Energy's Federal Technology alert (1998), the general working guideline for the attractive innovation is an aftereffect of the material science of cooperation between an attractive field and a moving electric charge. At the point when particles go through the attractive field, a Lorentz power is applied on every particle which is the other way of one another. The redirection of the particles will in general increment the recurrence with which particles of inverse charge impact and join to frame a mineral.

A diary article from **Quinn (1997)** clarifies the sub-atomic cosmetics of water and its extremity. A particle of water comprises of one molecule of oxygen and two iotas of hydrogen, H2O. The covalent bond that holds every hydrogen iota to the oxygen molecule results from a couple of electrons being shared. Figure 2.1 shows an atom of water.



Lower (2009) states passionately "The H_2O molecule is an electrical dipole, not a magnetic one; it is not a magnet, and is not affected by a magnet. Equating the S and N poles of a magnet with the [electrical] "potential" is pure fantasy."

According to **Quinn (1997),** the polar molecules attain different orientation under the influence of a magnetic field. The stronger the magnetic field, the greater the number of dipoles pointing in the direction of the field.

The unusual properties of water can be attributed to extensive hydrogen bonding between its molecules. It has been suggested that the molecules could form clusters as illustrated in Figure 2.2(a) .According to **Su & Wu, 2002,** these associations and disassociations of water molecules are in thermodynamic equilibrium. In general, each cluster contains about 100 water molecules at room temperature as shown in Figure 2.2(c). In a magnetic field, magnetic force can break apart water clusters into single molecules or smaller ones as shown in Figure 2.2(b).Therefore, the activity of water is improved. It should be noted that theories of water clusters are just that, theories and have not been proven yet, according to **Lower (2009).**

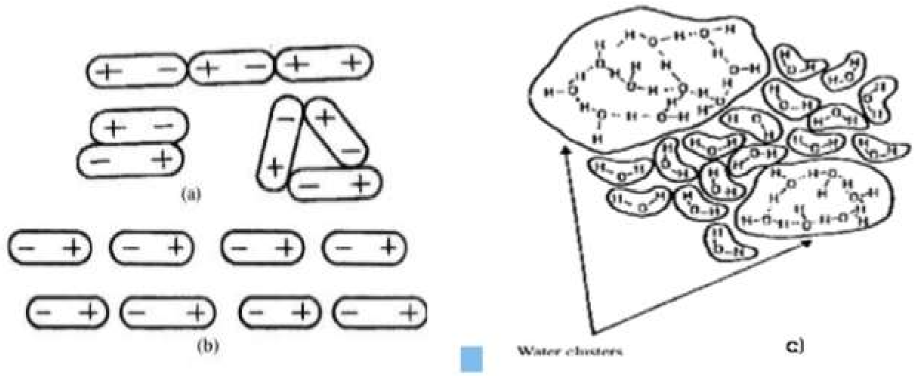


Figure 2. 2 Water molecules. Dipole Effect of magnetic field on water molecules: (a) thermodynamically stable water clusters, (b) water molecules after passing through a magnetic field. (Right c) Structure of molecule cluster of water.

In relation to scale reduction, according to several authors **(Higashitani *et al* 1993; Parsons et al. 1998),** the MWT would tend to reduce the nucleation rate and to accelerate the crystal growth. **Coey & Cass, (2000)** proposed the scale modification could also result from the preferential formation of the aragonite crystal structure instead of calcite. Aragonite, which may result from the transformation of metastable vaterite nuclei according to **(Gabrielli *et al,* 2000)**, exhibits a characteristic needle shape morphology with a rather weak adhesion to the substrate. Therefore, they could be carried away by the liquid flow. On the contrary, calcite which is the more stable calcium carbonate polymorph at room temperature forms dense and tenacious layers, which are difficult to remove mechanically.

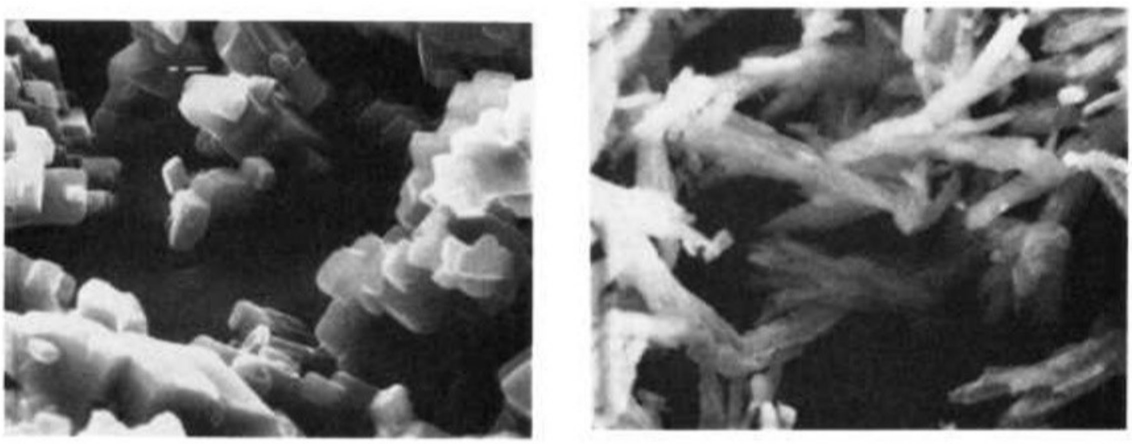


Figure 2. 3 (left) scanning electron micrograph of synthetic calcite crystals, magnified 4700X. (right) Scanning electron micrograph of synthetic aragonite crystals, magnified 6700X. (Ruth 1989)

It was advanced by **Busch, (1997**) that the magnetic effect concerns ferromagnetic impurities which are nucleation seeds. **Ruth's (1989)** research found similar results. They noted that trace concentrations of Fe^{2+} strongly inhibited calcite growth but not aragonite growth and trace concentrations of Fe^{2+} also inhibited the transformation of aragonite into calcite. A similar effect was observed with Fe^{3+} but to a lesser degree. They concluded that magnetic water treatment devices may be effective only to the extent that they cause an increase in the Fe^{2+} concentrations in treated water and that the Fe^{2+} in turn, inhibited scale build-up.

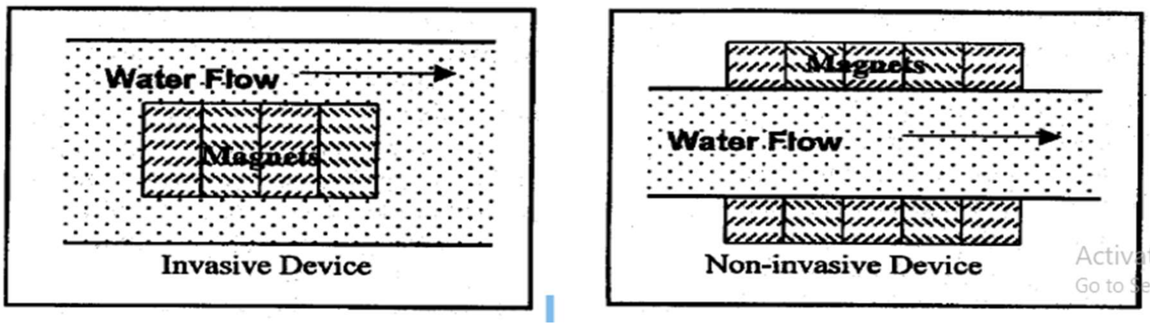
Gabriell *et al* (2000) noted however that the scale reduction effect also happened in non-conducting pipes and suggested that Busch's findings be revisited.

Other complex explanations revolve around Loretnz forces. **Higashitani (1998)** and double ionic layer surrounding the colloidal particles and their zeta **potential (Gamayunov, 1983; Higashitani, 1998; Parsons,1997).**

2.4 Optimum configuration of MTD's

Classifications of MTD's

Baker & Judd (1995) explains that commercial magnetic treatment devices (MTD's) are available in various configurations. As can be seen in Figure, MTD's are invasive (i.e. plumbed in, and therefore have to satisfy relevant legislation) or non- invasive (i.e. clamped on).



Gruber and Carda (1981) classified MTD's utilizing permanent magnets into four categories, each employing different orientations of magnetic field. Some units employ a field that is orientated approximately orthogonal to the direction of flow (class II and class III) whilst others employ a mostly parallel field (class I and IV).

CHAPTER- 3
MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Magnet and properties

In order to survey of magnetic field effect on hardness water reducing, has done water treatment experiment in presence of magnetic field.

3.2 The method of preparing magnetic field

The device is containing of magnets with dimensions 40mm length, 25mm breadth, 10mm thick of ferrite black magnet with north pole and south pole as shown in Fig 3.1, That have consoled in form of same axis and is create length equal 40mm length on the magnetic field.

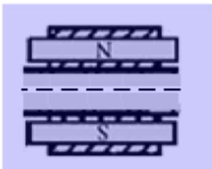


Fig: 3.1 Sample of magnet with north pole and south pole

For measuring magnetic field intensity of each magnet, we used the gauss meter. The magnetic field intensity of magnets is calculated the reading by gauss meter device and the magnets is 5700 gauss each.

3.3 Magnetic field

Permanent magnets of 5700 gauss were used during the experiments. Two pairs of magnet with north and south faces facing each other were associated at the surface of tube as shown in fig 3.2. In this position the induction of the MF was perpendicular to the solution flow. The water flow rate was about 5lit/min and 7lit/min. Each magnets was the assembly of two rectangular permanent magnets. The MF strength produced by each magnet was about 5700 (gauss).

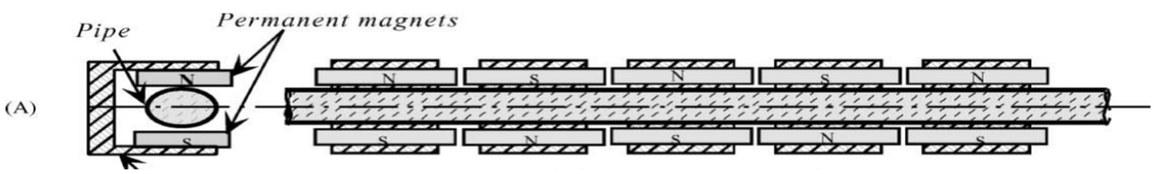


Fig: 3.2 Inverted Permanent magnet

3.4 Magneto hydrodynamics

Magneto hydrodynamics (MHD) is a branch of mechanics that deals with the motion of an electrically conducting fluid in the presence of a magnetic field. Therefore, the magnetic unit may be considered as a MHD device which is the key for the explanation of its performance under various conditions and applications. The motion of conducting material across the magnetic lines of force creates potential differences which, in general, cause electric current to flow. The magnetic field associated with these currents modifies the applied (imposed) magnetic field which creates them. In other words, the fluid flow alters the electromagnetic state of the system. When a conducting fluid passes down an insulating pipe across which a steady magnetic field is applied, a potential gradient (proportional to the flow rate) is created and can be measured by probes embedded in the walls of the pipe.

3.5 Magneto chemistry

Disassociated dissolved molecules of $CaCO_3$ in water have a tendency to recombine by forming scale which adheres to the inner walls of the piping system, containers, steam vessels, etc. When the water flows through a magnetic field of relatively low intensity, the formation of scale in the treated water is prevented in many instances. Instead, aragonite is formed within the flowing bulk water (aragonite forms dilute slurry in the water, the sediment of which can be easily removed by blow-down or bleed-off). In other words, the magnetic field causes preferentially the recombination of the disassociated $CaCO_3$ molecule into aragonite form. It, apparently, takes place by as little energy as needed for spin flopping in the electronic or nuclear energy levels, a process of very low energy of activation. The magneto chemical reaction, is only one of the many cross effect reactions that enable the transformation of calcite to aragonite. Other reactions include: the thermo chemical and mechano chemical reaction.

3.6 Pipe material and their properties

The pipe material we were used is PVC, Iron, copper with the diameter of 0.5 each and length of pipes is 1.5m, 1m, 0.5m respectively shown in figure (3.3). we were used three sets of each pipes for analysis with magnets and without magnets and the flow of water in each pipes is 5 L/m and 7L/m the valves are set on 5 L/m and 7L/m flow with the help of a digital flow meter shown in fig 3.5.

Fig: 3.3 Pipes and these materials used in the setup

The pipes are essential components in any water supply and distribution network. Water supply is the process of supply of water from public water supply system to individual building and subsequent distribution of water to various parts of the building. The water from public water supply system to individual buildings is supplied through pipes. A large proportion of capital is invested on pipes while designing water supply distribution system.

The domestic pipes are available in several types and sizes. They may be classified into three groups according to the material used in their manufacturing as Metallic pipes such as Copper (AC) pipes, iron pipes PVC pipes and Polythene pipes (low density).

In recent time, internal corrosion in water pipes is one of the major contamination sources of tap water. Internal corrosion in distribution networks has a close relation with the quality of water flowing through the pipe. From the experimental investigation, it was found that dissolved oxygen is the most critical parameter on the corrosion of metal pipes. Internal corrosion of water pipes could be effectively prevented by reducing dissolved oxygen concentration. The corrosion products on the surface of copper pipe were appeared as light brown and/or blue green color.

3.7 Scale formation in pipes

It has been observed practically that when water, especially ground water, flows through a pipe, the salts and various dissolved particles present in water, generally tend to deposit on the inner walls of the pipe. Such deposits may strengthen over a period of time, thus hindering the flow as well as friction factor and eventually even close the pipe completely. Thus in the case of water supply pipes, it is observed that as the usage increases, the diameter of the pipe is getting reduced because of the deposits that are taking place along the inner walls of the pipes as shown in the fig 3.4. In the coastal regions, where the water is saline in nature, the deposits have occupied the entire area of cross section of the pipe because of which the entire pipe system had to be replaced.

Fig: 3.4 scale formation inside pipe

Practical observations in the case of domestic pipes revealed the presence of certain deposits on the inner walls of the pipes over a period of usage. This problem increases when the fluid of appreciable hardness flows for a considerable period of time. This phenomenon will render the pipes less useful when the hardness or salinity of the water flowing in the pipes is high. The white colored deposits on the inner walls of domestic pipes and other plumbing fittings are deposits of calcium compounds - they are present where there is hard water or water with high mineral content. As the water runs through the pipes and fittings, the calcium ions present in the water, which are highly reactive, react with the air inside the pipes to form compounds of calcium, that deposit all around the inner surface of the pipe, making the smooth passage of water difficult or causing hot water to cool down too fast. Buildup of calcium in pipes and plumbing fittings can cause them to clog partially or completely, making them partially or totally dysfunctional. If the water has a high content of minerals in it, it will take as less as a month for the calcium deposits to build up in and around the pipes and plumbing fittings. Thus, the importance of cleaning the plumbing fittings and other pipes regularly cannot be over emphasized.

The reasons for scale to take place on the inner walls of the pipe may be attributed to the electromagnetic forces that are being developed in between the flow of fluid and the walls of the pipes, which is a common phenomenon of any pipe material. These electromagnetic forces may be probably acting on the water flowing through the pipe, thus precipitating the salts on the pipe surface that is in contact with the flow. Such salt particles, because of their affinity, stick to the walls of the pipes and remain there. Gradually as the phenomena of deposition continues with the time of usage, the thickness of the deposit also increases. The pressure in the fluid flow and the crystalline nature of the particles (dissolved or suspended) present in the fluid are the main factors affecting the thickness of the deposit.

3.8 Equipments used in the setup

Digital flow meter: Volumetric flow meters directly measure the volume of fluid passing through the flow meter. The only flow meter technology that measures volume directly is the positive displacement flow meter. Velocity flow meters utilize techniques that measure the velocity (v) of the flowing stream to determine the volumetric flow.

Fig: 3.5 Digital flow meter

Water pump: this pump is used in this setup for proper flow of water in specific quantity according to the height of setup the pump capacity 0.5hp.

Fig: 3.6 Water pump of 0.5 hp.

Opening closing valve: A valve is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids by opening, closing, or partially obstructing various passageways. Valves are technically fittings but are usually discussed as a separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure.

Fig: 3.7 opening and closing valves

Mini pump: The mini water pump is used in the setup for water reveres to main tank for balance the water level in both of the tanks.

Fig: 3.8 A mini pump for reveres flow of water to the main tank.

Weighing balance: A beam balance is a device to measure weight or mass.

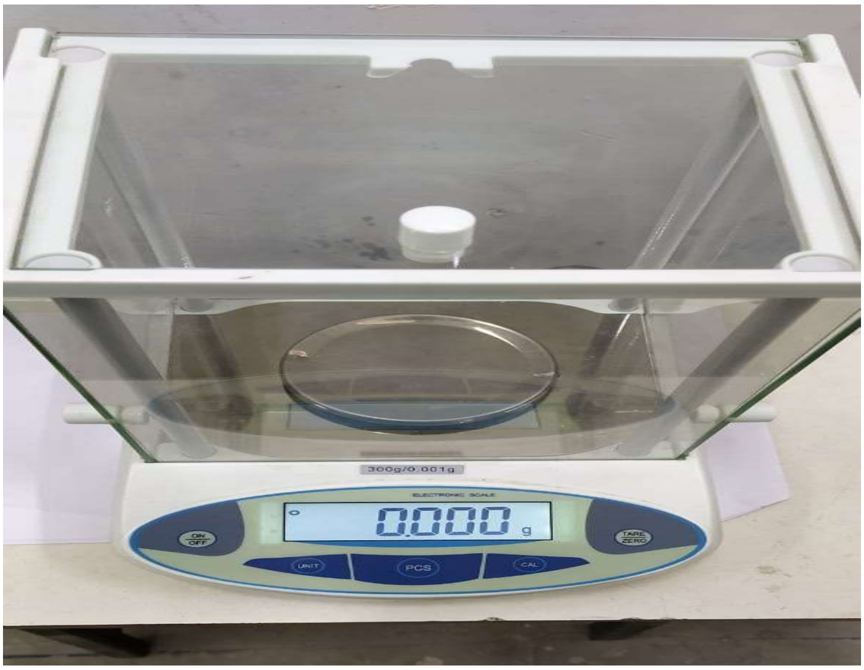


Fig 3.9: Weighing balance

TDS and EC meter: This Advanced Water Meter Combines TDS (Total Dissolved Solids), EC (Electrical Conductivity) And a Temperature Meter.

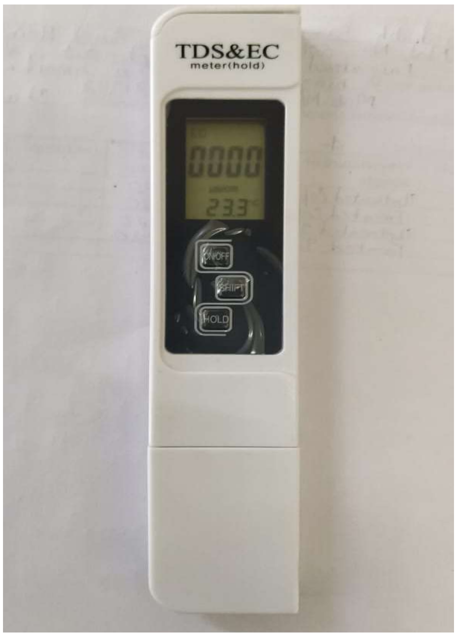


Fig 3.10: TDS And EC meter

Scanning electron microscope: A **scanning electron microscope** (**SEM**) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.

Fig 3.11: A **scanning electron microscope (SEM)**

Fig: 3.12 Two metallic tanks of 40 Lit each.

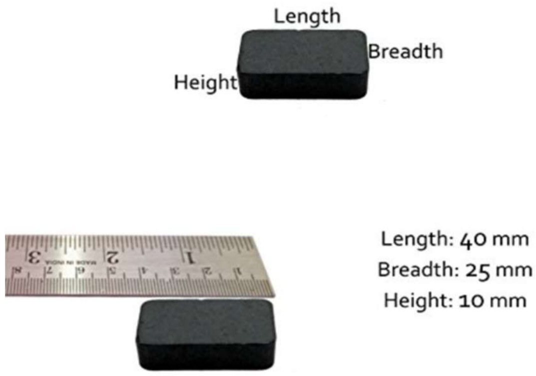


Fig: 3.13 8 pieces of ferrite black 5700 gauss magnet 40*25*10.

Chemical used: Calcium carbonate.

Fig: 3.14 Calcium carbonate 250mg/Lit

CHAPTER- 4
EXPERIMENTAL PROCEDURE

EXPERIMENTAL PROCEDURE

Water passes through the magnetic field, all super- molecules vibrate this will intensify the internal vibration of these super-molecules to the breaking point. These super-molecules fracture and release their encaged particles (Ca, Mg). Precipitates come out of solution as a sludge and can be easily removed from the system.

Fig: 4.1 Setup image

The home-made magnetic device It consisted of a series of pairs of permanent magnets with north and south poles facing each other, which can be associated alternately. The investigations were carried out using the experimental set-up shown in Fig (4.1) In this study, we used model water that was prepared following the method of Parsons who reported that the optimum concentration of Ca^{2+} ions for the best response to the magnetic treatment. Sample solutions of calcium carbonate ($CaCo_3$) were prepared by dissolving finely ground calcium carbonate powder of analytical purity in demonized water and bubbling the suspension with carbon dioxide gas through a porous frit. As CO_2 is removed from the system, by bubbling air through the solution.

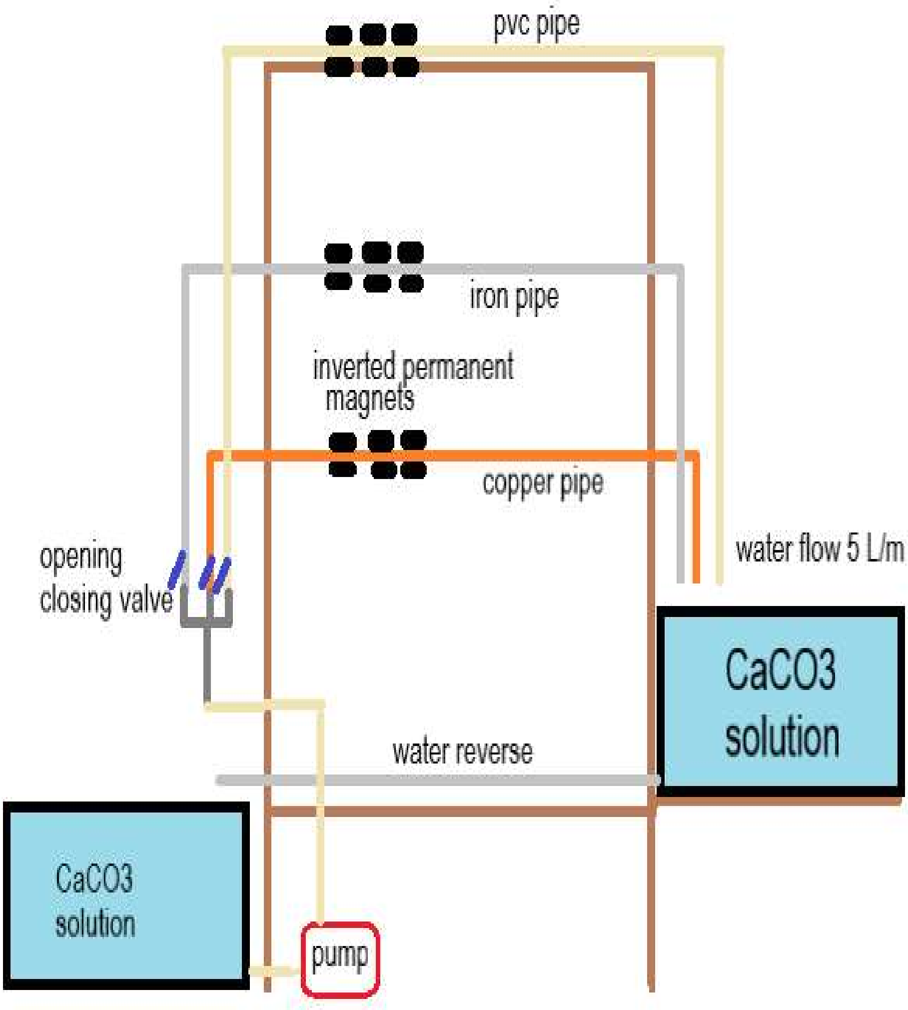


Fig: 4.2 setup layout

Fig. shows the schematic diagram of the magnetic treatment device (MTD) in a closed circulation system. Experiments were performed in parallel runs. One of the runs was treated with a magnetic field of 5700 gauss and the other was without magnetic field For the magnetic water treatment. . The scaling water to be treated was circulated in a pipe through the gap by means of a centrifugal pump. The pipe, unless specified, was of copper, iron, PVC. The water velocity can be uniform with 5 lit/min and 7lit/min.

Fig: 4.3 flow rate

The water to treat passed through a pipe inserted between the polar pieces in opposition of polarity. In this configuration the magnetic induction was perpendicular to the solution flow. Each polar piece is the assembling of two rectangular permanent magnets (40mm length, 25mm breadth, 10 mm thick). Here the magnetic field was almost uniform in the gap (mean value 5700 gauss). The without magnetic water was treated for no memory effect that's why we were firstly circulate water in without magnetic field pipes up to 30 hours at a constant flow of 5lit/min and 7lit/min and after that we close the valve of all three pipes of non-magnetic flow and after this process we were open the valve of magnetic field pipes which has the two pair of magnets which is bound around the pipe walls with the stick tape for creating a strong magnetic field of 5700 gauss and the hard water was start flow through the magnetized pipes and this flow of water is also flows up to 30 hours.

Now after that all process we are discussing about pipe materials, in previous researches we found that the researchers generally use PVC, Iron and copper pipes because this pipes are generally used in houses and household products of certain length 1.5m, 1m, 0.5m respectively and diameter 0.5 inch each copper, iron, PVC for comparing the effect of hard water effect on the materials of pipes with or without magnetic treatment.

4.1 Magnetic 'MEMORY' of water

It has been claimed that preliminary water treatment with magnetic or electromagnetic (EM) fields can help descale metal surfaces, improve cement hydration, change z potential of colloids, make plants irrigated with such water grow faster, enhance efflux of calcium through bio-membranes or influence the structure of model liposome's. The effects persist minutes or hours after the water treatment. It is well known that relaxation phenomena in water occur on a picoseconds to second timescale. The nature of these ‘mysterious’ and questionable phenomena uniquely known as the ‘magnetic memory of water’ has recently been scrutinized.

4.2 Microscopic analysis and method

The crystal morphology, and particle size and structure of scale were all changed after exposure to the electromagnetic field. After experiments, we collected scale on the heat transfer surface in the heat exchanger, and the scale samples were analyzed by EDS, SEM. The material of the pipe and the composition of the treated water were investigated. The morphology of crystal $CaCO_3$ on pipe walls was analyzed by field emission scanning electron microscope (FESEM). A small amount of deposited scales was taken from the pipe walls prior to the commencement of the experiment and was analyzed using FESEM which shows the morphology and size of the scales. The sample consists of a mixture of square and hexagonal shaped crystals characterized as calcite, which is very hard to remove as it attached strongly on pipe walls.

Now after FESEM investigation we found that the structure of water molecules would be changed of magnetised water scaling and the cluster is breaks into small hexagonal clusters while the non magnetized water scale is after FESEM found that the clusters is heavy in comparision to the magnetised water scale.

CHAPTER- 5
RESULT AND DISCUSSION

RESULT AND DISCUSSION

5.1 Preliminary test on magnetic effect

In the early stage of this research, the experimental mode was similar to that using the commercial MWTD, the magnet was used to magnetize the solution. The results of calcite growth at various levels of super saturation using the 5700 gauss magnet to magnetize the super saturated solution for 30h prior to growth of seed crystals in which the calcite growth rates without magnetic treatment are also presented. The calcite growth rate increased with an increase in super saturation for either case, and there was almost much difference between these two sets of data. These results meant that the magnetic force induced by 5700 gauss magnet works after magnetizing the solution for 30h.

Table 5.1 and 5.2 summarizes the results obtained from statistical physico-chemical analyses of the magnetically treated and non-treated water at 5l/min velocity and 7l/min velocity respectively. The mean, maximum and minimum values, as well as the standard deviation are presented.

This study also found that the calcium content from copper pipes was higher than iron and PVC. Even though few parameters react with positive results to the MWT such as water hardness, pH, alkalinity, EC and amount of CaCO3 in the water, but there is also other parameters such as water quality parameters (temperature, ammonium, nitrite, nitrate, chloride) which do not contribute much and can be neglected due to the slight difference in value before and after MWT implementation. MWT has very little effect on water quality parameters. Magnetic water treatment has different effectiveness on metallic and non-metallic pipes.

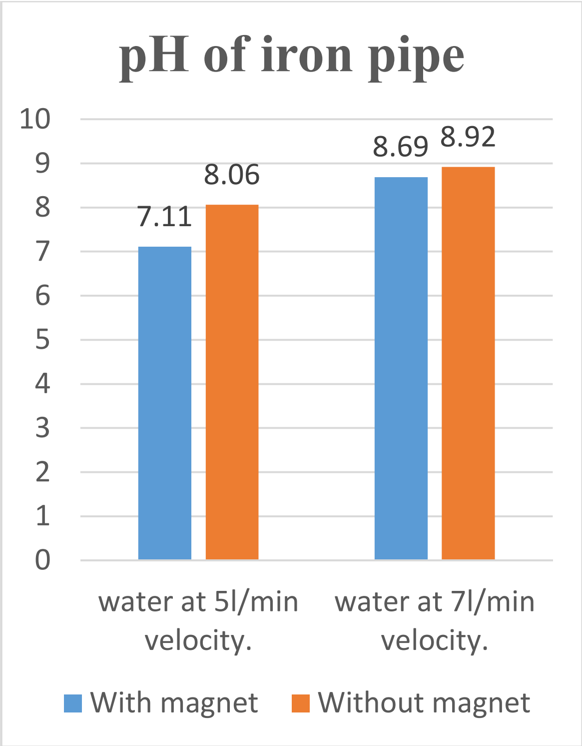
Alimi *et al.* (2009) showed that non-metallic material of pipe had the most efficient results in magnetic water treatment. However, it was due to the presence of the contaminants in water while passing the magnetic field.

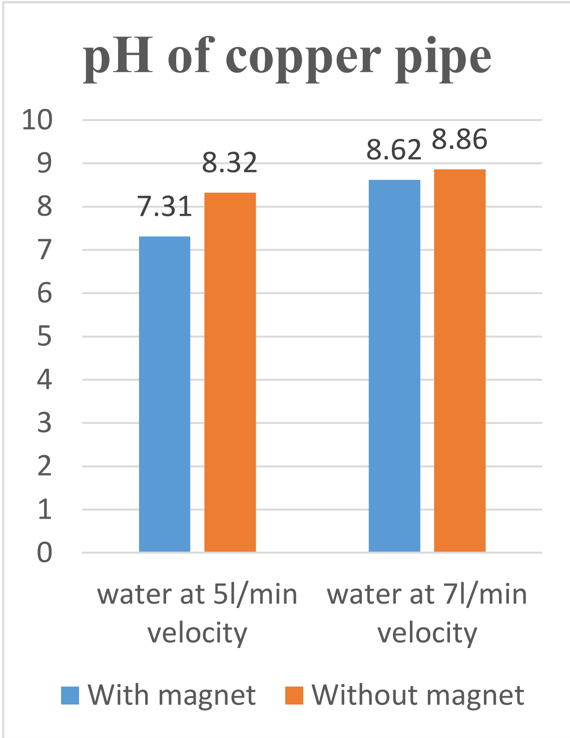
Table 5.1 Effect of magnetic field on characteristics of water at 5l/min velocity.

S.No.	Parameters	Iron		Copper		PVC	
		With magnet	Without magnet	With magnet	Without magnet	With magnet	Without magnet
1.	Ph	7.11	8.06	7.31	8.32	7.22	8.20
2.	Electrical conductivity (µs/cm)	596	619	543	600	547	611
3.	Total dissolve solids (mg/l)	328	382	358	396	318	366
4.	Hardness as $CaCO_3$	211	239	227	242	207	236
5.	Alkalinity as $CaCO_3$	309	333	329	373	303	321

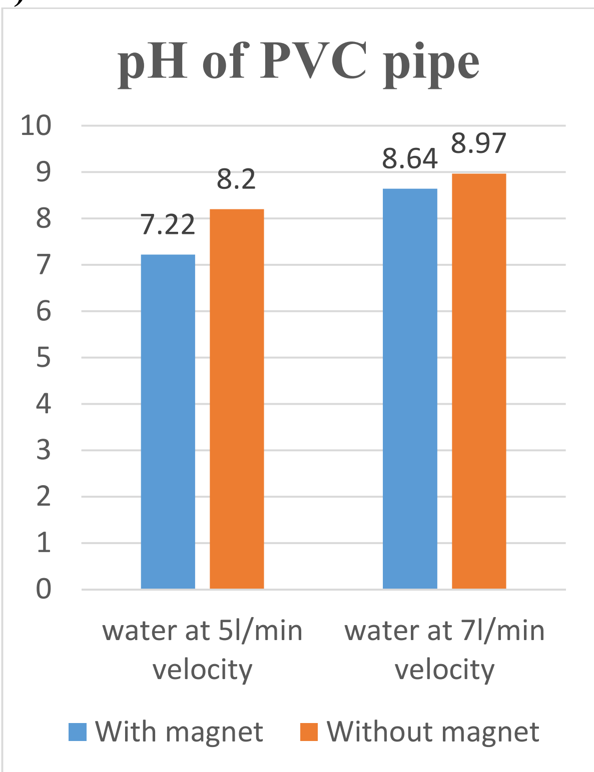
Table 5.2 Effect of magnetic field on characteristics of water at 7l/min velocity.

S.No.	Parameters	Iron		Copper		PVC	
		With magnet	Without magnet	With magnet	Without magnet	With magnet	Without magnet
1.	pH	8.69	8.92	8.62	8.86	8.64	8.97
2.	Electrical conductivity (µs/cm)	261	272	256	295	283	298
3.	Total dissolve solids (mg/l)	130	144	127	140	118	135
4.	Hardness as $CaCO_3$	190	205	180	198	182	210
5.	Alkalinity as $CaCO_3$	200	210	190	201	204	218



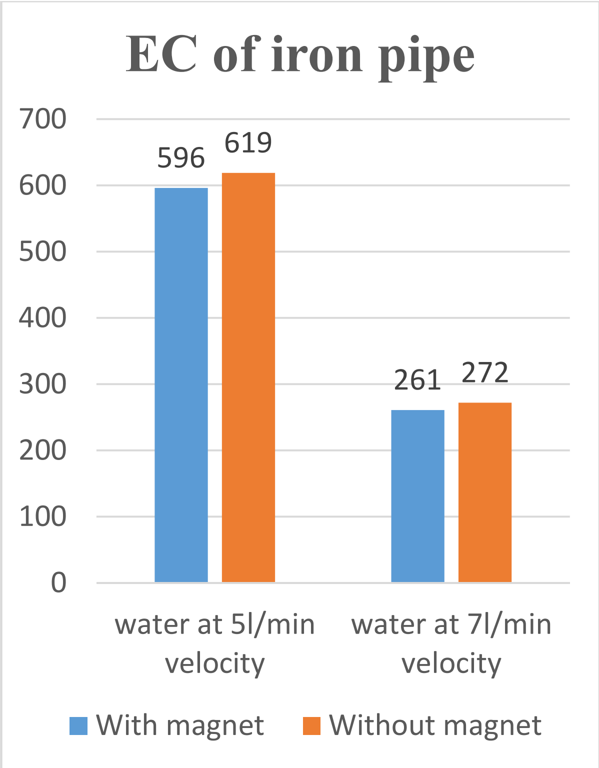


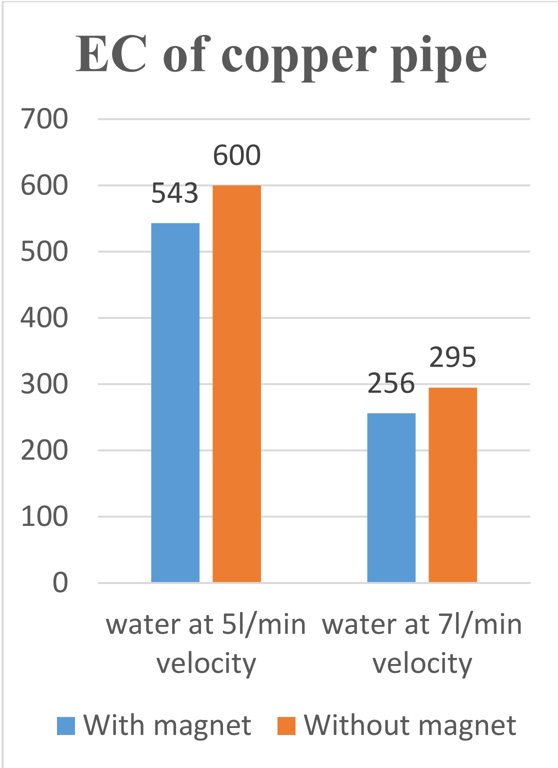
(a) **(b)**



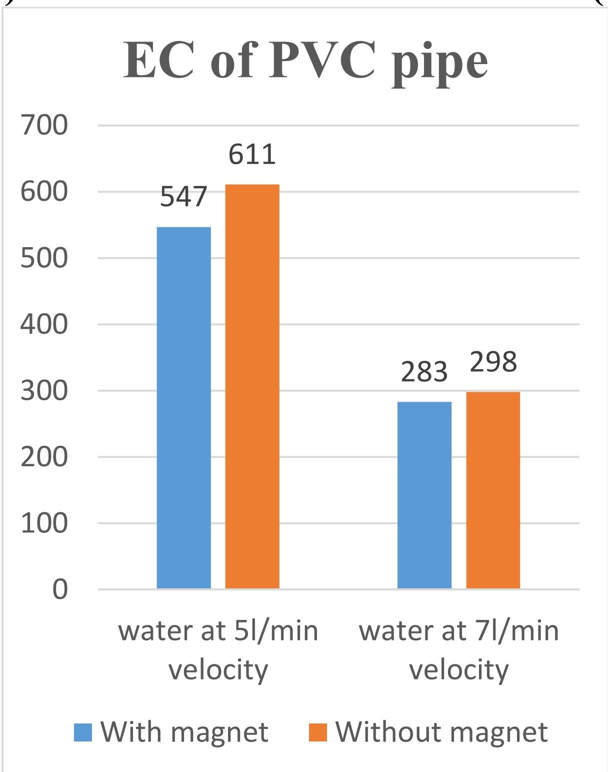
(c)

Fig: 5.1(a) to 5.1(c) Effect of magnetic field on pH of water at 5l/min velocity and 7l/min velocity



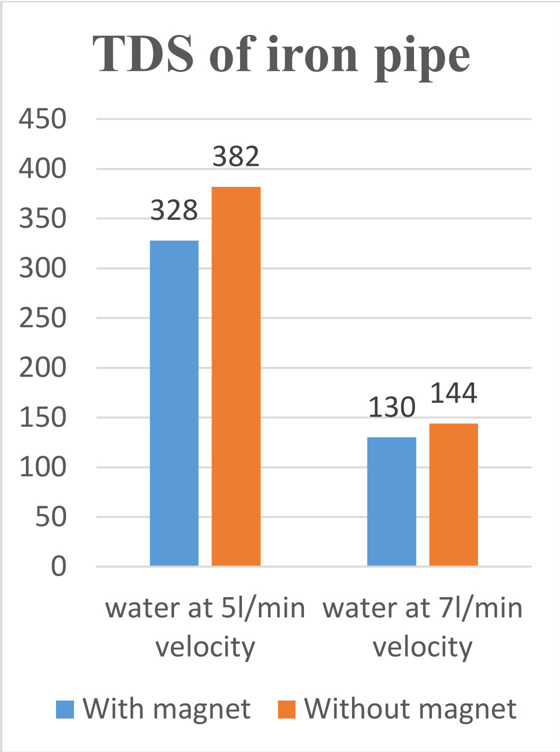


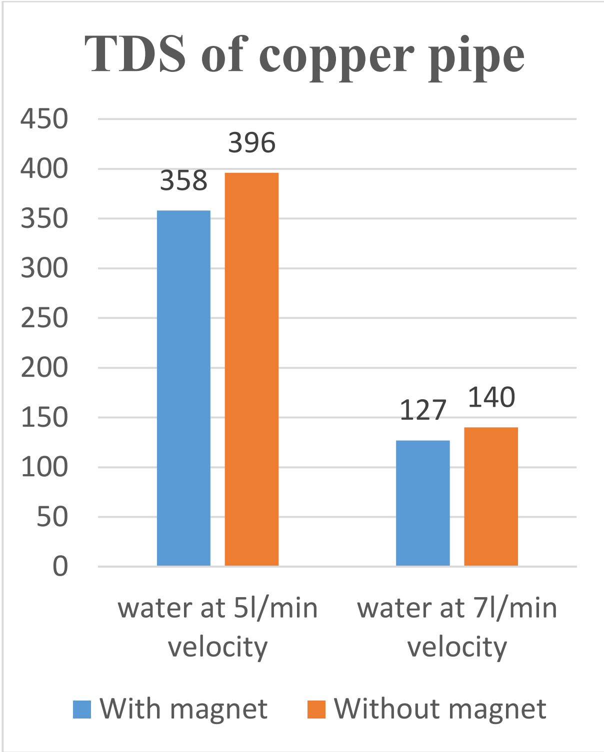
(a) **(b)**



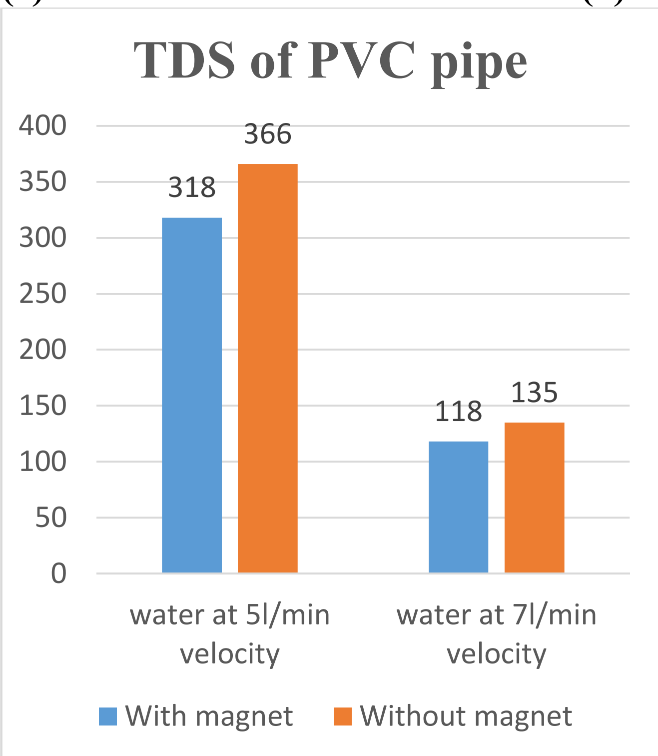
(c)

Fig: 5.2(a) to 5.2(c) Effect of magnetic field on Electrical Conductivity (µs/cm) of water at 5l/min velocity and 7l/min velocity.



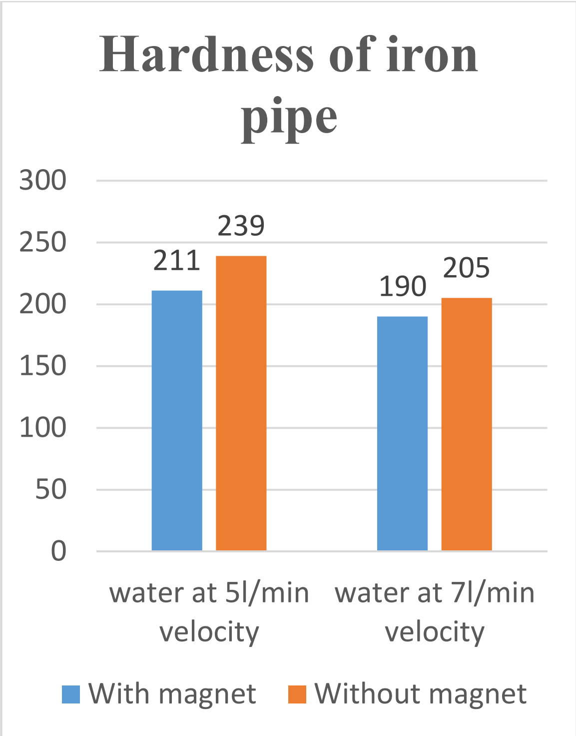


(a) **(b)**

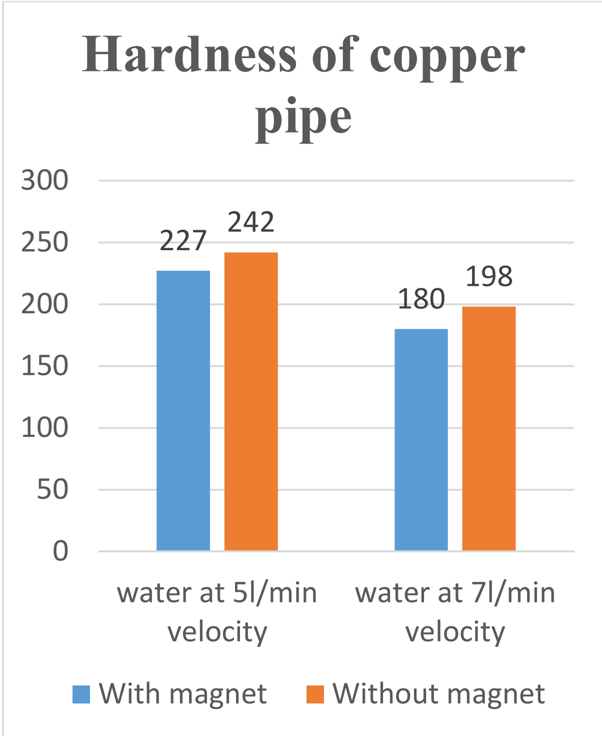


(c)

Fig: 5.3(a) to 5.3(c) Effect of magnetic field on Total Dissolve solids (mg/l) of water at 5l/min velocity and 7l/min velocity.



(a)



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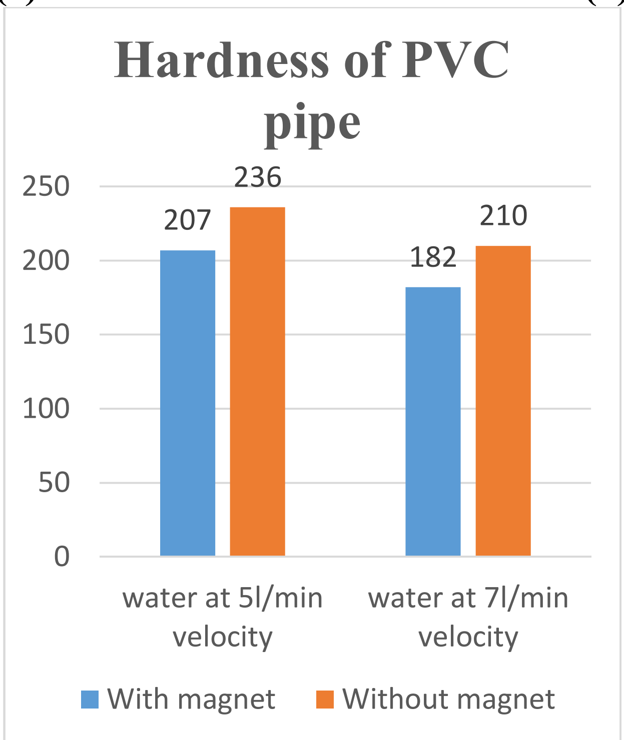
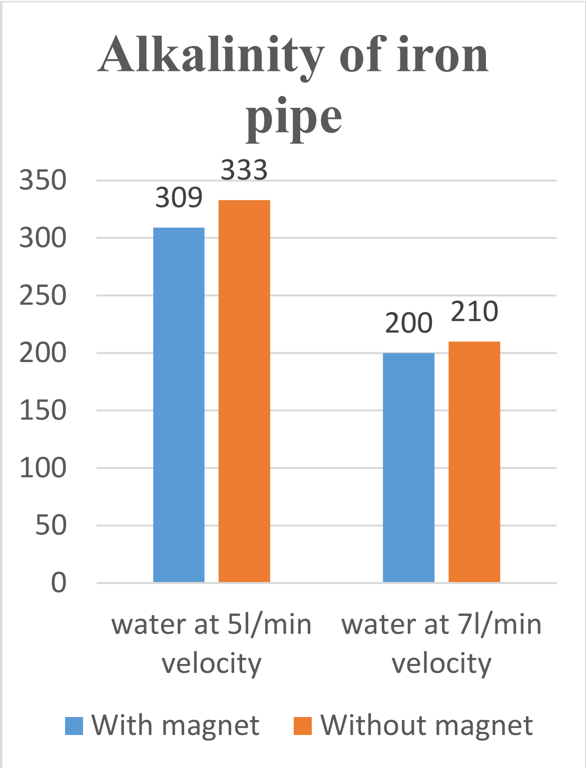
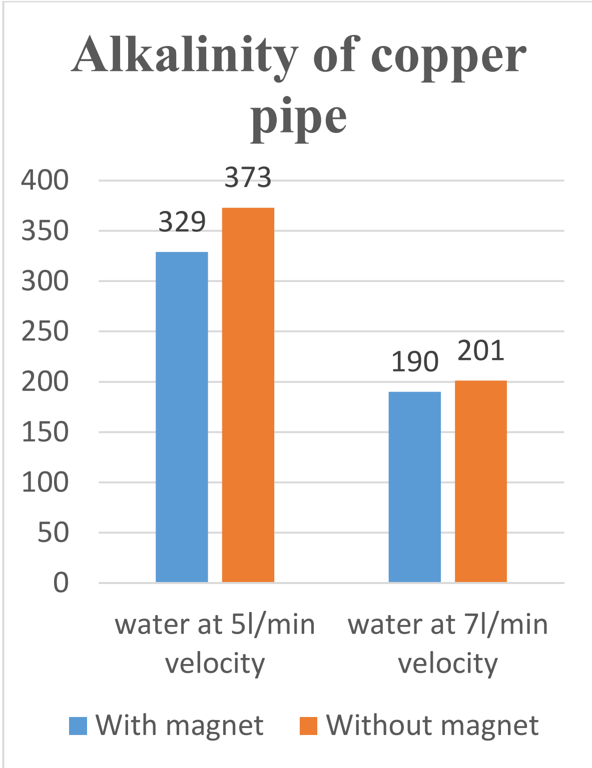


(c)

Fig: 5.4(a) to 5.4(c) Effect of magnetic field on Hardness as $CaCO3$ of water at 5l/min velocity and 7l/min velocity.



(a)



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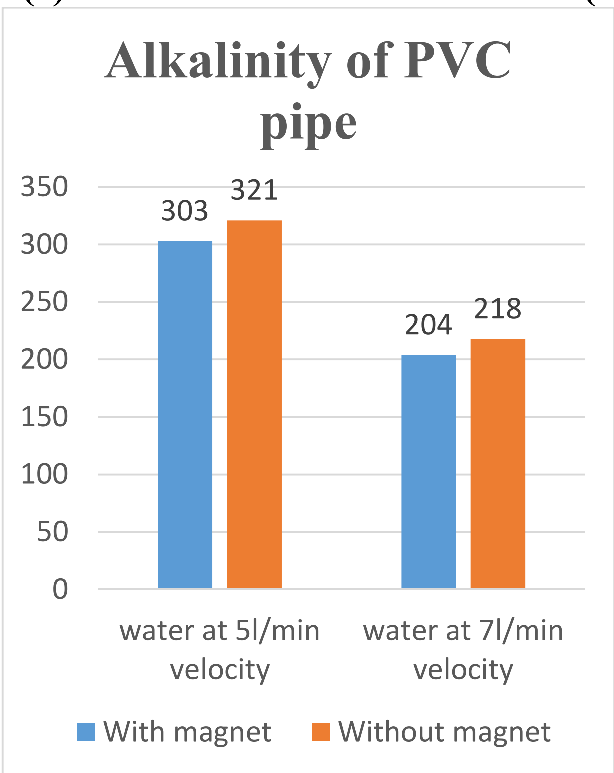


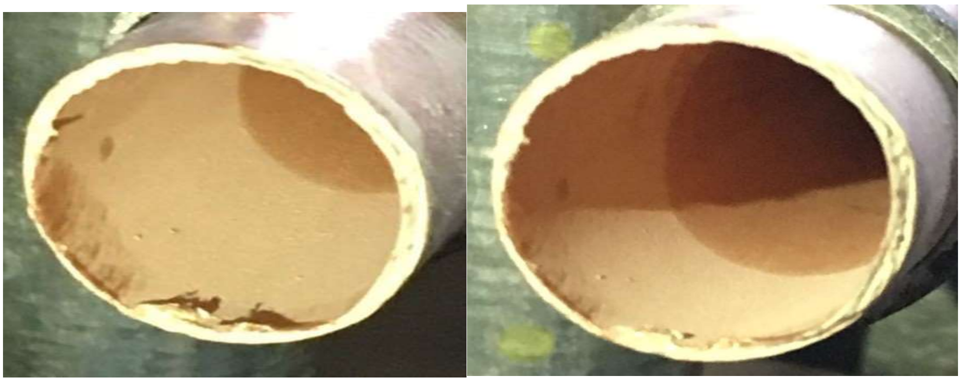
(c)

Fig: 5.5(a) to 5.5(c) Effect of magnetic field on Alkalinity as CaCO3 of water at 5l/min velocity and 7l/min velocity.

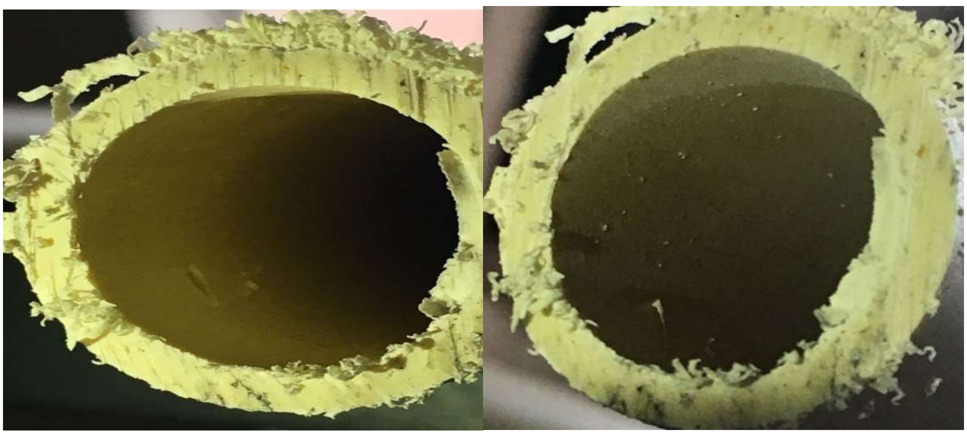
5.2 Actual images of inner walls of pipes of different materials copper, PVC, iron with magnetize and without magnetize treatment

After treatment we found that in iron pipes the scale formation in 30 hr with magnetic treatment has less amount of scale deposition in comparison to the treated iron pipe, and the scale deposition in copper pipe and PVC pipe is less in comparison to the iron pipe as shown in fig.

(a) Treated **(b) Untreated**



(a) Treated **(b) Untreated**

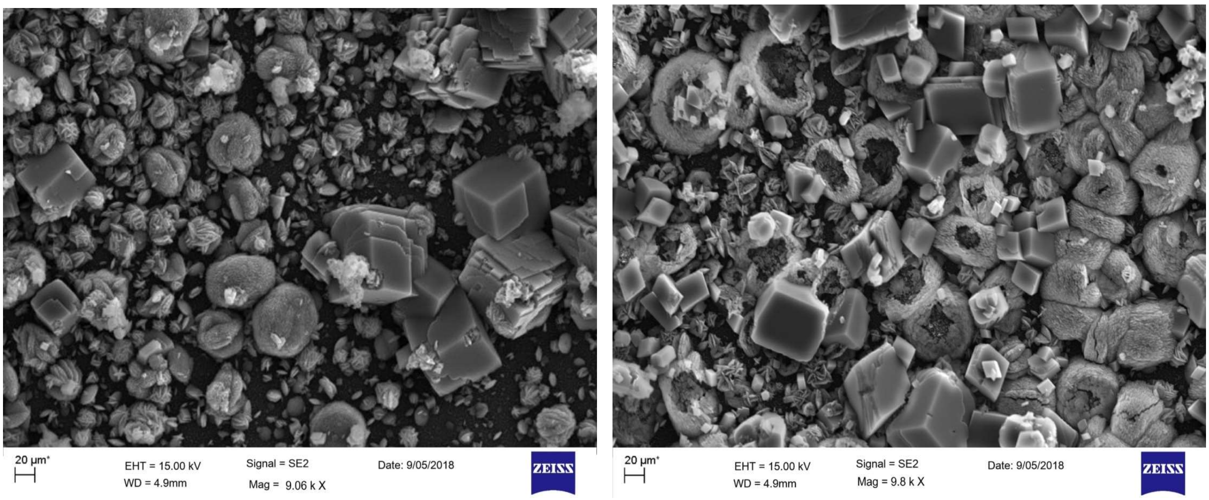


(a) Treated **(b) Untreated**

Fig 5.6 Treated and untreated pipe after cutting

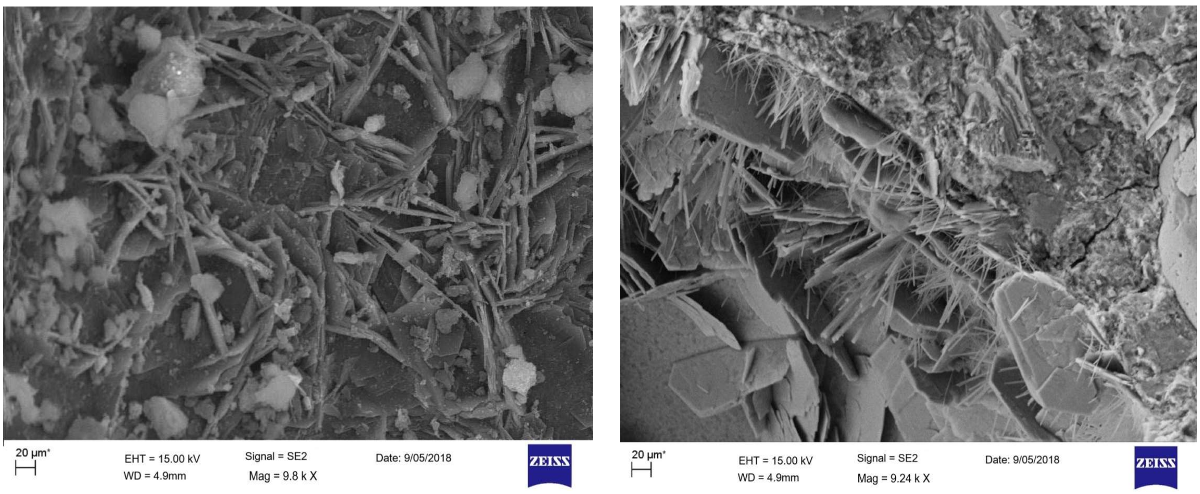
5.3 Scale formation on pipe walls (at 5lit/min velocity) examine by SEM:

We use different pipe materials iron, copper, PVC we found that the copper and iron pipes was more effective then the PVC. In this experiment, growth rate results were compared between two cases when the magnet 5700 gauss 6 pieces was fixed on all the pipes which is magnetized and other one is un magnetized, respectively. The results at various levels of super saturation are present in fig therefore we find that the magnetized pipes of different materials are having the less amount of calcite crystals and the pipes who do not magnetized are having the large amount of calcite crystals. The scanning electron microscopy images are set on nearby 10,000 X zooming.



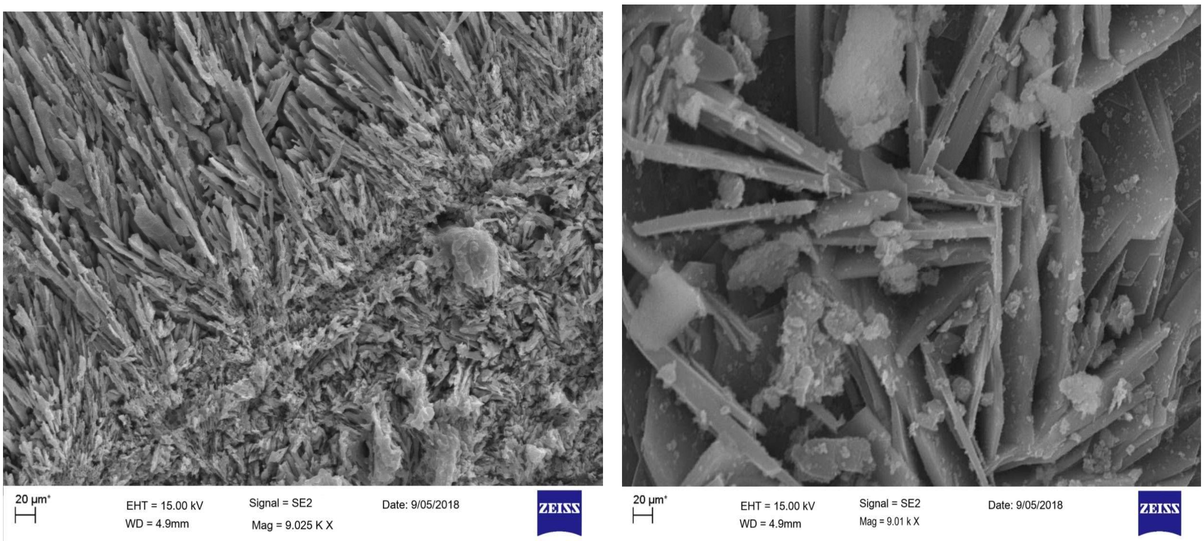
(a) Treated copper pipe (b) Untreated copper pipe

Fig: 5.7 SEM image of treated and untreated copper pipe



(a) Treated iron pipe (b) Untreated iron pipe

Fig: 5.8 SEM image of treated and untreated iron pipe



(a) Treated PVC pipe (b) Untreated PVC pipe

Fig: 5.9 SEM image of treated and untreated PVC pipe

5.4 scale formation on pipe walls (at 7lit/min velocity) examine by SEM:

We use different pipe materials iron, copper, PVC we found that the copper and iron pipes was more effective then the PVC. In this experiment, growth rate results were compared between two cases when the magnet 5700 gauss 6 pieces was fixed on all the pipes which is magnetized and other one is un magnetized, respectively. The results at various levels of super saturation are present in fig therefore we find that the magnetized pipes of different materials are having the less amount of calcite crystals and the pipes who do not magnetized are having the large amount of calcite crystals. The scanning electron microscopy images are set on nearby 10,000 X zooming.

CONCLUSION

Hard water contains high grouping of broke up calcium and magnesium bicarbonate (brief hardness) notwithstanding calcium and magnesium chloride, sulfate and nitrate salts (changeless hardness). Scale is a made out of calcite and aragonite which framed from calcium carbonate present in the water. The dissolvable salt calcium carbonate sparingly presents in water. After quite a while it moves through the pipeline, the dissolvable calcium carbonate will shape an encrustation on defenseless surface in the water pipeline. At the point when the water pipelines, which contained scale, uncovered with charged water the centralization of Ca2+ in the outlet of water test will increment because of the expulsion of Ca2+ from the water pipeline. This paper study can be a potential finding for genuine application in taking care of scale issue in water pipeline. Attractive fields can change the physicochemical properties of water atoms when the water test went through an attractive field. In this way, it will assist with forestalling the crystallization of calcium carbonate in water test and this prompts forestall the arrangement of in water pipeline.

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