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Investigation of the quality of water treated by magnetic fields

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Craig Andrew McMahon

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Craig McMahon
0050041674

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Date

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Mr. Kim Larsen

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Mr. Garry McMahon

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Abstract

Passing water through a magnetic field has been claimed to improve chemical, physical and bacteriological quality of water in many different applications. Although the treatment process has been used for decades, it still remains in the realms of pseudoscience. If the claims of treating water with magnets are true, the process offers improvements on many of our applications of water in today's world.

A large number of peer reviewed journal articles have reported contradictory claims about the treatment.. Some of the most beneficial claimed water applications from magnetically treated water include improvement in scale reduction in pipes and enhanced crop yields with reduced water usage. Today we are still unsure whether the technology works and those who do believe it works are still trying to understand the mechanisms of how it works.

Many research papers are starting to develop similar theories behind the mechanism of the treatment. From previous studies, it has been determined that the most successful MTD's are those with alternating poles.

The majority of the experiments performed during this research were determined to have insufficient controls to produce conclusive results. The conclusions from this research were focused on designing improved experiments to provide more conclusive results.

A theory was developed to explain the MTD's mechanisms of scale reduction. While the experimental results were not conclusive, the results attained backed the theory.

Magnetically treated water does not do all that it is claimed it does. However, some of the positive results obtained during this research suggest that the improved experiments developed from this research may provide conclusive results on this controversial topic.

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CHAPTER 1

INTRODUCTION

Chapter 1 Introduction

1.1 Introduction

What is magnetised water? Magnetised water is water passed through a magnetic field. It is an inexpensive, environmentally friendly water treatment that has small installation fees and no energy requirements. The effects of magnetism on water, however, is the subject of controversial debate.

Many claim magnetised water gives increased performance in regards to scale reduction (Alim et al 2006), increased crop yields (Lin & Yotvat, 1990), health benefits (Yue et al. 1983), change in pH (Busche, 1985), water tension reduction (Cho & Lee, 2005) and increased cement compressive and tensile strength (Nan et al. 2000) to name a few.

Other scientific journals and research claim that magnetising water has no effect and the current successes have not been able to be reproduced (Krauter et al. 1996). Currently, there are hundreds of peer reviewed papers and experiments done on magnetic water treatment with a substantial percentage attaining success in the treatment.

Water is a difficult substance to examine properties for, as it carries a variety of foreign particles in the form of micro contaminants and other dissolved solids. This adds to the confusion about magnetised water with many claiming that certain chemicals in the water determine the success rates of the treatments. Around the world, in different laboratories, the water being treated varies from experiment to experiment, except when using distilled water.

To add to the confusion, retailers of magnetic treatment devices (MTD's) only quote the successes and claim assumptions of the mechanics of magnetised water as fact. These claims add to the scepticism of the treatment with sceptics focusing their attack on the incorrect chemistry of retailers who have little knowledge of the subject. The first result of a google search for "magnetised water" is a page about magnetised water being a scam, and is written by a retired chemistry lecturer (Lower, 2009).

According to (Magnetic Water explained, 2007) a lot of the sceptical studies are done in the interests, or under the pressure of big chemical companies who stand to lose millions of dollars if new alternatives are developed for the treatment of hard water, algae and bacteria related conditions.

While most chemistry scientists (who have minimal experience in magnetism) seem to believe that magnetising water will have no effect and is a “snake oil” scam, the successes cannot be easily overlooked. The claims, if proved correct, offer huge benefits for major industries around the world. It should not be a case of “once proved correct then we shall study it”, but a case of “we should study this till we prove it does not work”.

1.2 Background

At this point in time, magnetised water is classed by many to be pseudoscience while others are enjoying the benefits of this unknown science. The motivation for this study comes from the fact that such a simple technology can have beneficial impacts on industries utilizing water. The technology of MTDs is cheap, requires no energy to run, and creates no pollutants. The claims about increased performances in scale reduction and crop yields are too beneficial to ignore.

The fact that MTDs are a relatively new concept creates a large perception of scepticism as many believe that, if the treatment works, why haven’t they heard about it. By investigating the effects of MTD’s, I hope to discover information and evidence about whether the technology has the potential to work or not.

The two major benefits of magnetic water treatment (MWT) are scale reduction and improved crop yields with less water. According to Smith, (2003) the cost involved due to heat transfer inefficiency and the removal of scale in Britain alone was estimated at £1 billion per annum in the early 90’s. Properly installed and configured MTDs have had many successes in reducing the amount of scale build up in pipes. In an experiment performed by Smith (2006), permanent magnets reduced the formation of scale by 70%.

Bogatin (1999) concludes from their findings that MWT induces an increased crop yield by 10-15%. The magnetic treatment improves conditions of root layers due to (a) leaching of superfluous salts (b) better permeability of irrigated water and (c) better dissociation of mineral fertilizers. Increased permeability of water reduces the amount of water required for each irrigation event.

In regards to scale reduction, occasionally the MTDs work (Smith 2003) while in other circumstance they have no effect (Krauter et al 1996). A test needs to be created to determine if the MTD is installed correctly and if the water quality is susceptible to magnetic treatment.

If this study can find a property of water that is modified by a MWT, then this property can be used to determine if the MTD is successful in different systems. This will allow quick evaluations of MTDs and their configuration. As of now, one has to wait several months to determine if the MTD has been successful in reducing scale build up.

Focusing on a property influenced by MTDs will also allow the assessment of current MTDs and optimal configuration.

If this study can prove any of the properties or applications of magnetically treated water are successful, then it will help the science become more acceptable. If the science is real and the claims are correct, once mainstream, we should expect to see an efficiency improvement in the majority of industrial uses for water once treated correctly by magnets.

Agriculture will benefit greatly if what has been reported can be replicated. Magnetically treated water is reported to save on average, 20% water with 10% increased yields (Lin & Yotvat1990). This treatment would be beneficial in today's world with water scarcity and food shortages in many regions.

1.3 Aims and Objectives

The aim of this study is to observe whether any properties of water, such as pH, surface tension, heat capacity, dissolved oxygen or water hardness are affected by MTD's. If one of these properties is found to be affected, then this property will be used to determine an optimum configuration of a MTD.

Once an optimum MTD has been designed, applications of the treated water will be evaluated. If no properties are found to be modified by the MTD and no optimum magnetic configuration can be calculated, then a design from past literature will be used.

Applications of the magnetically treated water to be evaluated will include:

- Germination rate of seeds
- Plant growth
- Precipitation Rates of Calcium Carbonate (scale reduction)
- Cement compressive and tensile strength

During the course of the investigation it is also intended to collect published and unpublished knowledge of MWT and summarise the current theories. By presenting this information in a summarised, straightforward way it is more likely to be understood by a wider and more diverse audience.

1.4 Scope

This project is aimed at experimenting on a wide range of properties and applications to get a broad understanding of what is possible from MWT. The water to be used in the experiments includes:

- pH experiment = Tap water, Japanese Gardens water
- DO experiment = Tap water, Japanese Gardens water
- Heat Capacity experiments = Tap water

- Dissolution rate experiments = Tap water
- $CaCO_3$ precipitate experiment = Tap water, Distilled water
- Plant growth experiments = Tap water, Salt water (Tap + Salt %)
- Cement compressive experiment = Tap water

1.5 Overview of dissertation

Chapter two will consist of a literature review of previous research on the subject. The purpose of chapter three is to provide a detailed explanation of the methods used for the thesis's experiments. The following two chapters will consist of the results received from the student project and an in depth discussion of what has been derived from these results. The final chapter will provide a conclusion to the study and give an insight into further research that could be continued in this field.

CHAPTER 2

LITERATURE REVIEW

Chapter 2 Literature Review

2.1 History of magnetised water

According to Brower (2005), case histories of the success of magnetically treated water date back to 1803. The magnetic effect was first recorded when there was a notable difference in the texture of the mineral accumulation inside of soup and laundry kettles. These kettles were placed over fires and large stones were placed in the bottom to keep them from swinging in the windy weather.

Reportedly, two of the five kettles, which were all made from the same cast iron metal, did not have hard scale formation. Instead, they had a soft, powdery substance which was brushed off easily. It was later found that the two of the five rocks used to stabilize the kettles in the wind were lodestones which are natural magnetic rocks.

According to the Marshutz et al (1996) Michael Faraday was the first researcher who seriously dug into magneto chemistry beginning in 1863. From 1890 and onwards, the subject of magnetically treating water had become extremely controversial, and was labelled “gadgetry” and “not sustainable under scientific scrutiny”. A company called Solavite, based in France, began to market a MTD in 1936. In the Eastern Bloc Countries, particularly Russia, increased research and applications of MTDs began after the Second World War. This was largely due to the fact that the U.S.S.R did not have the chemical expertise or funding to treat their water chemically like that in the U.S.A. (Lobley, 1990)

Marshutz(1996) reports that in 1954 the Federal Trade Commission filed a complaint against the Evis Manufacturing Company, which manufactured an early magnetic water conditioner. They charged the company with unfair competition and false advertising by its competitors. Following extensive hearings, the complaint was dismissed two years later.

Experiments and studies in the west increased after numerous successful applications of MTDs came out of the U.S.S.R. By the 1990’s, many credible institutions were researching the topic with mixed results.

Today, there are numerous varieties of MTDs for sale, ranging from $100 up to $10000. The controversial debate over the effectiveness of magnetised water is still undecided. There have been many successful industrial applications of MTDs in the west, including systems for NASA, yet the treatment has not been released mainstream or accepted by the Water Quality Association (Federal Technology Alert, 1996).

"If you look at the publications and split them down the middle, you would find that anything written outside of the U.S. generally favors magnetic water treatment, while anything you read on the subject written inside the U.S. tends to be questionable," explains Donald McClellan of MC^2 Resource Management, a distributor for the Descal-A-Matic Corp as cited in (Marshutz,1996).

2.2 Past experiments of magnetised water

2.2.1 Property Changes from MTD

pH change

Changes in the pH of distilled water of up to 0.4 pH units have been reported by Joshi and Kamat (1966). However Quickenden (2002) found no pH change in double distilled water subjected to a very strong magnetic field of 24 000 Gauss.

Tai et al (2008) cited that Ellingsen and Kristiansen showed that their water sample's pH decreased from pH 9.2 to 8.5 after magnetic treatment. (Busche et al, 1985) showed an initial decrease in pH of 0.5pH units from 7.0 to 6.5, followed by a gradual increase throughout the time of the experiment to pH 7.5 – 8.0. Parsons et al (1996) also recorded a decrease of 0.5 pH units after passing water through a MTD as can be seen in the Figure 2.1.

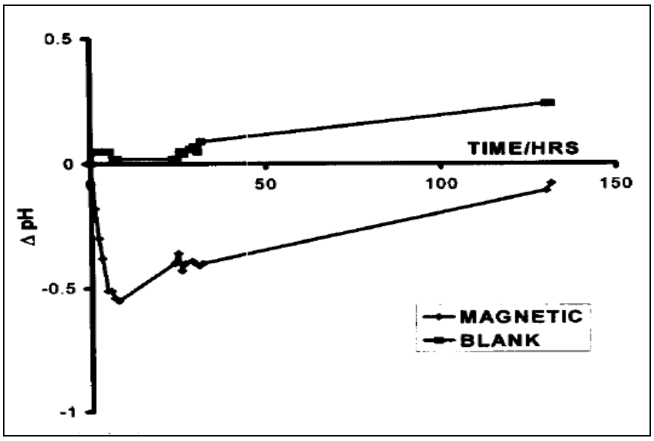

Figure 2.1 Parsons et al (1996) the bottom line represents magnetically treated water.

Yamashita et al. (2003) witnessed, what he considered, slow and large pH fluctuations (0.05 -0.1) during the first several hours of magnetically treating distilled water. His results indicated that to accurately evaluate the effects of magnetic fields on water, subtle experimental conditions such as field conditions produced by common lab devices and procedures cannot be ignored. He also states that extending measurements beyond several hours may be essential to observe accurately the effects of magnetizing water.

From these experiments, it appears the fluctuations in pH change from experiment to experiment suggest that unforeseen interactions are contributing to pH change. While pH change may be an indicator for magnetically treated water in some situations, it cannot be solely relied upon.

Surface Tension

Sueda et al. (2007) examined the maximum mass and diameter of a dripped water droplet on the tip of a glass capillary, and found both were affected strongly by magnetic fields.

Otsuka et al. (2006) concluded that no changes in properties of pure water, distilled from ultrapure water in vacuum, were observed after magnetic treatment. However, when the same magnetic treatment was carried out after the distilled water was exposed to O_2, properties such as surface tension were changed. The degree of magnetic treatment effect on water was quantitatively evaluated by contact angle as can be seen in Figure 2.2

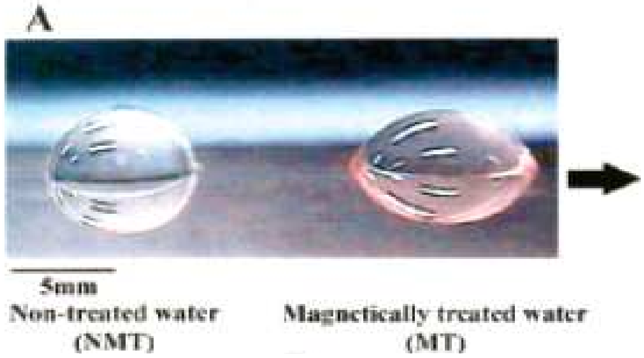

Figure 2.2 Comparing contact angle of magnetised water droplets

Cho & Lee (2005) studied the effects of amount of magnetic treatment by a permanent magnet on surface tension. Two separate experiments were conducted: one was the measurement of surface tension and the other was a flow-visualization of dye behaviour in water samples. Both experiments showed that as the number of treatments increased, the surface tension of the sample decreased.

The first experiment used precision glass capillary tubes, Corning Pyrex, to measure surface tension. Figure 2.3 shows a schematic diagram of the capillary-tube system used.

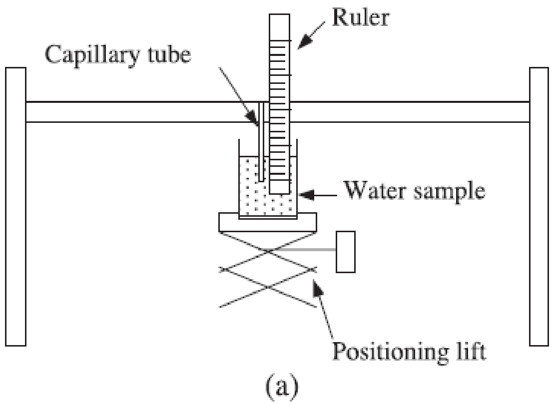

Figure 2.3 Schematic diagram of capillary-tube system used for determining MTDs efficacy

A glass capillary tube was attached beside a ruler, and then a beaker was placed on an adjustable jack so that the capillary tube was positioned at the centre of the water sample in the beaker. When the water level reached near the bottom of the capillary tube, a point exactly 5 mm from the bottom, the height of the water level inside the capillary tube was read. This step was repeated 10 times for each water sample and the average of the 10 measurements was used.

This experiment appears to be a quick, cheap, relatively accurate way to determine the efficiency and effectiveness of MTD's and can be performed in the field if correctly organized.

Amiri & Dadkhah (2006) first noticed a sizeable change in surface tension in relation to magnetic treatment, but after further investigations determined that impurities from the TYGON plastic pipe used were contributing to the surface tension modification. This was concluded due to the fact that water passed through the same apparatus without the permanent magnet mirrored the characteristics of the sample magnetized, as can be seen in Figure 2.4.

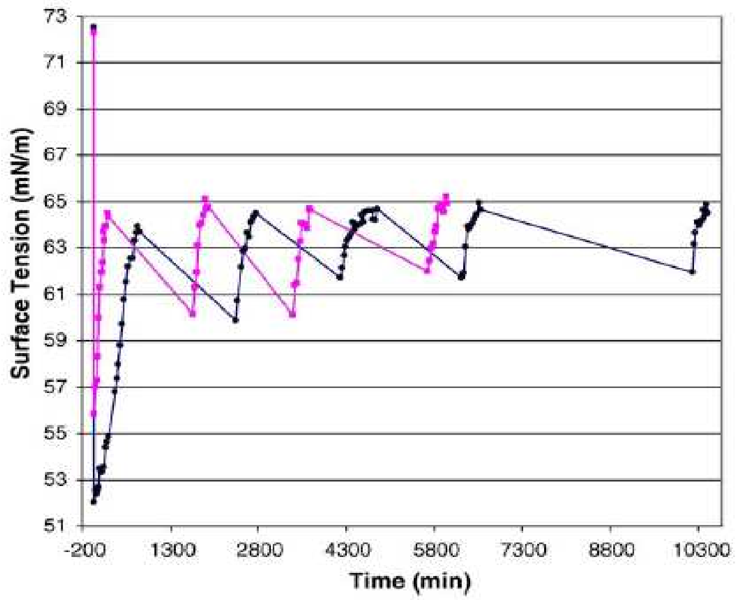

Figure 2.4 the pink curve is tap water circulated ten times in presence of magnetic field. The lower curve sample was circulated ten times without magnetic field but using a new pipe.

Amiri & Dadkhah (2006) findings are very important in regards to testing the effects of MTD's. To limit the chance of results being influenced by different contact materials, the sample being compared to the magnetized water should always be run through the same

MTD apparatus minus the permanent magnets. If the modified properties are evident in both samples, then the change is due to an effect from the apparatus and not the magnetic field.

Other Physical Properties

It has been shown that the water vaporization rate, an essential process for all biological processes, is significantly affected by the application of a static magnetic according to Nakagawa et al (1999).

Studies by Lee et al (2003) and Iwasaka & Ueno (1998) have found that the size of the water clusters, changes when exposed to a magnetic field.

It has been reported by Nakagawa et al (1999) that the dissolution rate into water of oxygen is significantly accelerated by the presence of a magnetic field.

Applying an increasing magnetic field to water can also reduce critical supercooling and prompt equilibrium solidification when the strength of the magnetic field is higher than 0.5 T according to Aleksandrov (2000).

2.2.2 Scale Reduction

Scaling problems from hard water in heating or cooling systems can heavily reduce the efficiency of the system in two ways. First it can reduce the heat transfer rate with the formation of an insulating deposit on a heat transfer surface significantly reducing the cooling or heating efficiency of the equipment. Secondly it can block pipes, condenser tubes or other openings decreasing flow rate and pumping efficiency.

According to Smith (2003) the cost involved due to heat transfer inefficiency and the removal of scale in Britain alone was estimated at £1 billion per annum in the early 90's. A 25mm thick $CaCO_3$ scale layer can decrease the heat transfer by 95%,

Properly installed and configured MTDs have had many successes in reducing the amount of scale build up in pipes. In an experiment performed by Smith (2003), permanent magnets reduced the formation of scale in 6 out of 6 hot-water storage tanks with an average of 34% . The maximum reduction was 70% and the minimum reduction was 17%.

Lipusa & Dobersekb, (2007) attained successful results, with the scale on a heating copper-pipe spiral being 2.5 times thinner due to Magnetic Water Treatment (MWT) compared with untreated water. Another major difference was found inside the outlet steel piping where only a small amount of powder-like coating was found in the magnetically treated line. This amount was negligible in comparison to the abundant scale from the untreated water. Figure 2.5 compares similar steel pipes. Picture D shows reduced amounts of scale build up due to MWT.

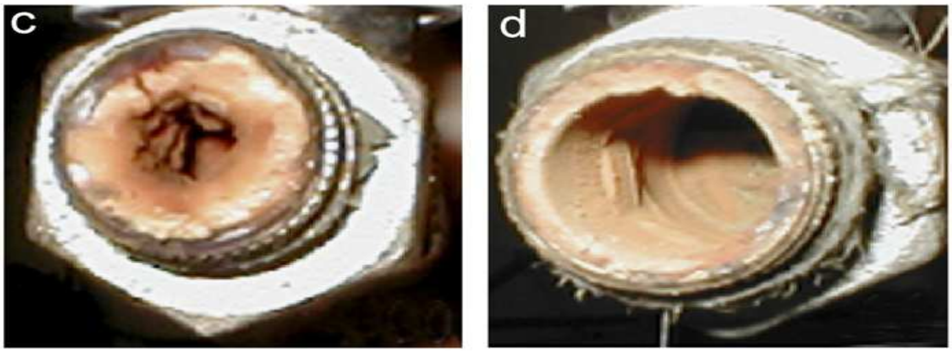

Figure 2.5 Results from Lipusa &, Dobersekb 2007 experiment. Picture (C) is steel pipe without treated water and abundant hard scale (D) shows a similar pipe with magnetically treated water and negligible amounts of scale.

Kobe et al (2001) concluded in his research that the chemical treatment of scale was only fractionally superior to the treatment with MTDs. Busch (1997) attained a 22% reduction in scale using artificially prepared hard water. Parsons et al (1996) recorded a 48% reduction in scale in his experiment.

An article by Quinn et al (1997) in the Iron and Steel engineering journal states that at a steel plant, a 60-inch hot strip mill was plagued with lengthy electrical delays because of inadequate motor room cooling due to lime scale build-up on the heat exchangers. A heat exchanger before the installation of MTDs is shown in Figure 2.6a. Six months after installing the MTDs, no mill delays were attributed to motor room cooling failure due to scale build-up. Figure 2.6b shows a heat exchanger after 1 year's service, while Figure 2.6c shows a heat exchanger after 1 year service washed with a hose. It should be noted that these 3 heat exchangers are 3 different systems and not the same one cleaned.

Figure 2.6a **Figure 2.6 b** **Figure 2.6c**

Figure (2.6a) before installation of MTD (2.6b) after 1 year service with MTD(2.6c) after one year washed with water.

Lobley (1990) witnessed the effects of magnetic treatment on scale reduction. In 1988 an MTD was installed on an air conditioning system that consistently required condenser cleaning twice per year. The system was in place on 12th August 1988 and regularly inspected and photographed up to June 1990. During the period of nearly two years the condenser did not require cleaning - scaling and sludging had been nonexistent. The inhibitor dosing had been suspended and revenue savings were calculated at $1100/annum.

Not all scale reduction experiments have yielded positive results however. According to Hassen & Bramsson (1985) the **process** of magnetic exposure on scale suppression showed no effect on deposit growth. Similarly, magnetic exposure exerted no effect on the adhesive nature of the deposits. They concluded that it does not seem plausible to expect magnetic treatment to exert a meaningful scale suppression effect at sufficiently high super saturation conditions.

Krauter et al (1996) installed an MTD Lawrence Livermore National Laboratory Treatment Facility D. At this facility, volatile organic contaminants (VOCs) were removed by air stripping, which raised the water pH, causing the deposition of calcium carbonate as calcite scale downstream. The MTD was installed before the air stripping unit and no beneficial scale reduction was recorded by the study.

Tai (2008) discovered in their research that the crystal growth rates of calcite were ssuppressed completely in the presence of the magnetic field under low pH and supersaturating conditions. By contrast, the growth rate seemed to increase at high pH and relative supersaturating as can be seen in Figure 2.7

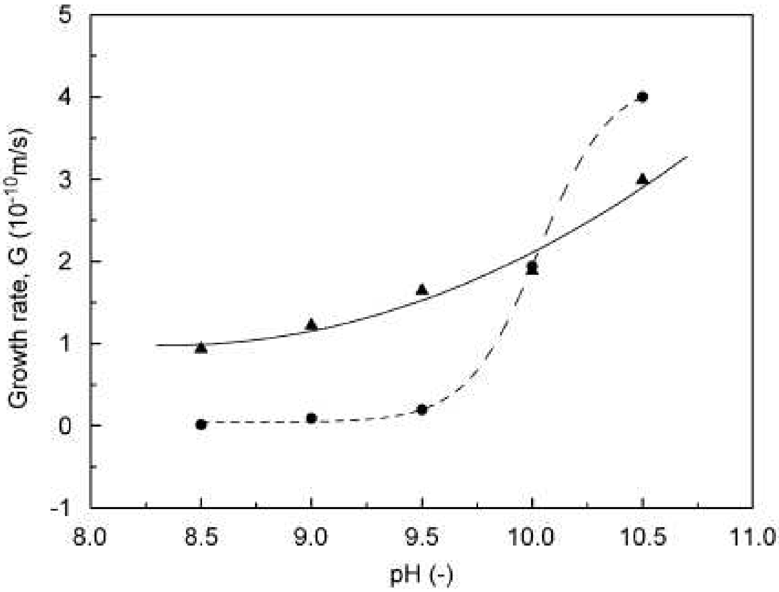

Figure 2.7 (Growth rates of calcite as a function of pH, with other variables kept constant.Δ Without magnetic treatment.•With magnetic treatment of Descal-A-Matic DC-3. Tai (2007)

According to Alimi et al (2006) the treatment-pH and the water flow rate of the MTD have an important impact on the nucleation type and on the amount of calcium carbonate. The Figure 2.8 exemplifies these findings.

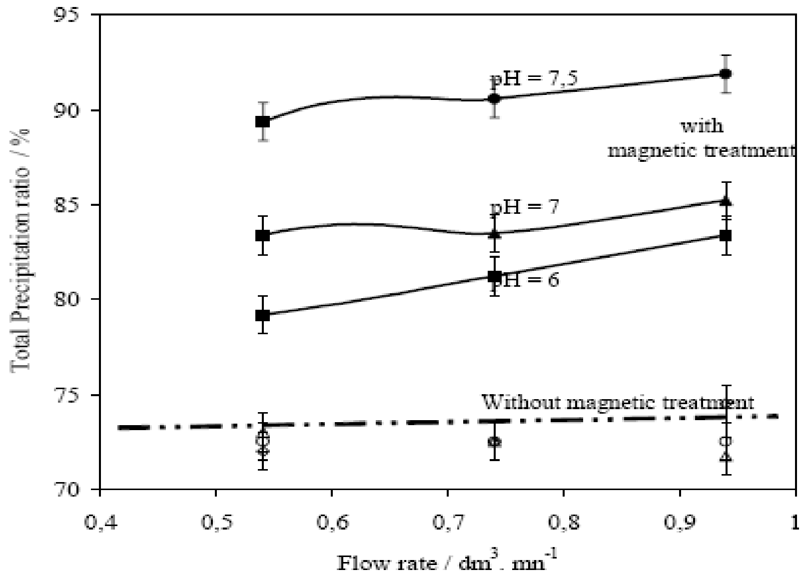

Figure 2.8 Variations of the total precipitation ratio in % of the amount of dissolved $CaCO_3$ vs. the flow rate, for treated waters at various pH in the presence and absence of magnetic treatment

In a research paper done by Parsons et al (1996) when the pH of their treated water was free to fluctuate, they observed a scale reduction of 48%. However, when they controlled the pH at 8.0 and 8.5 they witnessed increased scaling and the effects of magnetic treatment on scale removal were apparently destroyed.

It is apparent that that pH level has a direct relation to the effectiveness of scale removal by MTD's. In what way this relationship works is not fully understood. It would be beneficial to install more MTD's around the world and categorize the successful and unsuccessful cases with properties of the water treated also recorded. This would allow similarities to be compared which my give an indication as to what circumstances the scale reduction of magnetic treated water is successful.

2.2.3 Agricultural Benefits

Bogatin's et al (1999) analysis showed that the main effects of magnetised water were the increase of the number of crystallization centres and the change of the free gas content.

Degassing of water increases permeability in soil which results in an appreciable increase in irrigation efficiency.

According to Bogatin et al (1999) an increase in the amount of CO_2 and H+ in alkaline soils is similar to the addition of fertilizers. In wet soil, CO_2 forms H_2CO_3, which converts insoluble carbonates into soluble bicarbonates. Bicarbonates exchange with Na of the cation exchange complex. As a result of the exchange reaction, Na is removed from cation exchange complex into the soil, which improves properties of alkaline soils and accelerates their leaching.

Bogatin (1999) concludes from their findings that MWT induces an increased yield by 10-15%, a more intensive root formation, the transfer of phosphorus fertilizers into more soluble form and a decrease in the risk of secondary salinification of soil. The magnetic treatment improves conditions of root layers due to (a) leaching of superfluous salts (b) better permeability of irrigated water and (c) better dissociation of mineral fertilizers.

Lin & Yotvat experimented on the effects of magnetised water in agriculture with tests done on 14 experimentally established agricultural sites. In regards to using magnetic water for stock drinking supply, they recorded several noticeable effects. These included:

- Larger weight in cattle, meat calves, goats and poultry
- Extended production season: stabilized peak in yield-time curves; moderated decrease towards end of lactation and laying season; smooth continuity beyond normal production.
- Increased yields at accelerated rates: milk, meat, eggs (fertility and hatching)
- Improved final product quality; meat/fat, hide gloss, external appearance, milk protein
- Reduced mortality, improved health, vitality and fertility rates.
- Improved water quality in troughs and reservoirs; suppression of algae, reduced scale deposition and blockage

When using magnetic water for irrigating crops, they recorded the following observations

- Increased cumulative yield per unit plot

- Extended crop season (growth, ripening, fruit-bearing); improved vegetative deployment.
- Improved fruit quality; size, shape, texture, sugar level, greener leaves.
- Larger fruit
- Improved growth uniformity; vitality
- Cleaner piping, reduced scale deposition in piping and drip heads

Field Test 2.1 Dairy farm on Kibbutz Gvat

Cows on treated water yielded more milk, with the same percentage fat. Lactation period, non-productive days and veterinary conditions were better. Impregnation was better.

Field Test 2.2 Calves on Kibbutz Gvat

Week old calves on magnetic water grew 12% faster than the control group. Three-month old calves showed increased weight gains compared to controlled groups. Their meat contained 30 to 40 less kg fat at 10 to 12 months.

Field Test 2.3 Sheep farm ut Givat Zayad

Sheep were cultivated for milk, meat and wool. All three factors showed a considerable increase in yield after drinking magnetic water.

Field Test 2.4 Geese on farm Hayogev

Magnetic pre-treatment of gosling's water resulted in improved performance: increased daily weight gains, generally improved health and a greater economic return to the farmer.

Field Test 2.5 Turkeys at Nahalal

Weight increases. Increase in percentage of layers, longer laying period, improvement in fertility.

Testimonies from Omni Environmental Group's website of Australian farmers using magnetic water treatment follow similar claims as to those above. It must be realized however that testimonies are based on observations with no controls and are easy to fake.

Australian Strawberry Distributors are one of the biggest growers and distributors of strawberries, supplying such chain stores as Woolworths and Coles Myer. They claim, after treating their water magnetically, their production had increased; the quality had improved and they were saving at least 20% water if not more.

Other testimonies also claim larger yields, increased water savings, increased water penetration and increased seed germination rates,

An interesting experiment done for AQUATOMIC MTD's by Pederson (2005), was performed by comparing germination rates of seeds treated with tap water, filtered water, North / South pole magnetically treated tap water, South pole treated tap water and North pole treated tap water.

They noticed that the germination rates of the magnetised waters were 100% while the untreated filtered water had 85% and the untreated tap water had 15%.

The South Pole treated water gave the fastest growing seedlings, yet the stems were not strong enough to support their leaves. The average height of the seedlings was 14.13cm. The North Pole treated water gave a slower growing seedling which was able to support its leaves. The average height of these seedlings was 11.95. The North / South Pole treated water gave the best results with a healthy seedling growing an average of 12.28cm. Figure 2.9 shows some results from the experiment.

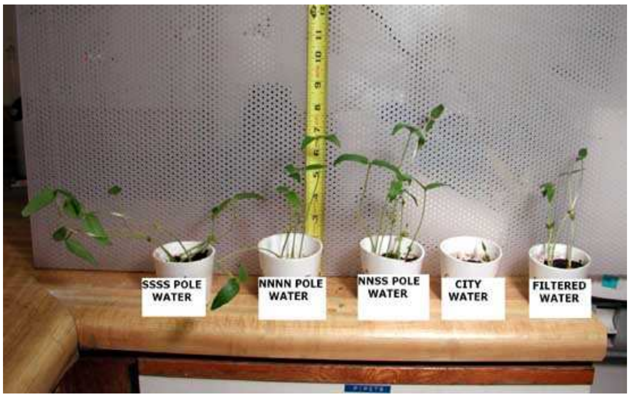

Figure 2.9 Seedling germination and growth rates varied depending on orientation of magnets

While this experiment did not appear to be peer reviewed, and also had links to the retailer of an MTD, it does open up the possibility that different orientations of the magnets may have different effects. This experiment is easy to replicate and could prove whether these findings are real or bogus.

2.2.4 Improved cement compressive strength

Su & Wu (2000) discussed how MWT can break up water clusters into smaller clusters which allow the water to penetrate the core region of the cement particles more easily. Hence, hydration can be done more efficiently, which in turn improves concrete strength. The magnetized water can be kept in a reservoir for 0–12 hours but over this range, its advantage may be lost (Fu & Wang 1994)

Wang & Zhao's (2008) study showed that when mixed with magnetic water, the properties of the cement paste and mortar improved. The magnetic treatment had a positive influence on the compressive strength, the pore size distribution and the durability of concrete

Su & Wu(2000) investigated the compressive strength and workability of concrete and mortar, which were mixed with magnetic water and contained granulated blast-furnace slag. Results showed that the compressive strength of mortar samples mixed with magnetic water increased 9-19% more than those mixed with tap water. The compressive strength of concrete prepared with magnetic water increased 10-23% more than that of the tap water samples. It was also found that magnetic water improved the fluidity of mortar, the slump, and the degree of hydration of concrete.

Weilin et al (1992) obtained results showing that cement strengths can be significantly increased by slurry magnetic treatment. It was observed that the cement compressive strength was improved by 54%, cement bending strength was improved by 39%, and cement bonding strength was improved by 20%. The experimental results also show that the initial set time and final set time of cement slurry can be shortened by 39% and 31%, respectively, after magnetization.

2.2.5 Other applications of magnetic water treatment

Anti Corrosion

Bikul'chyus (2003) found that the magnetic treatment of water decreased the corrosion rate of steel by 14% on the average, with these results being constant over a range of temperatures.

According to The Department of Energy’s Federal Technology alert (1998), the National Aeronautics and Space Administration (NASA) tested magnetically treated water, for corrosion rates of steel corrosion coupons. Corrosion rates of 1 to 50 mils/year were obtained using chemical inhibitors, with corrosion rates of 0.0 mils/year obtained for the magnetically treated water. 0.4mils / year is considered acceptable.

Treatment of urinary stones

Yue et al. (1983) reports that through laboratory and clinical experiments including enzyme and animal tests and clinical trials, it clearly showed that the curing efficacy is over 70% in the treatment of urinary stone and over 93. 9% for salivary calculus.

Increased efficiency of desalination using reverse osmosis.

According to Al-Qahtani (1996) using Reverse Osmosis (RO), both treated and untreated solutions were desalinated in a seawater RO unit at several pressures. It was found that the permeate salt concentrations of the treated solutions were usually lower than that for untreated ones.

Water transfer behaviour in dampening unit of a printing machine

Dietmar (1998) conducted laboratory tests to find out whether the water transfer behavior in the dampening unit of a printing machine could be improved by the installation of a permanent magnetic water treatment device. With a 1-5 percent alcohol-water-mixture, water transfer increased by up to 100 percent.

Improved efficiency of electrolysis

Iida (2004) showed on 2 occasions that the efficiency of water electrolysis improved significantly under a strong magnetic field.

2.3 Current theories of magnetised water

The principle of this phenomenon is still not well understood and various contradictory hypotheses have been proposed.

Brower (2005) explains that magnetic systems treat water by passing it through a multi-pole, multi-reversing polarity magnetic field. The dipolar movements of the molecules of dissolved solids and water molecules are affected in such a way that at the instant of crystal formation, the crystal form is divided into thin layers and the ions align according to a single magnetic axis. The magnetic field then influences the production of a much greater number of nuclei. Hence, the solids precipitate as much finer crystals, which tend to remain separated because of the excess similar charge. The calcium carbonate powder is now in a sludge form and can be easily maintained as it will not stick to elements and piping.

According to the The Department of Energy’s Federal Technology alert (1998) , the general operating principle for the magnetic technology is a result of the physics of interaction between a magnetic field and a moving electric charge. When ions pass through the magnetic field, a Lorentz force is exerted on each ion which is in the opposite direction of each other. The redirection of the particles tends to increase the frequency with which ions of opposite charge collide and combine to form a mineral.

A journal article from Quinn (1997) explains the molecular makeup of water and its polarity. A molecule of water consists of one atom of oxygen and two atoms of hydrogen, H_2O. The covalent bond that holds each hydrogen atom to the oxygen atom results from a pair of electrons being shared. Figure 2.10 shows a molecule of water.

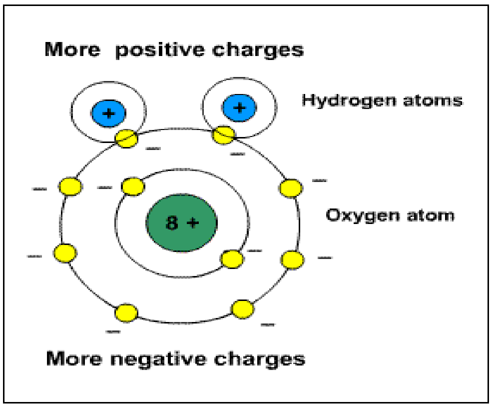

Figure 2.10 Molecule of H_2O

Because of the two hydrogen atoms sharing electrons on one end, the molecule possesses a positive charge on one end and a negative charge on the other. Some suggest this may cause the molecule to act similarly in some ways to a small bar magnet (Water Properties Tutorial , 2007). This is referred to as the dipole moment of a molecule. The dipole moment is a vector quantity and is responsible for solubility, one of the most important properties of water. Figure 2.11 shows how the dipole moment of a water molecule is similar to a magnet as claimed by Water Properties Tutorial , 2007.

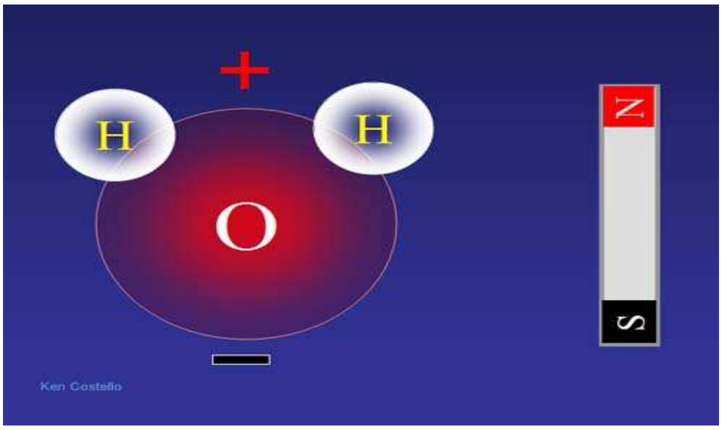

Figure 2.11 Water molecules. Dipole moment of a molecule (Water's Properties Tutorial, 2004)

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 2.12(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 2.12(c). In a magnetic field, magnetic force can break apart water clusters into single molecules or smaller ones as shown in Figure 2.12(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).

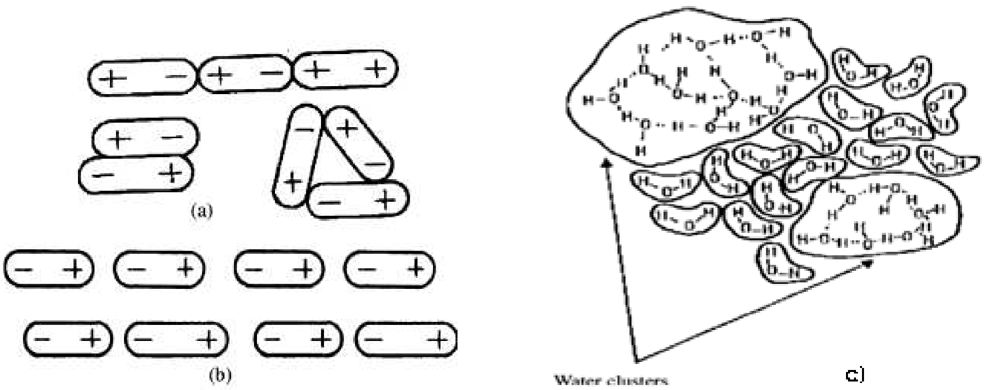

Figure 2.12 Water molecules. Dipole Effect of magnetic field on water molecules: (a) thermodynamically stable water clusters, (b) water molecules after passing through a magnetic field. (Right c) Structure of molecule cluster of water.

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 2.14 shows the different structure of calcite and aragonite crystal structures.

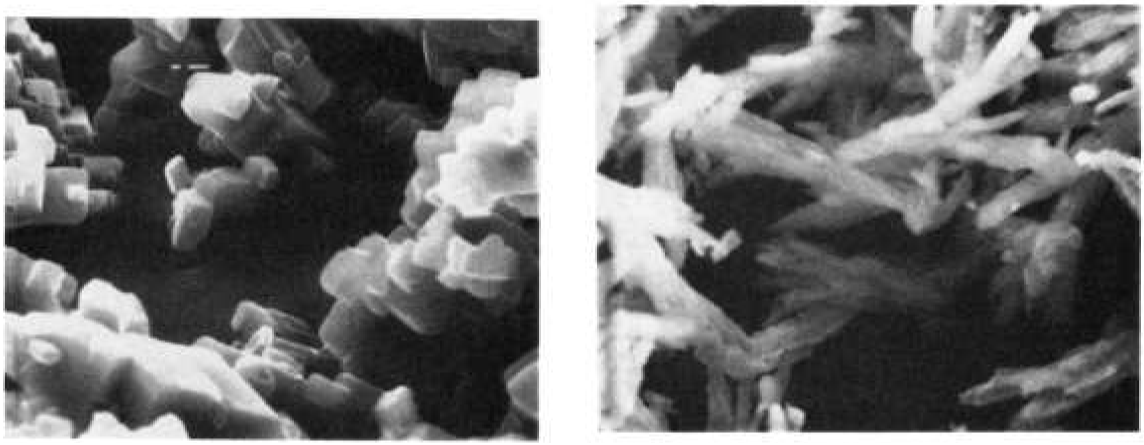

Figure 2.13 (left) scanning electron micrograph of synthetic calcite crystals, magnified 4700X. (right) Scanning electron micrograph of synthetic aragonite crystals, magnified 6700X. (Ruth 1989)

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).

Scientists are still unsure of the exact mechanisms by which treating water with magnets modifies its behaviours. There are numerous scientifically accurate theories, as well as several theories that apparently defy science as we know it. It should be pointed out however, that our current science isn't guaranteed 100% accurate and that we do not know everything about elements and molecules in the universe. We cannot throw new theories easily away just because they don't match with our past theories. We cannot throw new technology away either, just because we don't understand why it works.

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 2.14, MTD's are invasive (i.e. plumbed in, and therefore have to satisfy relevant legislation) or non- invasive (i.e. clamped on).

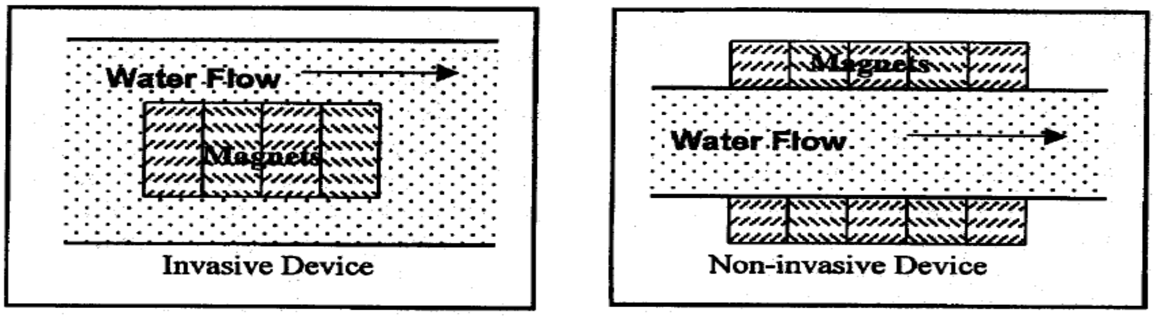

Figure 2.14 Left: invasive device, right : Non-invasive device

Gruber and Carda (1981) classified MTD's utilizing permanent magnets into four categories (Fig 2.15), 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).

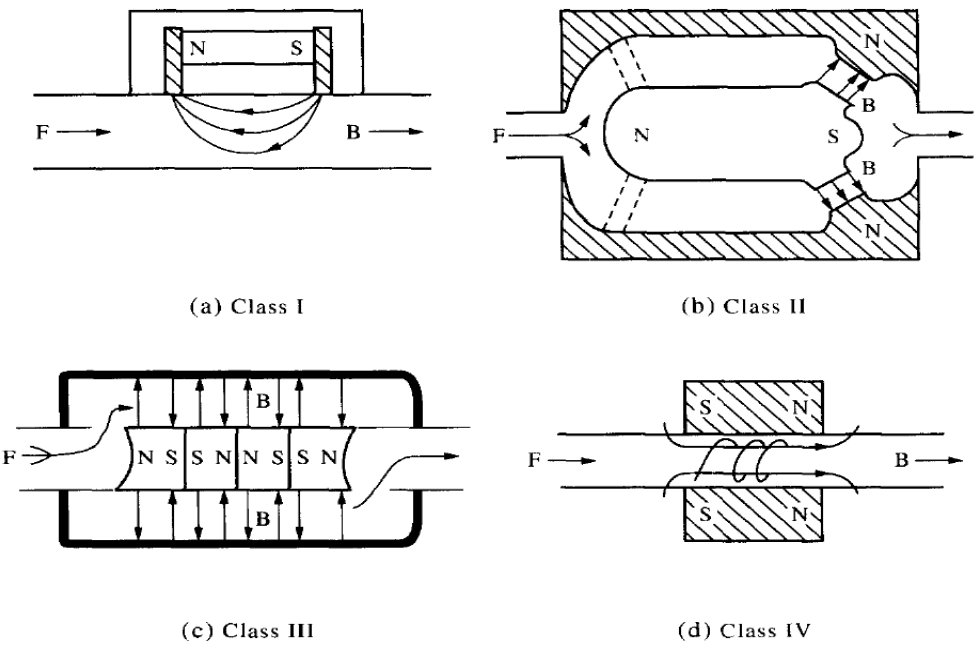

Figure 2.15 Classification of permanent magnet type MTD's proposed by Gruber and Carda (1981). (Reproduced from Gruber and Carda, 1981.)

Baker & Judd (1995) conclude from their findings and others that magnetic treatment is more successful when recalculating the solution or prolonging the magnetic exposure. Gabrielli’s et al (2000) study agrees with this finding. In regards to velocity however, there is still conflict in discussion. *Polar International* claim that the optimum speed through one MTD device is from 1.5 to 3.0 m/s, such that turbulent flow prevails during a very brief magnetic contact. On the other hand the manufacturers of *CEPI (Conditionnement Electromagnktique Par Induction)* devices claim that turbulence downstream of treatment causes destructive perturbations to the magnetic treatment. According to Lipus et al (2006) the velocity should be in the order of 0.5 – 2m/s.

Gabrielli’s et al (2000) results showed that inverted magnet orientation yielded better results in scale reduction compared to non- orientated magnets. Brower’s (2005) view agrees with Gabrielli’s. Figure 2.16 shows the different configurations for the MTD’s. Figure 2.17 shows the results attained by using the different configurations.

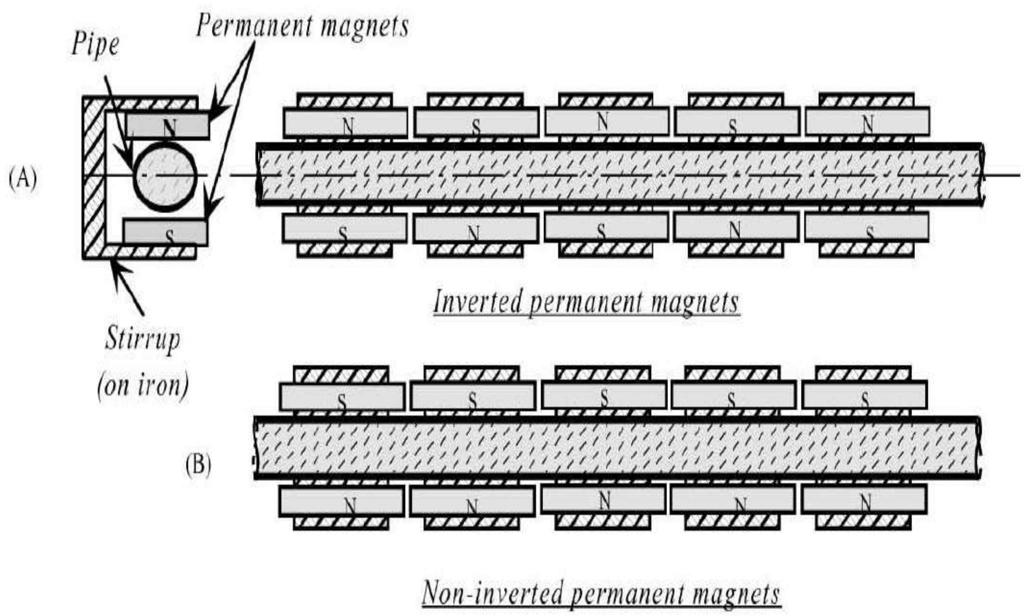

Figure 2.16 Different orientations of magnets. Inverted magnets are recorded to be more effective

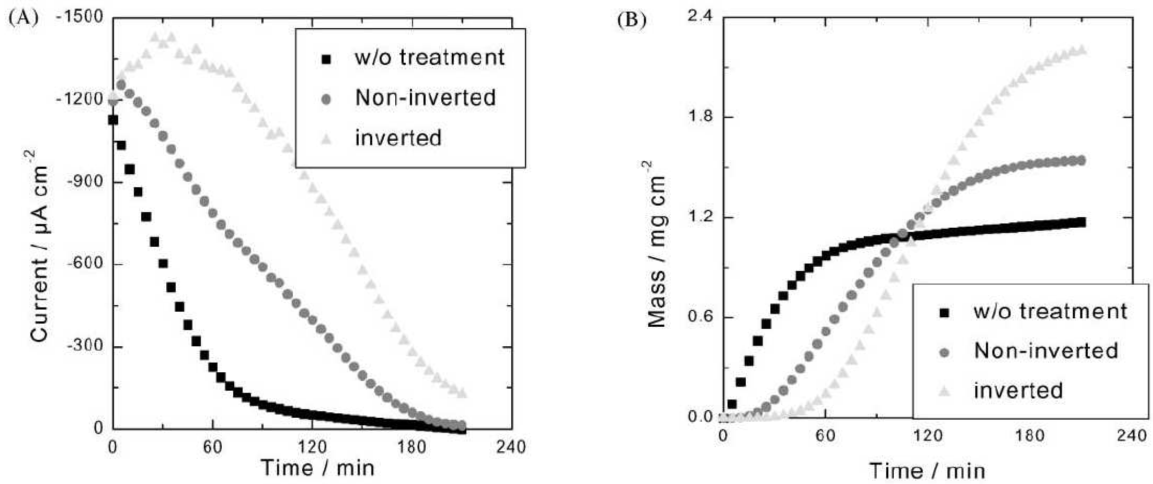

Figure 2.17 two different experiments done by Gabrielli (1999) show inverted magnet orientation is more effective.

From Gabrielli's et al (2000) study it was also found that the type of pipe material can affect the effectiveness of magnetic treatment. In the study, four different types of pipe material were used; clear flexible PVC, Steel, Copper and PVC II which is used for plumbing.

The results showed that the flexible PVC destroyed the effects of magnetic treatment and Steel produced increased results compared to copper and PVC II. This is a very interesting finding and could point out why other experiments have failed to produce results.

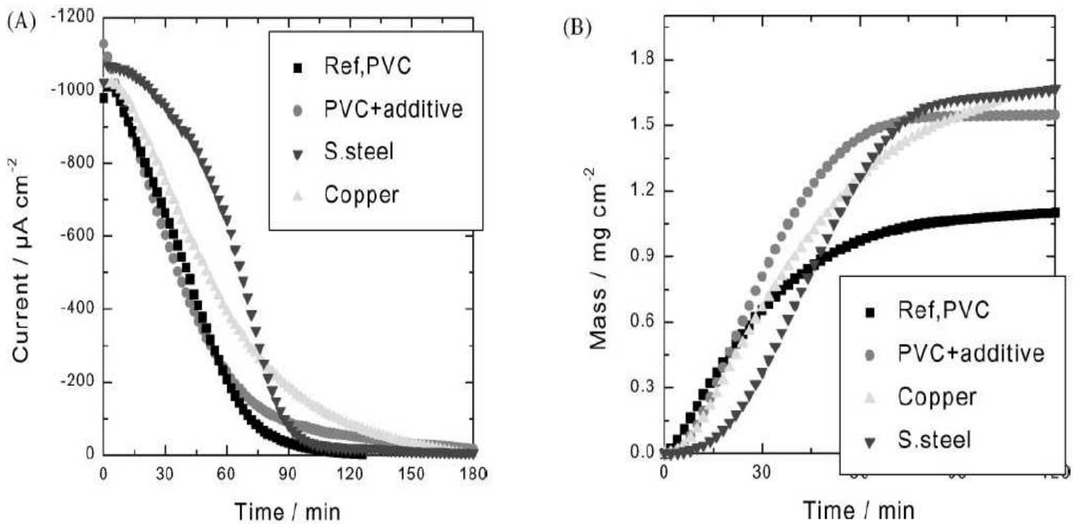

Figure 2.18 two different experiments done by Gabrielli et al (2000) show different pipe materials can effect magnetic treatment results. .

In regards to strength of magnets, successful results have been achieved from magnets with as little as 150 Gauss (Gabrielliet al ,2000) . The average strength of retail MTDs would lie around the 3000-5000 Gauss level. Many studies have been done with extremely powerful magnets as well. For example Iwasaka (1998) used a 14 000 Gauss magnet.

2.5 Literature review summary

The mechanisms for MWT seem to be different for different applications.

- MWT increases cement strength by decreasing the sizes of water clusters,
- Creates extra collisions of ions to precipitate $CaCO_3$,
- Changes the free gas content in regards to improved crop yields.

With the combined past studies, a clearer picture is beginning to be built over what is the best configuration of magnets for a MTD. The magnets should have a strength reading of around 3000 Gauss, the solution should be passed through the device more than 3 times, the piping material should be steel , copper or PVCII and the orientation of the magnets should be alternating.

CHAPTER 3

METHODOLOGY

Chapter 3 Methodology

3.1 Design of MTD

The design and configuration of the MTD to be used in these experiments is based on what has been learnt from the literature review. The MTD is made up of 6 pairs of approximately 4400 Gauss magnets arranged in an alternating configuration. One of these magnets can hold 25 kg of mass. Figure 3.1 shows the MTD designed for the experiments.

Figure 3.1 Homemade MTD with approximately 4400 Gauss magnets,

3.2 Testing change in properties of water

3.2.1 pH and Dissolved Oxygen

Tap water and water from a local reservoir were tested for their pH and DO values. Before passing the samples through the MTD, pH and DO values were recorded for each sample. The water samples were then passed through the MTD, as seen in Figure 3.2, and then tested with a pH meter and a DO meter. The samples were magnetically stirred at a low velocity while the data was collected to keep the sample thoroughly mixed.

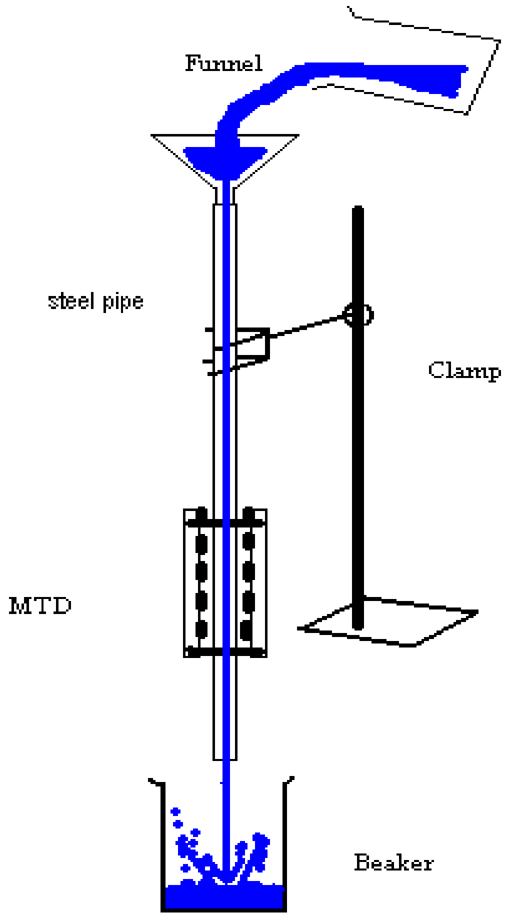

Figure 3.2 (Left) apparatus setup for treating water.

Each water sample was tested at 1x pass through the MTD, 2x and 5x to evaluate whether successive passes altered the sample's properties. The non-magnetic samples were also passed through the funnel without the magnets attached so the only difference in the water's treatment was the absence of magnets. After initial readings had been taken, the solutions were rapidly stirred for 2 minutes by the magnet stirrer to induce a vortex and introduce more oxygen into the solution. The DO was tested again after the sample was mixed.

3.2.3 Heat Capacity

Heat Capacity test 1

Magnetically treated water's heat capacity was compared with that of normal tap water. This was done by heating the sample with a Bunsen burner and recording the temperature of the solution at every 30 second interval.

Magnetic water was prepared by passing tap water through the MTD 5 times. Non-magnetic water was also passed 5 times through the funnel without the magnets attached.

For this test to be accurate, the beakers had to contain the exact amount in each trial. This was achieved by measuring 200mls exactly for each test with pipettes. The thermometer had to be in the same position and the Bunsen burner flame had to be of the same intensity for each test. The temperature reading was taken every 30 seconds, and several trials were performed to make sure the results were reproducible. Figure 3.3 shows the apparatus used for the experiment.

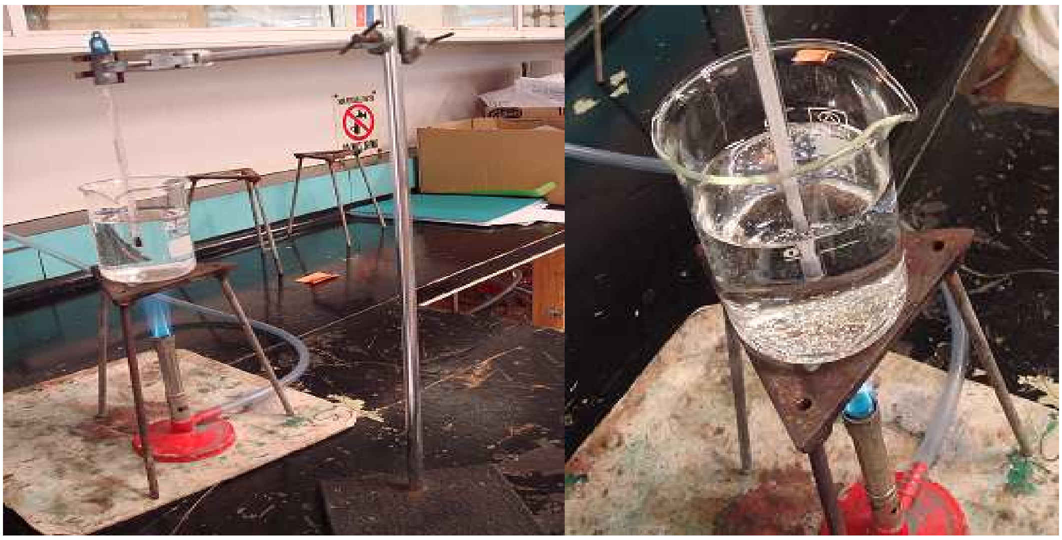

Figure 3.3 Apparatus for heat capacity test

Heat Capacity test 2

The second heat capacity test compared the cooling rates of magnetically treated water with that of normal tap water. Both water samples were passed through treatment device with and without magnets, 5 times.

20mls of each sample was carefully measured by a pipette and put into test tubes. A thermometer was then placed inside each test tube and held in place by a stopper. The thermometers were attached to stands. Figure 3.4 shows the setup of the test tubes.

A 1 litre beaker was half filled with tap water and heated till boiling point on an electric hotplate. Once the beaker water had begun to boil, both test tubes were submerged into the boiled water. Once they reached the same temperature as the beaker water, they were taken out simultaneously and their temperatures were read every 1 minute.

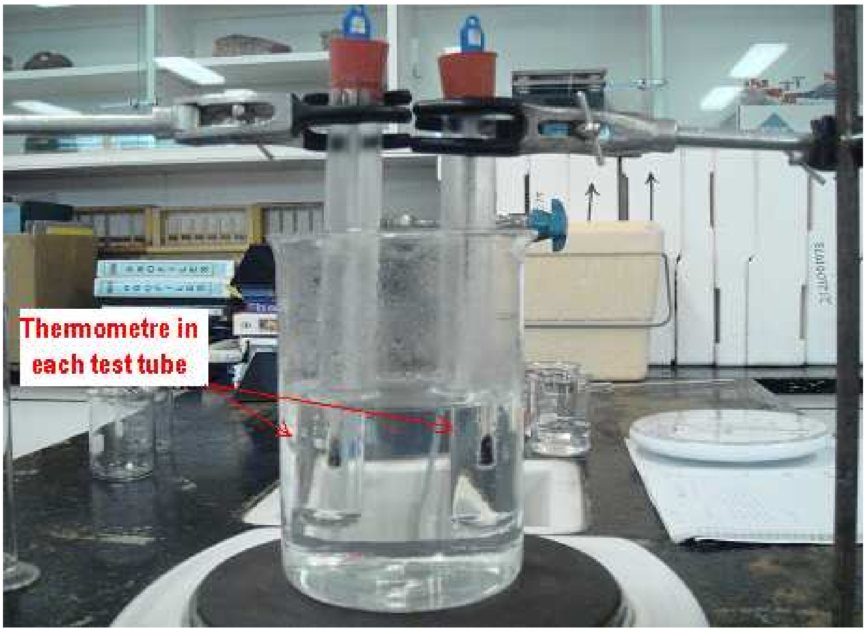

Figure 3.4 Setup of heat capacity test 2

3.2.4 Dissolution rate

The dissolution rates of tap and magnetically treated tap water were compared. Both water samples were run through the treatment apparatus 5 times. When the tap water was run through the treatment device the magnets were removed.

7.26 grams of potassium nitrate was measured accurately using an electronic balance. The potassium nitrate was then added to a test tube. Exactly 7mls of magnetically treated water measured by a pipette was combined in the test tube. The test tube was submerged into a hot water bath with a temperature over 70^{o}C and stirred until all the potassium nitrate was dissolved.

Once all solids were dissolved, the test tube was taken out of the hot water bath and cooled at air temperature. The test tube was constantly swirled and examined for when the potassium nitrate began to precipitate out. The moment a single crystal could be seen to precipitate, the temperature was recorded. The experiment was done 2 times for each sample. Figure 3.5 shows the potassium nitrate after it has precipitated out.

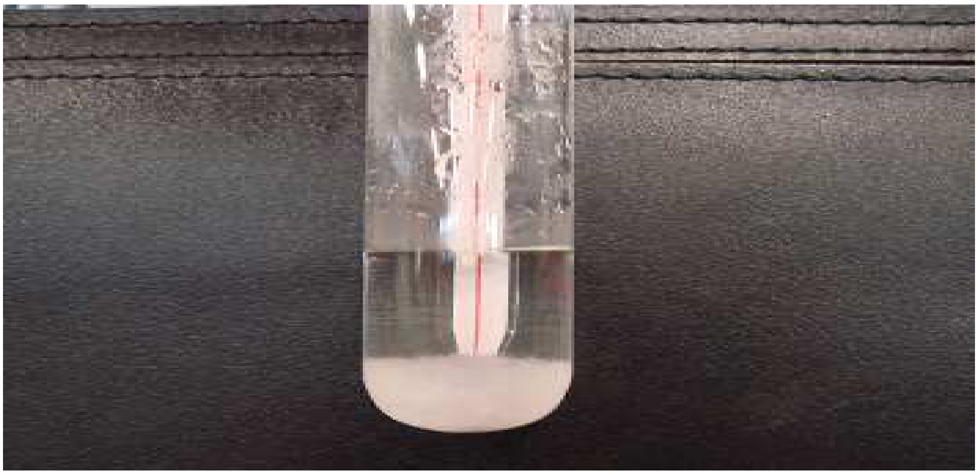

Figure 3.5 Precipitated potassium nitrate

3.3 Testing Applications of Magnetised Water

3.3.1 Seed Germination Test

64 snow pea seeds were germinated with different waters. 32 seeds were watered with tap water. 32 seeds were watered with magnetically treated tap water. The water was treated 5 times through the correlating treatment device.

All seeds were soaked in their correlating water for 1 hr before planting. The seeds were planted in seedling containers with 8 cells each, as can be seen in Figure 3.9. There were 4 seedling containers per water sample. All containers contained standard potting mix from the same bag. Prior to sowing, all containers were soaked in their correlating water to saturation point. All seeds were planted at the same depth.

Once a week the seedlings were watered by filling a tidy tray up with exactly 4 litres of their correlating water and then placing the seedling containers in the water. Figure 3.6 shows how the seedlings were watered. The seedlings were left to soak for exactly 5 minutes before being removed. This was done once a week.

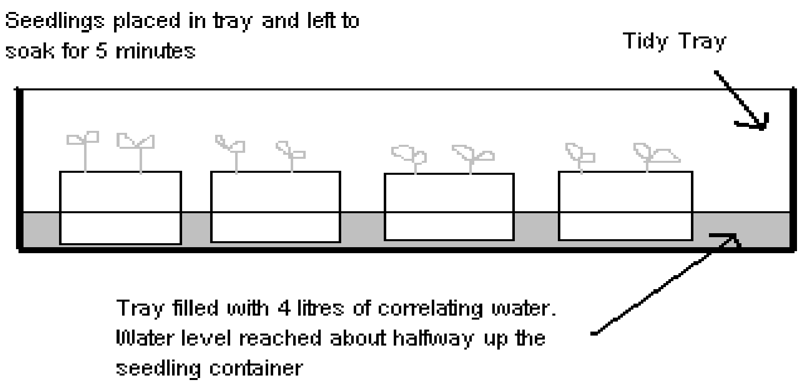

Figure 3.6 Watering Method for seedlings

The seedlings were placed under an outside pergola where they were open to all the elements except for rain. They received approximately half a day's sun each day. They were placed in an alternating pattern as can be seen in Figure 3.7. Each week, after been watered, their positions were reversed just in case a certain position had an advantage over any other.

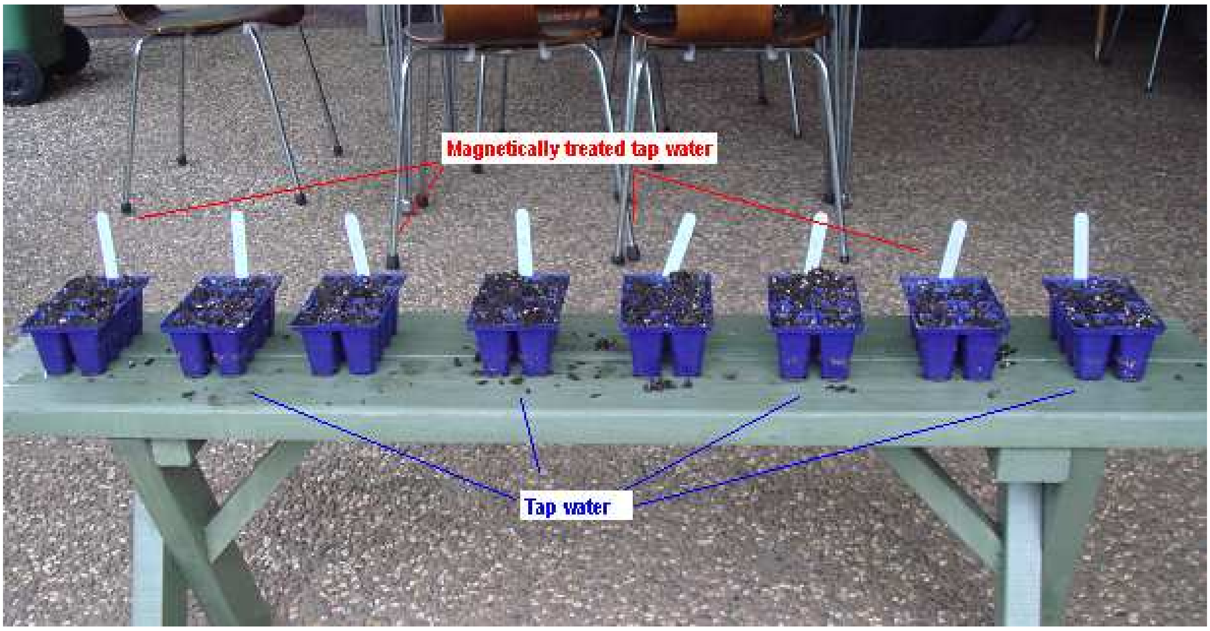

Figure 3.7 Seedlings placed in alternating potions. There were 4 seedling containers per type of water.

After 4 weeks the seedlings were measured. Figure 3.8 shows the seedlings after 5 weeks.

Figure 3.8 Seedlings after 4 weeks of growth

The seedlings were compared using the mass of each plant above the roots. Each seedling was trimmed just above the soil line (Figure 3.9) before being weighed on an electronic balance (Figure 3.10).

Figure 3.9 Snow peas trimmed just above soil line

Figure 3.10 Snow peas weighed on precision scales.

3.3.2 Plant Growth Test

64 snow pea seedlings were bought from Bunnings and grown with 4 different types of water. Tap water, magnetically treated water, salt water and magnetically treated salt water were used. All water samples were passed through their treatment device 5 times.

8 snow pea seedlings were placed in each 200mm pot. Each pot contained a mix of fertilizer and potting mix all from the same bag. There were 8 pots in total giving each water group 16 seedlings or 2 pots each. 2 of these plant groups were tested with salt water. The salt tolerance of snow peas is low and around 2 ds/m (Dunn 2001). Multiplying this number by 55 gives their approximate salt limit in part per million (ppm). This gives snow peas a salt limit of 110 ppm or 1gram of salt per litre. The salt concentration of the water used to water

the salt groups was raised each week until there was a noticeable yield reduction. The following table shows the salt concentrations used.

Table 3.1 Salt concentrations for watering salt tolerance groups.

Week	Salt concentration (ppm)
First water	62.5ppm
1	125ppm
2	187ppm
3	312ppm
4	437ppm
5	562ppm (noticeable effect)
6	187ppm

Each pot was watered once a week by placing it inside a 10 L bucket and watering it with a watering can. The watering can was filled with 1.8 L of water each time. Once watered, the pot was left to stay in the bucket for 5 minutes to allow more adsorption. Figure 3.11 shows an example of the watering method.

Figure 3.11 Watering method for plant growth test.

When making the salt water, sea salt was added to 8 litres of water in a bucket. The 8 litres was then split into two lots of 4 litres, where one batch was magnetised and the other wasn't. This allowed the plants to receive very similar concentrations of salt.

A basic green house was made for the plants. This was to keep rainfall out and to decrease the possibility of frost. The plants positions were reversed each week just in case any particular position in the greenhouse had an advantage over another. Figured 3.12 shows a picture of the basic green house.

Figure 3.12 Basic green house made to keep rainfall and frost off plants

The plants were grown for 45 days; each being watered 7 times each. On the 45th day, the plants were weighed on precision electric scales. Each plant was cut off at the soil level before being weighed. An example of this can be seen in Figure 3.13

Figure 3.13

3.3.3 Cement compressive strength

The compressive strength of cement mixed with magnetically treated water was compared to cement mixed with tap water. The water samples were passed through their treatment device 5 times. The cement used was builder's cement with no fly ash. The mixture quantities for each test group are in Table 3.2.

Table 3.2 Mixture quantities for the cement used

Component	**Quantity**
Builders Cement	3.25 kg
10mm aggregate	5.8 kg
7mm aggregate	3.05 kg
Sand	3.55 kg
Water	1.45 L

Each mixture was made separately. The first mixture was made with magnetic water and mixed with a cement pan mixer. The cement was mixed until it was deemed sufficient by judgment of eye by the lab technician. The cement was then put into a cylinder mould similar to the one in Figure 3.14.

Figure 3.14 (left) Type of mould used to make cylinders (right) Cylinders after they were cured for 31 days.

The method for filling the mould involved:

- Filling it to 1/3 full and then compacting it with a steel rod 25 times in a circle
- Filling it to 2/3 full and then compacting it with a steel rod 25 times in a circle
- Filling it to the top and then compacting it with a steel rod 25 times in a circle.
- Making flush with a cement trowel

Once complete, the second batch of cement was mixed with tap water and moulded with the same method. Once complete, the moulds were left to sit for 24 hours. After 24 hours, the moulds were marked and placed in a humidity room to cure. The humidity in the room was set at 84% with a temperature of 18^{o}C. Figure 3.15 shows inside the humidity room.

Figure 3.15 inside the humidity room

The cement was cured for 31 days and then compressed with a cement compression tester. The machine was operated by the lab assistant. A picture of the compression tester is featured in Figure 3.16. The machine gave readings of kilo newtons required to cause failure in the cement cylinder. The maximum forces required to cause failure in each cylinder were recorded.

Figure 3.16 (Left) Cement compression testing machine.(right) close up of the compression mechanism.

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3.3.4 Precipitation of $CaCO_3$ and other salts

First test

Samples of synthetic hard water were made from Calcium carbonate ($CaCO_3$) and Magnesium sulphate ($MgSO_4$). Salt water was also made from sodium chloride NaCl. Varying quantities of concentrations were mixed with 1 litre of distilled water. The concentrations of solutions used are in table 3.3 below

Table 3.3 Concentrations of synthetic hard water used.

Chemical used	**Quantity**
$CaCO_3$	0.6g
$CaCO_3$	0.37g
$MgSO_4$	4g
$MgSO_4$	1.1g
$MgSO_4$	Approx 10g
NaCl	Approx 130g
NaCl	25g

After mixed, each sample was split into 2 equal quantities where one was passed through the MTD 5 times and the other was passed through the same device 5 times but without the magnets.

Once treated, each sample was tested with an electro conductivity (EC) probe to determine the amount of ions in the solution. A picture of the probes setup can be seen in figure 3.17. The theory behind this method was that if the magnets increased the collision rate of ions, then they should form small crystals and reduce the amount of ions in the solution. (The Department of Energy's Federal Technology alert 1998) The probe was calibrated after every 3 experiments.

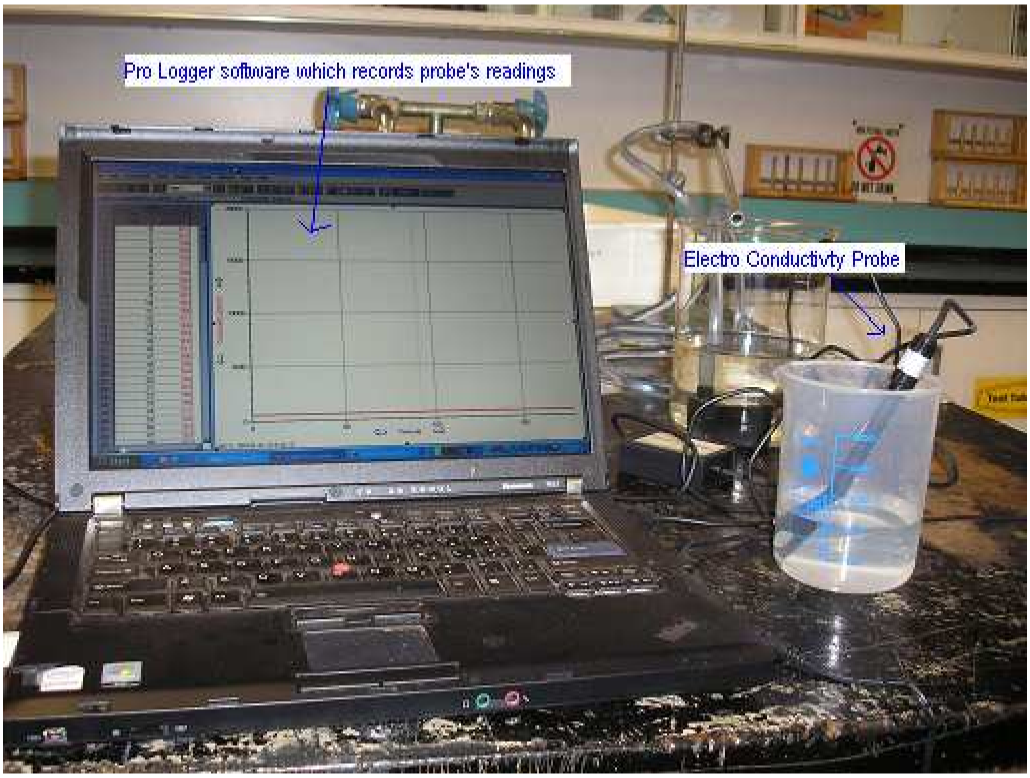

Figure 3.17 Logger Pro software with Electro conductivity probe.

Second Test

The second test was set up so that the solutions were made to constantly flow through the treatment device while logging continuously the EC of the solution. A 333 Litre per hour submersible pump was used to pump the solution. The solution was pumped through a clear PVC tube with a diameter of approximately 14mm. The water was passed through the treatment device in an aluminium pipe as Gabrielli's et al (2000) findings suggested the treatment would not work through PVC clear tube. The EC probe was able to log approximately 2 readings a second over a 3 minute range. Figure 3.18 and 3.19 shows the apparatus setup.

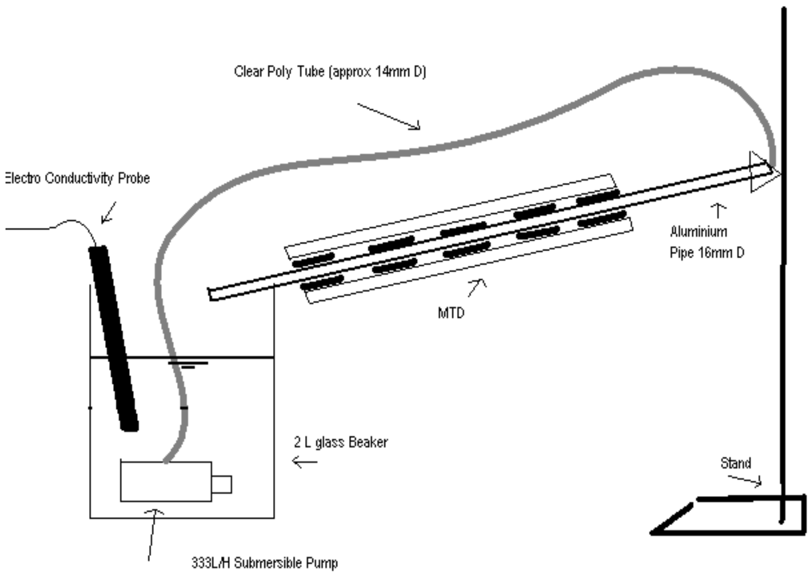

Figure 3.18 Apparatus setup for the second precipitate test.

Figure 3.19 Apparatus setup for the second precipitate test.

Different concentrations of synthetic hard water were made up from Calcium Chloride ($CaCl_2$) ,Sodium Carbonate (Na_2CO_3) and distilled water.

- Test A had the magnets attached. To make the hard water, 400mg of $CaCl_2$ was mixed with 50ml of distiller water and poured into the 2L beaker. 400mg of Na_2CO_3 was also mixed with 50ml of distilled water and poured into the 2 L beaker. The beaker was then filled up the 1.5 L mark with distilled water. The solution was stirred with a glass stirrer until the solution had no visible precipitates. The EC probe and the pump were turned on and the conductivity was logged for 9 minutes. After 9 minutes, the pump was turned off and the conductivity was logged for 6 minutes,

- Test B followed the exact same procedure, except the pump was not turned on at first and therefore no water was being magnetised. The logger read the conductivity of the solution for 4 minutes. After 4 minutes, the pump was turned on and logged for 2 minutes.

- For test C, 60mg of $CaCl_2$ and 60 mg Na_2CO_3 were mixed with 1000ml of distilled water. The solution was tested at first without the pump for 3 minutes, and then with the pump for 6 minutes.

- Test D used 100mg of $CaCl_{2,}$ 100 mg Na_2CO_3 and 1000ml of distilled water. The solution was tested at first without the pump for 6 minutes, and then with the pump for 15minutes.

- Test E used equal parts of $CaCl_2$ and Na_2CO_3 with distilled water to get the solution used in test D back to its beginning EC reading. The conductivity was logged for 6 minutes without the pump running. After 6 minutes, it was then run through the pump for 9 minutes without the magnets attached as can be seen in Figure 3.20. After 9 minutes the pump was turned off and the data was logged for 3 minutes.

Figure 3.20 Apparatus with no magnets attached.

- Test F diluted the solution from test E back down to an EC reading of 500 ds/m. The outlet of the aluminium pipe was moved so that it was under the water's surface as can be seen in Figure 3.21.

Figure 3.21 (left) pipe position for Test A-G (right) submerged pipe position for Test F – onwards.

The sample was logged for 3 minutes with the pump off. The pump was then turned on and run without the magnets for 6 minutes. The magnets were attached back to the apparatus and the pump was turned on and logged for 21 minutes.

- Test G used the solution from test B after it had sat for 1 hour. The solution was logged for 3 minutes without the pump, and then 12 minutes with the pump and magnets.

- Test H tested tap water, with the magnets attached. The data was logged for 3 minutes with the pump off and then 9 minutes with the pump on.

- Test I used tap water without magnets attached. The data was logged for 3 minutes without the pump and then 9 minutes with the pump. After the 9 minutes the magnets were attached and the data was logged for 3 more minutes.

- Test J used tap water with approximately 50 g of sodium chloride dissolved. The pump was run until the conductivity logger showed all salts were dissolved. Once all salts had been dissolved the data logger recorded 30 minutes of pumping through the magnets.

CHAPTER 4

RESULTS AND DISCUSSION

Chapter 4 Results and Discussion

4.1.1 Results on pH Test

The first test compared tap water passed through the device with MTD 3x, tap water passed through the device with MTD 5x, tap water passed through the device without MTD 3x and tap water not passed through the device at all. The results can be seen in Figure 4.1

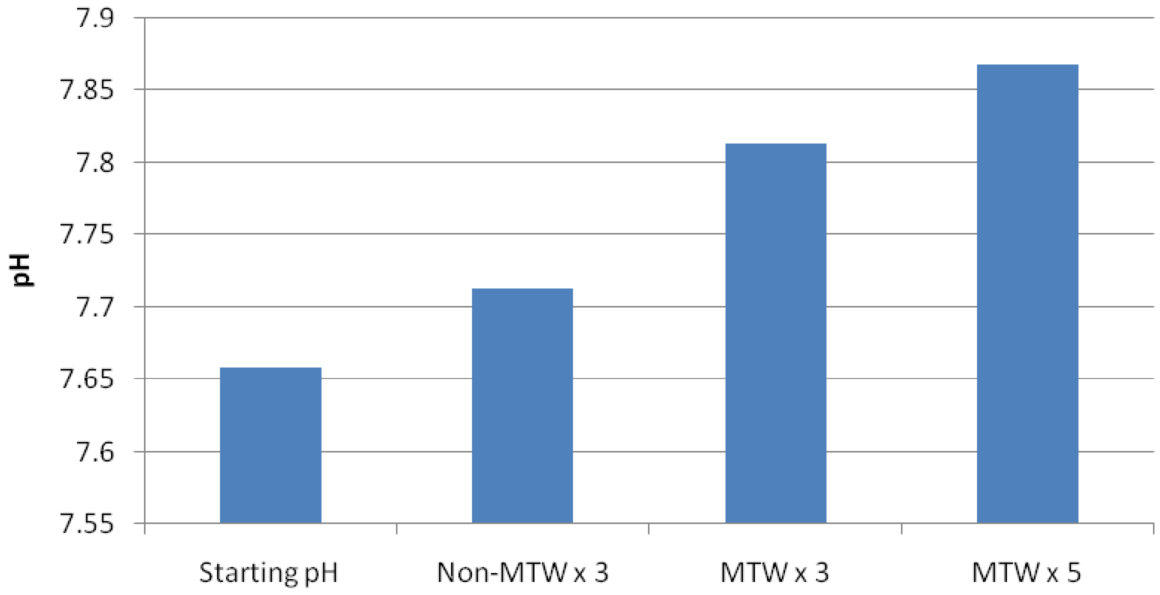

Figure 4.1 Comparison of pH values passed through MTD

While this test showed trends that the more passes through the device the higher the pH, other tests showed different results.

The second test had a more comprehensive analysis with each pH value being read twice and then using the average. This was because the pH reader would constanlty change its reading. There was an alarm on the pH reader which went off when the reader had finsished calculating the pH. However, after this alarm, the pH value would continue to rise. For comparitive reasons, all pH readings were taken when the first alarm went off. 3 trials were done on the MTW to get some reproducability in the results. Figure 4.2 shows the results of test 2.

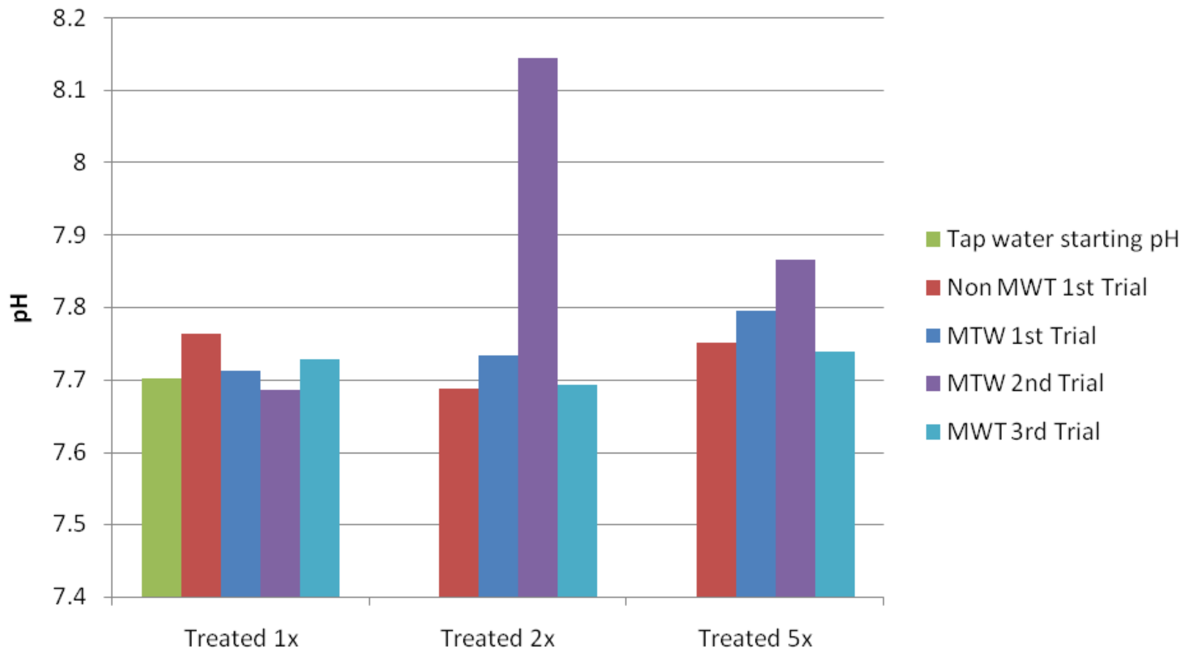

Figure 4.2 Comparison of pH values passed through MTD (test 2)

It can be seen from the Figure 4.2 that the first MWT trial in test 2 shows similar trends to that in test 1. The more passes through the MTD, the higher the pH. However , this is not reproduced in the 2nd and 3rd trial. The 2nd MTW trial had a large, unexplained increase when treated 2x by the MTD.

As for the Tap water passed through the device without the magnets attached, its pH values still fluctuated. It is assumed that this is either due to impurities from the treatment device or from errors in the pH reader. The third test produced similar fluctuations in the readings as can be seen in Figure 4.3.

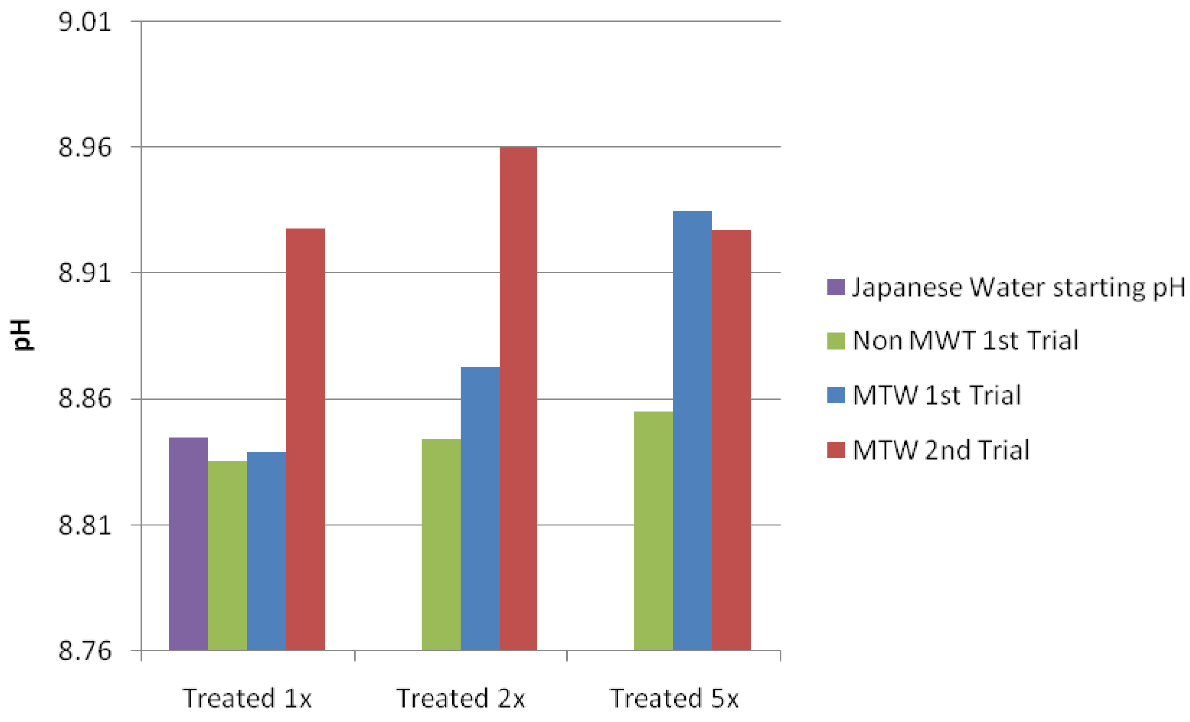

Figure 4.3 Comparing the pH of MTW with water from the Japanese gardens.

The third test used water from the Japanese gardens which had an unusually high pH of around 8.84pH. Once again, the first MWT trial shows an increasing pH with successive passes through the treatment device. This was not reproduced in the second trial however. It can be seen that passing the water through the treatment device without the magnets attached also had an increasing pH with successive passes.

The forth test looked at the change of the pH of the Japanese Garden's water over time after being treated. The results can be seen in Figure 4.4

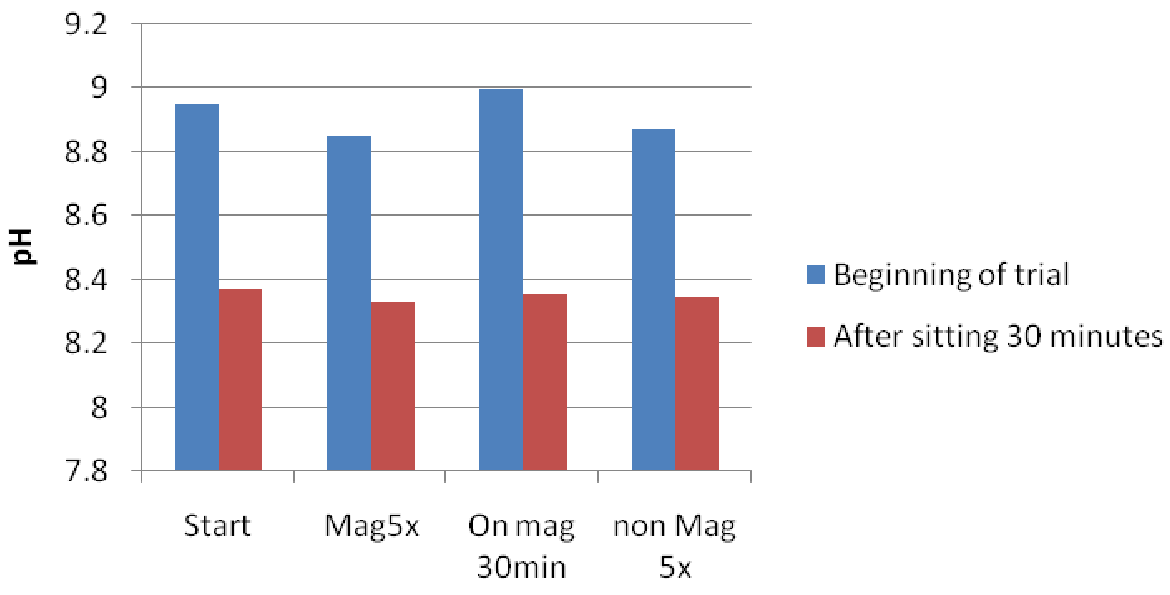

Figure 4.4 Change in pH of the Japanese Garden's Water over time.

The samples were treated and left to sit for 30 minutes. The "On mag 30min" sample was placed on a magnet for 30 minutes before its intial pH reading was recorded. It can be seen that no matter what their intial treatment was, after 30 minutes they all ended up with very similar pH readings.

4.1.2 Discussion on pH Test

Not a lot can be concluded about the effectiveness of MTDs ability to increase or decrease the pH of water samples. In some instances the MTD was able to increase the pH with successive passes through the MTD, however, this was not possible to be reproduced.

The pH reader would continually change its pH value, and even when the instrument's alarm stated that it had reached its end point, the numbers would still increase. This suggested that many of the pH values recorded were close to their real values but the accuracy of + or – 0.20 pH was lacking.

If the MTDs are changing the pH values, from these tests it would suggest it is only in the range of + or – 0.20 pH. It should be noted that impurities from the treatment device could also be affecting the pH readings. In Figure 4.2 it can be seen that the water passed through the treatment device increased its pH value even without the magnets attached. It is unclear if this was because of impurities picked up from the treatment device or inaccuracies in the pH meter.

For the test to be more accurate the method should be modified. It is concluded from this experiment that the following methods should be modified in this experiment.

- All samples to be compared should be premixed and left to sit for at least 30 minutes.

- Instead of passing the water through the treatment device and then testing its pH, it would be more accurate to pump the water through the MTD constantly while taking real time readings of the pH. The setup required for this method can be seen in Figure 4.5. A Variable speed pump would allow observation of the effects of different velocities.

- A logging program would be required so pH values are recored every second approximatley. The solution would need to be let sit until the pH value had stabalized. Once stabalized, the pump should be turned on and the change, if any at all, should be logged over a period of time.

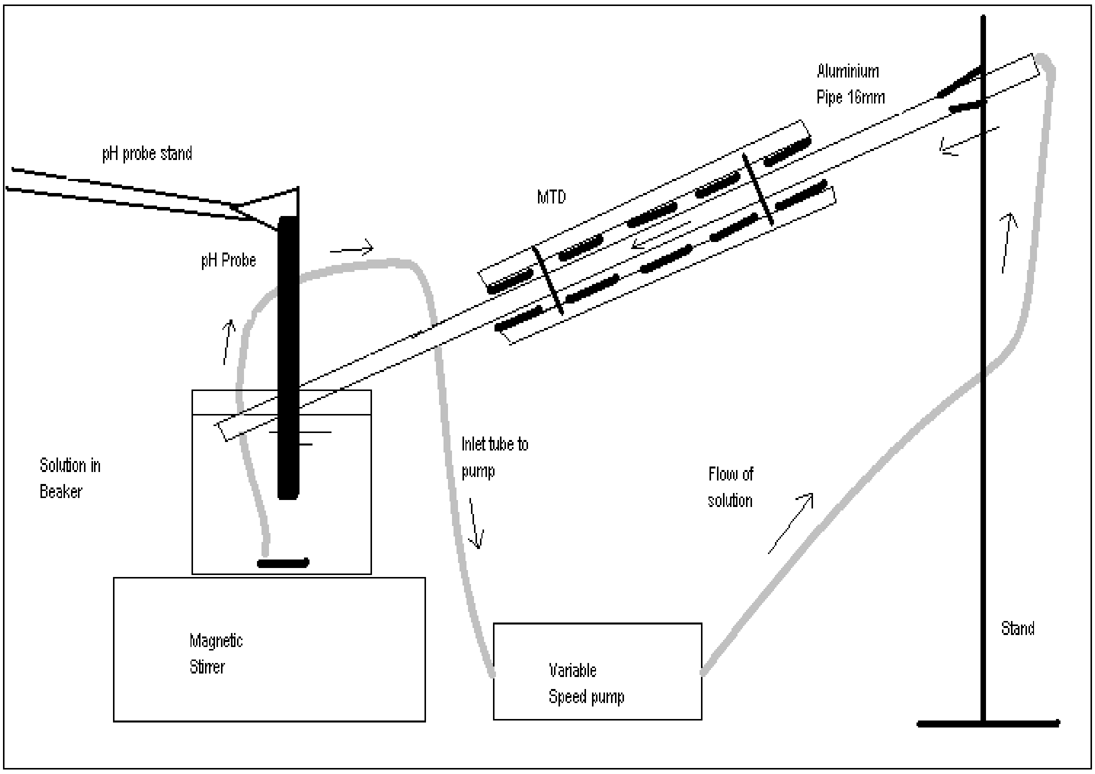

Figure 4.5 Recommended setup for further experiments to test pH change from MTDs

4.2.1 Results on Dissolved Oxygen Tests

The first of the Dissolved Oxygen (DO) tests compared the amount of DO in samples before being treated, after being treated, and after being stirred rapidly (inducing a vortex) for 1 minute. The first set of tests was done on Japanese Garden's water which had a starting temperature of 20^0C. The results can be seen in Figure 4.6

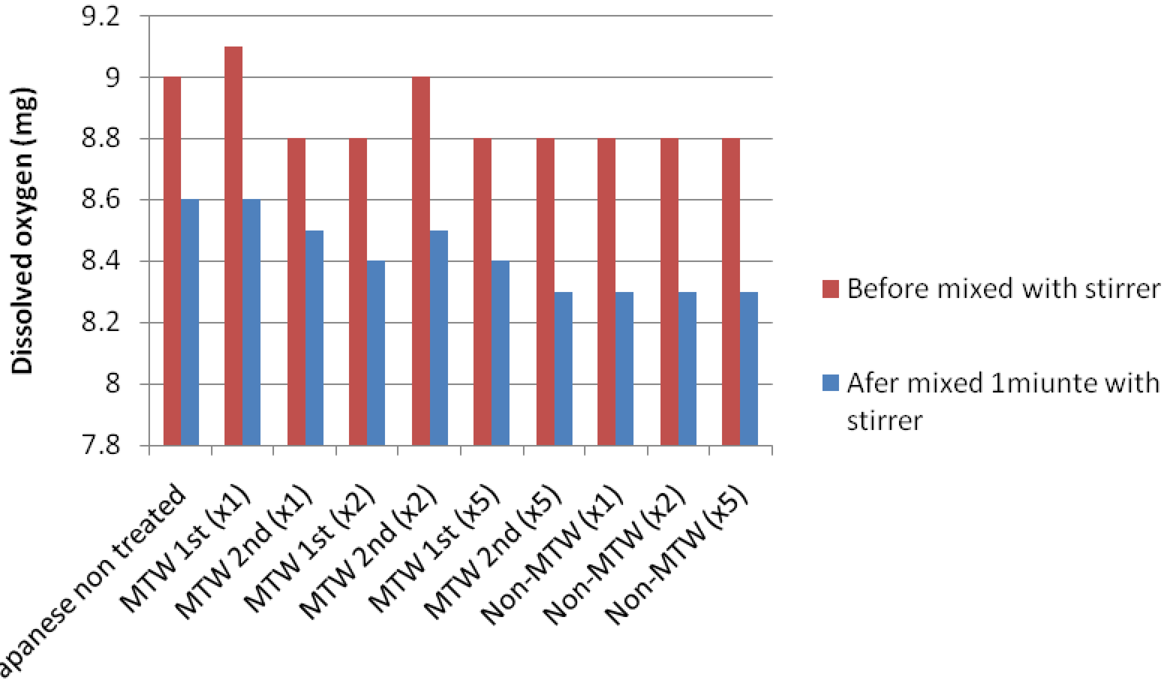

Figure 4.6 Comparison of DO levels in Japanese water, treated and non-treated

From Figure 4.6, it can be seen that no treatment method gave reproducible evidence to MTDs affecting the DO levels in solutions

It can also be seen from Figure 4.6 that after each sample was stirred rapidly by the magnetic stirrer, it reduced its DO levels. Before the test was done, it was assumed that the DO levels would rise after being subjected to rapid stirring.

One of the major flaws of this experiment was that the temperature readings from each test were not recorded. DO saturation levels are higher at lower temperatures. The Japanese water when first tested was 20^{o}C. By the end of the tests, the water temperature had risen to 21.3^{o}C. This would have affected the amount of DO in the samples but is not likely to be accountable for the full decrease.

More information about what is in The Japanese Gardens water may be needed to understand why the DO levels were decreasing after rapid mixing. A second similar Test was done with similar results as can be seen in Figure 4.7

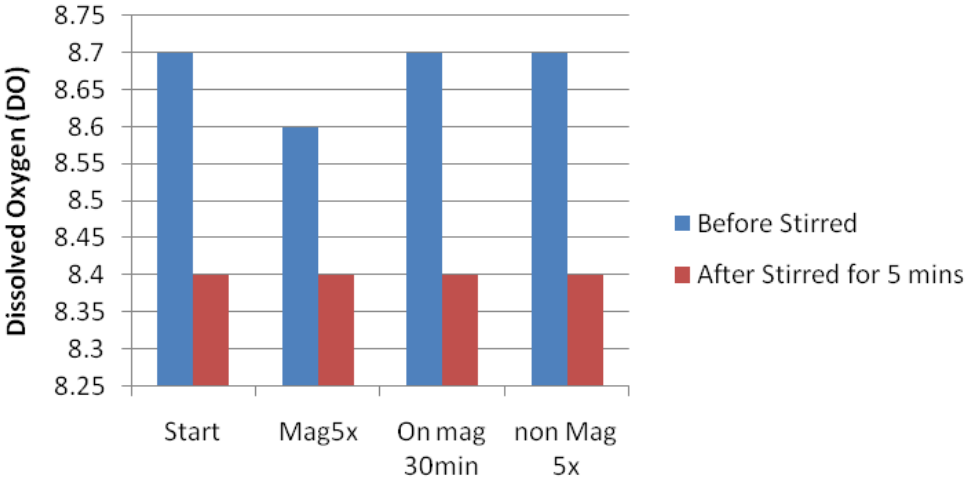

Figure 4.7 Similar results are attained in second test with DO decreasing after rapid mixing.

A third DO test was done on Tap water to deteimine if its DO value would decrease after being rapidly mixed. Figure 4.8 shows the results.

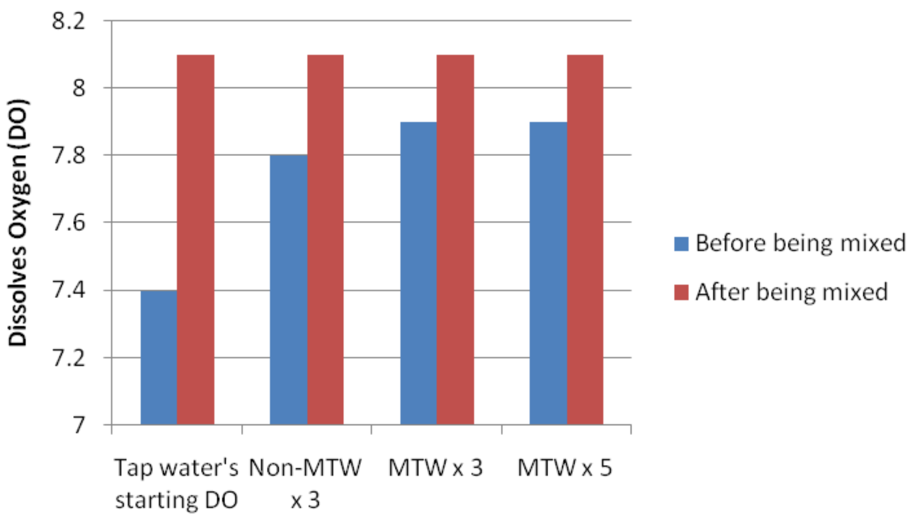

Figure 4.8 DO test on Tap water

At first glance at Figure 4.8 it may be assumed that passing water through the MTD increases DO. This is true, but the increased DO is not likely to be from the magnets, but from the turbulent mixing when the sample exits the device. This can be seen in the fact that the sample passed through the device without the magnets attached also increased its DO levels.

After being treated, each sample was mixed rapidly for 5 minutes to try and increase its DO. From Figure 4.8 it can be seen that every sample increased its DO levels. In fact, each sample reached its saturation level for the sample's temperature. These results were not useful as too much oxygen was introduced into the sample during the 5 minutes of mixing.

4.2.2 Discussion on Dissolved Oxygen Tests

These tests were a failure in determining whether MTDs affect the DO quantities in water. Several lessons were learnt however on how to improve the method of the experiments to attain more realistic results.

It was unclear as to why the Japanese Gardens water's DO level dropped when being mixed rapidly. While the temperature change of the solution would have dropped the DO levels some, it was not likely to be the cause of the whole drop. This test was a perfect example as to why the temperature should be recorded as well as the DO levels.

The Tap water experiment worked in the fact that the DO increased after inducing a vortex by mixing the solution rapidly. The problem with the Tap water experiment was that too much mixing was involved saturating all the solutions. This way, it was unclear if one solution was saturated at 1 min compared to others being saturated at 4. The time for them to become saturated was unable to be determined. It was also unclear whether mixing the solutions with the vortex provided a constant, equal input of oxygen into all the samples.

For a more accurate DO experiment to be conducted, it was concluded that the following steps should be taken.

- The solution should be constantly pumped through the MTD while the dissolved oxygen and temperature should be recorded continuously with a logger program. Figure 4.9 shows the apparatus setup recommended.

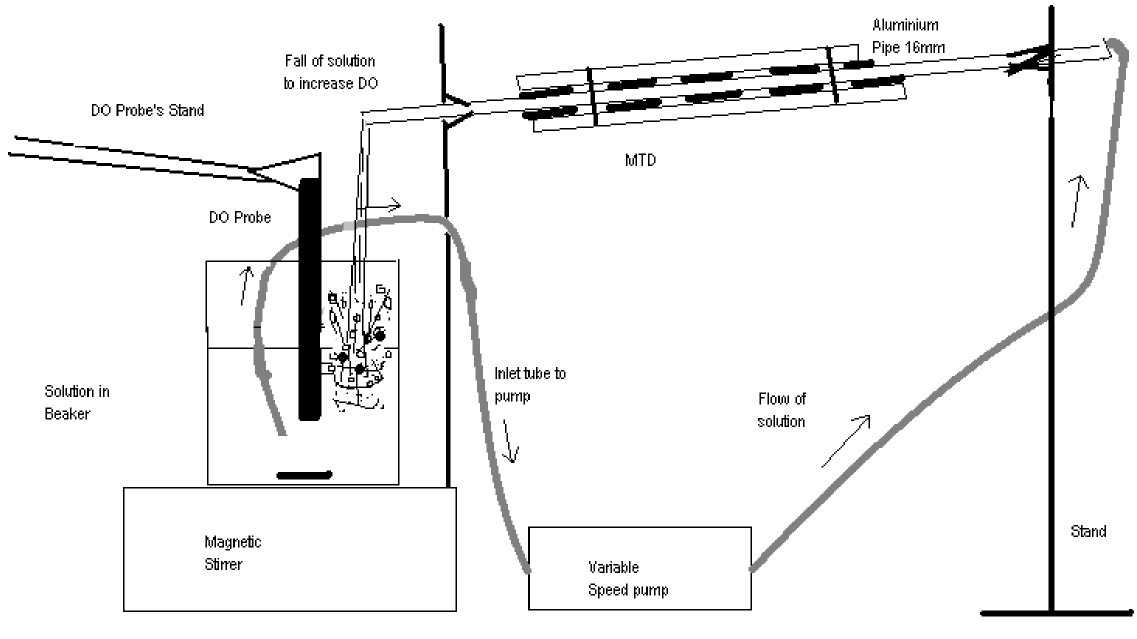

Figure 4.9 DO experiments recommended apparatus

- The outlet of the Aluminium pipe must be high enough above the beaker so that when the solution comes out, it falls into the beaker and induces mixing. This should dissolve oxygen into the solution at a constant rate. The height of the outlet of the pipe would need to be exactly constant through all comparative tests.

4.3.1 Results on Heat Capacity Tests

First Heat Capacity Test

The results from the first heat capacity test, which tested the temperature of water after being heated by a Bunsen burner over time, can be seen in Figure 4.10

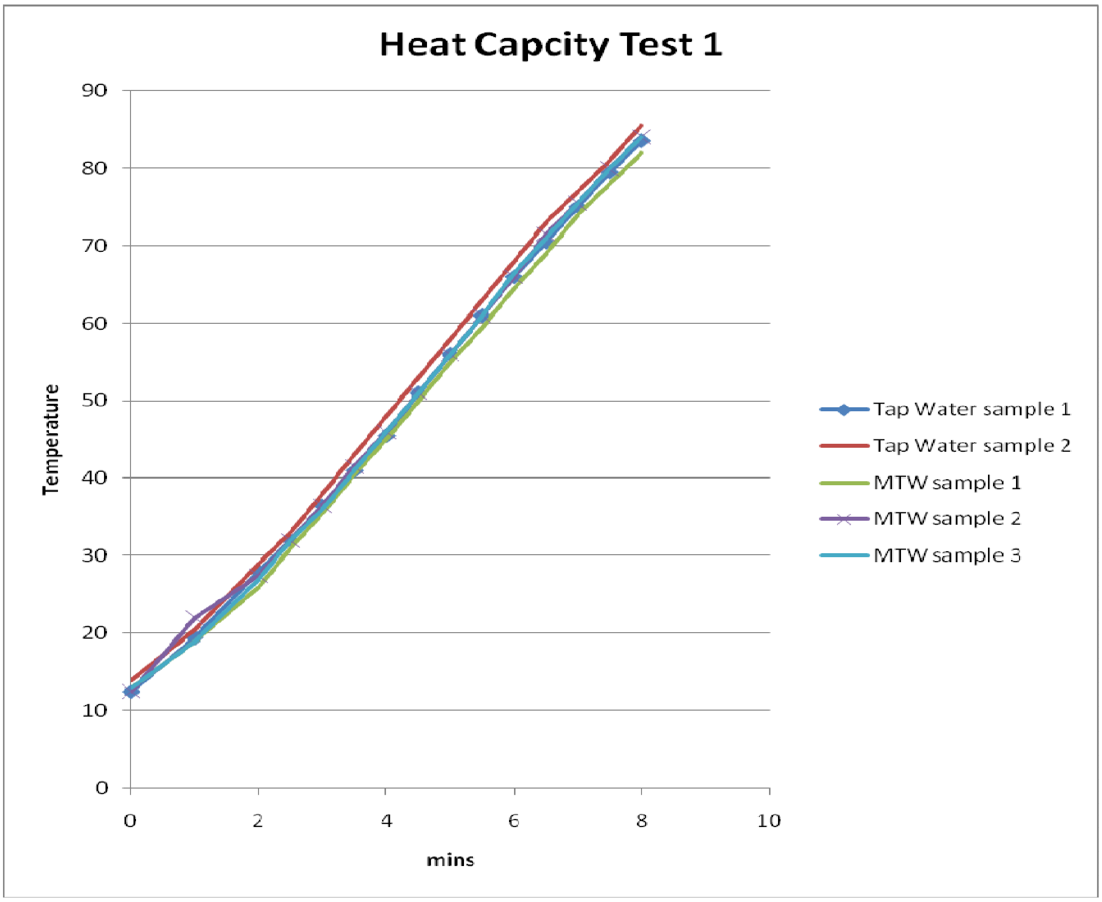

Figure 4.10 Temperature against time after being heated by a Bunsen burner.

It can be seen from Figure 4.10 that the MTD had no effect on the heat capacity of the water. Both water types were heated at very similar rates. Figure 4.11 compares the averages of each water type which shows an even closer similarity.

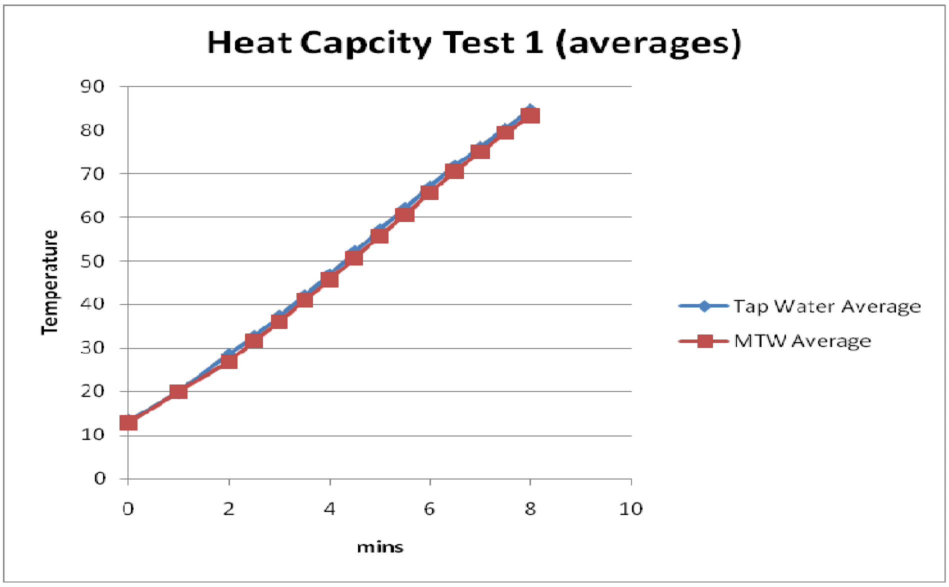

Figure 4.11 Averages of the MTW and normal tap water heat capacity tests.

Second Heat Capacity Test

The second heat capacity test looked at the cooling rate of MTW and normal tap water. The results can be seen in Figure 4.12 and 4.13

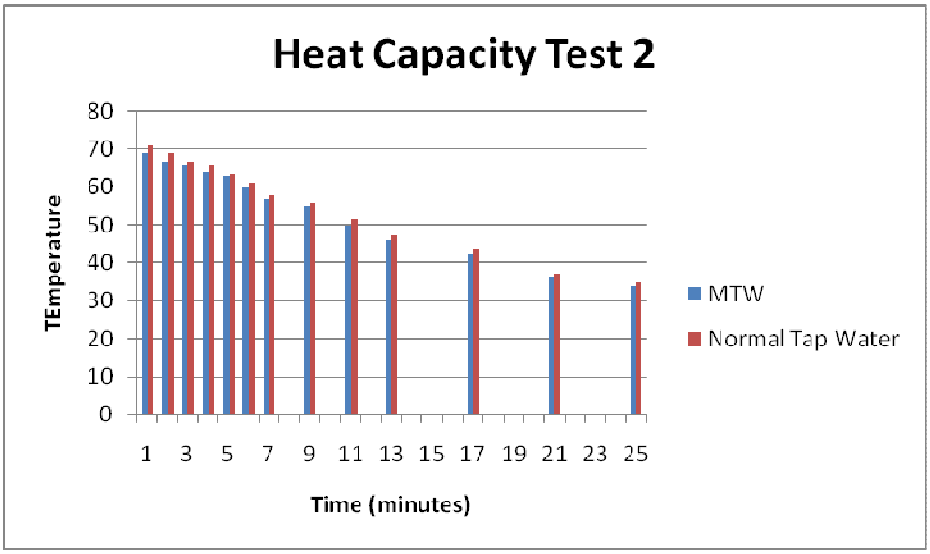

Figure 4.12 Heat capacity test looking at the cooling rate of both water samples

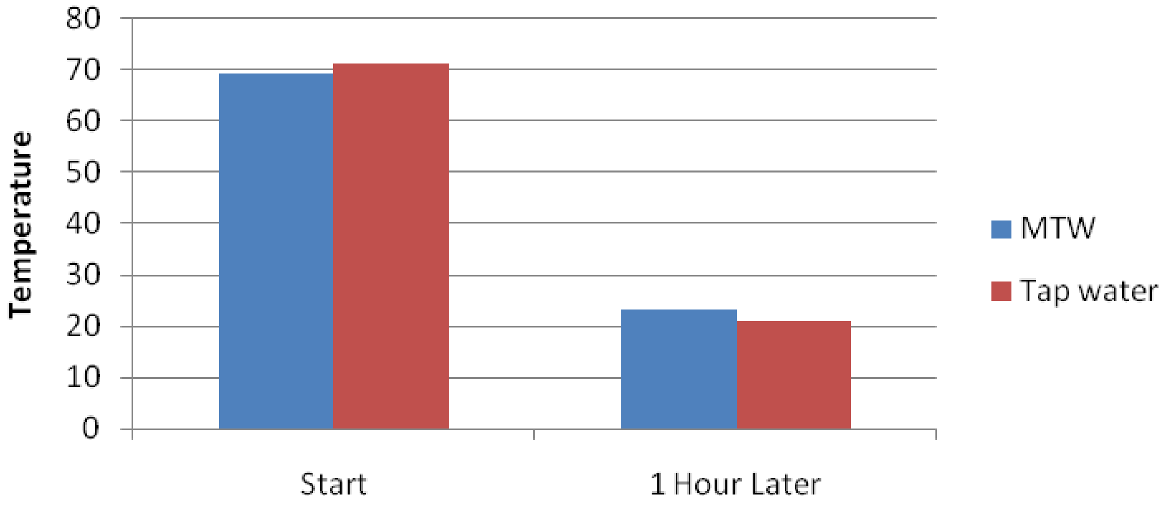

Figure 4.13 The starting and ending values for the cooling rate test.

Figure 4.12 shows both samples cooled at the same rate. Figure 4.13 shows that the MTW which started at a lower temperature ended up finishing at a warmer temperature than the normal tap water.

4.3.2 Discussion on Heat Capacity Tests

In the first heat capacity test, both types of water showed similar results. This showed that the controls of the experiment were set up well and it can be said with relative confidence that the MTD had no effect on the heating capacity of the water.

In the cooling rate test, both samples appeared to cool at the same rate for the 25 minutes they were monitored. After 1 hour however, the MTW was 2 degrees warmer than the tap water. It was expected that this should have been the other way around as the MTW started at a lower temperature (69 ^{o}C) than the normal tap water (71^{o}C). This suggests that the normal tap water cooled 4^{o}C more than the MTW over 1 hour.

It was also noticed that the MTW had more bubbles on the thermometer after 1 hour of cooling. This can be seen in Figure 4.14

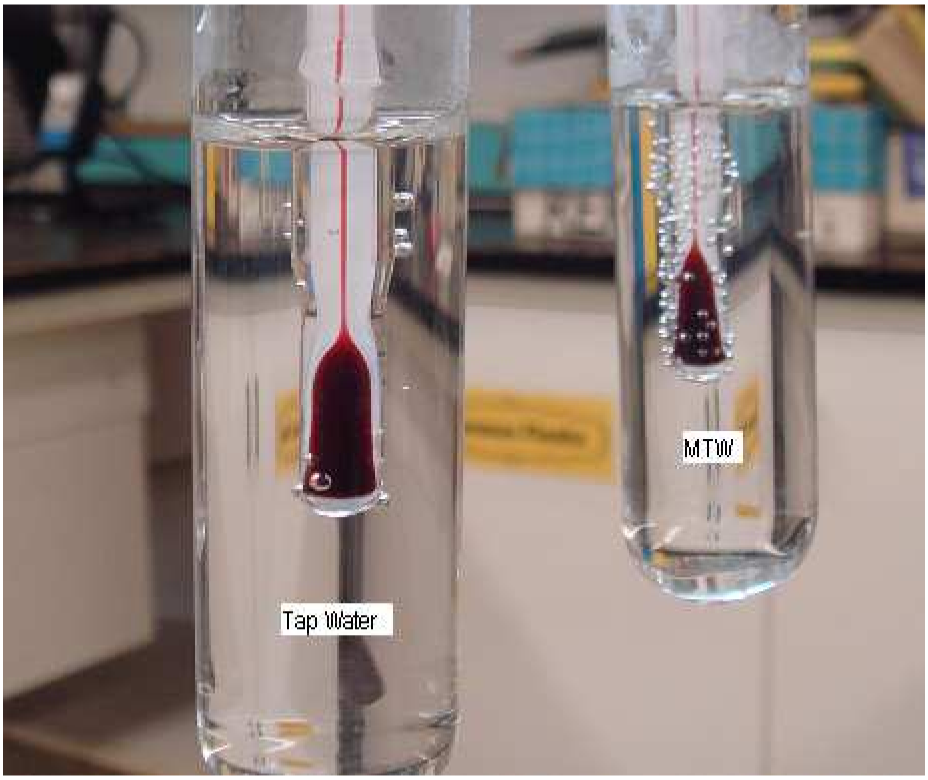

Figure 4.14 The MTW had a lot more bubbles on the thermometer than the tap water.

It should be pointed out that both samples were passed through the treatment device, so both were subjected to heavy turbulence and mixing. The tap water was passed through the treatment device without the magnets.

This test was only performed once, and it is unsure of the accuracy of the thermometers. For this test to show more conclusive results, it would be advised to do the same experiment again, but next time with larger test tubes or beakers. This way, the temperature drops will happen over a slower period giving more accuracy in comparison.

4.4.1 Results on First Precipitation Tests

Table 4.1 Results for first precipitation tests.

Chemical used	**Quantity**	**Electro – conductivity in untreated solution**	**Electro – conductivity in Magnetically treated solution**
$CaCO_3$	0.6g	85 µS/cm	43 µS/cm
$CaCO_3$	0.37g	26-34 µS/cm	17-24 µS/cm
$MgSO_4$	4g	2287 µS/cm	2231 µS/cm
$MgSO_4$	1.1g	906-917 µS/cm	897-906 µS/cm
$MgSO_4$	Approx 10g	4557 µS/cm	4496 µS/cm
NaCl	Approx 130g	25107 µS/cm	25064 µS/cm
NaCl	25g	18160 µS/cm	17940 µS/cm

4.4.2 Discussion on First Precipitation Tests

While the results for this test looked promising, it was discovered that there were several errors with the method used for this test. They included:

- The logger was only showing the current reading of the solution when it was possible to record approximately 1 reading a second. As the readings would fluctuate twice a second, an average was taken from the readings. The readings were taken when they appeared to stabilize which was at different time intervals for each solution. This method did not give historical readings of what was happening in the solution.

- The solutions were passed through the treatment device and then their conductivities were logged. This did not show in real-time what was happening as the water passed through the device. Passing the solutions through the device also caused a lot of turbulence.

- The EC probe would sit in distilled water while the solutions were being treated. It was found out that going from the distilled water to the solution would drop the conductivity of the solution over a short period giving unrealistic readings.

From these method errors it was concluded that none of the results were very reliable and a new set of tests needed to be performed. It was learnt that the solution should be pumped continuously through the MTD while the logger should continually take readings as the solution is mixed. This removes the need to take the probe in and out of the solution and the logger software can be used to record constantly, giving a timeline of EC values.

4.4.1 Second Precipitation Test's Results

The data logger gave real-time EC readings of the solution as can be seen in Figure 4.15

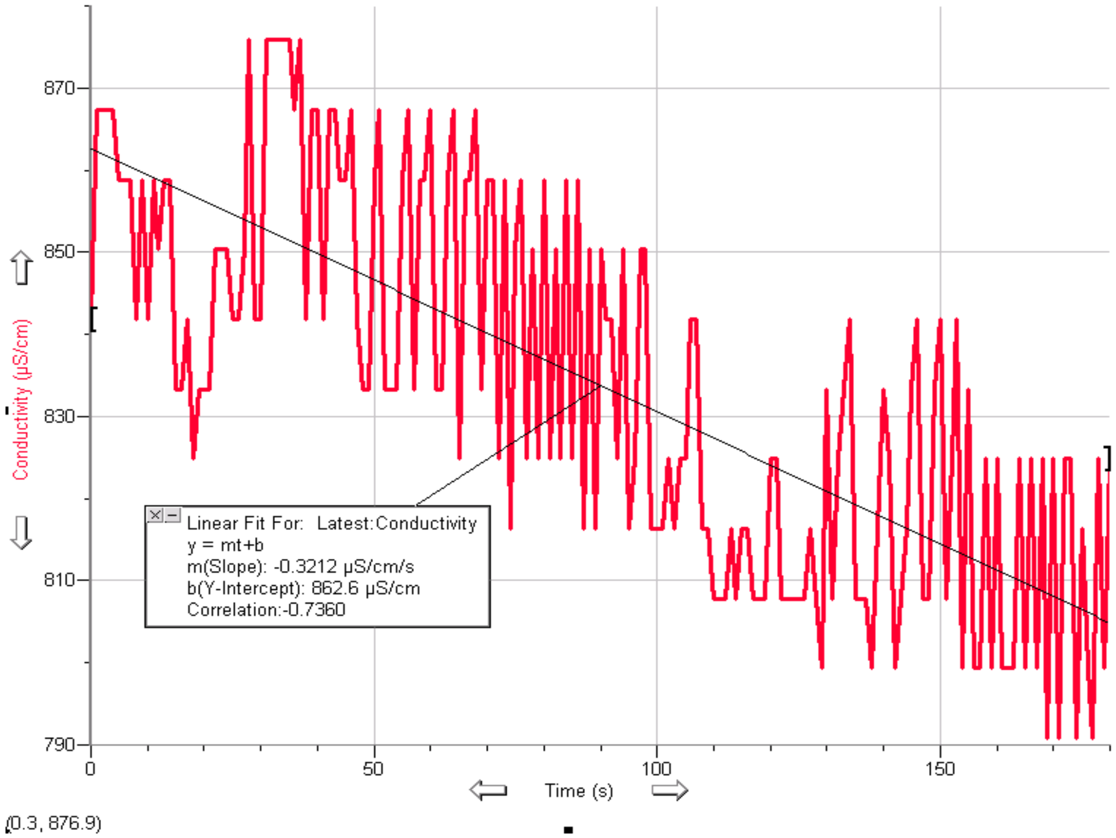

Figure 4.15 three minutes of electro conductivity readings logged by Logger Pro software.

Each reading lasted for 3 minutes. Once complete, the software added a linear trend line. The readings from each Test can be found in Appendix B. Each test recorded approximately 15 minutes of data, which equalled 4-5 graphs similar to the one above. For comparative reasons, the slope from each graph was linked to each other so that an overall trend of the 15 minutes could be seen. 4 of the 5 graphs from Test A are featured in Figure 4.16

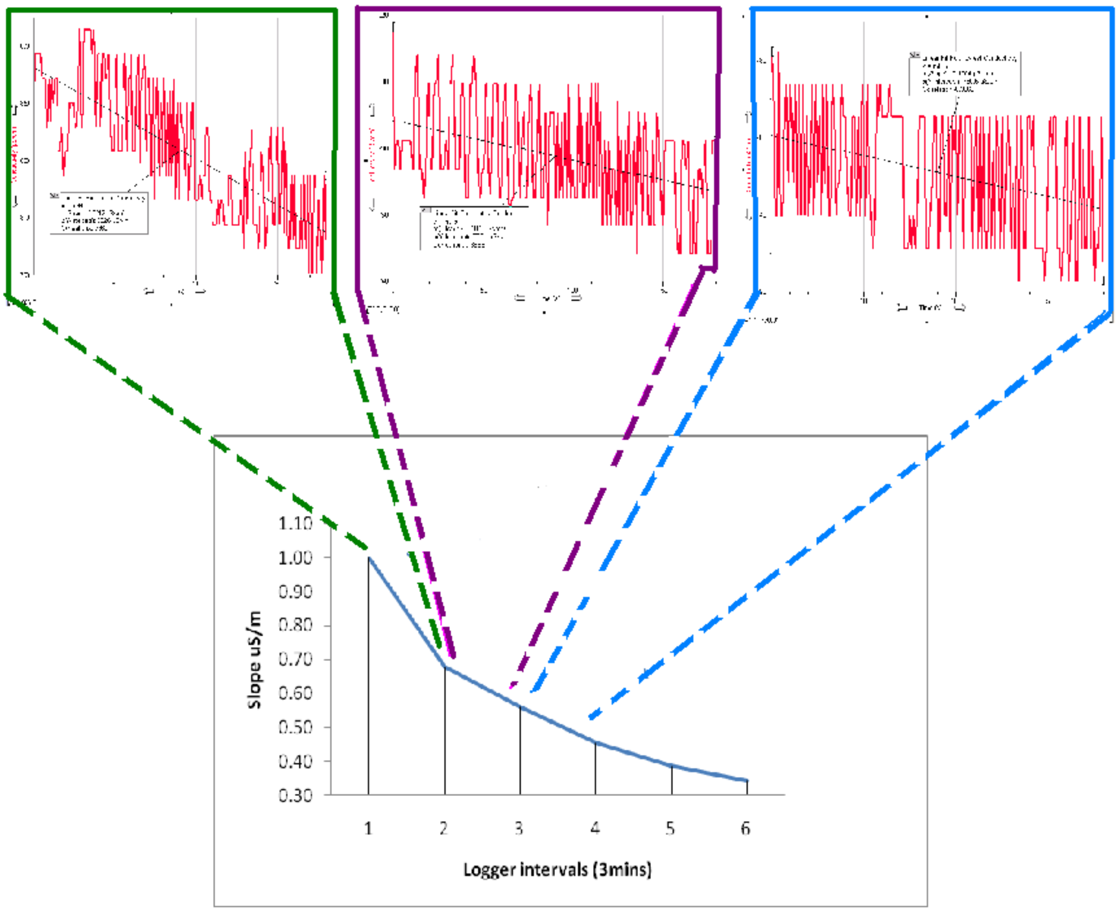

Figure 4.16 EC value readings logged by Logger Pro for Test A

The slopes of each graph are as follows: (a) -0.3212 μS/cm/s (b) -0.1184 μS/cm/s (c) -0.1064 μS/cm/s (d) -0.06718 μS/cm/s

To compile the graphs from each test into excel, the first slope was added to 1 giving the value (1 + -0.3212) = 0.6788. The next slope was added to this figure (0.6788 + -0.1184 =0.5604) and so on. The following method was used to make the following graphs which allowed a more comprehensive overview of the data. Each interval represents a 3 minutes graph created from the logger pro software. All EC logs can be found in the Appendix B

TEST A

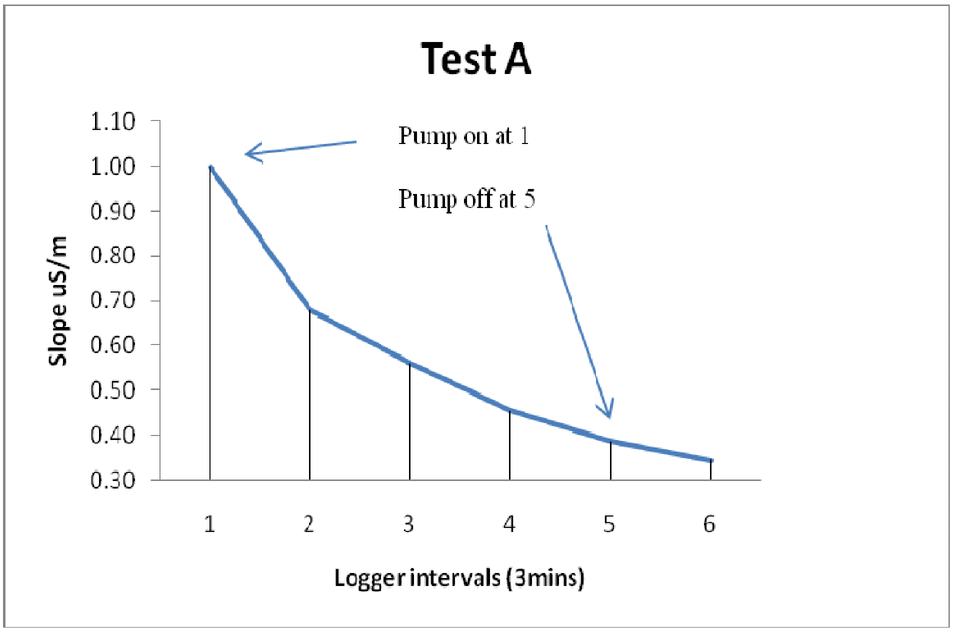

Figure 4.18 Test A = 400mg of $CaCl_2$ + 400mg of Na_2CO_3 + 1500 ml of distilled water.(Electro conductivity log graphs can be found in Appendix C)

TEST A Starting EC value	862.6 µS/cm.
Finishing EC value	714 µS/cm.
Time of data collected	15 mins

From the above graph it can be seen that as soon as the pump was passing water through the MTD, the EC of the solution was decreasing. It is hypothesized that the electro conductivity is going down due to ions precipitating out of solution, reducing the amount of ions, reducing the EC. The effect was decreasing with time. While this test shows that the EC value is decreasing, it was needed to be seen how the solution would react when not being pumped at all. That is what Test B was used for.

Test B

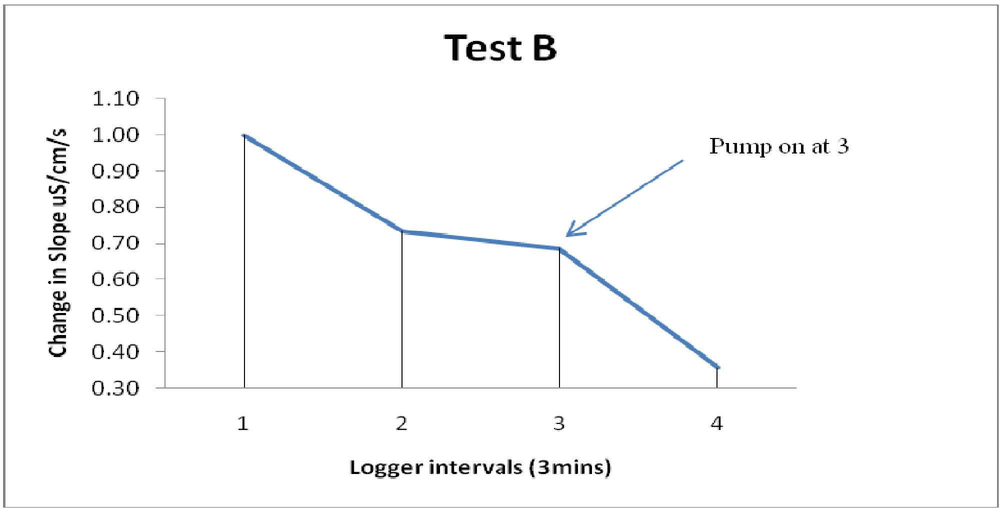

Figure 4.19 Test B = 400mg of $CaCl_2$ + 400mg of Na_2CO_3 + 1500 ml of distilled water. (Electro conductivity log graphs can be found in Appendix C)

TEST B Starting EC value	1070 µS/cm
Finishing EC value	Approx 980 µS/cm
Time of data collected	9 mins

Test B's starting EC value was a lot higher than Test A even though they had the exact same amount of $CaCl_2$ and Na_2CO_3. It is possible that this was due to the way they were mixed. The method for mixing Test A involved mixing 400mg of $CaCl_2$ in 50ml of distilled water with 400mg of Na_2CO_3 in 50ml of distiller water. Instantaneously, $CaCO_3$ precipitated out. At this point distilled water was added until there was 1500ml of solution. The precipitated $CaCO_3$ appeared to dissolve again.

For Test B, the 400mg of $CaCl_2$ in 50ml of distilled water was mixed with 1000ml of distilled water and then the 400mg of Na_2CO_3 in 50 ml of distilled water was added. The solution was then topped up to 1500ml. This way, no large quantities of $CaCO_3$ precipitated immediately. The lesson from this experiment showed, all solutions to be mixed should be mixed in bulk and split into smaller groups. It was also noticed for future experiments that the EC probe needed to be constantly calibrated, after every 1 or 2 experiments. When the probe needed calibration, it appeared to still read fluctuations properly, but it reported the overall values larger.

Comparing Test A and Test B

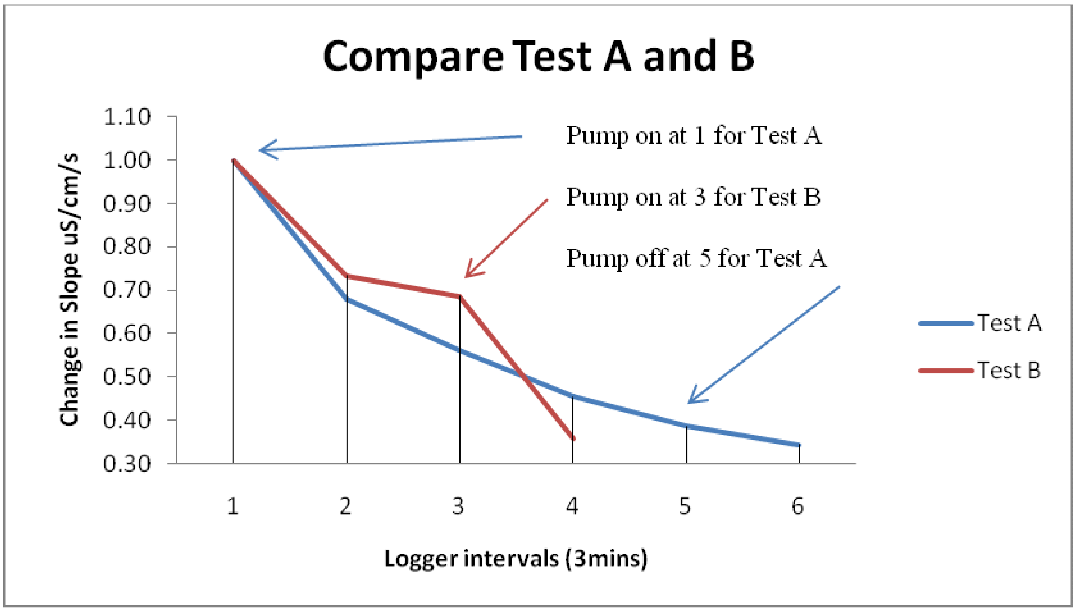

Figure 4.20 Comparing Test A and B (Electro conductivity log graphs can be found in Appendix C)

With consideration that the the two test samples contained the same amount of $CaCl_2$ and Na_2CO_3, the data shows that Test B (which had no pump) still showed that precipitates were forming thus the EC was going down. This may be because $CaCO_3$ has a low saturation point and that the solution was becoming saturated. Another theory is that CO_2 from the air could be dissolving into the solution causing more $CaCO_3$ to precipitate.

From Figure 4.4.5 it can be seen that Test B was levelling out between 2 and 3. This interval was not a full 3 minute interval as can be seen in Appendix B. Still, when the pump was turned on and the solution passed through the MTD, the rate at which the precipitate formed was quicker.

After testing, Test B was left to sit and allow its EC value to stabilize.

TEST C

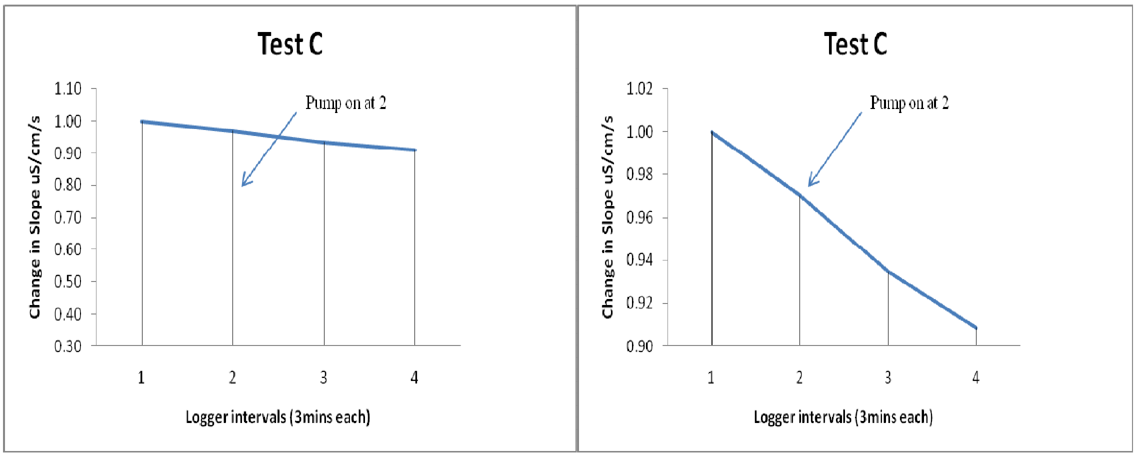

Figure 4.21 Test C = 60mg of $CaCl_2$ + 60mg of Na_2CO_3 + 1000 ml of distilled water. (Electro conductivity log graphs can be found in Appendix C)

TEST C Starting EC value	378.8 µS/cm
Finishing EC value	Approx 369 µS/cm
Time of data collected	9 mins

Test C showed minimum amounts of precipitation with the pump off. When the pump was turned on and the solution was passed through the MTD, the rate of decline of the EC value increased marginally as can be seen in Figure 4.21 on the right.

It would appear that the reason less precipitate formed in Test C was that it was not as concentrated, and therefore there were not as many ions colliding into each other in the solution. From this experiment it was learnt that the EC value of the solution to be tested should be between 400 µS/m and 700 µS/m. Around the 700 µS/m, the precipitate forms without pumping, and around the 400 µS/m the precipitate barley formed even with the pump running.

TEST D

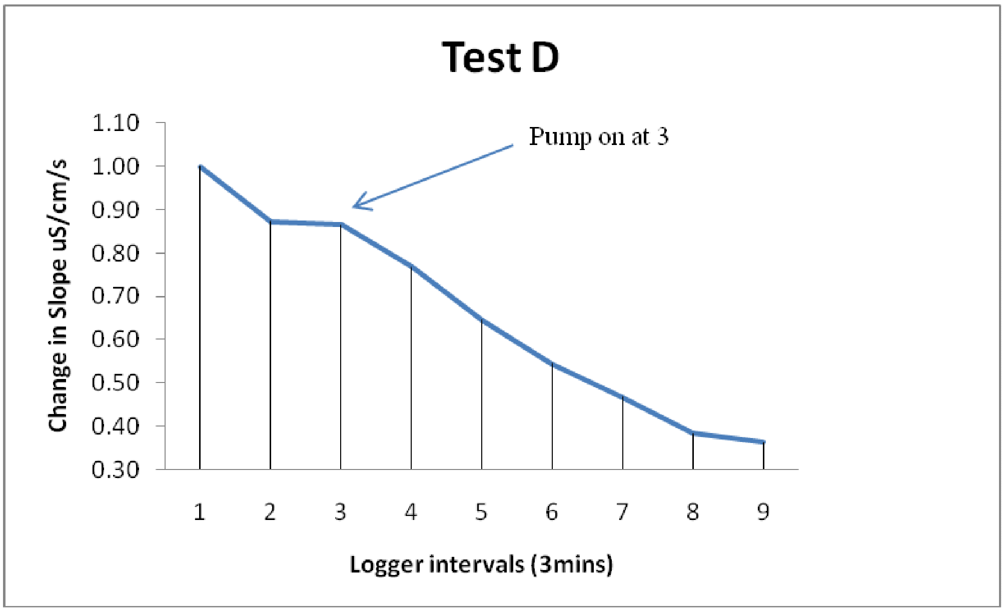

Figure 4.22 Test D = 100mg of $CaCl_2$ + 100mg of Na_2CO_3 + 1000 ml of distilled water. (Electro conductivity log graphs can be found in Appendix C)

TEST D Starting EC value	714.9 µS/cm
Finishing EC value	Approx 594.5 µS/cm
Time of data collected	24 mins

Test D behaved similarly to the other tests in that once it was mixed and left to sit with the pump off, the EC value would drop at first and then level out. This can be seen in Figure 4.22 between points 1 to 3. Once the pump was turned on and the solution was passed through the MTD, the EC value dropped again which showed that the pump did increase the rate of precipitation.

The question was, did the pump create precipitation from the magnets, from the turbulence or from the introduction of CO_2 into the solution. Test E was setup to monitor the same scenario as Test D, but without the magnets attached.

TEST E

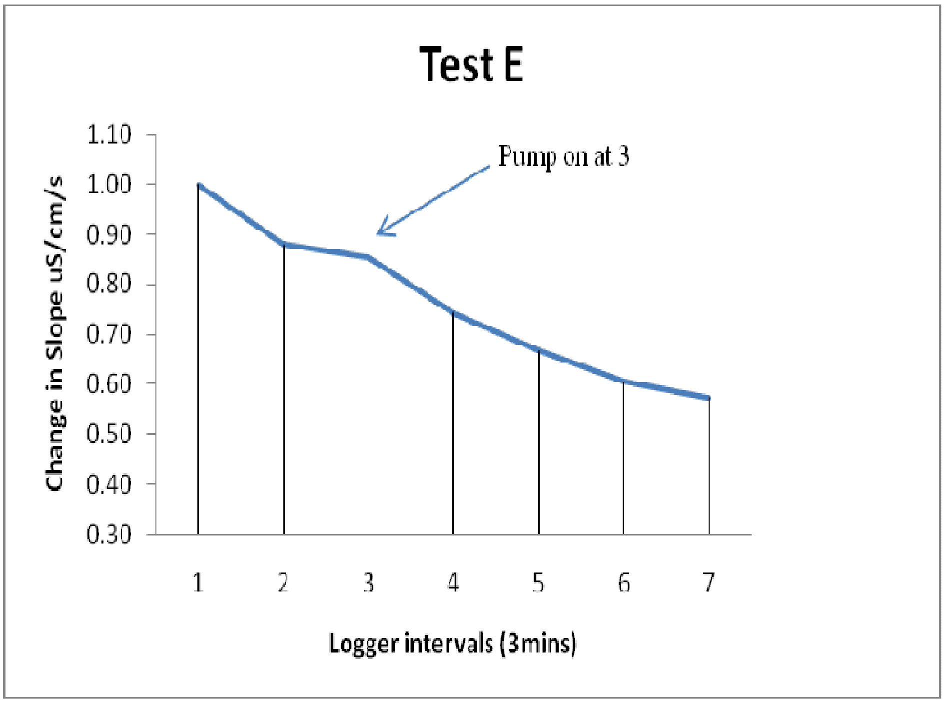

Figure 4.23 Test E = Approx 100mg of $CaCl_2$ + 100mg of Na_2CO_3 + 1000 ml of distilled water. (Electro conductivity log graphs can be found in Appendix C)

TEST E Starting EC value	778 µS/cm
Finishing EC value	Approx 742.5 µS/cm.
Time of data collected	21 mins

Test E performed very similar to Test D. In the first 3 mins the EC value dropped. In the next 3 minutes the EC value stabilised and when the pump was turned on, the EC value started to drop again.

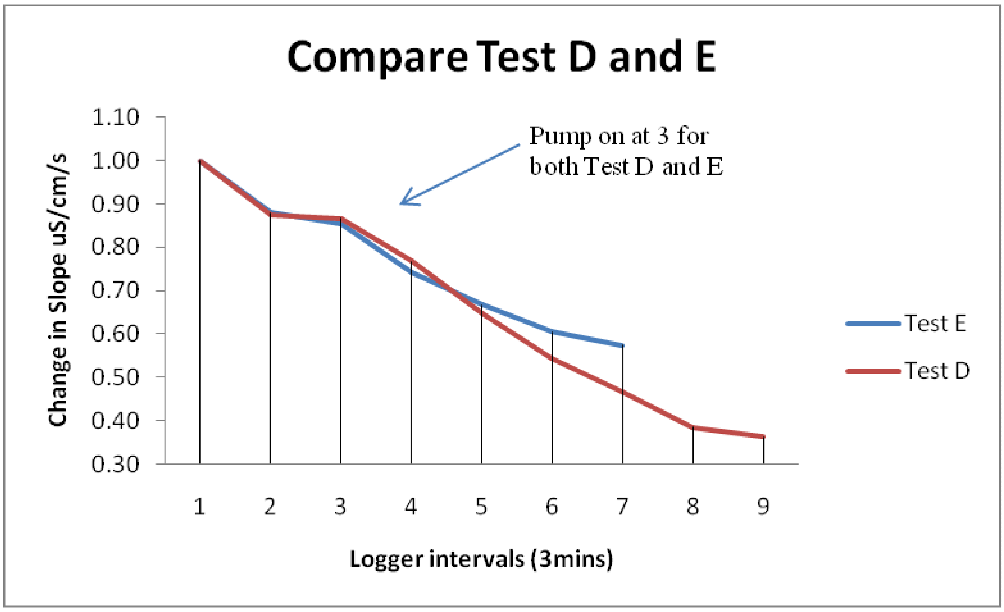

Figure 4.24 Comparing Test D (magnets) and Test E (no magnets) (Electro conductivity log graphs can be found in Appendix C)

It can be seen from Figure 4.24 that the rate at which Test E precipitated was leveling out quicker than test D. The extra rate of precipitation in Test D may be due to the magnets however; this cannot be fully concluded as there were several errors in the method for this comparison.

The solution for Test E was made by mixing equal parts of $CaCl_2$ and Na_2CO_3 and adding them to the Test D solution, to increase its EC value back up to the 700s. Both solutions did not begin with the same EC value, and the solution in Test E had been magnetised previously in Test D. If the magnets had a lasting effect on the crystallisation process then the results from E would be unrealistic.

This once again shows the importance of when comparing 2 solutions, a bulk sample must be mixed in which the 2 samples should then come from. This would give each sample the same concentration to start with.

It was also concluded from this Test that the solution falling from the pipe may be dissolving CO_2 into the solution causing $CaCO_3$ to precipitate. The pipe was submerged below the water line for future experiments as can be seen in Figure 4.25.

Figure 4.25 (left) pipe position up to test E (right) pipe position after test E

TEST F

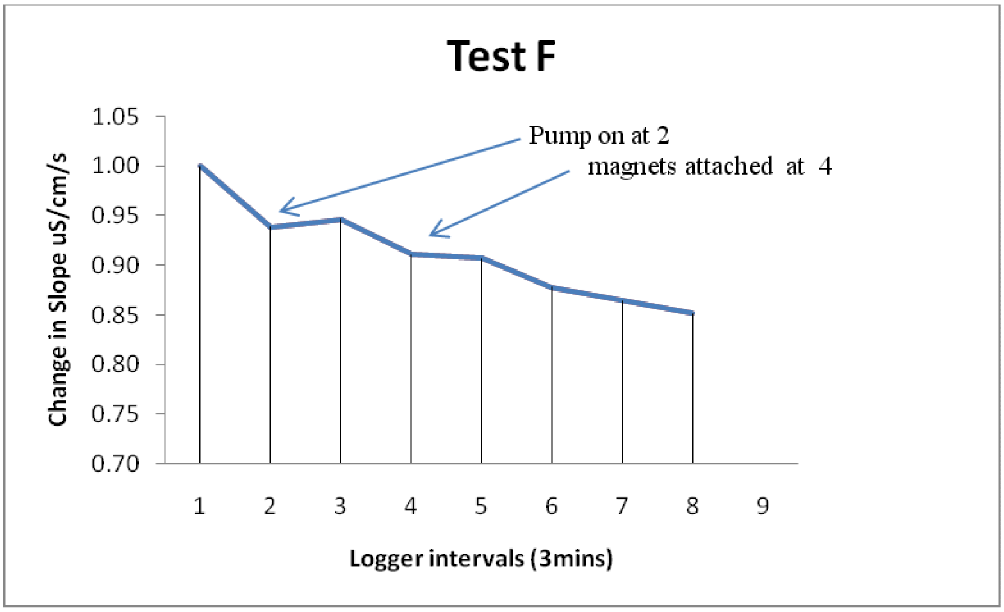

Figure 4.26 Test F =. Diluted test E down to 500 µS/m approximately. (Electro conductivity log graphs can be found in Appendix C)

TEST F Starting EC value	501 µS/cm.
Finishing EC value	493 µS/cm
Time of data collected	21 mins

Test F also had error in its method in that it reused solution E, which had previously been solution D. What was learnt from Test F was that it was imperative to flush the pump tubing after each test. In Figure 4.26 it can be seen at interval 2, once the pump is turned on the EC values rise. This was due to small amounts of solutions from Test E still remaining in the pump tubing. Test E's solutions had a EC value of around 700 µS/cm/s so that when it was pumped into Test F's solution of 500µS/m, it increased its EC value momentarily.

TEST G

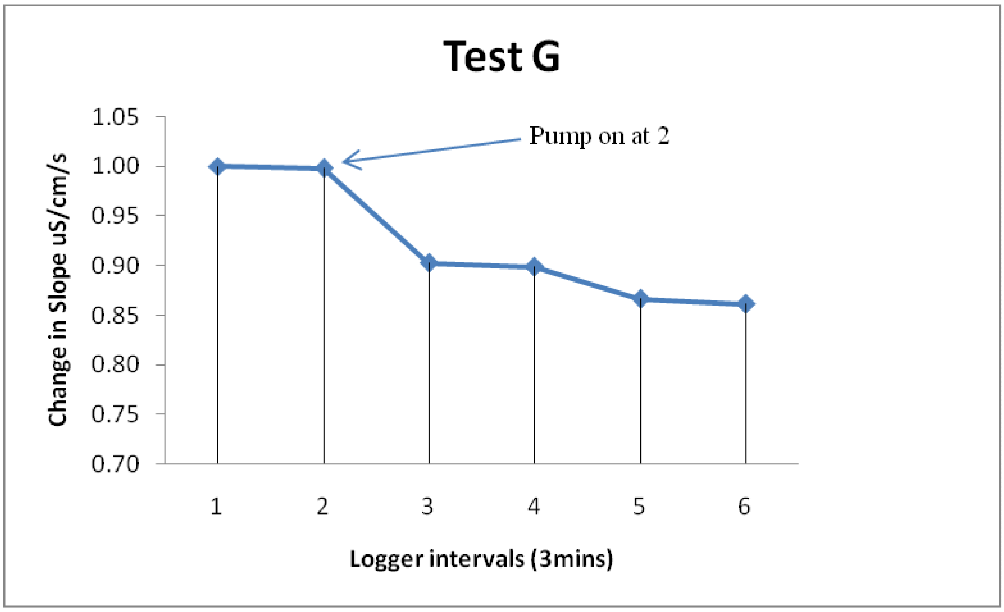

Figure 4.27 Test G = Test B after 1 hour. (Electro conductivity log graphs can be found in Appendix C)

TEST F Starting EC value	723.4 µS/cm/
Finishing EC value	709 µS/cm
Time of data collected	15 mins

Test G was Test B after it had reached equilibrium. It can be seen from Figure 4.27, that the first 3 minutes showed that ions in the solution from test B were in equilibrium where the amount of crystals precipitating were the same amount as the ones dissolving.

Once the pump was turned on and the solution was passed through the MTD, precipitates started to form. This time, it was not likely to be cause from CO_2, as the pipe outlet was submerged. The increased precipitation is likely to have been from either the magnets exerting forces on the ions in opposite directions causing them to collide, or turbulence at the outlet of the pipe causing the ions to collide. This test would need to be repeated without the magnets to determine the difference in rate of precipitation.

TEST H and I

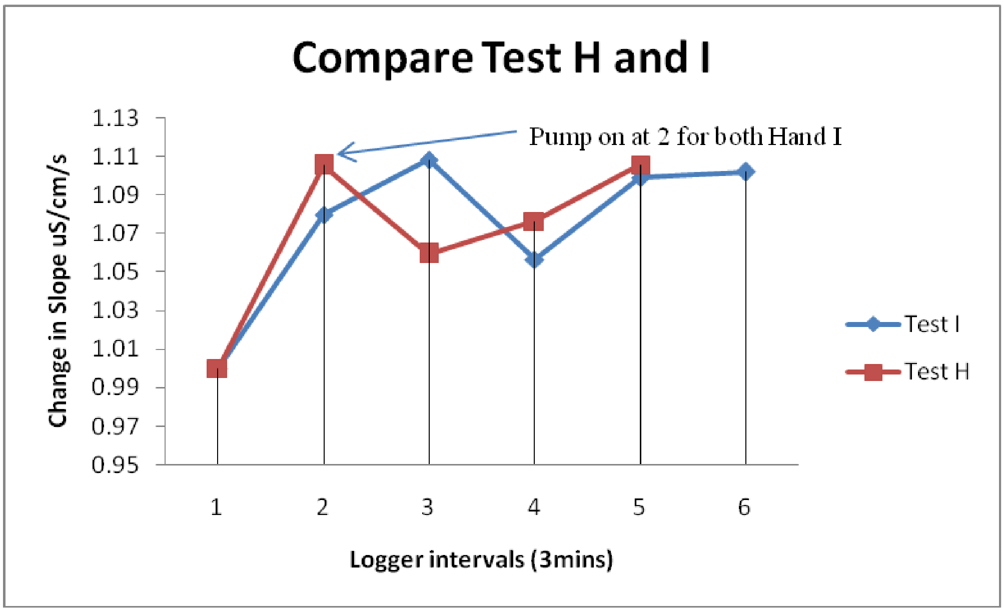

Figure 4.28 Test H and I = Test H magnetic tap water, Test I tap water. (Electro conductivity log graphs can be found in Appendix C)

TEST H Starting EC value	708.1µS/cm
Finishing EC value	715 µS/cm
Time of data collected	12 mins
TEST I Starting EC value	589.6µS/cm
Finishing EC value	604µS/cm.
Time of data collected	15 mins

An example of how the probe needed constant calibration is evident from the comparison of Test H and I. Both were tap water from the same beakers. The probe in Test H had been calibrated in Test G. The probe in Test I had been calibrated just prior. It can be seen in Test H the probe had reading errors and had over read the EC values by about 100 µS/m. This didn't appear to change the fluctuation but altered the lower calibration value of the probe. Distilled water should show an EC value of 0, but when the probe fell out of calibration, distilled water would show an EC value of 100.

It was unclear as to why the tap water was increasing its EC value while sitting in the beaker without the pump running. This occurred with both samples. In Test H, as soon as the solution was passed through the MTD, the EC value dropped. This was not the same case for Test I which continued to increase after the pump was turned on, and started to decrease after 3 minutes of the pump running.

Both samples showed after the initial decrease caused by the pumping, the EC value began to increase again. In Test I, at the 5th interval, the MTD was attached. This caused the EC values to level out.

The lesson from this test was that the probe should be calibrated before each test, and tested in distilled water at the end of each test to make sure it was still giving correct readings.

TEST J

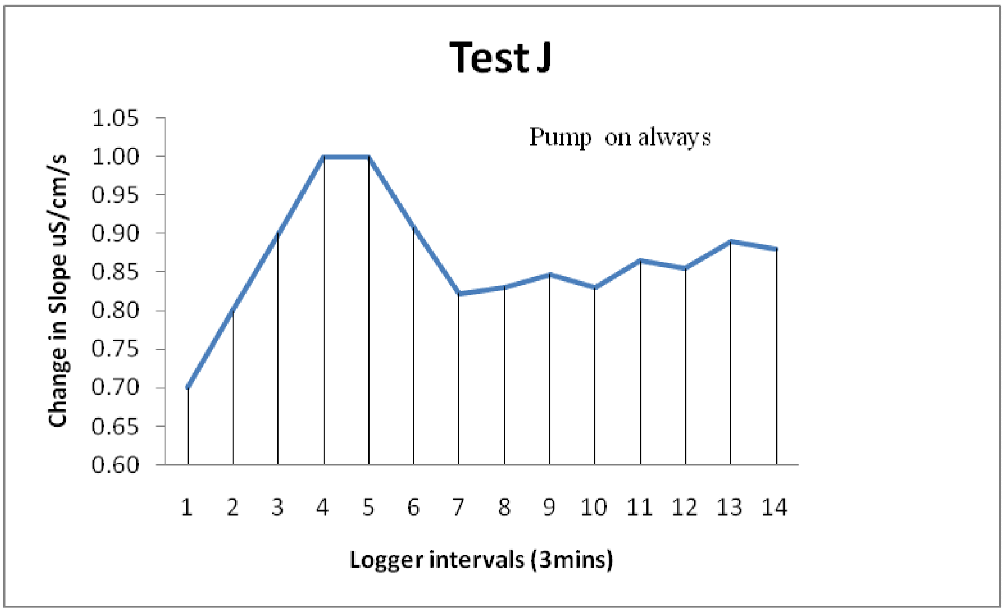

Figure 4.29 Test J = Tap water with approximately 50grams of NaCl. (Electro conductivity log graphs can be found in Appendix C)

Intervals 1 to 5 were witnessed but not recorded. The NaCl was added to tap water and dissolved with a glass stirrer. It was witnessed that the EC value was constantly increasing. This was due to the salts dissolving into ions. After a while, the pump was turned on and the solution was passed through the MTD. The EC values were still going up. After a few minutes of pumping, the EC values began to stabilize At this point the values were recorded and graphed.

From interval 1-5 is an approximation of what was witnessed. Intervals 5 to 14 were recorded and can be found in Appendix B.

It can be seen from Test J that at interval 5, salts start precipitating out. This was not due to the saturation point being met as it is a lot higher than 50g of NaCl to 1000ml of water. It was either caused by turbulence or the MTD it was assumed.

4.4.2 Discussion on Second Precipitation Tests

No clear cut conclusions can be made about MTDs effectiveness of increasing precipitation of $CaCO_3$. From the tests, it could be seen that running the solution through the MTD was increasing precipitation, but it was unknown whether this was from the magnets creating a force on the ions which would cause them to collide and precipitate, or from turbulence which may also cause them to collide and precipitate.

Busch (1997) witnessed that the MTD increased scale removal by approximately 25%, but when the magnets were removed from the device he still witnessed a 20% reduction in scale. He concluded that the magnets only removed 5% of scale while the turbulence removed 20%.

Further tests need to be conducted with the method improved upon. Recommendations for improving the method include:

- The EC probe needs to be calibrated before every experiment and tested at the end of each experiment to make sure it is still calibrated.
- No solution should be tested twice as the lasting effects of magnetism on the solution is unknown.
- When comparing the effectiveness of passing the solution through the treatment device with or without magnets, both solutions should come from a pre mixed bulk

solution. This way both samples should have exactly the same concentrations. The bulk sample should be mixed, split into 2 samples, and then left to sit until all ions are in equilibrium.

- A variable speed pump should be used so the effect of varied velocities can be investigated.

What appears to be happening with MTDs removal of scale is that through turbulence and magnetic forces acting on ions, the ions are subjected to more collisions which create precipitates in the solution. When the solution is passed through a heat exchange, precipitation is encouraged, and further crystals grow from the precipitated seeds caused from the magnetic treatment device. This precipitated $CaCO_3$ is now in solution and flows through the heat exchange unit as sludge.

Without the MTD installed, when the Ca^+ and CO_3^- ions flow through the heat exchange, once again they are encouraged to precipitate out. The $CaCO_3$ needs to grow from a surface, but with little to no precipitates formed, they must grow from the surface of the pipe which builds up over time causing less heat transfer efficiency.

This hypothesis may help understand why some MTDs work while others don't. Two factors would have a large effect on the MTD. First, if the concentration of ions is low, then there is going to be only a few precipitates formed as a result of passing them through a MTD. This seemed to be the case in Test C. This may mean that $CaCO_3$ may still form on the pipes walls. Secondly, if the MTD is placed at a large distance from the heat exchange, even though the

MTD may have created some precipitate seeds, by the time they get to the heat exchange then may have dissolved back into solution. This would also cause $CaCO_3$ to form on the walls of the pipe instead of flowing through as sludge in solution.

4.5.1 Results on Cement Compressive Test

The results of the cement compressive test can be seen below. Each test group, MTW and normal water, were graphed from the strongest cylinder to the weakest. It can be seen that Cement Group B out performed Group A. Group B was normal tap water and Group A was the MTW.

Group A acted as if it was a normal mixture. The estimate of the force required to cause failure in the mixture was 425kN. The average force that caused failure in Group A was 420kN. This would suggest that the MWT did nothing to the mixture and the mixture acted as was expected.

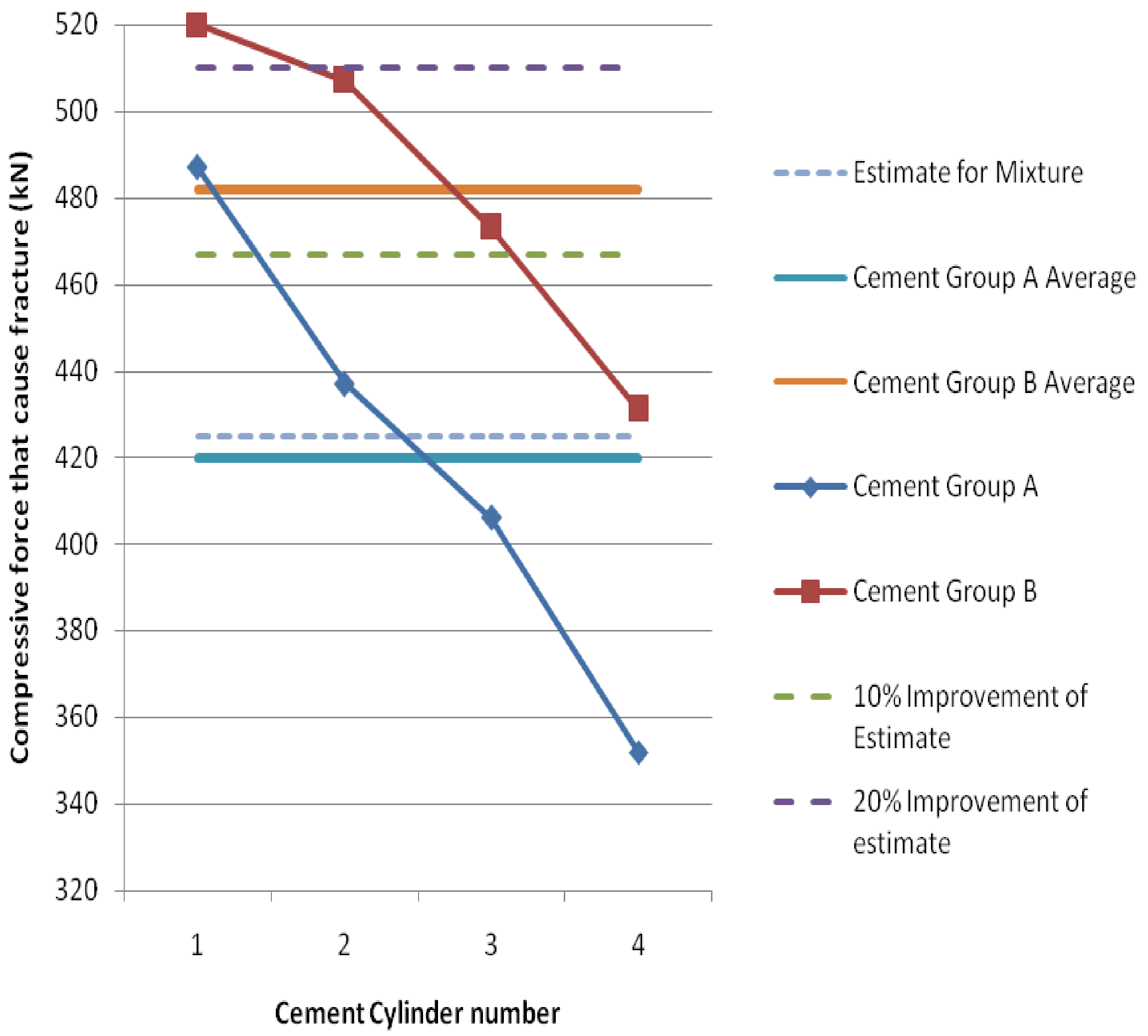

Figure 4.30 Results from Cement Compressive Test.

The lines "10% improvement of estimate" and "20% improvement of estimate" in Figure 4.30 are where the required force to cause failure in the MTW cement were expected to be. Su & Wu (2000) stated that after using MTW in mixing cement the compressive strengths were meant to be 10 – 23 % stronger.

Cement Group B, which was mixed with tap water, averaged 12% stronger than the expected range. One of the cylinders from Group B also had "a perfect break" as quoted by the lab technician. A picture of the fracture can be seen in Figure 4.31.

Figure 4.31 One of the Group B cylinders showing a perfect failure.

4.5.2 Discussion on Cement Compressive Test

With the Group A (MTW) cylinders behaving like cement mixed with normal water, and the Group B (normal water) cylinders behaving in the expected range of cement mixed with MTW, questions were raised whether there was a possibility these cylinders got mixed up.

If MTW did not affect the cylinders, it would be assumed that their averages should be equal. Each cylinder was subjected to exactly the same mix, the same humidity and the same curing time. With that said, it can be seen from the graph how much each cylinder's strength from the same group fluctuates.

One difference between each cylinder made was the method of packing the cement into the mould. While each cylinder was packed in the same method, the force one packs the mould and the position where the rod packs is different each time. This is likely to be the cause of the large fluctuations of strength within each group. Figure 4.32 shows some of the cylinders that were not as well packed into the moulds as others.

Figure 4.32 Cylinders that weren’t packed as well as could have been.

For future tests to show more conclusive results there would need to be more cylinders per group and the packing into the mould must be done as evenly as possible.

4.6.1 Results on Seed Germination Test

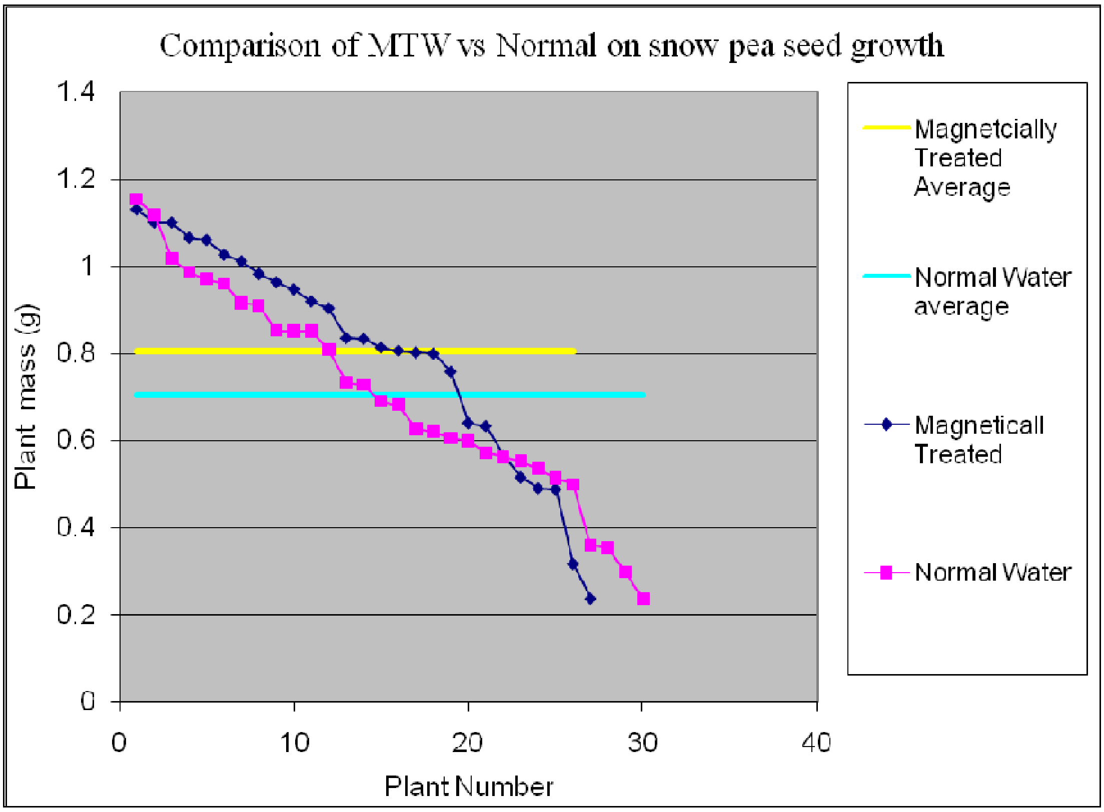

Figure 4.33 Comparison of snow pea seed's growth when treated with different waters.

It can be seen from Figure 4.33 that the snow peas grown (from seed) with MTW, outperformed the seeds grown with tap water. The average plant mass for the plants that used MTW was 0.805 g. The average plant mass for the plants that used the normal tap water was 0.705g. This was an increase of 12.5 % of the average value by the plants that used the MTW.

The median plant mass for the plants that used MTW was 0.833 g. The median plant mass for the plants that used the normal tap water was 0.686g. This was an increase of 17.5 % of value by the plants that used the MTW.

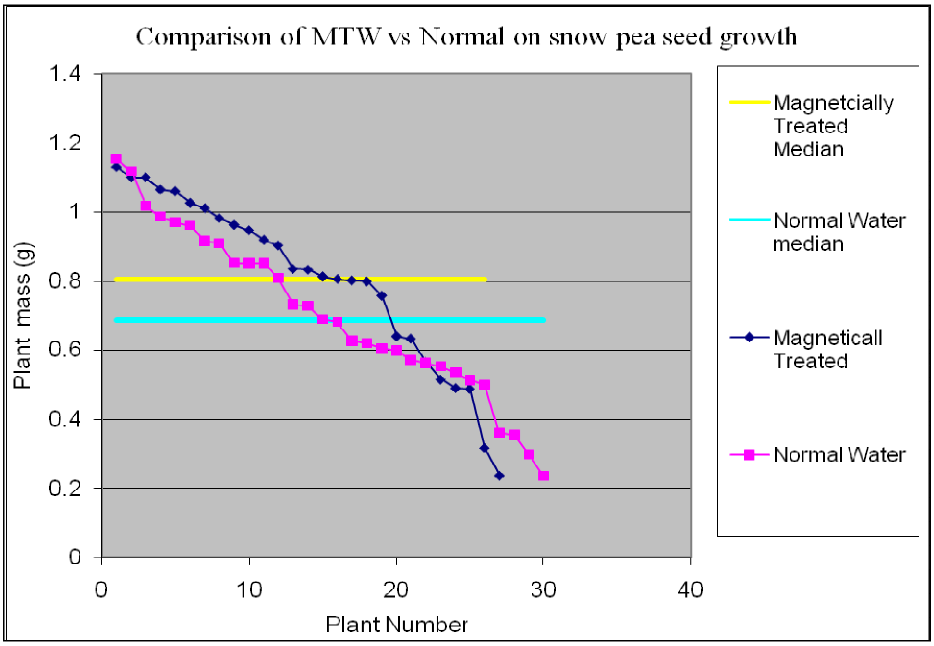

Figure 4.34 Median Version: Comparison of snow pea seed's growth when treated with different waters

The standard deviation for the plants that used MTW was 0.245g. The standard deviation for the plants that used the normal tap water was 0.240g. Even when the 3 lowest plant masses were taken off as outliers, the graphs still showed similar results.

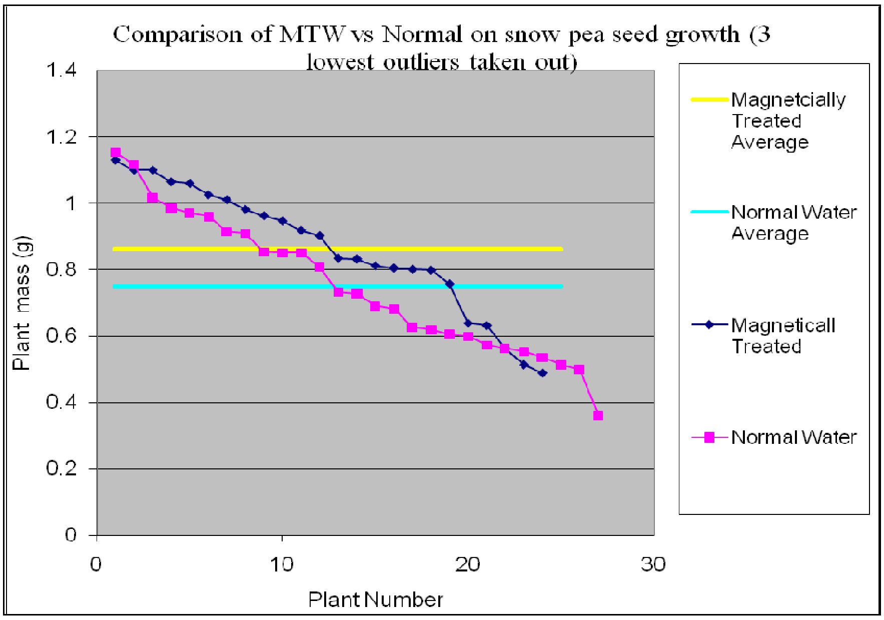

Figure 4.35 Outliers version : Comparison of snow pea seed's growth when treated with different waters

A T-Test was performed to determine whether the means of the two groups were statistically different from each other. According to Trochim (2006) in most social research, the "rule of thumb" is to set the alpha level at .05. This means that five times out of a hundred you would find a statistically significant difference between the means even if there was none.

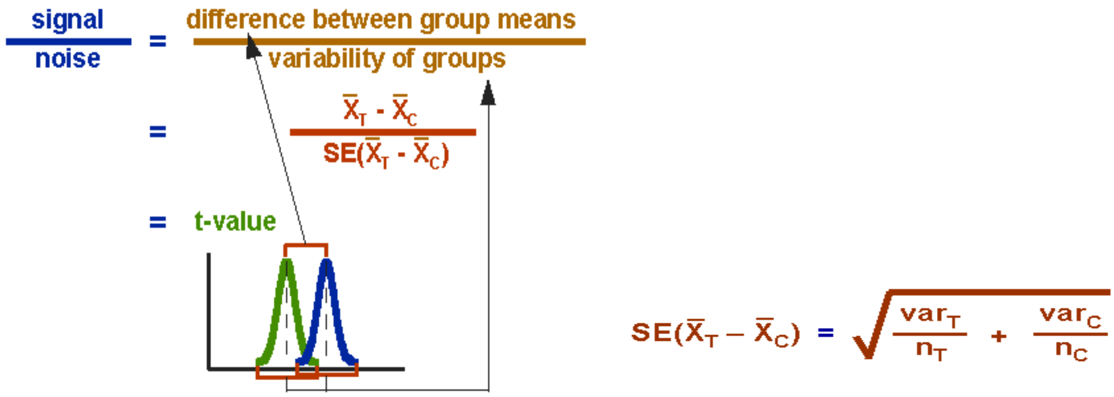

Table 4.2 T-Test Calculations (seedlings)

	Group Mean	STDEV	Sq STDEV	Number
MTD	8.136	2.068238	4.27760952	15
No MTD	7.169	1.312329	1.72220667	15
T=	1.5289			
Degree Freedom	28			

Table 4.3 T-Test Table

Degrees of Freedom	Probability, *p*			
	0.1	0.05	0.01	0.001
26	1.71	2.06	2.78	3.71
27	1.70	2.05	2.77	3.69
28	1.70	2.05	2.76	3.67
29	1.70	2.05	2.76	3.66

The T value of the results was calculated to be 1.5289. The T value from the T-Table for a p of 0.05 and a df of 28 was 2.05. The fact that the T-table value is greater than the calculated T value suggests that the results from the experiment are not significant enough to be conclusive. These results could have been due to chance variations rather than experimental method.

4.6.2 Results on Mature Plant Growth

Figure 4.36 shows the plants from the second test at their final stage of growth before being weighed. The two pots on the left were watered with MTW. The two on the right were watered with normal water. From looking at them it is very hard to notice any major differences. There was however, a significant difference which can be seen in Figure 4.37.

Figure 4.36 Plants at final stage of test

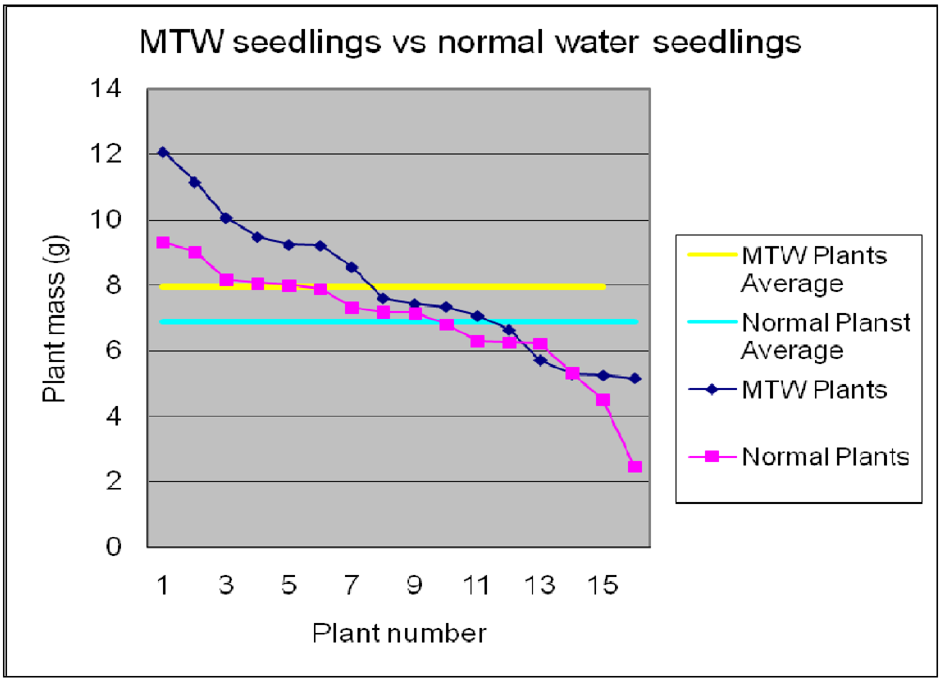

Figure 4.37 Comparison of larger plants test shows similar results compared to the smaller plants test.

The second test, which compared more mature plants, shows similar results to that achieved in the first test. The average plant mass for the plants that used MTW was 8.13g. The average plant mass for the plants that used the normal tap water was 6.87g. This was an increase of 15.5 % of the average value by the plants that used the MTW.

The median plant mass for the plants that used MTW was 7.51g. The median plant mass for the plants that used the normal tap water was 7.17g. This was an increase of 4.5 % of the median value.

The standard deviation for the plants that used MTW was 2.133g. The standard deviation for the plants that used the normal tap water was 1.73g.

When the smallest plant was taken away from each test sample as an outlier, the results were still similar.

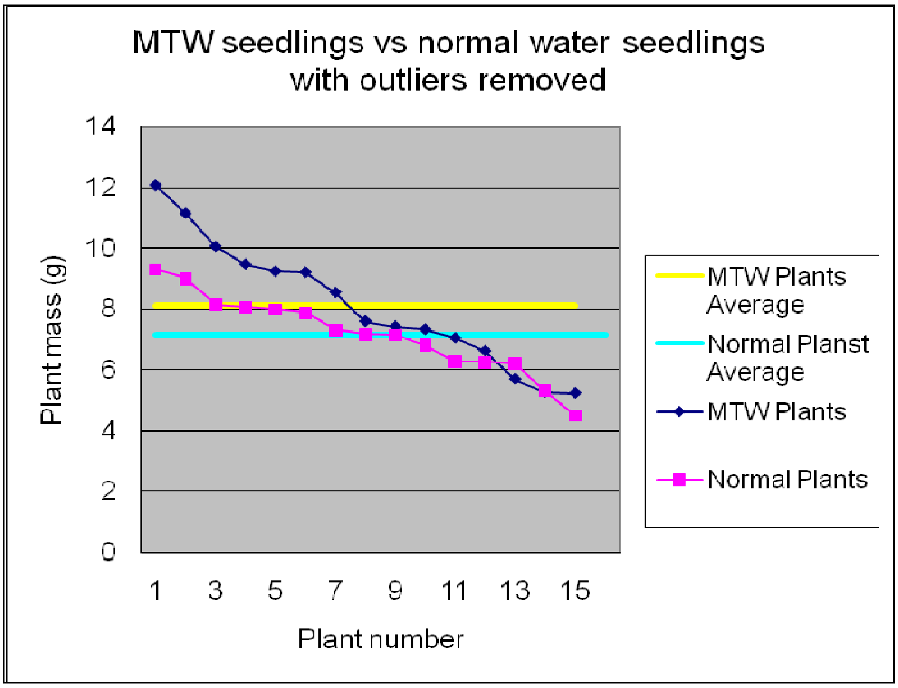

Figure 4.38 Outliers version : Comparison of snow pea mature growth when treated with different waters

A T-Test was performed to determine whether the means of the two groups were statistically different from each other.

4.4 T-Test Calculations (Mature Plants)

	GroupMean	STDEV	Sq STDEV	Number
MTD	0.805074074	0.245390415	0.060216	27
No MTD	0.705766667	0.240549326	0.0578639	30
T=	1.539877586			
Degree Freedom	55			

4.5 T-Test Table

Degrees of Freedom	Probability, *p*			
	0.1	**0.05**	**0.01**	**0.001**
26	1.71	2.06	2.78	3.71
27	1.70	2.05	2.77	3.69
28	1.70	2.05	2.76	3.67
29	1.70	2.05	2.76	3.66
30	1.70	2.04	2.75	3.65
40	1.68	2.02	2.70	3.55
60	1.67	2.00	2.66	3.46
120	1.66	1.98	2.62	3.37

The T value of the results was calculated to be 1.5398. The T value from the T-Table for a p of 0.05 and a df of 55 was 2.00. The fact that the T-table value is greater than the calculated T value suggests that the results from the experiment are not significant enough to be conclusive. These results could have been due to chance variations rather than experimental method.

The mature plant test was finished earlier than expected due to changing weather conditions and other unforseen events. It would have been informative to be able to weigh the snow pea pods that the plants produced.

Several of the snow peas had flowers and buds growing with one of the MTW plants growing a snow pea. Each bud / flower that was bigger than $1cm^2$ was taken off each plant to compare. Figure 4.39 shows the buds/ flowers produced by each group of plants.

Figure 4.39 Comparing buds from each group

From figure 4.39 it can be seen that the plants watered with MTW where beginning to flower earlier.

4.6.3 Results on Salt Tolerance Test

The salt tolerance plant test was a failure as the plants were killed from too much salt. Figure 4.40 shows the plants at the end of the test.

Figure 4.40 Plants were killed with too high salt concentrations. Plants on right are MWT

When watering these plants, they seemed healthy by the end of the 3rd week. Figure 4.20 shows the plants at the beginning of the 4th week just before being watered with a 437ppm sodium chloride solution. Even after a week of being watered by the 437ppm solution, the plants were still growing well so a higher solution was used. On the 5th week a solution of 562ppm was used. From this point on the plants started to die. From this, it would be advised that salt water with a concentration of around 400ppm be used for each watering event in further experiments.

Figure 4.41 Plant groups being watered with salt water still healthy at end of week

It was also concluded from this test that when watering with salt water, it is important not to pour the salt water on the leaves of the plant. From figure 4.41, it can be seen that every leaf that would have been watered on, died, while the leaves that escaped the water were healthier. An alternative to watering the pots from above would be to place the pots in a bucket filled with a certain amount of water. That way the water can soak into the soil without touching the plant leaves.

The results for the salt tolerance plant test were still recorded and shown in Figure 4.42. No conclusions about the ability for MTW to improve salt tolerance can be made from the experiment as the method contained inconsistencies.

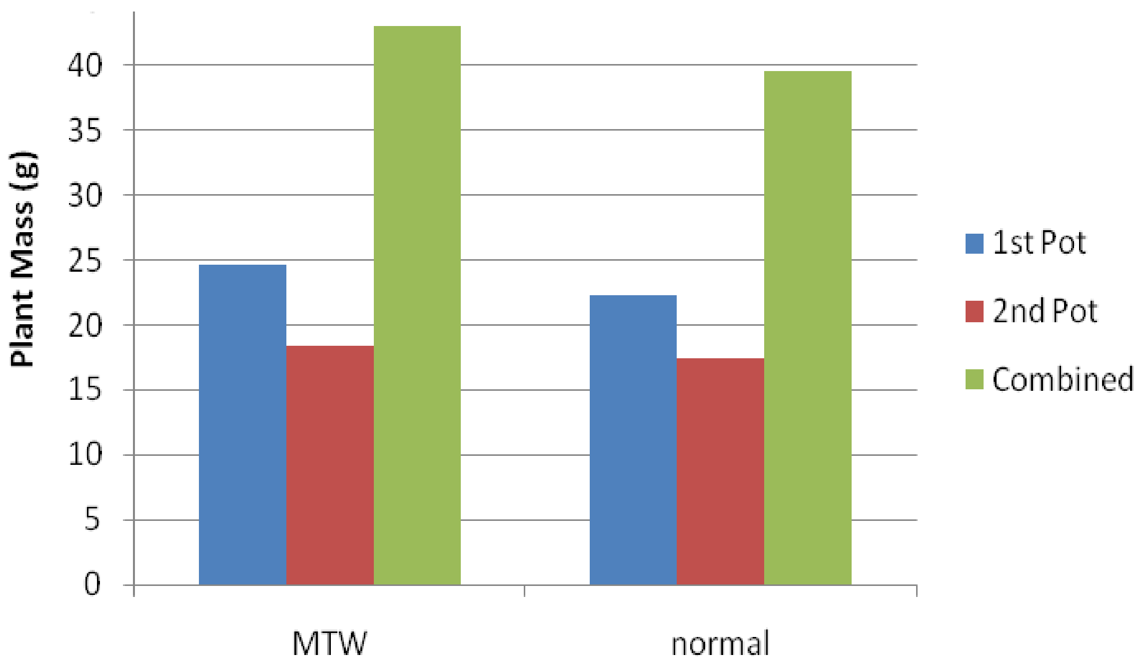

Figure 4.42 Failed Salt tolerance experiment results.

4.6.4 Discussion on Plant Growth Test

The MTW out performed the Tap water in all 3 of the tests conducted. The 1st test achieved a 12.5% increase by the MTW plants compared to the normal tap water plants. In the 2nd test a 15.5% increase was achieved by the MTW plants compared to the normal tap water plants. This is similar to the results achieved by Bogatin (1999) who concluded from their findings that MWT induces an increased yield by 10-15%.

The 3rd test's results are unreliable as the method contained errors. To do the 3rd salt tolerance test again, it would be recommended to modify the method by the following ways.

- The snow peas should be watered with salt water which has about a 200 – 250 ppm concentration. This figure is used as Dunn (2001) claims that snow peas have a salt tolerance of around 110ppm. Using a concentraiton larger than this will reduce yields in plants watered with untreated water. Plants that use MTW can then be compared if their yield is reduced by the same amount.
- There would be two different watering methods depending on which irrigation event is to be simulated. To simulate plants being watered from above, it is recommended to follow the same method used in this experiment. To simulated plants being watered from below, it is recommended to fill buckets up with a set level of water, and place the pots inside allowing the water to soak in from the bottom.
- The more plants and pots used, the more valid the results will be.

As for the first 2 tests, it is hard to find any other reason for the increase in crop yields other than the MTW. Each plant had the same quantity of water, same medium to grow in and was from the same bag of seeds. It is possible that healthier seeds had ended up in the MTW samples by chance allowing greater growth. It was also possible that microclimates may have had an advantage on certain pots even though all pots were rotated.

The next step in this experiment would be to conduct a plant growth test on a larger scale. This would decrease the likelihood of quality of seeds effecting the results. It would be difficult to test the effectivness of MTW on a field of crops, as it would be difficult to find 2 fields exactly the same to compare.

An alternative to doing a field test would be to test MTW's effectiveness on a hydroponic farm. This way, all plants are in the same medium and can be given the same nutrients and amount of water. It would also be recommended to test the MTW on irrigation water that is saline as this is where the claims of greatest crop yield increases are reported. (Bogatin 1999)

From these findings it would be recommended for irrigators to begin placing strong magnets (above 4000 gauss) in alternating arrangements over small (< 2 inch) irrigation pipes. Farmers will know their field's characteristics, and will be able to conclude whether the MWT is successful for them or not. By testing MWT on a large scale, over many sites, more will be learnt about the effectiveness of the treatment.

The advantage of this treatment is that it can be installed and tested for a low cost. Magnets with a pull force of 75kg can be purchased for $10 each meaning an alternating MTD with 5 sets of magnets can be made for $100. The problem with building your own MTD is that it is of an external type and the effectivenes of external MTDs on large pipes is unknown. Figure 4.43 shows an example of how an external MTD may lose effectiveness on large pipes.

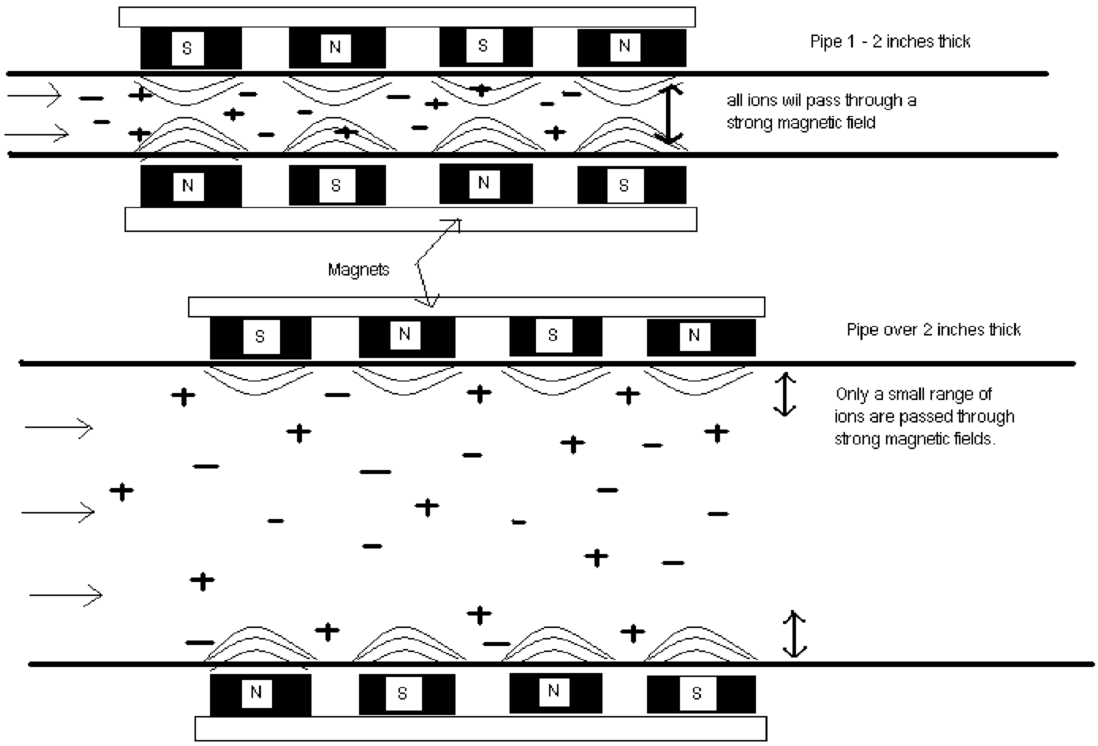

Figure 4.43 Why external MTD may not be as effective on larger pipes.

For larger pipes, internal MTDs would need to be designed or purchased. It would be difficult to make any definite conclusions about the efectiveness of MWT on plant growth. From the positive results attained in this experiment, it would be recommended that a number of further tests need to be conducted on larger scales. Only after a 100 or so field tests have been done will we be able to see a clear picture of how MWT affects plant growth in pure and saline water.

CHAPTER 5

CONSLUSIONS

Chapter 5 Conclusion

5.1 Conclusion

No conclusive results that proved the effectiveness of MTDs were attained throughout the experiment. After observing and analysing the results attained from each experiment, it was concluded that the experiments could be modified to improve the controls. The majority of the findings from this research were focused on what outside influences were affecting the results and how to eliminate them.

Improvements to the pH, DO, Precipitation, Plant Growth and Cement Tests were found. It is believed that performing tests with these improvements should produce conclusive results regarding the effectiveness of MTDs.

Several of the experiments appeared to have effective controls. The heat capacity test showed reproducible results showing that MTW had no effect on the heating capacity of tap water.

The plant growth tests had effective controls but as the T- test showed, the results were not significant enough to be conclusive. The plants test needs to be performed over a larger number of plants. The promising results attained do show the need for the experiment to be taken to a larger scale.

To do a larger controlled plant test would require a large green house with over 200 plants. It would be simpler to attach a large range of MTDs to farmland irrigation pipes. MTDs are cheap and have no operating costs. If the MTDs do not work, they will not affect the crop. On a farm there will be limited controls and therefore limited conclusive results will be derived from the experiments. However, if many farms see an improvement it will increase the use of MTDs and will slowly give us a larger understanding of the mechanism.

The $CaCO_3$ precipitation test produced some interesting results in that by pumping water through the MTD caused precipitation of $CaCO_{3.}$ The experimental procedure had some flaws in the controls however, which made it unable to conclude how much of the precipitation was caused by turbulence. The refined experimental procedure should give conclusive results showing the difference with and without the MTD attached.

One of the objectives of this thesis was to find a property of water that was influenced by MTDs and use that to optimise a MTD. From the experiments done, the refined $CaCO_3$ precipitation test may be a useful field test for checking MTDs. The experiment could be performed onsite with a small amount of equipment such as, laptop, EC meter, battery powered pump and MTD. Although the experiments done were not conclusive, a solution of calcium chloride and sodium carbonate with an EC value of around 500µS/cm would be recommended to be used for the test.

This theis was successful in the way that it compiled a large ranged of published journal papers on the effectiveness of MTD's and summerised the theroies behind the mechanisms. It proposed a hypothisis of how the MTD's reduce scale and the experiments performed could not prove the hypothesis wrong. The theoies of how MTDs improve water quality are within the realms of science and may even teach us new science about how the molecules of water interact.

From the literatcure, a range of experiments were developed to test the claims form the published journal papers. While the experiments developed were not conclusive they were the foundation for the design of the improved experiments. The improved experiments should give more conclusive results to the effectiveness of MTDs.

5.2 Future Research

Future experiments needs to be done on the pH, DO, Cement, $CaCO_3$ Precipiation and plant growth tests. These experiments need to follow the reccomendations learnt from this papers research.

If it is found that MTDs alter the rate of precipiation of $CaCO_3$, this exeriment should be used to optimise the configurations of MTDs. Parametres such as strength of magnets, number of magnets, orientation of magnets and velocity of soultions passed through the magnets should be used to determine what configuration is optimal.

6.0 References

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Appendix A Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 Research Project

PROJECT SPECIFICATION

FOR :	Craig McMahon
TOPIC:	Investigation of the quality of water treated by magnetic fields
SUPERVISORS:	Dr Vasantha Aravinthan
ENROLMENT :	ENG 4111 – S1, D, 2009: ENG 4112 – S2, D, 2009
PROJECT AIM:	This project seeks to investigate what effects passing water through a magnetic field has on the water quality and what applications this can be used for.
PROGRAMME:	Issue A, 20th March 2007

1. Conduct a comprehensive literature review on magnetically treated water and its effects on water quality, and in applications.
2. Design an apparatus to treat the water magnetically and monitor the water quality using PH as a performance indicator.
3. Optimize the treatment varying the parameters that can affect the water quality such as strength of magnet, detention time and varying initial concentration of minerals in water.
4. Use successful magnetic configuration from (3) and observe changes in other water quality parameters such as water hardness and dissolved oxygen.
5. Experiment on applications of magnetically treated water: these include, plant growth, anti - corrosion, increased salt tolerance in plants and evaporation rates.
6. Submit an academic dissertation on the research.

As time permits:

7. Test additional applications of magnetically treated water. These include, compressive and tensile strength of cement mixed with magnetically treated water, compressive strength of ice made from treated water and effects of heating treated water in evacuated tubes.
8. Create electricity by passing conductive liquid through a magnetic field.

AGREED __________________(student) __________________(supervisor)

Date : / / 2009 Date : / / 2009

Appendix B Results Data

Seedling Test Data

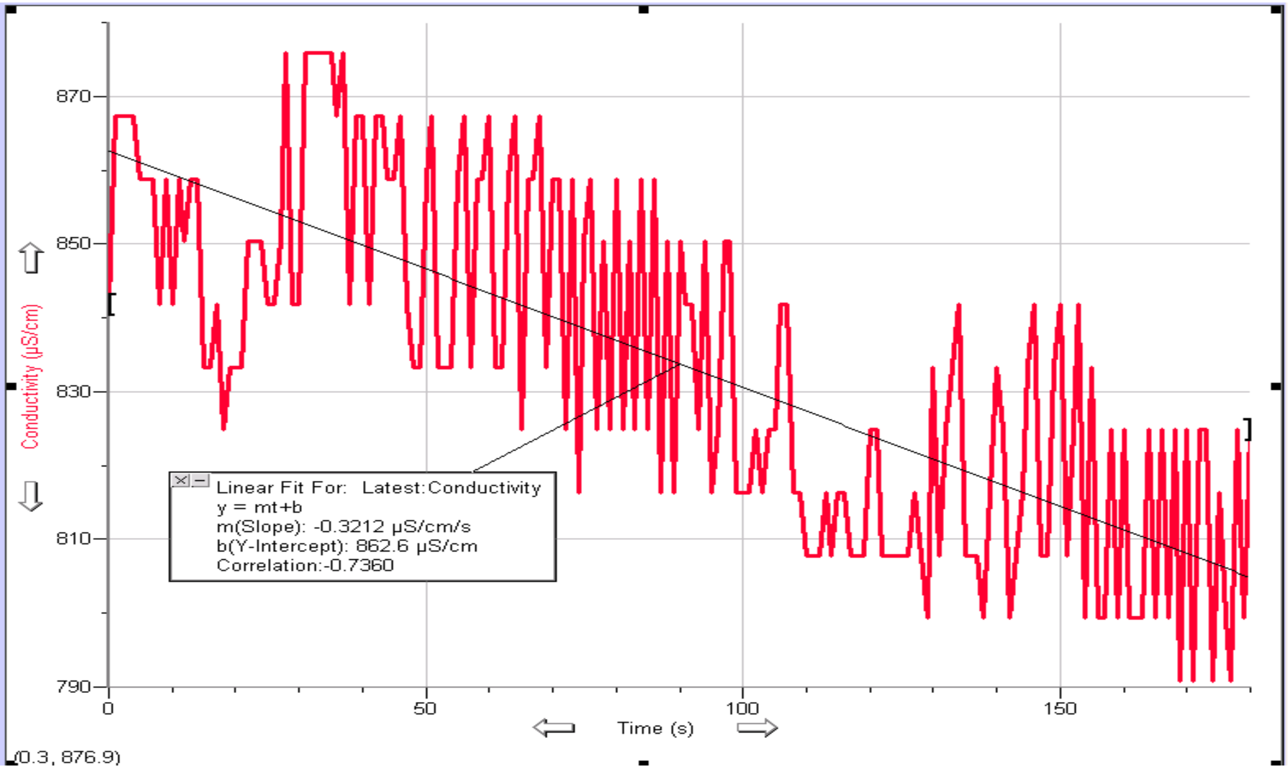
	Mass(g)		Mass(g)
Magnet	1.13	**Tap**	1.154
	1.1		1.118
	1.1		1.018
	1.065		0.987
	1.06		0.971
	1.026		0.961
	1.011		0.916
	0.982		0.91
	0.963		0.853
	0.947		0.851
	0.919		0.851
	0.903		0.809
	0.835		0.733
	0.833		0.729
	0.813		0.69
	0.806		0.682
	0.802		0.627
	0.799		0.62
	0.758		0.606
	0.64		0.599
	0.633		0.572
	0.565		0.563
	0.515		0.553
	0.49		0.535
	0.488		0.514
	0.317		0.5
	0.237		0.361
			0.354
			0.299
			0.237

Mature Plant Data

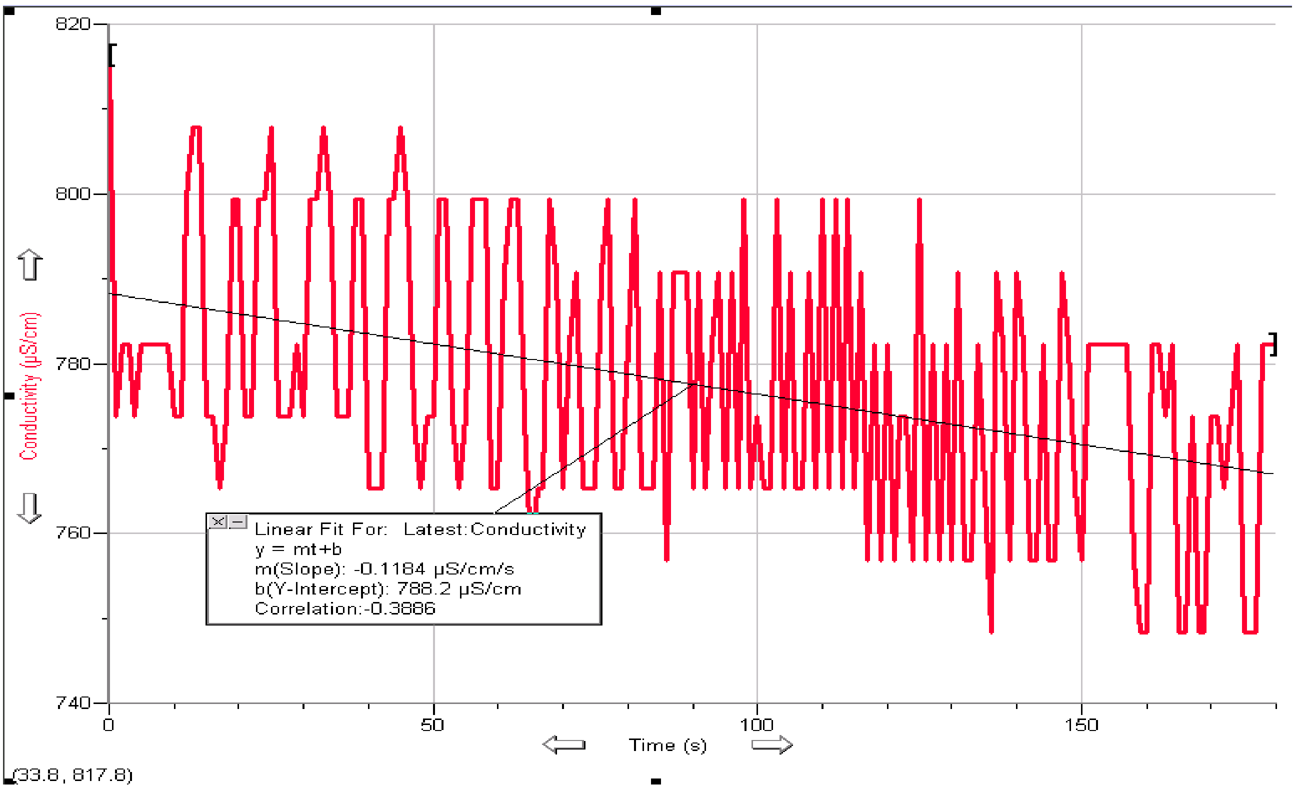
	Mass(g)		Mass(g)
Magnet	12.07	Tap	9.31
	11.15		9.02
	10.06		8.16
	9.48		8.07
	9.24		8
	9.21		7.89
	8.55		7.32
	7.6		7.18
	7.43		7.16
	7.34		6.82
	7.06		6.29
	6.63		6.26
	5.71		6.22
	5.28		5.33
	5.24		4.51

Appendix C Electro Conductivty Data

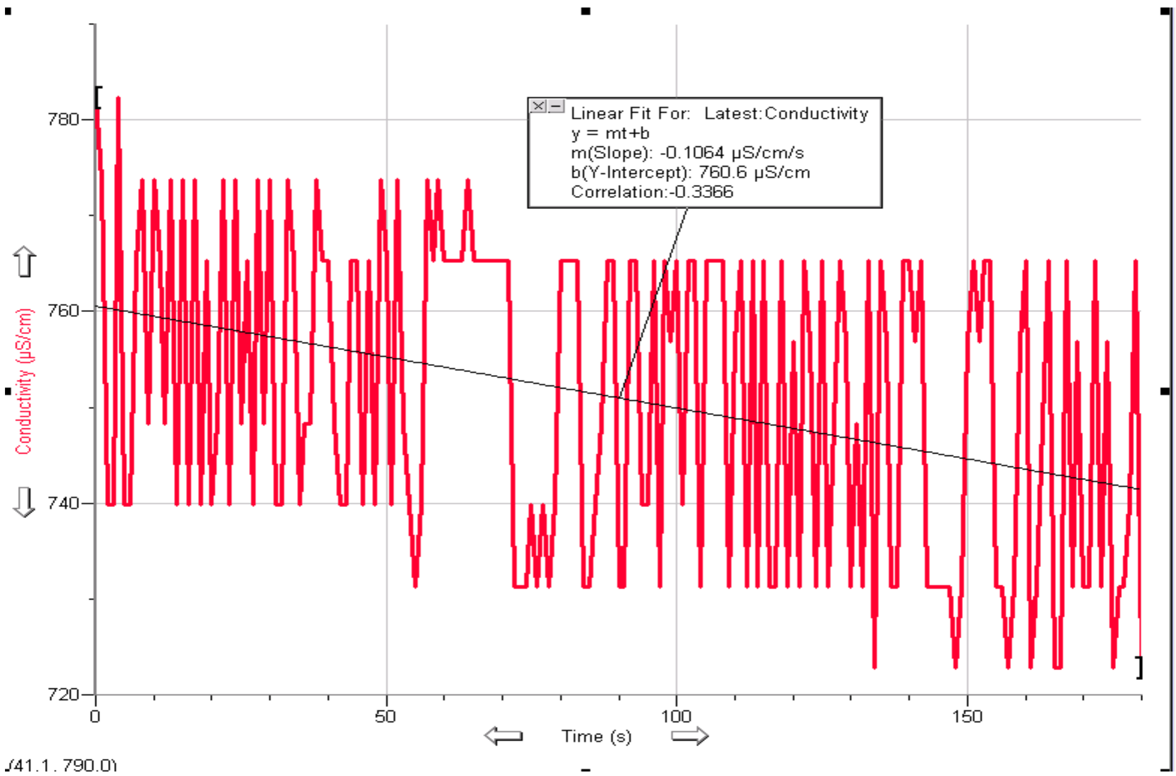
TEST A 1-3min



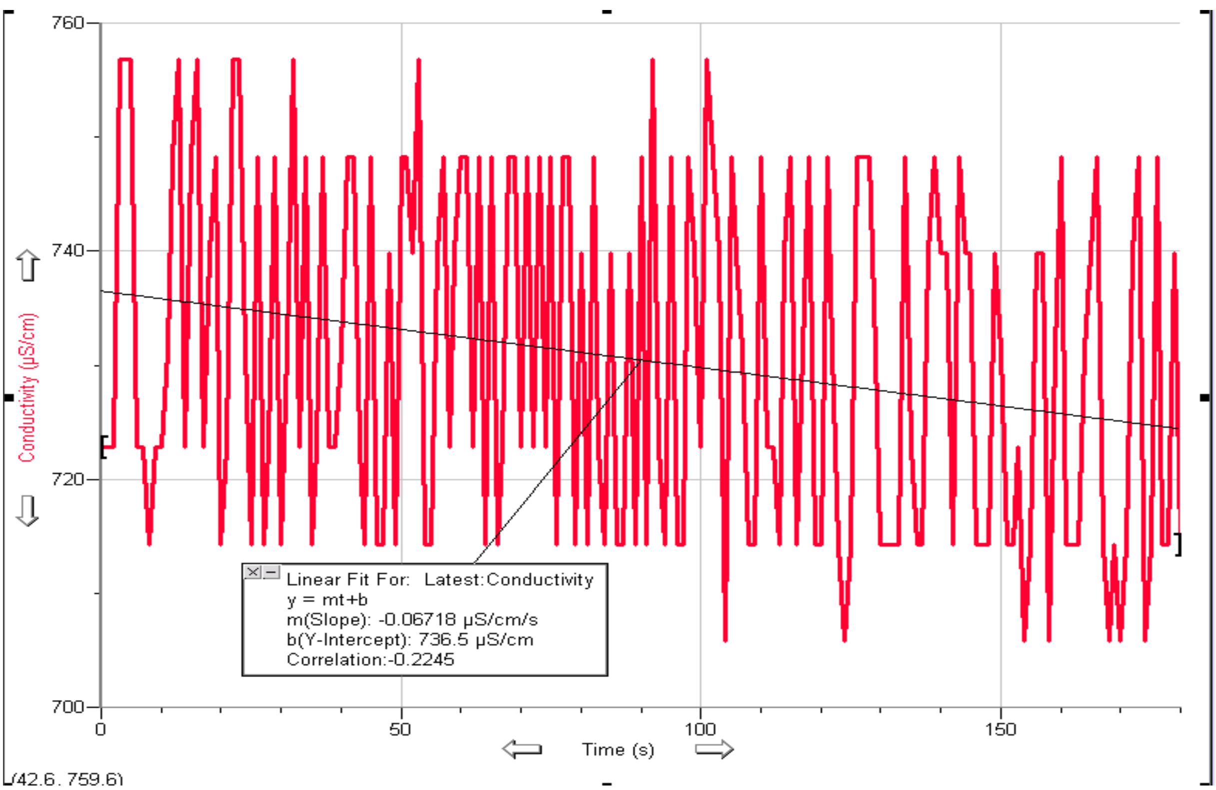
TEST A 3-6min



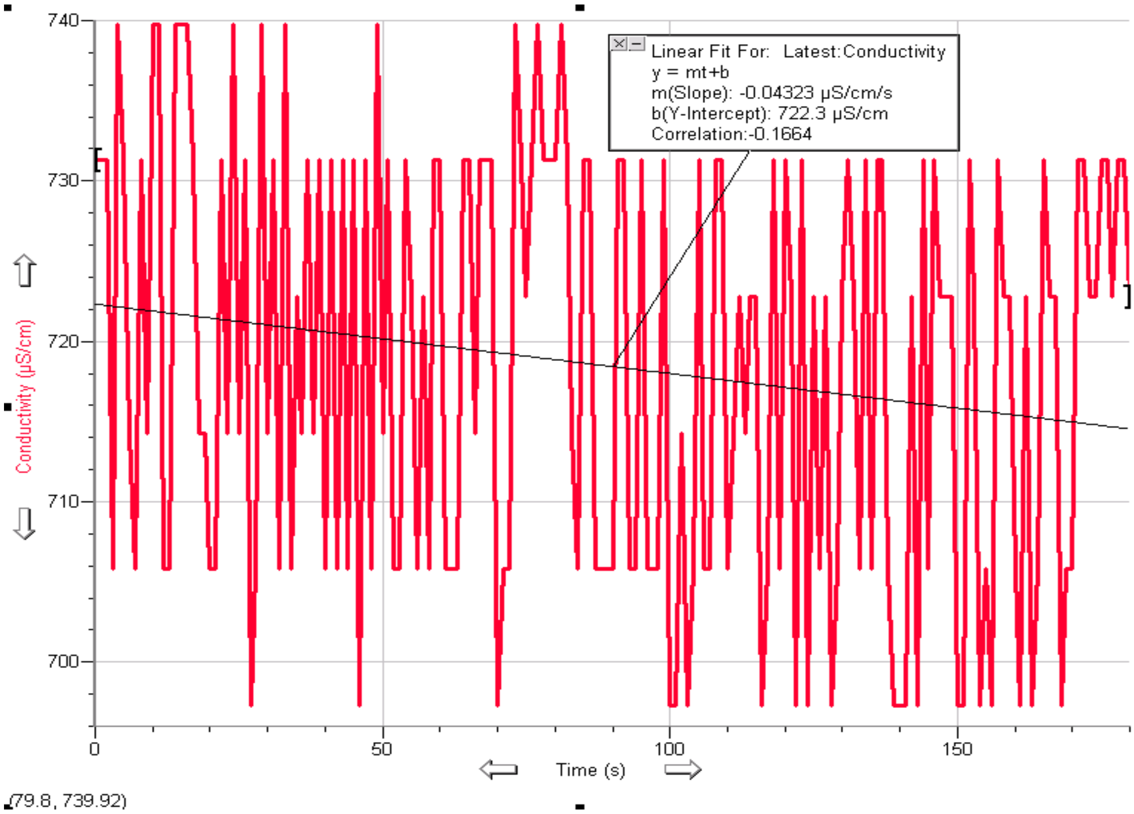
TEST A 6-9min



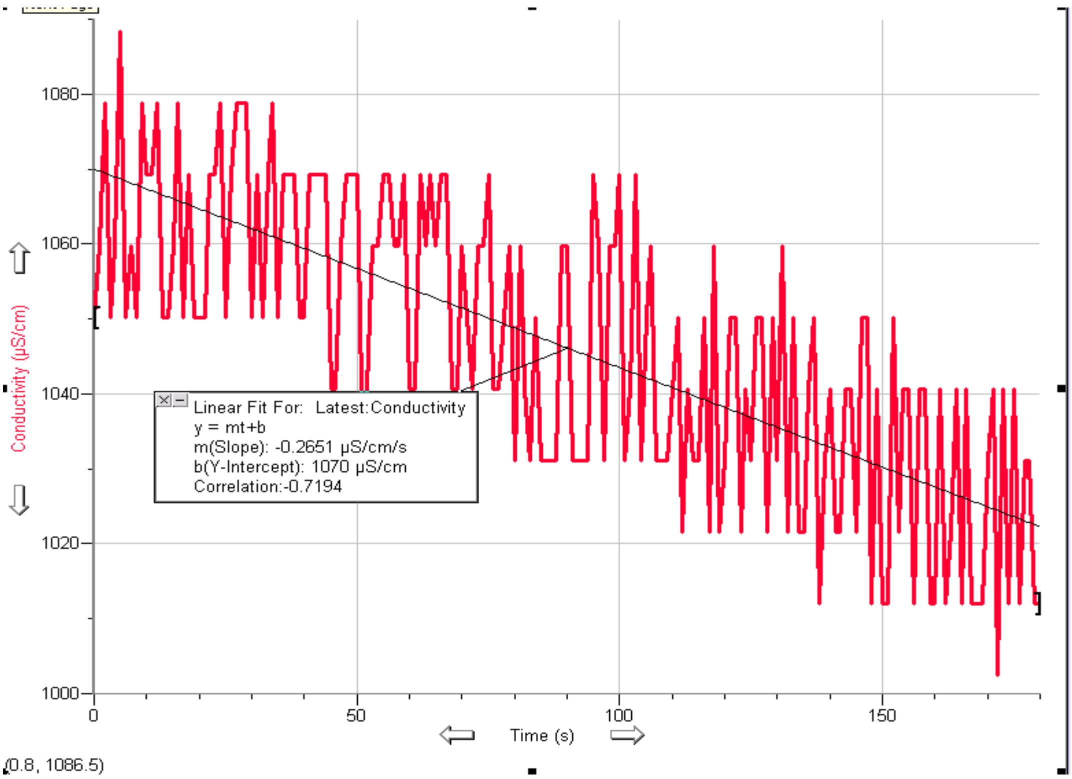
TEST A 9-12min



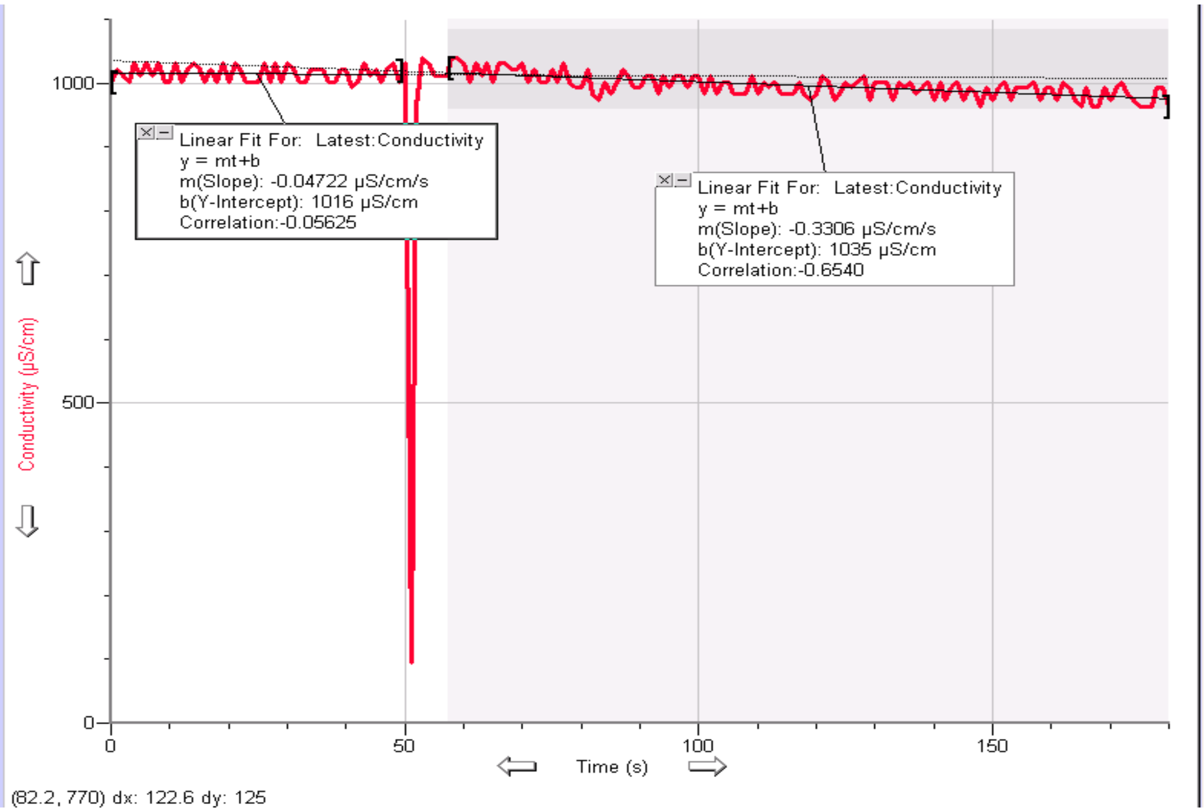
TEST A 12-15min PUMP OFF



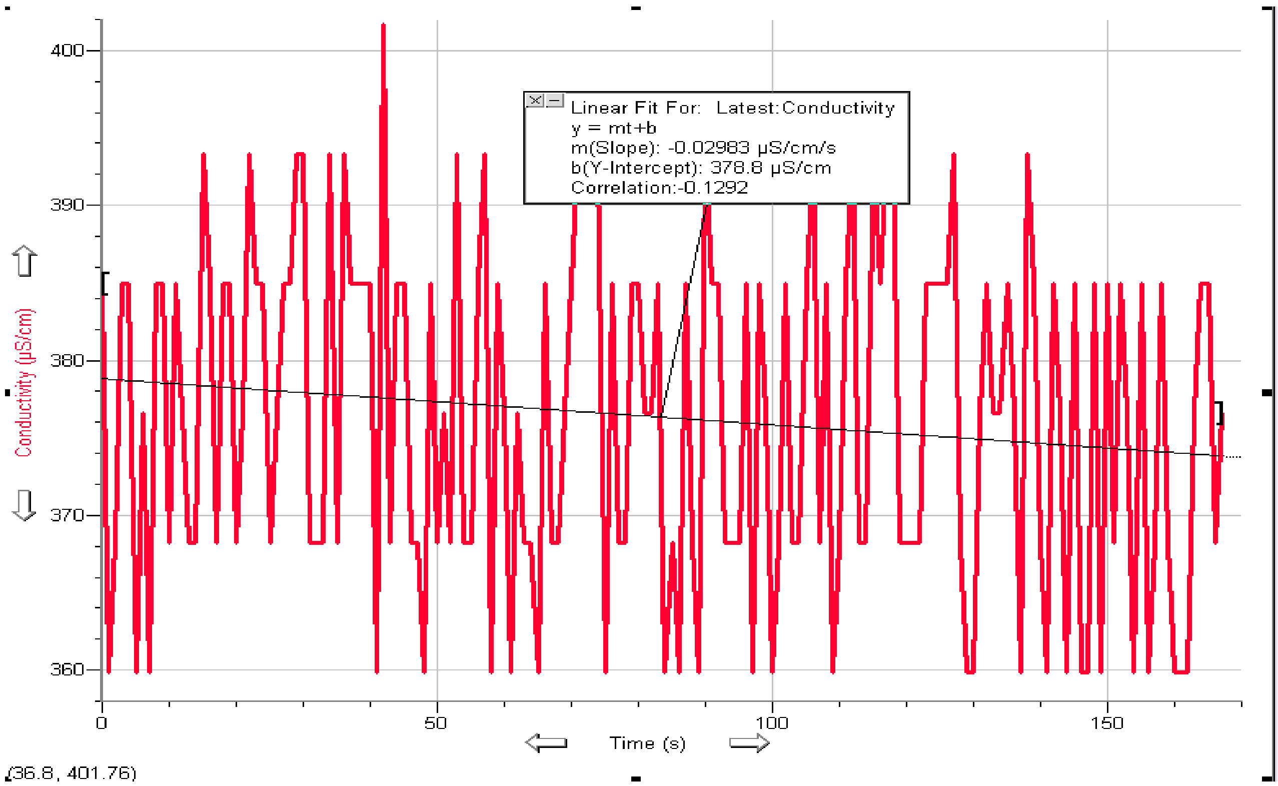
TEST B 1-3min



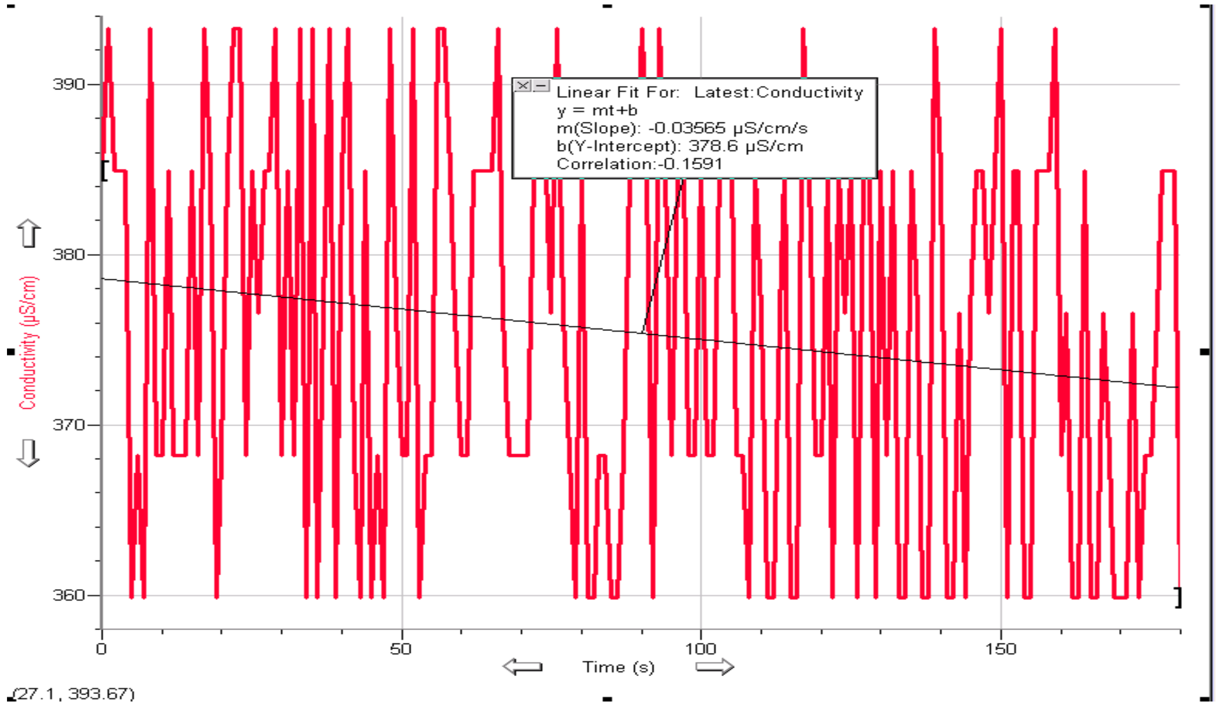
TEST B 3-4min Pump On 4-6 min Pump off



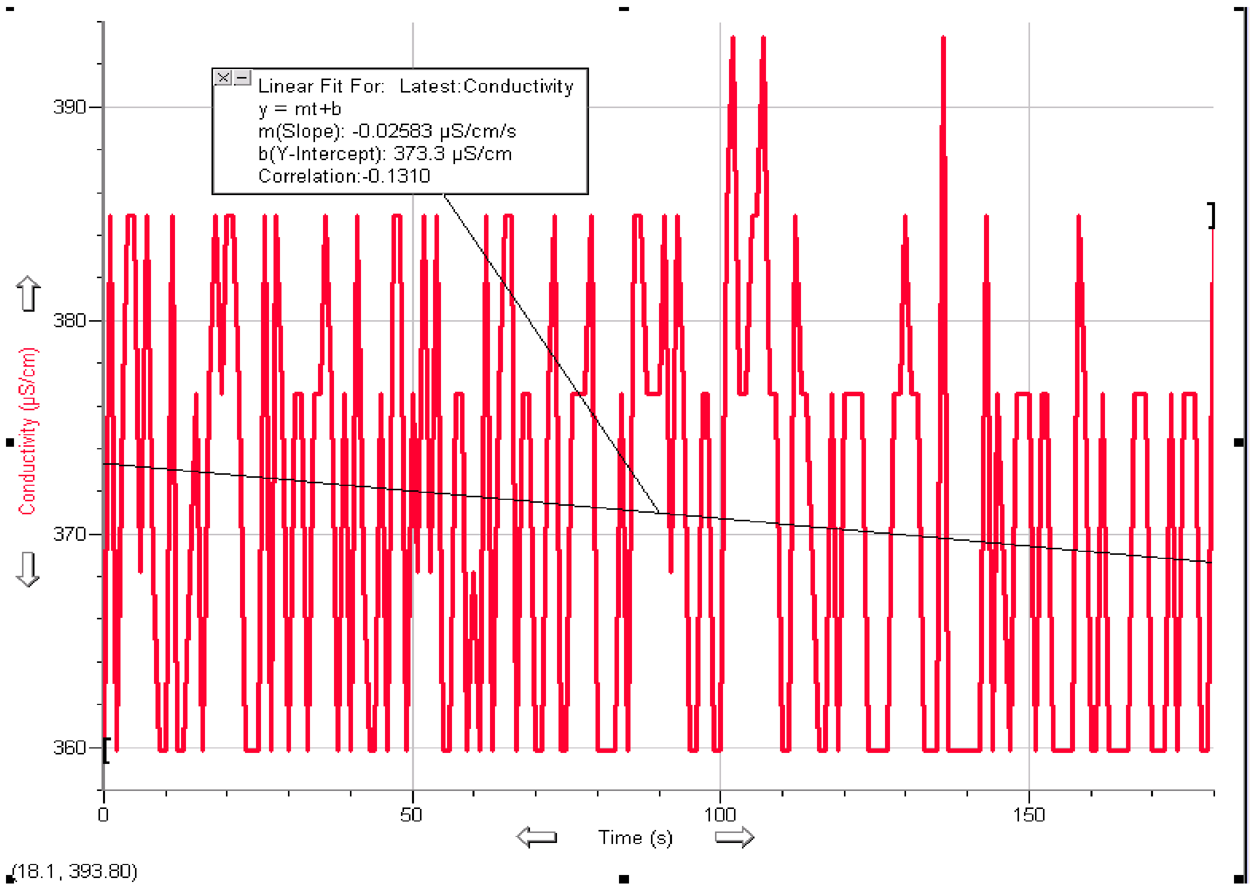
TEST C 1-3min



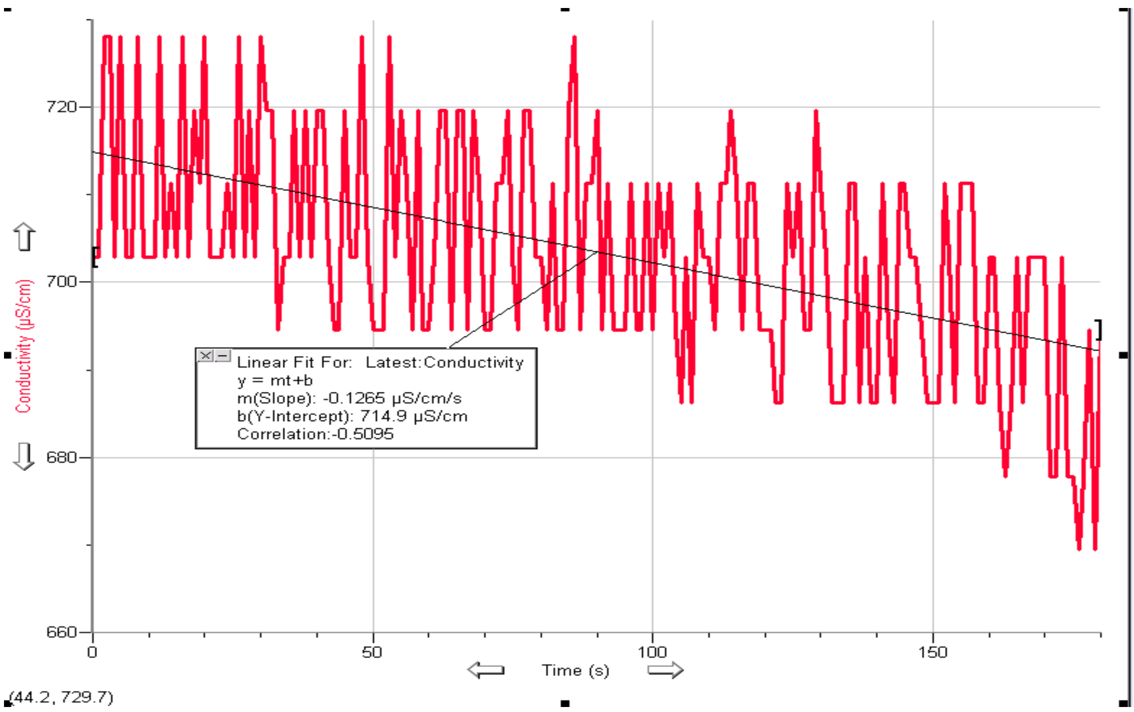
TEST C 3-6 min PUMPON



TEST C 6-9 min PUMPON



TEST D 1-3min NO PUMP



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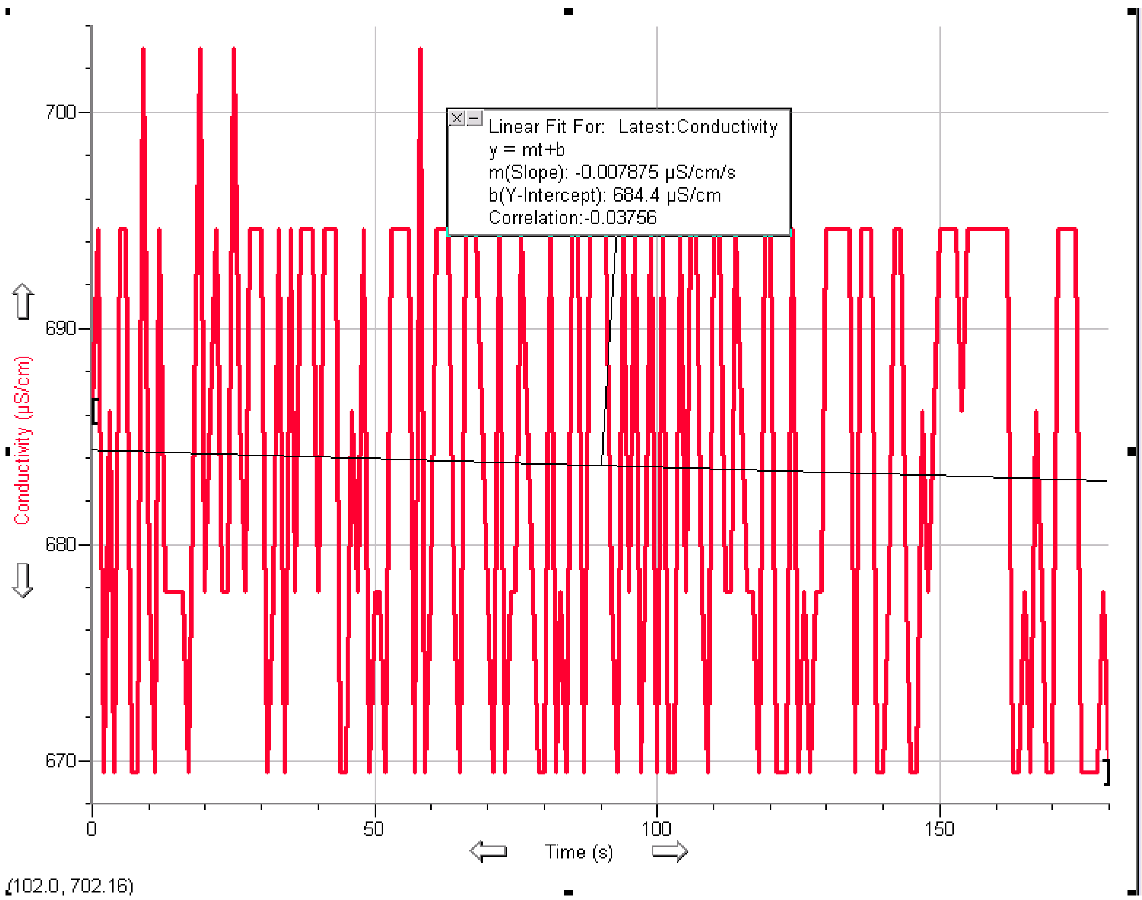
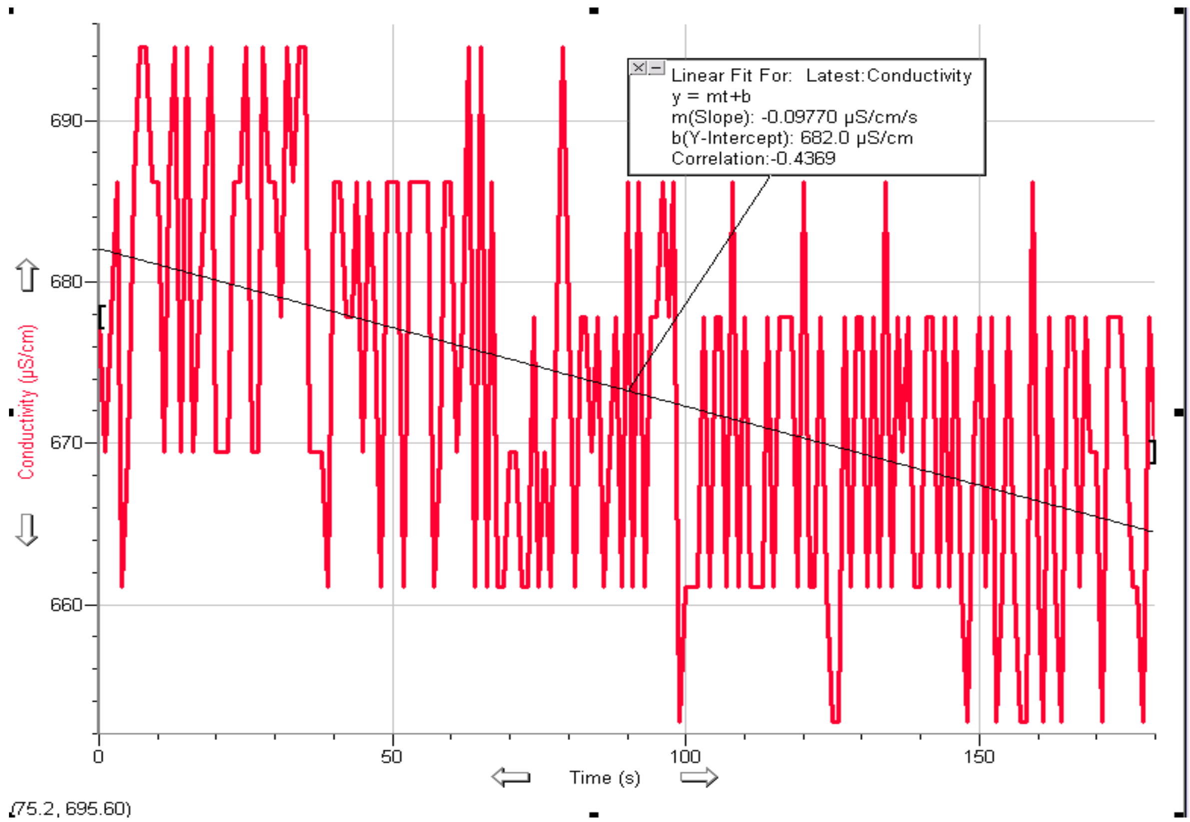
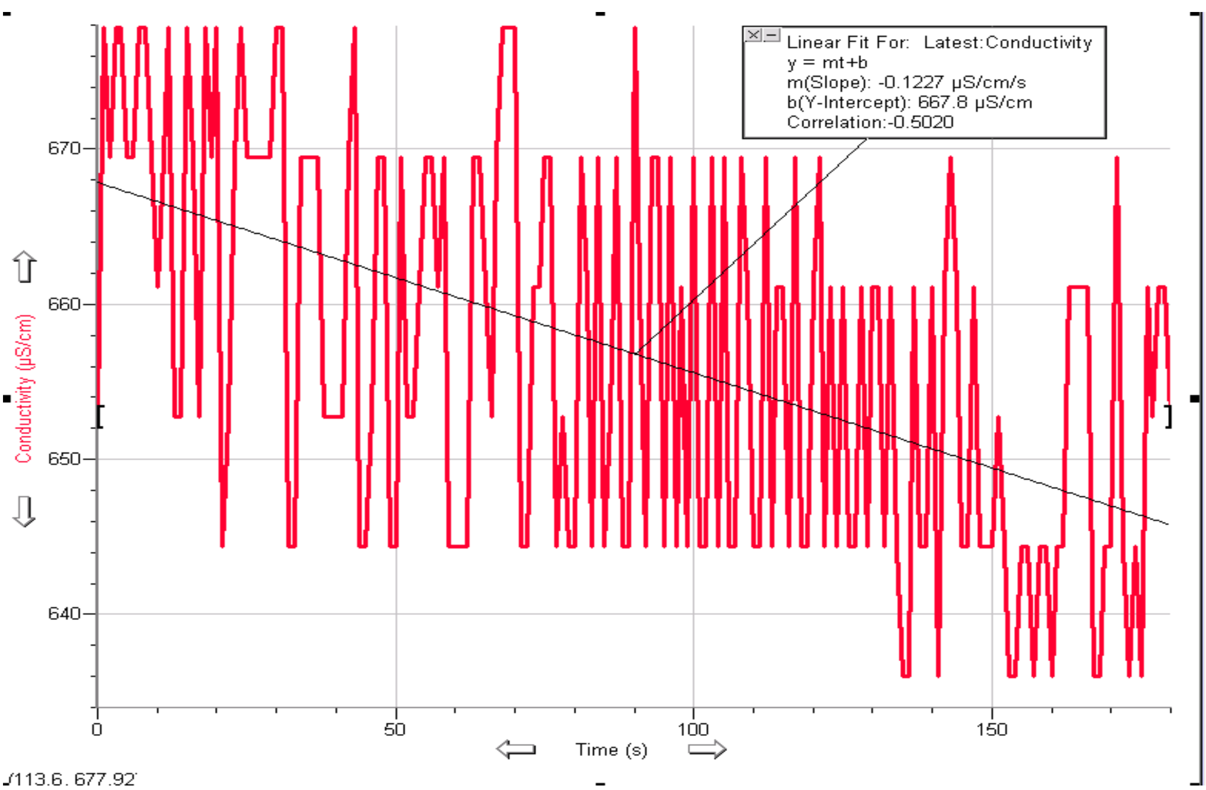


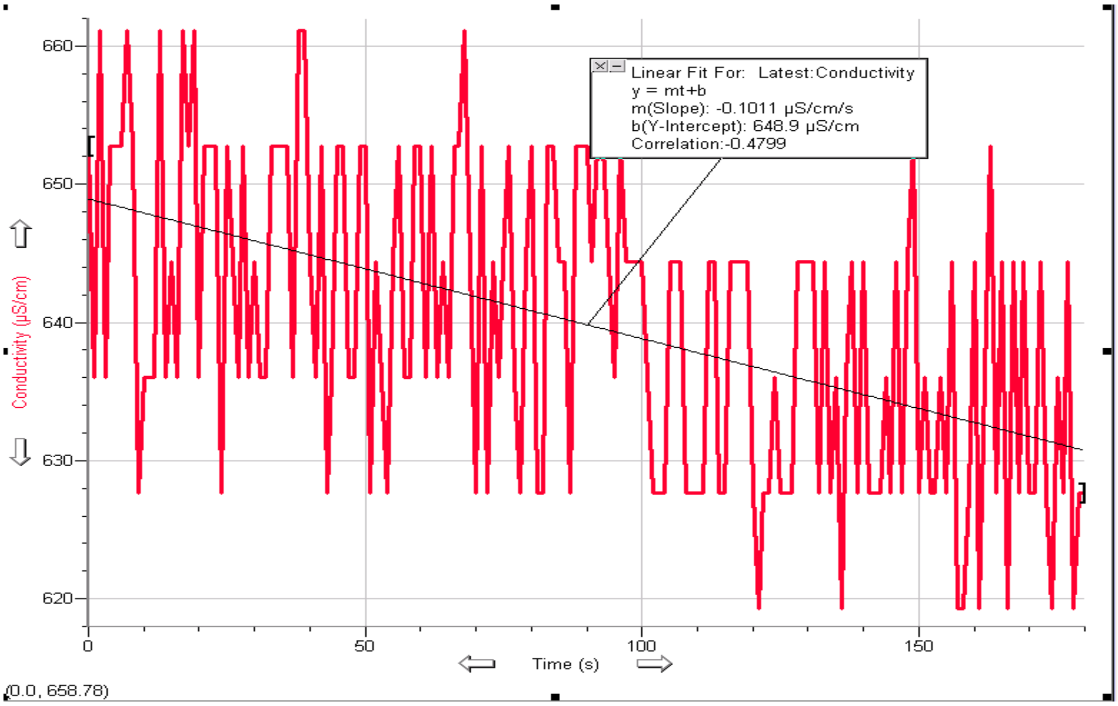
TEST D 6-9min PUMP ON



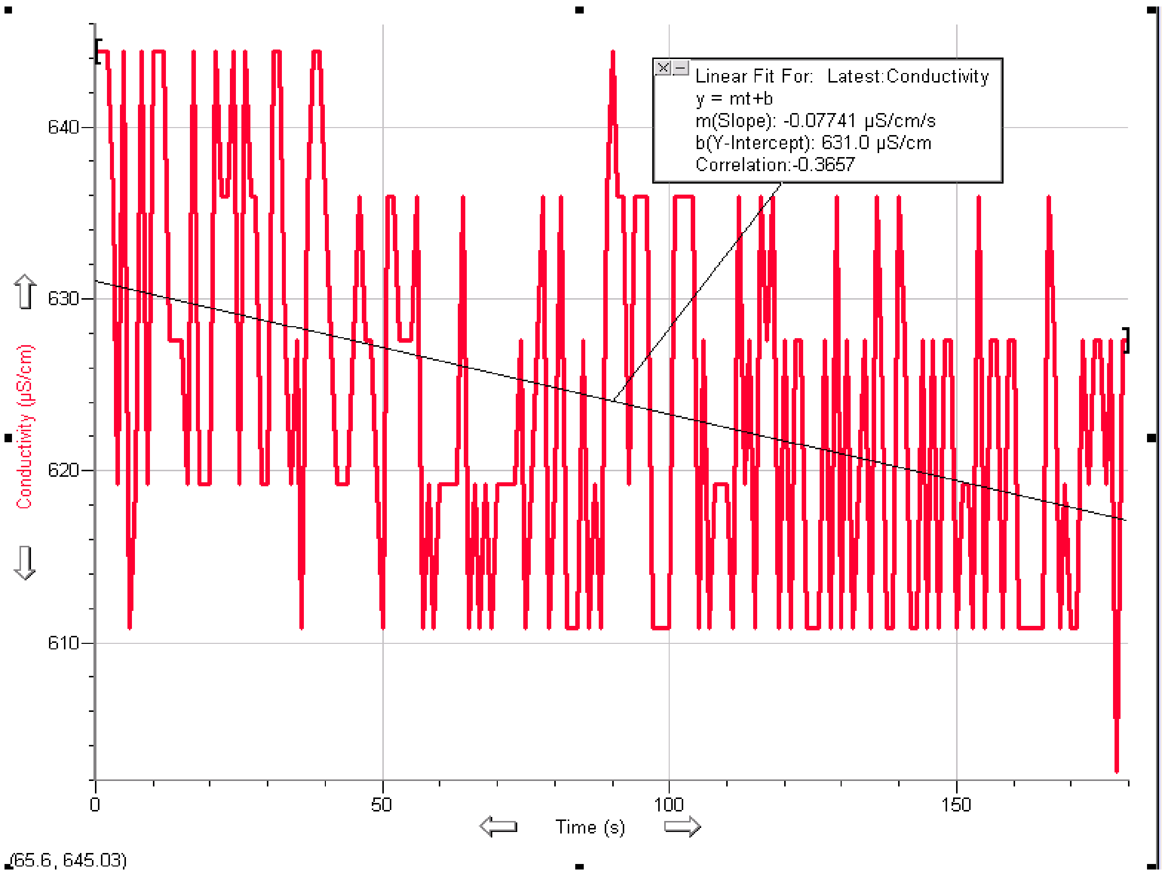
TEST D 9-12min



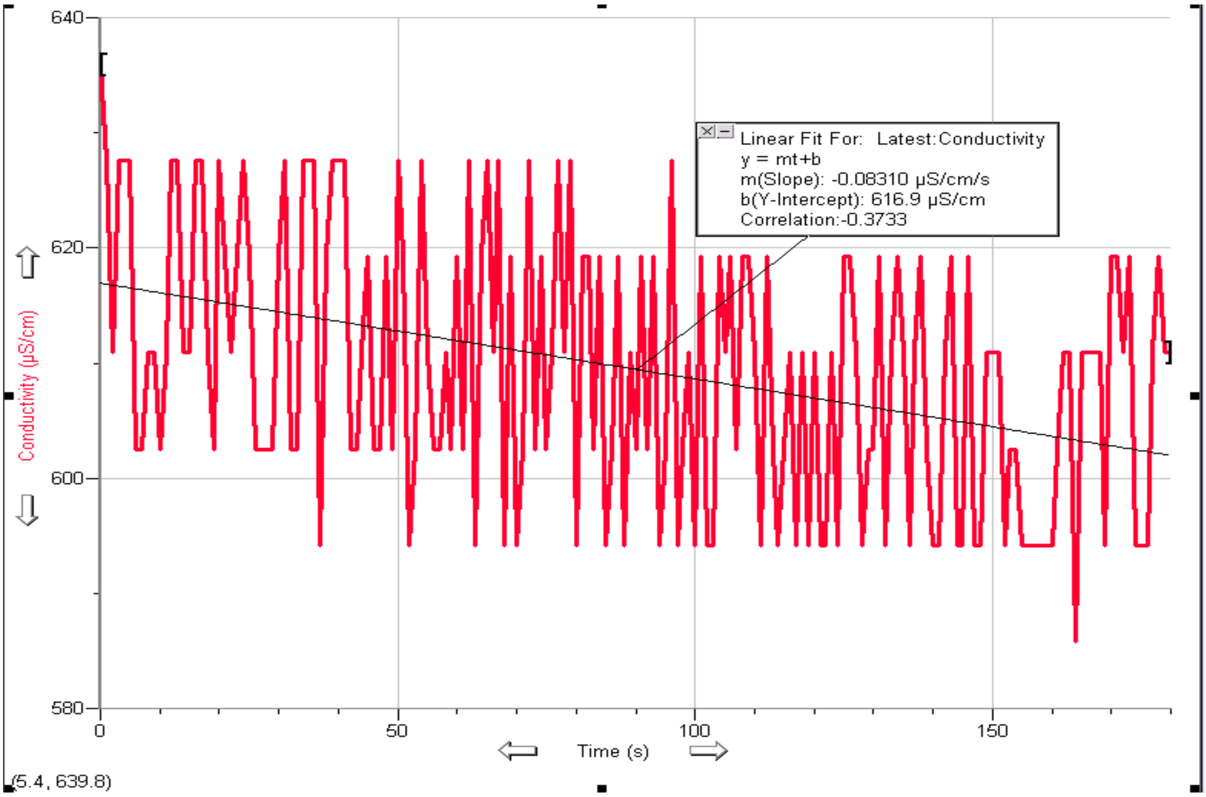
TEST D 12- 15 min



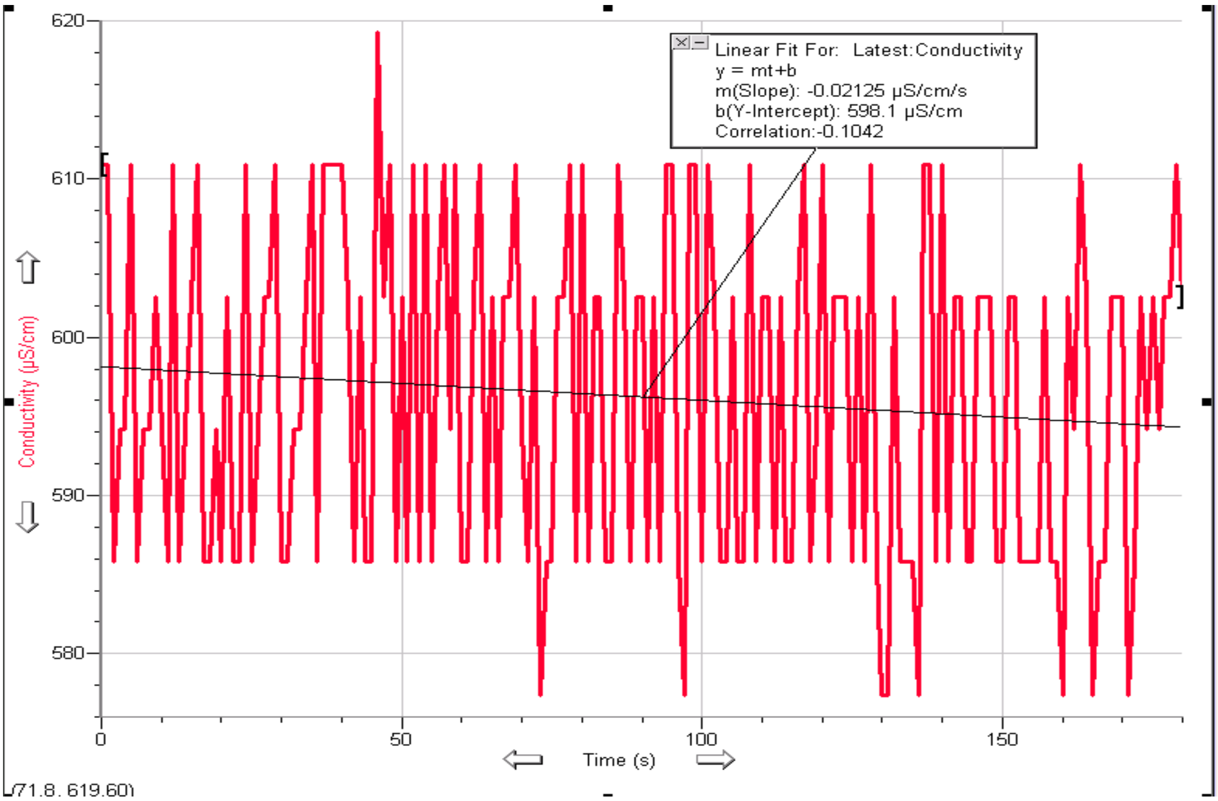
TEST D 15-18min



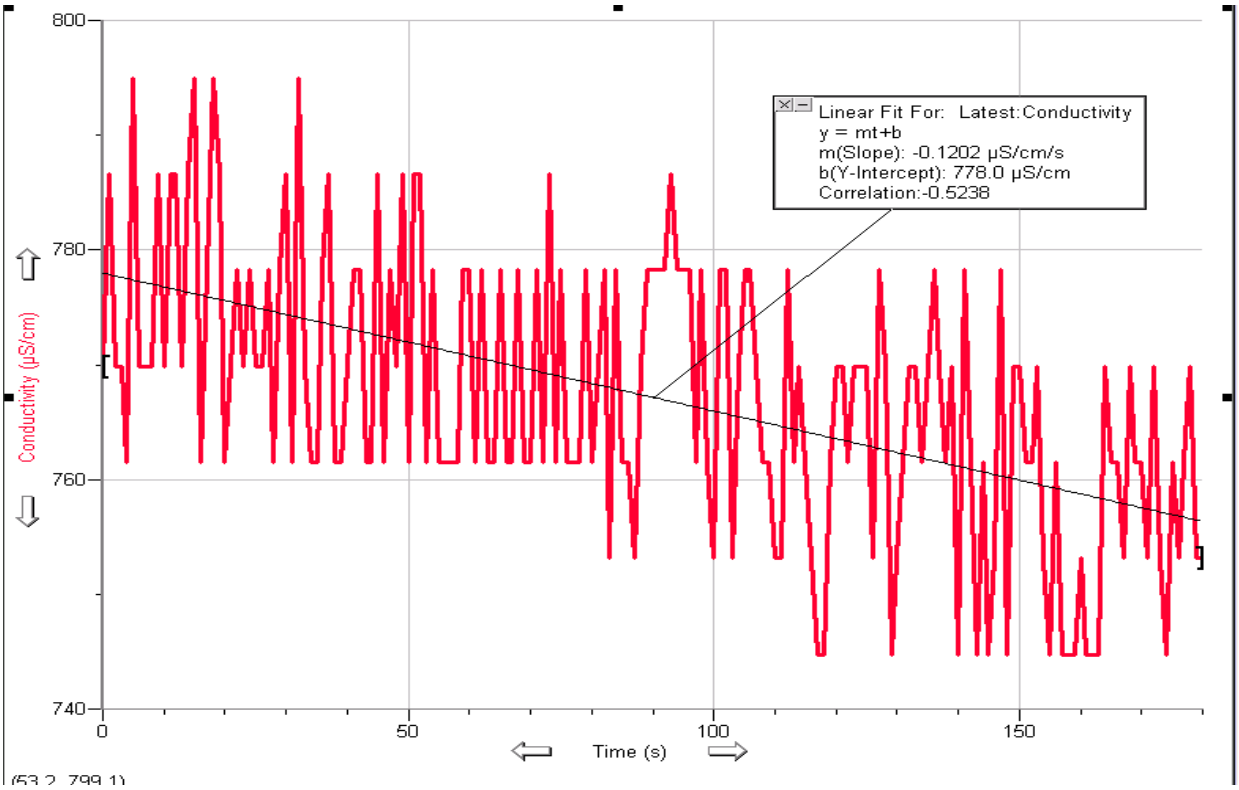
TEST D 18-21min



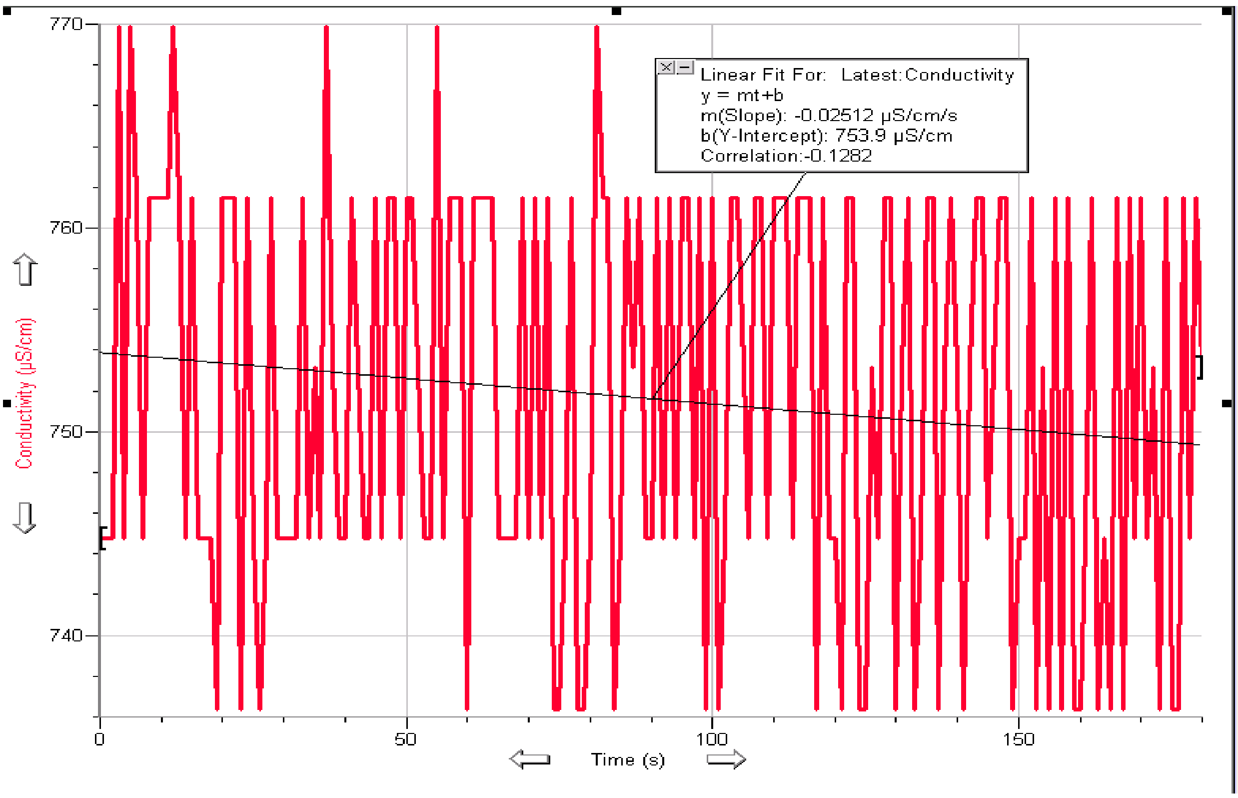
TEST D 21-24min



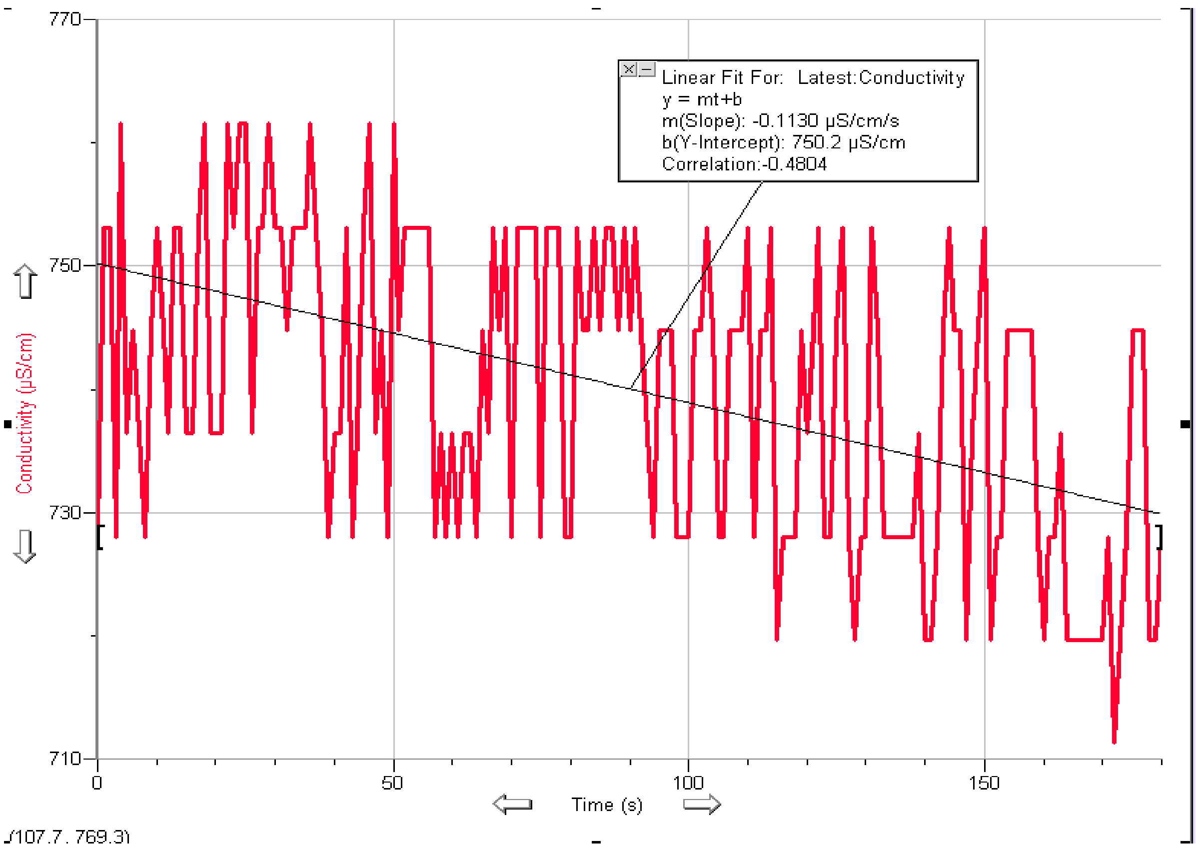
TEST E 1-3min NO Pump



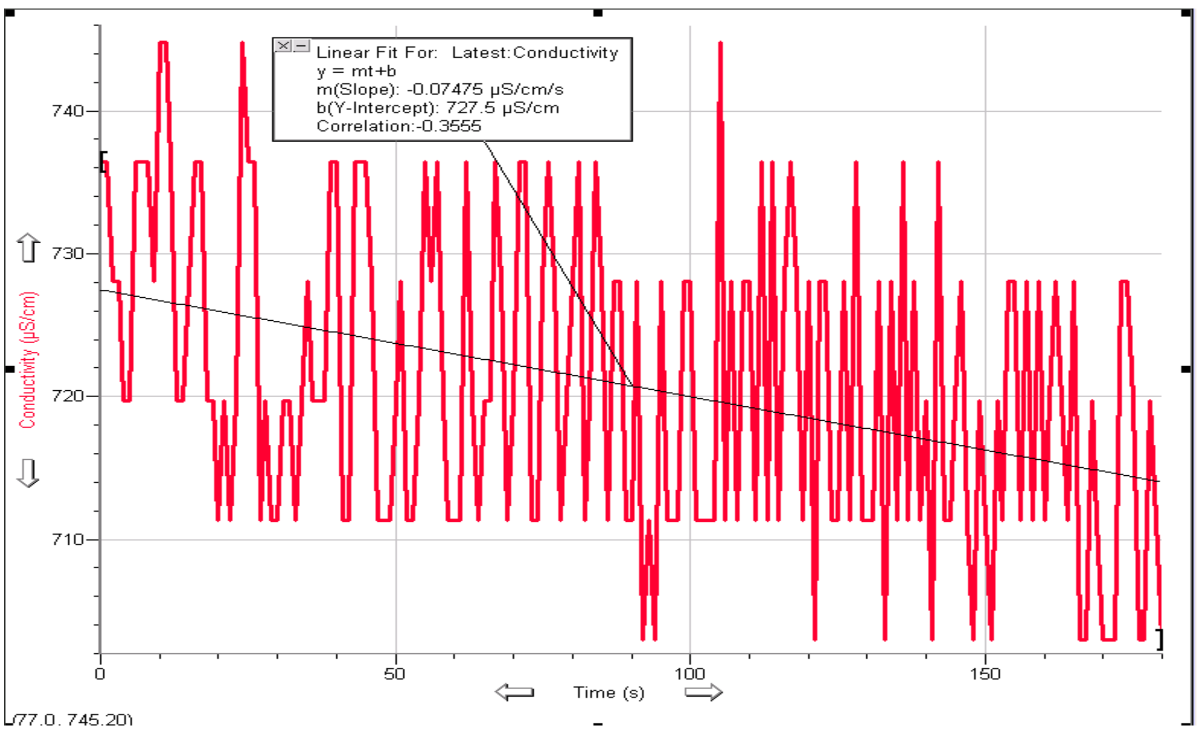
TEST E 3-6min NO Pump



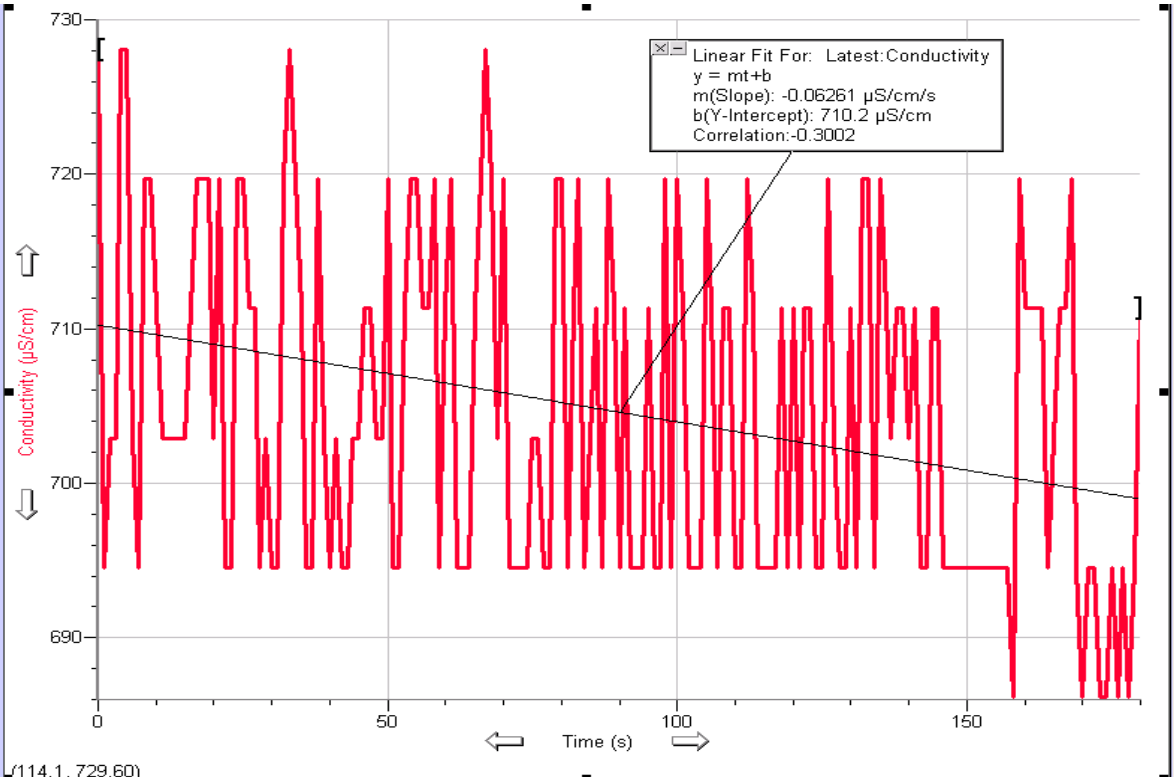
TEST E 6-9min Pump On



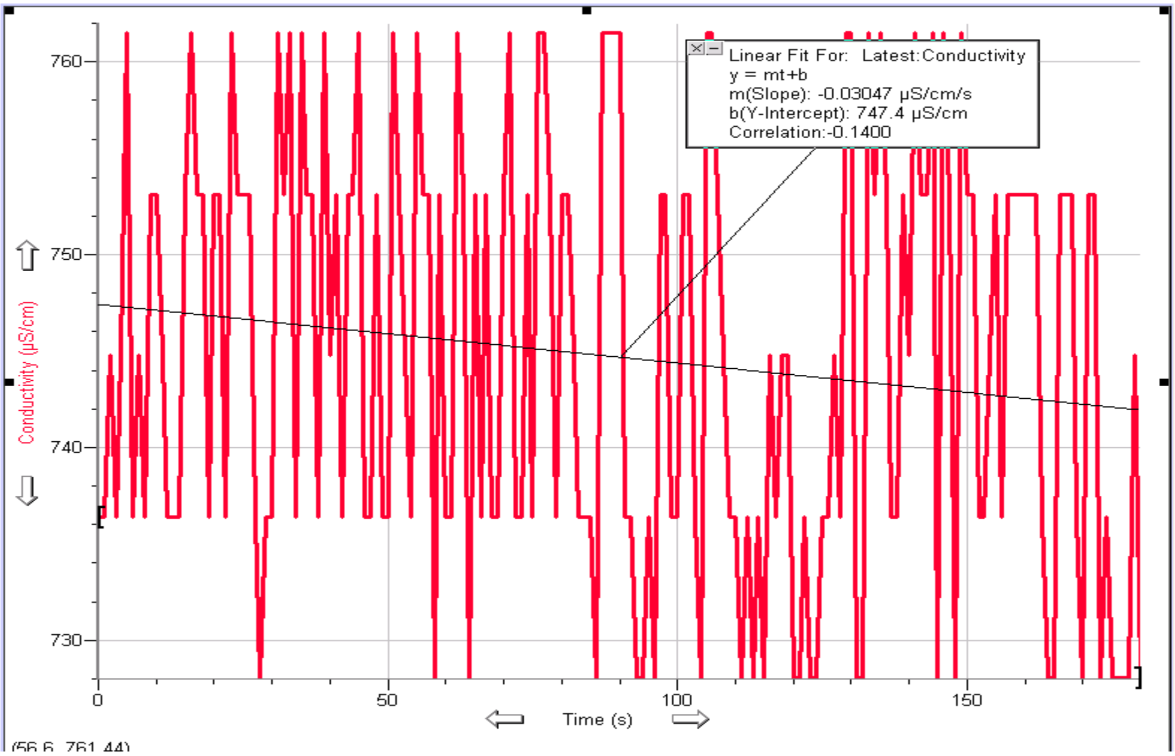
TEST E 9-12min



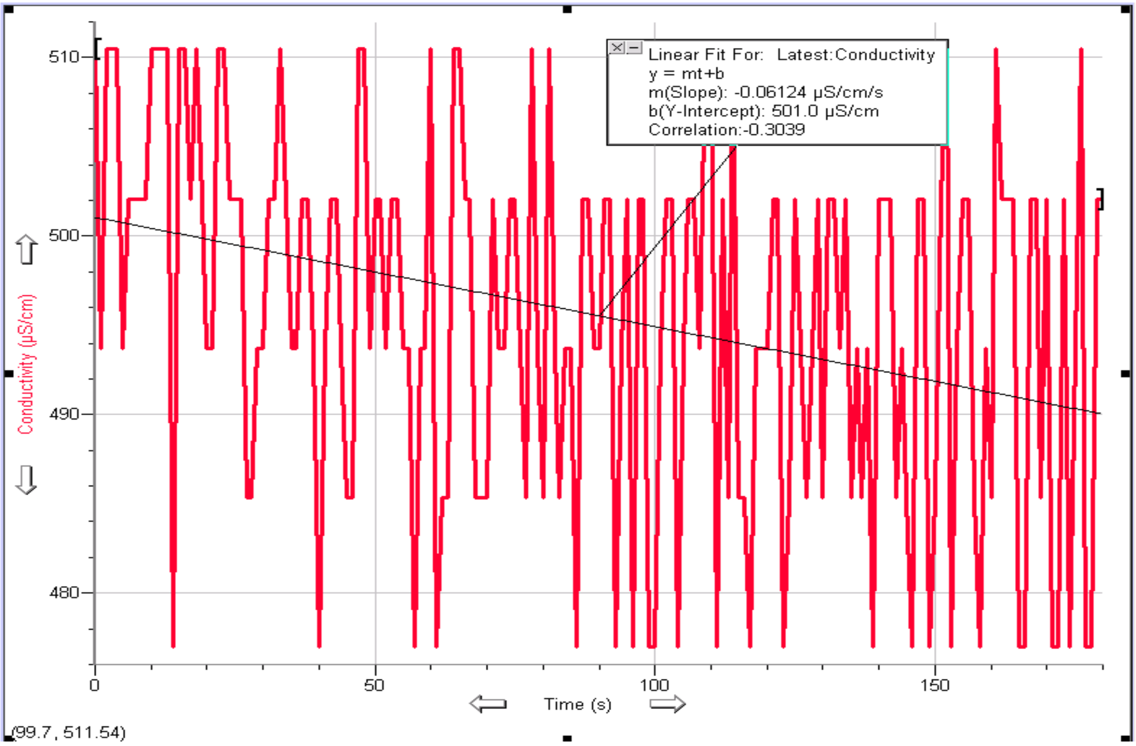
TEST E 9-12min



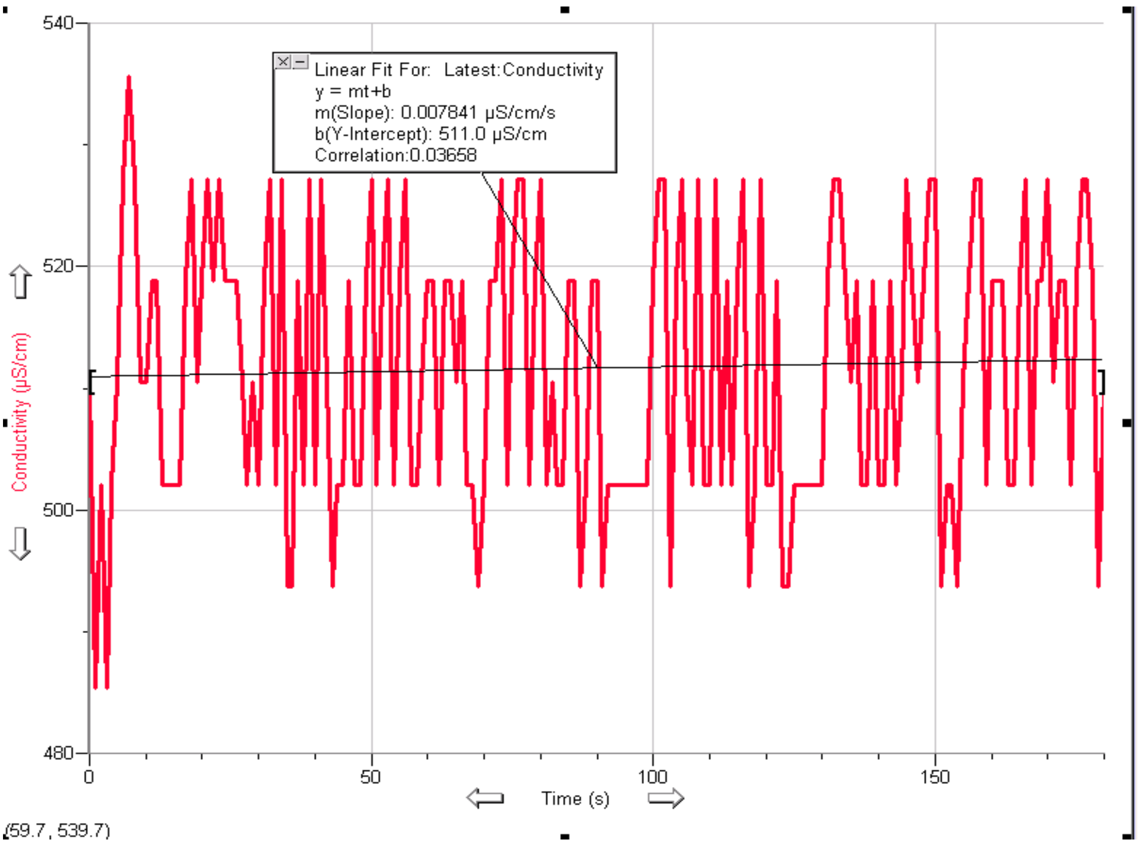
TEST E 12-15min



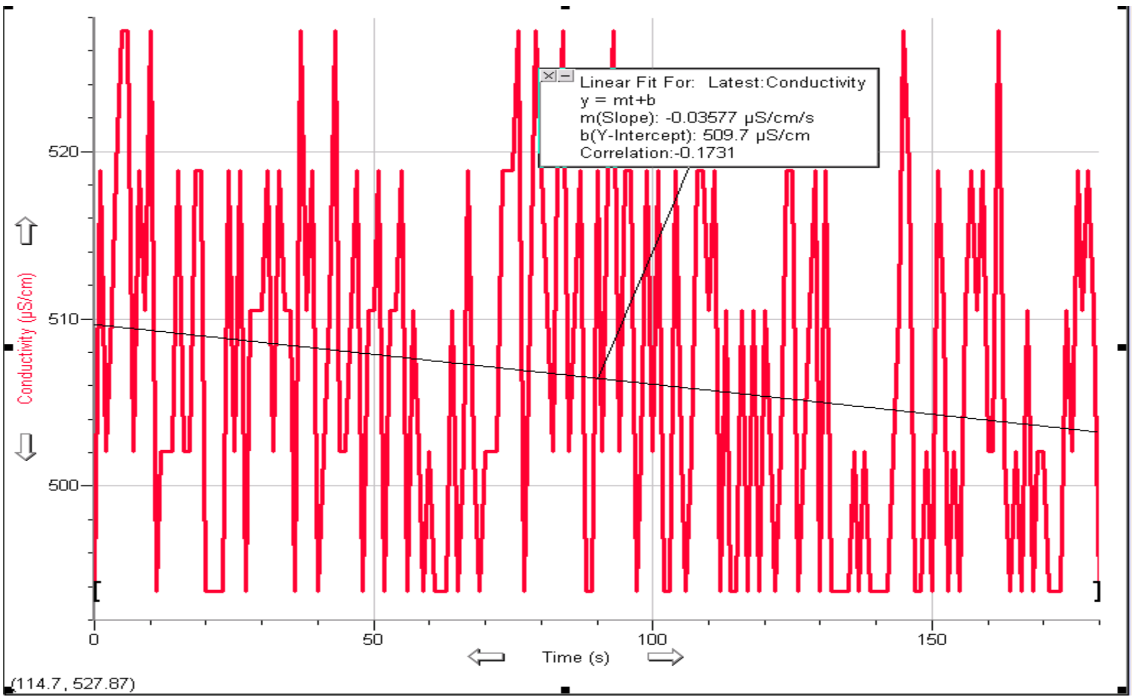
TEST F 1-3min NO MAGNETS PUMP OFF



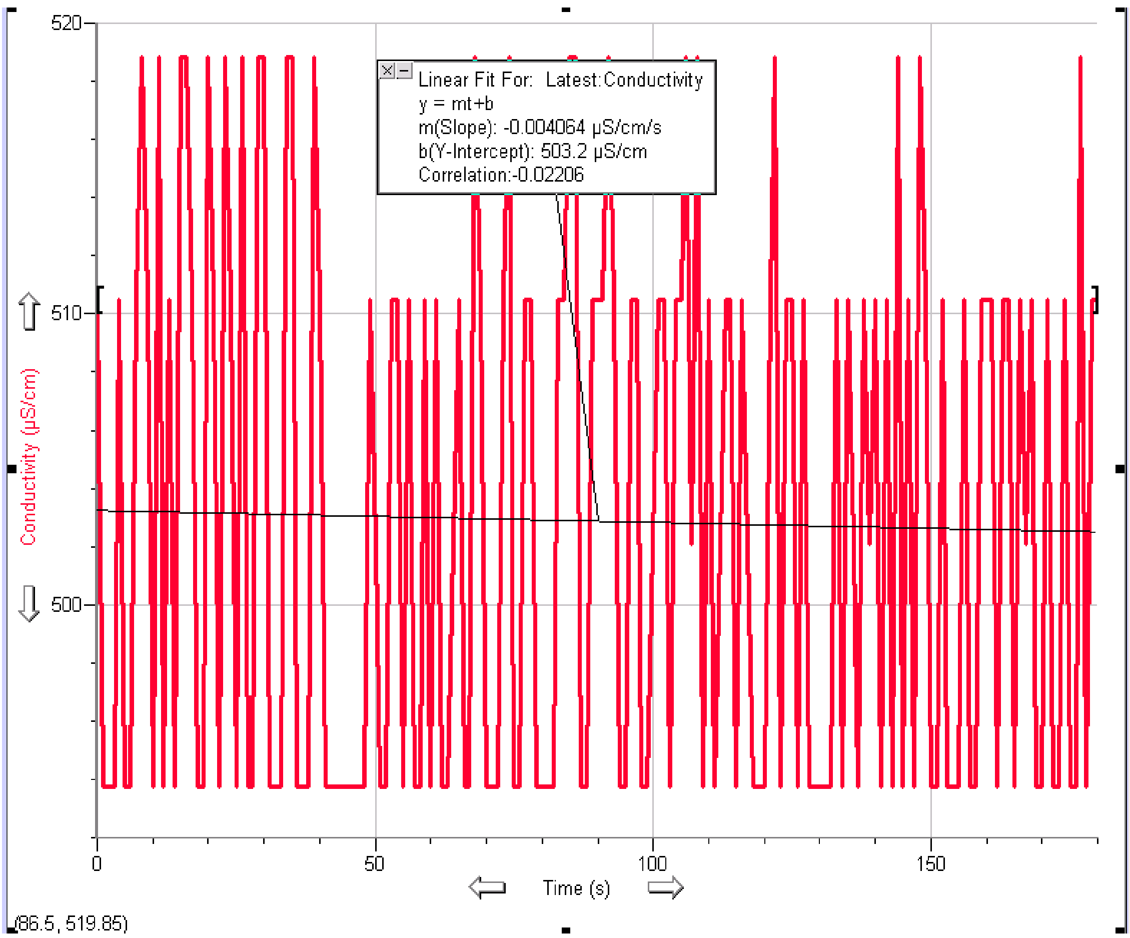
TEST F 3-6mins NO MAGNETS PUMP ON



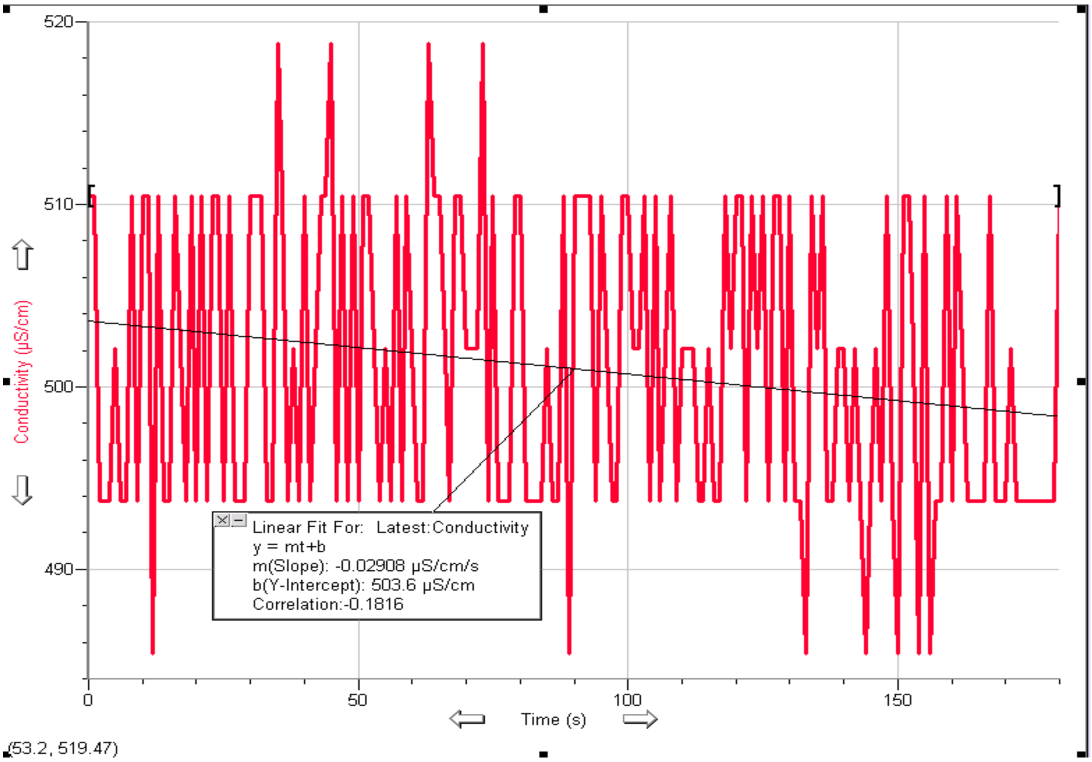
TEST F 6-9 mins No MAGNETS PUMP On



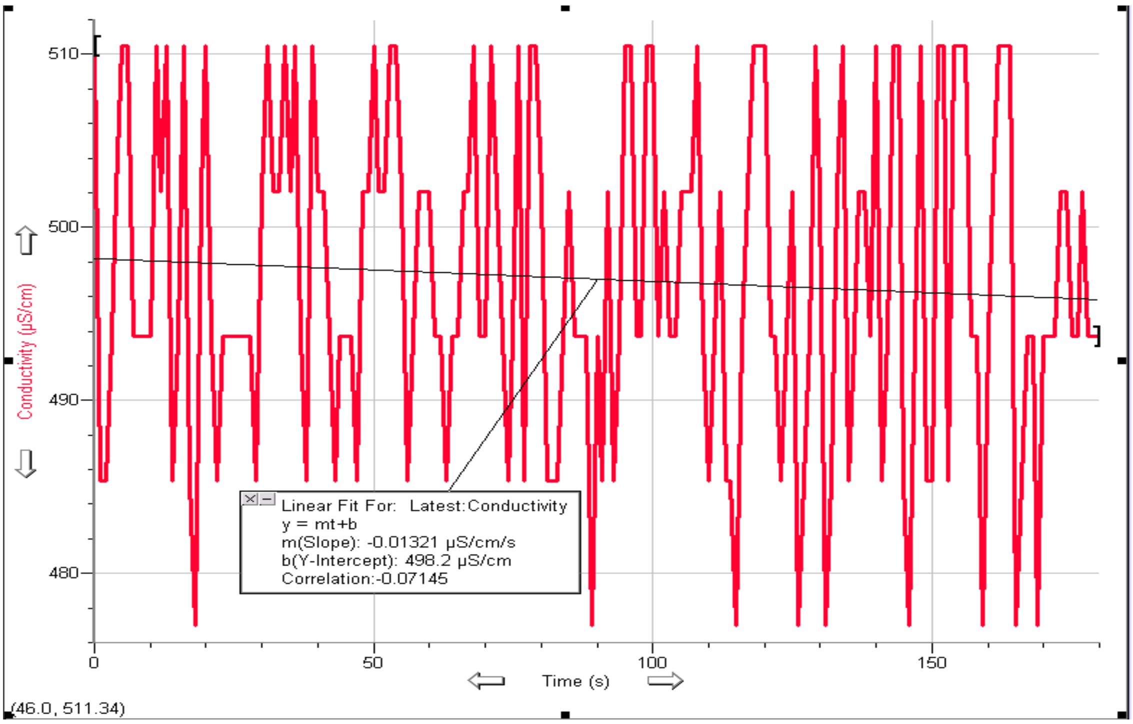
TEST F 9-12mins MAGNETS ATTACHED PUMP



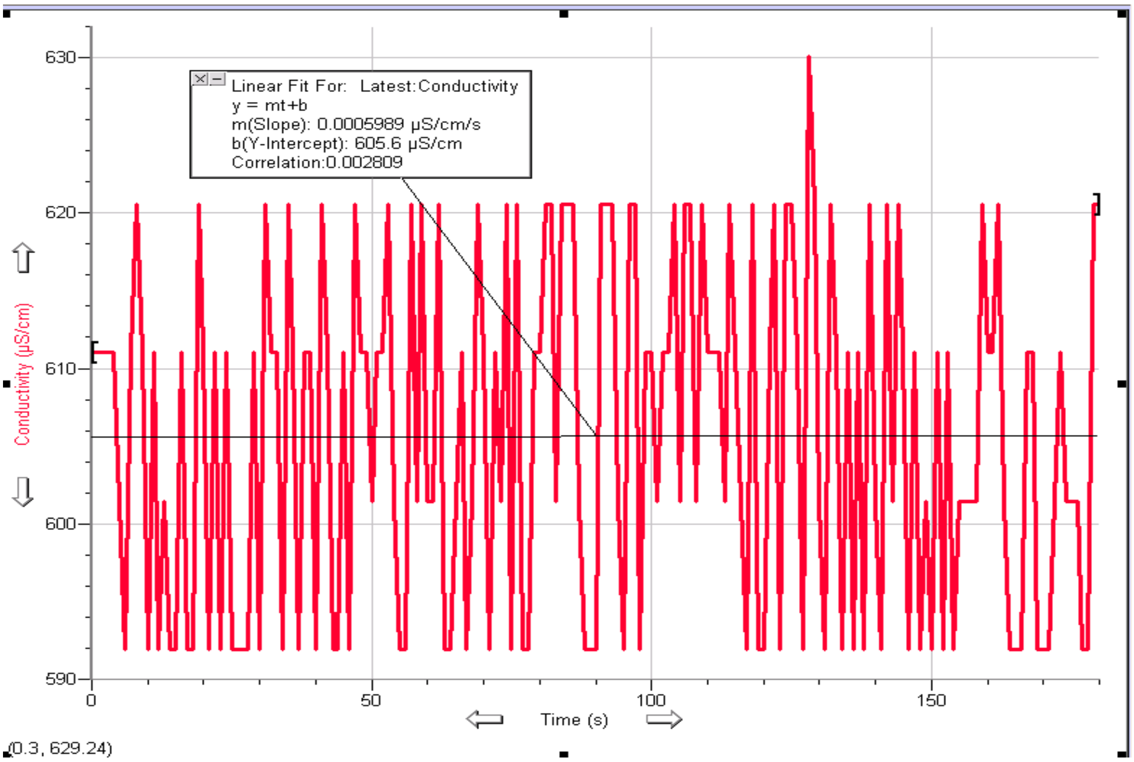
TEST F 12-15mins MAGNETS ATTACHED PUMP



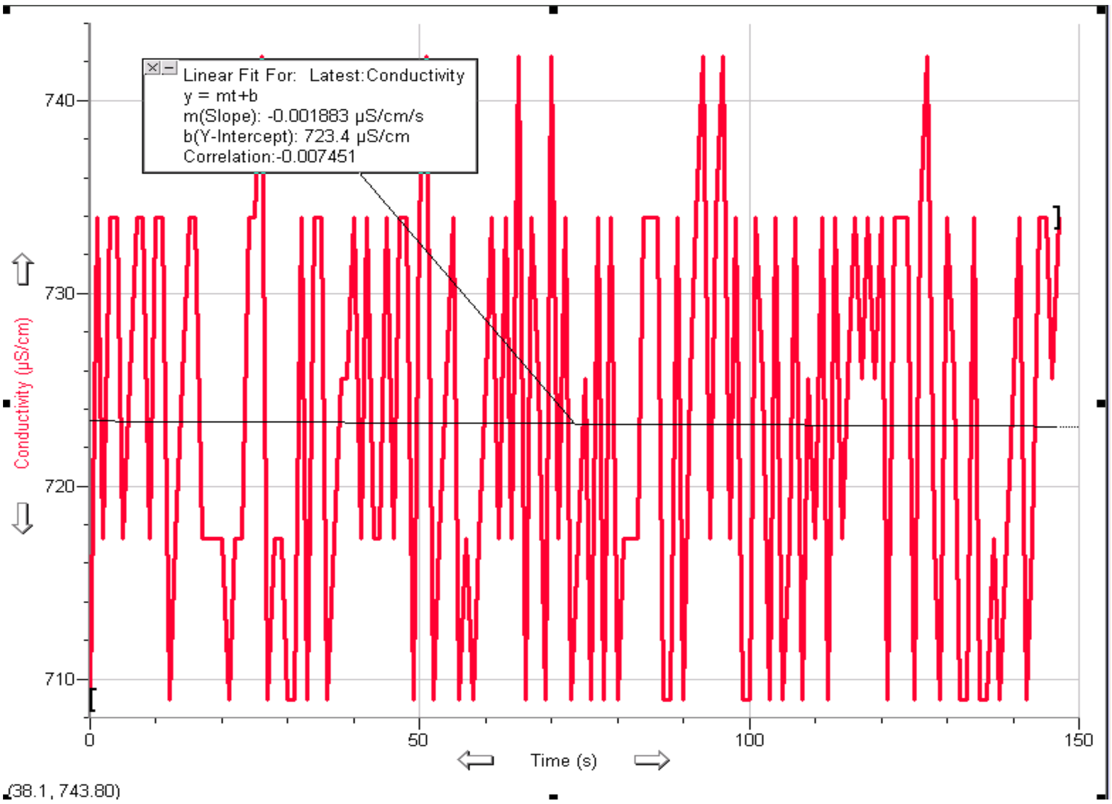
TEST F 15-18mins MAGNETS ATTACHED PUMP



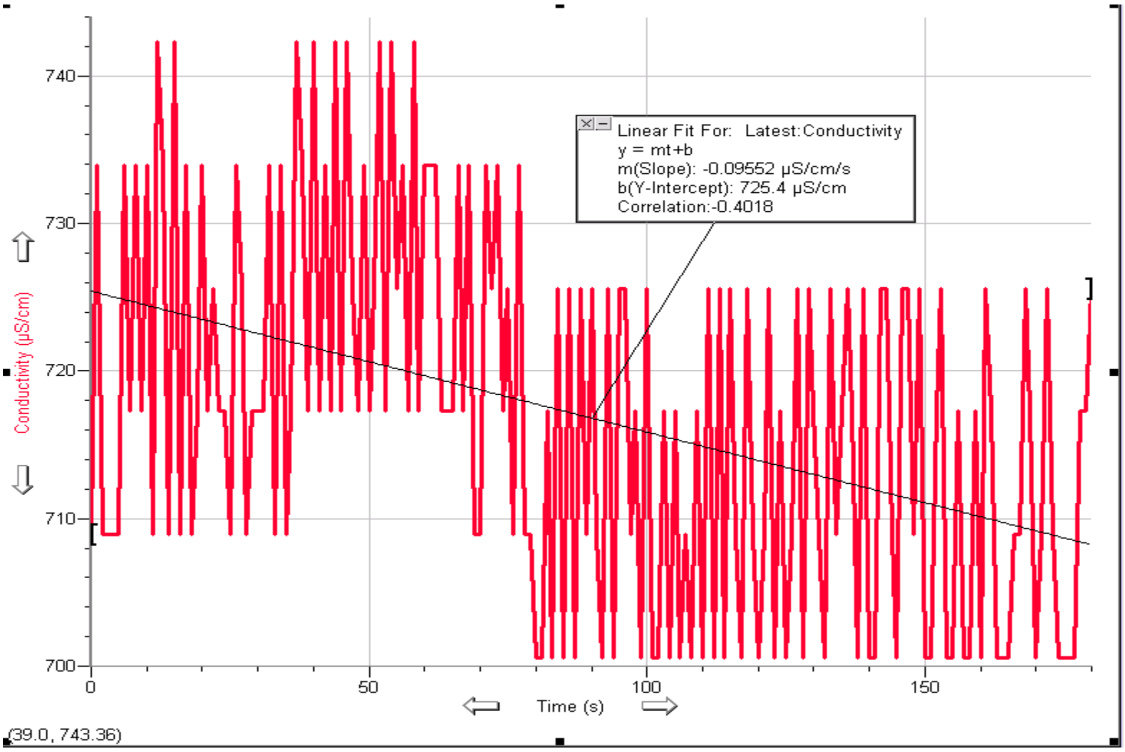
TEST F 18-21 mins MAGNETS ATTACHED PUMP



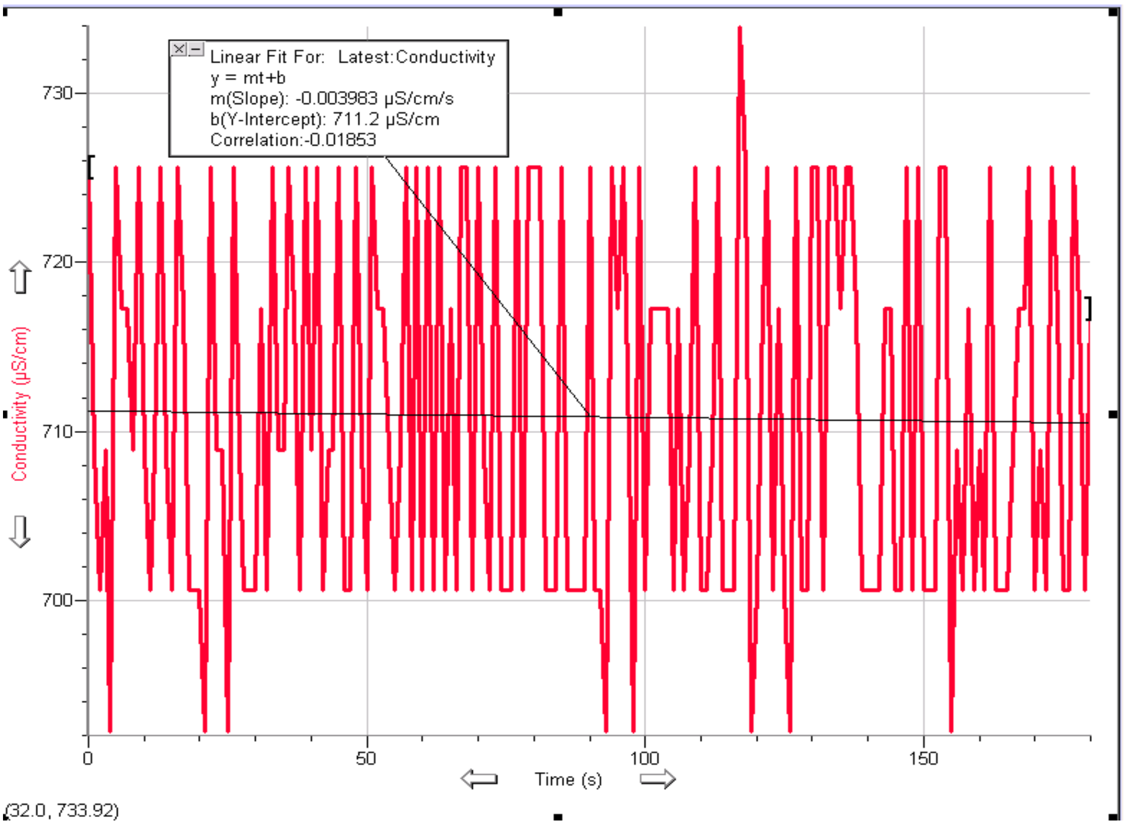
TEST G 1-3 mins MAGNETS ATTACHED No Pump



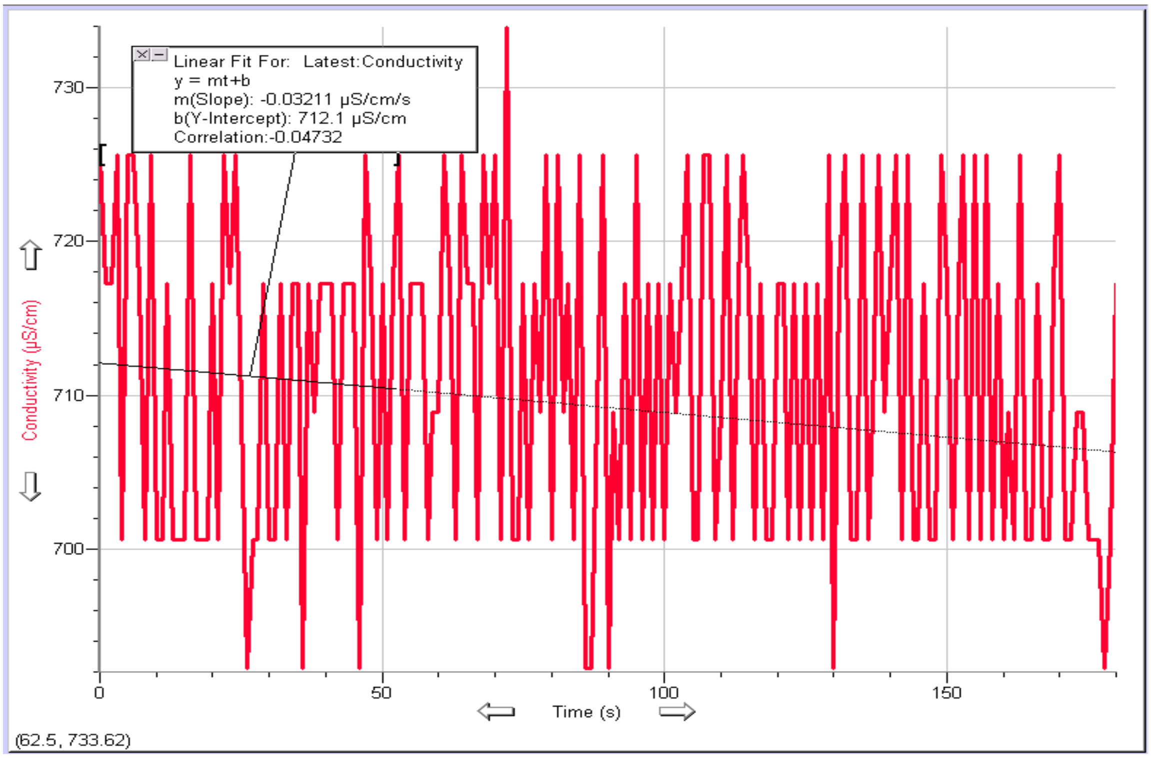
TEST G 3-6 mins Pump On



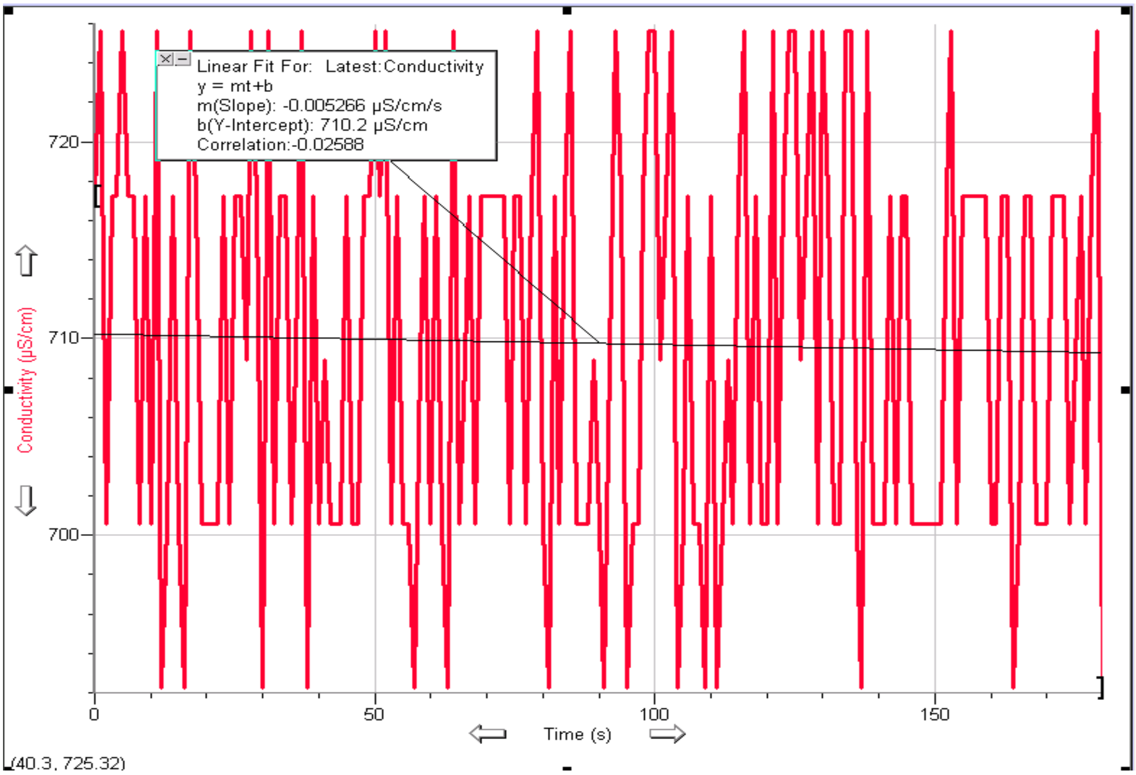
TEST G 6-9 mins Pump On



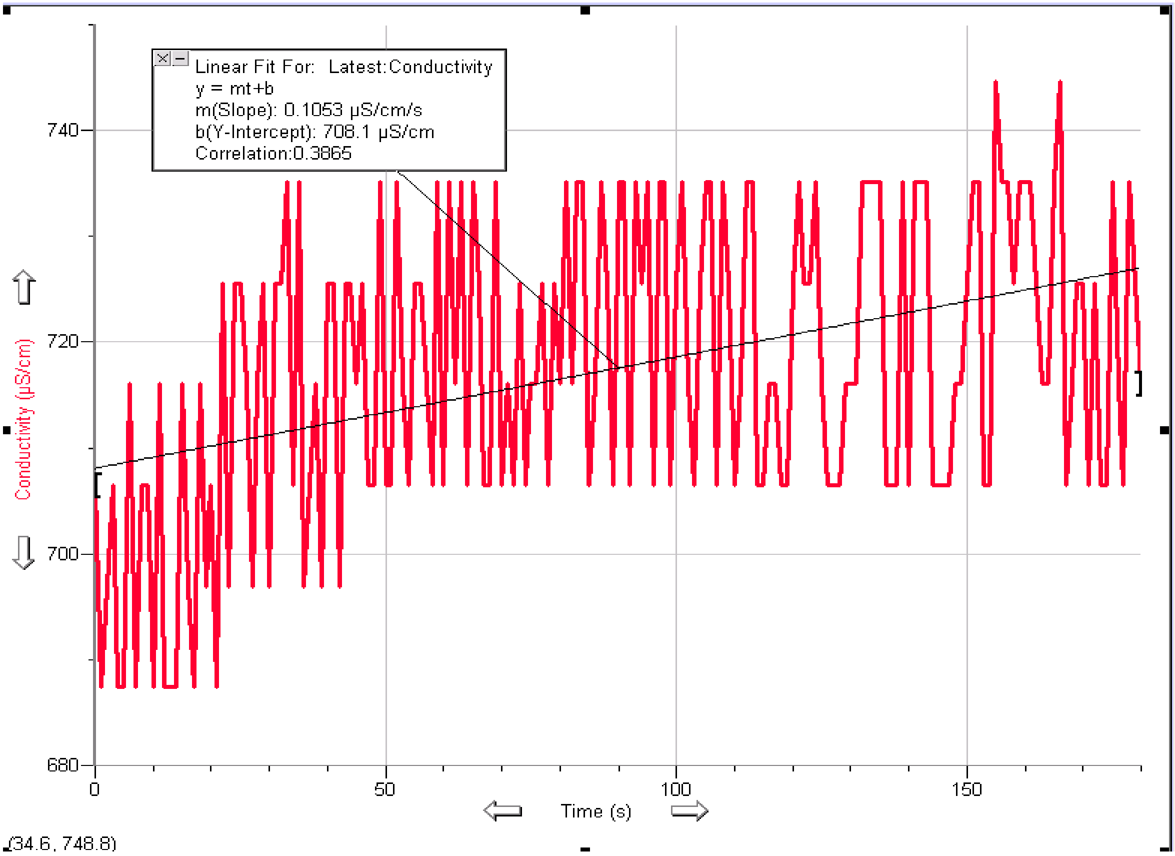
TEST G 9-12 mins Pump On



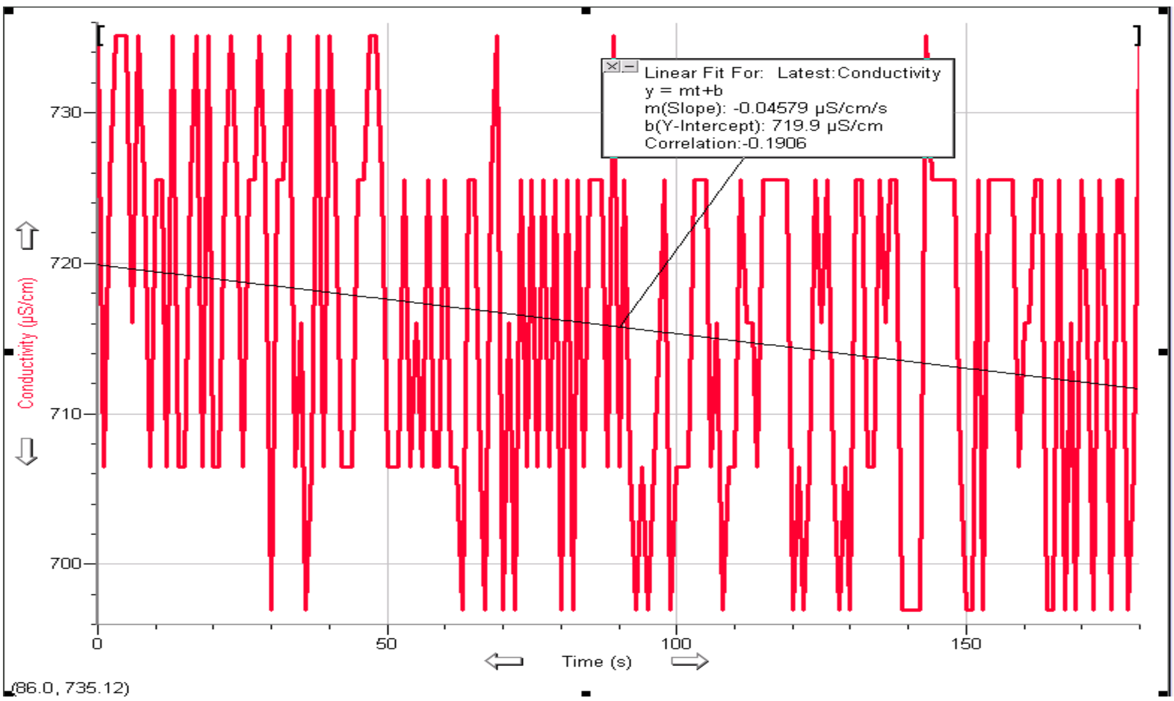
TEST G 9-12 mins Pump On



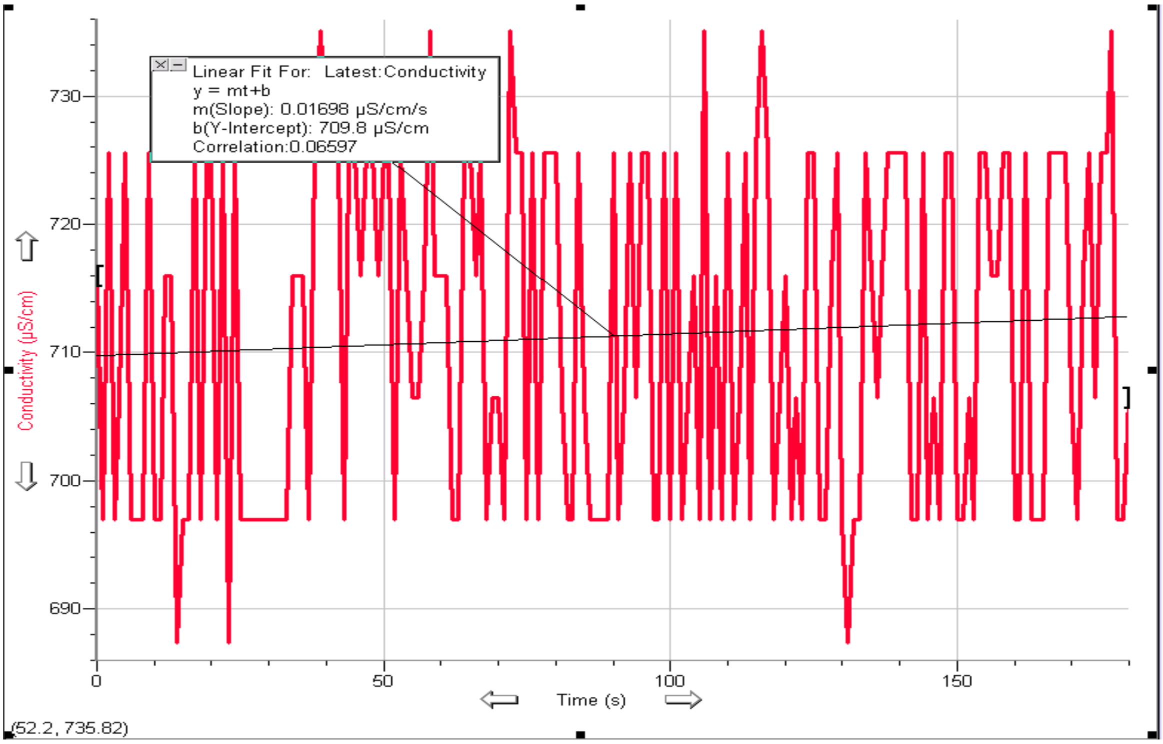
TEST H 1-3 mins Pump Off



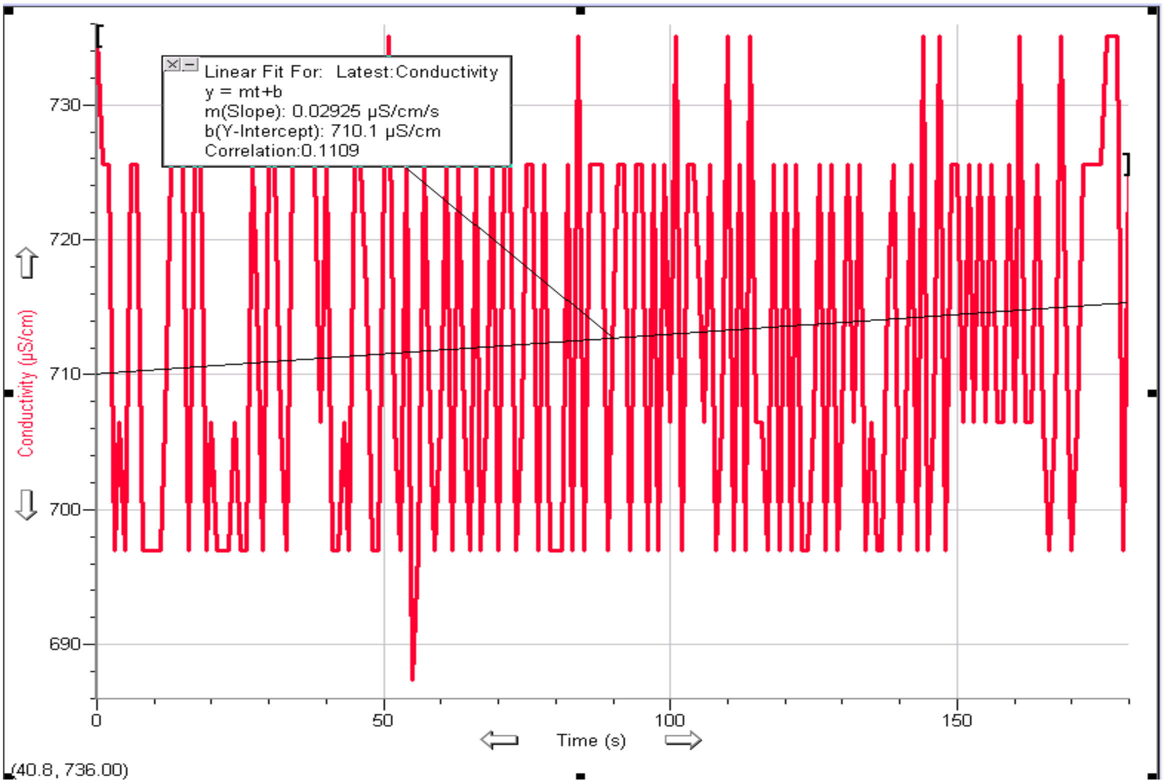
TEST H 3-6 mins Pump On



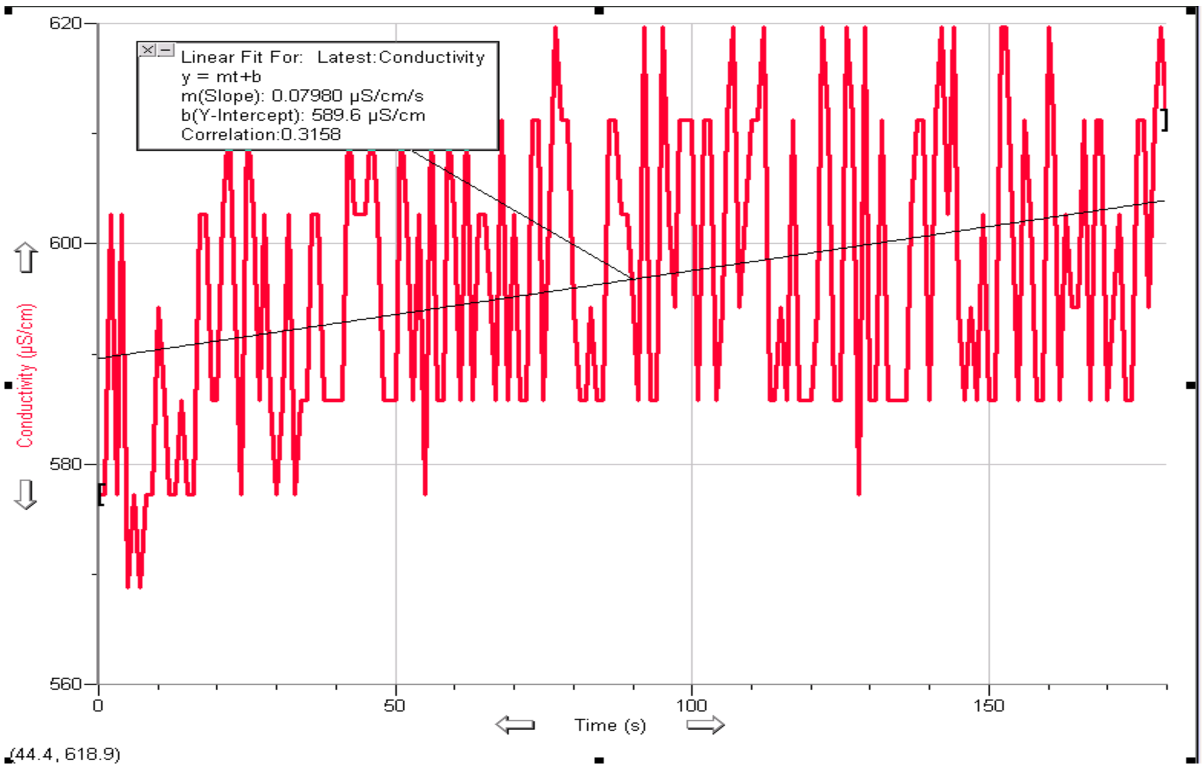
TEST H 6-9 mins Pump On



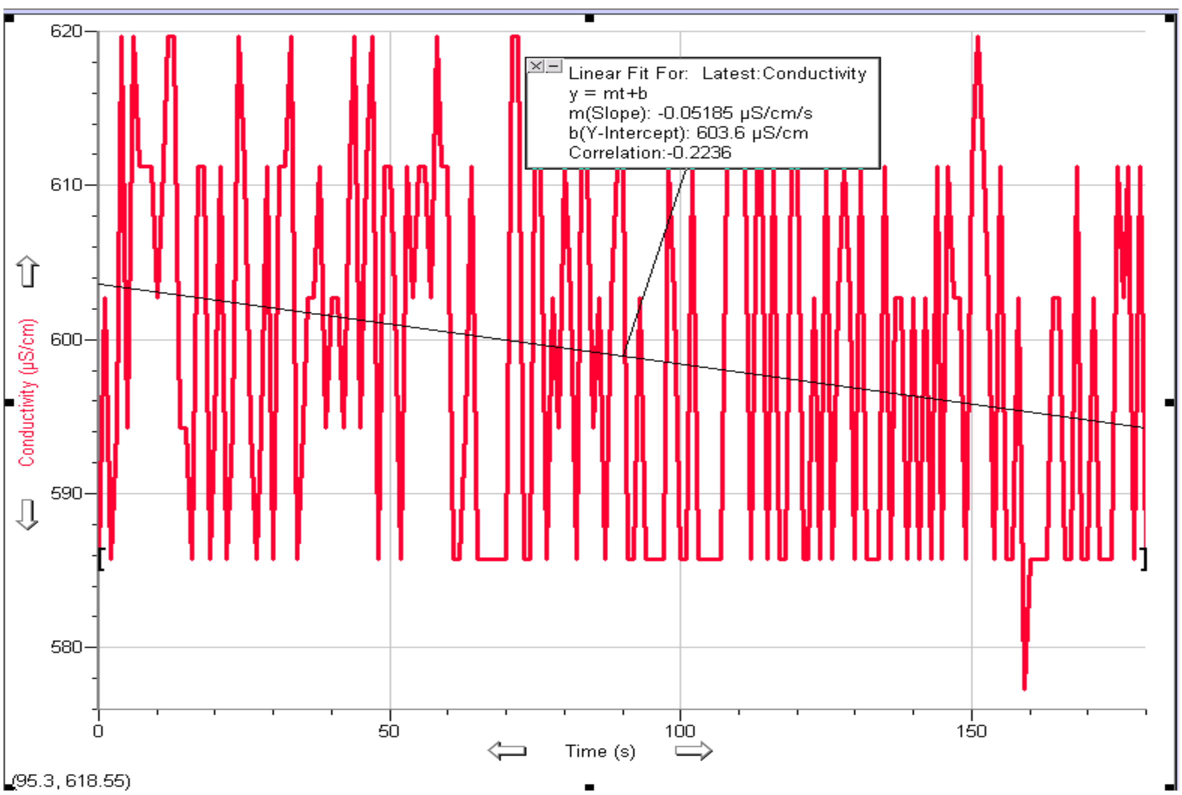
TEST H 9-12 mins Pump On



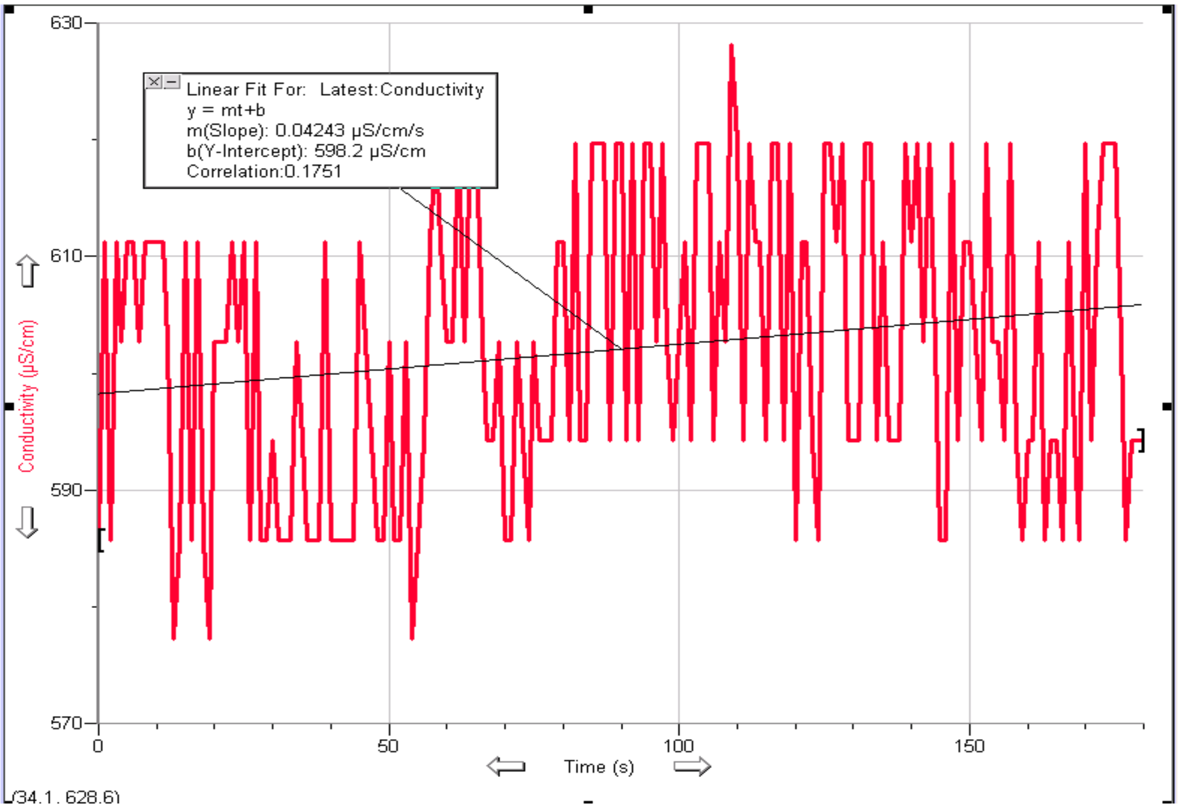
TEST I 1-3 mins Pump Off No Magnets



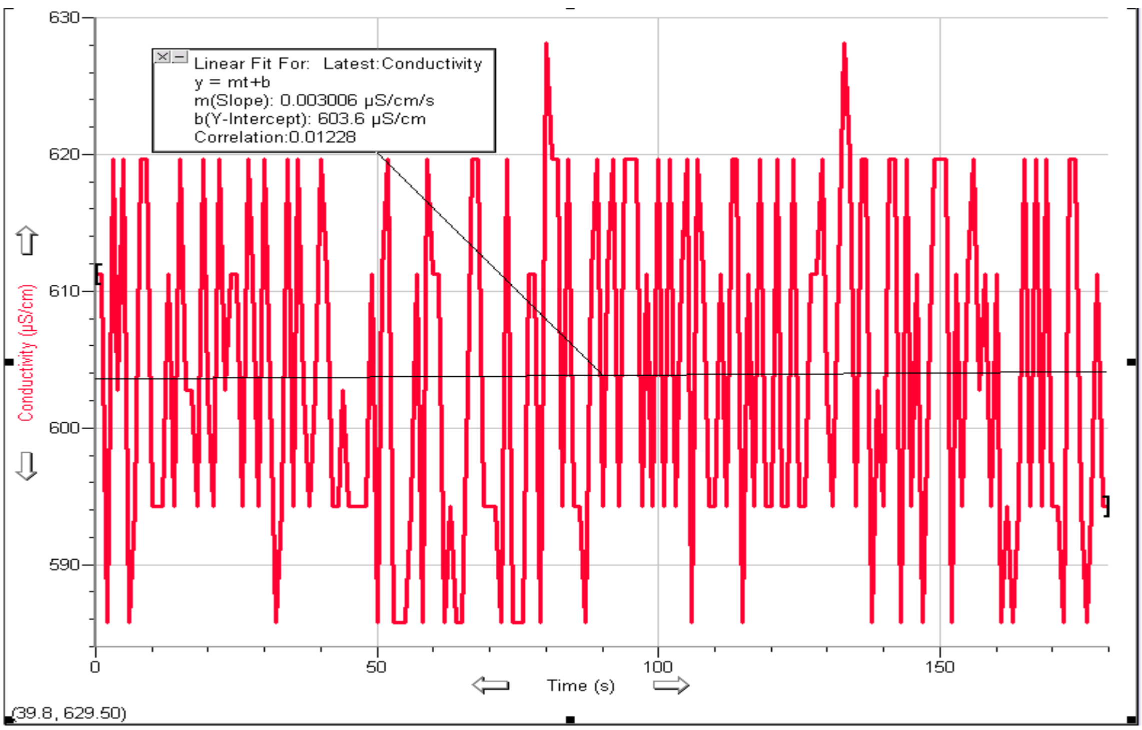
TEST I 3-6 mins Pump On



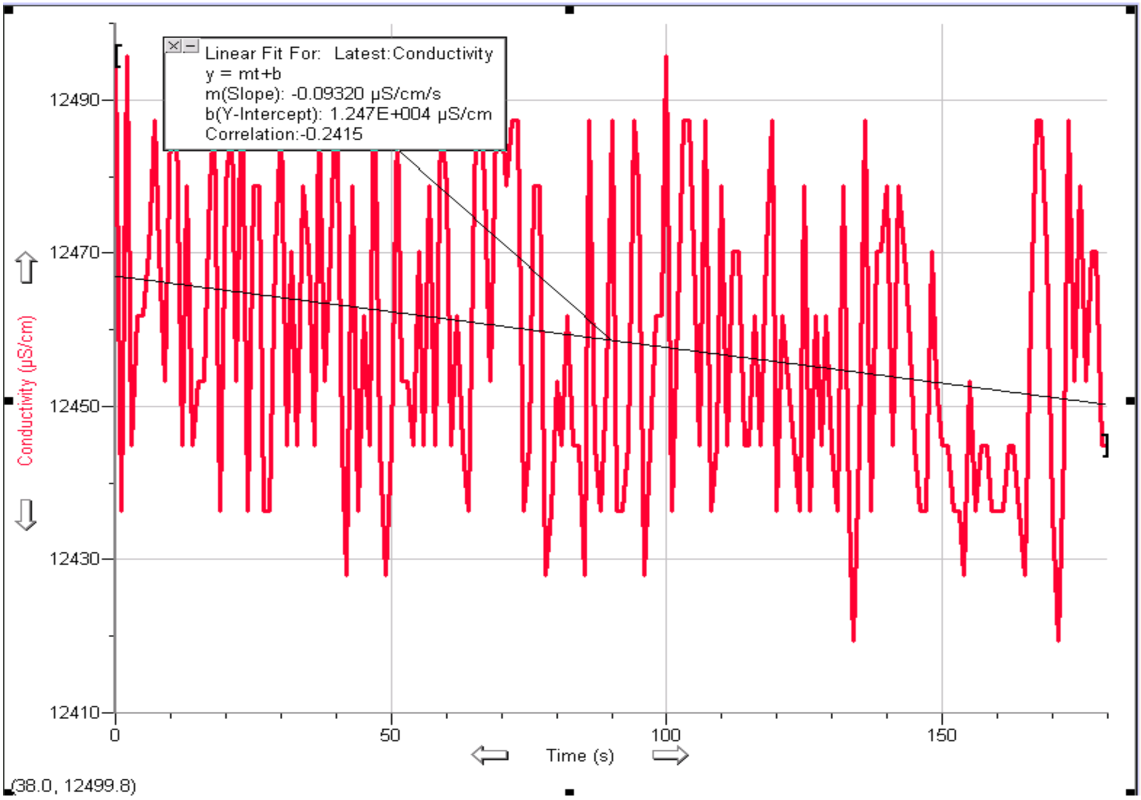
TEST I 6-9 mins Pump On



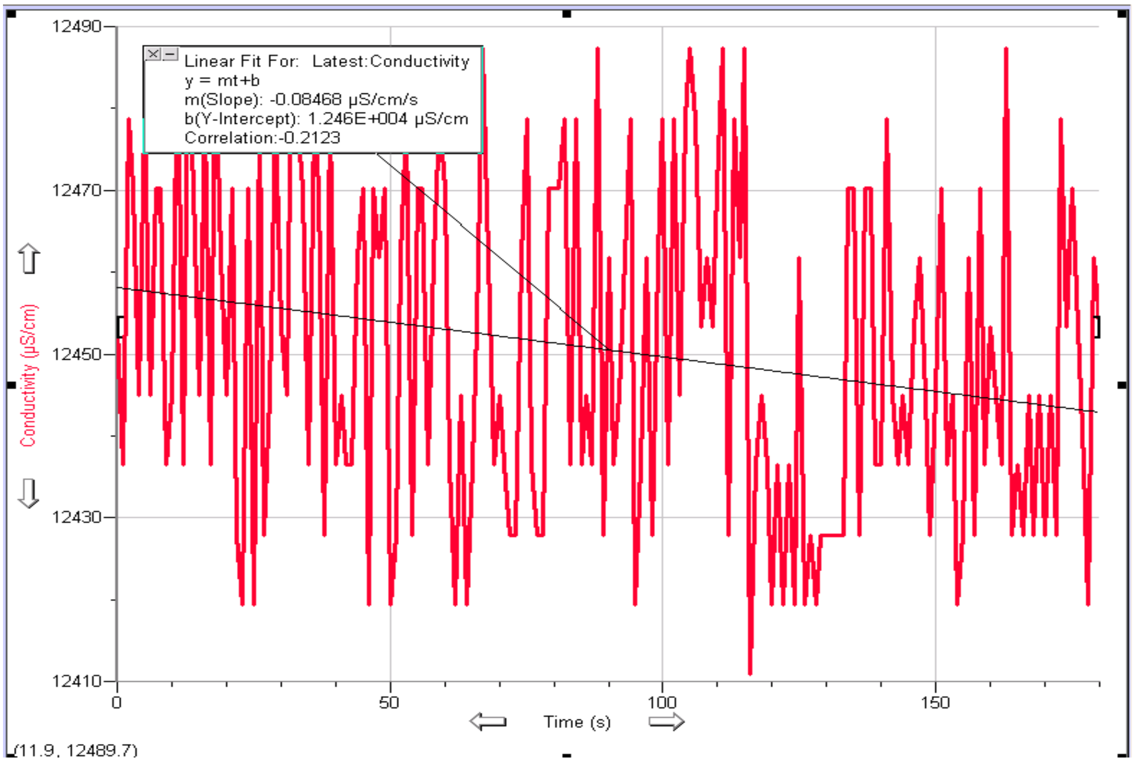
TEST I 9-12 mins Pump On Magnets on



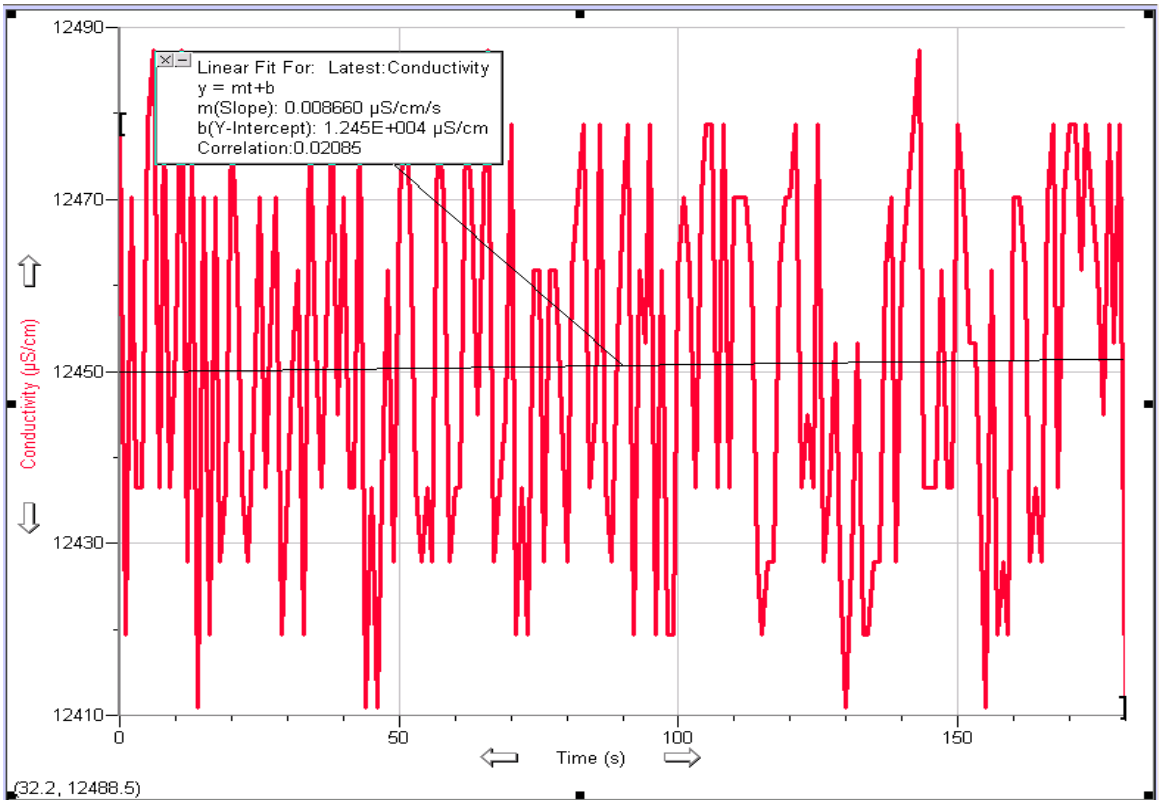
TEST J 1-3 mins Pump On Magnets on



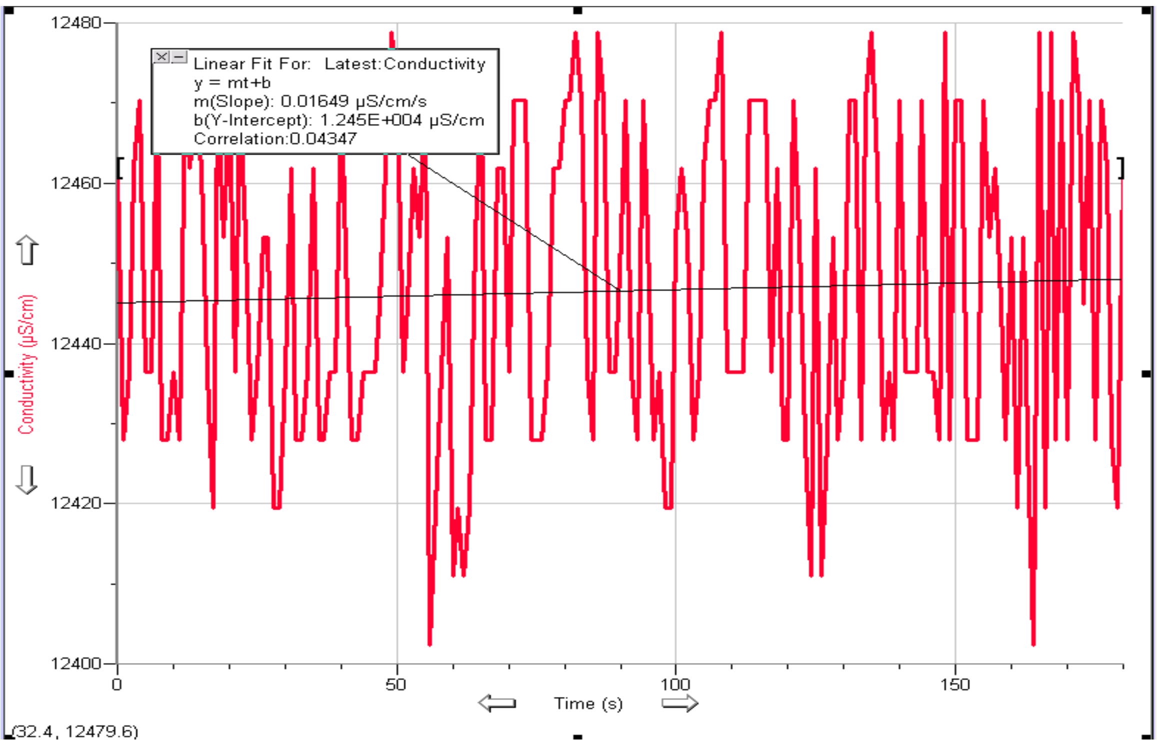
TEST J 3-6 mins Pump On Magnets on



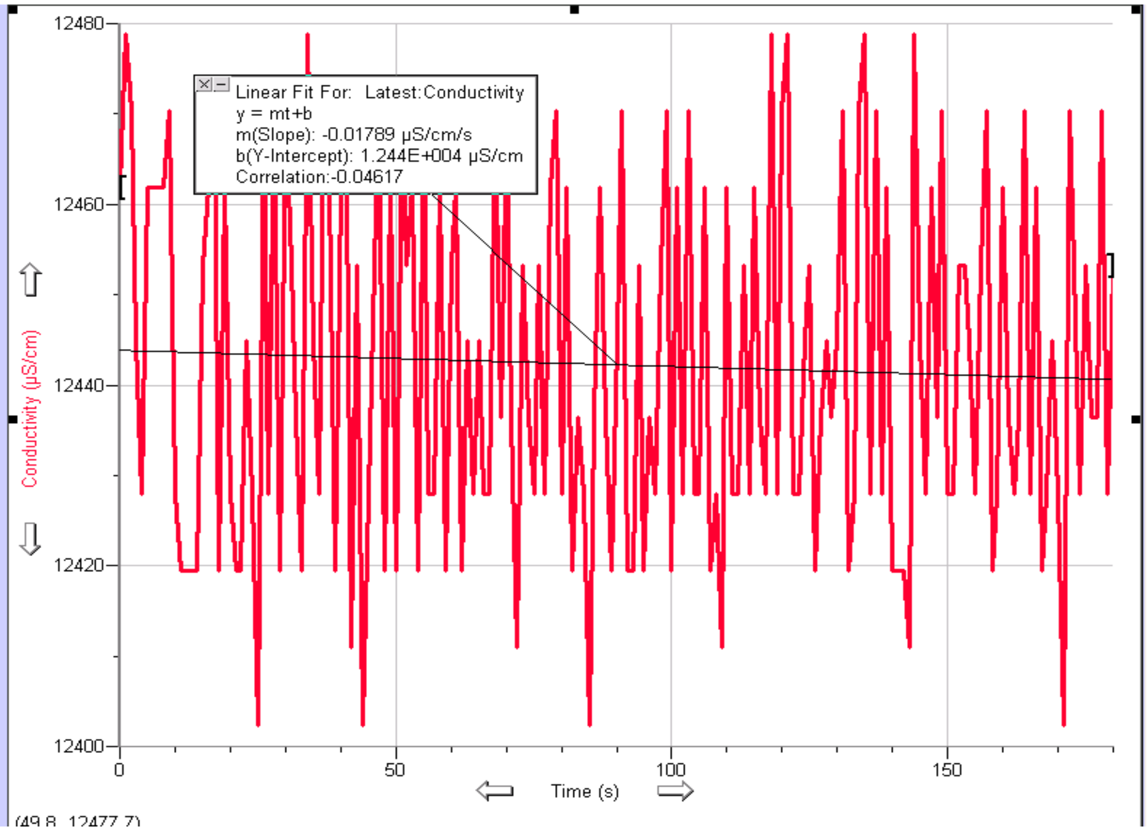
TEST J 6-9 mins Pump On Magnets on



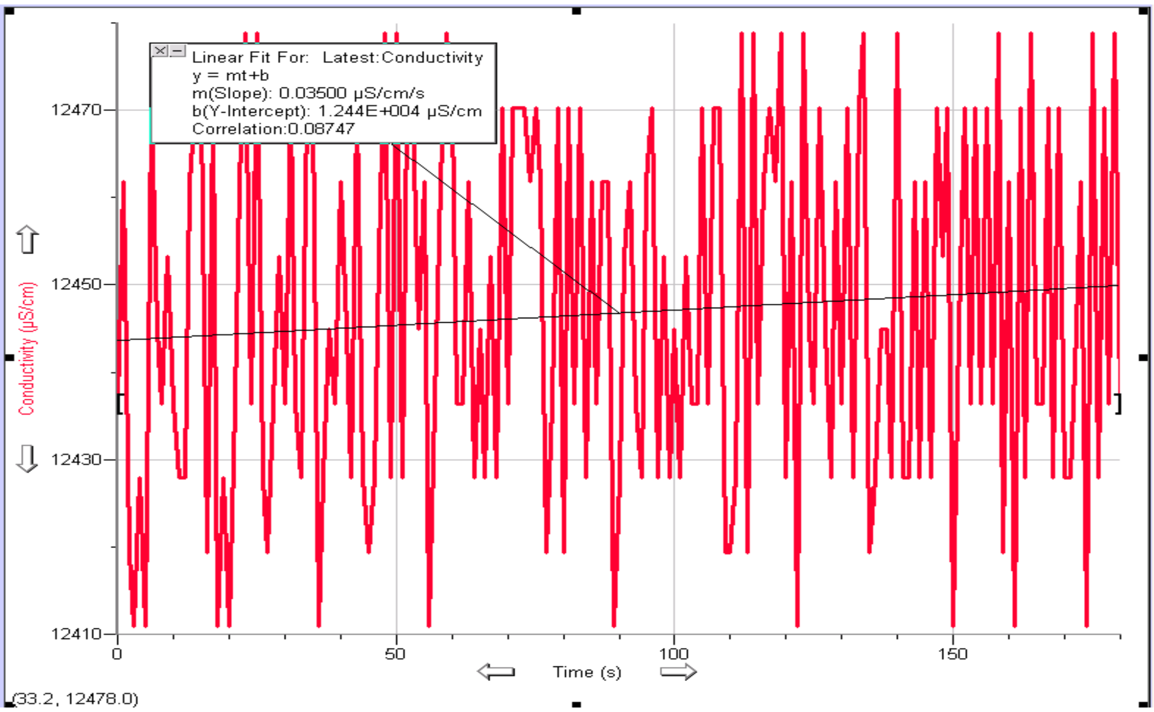
TEST J 9-12 mins Pump On Magnets on



TEST J 12-15 mins Pump On Magnets on



TEST J 15-18 mins Pump On Magnets on



TEST J 18-21 mins Pump On Magnets on