SINGAPORE POLYTECHNIC

SCHOOL OF BUILDING ENVIRONMENT

Diploma in Property Development and Facility Management

A Study of Effectiveness of Galvanic Water Treatment

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Introduction:

This report determines the effectiveness of a galvanic water treatment AQUABION and compares the AQUABION with traditional methods and a similar water treatment system. It also proposes ways to introduce this galvanic water treatment system for the use in Singapore within ordinary factory pipe works, which are used to chill down machines and cooling tower systems.

Information for the report was obtained by using a special experiment. The experiment was conducted using two similar models, which bear a resemblance to the cooling tower system. These two where then compared during testing.

Because of the low amount of zinc content in the water that creates scale and corrosion to internal surfaces of the copper pipe, AQUABION could be introduced to Singapore to save on maintenance costs, reduce expenses involved in water treatment and energy consumption helping Singapore to support the green movement against global warming. Thousands of AQUABION units have already been introduced into Europe and the Americas. According to the information found, it has been proven that the AQUABION can effectively control the hardness of the water to prevent scaling and corrosion inside copper piping. AQUABION is environmentally safe to use and there is a definite cost saving aspect in the long-term period. The results obtained are to show, whether AQUABION could be advantageous in the prevention of scale and corrosion to the water in Singapore.

There is hope, that the Government of Singapore can encourage industry and cooling tower owners to use AQUABION galvanic water treatment systems to solve their scale and corrosion problems, reduce maintenance costs and the need for replacing hardware.

Acknowledgements

I would like to thank the following people who have assisted in the preparation of this project:

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≅ Mr. Walkie, Technician of W511

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≅ Dr. Ng Khee Yang,

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REPORT ON THE EFFECTIVENESS OF AQUABION GALVANIC WATER TREATMENT

1 INTRODUCTION

1.1 Purpose

This report examines the effectiveness of the AQUABION Galvanic Water Treatment System on a cooling tower system and piping system used in industry and compares between AQUABION and another physical water treatment system with water from the Singapore Municipal Water Supply. It also proposes ways to introduce AQUABION for the use in cooling systems that are used to chill down different machines and cooling tower systems.

1.2 Background

The current and best-known method to reduce scaling and prevent corrosion is the use of chemical substances. By using chemicals the water can e.g. be softened. There are some side effects that can harm the health of a human body or effect the environment.

In addition to this regular maintenance intervals, repairs and replacements of materials are necessary, to solve this problem. This conventional method can effectively reduce scaling and prevent corrosion, but it is neither time- nor cost-effective. The factory probably has to stop manufacturing for a few days during maintenance.

Eventually productivity will come down. Furthermore the cleaning down process of pipes in the whole factory is very labour intensive with labour costs increasing all the time.

1.3 Method of Investigation

Data for this report was obtained through interviews with technicians and also the official supplier of AquaBion for Singapore - Mr. Eng. Information was also obtained from research using the internet and various magazines.

1.4 Scope of Investigation

The interviews were held at the Singapore Polytechnic and Mr. Eng, the supplier of AquaBion, supplied information about his product and how it works in preventing corrosion and scale to the students involved.

The technicians explained exactly how their current method works in order to prevent corrosion and scale in the factory and precisely how their cooling tower operates.

2 Scale and Corrosion

2.1 Definition of SCALE

Scale can be defined as an accumulation of mineral deposits absorbed from water. The water comes down as rain and runs through mountains, hills, the sea, and rivers. The water permeates through limestone, marble, and other minerals, and will then have dissolved to a form of calcium carbonate, also known as calcite. The calcite is the most common form of scale. It will exhibit reverse solubility and becomes less soluble as the temperature of the water increases.

Scale can be deposited through certain chemical precipitation processes, where the dissolved salts e.g. in cooling water on surfaces come into contact with the water due to the solubility limits being exceeded. The hard crystalline deposits are formed by calcium, magnesium and carbonate ions.

The same principle applies when hard water is heated or when evaporation takes place, calcite precipitated layers are deposited on the inner surface of pipes and around fixtures. In other words, the formation of scale will take place in the most sensitive areas, especially on heat transfer surfaces of production equipment.

(Source:http://www.prochemtech.com/Literature/chemical_treatment.html)

2.2 Definition of Corrosion

Corrosion can be defined as an action destroying material in slow motion over a long period. Corrosion is visible, when metals are exposed to pure water, aqueous solutions of water-soluble materials or to a mixture of water with substances, which are neither soluble nor solvent with water.

Corrosion is a deterioration of internal properties in materials due to the reaction with the environment. The reaction is normally due to the oxidation of metals reacting with water or oxygen.

(Source: http://en.wikipedia.org/wiki/Corrosion)

2.3 Problems of Scale and Corrosion in the Industrial Sector

Both scale and corrosion depositions are an unwanted occurrence, because they cause a number of problems in industry. When scale encrustations form on internal surfaces of pipes and the layer gets thicker, the water flow of that pipe will be slower. Eventually it will need an expensive high pressure pump to pump the water through. This will ensue in higher costs for purchasing extra machines in order that the technicians are able to carry out the job in a professional manner.

Scale also causes premature deterioration of plants and equipments. Water is needed for plants and equipments in the factory to chill down temperatures. When scale builds up due to the reaction, the water flow will be reduced. This will force the machines to work under higher temperatures and therefore to deteriorate in a much shorter time. Once there is damage done to the machine, utility costs are increased. At the same time, the productivity on this machine is reduced.

Equipment and machines are also affected by corrosion due to the presence of oxygen and water. The reaction between the oxygen and water with metal will slowly introduce corrosion to the pipes and lead to deterioration.

2.4 Consequences of Scale and Corrosion

To prevent scaling and corrosion, regular, routine maintenance work must be carried out to ensure that the machines are performing normally. Part of this maintenance process is the chemical treatment and cleaning process. This conventional method of treatment will cost time and money and is very complex. During the maintenance the plant has to interrupt production. This will directly affect the productivity of the plant and its profits.

When scale adheres to the inner surface of pipes, water flow will be lower. Eventually vacuum and centrifugal pumps will suffer and their operational life and that of the machine are reduced.

Scale and corrosion deposits will also build up in areas of piping which is not visible and will cause damage and leakage in the pipes and possible flooding in the plant may occur. The water flooding out may destroy the machines or the finished products of the plant and this again will add up to another loss of business.

Scale and corrosion can only be controlled by carrying out regular maintenance checks and by using chemical cocktails. These actions are time consuming and expensive for the individual equipment and production cost and will make the finished product more expensive within the market, resulting in a potentially negative situation regarding the competition aspect. This chemical method can also be dangerous for the staff as it is toxic and pollutes the waste-water, therefore damaging the environment. (Source: http://www.winbiz.com.sg/whyAquabion.htm)

3 COOLING TOWER

3.1 Working Principle

Figure 1 The photo shows the Cooling Towers of the Singapore Polytechnic

Water is the most common medium for cooling down heat from industrial equipment. Water for this process is very effective and efficient due to its heat transfer capabilities so water is ideal to reduce heat in cooling towers.

In a cooling tower, water is exposed to a high velocity of air with water being constantly spread over a large surface area. This natural evaporation process provides the cooling necessary to reuse the water.

As water evaporates naturally, occurring minerals within the water become more concentrated. These minerals and contaminants will eventually reach a concentration level, which will cause problems to the process and interfere with the performance of both the tower and the cooling system.

The most common and noticeable of these problems is the formation of scaling- although biological fouling and corrosion can be equally troublesome.
(Source: http://www.towerklean.com/tk/system_1.html)

3.2 Problem

3.2.1 Hardness

Water hardness is generally comprised of calcium and magnesium.

The most common water problem caused through hard water is the scaling and white build-up on water using appliances and fixtures. Hard water in the domestic and commercial areas is also the main cause for poor results in dishwashers, washing machines and general housekeeping. Hardness that builds up greatly reduces the effective life of virtually anything it comes in contact with.

Hardness is measured in terms of grains per gallon. The National Geological Society classifies hardness levels of 10 grains per gallon or more as “extremely hard”.

3.2.2 Iron/Rust

Iron in water, even in small amounts, will leave behind rust stains wherever there is contact. Water containing as little as 0.3 ppm of iron will already cause staining. The more iron there is in the water, the stronger the staining.

Iron can clog up pipes, appliances, and most water filters. In a short time rust can ruin the appearance of e.g. household fixtures because of unsightly staining or brown water.

Iron can be extremely difficult to remove if not treated properly, however, the correct system will remove all traces of iron effectively.

Iron occurs in two forms - "ferrous and ferric iron". Additionally it can be combined with iron reducing bacteria, which is referred to as "heme iron" or "iron bacteria". Iron bacteria can be indicated by a rust colour slime growth in the toilet flush tank, whereas normal ferrous iron will cause a hard rust stain. Although not a health hazard, iron bacteria tend to grow throughout plumbing systems, hot water tanks, and water softeners and filters.

3.2.3 pH / Acidity

pH is the measure of acidity of water. With a level of seven (7) water is neutral, levels above 7.0 indicate basic water; levels below 7.0 indicate acid water.

Acid water is indicated by excessive corrosion, blue green staining, and a shortened life for appliances, which are in contact with water, fixtures, and hot water tanks.

Ph levels above 7.0 are not usually a problem, but levels above 8.5 can cause accelerated precipitation of dissolved solids and extremely high pH levels could have a laxative effect on humans and result in the water having a bitter aftertaste.

3.2.4 Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of all elements in solution or dissolved in a fluid. The E.P.A. Secondary Water Treatment Standards advises that TDS levels should not exceed 500 ppm. Distilled Quality Water contains less than 10 ppm TDS, while Sea Water may be as high a 40,000 ppm TDS. Many wells and municipalities do deliver water with TDS levels substantially above the 500 ppm limit. Surface water is generally lower in dissolved solids than ground water sources.

3.2.5 Nitrates

Nitrates are regulated by health authorities as a potential health hazard.

Nitrate contamination is common in agricultural areas because of the high use of fertilizers. Potentially toxic to infants and small children, excessive amounts of nitrates are known to cause "blue baby syndrome" in which oxygen is displaced by nitrogen causing the baby to turn a blue colour because of the lack of oxygen. E.P.A. health standards for Nitrates are set at 45 ppm expressed as CaCo3 or 10ppm expressed as nitrate/nitrite.

3.2.6 Chlorine/Chloramines

The municipal water authorities add chlorine to the water in order to disinfect it prior to distribution. Chlorine leaves a residue and is therefore ideal in cases where water needs to be conveyed over great distances before reaching its final destination.

Organic substances present in the water break down the chlorine and, as these organic loads vary from day to day, so does the demand for chlorine, which can cause chlorine levels to be higher or lower than required for effective treatment. When chlorine reacts with the organisms in the water, chlorinated by-products are created in the form of Trihalomethanes (THMS). These substances are known to be carcinogens, and are monitored by the E.P.A. In cases where the THMS repeatedly exceed federal standards, the water supplier must notify their consumers. If it is not possible for the treatment operator to maintain the required chlorine levels without exceeding THM levels, it may be necessary to combine ammonia with the chlorine in order to reduce THMS to an acceptable level. This combination is called Chloramines, and causes a green cast in the water with an ammonia-like odour.

3.2.7 Bacteria

Bacteria will enter a water system in a number of ways and can cause dangerous contamination. Municipal systems utilize chlorine for disinfection and bacteria levels are constantly monitored however, private water suppliers and many small community systems remain vulnerable.

Bacteria can enter through faulty well seals and well casings, through openings in storage tanks, or any other place air can get into a water system. Bacteria can also be present in the water itself.

Extreme caution should be taken to assure a private water supply is bacteriologically safe. High bacteria counts could indicate the presence of potential disease causing organisms such as the deadly Legionella, also present in many cooling towers.

3.2.8 Hydrogen Sulphide

Hydrogen Sulphide (H2S) is recognisable by a rotten egg odour coming from the water. Even a trace of H2S produces a very offensive odour.

Being a gas, H2S will dissipate if the water is left undisturbed for a while.

Hydrogen Sulphide usually indicates bacterial activity.

The odour mainly occurs within the hot water system; this is caused by the anode rod inside the hot water tank and commonly confused with Hydrogen Sulphide. Being a gas H2S tends to dissipate as the water is being heated, therefore, will not be as noticeable in the hot water as it is in the cold water. This odour, occurring within the hot water tank can easily be eliminated by removing or replacing the rod in the hot water tank.

3.2.9 Salinity / Salty Water

Salty water is becoming more and more prevalent in coastal areas because of salt water intrusion. Salt water intrusion occurs as ground water levels drop and sea water enters the aquifer.

The Total Dissolved Solid Levels present in sea water, can range from 20,000 ppm to 40,000 ppm, whereas drinking water can begin tasting salty at TDS levels as little as 1200 ppm.

(Source: **http://h2osolutions.info/glossary.html**)

3.3 Consequences

Scale deposits reduce water flow, cut heat transfer, increase energy costs and cause high head pressure. The compressor has to work harder and draws extra current, increasing power costs and causing equipment to fail to produce to their designed capacity.

The life of the equipment itself is reduced. In fact, excessively high head pressure is a common cause for motor burnout, which costs considerable inconvenience and money world-wide.

(Source: **http://www.wsconet.com/Calgon/products/22f6.htm**)

3.4 Available Solution

3.4.1 Maintenance Manually

The most common method used to clean the cooling tower is by using a hydraulic jet to wash off the scales that stick to the internal surface of the copper pipe in combination with acids.

Maintenance performed by shutting down the whole system of the cooling tower and employing cleaning staff to wash away the scale inside the pipes.

Most of the factories use another method to prevent scale forming on the surface of the pipe, by applying a layer of cement to the internal surface of pipes. Therefore, no chemical reaction occurs and eventually scale is prevented from reforming. This is very complicated and expensive.

Instead of cement, a coat of paint can also prevent scale build – up inside copper pipes.

Part of the maintenance is to carry out regular, monthly tests on the water, to check if the parameter is showing a stable reading. The existing water will be discharged as expensive and often contaminated waste-water and new water is pumped in, until a stable reading is reached. The usage and cost of water therefore is immense and the method is environmentally unfriendly.

3.4.2 Chemical Dosage

Chemicals act as the inhibitors functioning by either selective adsorption on growing scale crystals, converting the crystal structure into a non-scaling type which does not form a hard scale, or chemical reaction with the scale forming ions, converting them into non-scale forming materials.

The following list notes some of the chemical scale inhibitors commonly encountered in this process.

Chemical	**Comments**
Polyacrylate	Commonly used, cost effective for calcium scale at 5 to 15 mg/l.(mw = 2000)
Polymetbacrylate	Less common for calcium scale at 5 to 15 mg/l.
Polymaleic	Very effective for calcium scales at 10 to 25 mg/l, costly.
Sulfonated	Effective calcium inhibitor, less polystyrene sensitive to iron levels, commonly used at levels of 10 to 20 mg/l.
Phosphonates	All three common phosphonates are excellent calcium scale inhibitors at levels from 5 to 20 mg/l.
Chemical	**Comments**
Chelants	Both EDTA and NTA, as well as citric acid and gluconate, have seen some limited use for calcium scale control at levels from 5 to 100 mg/l.
Dipolymers	These products commonly incorporate two active groups, such as sulfonate and

	carboxylate, to provide superior performance to a single group compound. Use levels at 5 to 20 mg/l.
Terpolymers	Like the dipolymers, only incorporate three active groups to give yet better performance under severe conditions. Use levels at 5 to 20 mg/l, costly.
Polyphosphates	Fairly good calcium scale control under mild conditions can revert and contribute to calcium phosphate scale.

Table1 Types of chemical for water treatment

(Source: http://www.prochemtech.com/Literature/chemical_treatment.html)

3.4.3 pH Adjustment

PH adjustment is a vital part of ensuring that our drinking water meets our health and safety needs.

It is an indicator of the various particles present in the water, and the quality of water itself. PH monitoring is a simple process involving the performing of regular testing. A good quality PH analyzer is essential for the proper monitoring and measuring of the PH levels.

Several companies regenerate their water through one of several processes as a way to save money and to be more environmentally friendly. After regenerating wastewater, it is vital to measure the PH levels and to make the proper adjustments.

PH adjustments are required, to ensure that the wastewater is properly regenerated, making it safe and ready for use once again. Although a neutral PH level may be desirable, it is not always the case. The specific PH level companies require within this process of recycling, is dependent upon what the water is required for.

4 AquaBion

4.1 Background of AQUABION

The AquaBion is a self-cleaning water treatment active anode system, marketed in Singapore by Winbiz International Company. Winbiz is the appointed agent for AQUABION GmbH. AquaBion is suitable for private, commercial and industrial applications to reduce scaling and corrosion problems as a non-chemical water treatment system. In our specific project we concentrate on the industrial markets.

(Source: http://www.winbiz.com.sg/aboutwinbiz.htm)

AQUABION® prevents deposits in pipeline systems and breaks down existing corrosion deposits and lime incrustations.

The device operates electrolytically, according to the galvanic principle, using a zinc reactive anode – without power connection and without magnets.

This environmentally-friendly method for treating water forms an homogenous lime protection layer on metal walls of e.g. pipes; in soft water areas, a thin cathodic protective layer on the metal walls of the pipes preventing the recurrence of corrosion.

(Source: **http://www.winbiz.com.sg/CommercialAquabion.htm)**

4.2 Working Principle

AquaBion works on the basis of the galvanic principle of a sacrificial zinc anode. The galvanic element builds up a potential, corresponding with and depending on, the actual water parameters. This results in the agglomeration of water constituents around the deposited /released Zn ion, known as particle crystallisation. This agglomeration of hardening components also promotes a controlled growth of crystals. These particles will agglomerate with other deposited products. According to the laws of hydrodynamics, these particles produce a larger surface area to attack and will finally be flushed away with the water flow. These agglomerates will not adhere to the inner pipe surface or existing scale build-up, meaning that the quantity of scaling is reduced.

The special eddy body of AquaBion made of “Nirosta” is placed up and downstream, before and after, the zinc anode causing the water to separate in the unit. The particles are then carried along before being whirled around. This method results in the zinc anode being protected and kept free of scale deposits meaning that the desired treatment is intensified.

The zinc anode within the AquaBion product, functions as a galvanic element and the water parameters are the main factors causing the difference in cell voltages. These lead to structural changes in the new scale of the particles carried along by the water.

(Source:http://www.winbiz.com.sg/whyAquabion.htm)

4.3 Advantages of Using Aquabion

The AquaBion contains no moving parts and functions without the need for external energy. Therefore, AquaBion is completely maintenance- free during its life expectancy.

AquaBion works with reliable performance stability in flowing water, depending on important water parameters.

AquaBion removes nutrients from the circulating water by reducing the use of hardness stabilisers (phosphates) - causing a reliable reduction in the formation of algae.

Aquabion saves on chemical additives and maintenance costs and reduces overall production costs.

AquaBion is scientifically tested.

(Source:http://www.winbiz.com.sg/whyAquabion.htm)

4.4 The Structure of Aquabion

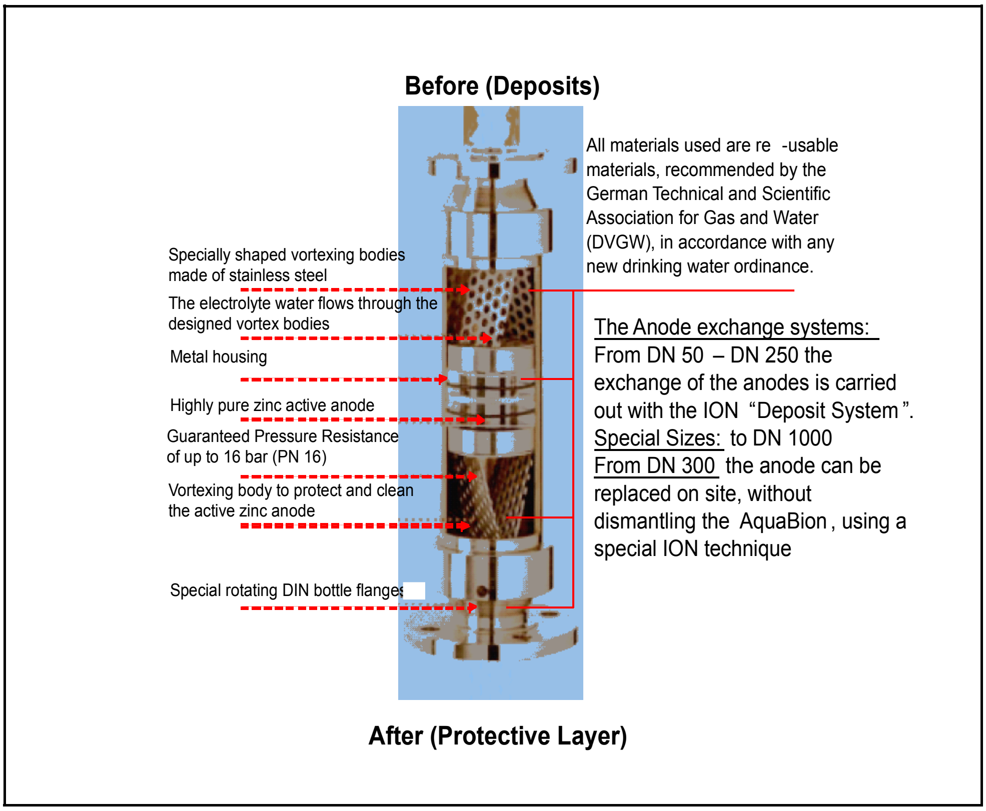


Figure 2 The structure of AquaBion

(Source:http://www.winbiz.com.sg/whyAquabion.htm)

4.5 Product

Figure 3 AquaBion

AB-S20	
Type	AB-S20 (3/4“)
Size	DN 20 (3/4“)
Threaded joint	3/4“ internal thread
Overall length	180 mm
External diameter	45 mm
Weight	1,60 kg
Materials	
Device body	Sleeve:CuZn 39 Pb3 (2.0401), pipe 30x4 drawn Threaded nipple: CuZn39Pb3, SKT SW30 drawn, nickel plated
Internal parts	Zinc anode: Zn2 DIN EN 1179 Coil inset: 1.4301 Distance ring: 1.4000 pipe 35x2 Din 17457 Sealing ring: PTFE
Construction	
The body of the device consists of a single sleeve with two threaded nipples.	
Nominal pressure	16 bar
Max. transmission	1,5 m3/h (25 l/min.)
Loss of pressure	0.04 bar @ max. transmission
Nominal operating temp	Drinking water application up to 60°C
Guarantee	
5 years – manufacturer’s guarantee	
2 years – return guarantee for function if failure is established	

Table 2Detail of the AquaBion

(Source: www.aquabion.com)

4.5 Proven quality of AquaBion

Figure 4 Certificates of International Quality Approvals by TÜV Rheinland Group

* TÜV Rheinland Group has provided International Approvals Services as they relate to product safety

Figure 5 Certificates of International Approvals by TÜV Rheinland Group.

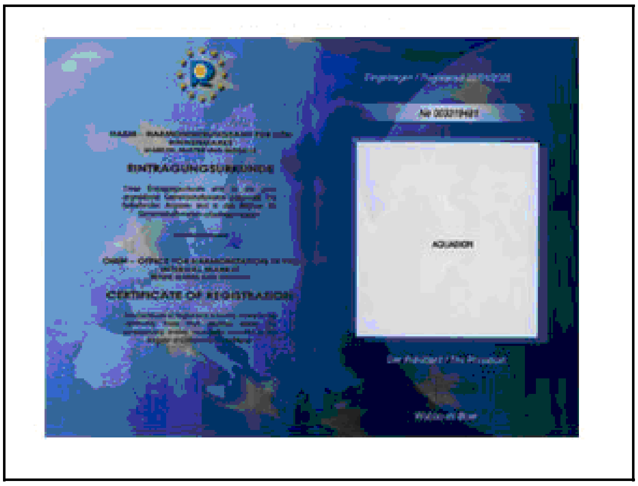


Figure 6 International Trade Mark Classification Certificate

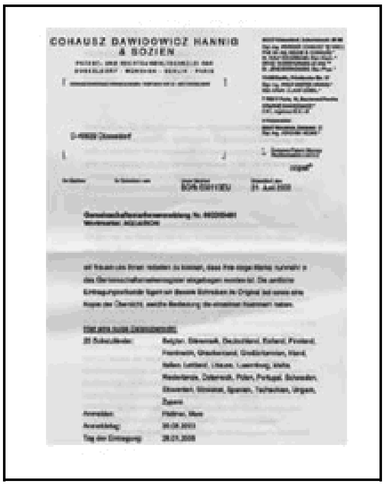

COHAUSZ DAWIDOWICZ HANNIG
& SOZIEN

Figure 7 Document of Patent Classification

(Source: http://www.aquabion.cn/cpzs4.asp)

6 TEST MODEL

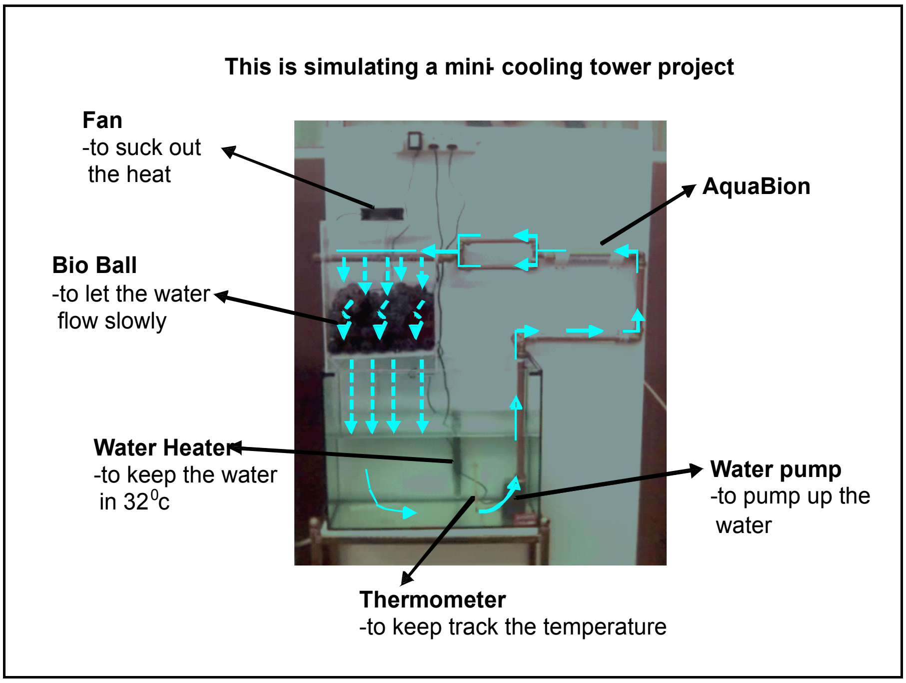


Figure 9 Mini Cooling Tower Model

6.1 Test Procedure

Figure 10 The upper clear acrylic container

First, order the clear acrylic container from SCAN Plastic Engineering and Rubber Pte Ltd.

Prepare all the materials needed for the test model. For example, copper pipes, copper pipe joints, water heater, water pump, thermometer, fan, adopter, copper pipe cutter etc.

All the copper pipes are cut into required length using a copper pipe special cutter.

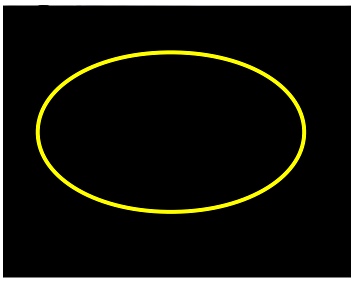


Figure 11 White tape around the copper pipe

The white tape is made of a kind of soft rubber, which tightens up the joints and prevents water from leaking out.

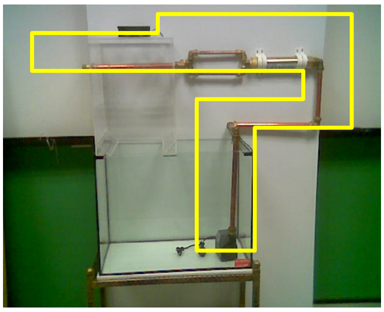


Figure 12 Copper pipes with AquaBion

All the required lengths of copper pipes were jointed together including the AquaBion Galvanic Water Treatment System.

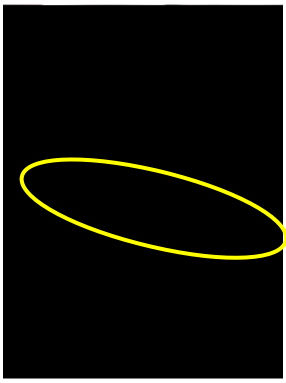


Figure 13 Copper pipes with holes

Drill holes into the copper pipes so that the water can flow free into the glass water tank and a circulation system is created.

Figure 14 White colour rubber rings

Place two white colour rubber rings at the opening to prevent the water flowing out through the opening.

Cut a small piece of glass and fix it in the middle of the top of the glass tank using silicone sealant to support the upper clear acrylic container to sit tight on the glass water tank.

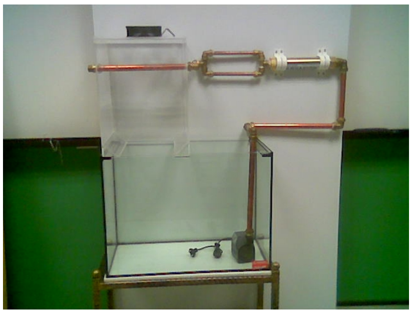


Figure 15 Cooling Tower Model

After that, combine everything together to form a model.

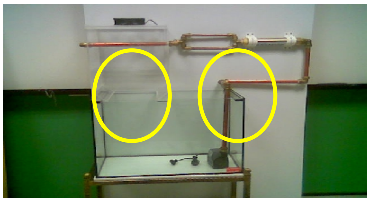


Figure 16 "U" channel and AquaBion

Fix up the "U" channel to the AquaBion to fix the position of the AquaBion so that AquaBion will not drop due to the heavy weight.

Then, move the whole model to the experiment lab and prepare to start testing.

Figure 17 Fan and adapter

Then, join the wire of the fan to the adopter.

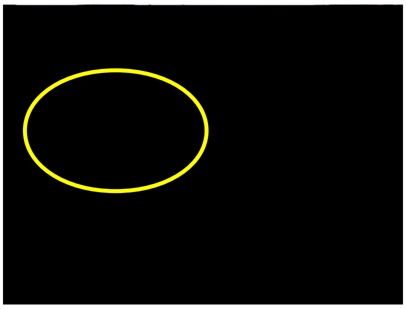


Figure 18 Bio Balls with the plastic mesh

Put the Bio Balls and plastic mesh inside the acrylic container. The purpose is to let the water flow slowly.

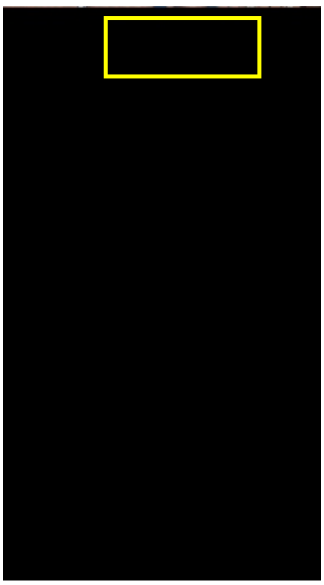


Figure 19 Wires of the water heater, water pump and fan.

After that, plug in the wire of the fan, water heater and water pump so that the elements can function well together and make sure that the results obtained will be as accurate as possible.

Once everything is in the correct position, pour water into the glass water tank and get ready to start the experiment.

Do the necessary testing on the water in the water tank (ie: pH, Dissolve Oxygen, Conductivity and etc)

6.2 Cost

6.2.1 Cost for the glass container

No	Description	Unit Price (S$)	Total (S$)
1	1 piece 8”x4”x12mm think finished plywood	26.00	26.00
2	2 Acrylic boxes size 290 x 300 x 400 height x 5mm think	52.50	105.00
3	2 Aquariums	20.00	40.00
4	2 feet aquarium stands	30.00	60.00
5	2 Heater, 100W	20.00	40.00
6	2 bags of Bio Balls	10.00	20.00
7	2 Thermometers	1.50	3.00
8	2 Heater, 300W	27.00	54.00
9	2 water pumps, 2500 l/hr	65.00	130.00

Table 3Cost for glass container

6.2.2 Cost for Copper pipe

No	Description	Total (S$)
1	¾" copper pipe that used	41.00
2	½" copper pipe that used	11.20

Table 4Cost for Copper pipe

6.2.3 Cost for Fittings

No	Description	Total (S$)
1	Fittings including white tape, jointing, bolt & nut, screw, rubber ring and etc	129.50
2	Double sided tape	4.95

Table 5Cost for Fittings

6.2.4 Cost for Tools

No	Description	Total (S$)
1	Copper pipe cutter	6.00
2	Zink test reagent (100 test)	159.00

Table 6Cost for Tools

6.2.5 Cost for Electrical

No	Description	Unit price (S$)	Total (S$)
1	2 fans size 120 x 120 x 24mm	15.00	30.00

2	2 adaptors	5.00	10.00
3	4 ways extension cable	28.00	56.00

Table 7Cost for Electrical

6.2.6 Cost for AquaBion

No	Description	Total (S$)
1	Model: AB-S20 (3/4”) with guarantee for 5 years	1650.00

Table 8Cost for AquaBion

6.3 Observations

These are the effects found on the models after 2 months of experiments. The results of these effects are only preliminary test results, due to the short time of the testing period and limited testing equipment.

6.3.1 Blocked hole

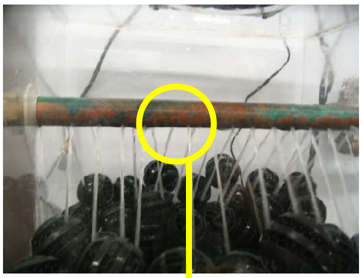


Figure 20 sprinkler without AquaBion

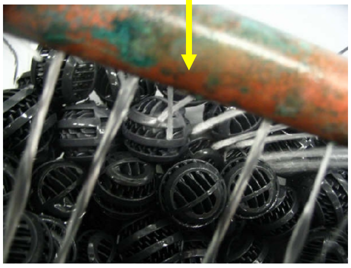


Figure 21 sprinkler close up

Figure 22 Blocked holes

The close-up photos above show that one of the holes of the model without AquaBion was blocked up. The hole is presumably blocked by scale build up inside the copper pipe.

6.3.2 Turbidity in the water

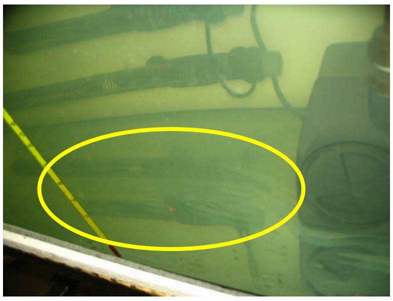


Figure 23 Model without AquaBion

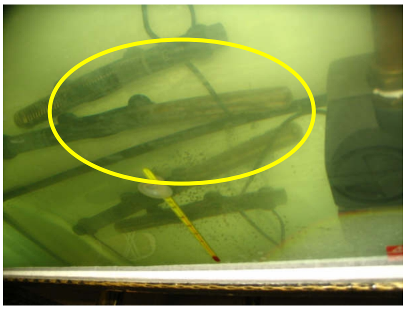


Figure 24 Model with AquaBion

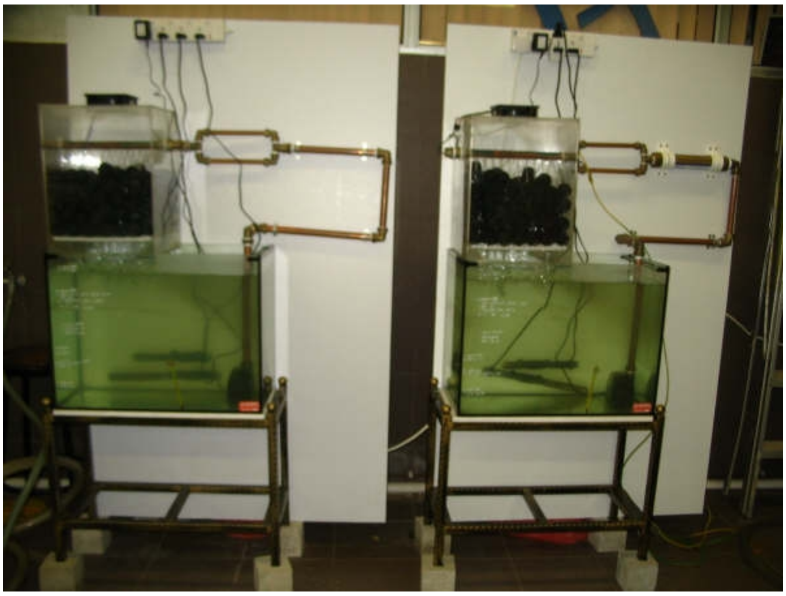


Figure 25 Both models in comparison

The photos above, show that the water in the model with AquaBion is clearer than the water in the model without AquaBion. This statement can be supported, by looking at the reflection of the heaters inside the water tank. The reason for the turbidity in the water is due to dust getting into the tank and, algae forming during the testing period.

6.3.3 White colour stains

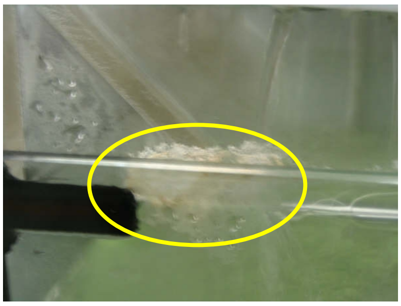


Figure 26 White stains were formed on the gaps between the water tank and the acrylic box

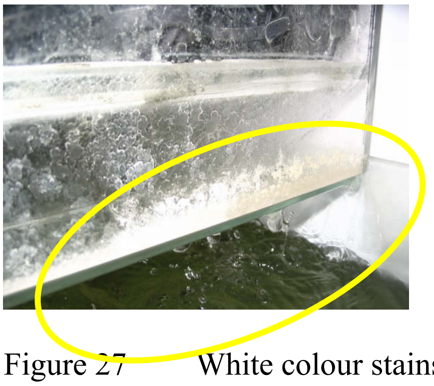


Figure 27 White colour stains were found on the side of the acrylic box

After a month's testing, we noticed that there were already some white colour stains stuck to the surface of the plastic container and in between the glass water tank and plastic container. These white colour stains were increasing continuously. The assumption is ,that these deposits are the salts in the water.

6.4 Testing

The water quality test had been carried out on the water sample, which was used during the test. The water quality test involved the testing of:

1. Total Dissolved Solid (TDS)
2. Dissolved Oxygen (DO)
3. Conductivity
4. pH
5. Turbidity
6. Zinc Content

6.4.1 Total Dissolved Solid (TDS)

6.4.1.1 Description

Total dissolved solids refer to minerals, salts, metals, cations or anions dissolved in water. For example calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates and some small amounts of organic matter are dissolved in water.

The total dissolved solids will make water become hard water and, are responsible for a lot of problems for the piping system because of the residues they form, resulting in the so-called hard water, which forms scaling on all washable surfaces.

Over a period of time, hard water scaling can clog the plumbing system and reduce water pressure.
This scaling may damage equipment and machines, through which the hard water passes.

The Total Dissolved Solids Test, is a qualitative measure of the dissolved solid material present in water, it also refers to the sum of the cations (positively charged) and anions (negatively charged) ions found in the water.

The total dissolved solid test is used as one of the indicator tests to determine the general quality of water.

Cations combined with Carbonates $CaCO3$, $MgCO3$ etc	Associated with hardness, scale formation, bitter taste
Cations combined with Chloride $NaCl$, KCl	Salty or brackish taste, increase in corrosiveness

F

Table 9The relationship between dissolved cations and anions as well as the

problems that are being generated.

http://www.water-research.net/totaldissolvedsolids.htm

6.4.1.2 Procedures

Figure 28 The Hanna HI 9835 Microprocessor Conductivity and Total Dissolved Solid Meter.

Figure 29 The sensor is immersed in the water

1. Prepare and switch on the Total Dissolved Solid and conductivity meter.
2. Rinse the plastic vessel with the water sample and fill it to the 500ml mark.
3. Clean the sensor with ionised water
4. Dip the sensor into the water sample.

5. Take a reading from the screen when the reading is stable.

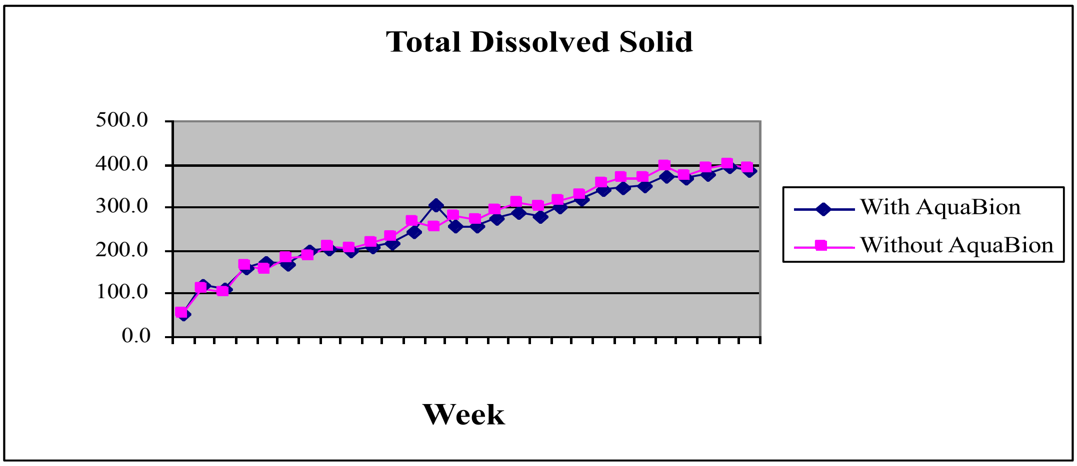
6. Press the ‘Range’ button to take the various test-reading. (Total Dissolved Solid and Conductivity)

6.4.1.2 Result

Week	Total water in tank (l)	The content of Total Dissolved Solids (ppm)		Temperature (°C)
		With AquaBion	Without AquaBion	
1	0.0392	51.7	51.7	25.6
	0.0635	118.3	111.9	28.8
	0.0986	108.8	103.3	28.0
2	0.1418	159.0	163.0	26.9
	0.1728	172.0	154.0	26.9
	0.1850	170.0	181.0	26.8
3	0.2295	198.0	188.0	26.1
	0.2390	205.0	206.0	25.6
	0.2511	199.0	202.0	26.7
4	0.2633	209.0	215.0	26.9
	0.2741	218.0	230.0	26.7
	0.3112	243.0	265.0	26.4
5	0.3220	306.0	253.0	27.2
	0.3368	255.0	277.0	26.4
	0.3476	258.0	270.0	26.7
6	0.3929	275.0	293.0	26.4
	0.4178	286.0	310.0	26.3
	0.4313	278.0	302.0	27.1
7	0.4408	300.0	313.0	27.0
Week	Total water in tank (l)	The content of Total Dissolved Solids (ppm)		Temperature(°C)
		With AquaBion	Without AquaBion	
	0.4779	320.0	327.0	27.1
	0.5002	340.0	353.0	26.6

8	0.5096	345.00	366.0	27.1
	0.5191	349.00	368.0	26.4
	0.5555	370.00	392.0	27.0
	0.5663	368.00	370.0	27.1
9	0.5798	375.00	389.0	27.5
	0.5893	392.00	400.0	26.6
	0.5987	387.00	391.0	26.7

Table 10 Total Dissolved Solid Reading



*ppm - parts per million

Graph 1 Total Dissolved Solid Graph

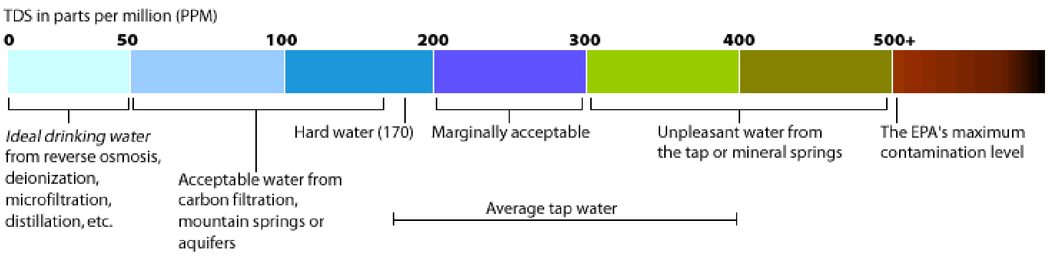


Figure 30 Guideline of Total Dissolved Solids

Source from: http://www.tdsmeter.co.uk/abouttds.html

6.4.1.4 Conclusion

According to the readings shown in the results-table above, we conclude that the water without AquaBion has a higher content in total dissolved solids as opposed to the water with AquaBion if they are measured in the same volume of water. Therefore, we conclude, that the AquaBion is effective in softening the hard water, by changing the total dissolved solids in the form of Calcite (hard scale) to Aragonite (soft scale).

The Galvanic principle of a sacrificial zinc anode, which goes into solution, causes a certain agglomeration of water constituent around the deposited Zn^{2+} ion (crystalline particle). As a result, that crystalline particle will not adhere to the surface of any plumbing and, is flushed away with the water flow.

As the report model is a cooling tower, the water inside would in practice, be recycled and heated up continuously hence, the total dissolved solids would continue to increase, as long as the model is running.(as shown with figure 30)

* Assumption, in addition to further testing, will be continued by the next batch of students.

6.4.2 Dissolved Oxygen

6.4.2.1 Description

Dissolved oxygen (DO) is essential for the maintenance of the corrosion level for the piping the water comes into contact with. This is due to the presence of oxygen in the water, which makes it a good environment for the development of corrosion (i.e. Rust). It is a mixture of iron oxides and hydroxides. The dissolved oxygen in the water can be removed by raising the water temperature.

http://en.wikipedia.org/wiki/Rust

The dissolved oxygen levels also depends on the dissolved solids in the water. This is because ions of dissolved solids will attract the dissolved oxygen molecules out of polar water.

6.4.2.2 Procedures

Figure 31 YSI 52 Dissolved Oxygen Meter

Figure 32 Photo above shows the sensor, which is dipped into the water sample

1. Prepare and switch on the meter and let it warm up for at least 20 minutes.
2. Clean out the sensor
3. Dip the sensor into the water sample.

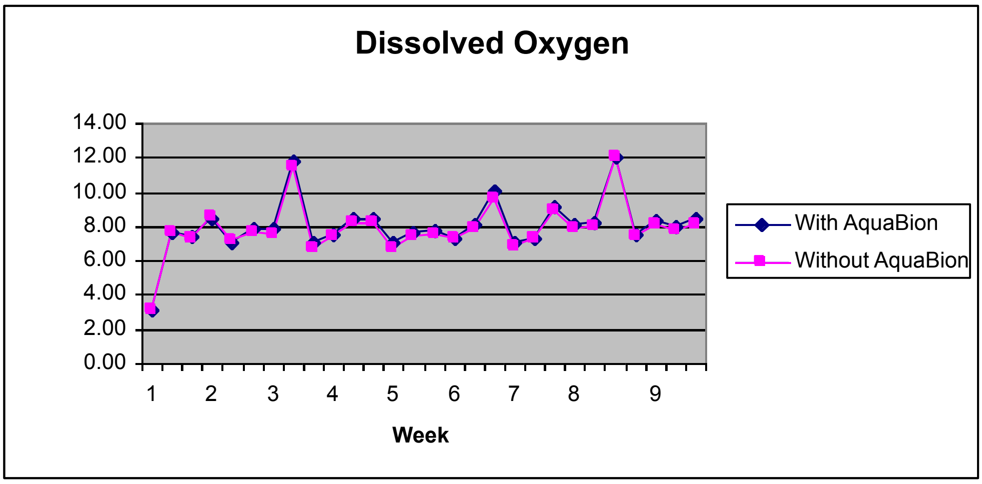
   *Water sample is used constantly throughout all the water quality testing.
4. Take a reading from the screen when the reading is stable.

6.4.2.3 Result

Week	Total Volume of Water in tank	Dissolved Oxygen (mg/l)	
		With AquaBion	Without AquaBion

	(l)		
1	0.0392	3.18	3.18
	0.0635	7.58	7.62
	0.0986	7.41	7.25
2	0.1418	8.48	8.51
	0.1728	7.09	7.12
	0.1850	7.85	7.61
3	0.2295	7.89	7.52
	0.2390	11.77	11.42
	0.2511	7.04	6.72
4	0.2633	7.51	7.42
	0.2741	8.43	8.23
	0.3112	8.44	8.17
Week	Total Volume of Water in tank (l)	Dissolved Oxygen (mg/l)	
		With AquaBion	Without AquaBion
5	0.3220	7.07	6.74
	0.3368	7.67	7.38
	0.3476	7.71	7.50
6	0.3929	7.34	7.29
	0.4178	8.13	7.82
	0.4313	10.06	9.61
7	0.4408	7.10	6.87
	0.4779	7.28	7.24
	0.5002	9.18	8.88
8	0.5096	8.14	7.85
	0.5191	8.25	8.02
	0.5555	12.02	12.08
	0.5663	7.47	7.46
9	0.5798	8.30	8.07
	0.5893	7.96	7.77
	0.5987	8.47	8.06

Table 11 Reading of Total Dissolved Solids



Graph 2 Graph of Dissolved Oxygen

6.2.4.4 Conclusion

The water flowing back to the tank by passing through the pipe has brought oxygen to the water, therefore the dissolved oxygen level in the water should be the same but, based on the readings as shown in the table above, we found that the water in the model with AquaBion has a higher level of dissolved oxygen than the model without AquaBion.

This is because there are dissolved solids inside the water and the ions from the dissolved solids introduced, will attract the water molecules and solvate it. The ions of the dissolved solids will drive the dissolved oxygen molecules out of the polar water. Normally the gas dissolved in a solvent is affected significantly by the presence of other solutes in the solution. The gas, which is dissolved in water, will be decreased by the addition of other solutes, particularly the electrolytes.

Therefore the model without AquaBion, is richer in total dissolved solid, which will lead to a decrease in dissolved oxygen levels in the water.

On the other hand, the zinc ions that have been released by AquaBion, will combine with the dissolved solid ions, so the water ions will not be attracted and solvated, remaining in the original form.

Hence, we can assume that AquaBion can produce a better quality of water.

Source from:

http://www.science.edu.sg/ssc/detailed.jsp?artid=5686&type=6&root=5&parent=5&cat=60

* Assumption and this testing will be continued by next batch of students.

6.4.3 pH

6.4.3.1 Description

PH is a measure of the hydrogen ion (H^+) concentration of a solution in order to determine the changing physical and chemical conditions of the water. PH is measured in the scale of 1-14 when the water in the acid level (i.e. less than 7) there will be a stronger corrosion development, whilst with a pH level greater than 7, water is in the alkaline condition meaning that the content of dissolved solid is high.
http://www.kittiwake.com/Default.aspx/ProductSection/90/ProductSubSection/106/ProductSubSubSection/247/Product/542

6.4.3.2 Procedures

Figure 33 Cyber Scan 510 pH meter.

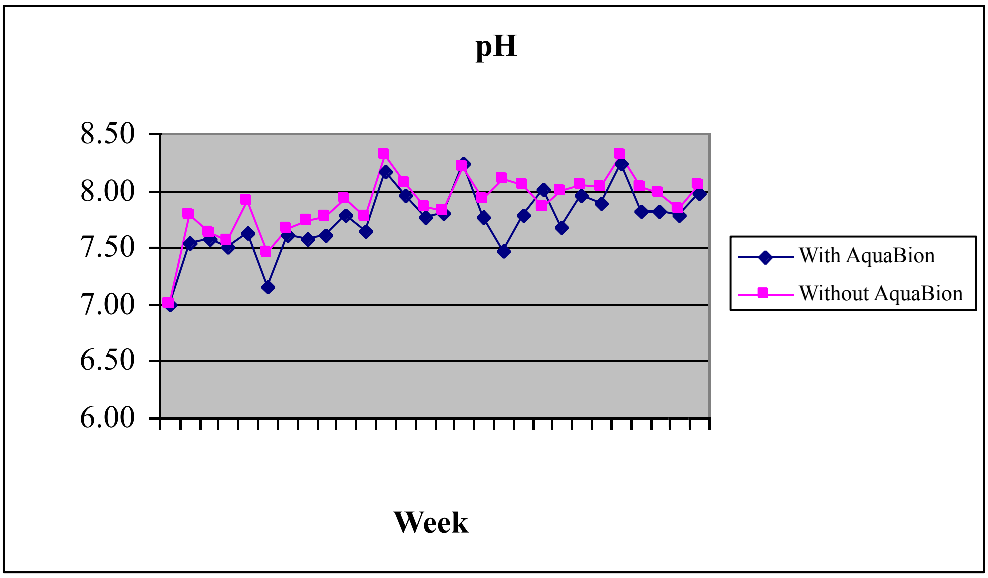
1. Prepare and switch on the meter.
2. Clean out the sensor from buffer solution by using ionised water.
3. Dip the sensor into the water sample (consistently used).
4. Take a reading from screen when the reading has stable.

6.4.3.3 Result

Week	Total Volume of Water in tank (l)	pH	
		With AquaBion	Without AquaBion
1	0.0392	6.99	6.99
	0.0635	7.54	7.78
	0.0986	7.57	7.63
2	0.1418	7.50	7.56
	0.1728	7.63	7.90
	0.1850	7.15	7.45

3	0.2295	7.60	7.66
	0.2390	7.58	7.73
	0.2511	7.61	7.77
4	0.2633	7.78	7.93
Week	Total Volume of Water in tank (l)	pH	
		With AquaBion	Without AquaBion
	0.2741	7.65	7.76
	0.3112	8.17	8.30
5	0.3220	7.96	8.06
	0.3368	7.77	7.86
	0.3476	7.80	7.81
6	0.3929	8.23	8.21
	0.4178	7.77	7.92
	0.4313	7.47	8.10
7	0.4408	7.78	8.05
	0.4779	8.01	7.86
	0.5002	7.68	8.00
8	0.5096	7.96	8.04
	0.5191	7.88	8.03
	0.5555	8.24	8.30
	0.5663	7.81	8.02
9	0.5798	7.82	7.97
	0.5893	7.79	7.83
	0.5987	7.98	8.04

Table 12 Reading of pH



Graph 3 Graph of pH

Acidic	< 7 pH
Neutral	7 pH
Alkaline	>7 pH

Table 13 Guideline of pH Level

6.4.3.4 Conclusion

Based on the reading we took, we conclude that the pH level in the water without AquaBion, is lower than the water with AqauBion.

* Assumption and the testing will be continued through next batch of students.

6.4.4 Conductivity

6.4.4.1 Description

Conductivity of a substance can be defined as the ability to conduct electricity in water. Therefore a water conductivity test provides a good indication of the quantity of dissolved material present (e.g. minerals) and it is useful information, to determine the level of scaling, corrosion, and deposits present in the water sample.

6.4.4.2 Procedures

The procedures for conductivity testing is the same as with the total dissolved solids - just press the ‘range’ button to switch the Total Dissolved Solid’s reading to the Conductivity.

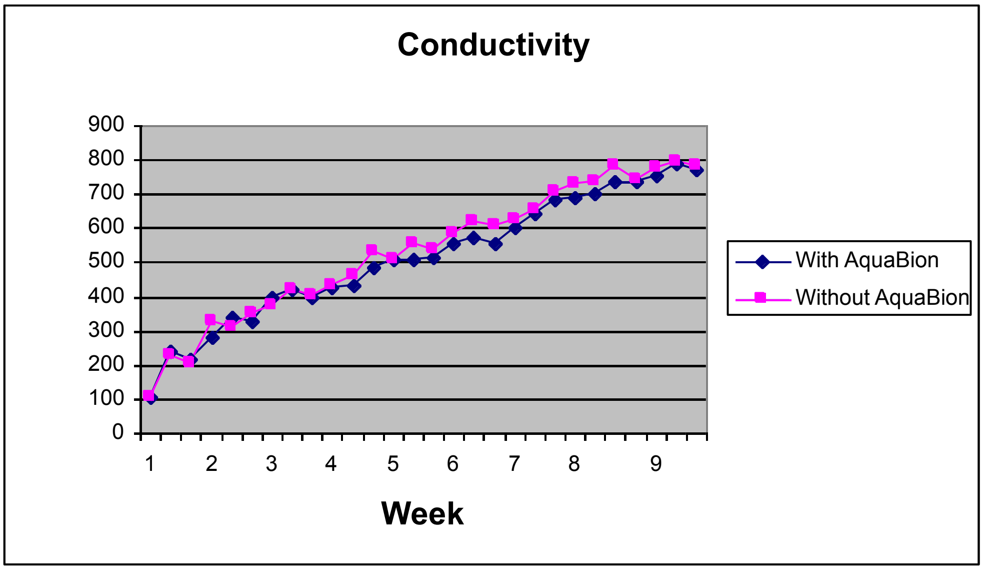
6.4.4.3 Result

Week	Volume	Conductivity

	of water (l)	(microsiemens/centimetre)	
		With AquaBion	Without AquaBion
1	0.0392	103.4	103.4
	0.0635	237.2	225.3
	0.0986	218.5	206.6
2	0.1418	280	325
	0.1728	337	310
	0.1850	330	349
3	0.2295	400	376
	0.2390	418	420
	0.2511	397	403
4	0.2633	424	431
	0.2741	434	459
	0.3112	484	530
5	0.3220	508	507
	0.3368	509	553
	0.3476	517	540
6	0.3929	556	585
	0.4178	574	618
	0.4313	553	606
7	0.4408	604	626
Week	Volume of water (l)	Conductivity (microsiemens/centimetre)	
		With AquaBion	Without AquaBion
	0.4779	643	654
	0.5002	682	705
8	0.5096	688	731
	0.5191	701	736
	0.5555	738	785
	0.5663	735	740
9	0.5798	755	776
	0.5893	788	797
	0.5987	771	781

Table 14 Reading of Conductivity

* µs /cm – microsiemens per centimetre



Graph 4 Graph of Conductivity

6.4.4.4 Conclusion

The conductivity of the water solution is interrelated with the total dissolved solid. If water has a high content in dissolved solids in the form of elements (e.g. minerals) then, it has a high current conducted.

The minerals will be dissolved in the water and become part of the liquid water and, its molecules have an electrical charge, known as IONs. When ANIONS are charged with CATIONS, conductivity is produced.

From the readings we obtained, we found that the conductivity in the water without AquaBion is higher than that with AquaBion. AquaBion will release zinc ions so, when the water passes through the system, the Hydroxide (OH^-) from the water molecule will be charged with Zinc (Zn^{2+}) ions forming Zinc hydroxide ($Zn(OH)_2$). On the other hand, the element dissolved in the water solution remains as an ion form, therefore the electrolysis process is conducted and, as a result it, has increased the conductivity of the water.

Source from:

http://experts.about.com/q/Water-Quality-2463/Conductivity-water-1.htm

* Assumption and the testing will be continued through next batch of students.

6.4.5 Turbidity

6.4.5.1 Description

Turbidity is the measure of the clarity of the water sample and it is a good basis to indicate the quality of the water. Normally clear water has a low turbidity, while murky water has a high turbidity. Small particles suspended in the water such as algae, clay, micro-organisms, silt, organic chemicals, decaying vegetation, or chemical wastes, can result in the water becoming turbid.

Source: http://www.waterqualities.50megs.com/catalog.html

6.4.5.2 Procedures

Figure 34 Small visible vessel.

Figure 35 Ionised water.

Figure 36 Portable Data logging Spectrophotometer

HACH DR / 2010.

1. Prepare and switch on the meter.
2. Select the correct function and programme for the turbidity testing.
3. Rinse the small glass vessel with deionised water.
4. Use the tissue paper to clean out the fingerprints which are on the glass vessel surface.
5. Put the vessel into the meter.
6. Press the 'Zero' button.(to act as a reference)
7. Take a reading from the screen where normally 0 NTU will be shown.
8. Take out the deionised water from meter.
9. Rinse the small glass vessel with water sample.
10. Use the tissue paper to clean out the fingerprints on the glass vessel surface.
11. Put the vessel into the meter.
12. Press the 'Read' button.
13. Take a reading from the screen.

*Deionised water, is water that lacks ions (e.g. calcium, iron, copper and chloride) so, it also means that it has been purified from other ions with the exclusion of

H_3O^+ and OH^- and some non-ionic types of impurities, such as the organickind which still may be present in the water.

http://en.wikipedia.org/wiki/Deionized_water

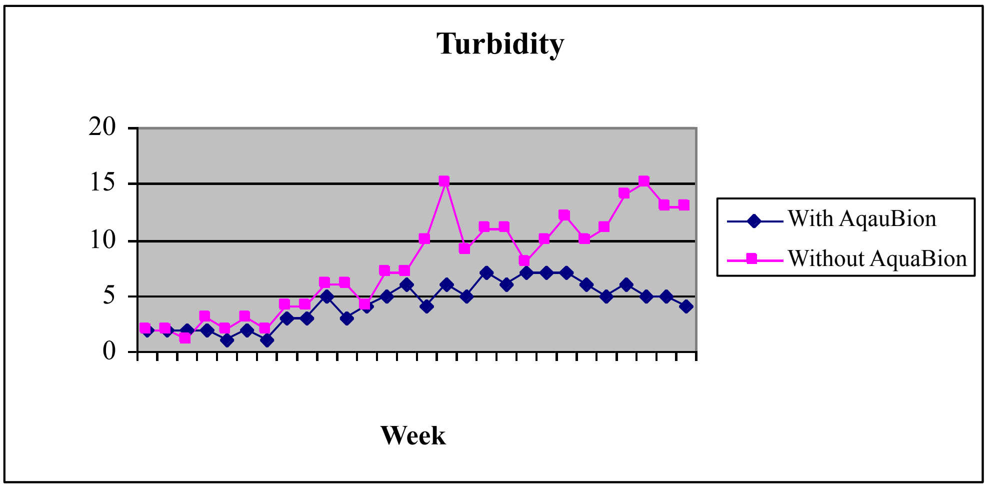
6.4.5.3 Result

Week	Volume of Water in tank(l)	Turbidity(NTU)	
		With AquaBion	Without AquaBion
1	0.0392	2	2
	0.0635	2	2
	0.0986	2	1
2	0.1418	2	3
	0.1728	1	2
	0.1850	2	3
3	0.2295	1	2
	0.2390	3	4
	0.2511	3	4
4	0.2633	5	6
	0.2741	3	6
	0.3112	4	4
5	0.3220	5	7
	0.3368	6	7
	0.3476	4	10
6	0.3929	6	15
	0.4178	5	9
	0.4313	7	11
Week	Volume of Water in tank(l)	Turbidity(NTU)	
		With AquaBion	Without AquaBion
7	0.4408	6	11

	0.4779	7	8
	0.5002	7	10
8	0.5096	7	12
	0.5191	6	10
	0.5555	5	11
	0.5663	6	14
9	0.5798	5	15
	0.5893	5	13
	0.5987	4	13

Table 15 Reading of Turbidity

*NTU – Nephelometric Turbidity Unit



Graph 5 Graph of Turbidity

6.4.5.4 Conclusion

The reading above indicates, that the water showed a big difference between the model with AquaBion and that without the AquaBion. Therefore, we conclude that the AquaBion is effective in lowering the turbidity of water, making the water become less cloudy. We are also assuming that there is a suspended matter. Apart from the presence of algae, there are some other suspended particles dissolved in the water - for example silt, micro organism, plant fibres, sawdust, wood ashes, chemicals and coal dust and they are able to block the light from penetrating the water.

Turbidity is to be measured by the ability of light being able to pass through the water.

If there is a lot of suspended material in the water, the turbidity will increase instantly.

http://www.h2ou.com/h2wtrqual.htm

* Assumption and the testing will be continued through next batch of students.

6.4.6 Zinc Test

6.4.6.1 Description

Zinc Testing was carried out to determine the amount of dissolved solids, which are diluted inside the water sample. This is because AquaBion is working on the basis of the galvanic principle using a sacrificial zinc anode - therefore the agglomeration of water will constitute around the deposited Zn ion (i.e. crystallization particles). After water has passed through the AquaBion, the amount of Zinc should be slightly increased,s therefore the testing is able to prove the effectiveness of this galvanic water treatment device.

6.4.6.2 Procedures

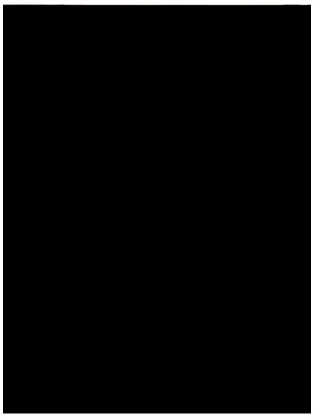


Figure 37 Hanna C200 Multiparameter Bench Photomers Instrument.

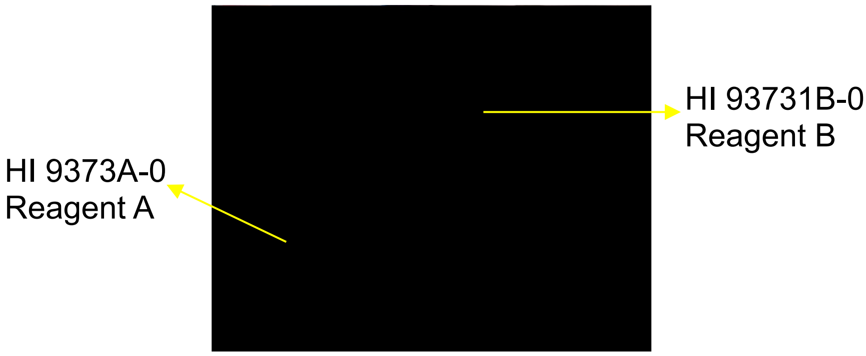


Figure 38 Reagents for Zinc Test.

Figure 39 Photo shows the cuvet is inserted into the cell.

1. Select the programme corresponding to Zinc on the secondary LCD, by pressing both the programme and arrow button to number 20.
2. Fill one graduated mixing cylinder up to the 10 ml mark with the sample.

3. Add the content of one packet of HI 93731A zinc reagent, close the cylinder and invert several times to mix until dissolution is complete.
4. Fill one cuvet with 10ml of the reacted sample up to the mark.
5. Place the cap and insert the cuvet into the cell and ensure that the notch on the cap is positioned securely into the groove.
6. Press ZERO and “SIP” will blink on the display.
7. Wait for a few seconds and the display will show “0.0”. Now the meter is zeroed and ready for measurement.
8. Remove the cuvet and add 0.5 ml of HI 93731B cyclohexanone to the cuvet.
9. Replace the cap and mix the sample for 15 seconds.
10. Insert the sample into the instrument.

11. Press TIMER button and the display will show the countdown prior to the measurement or, alternatively, wait for 3 minutes and 30 seconds and press READ DIRECT button. In both case “SIP” will blink during measurement.

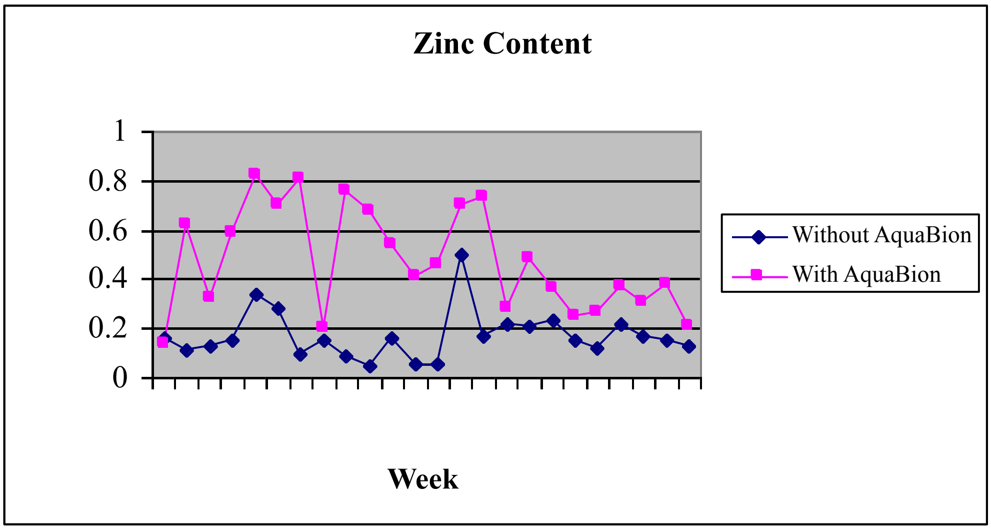
12. The instrument directly displays concentration in mg/L of zinc on the Liquid Crystal Display.

6.4.6.3 Result

Week	Volume of Water in tank(l)	Zinc Content (mg/L)	
		With AquaBion	Without AquaBion
	0.1728	0.14	0.16
	0.1850	0.62	0.11
3	0.2295	0.32	0.13
	0.2390	0.59	0.15
	0.2511	0.82	0.34
4	0.2633	0.70	0.28
	0.2741	0.81	0.10
	0.3112	0.20	0.15
5	0.3220	0.76	0.09
	0.3368	0.68	0.05
	0.3476	0.54	0.16
Week	Volume of Water in tank(l)	Zinc Content (mg/L)	
		With AquaBion	Without AquaBion
6	0.3929	0.41	0.06
	0.4178	0.46	0.06
	0.4313	0.70	0.5
7	0.4408	0.73	0.17
	0.4779	0.28	0.22
	0.5002	0.48	0.21
8	0.5096	0.36	0.23
	0.5191	0.25	0.15
	0.5555	0.27	0.12
	0.5663	0.37	0.22
9	0.5798	0.31	0.17
	0.5893	0.38	0.15

	0.5987	0.21	0.13

Table 16 Reading of Zinc Content



Graph 6 Graph of Zinc Content

6.4.6.4 Conclusion

The water in the model with AquaBion has a higher content of zinc ion because the AquaBion is working upon the galvanic principle of a sacrificial zinc anode, which goes into solution. Due to the re-circulatory water in a cooling tower test rig, the Zinc content will have increased more than in a normal, one through-flow situation. The water without AquaBion has a lower content in zinc ion, which is measured just as a normal amount of mineral dissolved in the water or solution.

* Assumption and the testing will be continued through next batch of students.

Conclusion

After the completion of the two months testing period, the results clearly show that AquaBion can have a very positive effect on Singapore's water.

The results observed, are as accurate as possible for a two month's testing period taking into consideration, that some inexperience amongst the students involved existed, due to the testing of a new and unknown water treatment system. There may also be some shortfalls in the results of the tests, due to the short period of time we had for testing purposes, as some of the tests have to be repeated over a certain period of time. For the actual testing itself, it will take more than just one test over a longer period of time, to prove how effective AquaBion can really be. Furthermore, the test equipment in the laboratory was quite limited and should be adapted to the possible challenges of a further test.

Each test result showed a clear result for the AquaBion, but further tests should be carried out under different circumstances – such as different water qualities, applications and different ranges of temperatures.

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Recommendation

This testing will be continued by a new group of students later this year. It was recommended to continue with further testing in the future. The tests will involve algae, caesium, iron, copper, hardness of the water and the effect of scaling on heating elements in relation to loss of energy etc.

Experiments have to be carried out to find out all about the particles inside the water, including the volume, size and the numbers of particles. The suitable instrument for researching this further, is a Particles Analysis/Particle Counter.

The test of both models with and without AquaBion, has to run for a longer period to ascertain more visible effects and more extensive data for comparison. For example, how scale appears on the inner surfaces of copper piping.

A heater with a higher wattage, will be needed for the new test, because scaling will be created faster when water is at a higher temperature. The higher the temperature, the more scale is created.

We have to plan properly , before starting a new set of test runs, thus avoiding testing failure as a result of carelessness. The testing must be conducted consistently to obtain more accurate results.

The white colour stains, blocked holes of copper pipes and the others affects can be examined by using new equipment called XRD. XRD can be used to see the layer inside the copper pipe. Based on the recommendation from Dr. Yang, there actually was a layer inside the copper pipe, which could not be seen by the human eye, so XRD is needed.