Project

The Effects of MagnaBlu Minerals used in a Domestic System

Company

Poolrite Research

Prepared by

Jessica Sticklen

Mechanical Engineering Student

University of Queensland

June 2007

Details of Course and Stakeholders

Course Code: ENGG4011
Course Title: Professional Engineering Project
Number of Units: 6

Poolrite Research
Client
Address: 415 Creek Road
P.O Box 520
Mt Gravatt 4122
Telephone: 3323 6555
Fax: 3323 6599
Email: info@poolrite.com.au
Web Page: www.poolrite.com.au

Colin Redmond
Company Supervisor
General Manager – Poolrite Research
Executive Manager – Poolrite Equipment
Email: credmond@poolrite.com.au

Jessica Sticklen
Student and author
Mechanical Engineering Student University of Queensland
Mobile: 0412 946 996
Email: s40539955@student.uq.edu.au

Dr Matthew Dargusch
University Supervisor
Telephone: 3346 9225
Email: M.Dargusch@minmet.uq.edu.au

Mr Graham Willett
CEED Program Coordinator
Address: 19 Buckinghamia Place
Stretton Q 4116
Telephone: 3273 2804
Email: ceed@bigpond.net.au

Statement of Originality

The work presented in this thesis is, to the best of the author's knowledge and belief, original and the author's own, except as acknowledged in the text. The material contained in this thesis has not been submitted, either in whole or part, for another degree at The University of Queensland or any other university.

Jessica Sticklen

Abstract

Poolrite Research is currently investigating the feasibility of the use of a processed form of bitterns (MagnaBlu Minerals) in the MagnaPool domestic system. The project aims to assess the impact that MagnaBlu Minerals may have on a domestic system by developing and undertaking a program of preliminary testing. The impact that MagnaBlu Minerals may have on various aspects of a domestic system has been assessed by performing a series of tests on candidate materials that would normally be in contact with water at various points in the domestic system. The procedures of each test where chosen for their relevance to the operating conditions of the contact points in the domestic system and were chosen in close collaboration with Poolrite Research. The tests that have been performed are:

- Composition of MagnaBlu Minerals
- Hardness level of MagnaBlu Minerals
- pH level of MagnaBlu Minerals
- Lather test
- Stain test
- Degradation and precipitate test
- Elasticity test
- High temperature test

The preliminary analysis of the effects of MagnaBlu Minerals has on a domestic system has shown that MagnaBlu Minerals is compatible with the domestic system and that MagnaBlu Minerals can be used in a domestic system with no adverse effects to the materials it will come in contact with. The positive findings from this project will need to be confirmed with a more extensive analysis in the further before implementation into a domestic system.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Client Profile

Poolrite Equipment is a well established Australian owned company celebrating 25 years manufacturing in 2006. Poolrite is a major stakeholder in the international swimming pool accessories market, manufacturing over 700 products on site at its Mt Gravatt headquarters. Poolrite Equipment dominates Australian and New Zealand markets with a strong established brand built on quality. In 2005 Poolrite Research was established to develop advanced products for the swimming pool accessories market.

1.2 Background

Poolrite Research has designed a new pool filtration system called the MagnaPool system. The MagnaPool system is a system designed to use less water. The system uses less water when a backwash is performed and will draw little, if any, water from the town water supply. The initial filling of the pool will be performed with Bitterns and purchased water. Bitterns is concentrated seawater with approximately 70% of the sodium chloride (salt) removed through the salt production process[19]. The pool is to be topped up with water from a rainwater tank so as to not draw water from the town water supply. The diluted Bitterns to be used in the MagnaPool system is called MagnaBlu Minerals.

The MagnaPool system is to be employed in two stages.

The first stage of the design is to backwash into a holding tank or settling tank where many of the suspended particles in the water will settle out of the water to the bottom of the tank. This water then may be used on the gardens and lawn around the house. The first stage of the MagnaPool system is represented in Figure 1.1.

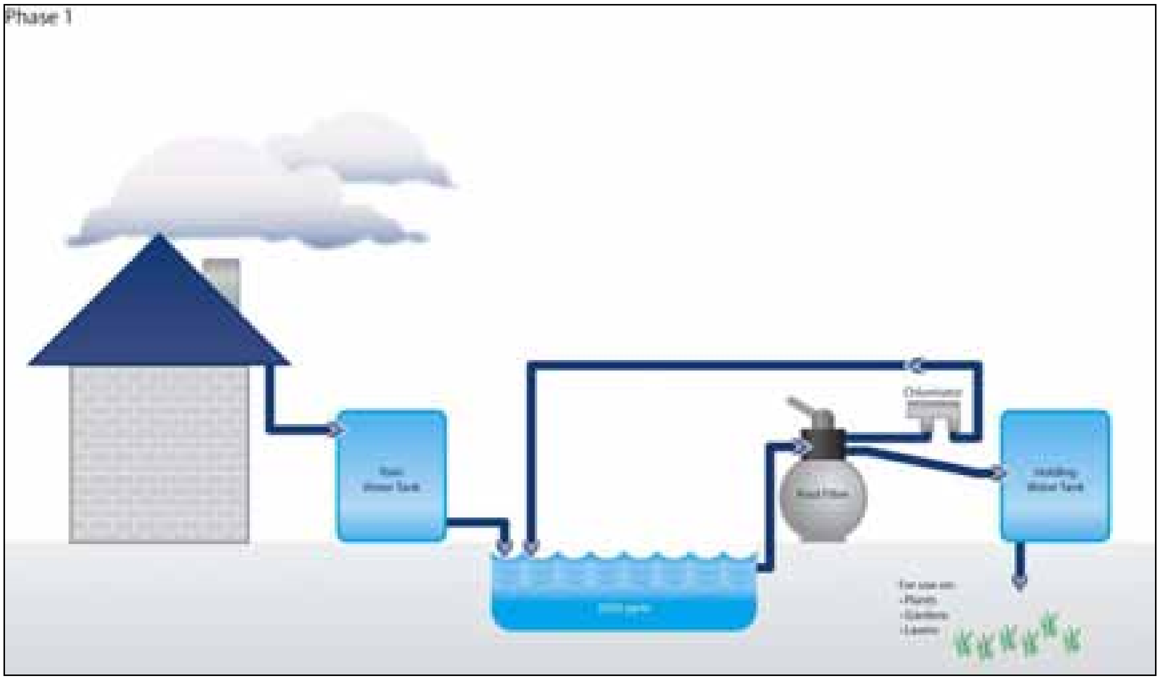

Figure 1.1: Phase 1

The second stage of the system is shown is Figure 1.2. In this design the pool water travels through the pool filter and chlorinator and be placed into the household rainwater tank. To comply with water guidelines the level of total dissolved salts will be monitored and it will be kept below the guideline of 500 mg/l. Only when the total dissolved salts are below this level will more MagnaBlu Minerals be permitted into the rainwater tank. The MagnaBlu Minerals would then mix with the rainwater and would be used in the household or go back into the pool. The water would be used inside the household for applications such as in toilets, dishwashers, and in washing machines. The backwashed water will still be placed into the holding tank to be used on the lawn and garden.

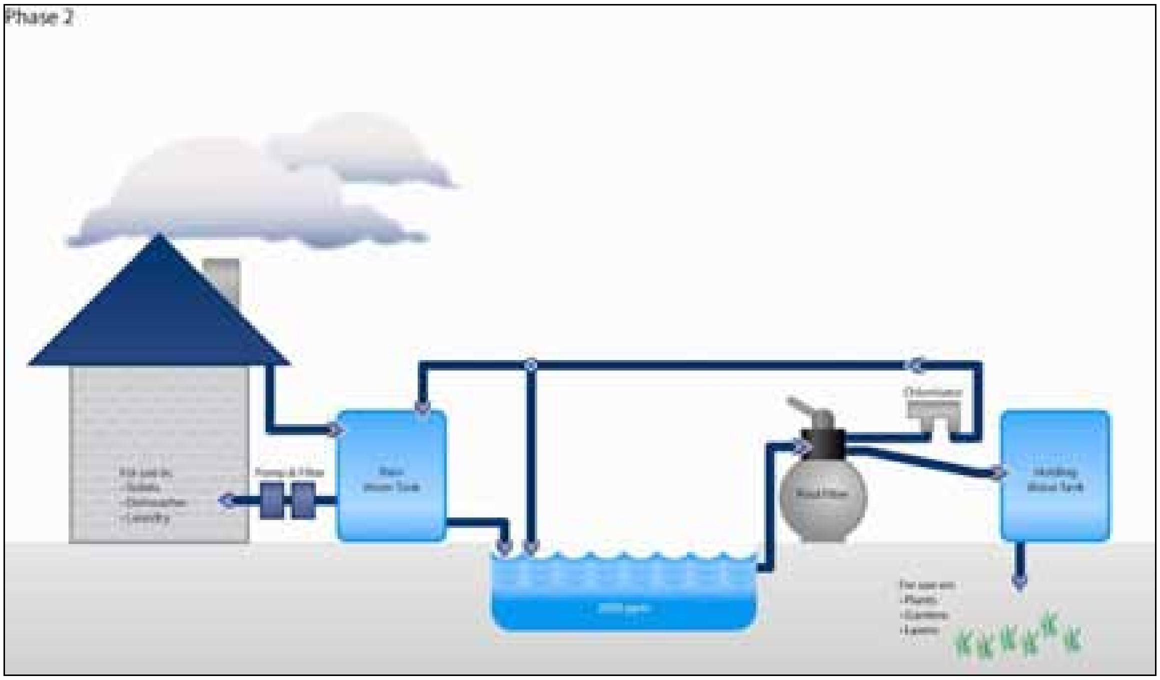

Figure 1.2: Phase 2

The possible effect, if any, the MagnaBlu Minerals may have on the domestic system is unknown. Therefore a primary analysis of MagnaBlu Minerals in a domestic system is required.

1.3 Project Description

The project involved a preliminary analysis of the effects MagnaBlu Minerals will have on a domestic system. The domestic system will encompass the entire plumbing system of a house and any surfaces or materials the MagnaBlu Minerals may come in contact with. The project will require a list of the possible contact points in the domestic system to be compiled. Part or all of the materials on the list of contact points will be used to test the effects of MagnaBlu Minerals. The possible effects to be tested for include:

- Reduced ability to produce lather with soap
- Materials being stained by MagnaBlu Minerals
- Degradation of material from contact with MagnaBlu Minerals
- A precipitate forms on surfaces after contact with MagnaBlu Minerals

The test will be designed to simulate the use of MagnaBlu Minerals in a domestic system. The tests will only preliminary test and will not indicate the rate or severity at which a material will be affected.

1.4 Project Objectives

Key project objectives are as follows:

- Identify all points of contact of MagnaBlu Minerals in a domestic system
- Identify if MagnaBlu Minerals will reduce the ability to produce lather with soap
- Identify if MagnaBlu Minerals will stain a material
- Identify if MagnaBlu Minerals will degrade a material that it comes in contact with
- Identify if a material will have a precipitate left on the surface after contact with MagnaBlu Minerals

Chapter 2

Literature Review

2.1 Hard Water

MagnaBlu Minerals is of a different composition to standard water found in a domestic system and therefore may affect a domestic system differently. The Brisbane City Council gives examples of problems that can affect water quality; these are water hardness and corrosion or degradation of pipes or plumbing fittings. The hardness of water can make it difficult to produce lather or suds when washing. The calcium and magnesium content causes the hardness in water. Water with a high hardness level tends to generate chemical precipitates (Polevoy 1996). Elevated temperatures can increase the amount of precipitation from the water.

The Brisbane City Council gives the following scale of water hardness.

- Soft: 0 – 50 mg/L or ppm as calcium carbonate
- Moderately soft: 51 – 100 mg/L or ppm as calcium carbonate
- Slightly hard: 101 – 150 mg/L or ppm as calcium carbonate
- Moderately hard: 151 – 200 mg/L as ppm calcium carbonate
- Hard: 201 – 300 mg/L or ppm as calcium carbonate
- Very hard: >300 mg/L or ppm as calcium carbonate

2.2 Lather

Atkins and Beran (1992) define soaps as sodium salts of organic acids with long hydrocarbon chains (let soap be denoted as NaA and the parent organic acid as HA). The anions (A^-) have a negatively charged segment, called the head group, at one end of a non-polar hydrocarbon chain. The non-polar hydrocarbon tail sinks into a blob of grease with the head group remaining on the surface of the grease. The head groups are hydrophilic (water-attracting) thus enabling the blob of grease to dissolve into the water and be washed away. The problem with hard water is that the soap will form a scum. This scum is a product of a precipitation reaction that occurs because calcium salts are less soluble than sodium salt, therefore decreasing the ability of the soaps to dissolve the grease.

2.3 Precipitation and Crystallization

2.3.1 General Remarks

Crystallization or precipitation involves the removal of salts from a aqueous solution, these salts may then be deposited onto the solid surfaces the solution is in contact with. Before crystallization can occur, supersaturation of the depositing species in the solution must be present near the solid surface. Cooling of a saturated solution containing a salt or salts with normal solubility characteristics will generally result in supersaturation and deposition will occur on the cold surface. Supersaturation and deposition may also occur when a aqueous solution containing inverse solubility salt or salts is heated, such as $CaSO_4$ and $CaCO_3$. The evaporation of water may also cause supersaturation of a salt. Crystallization deposits can become very thick and can cause tubes or pipes to become blocked (Bott 1990).

2.3.2 Stages of Precipitation

Precipitation has been observed to occur in three steps, Nucleation, crystal growth, and agglomeration and the ripening of the solids (Jenkins & Snoeyink 1980).

Nucleation

A nucleus is a fine particle on which the precipitation of a solid phase can take place. Nuclei can form from a cluster of molecules or ion pairs of the component ions of the precipitate, or they may be fine particles unrelated chemically to the precipitate but with some similarity of crystal lattice structure. If nuclei are formed from the component ions of the precipitate, the initial phase of precipitation is known as homogeneous nucleation; if foreign particles are the nuclei, the nucleation is said to be heterogeneous.

Crystal Growth

Crystals form by the deposition of the precipitate ions onto nuclei. There is no simple or generally accepted method of expressing the rate of the growth of a crystal, since it has a complex dependence on temperature, supersaturation, size, habit, system turbulence, and so on (Mullin 2001).

Agglomeration and Ripening

The initial solid formed from precipitation may not be the most stable solid. If this is the case, then over a period of time the crystal structure may change to that of a stable phase. This change can be accompanied by extra precipitation and a reduction in the solution concentration because the more stable phase usually has a lower solubility. Ripening may also take place, in this situation the crystal size of the precipitate increases.

2.3.3 Solubility

A saturated solution is a solution that is in equilibrium with soluble solid phase. Once the salt concentration exceeds its saturation limit, it has the potential to precipitate from the solution. In general, salts can be classified into two categories according to their solubility characteristics. As the temperature increases some salts have greater solubility; these salts are referred to as normal soluble salts, such as NaCl and $NaNO_3$. On the other hand some salts have a decrease in solubility as the temperature is raised, such as $CaSo_4$ and $CaCO_3$. These salts are referred to as sparingly soluble salts.

The solubility of an ideal solution can be predicted from the van’t Hoff equation (Mullin 2001):

$$\ln x = \frac{\Delta H_f}{R}\left[\frac{1}{T_f} - \frac{1}{T}\right] \tag{2.1}$$

Where

x is the mole fraction of the solute in the solution

T is the solution temperature (K)

T_f is the fusion temperature (melting point) of the solute (K)

ΔH_f is the molal enthalpy of fusion of the solute (J mol^{-1})

R is the gas constant (8.314 J mol^{-1} K^{-1})

The van't Hoff equation can also be written in the form (Mullin 2001):

$$\ln x = \frac{-\Delta H_f}{RT} + \frac{\Delta S_f}{R} \tag{2.2}$$

Where

ΔS_f is the modal entropy of fusion.

For solutions that exhibit non-ideal behaviour, the enthalpy and entropy of mixing must be taken into account by replacing ΔH_f with ΔH_d and ΔS_f by ΔS_d using (Mullin 2001):

$$\ln x = \frac{-\Delta H_d}{RT} + \frac{\Delta Sd}{R} \tag{2.3}$$

2.3.4 Supersaturation

A supersaturated solution is a solution that contains more dissolved solid than that represented by equilibrium saturation. For precipitation to occur, a solution has to be supersaturated, but not necessarily all supersaturated solutions will precipitate. The state of a solution can generally be described as a solubility-supersolubility diagram (Fig 2.1). The diagram is split into three regions. In region 1, the solution is undersaturated where crystallization is impossible to occur. Region 2 is the metastable region in which the solution is supersaturated. In this region, spontaneous crystallization is improvable. However, once the nucleation starts, the solution becomes unstable which is indicated as region 3. Region 3 is also the supersaturated region where spontaneous crystallization is likely to occur but not certain.

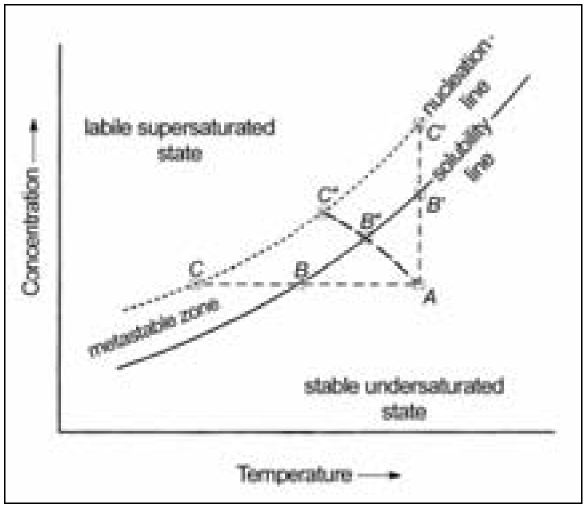

Figure 2.1: The solubility-supersolubility diagram (Mullin 2001)

The most common expression of supersaturation is defines as (Mullin 2001):

$$SS = \frac{c}{c^*} \tag{2.4}$$

Where

c is the solution concentration

c^* is the equilibrium saturation at the given temperature

Supersaturation in aqueous solutions of sparingly soluble salts is (Mullin 2001):

$$SS = \left(\frac{IAP}{K_{sp}}\right)^{1/v} \tag{2.5}$$

Where

IAP is the ion activity product of the lattice ions in the solution

K_{sp} is the solubility product

v is the number of ions in a formula unit of the salt

For calcium carbonate, $Ca^{2+} + CO_3^{2-} \xleftrightarrow[K_{sp}]{} CaCO_3$

$$IAP = \{Ca^{2+}\} \cdot \{CO_3^{2-}\} = \gamma_{\pm}[Ca^{2+}] \cdot [CO_3^{2-}] \tag{2.6}$$

Where

$\{Ca^{2+}\}, \{CO_3^{2-}\}$ is the activity of $Ca^{2+} and CO_3^{2-}$ respectively

$[Ca^{2+}], [CO_3^{2-}]$ is the concentration of $Ca^{2+} and CO_3^{2-}$ respectively.

2.3.5 Calcium Carbonate

Calcium Carbonate is an inverse soluble salt or sparingly soluble and the preposition of calcium carbonate is pH dependent (Redd & Nancollas 1976). The formation of calcium carbonate in a $CO_2 - H_2O$ system is related to the following reactions (Garside & Söhnel 1992)

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \tag{2.7}$$

$$H_2CO_3 \Leftrightarrow H^+ + HCO_3^- \tag{2.8}$$

$$HCO_3^- \Leftrightarrow CO_3^{2-} + H^+ \tag{2.9}$$

$$Ca^{2+} + HCO_3^- \Leftrightarrow CaHCO_3^+ \tag{2.10}$$

$$Ca^{2+} + CO_3^- \Leftrightarrow CaCO_3^0 \tag{2.11}$$

$$Ca^{2+} + OH^- \Leftrightarrow CaOH^+ \tag{2.12}$$

$$Ca^{2+} + CO_3^{2-} \Leftrightarrow CaCO_3(solid) \tag{2.13}$$

To determine if a solution is in equilibrium with $CaCO_3$ the Langelier Index (L.I.) or the Saturation Index (S.I.) can be calculated. If the water has a S.I. of zero, it is in equilibrium; if the S.I. is a positive value, the water is oversaturated and will tend to precipitate $CaCO_3$; and if the S.I. is a negative value, the water is undersaturated and will tend to dissolve $CaCO_3$ (Jenkins & Snoeyink 1980).

The Langelier Index or Saturation Index is defined as follows (Elfil & Hannachi 2006).

$$L.I. or S.I. = pH - pH_s \tag{2.14}$$

Where

pH is the actual pH of the water

pH_s is the saturation pH, relative to calcite

pH_s is defined by the equation below (Elfil & Hannachi 2006).

$$pH_s = pK_2^{'} + pK_s^{'} - \log[Ca^{2+}] - \log[Alc] \quad (2.15)$$

Where

Alc is the solution alkalinity

$pK_2^{'}$ & $pK_s^{'}$ are the apparent equilibrium constants at a given ionic strength, for calcite solubility product and second carbonic acid dissociates, respectively

It is possible to consider the activities instead of concentrations to derive the water saturation pH from the $CaCO_3$ solubility product and the carbonic acid second dissociation (Elfil & Hannachi 2006).

$$pH_s = pK_2 - pK_s - \log[Ca^{2+}] - \log[HCO_3^-] - \log\gamma_{HCO_3^-} - \log\gamma_{Ca^{2+}} \quad (2.16)$$

Where

γ_i is the activity coefficient relative to ion i

Given that

$$[Alc] = 2[CO_3^{2-}] + [HCO_3^-] + [OH^-]$$

For pH below 9, the OH^- and CO_3^{2-} concentrations can be neglected when compared to that of HCO_3^-. Therefore pH_s can be written in the following form (Elfil & Hannachi 2006).

$$pH_s = pK_2 - pK_s - \log\gamma_{HCO_3^-} - \log\gamma_{Ca^{2+}} - \log[Ca^{2+}] - \log[Alc] \quad (2.17)$$

pH_s may also be written in the following form, this is the form the company uses(Poolrite Research).

$$pH_s = (9.3 + A + B) - (C + D) \tag{2.18}$$

Where

$$A = (Log_{10}[TDS] - 1)/10 \quad \text{(TDS is total dissolved solids)} \tag{2.19}$$

$$B = -13.12 * Log_{10}(^0C + 273) + 34.55 \tag{2.20}$$

$$C = Log_{10}[Ca^{2+} asCaCO_3] - 0.4 \tag{2.21}$$

$$D = Log_{10}[AlkalinityasCaCO_3] \tag{2.22}$$

If S.I. is above +0.3, scaling will occur and if S.I. is below -0.3, corrosion will occur by leaching the calcium from material.

2.4 Degradation

2.4.1 General Remarks

Callister and William (2003) state that deteriorative mechanisms are different for the three types of materials (metals, ceramics and plastics). In metals there is material loss either by dissolution (corrosion) or by the formation of a nonmetallic scale of film (oxidation). Ceramic materials are relatively resistant to deterioration. If deterioration does occur it happens at elevated temperatures or in extreme environments. The mechanism and consequences in the case of polymers are different from those of metals and ceramics, the process is most frequently described as degradation. Polymers can dissolve when exposed to a liquid solvent, or it may absorb the solvent and swell. Electromagnetic radiation and heat may also cause alternation in a polymers molecular structure.

2.4.2 Metals

2.4.2.1 *Electrochemical Nature of Corrosion*

In aqueous environments the majority of metallic corrosion processes are electrochemical. The reaction at the less stable anodic sites (A) on metal (M) (i.e. where there are dislocations, imperfections) can be explained by simple equation as below.

$$M(s) \rightarrow M^{n+}(aq) + ne^{-}(aq) \qquad (2.23)$$

The corresponding cathodic reaction occurs at the cathodic sites (C) at the metal/solution interface.

$$R(aq) + ne^{-}(s) \rightarrow R^{n-}(aq) \qquad (2.24)$$

The species R is an oxidsing agent in the solution that can receive electrons from the metal.

In the corrosion process, all the electrons produced by the anodic reaction move through the remaining sound metal to the cathodic site and are accepted by the oxidizing agent. The overall reaction of the corrosion process is given below.

$$M(s) + R(aq) \rightarrow M^{n+}(aq) + R^{n-}(aq) \qquad (2.25)$$

On the metal surface many short-circuited galvanic cells are set up. The metal will continue to dissolve in the presence of excess oxidant and this process is spontaneous as long as the equilibrium potential for $M(s)/M^{n+}(aq)$ is move negative than that of $R(aq)/R^{n-}(aq)$.

For copper the main anodic reaction is copper dissolution:

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e \qquad (2.26)$$

Several cathodic reactions can occur in aqueous solutions corresponding to the copper dissolution reaction. In acidic solutions containing oxygen the main cathodic reaction is:

$$O_2(aq) + 4H^+(aq) + 4e^-(s) \rightarrow 2H_2O(l) \quad (2.27)$$

In basic environments where there is sufficient oxygen, the following reaction occurs:

$$O_2(aq) + 2H_2O(l) + 4e^-(s) \rightarrow 4OH^-(aq) \quad (2.28)$$

2.4.2.2 *Forms of Corrosion*

The forms of corrosion in metals are as follows (Callister & William 2003, Schweitzer 1996).

Uniform Attack

This is a form of electrochemical corrosion that occurs with equal intensity over the entire exposed surface and often leaves behind a scale or deposit. Some examples include general rusting of steel and iron and the tarnishing of silverware.

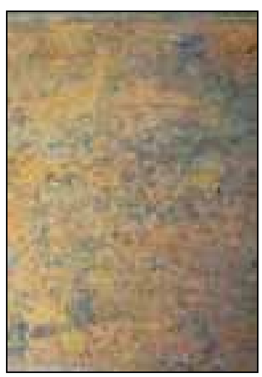

Figure 2.2: Uniform Corrosion (www.materialsengineer.com)

Galvanic Corrosion

This corrosion occurs when two metals or alloys with different compositions are electrically coupled while exposed to an electrolyte. For example, steel screws erode when in contact with brass in a marine environment.

Crevice Corrosion

Electrochemical corrosion can also occur as a consequence of concentration differences of ions or dissolved gases in the electrolyte solution, and between two regions of the same metal piece. This type of corrosion occurs in crevices and recesses or under deposits of dirt or corrosion products where the solution becomes stagnant and there is localized depletion of dissolved oxygen. The crevice must be wide enough for the solution to penetrate, yet narrow enough for stagnancy.

Figure 2.3: Crevice Corrosion (www.corrosion-doctors.org)

Pitting

This is another form of localized corrosion attack in which small pits or holes form. The pits or holes ordinarily penetrate from the top of a horizontal surface downward in nearly vertical direction. The mechanism for pitting is probably the same as for crevice corrosion in that oxidation occurs within the pit itself, with complementary reduction at the surface. Stainless steels are somewhat susceptible to this form of corrosion; however, alloying with about 2% molybdenum enhances their resistance significantly.

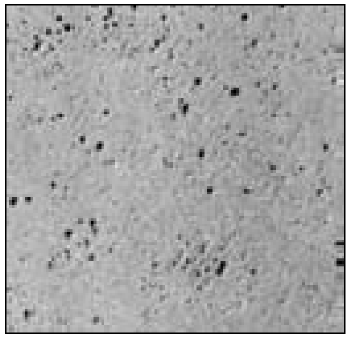

Figure 2.4: Pitting Corrosion (www.materialsengineer.com)

Intergranular Corrosion

This form of corrosion occurs preferentially along grain boundaries. The net result is that a macroscopic specimen disintegrates along its grain boundaries. This type of corrosion occurs a lot in stainless steels that are heated to temperatures between 500 to 800 ^{o}C for sufficiently long periods of time. This corrosion is an especially severe problem in the welding of stainless steels, which is often termed weld decay.

Figure 2.5: Intergranular Corrosion (www.corrosion-club.com)

Selective Leaching

This is found in solid solution alloys and occurs when one element or constituent is preferentially removed as a consequence of corrosion processes. An example of this corrosion is the dezincification of brass, in which zinc is selectively leached from a copper-zinc brass alloy.

Figure 2.6: Selective Leaching of Brass (www.corrosion-doctors.org)

Erosion-Corrosion

This arises from the combined action of chemical attack and mechanical abrasion or wear as a consequence of fluid motion. It is especially harmful to alloys that passivate by forming a protective surface film. Soft metals such as copper and lead are also sensitive to this form of attack. Erosion-corrosion can be identified by surface grooves and waves. This corrosion is commonly found in piping, especially at bends, elbows, and abrupt changes in pipe diameter.

Stress Corrosion

This can also be termed stress corrosion cracking, it results from the combined action of an applied tensile stress and a corrosive environment; both influences are necessary. Small cracks form and then propagate in a direction perpendicular to the stress, failure may eventually occur.

Oxidation

Oxidation occurs in gaseous atmospheres, normally air, wherein an oxide layer or scale forms on the surface of the metal. This is often termed scaling, tarnishing, or dry corrosion.

2.4.3 Ceramics

Ceramic materials are compounds between metallic and nonmetallic elements and therefore may be thought of as already having been corroded. Thus, ceramics are extremely immune to corrosion, although, the porosity of ceramics may greatly affect the corrosion resistance by providing a greater surface area for corrosion attack (Callister & William 2003, Schweitzer 1996). Corrosion generally occurs at elevated temperatures or in extreme environments

2.4.4 Plastics

The forms of degradation of polymers are as follows (Callister & William 2003).

Swelling and Dissolution

In swelling, the liquid or solute diffuses into and is absorbed by the polymer. As a result the polymer becomes softer and more ductile. Swelling may be considered to be a partial dissolution process in which there is limited solubility of the polymer in the solvent. Dissolution is when the polymer is completely soluble. In general, polymers are more resistant to attack by acidic and alkaline solutions than metals.

Callister and William's Table 17.4 (p595) lists selected plastic materials and their resistance to various environments. One of the environments is aqueous salt solutions and all selected materials show a satisfactory resistance to degradation in this environment.

Bond Rapture

Polymers may experience degradation by a process called scission. This is the severance or rupture of molecular chain bonds. This causes a separation of a chain segment at the point of scission and thus a reduction in the molecular weight. Consequently, some of the chemical and physical properties may be affected. Bond rupture may result from exposure to radiation or heat, and from a chemical reaction.

Weathering

Polymers that require exposure to outdoor conditions can be degraded by weathering. The primary deterioration is by oxidation, which is initiated by the ultraviolet radiation from the sun.

2.5 Tests:

2.5.1 Metals and Ceramics

There are three basic types of corrosion tests (Baboian 1995), laboratory, field and service test. The laboratory tests consist of electrochemical, cabinet, immersion and high-temperature and high-pressure tests. Field tests consist of atmospheric, seawater, freshwater and soils tests. Finally the service tests consist of testing of prototype components in the industrial environment. The type of test to perform is dependent on the way the material will be used in service. Field tests cannot be performed for all the contact points of MagnaBlu Minerals inside the domestic system therefore immersion laboratory tests will be performed as it is the most relevant and best simulates service environments.

The immersion test to be used in any particular application is mostly determined by the environmental conditions to be simulated, that is, if the material is immersed in service, then the test material should be immersed in the test; or if the material exposure is alternating immersion and atmospheric exposure, then a cyclic exposure test should be performed.

2.5.2 Plastics

Brown (1999) & Ives, Mead, & Riley's (1971) Handbooks for polymer and plastics testing set out procedures to test environmental effect and the effect of liquids, which is, swelling, chemical reactions , extraction of constituents of the materials, or all three. The test methods entail contact with the material expected to cause degradation, this is one of the method used for corrosion of metals and ceramics, which happens to be the test method that will be used.

2.6 Standards

Standard AS/NZS 4020:2005 looks at the suitability of the products for use in contact with drinking water. Although this standard does not directly relate to the testing of MagnaBlu Minerals it does indicate that any material in contact with drinking water will have to satisfy the test requirements in accordance with this standard and thus the tests performed in this standard will not be required.

Stain and Chemical Resistance:

- AS 3558.2 – 1999
- AS 4459.14-1999
- AS/NZS 4266.25:2004

These standards set out procedures for testing the stain resistance of certain materials; they also give the reagents to use. The project requires determination of the staining ability of MagnaBlu Minerals thus these standards give a guide to the test procedures to use when testing MagnaBlu Minerals. There are also international standards for stain resistance they are note referred to as the Australian Standards are technically equivalent to them.

Degradation:

- ISO 11130:1999
- ISO 175:1999
- ISO 4433-1:1997
- ISO 1817-2005

These standards set out procedures for testing effects of immersion in certain solutions; they also give the reagents to use for the immersion. The project requires determining the effects of MagnaBlu Minerals thus these standards give a guide to the test procedures to use when testing MagnaBlu Minerals.

The performance of advanced ceramics in aqueous environments is not well documented and thus the corrosion test procedures are not yet standardized (Schweitzer 1996).

2.7 Contact points in domestic system

McIntyre & Mercer (1993) discusses the corrosion of potable water supplies and in doing so details some of the materials used with potable water. The materials are only the materials that corrode which are some metals and some plastics. The World Health Organization (2006) also gives a brief overview of the materials found in pipes. Scott (2000) discusses all the composites and thermoplastics used in water handling. The full list of the materials found is in Appendix L.

The ActewAGL company website lists all the Australian standards covering water supply practice. ActewAGL is Australia's first multi-utility to offer electricity, natural gas, water and waste water services all under one roof. The ActewAGL list the following Australian standards relating to water supply. These standards state many of the materials used in water supply.

Materials DICL pipes and fittings:

AS 1646:	Elastomeric Seals for Waterworks Purposes (1992)
AS 2280:	Ductile Iron Pressure Pipes and Fittings (1995)
AS 3680:	Polyethylene Sleeving for Ductile Iron Pipelines (1989)
AS 3681:	Guidelines for Application of Polyethylene Sleeving to Ductile Iron Pipes and Fittings (1989)

Materials PVC pipes:

AS/NZS 1477:	PVC Pipes and Fittings for Pressure Applications (1996)
AS/NZS 4441 (Int):	Molecular Orientated PVC (PVC-O) Pipes for Pressure Applications (1996)
AS/NZS 4765 (Int):	Modified PVC (PVC-M) Pipes for Pressure Applications (2000)

Materials PE pipes:

AS/NZS 4129 (Int):	Fittings for Polyethylene (PE) Pipes for Pressure Applications (1997)
AS/NZS 4130:	Polyethylene (PE) Pipes, Pressure Applications (1997)
AS/NZS 4131:	Polyethylene (PE) Compounds for Pressure Pipes and Fittings (1997)

Materials steel pipes and specials:

AS 1281:	Cement Mortar Lining of Steel Pipes and Fittings (1993)

AS 1548: Steel Plates for Pressure Equipment (1995)

AS 1579: Arc Welded Steel Pipes and Fittings for Water and Waste Water

AS 1646: Elastomeric Seals for Waterworks Purposes (1992)

AS/NZS 3678: Structural Steel-Hot Rolled Plates, Floorplates and Slabs (1996)

AS 4087: Metallic Flanges for Waterworks Purposes (1996)

AS 4321: Fusion-Bonded Medium Density Polyethylene Coating and Lining for Pipes and Fittings (1995)

Valves and miscellaneous:

AS 1432: Copper Tubes for Plumbing, Gasfitting and Drainage Applications (1996)

AS 1628: Water Supply Copper Alloy Gate, Globe or Non-Return Valves (1994)

AS 2528: Bolts, Studbolts and Nuts for Flandes and other High and Low Temperature Applications (1982)

AS 2638: Sluice Valves for Waterworks Purposes (1991)

AS 3578: Cast Iron Non-Return Valves for General Purposes (1991)

AS 4087: Metallic Flanges for Waterworks Purposes (1996)

2.8 Previous Work Done on Tap water Interaction with Materials

There have been many journal articles about corrosion of materials from tap water. These articles look specifically at a certain material and their behaviour under exposure to a particular water chemistry. Although not all of the material in the articles are relevant to this topic is does provide important background on corrosion for a range of materials.

Kim & Shim tested the influence of copper products on the corrosion behaviour of copper in potable water distribution systems. It was investigated using electrochemical impedance spectroscopy (EIS) and X-ray photoelectron spectroscopy (XPS). They found that copper experienced only uniform corrosion and as the protective oxide film thickened, it did not separate from the copper surface. Another article involving copper is written by Scanchez and Valcare where a comparative analysis of copper and brass surface films was performed. The corrosion behaviour of copper in neutral tap water has also been investigated by Feng and Hsieh.

Low carbon steel has been shown to corrode in contact with tap water which has been investigated by Jae-Joo, Jung-Gu & Yoon-Seok. Another metal to corrode in tap water is lead. Elboujdaini & Perumareddi have investigated the corrosion of lead by studying the inhibition of the release of lead into tap water owing to galvanic corrosion of lead solders. The effect of soft tap water chemistry on fatigue crack growth of steel has been investigated by Alawi and Alhaiji. The results obtained showed that by changing the Langelier index from negative values to positive values, the fatigue crack growth rate is reduced. The results have also shown that as long as the Langelier index is greater than 0.3, both uniform and localized corrosion tendencies are reduced.

The degradation of plastic pipes can be tested through oxidation induction time tests and this can be used to perform an assessment on the lifetime of the pipes. The test has been performed for poly(1-butene) and polyethylene pipes with the results found by Badowski & Bigg and Gedde & Viebke respectfully. The theory behind an OIT test is that is measures the ability of a material to resist oxidation. In the OIT test, the test sample is heated under an inert nitrogen atmosphere until thermal equilibrium is achieved. At the point, the nitrogen is flushed from the system and pure oxygen is introduced. The time is then monitored until the exothermic oxidation reaction is observed. Short times before oxidation occurs indicate a strong propensity to oxidation. When a polymer contains an antioxidant a short OIT time indicates that the antioxidant is either ineffective, been consumed, or has been lost (Badowski & Bigg). The OIT is performed after the specimen has been in contact with the water

Chapter 3

MagnaBlu Minerals Contact Points

The contact points of MagnaBlu Minerals refer to the materials inside a domestic system which may come into contact with MagnaBlu Minerals. Below is a preliminary list of the materials MagnaBlu Minerals may come in contact with in a domestic system (McIntyre & Mercer 1993, Scott 2000, World health organization 2006).

- ABS (Acrylonitrile butadiene styrene)
- PVC (Polyvinyl Chloride)
- CPVC (Chlorinated Polyvinyl Chloride)
- FEP (Fluorinated ethylene propylene)
- PS (Polystyrene)
- PP (Polypropylene)
- PE (Polyethylene)
- Polycarbonate
- Copper
- Stainless Steel
- Galvanized Steel
- Aluminum
- Galvanized Iron
- Brass
- PTFE
- Rubber
- Vinyl
- Nylon
- Porcelain
- Glass
- Ceramic
- China

- Teflon coating
- Laminate
- Pine
- Plywood
- Marble
- Quartz
- Concrete
- Acrylic
- Fiberglass
- Brick (all types)

For the full list of contact points and the materials associated with each point refer to Appendix J.

The materials that are to be tested for the interaction with MagnaBlu Minerals are listed below:

- Ceramic
- Porcelain
- Acrylic
- Brass
- Copper
- ABS
- Polycarbonate
- Fibreglass
- Glass
- Vinyl
- Nylon
- Pine
- Plywood
- Concrete
- Marble
- Granite

- Clay Brick

These materials have been chosen in consultation with Poolrite Research. They were chosen as they are frequently used in a domestic system and are the best representatives for all of the materials. All the possible materials could not be tested as this is a preliminary test of MagnaBlu Minerals and time restrictions did not allow for complete testing of all possible materials.

Chapter 4

Tests

4.1 General Remarks

The tests are based on standards referenced in the procedure or on internal Poolrite procedures which have been developed by the company in close collaboration with their customers. The full test procedures can be found in Appendix A-I. These tests will not take into account the concentration of MagnaBlu Minerals after it leaves the water tank and enters the house, the test will be performed using MagnaBlu Minerals levels found in the pool and a concentrated version of the MagnaBlu Minerals that will be found in the rainwater tank. The pool levels are much higher than the levels that will be found in the rainwater tank, thus the tests are a worst case scenario of exposure to MagnaBlu Minerals.

4.2 Test 1: MagnaBlu Minerals Composition

This test is performed to give a breakdown of the main constituents of the concentrated form of MagnaBlu Minerals. The composition of MagnaBlu Minerals may be used to indicate sources of possible effects to a domestic system.

The principle of the test is; a sample of the concentrated form or pure MagnaBlu Minerals is collected in a sample bottle. The bottle is then sent away to ALS labs and tested for composition. The results will be received from the lab and then analyzed and compared to tap water and rainwater.

4.3 Test 2: Hardness Level of MagnaBlu Minerals

The hardness level test is performed to identify the hardness level of MagnaBlu Minerals. The level of hardness will help indicate the results expected for test 4: The lather test. The higher the level of hardness of the water the harder it is to form suds or lather. Hard water can also cause limescale buildup in pipes which increases household energy bills. Hard water is also considered to have a detrimental affect on cloths causing them to look dingy and feel harsh and scratchy. Hard water can cause spotting and film to form on the crockery and pots.

The principle of the test is; the hardness level of the MagnaBlu Minerals will be determined following the instructions provided in the Palintest manual (Appendix C5.2.2). The hardness level will be found for all the tests using the pool water concentration.

4.4 Test 3: pH Level of MagnaBlu Minerals

This test is performed to identify the pH level of MagnaBlu Minerals. This test will give more information about MagnaBlu Minerals and the effects it could have in a domestic system. The effects include corrosion which can be accelerated by a high pH and a low pH.

The principle of the test is; the pH level of the MagnaBlu Minerals will be determined following the instructions provided in the Palintest manual, the pH will be determined for each sample of MagnaBlu Minerals used.

4.5 Test 4: Lather Test

This test is performed to identify if MagnaBlu Minerals is suitable for use with washing procedures in a domestic system. The higher the level of hardness the fewer suds will form and thus the less suitable MagnaBlu Minerals is to use for washing and cleaning. This test was designed to the specifications of the company procedure.

The principle of the test is; a test container is filled with 2 litres of MagnaBlu Minerals, and then 25mL of detergent is added. The suds will be produced by scrubbing two pieces of cloth together similar to hand washing cloths. The test will also be performed with normal tap water as a reference for the amount and quality of suds produced.

4.6 Test 5: Stain Test

This test is performed to identify the suitability of MagnaBlu Minerals for use in the bathroom, kitchen and any place or surface in the domestic system that could stain or be discoloured. If MagnaBlu Minerals shows a sign of a stain on any material it would not be recommended for use in a domestic system.

The principle of the test is; surfaces that are found around the home are to be half submerged in concentrated MagnaBlu Minerals for a duration of 24h. On completion of the test the final results will be recorded and analyzed.

This test was adapted from the Australian standards[5, 6, 7] for stain testing of certain materials. In the standards the specific reagents for use in the testing of stains are listed and MagnaBlu Minerals does not form a part of this list of reagents. Thus the procedure was followed but instead of using the given reagents MagnaBlu Minerals was used.

Below are some examples of the materials to be used in the stain test and the degradation test.

Figure 4.1: Marble

Figure 4.2: Ceramic tile

Figure 4.3: ABS plastic

Figure 4.4: Brass

Figure 4.5: Vinyl Flooring

4.7 Test 6: Degradation and Precipitation Test

The degradation test is only a preliminary qualitative test to visually examine if degradation occurs in the materials tested. An immersion test was performed as it best simulates the operating conditions of the materials found in a domestic system. This test specifically targets certain types of corrosion and degradation. The test simulated the stagnant conditions needed for crevice, pitting and selective leaching corrosion.

The principal of the test; materials found in a domestic system have been submerged in MagnaBlu Minerals for 14 days to test for degradation. After the test was complete the materials were analyzed for any signs of degradation by the assessment criteria of appearance after the test as specified in ISO 11130. The test also involved washing certain materials in MagnaBlu Minerals and drying them one way by cloth and the another way by heat lamp, this simulates washing dishes in the domestic system and will indicate if this will cause unwanted precipitates or degradation.

4.8 Test 7: Elastic Material Test

MagnaBlu Minerals may cause elastic materials, such as that used in O ring material, to lose their elasticity and become brittle. The purpose of this test is to perform a preliminary test on a standard O ring and examine the effect of immersion in MagnaBlu Minerals. The effect is studied through mass, dimensions and appearance changes as set out in standard ISO 1817 and ISO 175.

The principle of the test is; a number of rubber O rings will be submerged in MagnaBlu Minerals for a period of 14 days. An O ring was removed after 3 days, 6 days, 10 days and 14 days and the effect was tested.

4.9 Test 8: High Temperature Test

When temperatures are raised precipitates such as calcium carbonate, a reverse soluble salt, are formed more readily. This test is used to predict the effects in household items in contact with heated water such as a kettle or hot water pipe. The test found the likelihood of items becoming encrusted with precipitates, particularly calcium carbonate.

The principle of the test is; an amount of MagnaBlu Minerals will be heated up to 100^{o}C in a glass beaker. At specific temperatures observations will be made on the appearances of the MagnaBlu Minerals and if precipitates are visible.

Chapter 5

Results and Discussion

5.1 Test 1: MagnaBlu Minerals Composition

The procedure found in Appendix B was followed without incident and the results were obtained from ALS labs.

5.1.1 Results and Observations

Table 5.1: Composition of pure MagnaBlu Minerals Results Table

Element	%w/w
Calcium	0.0061
Magnesium	8.4
Sodium	2.14
Potassium	3.41
Arsenic	0.0000015
Cadmium	0.0000001
Chromium	0.0000135
Copper	0.000013
Lead	0.000001
Nickel	0.000004
Zinc	0.0000263
Mercury	0.00000001
Chloride	23.6
Sulphate as SO4 2-	6.22

Below is a sample of tap water composition (Table 5.2) and a sample of rainwater composition (Table 5.3).

The tap water composition is from the Brisbane city councils water quality analysis performed in January 2007.

Table 5.2: Chemical Analysis MT Crosby January 2007 (Brisbane City Council)

Parameter	Units	Max	Min	Average	NHMRC*
pH		8.1	7.9	8	6.5-8.5
TDS	mg/l	306	294	300	500
Alkalinity	mg/l	92	87	90	
Langelier Index		0	-0.2	-0.1	
Calcium Hardness	mg/l	55	50	53	
Aluminium	mg/l	0.096	0.055	0.073	0.2
Arsenic	mg/l	NT	NT	NT	0.007
Barium	mg/l	0.031	0.028	0.029	0.7
Cadmium	mg/l	<0.001	<0.001	<0.001	0.002
Calcium	mg/l	22	20	21	
Chloride	mg/l	77	73	75	250
Chromium	mg/l	<0.002	<0.002	<0.002	0.05
Copper	mg/l	0.002	<0.001	0.001	1
Iron	mg/l	0.019	<0.01	<0.01	0.3
Lead	mg/l	<0.01	<0.01	<0.01	0.01
Magnesium	mg/l	16	15	16	
Manganese	mg/l	0.008	0.006	0.007	0.1
Mercury	mg/l	NT	NT	NT	0.001
Nickel	mg/l	<0.002	<0.002	<0.002	0.02
Orthophosphate	mg/l	0.008	0.004	0.006	
Potassium	mg/l	4.5	3.8	4.2	
Silica	mg/l	2.9	2.6	2.8	
Sodium	mg/l	47	42	44	180
Sulphur	mg/l	24	21	22	250
Zinc	mg/l	<0.001	<0.001	<0.001	3

* National Health & Medical Research Council's Australian Drinking Water Guidelines

The rainwater quality comes from a test undertaken by Coombes, Kuczera, Kalma and Dustan from the University of Newcastle, New South Wales

Table 5.3: Rainwater quality at Figtree Place (Coombes & Dunstan)

Parameter	Units	Max	Min	Average	Guidelines
pH		6.4	5.5	5.95	
Dissolved solids	mg/l	34	8	21	500
Suspended solids	mg/l	8.4	8.4	8.4	500
Sodium	mg/l	9.9	9.9	9.9	180
Calcium	mg/l	2	2	2	200
Chloride	mg/l	14.6	0.46	7.53	250
Nitrate	mg/l	0.2	<0.1	0.15	3
Nitride	mg/l	0.7	<0.1	0.4	50
Sulphate	mg/l	5.3	1.7	3.5	250
Ammonia	mg/l	0.39	0.2	0.295	0.5
Lead	mg/l	0.015	<0.01	<0.01	0.01
Iron	mg/l	<0.01	<0.01	<0.01	0.3
Cadmium	mg/l	<0.002	<0.002	<0.002	0.002

5.1.2 Discussion

The concentrated form of MagnaBlu Minerals consist of about 35% salts, the solution will be diluted down to about 0.3% salts when it is in the pool, from here it will be diluted again when it enters the rainwater tank. Therefore the concentrated MagnaBlu Minerals will be diluted down by over a factor of 100 before it is mixed with rainwater. Because of this dilution MagnaBlu Minerals should be below the salt levels acceptable in the Drinking Water Guidelines[3]. To be sure further tests should be performed on the combination of rainwater and MagnaBlu Minerals.

The main constituents of MagnaBlu Minerals are Magnesium, Sodium and Potassium. Comparing with tap water of which the main constituents are Magnesium, Sodium and Calcium it can be seen that the only difference in the main constituents is Calcium instead of Potassium in the tap water. The concentrated form of MagnaBlu Minerals is diluted with tap water when the pool is filled, this would lead to the main constituents of the MagnaBlu Minerals becoming Magnesium, Sodium and Calcium. The Calcium will take the place of the Potassium as there is a low level of Potassium in the tap water.

The MagnaBlu Minerals in concentrated form is acidic, listed in Table 5.5, by the time it is diluted down to the pool concentration it is basic, also listed in Table 5.5. The example of rainwater shows that rainwater can be acidic therefore the mixed solution of rainwater and MagnaBlu Minerals could be acidic or alkaline depending on the rainwater in the specific collection region.

In the example of rainwater it can be seen that is has a low level of dissolved solids. This indicates that a fairly large amount of MagnaBlu Minerals can be added before the guideline is reached. The levels of all constituents in the rainwater are actually quite low, this indicated that the rainwater will not affect the MagnaBlu Minerals too greatly when they are mixed, it will simply diluted it and only slightly add to certain constituents.

5.1.3 Sources of Errors

The MagnaBlu Minerals could have been contaminated before collection from the barrels. This contamination could affect the composition of the MagnaBlu Minerals and thus affect the results of the test.

The sample bottle was washed thoroughly before the sample was taken as per Appendix B. The possibility of the sample being contaminated is negligible.

On arrival to the ALS lab the sample could have been contaminated unintentionally. The sample could also have been tested incorrectly by the lab. Errors could also have occurred when the data sheet of the results was being prepared ready to be sent back. These scenarios of possible errors from the lab are unlikely to have occurred as ALS labs are a reputable lab and Poolrite has used them on many occasions.

5.2 Test 2: Hardness Level of MagnaBlu Minerals

5.2.1 Results and Observations

The instructions of the test procedure found in Appendix C5.2 were followed with no difficulties arising.

Table 5.4: Hardness Level Results Table

Test Waters	Hardness Level
Test 4 - Normal	71
Test 5 - Normal	61
Test 5 - 2nd - Brass - Normal	60
Test 8 - Normal	33
Average	56.25
Average without Test 8	64

Note: The night before the test water for test 8 was taken out of the pool there was rainfall.

Test 5 was repeated for Brass for the reason given in section 5.5.1.

5.2.2 Discussion

The hardness level seemed to be affected by rainfall into the pool as when rainfall was recorded the hardness of the water record was below the average. The hardness level could have been affected by other influences such as new chlorinators being installed or when the pool was topped up the concentration of MagnaBlu Minerals could have been miscalculated.

On average the hardness level of the pool without any abnormal reading is about 64 mg/l. This is only slightly higher than the hardness level recorded in Brisbane tap water.

The hardness level recorded for Test 4 was the highest level recorded which indicates that it might be difficult to produce a good lather in the MagnaBlu Minerals used for that test. The results also suggest that lather will be harder to form in the MagnaBlu Minerals than in the tap water.

The hardness level of the MagnaBlu Minerals after it has been backwashed and been in the holding tank may be vary different than the hardness level recorded in the pool. In the future tests should also be performed on the MagnaBlu Minerals found in the holding tank to have a complete understanding of the behaviour of MagnaBlu Minerals and what characteristics it will have when it is mixed with the rainwater.

5.2.3 Sources of Errors

The sample bottle was washed thoroughly before the sample was taken as per Appendix C. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

The measurement of the values using the photometer may be inaccurate from the inaccuracies of the photometer and the glass tubes used. The accuracy of the photometer is ±0.5mg/l for the hardness level test. The glass test tubes used with the photometer are accurate to ±0.1mL. The photometer was fully calibrated before the tests and these inaccuracies are the same for each test of the hardness level.

5.3 Test 3: pH Level of MagnaBlu Minerals

The instructions of the test procedure found in Appendix D5.2 were followed with no difficulties arising.

5.3.1 Results and Observations

Table 5.5: pH Level Results Table

Test Waters	pH
Test 4 - Normal	7.75
Test 5 - Normal	8.25
Test 5 - 2nd - Brass - Normal	8.35
Test 6 - Concentrated	6.2
Test 6 - Normal	7.75
Test 7 - Concentrated	6.2
Test 8 - Normal	8.25
Average Not Including Tests 6& 7	8.07

The pH of the test pool did vary from day to day which is an event that does happen in every pool. Although it does change the pH does usually sit above 8.

5.3.2 Discussion

The pH of a normal domestic pool will experience change and in a well maintained pool this change should not be great. This change in pH may affect the water that eventually goes into the house although with the mixing with rainwater the affect should be minimal.

The pH of the MagnaBlu Minerals after it has been backwashed and been in the holding tank may be vary different than the pH recorded in the pool. Tests should be performed on the MagnaBlu Minerals found in the holding tank to have a complete understanding of the behaviour of MagnaBlu Minerals and what characteristics it will have when it is mixed with the rainwater.

5.3.3 Sources of Errors

The sample bottle was washed thoroughly before the sample was taken as per Appendix D. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

The measurement of the values using the photometer may be inaccurate from the inaccuracies of the photometer and the glass tubes used. The accuracy of the photometer is ±0.005 for the pH level test. The glass test tubes used with the photometer are accurate to ±0.1mL. The photometer was fully calibrated before the tests and these inaccuracies are the same for each test of the pH level.

5.4 Test 4: Lather Test

The lather test was performed according to the procedure set out in Appendix E8. The experiment was performed without contamination from foreign materials or rainwater.

5.4.1 Results and Observations

The results obtained by the lather test are listed in Table 5.6 below.

Table 5.6: Lather Test Results Table

Solutions	Rating
MagnaBlu Minerals with dishwashing liquid	3
MagnaBlu Minerals with hand soap	3
Tap water with dishwashing liquid	4
Tap water with hand soap	4

Where

- rating 3 is 50-75% surface coverage of suds
- rating 4 is 75-100% surface coverage of suds

It was observed that overall suds production in the MagnaBlu Minerals was slightly more difficult to produce than in normal Brisbane tap water. It was also noted that the time it took to produce suds was longer in the MagnaBlu Minerals than in the tap water.

Figure 5.2 shows the amount of suds produced in the MagnaBlu Minerals with the dishwashing liquid and Figure 5.4 shows the amount of suds in tap water with the dishwashing liquid. As can be seen there is a larger amount and larger bubbles formed in the tap water compared to the bubbles in the MagnaBlu Minerals.

Figure 5.3 shows the amount of suds produced in the MagnaBlu Minerals with the hand soap and Figure 5.5 shows the amount of suds in tap water with the hand soap. As with the dishwashing liquid there is a larger amount and larger bubbles formed in the tap water compared to the bubbles in the MagnaBlu Minerals.

The amount of suds produced in the test is shown in the following pictures.

Figure 5.1: Water without Detergent

Figure 5.2: MagnaBlu Minerals with Dishwashing liquid

Figure 5.3: MagnaBlu Minerals with Hand soap

Figure 5.4: Tap water with dishwashing liquid

Figure 5.5: Tap water with hand soap

5.4.2 Discussion

The hardness level or calcium hardness of normal Brisbane tap water is around 53 mg/l and the hardness level of the MagnaBlu Minerals is 71 mg/l thus MagnaBlu Minerals has a higher hardness level and it is expected that suds would be more difficult to produce. Although it is more difficult, it is not impossible to produce a good amount of suds, therefore when washing in MagnaBlu Minerals a large amount of scum would not be formed. If a large amount of scum is formed it hinders the washing process such that the object does not become clean.

The detergents used are everyday household detergents and while some detergents may produce more suds than others this test use the same detergent in both the MagnaBlu Minerals and the tap water. Therefore the comparison between them is based on the amount of suds from the same detergent. Different detergents may produce more suds in the MagnaBlu Minerals than the detergents used in this test but the aim of this test was to identify the difference in lather between MagnaBlu Minerals and tap water.

It should be noted that the pool concentration of MagnaBlu Minerals is not the concentration that will eventually be entering into the domestic system. The MagnaBlu Minerals will be mixed with rainwater which will in effect dilute the MagnaBlu Minerals and thus lower the hardness level and increase the ability to produce lather.

5.4.3 Sources of Errors

The test container was washed thoroughly before the sample was taken as per Appendix E. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

The cloth being used to produce the suds may have foreign material on them that could interfere with the results. The cloth wash washed prior to the test removing any dirt or such material from them. This being a suds test, dirt or anything as such would not interfere with the test results as the results depend on the hardness level of the MagnaBlu Minerals. Therefore baring anything that could increase or decrease this level the test would be difficult to contaminate.

The hardness level test indicated the expected results for the later test therefore the error associated with the hardness level test should be mentioned. The measurement of the values using the photometer may be inaccurate from the inaccuracies of the photometer and the glass tubes used. The accuracy of the photometer is ±0.5mg/l for the hardness level test. The glass test tubes used with the photometer are accurate to ±0.1mL. The photometer was fully calibrated before the tests and these inaccuracies are the same for each test of the hardness level.

5.5 Test 5: Stain Test

The stain test was performed according to the procedure set out in Appendix F. There was no interruption to the experiment from outside sources such as rainwater contamination.

5.5.1 Results and Observations

The results obtained from the stain test are in Table 5.7.

Table 5.7: Stain Test Results Table

Container	Stain Rating
1	1
2	1
3	1
4	1
5	Inconclusive
5 – 2nd	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1

Where

- rating 1 is no visible sign of a stain on the material surface

On inspection of each material surface there was no sign of a stain. Although it was observed that after the brick dried there was a chalky deposit left on the surface which was removed by wetting the surface again and drying with a cloth.

Test 5 was performed again for Brass because the first test was inconclusive such that it could not be deduced if the effect was a stain or some form of corrosion. Before the second test the Brass was chemically cleaned instead of just clean with tap water. This method of cleaning clarified the test results and it was clear that there was no stain left from the MagnaBlu Minerals.

5.5.2 Discussion

With no observed stains on any material it can be assumed that MagnaBlu Minerals does not contain any constituent that is likely to stain surfaces inside a domestic system.

The first stain test on the Brass showed an effect on the surface of the Brass. The effect could not be deduced from first inspection thus the test was performed again with the results that no stain was seen on the surface. The hardness level and the pH of the MagnaBlu Minerals found in Table 5.4 and Table 5.5 were within the normal range and are not to have been expected to contribute to the inconclusive result of the first test with Brass. It can be assumed that the effect witnessed in the first test was a form of corrosion of the metal or possibly foreign material on the surface of the metal.

The chalky deposit left on the surface of the brick is most likely the dissolved salts in the MagnaBlu Minerals which have been left behind after the water has evaporated from the MagnaBlu Minerals.

5.5.3 Sources of Errors

The test container was washed thoroughly before the sample was taken as per Appendix F. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

Foreign material may be present on the surface of the material to be test. This material could act as a barrier preventing proper contact between the test material and the MagnaBlu Minerals.

Although highly unlikely someone could have tampered with the test by removing the aluminium foil cover on the containers for a short period of time allowing a contaminant, such as rainwater, into the test contain. During the duration of the test there was no recorded rainfall in the area.

The MagnaBlu Minerals could have been contaminated before collection from the test pool, that is, a staining agent could have been introduced. This contamination could affect the composition of the MagnaBlu Minerals and thus affect the accuracy of the results.

5.6 Test 6: Degradation and Precipitation Test

The degradation and precipitation test was performed according to the procedure set out in Appendix G. There was an interruption to the experiment from outside sources this was rainwater on the last night of the test, the aluminium foil was blown off the container and water could get in. Since this happened the last night of the test and a small amount of rainfall was recorded the effects can be neglected.

5.6.1 Results and Observations

The results obtained from the preliminary degradation test of the selected materials are listed in the Table 5.8 below.

Table 5.8: Degradation Test Results Table

Container	Rating of Degradation
1	1
2	1
3	1
4	5
5	1
6	1
7	1
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	5

Where

- rating 1 is 0-20% surface degradation
- rating 5 is 80-100% surface degradation

As can be seen in the Table the only materials to show any sign of degradation was the copper and the brass. These two materials being metals were the most likely to degrade as metals corrode readily when in aqueous environments (Butler & Ison).

The following pictures show the effect to Brass after immersion in MagnaBlu Minerals.

Figure 5.6: Brass

Figure 5.7: Brass after Test 6

The small section is the section that was immersed in the MagnaBlu Minerals. It is extremely visible that the Brass has been corroded indicating further tests should be performed to identify the rate at which it will corrode and time to sample failure.

The results obtained from the precipitation test of drying dishes are listed in Tables 5.9 and 5.10 below.

Table 5.9: Precipitate Test Results Table Dying Method 1

	Wash									
Cup or mug	1	2	3	4	5	6	7	8	9	10
Glass Cup	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75
China Mug	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45

The mass measurements are made in grams.

There was no sign of anything on the surface of the cup or mug after any time they were washed and dried by a tea towel.

Table 5.10: Precipitate Test Results Table Dying Method 2

	Wash									
Cup or mug	1	2	3	4	5	6	7	8	9	10
Glass Cup	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75	208.75
China Mug	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45	166.45

The mass measurements are made in grams.

There was no sign of anything on the surface of the cup or mug after any time they were washed and dried by the heat.

5.6.2 Discussion

The primary test for signs of visible degradation has shown that most materials are not affected by MagnaBlu Minerals. The only materials to show signs of degradation are metals. Metals are easily corroded and are already found to corrode when in contact with tap water in a domestic system. There is corrosion prevention methods employed in domestic systems which should prevent most forms of corrosion. Therefore if MagnaBlu Minerals was to enter a domestic system the corrosion effect experienced should not be any different then that experienced with normal tap water.

This test only examined if a material was visible degraded and not what type of degradation occurred. To find the type of degradation further tests should be performed.

The pH of the concentrated for of the MagnaBlu Minerals, found in Table 5.5, is acidic and could possible effect the materials different than the normal pH level of MagnaBlu Minerals. Corrosion is only generally accelerated when the pH is at extreme low or extreme high thus for this test it is assumed that the pH is not in the range to affect the rate at which the material is corroded. To find the rate at which a material will corrode further tests will need to be performed factoring in a change in pH level.

MagnaBlu Minerals has been used in the test pool for over a period of 9 months and there has been no sign of degradation of the pool material or pipe material used. This indicates that the results obtained from the preliminary degradation test are consistent with a real life situation.

The precipitate on the dishes test results were positive as they showed that if MagnaBlu Minerals is used to wash dishes there will not be a visible or measurable residue left once the dishes had dried. The MagnaBlu Minerals for this test was of pool concentration and thus are a great deal higher in salts than that found in the rainwater tank thus it can be assumed that if this concentration of MagnaBlu Minerals does not leave a residue after contact then the diluted version that will be introduced into the house will also not leave a residue.

5.6.3 Sources of Errors

The test container was washed thoroughly before the sample was taken as per Appendix G. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

Estimating the amount of the area effect by the MagnaBlu Minerals could have been inaccurate by ±10%. The balance used to measure the glass and mug also has an inaccuracy, this value is ±0.005g.

Foreign material may be present on the surface of the material to be test. This material could act as a barrier preventing proper contact between the test material and the MagnaBlu Minerals.

Although highly unlikely someone could have tampered with the test by removing the aluminium foil cover on the containers for a short period of time allowing a contaminant, such as rainwater, into the test contain. The aluminium foil was removed from certain containers during the test but the believed cause of this was strong wind. There last night of the test rainwater was able to enter some test containers although the amount of rain was insignificant and the effect can be neglected.

The MagnaBlu Minerals could have been contaminated before collection from the test pool. This contamination could affect the composition of the MagnaBlu Minerals and thus affect the results of the test.

5.7 Test 7: Elastic Material Test

The elasticity test was performed according to the procedure set out in Appendix F. There was no known interruption to the experiment from outside sources such as rain water or human interference.

5.7.1 Results and Observations

The elasticity test results are listed in Table 5.11 below.

Table 5.11: Elastic Material Test Mass Results Table

Duration	Mass (g)
0 Days	0.30
3 Days	0.30
6 Days	0.30
10 Days	0.30
14 Days	0.30

Table 5.12: Elastic Material Test Dimension Results Table

Duration	Inner Diameter (mm)	Outer Diameter (mm)
0 Days	12	17
3 Days	12	17
6 Days	12	17
10 Days	12	17
14 Days	12	17

Table 5.13: Elastic Material Test Colour Change Results Table

Duration	Rating
0 Days	1
3 Days	1
6 Days	1
10 Days	1
14 Days	1

Change in mass:

Δm = amount of liquid absorbed if positive and amount of material lost is negative

$\Delta m = m_2 - m_1$

$m_1 = 0.3g$, $m_2 = 0.3g$

$\Delta m = 0g$

The mass was measured as the same value on all the test days therefore the calculation for the change in mass is the same for all days also resulting in the same change in mass (0g).

For percentage change in mass:

$$\frac{m_2 - m_1}{m_1} * 100 = 0\%$$

The percentage change is the same for all test days therefore the calculation is the same for all.

Change in dimensions:

ΔL_i = change in length of inner diameter

$\Delta L_i = L_2 - L_1$

$L_1 = 12mm$, $L_2 = 12mm$

$\Delta L_i = 0mm$

The inner diameter was measured as the same value on all the tested O rings; therefore the calculation for the change in length is the same for all (0mm).

ΔL_o = change in length of outer diameter

$\Delta L_o = L_2 - L_1$

$L_1 = 17mm$, $L_2 = 17mm$

$\Delta L_o = 0mm$

The inner diameter was measured as the same value on all the tested O rings; therefore the calculation for the change in length is the same for all (0mm).

5.7.2 Discussion

The results of this test are not intended to give any direct correlation with service conditions in view of the wide range of variations in temperatures and water composition.

The results for the change in mass throughout the testing showed no absorption of the MagnaBlu Minerals or loss of material from the O ring. This suggests that there is no effect on the O ring material from immersion in MagnaBlu Minerals. With no change in mass it could also be assumed that it is unlikely a change in the volume would be experienced.

The results for the change in length of the O ring found that there was no change. This indicates that the MagnaBlu Minerals did not affect the material of the O ring. Although the MagnaBlu Minerals did not affect the diameter the elasticity could have been affected although it is unlikely, further tests should be performed to verify this.

The pH of the concentrated MagnaBlu Minerals is 6.2 which is acidic and thus may affect the O ring differently than the water that will be found in the rainwater tank which is expected to have a pH above 7. Although the pH of the concentrated MagnaBlu Minerals is below 7 it is not considered to affect the interaction of MagnaBlu Minerals with the O ring material.

5.7.3 Sources of Errors

The test container was washed thoroughly before the sample was taken as per Appendix H. There was not addition of any foreign materials after the collection therefore the possibility of the sample being contaminated prior to the test is negligible.

As with the stain test and degradation test the test was performed outside in the Poolrite test pool area therefore the main source of an error is rainwater contamination. The aluminium foil placed and secured over the top of the test container was not damaged and did not appear to have let any water inside thus the contamination of rainwater is unlikely.

The balance used to measure the mass of the O rings has an inaccuracy which is a source of error. The error this value is ±0.005g. The calipers also have an inaccuracy of ±0.05mm.

The test container itself could have contributed to an error due to it degrading during the test. On completion of the test the container was inspected and compared to a new test container and there was no obvious sign of degradation and thus can be assumed did not affect the test in any way.

5.8 Test 8: High Temperature Test

The high temperature precipitation test was preformed according to the procedure set out in Appendix I. There were no difficulties or interruptions to the test.

5.8.1 Results and Observations

The results that were found when the test was performed are listed in the table below.

Table 5.14: High Temperature Test Results

	Rating		
Temperature	**Test 1**	**Test 2**	**Test 3**
20	1	1	1
40	1	1	1
60	1	1	1
80	1	1	1
100	1	1	1

Where

- rating 1 is 0-5g of precipitates

Throughout the test it was observed that there was no sign of any precipitates inside the glass beaker.

Saturation Index calculations:

Using equations 2.14, 2.18-2.22 the saturation index can be found using the following values found for Test 8.

pH = 8.25

TDS = 4828 (mg/l)

Ca^{2+} = 33 (mg/l)

Alkalinity = 195 (mg/l)

Temperature = 22°C

Therefore

$$A = (\log_{10}[4828] - 1)/10$$

$$A = 0.268$$

$$B = -13.12 * \log_{10}(22 + 273) + 34.55$$

$$B = 2.146$$

$$C = \log_{10}(33) - 0.4$$

$$C = 1.119$$

$$D = \log_{10}(195)$$

$$D = 2.29$$

Therefore

$$pH_s = (9.3 + A + B) - (C + D)$$

$$pH_s = 8.305$$

$$S.I. = pH - pH_s$$

$$S.I. = -0.06$$

This indicates that MagnaBlu Minerals at 22^{o}C will not precipitate Calcium Carbonate.

Assuming the only thing to vary when the temperature is raised is the temperature then the following graph shows the trend of the Saturation Index with increased temperature. The below results were obtained using the calculation above.

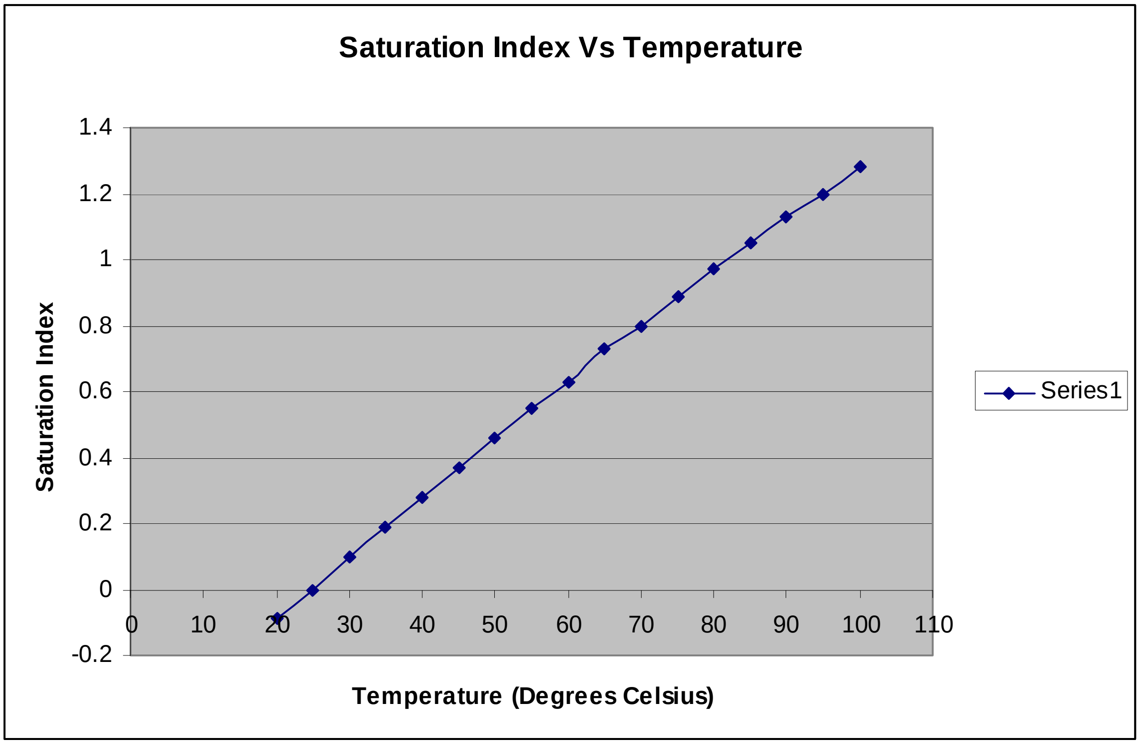

Figure 5.8: Saturation Index Graph

5.8.2 Discussion

The expected precipitates to form when the solution was heated are sparingly soluble salts such as Calcium Carbonate. There was no sign of precipitate formation throughout the entire test. Although this does not indicate results for a long period of time of exposure to the temperature it should have been enough time for precipitates to form. This indicates that when the MagnaBlu Minerals is heated in the domestic system it is unlikely to have undesired precipitates forming. The test does not take into account the flow of the water in pipes which may affect the precipitation rate or could cause precipitation to start. Further tests are required to determine the affect when the fluid is flowing and heated.

The hardness level of the MagnaBlu Minerals as per Table 5.3 was lower than normal. This could possible be attributed to the rainfall the night before the test was performed. A lower hardness level indicates a lower amount of calcium carbonate in the MagnaBlu Minerals thus it is less calcium carbonate to precipitate out upon heating. This may have contributed to no precipitates forming in the glass beaker when the temperature was raised.

As can be seen from Figure 5.8 Calcium Carbonate should have started to precipitate out at about 40^{o}C the reason for this may simple be that there was not enough Calcium Carbonate in the MagnaBlu Minerals. The results may be different for different hardness levels of MagnaBlu Minerals therefore further tests should be performed to determine the effects over long periods of time.

5.8.3 Sources of Errors

The test may have been affected by the inaccuracy of the glass beaker. The glass beaker is accurate to ±0.5mL.

The measurement of the values using the photometer may be inaccurate from the inaccuracies of the photometer and the glass tubes used. The accuracy of the photometer is ±0.005 for the pH, ±0.5mg/l for the Ca^{2+}, ±0.5mg/l for the alkalinity. The temperature reading accuracy is ±0.5^{o}C.

The TDS reading is ±0.5 mg/l accurate. Finally the glass test tubes used with the photometer are accurate to ±0.1mL.

The measurement of the precipitates may have been incorrect as the balance has slight errors. The accuracy of the balance is ±0.005g which could account for an error.

The temperature reading on the thermocouple has an error of ±0.5^{o}C. There was no indication that this error reading was increased wrong.

Chapter 6

Conclusions and Recommendations

6.1 Conclusions

MagnaBlu Minerals has been subjected to a number of testing procedures in order to assess its compatibility with materials and components in a domestic system.

The results have shown that MagnaBlu Minerals does not stain a representative range of materials found in the domestic system therefore it can be concluded that it is unlikely MagnaBlu Minerals will stain any material it could come into contact with in a domestic system.

MagnaBlu Minerals also performed at a satisfactory level in the lather assessment test but it is more difficult to produce lather with MagnaBlu Minerals than tap water. Therefore the conclusion on the lather test is that MagnaBlu Minerals can generally be substituted for tap water when washing. Once the MagnaBlu Minerals has mixed with rainwater the ability to produce lather will be much greater with possibly no difference to that of tap water.

The corrosion test found that some metal samples showed visual evidence of corrosion after immersion MagnaBlu Minerals. Metals are easily corroded when in aqueous environments and corrosion of metals is found for some metals with normal tap water. It has been concluded that when the water from the rainwater tank containing MagnaBlu Minerals enters the domestic system it will have a similar corrosive effect that is experienced with tap water.

If MagnaBlu Minerals is to be used to wash dishes in the domestic system it could leave a residue on the dish when it has dried. Preliminary testing has shown that there is very little evidence of a residue being left once MagnaBlu Minerals has dried on the surface of typical kitchenware. From these results it can be concluded that the concentration of MagnaBlu Minerals found in the rainwater tank will be safe to use when washing dishes due to that fact that the pool concentration left no residue thus a diluted version will also leave no residue.

A simple elastic material test was performed with the results suggesting that the O ring could perform in a similar way when subjected to MagnaBlu Minerals as would be the case for tap water. From the preliminary results it can be concluded that MagnaBlu Minerals can be used in contact with O rings and other elastic material with little effect. More testing is required though to be certain of the effect when the O ring is in use in the domestic system.

If MagnaBlu Minerals is heated theoretically it is expected that sparingly soluble salts such as Calcium Carbonate will precipitate out of the solution. Tests were performed to assess the effect of heating on MagnaBlu Minerals. The preliminary test found no evidence of precipitates after heating. This indicates that if MagnaBlu Minerals is heated in a typical domestic system excessive precipitation should not be expected. Once again more rigorous test should be performed to confirm this.

The preliminary analysis of the effects MagnaBlu Minerals has on a domestic system has shown there is little to no negative effects. The overall conclusion is that MagnaBlu Minerals can be used in a domestic system with no adverse effects on the materials it will come in contact with. More extensive analysis should be performed before implementation into a domestic system.

6.2 Recommendations

With the conclusions drawn from the project it is clear that from first inspection MagnaBlu Minerals could be used in a domestic system with little detrimental effect. The tests are only preliminary tests therefore I recommend that more tests should be performed. Tests should be especially performed on the corrosion of materials before the second phase of the MagnaPool system is implemented and MagnaBlu Minerals is put into the rainwater tank and then into the domestic system.

The evidence presented in this report of the corrosion of copper and brass indicates that more corrosion tests are required to determine the severity of the problem. The corrosion tests should investigate the rate at which materials corrode and the life expectancy of components. These tests should be performed with the different levels of concentration of MagnaBlu Minerals that may be found in the rainwater tank.

Plastics may not degrade when just simply immersed in MagnaBlu Minerals. But a study of the way plastics behaves when under stress and in contact with MagnaBlu Minerals needs to be performed. Tests that could be performed for plastics are oxidation induction time tests (OIT) which would give a life expectancy of the plastic.

Pipes can become encrusted with precipitates such as Calcium Carbonate and become clogged. Although the preliminary tests showed no precipitation was formed at elevated temperatures I think it is important to perform tests where the water is heated and flowing through a pipe as flow interactions may cause different effects.

Overall I recommend experiments to be performed to examine the lifetime expected for all materials that could be used in contact with MagnaBlu Minerals. Once the life expectancy has been found with MagnaBlu Minerals a comparison with the life expectancy of materials in contact with normal tap water should be performed. It is only after this long term testing is complete that it will be possible to determine whether MagnaBlu Minerals is fully compatible for use in a domestic system.

References:

1. Alawi, H. Alhaiji, J.N. & Reda, M.R. 1996, Effect of Soft Water Chemistry on Fatigue Crack Growth of Steel, Engineering Fracture Mechanics, vol. 53, iss.3, pp.387-398.

2. Atkins, P.W. & Beran, J.A. 1992, *General Chemistry*, Scientific American Books, New York, 416-417.

3. Australian Drinking Water Guidelines 2004, Australian Government – National Health and Medical Research Council, viewed 23 March 2007, <http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm>

4. *Australian Standards Covering Water Supply*, 2007, ActewAGL, viewed 23 March 2007, <http://www.actewagl.com.au/water/standards/as.aspx>

5. Australian Standards 1999, *Method of testing plastics and composite materials sanitary plumbing fixtures – Method 2: Determination of chemical and stain resistance,* AS 3558.2-1999, Standards Australia, Sydney.

6. Australian Standards 1999, *Methods of sampling and testing ceramic tiles – Method 14: Determination of resistance to stains*, AS 4459.14-1999, Standards Australia, Sydney.

7. Australian/New Zealand Standard 2004, *Reconstituted wood-based panels-Methods of test Method 25: Resistance to staining,* AS/NZS 4266.25:2004, Standards Australia & Standards New Zealand, Sydney & Wellington.

8. Australian/New Zealand Standard 2005, *Testing of products in contact with drinking water,* AS/NZS 4020:2005, Standards Australia & Standards New Zealand, Sydney & Wellington.

9. Baboian, R. 1995, *Corrosion Tests and Standards*, American Society for Testing and Materials, Fredericksburg.

10. Badowski, D.E., Bigg, D.M., Brasch, J, Grunden, B.L, Heather, K.J. & Ricks, J.G. 2005, *Analysis of Degradation of Poly(1-butene) Pipe through Oxidation Induction Time Tests*, Advances in Polymer Technology, vol. 24, iss. 3, pp 215-225.

11. Bott, T.R. 1990, *Fouling Notebook*, Institution of Chemical Engineers, England.

12. Brown, R. 1999, *Handbook of Polymer Testing*, Marcel Dekker, United States of America.

13. Bulter, G & Ison, H.C.K 1966, Corrosion and its Prevention in Waters, Leonard Hill, London.

14. Callister, Jr & William, D 2003, *Materials Science and Engineering an Introduction*, John Wiley & Sons, New York, 570-598.

15. Coombes, P.J, Dunstan, H.R, Kalma, J.D & Kuczera, G, *Rainwater Quality from Roofs, Tanks and Hot Water Systems at Figtree Place*, <http://www.wsud.org/downloads/Info%20Exchange%20&%20Lit/Coombes%20RAINWATER%20QUALITY.pdf>

16. *Drinking Water*, n.d., Brisbane City Council, viewed 28 March 2007, <http://www.brisbane.qld.gov.au/BCC:BRISWATER::pc=PC 1397>

17. Elboujdaini, M. Perumareddi, J.R, Sastri, V.S. & Subramanian, K.S. 2006, Inhibition of Release of Lead into Water Owing to Galvanic Corrosion of Lead Solders, Corrosion Engineering, Science and Technology, vol. 41, iss. 3, pp.249-54.

18. Elfil, H & Hannachi, A 2006, *Reconsidering Water Scaling Tendency Assessment*, AIChE Journal, vol. 52, No. 10, pp 3583-3591.

19. *Fact Sheet # 1 Bitterns*, n.d., Straits Yannarie Salt, viewed13 March 2007, <http://www.straits.com.au/files/expl/salt/fact_Sheets/Fact_Sheet_1_-_Bitterns.pdf>

20. Feng, Y. Hsieh, A.K. Siow, K.S. Tan, K.L. & Teo, W.K. 1986, *The Corrosion Behaviour of Copper in Neutral Tap Water*, Corrosion Science, vol. 38, iss. 3, pp. 387-95.

21. Garside, J & Söhnel, O 1992, *Precipitation*, Butterworth-Heinemann, Oxford.

22. Gedde, U.W. & Viebke, J. 1998, *Assessment of Lifetime of Hot-Water Polyethylene Pipes Based on Oxidation Induction Time Data*, Polymer Engineering and Science, vol. 38, iss. 8, pp1244-1250.

23. International Organization for Standardization 1999, *Corrosion of metals and alloys – Alternate immersion test in salt solution*, ISO 11130:1999, International Organization for Standardization, Switzerland.

24. International Organization for Standardization 1999, *Plastics – Methods of test for the determination of the effects of immersion in liquid chemicals*, ISO 175:1999, International Organization for Standardization, Switzerland.

25. International Organization for Standardization 2005, *Rubber, vulcanized – Determination of the Effect of Liquids*, ISO 1817-2005, International Organization for Standardization, Switzerland.

26. International Organization for Standardization 1997, *Thermoplastics pipes – Resistance to liquid chemicals – classification – part 1: Immersion method*, ISO 4433-1:1997, International Organization for Standardization, Switzerland.

27. Ives, G.C. & Mead, J.A. & Riley, M.M. 1971, *Handbook of Plastics Test Methods,* Iliffe Books, London.

28. Jae-Joo, S. Jun-Gu, K. & Yoon-Seok, C. 2005, *Effects of Cr, Cu, Ni and Ca on the Corrosion Behaviour of Low Carbon Steel in Synthetic Tap Water*, Journal of Alloys and Compounds, vol. 391, iss. 1-2, pp. 162-9.

29. Jenkins, D & Snoeyink, V 1980, *Water Chemistry*, John Wiley & Sons, United States.

30. Kin, J.G. & Shim, J.J. 2004, *Copper Corrosion in Potable Water Distribution Systems: Influence of Copper Products on the Corrosion Behaviour*, Materials Letters, vol. 58, iss. 14, pp. 2002-6.

31. McIntyre, P. & Mercer, A.D. 1993, *Corrosion and Related Aspects of Materials for Potable Water Supplies*, the Institute of Materials, Great Britain.

32. Mullin, J.W. 2001, *Crystallization*, Reed Education and Professional Publishing, Great Britain.

33. Polevoy, S.L. 1996, *Water Science and Engineering*, Chapman & Hall, Great Britain.

34. Reddy, M.M. & Nancollas, G.H. 1976, *The Crystallization of Calcium Carbonate*, Journal of Crystal Growth, vol. 35, pp 33-38.

35. Schweitzer, P.A. 1996, *Corrosion Engineering Handbook*, Marcel Dekker, New York.

36. Sanchez, S.R. Valcarce, M.B. & Vazquez, M. 2006, *A Comparative Analysis of Copper and Brass Surface Films in Contact with Tap Water*, Journal of Material Science, vol. 41, iss. 7, pp. 1999-2007.

37. Scott, D 2000, *Advanced Materials for Water Handling: Composites and Thermoplastics*, Elsevier Advanced Technology, United Kingdom.

38. World Health Organization, 2006, *Health Aspects of Plumbing*, World Health Organization and World Plumbing Council, Switzerland.

Bibliography:

- *Acrylic Toilet Seat*, n.d., viewed 28 March 2007, <http://www.china-toilet-seat.com/Acrylic_Toilet_Seat.htm>

- American Water Works Association 2004, *External Corrosion – Introduction to Chemistry and Control*, American Water Works Association, Denver.

- *Bathtub Basics*, n.d., Home Building Club, viewed 23 March 2007, <http://www.homebuildingclub.com/products/article.asp?art=70>

- *Corrosion Caused by Softened Water*, n.d., Water Heating-info, viewed 16 March 2007, <http://www.waterheater-info.com/corrosion/water%20heater.aspx>

- *Corrosion, Saturation Index, Balanced Water in Drinking Water System*, n,d, Wilkes University, viewed 19 March 2007, <http://www.water-research.net/corrosion.htm>

- *Countertops*, n.d., Kitchens.com, viewed 23 March 2007, <http://www.kitchens.com/02-Kitchen-Products/Kitchen-Countertops/default.asp>

- Cragnolino, G. & Sridhar, N. 1994, *Applications of Accelerated Corrosion Tests to Service Life Predictions of Materials*, American Society for Tests and Materials, Ann Arbor.

- *Effects on Plumbing*, n.d., Citizens Concerned about Chloramine, viewed 14 March 2007, <http://chloramine.org/effectsonplumbing.htm>.

- *The Filtration Spectrum*, n.d., Osmonics, viewed 19 March 2007, <http://www.osmonics.com/library/1117987-%20Lit-%20Filtration%20Spectrum.pdf>

- *Flooring*, n.d., Kitchens.com, viewed 23 March 2007, <http://www.kitchens.com/02-Kitchen-Products/Flooring/default.asp>

- Formisano, B, n.d., *Teflon Tape*, viewed 23 March 2007, <http://homerepair.about.com/od/termsst/g/teflon_tape.htm>

- *Glossary Dishwashers*, n.d., Sears, viewed 20 March 2007, <http://www.sears.ca/gp/browse.html?ie=UTF8&node=16396561&no=16348291&searsBrand=core&me=A10FHFRJZ0GJG3>

- *Hard Water Problems*, n.d., viewed 16 March 2007, <http://www.hardwater.org/hard_water_problems.html>

- *A Hidden Time Bomb – Corrosion of Piping Systems*, n.d., Hotel Onlline, viewed 16 March 2007, <http://hotel-online.com/News/PressReleases2000_1st/Jan00_TimeBomb.html>

- *Home Water Quality Problems, Causes and Treatments,* n.d., Clemson Extension, viewed 16 March 2007, <http://www.cdc.gov/NASD/docs/d001201-d001300/d001240/d001240.html>

- *Hose Fittings*, n.d., Irrigation Warehouse Group Pty Ltd, viewed 26 March 2007, <http://www.irrigationwarehouse.com.au/category67_1.htm>

- *How washing Machines Work,* n.d., Repair Clinic.com, viewed 19 March 2007, <http://www.repairclinic.com/0088_11_3.asp>

- *Kettle Heating Elements*, n.d., viewed 27 March 2007, <http://www.made-in-china.com/showroom/sanchang/product-detailoeMQkqRdAnlX/China-Kettle-Heating-Elements-SC-43-.html>

- *Pipes, Fittings, and Valves,* n.d., ACE, viewed 20 March 2007, <http://www.acehardware.com/info/index.jsp?categoryId=1267591&backTo=1278941&savePath=&infoType=infosport>

- *Plastics: Corrosion Hazards Overview*, n.d., viewed 19 March 2007, <http://httd.njuct.edu.cn/matweb/mat-cor/pl___ccc.htm>

- *Reverse Osmosis*, n.d., viewed 19 March 2007, <http://www.osmoflo.com.au/index.php/selectedContent/1706971244>

- *Sinks and Faucets*, n.d., Kitchens.com, viewed 23 March 2007, <http://www.kitchens.com/02-Kitchen-Products/Sinks-And-Faucets/faucet-materials.asp>

- *Showers*, n.d., Home Building Club, viewed 23 March 2007, <http://www.homebuildingclub.com/products/article.asp?art=27>

- *Shower Heads and Shower Sets*, n.d., Alibaba.com, viewed 26 March 2007, <http://www.alibaba.com/trade/search?Type=&SearchText=+Shower+Head&IndexArea=product_en>

- *Sprinklers*, n.d., Irrigation Warehouse Group Pty Ltd, viewed 26 March 2007, <http://www.irrigationwarehouse.com.au/category51_1.htm>

- *Tank Material*, 2005., Your Home Technical Manual, <http://www.greenhouse.gov.au/yourhome/technical/fs22.htm>

- *Toilet*, n.d., Home Building Club, viewed 23 March 2007, <http://www.homebuildingclub.com/products/article.asp?art=71>

- Walton, A.G. 1967, *The formation and Properties of Precipitates*, John Wiley & Sons, United States of America.

- Walkington, B, 2006, *Domestic Water Heating Elements*, viewed 27 March 2007, <http://www.ferret.com.au/articles/C0/0C03DDC0.asp>

- *Water Softener FAQ*, n.d., Lenntech, viewed 14 March 2007, <http://www.lenntech.com/water-softener-FAQ.htm>

- *What is a Washing Machine*, n.d., Aswers.com, viewed 19 March 2007, <http://www.answers.com/topic/washing-machine>

- *What is a Lawn Sprinkler?*, n.d., Answers.com, viewed 26 March 2007, <http://www.answers.com/topic/lawn-sprinkler-1>

- *Why Tanks Fail*, n.d., Cole Plumbing, viewed 28 March 2007, <http://www.coleplumbing.com/heater.html>

- Wypych, G. 1999, *Weathering of Plastics*, Plastics Design Library, Norwich.

Appendix A

Sample Preparation

A1 Scope

This Appendix specifies the preparation of samples of products, for testing the effects caused by contact with MagnaBlu Minerals. This Appendix is applicably to both metallic and non-metallic samples.

A2 Apparatus

A2.1 Test Containers

For immersion exposure testing the containers to be used will predominantly be buckets already owned by Poolrite Research. The buckets are of standard household size with a rectangular shape. The tests requiring larger containers will use containers acquired specifically for the required test size. Polyethylene film, aluminium foil and glass covers are fine to use as sealing material. The use of these covers is determined according to the requirements of the test.

Figure A.1: Test Container

A2.2 Sample Bottles

For test of MagnaBlu Minerals composition, test of water hardness and test of bacterial content, a standard water sample bottle will be used.

A2.3 Temperature-measuring Device

A2.4 Measuring Cylinders

A2.5 Palintest Photometer Tubes

Round test tubes, 10mL glass

A2.6 Palintest Phenol Red Clear tablets

These tables are used to find the pH level.

A2.7 Palintest Photometer

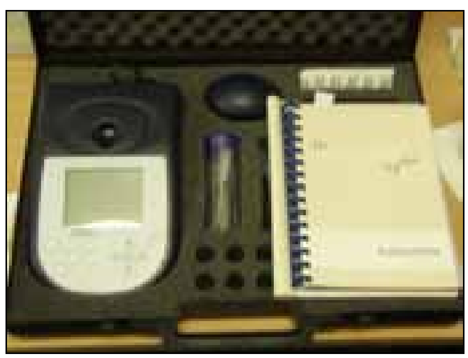

Figure A.2: Palintest Photometer

The Palintest system has been used in laboratories, treatment plants, leisure facilities and industrial premises throughout the world for over 45 year. The photometers are pre-programmed with test calibrations and give direct-reading of the test results.

A2.8 Palintest Calcicol No 1 & 2 Tablets

These tables are uses to find the calcium hardness.

A2.9 Aluminum Foil

A2.10 Glass Beaker

A2.11 Hot Plate

The hot plate will have a thermocouple attached which has accuracy to within 0.5^{o}C.

A2.12 Balance

A2.13 Thermocouple

A2.14 Calipers

A3 Samples

A3.1 Nature of Samples of Contact Points

Samples for testing shall, wherever possible, be manufactured products or components of manufactured products. If manufactured products are not possible samples for testing shall be pieces of the material to be tested.

A3.2 Concentrated MagnaBlu Minerals

The MagnaBlu Minerals used in the tests will be a concentrated for of the solution found in the pool. The concentration is at a ratio of 300:1, this will decrease the time required to test for effects. Using this concentration tests performed over 4 weeks will be equivalent to over 20 years of exposure to MagnaBlu Minerals.

A3.3 Tap Water

A3.4 Bottled Water

A4 Suds Producing Objects

A4.1 Cloth

The cloth will be rags produced from clothing.

A4.2 Hand Soap

Standard hand soap will be used.

A4.3 Detergent

Dishwashing detergent will be used.

A5 Product Exposure

A5.1 In-the-product Exposure

In-the-product exposure shall be used, wherever possible, for the tests. Samples are filled with MagnaBlu Minerals so the surface area-to-volume ratio is equal to the actually ratio in use.

A5.2 Immersion Exposure

Immersion exposure shall be used for samples that cannot be evaluated by in-the-product exposure. The sample is immersed in MagnaBlu Minerals contained in test container (A2.1).

During the test, samples shall be completely submerged in the MagnaBlu Minerals.

A6 Sample Transport and Storage

During the period between packaging and receipt by the laboratory, and during storage in the laboratory, the samples shall be protected from contamination by dirt, oil, grease, excessive heat, sunlight and volatile chemicals.

A7 Sample Washing

On the day the testing is to start, samples of the products to be tested shall be rinsed thoroughly with MagnaBlu Minerals or otherwise stated in the procedure, to remove dirt, dust or other foreign material.

Appendix B

Test 1

MagnaBlu Minerals Composition

B1 Scope

This Appendix sets out a method for acquiring the composition of the concentrated form of MagnaBlu Minerals.

B2 Principle

A sample of the concentrated form of MagnaBlu Minerals is collected in a sample bottle. The bottle is then sent away to ALS labs and tested for composition. The results are than received from the ALS lab and analyzed.

B3 Apparatus

B3.1 Sample Bottle

Bottle as specified in Appendix A (A2.2)

B4 Sample

Sample MagnaBlu Minerals will be acquired from the companies Research and Development MagnaBlu Minerals barrels. There will be no treatment of the sample after it is taken out of the barrel. The sample will be sent to the lab straight after it is obtained.

B5 Test Procedure

B5.1 Sample Gathering

On the day of the test, rinse the sample bottle out with tap water and then deionised water to remove any foreign material from inside the bottle. Fill sample bottle with MagnaBlu Minerals from the Research and Development MagnaBlu Minerals barrel.

B5.2 Sample Testing

On completion of sample gathering prepare the sample to be sent to the ALS labs, once the sample is prepared for transport, send it to the lab. ALS Environmental operates a management system that complies with the requirements of ISO 9001: 2000 and all laboratories operate according to the guidelines set out in ISO/IEC 17025.

B6 Analysis of Results

On arrival of results from ALS labs identify the composition of MagnaBlu Minerals. Identify the level of the elements in MagnaBlu Minerals expected to cause an effect on a domestic system. These levels will be use in the analysis of the cause of any effects.

Appendix C

Test 2

Hardness Level of MagnaBlu Minerals

C1 Scope

This Appendix sets out a method for acquiring the level of hardness of MagnaBlu Minerals.

C2 Principle

The hardness level of the MagnaBlu Minerals will be found following the instructions laid out in the Palintest manual.

.

C3 Apparatus

B3.1 Palintest Photometer Tubes

Tube as specified in Appendix A (A2.5).

C3.2 Palintest Photometer

C3.3 Palintest Calcicol No 1 & 2 Tablets

C4 Sample

Sample MagnaBlu Water will be acquired from the companies Research and Development pool. There will be no treatment of the sample after it is taken out of the pool.

C5 Test Procedure

C5.1 Sample Gathering

On the day of the test, rinse the Palintest Photometer Tube out with tap water and then deionised water to remove any foreign material from inside the tube. Fill sample bottle with MagnaBlu Minerals from the Research and Development pool.

C5.2 Sample Testing

C5.2.1 *Method*

The Palintest Calcium Hardness test is based on the Calcicol indicator reagents method. Calcium ions react specially with Calcicol indicator in alkaline solution to give an orange colouration. The reagent itself gives a violet colour in solution. Thus at different calcium levels a distinctive range of colours from violet to orange is produced.

The reagents for the method are provided in the form of two tables. The test is carried out simply by adding one of each tablet to a sample of the water. The colour produced is indicative of the calcium hardness and is measured using a Palintest Photometer.

C5.2.2 *Procedure*

1. Filter sample if necessary to obtain a clear solution
2. Fill the test tube with sample to the 10mL mark
3. Add one Calcicol No 1 tablet, crush and mix to dissolve
4. Add one Calcicol No 2 tablet, crush and mix to dissolve
5. Stand for two minutes to allow full colour development
6. Select Phot 12 on the Photometer for results as mg/L $CaCO_3$, or Phot 60 for results as mg/L Ca
7. Take Photometer reading in the usual manner (see Photometer instructions)

C5.2.3 *Results*

The results will be recorded in the following table.

Table C.1: Hardness Level Results Table

Test Waters	Hardness Level
Test 4 - Normal	
Test 5 - Normal	
Test 6 - Normal	
Test 7 - Normal	
Test 8 - Normal	

C6 Analysis of Results

On arrival of results from ALS labs identify the level of hardness of MagnaBlu Minerals. Classify MagnaBlu Minerals as hard or soft water using the hardness description (add a reference here of Brisbane city council) below.

- Soft: 0 – 50 mg/L or ppm as calcium carbonate
- Moderately soft: 51 – 100 mg/L or ppm as calcium carbonate
- Slightly hard: 101 – 150 mg/L or ppm as calcium carbonate
- Moderately hard: 151 – 200 mg/L as ppm calcium carbonate
- Hard: 201 – 300 mg/L or ppm as calcium carbonate
- Very hard: >300 mg/L or ppm as calcium carbonate

This result will be used with the analysis of tests 4, 5 and 7.

Appendix D

Test 3

pH Level of MagnaBlu Minerals

D1 Scope

This Appendix sets out a method for testing the pH level of MagnaBlu Minerals.

D2 Principle

The pH level of the MagnaBlu Minerals will be found following the instructions laid out in the Palintest manual, the pH will be found for each test which uses a different sample of MagnaBlu Minerals.

D3 Apparatus

D3.1 Palintest Photometer Tubes

Bottle as specified in Appendix A (A2.5).

D3.2 Palintest Photometer

D3.3 Palintest Phenol Red Clear Tablets

D4 Sample

Sample MagnaBlu will be acquired from the companies Research and Development pool. There will be no treatment of the sample after it is taken out of the pool.

D5 Test Procedure

D5.1 Sample Gathering

On the day of the test, rinse the Palintest Photometer Tube out with tap water and then deionised water to remove any foreign material from inside the tube. Fill sample bottle with MagnaBlu Minerals from the Research and Development pool.

D5.2 Sample Testing

D5.2.1 *Method*

The Palintest Phenol Red test used a tablet reagent containing the precise amount of phenol red indicator required for the test. Phenol red reacts in water at different pH values over a range 6.8 – 8.4 to produce a distinctive range of colours from yellow to red. The colour of the test solution is indicative of the pH value and is measured using the Palintest Photometer.

Phenol red tablets contain a dechlorinating agent so that the test can be carried out in water containing normal levels of chlorine or other disinfectants residuals.

D5.2.2 *Procedure*

1. Fill test tube with sample at 10mL mark.
2. Add one Phenol Red Table, crush and mix to dissolve.
3. Select Phot 27 on Photometer.
4. Take Photometer reading in user manual (see Photometer instructions).
5. This test is to be performed on the MagnaBlu Minerals to be used in each test.

D5.2.3 *Results*

The results will be recorded in the following table.

Table D.1: pH Level Results Table

Test Waters	pH
Test 4 - Normal	
Test 5 - Normal	
Test 6 - Normal	
Test 6 - Concentrated	
Test 7 - Concentrated	
Test 8 - Normal	

D6 Analysis of Results

MagnaBlu minerals will be acidic if it has a low pH level and it will be alkaline if it has a high pH level. The pH level will be used when analyzing the corrosive effects of MagnaBlu Minerals.

Appendix E

Test 4

Lather Test

E1 Scope

This Appendix sets out a method for testing MagnaBlu Minerals to produce suds when in contact with soaps or detergents. The test was designed to the specifications of the company procedure.

E2 Introduction

The level of water hardness does affect soaps ability to lather well. The higher the level of hardness the harder it is for soap to lather. Test 2 (Appendix C) will find the level of hardness of MagnaBlu Minerals which will indicate the results to expect when performing this test.

E3 Principle

A test container is filled with 2 litres of MagnaBlu Minerals, and then 25mL of detergent is added. The suds will be produced by scrubbing two pieces of cloth together like hand washing cloths. The test will also be performed with normal tap water as a reference for the amount and quality of suds produced.

E4 Reagents

E4.1 Test Water

The MagnaBlu Minerals will be obtained from the companies Research and Development pool and placed in the test container. There will be no treatment of the sample after it is taken out of the pool. Each test will use 2 litres of MagnaBlu Minerals.

E4.2 Tap Water

E4.3 Detergent and Soaps

Detergent and soaps will be normal household products listed below

- Dishwashing liquid
- Hand Soap

Each test will use 25mL of detergent or soap.

E5 Apparatus

E5.1 Test Container

Container as specified in Appendix A (A2.1).

E5.2 Measuring Cylinders

The measuring cylinder will be used to measure the correct amount of test water and detergents and soaps.

E6 Suds Producing Objects

E6.1 Cloth

Cloth as specified in Appendix A (A4.1). Two pieces of cloth will be used for each test.

E7 Recording of Findings

Photographs were taken and observations were recorded in a log book

E8 Test Procedure

E8.1 Water Solution and Detergent or Soap

E8.1.1 *Combinations*

Water solutions and detergent or soap

- MagnaBlu Minerals with dishwashing liquid
- MagnaBlu Minerals with hand soap
- Tap water with dishwashing liquid
- Tap water with hand soap

E8.2 Procedure

E8.2.1 *Water Solution*

On the day of the test, rinse the measuring cylinders and the test containers to remove any foreign material. Measure out 2 Litres of MagnaBlu Minerals into three test containers and 2 Litres of tap water in another three test containers. The test will be performed at ambient air temperature.

E8.2.2 *Detergent and Soap*

Measure out 25mL of dishwashing liquid and hand soap and place one in each of the two water solutions in the separate test containers.

E8.2.3 *Suds Production with Cloth*

1. Prior to testing rinse the cloth in tap water to remove any foreign materials.

2. In the test container scrub the two pieces of cloth together to produce the largest amount of suds.
3. Perform this action for two minutes. When the test has been performed record the findings.

E8.2.4 *Results*

The results will be recorded in the following table.

Table E.1: Lather Test Results Table

Solutions	Rating
MagnaBlu Minerals with dishwashing liquid	
MagnaBlu Minerals with hand soap	
Tap water with dishwashing liquid	
Tap water with hand soap	

The following rating will be used:

Rating 1: 0-25% surface coverage of suds
Rating 2: 25-50% surface coverage of suds
Rating 3: 50-75% surface coverage of suds
Rating 4: 75-100% surface coverage of suds

E9 Analysis of Results

When the tests are completed and all data recorded, the effect of MagnaBlu Minerals on the ability of soap to lather can be documented. All the results obtained from the MagnaBlu Minerals will be compared to the results obtained from the tap water tests. A comparison will also be made between each detergent's ability to lather.

Appendix F

Test 5

Stain Test

F1 Scope

This Appendix sets out a method for testing the ability of MagnaBlu Minerals to stain products in the domestic system. The test was designed from the appropriate Australian standards[5, 6, 7].

F2 Introduction

The effects of stains will only be considered in relation to products in the domestic system where stains are undesired. The areas in a domestic system where stains are noticeable are the bathroom, kitchen, and laundry. The test for stains will be testing different surfaces found in these areas. This test is in accordance with the standards for stain resistance.

F3 Principle

The principle of the test is; surfaces that are found around the home are to be half submerged in concentrated MagnaBlu Minerals for a duration of 24h. On completion of the test the final results will be recorded and analyzed.

F4 Reagents

F4.1 Test Water

The MagnaBlu Minerals will be obtained from the companies Research and Development pool and placed in the test container. There will be no treatment of the sample after it is taken out of the pool.

F4.2 Detergent

F5 Apparatus

F5.1 Test Container

Container as specified in Appendix A (A2.1).

F5. Aluminum Foil

F6 Samples

The following sample material is to be used when testing the effect on plumbing equipment and flooring.

- Container 1: Ceramic
- Container 2: Porcelain
- Container 3: Acrylic
- Container 4: Brass
- Container 5: ABS
- Container 6: Polycarbonate
- Container 7: Fiberglass
- Container 8: Glass
- Container 9: Vinyl
- Container 10: Nylon
- Container 11: Pine
- Container 12: Plywood
- Container 13: Concrete
- Container 14: Marble
- Container 15: Granite

- Container 16: Clay Brick

The product tested will be a sample of the above materials. This is the best procedure as it allows for multiple tests to be performed without requiring a great amount of space.

F7 Recording of Findings

Photographs were taken and observations were recorded in a log book

F8 Test Procedure

F8.1 Test Preparation

F8.1.1 *Test Container*

On the day of the test wash the test container with MagnaBlu Minerals to remove any foreign materials.

F8.1.2 *Product*

On the day of the test wash the sample with tap water to remove any foreign materials.

F8.1.3 *Test Location*

On the day of the test prepare an appropriate sized space inside; the space must be available for the duration of the test with no interference.

F8.2 Procedure

F8.2.1 *Test with MagnaBlu Minerals*

1. Place the sample into the test container and fill container with MagnaBlu Minerals until sample is half submerged.
2. Cover container with aluminum foil.
3. Leave sample in container for 24h. (The test will be performed at ambient air temperature)
4. After the 24h period remove sample and if there is a sign of a stain wash product with detergent and if the stain is still visible then the stain is permanent.

F8.2.3*Results*

Record any signs of stains in the following table and take a visual record.

Table F.1: Stain Test Results Table

Container	Stain Rating
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

F9 Analysis of Results

When the tests are completed and all data recorded, quantify the staining power of MagnaBlu Minerals. Does MagnaBlu Minerals stain or discolour material? Visually assess the surface using the following rating found in the Australian Standard 4266.25.

(i) Rating 1 – No stain visible on surface
(ii) Rating 2 – Faint stain visible on surface
(iii) Rating 3 – Slight stain visible on surface
(iv) Rating 4 – Moderate stain visible on surface
(v) Rating 5 – Very obvious stain on surface

Appendix G

Test 6

Degradation and Precipitate Test

G1 Scope

This Appendix sets out a method for testing if MagnaBlu Minerals will cause degradation of materials or cause precipitates to form. The test was designed to comply with the relevant standards[23, 24, 26].

G2 Introduction

There are three types of materials, metals, ceramics and plastics. Deteriorative mechanisms are different for each type of material. In metals, there is a loss of material either by corrosion or by the formation of nonmetalic scale or film (oxidation). Ceramic materials are relative resistant to deterioration (corrosion), which generally occurs at elevated temperatures or in extreme environments. Polymers may degrade by being dissolved when exposed to a liquid solvent, or they may absorb the solvent and swell; also electromagnetic reaction and heat can cause degradation. When a solution is supersaturated with a particular element the element will tend to precipitate out of the solution and thus form a scale on the solutions container.

G3 Principle

Materials found in a domestic system will be submerged in MagnaBlu Minerals for 14 days to test for degradation or the formation of precipitates. After the test is complete the materials will be analyzed for any signs of degradation. The test also involves washing some material in MagnaBlu Minerals and drying them one way by cloth and the other way by heat lamp, this simulates washing dishes in the domestic system and will show if this will cause unwanted precipitates.

G4 Reagents

G4.1 Test Water

The MagnaBlu Water will be obtained from the bittern barrels at the company, this is a concentrated form. To comply with the composition of the pool water the concentrated bittern will have MagnaBlu minerals added to it.

For washing the MagnaBlu Minerals will be obtained from the companies Research and Development pool and placed in the test container. There will be no treatment of the sample after it is taken out of the pool.

G5 Apparatus

G5.1 Test Container

Container as specified in Appendix A (A2.1).

G5.2 Aluminum Foil

G5.3 Balance

G6 Samples

The following sample material is to be used when testing the effect on plumbing equipment and flooring.

- Container 1: Ceramic
- Container 2: Porcelain
- Container 3: Acrylic

- Container 4: Brass
- Container 5: ABS
- Container 6: Polycarbonate
- Container 7: Fiberglass
- Container 8: Glass
- Container 9: Vinyl
- Container 10: Nylon
- Container 11: Pine
- Container 12: Plywood
- Container 13: Concrete
- Container 14: Marble
- Container 15: Granite
- Container 16: Clay Brick
- Container 17: Copper

The product tested will be a sample of the above materials. This is the best procedure as it allows for multiple tests to be performed without requiring a great amount of space.

The following cup or mug will be tested for the testing of the corrosive effect or precipitate forming when washing dishes.

- Glass cup
- China mug

Two of each type of cup or mug will be required as two ways of drying the dish will be tested.

G7 Recording of Findings

Photographs were taken and observations were recorded in a log book

G8 Test Procedure

G8.1 Test Preparation

G8.1.1 *Test Container*

On the day of the test wash the test container with MagnaBlu Minerals to remove any foreign materials.

G8.1.2 *Product*

On the day of the test wash the sample with MagnaBlu Minerals to remove any foreign materials.

G8.1.3 *Test Location*

On the day of the test prepare an appropriate sized space inside; the space must be available for the duration of the test with no interference.

G8.2 Procedure for Plumbing Equipment Materials

G8.2.1 *Test with Concentrated MagnaBlu Minerals*

1. Place the sample into the test container and fill container with MagnaBlu Minerals until sample is completely submerged.
2. Cover container with aluminum.
3. Repeat this for each sample.
4. Leave sample in container for 14 days. (The test is to be performed at ambient air temperature)

G8.2.2 *Results*

A visual observation of degradation will be recorded everyday with a picture being taken on completion of the test. The results will be recorded in the following table.

Table G.1: Degradation Test Results Table

Container	Rating of Degradation
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	

The following rating will be used:

Rating 1: 0-20% surface degradation

Rating 2: 20-40% surface degradation

Rating 3: 40-60% surface degradation

Rating 4: 60-80% surface degradation

Rating 5: 80-100% surface degradation

G8.3 Procedure for Dishes to be washed

1. Weigh the dishes to find the starting mass.
2. Half fill a test container with heated MagnaBlu Minerals and place a small amount of dishwashing liquid into the container. The MagnaBlu Minerals will be at an elevated temperature to simulate the temperature at which dishes are washed.
3. Wash the dish in the MagnaBlu Minerals and dishwashing liquid.
4. The two dishes of each dish type will be dried a different way. The first dish will be dried by a tea towel; the second will be dried by heat lamp. This procedure will be repeated 10 times for each dish.
5. After each time the dish has dried, weigh the dish.

G8.3.4 *Results*

After the dish has been dried record any sign of degradation and precipitation in the following tables.

Dried with a tea towel:

Table G.2: Precipitate Test Results Table Dying Method 1

	Wash									
Cup or mug	1	2	3	4	5	6	7	8	9	10
Glass Cup										
China Mug										

Dried with a heat lamp:

Table G.3: Precipitate Test Results Table Dying Method 2

	Wash									
Cup or mug	1	2	3	4	5	6	7	8	9	10
Glass Cup										
China Mug										

If the mass increases there is a residue on the surface. The change in mass will be found as follows.

$\Delta m = m_2 - m_1$

Δm = amount of residue left on surface

All calculations will be performed with m_1 being the initial mass.

G9 Analysis of Results

When analyzing the degradation specify the degree of degradation and the type. The colour of the water should be noted in the analysis. The amount of precipitates and the amount of time they required to form when washing will also be noted.

Appendix H

Test 7

Elastic Material Test

H1 Scope

This Appendix sets out a method for testing the effect MagnaBlu Minerals will have on a particular elastic Material.

H2 Principle

A number of rubber O rings will be submerged in MagnaBlu Minerals for a period of 14 days. The effect will be tested after 3 days, 6 days, 10 days and 14 days.

H3 Reagents

H3.1 Test Water

The MagnaBlu Water will be obtained from the bittern barrels at the company, this is a concentrated form. To comply with the composition of the pool water the concentrated bittern will have MagnaBlu minerals added to it.

H4 Apparatus

H4.1 Test Container

Container as specified in Appendix A (A2.1).

H4.2 Measuring Cylinders

H4.3 Balance

H4.4 Calipers

H5 Samples

Four O rings will be tested.

H6 Recording of Findings

Photographs were taken and observations were recorded in a log book

H7 Test Procedure

H7.1 Test Preparation

H7.1.1 *Test Container*

On the day of the test wash the test container with MagnaBlu Minerals to remove any foreign materials.

H7.1.2 *Measuring Cylinder*

On the day of the test wash the measuring cylinder with MagnaBlu Minerals to any foreign material.

H7.1.3 *Product*

On the day of the test wash the sample with MagnaBlu Minerals to remove any foreign materials.

H7.1.4 *Test Location*

On the day of the test prepare an appropriate sized space inside; the space must be available for the duration of the test with no interference.

H7.2 Test with MagnaBlu Minerals

H7.2.1 *Test*

Measure out 1 Litre of MagnaBlu Minerals and pour it in the test container, then place the four O rings into the test container. Measure the starting mass and inner and outer diameter of the O rings. If each is different keep track of the O ring that is tested and it's starting values.

H7.2.2 *Results*

1. 3 days from the commencement date remove one O ring from the test container.
2. Measure the mass of the O ring.
3. Measure the inner and outer diameter of the O ring.
4. Observe any changes in the colour of the O ring.
5. Repeat this observation as specified in the table below.
6. Examine each specimen in comparison with an untested specimen.

Note: Do not replace tested O ring back into the test container.

The results will be recorded in the following tables.

Table H.1: Elastic Material Test Mass Results Table

Duration	Mass
0 Days	
3 Days	
6 Days	
10 Days	
14 Days	

Table H.2: Elastic Material Test Dimension Results Table

Duration	Inner Diameter	Outer Diameter
0 Days		
3 Days		
6 Days		
10 Days		
14 Days		

Table H.3: Elastic Material Test Colour Change Results Table

Duration	Rating
0 Days	
3 Days	
6 Days	
10 Days	
14 Days	

Use the following scale found in ISO 175 to measure the colour changes.

Rating 1: None

Rating 2: Barely perceptible

Rating 3: Slight

Rating 4: Moderate

Rating 5: Substantial

H8 Analysis of Results

Calculation and expression of mass results:

Change in mass:

Report the measured mass in grams.

$\Delta m = m_2 - m_1$

Δm = amount of liquid absorbed if positive and amount of material lost is negative

For percentage change in mass:

$$\frac{m_2 - m_1}{m_1} * 100$$

Change in dimensions:

Report diameter measurements in millimeters.

$\Delta L_i = L_2 - L_1$

ΔL_i = change in length of inner diameter

$\Delta L_o = L_2 - L_1$

ΔL_o = change in length of outer diameter

Repeat calculations after each removal time.

Appendix I

Test 8

High Temperature Test

I1 Scope

This Appendix sets out a method for testing the effect MagnaBlu Minerals will have on products regularly heated in the domestic system.

I2 Introduction

When temperatures are raised reverse soluble precipitates are formed more readily. The mechanisms of corrosion change as the temperature increases. This test is to determine if precipitates will form if MagnaBlu Minerals is heated.

I2 Principle

An amount of MagnaBlu Minerals will be heated up to 100^{o}C in a glass beaker. At specific temperatures observations will be made on the appearances of the MagnaBlu Minerals and if precipitates are visible.

I3 Reagents

I3.1 Test Water

The MagnaBlu Minerals will be obtained from the companies Research and Development pool and placed in the test container. There will be no treatment of the sample after it is taken out of the pool.

I4 Apparatus

I4.1 Test Container

Container as specified in Appendix A (A2.1).

I4.2 Measuring Cylinders

I4.3 Glass Beaker

I4.4 Hot Plate

I4.5 Thermocouple

I4.6 Balance

I5 Recording of Findings

Photographs were taken and observations were recorded in a log book

I6 Test Procedure

I6.1 Test preparation

I6.1.1 *Glass Beaker*

On the day of the test wash the glass beaker with MagnaBlu Minerals to remove any foreign materials.

I6.1.2 *Test Location*

On the day of the test prepare an appropriate sized space inside; the space must be available for the duration of the test with no interference.

I6.2 Test with MagnaBlu Minerals

I6.2.1 *Test*

1. Measure out 0.5L of MagnaBlu Minerals and place into the Glass Beaker
2. Heat the MagnaBlu Minerals to the 20^{o}C. Once the temperature has been reached observe and record signs of a precipitate. The temperature is measured with the thermocouple with accuracy ±0.5^o.
3. If precipitates are visible drain water and measure the mass of the precipitates.
4. Measure out another 0.5L of MagnaBlu Minerals and heat to the next temperature and record any signs of a precipitate.
5. Repeat steps 1-4 until 100^{o}C has been reached
6. Repeat procedure two times to confirm accuracy

I6.2.2 *Results*

After cooling record any precipitates on the inside of the kettle or any signs of corrosion, especially note the heating element. The results will be recorded in the following table:

Table I.1: High Temperature Test Results Table

	Rating		
Temperature	Test 1	Test 2	Test 3
20			
40			
60			
80			
100			

The following rating will be used:

Rating 1: 0-5g of precipitates

Rating 2: 5-10g of precipitates

Rating 3: 10-15g of precipitates

Rating 4: 15-20g of precipitates

Rating 5: >20g of precipitates

Appendix J

Contact Points

J1 Inside

J1.1 Piping

- Plastic pipes
    - ABS (Acrylonitrile butadiene styrene)
    - PVC (Polyvinyl Chloride)
    - CPVC (Chlorinated Polyvinyl Chloride)
    - FEP (Fluorinated ethylene propylene)
    - PS (Polystyrene)
    - PP (Polypropylene)
    - PE (Polyethylene)
    - Nylon

- Metal pipes
    - Copper
    - Stainless steel
    - Galvanized steel
    - Aluminum
    - Galvanized iron
    - Brass

J1.2 Fittings

- Fitting are made from the same material as the pipes or tubing they are connecting to

J1.3 Teflon Tape (Plumbers tape)

- PTFE (polytetrafluoroethylene)

J1.4 Dishwasher

- Components of dishwasher
  - Drain hose
    - Plastic
    - Stainless steel
  - Inlet pipe
    - Stainless steel
    - Plastic
    - Copper
  - Holding racks
    - Vinyl – PVC coating
    - Nylon – Nylon coating
    - Stainless steel
  - Water spraying arms
    - Plastic – PVC
  - Heating element
    - Copper
    - Stainless steel
  - Detergent and rinse-agent dispenser
    - Plastic – PVC
  - Tub
    - Plastic – PP (Polypropylene)
    - Porcelain on steel
    - Stainless steel

- Products in dishwasher
  - Cups/mugs
    - Plastic – general
    - Glass
    - Porcelain
    - Crystal
  - Plates

        - Plastic
        - China
        - Porcelain
        - Stoneware
        - Glass
    - Cutlery
        - Plastic
        - Stainless steel
    - Pots and Pans
        - Cast iron
        - Stainless steel
        - Teflon
    - Casserole dish
        - Glazed ceramics
    - Roaster
        - Aluminum
        - Stainless steel
    - Tupperware
        - Plastic
        - Glass

J1.5 Kettle and Coffee Marker

- Heating element
    - Copper
    - Stainless steel
- Body of product
    - Plastic
    - Stainless steel
    - Aluminum

J1.6 Kitchen Floor

- Vinyl

- Laminate
- Granite
- Marble
- Slate
- Ceramic tile
- Wood
- Concrete
- Carpet

J1.7 Countertop

- Natural stone
- Laminate
- Tile
- Wood
- Stainless steel
- Concrete
- Glass

J1.8 Iron and Steamers

- Plastic
- Stainless steel

J1.9 Hot Water System

- Pipes
  - Copper
  - Stainless steel
- Water chamber
  - Stainless steel
  - Ceramic
- Heating element
  - Copper

    - Stainless steel
    - Alloy 800
    - Alloy 825

J1.10 Washing Machine

- Products in washing machine
    - Clothes material

- Components of washing machine
    - Inlet pipe
        - Plastic
        - Stainless steel
    - Outlet pipe
        - Plastic
        - Stainless steel
    - Outer tub
        - Porcelain on steel
        - Stainless steel
        - Plastic – PP (Polypropylene)
    - Wash basket
        - Stainless steel
        - Porcelain on steel
        - Plastic – PP (Polypropylene)

J1.11 Toilet

- Toilet set
    - Plastic
    - Acrylic
- Bowl
    - Ceramic
    - Porcelain

J1.12 Tap

- Washers
    - Rubber
    - Plastic
- O rings
    - Rubber
- Body of tap
    - Plastic
    - Ceramic
    - Brass
    - Stainless steel

J1.13 Sink

- Stainless steel
- Porcelain enameled cast iron
- Acrylic

J1.14 Bathtub

- Porcelain on steel
- Acrylic
- Ceramic
- Fiberglass
- Cultured marble

J1.15 Shower

- Surrounds
    - Fiberglass
    - Acrylic
    - Vinyl
    - Plastic laminate
    - Synthetic stone

    - Ceramic tile
- Shower doors
    - Glass
- Nozzle
    - Plastic – ABS
    - Brass
- Soap Dish
    - Plastics – Polycarbonate

J1.16 Bathroom Floor

- Ceramic tiles
- Vinyl
- Laminate
- Marble

J2 Outside

J2.1 Car

- Windscreen
    - Glass
- Windscreen Wiper
    - Rubber
- Car Paint
- Tyres
    - Rubber
- Wheel Rims and Covers
    - Aluminum
    - Stainless steel
    - Plastic – ABS
- Cloth to wipe car

J2.2 Floor Surface

- Concrete
- Brick (all types)

J2.3 Hose

- Rubber
- Vinyl
- Nylon

J2.4 Hose Fittings

- Aluminum
- Brass
- Stainless steel
- Plastic

J2.5 Sprinkler

- Rubber
- Plastic
- Aluminum
- Stainless steel
- Brass

J2.6 Tap

- Washers
    - Rubber
    - Plastic
- O rings
    - Rubber
- Body of tap
    - Plastic
    - Ceramic

    - Brass
    - Stainless steel

J2.7 Water Tank

- Polyethylene
- Concrete
- Galvanized steel
- Fiberglass