Controlling Lead Release from Premise Plumbing: A Pilot Scale Comparison of Sodium Silicates and Phosphate

by

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Dedicated to the people that believed in me to finish this. Here’s to finally getting out of the “jedi” cave.

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ABSTRACT

Lead and lead-tin solder were widely used in premise plumbing in North America until the 1980's. Although this soldering practice has reduced significantly, lead release from older premise plumbing remains a concern. Utilities often use corrosion inhibitors to protect the piping in the distribution system and reduce lead release in premise plumbing. This study compares sodium silicates and phosphates as corrosion inhibitors for lead release in low alkalinity water. The study was carried out at the J.D. Kline Water Treatment Plant in Halifax, Nova Scotia, Canada. The experimental design compared sodium silicates (concentration of 18mg/L) and zinc orthophosphate (concentration of 0.8mg/L) as corrosion inhibitors at a pH of 7.3 for three disinfectant treatment groups (high chloramines (3mg/L), low chloramines (1mg/L), and chlorine (1mg/L)).

The pilot scale experiments used six recirculating pipe loops; each pipe loop fed into a corresponding copper pipe rack with 50:50 lead:tin solder. An automated pump was used to provide a stagnation time of 24-hr and 30-min in the copper pipe racks. Samples were taken twice a week, at the influent and effluent of the pipe loops. The copper pipe racks were also sampled twice a week after the 24-hr and 30-min stagnation time. Samples were measured for total and dissolved lead, copper, silica, phosphate, total and free chlorine, pH, oxidation-reduction potential, temperature, dissolved oxygen, turbidity, and disinfection by-productions.

The results of the pipe loop experiments showed that sodium silicate releases more lead and copper then when using phosphate as a corrosion inhibitor. In addition using chloramines as a disinfectant released more lead then using chlorine. Greater lead concentrations were also released during a long stagnation time (24-h) than a short stagnation time (30-min). Overall, these results add to the knowledgebase in understanding the interactions of corrosion inhibitors, and disinfectants and their contributions to lead release. In particular, this study provided new data for sodium silicates as a corrosion inhibitor and the application of chloramines in low alkalinity drinking water.

LIST OF ABBREVIATIONS USED

ANOVA	Analysis of Variance
AOB	Ammonia Oxidizing Bacteria
DO	Dissolved Oxygen
DBPs	Disinfectant By products
EMR	Electromotive Force
HAAs	Haloacetic acids
HPC	Heterotrophic Plate count
JDKWSP	J.D. Kline Water Supply Plant
MDL	Minimum Detection Limit
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
THM	Trihalomethanes
TOC	Total Organic Carbon

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Chapter 1.0 Introduction

Lead and lead-tin solder were widely used in premise plumbing in North America until the 1980's. Although this soldering practice has reduced significantly, lead release from older premise plumbing remains a concern. There is evidence that lead in drinking water has adverse effects on human health. (Cech et al. 2006, Miranda et al., 2006, and Watt et al. 1996). Utilities often use corrosion inhibitors to protect the piping in the distribution system and reduce lead release in premise plumbing. This study compares sodium silicates and phosphates as corrosion inhibitors for lead release in low alkalinity water.

Sodium silicates are rarely used as corrosion inhibitors in drinking water. They have been used in the laundry, cement, and steel industry. Sodium Silicates are also able to increase the pH of the water, which helps to reduce metal release.

Using phosphate as a corrosion inhibitor in drinking water is a proven method in reducing corrosion. However a specific pH is required and the price of phosphates has been increasing. There is a need to look at other corrosion inhibitors.

Pilot scale studies are important to minimize the effect of unintended consequences of lead release. Using pipe loops, one is able to see what may happen if certain conditions are changed without risking the health and safety of people. Unintended consequences of increased lead release have occurred from switching from chlorine as a disinfectant to chloramines. The switch to chloramines is favorable due to producing less disinfection by-products (DBPs), such as haloacetic acids (HAAs). However, Edwards and Dudi (2004) reported that a switch from chlorine to chloramines produced a striking increase of lead in drinking water in Washington, DC. This phenomenon was not known until the public was exposed to the increased level of lead.

1.1 Objective

The overall objective of this thesis was to evaluate corrosion control and disinfection strategies on lead and copper release from premise plumbing. Specifically, phosphate and sodium silicate were the two corrosion control strategies that were evaluated in this thesis. Furthermore, the impact that either free chlorine or chloramines would have on lead and copper release in combination with these corrosion inhibitors were evaluated. The research was conducted using copper pipe racks and recirculation pipe loops. Water with low alkalinity was used for this work, which is applicable to many utilities that use surface water in Atlantic Canada and the New England states of the US. The experiments were conducted at the J.D. Kline Water Supply Plant in Halifax, Nova Scotia Canada. Pipe loops were used to similar a water distribution system, while copper pipe racks simulated premise plumbing in a home. The solder on the pipe loops was 50:50 lead:tin solder, although not in use not this solder was used up until the 1980's. Disinfectant treatments for the pilot scale used chlorine, a low dose of chloramines, and a high dose of chloramines. Zinc ortho-phosphates and sodium silicate were used as corrosion inhibitors.

Chapter 2.0 Literature Review

2.1 Corrosion in Premise Plumbing

Corrosion is a concern for many engineering applications. In particular, corrosion in drinking water distribution systems can cause economical, safety, and environmental damage (Revie and Uhlig, 2008; Sastri et al., 2007). Due to corrosion in the drinking water distribution system, pipes have to be replaced which is of great economical cost. In addition lead corrosion in premise plumbing increases the health risk of lead in drinking water.

Premise plumbing is defined as copper piping soldered together with lead/tin solder in schools, public and private housing, and other buildings. The upkeep of premise plumbing is not the responsibility of a water utility; the building's owner is accountable for the maintenance of premise plumbing. Premise plumbing is connected to the distribution system via a service line. The length, composition, and age of premise plumbing will vary from building to building.

Lead has the ability to contaminate drinking water through lead service lines, lead/tin solder in premise plumbing, brass values, and drinking taps. For this research, the only source of lead is from 50:50 lead:tin solder in premise plumbing. The following section will discuss corrosion as it pertains to premise plumbing.

2.1.1 Types of Corrosion

In general, corrosion is an electrochemical reaction that involves the transfer of electrons through oxidation and reduction reactions (Roberge, 2008). The five main types of corrosion are : (1) *uniform corrosion* – corrosion that occurs consistently on a surface, (2) *pitting* – corrosion in a localized area, (3) *dealloying* – selective removal of an element from an alloy, (4) *intergranual corrosion* – corrosion at the grain boundaries of metals, and (5) *cracking* – a crack that occurs due to repeated stresses (Revie & Uhlig, 2008 , Sastri et al., 2007) .

Although not included in the 5 main types of corrosion, the corrosion most often associated with premise plumbing is galvanic corrosion. Specifically galvanic corrosion occurs due to dissimilar metals of copper, from the premise plumbing, and lead, from the lead:tin solder. Galvanic corrosion involves the formation of a galvanic cell. A galvanic cell is created by two electrical conductors immersed in an electrolyte. (Revie and Uhlig 2008). In premise plumbing, copper and lead are the electrical conductors and water in the pipe acts as the electrolyte. When the two electrodes are connected, such as the case for lead/tin solder that is soldered/connected to the copper pipe, a positive current will flow from the positive electrode to the negative electrode. The positive electrode, where the metal is reduced, is called the cathode, and the negative electrode, where the metal is oxidized, is called the anode.

The electromotive force (EMF) series is the ranking of the potentials of pure elements in relation to the thermodynamic free-energy changes in standard state conditions. The EMF series (Table 2.1) is used to determine which metal is the anode and cathode, in a galvanic series. Copper is closer to the cathodic/noble end and has a standard potential of 0.522 V hence copper is the cathode. Lead is closer to the anode end and has a standard potential of -0.126V, thus lead is the anode. Equations 1 demonstrates the oxidization of lead (Pb). Equation 2 demonstrates the reduction of copper (Cu).

Equation 1

$$Pb \rightarrow Pb^{+2} + 2e^{-}$$

Equation 2

$$Cu^{2+} + 2e^{-} \rightarrow Cu$$

In addition to galvanic corrosion, another significant type of corrosion in premise plumbing is microbial corrosion. Due to the presence of microorganisms in premise plumbing, corrosion can be caused by their biological activities. Bacteria grow by feeding on dissolved nutrients in the distribution system, and producing cell material (Sand, W., 2002). Microorganism can also attach to the copper inside the premise plumbing to form a biofilm. The biofilm is a slimly like substance which is made up of extracellular materials (ASM Metals, 1987). Due the metabolical processes of the bacteria, acidic products will be produced that can cause an increase in the pH of the water (Little and Lee 2007). The bacteria are also able use the copper for biological functions, even though copper is toxic to some organisms such as seaweed and shellfish. (Stott, 2003). Corrosion products from the copper can cause a metallic taste to the water, contain blue-green staining particles, and discolour water (Roberge 2008). The role that microorganisms have in regards to corrosion in premise plumbing is difficult to determine, due to the extensive microbiology techniques to identify specific bacterial species.

Table 2.1 Standard Electromotive Force (EMF) Series (Bosich 1970)

Cathodic End (noble end)	Standard Potential, V
Gold	1.42
Platinum	1.2
Slice	0.800
Copper	0.522
Hydrogen	0.00
Lead	-0.126
Tin	-0.136
Nickel	-0.250
Cobalt	-0.277
Iron	-0.44
Chromium	-0.71
Zinc	-0.765
Maganese	-1.05
Aluminum	-1.67
Magnesium	-2.34
Sodium	-2.712
Anode End (active end)	

2.2 Factors That Affect Corrosion in Drinking Water

Factors that affect the corrosion in drinking water are outlined below

- *Stagnation time:* Metal level increases with stagnation time. Lytle and Schock (2000) showed that metal level increased exponentially with time.
- *Temperature:* An increase in temperature will increase the rate of corrosion (Droste, 1997)
- *pH:* low pHs will increase corrosion rate, while high pHs can decrease corrosion rate (Droste, 1997)
- *Alkalinity:* Alkalinity helps to buffer the pH of the water, thus at lower alkalinities there is more pH fluctuations and an increase in corrosion rate (Droste 1997)
- *Disinfectant:* Studies have found that there is more lead corrosion when comparing chlorine with chloramines (Renner, 2005, Miranda, 2007, Edwards and Dudi, 2004)
- *Total dissolved solids:* An increase in total dissolved solids will increase the conductivity and thus increase the corrosion rate (Droste 1997)
- *Hardness:* Hard water has dissolved calcium and magnesium ions, which make the water less corrosive because a protective film made of carbonate is formed (Jones, 1992)
- *Organic Matter:* The amount of natural organic matter may increase corrosion (Korshin, Ferguson, and Lancaster 2005, Lin and Valentine, 2008, Dryer and Korshin).

2.3 Inhibitors for Corrosion Control

There are several methods for corrosion control in the drinking water distribution system. The water chemistry can be changed to make it less corrosive, pipe materials that are corrosive can be replaced with non-corrosive materials, and corrosion inhibitors can be used to form a barrier to prevent galvanic corrosion. Changing the water chemistry and replacing pipe is expensive, a more economical choice is for a water utility to use a corrosion inhibitor. Corrosion inhibitors are defined as a substance that will form a film on exposed metal surfaces to prevent the transfer of electrons in a galvanic cell. This research focuses on two corrosion inhibitors, phosphate and sodium silicate. Phosphate as a corrosion inhibitor is currently being used at the J.D. Kline Water Supply Plant(JDKWSP) in Halifax, NS, Canada (site of pilot scale experiments). Sodium silicates are not widely used in the water industry. There are mixed results on the effectiveness of sodium silicate as a corrosion inhibitor and limited research.

2.3.1 Phosphates

To control lead release, phosphates (orthophosphate, polyphosphate) are widely used. However, due to the increase in phosphate demands, other means are being investigated for corrosion control, such as silicates (Schock, et al., 2005, and Renner, 2008).

There are several different types of phosphate used as a corrosion inhibitor: orthophosphate, polyphosphate, ortho-polyphophate blends, and zinc phosphates. Orthophosphates are made up of phosphoric acid, and mono, dibasic, and tri basic sodium phosphate. Insufficient sodium phosphate dosages have shown to accelerate corrosion (AWWARF, 1996) therefore a large start up dosage is needed to form the passivation layer. Polyphosphates are a chain of orthophosphate species which can also sequester iron and manganese to reduce red water problems (AWWARF 1996). Ortho polyphosphates blends are a mixture of orthophosphate and polyphosphate where the orthophosphate species will impact the lead corrosion and the phosphate species will sequester iron and magnesium (Boffardi, 1995). With zinc phosphates, the zinc will help to accelerate the passivation film formed by the phosphates (Boffardi, 1995) .

2.3.2 Sodium Silicate

Sodium silicate is often referred to as “waterglass”. Sodium silicate (Na_2SiO_3) has a variety of uses including, aid in laundry detergents, and coating stainless steel for corrosion protection(Asrar et al., 1998). There is limited use of sodium silicate for corrosion inhibition in water treatment. Sodium silicates are made by fusing silica sand and sodium carbonate at very high temperatures. This process results in a solid glass that is then dissolved in water to make a silica solution. Sodium silicate works in two ways to reduce the amount of corrosion in drinking water: pH increase and passivation. Sodium silicate is an alkaline chemical, which raises the pH of the water. Generally at higher pHs the corrosion rate will reduce. Secondly sodium silicate can reduce corrosion by passivation. Passivation occurs when an oxide layer, which inhibits corrosion, is formed on the pipe surface.

The ratio between silica and alkali in sodium silicate will depend on its intended use. The weight ratio of SiO_2/Na_2O is general between 2.00 to 3.22 for water treatment. The ratio recommended for water that has a pH greater than 6.0 is 3.22, whereas a ratio of 2.00 is recommended for water below a pH of 6.0 (Thompson et al, 1997). The use of sodium silicate for corrosion control in drinking water is approved by the American Water Works Association and the US Environmental Protection Agency (EPA).

Sodium silicates are also an alternative treatment for red water problems in distribution systems. Sodium silicates are able help the sequestration of iron and manganese (Robinson, R.B. et al., 1992, and Lehrman & Shuldener 1985). In studies conducted by Dart and Foley 1971, sequestration of iron was found successful when sodium silicate and chlorine were added at the same time.

There is limited data about the effectiveness of sodium silicates as a corrosion inhibitor for lead and copper. Below is a review of some studies performed with sodium silicates. A summary table of the literature is shown in Table 2.2.

- In Hopkinton, Massachusetts, emergency wells were dosed with sodium silicate at 25 – 30mg/L which increased the pH from 6.3 to 7.1. As a result a 55% reduction of lead levels were observed. When the silicate dose was elevated to 45 – 55mg/L ,the pH elevated to 7.5, resulting in a 95% reduction of lead. The aesthetic quality of the water was equivalent or better than the quality before the use of sodium silicate (Schock et al., 2005).
- In Wilbraham, Massachusetts sodium silicate at a dose of 12mg/L, successfully reduced lead and copper concentrations at full-scale to meet the lead and copper rule. (Chiodini, 1998)
- Sodium silicate increases the pH of the water. An increase in pH can reduce the amount of corrosion. When comparing sodium silicate against pH control water, during a 68-hr stagnation time the pH control water reduced less lead than sodium

silicate. During an 8-hr stagnation period, both the sodium silicate and pH adjustment resulted in similar lead release (Pinto et al., 1997).

- Studies performed on 50:50 lead:tin coupons, showed that increasing the sodium silicate dose resulted in a decrease of lead release (Lintereur et al., 2010).
- Lytle et al., (1996) studied zinc orthophosphate, alkai-metal orthophosphate, and sodium silicate as corrosion inhibitors in a isolated building. Sodium silicate was dosed at 32mg/L, which raised the pH to 9.5. Then the concentration was dropped to 16 mg/L as a maintenance dose, which lowered the pH to the range of 8.8 – 9.1. The sodium silicate reduced the lead and copper concentration, however due to no baseline data and different plumbing configurations it was impossible to compare each treatment.(Lytle et al.,1996)

2.4 Disinfectants

2.4.1 Chlorine

Chlorine is the most commonly used disinfectant in water treatment. It is a cost effective method of disinfecting the water and reduces microbial corrosion (Droste 1997). Chlorine is also a very strong oxidant; it has a high oxidation reduction potential. It is able to oxidize metallic lead to lead oxide which is insoluble in water and thus reduces lead in the water (Davidson et al., 2004). The down side to chlorine are the carcinogenic products called disinfection by products (DBPs) that are formed.

DBPs are the results of the reaction between the natural organic matter in the water and the disinfectant. The two main types of DBPs are trihalomethanes (THM) and haloacetic acids (HAA). The DBP rule was put into place by the EPA to limit the public exposure to DBP’s. In an effort to comply with the DBP rule, many water treatment plants are looking for an alternative disinfectant to chlorine.

Table 2.2 Summary of sodium silicate studies

Purpose	**Place**	**Configuration**	**Disinfectant**	**Stagnation time**	**Metals**	**pH**	**Sodium silicate conc.**	**Author**
Using silicate to solve iron problems	Well water Hopkinton, Mass. USA	Distribution system, lead servi	Chlorine	6 to 10 hrs	Pb, Cu, Fe	7.1 7.5	25 - 30mg/L 45 - 55mg/L	Schock et al.,2005
Treatment of iron deposition	Various well water systems in Ontario	Distribution system	Chlorine	various	Fe	various	1 - 10mg/L	Dart, F. and Foley P. 1972
Sequestration using sodium silicate	Groundwater systems in Wisconsin and Ontario	Distribution system	Chlorine	various	Fe, Mn	various	4 – 18mg/L	Robinson R.B. et al., 1992
Control lead corrosion in a building	New building	Premise plumbing	Chlorine	12hrs	Pb, Cu, Zn, Fe	7.7	32mg/L	Lytle et al., 1996
Effect of Sodium silicate on lead release	Various (groundwater, surface water, desalinated water)	50:50 lead:tin coupons in copper loops	Chlorine	6hrs	Pb	8.7	8.4 mg/L, 21.6mg/L, and 43.1mg/L	Lintereur et al., 2010
Comparing corrosion inhibitors	Seymour Dam (North Vancouver)	Copper coils with 50:50 lead:tin solder	Chloramines	24hr	Cu, Pb,	8.0	12mg/L	MacQuarrie, D.M. 1997
Corrosion Control for Lead and Copper Rule	Wachusett Rservouir Massachusetts	Bench scale, metal coupons of sell, copper and lead	Chloramines	68hr	Cu, Fe, Pb	8.5 – 9.0	20mg/L and 10mg/L	Johnson, B. et al., 1993
Lead and Copper Control	Wilbraham, Massachusetts	Distribution system	Chlorine	6 to 8 hrs	Pb, Cu	7.0-8.0	20mg/L to 12mg/L	Chiodini, R. A. 1998
Sodium silicate compared to pH control	South Carolina	Batch treatment system with copper and lead:tin solder	Chlorine	8 and 68hr	Pb Cu	7.6 – 8.5	15mg/L 20mg/L	Pinto et al., 1997

2.4.2 Chloramines

As an alternative choice to chlorine, chloramines are used as a disinfectant. Chloramines are a combination of free chlorine and ammonia (NH_3Cl). Chloramines are formed from the reaction of ammonia and free chlorine. The simplified chlorine – ammonia reactions are shown in equations 3, 4, and 5 (Qiang & Adams, 2004).

Equation 3

$HOCl + NH_3 \rightarrow NH_2Cl + H_2O$ (monochloramine)

Equation 4

$HOCl + NH_2Cl \rightarrow NHCl_2 + H_2O$ (dichloramine)

Equation 5

$HOCl + NHCl_2 \rightarrow NCl_3 + H_2O$ (trichloramine)

To comply with the limits on DBPs in drinking water, water treatment plants are switching from chlorine to chloramines (Miranda et al., 2007). The effects of chloramines on the water distribution system are poorly understood (Renner, 2005). For example, treatment plants switching from chlorine to chloramines in Wayne County, North Carolina, (Tibbets, 2007), Greenville, North Caroline (Renner, 2005) and Washington DC (Renner, 2004) experienced elevated lead levels.

The most well-known occasion for an increase in lead with a switch from chlorine to chloramines was in Washington, D.C.. In the early 2000's, the District of Columbia Water and Sewer Authority, responsible for drinking water in Washington D.C., switched from chlorine to chloramines. The switch was done in order to meet the DBP rule. The change in disinfectant resulted in an unexpected high lead release, exceeding EPA regulatory limits of 15μg/L for lead. In Figure 2.1, the evolution of lead from the switch in disinfectant from chlorine to chloramines is shown.

The change in water chemistry was the cause of the high lead release due to the switch from chlorine to chloramines. Years of using chlorine assisted the oxidation of Pb(II) in the lead service lines to lead oxide on the surface of the pipes. After the disinfectant changeover, chloramines caused the lead oxide to reduce to soluble Pb(II), resulting in high lead levels.

The consequents of changing disinfectants from chlorine to chloramines were rarely understood until Washington D.C. Lessons learned from Washington were applied to other utilities switching from chlorine to chloramines. San Francisco's distribution system is an example where a switch from chlorine to chloramines did not cause high lead release. Factors that achieved this were: removing lead service lines, moderating free chlorine residual before switching to chloramines, and maintain a high pH in the distribution system (Wilczak et al., 2010).

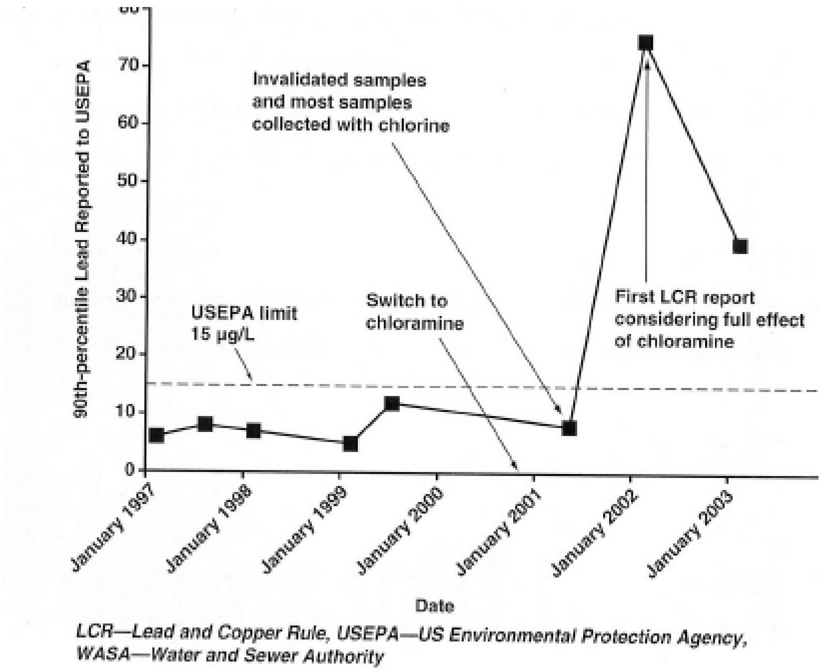


Figure 2.1 Lead sampling reported in Washington D.C. (Edwards & Dudi, 2004)

2.4.2.1 Comparing the Water Chemistry of Chlorine and Chloramines

Free chlorine is a very strong oxidantizer. It is able to oxidize (the loss of electrons and the gain of oxygen) Pb(0), metallic lead, and Pb(II), a lead ion, to lead oxide (PbO_2), which is the Pb(IV) solid phase(Davidson, et al.,2004). Lead oxide is insoluble in water and thus reduces the amount of lead in drinking water. In Edwards and Dudi (1996) it was found that chlorine reacts with soluble Pb(II) to rapidly precipitate to insoluble lead at the bench scale level. Similar results have also shown that Pb(IV) oxides will form over time in chlorinated water (< 3mg/l as Cl_2) with a pH range of 6.65 – 10 (Lytle & Schock, 2005).

On the other hand, chloramines, NH_2Cl, are a weaker oxidant. Chloramines create an environment that will reduce (gain of electron and the loss of oxygen) PbO_2 and/or destabilize PbO_2 to Pb(II). Pb(II) is the lead ion that is soluble, contributing to the increase of lead in drinking water. The decomposition of chloramines is increased at lower pH values. In addition to lead, chloramines have been shown to reduce Fe(II) (Vikesland and Valentine, 2000). The switch to chloramines will cause the oxidization reduction potential of the water to decrease. This may cause the reduction of lead oxide to the soluble Pb(II), which causes increased lead levels in drinking water(Lin and Valentine, 2008, Switzer et al., 2006). The rate at which Pb(II) is released may be proportional to the rate of chloramines decomposition. Figure 2.2 suggests that the species responsible for the reduction of lead oxide is likely a species that is produced during the decay of chloramines (Lin and Valentine, 2008).

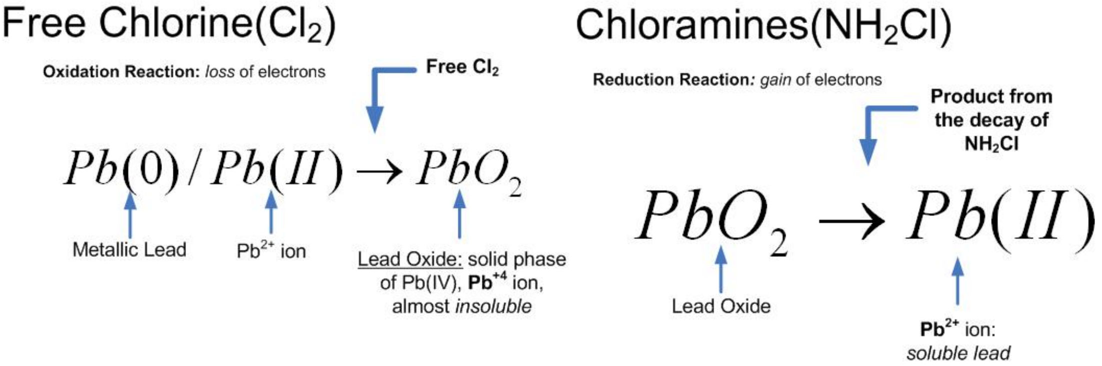


Figure 2.2 Reduction and oxidation of Lead (Lin and Valentine, 2008)

2.4.2.2 Nitrification

Nitrification is a microbiological process that oxidizes ammonia to nitrite and then nitrate. Nitrification is associated with the use of chloramines as a disinfectant and can cause additional lead release. When ammonia is added to water, it will react with free chlorine to form chloramines. Over time, chloramines will degrade and ammonia will be released. Nitrification is a two-step process. First ammonia is oxidized by oxygen through the utilization of ammonia oxidizing bacteria (AOB) and converted to nitrite (equation 6). *Nitrosomas* is an example of AOB that involved with this step (Watson et al., 1981).

Equation 6

$$NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$$

In the second step, nitrite is oxidized by nitrite oxidizing bacteria to nitrate (equation 7). The genus most associated with this step, is *Nitrobacteri* (Watson et al.,1981).

Equation 7

$$NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ 2e^-$$

In wastewater treatment, nitrification is a beneficial mechanism to remove ammonia. However in drinking water distribution systems, nitrification can cause the following adverse impacts to happen: increase in the amount of bacteria, decreased in the dissolved oxygen, lower the pH, and accelerate the loss of disinfectant (Zhang et al., 2008a; Wolfe et al., 1990; Zhang et al., 2009; Wilczak, et al., 1996; Edwards & Dudi, 2004; Zhang et al., 2007).

The process of nitrification will most often happen in a residential house due to the stagnation times in premise plumbing. In the distribution system water is continually moving, but overnight stagnation in likely to occur in a home. In a study conducted by Zhang et al., (2008b) lead pipes showed more nitrification indicators than PVC pipe. The equation 8 exhibit how lead and nitrate react to form nitrite (Uchida and Okuwaki, 1998), which allows the nitrite oxidizing bacteria to utilize more nitrite.

Equation 8

$$Pb + NO_3^- \rightarrow NO_2^- + PbO$$

The oxidation of ammonia to nitrite and then to nitrate, by bacteria produces acid that in turn will lower the pH, which further enhance leads release. However, other effects of nitrification including the amount of nitrite and nitrate produced, and the reduction in inorganic carbon and dissolved oxygen, did not cause significantly more lead leaching (Zhang et al., 2009). The amount of nitrate in potable water can lead to lead increase from solder (Nguyen, 2010).

Ammonia oxidizing bacteria (AOB) are responsible for the oxidation of ammonia to nitrite and then to nitrate. There is great difficulty in growing AOB for quality control and comparison for gel techniques. The process is lengthy, and requires specific conditions. Most often measuring pH, nitrite, nitride, and the loss of ammonia can determine the presence of nitrifying bacteria. AOB has shown resistance to chloramines more so than free chlorine (Wolfe et al., 1990). When disinfectant are removed from water, such as with granular activated carbon (GAC) in home filters, nitrification can quickly be established again (Zhang et al., 2008a).

2.5 Lead Sampling in Canada

Health Canada has a maximum level of lead in drinking water to be 10µg/L. Health Canada takes a two tier approach to measuring lead in residential homes. With the first tier approach, testing for lead is done after a least a 6 hr station time with a 1L first draw sample. If more than 10% of samples sites are greater than 15µg/L (the lead action level), then tier 2 sampling is started. Tier 2 sampling only occurs that those taps that exceeded the 15µg/L limit. With tier 2 sampling, 4 consecutive 1 L samples are taken after a minimum stagnation time of 6 hours. Each 1L sample is analyzed separately to develop a profile of lead contributions from the facet, household plumbing, and lead service line. From there correction action can be taken to determine the cause of the lead contamination and the solution.

Chapter 3.0 Methodology

3.1 Location of Study

The pilot studies were done in Halifax, Nova Scotia at the J.D. Kline Water Supply Plant. The source of raw water is from Pockwock Lake. The plant provides water for the regions of Halifax, Bedford, Sackville, Timberlea, Fall River and Waverley. The watershed is approximately 5661 hectares and is jointly managed by the Halifax Regional Water Commission. The J. Douglas Kline Water Supply Plant (JDKWSP) at Pockwock Lake was commissioned in 1977. Its current daily production of water is 90 Million Litres(ML)/day, but has a maximum capacity of up to 220 ML/day.

The JDKWSP was used for the pilot scales experiments due to the close relationship between the Halifax Water Commission and Dalhousie University. With Halifax Water's Water Quality Master Plan this research partnership is able to provide innovation into water treatment to insure that Halifax's population is being provided with the best water quality possibleTable 3.1 provides an indication of the general water characteristics that are being treated at the JDKWSP during 2009. This water is characterized by low turbidity, pH, and alkalinity; very typical of surface water in Nova Scotia.

Table 3.1 Raw water characteristics of Pockwock Lake during 2009

Parameter	**Raw Water**
pH	5.16
Turbidity (NTU)	0.4511
Temperature (°C)	8.85

The JDKWSP is a direct filtration water treatment plant, as seen in **Error! Reference ource not found.**. Water was pumped from Pockwock Lake to the plant. Lime and potassium permanganate are then added for the oxidation of iron and manganese. Next the pH is lowered with carbon dioxide to ensure proper coagulation with alum. During the winter months, a polymer is added to assist with coagulation. Mixing and flocculation occurs next in three parallel flocculation tanks. After flocculation, filtration occurs in dual layer media (sand and anthracite), free chlorine is added prior to filtration. Directly after filtration the water is stored in a clear-well. Right before the water is sent to the distribution system, free chlorine, fluoride, sodium hydroxide (pH adjustment) and polyphosphates (corrosion control) are added.

The bulk of the distribution system in Halifax is made up of a combination of cast iron, and ductile iron pipes, there is a small percentage of PVC piping. The Halifax Water Commission has set out to replace lead service lines leading all the way to the customers' house.

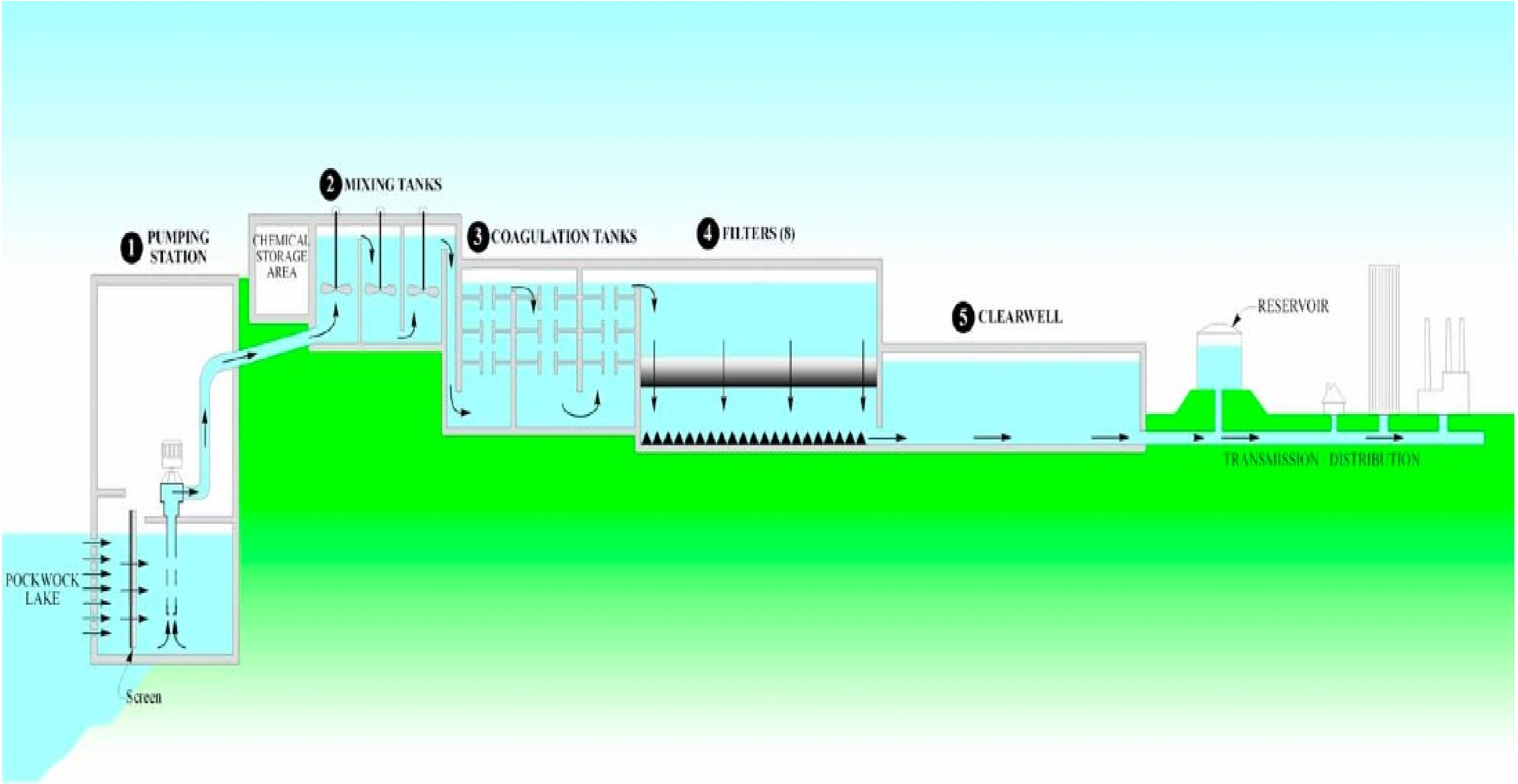
3.2 Experimental Set-up

The pilot scale experiments were done in the basement of the (JDKWSP) Halifax, Nova Scotia. The following section will describe how the pipe loops and copper pipe rigs were operated.

On the full-scale level, assessing the impacts of corrosion is difficult and can be impossible due to the unknown impacts to public health. On the other hand, pilot scale studies can determine what the full scale consequences of making changes to water chemistry are. Pipe rigs are an effective tool to evaluate many alternated conditions for corrosion control in a distribution system.

The pipe loops that are used in this study are used simulate the distribution system. They have been used in many studies in Dr. Gagnon's laboratory (Maddison, 2000; Esinor,. 2002; Rutledge, 2003). These studies have focused on just on the drinking water distribution system.

Figure 3.1 Process diagram of JDKWSP



Copper pipe rigs were added to study the effect of corrosion in the home. Studying the implication of corrosion in premise plumbing can be challenging, as stagnation time can vary in households. The advantages of the copper pipe rigs are that variables, such as stagnation time, can be controlled and evaluated against other conditions.

The copper pipe rigs used for this study were created for another thesis (Dobrough, 2009) also focused on lead in domestic plumbing. Stagnation time was based on Joelle's theses, which were designed for the upcoming Health Canada Drinking Water Guidelines.

3.2.1 Pipe Loop Set up

There were six recirculating pipe loops used for the pilot scale. The pipe loops were used to simulate water aging that would occur in an actual drinking water distribution system. The hydraulic retention time of the water in the pipe loops could vary up to 24 hours. For this study it was set at a time of 12 hr. The velocity of the water is also a representative of a real distribution system as proven in this thesis (Rutledge, S. 2003) at 0.03m/s(1fgs).

To simulate premise plumbing in a home, once through copper pipe racks were constructed for each pipe loop. The copper pipe racks were first used in Joelle's thesis for approximately one year. The design of the copper pipe racks was based on studies done by Yannoni and Covellone (1998) and Churchill et al., (2000). The copper pipe racks are made up of seven, 13 foot length of ½"diameter Class M copper pipe. There are twenty four 50:50 lead:tin solder joints that connected the seven 12 foot pieces together. At each end of the copper pipe racks there was a brass fitting to connect tubing from the reservoir bins to the copper pipe racks and at the other end to collect samples. All six pipe loops operated independently from each other. The pipe loops are arranged in 3 stacks of 2. Figure 3.2 shows the actual set up of the pipe loops in the basement of the JDKWSP.

Figure 3.2 Actual set up of pipe loop in the basement of JDKWSP

As described by Rutledge (2003), the Dalhousie pipe loops are made up of five components. These components are: the test section, the recirculation pump, the return section, the transition section, and the steel support frame. Figure 3.3 provides a detailed drawing of these components. For this study the addition the copper pipe racks (as seen in the background of Figure 3.2) was attached to reservoir bins that collected water from the effluent of the pipe loops.

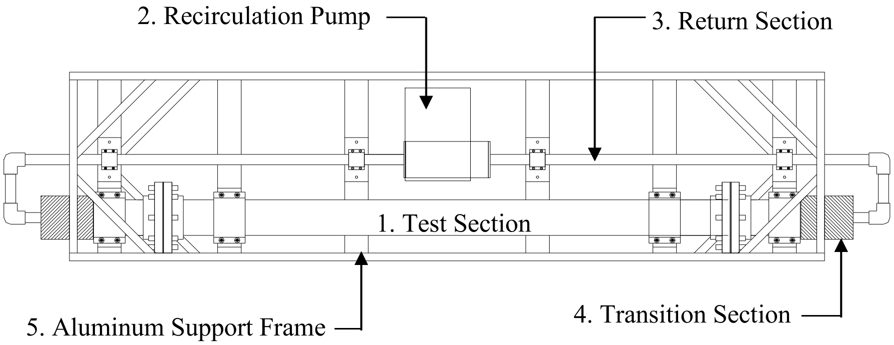


Figure 3.3 Detailed drawing of pipe loop (Rutledge 2003)

For this thesis, the test section in the pipe loop was PVC pipe that had a diameter of 100-mm (4”) pipe and 1.82m (72”) in length. This can be changed depending on the purpose of the study; previous studies with the pipe loops have used cast iron pipes. PVC was chosen because this material limited corrosion to only that coming from the premise plumbing of the copper pipe racks. To connect the test section to the rest of the pipe loop Class 150 Flanges were mounted to the transition section of the pipe loop. Figure 3.4 shows the test section used for this study along with the flange connection.

Figure 3.4 Close up of PVC test section of pipe loop

To recirculate the water through the pipe loop a Grundfos (Grundfos Canada Inc.,, Burlington ON) centrifugal pump rated at 146 L/min (38.5gpm) at 2.1 m (7.0) of head was used (Figure 3.5). This pump had 3 speeds. The pump was set at the lowest setting of 0.3m/s (1 fps), which is typical of drinking water distribution system velocities (McAnally and Kumaraswany 1994; Camper 1996).

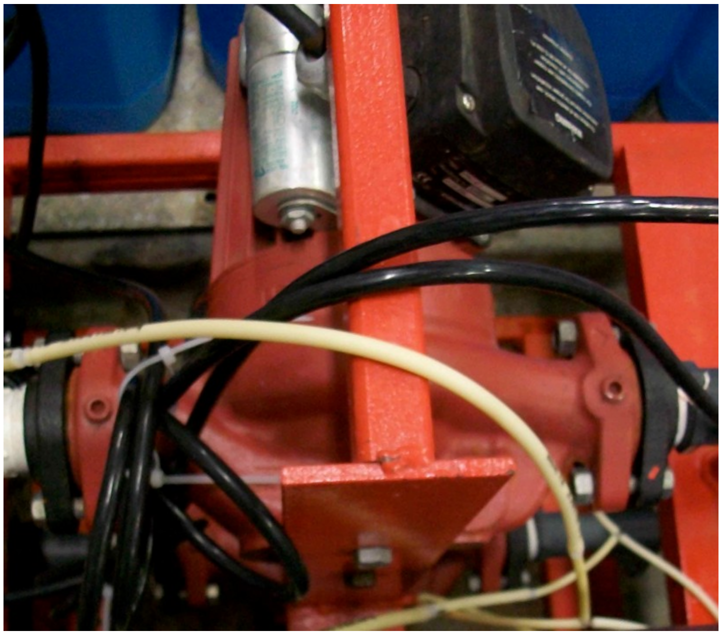


Figure 3.5 Recirculation pump used in the pipe loops

The transition section of the pipe loops used a series of PVC coupling to change the size from 25mm (1”) to 100mm (4”) pipe to provide a connection between the test section and the return section. The transition section also contained a 250mm (10”) long 100mm (4”) PVC pipe section with a Class 150 flange. This proved a located for attaching the effluent port. The effluent port would then discharged water to the reservoir bins to be pumped in the copper pipe rigs

The function of the return section was to move fluid from the test section to the influent of the recirculation pumps, then from the pump back to the test section. The return section was made up of 25mm (1”) schedule 40 PVC pipe and pipe fittings. The influent port (Figure 3.6) was located on the return section of the pipe loops. An external chemical feed pump pumps the water through the influent port. The amount of water that is flowing through the influent determine the hydraulic retention time in the pipe loop.

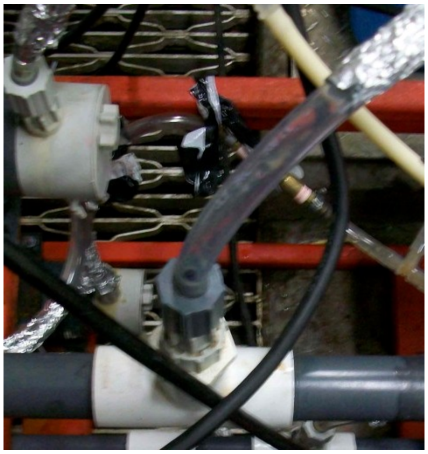


Figure 3.6 Influent port for the pipe loop

The steel frame of the pipe loop encases all sections of the pipe loop. It is painted in red corrosion reduction paint. The weight of a pipe loop with no water in it is approximately 120kg (260lbs). The steel frame can also be stacked, up to three pipe loops, to minimize the footprint if necessary.

3.2.1.1 Pipe Loop Process

Before the use of the Dalhousie Pipe Loops at the JDKWSP they were used for another project in the Bridgewater, Nova Scotia Drinking Water Treatment Facility. Following their pick up from Bridgewater, the pipe loops required minimal amount of maintenance before they were operational. The same test sections were used. Recirculation pumps and feed pumps were cleaned and tested before the installation for the current study. Filtered water was send through the pipes to clean them out, and all the tubing was replaced.

Filtered water was used in this study so that chemically could be added to the desire of the student. This then required that each pipe loop have it own chemical feed tanks. Blue 20L water jugs were used as chemical feed tanks, peristaltic pumps were used to feed the chemicals into the influent water line just prior to entering the closed pope loops system (Figure 3.7).

Due to the seasonal variation in feed water and the nature of pipe loops the chemical dosages were very difficult to maintain. A trial and error system was used were used by adjusting pump speeds and chemical stock concentrations. Chemical dosages were adjusted until the desired treatment was observed at the effluent of the pipe loop and was changed constantly due to the changing of filtered water.

Figure 3.7 Chemical jugs set up for pipe loops

Due to the 12 hr retention time in the pipe loops, the effluent of the pipe loops has a low flow rate. Therefore holding tanks (Figure 3.8) were attached to the effluent ports to hold the water for the computer timed pumps to go through the copper pipe rigs.

Figure 3.8 Reservoir bins

The overall pipe loop process is seen in the Figure 3.9. The feed water, filter water from the clear well, for the pipe loops firsts enters an over flow container. From the overflow container water is brought to each pipe loop by a diaphragm pump with 1.91cm (3/4”) ID flexible Tygon Tubing. This was done individually to allowing each pipe loops to be able to be separately for flow control, which would be impossible under pressurized condition, such as with a hose.

A brass valve was used to control the flow rate of the effluent of the pipe loopsat 44mL/min. The valves were installed before the treated filtered water enters the pipe loops through the influent port. . To control the flow of chemicals for disinfectant, corrosion inhibitor, and pH adjustment, a variable speed peristaltic pump (Masterflex, Vernon Hills, IL) with a 1 to 100rpm motor and L/S 14 PHAR-MED tubing with an inner diameter of 1.6mm was used. The flow rates for the chemical stocks were variable and readjusted through trial and error to achieve the desired chemical concentrations again by a trial and error method.

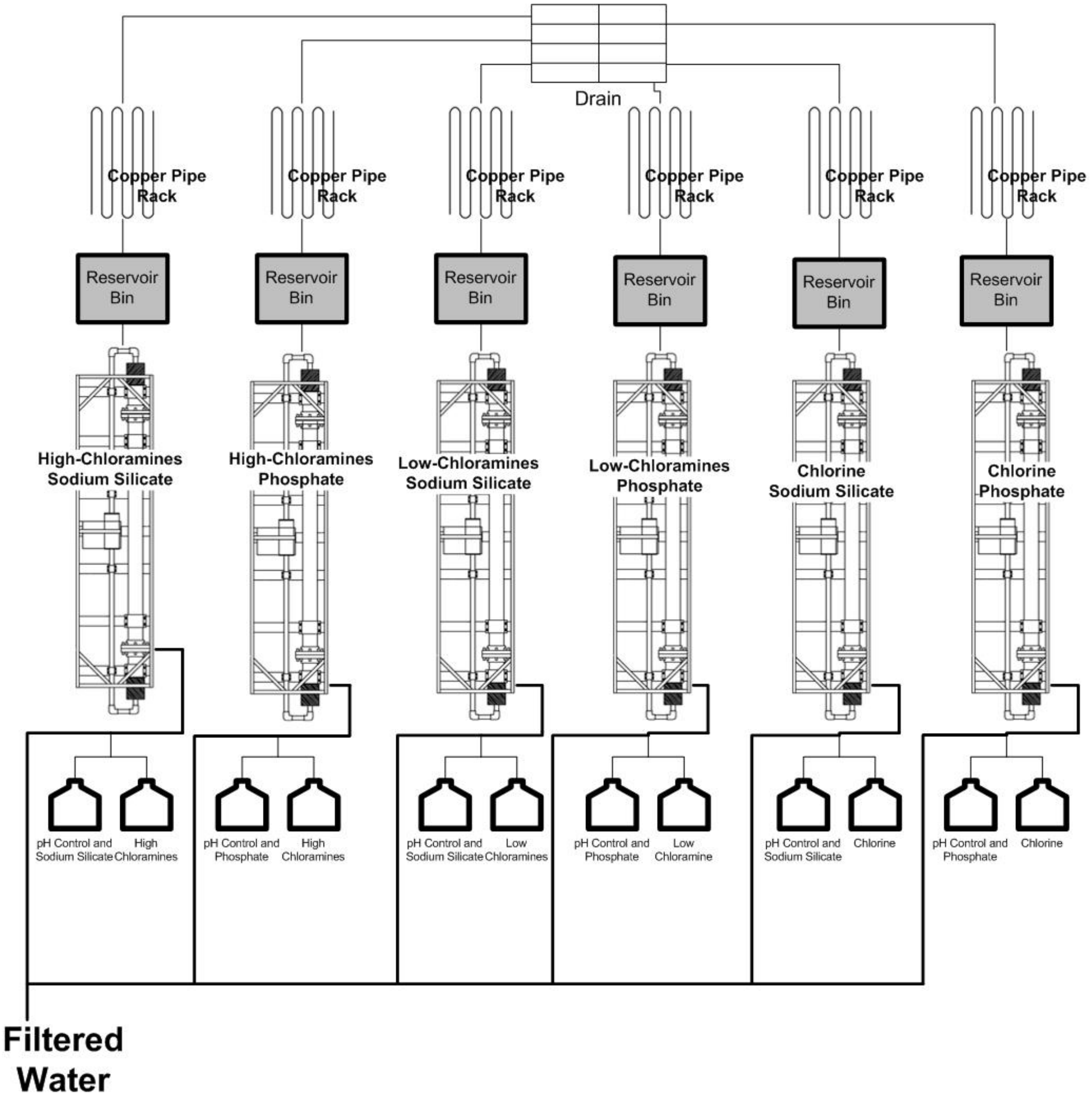


Figure 3.9 Flow diagram of pipe loop set up

After the 12 h retention time in the pipe loop, water was carried from the effluent port, using I/P Masterflex ® Norprene tubing to modified 68.1L Rubbermaid storage containers(reservoir bins). This dark tubing was used to limit bacterial and algal growth as light could not enter. The reservoir container was modified using hardware store fitting to allow water to enter from the bottom of the container. To pump the water from the reservoir bins to the copper racks a Masterflex ® I/P ® precision brushless drive pumps with motor sped of 33 to 650 rpm were used. These pumps were attached to a computer that implemented a stagnant/flush cycle. I/P 73 Norprene tubing was used to transfer the water from the reservoir bins to the copper pipe racks. At the other end of the copper pipe racks water passed through 1.91 cm (3/4”) ID flexible Tygon tubing then to the drainage system in the basement. From this point samples could be taken after the stagnation times.

3.2.2 Determining Flow Rates

To have a retention time of 12 hrs in the pipe loops, (pipe loops have an internal capacity of 32L) a flow rate of 44mL per min was needed. The flow required for the copper pipe racks was much faster than the flow rate out of the pipe loops.

A flow rate of 5.6 L/min through the copper pipe racks was chosen to simulate household conditions. The pumps were controlled by a computer program using LabView. The computer program had a 24h cycle. The pumps would turn on for 5min, then off for 30min (allowing for a 30min stagnation time in the copper pipe racks). After this the pumps would turn on for 5min, then off for 23hr and 20min(allowing for a 23hr and 20min stagnation time in the copper pipe racks) This 24 hr cycle was chosen to ensure samples could be collected at the same time each day.

3.2.3 Routine Pipe Loop Maintenance

On samples days the pipe loops and copper pipe racks were visually inspected for any damage or leaks. Circulation pumps were also felt to make sure they were not warm. If the pump was warm it meant that it was not turning, therefore they had to be manual turned so they would operate again. If that did not result in the pump turning again, the pipe loop was empty the pump was open up, clean, and put back to work.

The L/S 14 PHAR_MED tubing from the peristaltic pump for the chemical feed had to be regular changed. This tubing would often get clogged and would stop working.

3.2.3.1 Stock Chemical Preparation

The chemical feed stock was held in 20-L blue water jugs for the pilot scale system. A trial and error system was usages to achieve the desired chemical dosages. The peristaltic pumps and chemical concentrations until the effluent samples collected in the pilot scale system displayed the desired results.

Disinfectants. VVR Sodium Hypochlorite Laboratory Grade from Fisher Scientific 6% with a approximate concentration of 60,000ppm was diluted to a concentration of 900ppm. This was done by taking 15mL of solution and diluting it in 1L of distilled water. The suitable volume of this stock solution was then added to the chemical jugs.

The Borate Buffer Method of monochloramine formation was used throughtout the whole pilot scale study. Concentrations were between 500mg/L to 800mg/L using this method.

For the Borate Buffer Method, 1.0M (1mol/L x 61.832 g/mol = 61.832g) of Boric Acid (Certified ACE Crystalline from Fisher Scientific) was combined with 0.26M (0.26mol/L x 39.9971g/mol=10.399g) of Sodium hydroxide in 1L of distilled water then mixed well. This begin the borate buffer stock solution.

To make 1L of mono-chloramines, 100mL of borate buffer stock solution was diluted into 900mL of distilled water. The pH of this solution was adjusted to a pH of 9.4 using Sodium hydroxide. T Then 4g of Ammonium chloride was added to 500mL of the diluted borate buffer solution, while 18.7 mL of Hypochlorite 6% solution was added to the remaining 500m: of diluted borate bugger solution. Once each solution was mixed well, then were then mixed together.

Acid/Base Solutions. Nitric acid (Fisher Scientific) was used to lower the pH to the desired level. This was done using the stock concentration to dose in small solutions to the appropriate chemical feed jugs. A 4.0M solution of NaOH was used to increase the pH . Small columes of the solution were addred directed into the chemical feed jugs.

Corrosion inhibitor. Zinc orthophosphate (Carus 3180; Carus Chemical Corporation) was used for the pilot scale. The JDKWSP uses a 25% zinc ortho phosphate /75% poly phosphate blend (Virchem 937, Carus Chemical Corporation). Due to sequestering of iron in the circulation pumps by polyphosphate in Joelle Doubrough thesis, an zinc orthophosphate was chosen to reduce corrosion contamination. The zinc orthophosphate (Carus 3180) comes in liquid form, which is diluted in distilled water then added to the chemical feed jugs attached to the pipe loops. The approximate concentration of the stock solution was 36000ppm. A concentration of 3mg/L was used during the condition period condition the loops. It was then lowered to 1mg/L for the duration of the study. The condition period was not included in the data analyzed in chapter 4.

Sodium silicate solution (National Silicates) with a 3.22 weight ration of sodium silicate was used in this study. The solution came in liquid form. It was mixed in 1L of distilled water then diluted within the chemical feed jugs.

PQ Corporation (the company that made the sodium silicates for this project), recommends that when first introducing silicates to a water distribution system, a high maintenance dosages of 24mg/l or greater. The high dosages should be done for a period of 30 to 60 days. This insures that a protective coating form. The film is first formed in the distribution system then in the premise plumbing of homes. Once the concentration of sodium silicate at the end of the line is the same as the concentration going in, the protective film of sodium silicate has been formed. It is recommended by PQ Corporation that lowering to maintenance dosages should be done in steps. First lowering to 12mg/L, 8mg/L , and possible down to 4mg/L. However for this experiment, a goal of approximately 18mg/L at the effluent of the copper rack was chosen due to this concentration being used in a plant in New England.

In the New England area a drinking water treatment plant that uses low alkalinity, low softness, and high pH surface water uses sodium silicates as the corrosion inhibitor. Sodium silicate was chosen as the corrosion inhibitor implemented due to the unfeasibility of other method of corrosion inhibition. Calcium carbonate required expensive equipment. While poly orthophosphate required a lower pH, thus increases costs and with zinc orthophosphate there was a concern for zinc in the waste water plant (EPA 1993). Currently the plant dosses the water at 18mg/L of sodium silicate. This raises the pH form 8.3 to 9.0 and in addition solves the red water problems.

3.2.4 Pilot-Scale Experiment

Once the pipe loops were moved from Bridgewater, the pipe loops were set up in the basement of the J.D. Kline water plant. The tubing was all replaces and recirculating pumps were cleaned and tested. A condition period of approx. 1 month started. Filter water, from the clear well was pumped through the pipe loops and copper pipes. This was to flush out stuff from the previous thesis.

Next disinfectants and pH control were introduced to the system. That was done for a month. Next the corrosion inhibitors (sodium silicate and phosphate) were introduced at a higher concentration for approximately 3 weeks then brought down to the deserved levels (1mg/L for Phosphate and 18mg/L for silica).

3.2.4.1 Experimental Design

The intention of the experimental design is to enable utilities to compare corrosion inhibitors amount different disinfection options. Changes to distribution systems, such as the switch from chlorine to chloramines, are done to meet the disinfection by production rule, but have caused unintended consequences such as the release of more lead.

For the disinfectant variable parameters were chosen based on maximum and minimum limits for chloramines and current condition at JDKSWP. The maximum amount of chloramines that are allowed in drinking water is 3.0mg/L and the minimum is 1mg/L (Ontario Ministry of Environment, 2006) The conditions at JDKWSP had a free chlorine residual of 1mg/L.

JDKWSP used a zinc polyphosphate to a concentration of approximately 0.8mg/L (Table 3.2). Zinc-orthophosphate was used in the pipe loops to reduce the amount of sequestering of iron form the poly phosphate. The dose used of zinc-orthophosphate was 0.8mg/L. There is limited data of sodium silicate, and dosages vary greatly. A dose of 18mg/L was chosen due to a utility in New England using sodium silicate as a corrosion inhibitor with similar raw water condition to Pockwock Lake.

Table 3.3 displays evolution of the pilot scale experiments over a one-year period. From April to June 2009, there was a conditioning period. During the conditioning period, the pilot scale system had filtered water flowing through it from April to May. In June, the disinfectant, pH control (acid/base), and corrosion inhibitors were added. From July 2009 to December 2009, data was collected for statistical analysis. For a two-week break during the winter holidays in December 2009, the pilot scale system only had phosphate and sodium silicate circulating through. In January 2010, disinfectant and pH control for phosphate loops were along with the corrosion inhibitor added for conditioning. Data was then collected for statistical analysis from February 2010 to June 2010.

Throughout the one year study, pipe loops using phosphate as a corrosion inhibitor were buffered with an acid/base to approximately pH of 7.3 at the effluent of the pipe loops. This was done to duplicate pH and phosphate concentrations at the JDKWSP.

For the pipe loops using sodium silicate, two conditions were used. From June 2009 to December 2009, pipe loops using sodium silicate were buffered with an acid/base to a pH of 7.3. This was done to reproduce the pH level at the JDKWSP. From January 2010 to June 2010, pipe loops using sodium silicate were not buffered with an acid/base. The pH depended on the sodium silicate. Using sodium silicate to buffer pH is a cost saving measure to utilities as no extra chemicals are needed. Phosphate at the JDKWSP needs caustic (NaOH) to raise the pH of the water to optimize the use of phosphate as a corrosion inhibitor.

Table 3.2 Experiments conditions for pipe loops

Pipe Loop	Disinfectant	Corrosion Inhibitor
1	High Chloramines(3mg/L)	Sodium Silicate (18mg/L)
2	High Chloramines(3mg/L)	Zinc Orthophosphate (0.8mg/L)
3	Low Chloramines(1mg/L)	Sodium Silicate(18mg/L)
4	Low Chloramines(1mg/L)	Zinc Orthophosphate (0.8mg/L)
5	Chlorine (1mg/L)	Sodium Silicate(18mg/L)
6	Chlorine (1mg/L)	Zinc Orthophosphate (0.8mg/L)

Table 3.3 Experimental timeline for pipe loop study

	2009									2010					
	April	May	June	July	Aug.	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Conditioning	■	■	■												
Phosphate and sodium silicate: Buffered with Acid/Base				■	■	■	■	■	■						
Winter Break Just Corrosion Inhibitor									■	■					
Conditioning										■					
Phosphate: Buffered with Acid/Base Sodium silicate: Buffered with Sodium Silicate											■	■	■	■	■

Samples were taken from the pipe loops twice a week, on Mondays and Thursdays. During these days the pipe loop would be inspected and chemical jugs refill. Chemical levels were monitored and regulated based on their concentrations at the effluent ports of the pipe loops. Due to time between samples days, the chemical feed jugs would be almost empty and the disinfect concentration would be low, influent samples were taken after the chemical jugs were filled with corrosion inhibitor, disinfectant, and ph control. Due to the 12h retention time in the pipe loops and wait time before entering the copper pipe racks, the concentration of disinfectant was very difficult to maintain. It would not be until the next sample day changes to the disinfectant could be seen.

3.3 Analytical Methods

A variety of water quality parameters were measured on the influent and effluent ports of the pipe loops and for the long and short stagnation time for the copper pipe racks. Dissolved oxygen, temperature, oxidation reduction potential, pH, corrosion rate, free and total chlorine, turbidity, and silica were always analysed at the JDKWSP. Alkalinity, total organic carbon, total nitrogen, heterotrophic plate count bacteria, phosphates, ammonia, nitrite, nitrate, and total and dissolved lead and copper were analyzed at the Centre for Water Resources Studies at Dalhousie University.

Due to the pipe loops being in the basement, many parameter requiring at least 50mL of sample, and the slow flow rate of the pipe loops, samples were collected in 500mL bottle for each influent, and effluent. For the copper pipe racks the water came out at a flow rate of 5.6 L/min. Again 500mL bottle were used to make collection simple.

The 500mL samples were collected in plastic Nalgen bottles. Right after collections samples were measure for dissolved oxygen, temperature, oxidation-reduction potential, free and total chlorine residual, and pH. Parameters that were measured at the Center for Water Resources Studies at Dalhousie University were transported in a cooler from the JDKWSP to the laboratory. All parameters were measured or preserved within 24 hrs of sample collection.

3.3.1 Bulk Water Quality

The water samples were measured according to *Standard Methods for the Examination of Water and Wastewater, 19th Edition.* The parameters that were measured were oxidation reduction potential, turbidity, temperature, pH, dissolved oxygen, alkalinity, free and total chlorine residual, total organic carbon, total nitrogen, total phosphates, total and dissolved lead, total and dissolved copper, heterotrophic plate count, silicate, nitrate, nitride, ammonia and disinfectant by products (DBPs).

Oxidation Reduction Potential (ORP)

A Platinum AC/AGCL combination electrode with BNC was used with an Accumat. The probe was rinsed after each sample to prevent contamination. This measure was done as soon as possible.

Turbidity

Turbidity was measured with a HACH 2100 Turbidimeter at the JDKWSP. The samples were measured within 24hr. The instrument of standardized each day by plant staff.

Temperature

Temperature was measured simultaneously with dissolved oxygen by using a VWR SP50D portable dissolved oxygen meter and temperature probe. Between each sample the probe tip was rinsed with distilled water.

pH

pH was measured in the basement of JDKWSP with a pH electrode (Fisher Scientific, Accumet AccuCap, 13-620-132) with an Accumat X60. The probe was rinsed between samples with distilled water.

Dissolved Oxygen

Dissolved oxygen was measured with temperature using a VWR SP50D portable DO meter and temperature probe. Between each sample the probe tip was rinsed with distilled water.

Alkalinity

Alkalinity was measured using Standard Methods 2320 B Alkalinity Titration Method. The pH of a 100mL sample was measured before being brought down to a range of 4.3 to 4.7 using 0.2N H2SO4. The volume of H_2SO_4 was recorded and then the pH was lowered by 0.3 units. The following equation was used to calculate the alkalinity (N=0.2eq/L) and V = 100mL

$$Alkalinity = \frac{\left[\, x(V_2 - V_1) - (V_3 - V_1)\right] x 5000\, xN}{V}$$

Free and Total Chlorine Residual

By using the DPD colorimetric method, both free and total chlorine were measured at the JDKWSP, the results were measured with the DR 5000 UV-VIS spectrophotometer (HACH Co., Loveland Co).

Chloramines concentrations were determine by the difference between the total and free chlorine then as seen in the following equation.

Total Chlorine – Free Chlorine = Monochloramine (mg/L)

The equipment had a measurement range of 0.0 to 2.0mg/L. Samples that were over this ranger were diluted and reported at their calculated concentration from the dilution.

Total Organic Carbon (TOC)

Total organic carbon (TOC) was measured on the SHIMADSZU TOC-V cph Total Organic Carbon Analyzer. The samples were preserved on location to a pH of less than 2 with concentrated phosphoric acid. Then the samples were taken to Water Resources Studies at Dalhousie University, where a temperature of 4°C was maintained until analysis.

Total Nitrogen

Total Nitrogen was measured on the SHIMADZU Total Nitrogen Measuring Unit (attached to the SHIMADSZU TOC-V cph Total Organic Carbon Analyzer). The samples were preserved on location to a pH of less than 2 with concentrated phosphoric acid. Then the samples were taken to Center for Water Resources Studies at Dalhousie University where a temperature of 4C was maintained until analysis.

Total Phosphates

From Phase A, controlled pH total phosphates were measured using the Total Phosphate Test N'Tube Reagent Set. Measurement occurred on the DR/2010 spectrophotometer (Hach Co., Loveland Co). This method is able to measure phosphorus in the range of 0.5 to 3.5 mg/L.

After January 2010 ion chromatography with a Metrohm 788 IC Filtration Sample Processor and 761 Compact IC according to Standard Methods was used to measure phosphate.

Total Lead

Within 24 hours of collection, samples were preserved to a pH of less than two using concentrated nitric acid. Samples were then kept at 4C before being analyzed on the Perkin Elmer AAnalyst200 Atomic Absorption Spectrometer HGA900 Graphite Furnace (Perkin Elmer, Waltham, MA) using the Pb lamp. The spectrophotometer was calibrated with five standard solutions before the samples were measured.

Dissolved Lead

Before being preserved to a pH of less than two using concentrated nitric acid, sample were filter through a Whateman 0.45-micron filter, using standard filter apparatus. The samples were then treated in the same manner as for total lead.

Total Copper

Within 24 hours of collection, samples were preserved to a pH of less than two using concentrated nitric acid. Samples were then kept at 4°C before being analyzed on the Perkin Elmer AAnalyst200 Atomic Absorption Spectrometer HGA900 Graphite Furnace (Perkin Elmer, Waltham, MA) using the Cu lamp. The spectrophotometer was calibrated with five standard solutions before the samples were measured.

Dissolved Copper

Before being preserved to a pH of less than two using concentrated nitric acid, sample were filter through a Whateman 0.45-micron filter, using standard filter apparatus. The samples were then treated in the same manner as for total copper.

Heterotropic Plate Counts (HPC's)

Water samples for HPC were collected in 15mL sterile disposable centrifuge Fisher Brand Tube. The separate sterile container collected water separate from the bulk water to improve quality control for plate counts.

Standard microbiological methods spread technique on R2A agar, as described in Standard Methods for Examination of Water and Wastewater 20th edition, were used for the samples. Plates were incubated for 7 days at 20ºC before being counted.

Nitrite (NO_2^-)

Nitrite was measured using ion chromatography with a Metrohm 788 IC Filtration Sample Processor and 761 Compact IC according to Standard Methods.

Nitrate (NO_3^-)

Nitrate was measured using ion chromatography with a Metrohm 788 IC Filtration Sample Processor and 761 Compact IC according to Standard Methods.

Sodium Silicate

Sodium silicate was measured using the Silicomolybdale Method high range (0 – 100mg/L) method. It was measured using the DR 5000 UV-VIS spectrophotometer (HACH Co., Loveland Co). This method had a range from 0 to 100mg/L,

Ammonia

Ammonia samples were analyzed within 24hr of collection. To determine the amount of ammonia an Accument ® Ammonia Combination Ion Selection Electrode from Fisher Scientific was used. The probe had a range of 0.01mg/L to 17 000mg/L. The samples were analyzed at room temperature. The Accumate was first calibrated using a set of 4 standards for ammonia (5mg/L, 10mg/L, 20mg/L, 30mg/L). 100mL of sample was measured out and 2mL of pH Ionic Strength Adjuster (ISA) was added to the solution.

The solution was stirred moderately while the electrode was immersed into it. The concentration of the sample was recorded once the reading stabilized. The electrode was removed and rinsed before the next sample.

Disinfection By-Products (DBP)

Samples were collected for trihalomethanes and haloacetic acids at three different times during the study. Once in October 2009, December 2009, and April 2010.

Haloacetic Acids (HAAs)

Every HAA sample was collected in a 20mL glass bottle, which was baked for at least 4 hours. Then each glass bottles was preserved with 1 drop of 50g/L ammonium chloride solution. Samples were then stored at 4C until being analyzed using EPA method 552.2.

Trihalomethanes (THMs)

Every THM sample was collected in a 20mL glass bottle, the same as the HAAs, that was backed for at least 4 hours. The samples were preserved with 1 drop of 50g/L ammonium chloride solution, 2 drops of 8g/L sodium triosulfate solution, and 3 drops of 0.1 N HCl. Samples were then stored at 4C until being analyzed using EPA 551.1 and Standard Method 6232B.

Corrosion Monitoring

The Rhorback Cosaco System 9030 Plus Corrater was used with two-electrode linear polarization probes, Model 6112 (Rohrback Cosasco Systems, Stanta Fe Springs, CA) probes for corrosion readings. The design of the pipe loops had a location for linear polarization probes (Figure 3.10). The Corrator probes had carbon steel tips, to compare the corrosion rate for each pipe loop. Carbon steel electrodes were chosen due other research using this same material (Esinor and Gagnon, 2004, Gagnon et al.,, 2008) that it could be compared to. Corrosion rate was reported as mil/year and readings were taken each sample day.

Figure 3.10 Two-electrode linear polarization probe used in pipe loop

Flow Rate

The flow rate of the pipe loops were monitored by the amount of water that spilled out of the effluent in 1min. For the retention time of 12 hours in the pipe loops, a goal flow rate of the pipe loops 44mL per min was needed.

3.4 Statistical Analysis

To determine if there were any similarities or differences between conditions statistical analysis was done. Basic statistical values were displayed by using the sample mean, standard deviation and 95 % confidence intervals. Analysis of variance (ANOVA) test was used to test the three disinfectant conditions to see if the sample means were similar. ANOVA works by estimating the amount of variation within one treatments and then comparing it to the variance between treatments (Berthouex and Brown 2002)

Student t-tests were also used to determine which significant treatments were significantly similar or difference. Independent t-tests were used to access the difference between the averages of different treatment groups. Paired t-test was not used because none of the treatments were paired, there many each pipe loops had a different corrosion inhibitor, disinfectant, and the influent water was always changing. A 95% significance level was used. This corresponds to an alpha of 0.05. Two tailed t-tests results then indicated that alpha of 0.025. All statistical analysis was done using Microsoft ® Excel ® 2008 for the Mac.

For the lead and copper data, a box and whisker plot was used to show the data. The box was used to represent the 25th and 75th percentiles, whereas the whiskers represented the 5th and 95th percentile

Chapter 4.0 Results

4.1 Feed Water Quality

The water used for the pilot scale study was obtained from the clear well at the JDKWSP. The clear well water at the JDKWSP is filtered water, with minimal amount of chlorine from pre-chlorination at the flocculation tanks. No other chemicals are added to the water in the clear well. At JDKWSP, chlorine, fluorine, and the phosphate corrosion inhibitor are added once the water goes to the distribution system. Using the clear well water at the JDKWSP allows the pipe loops to be treated in a similar way to the full scale. There is great flexibility for pH, corrosion inhibitors, and disinfection type.

A summary of average water quality parameters is located in Table 4.1. More detailed results may be found in Appendix A.

Table 4.1 Water quality parameters for the feed water for the pipe loops. Values are reported by their mean then standard deviation.

	pH Controlled at 7.3 *June 2009 to December 2009*	pH Controlled at 7.3 for Phosphate pipe loops, uncontrolled pH for Silica pipe loops *January 2010 to June 2010*
pH	5.7 ± 0.5	5.9 ± 0.7
Free Chlorine (mg/L)	0.03 ± 0.02	0.03 ± 0.02
Dissolved Oxygen (mg/L)	7.2 ± 1.6	11.2 ± 1.5
Temperature (mg/L)	16.1 ± 4.3	7.5 ± 2.1
Turbidity (mg/L)	0.172 ± 0.002	0.361 ± 0.342
TOC (mg/L)	2.14 ± 1.44	2.24 ± 0.27
Alkalinity (mg/L)	7.3 ± 2.8	4.3 ± 2.7
Sodium Silicate (mg/L)	1.8 ± 1.9	2.1 ± 0.13
Total Lead	0.00	0.00

4.2 Results for Sodium Silicates

The following section discusses the results of the pipe loops and copper pipe racks that used sodium silicates as a corrosion inhibitor. Supporting data are available in Appendix B.

4.2.1 Buffered with Acid/Base Phase

The following section analysis data from pipe loops and copper pipe racks that used sodium silicates as a corrosion inhibitor when pH was buffered with an acid/base. This occurred during the period of June 2009 to December 2009. A conditioning period was done for June 2009, data was not included in the analysis.

4.2.1.1 Water Quality Parameters

Table 4.2 shows the average of each water quality parameter. None of the treatments showed a significant difference for sodium silicate (p-value=0.31), turbidity(p-value=0.46), temperature(p-value=0.34), dissolved oxygen(p-value=.38), corrosion rate(p-value=0.24), and pH (p-value=0.70). There was a significant difference with ORP between chlorine and the two doses of chloramines (p-value=7.61E-15). Chloramines are known to have a lower oxidation potential than chlorine. However, the high chloramines conditions and low chloramines condition were not significantly different (p-value=0.24).

Table 4.2 Summary of water quality parameters of the effluent of the pipe loop for sodium silicate when buffered with sodium acid/base

Water Quality Parameter	High Chloramines	Low Chloramines	Chlorine
pH	7.5	7.51	7.08
Disinfectant (mg/L)	2.46	1.84	1.5
Corrosion Rate (MPY)	2.92	2.39	2.72
Dissolved Oxygen (mg/L)	8.05	6.5	6.75
Temperature (°C)	21.7	21.15	22.24
Corrosion Inhibitor (mg/L)	17.78	21.16	18.3
ORP (mV)	458	481	650
Turbidity (NTU)	0.315	0.309	0.431

4.2.1.2 pH

From the ANOVA analysis, pH values entering the copper pipe racks (effluent of the pipe loops) were not significantly different between the three treatment groups (p-value=0.10). The pH range for the three treatments groups was 7.1 to 7.5. Table 4.3 displays the target and actual pH observed throughout the experiments

4.2.1.3 Disinfectant

The disinfectant in the high chloramines and low chloramines treatment type was not significantly different (p-value=0.30). The high chloramines had an average of 2.46 ± 3.30 mg/L and the low chloramines had an average of 1.84 ± 2.04 mg/L. The large standard deviation reflected the variability of chloramines in the pipe loop and degradation in the stock solution.

Chlorine concentrations had an average of 1.5mg/L as free chlorine. The target was 1.0mg/L to relate to the conditions at the JDKWSP. Due to the trial and error method of dosing chlorine, the dosage tended to be extremely high. Thus affecting the overall average.

Table 4.3 Target and actual pH and disinfectant residual values, measured at the effluent of the pipe loop. Values are displayed as their mean with standard deviation

Treatment Type	pH		Disinfectant Residual (mg/L)		
	Target	Actual	Target	Actual	
High Chloramines	7.3	7.34 ± 1.14	~3.0	2.46 ± 3.30	As Chloramines
Low Chloramines	7.3	7.53 ± 0.68	~1.0	1.84 ± 2.04	As Chloramines
Chlorine	7.3	7.09 ± 0.86	~1.0	1.50 ± 1.37	As Free Chlorine

4.2.1.4 Lead

Long Stagnation Time

The box and whisker plot displayed in Figure 4.1 shows the total lead concentration following the long stagnation time (23 hours and 20 min) in the copper pipe racks. The greatest lead released occurs with the high chloramines treatment followed by the low chloramines, and then chlorine. The high chloramines condition has the most variability shown in the large range of the whiskers. All treatment conditions are above the 10µg/L limit for lead in Canada.

During the long stagnation time when buffered with an acid/base, t-test with statistical differences being those of values less than 0.025, indicated that high chloramines, low chloramines, and chlorine are all statistically different.

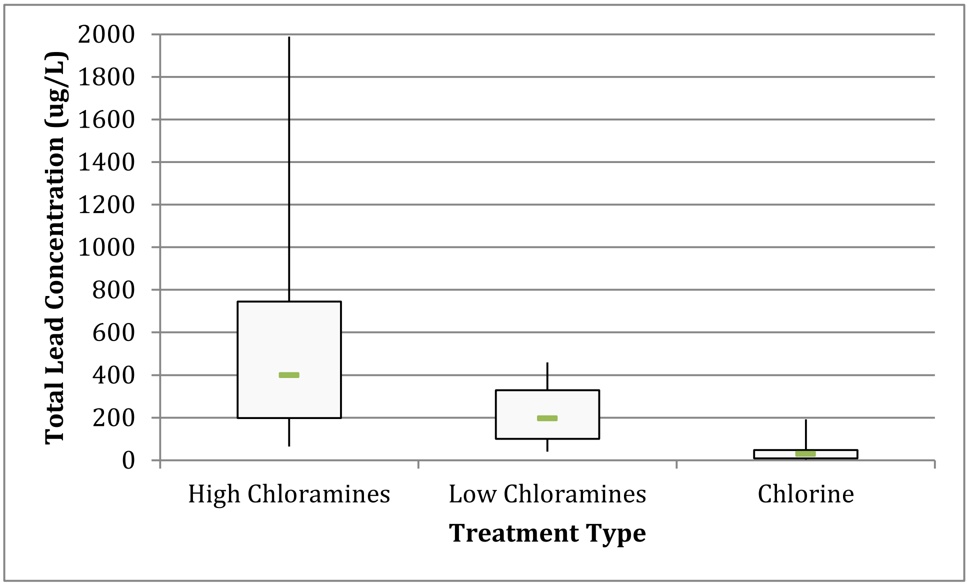


Figure 4.1 Box and whisker plot displaying 5th and 95th percentile, 1st and 3rd quartile range, and median of total lead concentration for each treatment type using Sodium Silicate during the long stagnation time

For the long stagnation time, Figure 4.2 displays the contribution of dissolved and particulate lead to the overall total lead. There is no overlap in the 95% confidence interval indicating there is a significantly difference for all treatment groups. The amount of dissolved and particulate lead contributes approximately the same amount of lead towards the total average of lead.

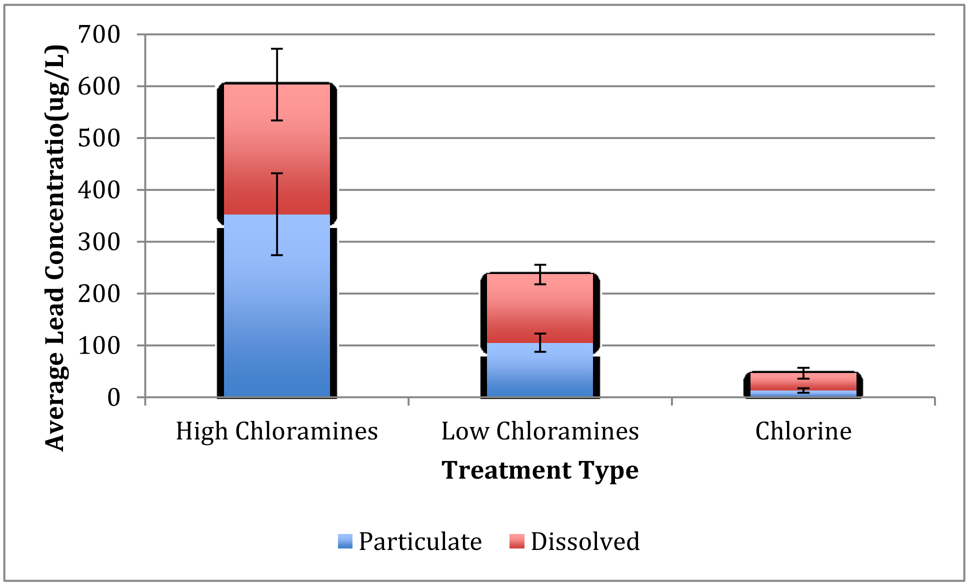


Figure 4.2 Particulate and dissolved lead contribution to the total lead concentration with sodium silicate during a long stagnation time. Error bars represent the 95% confidence interval.

Short Stagnation Time

The box and whisker plot in Figure 4.3 shows total lead concentrations following the short stagnation time (30min) in the copper pipe racks. The concentrations of total lead are considerably less for the short stagnation time than the long stagnation time. Lead release for the long stagnation was nearly 100 times greater than for the short stagnation time. The high chloramines condition has more variability then low chloramines and chlorine. For the short stagnation time, the lead release for the high chloramines and low chloramines doses were not statistically different.

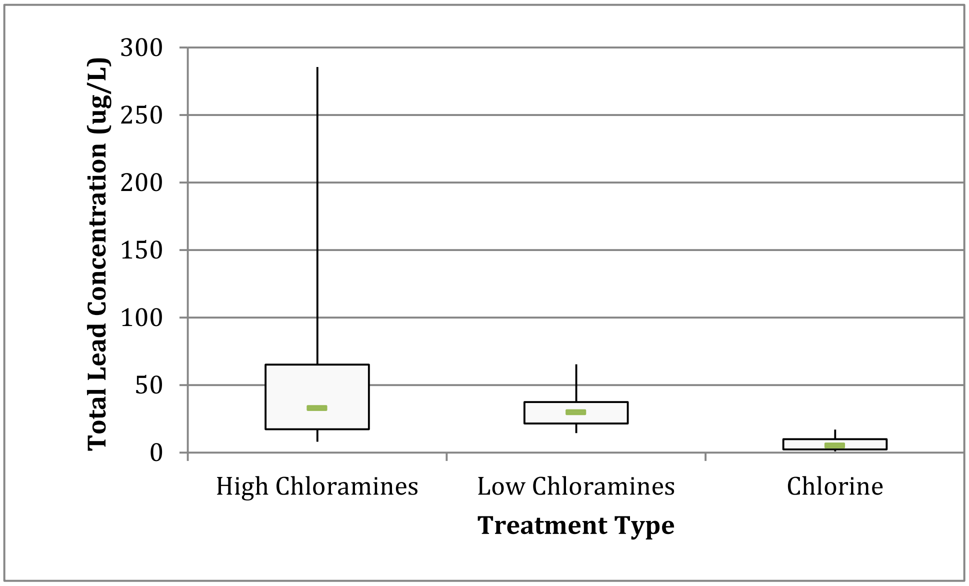


Figure 4.3 Box and whisker plot displaying 95% percentile, 1st and 3rd quartile range, and median of total lead concentration for each treatment type using sodium silicate during the short stagnation time

For the short stagnation time, Figure 4.4 displays the contribution of dissolved and particulate lead to the overall total lead. There is no overlap in the 95% confidence interval, indicating there is a significantly difference for all treatment groups. The dissolved portion seems to make up most of the total lead concentration; where as dissolved and particulate concentrations are very similar for the long stagnation time.

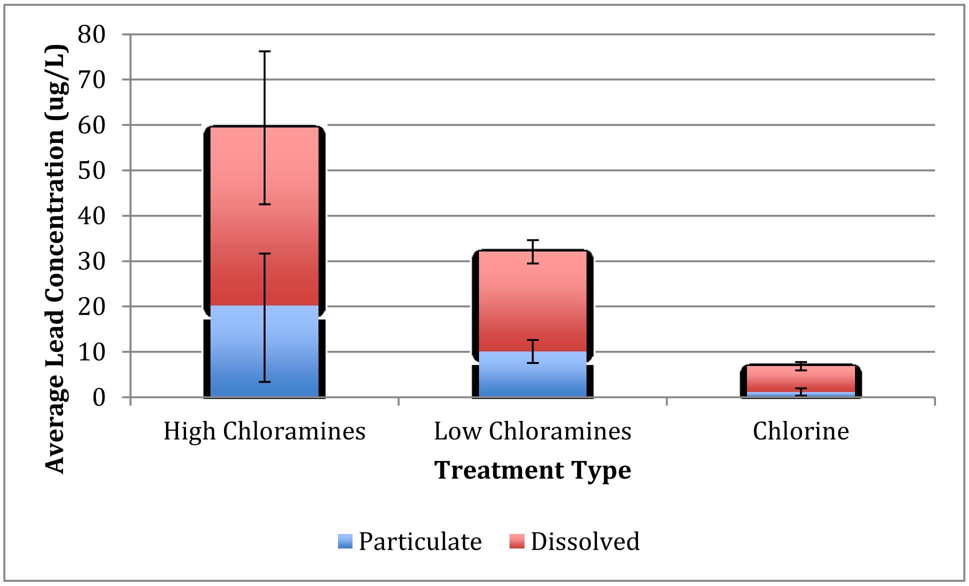


Figure 4.4 Particulate and dissolved lead contribution to the total lead Concentration with sodium silicate during a short stagnation time. Error bars represent the 95% confidence interval.

Effect of stagnation time on total lead concentration

The difference between the long and short stagnation time was found to have statistically significant impact on increasing lead concentrations for each treatment condition. T-tests are available in detail in Appendix E. For example the high chloramine treatment had an average lead concentration of 604µg/L and 59µg/L for the long and short stagnation time. Similarly, the low chloramine treatment had an average lead concentration of 237µg/L and 49µg/L for the long and short stagnation time. Free chlorine had an average lead concentration of 46µg/L and 7µg/L for the long and short stagnation time. Overall, the lead concentration at a 24hr stagnation time was between 6 – 10 times greater than the lead concentration for a 30min stagnation time. This is consistent with literature (Volk et al., 2000) that has reported that increased stagnation time results in greater metals release.

Effect of disinfectant concentration on lead

Long Stagnation Time

During the long stagnation time high chloramines and low chloramines had a lead concentration of 604µg/L, and 237µg/L, respectively. The difference between the two treatment groups is statistically significant. Chlorine has an average lead concentration of 46μg/L.

Short Stagnation Time

During the short stagnation time high chloramines and low chloramines had a lead concentration of 59μg/L, and 49μg/L respectively. The lead concentrations under high chloramines and low chloramines doses are not statistically different. Chlorine had an average of 7μg/L for lead, this is below the 10μg/L limit for lead in drinking water.

During the short stagnation time, there was not a significant different in the lead concentration between the high and low chloramines treatments. However for the long stagnation time, there was a significant difference in the lead concentration between the high and low chloramines treatment. For the short stagnation time of 30min the dosage of chloramines did not have a significant impact on lead release. For the long stagnation time of 24 hr, the dosage of chloramines did have a significant impact on lead release.

4.2.1.5 Copper

Long Stagnation Time

The box and whisker plot Figure 4.5 illustrates the total copper concentration following the long stagnation time (23 hours and 20 min) in the copper pipe racks. The high chloramine condition has the most variability shown by the wide range of whiskers.

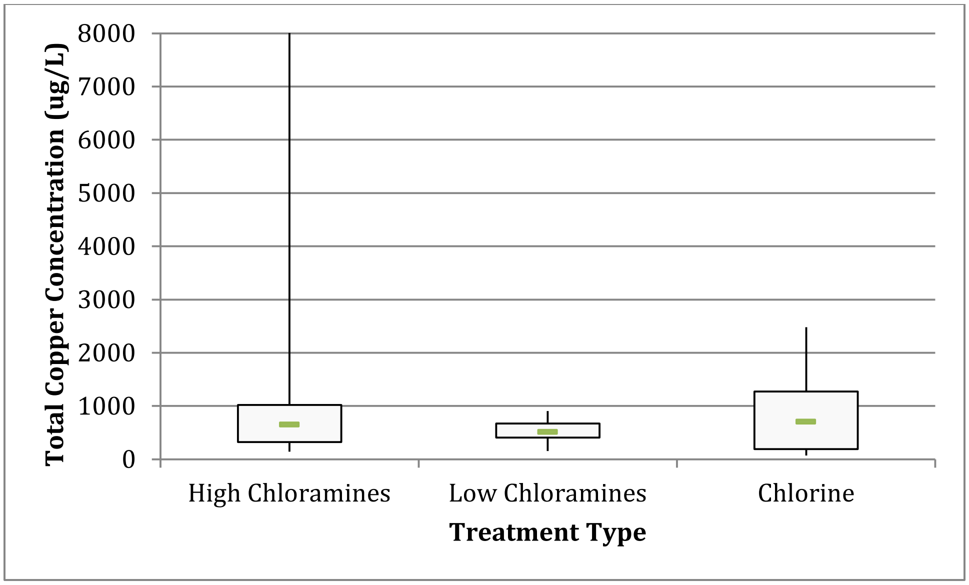


Figure 4.5 Box and whisker plot showing the 95% percentile range, median and quartile range of total copper concentrations during a long stagnation time using sodium silicate as a corrosion inhibitor

For the long stagnation time, Figure 4.6 displays the contribution of dissolved and particulate copper to the overall total copper.

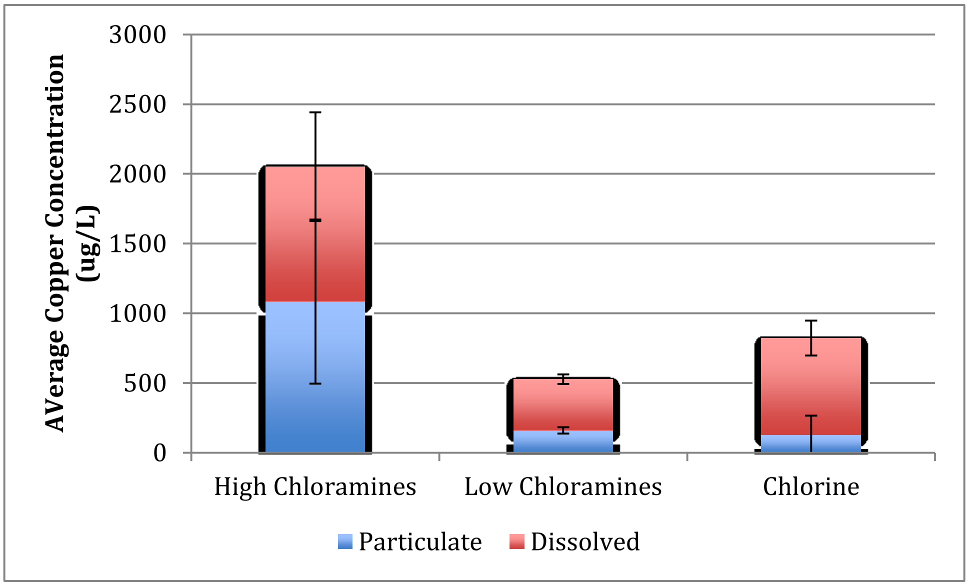


Figure 4.6 Particulate and dissolved copper contribution to the total copper concentration with sodium silicate during a long stagnation time. Error bars represent the 95% confidence interval

Short Stagnation Time

The following box and whisker plot in Figure 4.7 illustrates total copper concentrations following the short stagnation time (30min) in the copper pipe racks. The concentrations of total copper are conversably less than the long stagnation time.

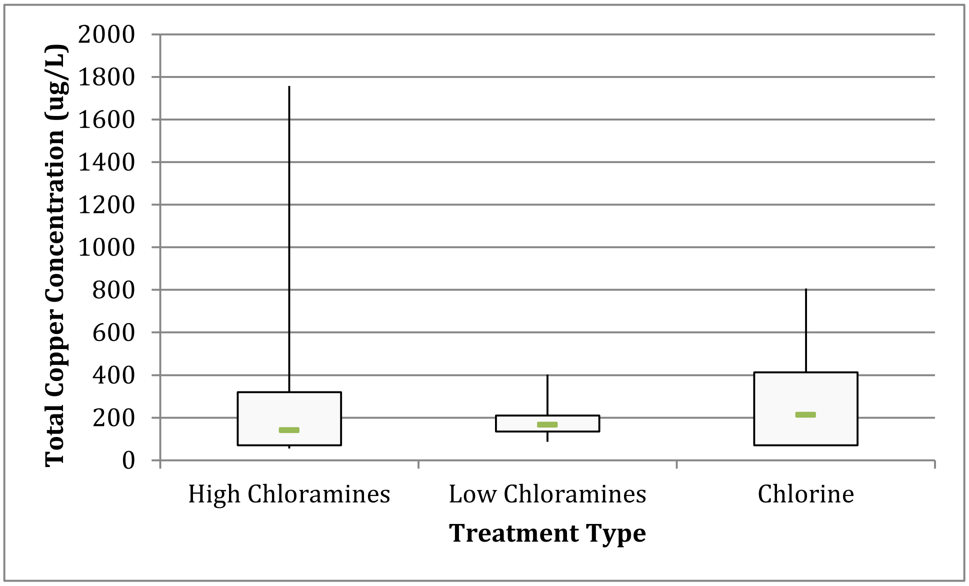


Figure 4.7 Box and whisker plot showing the 95% percentile range, median and quartile ran of total copper concentrations during a short stagnation time using sodium silicate as a corrosion inhibitor

For the short stagnation time, concentrations of particulate and dissolved copper are illustrated in Figure 4.8. It is shown that most of the total copper is found in particulate form.

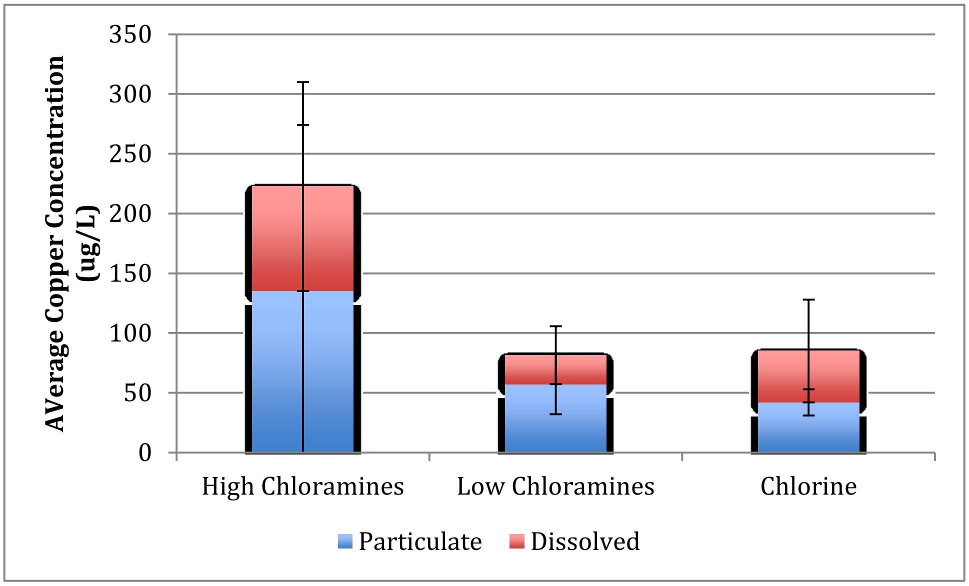


Figure 4.8 Particulate and dissolved copper contribution to the total copper concentration with sodium silicate during a short stagnation time. Error bars represent the 95% confidence interval

Effect of stagnation time on total copper concentration

For each treatment condition, more copper was released during the long stagnation time than the short stagnation time. For instance, high chloramines had an average lead concentration of 2162µg/L and 441µg/L for the long and short stagnation time, respectively. Similarly, low chloramines had an average lead concentration of 538µg/L and 223µg/L for the long and short stagnation time, respectively. Chlorine had an average lead concentration of 900µg/L and 309µg/L for the long and short stagnation time. Overall, the copper concentration at a 24hr stagnation time was 3 – 5 times greater than the copper concentration at a 30min stagnation time. This is consistent with literature (Fabbrinicio et al., 2005, and Merkel et al., 2002) that has associated increased stagnation time with increase copper release.

Effect of disinfectant concentration on copper

Long Stagnation Time

During the long stagnation time high chloramines and low chloramines had a copper concentration of 2162 µg/L, and 538 µg/L, respectively. The difference between the two treatment groups is statistically significant. Chlorine had a copper concentration of 900µg/L. The total copper concentration for the high chloramines condition is above Health Canada aesthetic objective of 1.0mg/L and the EPA action level of 1.3mg/L for copper in drinking water.

Short Stagnation Time

During the short stagnation time high chloramines and low chloramines had a copper concentration of 441µg/L, and 223µg/L respectively. High chloramines were not statistically different from low chloramines. Chlorine had a copper concentration of 900µg/L.

4.2.2 Buffered with Sodium Silicate

The following section analysis data from pipe loops that used sodium silicate as a corrosion inhibitor for the uncontrolled pH phase, the period of January 2010 to April 2010. A conditioning period was done for January. That data was not included in this analysis. Three disinfectant treatments were used: high chloramines, low chloramines, and chlorine.

4.2.2.1 Water Quality Parameters

Averages for water quality parameters are shown with their standard deviations are shown in Table 4.3. There for not a significant difference for sodium silicate (p-value=0.93), turbidity (p-value=0.80), or temperature (p-value=0.20) in all the treatment condiditon. There was a significant difference with ORP (p-value< 0.01), corrosion rate (p-value=<0.01) and dissolved oxygen (p-value=0.001).

When doing separate t-test for ORP, it was determine that all three treatments are significantly different. This is what is expected as ORP in chlorine is greater than that of chloramines.

For dissolved oxygen, using separate t-test it was determined that low chloramines and chlorine were not significantly different, while the rest were. This could be due to the fact that less data was collected during this phase as compared to the one before.

Using separate t-test for corrosion rate also show that they are significantly different. For the corrosion rate, separate t-test indicates all the treatment groups are different.

Table 4.4 Summary of water quality parameters of the effluent of the pipe loop for sodium silicate when buffered with sodium silicate

Sodium Silicate: Buffered with Sodium Silicate			
Water Quality Parameter	High Chloramines	Low Chloramines	Chlorine
pH	8.0	6.87	6.33
Disinfectant (mg/L)	4.02	2.23	0.79
Corrosion Rate (MPY)	1.26	2.24	1.41
Dissolved Oxygen (mg/L)	8.35	8.77	9.2
Temperature (°C)	17.8	16.86	17.0
Corrosion Inhibitor (mg/L)	22.10	20.73	21.43
ORP (mV)	439	480	657
Turbidity (NTU)	0.041	0.05	0.061

4.2.2.2 pH

Using t-test pH values entering the copper pipe racks when buffered with an sodium silicate were statistically different between the three treatment groups. High chloramines had an average pH of 8.0, low chloramines had an average pH of 6.7, and chlorine had an average pH of 6.3.

4.2.2.3 Disinfectant

Chloramines concentrations for the high chloramines treatment group had an average of 4.05mg/L. For the low chloramines treatment group, it had an average disinfectant concentration of 2.4mg/L. Significant differences exist (p-value=0.019) between the high and low chloramines groups.

For chlorine there was a disinfectant residual as free chlorine of 0.65mg/L.

Table 4.5 Target and actual pH and disinfectant residual measured at the effluent of the pipe loops. Values are displayed as their mean and standard deviation

Treatment Type	pH		Disinfectant Residual (mg/L)		
	Target	Actual	Target	Actual	
High Chloramines	Uncontrolled	7.95±0.96	~3.0	4.48±3.89	As Chloramines
Low Chloramines	Uncontrolled	6.70±0.48	~1.0	2.42±1.92	As Chloramines
Chlorine	Uncontrolled	6.30±0.82	~1.0	0.65±0.48	As Free Chlorine

4.2.2.4 Lead

Long Stagnation Time

Figure 4.9 box and whisker plot shows total lead concentration following the long stagnation time (23 hours and 20 min) in the copper pipe racks. Again there is a greater variability in the high chloramines condition. The chlorine treatment released the least amount of lead.

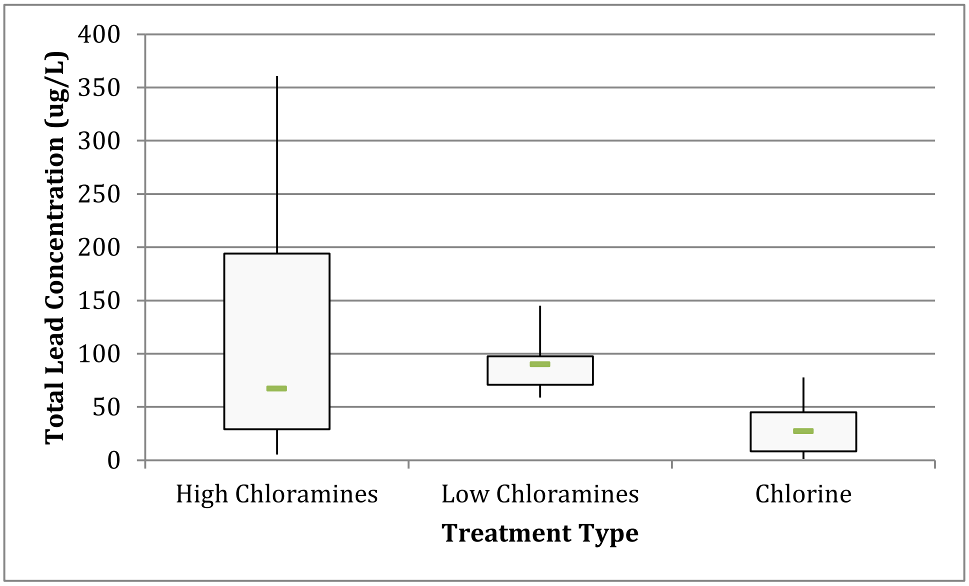


Figure 4.9 Box and whisker plot showing the 95% percentile range, median and quartile range of total lead concentrations during a long stagnation time for the uncontrolled pH phase using sodium silicate as a corrosion inhibitor

For the long stagnation time, Figure 4.10 displays the contribution of dissolved and particulate lead to the overall total lead.

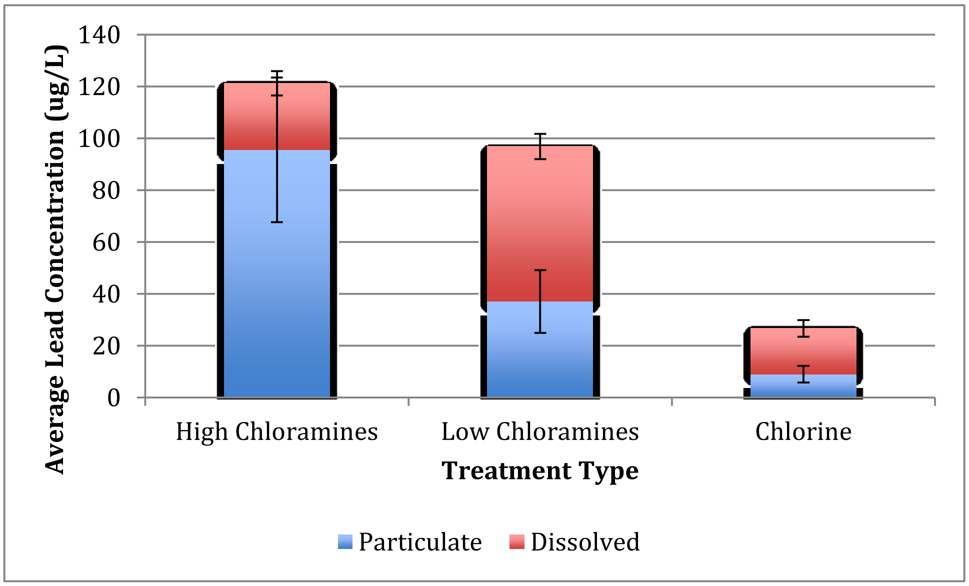


Figure 4.10 Particulate and dissolved copper contribution to the total lead concentration with sodium silicate during a long stagnation time. Error bars represent the 95% confidence interval

Short Stagnation Time

Figure 4.11box and whisker plots shows total lead concentrations following the short stagnation time (30min) in the copper pipe racks. The concentrations of total lead are less than the long stagnation time. Low chloramines released the most lead, followed by high chloramines and chlorine. Low chloramines releasing the most lead is unusually as in all other cases high chloramines releases the most followed by low chloramines and then chlorine.

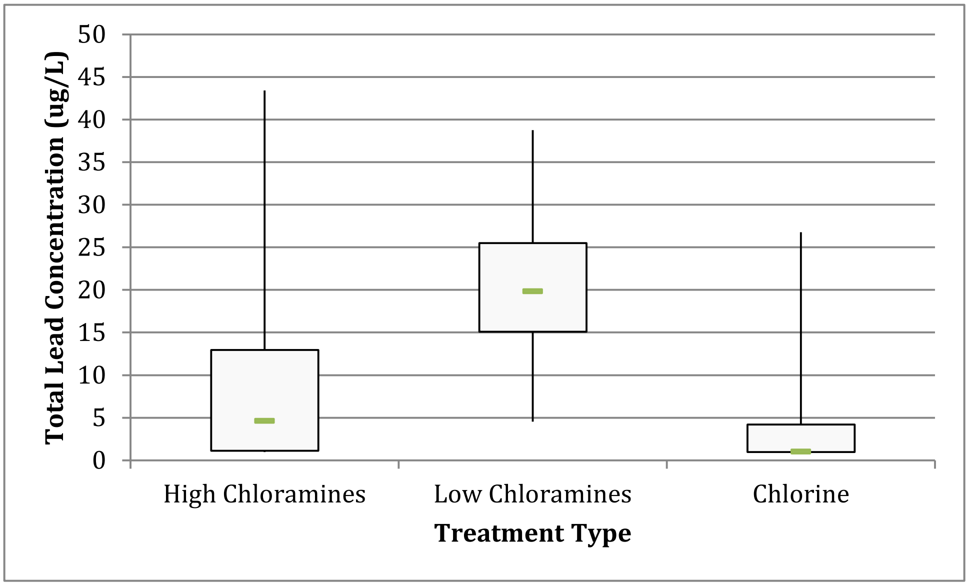


Figure 4.11 Box and whisker plot showing the 95% percentile range, median and quartile range of total lead concentrations during a short stagnation time for the uncontrolled pH phase using sodium silicate as a corrosion inhibitor

The contribution of dissolved and particulate lead to the total lead is shown in Figure 4.12. The percentage of dissolved lead is greater in the chlorine then in both chloramines conditions.

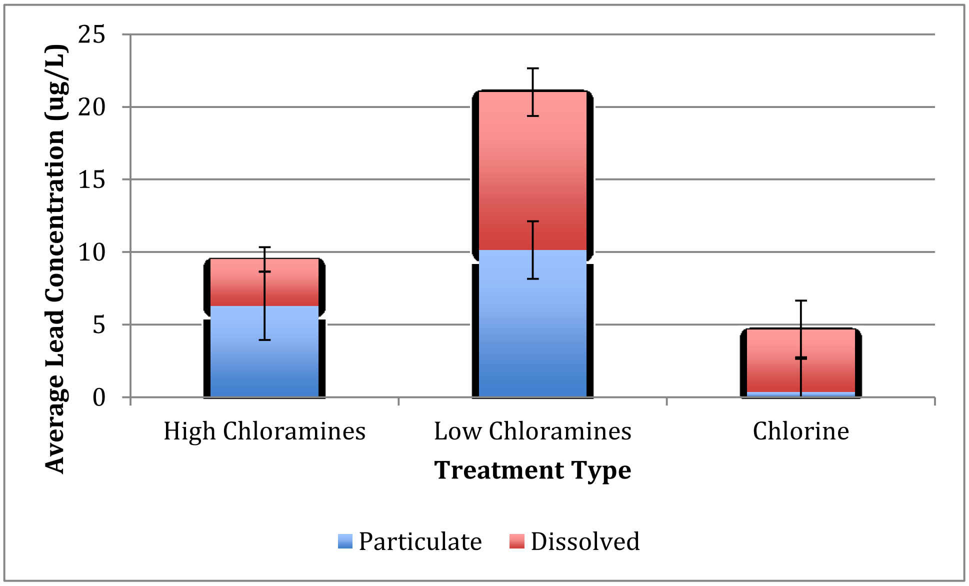


Figure 4.12 Particulate and dissolved copper contribution to the total lead concentration with sodium silicate during a short stagnation time. Error bars represent the 95% confidence interval

Effect of Stagnation Time on Lead

Similar to when sodium silicate was buffered with an acid/base, the difference between the long and short stagnation time had a statistically significant impact on lead release. T-test with statistical differences being less than 0.025 signifies the differences between the long and short stagnation time. For example, high chloramines had a concentration of lead during a long and short stagnation time of 125µg/L and 10µg/L respectively. In addition, low chloramines had a concentration of lead during the long and short stagnation time of 98µg/L, and 21µg/L respectively. Chlorine had a concentration of lead during a long and short stagnation time of 27µg/L and 5µg/L respectively. Overall, lead concentrations for the long stagnation time were 5 - 13 times greater than lead concentration for the short stagnation time. This is consistent with literature (Schock 1990) that has reported increased metals release with stagnation time. Indicate

Effect of Disinfectant Concentration on Lead

Long Stagnation Time

The concentration of lead during the long stagnation time for high chloramines, and low chloramines was 125µg/L and 98 µg/L , respectively. T-test with statistical differences being those of values less than 0.025 indicate that lead concentration for high chloramines and low chloramines were not statistically different (p-value=0.14). Chlorine had a total lead concentration of 27µg/L.

Short Stagnation Time

The concentration of lead during the short stagnation time for high chloramines, and low chloramines was 10µg/L and 21 µg/L respectively. T-test with statistical differences being those of values less than 0.025 indicate the difference between the two treatment groups is statistically significant. Chlorine had a total lead concentration of 5µg/L, this is below the 10µg/L limit for lead in drinking water.

During the long stagnation time, there are no differences between the high and low chloramines total lead concentrations, while there is for the short stagnation time. This shows that during a long stagnation time the concentrations of chloramines do not affect the release of lead. However during a short stagnation time the concentration of chloramines did affect lead release.

4.2.2.5 Copper

Long Stagnation Time

Figure 4.13 shows the total copper concentrations following the short stagnation time (30min) in the copper pipe racks. Chlorine releases the most copper compared to the chloramines conditions, which is the opposite trend to lead release.

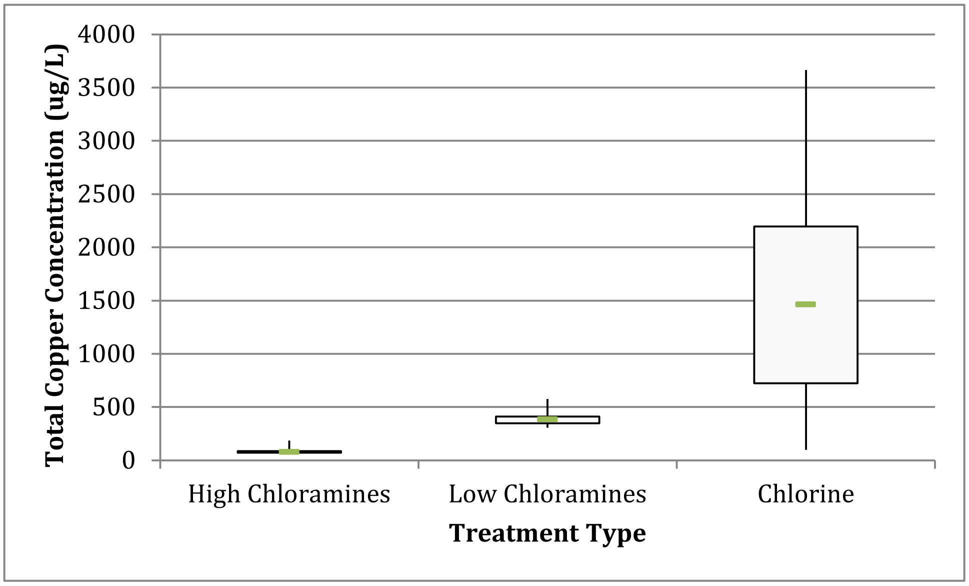


Figure 4.13 Box and whisker plot showing the 95% percentile range, median and quartile range of total copper concentrations during a long stagnation time for the uncontrolled pH phase using sodium silicate as a corrosion inhibitor

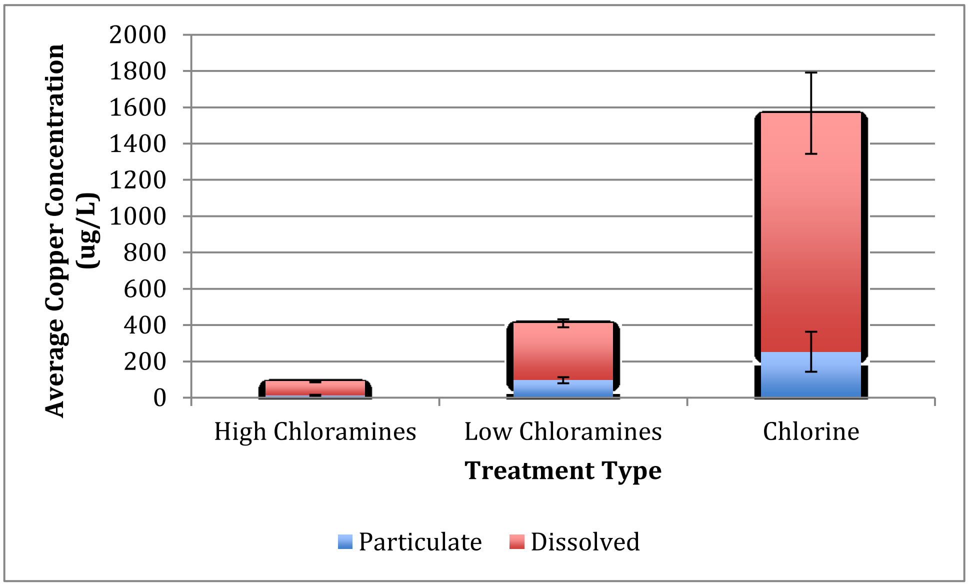


Figure 4.14 Particulate and dissolved copper contribution to the Total copper concentration with sodium silicate during a long stagnation time. Error bars represent the 95% confidence interval

For a long stagnation time, Figure 4.14 shows the contribution of particulate and dissolved copper. Chlorine releases the most in the form of dissolved copper.

Short Stagnation Time

Figure 4.15 shows total copper concentrations following the short stagnation time (30min) in the copper pipe racks. The concentrations of total copper are less than the long stagnation time.

During the long and short stagnation time when buffered with sodium silicate, t-test with statistical differences being those of values less than 0.025, indicated that high chloramines, low chloramines, and chlorine are all statistically different.

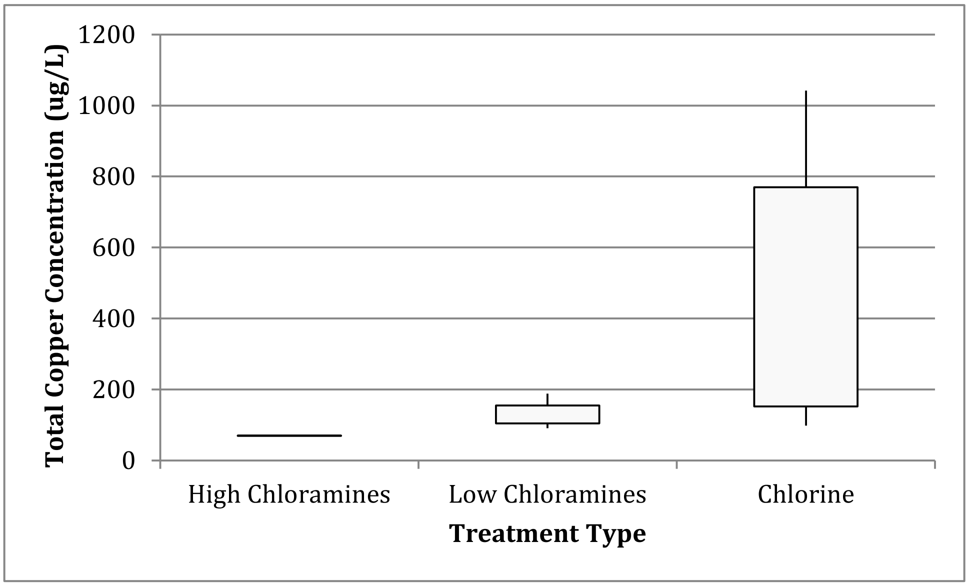


Figure 4.15 Box and whisker plot showing the 95% percentile range, median and quartile range of total lead concentrations during a short stagnation time for the uncontrolled pH phase using sodium silicate as a corrosion inhibitor

For a short stagnation time, Figure 4.16 shows the contribution of particulate and dissolved copper. The total copper is mostly made of dissolved copper. Chlorine releases the most in the form of dissolved copper.

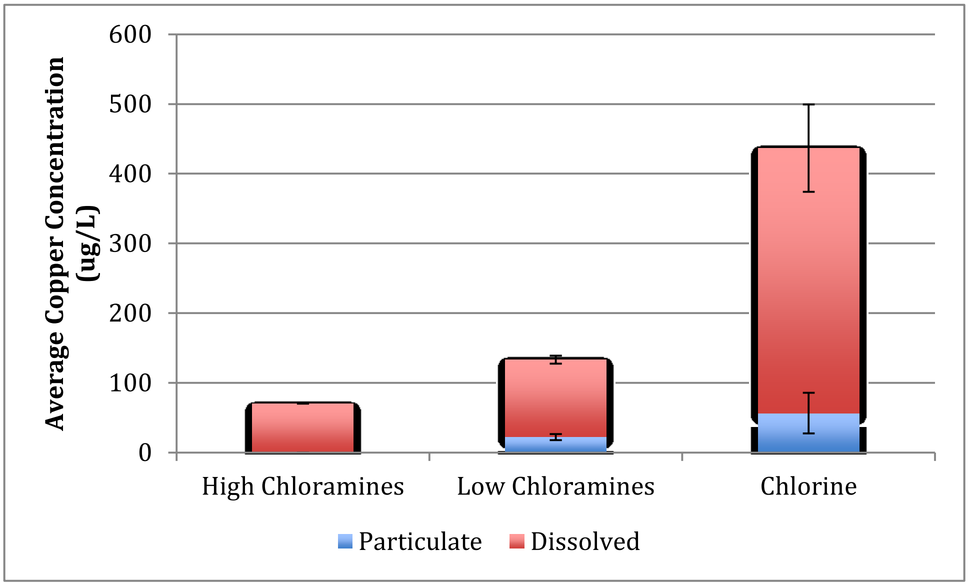


Figure 4.16 Particulate and dissolved copper contribution to the Total copper concentration with sodium silicate during a short stagnation time. Error bars represent the 95% confidence interval

Effect of Stagnation Time on Copper

There is a statistically significant impact between the long and short stagnation time on increasing copper concentrations for each treatment condition. For instance, high chloramines had a copper concentration during a long and short stagnation times of 88µg/L and 70µg/L. In addition, low chloramines condition had a concentration of copper during the long and short stagnation time of 409µg/L, and 133µg/L respectively. Chlorine had a concentration of copper during a long and short stagnation time of 1566µg/L and 438µg/L respectively. Overall, the copper concentration at the long stagnation time was 1 – 4 times greater than the copper concentration at the short stagnation time. This is consistent with literature (Fabbrincio et al., 2005 and Merkel et al., 2002)

Effect of Disinfectant Concentration on Copper

Long Stagnation Time

The concentration of copper during the long stagnation time for high chloramines, and low chloramines was 88µg/L and 409 µg/L. T-test with statistical differences being those of values less than 0.025 indicate the difference in total lead concentration between the two chloramines treatment groups is statistically significant. Chlorine had a copper concentration of 1566µg/L, this is above the Health Canada's aesthetic objective of <1.0mg/L for copper.

Short Stagnation Time

The concentration of copper during the short stagnation time for high chloramines, and low chloramines was 70µg/L and 133 µg/L. T-test with statistical differences being those of values less than 0.025 indicate the difference between the two treatment groups is statistically significant. The chlorine treatment had a copper concentration of 438µg/L.

4.2.3 Comparison of Buffered with Acid/Base and Buffered with Sodium Silicates

The following section with compared results from the controlled pH and uncontrolled pH phase with pipe loops using sodium silicate.

4.2.3.1 Water Quality Parameters

Table 4.6 Comparison of water quality parameters averages between sodium silicate buffered with acid/base and sodium silicate buffered with sodium silicate using high chloramines as a disinfecant

High Chloramines			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Sodium Silicate: Buffered with Sodium Silicate	p-value: statistical differences being values < 0.025
pH	7.5	8.0	0.00176
Disinfectant (mg/L)	2.46	4.02	0.05
Corrosion Rate (MPY)	2.92	1.26	6.67E-6
Dissolved Oxygen (mg/L)	8.05	8.35	0.835
Temperature (°C)	21.7	17.8	3.78E-6
Corrosion Inhibitor (mg/L)	17.78	22.10	0.151
ORP (mV)	458	439	0.34
Turbidity (NTU)	0.315	0.041	0.00409

Table 4.7 Comparison of water quality parameters averages between sodium silicate buffered with acid/base and sodium silicate buffered with sodium silicate using low chloramines as a disinfecant

Low Chloramines			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Sodium Silicate: Buffered with Sodium Silicate	p-value: statistical differences being values < 0.025
pH	7.51	6.87	7.07E-6
Disinfectant (mg/L)	1.84	2.23	0.35
Corrosion Rate (MPY)	2.39	2.24	0.36
Dissolved Oxygen (mg/L)	6.5	8.77	1.59E-6
Temperature (°C)	21.15	16.86	2.98E-7
Corrosion Inhibitor (mg/L)	21.16	20.73	0.9
ORP (mV)	481	480	0.95
Turbidity (NTU)	0.309	0.05	9.93E-05

Table 4.8 Comparison of water quality parameters averages between sodium silicate buffered with acid/base and sodium silicate buffered with sodium silicate using chlorine as a disinfecant

Chlorine			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Sodium Silicate: Buffered with Sodium Silicate	p-value: statistical differences being values < 0.025
pH	7.08	6.33	0.0028
Disinfectant (mg/L)	1.5	0.79	0.0053
Corrosion Rate (MPY)	2.72	1.41	2.32E-6
Dissolved Oxygen (mg/L)	6.75	9.2	2.7E-10
Temperature (°C)	22.24	17.0	1.24E-8
Corrosion Inhibitor (mg/L)	18.3	21.43	0.63
ORP (mV)	650	657	0.78
Turbidity (NTU)	0.431	0.061	0.0013

4.2.3.2 pH

When comparing pH between when it was buffered with an acid/base and when buffered with sodium silicate there are differences in each of the three treatment groups. With high chloramines there is an increase in pH, but with low chloramines and chlorine there is a decrease in pH.

4.2.3.3 Disinfectant Concentration

Differences between disinfectants residuals may be due to the stock trial and error dosage system. This difference occurring in the disinfectants could have also affected the amount of lead released in the copper pipe racks. Samples collected after the long stagnation time had low disinfectant residuals; sometimes near zero. Disinfectant residuals for the short stagnation time were greater than the long stagnation and closer to what the effluent of the pipe loops had.

4.2.3.4 Corrosion Inhibitor

Using ANOVA, the concentration of sodium silicate between when buffered with acid/base and when buffered with sodium silicate was not significantly different.

4.2.3.5 Effect of Buffered with an Acid/Base versus Buffered with Sodium Silicate on Total Lead

During the long stagnation time, high chloramines when buffered with acid/base had the greatest lead release, median value of 400µg/L, following by low chloramines, median value of 200µg/L, and chlorine, median value of 30µg/L. When buffered with sodium silicate, low chloramines had the greatest lead release, median value of 90µg/L, followed by high chloramines, median value of 70µg/L, and chlorine, median value of 27µg/L.

A similar trend occurs during the short stagnation time. High chloramines when buffered with acid/base had the greatest lead release, median value of 33µg/L, following by low chloramines, median value of 30µg/L, and chlorine, median value of 5µg/L. When buffered with sodium silicate, low chloramines had the greatest lead release, median value of 20µg/L, followed by high chloramines, median value of 5µg/L, and chlorine, median value of 1µg/L.

For the high chloramines, the decrease in lead release can be explained by the greater pH increase when buffered from sodium silicate (pH of 8.0) than from when buffered with an acid/base(pH of 7.3). A higher pH is associated with a reduction in metals release. The high chloramines had a higher pH when it was buffered with sodium silicate than when buffered with acid/base.

For low chloramines and chlorine there is a pH decrease (from 7.5 to 6.7 for low chloramines and from 7.1 to 6.3 for chlorine. A decrease in pH can lead to an increase in metals release. For the long stagnation time, there is less lead being released at a lower pH for low chloramines and chlorine. For the short stagnation time low chloramines and chlorine are not statically different between when buffered with a acid/base and when buffered with sodium silicate.

4.2.3.5 Effect of Buffered with an Acid/Base versus Buffered with Sodium Silicate on Total Copper

T-tests indicate that total copper is statistically different for all treatment types for the long stagnation time. During the short stagnation time statistical differences occurred between all the treatments groups.

The condition that released the most copper was chlorine during the long stagnation time when buffered with sodium silicate. This is opposite of the trend for total lead, as chlorine released the least amount. A reason for this could be the amount of sodium silicate (at 18mg/L) was not enough to protect all of the copper pipe racks. If not enough corrosion inhibitor is used the areas that are not protected will corrode aggressively.

4.3 Results for Phosphate

This section will discuss all results associated with pipe loops using phosphate. Detail information is provided in Appendix C.

4.3.1 Water Quality Parameters

Table 4.9 is a summary of the water quality parameters for pipe loops using phosphate. Using ANOVA, water quality parameters that are not statistically different for the various disinfectant conditions are dissolved oxygen (p-value=0.65), and temperature (p-value=0.33), phosphate (p-value=0.35). ORP is statistically different (p-value=0.51); however between high chloramines and low chloramines are statistically not different (p-value=0.51). Turbidity is statistically different between the three treatment groups, however a t-test between high and low chloramines are statistically not different (p-value= 0.04). Corrosion rate is statistically different between the three treatments groups, however between high and low chloramines are not statistically different (p-value = 0.56).

Table 4.9 Averages of water quality parameters of the effluent of the pipe loops for phosphate

Phosphate: Buffered with Acid/Base			
Water Quality Parameter	High Chloramines	Low Chloramines	Chlorine
pH	7.18	6.7	6.9
Disinfectant (mg/L)	3.14	1.25	1.3
Corrosion Rate (MPY)	3.5	3.2	2.1
Dissolved Oxygen (mg/L)	7.22	7.5	7.3
Temperature (°C)	19.1	18.3	19.1
Corrosion Inhibitor (mg/L)	1.00	1.12	1.3
ORP (mV)	487	478	650
Turbidity (NTU)	0.498	0.348	1.076

4.3.2 pH

Using ANOVA pH is statistically different between the three treatment groups (p-value = 0.0004). When doing separate t-tests, only low chloramines and chlorine are not statistically different (p-value=0.13).

4.3.3 Disinfectant Concentration

Chloramines concentrations for the high chloramine treatment group had an average of 3.14mg/L. For the low chloramines treatment group, it had an average disinfectant concentration of 1.25mg/L. Through a t-test, disinfectant residuals between high and low chloramines were different (p-value=0.0008). Even though the concentrations are not at the target, the most important aspect is that high chloramines has a greater concentration than low chloramines.

Chlorine residuals (measured as free chlorine) were 1.3mg/L. This is greater than the free chlorine measurement at the JDKWSP. This higher dosage is due to the trial and error dosage method for the pipe loops.

Table 4.10 Actual versus target pH and disinfectant values for pipe loops using phosphate

Treatment Type	pH		Disinfectant Residual (mg/L)		
	Target	Actual	Target	Actual	
High Chloramines	7.3	7.2±0.8	~3.0	3.14±4.3	As Chloramines
Low Chloramines	7.3	6.7±0.8	~1.0	1.25±1.9	As Chloramines
Chlorine	7.3	6.9±0.8	~1.0	1.3±1.4	As Free Chlorine

The pH of the phosphate pipe loops never changed, unlike the sodium silicate pipe loops. The same conditions were run for one year over a variety of seasonal temperatures. When comparing lead release with temperature, correlations were insignificant. Thus phosphate data was grouped together and compared against sodium silicate data.

4.3.4 Lead

Long Stagnation Time

Figure 4.17 shows a box and whisker plot for the long stagnation time. High chloramines released the most lead followed by low chloramines and then chlorine. High chloramines also had the most variation shown by to the wide whiskers.

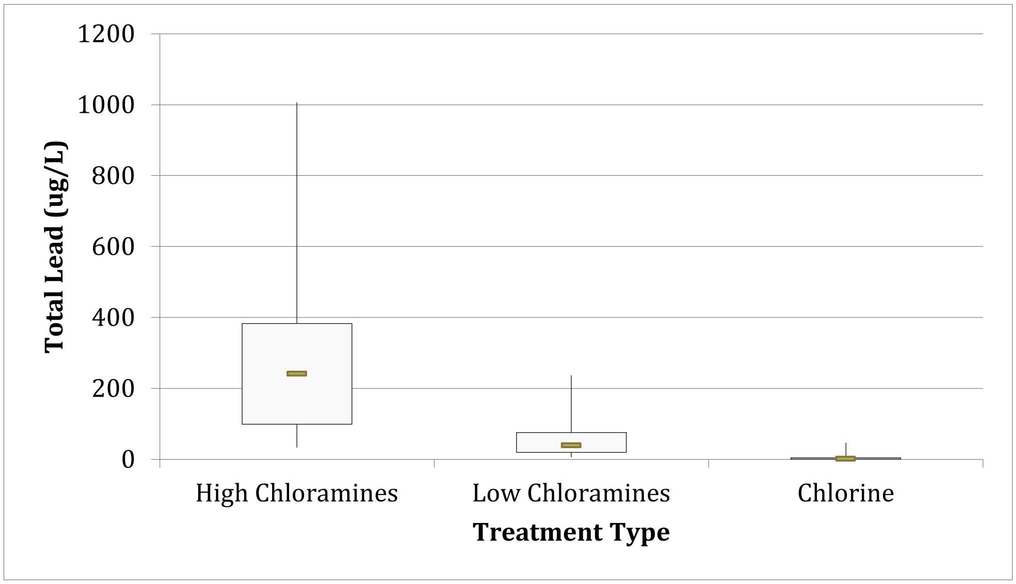


Figure 4.17 Box and whisker plot displaying 5^{th} and 95th percentile, 1st and 3rd quartile range, and median of total lead concentration for each treatment type using phosphate during the long stagnation time

Figure 4.18 is a bar graph showing the amount of particulate and dissolved lead. Particulate and dissolved lead each approximately makes up 50% of the average total lead.

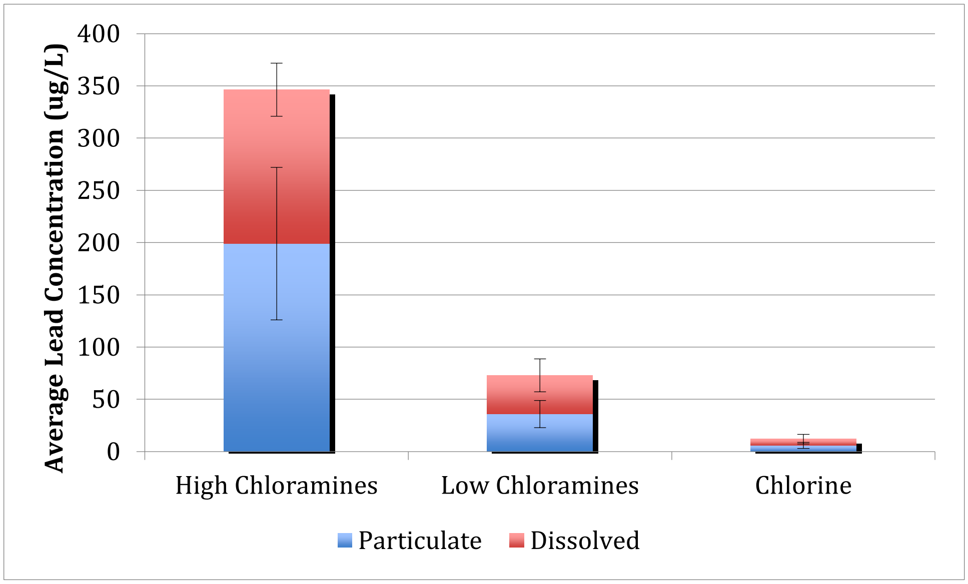


Figure 4.18 Particulate and dissolved lead contribution to the total lead concentration with phosphate during a long stagnation time. Error bars represent the 95% confidence interval

Short Stagnation Time

Figure 4.19 shows a box and whisker graphs for the short stagnation. Like the long stagnation time, high chloramine released the most lead followed by low chloramines, then chlorine.

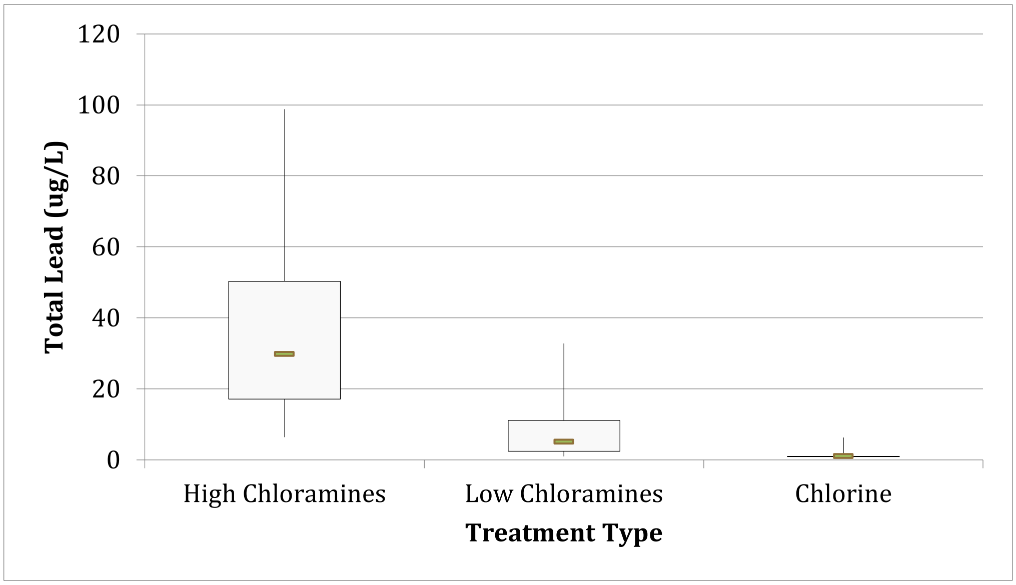


Figure 4.19 Box and whisker plot displaying 5^{th} and 95th percentile, 1st and 3rd quartile range, and median of total lead concentration for each treatment type using phosphate during the short stagnation time

Figure 4.19 shows the amount of particulate and dissolved lead making up the total average lead. Again like the long stagnation is an approximately 50/50 split.

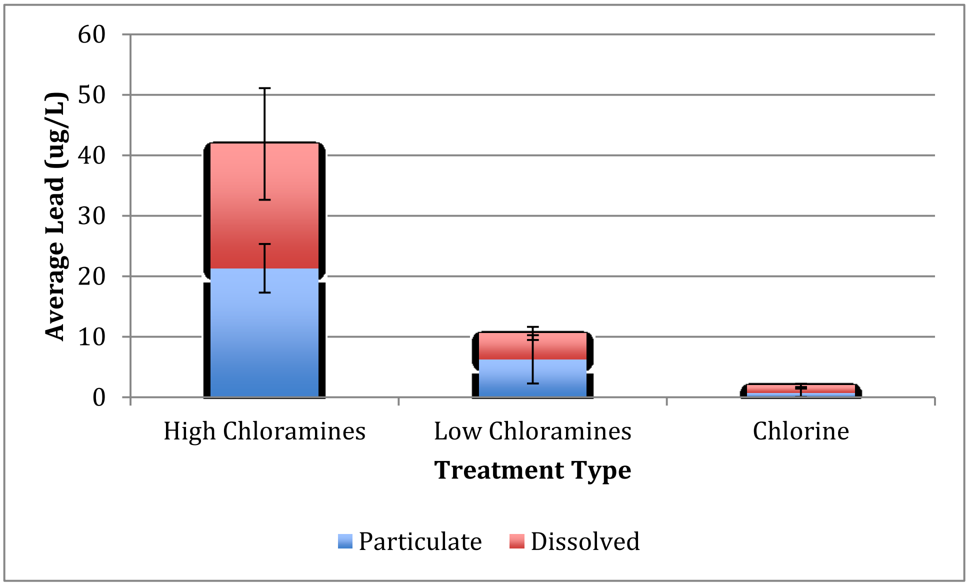


Figure 4.20 Particulate and dissolved lead contribution to the total lead concentration with phosphate during a short stagnation time. Error bars represent the 95% confidence interval

Effect of Stagnation Time on Lead

There was a statistical significant increase in lead concentrations between the long and short stagnation times for each treatment condition. For example, high chloramines had a lead concentration for the long and short stagnation time of 351µg/L and 42µg/L respectively. In addition, low chloramines had a concentration of lead during the long and short stagnation time of 74µg/L, and 10µg/L respectively. Chlorine had a concentration of lead during a long and short stagnation time of 12µg/L and 2µg/L respectively. In general, the lead concentration at the long stagnation time was between 6 to 8 times greater than the lead concentration for the short stagnation time. This is consentient with literature (Volk et al., 2000) that has reported increased metals release with stagnation time.

Effect of Disinfectant Concentration on Lead

Long Stagnation Time

The concentration of lead during the long stagnation time for high chloramines and low chloramines was 351µg/L, and 73 µg/L respectively. T-test with statistical differences being those of values less than 0.025 indicate the difference between the two treatment groups is statistically significant. Chlorine had a lead concentration of 12µg/L.

Short Stagnation Time

The concentration of lead during the short stagnation time for high chloramines and low chloramines was 42 µg/L and 10 µg/L respectively. T-test with statistical differences being those of values less than 0.025 indicate the difference between the two treatment groups is statistically significant. Chlorine had a lead concentration of 2µg/L, this is below the 10µg/L limit for lead in drinking water.

4.3.5 Copper

Long Stagnation Time

Figure 4.21 shows a box and whisker graph for copper during the long stagnation time. High chloramine had the greatest variation as shown by the wide whiskers.

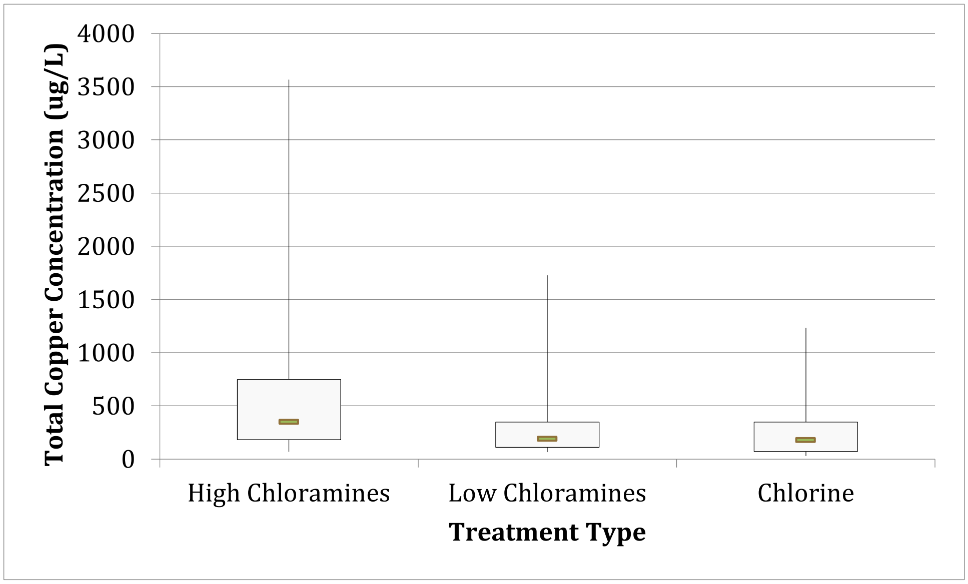


Figure 4.21 Box and whisker plot displaying 5^{th} and 95th percentile, 1st and 3rd quartile range, and median of total copper concentration for each treatment type using phosphate during the long stagnation time

Figure 4.22 shows the particulate and dissolved lead in the total average copper. Here dissolved copper makes up most of the total average copper.

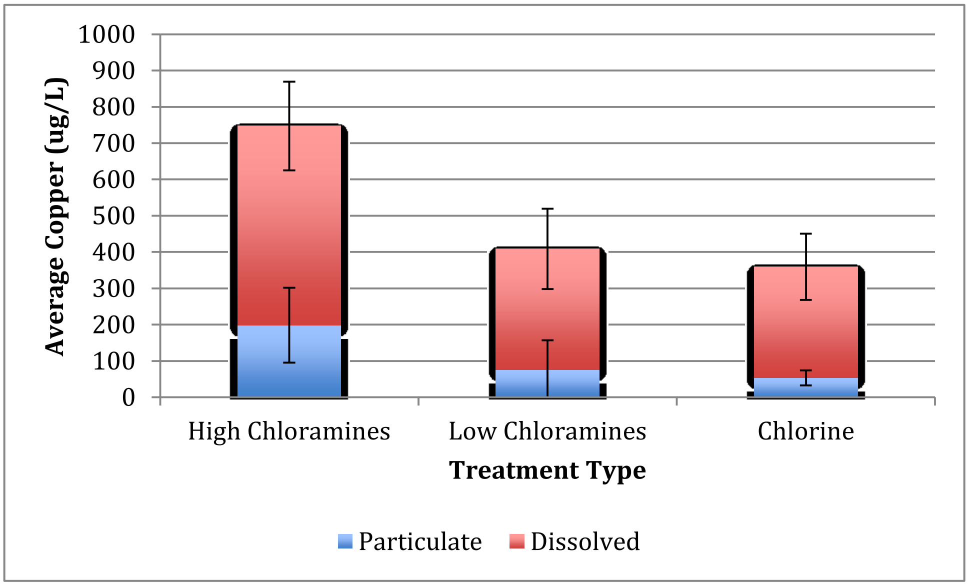


Figure 4.22 Particulate and dissolved copper contribution to the total copper concentration with phosphate during a long stagnation time. Error bars represent the 95% confidence interval

Short Stagnation Time

Figure 4.23 shows a box and whisker graph for copper during the short stagnation time. Again similar to the long stagnation time, high chloramine is more variable as shown by the long whiskers.

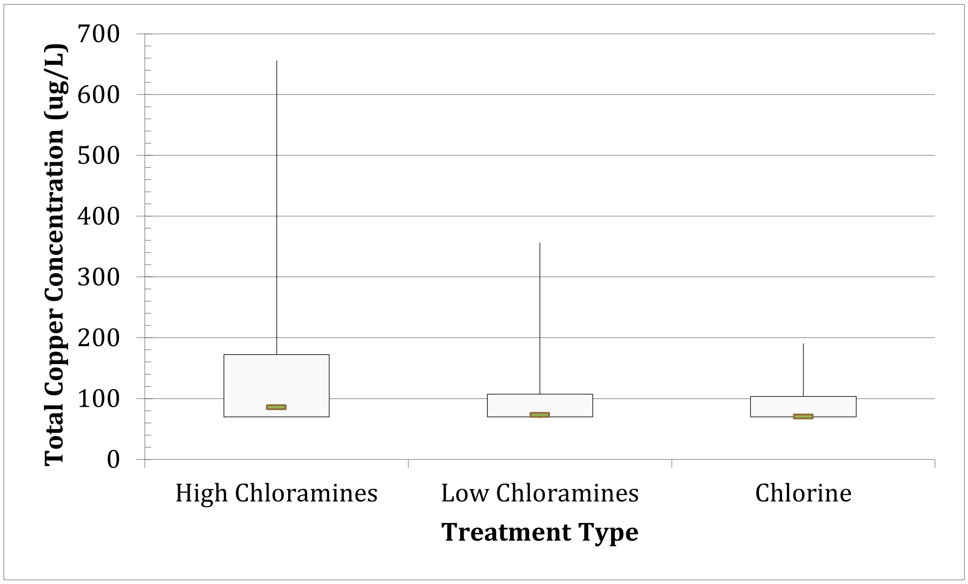


Figure 4.23 Box and whisker plot displaying 5th and 95th percentile, 1st and 3rd quartile range, and median of total copper concentration for each treatment type using phosphate during the short stagnation time

Figure 4.24 shows the amount of particulate and dissolved copper in the total average copper. For high chloramine, total copper is mostly made of particulate copper while for the low chloramines and chlorine, total copper mainly consists of dissolved copper.

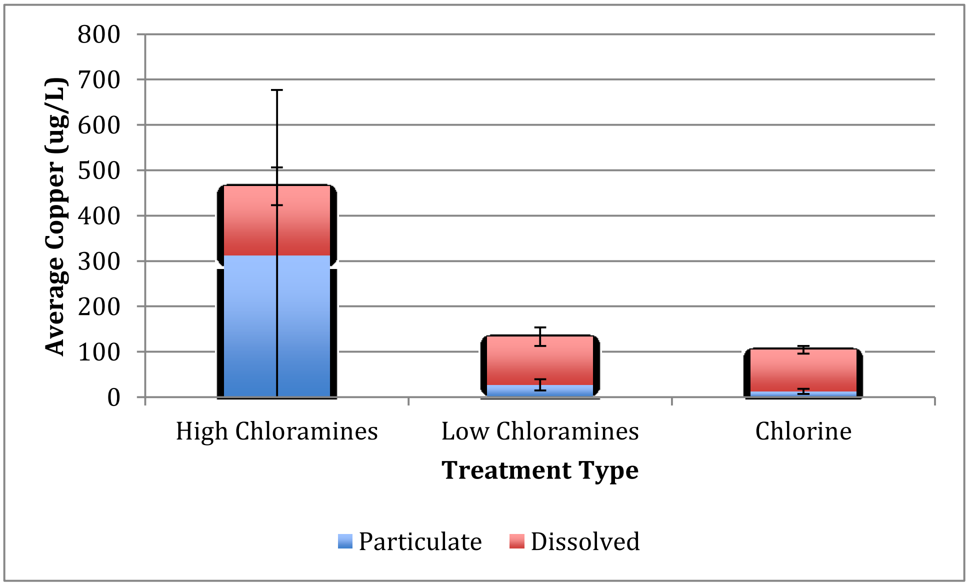


Figure 4.24 Particulate and dissolved copper contribution to the total copper concentration with phosphate during a short stagnation time. Error bars represent the 95% confidence interval

Effect of Stagnation Time on Copper

There was a statistically significant impact on copper concentration between the long and short stagnation time. T-tests with statistical differences being those of values less than 0.025 indicate the difference between the long and short stagnation time is statistically significant. For example, high chloramines had a concentration of copper during a long and short stagnation time of 747µg/L and 467µg/L respectively. Similar to this, low chloramines had a concentration of copper during the long and short stagnation time of 416µg/L, and 133µg/L respectively. Chlorine had a concentration of copper during a long and short stagnation time of 360µg/L and 104µg/L respectively. Overall, the copper concentration during the long stagnation time was between 2 to 4 times greater than the lead concentration for the short stagnation time. This is consistent with literature (Fabbrincio et al., 2005, Merkel et al., 2002) that has reported increased copper release with increased stagnation time.

Effect of Disinfectant Concentration on Copper

Long Stagnation Time

The concentration of copper during the long stagnation time for high chloramines and low chloramines was 747µg/L and 416 µg/L respectively. T-test with statistical differences being those of values less than 0.025 indicate the difference between the two treatment groups is statistically significant. Chlorine had a total lead concentration of 360µg/L.

Short Stagnation Time

The concentration of copper during the short stagnation time for high chloramines and low chloramines was 467µg/L, and 133 µg/L respectively. T-test with statistical differences being those of values less than 0.025 indicate there is not a statistically significant difference between the two treatment groups. Chlorine had a total lead concentration of 104µg/L.

4.4 Comparison of Sodium Silicates and Phosphate

4.4.1 Copper Pipe Racks

Since all the copper pipe racks were independent from one another there is variability within each rack. Each copper pipe rack was soldered generously with 50:50 lead:tin solder, however each copper pipe rack would have slight differences with solder.

4.4.2 Variation with Influent Parameters

There were fluctuations in disinfectants concentration, pH, and corrosion inhibitor within the pilot scale system. Due to the 12 hr retention time of the pipe loops, the trial and error method of chemical adjustments was difficult. The dosage of stock chemicals were done at the influent of the pipe loop and chemical changes were not noticed until the next sample day, 3 to 4 days later.

Many of the water quality parameters monitored remained stable throughout the study. Temperature changes throughout the study were due to seasonal variations. The temperature of the effluent of the pipe loop was approximately the room temperature of the basement of JDKWSP. The influent water of the pipe loop had a more pronounced seasonal variation than the effluent. This is due to the 12 hour retention time of the water in the pipe loops.

4.4.3 Phosphate compared to Sodium Silicate when buffered with Acid/Base

4.4.3.1 Water Quality Parameters

Table 4.11, Table 4.12, and Table 4.13 compare water quality parameters between high chloramines, low chloramines, and chlorine. P-values are also reported. Statistical differences are shown by p-values are less than 0.025.

For high chloramines, all the water quality parameters are not statistical different except for temperature. For low chloramines, water quality parameters that are statistically different are pH, corrosion rate, dissolved oxygen, and temperature. For chlorine, water quality parameters that are statistically different are corrosion rate, temperature, and turbidity.

Table 4.11 Comparison of averages between sodium silicate buffered with acid/base and phosphate of water quality parameters using high chloramines as a disinfecant

High Chloramines			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Phosphate: Buffered with Acid/Base	p-value: statistical differences being values < 0.025
pH	7.5	7.18	0.41
Disinfectant (mg/L)	2.46	3.14	0.32
Corrosion Rate (MPY)	2.92	3.5	0.31
Dissolved Oxygen (mg/L)	8.05	7.22	0.55
Temperature (°C)	21.7	19.12	0.000691
ORP (mV)	458	487	0.12
Turbidity (NTU)	0.315	0.498	0.14

Table 4.12 Comparison of averages between sodium silicate buffered with acid/base and phosphate of water quality parameters using low chloramines as a disinfecant

Low Chloramines			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Phosphate: Buffered with Acid/Base	p-value: statistical differences being values < 0.025
pH	7.51	6.7	1.6E-8
Disinfectant (mg/L)	1.84	1.25	0.12
Corrosion Rate (MPY)	2.39	3.2	0.002
Dissolved Oxygen (mg/L)	6.5	7.5	.0075
Temperature (°C)	21.16	18.3	5.34E-5
ORP (mV)	481	478	0.84
Turbidity (NTU)	0.309	0.348	0.57

Table 4.13 Comparison of averages between sodium silicate buffered with acid/base and phosphate of water quality parameters using chlorine as a disinfecant

Chlorine			
Water Quality Parameter	Sodium Silicate: Buffered with Acid/Base	Phosphate: Buffered with Acid/Base	p-value: statistical differences being values < 0.025
pH	7.08	6.9	0.23
Disinfectant (mg/L)	1.5	1.3	0.43
Corrosion Rate (MPY)	2.72	2.1	0.071
Dissolved Oxygen (mg/L)	6.75	7.3	0.135
Temperature (°C)	22.24	19.18	1.5E-5
ORP (mV)	650	650	0.99
Turbidity (NTU)	0.431	1.076	0.003

4.4.3.2 Corrosion Inhibitor

As presented in a previous chapter, the concentration of phosphate and sodium in the effluent of the pipe-loops is not different within the three treatment groups.

4.4.3.3 Effect of Corrosion Inhibitor on Total Lead

The following will present the effect of corrosion inhibitor on total lead release from the copper pipe racks for a long and short stagnation time. Comparisons are only made between each treatment group.

Long Stagnation Time

During a long stagnation time, t-tests with statistical differences being those of values less than 0.025 indicate results between phosphate and sodium silicate are statistically different. Using phosphate as a corrosion inhibitor released less total lead than sodium silicate. For example, for the high chloramines treatment, the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 319 µg/L and 604 µg/L respectively (p-value=8.7E-5). For low chloramines treatment, the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 71 µg/L and 236 µg/L respectively (p-value=9.6E-17). For chlorine, the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 11µg/L and 46 µg/L respectively (p-value=9.7E-7)..

Short Stagnation time

During the short stagnation time, t-tests with statistical differences being those values less than 0.025 indicate statistical differences between the total lead release with phosphate and sodium silicate. For the high chloramines condition, the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 39µg/L and 59µg/L respectively. T-tests with statistical differences being those of values less than 0.025 indicate results between phosphate and sodium silicate are statistically not different (p-value=0.028). However for the low chloramines and chlorine treatments, phosphate releases less total lead than sodium silicate. For example for the low chloramines treatment, the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 10µg/L and 49µg/L respectively (p-value=0.022). In addition, for the chlorine treatment the average concentration of total lead using phosphate and sodium silicate buffered with an acid/base was 2µg/L and 7µg/L respectively (p-value=6.2E-14).

4.4.3.4 Discussion of the Effect of Corrosion Inhibitor on Total Lead

For a long stagnation time, high chloramines, low chloramines, and chlorine disinfectant conditions released less total lead using phosphate then sodium silicate. For the short stagnation time, the amount of total lead release for the high chloramines treatment is not statistically different between phosphate and sodium silicate. However for low chloramines and chlorine treatment phosphate released less total lead than sodium silicate.

Previous studies done by Maddison et al., (2001) optimize polyphosphate at a dose of 0.8 mg/L for the JDKWSP. However, the dosage of sodium silicate was not optimized for the JDKWSP. The dosage of 18 mg/L was used based on a utility in New England with similar source water that uses sodium silicate. The optimized dose of phosphate for the JDKWSP could explain why phosphate released less lead than sodium silicate. An increased dosage of sodium silicate could result in less lead release, further studies are required to find what dose of sodium silicate is needed.

4.4.3.5 Effect of Corrosion Inhibitor on Total Copper

The following will present the effect of corrosion inhibitor on total copper release from the copper pipe racks for a long and short stagnation time. Comparisons are only made between each treatment group.

Long Stagnation Time

During the long stagnation time less total copper is released using phosphate as a corrosion inhibitor than sodium silicate. T-test with statistical differences being those of values less than 0.025 indicate results between phosphate and sodium silicate are statistically different For high chloramines treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 692μg/L and 2162μg/L respectively (p-value=0.002). For the low chloramines treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 382 μg/L and 539μg/L respectively (p-value=0.019). In addition for the chlorine treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 348 μg/L and 901 μg/L respectively (p-value=3.91E-6).

Short Stagnation Time

During the short stagnation time, t-tests with statistical differences being those values less than 0.025 indicate statistical differences between the total copper released with phosphate and sodium silicate. For the high chloramines treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 430µg/L and 441µg/L respectively. T-tests indicate that phosphate and sodium silicate are statistically not different (p-value=0.97). However the opposition is true with the low chloramines and chorine treatment conditions. For the low chloramines treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 124µg/L and 223 µg/L, respectively. T-tests indicate phosphate and sodium silicate are statistically different (p-value=0.00035). For the chlorine treatment, the average concentration of total copper using phosphate and sodium silicate buffered with an acid/base were 101µg/L and 309µg/L respectively(p-value=1.81E-12).

4.4.3.6 Discussion of the Effect of Corrosion Inhibitor on Total Copper

The trend for total copper release is similar to that for total lead release. For a long stagnation time, high chloramines, low chloramines, and chlorine disinfectant conditions released less total copper using phosphate than sodium silicate. For the short stagnation time, the amount of total copper released for the high chloramines treatment is not statistically different between phosphate and sodium silicate. However for low chloramines and chlorine treatment phosphate released less total lead than sodium silicate.

4.4 Unintentional Consequences

4.4.1 Disinfectants by-products (DBPs)

To meet DBP standards utilities will often switch from chlorine to chloramines. As the results indicate at the beginning of this chapter, doing chloramines resulted in greater release of lead than when dosed with chlorine as a disinfectant. Samples for instantaneous total trihalomethanes (THMs) and total haloacetic acids (HAAs) were taken at the influent and effluent of the pipe loops and following the long and short stagnation time in the copper pipe racks. The limit from Health Canada for THMs and HAAs is 80mg/L and 100mg/L/. Halifax Water want achieve DBP concentration below the Health Canada standard and meet the EPA's limit for DBP's which are 80mg/L for THMs and 60mg/L for HAAs. Samples were taken three times, in October 2009, December 2009, and April 2010. Due to the sensitive nature of DBP extraction some data from each sample day is missing for the influent and effluent of the pipe loops.

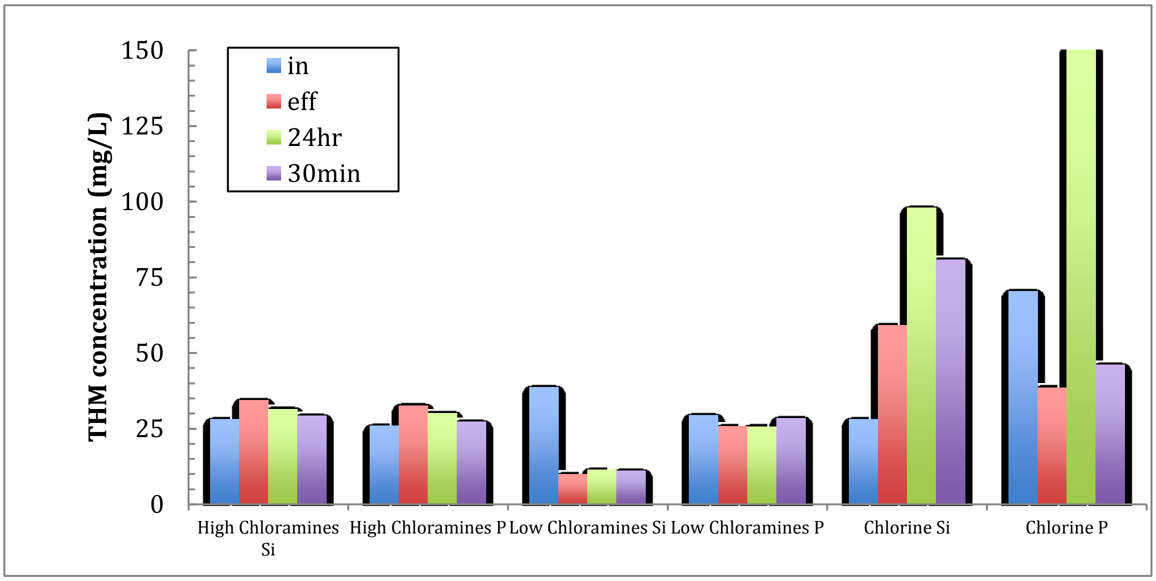


Figure 4.25 Total THMs October 2009

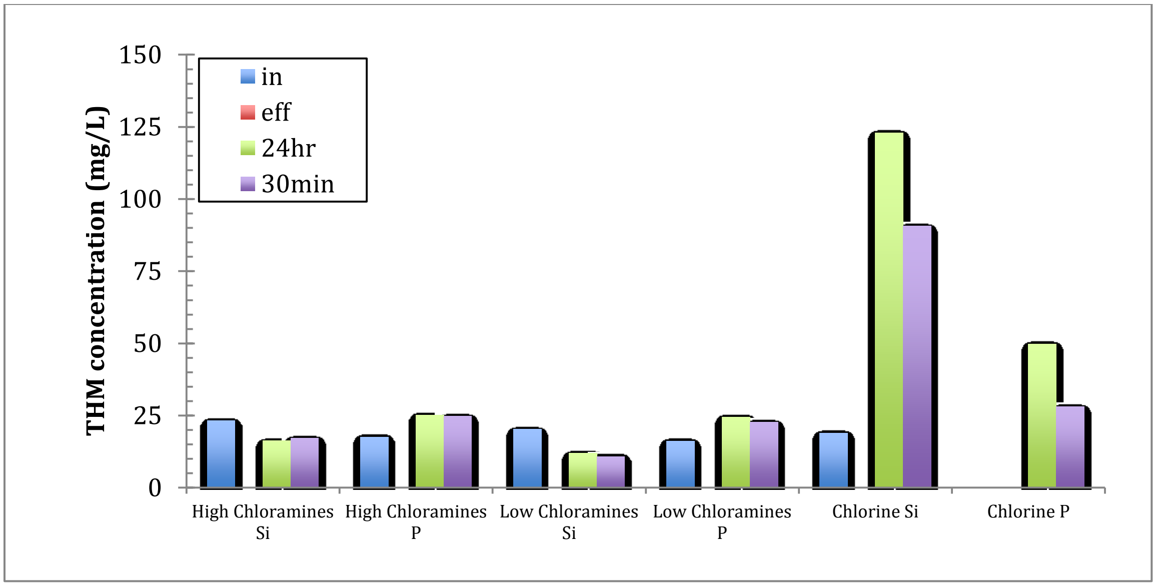


Figure 4.26 Total THMs December 2009

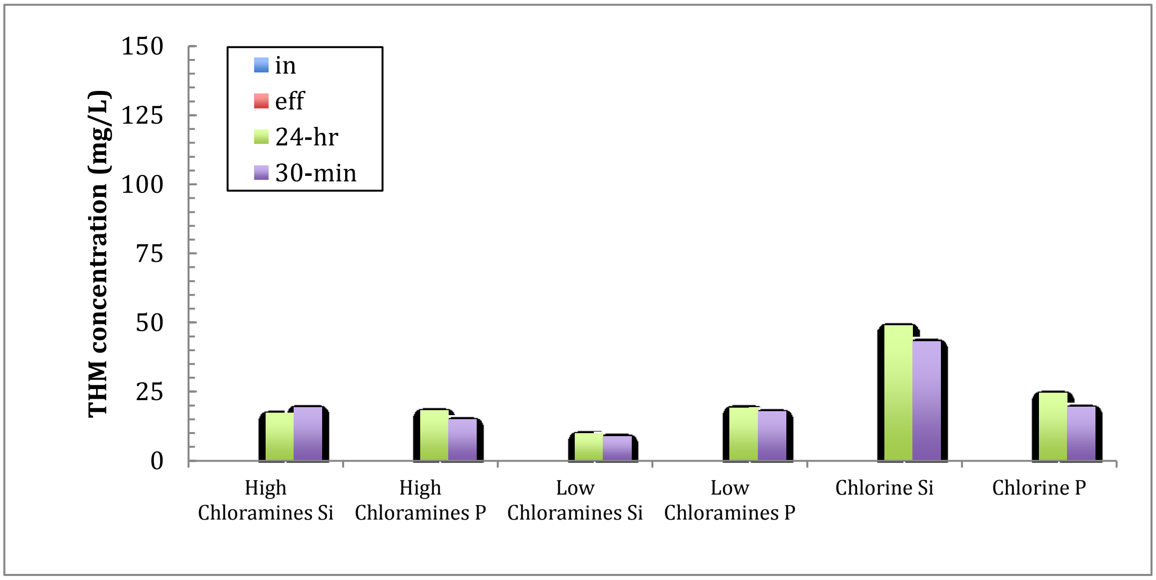


Figure 4.27 Total THMs April 2010

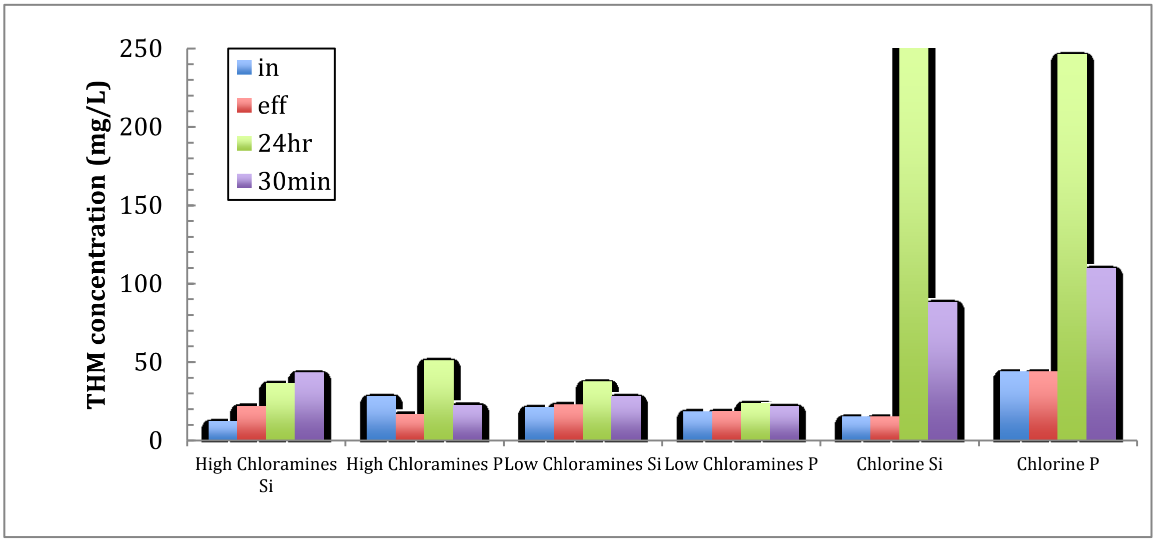


Figure 4.28 Total HAAs October 2009

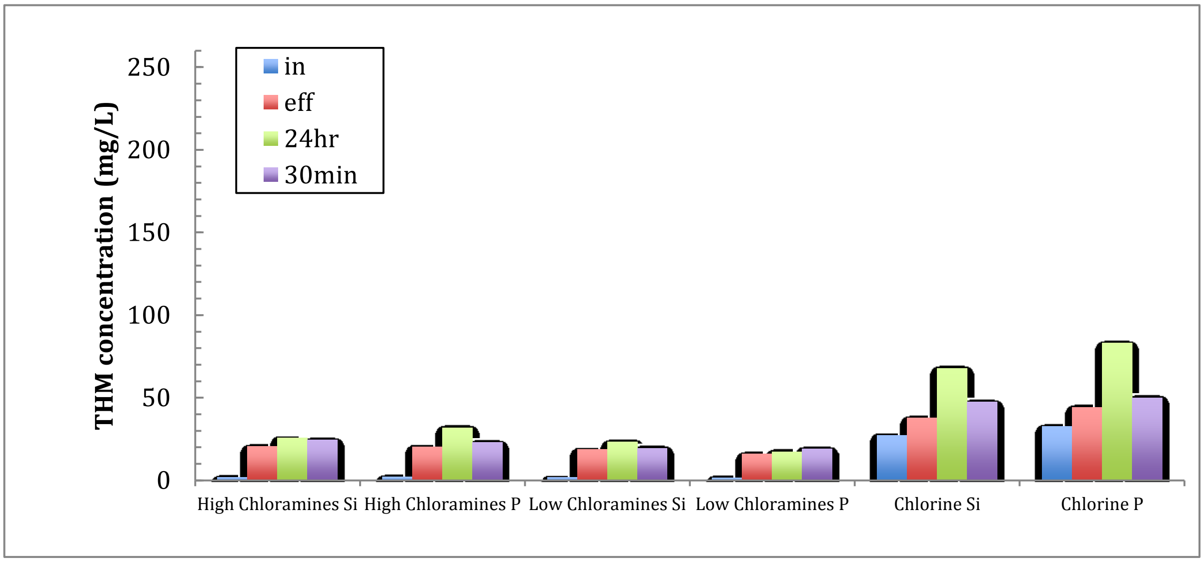


Figure 4.29 Total HAAs December 2009

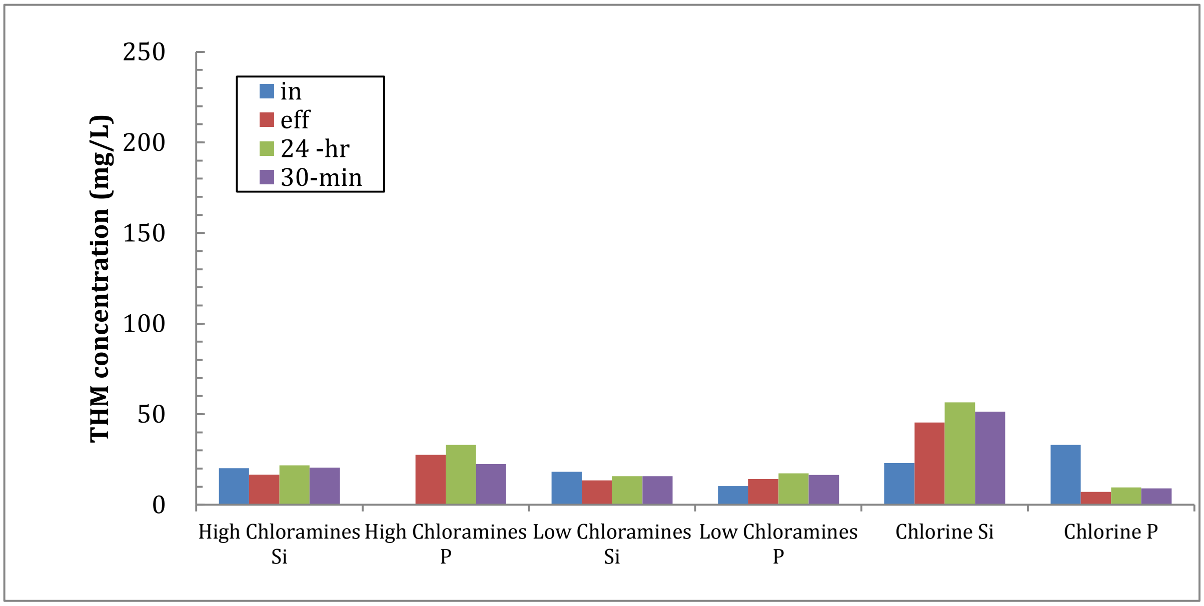


Figure 4.30 Total HAA's April 2010

The total THMs are displayed in Figure 4.25, Figure 4.26, and Figure 4.27. The total HAAs are displayed in Figure 4.28, Figure 4.29, and Figure 4.30. The lowest DBPs occur with the chloramines. From the three samples day from DBP there does not seem to be a difference between sodium silicate and phosphate, although more data is needed to be sure. The highest level of DBPs occurred with chlorine during a 24 hr stagnation time. The highest occurrence of both THMs and HAAs occurred during the October 2009 sample period

The average concentrations of total organic carbon (TOC) are as displayed in Table 4.14. TOC is an gauge for water quality as it indicates the amount of NOM in the water that could react with chlorine to form DBPs. The average TOC concentrations during the pilot scale study range from 1.9 to 2.7mg/L

Table 4.14 Average TOC Concentration (mg/L)

	High Chloramines Sodium silicate	High Chloramines Phosphate	Low Chloramines Sodium Silicate	Low Chloramines Phosphate	Chlorine Sodium silicate	Chlorine Phosphate
Influent of pipe loop	2.2 ± 0.5	2.2± 0.2	2.1± 0.1	2.2± 0.2	2.2± 0.2	2.1± 0.1
Effluent of pipe loop	2.3 ± 0.6	2.0 ± 0.1	2.7± 0.1	2.0± 0.1	2± 0.2	2.1± 0.1
24hr stagnation time in copper pipe racks	2.1 ± 0.3	2.1 ± 0.3	2.2± 0.3	2.1± 0.3	2.0± 0.2	2.0± 0.2
30min stagnation time in copper pipe racks	2.1 ± 0.2	2.1 ± 0.1	2.1± 0.1	2.1± 0.1	2.1± 0.2	1.9± 0.1

4.4.2 Nitrification

Nitrification occurs when ammonia is oxidized to nitrite and then to nitrate. For this study, nitrification occurs only with pipe loops using chloramines as a disinfectant. As indicated before chloramines are a combination of ammonia and chlorine. The breakdown of chloramines releases ammonia which ammonia oxidizing bacteria use to convert ammonia to nitrite and then to nitrate. The pipe loop that used high chloramines with phosphate was not included because nitric acid was used to lower the pH, which would then interfere with the nitrate results.

Figure 4.31 displays the data for the pipe loop using the low chloramines conditions using phosphate as the corrosion inhibitor. The rest of the data is in Appendix D. The data is expressed as the amount of molar nitrogen in mg/L (N-mg/L) for the amount of nitrite, nitrate, ammonia and total nitrogen. Very low levels of nitrite were detected; this is expected because the reaction of nitrite to nitrate is very fast. At the influent of the pipe loop to the 30min and 24hr stagnation time in the copper pipe racks, the amount of ammonia is relatively similar. This is not what is expected as ammonia is being converted to nitrite and nitrate. Ammonia is also known to complex with lead to form lead ammonia. There is an increase in nitrate from the influent of the pipe loops to the 30min stagnation time to the 24 hr stagnation time in the copper pipe racks. Other results using sodium silicates as a corrosion inhibitor did not show increase in nitrate from the influent of the pipe loop, to the 30min stagnation time, to the 24 hr stagnation time. Bacteria can use phosphate to grow and perhaps that is why there was an increase in nitrate between the 30min stagnation time and the 24 hr stagnation time.

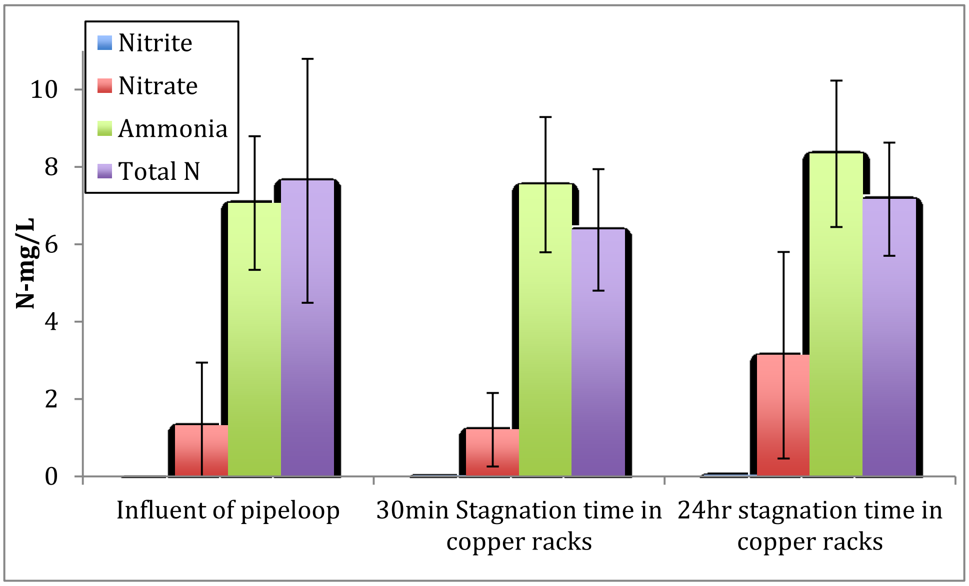


Figure 4.31 Nitrification data for low chloramines using phosphate. Error bars represent 95% percent confidence intervolves.

Sampling was done for the heterotropic plate count (HPC) periodically throughout the study. HPC is an indicator of the culturable organisms that are present in a sample. However sampling resulted in a bacteria count of zero. This could be due to a variety of reasons such as chlorine not being quenched enough, and the temperature being too low. The amount of bacteria that would grow on a plate is around 1% of what is actually present in the water. However the increase in nitrate from the 30min to 24hr stagnation time does indicate a presence of microbes. What and how many bacteria are present will have to be investigated through other micro bacteria techniques.

Chapter 5.0 Discussion

5.1 Sodium Silicates as a Corrosion Inhibitor

5.1.1 Dosage of Sodium Silicates

For this study, pipe loops using sodium silicates at concentration of 18mg/L released more lead than using phosphate as a corrosion inhibitor. With the limited literature and limited full scale use of sodium silicates, the optimal concentration of sodium silicates was difficult to determine. The decision to dose sodium silicates at 18mg/L for this study was made to duplicate a water treatment plant that uses sodium silicates in New England. More studies are required to determine the optimal dose of sodium silicate in order to reduce the lead concentrations to less than 10µg/L.

Sodium silicates contain an OH group that will increase the pH of low alkalinity water. pH can also be controlled by adding an acid or base. In this experiment, two experimental conditions were used: pH was controlled at 7.3 by an acid or base, and no pH control was used, pH was dependant on sodium silicate concentration. Using sodium silicate to increase pH is a cost saving benefit to utilities as it eliminates the need for extra chemicals such as sodium hydroxide to increase the pH.

For the high chloramines treatment, when an acid/base was used for pH control the average pH was 7.3. At an average pH of 7.3 the median lead concentration was 400µg/L in the copper pipe racks for a 24hr stagnation time. When no pH control was applied the average pH was 8.0. At pH 8.0 the median lead concentration was 70µg/L in the copper pipe racks. There was a statically significant decrease in lead release when the pH was raised from 7.3 to 8.0 for high chloramines after the 24hr stagnation time

For the low chloramines treatment, when an acid/base was used for pH control the average pH was 7.5. At an average pH of 7.5 the median lead concentration was 200µg/L in the copper pipe racks for a 24hr stagnation time. When no pH control was applied the average pH was 6.7. At pH 6.7 the median lead concentration was 90µg/L in the copper pipe racks. There was a statically significant decrease in lead release when the pH was decreased from 7.5 to 6.7 for low chloramines after the 24hr stagnation time

For the chlorine treatment, when an acid/base was used for pH control the average pH was 7.1. At an average pH of 7.1 the median lead concentration was 30µg/L in the copper pipe racks for a 24hr stagnation time. When no pH control was applied the average pH was 6.3. At pH 6.3 the median lead concentration was 27µg/L in the copper pipe racks. There was a statically significant decrease in lead release when the pH was decreased from 7.1 to 6.3 for chlorine after the 24hr stagnation time

For the high chloramines treatment, when the pH increased there was a decrease in lead release. For the low chloramines and chlorine treatment, there was a decrease in pH but also a decrease in lead release. The effect of pH control on the pH of the system was different, but the effect on lead was the same for each treatment condition.

In Pinto et al., (1997) sodium silicate addition was compared against pH adjustment for lead release. Water with a total chlorine concentration of 0.5mg/L and an alkalinity of 2.0mg/L was used in a batch system. The batch system was made up of 7 acrylic sleeves with 10 copper coupons that were partially covered with lead/tin solder. One was a control that used untreated ground water with chlorine, three were treated with sodium silicate to provide concentrations of 15, 20, and 25 mg/L, and three were controls treated with NaOH to provide similar pH increase seen with each sodium silicate concentration. After a 68 hour stagnation time in the batch system, there was greater lead reduction in the systems that used pH adjustment rather than using sodium silicate. This suggested that lower lead concentrations are a result of pH increase and not sodium silicate. However during the last month of experiments (the experiments ran for six months), the batch system at 20mg/L released less lead than its corresponding pH adjustment system. The decrease in lead release in the batch system using 20mg/L of sodium silicate near the end of the experiments suggests that the passivation film of sodium silicates forms at a slow rate.

In this study, the copper pipe racks treated with sodium silicate with no pH control during the last 6 months of the 12 month study. During the first 6 months, the copper pipe racks treated with sodium silicate were buffered with an acid/base. Less lead was released when sodium silicate had no pH control done during the last 6 months of the 12 month study which parallels the findings in Pinto et al. (1997), which suggest that sodium silicate form a film very slowly. The slow forming film of sodium silicate suggests why for the low chloramines and chlorine treatment, there was a decrease in pH but also a decrease in lead release. This is not consistent with general knowledge that a decrease in pH will lead to an increase in lead concentration.

5.1.2 Sodium Silicate and Copper Release

When comparing phosphate buffered with an acid/base and sodium silicates buffered with sodium silicate, during a 24hr stagnation time, sodium silicate release more total copper than phosphate for all three disinfectant treatments (high chloramines, low chloramines, chlorine). During the 30min stagnation time, total copper was statistically not different for high chloramines treatment between sodium silicate and phosphate. However for the low chloramines and chlorine condition total copper concentration was greater with sodium silicate than phosphate.

In Chiodini, (1998) a pilot scale study was done using sodium silicate on an isolated section of the Wilbraham, Massachusetts distribution system. The water quality expected after chemical injection at the taps was calcium at 2.7mg/L, alkalinity at 5.0mg/L, and pH at 9.7. The sodium silicate concentration was 20mg/L at the tap, it was then lowered to 12mg/L as a maintenance dose. Samples were tested for lead and copper after a stagnation time of 6 to 8 hours in house plumbing. This study did not find extensive copper release, concentrations were below standards.

In pilot scale experiments using lead soldered copper plumbing coils disinfected with 2.5mg/L of chloramines in North Vancouver, 7 conditions were tested. The 7 conditions were: 1. controlled, raw water, 2.treated control at a pH of 8.0 and alkalinity of 20mg/L, 3. pH 8.0, alkalinity of 20mg/L, TPC 223 (blend of silicate and orthophosphate) at 5mg/L, 4. pH 8, alkalinity of 20mg/L, sodium silicate at 12mg/L, 5. pH 8, alkalinity of

20mg/L, Virchem 939 (1:3 zinc to phosphate) at 1.5mg/L. 6. pH 8, alkalinity of 20mg/L, Virchem 939 at 4.5mg/L, and 7. pH 7.5, alkalinity of 10-12mg/L, Virchem 939 (1:3 zinc to phosphate) at 1.5mg/L. After a stagnation time of 24 hours in the lead soldered copper plumbing coils, extremely high copper concentration were seen in conditions 5., 6., and 7, all that used zinc orthophosphate (MacQuarrie et al., 1997). This is not consistent with one's study; greater copper release was encountered using sodium silicate than with zinc orthophosphate.

In MacQuarrie et al., (1997) TPC 223 (a blend of silicate and orthophosphate) is used as one of the corrosion inhibitors. Sodium silicate is an anodic inhibitor, while phosphate is an cathodic inhibitor. In using only sodium silicate, more copper could be released because the sodium silicate is covering the anode (lead) and leaving the cathode (copper) to corrode. While a blend of silicate and orthophosphate, a blend of a anodic and cathodic corrosion inhibitor, would reduce the amount of copper corrosion.

Sodium silicates treated copper pipe racks also released more copper than phosphate treated copper pipe racks, which is not consistence with the works of (MacQuarrie et al., 1997, Lytle et al., 1996, Pinto et al., 1997 & Johnson et al.,. 1993). Table 5.1 compares previous work with the results of this thesis. The study with the lowest alkalinity is from the JDKWSP (this thesis). In addition, this thesis had the greatest lead and copper release compared to MacQuarrie et al., 1997, Lytle et al., 1996, and Pinto et al., 1997, which implies that the low alkalinity at the JDKWSP has a great effect on lead and copper release.

During the course of the study, pumps shut off and/or there were blockages in tubing that stopped the flow of sodium silicate. Technical difficulties could have damaged the protective film that sodium silicates formed inside the copper pipe racks. If the protective layer of the sodium silicate is no properly formed in the premise plumbing, this could accelerate corrosion in the unprotected places. The area where the lead/tin solder meets the copper pipes is minute, compared to the area of copper pipe exposed to the water. If the anodic lead is protected by sodium silicate and the rest of the copper pipe is not, the copper may become the anode and corrode.

Another possible explanation to the high copper concentration is that the sodium silicate is reacting with a existing layer on the copper pipes. In the Pourbaix diagram for the copper water system (Figure 5.1) at a pH of around 7.3, copper is passivated. The pourbaix diagram that is shown is only a guideline, as it only takes into account only for copper in water. For the copper pipe racks other factors, such as corrosion inhibitors, disinfectant, and temperature, will change the pourbaix diagram. Copper will become unpassivated when there is a shifted to a more acidic condition. Since the pH did not go below 4, it is possible sodium silicate reacted with a copper species that causes soluble copper to be exposed. However more research is needed to determine this.

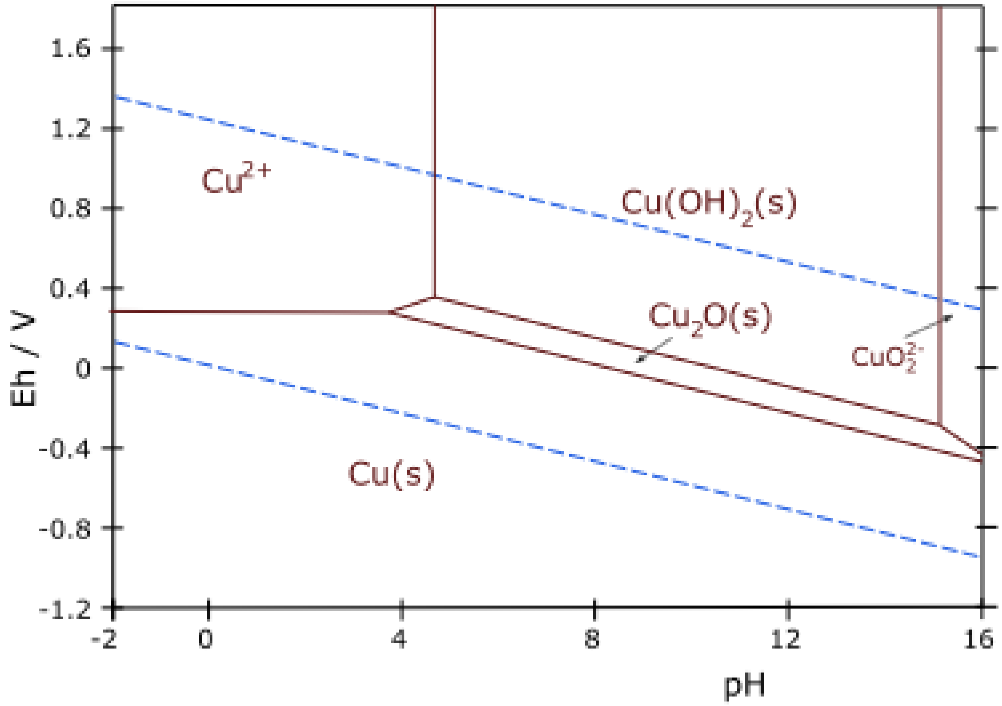


Figure 5.1 Pourbaix diagram for copper-water system

Table 5.1 Summary of sodium silicate papers compared to thesis study

Author	pH	Sodium Silicate Dose	Average Lead Concentration	Copper Concentration	Alk
Lytle et al., 1996	7.7	32mg/L dropped to 16mg/L	<10 µg/L to 25 µg/L	<0.25mg/L	32mg/L
MacQuarrie, D.M. 1997	8.0	12mg/L	0.025mg/L to 0.12mg/L	0.01mg/L to 0.2mg/L	20mg/L
Pinto et al., 1997	7.5 – 8.5	15,20,25mg/L	15mg/L Sodium Silicate = 2538 µg/L, 20mg/L Sodium Silicate = 1086 µg/L, 25mg/L Sodium Silicate = 1345 µg/L	15mg/L Sodium Silicate = 0.030 mg/L, 20mg/L Sodium Silicate = 0.030mg/L, 25mg/L Sodium Silicate = 0.050mg/L	0.0-2.0 mg $CaCO_3$/L
Woszczynski Chloramines Low	7.5	18mg/L	240±170 µg/L	540±240 mg/L	7.3 ± 2.8mg/L
Woszczynski Chloramines High	7.5	18mg/L	600±630 µg/L	2100±4200 mg/L	7.3 ± 2.8 mg/L
Woszczynski Chlorine	7.1	18mg/L	47±65 µg/L	900±1000 mg/L	7.3 ± 2.8 mg/L
Woszczynski Chloramines Low	6.9	18mg/L	100±62 µg/L	410±114 mg/L	4.3 ± 2.7 mg/L
Woszczynski Chloramines High	8.0	18mg/L	125±140 µg/L	88±36 mg/L	4.3 ± 2.7 mg/L
Woszczynski Chlorine	6.3	18mg/L	28±23 µg/L	1500±1100 mg/L	4.3 ± 2.7 mg/L

5.1.3 Health Concerns of Sodium Silicate

There is concern with the amount of sodium that sodium silicate would add to the drinking water. According to PQ Corporation, approximately 0.23mg of Na/L is added to the water with each 1mg/L concentration of Sodium Silicate type N. Therefore for a sodium silicate dosage of 18mg/L this adds 4.2mgNa/L. The Canadian food guide recommends 1.9L of water per day. If sodium silicate was in the water this would add an addition 8mg of sodium per day. Health Canada has an tolerable upper intake limit of 2300mg per day of sodium, with 1500mg per day because adequate. However during a survey done by the Canadian Community Health Survey in 2004 (CCHS 2.2) it found that Canadian adults were consuming an average of 3092 mg per day of sodium. The above average consumption of sodium in Canadian diets does raise concern over the amount of sodium in diets. But the amount of sodium coming from the water is only a fraction of what one can get from food.

5.2 Chloramines and the Corrosion Control Program

Chloramines are an attractive alternative to chlorine as they form fewer DBPs. Halifax Water currently meets Health Canada's DBP standard, but they would like to meet the more stringent EPA standards for DBPs. However, there are some concerns that switching from chlorine to chloramines will affect water quality and promote lead release.

In this study, the oxidation reduction potential (ORP) was in the 400mV range for chloramines and in the 600mV range for chlorine. Under high ORP conditions and in the presence of chlorine, metallic lead (Pb(s)) and Pb^{2+} will oxidize to lead oxide (PbO_2). Lead oxide is insoluble and will accumulate on the inside of the pipe. In Lytle & Schock (2005), lead oxide was formed in chlorinated water (< 3mg/L) with a pH range of 6.65 – 10. In Lin & Valentine (2008), lead oxide was reduced to soluble Pb^{2+}, and the ORP of the system decreased when the system was exposed to chloramines (14.1-70 μM NH_2Cl) at pH 7.

Edwards and Dudi (2004) conducted a bench-scale study with a pure lead pipe, using synthesized water (82mg/L $CaCl_2$, 89.6mg/L of $CaSO_4$, and 84.1 $NaHCO_3$) at a pH of 8.5. Several different conditions were tested (synthesized water, synthesized water plus ammonia, synthesized water plus chlorine, synthesized water plus chloramines, and synthesized water plus chloramines and orthophosphate). The condition that released the most amount of lead during a 16-h stagnation time was synthesized water with chloramines (at a mass ratio of 1:3.7 to N to Cl_2) and phosphate (at a concentration of 1mg/L as P with NaH_2PO_4)(Edwards and Dudi, 2004). The high lead release indicates that phosphate is not always beneficial to corrosion inhibition of lead when combined with chloramines. In addition, lead concentrations were similar between the synthesized water with chlorine and the synthesized water with chloramines. Since the lead pipes were cleaned before the experiments, there would be no build up of lead oxide in the test lead pipes that could react with the chloramines (causing increased lead release).

In this study, it was not possible to determine if the copper pipe racks had a build up of lead oxide. The inside of the copper pipe racks were not analyzed before or after experiments. Only filtered water was run through the copper pipe racks for a month at the beginning of the study. The copper pipe racks were not cleaned with an acid. However since the copper pipe racks that used chloramines as a disinfectant released more lead then chlorine, it is hypothesis that there was a build up of lead oxide. However more experiments would be needed to determine what type of oxide layer has formed on the inside of the copper pipe racks.

Switzer et al., (2006) found that a 0.5µm lead film was almost dissolved by a 1mM NH_2Cl, 4mM $NH^{4+,}$ and 1mM Cl^- solution of chloramines at a pH of 8. That study also found that the same type of lead film was passivated with $HOCl/OCl^-$ (from a sodium hypochlorite solution with 10-13% available chlorine) (Switzer et al., 2006). Those findings were consistent with results from this study in which chloramines released more lead than chlorine.

In an experiment using copper coupons half coated with 50:50 tin:lead solder, free chlorine at a dose of 1.9mg/L over a pH range of 7.2 to 8.4 released more lead than chloramines at a dose of 3.2mg/L over the same pH range (Lin et al., 1997). This is not consistent with this current study where chloramines released more lead than chlorine.

Based on the findings of this study and the works of (Edwards and Dudi, 2004, Switzer et al., 2006, and Renner 2005), if Halifax was to switch from chlorine to chloramines, increased lead release would be expected. However, the water utility in San Francisco switched to chloramines without experiencing high lead levels. This attributed to the replacement of lead service lines in the system, monitoring free chlorine residual before the switch to chloramines and using a high pH in their finished water (Wilczak et al., 2010).

5.2.1 Suspected Nitrification of Pipe Loops

Nitrification is the microbiological process that oxidizes ammonia to nitrite and then to nitrate (Zhang, Y., N. Love, and M. Edwards, 2009). Due to the drastic difference in lead release during the short and long stagnation time, nitrification was suspected. Heterotrophic plate count (HPC) bacteria were measured several times in the study; however none were detected. HPCs are used as an indicator of nitrification (Wolfe et al., 1990). Ammonia, nitrate, nitride and total nitrogen were also measured. Only during the low chloramines treatment with phosphate inhibitor was an increased level of nitrate from the 30min stagnation time to the 24hr stagnation time in the copper pipe rack effluent. Since nitrate levels were higher this could indicate that nitrification was occurring; however there may have been issues with the testing method. There are no results from the high chloramines pipe loops because nitric acid was used to adjust the pH of those pipe loops. Ideally, additional experiments would have daily sampling to ensure that daily water fluctuations were accounted for in the results, measuring the same water that is entering the copper pipe racks immediately before the stagnation period begins. Therefore, nitrification results are inconclusive.

5.3 Current Plant Conditions for Halifax Water

To test lead in drinking water the protocol for Health Canada is to take a 1L first drawn sample after a stagnation time for over 6 hours (Health Canada 2009). With the pilot scale experiments, there is a long stagnation time of 23hr and 30min, which is greater than 6 hours and thus meets the requirements for a first drawn sample.

The current plant conditions for the JDKWSP has a pH of 7.3, total chlorine level of 1.0mg/L and a poly/ortho phosphate level of 0.8mg/L. For this thesis, a pipe loop was used to replicate these conditions. Over the course of the experimental timeline, the average pH was 6.9±0.8, total chlorine residual was 1.3±1.4mg/L, and orthophosphate was 1.3mg/L. Due to the trial and error dosage method, the exact value that the JDKWSP was operating at is very difficult to maintain, however the data is reasonably close to actual plant conditions.

From data collected starting in June 2009 to June 2010, the average total lead concentration for the 24hr stagnation time was 12µg/L(median of 0.97µg/L), and for a short stagnation time 2µg/L (median of 0.97µg/L). The limit for lead is 10µg/L. The 24hr stagnation time does exceed this limit; however the 12µg/L is an average and is greatly affected by the extreme values, that did occur throughout the study. When looking at the median, the middle number not affect by the extreme values, it is 0.97µg/L which is well below the limit of 10µg/L.

Similar pilot scale studies were conducted by Maddison et al., 2000; where different corrosion control options were compared for the Halifax regional distribution system. Due to the pilot and full scale data collection, polyphosphate was chosen and is still used by the utility today (Maddison et al., 2000). Through unpublished data of lead testing at Dalhousie University in Halifax, lead limits were within the Health Canada limit of 10µg/L. The pipe loops can be seen as an acceptable pilot scale set up to replicate a full scale system.

Chapter 6.0 Recommendations

In this chapter, the recommendations are proposed to future studies of lead release in premise plumbing. In addition, experimental changes are proposed that would make future pipe loop studies easier.

6.1 Sodium Silicates as a Corrosion Inhibitor

The next steps in this research would be to determine the concentration of sodium silicate needed to reduce lead levels to be below 10μg/L limit. This would require increasing the concentration of sodium silicate until the lead concentration was below the 10μg/L limit.

In this study greater amount of copper release were observed with sodium silicate than with phosphate. Analytical tools such as X-ray diffraction would help identify the chemical changes on the copper pipe surface and help explain the interaction of copper-water and sodium silicates. It is important to determine if increased copper release is a general trend with copper and sodium silicate or if it is just a one-time occurrence observed in this study.

6.2 Chloramines and the Corrosion Control Program

Chloramines are an attractive alternative to chlorine as they form fewer DBPs; however increased lead release is associated with chloramines. Further investigation on how to successfully switch from chlorine to chloramines without increasing lead release would be beneficial to Halifax Water to comply with the EPA's DBP regulations.

To determine the effect of nitrification in the copper pipe racks, additional experiments are needed. This would involve daily sampling of the pipe loops and copper pipe racks to ensure that daily water fluctuations were accounted for in the results. This would require measuring the same water that is entering the copper pipe racks immediately before the stagnation period begins.

6.3 Pipe Loop Operation

To improve the operation of the pipe loops the following changes have been proposed.

- Many times during the study the circulation pump would shut down as it would require cleaning. This caused the pipe loops to be out of commission for a short period of time. Using a smaller circulation pumps would ensure a shorter cleaning time. Also the current circulation pumps are made of iron, which do corrode and contribute to turbidity. A smaller pump made of plastic would be beneficial.
- The lead/tin solder was the only lead source for this study. Other lead sources such as brassfacets and lead service lines would be interesting to compare sodium silicates and phosphates, as corrosion inhibitors.
- The trial and error chemical dosage system made maintaining similar conditions such as pH between pipe loops difficult. An automatic dosage and monitoring system would improve the consistency between pipe loops.
- Chloramines for this study were made using a borate buffer. The solution was made the day before, so there was variability in the concentration of chloramines. To mimic full scale plant conditions using ammonia gas would be ideal to produce more consistent chloramines concentrations.

Chapter 7.0 Conclusions

7.1 Sodium Silicates as a Corrosion Inhibitor

In general, the pipe loop with sodium silicate released more lead than the pipe loops with phosphate. The highest amount of lead was observed with high chloramines after a 24hr-stagnation time when sodium silicate was buffered with an acid/base. The lowest amount of lead was seen with chlorine after a 30min stagnation time with the phosphate corrosion inhibitor. More lead was released when sodium silicate was buffered with an acid/base than when it was buffered just with sodium silicate.

In addition, sodium silicates treated copper pipe racks also released more copper than phosphate treated copper pipe racks (most notably with chlorine as a disinfectant).

7.2 Chloramines and the Corrosion Control Program

This study shows that more lead is released with chloramines as a disinfectant than with chlorine. However, chloramines produce less DBPs than chlorine.

7.3 Current Plant Conditions for Halifax Water

The pipe loops in this study have been used in previous experiments in Dr. Gagnon's water research group. Even though there were some challenges in terms of trial and error dosage, the pipe loops are still an effective tool to study the full scale system. The pipe loops that used chlorine as a disinfectant and phosphate as the corrosion inhibitor mimicked the conditions at the JDKWSP and the Halifax distribution system. The lead concentrations of this pipe loop were consistent with unpublished data from full scale sampling at Dalhousie University.

References

ASM Metals Handbook. 1987. Corrosion Vol 13 9th edition 87 – 88

AWWARF. 1996. Internal corrosion of water distribution systems. Second edition. American Water Works Association Research Foundation. Denver CO.

Berthouex P. M. and L.C. Brown. 2002. Statistics for environmental engineers: Second Edition. Lewis Publishers. Boca Raton

Bosich, J.F. 1970. Corrosion prevention for practicing engineering, Barnes & Noble, New York

Camper, A.K. 1996. *Factors limiting microbial growth in distribution systems: laboratory and pilot-scale experiments.* AWWA Research foundation, Denver. Colorado

Cech I., M.H. Smolensky, M. Afshar, G. Broyles, M. Barczyk, K. Burau, and R Emery. 2006. Lead and copper in drinking water fountains – information for physicians. Southern Medical Journal. Vol. 99 (2): pp. 137 – 142

Chiodini, R.A. 1998. The use of sodium silicate for the control of lead and copper. *Journal of the New England Water Works Association.* 112(2) 147 – 152

Churchill D.M., D.S. Mavinic, D. G. Neden, and D.M. MacQuarrie. 2000. The effect of zinc orthophosphate and pH – alkalinity adjustment on metal levels leached into drinking water. Canadian Journal of Civil Engineering. Vol.27 (6): pp 33 – 43

Dart, F. J. and P.D. Foley. 1972. Silicate as Fe, Mn Deposition preventative in distribution systems. *Journal of American Water Works Association.* 64(4) 244 – 249

Davidson, C. M., Peters, N. J., Britton, A., Brady, L., Gardiner, P., & Lewis, B. D. 2004. Surface analysis and depth profiling of corrosion products formed in lead pipes used to supply low alkalinity drinking water. *Water Science and Technology: A Journal of the International Association on Water Pollution Research , 49* (2), 49 - 54.

Droste, R. 1997. *Theory and Practice of Water and Wastewater Treatment*. New Jersey: John Wiley & Sons, Inc.

Dryer, D.J. and G.V. Korshin. 2007. Investigation of the reduction of lead dioxide by nautral organic matter. *Environmental Science and Technology.* 41 (15) 5510 – 5514

Doubrough, J . 2009. A pilot scale examination of lead release in simulated premise plumbing systems. Master's Thesis Dalhousie University

Edwards, M., & Dudi, A. 2004. Role of chlorine and chloramine in corrosion of lead-bearing plumbing materials. *Journal AWWA , 96* (10), 69 - 81.

EPA 1993. Control of lead and copper in drinking water. Seminar publication.

Eisnor, J.D. 2002. Corrosion of cast iron water distribution system pipes: impact on secondary disinfection. Master's thesis Dalhousie University

Eisnor, J.D. and G.A. Gagnon. 2004. Impact of secondary disinfection on corrosion in a model water distribution system. *Journal of Water Supply: Research and Technology – AQUA.* 53 (7) 441 – 452

Gagnon G. A., H. Baribeau, S.O. Rutledge, R.Dumancic, A. Oehmen, C. Chauret, and S. Andrews. 2008. Disinfectant efficacy in distribution systems: a pilot-scale assessment. Journal of Water Supply Research and Technology – AQUA. Vol. 57 (7): pp. 507 – 518

Health Canada 2009 Guidance on controlling corrosion in drinking water distribution systems.

Fabbricino, M., A. Panico, and M. Trifuoggi. 2005. Copper release in drinking water due to internal corrosion of distribution pipes. *Global NEST Journal.* 7 (2) 163 - 171

Johnson, B., R. Yorton, T. Tran, and J. Kim. 1993. Evaluation of corrosion control alternatives to meet the lead and copper rule for eastern Massachusetts. *Journal New England Water Works Association.*107(1) 24 – 45

Jones, D. 1992. Principles and Prevention of Corrosion. Macmillan Publishing Company. New York, NY.

Lehrman, L. and H.L. Shuldener. 1961. The role of sodium silicate in inhibiting corrosion by film formation on water piping. *Journal American Water Works Association.*43(3) 175 – 188

Lemieux, F., Benard, S., & Schock, M. 2006. Getting the Lead Out at the Tap: Corrosion Control Guidance for Canada. *American Water Works Association WQTC Conference* (pp. 1-7). Quebec: AWWA.

Lin, N.H., A. Torrents, A.P. Davis, and M. Zeinali. 1997. Lead corrosion control from lead, copper-lead solder, and brass coupons in drinking water employing free and combine chlorine. *Journal of Environnemental Science and Health.* 32 (4) 865 - 884

Lin, Y.P. and R.L. Valentine. 2008. The release of lead from the réduction of lead oxide (PbO2) by natural organic matter. *Environnemental Science and Technology.* 42 (3)760 – 765

Lin, Y.-P., & Valentine, R. L. 2008. Release of Pb(II) from Monochloramine-Mediated Reduction of Lead Oxide (PbO_2). *Environemental Science Technology , 42* (42), 9137 - 9143.

Little B.J. and J. S. Lee, 2007. *Microbiologically influenced Corrosion,* Wiley Series in Corrosion, R. W. Revie, series editor, Wiley, New York pg 1

Lytle, D., & Schock, M. R. 2005. Formation of Pb(IV) oxides in chlorinated water. *Journal AWWA , 97* (11), 102 - 113

Lytle, D.A., M.R. Schock, and T.J. Sorg. 1996. Controlling lead corrosion in the drinking water of a building by orthophosphate and silicate treatment. *Journal of New England Water Works Association.* 110(3) 202 – 217

Lytle D.A., and M.R. Schock. 2000. Impact of stagnation time on metal dissolution from plumbing materials in drinking water. Journal of Water Supply : Research and Technology – AQUA 49 (5)

McAnally, A.S.,and S. Kumaraswamy. 1994. Lead and copper corrosion control. *Journal of Environmental Science and Health Part B, Pesticides, Food Contaminants and Agricultural Wastes.* 29(8) 1587 – 1606

MacQuarrie D.M., D.S. Mavinic, and D.G. Neden. 1997. Greater Vancouver Water District drinking water corrosion inhibitor testing. Canadian Journal of Civil Engineering. Vol. 24 (8): pp 34 – 52

Maddison, L.A., G.A. Gagnon, and J.D. Eisnor. 2001.Corrosion control strategies for the Halifax regional distribution system. Canadian Journal of Civil Engineering. Vol. 28: pp. 305 – 313

Merkel, T.H., H.J. Grob, W. Werner, T. Dahike, S. Reicherter, G. Beuchie, and S. H. Eberle. 2002. Copper corrosion by-product release in long-term stagnation experiments. *Water Research.* 36(6) 1547 - 1555

Miranda, M. L., Kim, D., Hull, A. P., Paul, C. J., & Galeano, A. (2007). Changes in Blood Lead Levels Assoicated with Use of Chloramins in Water Treatment Systems. *Environmental Health Perspectives , 115* (2), 221 - 225.

Ontario Ministry of Environment. 2006. Procedure for disinfecting of Drinking water in Ontario. http://www.ontario.ca/drinkingwater/stel01_046942.pdf. Cited May 2010

Pinto, J.A., A. S. McAnally, and J.R. Flora. (1997) Evaluation of Lead and Copper Corrosion control techniques. *Journal of Environmental Science and Health.* A32(1) 31 – 53

Qiang, Z., and C.D. Adams. 2004. Determination of monochloramine formation rate constants with stopped-flow spectrophotometry. Environmental Science & Technology. Vol. 38 (5): 1435 – 1444

Rutledge S. O. 2003. Disinfectant efficacy in distribution systems: a field scale evaluation. Master's thesis.

Renner, R. 2005. Chloramines again linked to lead in drinking water. *Environmental Science & Technology , 39* (15), 314A.

Renner, R. 2008.. Fertilizer phosphate demands could corrode water safety. *Environ. Sci. Technol.*

Renner, R. 2004. Plumbing the depths of the D.C.'s drinking water crisis. *Environ. Sci. Technol. , 38* (12), 224A - 227A.

Revie, R. W., and H. H. Uhlig. 2008. Corrosion and Corrosion Control: An introduction to corrosion science and engineering. Wiley 4th edition

Roberge, P. R. 2008. Corrosion Engineering: Principles and Practice. McGraw-Hill Company US pg 35

Robinson, R.B., G. D. Reed, and B. Frazier. 1992. Iron and Manganese sequestration facilities using sodium silicate. *Journal of American Water Works Assoication.* 84 (2) 77 – 82

Sastri, V.S., Ghali, E., and M. Elboujdaini. 2007. Corrosion prevention and protection practical solutions. Wiley

Sand, W., 2002. Microbial Corrosion in Corrosion and Environmental Degradation , M. Schutze, Wiley VCH Weinheim pp 172 – 121

Schock, M.R. 1990. Causes of temporal variability of lead in domestic plumbing systems. *Environmental Monitoring and assessment.* 15 91) 59 - 82

Schock, M., Lytle, D., Sandvig, A., Clement, J., & Harmon, S. 2005. Replacing polyphosphate with silicate to solve lead, copper, and source water iron problems. *Journal AWWA , 97* (11), 84-93.

Stott J.F. 2003. Evaluating microbioligcally influenced corrosion in ASM handbook Vol. 13A Corrosion Fundamental Testing and protection ASM International Materials Park OH, 2003 P 645

Switzer, J.A., V.V. Rajasekharn, S. Boonsalee, E.A. Kulp, and E.W. Bohannan. Evidence that Monochloramine disinfection could lead to elevated Pb levels in drinking water. *Environmental Science & Technology,* 40 (10) 3384 – 3387

Thompson, J.L., B.E. Scheetz, M.R. Schock, D.A. Lytle, and P. J. Delaney (1997) Sodium silicate corrosion inhibitors: issues of effectiveness and mechanism. AWWA Water Quality Technology Conference Denvor CO

Uchida, M. and A. Okuwaki. 1998. Decomposition of nitrate by in stiu buff abrasion of lead plate. *Hydrometallurgy.* 49 297 – 308

Volk, C., E. Dundore, J. Schiermann and M. Lechevallier. 2000. Practival eveluation of iron corrosion control in a drinking water distribution system.*Water Research.* 34 (6) 1967 – 1974

Watson, S.W., F.W. Valos, and J.B. Waterbury. 1981. the Familty Nitrobacteraceae. *The Prokaryotes,* Spring-Verlag, Berlin

Watt, G., Britton, A., Gilmour, H., Moore, M., Murray, G., Robertson, S., et al.,. 1996. Is lead in tap water still a public health problem? An observational sutdy in Glasgow. *BMJ , 313*, 979-981.

Wilczak, A., J.G. Jacangelo, J.P. Marcinko, L.H. Odell, G.J. Kirmeyer, & R.L. Wolfe. 1996. Occurrence of nitrification in chloraminated distribution systems. *American Water Works Association,* 88 (7) 74 – 85

Wolfe, R.L., N.I Lieu, G. Izaguirre, and E.G. Means 1990. Ammonia-oxidizing bacteria in a chloraminated distribution system: seasonal occurrence, distribution, and disinfection resistance. *Applired and Environmental Microbiology*, 56(2), 451 – 462

Yannoi, C.C., and Covellone, M.A. 1998. Pipe loop demonstration study of corrosion control alternatives at a pH of 10.*Journal of New England Water Works*, 112(22) 132 - 146

Zhang, Y., S. Triantafyllidou, and M. Edwards 2008a. Effect of nitrification and GAC filtration on copper and lead leaching in home plumbing systems. *Journal of Environmental Engineering,* 134 (7) 521 - 530

Zhang, Y., A. Griffin, and M. Edwards. 2008b. Nitrification in premise plumbing: role of phosphate, pH and pipe corrosion. *Environmental Science Technology,* 42(12), 4280 – 4284

Zhang, Y., N. Love, and M. Edwards. 2009. Nitrification in Drinking Water Systems. Environmental Science and Technology. Vol. 39 : pp. 183 – 208

Zhang, Y., A. Griffin, M. Rahman, A. Camper, H. Baribeau, and M. Edwards.2009. Lead contamination of potable water due to nitrification. *Environmental Science & Technology.* 43 (6) 1890 – 1895

Zhang, Y., A. Griffin, and M. Edwards. 2010. Effect of nitrification on corrosion of galvanized iron, copper, and concrete. *American Water Works Association Journal.* 102 (4) 83

APPENDIX A – Filtered Water Data

Table A.1 Raw data pertaining to the filtered water at the J D Kline Water Supply Plant (JDKWSP) that was then chemical treated specifically for each pipe loop. Data is presented in chronological order.

Date	pH	ORP (mV)	DO (mg/L)	Temp (°C)	Total Chlorine (mg/L)	Free Chlorine (mg/L)	Turbidity (NTU)	Silica (mg/L)	ALK (mg/L)	Phosphate (mg/)
02-Jul	5.59	581	5.7	17.9	0.09	0.02	0.122	2.3		0.05
06-Jul	5.93	366	5.1	19.1	0.04	0.04	0.269	1.7		0.04
09-Jul	6.1	341	5.1	18.5	0.1	0.03	0.165	0		0.09
13-Jul	5.71	415	5.6	19.5	0.09	0.03	0.155	-0.9	5.3	0.06
16-Jul	5.73	444	5	19.9	0.1	0.06	0.139	0.7		0.08
20-Jul	5.64	401	4.6	19.7	0.09	0.02	0.096	0.9		0.09
23-Jul	7.25	632	5.2	19.9	0.11	0.02	0.127	3.4		0.24
27-Jul	5.5	401	4.5	20.5	0.08	0.03	0.132	2.6		0.14
30-Jul	5.5	572		21.3	0.05	0.03	0.101	2		0.02
03-Aug	5.7	409		21.4	0.07	0.05	0.129	2.8		-0.02
06-Aug	5.57	381	6.6	21.8	0.11	0.09	0.092	1.4	7	0.11
10-Aug	5.45		7.3	22.1	0.08	0.05	0.103	-0.7		0.07
14-Aug	5.87	379	6.9	22.2	0.09	0.04	0.112	3.2		0.08
17-Aug	5.58	381	10.6	22.4	0.09	0.06	0.13	2.2		0.01
20-Aug	6.56	467	11.2	23.7	0.08	0.05	0.177	1.7		0.02
24-Aug	5.64	403	6	22.5	0.11	0.04	0.114	0.5	8.7	0.09
27-Aug	5.48	366	5.9	20.9	0.09	0.08	0.117	-1.2		0.06
31-Aug	6.92	399	11.9		0.09	0.05	1.25	0.2		0.11
03-Sep	5.63	399	11.8	18.8	0.02	0.02	0.117	1.3		0.01
14-Sep	5.3	404	6.6	18.2	0.06	0.03	0.389	11		0.05
17-Sep	5.8	407	7	18.2	0.04	0.02	0.101	2		0.11
21-Sep	5.31	395	6.3	17.6	0.06	0.03	0.318	1		0.08
24-Sep	5.32	413	7.4	17.1	0.04	0.02	0.416	2		0.08
28-Sep	5.56	412	7.1	16.6	0.03	0.03	0.091	2		0.06
01-Oct	5.4	388	7	16.2	0.05	0.04	0.13	2		0.03
05-Oct	5.37	356	7.3	15.4	0.05	0.02	0.374	1		0.09
08-Oct	5.41	399	7.7	14.7	0.05	0.02	0.09	2		0.04
12-Oct	5.79	382	7.4	13	0.06	0.02	0.097	2		0.09
15-Oct	5.31	404	7.8	13.9	0.05	0.02	0.344			0.05
19-Oct	5.35	419	7.4	13.7	0.08	0.05	0	2		0.09
22-Oct	5.48	402	7.9	12.4	0.04	0.02	0.139	1		0.22
29-Oct	5.58	4.05	7.9	12	0.07	0.03	0.12			0.05
02-Nov	5.28	420	8	11.2	0.08	0.02	0.038	2		0.11
05-Nov	5.9	412		11.2	0.08	0.03	0.146	2		-0.01
09-Nov	5.3	407		10.8	0.04	0.04	n/a			0.01
12-Nov	5.3	391		10.1	0.04	0.02	0.163	2		0.1
16-Nov	5.42	401		10.1	0.06	0.03	0.77			0
19-Nov	5.25	416		9.9	0.03	0.02	0.533	2		0
23-Nov	5.34			9.9	0.04	0.02	1.03	4		0

Table A.1 continued Raw data pertaining to the filtered water at the J D Kline Water Supply Plant (JDKWSP) that was then chemical treated specifically for each pipe loop. Data is presented in chronological order.

Date	pH	ORP (mV)	DO (mg/L)	Temp (C)	Total Chlorine (mg/L)	Free Chlorine (mg/L)	Turbidity (NTU)	Silica (mg/L)	ALK (mg/L)	Phosphate (mg/)
26-Nov	5.24			9.6	0.03	0.03	0.143	2		0
30-Nov	5.34			10			0.158			
03-Dec	5.34			8.8	0.05	0.02	0.163			
07-Dec	5.49			9	0.04	0.04	0.04			
09-Dec	8				0.06	0.02	0.02			
01-Feb	6.92	430		4.8	0.06	0.02	0.261			
04-Feb	7.93	395		9.9	0.05	0.05	0.042			
08-Feb	6.38	396		10.4	0.04	0.02	1.079	1.9	9.8	
11-Feb	6.71	491		5.3	0.06	0.02	0.193			
15-Feb	4.78	328		11.2	0.04	0	0.601			0
18-Feb	5.8	598	10.7	4.8	0.04	0.03	0.709			0.14
22-Feb	5.63	367	11.4	5.8	0.07	0.06	0.333			0.069
25-Feb	7.17	565	12.4	5.5	0.01	0	0.378		4.3	0.345
01-Mar	5.22	366	10.8	6.3	0.05	0.05	1.653		4.6	0.3
04-Mar	5.41	359	10.6	6.4	0.02	0.02	0.417			0
08-Mar	5.97	390	10.2	6.8	0.03	0.02	0.413			0
11-Mar	5.99	370	10.4	7.1	0.06	0.02	0.181			0
15-Mar	5.44	463	10.1	7.1	0.03	0.03	0.558			0.036
18-Mar	5.39	358	10.5	7.1	0.02	0.02	0.082			0.063
22-Mar	5.56	328	10.3	7.8	0.03	0.02	0.534			0
25-Mar	6.73	293	10.9	7.3	0.03	0.03	0.062			0
29-Mar	5.27	449	11	8.7	0.03	0.03	0.828		1.6	0.087
01-Apr	5.8	335	10.5	8.3	0.04	0.03	0.141			0.091
05-Apr	6.12	310	10.8	7.4	0.03	0.03	0.148	2.2		0.11
09-Apr	5.48	360	11	11.1	0.02	0.02	-0.04	2.2		0
12-Apr	5.43	408	10.2	8.4	0.05	0.03	0.311	2.1		0.028
15-Apr	5.91	392	10.5	9.2	0.04	0.03	0.061			0
19-Apr	5.15	651	10	9.9	0.04	0.01	0.135			0
22-Apr	5.38	436	10.5	9.7	0.04	0.01	0.313	2.3	1	0
26-Apr	5.34	381	11	11.7	0.06	0.05	0.109	2.1		
29-Apr	5.52	407	9.7		0.08	0.06			2.7	
10-May	5.16			13	0.03	0.01				
17-May	5.43			20.9	0.02	0.01				
25-May	5.48			17.8	-			2.1		
31-May	5.43			18.4	0.03	0		2		
07-Jun	5.45			18.3	0.02	0		-		
14-Jun	5.23			17.1	0.5	0.3		2.1		
21-Jun	5.02			20.8	0.04	0.02		2		
28-Jun	5.62			19.7	0	0				

APPENDIX B – Sodium Silicate Data

Tables presented in this section are the raw data pertaining to the pipe loops that used sodium silicate as a corrosion inhibitor. Data is presented in chronological order from which it was collected. Data is presented first for when the pH was buffered with an acid/base and then when it was buffered with just sodium silicate. For each section the data is presented first for the influent and effluent of the pipe loops then for the long and short stagnation time.

Buffered with Acid/Base

Corrosion Rate (mil/year)

Table B.1 Raw data displaying corrosion rate value for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with an acid/base.

Date	High Chloramines	Low Chloramines	Chlorine
16-Jul		1.97	
20-Jul		4.62	
23-Jul		5.05	
27-Jul		4.43	
30-Jul		2.36	
03-Aug		1.98	2.08
06-Aug		1.74	1.98
10-Aug	2.52	2.48	9.69
14-Aug	4.5	2.39	3.68
17-Aug	5.47	2.03	2.8
20-Aug	3.63	2.79	2.85
24-Aug	9.2	1.75	2.65
27-Aug	4.74	1.6	2.97
31-Aug	2.59	2.55	2.42
03-Sep	3.67	2.17	1.93
14-Sep	2.2	1.35	2.32
17-Sep	5.09	2.33	1.82
21-Sep	2.02	2.32	2.28
24-Sep	7.93	2.39	1.5
28-Sep	2.83	1.59	3.86
01-Oct	3.98	2.46	4.5
05-Oct	2.36	1.98	2.66
08-Oct	2.04	2.87	2.74
12-Oct	1.48	1.64	2.97
15-Oct	1.49	1.97	2.28
19-Oct	1.14	1.43	2.37
22-Oct	2.12	1.41	2.98
26-Oct	1.31	1.52	2.5
29-Oct	1.59	1.62	2.93
02-Nov	2.3	1.62	2.28
05-Nov	1.94	1.6	1.76
09-Nov	2.03	1.2	1.56
12-Nov	3.01	1.71	1.93
16-Nov	1.6	2.31	2

Table B.1 continued Raw data displaying corrosion rate value for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with an acid/base.

Date	**High Chloramines**	**Low Chloramines**	**Chlorine**
19-Nov	2.06	4	2.56
23-Nov	2.23	4.3	1.63
26-Nov	2.03	3.21	1.88
30-Nov	1.51	2.59	2.4
03-Dec	2.28	2.96	4.28
07-Dec	2.36	2.44	1.82
09-Dec	2.25	3.55	3.26

pH

Table B.2 Raw data showing the pH values for the influent and effluent of the pipe loops using sodium silicate as a corrosion inhibitor that was buffered by an acid/base.

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	6.62	9.25	6.6	6.35	8.49	6.71
06-Jul	6.57	7.11	6.7	6.71	7.78	6.29
09-Jul	9.14	9.35	7.17	9.05	8.86	7.9
13-Jul	8.65	8.48	7.28	8.67	7.4	7.4
16-Jul	8.6	8.39	9.01	6.01	7.68	9.12
20-Jul	8.22	7.09	6.73	8.53	7.91	7.39
23-Jul	8.69	8.31	7.95	8.7	7.6	9.22
27-Jul	8.34	6.28	6.46	7.82	7.61	9.4
30-Jul	5.87	8.23		8.87	9.66	
03-Aug	6.37	9.97	6.14	7.03	7.98	6.71
06-Aug	7.46	9.07	6.64	7.61	8.31	6.77
10-Aug	6.1	7.43	6.43	6.07	6.84	6.68
14-Aug	4.7	8.59	6.38	6.42	7.88	6.16
17-Aug	8.63		6.06	8.52		6.21
20-Aug	8.45	8.06	7.69	8.43	6.99	6.78
24-Aug	6.04	6.94	6.06	6.25	6.89	6.66
27-Aug	7.45	6.79	7.45	7.32	7.79	8.23
31-Aug		6.65	9.09	7.2	7.62	8.64
03-Sep		8.43	7.52		8.03	7.21
14-Sep				8.01	6.92	7.61
17-Sep	6.1	7.5	6.12	6.5	7.24	6.44
21-Sep	3.15	8.3	9.12	5.32	7.31	7.42
24-Sep	3.45	8.31	7.16	4.72	7.69	7.1
28-Sep	6.03	8.37	6.89	7.6	6.69	6.77
01-Oct	8.32	8.73	7.43	7	7.29	6.68
05-Oct	8.71	6.91	6.89	8.51	6.8	6.22
08-Oct	8.49	8.42	7.65	8.45	7.84	7.6
12-Oct				6.91	7.15	6.6
15-Oct	8.65	8.76	6.88	8.7	7.89	6.56
19-Oct				8.17	6.81	
22-Oct				8.7	7.71	
29-Oct	5.65	6.33	6.94	6.1	6.09	6.83
02-Nov	3.96	5.94	5.89		7.09	7.25
05-Nov	8.7	8.41	6.72	8.53	7.72	7.05
09-Nov	7.24	6.64	5.98	7.42	7.37	6.67
12-Nov	8.7	8.25	6.51	7.02	7.23	6.87
16-Nov				6	6.44	6.7
19-Nov	6.16	8.38	7.04	6.82	7.51	7.56
23-Nov				7.6	7.02	6.27
26-Nov				8.23	9.04	6.64
30-Nov				6.19	7.01	
03-Dec	8.59	8.23		6.55	7.33	
07-Dec				8.46	7.62	6.5
09-Dec	6.8	7.2	6.7	5.3	7.2	5.6

Oxidation Reduction Potential (ORP) (mV)

Table B.3 Raw data displaying the ORP values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	622	444	808	402	424	698
06-Jul	547	581	832	422	540	790
09-Jul	420	507	788	430	470	723
13-Jul	450	434	483	429	485	700
16-Jul	490	484	529	350	540	533
20-Jul	426	763	624	398	479	633
23-Jul	410	420	673	396	464	385
27-Jul	437	624	775	391	471	491
30-Jul	388	302		342	443	
03-Aug	544	315	485	448	438	430
06-Aug	769	370	732	470	395	482
10-Aug	558	485	766	469	464	749
14-Aug	678	436	757	535	474	730
17-Aug	441		756	437		723
20-Aug	432	462	714	452	421	688
24-Aug	610	526	764	575	530	701
27-Aug	481	519	587	532	478	580
31-Aug						
03-Sep		514	757		439	657
14-Sep				420	454	560
17-Sep	643	498	799	523	570	760
21-Sep	692	500	554	495	527	698
28-Sep	680	534	664	402	450	486
01-Oct	782	435	772	462	416	768
05-Oct	399	513	447	441	524	717
08-Oct	492	456	774	412	479	755
12-Oct				657	449	737
15-Oct	516	450	756	388	451	751
19-Oct				422	450	
22-Oct				408	447	
26-Oct				382	424	467
29-Oct	515	547	738	602	525	712
02-Nov					606	730
05-Nov	346	399	750	604	545	757
09-Nov	368	438	789	661	605	707
12-Nov	353	426	752	589	500	645
16-Nov				362	337	664
19-Nov	394	372	728	649	522	580
23-Nov				378	435	821
26-Nov				341	378	516
30-Nov				363	377	
03-Dec	339	403		692	549	
07-Dec				340	437	722
09-Dec	345	405	710	232	514	480

Dissolved Oxygen (mg/L)

Table B.4 Raw data displaying the dissolved oxygen values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	6.9	6.6	8	7.3	6.6	6.7
06-Jul	7.5	8.2	8	7.5	7.6	7
09-Jul	6.9	6.5	7.3	6.2	6.5	6.4
13-Jul	6.8	7.2	6.9	6.5	6.6	6.7
16-Jul	7.3	7.4	7.3	6.8	7	7.5
20-Jul	8.4	7.9	7.9	7.6	7.1	7.4
23-Jul	6.2	5.9	6.2	5.6	5.8	5.5
27-Jul	5.6	6.7	6.3	6.9	6.3	6.3
30-Jul	6.2	6.1		7	6.5	
03-Aug	5.8	5.8	5.9	6.8	6.4	6.5
06-Aug	5.2	5.4	5.7	5.9	5.2	5.8
10-Aug	5.2	5.8	5.3	5.5	5.3	5.6
14-Aug	5.1	4.8	5.4	5.2	5.1	5.2
17-Aug	6.1		5	6.6		7
20-Aug	5.1	4.8	4.4	4.8	4.9	5
24-Aug	4.9	4.5	4.6	4.7	4.5	5
27-Aug	5.7	5.3	5.6	5.6	5.5	5.9
31-Aug		4.7	4.8	4.5	5.6	4.6
03-Sep						
14-Sep						
17-Sep	6.6	7.1	6.8	6.3	6.1	6.4
21-Sep	10.3	9.9	10.5	7.4	7.5	7.6
24-Sep	6	6.7	6.7	5.8	6.3	6.5
28-Sep	10	9.9	9.1	10.8	9.2	9.7
01-Oct	10.7	10.7	12.1	11.1	10.7	10
05-Oct	5.6	5.8	5.7	4.7	5.4	5.5
08-Oct	5.7	5.3	5.5	6.3	5.5	5.4
12-Oct				11	11.9	10.6
15-Oct	11.8	10.1	12.2	12.6	11.7	11.3
19-Oct				6	6.5	
22-Oct				6.7	5.9	
26-Oct				5.6	5.5	6.4
05-Nov	7.7	6.9	7.4	7	7	6
09-Nov	7.5	6.2	7.4	62	5.3	6.9
12-Nov	7.7	7.4	7.2	5.7	5.5	6.6
16-Nov				5.8	4.8	6.7
19-Nov	7.8	6.2	7.3	7.1	5.5	6.8
23-Nov				5.7	6.5	7.4
26-Nov				7.2	6.3	7.4
30-Nov				7.1	5.8	
03-Dec	7.3	7.7		6.9	4.9	
07-Dec				5.2	6.8	6.2
09-Dec	6.8	7.2	6.7	5.3	7.2	5.6

Temperature(°C)

Table B.5 Raw data displaying the temperature values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	18.2	19	18.5	22.3	22.2	22.9
06-Jul	18.3	18.6	18.3	22.8	22.4	22.9
09-Jul	19	19	18.8	23.3	22.6	23.3
13-Jul	18.8	19.4	19.1	23.5	22.1	23.7
16-Jul	19.8	19.9	19.5	23.9	24	23.1
20-Jul	20.2	20.1	20.1	24.2	23.4	24.2
23-Jul	19.9	20.6	20	24.2	23.2	23.2
27-Jul	20.1	20.7	20.2	24.4	23.9	24.9
30-Jul	20.6	21		24.4	24	
03-Aug	21.5	21.6	21.5	25.4	25.6	25.7
06-Aug	21.7	21.6	21.8	24.9	26	25.6
10-Aug	21.8	21.8	21.6	25.7	25.7	22
14-Aug	21.9	22.2	22.5	25.8	25.4	26.2
17-Aug	22.2		22.4	26		25.8
20-Aug	22.4	22.6	22.3	27	26.2	27
24-Aug	23.1	23.3	23.3	25.5	26.6	26.8
27-Aug	22.4	22.6	22.7	27	26.2	26.5
31-Aug		21	21.3	26.3	21.5	25.7
03-Sep						
17-Sep	19	19.1	19.3	23.7	23.3	23.9
21-Sep	18.3	18.7	18.9	23.3	22.6	23.5
24-Sep	18.7	18.6	18.9	23.7	22.8	23.2
28-Sep	18.1	18.2	18.5	22.2	22	22.8
01-Oct	18.1	18.1	18.3	23	21.9	22.7
05-Oct	17.4	17.5	17.5	22	21.8	22.7
08-Oct	17.6	17.1	17.2	21.4	21.5	21.5
12-Oct				21.3	19.8	21.3
15-Oct	16.2	15.9	15.7	20	19.8	20.9
18-Oct				20.4	18.5	
22-Oct				19.3	19.7	
26-Oct				20.8	20	20.3
29-Oct	14.3	14	13.8	19.9	18.8	19.7
02-Nov					18.8	19.4
05-Nov	13	13.6	13.5	18.2	17.6	17.7
09-Nov	12.5	12.7	12.9	17.2	17.5	18.6
12-Nov	12.6	12.8	12.8	17.1	17	18.6
16-Nov	12	12.4	12.6	15.6	16.5	18.7
19-Nov	12	12.4	12.6	15.6	16.5	18.7
23-Nov				17.5	16.9	17.6
26-Nov				16.9	18.5	19
30-Nov				17	18	
03-Dec	12.2	12.1		13.3	15.9	
07-Dec				17.8	16.5	17.7
09-Dec	11.3	11.4	11.4	17.4	15.3	17.4

Total Chlorine (mg/L)

Table B.6 Raw data displaying the total chlorine values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	0.2	13	6.3	0.15	9.5	3.5
06-Jul	0.06	1.3	8	0.4	3.1	4.1
09-Jul	10	0.5	6.3	10.9	11.9	3.2
13-Jul	13.1	5.9	0.08	8.8	2.15	4
16-Jul	15.3	10.8	6	0.04	5.6	1.47
20-Jul	5.4	3.2	0.35	8.1	8.2	0.62
23-Jul	7.5	5.4	1.5	8.2	5.1	0.9
27-Jul	4.1	1.5	2	4	4.8	4.1
30-Jul	9.3	3.5		0.07	6.3	
03-Aug	0.73	0.04	0.06	1.4	3.4	0.3
06-Aug	2.8	1.2	1.3	2.7	3.6	1.1
10-Aug	1.7	2.6	3.1	0.7	0.26	3.6
14-Aug	0.15	9.1	1.62	0.23	13	1.7
17-Aug	14.8		2.8	14.2		1.8
20-Aug	11.7	5.4	2.1	12.4	0.11	0.81
24-Aug	2.1	1.1	2	2.3	1.6	1.5
27-Aug	4.4	2.4	2.5	3.5	4.9	0.85
31-Aug		2.1	4.4	0.08	3.7	3.1
03-Sep		10.4	1.06		10	0.97
14-Sep				3.5	0.4	0.8
17-Sep	2	5.6	1.8	3.5	4.8	0.9
21-Sep	0.2	0.2	8.2	0.3	3.7	3.1
24-Sep	0.05	14.4	0.49	0.02	10.1	0.08
28-Sep	0.04	8	0.22	2.2	1.3	0.05
01-Oct	10.8	5.3	9.8	1.9	3.5	4.5
05-Oct	10.8	0.04	0.3	9.9	2.7	0.7
08-Oct	12.9	6.1	5.7	11.6	4.9	3.4
12-Oct				1.3	3.3	1.1
15-Oct	8	6	1.11	15.9	5.8	0.82
19-Oct				3.2	3.5	
22-Oct				13.9	4.7	
26-Oct				6	2.4	0.06
29-Oct	11.6	3.5	5.8	8.9	2.8	5.3
02-Nov	0.04	1	0.11		2.6	2.8
05-Nov	8.7	3.1	1.8	9.5	3.5	2
09-Nov	4.6	1.6	1.85	5.4	1.8	1.08
12-Nov	10.8	6.5	1.7	3.6	4.2	1
16-Nov				0.08	1.57	1.14
19-Nov	1.51	6.4	2.3	2.5	5.1	1.62
23-Nov				4.5	2.3	3.2
26-Nov				7.6	12.1	0.24
30-Nov						
03-Dec	13.1	6.8		2.17	5.9	
07-Dec				7	2.9	0.5
09-Dec	9.6	5.5	0.9	8.9	5.4	0.26

Free Chlorine (mg/L)

Table B.7 Raw data displaying the free chlorine values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	0.02	1.1	6.2	0.14	8.3	3.5
06-Jul	0.02	0.81	8	0.02	3.1	3.9
09-Jul	9.8	0.05	5.5	9.2	11.9	3.21
13-Jul	1.3	0.12	3.3	3.7	0.8	0.06
16-Jul	2.9	0.11	1.3	0.01	2.9	1.36
20-Jul	4.5	1.9	0.21	1.5	7.8	0.52
23-Jul	1.8	5.1	1.2	2.9	1.8	0.08
27-Jul	0.8	0.6	1.6	0.3	0.2	3.8
30-Jul	4.5	0.6		0.05	0.12	
03-Aug	0.69	0.03	0.03	0.7	2.8	0.02
06-Aug	2.4	0.7	0.8	0.6	1.3	0.08
10-Aug	1.3	1.3	3	0.15	0.1	2.1
14-Aug	0.06	4.2	1.46	0.06	4.8	0.93
17-Aug	1.2		2.6	3.4		0.69
20-Aug	10.3	4.3	1.8	0.34	0.08	0.75
24-Aug	0.9	0.12	1.9	1	1.1	1.2
27-Aug	2.9	1.2	1.8	1.1	1.6	0.67
31-Aug		1.9	3.7	0.05	3.3	2.6
03-Sep		5.8	0.91		2.7	0.88
14-Sep				3.5	0.3	0.7
17-Sep	2.4	4.8	1.7	3.3	4.7	0.9
21-Sep	0.03	0.17	8.1	0.2	3.4	2.8
24-Sep	0.02	13	0.42	0.02	6.3	0.04
28-Sep	0.03	7.4	0.21	1.8	1.1	0.03
01-Oct	9.7	5.1	8.1	1	0.24	4.3
05-Oct	10.6	0.05	0.2	7.9	2.2	0.2
08-Oct	10.3	6	5.4	8.5	4.8	3.2
12-Oct				1.3	3.1	1
15-Oct	10.3	5.5	0.73	10.3	5.5	0.73
19-Oct				0.13	0.21	
22-Oct				0.34	0.9	
26-Oct				2.2	0.09	0.03
29-Oct	0.24	1.3	4.7	3.4	0.65	3.9
02-Nov	0.02	0.88	0.1		0.09	1.3
05-Nov	3	1	1.55	2.6	2.2	1.84
09-Nov	2	0.08	1.71	1.8	0.7	1.09
12-Nov	6	2	1.6	2.2	1.07	0.92
16-Nov				0.08	1.54	1.19
19-Nov	1.01	0.12	2.09	0.21	1.8	1.57
23-Nov				1.49	1.36	3.1
26-Nov				7.2	10.6	0.02
30-Nov						
03-Dec	12.9	6.4		2.16	1.4	
07-Dec				6.6	3	4
09-Dec	9.6	4.6	0.7	7.4	3.6	0.24

Turbidity (NTU)

Table B.8 Raw data displaying the turbidity values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	0.12	0.435	0.294	0.115	1.991	0.629
06-Jul	-0.038	-0.026	0.003	0.014	0.038	0.101
09-Jul	0.228	0.11	0.26	0.256	0.225	0.233
13-Jul	0.337	0.104	0.266	0.115	0.096	0.324
16-Jul	0.081	0.101	0.195	0.06	0.336	0.216
20-Jul	0.112	0.257	0.365	0.084	0.101	0.489
23-Jul	0.049	0.103	0.119	0.058	0.249	1.185
27-Jul	0.263	0.253	0.158	0.08	0.502	0.977
30-Jul	0.148	0.187		0.212	0.153	
03-Aug	0.12	0.19	0.237	0.072	0.246	0.247
06-Aug	0.112	0.067	0.404	0.076	0.165	0.124
10-Aug	0.282	0.065	0.594	0.017	0.125	3.609
14-Aug				0.219	0.381	0.06
17-Aug	0.821		0.175	0.067		0.086
20-Aug	0.056	0.238	0.102	0.289	0.17	0.027
24-Aug	0.653	0.181	0.367	0.233	0.185	1.448
27-Aug	0.196	0.128	0.302	0.087	0.008	0.477
31-Aug		0.08	0.368	0.103	0.41	0.048
03-Sep		0.097	0.323		0.042	0.073
14-Sep				0.066	0.287	0.045
17-Sep	0.234	0.11	0.118	0.065	0.132	0.165
21-Sep	0.122	0.052	0.197	0.086	0.235	0.069
24-Sep	0.408	0.361	0.15	1.458	0.275	0.157
28-Sep	0.308	0.118	0.527	0.31	0.134	0.868
01-Oct	0.242	0.285	0.376	1.31	0.072	0.385
05-Oct	0.228	0.09	0.295	0.129	0.361	0.338
08-Oct	0.36	0.326	0.263	0.243	0.299	0.355
12-Oct				0.096	0.13	0.141
15-Oct	0.309	0.323	0.079	0.28	0.641	0.34
19-Oct				0.205	0.375	
22-Oct				0.243	0.214	
26-Oct				0.114	0.276	0.38
29-Oct	0.059	0.074	0.47	0.147	0.326	0.319
02-Nov	0.459	0.258	0.423		0.185	0.476
05-Nov	0.187	0.015	0.529	1.585	0.106	0.074
09-Nov						
12-Nov	0.11	0.183	0.168	0.46	0.268	0.533
16-Nov				0.039	0.079	0.413
19-Nov	0.345	0.068	0.317	0.62	0.529	0.338
23-Nov				0.252	1.389	0.195
26-Nov				0.468	0.445	0.034
30-Nov				0.493	0.189	
03-Dec	0.356	0.074		1.77	0.338	

Sodium Silicate(mg/L)

Table B.9 Raw data displaying the sodium silicate values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul				2.2	1.6	2.4
06-Jul	15.5	19.1	1.9	17.9	16.2	4.5
09-Jul	12.8	61.9	15.6	15.5	49.5	25.2
13-Jul	-1.5	13.4	7.6	25.8	2.5	9.8
16-Jul	10	7.8	8.1	10.2	28.5	10.9
20-Jul	5.9	4.9	16.3	14.8	8.3	25.1
23-Jul	29	2.9	23.2	52	18.6	83.2
27-Jul	1.3	1.7	4	6	1.5	89.9
30-Jul	24.7	110 (Over)		3.9	2.6	
03-Aug	10.5	110 (Over)	6.2	29.5	54.2	13
06-Aug	17.5	55.8	4.9	15.5	64.7	14.9
10-Aug	13.4	5.2	3.2	19.5	54.5	15.1
14-Aug				43.8	52.3	19.8
17-Aug	28.5		9	27		15.1
20-Aug	16.4	36.9	10.4	14	3.5	10.3
24-Aug	21.4	4.2	2.2	24	9.8	17.7
27-Aug	22	6.5	17.6	26.9	23.7	18.6
31-Aug		21.5	30.9	5.9	4.2	28.7
03-Sep		28.2	9.9		33.5	23.2
24-Sep				17	23	14
28-Sep				7	18	5
01-Oct						
05-Oct				18	15	22
08-Oct				20	28	20
12-Oct					16	
15-Oct						
19-Oct						
22-Oct	25	24				
26-Oct						
29-Oct						
02-Nov					12	18
05-Nov				15	25	15
09-Nov						
12-Nov				8	13	14
16-Nov						
19-Nov						
23-Nov						
26-Nov				12	3	6
30-Nov				11	10	
03-Dec						

Alkalinity(mg/L)

Table B.10 Raw data displaying the alkalinity values for the influent and effluent of the pipe loops when using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Influent			*Effluent*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
27-May	11.3	33.2	8.1	10.6	35.8	6.3
08-Jun	36	7.8	11.8	31.1	14.2	7.2
13-Jul	40.2	27	14.2	50.3	21.8	21.1
03-Aug	11.7	131		19.6	51.8	19.3
24-Aug	3.5	8.9	9.9	5.7	12.6	20.3
11-Jan	75.7	34.1	12.5	35.4	33.1	14
25-Jan	8.7	54.8	19.7	24.5	131.2	20.1
08-Feb	n/a	n/a	n/a	19.9	29.3	16.9
25-Feb	128.4	31.5	13.9	51.2	47.3	11.2
01-Mar	112.9	25.7	16.2	31.6	15.8	11.1
29-Mar	103	25.4	9.7	36.9	9	12.3
20-Apr	47.6	n/a	14.4	19.3	13	13.4
26-Apr	45.4	38.3	14.1	30.1	18.7	11.7

Copper Pipe Racks

pH

Table B.11 Raw data displaying the pH values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	8.74	8.34	6.54	8.21	8.4	6.55
06-Jul	8.53	8.39	6.36	7.57	8.51	6.64
09-Jul	8.62	7.26	6.75	9.02	7.87	7.23
13-Jul	8.67	8.08	7.85	8.6	7.44	7.39
16-Jul	7.72	7.74	8.19	7.31	7.61	8.51
20-Jul	8.52	8.04	7.36	8.55	7.74	7.04
23-Jul	8.5	7.89	8.19	8.7	7.66	7.69
27-Jul	8.06	7.55	9.18	7.85	7.71	9.29
30-Jul	6.5	8.44		7.26	8.64	
03-Aug	8.88	9.13	8.78	8.71	8.87	8.15
06-Aug	8.05	8.67	6.38	7.74	8.62	6.37
10-Aug	7	6.83	6.28	6.77	6.64	6.6
14-Aug				6.87	7.87	6.18
17-Aug	8.53		6.08	8.57		6.17
20-Aug	8.41	6.84	6.98	8.39	7.24	7.06
24-Aug	7.35	7.32	7.33	6.85	7.15	7.37
27-Aug	7.46	7.85	7.73	7.5	7.93	6.99
31-Aug		7.31	8.4		7.56	8.64
03-Sep		7.66	7.64		8.28	7.05
14-Sep	8.76	7.95	6.92	8.77	735	7.06
17-Sep	7.65	7.34	6.62	7	7.34	6.79
21-Sep	5.09	7.78	8.24	5.44	7.61	7.38
24-Sep	4.58	7.45	7.08	5.12	7.71	7.31
28-Sep	8.13	7.6	7.72	8.26	7.28	6.65
01-Oct	7.91	7.77	7.99	7.61	7.63	7.07
05-Oct	8.24	7.3	6.46	8.48	762	7.14
08-Oct	8.4	7.35	7.04	8.41	7.86	7.15
12-Oct	8.28	7.38	6.13	8.39	7.09	6.37
15-Oct	8.15	7.75	7.61	8.56	7.65	6.12
19-Oct	8.71	7.75	5.65	8.78	7.41	6.41
22-Oct	7.56	7.74	6.67	8.36	7.16	6
29-Oct	7.16	7.03	6.46	6.84	6.79	7.68
02-Nov				6.29		7.31
05-Nov	7.6	7.79	6.41	8.21	7.22	6.52
09-Nov	7.32	7.43	6.64	7.32	7.25	6.38
12-Nov	5.7	7.94	8.3	5.6	7.22	7.12
16-Nov	8.11	7.57	8.3	8.03	6.63	6.7
19-Nov	6.74	7.68	8.96	7.34	7.71	8.86
23-Nov	6	7.24	6.39	6.07	7.1	6.47
26-Nov				7.08	6.87	6.13
30-Nov	8.34	7.8		8.3	7.37	
03-Dec	5.72	8.14		6.23	7.3	
07-Dec	7.98	7.54	6.4	8.37	7.39	6.57
09-Dec	5.3	5.9	5.9	6	5.7	5.9

Oxidation Reduction Potential (ORP) (mV)

Table B.12 Raw data displaying the ORP values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	423	402	464	487	510	771
06-Jul	429	442	550	484	478	798
09-Jul	455	529	550	482	584	682
13-Jul	434	468	502	481	550	688
16-Jul	419	467	465	502	541	570
20-Jul	419	427	467	479	547	612
23-Jul	376	414	432	432	471	714
27-Jul	398	457	515	462	549	532
30-Jul	400	321		418	378	
03-Aug	309	298	302	455	473	574
06-Aug	332	327	398	419	434	716
10-Aug	397	401	438	501	525	711
14-Aug				493	483	668
17-Aug	357		425	441		683
20-Aug	419	522	480	472	454	660
24-Aug	350	347	383	492	472	654
27-Aug	464	495	532	484	524	602
31-Aug						
03-Sep		470	545		519	684
14-Sep	383	338	335	429	513	619
17-Sep	429	475	562	515	550	716
21-Sep	404	509	589	388	613	708
28-Sep	400	474	647	477	601	754
01-Oct	492	582	717	481	559	749
05-Oct	379	509	487	465	492	725
08-Oct	527	588	668	544	622	752
12-Oct	485	524	590	548	672	780
15-Oct	550	635	785	522	646	744
19-Oct	426	405	428	439	453	442
22-Oct	394	390	479	487	511	662
26-Oct	377	357	405	422	431	443
29-Oct	567	629	665	604	653	728
02-Nov				714		676
05-Nov	525	564	608	516	557	692
09-Nov	542	557	680	548	562	707
12-Nov	644	610	576	618	592	598
16-Nov	501	561	578	513	588	558
19-Nov	589	569	558	574	622	515
23-Nov	638	605	687	581	681	772
26-Nov				444	384	405
30-Nov	429	424		405	434	
03-Dec	515	473		594	545	
07-Dec	485	510	575	520	625	710

Dissolved Oxygen (mg/L)

Table B.12 Raw data displaying the dissolved oxygen values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	6.2	6.2	6	6.8	6.5	6.5
06-Jul	7	6.2	6.2	7.3	7.5	7.6
09-Jul	6.3	6.2	5.9	6.5	6.5	6.4
13-Jul	6.2	6.3	5.7	7	6.7	6.5
16-Jul	6	9.9	6.6	7	6.5	5.5
20-Jul	6.9	6.9	7.7	7.5	6.8	7.2
23-Jul	5.3	5.4	5.4	6.5	6.4	6.3
27-Jul	5.1	5	5.5	5.7	5.3	6.5
30-Jul	4.2	5.5		5.9	6.2	
03-Aug	5.7	6.6	5.5	6.2	6.1	5.5
06-Aug	4.4	5.2	5	5.3	5.1	5.4
10-Aug	3.4	4.5	4.2	5	4.8	4.9
14-Aug				5.3	5.5	5.2
17-Aug	5.2		4.1	5.4		6
20-Aug	4.1	4.8	3.3	4.9	5	4.8
24-Aug	3.2	4.2	3.8	4.6	4.6	4.4
27-Aug	4	6	4.9	5.3	5.4	5
31-Aug		4.6	4.3		4.8	4.3
03-Sep						
14-Sep						
17-Sep	5	6.3	5.6	6.8	6.5	6.3
21-Sep	1.5	9.9	8.8	9.5	9.7	9.6
28-Sep	0.6	5.6	5.4	58	6.3	6.1
01-Oct	5.4	9.3	7.4	8.5	9.4	9
05-Oct	9.3	9.8	9.7	9.2	9.4	10.1
08-Oct	5	4.6	4.6	5.5	5.1	5.1
12-Oct	4.9	4.9	5	5.2	5.2	5.3
15-Oct	8.3	9.9	9.1	9.4	10.1	10
19-Oct	9.7	9.6	11.3	11.1	10.3	10.1
22-Oct	5.1	5.1	4.4	5.9	5.2	5.1
26-Oct	5.4	6.5	4.7	5.1	5.4	5.4
29-Oct	5.6	5.2	4.7	5.8	5.3	5.6
02-Nov	5.1	5.6	5.5	6.2	6.7	6
05-Nov	5.6	5.9	5.8	6.5	6.5	6.2
09-Nov	5	5.8	6.1	6.3	5.7	6.1
12-Nov	5.5	5.6	5.6	5.4	5.7	5.8
16-Nov	53	6.2	6.4	5.8	6.4	6.1
19-Nov	5	6.2	5.8	6.2	6.3	5.9
23-Nov				6	5.4	5.9
26-Nov	6	5.8		5.8	6.3	
30-Nov	4.3	5.9		6.3	6	
03-Dec	6.4	6.3	5.8	6.1	6.3	6.2
07-Dec	5.3	5.9	5.9	6	5.7	5.9

Temperature(°C)

Table B.14 Raw data displaying the temperature values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	19.1	19	18.9	19.2	19	19
06-Jul	18.9	19	18.8	19	18.9	19
09-Jul	19	19.2	19.3	19.4	19.2	19.3
13-Jul	19.6	19.2	19.5	19.5	19	19.4
16-Jul	19.9	19.5	19.9	20	19.7	19.8
20-Jul	20.3	20.4	19.6	20.6	20.2	20.2
23-Jul	20.6	20.5	20.6	20.7	20.5	20.2
27-Jul	20.8	20.7	20.8	20.9	20.4	20.7
30-Jul	21.2	21.1		21.3	20.9	
03-Aug	21.8	21.8	21.7	22	21.6	21.7
06-Aug	21.6	21.8	21.7	22	21.9	21.8
10-Aug	22.1	22	21.8	22	21.87	21.5
14-Aug				22.2	22.1	22.3
17-Aug	22.7		22.7	22.6		22.6
20-Aug	22.7	22.2	22.7	22.6	22.5	22.6
24-Aug	23.5	23.4	23.5	23.3	23.1	23.3
27-Aug	22.2	22.3	22.3	22.7	22.5	22.6
31-Aug		21.7	21.7		21.6	21.7
03-Sep						
14-Sep	19.9	19.7	19.6	19.8	19	198
17-Sep	19.3	19.1	19.2	19	19	19.2
21-Sep	19.5	19.3	19	193	19.3	19.4
28-Sep	18.9	18.8	18.9	19	18.9	18.9
01-Oct	18.4	18.6	18.7	18.8	18.8	18.7
05-Oct	18.3	17.6	17.8	18.4	18.3	18.4
08-Oct	17.2	17.9	18.1	18	17.9	18
12-Oct	17.1	16.9	17	17.1	17.1	17.2
15-Oct	17.7	17.6	16.4	17.5	17.4	17.2
19-Oct	16.8	16.3	16.5	16.3	16.3	16.3
22-Oct	17.2	17.2	17.3	16.4	16.6	16.4
26-Oct	17	7	17.4	17	16.9	16.6
29-Oct	17	16.3	16.8	16.3	16.3	16.1
02-Nov				15.7		15.5
05-Nov	16.6	16.1	16.6	16	15.9	15.9
09-Nov	15	14.6	14.7	14.8	14.6	14.5
12-Nov	16	15.6	15.9	15	15.2	15.1
16-Nov	15.7	15.5	14.7	15.4	15.4	15.1
19-Nov	15.7	15.5	14.7	15.4	15.4	15.1
23-Nov	14.3	13.9	14.3	13.9	13.3	13.5
26-Nov				15.1	15.3	15.6
30-Nov	16.5	15.7		15.5	15.4	
03-Dec	16	15.7		14.9	14.7	
07-Dec	14.8	14.6	14.8	14.4	14.3	13.8
09-Dec	15.5	14.9	15.4	14.4	14.5	14.2

Total Chlorine(mg/L)

Table B.15 Raw data displaying the total chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	1.9	0.5	0.3	3.2	6.4	2
06-Jul	0.82	0.05	0.4	0.48	5.6	2.8
09-Jul	3.3	0.4	0.2	3.2	1.7	1.6
13-Jul	3.4	0.45	0.06	13	7.3	2.14
16-Jul	0.04	0.06	0.08	3.7	7.5	2.3
20-Jul	3.8	0.11	0.09	10.5	9.5	0.38
23-Jul	0.09	0.06	0.07	7.8	6.1	0.09
27-Jul	0.6	0.06	0.74	3.8	5.3	5.9
30-Jul	0.09	7.6		0.1	0.05	
03-Aug	1.2	1.6	0.4	5.3	4.8	1.1
06-Aug	0.04	0.72	0.05	3	6.3	2.7
10-Aug	0.04	0.07	0.06	1.4	0.11	0.85
14-Aug				0.62	9.5	1.7
17-Aug	2.11		0.05	12.5		0.24
20-Aug	2.8	0.36	0.07	8.9	1.4	0.2
24-Aug	0.08	0.08	0.08	2.9	0.6	0.4
27-Aug	0.5	0.06	0.14	2.5	4.4	0.37
31-Aug		0.07	0.09		1.48	1.88
03-Sep		0.11	0.06		9.7	0.49
14-Sep	5	0.2	2	7.3	1.17	0.64
17-Sep	0.3	0.3	0.5	2.9	6.5	0.55
21-Sep	0.05	0.4	0.2	0.05	3.8	1.84
28-Sep	0.28	0.04	0.05	0.15	5.4	0.04
01-Oct	0.02	0.04	0.02	4.9	3.1	1.68
05-Oct	0.3	0.04	0.04	1.5	4.1	3
08-Oct	0.01	1.6	0.03	9.4	3.2	0.12
12-Oct	13.3	0.03	0.03	11.2	4.3	3.8
15-Oct	7.5	0.03	0.04	7.9	1.6	1.84
19-Oct	2.1	0.05	1.33	1.42	0.37	0.96
22-Oct	8.6	0.07	0.06	11.6	4.3	0.05
26-Oct	0.4	0.06		10.8	3.3	0.28
29-Oct	0.02	1.31	0.03	5.8	2.8	0.06
02-Nov	0.03	0.05	0.03	6.1	2.6	5.5
05-Nov				2.3		1.8
09-Nov	0.03	1.1	0.03	6.5	3.8	0.8
12-Nov	0.03	0.24	0.02	3.8	3.9	0.64
16-Nov	0.04	0.08	0.2	0.8	4.5	0.71
19-Nov	0.06	0.13	0.03	3.5	3.6	0.92
23-Nov	0.05	0.14	0.55	1.81	4.2	1.48
26-Nov	0.05	0.19	0.04	2.2	3.7	2.4
30-Nov				0.32	0.04	0.04
03-Dec						
07-Dec	0.02	0.29		1.28	4.3	
09-Dec	0.01	0.44	0	6.4	4.6	0.8

Free Chlorine(mg/L)

Table B.16 Raw data displaying the free chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	1.9	0.36	0.02	3.1	5.6	2.6
06-Jul	0.79	0.04	0.02	0.47	5.6	2.4
09-Jul	3.3	0.03	0.02	3.2	1.7	1.6
13-Jul	0.9	0.02	0.05	5.2	3.5	1.96
16-Jul	0.02	0.02	0.02	0.9	1.4	1.9
20-Jul	1.6	0.08	0.05	2.6	2.4	0.33
23-Jul	0.04	0.02	0.04	3.7	5.1	0.05
27-Jul	0.2	0.04	0.66	2.2	4.5	2.7
30-Jul	0.05	3.1		0.06	0.03	
03-Aug	1.1	1.6	0.02	3.6	4.8	1
06-Aug	0.01	0.13	0.04	1.7	3.1	2.2
10-Aug	0.03	0.03	0.04	0.8	0.07	0.77
14-Aug				0.41	6.3	0.67
17-Aug	0.09		0.04	9.1		0.21
20-Aug	2.6	0.28	0.05	4.3	0.12	0.17
24-Aug	0.07	0.05	0.05	1.5	0.15	0.29
27-Aug	0.3	0.04	0.07	0.8	1	0.35
31-Aug		0.04	0.06		0.9	1.77
03-Sep		0.08	0.02		4.5	0.4
14-Sep	4.9	0.02	0.02	6.7	1.14	0.63
17-Sep	0.2	0.2	0.2	2.8	3	49
21-Sep	0.02	0.4	0.2	0.02	3.4	1.61
28-Sep	0.03	0.02	0.03	0.03	4.9	0.03
01-Oct	0.02	0.02	0.01	4.4	2.4	1.65
05-Oct	0.02	0.02	0.02	1.1	3.9	2.9
08-Oct	0.01	1.6	0.02	6.2	3.3	1.1
12-Oct	9.6	0.02	0.03	9.2	4.2	3.8
15-Oct	6.8	0.02	0.03	3	1.6	1.63
19-Oct	1.56	0.02	1.33	1.3	0.2	0.96
22-Oct	0.2	0.03	0.03	6.3	0.7	0.03
26-Oct	0.02	0.03	0.02	0.6	0.4	0.23
29-Oct	0.02	0.02	0.02	0.9	1.9	0.03
02-Nov	0.02	0.02	0.02	0.42	0.24	5.3
05-Nov				0.27		1.6
09-Nov	0.02	0.9	0.02	2.2	0.7	0.76
12-Nov	0.02	0.22	0.02	0.37	2.02	0.61
16-Nov	0.02	0.03	0.05	0.38	2	0.67
19-Nov	0.05	0.07	0.02	3.4	3.3	0.92
23-Nov	0.03	0.11	0.51	0.48	2.1	1.37
26-Nov	0.03	0.17	0.02	0.76	1.6	1.93
30-Nov				0.32	0.03	0.04
03-Dec						
07-Dec	0.01	0.29		1.16	4.3	
09-Dec	0.01	0.37	0	6.3	4.6	0.7

Turbidity (NTU)

Table B.17 Raw data displaying the turbidity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	0.305	0.523	0.356	0.26	0.313	0.475
06-Jul	3.246	0.477	0.072	0.259	0.399	0.022
09-Jul	0.446	0.427	0.223	1.486	0.788	0.346
13-Jul	0.917	0.475	0.122	0.108	0.322	0.172
16-Jul	0.047	0.638	0.152	0.092	0.444	0.163
20-Jul	1.188	0.692	0.636	0.106	0.367	0.632
23-Jul	0.814	0.884	0.278	0.137	0.317	0.763
27-Jul	1.627	2.327	0.287	0.326	0.294	0.37
30-Jul	0.131	0.693		0.075	2.233	
03-Aug	0.564	0.82	0.708	0.069	0.414	0.259
06-Aug	0.114	0.425	0.543	0.041	0.067	0.367
10-Aug	0.134	1.029	0.316	0.136	0.24	0.422
14-Aug				0.405	0.285	0.424
17-Aug	0.56		0.122	0.101		0.081
20-Aug	0.434	0.41	0.034	0.139	0.42	0.149
24-Aug	1.118	1.008	0.088	0.205	0.529	0.091
27-Aug	0.389	0.7	0.229	2.062	0.394	0.208
31-Aug		0.564	0.043		0.139	0.071
03-Sep		0.53	0.079		0.418	0.244
14-Sep	0.266	0.196	2.554	0.08	0.283	0.332
17-Sep	0.144	0.555	0.344	0.408	0.521	0.158
21-Sep	0.638	0.768	0.061		0.206	0.126
24-Sep	6.678	0.47	0.097	1.078	1.208	0.206
28-Sep	1.318	1.118	0.185	2.268	0.319	0.374
01-Oct	0.98	0.661	0.56	1.52	0.483	0.199
05-Oct	1.475	0.359	1.145	0.166	0.373	0.632
08-Oct	0.405	0.299	0.263	0.146	0.234	0.366
12-Oct	0.739	0.5	0.074	0.074	0.275	0.253
15-Oct	0.513	0.262	0.25	0.295	0.538	0.354
19-Oct	3.746	1.026	1.426	1.456	0.422	0.544
22-Oct	1.177	0.446	0.571	0.317	0.151	-0.022
26-Oct	0.534	0.494	0.123	0.742	0.2	0.147
29-Oct	0.68	1.859	0.109	0.319	0.367	0.347
02-Nov				1.047		0.341
05-Nov	1.775	0.566	0.132	0.506	0.482	0.223
09-Nov						
12-Nov	3.006	0.402	0.097	1.256	0.976	0.19
16-Nov	0.9	0.545	0.574	0.646	0.097	0.567
19-Nov	1.706	0.742	0.32	1.296	0.257	0.273
23-Nov	2.739	0.63	0.027	0.521	0.344	0.488
26-Nov				0.761	0.717	0.324
30-Nov	0.473	2.396		0.516	0.25	
03-Dec	3.86	0.083		1.6	0.512	

Sodium Silicate (mg/L)

Table B.18 Raw data displaying the sodium silicate values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			*Short Stagnation*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	2.3	2.7				
06-Jul	14.8	0.4	19.2	15.6	16.9	12.5
09-Jul	2.2	2.4	27.1	2.8	2	
13-Jul	1.1	-1.4	2.1			
16-Jul	10.6	6.5	12.9			
20-Jul	13.2	7.1	24.2			
23-Jul	12	5.3	25.2			
27-Jul	31.3	4.1	89.5			
30-Jul	4.1	96.8		4.1	52.6	
03-Aug	51	Over	64.5	53.1	Over	41
06-Aug	23.7	99.2	29.5	18.1	80	24.4
10-Aug	20.3	7.8	24.6	19.2	5.4	21.9
14-Aug				56.4	59.4	25.5
17-Aug	21.3		16.5	23.8		15.2
20-Aug	16.4	9.3	6.5	19.3	14.9	9.9
24-Aug	22.1	34.8	16.1	25.3	24.9	18.4
27-Aug	21.1	25.4	16.9	24.1	29.2	18
31-Aug		16.2	23.7		9.8	26.4
03-Sep		26.2	27		32.4	27.2
24-Sep	33	18	31	24	15	18
28-Sep	13	14	14	13	15	11
01-Oct	10	15	13			
05-Oct	12	17				
08-Oct	13	23	18			
12-Oct	18	4	16	17	3	16
15-Oct	17	18	13	19	21	13
19-Oct	22	23	3	32	16	4
22-Oct			8	17	19	9
26-Oct	16	27	10			
29-Oct	17	23	18			
02-Nov				12		19
05-Nov	16	20	14			
09-Nov	16	25	15			
12-Nov	12	21	11			
16-Nov	14	12	14			
19-Nov	21	12	19	21	14	14
23-Nov	13	24	9			
26-Nov						
30-Nov	26	28		29	22	
03-Dec	22	16				

Alkalinity (mg/L)

Table B.19 Raw data displaying the alkalinity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
27-May				10.6	19	4.8
08-Jun	27.7	19	2.7	29.4	13.9	10.2
13-Jul	51	59.5	12.3	60	27.3	23.6
03-Aug			35.1	48.6	102.2	28
24-Aug	19.1	25	20.8	13.8	18.3	20
11-Jan	35.8	33.7	14.1	35.5	33	11.9
25-Jan	91.1	65.1	24.2	66.3	68.2	21.1
08-Feb	56.5	29.5	n/a	45.1	29.2	18.5
25-Feb	n/a	49.4	18.1	n/a	36.8	11.9
01-Mar	50.1	25.7	15	47.1	21.5	12.4
29-Mar	52.3	28.4	16	50.1	19.3	10.9
20-Apr	37.8	23.9	15.6	34.8	19.9	15.2
26-Apr	16.1	27.9	16.1	35.5	21.9	11.1
29-Apr	35.4	29.1	10.7	41.9	28.4	11

Total Lead (µg/L)

Table B.20 Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			Shot (30min) Stagnation Time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
02-Jul	69.8	68.34	7.916	10.27	29.61	0.918
	72.24	59.37	12.8	10.93	31.81	0.256
	62.65	62.58	8.458	12.47	31.81	0.54
06-Jul	52.12	66.85	19.04	10.89	32.45	5.397
	55.69	72.8	19.43	11.74	32.53	5.627
	65.91	69.76	17.54	8.935	33.44	6.013
09-Jul	38.01	92.09	30.93	8.023	32.14	3.236
	38.09	93.61	29.93	8.226	34.49	2.56
	32.66	91.04	28.78	7.706	34.35	2.727
13-Jul	89.52	40.81	6.887	7.02	16.83	0.97
	84.43	40.87	7.527	7.067	18.45	0.97
	72.28	39.93	6.63	7.965	18.89	0.97
16-Jul	89.72	92.51	0.97	21.24	62.34	0.97
	92.79	92.71	0.97	19.07	50.68	0.97
	91.91	92.28	0.97	20.53	62.87	0.97
20-Jul	362.8	182.2	2.204	19.44	61.68	1.205
	362.7	213.9	4.333	18.59	48.34	1.749
	363.8	171.1	4.21	16.88	55.27	1.866
23-Jul	193.6	105.3	53.99	18.3	20.85	0.97
	197.8	97.41	54.52	17.33	21.59	0.97
	200.1	109.9	54.63	17.85	18.63	0.97
27-Jul	704.8	1044	12.54	13.46	21.28	4.216
			12.98	14.7	21.39	2.425
			14.77	12.96	21.78	2.608
30-Jul	622	196.58		50.24	1949	
	648.4	196.44		48.63		
	614.2	174.3		47.66		
03-Aug	190.56	764.6	15.83	12.62	18.97	2.999
	218.2	746.8	16.55	10.48	26.47	2.877
	203.4	941.2	16.84	11.08	20.12	3.359
06-Aug	257	201.6	166.9	16.07	8.362	16.9
	315.6	214.2	212.8	17.37	8.865	16.72
	289.4	193.46	168.9	17.62	9.889	16.42
10-Aug	344	190.12	76.17	67.99	36.36	15.72
	362	192.02	74.31	64.87	37.88	16.35
	343.2	180.78	77.66	66.66	39.12	15.6
13-Aug				108	46	20.02
				114.4	45.86	17.76
17-Aug	158.28		42.85	26.09	n/a	12.1
	151.46		48.41	37.21	n/a	16.27
	155.56		43.98	39.61	n/a	15.94
20-Aug	337.4	40.42	87.72	33.54	74.16	0.97
	241.6	42.54	92.48	35.46	70.18	0.97
	356.6	38.74	92.86	32.9	67.24	0.97

Table B.20 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			Shot (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
24-Aug	779.6	24.6	2.729	5.799	4.192	1.397
	727.4	22.68	2.748	5.284	4.161	1.079
	707.4	22.38	2.747	5.693	4.218	1.248
27-Aug	842.6	400.2	31.48	55.47	60	4.108
	701	451.6	29.42	54.56	57.5	5.785
	563	409.4	34.8	55.37	60.46	6.079
31-Aug		287.8	6.875		23.83	2.003
		284.4	9.199		21.62	1.558
		283.8	9.417		19.58	2.477
03-Sep		391.2	9.947		36.18	10.84
		296.4	9.708		34.92	10.61
		279	9.464		37	11.28
14-Sep	759.8	435.2	39.49	21.36	64.62	5.327
	835.2	377	38.12	20.98	59.1	5.029
	823.8	352	36.83	20.68	67.41	5.21
17-Sep	152.54	336.6	37.64	24.78	30.11	9.264
	140.2	338.2	34.58	27.08	30.98	9.846
	137.92	336.8	34.72	27.54	29.71	9.988
21-Sep	3170	239	26.33	309.2	27.79	2.45
	3200	236.8	28.52	282.6	26.76	2.409
	2006	234.2	29.45	292.8	26.81	2.183
24-Sep	2384	213.6	15.7	391.8	33.45	4.349
	2556	297.2	16.21	402.2	31.21	4.287
	2388	225.8	16.09	417	32.93	4.338
28-Sep	243.6	266.8	40.13	17.25	24.36	11.7
	246.2	295	43.47	15.88	25.22	11.76
	235.8	285.8	38.55	16.02	30.7	14.39
01-Oct	205.2	328.6	247.7	26.13	26	19.7
	205.4	331.4	348.1	37.22	24.33	18.75
	194.16	343.4	313.7	41.2	24.73	21.24
05-Oct	284	60.42	84.77	33.75	34.62	7.927
	265.8	100.64	89.95	32.87	32.81	7.895
	285	100.94	87.76	33.08	32.32	7.018
07-Oct	635	334.8	48	16.29	34.86	7.825
	656.2	317.4	56.67	16.81	46.96	8.776
	581.6	320.2	56.16	16.92	46.23	11.26
12-Oct	303.3	192.5	29.73	39.76	50.52	8.634
	313.8	215.3	28.79	37.73	62.23	8.156
	298.1	190.4	29.27	37.73	70.29	8.967
15-Oct	170.98	75.32	6.263	20	23.94	8.029
	166.24	73.14	6.462	21.15	25.72	8.327
	176	78.74	6.505	19.59	27.13	8.452
19-Oct	703.4	119.44	185	29.33	16.42	15.46
	642.4	123.76	190.6	34.11	16.75	15.14
	626.2	122.64	162.9	29.3	16.48	14.3

Table B.20 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			*Short (30min) Stagnation Time*		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
22-Oct	577.6	83.32	199	32.77	28.57	16.24
	425.2	86	193.6	21.61	27.68	15.59
	607.4	119.28	142.1	29.45	28.55	16.12
26-Oct	747.2	173.38	30.13	58.67	20.75	9.015
	744.6	170.04	29.2	52.64	20.27	9.424
	725	172.86	29.91	52.64	26.26	9.535
29-Oct	421.4	368.4	8.783	67.54	17.03	2.219
	439.4	373.4	9.141	67.73	18.83	2.34
	437.4	367.4	8.972	67.51	17.03	2.502
02-Nov				127.9		3.004
				123.2		2.851
				131.5		2.859
05-Nov	416.8	183.1	6.026	30.19	17	4.344
	398.4	182.24	6.171	29.87	22.85	4.735
	398.4	184.3	6.018	30.33	16.53	4.668
09-Nov	733	191.2	8.381	82.51	20.99	6.448
	692.2	176.96	10.6	83.32	19.49	7.954
	697.8	173.74	9.726	82.74	18.61	9.924
12-Nov	807.8	214.2	4.703	450	21.53	2.888
	773.8	194.92	4.694		22.86	2.845
	824.4	183.72	4.648		22.07	2.931
16-Nov	817.6	328.4	44.74	62.92	31.96	2.197
	817.8	337.6	46.12	65.28	30.91	2.046
	840.4	337	53.6	61.5	32.28	2.043
19-Nov	1342	320.8	2.464	72.89	33.89	0.977
	1341	306.4	3.184	62.81	33.11	0.801
	1339	318.6	2.428	71.01	35.72	0.646
23-Nov	1168	405.2	17.12	72.8	21.36	6.2
	1152	385.2	17.49	60.73	29.04	6.496
	849.8	469.4	17.91	67.59	22.02	6.186
03-Dec	1930	481.8		92.14	42.97	
	1965	435		96.19	51.3	
	1924	420.2		100.6	54.19	

Dissolved Lead(μg/L)

Table B.21 Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	17.25	49.07	1.442	0.97	13.56	0.97
	14.73	44.11	5.24	0.97	15.51	0.97
	14.73	43.54	1.664	0.97	15.13	0.97
06-Jul	40.92	52.82	15.82	3.345	19.77	2.254
	30.56	49.33	13.04	3.89	25.2	0.622
	30.87	48.91	11.21	3.845	23.81	1.291
09-Jul	15.91	66.76	24.73	0.748	13.81	2.234
	17.18	66.32	24.16	0.673	13.68	2.379
	17.2	64.53	24.14	0.161	14.86	2.184
13-Jul	45.58	35.45	3.306	3.366	7.038	0.97
	39.12	30.01	3.287	2.798	6.302	0.97
	37.54	29.95	3.144	2.122	6.782	0.97
16-Jul	0.97	24.91	0.97	0.97	0.97	0.97
	0.97	23.75	0.97	0.97	0.97	0.97
	0.97	22.66	0.97	0.97	0.97	0.97
20-Jul	69.83	69.3	0.97	13.78	0.97	2.264
	78.89	75.39	0.97	14.38	0.97	2.12
	73.9	77.37	0.97	16.09	0.97	2.236
23-Jul	68.16	44.26	34.65	9.33	9.33	0.97
	66.49	43.32	30.09	13.16	13.16	0.97
	64.17	46.25	35.11	14.2	14.2	0.97
27-Jul	183.6	477.5	0.97	7.746	17.85	3.456
	177.8		0.97	8.417	18.99	2.264
	168.6		0.97	8.193	17.33	2.195
30-Jul	374.8	156.6		72.39		
	362.8	158.58		75.64		
	374.4	158.18		73.95		
03-Aug	72.24	287.4	8.865	12.01	19.54	1.583
	49.62	479.6	8.048	9.006	16.04	2.243
	65.1	429.6	8.556	9.234	17.25	2.211
06-Aug	97.78	125.3	86.87	11.44	9.59	18.57
	94.46	113.54	101.9	15.07	10.23	18.05
	102.02	11.96	169	10.46	9.548	10.63
10-Aug	196.08	58.2	40.5	51.35	29.6	6.08
	186.08	55.46	38.96	50.33	30.51	6.047
	188.24	56.46	36.89	52.56	30.29	5.715
13-Aug				69.02	11.11	7.339
				52.44	10.93	7.14
				69.74	11.24	6.013
17-Aug	54.84	n/a	45.38	18.52	n/a	10.65
	51.36	n/a	42.35	16.99	n/a	9.762
	57.2	n/a	45.97	17.54	n/a	12.47

Table B.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
20-Aug	73.82	22.58	79.46	38.5	57.42	13.87
	76.24	13.1	77.66	37.61	54.88	13.84
	77.86	14.02	78.2	34.23	54.56	14.56
24-Aug	285.4	11.866	2.446	3.441	1.329	1.038
	295.6	11.464	2.382	3.278	1.489	0.974
	281.6	10.806	2.451	3.337	1.525	1.013
27-Aug	393	164.26	18.84	48.34	50.17	2.699
	362	180.2	19.52	50.07	43.17	2.609
	360.2	169.58	19.97	51.18	44	2.515
31-Aug		160.8	6.216		17.94	2.163
		156	4.972		18.17	2.039
		151.2	4.476		18.41	2.181
03-Sep		204.8	9.311		29.39	8.33
		210.6	8.452		30.62	8.656
		207	10.1		28.49	8.087
14-Sep	40.2	308.4	28.37	15.97	46.01	3.708
	41.76	267.6	28.09	16.53	44.04	3.21
	42	270.2	26.4	16.47	42.73	3.744
17-Sep	141.38	190.12	29.86	24.3	26.82	7.626
	129.5	181.14	27.74	24.47	29.53	7.543
	132.86	182.64	29.07	23.76	28.58	7.395
21-Sep	2084	94.2	15.85	382.4	38.9	2.704
	1343	132.12	16.06	270	37.82	2.376
	1340	101.36	16.16	266.8	36.44	2.484
24-Sep	193.8	8.282	6.669	605.9	24.92	4.568
	135.28	8.576	6.446		26.86	4.491
	176.48	8.13	6.416		26.39	4.606
28-Sep	74.02	214.6	36.31	8.089	21.95	13.3
	67.3	233.6	28.35	9.006	22.31	13.41
	72.68	171	40.74	8.474	20.84	11.11
01-Oct	115.08	212.8	267.6	28.29	19.2	19.67
	113.08	208.8	350.8	28.75	20.37	19.63
	108.82	216	275.1	28.68	21.57	19.51
05-Oct	96.72	45.76	53.91	11.28	20.35	11.2
	97.42	42.46	51.93	10.69	20.89	10.65
	100.56	54.56	51.5	10.05	20.26	11.91
07-Oct	112.4	142.5	43.72	8.234	20.12	4.213
	88.74	145.52	46.02	8.193	16.3	4.234
	11.3	45.12	69.29	6.111	16.01	5.421
12-Oct	60.73	120.6	20.69	25.47	61.82	7.069
	59.38	124.7	20.77	25.26	63.13	7.269
	61.25	120.7	20.89	21.87	66.71	7.229
15-Oct	102.92	62.74	5.658	12.97	11	6.492
	104.82	56.04	5.414	16.24	13.02	6.041
	102.58	59.76	6.027	16.11	11.16	6.561

Table B.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
19-Oct	132.26	72.92	159.5	23.35	11.59	16.87
	130.54	74.54	123.6	22.01	11.77	17.69
	128.1	72.18	154.6	22.42	11.15	17.22
22-Oct	263	91.44	78	8.401	19.55	13.03
	242.2	58.58	75.45	8.957	20.27	8.5
	75.8	89.08	76.59	8.933	12.28	8.786
26-Oct	273.4	100.2	19.76	16.46	20.49	6.781
	280.8	97.92	19.53	20.18	20.23	7.036
	284	99.98	17.48	19.87	20.54	7.065
29-Oct	102.18	238.8	9.843	64.78	15.81	2.469
	101.8	247.4	9.447	71.04	15.89	1.962
	102.24	246.6	7.927	50.74	15.28	2.076
02-Nov				35.58		2.48
				35.26		2.505
				33.46		2.417
05-Nov	251.4	122.04	4.533	30.24	19.44	3.757
	198.7	117.64	4.513	22.19	18.01	3.41
	174.78	119.48	4.557	30.4	14.29	3.192
09-Nov	325.8	104.5	8.649	18.49	19.13	6.15
	315	106.62	8.638	19.98	18.83	6.4
	321.6	103.66	8.46	19.81	17.98	5.503
12-Nov	629.8	124.14	3.238	602.6	19.64	1.864
	597.8	123.82	3.338		20.37	2.036
	599.8	120.84	3.711		19.33	1.795
16-Nov	104.08	211.6	1.911	9.559	26.12	1.241
	108.24	205	1.969	9.418	23.12	0.976
	100.18	211.8	2.032	8.91	23.06	1.444
19-Nov	667	155.14	1.355	9.249	20.73	0.185
	642.4	158.32	1.205	9.635	21.88	0.163
	689.8	156.1	1.242	9.263	21.61	0.203
23-Nov	614.8	272.2	13.66	12.91	17.64	5.725
	591.4	246.4	14.57	12.32	21.09	5.762
	602.2	259.6	16.7	12.12	19.95	6.458
03-Dec	1645	350		44.78	41.12	
	1617	345		40.33	53.05	
	1650	334		43.76	41.11	

Total Copper (µg/L)

Table B.22 Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	645.8	645.6	1326.2	99.5	392.4	520.2
	654.4	652	1345.2	88.78	397.2	507.4
	650.2	651.6	1359.8	86.72	391.6	505.4
06-Jul	200.6	864.2	1909.4	150.48	333	695.8
	205.2	866.8	1878.2	181.22	340.2	703.2
	208.6	858.4	1937.2	118.5	340.4	703.4
09-Jul	682	1018.8	1288.4	89.32	322.8	142.2
	711.2	1061.2	1272.2	82.12	322.6	128.96
	679.8	1082	1274.6	83.74	331.6	127.32
13-Jul	460.4	483	255.6	70	112.54	70
	515.4	501	248.4	70	124.68	70
	519	499	253.2	70	126.86	70
16-Jul	569.4	550.2	128.34	275.2	402.8	70
	827.6	771.2	127.14	264	398.2	70
	818.8	779.4	118.8	247.8	395.4	70
20-Jul	644.8	594	70	70	246.4	70
	657.6	605.4	70	70	212	70
	659.8	582.6	70	70	215.8	70
23-Jul	1157	750.4	650.8	140.52	218.2	102.74
	1177.6	785.4	672.6	140.46	199.04	100.52
	1238.2	793	664.4	133.68	212.4	100.46
27-Jul	888.5	898.9	137.7	99.46	188.4	70
	792.2	799.4	140.6	100.4	204.1	70
	858.3	737.1	140	98.82	193.3	70
30-Jul	1099	279.4		426.2	1713	
	1038	299		414.1	1726	
	1068	275.1		412.6	1725	
03-Aug	324.6	690.8	437.8	34.26	101	70
	336.8	693.6	439.2	33.42	99.52	70
	320.6	752.2	439.4	33.18	100.32	70
06-Aug	173.8	160.72	749.2	60.68	70	350.6
	175.4	159.42	745	60.12	70	341
	179.02	158.72	7342	59.74	70	351.2
10-Aug	737.9	216.1	831.1	215.1	161.8	268.1
	761.5	212.5	824.8	214.7	163.4	265.1
	765	215.7	846.5	216.1	161.7	259.7
13-Aug				402.4	137.74	382.8
				403.4	134.22	380.8
				400.2	134.22	378.8

Table B.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation time			Short (30min) Stagnation Time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
17-Aug	205.6		1963	70		717.6
	217.6		2038	70		754.2
	212.8		2090	70		760
20-Aug	273.4	70	3466	70	70	326.4
	276.2	70	3466	70	70	299
	264	70	3480	70	70	289.4
24-Aug	686	491.2	2488	366.6	156.72	216.2
	689.4	466.2	999.2	389.8	155.56	236.2
	628.4	460	1003	399.8	158.28	233
27-Aug	485.2	404.2	482.4	160.4	167.9	96.71
	570	408.2	468.2	159.8	170.3	95.74
	525.6	439.4	461.2	162	168.4	96.64
31-Aug		321.4	69.8		171.6	70
		265.2	69.3		149.2	70
		239	68.52		155.4	70
03-Sep		1196	70		212.3	196.6
		1194	70		217.5	230.3
		1210	70		212.6	233.2
14-Sep	70	586.8	195.2	27.49	178.6	70
	70	579.8	195.2	27.56	181.8	70
	70	571.4	191.6	26.21	182.8	70
17-Sep	216.4	520.8	976.4	217.4	276.3	385.2
	215	527	980.4	215.4	272.9	383.2
	156.56	530.2	988.3	199.4	273.4	390.3
21-Sep	10766	449.6	783.9	1758	205.5	70
	10714	417.2	777.2	1872	181.8	70
	10160	399	703.4	1929	205.9	70
24-Sep	19690	426.8	488.9	7532	164.1	141.8
	19554	442.2	495.3	7230	165	140
	19828	444.8	477.4	7256	154.2	147.6
28-Sep	365.4	496.8	2338	161.6	162.6	780.3
	366.6	481		166.4	158.2	781.6
	372.6	489		160.2	155.5	797.7
01-Oct	342.6	456.2	1736	153	161.5	502.4
	345	464.6	1511	151.6	166.3	507.4
	333.6	475.6	1545	147.8	164.4	537.4
05-Oct	251.8	125.92	916.6	70	97.59	89.8
	253.6	118.94	912.3	70	97.24	91.28
	255.8	118.3	864.6	70	96.07	91.92
07-Oct	76.7	646	1383	73.02	207.6	306.9
	74.64	629.6	1436	74.56	225.9	320.1
	79.1	681.2	1363	75.87	220.2	309.8
12-Oct	317.2	333		70	504.7	418.6
	320.9	339		70	484.9	460
	318.6	336.6		70	477	456.1

Table B.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
15-Oct	204	273.4	192.1	87.05	146.2	723.4
	205.6	273.8	192.4	87.08	142.2	735.2
	162.36	271.2	193.2	86.15	143.1	737.9
19-Oct	554.84	406.2	2425	55.59	88.11	1009
	553.6	422		54.85	88.26	985.7
	607.4	403.6		56.02	87.62	995.5
22-Oct	627.6	427.2	2726	174.5	181.5	1030
	654.6	399		180.2	187	988.4
	629.8	421.6		203.8	185.8	1061
26-Oct	965.8	603.2	2387	174.1	180	724.2
	976	607.6		177.2	180.8	719.4
	974.4	582.4		178.2	177.3	719.4
29-Oct	1034	775	1030	504.7	187.1	188.4
	948.2	766.6	1005	517.5	187	187.6
	1062	733	990.2	499.2	182	185.9
02-Nov				790		70
				788.9		70
				784.2		70
05-Nov	658	446.2	212.4	96.77	96.38	158.4
	657	444.8	204.7	97.03	100.3	156.4
	661.8	445.8	209.5	95.36	99.65	156.2
09-Nov	1013	373.6	520.3	209.3	87.41	212.5
	1019.6	295.4	513.9	210	88.67	212.4
	1010.8	291.2	505.9	212.2	87.13	205.9
12-Nov	16640	413.2	92.11	2802	195.9	70
	15980	412.2	92.43		191.5	70
	15340	407.8	93.17		191.2	70
16-Nov	634.6	560.2	76.2	84.04	108.7	70
	653.6	584.6	74.49	83.35	109.3	70
	652.8	580	75.51	82.63	108.2	70
19-Nov	3580	593.4	70	408.4	194.5	70
	3508	603.2	70	413.5	190.6	70
	3640	590.8	70	403.8	193.9	70
23-Nov	3154	855	778	342.7	166.3	396.5
	3014	855.4	733.9	319.9	159.5	410
	3100	857.6	770.8	338.6	147.9	408.9
30-Nov	3410	638.2		70	104.9	
	3300	666.8		70	105.5	
	3290	670.2		70	106	
03-Dec	10600	815		1067	151.7	
	11020	801.2		1047	150.7	

Dissolved Copper (μg/L)

Table B.23 Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) stagnation time			Short (30min) stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	70	489.8	1191.6	335.6	291.4	455.2
	70	488.4	1197.2	329.2	291.8	441.6
	70	487.2	1210.2	271	285.6	440.4
06-Jul	145.66	623.2	1645.8	112.44	184.74	462
	147.1	616	1691	91.82	202.6	486
	144.7	619.8	1381.2	87.26	212	508.8
09-Jul	188.68	535.4	690.2	12.36	178.48	94
	195.28	535	687.4	8.42	182.76	95.48
	187.08	534.4	700.8	7.04	178.96	95.9
13-Jul	165.64	292.8	160.34	70	70	70
	194.12	288.6	143.3	70	70	70
	194.08	267.8	154.28	70	70	70
16-Jul	434.8	451.4	112.9	42.24	376.2	70
	610	447	70	16.58	357.2	70
	633.2	616.6	6	109.44	361.2	70
20-Jul	261.8	309	70	70	167.34	70
	257.6	311.8	70	70	177.32	70
	292.6	310.6	70	70	172.16	70
23-Jul	546	538	441	97.1	143.42	109.36
	606.6	562.4	453.6	89.68	164.36	79.16
	619.4	574	453.6	90	163.38	94.56
27-Jul	246.8	336.9	48.58	67.28	164.1	11.15
	227.5	325.8	48.78	67.45	165.7	13.08
	241.7	340.1	48.53	68.94	168	12.9
30-Jul	909.8	189		338.2	313.8	
	909.5	189.7		338.2	1100	
	911.5	251		347.8	1099	
03-Aug	314	631.6	82.24	29.5	91.1	20.84
	315.6	633.8	81.4	28.3	90.34	18.196
	317.6	626.8	82.3	27.7	89.96	20.58
06-Aug	125.72	141.58	437.4	45.34	70	219.8
	125.88	137.44	431.8	43.72	70	219
	126.6	138.14	436.4	41.56	70	220
10-Aug	398.8	106.3	512.3	201.1	145.5	194.1
	387.8	101.8	491.7	199.6	141.9	186.6
	387.6	103.3	488.5	201.2	143.2	187.3
13-Aug				362.8	70	333.6
				370.4	70	329.4
					70	325

Table B.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
17-Aug	149.72		1587	70	70	548.4
	150.8		1648	70	70	544.6
	155.58		1695	70	70	552.8
20-Aug	70	70	2060	70	70	296.2
	70	70	2160	70	70	279.2
	70	70	2028	70	70	278
24-Aug	433.6	178	754.6	284	70	162.32
	429	185.38	749.4	292.2	70	165.46
	437.4	159.12	817.8	287.8	70	165.46
27-Aug	258	190.84	249.8	135.9	140.4	70.43
	257.8	188.66	256.4	129.3	139.5	71.33
	268	184.4	257.2	133.9	137.2	71.32
31-Aug		70	70		101	70
		70	70		98.61	70
		70	70		98.01	70
03-Sep		743.8	21.98		164.2	179.5
		757.6	31.53		161.2	172.8
		772	31.22		160.1	176.2
14-Sep	70	459.8	107.8	22.04	97.95	70
	70	446.2	108.5	20.94	95.63	70
	70	479.4	110.3	20.67	96.21	70
17-Sep	199.02	311.4	789.2	182.9	196.7	345
	193.38	326.4	800.2	182.5	202.6	348.2
	176.92	322.2	749	182	197.3	324.3
21-Sep	9786	356.2	487.5	2056	155.2	70
	10220	256.2	479.1	2072	159.3	70
	10294	344.6	478.8	2064	154.2	70
24-Sep	1870	70	185.3	2917	98.99	94.11
	1835	70	179.5		102.2	96.06
	1856	70	179.3		100.8	96.24
28-Sep	199.42	389.2	2012	93.16	151	762
	201.2	386.8	2032	90.92	144.4	794.4
	204	357.8	1895	90.14	149.1	788.7
01-Oct	228.8	348.8	1408	109.7	142.1	510.4
	224.8	361	1537	101.1	142.8	478.4
	226.4	363.2	1631	109.2	142.1	480.7
05-Oct	133.18	95.04	854.7	70	80.82	212.8
	132.7	92.42	862.7	70	94.14	186.3
	126.76	94.54	849.4	70	80.72	228.4
07-Oct	90.82	787	1013	70	171.7	279.5
	87.32	797.8	1015	70	171.9	278.7
	87.52	201.8	1038	70	166.2	279.2

Table B.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with an acid/base

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
12-Oct	201.8	219.7	1715	70	355.7	405.2
	201.2	218.6	1670	70	352.4	440.3
	200.8	218.8	1724	70	384.7	440.8
15-Oct	140.98	264	172.2	79.74	150.1	509.3
	141.92	260.6	180.3	79.02	107.2	508.9
	139.84	255	177.3	70	142.8	524.6
19-Oct	416.4	252.8	2325	70	74.72	939.2
	370.8	251.4		70	76.71	950.7
	448.8	247.2		70	78.02	935.3
22-Oct	321.8	405.2	2562	140.2	167.1	965.5
	328.4	402.2		136.9	165.7	936.8
	329.2	385.6		119.8	183.6	958.5
26-Oct	526.2	459	1898	106.2	165.3	548.7
	537.4	454.4	1758	106.2	164.5	547.1
	532.8	462.2	1881	106.5	162.6	544.5
29-Oct	426.6	612.4	919.1	365.3	162.4	175.5
	396	603.2	939.1	334.2	158.5	165
	376.6	532	808.3	398.5	159.4	164.6
02-Nov				417.1		70
				423.5		70
				425.9		70
05-Nov	372.4	355.2	184.9	84.56	91.48	107
	380.4	317.6	186.4	79.18	94.56	108
	381.6	325.2	186.3	79.48	96.24	107.5
09-Nov	669	196.1	416.6	158.2	85.63	202.7
	682.4	193.86	414.2	162.8	83.32	201.5
	659	191.22	409.2	163.7	88.33	201.8
12-Nov	1480	301.4	76.85	2748	177.4	70
	1420	270	76.34		172.1	70
	1420	274	76.74		172.7	70
16-Nov	284	421.4	70	70	101.2	70
	284.6	411	70	70	103.7	70
	287.4	368.8	70	70	99.5	70
19-Nov	3120	441.2	70	289.8	184.9	70
	3100	499.2	70	291.1	171.1	70
	3100	463	70	288.6	177.4	70
23-Nov	1944.6	728.8	509.7	176.2	102	322.5
	1921.8	589.4	502.6	178.7	107.1	316.2
	1915.8	561.6	546.5	191.2	107.4	319.5
30-Nov	248.8	415.6		53.73	101	
	236.8	421.8		52.76	101	
	234	429.2		53.8	99.85	
03-Dec	9800	707		949.2	97.43	
	9440	770.6		949.2	113.5	
	9300	711.2		959.6	113.5	

Buffered with Sodium Silicate

Pipe loops

Corrosion rate (mil/year)

Table B.24 Raw data displaying corrosion rate value for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

Date	High Chloramines	Low Chloramines	Chlorine
01-Feb	1.49	2.47	1.36
04-Feb	1.42	1.96	1.51
08-Feb	0.94	2.02	1.24
11-Feb	1.57	2.62	1.22
15-Feb	1.24	2.83	1.25
18-Feb	1.6	2.03	1.19
22-Feb	1.19	1.96	1.31
25-Feb	1.41	2.31	1.38
01-Mar	0.83	2.14	1.24
04-Mar	1.23	2.66	1.47
08-Mar	1.41	2.03	1.36
11-Mar	1.1	2.3	1.35
15-Mar	0.93	1.85	1.42
18-Mar	1.34	2.4	1.05
22-Mar	1.16	2.55	1.25
25-Mar	1.37	2.57	1.57
29-Mar	1.18	1.05	1.45
01-Apr	1.37	2.73	1.61
05-Apr	1.21	2.2	1.63
09-Apr	1.11	1.87	1.43
12-Apr	1.28	2.31	1.33
15-Apr	1.26	2.63	1.47
19-Apr	1.13	2.15	1.92
22-Apr	1.33	2.14	1.53
26-Apr	1.3	2.14	1.7
29-Apr	1.52	2.49	1.44

pH

Table B.25 Raw data displaying pH value for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	8.25	8.7	5.11	8.95	7.95	7.46
04-Feb	8.76	8.21	8.22	8.76	7.42	7.88
08-Feb	9.15	10.15	10.31	6.31	6.26	6.67
11-Feb	8.84	8.92	7.92	8.8	7.04	6.9
15-Feb	9.16	8.74	8.31	7.15	7.01	6.16
18-Feb	9.05	8.72	7.3	8.63	6.86	5.89
22-Feb	9.12	8.08	8.32	7.39	6.51	6.64
25-Feb	9.02	8.58	5.93	8.69	7.01	6.19
01-Mar	9.69	8.49	7.27	6.89	6.25	6.14
04-Mar	8.89	8.46	7.28	8.35	6.46	6.98
08-Mar	9.23	8.13	8.01	8.71	6.35	6.23
11-Mar	8.72	8.39	7.25	8.57	6.75	5.93
15-Mar	8.82	8.23	8.69	7.11	6.38	5.95
18-Mar	8.98	8.6	5.38	8.55	6.4	6.2
22-Mar	8.89	8.51	8.13	7.29	6.81	6.17
25-Mar	9.04	8.41	6.27	8.57	6.88	6.3
29-Mar	8.87	8.8	6.59	8.38	5.94	3.2
01-Apr	9.02	8.75	7.07	8.47	7.25	6.8
05-Apr	9.01	8.53	7.63	8.45	6.31	6.2
09-Apr	8.58	8.5	6.48	7.11	6.44	5.88
12-Apr	8.62	8.62	8.03	8.15	6.82	6.61
15-Apr	8.5	8.64	9.05	8.39	6.96	5.61
19-Apr	8.84	8.62	6.58	7.75	6.72	7.01
22-Apr	8.73	8.59	6.2	8.29	6.42	6.32
26-Apr	8.78	8.8	6.23	8.46	7.62	5.98
29-Apr	8.77	8.85	8.45	4.78	6.03	5.78
10-May				8.76	7.47	6.5
17-May				8.36	7.01	7.55
25-May				8.38	7.4	6.48
31-May				8.85	7.5	6.97
07-Jun				8.61	7.58	5.66
14-Jun				8.28	7.21	6.54
21-Jun				8.24	7.07	6.59
28-Jun				8.75	7.49	6.18

Oxidation Reduction Potential (ORP) (mV)

Table B.26 Raw data displaying ORP values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	464	528	603	386	466	487
04-Feb	368	360	415	439	456	591
08-Feb	463	376	469	557	584	634
11-Feb	450	412	748	427	414	672
15-Feb	413	416	608	448	521	706
18-Feb	391	379	713	481	619	734
22-Feb	454	419	743	498	398	766
25-Feb	439	565	720	450	469	669
01-Mar	771	502	722	422	561	692
04-Mar	522	504	760	456	407	677
08-Mar	485	406	643	498	353	650
11-Mar	458	448	736	463	482	684
15-Mar	515	371	640	459	581	718
18-Mar	456	509	723	464	483	681
22-Mar	430	393	583	377	523	710
25-Mar	474	406	641	437	466	434
29-Mar	422	486	716	467	435	451
01-Apr	425	543	697	413	416	694
05-Apr	400	550	736	483	414	720
09-Apr	428	484	728	390	532	661
12-Apr	469	559	741	468	434	714
15-Apr	474	502	460	483	548	725
19-Apr	489	512	785	402	593	710
22-Apr	444	344	689	326	398	654
26-Apr	430	395	704	415	514	699
29-Apr	404	377	671	528	392	735

Dissolved Oxygen (mg/L)

Table B.27 Raw data displaying dissolved oxygen values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb						
04-Feb						
08-Feb						
11-Feb						
15-Feb						
18-Feb	9.7	10.2	10.3	7.7	9.9	9.1
22-Feb	10.7	10.6	10.7	8.1	10	9.2
25-Feb	10.6	10.6	11	8	9.1	9.1
01-Mar	10.1	9.6	10.2	9.2	8.8	9.2
04-Mar	9.8	9.8	10	8.3	8.4	8.9
08-Mar	9.7	9.8	9.8	8.1	8.5	8.8
11-Mar	9.7	9.4	9.9	8.3	9.8	8.9
15-Mar	10	9.9	9.5	8.5	8.7	9.9
18-Mar	9.4	9.5	9.4	8.1	7.5	9.7
22-Mar	10	9.4	9.9	8.9	9	8.8
25-Mar	9.6	10.1	9.9	7.8	6.88	6.3
29-Mar	10.3	9.8	10.3	8.5	9.5	9.4
01-Apr	10.2	9.8	10.4	8.4	8.3	9.4
05-Apr	11.2	9.6	10.5	8.3	8.7	10.1
09-Apr	9.6	9.2	9.4	8.3	8	8.8
12-Apr	9.8	10.1	10	8.4	8.8	9.2
15-Apr	9.6	9.3	10.3	8.3	8.9	9.4
19-Apr	10.1	9.3	9.9	8.2	9	8.4
22-Apr	9.1	9.3	9.5	8.4	8	9.9
26-Apr	9.9	9.8	10.7		9	9.9
29-Apr	10.4	10.1	10.5	9.1	9.4	11

Temperature (°C)

Table B.28 Raw data displaying temperature values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	8.1	8.2	7.5	15.4	14.1	15
04-Feb	12.3	12.1	11.8	18.9	17.6	18.1
08-Feb	12.4	12.4	12.3	19.6	18	18.7
11-Feb	9.2	9.2	9.6	16.1	15.2	16
15-Feb	14.1	13.8	14.2	21.1	19.6	20.6
18-Feb	8.6	8.6	9	15.4	12.3	14.9
22-Feb	8.7	8.9	9.8	16.2	13.5	15.2
25-Feb	8.3	8.4	9.1	15	14.1	14.7
01-Mar	9.3	9	9.6	14.4	14.3	15.1
04-Mar	8.8	8.6	9.9	15.5	13.7	4.7
08-Mar	9	8.9	9.1	15.6	14.5	15.1
11-Mar	9.3	9.1	9.3	14.3	12.9	14.4
15-Mar	9.1	9.2	8.7	15.3	14.4	14.5
18-Mar	9.9	9.6	9.6	16.2	14.6	14.9
22-Mar	10	10	10.4	115.9	15.2	15.7
25-Mar	10	9.9	9.4	16.6	15.1	14.6
29-Mar	10.2	9.3	9.1	15.2	13.7	14.6
01-Apr	10.5	10.2	10.5	16.5	15.6	15.3
05-Apr	9.8	9.8	10.4	16.3	15.5	15
09-Apr	11.4	11.5	1.7	17.2	16.1	16.8
12-Apr	11.5	11.1	11.4	17.9	16.7	17.2
15-Apr	10.9	11.5	11.7	17.8	16.6	17.1
19-Apr	12.3	12	11.9	17.9	16.1	17.4
22-Apr	11.6	11.5	11.5		16.6	16.9
26-Apr	12.6	12.1	12.4	17.7	16.8	17.2
29-Apr				20.3	19.1	20
10-May				22.5	22.3	22.3
17-May				20.3	20.8	20.9
25-May				21.1	21.3	20.9
31-May				21.6	21.5	21.5
07-Jun				22.7	22.5	21.3
14-Jun				23.5	22.7	23
21-Jun				24.2	23.6	23.7

Total Chlorine (mg/L)

Table B.29 Raw data displaying total chlorine values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
01-Feb	0.04	9.3	0.05	8.5	6.6	0.09
04-Feb	14	7	0.05	11.7	5.6	0.48
08-Feb	35	13.9	5.4	2.6	3.9	0.9
11-Feb	17.8	5.5	1.8	1.38	5.8	0.43
15-Feb	36	4.8	3.6	2	5	0.06
18-Feb	19.9	7.5	3.9	7.4	4.7	2
22-Feb	85	4.9	1.82	4.1	1.3	1.88
25-Feb	64	6.6	1.28	13.5	4.7	0.65
01-Mar	6.6	4.4	5.1	3.1	8.4	0.6
04-Mar	19.1	5.5	2.5	12.1	3.7	0.38
08-Mar	86	6.2	5.3	10.6	1.2	0.38
11-Mar	12.7	4.8	2.4	53	4.44	1.1
15-Mar	19	6.6	0.25	4.3	1.8	0.89
18-Mar	45	6.2	1.62	15.2	4.3	0.47
22-Mar	99	4.4	2.06	4.6	5.1	0.78
25-Mar	21.2	5.9	4.9	11.5	4.2	0.56
29-Mar	65	6.7	1.96	8.1	1.1	0.06
01-Apr	40	6.5	2.3	14.2	4.6	1.1
05-Apr	19	5.1	2.6	7	2.4	1.2
09-Apr	19.2	4.8	1.9	2.2	0.7	0.4
12-Apr	16.4	5.8	1.41	10.3	4.3	0.51
15-Apr	6.6	10	6.3	13.4	5.3	0.98
19-Apr	14.4	3.9	3.4	5.3	1.29	0.96
22-Apr	14.7	9	1.68	6.5	3.9	0.55
26-Apr	9.8	9.7	1.41	6.2	1.4	0.79
29-Apr	11.3	7.3	2.8	9.1	3.5	0.9
10-May				3.1	1.4	1.6
17-May				5.5	3.3	1.7
25-May						
31-May				8.5	3.4	1.43
07-Jun				5.8	3.7	0.61
14-Jun				8.1	3.3	2.8
21-Jun				6.3	3.4	1
28-Jun				8.6	3.1	0.79

Free Chlorine(mg/L)

Table B.30 Raw data displaying free chlorine values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	0.04	8.8	0.05	5.6	6.4	0.06
04-Feb	13.5	6.2	0.01	11.7	5	0.47
08-Feb	2.7	0.29	5.3	0.13	0.17	0.28
11-Feb	15.2	2.4	1.4	0.3	3.5	0.36
15-Feb	7	0.5	4.4	1.93	0.6	0.04
18-Feb	1.2	7	3.9	2.4	1.4	1.9
22-Feb	0.8	1.1	1.67	1.6	0.8	1.76
25-Feb	41	0.5	1.15	3.2	4.6	0.61
01-Mar	4.3	0.4	5.1	0.8	0.9	0.58
04-Mar	12.5	4.8	2.5	4	2.5	0.33
08-Mar	9	0.2	4.9	3.3	1.2	0.31
11-Mar	3.3	2.1	2.3	53	0.6	1.1
15-Mar	1.6	4.5	0.25	4.3	0.4	0.8
18-Mar	4	0.7	1.53	1.5	0.5	0.46
22-Mar	36	0.3	1.68	0.9	0.4	0.72
25-Mar	0.4	2.9	4.6	7.6	0.3	0.52
29-Mar	34	4.1	1.85	5.9	0.4	0.06
01-Apr	35	4.2	2.3	3	0.8	1.1
05-Apr	1.5	0.3	2.6	5.2	1.7	1.1
09-Apr	2.6	1.1	1.8	0.3	0	0.2
12-Apr	2.2	5	1.27	7.2	0.5	0.49
15-Apr	2.9	5.9	6.3	1.6	1.5	0.83
19-Apr	8.7	3.2	3.4	0.7	0.94	0.93
22-Apr	1.6	5	1.7	0.4	0.2	0.47
26-Apr	0.5	1.1	1.37	2.9	0.4	0.69
29-Apr	1.9	0.6	2.6	1.9	0.4	0.9
10-May				2.4	0.4	1.4
17-May				4.1	0.6	1.5
25-May						
31-May				6.7	1.8	1.38
07-Jun				3.8	2.6	0.59
14-Jun				5.3	2.7	2.7
21-Jun				6	2.6	0.8
28-Jun				1.5	0.2	0.73

Turbidity (NTU)

Table B.31 Raw data displaying turbidity values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	0.136	0.02	0.947	0.174	0.074	0.08
04-Feb	0.138	0.2	0.638	0.058	0.133	0.086
08-Feb	0.596	0.482	0.511	-0.055	0.007	0.011
11-Feb	0.16	0.247	0.276	0.021	0.07	0.21
15-Feb	0.006	-0.048	0.942	-0.03	-0.06	0.037
18-Feb	1.111	0.196	0.146	0.268	0.138	0.384
22-Feb	0.118	0.202	0.201	0.004	0.173	0.021
25-Feb	0.107	0.197	0.008	0.093	0.374	0.071
01-Mar	0.2	0.369	0.401	0.028	-0.007	-0.008
04-Mar	0.733	0.245	0.594	0.015	0.074	0.05
08-Mar	0.38	0.238	0.117	0.095	0.042	0.048
11-Mar	0.068	-0.078	0.13	0.021	-0.132	-0.091
15-Mar	0.191	0.074	0.151	0.003	0.1	0.106
18-Mar	0.357	0.131	0.19	0.018	0.133	0.185
22-Mar	0.355	0.42	0.526	0.185	0.198	0.087
25-Mar	0.097	0.312	0.169	0.012	0.015	0.036
29-Mar	0.256	0.382	0.153	0.269	0.167	0.438
01-Apr	0.104	0.084	0.14	0.016	0.054	0.083
05-Apr	0.286	0.202	0.054	0.069	0.037	-0.013
09-Apr	0.301	0.103	0.413	-0.171	-0.126	-0.177
12-Apr	0.35	0.113	0.03	0.008	0.039	-0.005
15-Apr	0.028	0.004	0.108	-0.057	0.068	0.001
19-Apr	-0.016	0.579	0.029	-0.024	-0.048	-0.047
22-Apr	0.076	0.044	0.066	-0.023	-0.274	-0.015
26-Apr	0.435	0.506	0.779	0.026	0.132	0.016

Sodium Silicate(mg/L)

Table B.32 Raw data displaying sodium silicate values for pipe loops using sodium silicate as a corrosion inhibitor which was buffered with sodium silicate

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	39.2	25.6	8.8	27.9	29.1	2.4
04-Feb	21.9	16.8	8.4	21.7	16.5	19.1
08-Feb	20.5	over	over	8.9	23.4	21.1
11-Feb	32.9	24.3	14.7	15.3	24.3	14.7
15-Feb	59.7	22.6	32	27.7	24.2	18.6
18-Feb	34	24.8	24.2	23.1	22	22.6
22-Feb	42.5	23.9	19.5	15.9	20.2	19.2
25-Feb	53.5	27.9	19.6	21.8	24.6	16.2
01-Mar	over	29.4	20.7	20.7	12.4	20
04-Mar	33.5	22	24.7	25.1	27.2	11.1
08-Mar	over	24	30.9	23.5	18.9	12.1
11-Mar	20.8	26.3	19.7	62	22.8	13.6
15-Mar	27.4	24.1	20.8	19	22.3	15.6
22-Mar	68.4	23.4	21.5	15.8	20.6	16.2
25-Mar	37	21.7	20.4	23.8	21	167
29-Mar	33.1	21.4	15.1	9.4	8.4	10.2
01-Apr	50.1	28.4	25.1	18.9	19.9	14.1
05-Apr	30.7	24.3	17.3	20.8	7.8	17
09-Apr	21.2	19.9	17.7	22.9	9.6	17.7
12-Apr	16.1	24.3	18.9	20.1	20.6	14.8
15-Apr	14	26.4	17.1	14	26.4	17.1
19-Apr	30.2	24.3	19.7	8	15.8	19.3
22-Apr	30.6	24.3	18.5	29.8	25.4	15.2
26-Apr						
29-Apr						
10-May						
17-May						
25-May						
31-May				25.3	25.4	15.7
07-Jun				25.1	24.9	15.2
14-Jun						
21-Jun				25.2	24.2	16.8
28-Jun				25.1	21.9	16.2

Copper Racks

pH

Table B.33 Raw data displaying the pH values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	8.88	7.84	6.72	8.89	7.38	6.07
04-Feb	8.82	7.92	7.6	8.8	7.35	7.03
08-Feb	8.84	7.62	8.08	8.53	6.73	5.98
11-Feb	8.66	7.38	7.71	8.78	7.33	6.3
15-Feb	8.37	7.53	7.79	8.3	6.71	6.08
18-Feb	8.69	7.65	8.02	8.24	7.08	6.37
22-Feb	8.92	7.62	7.42	8.31	7.3	6.51
25-Feb	8.69	7.95	7.23	8.74	6.92	5.92
01-Mar	8.11	7.38	6.77	8.08	6.64	5.72
04-Mar	8.23	6.92	5.96		6.65	6.13
08-Mar	8.44	7.11	7.67	8.6	7.05	6.27
11-Mar	8.48	7.68	6.33	8.52	6.76	6.58
15-Mar	8.35	6.85	5.97	8.26	6.54	6.11
18-Mar	8.4	7.96	7.59	8.34	7.16	6.25
22-Mar	8.71	7.98	7.51	8.68	6.79	5.9
25-Mar	8.45	8.08	8.62	7.11	6.76	5.74
29-Mar	8.68	7.76	7.66	8.86	6.7	6.12
01-Apr				8.48	7	6.36
05-Apr	8.79	7.79	6.8	8.68	7.34	6.33
09-Apr	8.68	7.8	6.29	8.6	7.54	5.93
12-Apr	8.28	7.76	7.42	8.21	7.42	6.76
15-Apr	8.4	7.86	6.67	8.29	7.62	6.53
19-Apr	8.62	7.89	7.99	8.44	7.08	6.61
22-Apr	8.48	6.96	6.51	8.18	6.88	6.05
26-Apr	8.46	7.18	5.9	8.45	6.64	6.1
29-Apr	8.49	7.77	7.67	8.48	7.59	6.45
10-May	8.69	7.62	6.54			
17-May	8.48	7.5	7.35	8.17	7.53	7.43
25-May	8.31	7.4	6.21	8.33	7.41	6.37
31-May	8.74	7.69	7.33	8.74	7.47	7.45
07-Jun	8.5	6.97	6.23	8.58	7.43	6.71
14-Jun	7.99	6.79	6.03	7.96	7.48	4.9
21-Jun	8.53	7.39	6.6	8.43	7.4	6.97
28-Jun	8.49	7.66	6.73	8.75	7.57	6.64

Oxidation Reduction Potential (ORP) (mV)

Table B.34 Raw data displaying the ORP values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	464	528	603	518	573	736
04-Feb	390	394	412	506	529	588
08-Feb	380	397	403	491	547	649
11-Feb	420	464	537	437	503	516
15-Feb	372	406	450	373	503	650
18-Feb	506	615	442	489	609	700
22-Feb	431	482	532	535	603	746
25-Feb	414	486	508	459	601	713
01-Mar	513	527	513	481	493	636
04-Mar	488	499	555		555	618
08-Mar	463	488	533	452	511	524
11-Mar	490	464	564	457	495	642
15-Mar	471	502	569	480	522	576
18-Mar	456	487	542	474	539	670
22-Mar	449	459	552	470	431	602
25-Mar	447	456	454	474	497	489
29-Mar	416	489	542	453	542	720
01-Apr				475	581	737
05-Apr	416	460	553	519	583	711
09-Apr	427	511	711	431	511	662
12-Apr	445	463	538	477	581	687
15-Apr	496	595	718	498	609	719
19-Apr	8.6	599	673	453	648	710
22-Apr	408	427	490	398	397	677
26-Apr	510	577	498	486	560	737
29-Apr	509	518	565	431	554	686

Dissolved Oxygen (mg/L)

Table B.35 Raw data displaying the dissolved oxygen values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb						
04-Feb						
08-Feb						
11-Feb						
15-Feb						
18-Feb	8.5	8.3	7.9	9.2	8.9	8.5
22-Feb	9.1	8.3	7.9	8.4	8.3	9
25-Feb	10	9.4	8.1	9.2	8.5	9.2
01-Mar	9.4	8.2	7.7	9.6	7.9	9
04-Mar	9.3	8.3	7.5		7.8	8.6
08-Mar	9.3	8.4	8.8	8.2	8.6	8.7
11-Mar	8.8	9.2	7.3	9.2	8.5	8.8
15-Mar	8.3	8.4	7.7	8.7	8.7	8.5
18-Mar	7.6	8.8	8.4	8.7	8.8	8.8
22-Mar	8.1	8.8	9.2	9.3	8.4	8.3
25-Mar	8.45	8.08	8.62	7.11	6.76	5.74
29-Mar	9.6	8.2	9.2	8.2	9	8.6
01-Apr				9.5	8.9	8.8
05-Apr	9.2	8.3	10.3	8.6	8.7	8.9
09-Apr	8.5	9.3	9.2	8.2	8.3	9.4
12-Apr	9.5	8.2	7.9	8.3	9.1	9
15-Apr	7.4	8.3	9	7.4	8.3	9
19-Apr	8.5	8.1	9.4	8.6	9.1	9.7
22-Apr	9.4	8.1	7.7	8.6	8.8	9
26-Apr	9.3	8.7	8.3	8.8	8.5	8.7
29-Apr	9.6	10.4	10.1	8.6	8.5	9.1

Temperature (°C)

Table B.36 Raw data displaying the temperature values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	13.1	12.8	12	11.8	11.9	11.3
04-Feb	16.6	16	15.8	15.7	15.6	14.6
08-Feb	16.9	16	16.2	15.8	15.5	15.3
11-Feb	14.2	13	13.6	12.8	12.6	12.1
15-Feb	18.9	17.7	18.1	17.5	17.2	16.7
18-Feb	13.2	12.7	13.1	12.1	12.1	10.1
22-Feb	13.5	12.8	13.3	12.2	12.3	11.5
25-Feb	12.6	12	12.5	11.9	11.8	9.8
01-Mar	12.3	11.9	12.3	11.5	11.5	11.2
04-Mar	12.5	12.5	12.2		11.7	11.5
08-Mar	12.6	12.6	11.1	11.9	11.2	9.9
11-Mar	13.3	11.7	12.9	11.7	11.4	19.9
15-Mar	12.1	11.8	11.8	11.3	11.1	11.3
18-Mar	13.3	12.8	13	12.5	11.9	11.8
22-Mar	13.6	13.1	12.7	12.9	12.8	12.8
25-Mar	13.8	13.5	13.7	12.8	12.9	12.5
29-Mar	11.9	11.4	10.9	11.6	11.5	11.4
01-Apr				12.9	12.5	11.8
05-Apr	12.5	12.6	12.2	12	12	11.8
09-Apr	14.6	13.9	12.4	13.7	13.5	12.9
12-Apr	14.7	14.6	14.7	14.1	13.8	11.9
15-Apr	14.6	14.6	12.5	14	13.8	12.4
19-Apr	15.3	14	13.4	14.3	13.7	13.5
22-Apr	13.1	13	13	13	12.8	12.7
26-Apr	14.1	13.6	13.2	13.9	13.8	13.7
29-Apr	17.6	17.2	18.1			
10-May	21.6	21.1	21.5	21.4	20.7	21.4
17-May	18.5	17.7	19.4	18.3	18.4	19.5
25-May	19.3	19.4	19.3	18.9	19.1	18.9
31-May	20.5	20.3	20.3	20.2	20	20.2
07-Jun	19.6	20.8	19.3	20.4	20.7	20.5
14-Jun	21.5	21.3	21.1	20.9	20.9	20.7
21-Jun	21.2	20.7	21.2	21.1	21	20.8

Total Chlorine (mg/L)

Table B.37 Raw data displaying the total chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	12.2	2	0.04	11	5.7	1.51
04-Feb	8.6	0.37	0.02	13.2	5.3	0.4
08-Feb	10.3	0.3	0.04	9.2	3.2	0.16
11-Feb	0.91	0.34	0	14	5.5	0.11
15-Feb	6.9	0.36	0.03	10.4	5.6	0.22
18-Feb	7.7	0.38	0.04	10.7	0.44	1.01
22-Feb	13.3	0.63	0.01	13.5	3.9	1.53
25-Feb	11.1	2.8	0.06	10.9	3.4	0.61
01-Mar	12.5	0.22	0.02	14.9	3.5	0.26
04-Mar	10.6	0.6	0.04		4.5	0.17
08-Mar	12.9	0.3	0.05	16.9	2.9	0.38
11-Mar	12.6	0.8	0.03	4.9	4.6	0.5
15-Mar	11	0.38	0.04	11.3	3.9	0.22
18-Mar	11.8	0.25	0.03	15.2	4.4	0.25
22-Mar	15.4	4.4	0.5	12.3	0.44	0.41
25-Mar	12.6	0.34	0.01	15.2	4	0.29
29-Mar	14.1	1.2	0.03	14.1	2.7	0.54
01-Apr				10.6	5	0.8
05-Apr	15.6	1.2	0.06	18.7	4	1.7
09-Apr	11.3	1	1	10.5	2.5	0.2
12-Apr	7.4	2.5	0.05	8	0.74	0.38
15-Apr	10	1.5	0.58	10.9	4.1	0.59
19-Apr	11.2	1	1.02	11.6	2.7	0.8
22-Apr	6.2	0.64	0.03	6.7	3.4	0.3
26-Apr	8.4	1.4	0.02	0.92	0.29	0.62
29-Apr	7.1	1.7	0.29	0.87	4.6	0.24
10-May	8.1	1.6	0.03			
17-May	5.2	1.3	0.02	6.3	3	0.82
25-May						
31-May	6.4	0.47	1.15	7.2	2.9	0.87
07-Jun	6.3	1.1	0.01	7.1	2.8	0.19
14-Jun	6.3	1.3	0.02	8.4	4.1	0.5
21-Jun	7.9	0.6	0.01	8.2	3.3	0.28
28-Jun	6.5	0.7	0.03	11.7	3.1	0.04

Free Chlorine (mg/L)

Table B.37 Raw data displaying the free chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	10.1	1.7	0.04	10.6	5.6	1.5
04-Feb	8.6	0.34	0.02	1.06	4.7	0.38
08-Feb	0.26	0.27	0.04	1	0.8	0.05
11-Feb	0.62	0.01	0	11.8	1.9	0.06
15-Feb	6.8	0.08	0.03	2.2	0.46	0.17
18-Feb	1.5	0.06	0.02	1.1	0.05	0.89
22-Feb	8	0.42	0.01	1.1	0.8	1.3
25-Feb	5.1	0.9	0.03	0.5	0.3	0.57
01-Mar	1.9	0.17	0.02	13.2	1.5	0.19
04-Mar	9.7	0.2	0.04		0.1	0.17
08-Mar	0.3	0.9	0.05	1.3	1.4	0.3
11-Mar	8.5	0.6	0.03	4	0.8	0.5
15-Mar	1.9	0.16	0.03	4.7	0.5	0.18
18-Mar	4.3	0.24	0.03	2.8	1.3	0.21
22-Mar	0.5	0.1	0.05	0.8	0.04	0.37
25-Mar	0.5	0.22	0.01	12.4	2.4	0.26
29-Mar	2.1	0.7	0.03	7.4	1.2	0.45
01-Apr				6.9	4.1	0.7
05-Apr	1.3	0.2	0.04	2.1	1.1	1.7
09-Apr	0.3	0	0.5	0.9	0.1	0.1
12-Apr	1.3	1.3	0.05	7.4	0.24	0.37
15-Apr	1.9	0.6	0.58	1.9	2	0.56
19-Apr	3.8	0.3	0.85	7	0.6	0.72
22-Apr	0.8	0.52	0.02	1.9	1.7	0.29
26-Apr	4.3	0.4	0.02	0.7	0.2	0.57
29-Apr	3.4	0.5	0.23	0.28	0.05	0.21
10-May	1.4	1.2	0.01			
17-May	0.9	0.3	0.01	2.8	1.8	7.8
25-May						
31-May	2.8	0.27	1.1	2.4	2.9	0.8
07-Jun	0.3	0.6	0	3.4	0.4	0.14
14-Jun	2.9	0.8	0.01	0.6	2.6	0.3
21-Jun	5.9	0.6	0	7.7	3.1	0.23
28-Jun	5.4	0.2	0.02	9.2	1.9	0.02

Turbidity (NTU)

Table B.39 Raw data displaying the turbidity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	0.149	0.106	0.052	0.142	0.136	0.077
04-Feb	0.118	0.131	0.093	0.114	0.133	0.066
08-Feb	0.037	0.538	0.147	0.008	0.025	0.055
11-Feb	0.45	1.06	0.112	0.026	0.309	0.078
15-Feb	0.474	0.461	-0.034	0.028	-0.042	0.465
18-Feb	0.691	0.217	1.301	0.018	0.126	0.069
22-Feb	1.883	1.263	0.028	0.168	0.123	-0.002
25-Feb	0.098	1.266	0.008	0.075	0.199	0.005
01-Mar	0.058	-0.035	0.009	0.04	-0.057	2.863
04-Mar	0.951	0.045	0.069		0.026	0.088
08-Mar	0.737	0.047	0.186	0.125	0.268	0.047
11-Mar	0.995	-0.121	-0.125	0.205	-0.007	0.005
15-Mar	0.739	0.036	0.074	0.049	0.009	0.142
18-Mar	0.605	0.312	0.111	0.111	0.074	0.039
22-Mar	0.199	0.116	0.108	0.127	0.224	0.757
25-Mar	0.236	0.027	0.075	0.006	0.206	0.018
29-Mar				0.233	0.075	0.057
01-Apr	0.055	0.069	0.424	0.113	0.065	0.006
05-Apr	0.1	0.01	0.418	-0.029	0.281	-0.015
09-Apr	0.155	-0.051	-0.116	-0.201	-0.175	-0.152
12-Apr	0.088	0.252	0.01	0.033	0.017	0.006
15-Apr	-0.057	0.122	0.065	0.042	0.648	0.008
19-Apr	0.001	0.05	-0.033	0.042	-0.041	-0.044
22-Apr	-0.001	0.053	-0.005	0.024	-0.014	-0.027
26-Apr	0.138	0.069	0.105	0.056	0.033	0.062

Sodium Silicate (mg/L)

Table B.40 Raw data displaying the sodium silicate values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	24.7	25.4	23.7	7.2	24.6	17.2
04-Feb	27.5	19.1	24.5	23.5	16.3	26.3
08-Feb	20.7	20.9	20	16.9	23	20.4
11-Feb	14.8	22.9	19.3	15.7	23.1	36.8
15-Feb	22.8	28.9	16.2	22	26.3	18.2
18-Feb	22.5	21.9	21.1	23.4	21.6	22.5
22-Feb	27.6	22.2	20.2	22.8	23.1	19.5
25-Feb	21.1	21.7	17	22.1	23.3	17.1
01-Mar	26	23.1	17.5	25.8	23.7	17.6
04-Mar	24	23.8	13.7		27.3	11.6
08-Mar	22.2	23	14.6	22.7	23.6	
11-Mar	23.4	20.7	14.5	37.4	21.8	13.7
15-Mar	21.9	25.3	17	19.7	26.4	15.4
22-Mar	17.7	20.3	19.2	21	20.5	13.7
25-Mar	21.4	19.7	16.6	23.1	20	33.2
29-Mar	19.9	20.1	15.1	17.6	13.7	15.5
01-Apr				17.5	19.7	14.5
05-Apr	21.8	23.2	16.4	25.3	16	16.2
09-Apr	21	23	14.2	20.4	18.3	13.9
12-Apr	19.4	18.5	15.5	19.2	20.1	15.7
15-Apr	15.8	23.3	20.1	15.1	23.9	19.5
19-Apr	22	21	19.9	19.4	20.7	19.8
22-Apr	19.3	22.2	17.6	25	23.7	16.3
26-Apr	24.6	25.3	19.2			
29-Apr	25.4	29.4	17.3	9.8	30.4	16.2
10-May						
17-May						
25-May						
31-May	22.5	23.1	17.1	24.6	24.2	16.7
07-Jun	22.4	22.7	16.7	24.9	24	16.5
14-Jun						
21-Jun	24.1	23.3	15.7	24.1	23.1	15.9
28-Jun	24.6	19.3	14.7	25	22.5	14.6

Total Lead (µg/L)

Table B.42 Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation Time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	56.14	80.03	28.52	13.46	24.78	5.747
	63.05	82.99	29.52	12.47	27.07	5.474
	64.22	91.81	30.9	12.53	21.9	6.338
04-Feb	61.1	66.06	0.97	14.53	36.04	1.976
	54.43	65.01	0.78	5.676	38.27	1.639
	48.48	61.06	1.841	3.519	25.74	2.201
08-Feb	63.22	87.53	4.551	49.91	49.23	4.34
	75.26	81.52	4.137	48.19	37.58	1.959
	66.18	80.47	4.979	50.22	38.02	1.165
11-Feb	206.1	96.13	56.58	19.74	36.09	8.173
	196.5	84.86	47.31	18.78	22.56	6.128
	210.8	84.39	44.98	10.84	23.03	9.28
15-Feb	362.5	96.84	50.83	15.14	27.81	2.952
	310.1	92.94	47.99	17.49	32.39	3.478
	319	100.5	46.53	15.91	22.79	3.147
18-Feb	101.9	94.94	14.63	6.91	25.24	0.97
	101.1	94.38	14.33	11.44	23.75	0.97
	101.9	94.18	14	11.53	25.26	0.97
22-Feb	509.2	374.5	27.33	32.41	45.46	6.582
	605.9	374.7	27.76	43.02	46.41	8.431
	611.7	380.1	15.4	43.9	39.86	7.777
25-Feb	68.15	89.25	49.53	2.069	9.003	0.97
	69.77	91.82	46.33	4.796	8.948	0.97
	73.1	92.15	46.69	3.453	10.48	0.97
01-Mar	39.61	66.63	53.23	2.18	3.788	0.97
	39.17	72.21	46.23	2.364	4.841	0.97
	34.61	71.26	50.52	4.058	9.38	0.97
04-Mar	211.9	53.8	22.32		15.48	0.97
	210.1	53.25	19.13		16.61	0.97
	226.1	54.88	20.81		16.53	0.97
08-Mar	193.4	56.24	29.08	0.97	17.02	0.97
	176	63.8	29.97	0.97	22.05	0.97
	165.6	65.03	30.45	0.97	17.37	0.97
11-Mar	321.6	106.38	22.62	14.87	18.91	3.289
	359.2	108.24	24.34	16.07	18.38	3.658
	309.6	106.04	23.99	12.8	18.28	3.745
15-Mar	297	104.34	27.59	15.45	16.97	27.1
	307.6	94.94	27.25	15.31	17.31	26.17
	302.4	97.6	27.01	15.24	15.58	26.63
18-Mar	155.2	69.19	10.91	3.559	18.5	0.97
	183.5	72.99	17	4.052	15.61	0.97
	136.4	71.91	12.63	2.852	19.81	0.97

Table B.42 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation Time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
25-Mar	49.17	123.66	8.39	1.46	16.13	0.97
	67.74	125.38	7.144	1.364	17.46	0.97
	68.94	128.08	7.178	0.264	14.99	0.97
29-Mar	62.68	70.36	80.3	0.97	11.48	2.221
	38.32	69.9	78.25	0.97	12.19	2.065
	58.7	68.94	76.16	0.97	12.72	1.88
01-Apr				2.771	8.599	2.912
				3.685	7.453	0.892
				4.21	7.768	4.032
05-Apr	11.26	90.46	80.66	8.237	28.29	9.147
	12.932	91.02	81.5	7.983	28.05	9.237
	10.598	91.5	76.82	8.225	26.2	9.3
09-Apr	6.998	105.66		0.97	33.74	31.08
	4.404	89.38		0.97	36.18	30.91
	7.84	165.94		0.97	33.2	29.83
12-Apr	62.04	71	11.866	8.497	15.66	0.97
	64.9	70.84	11.784	11.64	14.77	0.97
	62.92	75.26	10.102	11.89	11.91	0.97
15-Apr	88.18	95.87	0.97	9.33	21.58	0.97
	83.85	101.2	0.97	9.394	22.77	0.97
	88.88	96.51	0.97	8.94	22.37	0.97
19-Apr	12.92	65.72	0.97	0.97	24.58	0.97
	12.18	67.38	0.97	0.97	25.27	0.97
	10.67	64.43	0.97	0.97	23.43	0.97
22-Apr	3.529	98.9	37.4	4.379	23.49	0.97
	2.112	100.9	30.59	2.792	24.34	0.97
	3.615	103.2	32.4	3.943	23.49	0.97
26-Apr	10.98	77.7	35.96	1.156	16.26	0.97
	10.01	79.55	34.84	0.564	13.49	0.97
	9.633	77.15	34.04	-0.28	15.22	0.97
29-Apr	5.898	97.86	0.97	0.97	0.97	0.97
	6.523	95.86	0.97	0.97	0.97	0.97
	6.706	96.3	0.97	0.97	0.97	0.97
10-May	4.465	95.97	70.42			
	4.91	89.66	66.69			
	4.947	94	60.16			
17-May	10.19	91.45	13.09	0	7.199	0.97
	8.765	87.05	12.54	0	4.448	0.97
	9.578	86.34	12.31	0	5.413	0.97
25-May	18.19	76.43	12.18	6.854	34.65	0.97
	17.78	77.23	10.45	6.475	35.92	0.97
	16.92	75.4	10.82	6.133	36.38	0.97

Table B.42 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation Time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
31-May	94.53	78.79	0.97	6.399	108.4	0.97
	96.43	69.48	0.97	9.715	106	0.97
	105.3	79.29	0.97	10.81	95.12	0.97
07-Jun	13.75	300	61.59	12.63	21.48	13.89
	19.3	313.6	63.34	11.63	23.55	14.86
	16.33	296.3	62.28	11.93	34.38	14.26
14-Jun	61.61	71.54	26.36	3.155	8.316	4.269
	61.45	75.29	24.48	2.967	8.99	4.497
	68.5	71.25	25.08	2.779	9.499	3.311
21-Jun	12.52	94.52	26.52	3.953	31.12	4.732
	13.9	97.66	27.17	4.956	31.75	7.029
	14.12	98.57	27	6.044	31.13	7.243
28-Jun	97.57	80.58	27.47	6.444	30.82	3.006
	106.9	82.1	26.26	6.567	29.67	3.235
	96.74	84.63	27.54	7.206	28.94	2.309

Dissolved Lead (µg/L)

Table B.44 Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	29.86	63.51	18.44	7.533	19.9	5.66
	29.08	62.44	18.84	8.257	17.62	3.796
	31.27	60.59	21.53	7.996	16.89	4.407
04-Feb	22.62	58.05	12.07	0.97	18.81	45.57
	22.88	54.06	10.17	0.97	16.36	44.44
	21.94	51.91	3.271	0.97	16.15	40.45
08-Feb	36	83.47	15.48	3.656	21.66	0.97
	33.45	81.98	15.71	1.93	10.92	0.97
	22.77	85	15.28	1.628	10.22	0.97
11-Feb	37.8	17.6	17.9	0.97	14.41	0.97
	36.25	12.55	17.7	0.97	14.73	0.97
	34.79	18.67	17.5	0.97	14.83	0.97
15-Feb	52.29	81.2	39.52	7.529	24.99	9.818
	51.65	95.92	40.29	7.182	23.83	10.35
	53.98	95.56	40.43	7.283	24.36	9.716
18-Feb	40.59	70.3	7.292	3.117	8.799	0.97
	42.74	73.01	4.396	2.586	9.585	0.97
	40.05	75.5	4.216	3.531	9.244	0.97
22-Feb	54.8	97.48	32.03	13.15	16.74	7.423
	46.05	102.3	37.24	14.53	20.25	7.52
	52.07	97.2	36.21	12.51	14.23	7.79
25-Feb	21.26	64.74	40.03	0.213	2.645	0.97
	21.64	61.64	37.86	0.92	4.084	0.97
	19.07	64.01	40.32	-1.523	3.583	0.97
01-Mar	11.83	46.56	30.81	0.97	0.952	0.97
	14.28	47.96	33.66	0.97	1.805	0.97
	15.57	51.96	33.72	0.97	1.328	0.97
04-Mar	56.93	44.07	14.14		9.691	0.97
	55.34	41.15	13.75		10.43	0.97
	55.38	40.26	15.03		9.783	0.97
08-Mar	45.62	53.87	20.1	1.246	21.08	0.97
	43.19	60.57	20.43	2.315	21.15	0.97
	47.81	58.89	19.74	2.305	21.03	0.97
11-Mar	54.66	64.27	16.12	10.69	0.937	3.22
	57.63	63.84	15.88	11.13	0.685	3.407
	54.8	70.91	16.94	11.37	0.673	3.477
15-Mar	58.74	56.2	7.774	8.293	14.46	17.08
	57.42	55.66	7.794	8.061	14.5	17.01
	56.2	58.46	7.928	8.379	13.66	16.79
18-Mar	28.34	52.53	9.67	0.97	1.728	0.97
	29.47	50.32	8.407	0.97	3.75	0.97
	29.9	51.67	9.227	0.97	3.49	0.97

Table B.44 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation time			Short (30min) Stagnation time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
25-Mar	16.264	95.84	0.97	0.97	8.449	0.97
	15.238	101.42	0.97	0.97	8.029	0.97
	14.4664	92.96	0.97	0.97	7.791	0.97
29-Mar	0.97	22.91	26.52	0.97	9.079	0.97
	0.97	22.56	24.75	0.97	8.996	0.97
	0.97	20.62	25.07	0.97	8.062	0.97
01-Apr				0.97	3.652	0.97
				0.97	4.15	0.97
				0.97	5.054	0.97
05-Apr	1.836	60.84	46.16	3.442	15.9	3.054
	49.12	61.48	42.76	3.291	12.38	3.035
	4.848	61.34	41.84	2.795	14.43	2.649
09-Apr	2.665	44.73		0.97	4.553	3.571
	0.125	40.3		0.97	3.62	1.578
	0.125	45.03		0.97	4.282	0.556
12-Apr	8.494	32.6	0.97	0.97	0.97	0.97
	10.582	34.2	0.97	0.97	0.97	0.97
	10.708	34.1	0.97	0.97	0.97	0.97
15-Apr	22.84	55.93	0.97	5.568	14.81	0.966
	19.17	56.99	0.97	5.004	14.8	1.1
	22.18	58.95	0.97	4.761	14.64	0.96
19-Apr	1.103	44.45	0.97	0.97	20.84	0.97
	3.898	42.08	0.97	0.97	22.32	0.97
	3.917	43.78	0.97	0.97	22.39	0.97
22-Apr	0.97	84.85	26.32	0.97	15.68	0.97
	0.97	85.02	28.24	0.97	15.09	0.97
	0.97	86.16	27.72	0.97	17.53	0.97
26-Apr	0.97	59.06	24.17	0.97	8.704	0.97
	0.97	57.05	25.25	0.97	8.503	0.97
	0.97	61.05	21.97	0.97	10.36	0.97
29-Apr	0.97	64.72	0.97	0.97	0.97	0.97
	0.97	65.81	0.97	0.97	0.97	0.97
	0.97	66.96	0.97	0.97	0.97	0.97
10-May	1.245	77.51	61.08			
	1.553	77.18	58.66			
	1.992	75.12	55.44			
17-May	5.211	77.74	12.61	0.97	5.798	0.97
	2.916	76.43	12.31	0.97	5.7	0.97
	1.018	76.36	13.5	0.97	7.515	0.97
25-May	5.652	61.08	4.853	1.999	0.97	0.97
	5.522	57.82	4.323	1.456	0.97	0.97
	5.82	57.93	5.774	1.154	0.97	0.97
31-May	49.9	64.86	0.97	5.502	23.06	0.97
	45.78	61.63	0.97	3.243	26.16	0.97
	53.83	64.38	0.97	2.938	25.26	0.97

Table B.44 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long(24hr) Stagnation time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
07-Jun	15.11	177.2	63.03	6.978	21.87	7.14
	13.32	162.3	55.88	6.313	21.13	8.953
	14.21	174.5	65.47	6.387	20.3	9.107
14-Jun	34.99	60.83	14.86	3.905	12.25	2.162
	35.08	71.39	16.94	3.331	11.49	2.663
	35.76	69.3	17.95	2.771	12.84	5.473
21-Jun	7.486	86.67	17.88	2.181	20.52	1.202
	9.982	93.34	18.27	1.211	21.56	1.948
	9.82	93.58	19.12	1.308	22.57	2.13
28-Jun	42.05	68.4	6.223	0.486	18.6	1.643
	51.16	67.94	5.404	1.799	18.04	0.97
	49.41	67.72	4.614	1.84	18.29	0.97

Total Copper (µg/L)

Table B.44 Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	70	303.6	427.4	70	98.73	210.7
	70	303.2	412.2	70	97.07	217.9
	70	307.2	413.3	70	98.88	211.5
04-Feb	70	401.4	402.1	70	150.9	106.1
	70	390.2	423	70	140.7	112.2
	70	374.6	402.1	70	155.1	108.3
08-Feb	76.01	332.7	880.7	70	107.3	177.4
	78.9	345.5	892	70	105.4	177.3
	76.85	355.8	919.1	70	105.4	176
11-Feb	70.07	289.9	1514	70	90.54	311.8
	70.63	313.1	1460	70	103.1	355.6
	69.97	276.1	1423	70	101.9	333
15-Feb	109.7	370.3	1448	70	106.4	483.1
	103.4	363.6	774.2	70	107.1	481
	102.7	346.8	780.4	70	103.9	468.7
18-Feb	84.7	334.8	1594	70	157.1	105.3
	76.78	335.6	717.3	70	155.5	106.8
	75.08	354.1	781.7	70	155.4	109.6
22-Feb	80.41	357.8	1006	70	150.5	549.2
	79.31	374.4	1173	70	132.8	558.6
	80.5	377.8	761.3	70	135.9	570.2
25-Feb	52.55	328.8	1554	70	160.6	156.8
	75.6	327	1538	70	163.1	149.8
	73.22	334	1444	70	157.6	139.2
01-Mar	211.5	836.1	2142	70	152.9	803.7
	213.5	820.7	1766.6	70	179.2	816.2
	209.2	836.5	2142	70	155.5	851.4
04-Mar	98.38	535.5	2280		188.5	908
	100.1	535.8	3440		181.7	811.7
	98.57	529.1	3332		190.1	986.3
08-Mar	122.12	394.8	3682	70	107.1	151
	123.36	392.6	3704	70	106	152.7
	123.48	405.8	2754	70	106.8	152.9
11-Mar	187.76	571.2	3232	70	146.3	183.1
	185.14	543.8	3524	70	141.1	188.3
	177.6	536.2	2468	70	145.5	174.2
15-Mar	83.5	405.3	1471	70	145.4	1082
	84.26	412.4	1590	70	161.5	1059
	86.31	411.6	1701	70	157.3	1100
18-Mar	87.43	385	1769.6	70	145.7	388
	82.61	364.6	1639.8	70	139.6	405.8
	81.34	364.8	2096	70	150.5	390.2

Table B.44 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
25-Mar	76.78	439	2348	70	188.6	778.5
	89.16	450.6	2196	70	187.8	740.8
	79.42	466.2	3358	70	185.1	760.3
29-Mar	70	322.6	821	70	105.9	39.92
	70	311.4	687.6	70	113.9	736.7
	70	309.8	881	70	114.3	530.9
01-Apr				70	182.8	1048
				70	177.6	1039
				70	198.4	979.3
05-Apr	78.4	383.6	3482	70	142.8	817.9
	77.92	394.2	3280	70	140.8	822.1
	80.26	395.6	3388	70	140.9	804.6
09-Apr	70	352		70	92.35	989
	70	353.4		70	90	974.5
	70	349.8		70	89.65	912.2
12-Apr	70	575	3922	70	153	176.4
	70	572.8	3694	70	151.6	175.7
	70	575.2	3644	70	151.7	173.7
15-Apr	70	379	96.72	70	103.8	87.88
	70	356	98.28	70	103.1	85.49
	70	351.4	100.44	70	102	90.46
19-Apr	70	413	70	70	91.09	108.2
	70	410.2	70	70	90.39	107.2
	70	411.8	70	70	91.75	107
22-Apr	70	379.2	838.8	70	105.8	308.3
	70	324.6	814.6	70	106.2	349.1
	70	350	723.8	70	105.4	317
26-Apr	70	429.6	1786.4	70	99.85	101.7
	70	398.4	1769.4	70	101	111.5
	70	395	1644.2	70	102.4	101.5
29-Apr	70	397.4	149.68	70	143.1	477.3
	70	404.2	149.4	70	146.2	470.7
	70	385.6	147.76	70	146.5	441.9
10-May	54.06	277.8	1865.2			
	53.96	274.8	2070			
	52.7	313.4	2082			
17-May	86.16	339.4	959.2		139.4	216
	83	339.2	926.2		133.5	214.6
	85.68	330.8	921.4		137.6	212.5
25-May	56.4	394.6	2660	14.44	86.6	887.3
	65.52	391	3336	19.72	88.93	917.6
	57.8	390	3574	19.24	96.52	897.1

Table B.44 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
31-May	92.26	578.4	137.42	24.14	160.7	363.1
	95.7	563.6	137.86	24.85	161.4	367.5
	98.22	562.6	137.42	23.62	153.7	365.9
07-Jun	88.84	420		28.52	141.9	2018
	89.7	373.2		27.13	140.1	2000
	88.22	359.8		25.65	131.6	2143
14-Jun	102.04	331	3908	70	70	419.2
	103.3	331.8	3848	70	70	418.2
	98.46	331.2	3850	70	70	419.4
21-Jun	89.62	501.8	4384	70	107.7	2069
	74.46	514.6	4426	70	109.5	2130
	92.98	568.8	4282	70	110.1	2112
28-Jun	252.8	359.2	4170	70	100.6	1463
	273	355.8	4148	70	107	1573
	266.6	352.4	4360	70	111.9	1933

Dissolved Copper (µg/L)

Table B.45 Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	70	195.28	401.4	70	89.02	200.8
	70	198.54	394	70	88.38	207.9
	70	195.42	385.8	70	88.36	201.7
04-Feb	70	313.8	382.7	70	98.59	105.4
	70	302.4	381.1	70	98.53	107.7
	70	286.4	368.2	70	102.2	104.4
08-Feb	70	309.1	789.6	70	96	184.5
	70	288.6	727.4	70	91.73	173.8
	70	321.4	672.2	70	90.51	165.8
11-Feb	70	141.7	882.4	70	84.94	266.4
	70	144.2	898.2	70	77.37	263.6
	70	152.9	925.5	70	77.19	219.4
15-Feb	89.75	300.5	631.1	70	99.98	397.5
	94.44	308.7	1261	70	93.22	411.9
	90.99	305.7	1334	70	98.95	415.3
18-Feb	70	272.6	1491	70	106.2	141.8
	71	273.6	795.6	70	106.2	142.7
	70.01	290.4	824.5	70	107.9	145.9
22-Feb	70	200.7	790.5	70	90.25	530.6
	70	204.2	760.2	70	87.7	477.7
	70	197.6	802.5	70	88.68	521.1
25-Feb	70	197.2	1320	70	102.7	158.7
	70	196.3	1530	70	99.69	162.6
	70	200.9	1542	70	101	165.4
01-Mar	154.8	491.3	1936.2	70	127.5	659.9
	156.6	493.8	1935.6	70	146.4	769.8
	152.2	493.7	1907	70	124.9	776.8
04-Mar	75.76	390.3	2178		185.4	929.6
	75.4	443.1	2170		185.9	966.8
	74.22	450	2202		176.9	959.4
08-Mar	88.74	381.8	2778	70	102.4	148.9
	87.36	379	2416	70	103.7	136.8
	84.32	79.6	3372	70	102.9	149.5
11-Mar	99.5	372.6	2410	70	139.2	190.6
	100.54	376.6	2244	70	127.1	188.7
	98.12	365.2	2528	70	139	179.9
15-Mar	86.23	361.6	1429	70	148.3	1007
	84.78	368.7	1317	70	143.4	1005
	82.84	372.7	1184	70	148.5	965
18-Mar	70	257.8	1378.2	70	109.5	401.6
	70	283.2	1457.8	70	109.7	384.3
	70	272.6	1410	70	113.6	389.9

Table B.45 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation time			Short (30min) Stagnation time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
25-Mar	78.6	424.8	2260	70	147.4	757.1
	79.94	398.4	2330	70	156	764.5
	78.2	442.2	2110	70	158.9	671.3
29-Mar	70	305	395.2	70	105.1	330.7
	70	296.2	395.2	70	105.7	427.6
	70	322.6	1570.8	70	107.3	447.2
01-Apr				70	149.2	513.3
				70	150	509.4
				70	150.6	507.8
05-Apr	70	328.6	2094	70	106.8	530.6
	70	329.2	2170	70	107.5	513.7
	70	358.4	2086	70	107.2	516.7
09-Apr	70	299.6		70	93.56	836.5
	70	294.2		70	83.29	828.8
	70	296.4		70	91.62	851.7
12-Apr	70	514	3580	70	106.3	198.9
	70	537	3990	70	108.1	167.3
	70	518	3544	70	109.7	167.3
15-Apr	70	216.2	87.5	70	93.05	74.56
	70	218.2	86.84	70	91.6	74.04
	70	221.2	89.3	70	90.96	74.78
19-Apr	70	374.6	70	70	91.9	101.6
	70	375.2	70	70	89.6	100.3
	70	376.6	70	70	92.42	99.79
22-Apr	70	285.6	730.2	70	90.9	272
	70	290	733.2	70	94.51	287.2
	70	283	751	70	91.2	269.7
26-Apr	70	370.8	1566.6	70	108.2	128.3
	70	331.2	1465.8	70	105.2	109.3
	70	315.2	1479	70	100.5	108.6
29-Apr	70	282.2	123.62	70	107.8	377.8
	70	266.8	122.94	70	110.4	420.3
	70	283.4	128.36	70	110.4	384.9
10-May	18.15	107	810.1			
	18.61	109	868.1			
	16.41	106	906.9			
17-May	50.28	335.4	802.2	30.85	169.6	277.2
	48.74	333.2	837.6	30.03	162.5	270
	48.54	340.8	819	30.04	152.4	283.2
25-May	39.04	345.8	3124	10.37	86.93	907.8
	40.62	344.2	3266	10.24	85.87	887.4
	40.4	343.4	3658	9.367	84.91	890
31-May	171.84	530.2	135.02	23.63	103.9	331.2
	173.84	540.2	138.14	22.63	106.8	325.7
	178.16	534.8	12996	23.4	106.5	334

Table B.45 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using sodium silicate as a corrosion inhibitor and buffered with sodium silicate. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation time			Short (30min) Stagnation time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
07-Jun	78.86	191.82	3980	29.57	101.7	1725
	74.54	192.08	4226	27.45	102	1585
	84.98	198.44	4312	27.12	94.15	2109
14-Jun	63.6	359.8	5738	70	70	409.9
	64.88	345.6	5944	70	70	413.5
	82.44	363.4	5742	70	70	407.3
21-Jun	66.58	400.8	4290	70	87.03	1751
	55.42	416.6	4226	70	91.83	1834
	53.82	398.2	4188	70	89.06	1650
28-Jun	180.92	373.2	8			
	178.52	310				
	176.12	309				

APPENDIX C – Phosphate Data

Pipe loops

Tables presented in this section are the raw data pertaining to the pipe loops that used phosphate as a corrosion inhibitor. Data is presented in chronological order from which it was collected. For each section the data is presented first for the influent and effluent of the pipe loops then for the long and short stagnation time.

Corrosion Rate(mil/year)

Table C.1 Raw data displaying corrosion rate value for pipe loops using phosphate as a corrosion inhibitor.

Date	High Chloramines	Low Chloramines	Chlorine
16-Jul			
20-Jul			
23-Jul			
27-Jul			
30-Jul		7.15	
03-Aug		2.98	4.54
06-Aug		5.9	3.14
10-Aug	1.86	3.03	1.84
14-Aug	2.98	8.63	3.22
17-Aug	2.76	3.31	2.91
20-Aug	29.1	4.25	2.94
24-Aug	2.32	3.38	2.63
27-Aug	5.91	5.3	2.87
31-Aug	1.97	4.36	2.83
03-Sep	2.27	4.99	3.14
14-Sep	2.32	3.73	2.58
17-Sep	3.27	4.32	2.72
21-Sep	6.95	4.46	2.55
24-Sep	4.06	3.58	2.06
28-Sep	3.45	3.45	2.76
01-Oct	3.92	4.43	2.35
05-Oct	2.76	2.71	2.15
08-Oct	4.89	5.97	2.11
12-Oct	3.56	2.43	1.84
15-Oct	6.91	2.32	1.64
19-Oct	4.25	2.56	1.48
22-Oct	3.69	2.41	1.53
26-Oct	3.14	2.14	1.45
29-Oct	5.6	1.73	1.65
02-Nov	3.92	1.85	1.53
05-Nov		1.79	1.18
09-Nov		1.66	1.16
12-Nov	1.96	1.72	1.13
16-Nov	2.19	1.62	1.13
19-Nov	2.65	1.53	1.1
23-Nov	2.64	1.54	0.41
26-Nov	3.66	3.19	1.73

Table C.1 continued Raw data displaying corrosion rate value for pipe loops using phosphate as a corrosion inhibitor.

Date	High Chloramines	Low Chloramines	Chlorine
30-Nov	2.25	1.72	1.09
03-Dec	1.35	1.76	1.12
07-Dec	3.14	1.49	0.89
09-Dec	2.7	1.82	0.96
01-Feb	2.33	2	0.82
04-Feb	3.01	1.65	0.8
08-Feb	2.14	1.83	0.81
11-Feb	4.36	1.45	0.99
15-Feb	2.05	1.66	0.85
18-Feb	3.34	1.7	0.79
22-Feb	2.03	1.62	0.86
25-Feb	2.39	1.56	0.85
01-Mar	2.11	2.52	0.67
04-Mar	2.64	2.97	0.82
08-Mar	2.38	3.38	0.95
11-Mar	2.62	3.56	1.3
15-Mar	1.9	3.85	0.78
18-Mar	2.6	4.14	0.91
22-Mar	2.12	6.58	13.66
25-Mar	2.51	3.79	2
29-Mar	1.85	3.05	1.67
01-Apr	2.32	3.17	1.42
05-Apr	1.66	2.99	1.3
09-Apr	2.07	3.12	1.36
12-Apr	2.27	3.17	1.2
15-Apr	1.7	3.05	1.21
19-Apr	1.86	2.81	1.21
22-Apr	2.97	8.89	13.4
26-Apr	2.34	3.1	2.32
29-Apr	9.71	3.09	1.87

pH

Table C.2 Raw data displaying pH values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	8.64	6.38	7.1	8.8	5.9	6.6
06-Jul	6.32	6.07	7	6.81	8.57	6.45
09-Jul	7.51	8.75	7.39	6.68	8.03	7.29
13-Jul	8.72	7.91	6.51	8.3	6.3	7.14
16-Jul	8.78	6.95	7.08	6	8.1	9.01
20-Jul	8.74	6.8	6.65	8.53	6.99	7.25
23-Jul	8.78	7.32	9.64	8.55	7.31	6.93
27-Jul	6.42	7.23	6.11	7.93	7.91	7.81
30-Jul	6.3	8.04		6.07	6.92	
03-Aug	6.42	6.61	6.82	5.8	6.23	6.4
06-Aug	7.55	6.2	6.43	7.06	6.97	6.51
10-Aug	8.59	6.15	6.26	7.2	5.9	6.68
14-Aug	6.82	7.96	6.25	6.99	7.61	5.99
17-Aug	6.6	6.1	6.08	7.01	6.38	6.29
20-Aug	6.22	7.82	9.97	6	7.13	8.39
24-Aug	6.92	5.89	10.01	6.72	6.19	10.14
27-Aug	7.75	6.67	6.72	8.1	6.49	6.88
31-Aug		8.64	9.69	6.67	8.1	9.39
03-Sep		7.09	6.68		7.7	8.12
14-Sep				6.72	5.94	6.72
17-Sep	7.06	6.01	6.93	7.1	6.32	6.65
21-Sep	5.51		7.47	7.21		6.98
24-Sep	3.28		5.53	8.27		6.95
28-Sep	3.74	64	8.02	6.67	5.43	7.46
01-Oct	8.42	7.34	6.93	7.15	6.7	8.9
05-Oct	8.56	6.42	9.59	6.1	5.59	8.32
08-Oct	5.57		6.57	8.64	8.36	7.25
12-Oct				7.98	5.63	6.98
15-Oct	8.52	7.13	6.76	8.4	6.6	7.35
19-Oct				6.77		
22-Oct				7.91	6.71	
29-Oct	3.22	5.97	7.24	3.48	6.06	6.83
02-Nov	5.99	5.51	6.07	6.2	6.84	7.11
05-Nov	7.37	7.25	6.43	7.63	7.3	7.02
09-Nov		5.76	6.05		6.83	6.74
12-Nov	7.1	6.4	6.47	6.04	6.6	7.15
16-Nov				5.63	5.71	6.75
19-Nov	5.56	6.97	654	7.33	6.78	7.45
23-Nov				6.98	6.32	6.94
26-Nov				8.52	7.79	9.41
30-Nov				6.62	6.75	7.03
03-Dec	6.87	685	6.49	6.22	8.15	8.31
07-Dec				8.41	6.58	6.6
09-Dec	6.8	7.2	7.2	6.6	5.7	6.4
01-Feb	7	5.51	7.36	8.92	7.96	7.55

Table C.2 continued Raw data displaying pH values for pipe loops using phosphate as a corrosion inhibitor

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	8.06	7.69	7.07	7.72	7.47	7.71
08-Feb	3.9	7.89	11.31	6.36	6.62	6.16
11-Feb	7.52	8.83	10.26	8.77	6.04	5.95
15-Feb	8.35	8.71	7.7	6.01	6.14	5.73
18-Feb	8.2	8.56	7.42	8.34	6.41	5.79
22-Feb	8.7	8.11	10.16	6.98	6.14	7.33
25-Feb	3.27	8.81	9.71	7.74	6.16	6.5
01-Mar	2.59	8.53	10.94	6.56	5.89	6.32
04-Mar	3.16	8.43	8.64	7.72	6.5	7.41
08-Mar	3.21	9.21	10.37	7.63	6.36	7.94
11-Mar	8.06	10.12		7.62	6.16	
15-Mar	3.39	8.74	8.11	6.56	6.92	7.15
18-Mar	6.16	6.05	2.72	7.91	7.12	7.5
22-Mar	7.99	9.73	11.2	6.34	2.96	3.06
25-Mar	8.06	9.63	10.73	7.67	6.6	6.56
29-Mar	8.17	9.78	10.37	7.47	6.13	6.58
01-Apr	8.4	9.65	9.96	7.58	6.71	7.35
05-Apr	7.77	8.23	10.3	6.4	6.38	6.62
09-Apr	7.66	10.43	10.71	5.98	6.77	6.31
12-Apr	7.53	10.46	10.77	5.55	6.25	6.68
15-Apr	8.34	9.09	9.28	6.08	7.1	6.8
19-Apr	6.96	3.44	3.34	6.82	6.68	6.32
22-Apr	3.74	9.64	10.3	8.02	3.36	3.27
26-Apr	3.37	10.76	7.02	7.89	6.27	5.85
29-Apr	7.24	11.15	10.57	3.5	7.02	6.51
10-May				7.78	6.95	6.05
17-May				6.5	8.47	9.43
25-May				6.46	7.3	6.81
31-May				6.66	8.06	7.24
07-Jun				6.88	7.87	6.82
14-Jun				6.39	7.12	6.87
21-Jun				6.71	6.82	6.34
28-Jun				7.83	6.98	6.84

Oxidation Reduction Potential (ORP) (mV)

Table C.3 Raw data displaying ORP values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	488	614	773	369	383	744
06-Jul	567	582	800	505	374	797
09-Jul	555	444	780	500	535	679
13-Jul	437	501	777	430	58	452
16-Jul	438	580	775	373	486	642
20-Jul	418	514	547	464	493	711
23-Jul	451	515	493	425	402	503
27-Jul	542	499	735	401	533	696
30-Jul	531	536		450	433	
03-Aug	541	517	514	404	483	438
06-Aug	447	607	635	377	468	720
10-Aug	393	551	637	475	407	732
14-Aug	542	497	773	513	457	700
17-Aug	560	586	746	525	529	523
20-Aug	628	431	481	574	380	431
24-Aug	469	508	438	473	492	440
27-Aug	438	464	757	430	380	670
31-Aug						
03-Sep		542	750		395	596
14-Sep				519	374	662
17-Sep	538	519	771	503	421	665
21-Sep	498		758	578		730
28-Sep	740	690	652	452	340	754
01-Oct	473	553	814	472	490	603
05-Oct	432	516	544	489	372	604
08-Oct	475		780	454	456	702
12-Oct				565	379	746
15-Oct	508	612	789	434	489	731
19-Oct				509		
22-Oct				484	476	
26-Oct				385	467	463
29-Oct	733	554	762	609	688	767
02-Nov				657	577	768
05-Nov	469	495	810	588	514	750
09-Nov		471	471		580	750
12-Nov	425	519	799	621	514	723
16-Nov				337	373	732
19-Nov	427	456	793	600	524	715
23-Nov				437	473	784
26-Nov				380	444	399
30-Nov				222	432	566
03-Dec	472	470	795	653	480	573
07-Dec				391	476	726

09-Dec	458	461	750	594	480	620
01-Feb	478	516	681	449	418	500

Table C.3 continued Raw data displaying ORP values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	398	433	468	492	519	701
08-Feb	705	537	397	373	499	741
11-Feb	467	418	498	418	482	653
15-Feb	418	503	569	589	564	678
18-Feb	432	380	742	454	574	735
22-Feb	493	414	435	546	615	711
25-Feb	745	426	483	498	408	731
01-Mar	782	499	392	469	491	687
04-Mar	761	456	565	505	628	691
08-Mar	752	458	434	512	445	671
11-Mar	595	384		486	558	
15-Mar	776	391	710	529	519	483
18-Mar	643	754	868	534	487	614
22-Mar	473	430	468	499	581	490
25-Mar	556	439	455	488	469	467
29-Mar	547	427	447	479	455	701
01-Apr	495	415	433	491	543	681
05-Apr	547	461	411	488	504	748
09-Apr	518	355	412	529	422	506
12-Apr	552	426	379	577	396	743
15-Apr	481	385	448	563	372	727
19-Apr	649	829	912	613	466	727
22-Apr	724	462	413	483	574	473
26-Apr	693	276	580	376	602	702
29-Apr	470	252	452	612	452	698

Dissolved Oxygen (mg/L)

Table C.4 Raw data displaying dissolved oxygen values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	6.9	7.8	6.9	6.9	7.3	6.6
06-Jul	7	8.4	7.7	7.1	7.6	7.1
09-Jul	6.8	7.3	7.3	6.4	6.3	6.1
13-Jul	6.9	7.2	6.6	7.2	6.3	6.5
16-Jul	7.3	7.1	7	6.7	6.8	6.5
20-Jul	7.1	8.3	8.6	7.1	7.3	6.9
23-Jul	5.7	5.9	5.7	5.8	5.5	5.6
27-Jul	6	6.2	6.5	6.1	6	6.1
30-Jul	6.3	6.2		6.5	5.8	
03-Aug	7.1	7.4	6.5	7.4	6.2	5.9
06-Aug	5.1	5.3	5.4	5.3	5.6	5.1
10-Aug	5.3	5.5	5.6	5.1	5.3	5.2
14-Aug	4.8	4.6	5	4.8	5.1	4.9
17-Aug	5.7	5.5	5.4	5.6	6.3	5.7
20-Aug	4.9	4.7	4.5	4.7	5.1	4.7
24-Aug	4.8	4.7	5.2	4.9	4.8	4.5
27-Aug	5.6	5.7	5.2	5.7	5.3	5.3
31-Aug		5	4.5	4.8	4.6	4.5
03-Sep						
14-Sep						
17-Sep	69	61	6.7	6.1	6.9	6.5
21-Sep	10		10	7.4		8.5
24-Sep	5.9		6.8	6		6.6
28-Sep	10.1	9.9	10.1	9.2	10.9	9.7
01-Oct	10.9	10.4	10.3	10.7	10.7	10.4
05-Oct	5.4	5.4	6.4	5.2	6	5.2
08-Oct	5		5.3	5.7	5.6	5.5
12-Oct				11	11.1	10.6
15-Oct	11.3	1.4	104	10.9	11.5	11
19-Oct				6.2		
22-Oct				5.9	6.1	
26-Oct				5.8	57	5.5
05-Nov	6.6	6.8	6.4	6.5	6.4	5.2
09-Nov		6.7	6.5		6.2	5.8
12-Nov	6.8	6.7	6.5	6.8	5.9	6.3
16-Nov				5.8	6	5.9
19-Nov	6.7	7	6.8	5.6	6.1	6.3
23-Nov				6.4	6.5	6.9
26-Nov				6.7	6.1	6.4
30-Nov				5.4	6.3	5.7
03-Dec	7	7.3	7	6.9	6.9	6.9
07-Dec				6.8	6.2	6
09-Dec	6.8	7.2	7.2	6.6	5.7	6.4
01-Feb						

04-Feb		

Table C.4 continued Raw data displaying dissolved oxygen values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
08-Feb						
11-Feb						
15-Feb						
18-Feb	10	10	10	8.4	9.8	8.8
22-Feb	9.9	10.5	10.5	8.3	9.6	9.8
25-Feb	10.5	11	10.4	9.2	9.5	9.8
01-Mar	10	9.7	9.9	8.1	9.9	9.1
04-Mar	9.3	10.1	9.7	8.7	9.3	9.1
08-Mar	9.7	10.4	9.6	8.2	9.6	7.9
11-Mar	9.7	9.5		8.8	8.2	
15-Mar	9.4	9.3	9.9	8.8	9.2	8.7
18-Mar	9	9.1	9.1	8.7	8.7	9
22-Mar	9.5	9.4	9.4	7.7	9.2	8.6
25-Mar	10.4	9.5	9.2	8.5	6.6	6.56
29-Mar	9.8	9.8	10.4	8.2	9.1	8.9
01-Apr	9.3	10	9.9	8.7	8.9	8.6
05-Apr	9.8	10	9.3	8.2	8.9	8.7
09-Apr	9.2	9.2	9.5	8.2	8.4	8.1
12-Apr	9.6	10.1	10.1	8.4	9.9	9.1
15-Apr	9.4	9.6	9.2	8.5	9.8	8.8
19-Apr	9.1	9.5	10.8	7.8	8.9	8.5
22-Apr	9.8	9.1	9.3	8.7	9.3	9.4
26-Apr	9.7	10.2	9.9	8.9	9.8	10
29-Apr	10.5	9.6	10.1	9.9	10.1	10.1

Temperature (°C)

Table C.5 Raw data displaying temperature values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	8.1	18.2	18.6	22.8	18.7	22.7
06-Jul	18.2	18	18.4	22.7	23.1	22.6
09-Jul	18.1	18.5	18.6	22.9	22.8	22.9
13-Jul	18.7	18.8	19	22.8	20.5	23.5
16-Jul	19	19.1	19.5	23.7	21.3	23.5
20-Jul	19.6	19.7	19.8	23.9	21.5	22.7
23-Jul	19.6	19.7	19.8	24.4	21.4	23.1
27-Jul	19.9	20	20.1	24	24	24.6
30-Jul	20.4	20.7		21.9	21.9	
03-Aug	21.8	21.5	22.4	21.6	21.5	23.3
06-Aug	21.2	21.4	22.3	26.1	23	23.4
10-Aug	21.2	21.5	20.8	25.3	21.3	23.3
14-Aug	21.3	21.9	21.8	25.5	23.2	24.8
17-Aug	21.8	21.7	21.8	26.4	22.6	26.5
20-Aug	22	21.9	21.8	26.6	22.3	25.5
24-Aug	22.5	23	23.3	26.2	23.1	27.2
27-Aug	21.9	22.3	21.7	25.7	23.7	26.5
31-Aug		20.9	21.4	25.3	24.6	25.7
03-Sep						
17-Sep	18.7	18.8	18.9	23	18.8	22.9
21-Sep	17.7		18.3	22.4		22.4
24-Sep	18.6		18.7	23.3		22
28-Sep	18	17.5	18	22.2	21.4	22.1
01-Oct	18.1	17.5	17.9	22.7	22.4	22.2
05-Oct	17	17.2	17.5	22	21.9	21.2
08-Oct	17.1		17	21.7	21.9	21.9
12-Oct				20.9	20.2	20.5
15-Oct	15.7	15	15.5	18.7	20	20.5
18-Oct				15.3		
22-Oct				20	19.5	
26-Oct				20.2	19.2	19.4
29-Oct	14	12.9	14	17.3	18.3	19.1
02-Nov				15.7	18.7	18.3
05-Nov	13	12.6	13.2	14.1	18.1	19.3
09-Nov		11.8	12.7		17.4	16.6
12-Nov	11.8	11.6	12.6	14.1	17.2	16.9
16-Nov	11.7	11.2	12.3	15.1	17	17.3
19-Nov	11.7	11.2	12.3	15.1	17	17.3
23-Nov				17.2	16.9	15.7
26-Nov				17.3	18.1	17.8
30-Nov				16.2	17.5	16.2
03-Dec	10.9	11.4	12.3	14.6	14.8	13.4
07-Dec				12.7	16.3	16.5
09-Dec	10.3	10.7	11.3	12.3	16	14.9

01-Feb	5.8	7.3	7.3	15.4	13.8	12.6

Table C.5 continued Raw data displaying temperature values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	11.1	11.3	11.3	17	17.5	16.8
08-Feb	12.2	10.6	12.4	17.4	17.1	17.9
11-Feb	8.9	8.3	9.2	14.2	14.3	14.9
15-Feb	12.2	12.9	13.6	19.6	19.1	19.8
18-Feb	8.9	8	9.1	14.3	13.5	14.3
22-Feb	8.7	7.8	8.7	14.6	13.7	13.2
25-Feb	8.7	7.9	8.4	13.2	13.3	13.4
01-Mar	8.9	8.1	9.2	14.5	11.4	14.1
04-Mar	8.6	7.9	9.2	14.3	11.4	13.4
08-Mar	8.8	8.3	9	14.4	11	11.9
11-Mar	8.7	8.6		13.6	11.6	
15-Mar	8.6	8.5	8.8	14.1	11.2	13
18-Mar	9.2	9.7	9.4	14.7	11.9	14
22-Mar	9.6	9.3	9.9	15.7	11.8	14.8
25-Mar	9.6	9.1	9.5	15.7	12.4	15.3
29-Mar	8.8	8.7	9	14.1	13.6	14
01-Apr	10.1	9.6	10.7	15.5	15.2	15.2
05-Apr	9.9	9	9.7	15.8	15.4	15.7
09-Apr	10.9	10.8	11.3	16.3	15.9	16.4
12-Apr	11.1	11	11.3	17.1	16.4	17.1
15-Apr	11.2	11	11.2	17.1	16.3	16.9
19-Apr	11.7	11.3	11.6	16.4	16.7	16.9
22-Apr	11.4	11.3	11.3	16.7	16.5	15.7
26-Apr	11.9	11.7	12	17.7	16.9	17.1
29-Apr						
10-May				18.7	16.5	19.7
17-May				22	21.8	22.5
25-May				20.4	21.2	21.7
31-May				21.5	20.8	21
07-Jun				21.3	21	20.4
14-Jun				22.6	21.9	22.5
21-Jun				23.3	22.9	21.8
28-Jun				22.9	23.2	21.3

Total Chlorine (mg/L)

Table C.6 Raw data displaying total chlorine values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	5.2	0.95	6.1	5.1	0.35	1.3
06-Jul	1.37	0.4	15.6	1.1	4.9	6.5
09-Jul	0.6	7	3.5	0.5	5.4	1
13-Jul	12.4	4.7	3.4	15.7	0.52	0.09
16-Jul	17.7	3.6	6.5	0.14	6.1	5.8
20-Jul	21	2.8	1.66	8.4	4	1.31
23-Jul	13.7	3.9	4.1	8	4	0.17
27-Jul	1.7	2.7	1.1	3.5	3.9	2.5
30-Jul	3.2	3		0.38	9.8	
03-Aug	1.75	0.05	0.12	0.4	0.6	0.05
06-Aug	8.1	0.11	0.31	5.6	3	2.8
10-Aug	8.6	2.1	0.22	11.5	0.13	4.5
14-Aug	9.3	9.3	1.9	15.1	5.2	0.21
17-Aug	11.5	0.43	0.68	8.9	0.39	0.1
20-Aug	4.5	4.6	3.4	3.4	1.5	1.95
24-Aug	5	0.27	3.4	4.2	0.11	3.1
27-Aug	7.8	1.4	4	10.1	0.67	0.25
31-Aug		2.3	5.5	0.1	2.4	4.2
03-Sep		5.1	1.2		5.3	1.29
14-Sep				0.3	0.3	0.02
17-Sep	2	0.02	1.54	5.2	1.5	0.46
21-Sep	0.06		7.3	0.8		3
24-Sep	0.04		0.45	11.2		0.13
28-Sep	0.05	0.04	15.1	0.14	0.03	10.1
01-Oct	19.3	0.22	6.9	4.1	1.8	5.5
05-Oct	11	0.05	3.8	0.2	0.03	4.4
08-Oct	21		0.78	19.9	12	0.34
12-Oct				4.7	0.03	1.4
15-Oct	18.4	0.06	2.7	17.2	0.42	2.08
19-Oct				2.6		
22-Oct				11.3	1	
26-Oct				1.8	0.05	0.05
29-Oct	3	0.05	7.4	1.47	0.36	6.5
02-Nov	3.4	0.4	3.5	1.9	0.05	5
05-Nov	7.1	0.06	2.3	7.7	0.5	1
09-Nov		0.03	2.18		0.2	1.36
12-Nov	7	1	2.2	0.68	0.7	1.4
16-Nov				0.01	0.04	1.1
19-Nov	0.06	0.12	1.89	4	0.25	1.02
23-Nov				1.9	0.07	2.5
26-Nov				9.9	5	0.63
30-Nov						
03-Dec	2.8	0.07	2.11	1.67	3.5	1.6
07-Dec				10.9	0.6	0.17
09-Dec	7.8	4.1	1.3	9.6	4.2	0.5

01-Feb	4.2	3.4	0.41	1.5	5.9	0.14

Table C.6 continued Raw data displaying total chlorine values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	9.8	4.8	0.06	7.3	4	1
08-Feb	14	5.7	12.8	0.38	4.6	1.11
11-Feb	11.9	6	0.18	32	3.7	0.11
15-Feb	9.3	5.2	2.7	1.85	3.4	0.41
18-Feb	18.2	8.8	6.4	10.5	4.5	1.3
22-Feb		5	4.1	2.4	2.8	2.12
25-Feb	14.2	8.3	1.85	13	3.1	0.15
01-Mar	16	4.1	2.1	4.2	1.1	0.37
04-Mar	12.6	4.9	3.1	13.8	4	0.73
08-Mar	4	4.4	10.5	6.1	4.4	0.53
11-Mar	21	3.9		10.7	6.9	
15-Mar	8.2	4.7	1.14	4.9	4.6	0.06
18-Mar	10.8	3.5	1.51	12.1	4.1	0.46
22-Mar	17.6	5.6	4.6	5	0.02	0.01
25-Mar	22	6.1	4.4	14.9	4.6	0.32
29-Mar	20.8	5.6	3.3	1.4	2.4	0.19
01-Apr	16.6	6.4	4.5	7.6	4.4	1
05-Apr	19	3.4	0.02	8	2	2.1
09-Apr	2.7	5.2	5	1.4	1.6	0
12-Apr	12.8	5.4	3.3	7.4	4.6	1.75
15-Apr	16.6	11.5	5	5.3	1.6	1.24
19-Apr	13.5	2.5	2.4	0.49	1.91	1.28
22-Apr	7.1	5.1	2.14	13.3	0.04	0.02
26-Apr	4.8	4.5	1.51	7.1	4.3	0.19
29-Apr	12.5	5.9	3.1	1.7	4	0.6
10-May				6.6	2.9	0.55
17-May				4.8	3.7	2.2
25-May						
31-May				6.5	2.5	1.72
07-Jun				5.8	3.5	1.19
14-Jun				1.7	2.4	0.15
21-Jun				0.8	2.6	2
28-Jun				6.8	3.2	1.33

Free Chlorine (mg/L)

Table C.7 Raw data displaying free chlorine values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	4.8	0.9	5.9	4.3	0.34	1.01
06-Jul	1.27	0.03	14.3	1.1	4.4	4.8
09-Jul	0.06	6.1	3.5	0.2	5.1	1
13-Jul	13.5	0.03	0.03	0.5	0.03	3.1
16-Jul	2.8	3	4.1	0.06	3.7	5.2
20-Jul	4.7	0.8	1.5	1.9	1.4	0.18
23-Jul	1.5	3.5	3.7	2.8	3.3	0.11
27-Jul	0.9	0.9	0.6	0.2	1.8	1.7
30-Jul	1.1	1.7		0.08	0.17	
03-Aug	1.2	0.05	0.02	0.2	0.1	0.03
06-Aug	7	0.05	0.26	2.1	2.5	2.4
10-Aug	5.8	1.1	0.09	3.3	0.09	4.3
14-Aug	6.8	4.7	1.19	4	0.15	0.18
17-Aug	5.9	0.17	0.56	2.5	0.11	0.06
20-Aug	1.6	2.9	2.5	0.17	0.16	1.94
24-Aug	1.3	0.2	2.8	1.8	0.1	2.7
27-Aug	4.1	0.45	2.1	3.5	0.44	0.15
31-Aug		0.3	4.8	0.07	2	3.3
03-Sep		1.4	1.13		1.22	1.06
14-Sep				0.2	0.3	0.02
17-Sep	1.6	0.02	1.46	4.9	1.4	0.44
21-Sep	0.03		6.4	0.5		2.4
24-Sep	0.03		0.38	10.9		0.05
28-Sep	0.02	0.04	13.1	0.1	0.02	9.1
01-Oct	17.3	0.21	6.5	1.3	1.6	5.2
05-Oct	10.1	0.03	3.6	0.1	0.01	3.2
08-Oct	19		0.68	3.5	11	0.27
12-Oct				4.5	0.02	1.3
15-Oct	14.9	0.36	2	14.9	0.36	2
19-Oct				0.1		
22-Oct				0.41	0.4	
26-Oct				0.07	0.04	0.02
29-Oct	0.61	0.02	7.4	0.05	0.32	5.6
02-Nov	1.63	0.03	3.4	0.15	0.02	4.8
05-Nov	2	0.02	2	2	0.16	0.77
09-Nov		0.02	2.09		0.07	1.3
12-Nov	2.1	0.53	1.93	0.58	0.23	1.24
16-Nov				0.01	0.02	1.05
19-Nov	0.03	0.03	1.69	1	0.23	0.93
23-Nov				1.54	0.03	2.4
26-Nov				9.7	5	0.6
30-Nov						
03-Dec	2.7	0.02	2.1	1.61	2.6	1.6
07-Dec				10.4	6	1.7
09-Dec	7.8	3.6	1.3	8.4	0.41	0.4

01-Feb	4.2	1.1	0.37	1.3	5.9	0.13

Table C.7 continued Raw data displaying free chlorine values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	9.4	4.6	0.03	7.3	3.5	0.82
08-Feb	4.9	3.5	11.3	0.19	0.17	1
11-Feb	10.2	1.8	0.17	9.9	0.9	0.06
15-Feb	1.2	4.1	2.7	0.07	0.5	0.39
18-Feb	1.7	0.5	5.8	11	0.4	0.13
22-Feb		1.3	1.6	0.2	2.3	2.04
25-Feb	2.6	5.9	1.75	12.4	0.7	0.12
01-Mar	0.3	1	1.9	3.5	0.3	0.31
04-Mar	2	3.3	2.6	11.5	3.5	0.73
08-Mar	0.2	0.8	10.3	2.1	2.3	0.49
11-Mar	12.8	1		1.5	0.6	
15-Mar	4.3	0.3	1.1	2.9	0.4	0.04
18-Mar	1.7	0.8	1.51	1.9	3	0.43
22-Mar	1.7	0.6	4.6	1.7	0.02	0.01
25-Mar	0.5	1.7	3.7	12.2	1.7	0.28
29-Mar	0.8	2.4	3.4	0.4	2.4	0.16
01-Apr	3	2.4	4.4	2.8	0.8	0.7
05-Apr	1.8	0.3	0.02	1	0.3	2
09-Apr	5.8	0.6	4.1	0.2	0.5	0
12-Apr	1.8	0.6	3.1	0.8	1	1.71
15-Apr	7.4	3.3	4.9	1.5	0.1	1.06
19-Apr	8.1	0.4	2.3	0.05	1.19	1.25
22-Apr	1.2	3.1	2.08	0.6	0.04	0.02
26-Apr	0.5	0.8	1.42	2.2	0.4	0.12
29-Apr	2.6	0.4	3.1	0.3	0.6	0.6
10-May				4.5	2.2	0.5
17-May				1.9	0.8	2
25-May						
31-May				5.3	0.8	1.65
07-Jun				3.8	1.3	1.17
14-Jun				1	2.4	0.11
21-Jun				0.6	2.5	1.8
28-Jun				0.8	1.8	1.32

Turbidity (NTU)

Table C.8 Raw data displaying turbidity values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	0.309	0.129	0.203	0.517	0.244	4.831
06-Jul	-0.027	0.176	0.427	3.086	0.07	4.396
09-Jul	0.106	0.456	1.376	0.042	0.285	2.966
13-Jul	0.241	0.168	0.103	0.943	0.27	3.323
16-Jul	0.36	0.384	0.198	1.781	0.657	5.001
20-Jul	0.166	0.557	2.498	0.449	1.108	0.489
23-Jul	0.14	0.259	2.705	0.581	0.2075	3.915
27-Jul	0.148	0.234	0.242	0.443	0.282	4.587
30-Jul	0.11	0.387		0.11	0.393	
03-Aug	0.181	0.137	2.622	0.209	0.468	0.531
06-Aug	0.195	0.29	0.611	0.363	0.26	0.552
10-Aug	0.149	0.289	0.604	0.599	0.086	0.716
14-Aug				1.966	0.092	0.199
17-Aug	0.272	1.171	0.137	1.211	0.099	5.281
20-Aug	0.24	0.045	0.575	1.088	0.158	0.799
24-Aug	0.149	2.188	5.268	1.258	0.227	0.403
27-Aug	0.07	0.861	0.982	0.763	0.161	1.092
31-Aug		0.256	0.693	1.115	0.023	0.19
03-Sep		0.572	0.654		0.104	0.24
14-Sep				0.197	0.212	4.224
17-Sep	0.272	0.182	147.961	0.194	0.394	0.648
21-Sep	0.131		4.177	0.372		2.417
24-Sep	0.079		0.195	0.096		0.338
28-Sep	0.115	0.082	0.42	0.221	0.159	0.545
01-Oct	0.478	0.345	0.231	0.76	0.465	0.533
05-Oct	0.269	0.241	4.225	0.161	0.379	0.407
08-Oct	0.396		0.414	0.073	0.449	0.145
12-Oct				0.076	0.454	0.2
15-Oct	0.146	0.338	0.247	0.295	0.147	0.197
19-Oct				0.333		
22-Oct				0.564	0.098	
26-Oct				0.228	0.372	0.332
29-Oct	0.372	0.472	0.719	1.079	0.235	0.206
02-Nov	0.101	0.383	0.201	2.047	0.472	0.627
05-Nov	0.173	0.18	0.179	0.389	0.063	0.414
09-Nov						
12-Nov	0.363	0.331	0.328	0.355	1.426	0.63
16-Nov				0.377	0.2	0.4016
19-Nov	0.385	0.21	0.343	2.456	0.402	0.381
23-Nov				1.389	0.03	0.696
26-Nov				0.439	1.461	0.389
30-Nov				3.906	0.216	0.642
03-Dec	0.305	0.123	0.665	0.643	0.216	0.246

07-Dec						
09-Dec						

Table C.8 continued Raw data displaying turbidity values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb	0.281	0.457	0.717	0.871	0.571	2.027
04-Feb	0.339	46.913	1.023	1.273	0.243	1.153
08-Feb	0.202	0.393	3.439	0.636	0.206	0.689
11-Feb	0.93	0.252	0.99	0.679	1.12	0.293
15-Feb	0.501	0.499	0.747	0.731	0.146	0.074
18-Feb	0.172	0.099	0.203	0.199	0.268	0.185
22-Feb	0.471	1.273	1.733	0.122	0.201	0.231
25-Feb	0.592	0.363	1.526	0.099	0.35	0.281
01-Mar	0.419	0.655	2.093	0.225	0.603	-0.002
04-Mar	0.077	2.331	2.491	0.308	0.338	0.492
08-Mar	0.138	0.471	2.358	0.38	0.233	1.018
11-Mar	0.397	0.179		-0.019	0.256	
15-Mar	0.674	0.488	0.726	0.407	0.55	0.286
18-Mar	0.14	0.677	1.525	0.365	0.664	0.098
22-Mar	1.272	0.762	1.342	0.34	0.87	1.472
25-Mar	0.261	1.051	0.509	0.151	0.855	0.756
29-Mar	0.355	0.748	2.353	0.135		0.657
01-Apr	0.248	0.252	1.306	0.128	0.645	
05-Apr		0.486	1.806	0.196	0.031	0.258
09-Apr	0.087	0.2	5.701	-0.03	0.132	-0.108
12-Apr	0.399	2.55	1.45	0.191	0.174	0.21
15-Apr	0.141	0.037	0.781	0.067	0.215	0.055
19-Apr	-0.036	0.139	0.532	0.056	-0.001	-0.003
22-Apr	0.144	0.609	0.57	0.093	0.203	1.833
26-Apr	0.666	1.952	1.862	0.08	0.016	0.673

Phosophate (mg/L)

Table C.9 Raw data displaying phosphate values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
06-Jul				2.69	0.39	1.52
09-Jul	7.98	OVER	OVER	0.27	4.84	4.55
13-Jul	0.2	1.06	3.41	1.14	2.54	OVER
16-Jul	0.07	5.17	1.81	3.6	3.77	2.97
20-Jul	0.16	OVER	OVER	0.54	4.07	3.85
23-Jul	0.05	4.96	OVER	1.34	4.58	3.68
27-Jul	0.12	1.23	3.154	0.79	0.51	OVER
30-Jul	2.2	3.9		0.46	Over	
03-Aug	2.32	1.86	Over	0.6	2.17	3.03
06-Aug	OR	OR	OR	5.37	OR	4.63
10-Aug	0.62	1.56	OR	OR	1.23	2.99
14-Aug				3.51	1.97	1.5
17-Aug	2.96	1.91	1.55	2.63	0.55	2.36
20-Aug	1.75	0.41	5	2.31	0.83	1.87
24-Aug	1.27	1.96	1.19	1.21	0.3	1.18
27-Aug	0.91	4.6	OR	1.39	0.51	0.47
31-Aug		1.7	1.46	0.58	1	1.19
03-Sep		2.67	3.27		0.98	0.49
14-Sep				0.22	over	over
24-Sep				0.35		0.39
28-Sep				0.12	0.4	1.62
01-Oct						
05-Oct				0.42	0.32	0.82
08-Oct				1.27	over	0.44
12-Oct						
15-Oct						
19-Oct				0.56		
22-Oct	3.23	2.97				
26-Oct						
29-Oct						
02-Nov				0.23	0.39	0.53
05-Nov				0.13	0.68	over
09-Nov					0.04	0.92
12-Nov				0.06	0.3	0.77
16-Nov						
19-Nov						
23-Nov						
26-Nov				0.72	0.05	0.77
30-Nov				0.1	0.8	2.01
03-Dec						
15-Feb	2.17	1.138	3.233	0.117	0.544	1.44
18-Feb	1.165	1.43	3.7	1.044	0.534	0.682
22-Feb	1.21	1.685	2.456	0.429	1.19	0.616
25-Feb	0.99	1.33	1.13	0.982	0.665	0.552

01-Mar	3.11	1.826	4.37	0	0.428	0
04-Mar	7.159	2.136	1.827	0.936	0.915	0.398

Table C.9 continued Raw data displaying phosphate values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
08-Mar	4.972	1.42	4.379	1.027	1.77	0.541
11-Mar	2.211	1.99	n/a	1.954	1.021	n/a
15-Mar	10.097	1.047	1.756	0.307	0.217	0.393
18-Mar	1.402	51.9	18.49	1.482	1.017	1.165
22-Mar	1.266	1.049	2.099	0.431	1.247	0.047
25-Mar	0.595	0.554	1.487	0.295	0.546	0.586
29-Mar	0.248	0.261	0.183	0.006	0.194	0
01-Apr	0.391	0.29	0.429	0.088	0.228	0.113
05-Apr	2.516	0.639	3.126	0.251	1.275	1.584
09-Apr	1.587	1.638	4.459	0.809	0.855	0.57
12-Apr	1.859	1.222	2.07	1.497	1.101	0.583
15-Apr	1.438	1.387	2.138	0.603	1.024	0.215
19-Apr	2.398	8.082	12.036	0.201	0.969	0.513
22-Apr	4.215		2.188	0.985	0.39	

Alklinity (mg/L)

Table C.10 Raw data displaying alkalinity values for pipe loops using phosphate as a corrosion inhibitor.

	Influent			Effluent		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
27-May	4.9	19.6	10	8.6	18	5
08-Jun	14.4	7.2	7.6	12.8	7.9	7.3
13-Jul	53.3	13.9	16.6	78.6		21.6
03-Aug	11.3		29		11.3	8.1
24-Aug	20.8	15.3	53.6	20.8	11.4	56.5
11-Jan		12.5	5.3	n/a	7	4
25-Jan	4.6	34	23	6.6	28.6	10.9
08-Feb		16.8	86.2	9.9	20.4	12.1
25-Feb		40.8	55.1	39.9	22.6	15.2
01-Mar		35.4	66.3	16.3	6.6	10.1
29-Mar		n/a	34.3	13	n/a	14.5
20-Apr	5.5	n/a	n/a	9.7	12.9	15.3
26-Apr		102.3	22.1	22.2	8.9	3.7
29-Apr						

Copper Pipe Racks

pH

Table C.11 Raw data displaying the pH values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	8.85	6.11	6.49	8.85	6.64	6.58
06-Jul	8.13	8.53	6.32	7.4	8.64	6.5
09-Jul	8.9	8.72	6.86	8.23	8.85	6.76
13-Jul	8.68	6.85	7.07	8.7	6.45	7.2
16-Jul	8.43	8.31	8.4	7.5	8.38	7.64
20-Jul	8.56	7.24	6.5	8.56	7.04	6.39
23-Jul	8.57	7.31	7.42	8.44	4.58	7.1
27-Jul	8.05	7.7	8.31	8.01	8.04	7.2
30-Jul	6.03	8.23		6.31	8	
03-Aug	7.08	7.85	6.49	7.07	7.01	6.33
06-Aug	7.06	7.02	6.5	7.2	6.7	6.17
10-Aug	7.25	7.22	6.57	7.15	6.53	6.39
14-Aug				7.15	7.92	6.08
17-Aug	7.38	7.74	6.01	7.17	6.65	6
20-Aug	6.6	8.68	8.63	6.65	8.62	9.75
24-Aug	7.12	7.88	10.05	7.11	6.89	10.12
27-Aug	8.01	8.68	8.27	8.07	8.62	6.59
31-Aug		8.19	9.01		7.88	9.22
03-Sep		8.71	8.08		7.95	7.75
14-Sep	8.57	7.65	6.06	8.24	7.32	6.04
17-Sep	7.46	7.02	7.12	7.24	7.11	7.12
21-Sep	8.38		8.92	8.1		7.02
24-Sep	8.73		7.24	5.5		8.12
28-Sep	8.3	7.1	8.96	8.02	6.33	7.65
01-Oct	7.72	8.47	10	7.37	7.08	9.79
05-Oct	7.81	6.54	8.16	7.37	7.06	8.41
08-Oct	8.31		7.13	8.54		6.72
12-Oct	8.47	7.49	6.34	8.37	7.53	6.35
15-Oct	7.93	8.04	8.64	8.23	7.51	7.8
19-Oct	8.18	8.66		7.97	7.94	6.62
22-Oct	6.52	8.03	7.24	6.92	7.77	6.1
29-Oct	6.04	7.35	7.12	5.18	6.69	7.31
02-Nov				6.07	6.7	7.13
05-Nov	8	8.8	6.2	7.89	7.88	6.41
09-Nov		7.7	6.55		6.61	6.24
12-Nov	6.46	8.73	7.94	5.67	7.99	6.72
16-Nov	6.5	7.37	7.8	7.4	6.14	6.29
19-Nov	7.58	8.52	7.53	7.59	8.02	6.35
23-Nov	7.34	7.15	6.5	7.17	6.71	6.64

26-Nov				8.34	6.54	6.34
30-Nov	8.77	8.57	9.3		7.14	8.5
03-Dec	6.24	8.63	9.03	6.08	7.86	6.45

Table C.11 continued Raw data displaying the pH values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation Time			Short(30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
07-Dec	8.12	7.7	6.32	8.03	6.52	6.44
09-Dec	6.1	5.4	5.7	6.7	6.2	6.1
01-Feb	8.23	8.43	7.78	8	8.4	6.38
04-Feb	6.86	7.85	7.5	7.4	7.48	6.87
08-Feb	7.49	7.53	7.72	6.95	7.06	6.07
11-Feb		7.29	8.02		7.14	6.29
15-Feb	7.29	7.24	7.58	6.74	6.67	6.1
18-Feb	8.06	7.63	8.2	8.31	6.61	6.07
22-Feb	8.59	7.45	7.31	8.76	7.07	6.65
25-Feb	7.48	7.23	7.81	7.91	6.2	6
01-Mar	7.54	6.76	8.48	7.7	6.38	5.91
04-Mar	6.96	6.43	6.33	6.63	6.25	6.22
08-Mar	7.52	6.58		7.86	6.3	6.19
11-Mar	7.1	7.88		7.95	7.07	
15-Mar	7.36	6.29	6.02	7.22	6.68	5.98
18-Mar	7.53	7.88	8.4	7.77	6.73	6.15
22-Mar	7.94	5.99	5.38	7.73	4.11	3.83
25-Mar	7.18	7.59	8.3	7.64	7.01	6.04
29-Mar	8.15	7.73	8.59	8.07	6.49	6.3
01-Apr				7.96	6.73	6.43
05-Apr	8.25	8.4	7.26	7.68	7.24	6.23
09-Apr	7.72	8.24	6.15	7.22	7.76	6.04
12-Apr	7.32	8.15	7.98	7.33	7.54	6.88
15-Apr	7.19	8.12	6.6	7.13	7.72	6.44
19-Apr	8.02	8.21	7.97	7.68	7.82	6.38
22-Apr	7.48	6.05	5.68	7.67	5.16	4.26
26-Apr	7.7	6.71	5.41	7.89	6.24	5.72
29-Apr	6.35	8.23	8.03	5.06	7.86	6.58
10-May	7.19	7.71	6.4			
17-May	7.11	8.3	9.06	6.96	8.26	9.29
25-May	6.74	7.93	7.73	6.54	7.62	7.2
31-May	7.1	8.58	8.01	6.92	8.33	8.35
07-Jun	7.07	7.53	6.91	7.37	7.63	6.72
14-Jun	7.62	7.82	7.11	7.21	7.35	6.35
21-Jun	7.79	7.38	7.24	7.41	7.25	7
28-Jun	8.05	7.74	7.54	8.08	7.52	7.47

Oxidation Reduction Potential (ORP) (mV)

Table C.12 Raw data displaying the ORP values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr)Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	414	482	475	478	638	741
06-Jul	447	440	540	550	522	807
09-Jul	443	458	538	491	513	704
13-Jul	433	469	542	480	587	702
16-Jul	434	424	443	493	493	588
20-Jul	423	441	480	484	561	710
23-Jul	375	415	484	444	491	447
27-Jul	442	450	535	454	517	630
30-Jul	435	350		506	447	
03-Aug	395	347	373	552	540	695
06-Aug	400	388	430	514	516	744
10-Aug	375	395	458	514	514	718
14-Aug				512	467	372
17-Aug	414	379	421	531	523	610
20-Aug	485	398	388	584	440	472
24-Aug	361	332	274	485	493	424
27-Aug	442	442	525	466	450	628
31-Aug						
03-Sep		439	450		514	558
14-Sep	380	354	369	437	500	661
17-Sep	445	497	520	523	620	688
21-Sep	467		600	550		714
28-Sep	446	512	586	495	618	714
01-Oct	534	529	532	541	547	540
05-Oct	449	547	459	521	514	606
08-Oct	535		668	557		724
12-Oct	479	502	561	533	595	751
15-Oct	567	602	654	560	623	610
19-Oct	441	374		478	409	417
22-Oct	452	368	450	553	506	622
26-Oct	406	360	382	450	414	424
29-Oct	632	594	688	701	677	720
02-Nov				644	606	746
05-Nov	512	498	628	541	551	748
09-Nov		568	661		646	724
12-Nov	615	539	660	628	584	679
16-Nov	555	583	609	600	634	650
19-Nov	541	557	656	559	580	663
23-Nov	579	628	677	575	737	750
26-Nov				380	409	391
30-Nov	423	393	360		435	375

03-Dec	516	438	526	597	538	581
07-Dec	492	521	568	559	610	730

Table C.12 continued Raw data displaying the ORP values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

Long (24hr) Stagnation

Short (30min) Stagnation

Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
09-Dec	489	485	578	525	511	562
01-Feb	478	516	681	539	584	728
04-Feb	463	393	466	533	536	607
08-Feb	412	406	432	525	572	705
11-Feb		496	525		533	438
15-Feb	402	444	449	387	533	615
18-Feb	512	580	430	511	581	719
22-Feb	455	507	523	525	677	722
25-Feb	530	520	449	494	581	698
01-Mar	511	605	614	497	511	642
04-Mar	533	518	559	561	583	640
08-Mar	492	525		480	535	
11-Mar	515	471		480	495	
15-Mar	527	505	553	536	540	547
18-Mar	590	510	488	491	542	604
22-Mar	464	503	540	534	559	454
25-Mar	474	462	489	466	481	451
29-Mar	466	466	500	488	520	693
01-Apr				512	554	703
05-Apr	435	431	500	538	524	712
09-Apr	485	466	627	533	458	614
12-Apr	514	424	442	571	527	665
15-Apr	586	544	721	609	555	717
19-Apr	416	392	633	503	573	686
22-Apr	471	469	508	435	473	469
26-Apr	514	669	513	502	595	718
29-Apr	620	476	556	611	516	664

Dissolved Oxygen (mg/L)

Table C.13 Raw data displaying the dissolved oxygen values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	5.9	4.6	5.5	6.1	6.8	5.5
06-Jul	6.7	6.7	6.1	7.8	7.6	7.5
09-Jul	6.2	6.3	5.9	7.1	6.9	6.6
13-Jul	6.1	5.2	5.9	6.5	6.8	6.8
16-Jul	6.3	6.2	6.4	6.7	6.8	6.6
20-Jul	6.5	6.4	6.4	6.5	8.2	7.2
23-Jul	5	5.1	3.6	5.7	5.9	6
27-Jul	5.7	5.2	5.4	5.8	6.5	6
30-Jul	4.6	5.5		6.1	5.6	
03-Aug	4.8	5.4	5.4	6	5.6	6
06-Aug	4.3	4.3	4.3	4.9	5.7	5.1
10-Aug	4.3	4.1	4.3	4.9	5.5	4.7
14-Aug				5.2	5.6	5.3
17-Aug	4.7	4.9	4.5	5.8	5.8	5.3
20-Aug	3.5	4.2	4.3	4.5	4.5	4.5
24-Aug	3.7	4.3	4.3	4.8	4.9	4.6
27-Aug	4.9	4.8	5.3	5.2	5.5	5.1
31-Aug		4.4	4.1		4.4	4.2
03-Sep						
14-Sep						
17-Sep	6	5.8	6.6	6.3	6.5	7.2
21-Sep	9.5		9.5	10		10
24-Sep	5.6		5.8	6.3		6.2
28-Sep	9	8.4	9.5	9.1	9.5	9
01-Oct	8	9.5	10.1	8.7	10	9.9
05-Oct	4.8	1.9	5.5	4.9	4.8	4.9
08-Oct	5.1		5.6	5.3		5.2
12-Oct	9.6	9.2	9.5	9.4	9.7	10.1
15-Oct	9.4	10.5	10.4	10.7	10.4	10.1
19-Oct	5.1	5.1		5.3	5	5
22-Oct	4.9	4.9	5.4	5.2	5.1	5.5
26-Oct	5.3	5.3	5.7	59	5.9	5.5
05-Nov	5.9	5.6	6.2	5.6	5.5	6.4
09-Nov		6	6.4		6.1	6.5
12-Nov	5.6	5.9	6	6.3	5.7	5.8
16-Nov	4.7	5.8	5.5	5.7	5.8	5.5
19-Nov	5.4	6.1	6.3	6	6.5	5.8
23-Nov	5.6	5.6	6.7	5.5	5.7	6.5
26-Nov				5.9	5	5.9
30-Nov	5.8	6	6.6		5.8	6.1
03-Dec	6	6.2	6.4	6.3	6	5.9

07-Dec	6.6	5.6	5.7	6.3	6.3	6.2
09-Dec	6.1	5.4	5.7	6.7	6.2	6.1

Table C.13 continued Raw data displaying the dissolved oxygen values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr)Stagnation			Short (30min)Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
01-Feb						
04-Feb						
08-Feb						
11-Feb						
15-Feb						
18-Feb	8	8.4	10.1	8.5	9.3	8.9
22-Feb	9.7	8.8	8.7	8.8	9.1	8.9
25-Feb	9.3	8.7	9.4	9.2	10.6	9.8
01-Mar	8.5	5.5	9.9	8.7	9.6	8.7
04-Mar	8.3	8	10.1	8.6	8.4	8.8
08-Mar	8.1	9.4	n/a	8.5	9.1	n/a
11-Mar	9	8.9		8.4	8.8	
15-Mar	9.5	8.4	9.2	8.5	8.5	8.8
18-Mar	9.3	8.7	9.7	10.1	9.1	8.3
22-Mar	8.3	5.2	1.4	8.2	8.6	7
25-Mar	7.18	7.59	8.3	7.64	7.01	6.04
29-Mar	8.4	7.9	8.2	8.5	8.4	8.6
01-Apr				8.3	9.5	9.4
05-Apr	8.7	8.2	7.6	8.3	9.1	9
09-Apr	9.1	8.4	8.4	8.5	8.9	8.2
12-Apr	8.1	8	9.4	8.7	10.4	9.4
15-Apr	8.4	9	8.6	8.4	9	8.6
19-Apr	8.4	7.9	9	8.3	8.7	9.4
22-Apr	8.2	6.6	4.9	8.7	8.2	7.7
26-Apr	9.1	7.3	5.3	8.4	8.6	8.5
29-Apr	9.2	10.1	10.5	8.4	8.3	8.7

Temperature (°C)

Table C.14 Raw data displaying the temperature values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	18.6	19.1	19	18.8	19	19.1
06-Jul	18.4	19	19	18.7	18.7	18.9
09-Jul	19.4	19.3	19.3	19.2	19.1	19.2
13-Jul	19.1	19.6	19.5	19.2	19.1	19.4
16-Jul	19.7	20	20	19.8	19.1	19.7
20-Jul	20.1	20.3	20	20.4	20.2	20.2
23-Jul	20.1	20.7	20.5	20.4	20.2	20.3
27-Jul	20.4	20.8	20.9	20.8	20.4	20.7
30-Jul	20.4	21.3		21.1	20.7	
03-Aug	21.7	21.9	21.8	21.9	21.4	21.5
06-Aug	21.6	21.7	21.4	22	21.8	21.7
10-Aug	21.9	22	22	21.9	21.8	21.8
14-Aug				22.1	22.2	22.6
17-Aug	22.5	22.6	22.8	22.5	22.3	22.6
20-Aug	22.5	22.9	22.8	22.6	22.2	22.5
24-Aug	23.4	23.5	23.4	23.3	23	23.4
27-Aug	22.3	22.3	22.4	22.4	22.5	22.6
31-Aug		21.8	21.8		21.4	21.4
03-Sep						
17-Sep	19.4	19.9	19.8	19	19.9	
21-Sep	18.9		19.3	18.8		19.3
24-Sep	19		19.6	19.1		19.5
28-Sep	18.5	18.9	18.9	18.6	19	18.9
01-Oct	18.8	18.8	18.9	18.6	18.8	18.8
05-Oct	17.9	17.7	18	18.2	18.5	18.3
08-Oct	17.3		18.2	17.7		18.1
12-Oct	16.7	16.9	17.3	16.9	17.1	17.1
15-Oct	17	17.8	16.1	16.9	17.4	17.4
18-Oct	15.5	16.5		15.5	16.2	16.3
22-Oct	16.4	17.6	17.6	16.1	16.6	16.6
26-Oct	16	17.3	17.8	16.3	7	17
29-Oct	16.1	16.5	17	15.6	16.4	16.3
02-Nov				15.6	16.2	15.8
05-Nov	15.6	16.7	16.6	14.7	16.1	15.9
09-Nov		14.6	15.3		14.8	14.8
12-Nov	14.2	16	16.3	14.2	15.3	15.1
16-Nov	14.5	15.9	16.1	14.6	15.6	15.2
19-Nov	14.5	15.9	16.1	14.6	15.6	15.2
26-Nov				14.1	15.6	15.8
30-Nov	14.9	16.4	16.2		15.4	15.6
03-Dec	15.1	15.6	15.9	14	15.1	15
07-Dec	13.5	15	15.1	13.2	14.3	14.2
09-Dec	13.9	15.4	15.7	13.3	14	14.5
01-Feb	11	13	12.9	10.4	11.7	11.6
04-Feb	14.7	15.7	16.5	14	15.7	15

Table C.14 continued Raw data displaying the temperature values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
08-Feb	14.9	16.9	16.8	14.6	15.3	15.8
11-Feb		13.7	13.8		12.7	12.7
15-Feb	16.6	18.5	18.5	15.9	17.6	17.4
18-Feb	11.6	13.4	12.5	11.1	12	9.9
22-Feb	11.7	13.4	13.7	10.7	12.2	11.9
25-Feb	10.6	12.5	13	10.8	11.6	9.9
01-Mar	10.9	12.1	12.2	10.1	11.6	11.6
04-Mar	11.2	12.7	11.8	10.6	11.5	11.6
08-Mar	11.2	12.5		11	11.2	
11-Mar	11.1	13.1		11	11.4	
15-Mar	10.6	12	11.8	10.4	10.9	11.2
18-Mar	11.7	12.9	12.7	11.5	11.7	12.5
22-Mar	11.8	13.6	13.7	12	12.7	13
25-Mar	12.6	13.9	13.1	11.7	12.6	13
29-Mar	10.9	11.8	11.5	10.6	11.5	11.5
01-Apr				11.5	12.2	11.9
05-Apr	11.4	12.6	12.5	11.3	12.1	12
09-Apr	12.9	14.4	11.9	12.6	13.5	12.9
12-Apr	13.5	14.8	14.7	13.2	13.5	12.5
15-Apr	13.6	14.2	12.3	13.2	13.6	13.1
19-Apr	13.3	14.7	12.6	12.9	14.2	13.9
22-Apr	12.3	13.1	13	12.3	12.9	12.5
26-Apr	13.5	14	12.4	13.4	13.9	13.8
29-Apr						
10-May	16.9	18.2	18.2	20.9	21.1	21.9
17-May	20.7	21.3	21.6	18.1	18.2	19.1
25-May	19.5	18.7	19.7	18.6	18.2	17.8
31-May	18.8	19.7	17.9	19.5	19.7	
07-Jun	20.1	20.4	20.1	20.5	20.8	20.5
14-Jun	18.2	20.3	19.6	20.4	20.9	20.9
21-Jun	20.8	21.4	21.4	20.8	21.1	21
28-Jun	20.5	21.2	20.8			

Total Chlorine (mg/L)

Table C.15 Raw data displaying the total chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min)Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	3.1	0.07	0.03	6.5	0.23	1
06-Jul	5.9	0.02	0.03	1.27	5.1	4.1
09-Jul	2.4	3.8	0.02	8.3	11.1	1.2
13-Jul	10.1	0.04	0.05	13.6	8.2	0.67
16-Jul	6.5	0.21	0.23	6.2	6.3	3.5
20-Jul	10.6	0.04	0.05	8.1	3.3	0.95
23-Jul	1.36	0.05	0.09	8.2	3.1	0.08
27-Jul	2.7	0.03	0.15	3.9	3	3.2
30-Jul	0.11	0.97		0.33	6.9	
03-Aug	0.06	0.2	0.02	0.6	0.8	0.8
06-Aug	0.07	0.11	0.09	4.1	4.3	5.6
10-Aug	0.12	0.08	0.05	6.1	1.21	1.79
14-Aug				15	6.4	1.1
17-Aug	0.45	0.61	0.07	7.8	1.28	0.08
20-Aug	1.2	1.52	0.11	3.6	1.52	1.39
24-Aug	0.23	0.23	0.42	4.1	0.42	2.02
27-Aug	1.4	1.24	0.07	8.1	2.05	0.26
31-Aug		0.42	0.5		1.54	3.2
03-Sep		3.8	0.14		5	1.08
14-Sep	7.2	0.53	0.02	4.8	0.85	0.06
17-Sep	2.3	0.2	0.4	8.3	2.5	0.31
21-Sep	15.3		1.41	10.3		2.9
24-Sep	49		0.04	36		0.04
28-Sep	11.9	0.02	5.4	5.8	1.3	10.1
01-Oct	1.3	1.3	3.7	3.4	3.2	6.1
05-Oct	9.1	0.05	0.63	5.5	0.8	0.48
08-Oct	0.04		0.14	18.5		1.1
12-Oct	11.7	0.04	0.06	12.5	4.3	1.38
15-Oct	10.7	0.39	2.19	1.51	2.1	3.5
19-Oct	10.6	4.2		9	2.2	0.02
22-Oct	1.42	1.84		7.8	3.4	0.05
26-Oct	1.8	0.27	0.03	6.2	0.5	0.05
29-Oct	0.04	0.03	0.36	1	1.7	5.2
02-Nov				6.5	0.8	2.9
05-Nov	0.8	1.85	0.03	8.7	1.5	1.9
09-Nov		0.29	0.04		0.25	1.19
12-Nov	0.03	1.86	0.04	0.4	2	1.32
16-Nov	0.01	0.06	0.04	0.7	0.21	0.92
19-Nov	0.08	1.93	0.06	5.2	2	0.89
23-Nov	0.31	0.34	0.29	5.4	0.68	2.1
26-Nov				8.5	0.02	0.03
30-Nov						
03-Dec	0.3	1.44	0.54	1.44	3.1	1.48
07-Dec	3.7	0.7	0	8	1.9	1.4
09-Dec	4.7	0.49	0.04	10.5	3.5	0.71
01-Feb	6	4.1	2.6	7.8	6.1	3.6

Table C.15 continued Raw data displaying the total chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min)Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	0.1	2	0.05	5.8	3	0.85
08-Feb	0.03	0.62	0.05	4.2	4.1	0.94
11-Feb		0.43	0		2.6	0
15-Feb	1.7	0.26	0.03	7	3.1	0.29
18-Feb	3.6	0.27	0.05	10	0.4	0.91
22-Feb	12.1	0.28	0.07	7.7	3.2	1.86
25-Feb	10.2	0.05	0.04	12	1.8	0.96
01-Mar	9.8	0.08	0.02	9.6	2.2	0.34
04-Mar	4.6	0.11	0.02	8.9	3	0.06
08-Mar	9.8	0.12		13.9	2.9	
11-Mar	3.4	0.6		10	3.1	
15-Mar	5.9	0.5	0.05	10.8	3.2	0.07
18-Mar	5.5	0.85	0.04	10	3.4	0.44
22-Mar	2	0.6	0.6	5.1	0.98	
25-Mar	7.1	0.04	0.04	12.9	3.9	0.08
29-Mar	12.6	0.04	0.02	13	3.5	0.46
01-Apr				14.7	2.7	0.8
05-Apr	12.3	1.5	0	8.1	4.6	1.4
09-Apr	11.8	1	0.5	8.4	3.2	0
12-Apr	7.8	1.07	0.04	1.07	0.38	1.44
15-Apr	12.4	2.2	1.1	10	3.7	0.85
19-Apr	7.8	0.07	1.04	5.6	4	0.79
22-Apr	9.9	0.03	0.06	11.1	0.37	0.02
26-Apr	6.2	0.07	0.03	1.09	0.24	0.08
29-Apr	1.3	0.06	0.1	0.27	3.3	0.03
10-May	2.4	0.06	0.03			
17-May	2.5	0.8	0.01	6.1	1.8	0.18
25-May						
31-May	4.2	0.83	1.14	6.5	2.6	1.51
07-Jun	2.5	0.02	0	5.3	2.7	0.58
14-Jun	4.9	0.2	0.02	6.9	3.2	1.27
21-Jun	5	0.04	0.24	4.4	2.3	1.47
28-Jun	6.2	0.09	0.04	8	1.82	1.02

Free Chlorine (mg/L)

Table C.16 Raw data displaying the free chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min)Stagnation		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
02-Jul	2.8	0.04	0.02	6.5	0.21	0.67
06-Jul	0.57	0.01	0.03	1.21	4.5	4.1
09-Jul	2	3.5	0.02	8.2	11.1	0.9
13-Jul	0.7	0.02	0.04	6.6	0.11	0.59
16-Jul	0.9	0.1	0.12	1.5	1.8	2.8
20-Jul	3.7	0.03	0.03	2.5	2.3	0.87
23-Jul	0.79	0.01	0.06	6.8	2.6	0.06
27-Jul	1.3	0.01	0.09	1.7	1.7	2.8
30-Jul	0.04	0.23		0.25	4	
03-Aug	0.02	0.2	0.02	0.22	0.59	0.66
06-Aug	0.06	0.06	0.05	3.5	1.7	5.4
10-Aug	0.08	0.03	0.02	5.2	0.09	1.69
14-Aug				7.6	2.53	0.55
17-Aug	0.39	0.28	0.05	6.4	0.86	0.04
20-Aug	0.08	1.08	0.07	2.1	1.27	1.31
24-Aug	0.05	0.07	0.38	3.3	0.11	2
27-Aug	0.08	0.11	0.03	7	0.13	0.17
31-Aug		0.12	0.4		0.5	2.9
03-Sep		0.9	0.06		4.7	1.02
14-Sep	6.9	0.46	0.02	46	0.81	0.04
17-Sep	2.2	0.2	0.3	6.5	2.46	0.2
21-Sep	13.3		0.36	6.3	3	2
24-Sep	47		0.01	32		0.04
28-Sep	11.6	0.02	4.6	5.5	0.4	9.2
01-Oct	1.1	0.63	2.4	3.2	3	5.9
05-Oct	8.6	0.07	0.58	5.5	0.8	2
08-Oct	0.02		0.12	16.3		1.1
12-Oct	2.4	0.02	0.05	0.3	3.8	1.15
15-Oct	8	0.37	2.18	1.21	2.1	3.4
19-Oct	0.2	2.2		8.2	1.5	0.02
22-Oct	0.78	1.23		0.7	0.2	0.03
26-Oct	0.95	0.27	0.07	1.6	0.3	0.02
29-Oct	0.03	0.02	0.25	0.2	1.4	4.8
02-Nov				5.9	0.67	2.7
05-Nov	0.4	1.42	0.02	1.7	0.06	1.75
09-Nov		0.27	0.02		0.21	1.12
12-Nov	0.02	0.44	0.02	0.12	1	1.23
16-Nov	0.01	0.04	0.02	0.52	0.18	0.92
19-Nov	0.04	1.04	0.04	0.26	1.72	0.81
23-Nov	0.29	0.33	0.23	2.4	0.61	1.97
26-Nov				8.5	0.02	0.01
30-Nov						
03-Dec	0.01	1.15	0.48	1.38	3.2	1.4
07-Dec	3.2	0.64	0	7.6	1.9	1.2
09-Dec	4.7	0.19	0.03	8.7	3	0.69
01-Feb	5.2	3	2.6	6.9	1	2.7

Table C.16 continued Raw data displaying the free chlorine values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min)Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Feb	0.06	0.6	0.02	4.8	3.4	0.85
08-Feb	0.02	0.63	0.03	1.2	3.4	0.89
11-Feb		0.06	0		0.9	0
15-Feb	0.7	0.06	0.02	1.1	0.06	0.22
18-Feb	3.3	0.05	0.04	0.3	0.09	0.84
22-Feb	1.3	0.2	0.01	1.1	0.5	1.55
25-Feb	3.9	0.02	0	11.2	0.1	0.87
01-Mar	1.6	0.07	0.02	1.4	0.8	0.26
04-Mar	4	0.08	0.02	3.8	1	0.06
08-Mar	2.7	0.08	n/a	0.8	1	n/a
11-Mar	0.4	0.5		6.8	2.8	
15-Mar	1.6	0.09	0.04	1.9	0.8	0.02
18-Mar	2.7	0.29	0.03	0.8	0.8	0.39
22-Mar	1.4	0.03	0.06	1.2	0.36	N/A
25-Mar	2	0.03	0.03	2.3	0.3	0.07
29-Mar	10.1	0.04	0.02	2.2	2.7	0.41
01-Apr				6.5	2	0.6
05-Apr	0.7	0.7	0	0.4	3.6	0.7
09-Apr	0.2	0.1	0.2	0.8	0.2	0
12-Apr	5.7	0.93	0.04	1	0.38	1.41
15-Apr	6.3	0.1	1	6.7	0.2	0.79
19-Apr	1.2	0	1.04	0.8	0.6	0.76
22-Apr	2.3	0.02	0.05	4.3	0.09	0.03
26-Apr	0.6	0.05	0.03	0.38	0.22	0.07
29-Apr	1.2	0.03	0.07	0.07	0.19	0
10-May	2	0.05	0.01			
17-May	0.4	0.4	0.01	3	0.4	1.7
25-May						
31-May	3.1	0.19	1.09	1.6	2.2	1.45
07-Jun	0.3	0.02	0	1.5	1.9	0.53
14-Jun	3.7	0.1	0.01	4.1	2.1	1.25
21-Jun	4.8	0.02	0.21	2.1	2	1.47
28-Jun	1.7	0.07	0.02	2	1.74	0.94

Turbidity (NTU)

Table C.17 Raw data displaying the turbidity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	1.441	0.094	3.801	1.531	0.164	5.141
06-Jul	1.926	0.116	4.516	2.706	0.085	5.786
09-Jul	0.405	0.211	1.776	0.488	1.88	2.306
13-Jul	0.865	0.303	0.622	0.863	0.295	1.343
16-Jul	0.91	0.971	1.261	0.815	0.971	4.731
20-Jul	0.794	0.569	0.312	0.559	0.201	0.352
23-Jul	0.935	0.259	0.276	0.459	0.178	2.225
27-Jul	1.567	0.446	0.816	0.773	0.282	2.257
30-Jul	0.271	1.753		0.153	0.571	
03-Aug	0.326	0.344	0.685	0.359	0.237	0.515
06-Aug	0.542	0.434	0.45	0.51	0.297	0.501
10-Aug	3.159	1.519	0.2	0.856	0.23	0.33
14-Aug				2.426	0.331	0.986
17-Aug		0.456	2.061	1.421	0.183	3.541
20-Aug	1.988	0.159	1.588	0.831	0.119	1.228
24-Aug	1.678	0.177	0.156	0.769	0.153	1.258
27-Aug	1.982	0.209	1.252	0.809	0.137	0.6
31-Aug		0.099	0.146		0.091	0.15
03-Sep		0.333	0.116		0.876	0.156
14-Sep	0.666	0.879	3.824	0.208	0.405	2.444
17-Sep	0.785	0.347	1.001	0.545	0.361	1.351
21-Sep	0.444		0.112	0.418		0.301
24-Sep	0.621		0.162	0.457		0.151
28-Sep	0.166	0.42	0.259	0.233	0.542	0.703
01-Oct	0.805	0.383	2.27	0.817	0.342	0.279
05-Oct	1.065	1.365	0.455	0.586	0.298	0.341
08-Oct	0.742		0.414	0.344		0.346
12-Oct	0.586	0.302	0.098	0.351	0.38	0.277
15-Oct	1.38	0.515	0.248		0.27	0.329
19-Oct	0.656	0.458		0.582	0.674	0.916
22-Oct	1.247	0.309		1.747	0.171	0.324
26-Oct	0.605	0.215	0.186	0.424	0.273	0.85
29-Oct	2.489	0.263	1.219	1.629	0.226	0.289
02-Nov				0.55	0.092	0.364
05-Nov	1.995	0.033	0.484	0.459	0.033	0.446
09-Nov						
12-Nov	0.379		0.211	0.287	0.378	0.226
16-Nov	0.8	0.406	0.57	0.578	0.308	0.141
19-Nov	2.016	0.338	0.113	1.886	0.33	0.347
23-Nov	3.459	0.339	0.385	2.019	0.291	0.299
26-Nov				0.882	0.018	0.123
30-Nov	1.126	0.052	0.454		0.045	0.293
03-Dec	0.227	0.02	0.071	0.423	0.317	0.122
07-Dec						

Table C.17 continued Raw data displaying the turbidity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
09-Dec						
01-Feb	2.567	0.324	0.521	0.502	0.253	0.957
04-Feb	1.703	0.292	0.203	2.243	0.341	0.34
08-Feb	1.489	0.298	0.026	1.989	0.034	0.109
11-Feb		0.345	0.243		0.162	0.311
15-Feb	0.972	0.002	0.03	0.397	0.156	0.041
18-Feb	1.381	0.234	0.081	0.342	0.098	0.402
22-Feb	1.533	0.162	0.387	1.383	0.092	0.4
25-Feb	0.589	0.154	0.21	0.14	0.613	0.089
01-Mar	3.043	5.473	0.058	0.495	0.863	0.077
04-Mar	0.734	0.436	0.154	0.621	0.398	0.126
08-Mar	0.869	0.42		0.344	0.366	
11-Mar	2.695	0.281		0.115	0.195	
15-Mar	0.584	0.338	1.005	0.219	0.5	0.406
18-Mar	0.38	3.365	6.605	0.224	2.475	0.781
22-Mar	0.628	0.962	2.462	0.432	1.272	4.282
25-Mar	0.211	1.801	1.051	0.185	2.241	0.891
29-Mar				0.337	0.933	0.844
01-Apr	0.694	0.854	0.538	0.122	0.511	0.488
05-Apr	0.115	0.109	0.241	0.142	0.276	0.476
09-Apr	-0.12	1.401	0.488	0.671	0.106	-0.075
12-Apr	0.053	0.675	0.392	0.109	0.324	0.478
15-Apr	0.743	1.203		0.128	0.258	0.145
19-Apr	0.541	1.083	2.383	0.217	1.403	0.427
22-Apr	0.819	0.544	1.803	0.15	0.645	1.573
26-Apr	0.51	0.794	0.535	4.182	0.275	0.509

Phosphate (mg/L)

Table C.18 Raw data displaying the phosphate values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
06-Jul	0.93	0.15	0.8	2.13	4.07	3.36
09-Jul	0.06	0.75	2.71			
13-Jul	2.01	1.1	4.55			
16-Jul	1.92	4.7	OVER			
20-Jul	1.1	1.88	2.65			
23-Jul	0.78	1.25	1.2			
27-Jul	1.82	0.86	OVER			
30-Jul	0.12	Over		0.39	Over	
03-Aug	0.17	3.03	OVER	0.51	4.06	Over
06-Aug	2.92	3.52	OR	3.45	OR	OR
10-Aug	2.69	0.86	3.47	OR	0.6	OR
14-Aug				3.9	2.1	1.93
17-Aug	1.43	1.26	1.6	2.36	1.02	2.31
20-Aug	0.99	1.31	4.05	2.34	0.86	3.03
24-Aug	0.86	0.47	1.62	1.27	0.34	1.27
27-Aug	1.13	0.91	0.75		0.76	0.54
31-Aug		0.74	1.45		0.89	1.19
03-Sep		1.21	1.12		1.05	0.75
14-Sep	1.5	0.57	1.49	2.04	over	1.29
24-Sep	0.85		1.61	0.58		0.81
28-Sep	0.5	0.14	0.6	0.32	0.47	0.83
01-Oct	0.15	1.01	2.89			
05-Oct	0.44	0.19	0.88			
08-Oct	1.11		0.34			
12-Oct	over	0.07	0.55	0.13	0.13	0.86
15-Oct	1.04	0.66	1.88	1.87	0.82	1.47
19-Oct	2.01	3.38		1.69	2.78	0.4
22-Oct				0.83	0.92	0.3
26-Oct	0.47	0.35	0.31			
29-Oct	2.29	0.37	1.16			
02-Nov				1.18	0.39	1.8
05-Nov						
09-Nov						
12-Nov	0.1	0.92	1.04			
16-Nov	0.08	0.14	1.15			
19-Nov	0.33	0.8	1.26	0.89	0.44	0.93
23-Nov	0.23	0.27	0.9			
26-Nov						
30-Nov	0.71	0.74	1.05		0.039	0.287
03-Dec	0.45	0.61	1.22			
15-Feb	0.123	0.486	1.123	0.352	0.519	1.521
18-Feb	0.391	0.228	0.952	0.954	0.441	0.979
22-Feb	0.869	0.207	0.612	0.996	0.541	0.619
25-Feb	0	0.144	0.128	0.573	0.403	0.505
01-Mar	0.551	0.168	0.02	0.835	0	0.049

Table C.18 continued Raw data displaying the phosphate values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long (24hr) Stagnation			Short (30min) Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
04-Mar	0.075	0.079	0.153	0.768	0.568	
08-Mar	2.302	0.726	n/a	1.073	1.213	n/a
11-Mar	0	0.799	n/a	1.737	1.142	n/a
15-Mar	0.034	0.603	0.631	0.625	0.725	0.714
18-Mar	0.3999	0.808	0.814	0	0.236	0
22-Mar	0.034	0	0	0.769	1.99	1.367
25-Mar	0.198	0	0	0.394	0.402	0.28
29-Mar	0.171	0.091	0	0.178	0.131	0.1
01-Apr				0.105	0.55	0.177
05-Apr	1.638	1.073	0.549	0.907	1.177	1.553
09-Apr	1.019	0.993	0.749	1.514	0.984	0.787
12-Apr	0.862	0.784	1.77	1.056	0.74	1.017
15-Apr	0.85	0.688	0.726	0.942	0.837	0.784
19-Apr	1.165	n/a	1.022	0.657	0.903	1.34
22-Apr	n/a	0	n/a	0.024	0.502	1.7

Alklinity (mg/L)

Table C.19 Raw data displaying the alkalinity values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor.

	Long Stagnation			Short Stagnation		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
27-May				9.7	15.9	4
08-Jun	24.8	17.2	14.2	17.4	11	
13-Jul	66	17.6	20.7	71.5	12.4	21
03-Aug	12.5	21.3	17.5	9.9	15.6	15.7
24-Aug	18.9	26.3	50	19.5	17.8	55.7
11-Jan	40.8	9.2	9.9	37.1	9.2	5.6
25-Jan	19.1	34.5	27.8	10.5	29.8	9.4
08-Feb	24.1	19.1	19.3	18	38.3	17.3
25-Feb	27.4	33.8	16.3	24.8	16.3	15.6
01-Mar	22.6	18	n/a	19.2	n/a	4.3
29-Mar	29.8	20.4	17.9	23.3	18.6	16.8
20-Apr	19.6	20.4	16.4	14.1	14.8	13.2
26-Apr	23.9	9.6	7.3	n/a	7.4	2.8
29-Apr	7.5	23.5	13.2	n/a	20.5	13.6

Total Lead (µg/L)

Table C.45 Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short Stagnation (30min) Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	72.72	71.04	7.435	14.76	12.29	0.97
	73.07	75.04	9.083	12.13	12.04	0.97
	74.14	74.54	4.712	14.1	9.609	0.97
06-Jul	140.9	29.91	32.36	14.28	0.97	0.97
	143.1	27.15	38.4	14.27	0.97	0.97
	130.7	25.31	33.06	16.71	0.97	0.97
09-Jul	58.53	25.39	9.765	8.149	2.621	0.97
	55.89	23.19	9.686	6.478	2.394	0.97
	56.94	26.04	9.983	6.886	2.327	0.97
13-Jul	80.51	20.39	1.528	6.885	0.97	0.97
	82.6	20.11	0.674	5.469	0.97	0.97
	94.2	18.09	0.836	5.057	0.97	0.97
16-Jul	171.7	20.05	0.97	8.943	0.97	0.97
	144.1	19.55	0.97	9.344	0.97	0.97
	160.4	19.17	0.97	9.719	0.97	0.97
20-Jul	258.8	10.42	0.97	17.05	1.348	0.97
	345.8	13.31	0.97	22.92	0.97	0.97
	323.3	9.509	0.97	20.96	0.97	0.97
23-Jul	186	46.93	29.48	8.052	0.97	0.97
	170.9	46.56	29.92	11.85	0.97	0.97
	185.9	46.93	15.24	11.51	0.97	0.97
27-Jul	1073	76.05	0.625	16.68	6.484	0.97
	over	84.06	1.04	20.43	5.549	0.97
		61.29	1.159	20.93	5.507	0.97
30-Jul	1095.6	135.18		88.62	9.97	
	over	135.86		94.23	8.488	
		139.42		97.36	8.648	
03-Aug	451	96.24	4.567	73.86	5.937	6.4
	658.2	37.82	3.798	75.86	7.077	6.35
	442	39.22	3.85	71.14	7.592	5.883
06-Aug	224.6	78.96	2.371	15.21	3.596	0.97
	255.28	81.88	2.418	15.84	3.84	0.97
	249	78.36	2.09	15.93	3.287	0.97
10-Aug	500	393.4	3.235	37.96	32.1	0.97
	544	397.2	3.844	37.84	28.78	0.97
	619.4	378.3	3.834	37.92	30.59	0.97
13-Aug				30.96	6.903	0.97
				28.72	6.425	0.97
				28.27	4.715	0.97
17-Aug	130.26	83.75	3.858	63.76	9.705	0.97
	144.48	86.38	4.103	61.32	10.73	0.97
	131.04	88.9	3.459	59.32	9.186	0.97

Table C.45 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short Stagnation (30min) Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
20-Aug	464.2	42.62	0.97	28.9	14.64	0.97
	490.8	41.38	0.97	24.7	8.32	0.97
	459.2	38.98	0.97	22.66	7.08	0.97
24-Aug	300.6	5.944	0.97	2.454	1.397	0.97
	312.6	5.166	0.97	2.523	1.147	0.97
	318.4	5.614	0.97	2.458	1.206	0.97
27-Aug	272.6	30.84	0.97	33.32	6.39	1.151
	239.4	30.34	0.97	35.1	6.048	1.11
	253.4	29.34	0.97	35.11	6.425	1.052
31-Aug		29.82	0.97		6.946	0.97
		32.26	0.97		6.805	0.97
		32.52	0.97		6.799	0.97
03-Sep		15.972	0.97		5.085	1.66
		17.846	0.97		5.082	1.563
		17.564	0.97		5.264	1.612
14-Sep	1032	153.4	4.773	19.14	20.62	0.97
	over	156.18	4.76	20.88	20.97	0.97
		157.2	4.44	21.53	20.79	0.97
17-Sep	216.2	71.74	1.616	28.8	11	0.97
	242	69.16	1.771	28	11.47	0.97
	245.4	69.44	1.694	27.05	11.15	0.97
21-Sep	325.2		0.97	21.99		0.97
	300.2		0.97	21.06		0.97
	322.2		0.97	22.85		0.97
24-Sep	119.4		0.97	18.22		0.97
	99.2		0.97	11.46		0.97
	87.4		0.97	14.04		0.97
28-Sep	273.6	32.36	1.152	35.2	11.53	0.97
	267.8	36.62	0.99	35.87	9.255	0.97
	259	31.02	1.269	37.61	11.03	0.97
01-Oct	3516	19.26	21.96	44.42	3.598	0.97
	303	15.5	21.91	41.65	3.128	0.97
	347	19.84	21.56	47.8	3.365	0.655
05-Oct	607.4	1.74	0.97	85.68	8.926	0.97
	593.6	5.32	0.97	88.8	8.66	0.97
	611	11.76	0.97	86.28	8.711	0.97
07-Oct	403		0.97	35.84		0.97
	404.2		0.97	38.67		0.97
	364.6		0.97	37.86		0.97
12-Oct	81.28	11.77	0.97	37.68	3.536	0.97
	86.1	12.22	0.97	35.24	3.261	0.97
	79.18	12.18	0.97	36.67	3.527	0.97
15-Oct	267.6	11.64	0.97	20.2	4.46	0.97
	260.4	10.54	0.97	28.17	4.027	0.97
	265.2	10.54	0.97	22.25	4.045	0.97

Table C.45 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short Stagnation (30min) Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
19-Oct	332.2	31.6		39.14	3.465	1.054
	338	30.6		41.02	3.262	0.88
	344	28.48		41.11	3.438	0.903
22-Oct	974.8	6.04		101.6	3.685	1.352
	975	2		98.96	3.6	0.955
	949.4	2.86		101.8	4.176	0.812
26-Oct	559.8	22.96	2.037	54.88	6.489	1.091
	546.4	22.22	2.132	59.93	5.915	0.927
	541.8	19.74	1.789	55.24	6.337	1.032
29-Oct	1533	24.58	1.089	753.6	5.424	0.97
	1404	21.3	0.97		5.28	0.97
	1470	20.98	0.97		4.949	0.97
02-Nov				64.14	5.078	0.97
				65.04	4.975	0.97
				66.49	4.929	0.97
05-Nov	507.8	13.88	1.868	20.37	2.537	1.128
	502.4	11.44	1.748	21.48	2.372	1.074
	469.2	14.28	1.785	20.76	2.111	1.181
09-Nov		11.06	1.641		3.541	0.97
		8.7	1.551		3.338	0.97
		9.72	1.449		3.45	0.97
12-Nov	417.4	69.8	1.071	61.66	2.402	1.06
	408.6	68.78	1.254	57.5	2.34	1.086
	381.2	70.78	1.107	58.34	2.086	1.177
16-Nov	559.4	17.46	8.04	60.55	4.171	0.97
	5304	15.98	4.34	59.66	4.056	0.97
	533.4	16.68	5.84	61.78	4.271	0.97
19-Nov	183.3	3.56	0.97	31.56	1.621	0.97
	219.2	2.56	0.97	29.76	1.586	0.97
	199.28	0.8	0.97	31.06	1.443	0.97
23-Nov	374.4	14.78	0.97	18.63	4.084	0.97
	431.4	11.66	0.97	18.88	3.941	0.97
	510	11.7	0.97	19.2	3.954	0.97
03-Dec	343.2	354	46.45	71.32	0.97	0.97
	288	345.2	49.71	72.98	0.97	0.97
	300.8	283.8	48.2	76.06	0.97	0.97
01-Feb	323.3	13.82	13.45	41.57	2.425	0.97
	367	13.93	10.29	40.25	3.434	0.97
	358.2	13.24	12.65	50.03	2.938	0.97
04-Feb	438.8	19.56	0.97	46.63	35.12	0.97
	449.6	19.55	0.97	46.17	27.15	0.97
	462	19.68	0.97	46.93	25.25	0.97
08-Feb	109.8	38.16	0.97	45.86	6.22	6.941
	109.8	37.33	0.97	51.62	6.568	6.923
	107.1	39.37	0.97	47.84	5.673	1.124

Table C.45 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short Stagnation (30min) Time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
11-Feb		46.18	4.245		0.97	0.97
		49.37	4.412		0.97	0.97
		48.45	5.405		0.97	0.97
15-Feb	164.5	23.51	0.97	57.73	12.78	0.97
	188.3	25.83	0.97	54.65	12.68	0.97
	171.3	24.21	0.97	57.31	11.61	0.97
18-Feb	99.57	62.07	0.97	19.16	12.43	0.97
	84.76	73.51	0.97	19.55	12.6	0.97
	89.71	72.15	0.97	19.56	12.88	0.97
22-Feb	379.3	45.58	0.97	188.4	12.01	0.97
	383.6	44.76	0.97	183.6	13.35	0.97
	409.4	48.39	0.97	177.7	7.327	0.97
25-Feb	75.9	79.67	0.97	24.05	5.058	0.97
	80.18	80.56	0.97	18.85	5.083	0.97
	76.32	75.56	0.97	21.26	3.816	0.97
01-Mar	380.9	216.8	0.97	33.43	48.18	0.97
	373.1	217.5	0.97	32.92	50.18	0.97
	374.9	221.7	0.97	33.13	50.33	0.97
04-Mar	83.97	73.38	0.97	50.51	0.97	0.97
	88.18	73.01	0.97	51.59	0.97	0.97
08-Mar	73.01	57.48		6.347	0.447	
	78.38	56.41		5.982	1.895	
	89.4	62.26		6.459	0.97	
11-Mar	358.6	53.86		20.75	8.063	
	341.4	53.02		22.93	7.612	
	369.8	51.06		23.48	7.917	
15-Mar	140.32	39.42	3.341	12.07	4.264	1.323
	142	34.46	3.649	12.21	4.982	1.205
	145.48	34.76	3.502	9.653	5.211	1.224
18-Mar	102	39.54	0.97	32.71	0.97	0.97
	98.72	33.5	0.97	32.54	0.97	0.97
	109.3	25.99	0.97	31.77	0.97	0.97
25-Mar	68.6	421.2		32.83	21.33	34.14
	75.94	423.8		33.15	21.75	35.2
	67.52	416.2		32.02	25	38.05
29-Mar	0.97	215.4		9.297	31.68	8.319
	0.97	209.6		11.65	29.91	8.874
	0.97	216		11.32	32.41	8.554
01-Apr				2.169	2.99	0.97
				1.808	2.909	0.97
				1.938	4.064	0.97
05-Apr	216.88	185.98	50.4	7.546	14.79	3.42
	2119.6	184.88	48.6	6.759	14.8	3.897
	216.2	186.68	48.5	6.796	13.23	3.597

Table C.45 continued Raw data displaying the total lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

Long (24hr) Stagnation Time

Short Stagnation (30min) Time

Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
09-Apr	159.36	147.46		41.19	32.91	3.095
	169.58	154.02		41.84	34.89	2.475
	165.94	159.44		43.5	36.68	2.155
12-Apr	26.72	69.58	30.26	84.4	0.97	0.97
	27.2	67.28	2.12	84.01	0.97	0.97
	26.78	70.6	29.92	81.45	0.97	0.97
15-Apr	33.8	59.29	0.97	29.69	18.15	0.97
	33.03	57.05	0.97	28.22	18.01	0.97
	32.06	57.4	0.97	27.76	18.61	0.97
19-Apr	205	68.57	0.97	19.92	16.29	0.97
	205.7	74.61	0.97	19.75	17.63	0.97
	214.7	69.24	0.97	19	17.42	0.97
22-Apr	213.8			17.16	349.9	
	208.2			18.27		
	215.9			16.11		
26-Apr	32.52	188.6	355.3	7.468		5.668
	40.78	196.9	318.3	8.075	44.84	5.346
	40.15	203	337.8	7.034	43.92	4.878
29-Apr	54.9	158.4	0.97	174.3	0.97	0.97
	62.64	158.7	0.97	155.2	0.97	0.97
	57.66	154.5	0.97	151.4	0.97	0.97
10-May	4.642	96.59	22.04	4.286	0.793	0.97
	3.313	99.48	17.58	5.177	0.508	0.97
	3.559	96.47	21.33	4.174	0.95	0.97
17-May	52.93	46.64	3.835	4.196	2.991	0.97
	50.23	50.19	4.747	4.162	1.854	0.97
	47.48	49.35	3.276	3.969	1.72	0.97
25-May	78.98	51.7	3.926	0.97	5.095	0.97
	82.95	53.69	5.346	0.97	1.753	0.97
	76.98	53.19	5.497	0.97	0.577	0.97
31-May	98.09	56.11	0.97	34.46	5.057	1.074
	98.38	52.63	0.97	35.97	5.656	0.97
	99.07	51.27	0.97	39.27	6.006	1.092
07-Jun	9.413	52.08	12.62	4.36	0.97	0.97
	10.67	51.78	16.26	6.457	0.97	0.97
	7.556	55.08	10.3	4.094	0.97	0.97
14-Jun	99.9	29.82	0.97	16.99	6.566	0.97
	99.9	31.2	0.97	17.51	5.219	0.97
	100.2	34.33	0.97	17.14	5.107	0.97
21-Jun	23.59	44.62	18.05	19.85	0.97	0.97
	26.72	45.1	18.37	19.73	0.97	0.97
	26.66	42.86	18.24	19.69	0.97	0.97
28-Jun	390.9	45.91	8.081			
	400.6	46	7.947			
	405	45.5	7.951			

Dissolved Lead (µg/L)

Table C.21 Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr)Stagnation Time			Short (30min)Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	13.46	68.43	2.327	0.97	2.007	0.97
	9.347	67.38	0.97	0.97	3.881	0.97
	10.97	59.83	2.396	0.97	2.888	0.97
06-Jul	78.65	9.797	24.25	1.605	22.71	0.97
	64.76	10.79	26.95	2.408	21.87	0.97
	77.48	15.06	22	4.777	21.77	0.97
09-Jul	30.77	23.65	8.037	2.423	1.753	0.97
	31.76	22.57	7.508	2.524	2.148	0.97
	31.26	23.97	7.515	2.438	1.354	0.97
13-Jul	10.17	0.97	0.97	0.97	0.97	0.97
	10.16	0.97	0.97	0.97	0.97	0.97
	9.856	0.97	0.97	0.97	0.97	0.97
16-Jul	76.57	72.47	0.97	1.085	51.25	0.97
	76.18	73.33	0.97	1.839	51.81	0.97
	76.02	72.21	0.97	2.297	49.5	0.97
20-Jul	37.27	0.97	0.97	9.135	1.761	0.97
	35.01	0.97	0.97	8.616	1.36	0.97
	34.65	0.97	0.97	7.686	1.25	0.97
23-Jul	46.69	7.747	0.97	0.97	0.97	0.97
	40.63	5.54	0.97	0.97	0.97	0.97
	39.23	5.667	0.97	0.97	0.97	0.97
27-Jul	218.8	18.69	12.28	11.67	2.243	0.97
	219.3	20.83	10.07	10.31	2.364	0.97
	222.9	21.2	10.23	14.54	1.981	0.97
30-Jul	924	3.756		38.62	3.699	
	over	3.884		32.67	3.699	
		3.928		34.87	3.818	
03-Aug	641.4	10.35	2.699	27.88	1.654	0.97
	593	8.676	4.35	29.25	1.779	0.97
	581	7.412	2.738	28.92	1.39	0.97
06-Aug	120.62	2.314	0.97	9.657	3.762	0.97
	113.54	1.926	0.97	9.826	2.529	0.97
	111.96	2.408	0.97	9.287	2.621	0.97
10-Aug	36.72	146.6	0.97	13.46	15.99	0.97
	37.1	156.7	0.97	13.5	19.56	0.97
	36.2	142.2	0.97	13	17.91	0.97
13-Aug				2.274	0.97	0.97
				2.67	0.97	0.97
				3.111	0.97	0.97
17-Aug	126.7	9.306	3.165	19.53	4.09	0.97
	126.68	10.92	4.08	20.04	4.124	0.97
	124.28	10.18	3.561	19.96	4.052	0.97

Table C.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr)Stagnation Time			Short (30min)Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
20-Aug	229	19	0.97	40.19	2.378	0.97
	200.4	19.24	0.97	38.36	2.642	0.97
	213	13.6	0.97	38.16	1.742	0.97
24-Aug	243	3.46	0.97	1.729	1.306	0.97
	251	4.174	0.97	1.608	0.97	0.97
	197.34	3.606	0.97	1.726	0.97	0.97
27-Aug	86.48	14.53	0.97	14.73	4.678	0.97
	86.3	13.534	0.97	14.6	4.777	0.97
	88.64	18.94	0.97	14.74	4.749	0.97
31-Aug		21.9	0.97		3.796	0.97
		18.6	0.97		3.34	0.97
		18.28	0.97		3.277	0.97
03-Sep		12.032	1.205		3.354	1.304
		12.17	1.335		3.532	2.633
		12.69	0.97		3.42	1.654
14-Sep	195.34	37.52	3.423	13.48	13.48	0.97
	165.06	38.98	3.039	13.58	13.17	0.97
	165.1	39.4	2.919	13.6	13.37	0.97
17-Sep	164.52	41.28	1.229	20.01	7.568	0.97
	176.96	40.02	1.231	19.33	7.809	0.97
	167.04	40.7	1.091	19.31	7.807	0.97
21-Sep	51.64		0.97	20.74		0.97
	54.54		0.97	20.52		0.97
	53.48		0.97	20.46		0.97
24-Sep	2.108		0.97	5.288		0.97
	2.708		0.97	5.345		0.97
	2.41		0.97	4.47		0.97
28-Sep	68.76	33.3	1.036	18.62	6.855	0.97
	74.14	35.28	0.97	22.38	7.828	0.97
	82.88	29.82	0.97	19.85	7.488	0.97
01-Oct	195.64	11.18	1.967	30.12	1.287	0.97
	207	10.24	1.985	28.81	1.25	0.97
	206	12.24	1.868	38.22	1.225	0.97
05-Oct	409.8	9.52	0.97	54.88	4.054	0.97
	449.2	15.14	1.278	50.19	3.891	0.97
	421.4	54.56	1.125	49.8	3.89	0.97
07-Oct	89.58		0.97	20.18		0.97
	97.9		0.97	11.91		0.97
	72		0.97	15.87		0.97
12-Oct	356.5	9.202	1.203	26.23	1.28	0.97
	297	9.671	0.97	27.57	1.542	0.97
	323.7	9.272	1.111	22.09	2.64	0.97
15-Oct	125.74	9.5	0.97	7.47	2.898	0.97
	130.68	7.36	0.97	7.514	3.11	0.97
	131.22	7.76	0.97	7.399	2.637	0.97

Table C.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr)Stagnation Time			Short (30min)Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
19-Oct	116.18	7.56		10.98	0.97	0.97
	119.34	5.6		10.03	0.97	0.97
	118.08	6.96		11.27	0.97	0.97
22-Oct	568	4.96	n/a	38.47	0.551	0.97
	714.6	7.44	n/a	38.52	1.441	0.97
	699.8	4.78	n/a	35.08	0.785	0.97
26-Oct	283.6	15.64	1.262	29.74	3.406	0.97
	297.4	13.54	1.198	28.89	3.222	0.97
	291.4	12.14	1.106	31.31	3.251	0.97
29-Oct	653.6	6.84	1.123	846.2	3.768	0.97
	635.2	8.12	1.117		2.471	0.97
	624.8	10.44	0.97		2.457	0.97
02-Nov				11.5	3.926	0.97
				11.94	4.162	0.97
				11.62	3.883	0.97
05-Nov	148.14	10.88	1.208	11.86	1.587	0.97
	152.44	9.52	1.25	12.21	1.514	0.97
	150.42	9.54	1.269	10.97	1.453	0.97
09-Nov		3.74	0.97		2.43	0.97
		4.04	0.97		2.317	0.97
		4.74	0.97		2.329	0.97
12-Nov	409	14.6	0.97	43.31	1.305	0.97
	433.8	15.58	0.97	42.67	1.265	0.97
	441.2	12.48	0.97	42.05	1.282	0.97
16-Nov	336.2	7.32	0.97	41.61	3.206	0.97
	320.4	8.9	0.97	41.12	3.205	0.97
	323.8	9.36	0.97	40.69	3.301	0.97
19-Nov	51.9	0.97	0.97	12.73	0.97	0.97
	54.92	0.97	0.97	13.7	0.97	0.97
	53.5	0.97	0.97	12.84	0.97	0.97
23-Nov	199.66	15.56	0.97	17.24	8.088	0.97
	200.4	9.94	0.97	18.3	8.692	0.97
	210	13	0.97	18.56	8.095	0.97
03-Dec	400.8	752.4	0.97	54.04	0.97	0.97
	366.8	830.4	0.97	55.55	0.97	0.97
	385.4	827.4	0.97	54.86	0.97	0.97
01-Feb	78.86	4.958	1.859	53.38	0.97	0.97
	89.18	4.448	1.857	52.13	0.97	0.97
	89.48	4.207	1.867	57.82	0.97	0.97
04-Feb	396	13.61	0.97	30.71	14.06	0.97
	399.6	11.54	0.97	28.42	5.615	0.97
	401.6	10.65	0.97	22.12	4.123	0.97
08-Feb	93.73	19.57	0.97	16.4	4.129	0.97
	86.77	22.19	0.97	14.72	2.85	0.97
	85.44	20.3	0.97	15.2	1.572	0.97

Table C.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr)Stagnation Time			Short (30min)Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
11-Feb		32.88	0.97		0.97	0.97
		33.18	0.97		0.97	0.97
		26.33	0.97		0.97	0.97
15-Feb	73.89	11.57	0.97	28.33	24.78	0.97
	70.11	10.98	0.97	26.91	26.89	0.97
	75.64	10.25	0.97	26.95	22.41	0.97
18-Feb	72.04	25.4	0.97	18.52	0.97	15.2
	75.83	28.52	0.97	19.15	0.97	15.16
	75.01	27.54	0.97	18.93	0.97	14.64
22-Feb	44.49	11.78	0.97	13.07	0.97	0.97
	42.98	8.696	0.97	12.81	0.97	0.97
	36.11	11.58	0.97	12.65	0.97	0.97
25-Feb	31.77	48.19	0.97	4.448	0.97	0.97
	32.03	48.44	0.97	2.279	0.97	0.97
	32.45	47.41	0.97	3.397	0.97	0.97
01-Mar	48.92	2.435	0.97	3.616	0.97	0.97
	51.8	4.462	0.97	1.687	0.97	0.97
	52.67	3.118	0.97	2.168	0.97	0.97
04-Mar	42.48	20.89	0.97	0.97	0.97	0.97
	43.32	21.63	0.97	0.97	0.97	0.97
	41.3	21.86	0.97	0.97	0.97	0.97
08-Mar	52.49	8.845		0.97	0.97	
	51.55	7.471		0.97	0.97	
	52.89	8.877		0.97	0.97	
11-Mar	90.15	4.093		13.89	2.76	
	88.8	4.123		14.28	3.542	
	100.3	4.041		14.59	3.28	
15-Mar	33.44	4.135	1.15	3.9	0.688	0.759
	32.26	4.328	1.031	3.944	0.571	0.749
	34.2	4.181	1.205	4.065	0.733	0.745
18-Mar	57.72	0.97		0.97	0.97	0.97
	66.93	0.97		0.97	0.97	0.97
	59.48	0.97		0.97	0.97	0.97
25-Mar	16.094	210.2		3.816	0.97	0.97
	14.758	209.8		4.876	0.97	0.97
	14.366	209.8		4.578	0.97	0.97
29-Mar	0.97	36.02		0.97	0.97	0.97
	0.97	40.86		0.97	0.97	0.97
	0.97	38.74		0.97	0.97	0.97
01-Apr				0.97	0.97	0.97
				0.97	0.97	0.97
				0.97	0.97	0.97
05-Apr	26.3	42.82	7.706	0.97	0.97	0.97
	28.5	43.34	7.692	0.97	0.97	0.97
	30.06	43.54	8.65	0.97	0.97	0.97

Table C.21 continued Raw data displaying the dissolved lead values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min)Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
09-Apr	35.77	17.52	n/a	0.97	0.97	0.97
	34.94	16.66	n/a	0.97	0.97	0.97
	33.59	15.53	n/a	0.97	0.97	0.97
12-Apr	9.686	0.97	0.97	0.97	0.97	0.97
	9.202	0.97	0.97	0.97	0.97	0.97
	7.26	0.97	0.97	0.97	0.97	0.97
15-Apr	16.11	14.27	0.97	7.872	3.354	0.97
	15.63	14.88	0.97	8.247	3.237	0.97
	15.11	13.78	0.97	8.612	3.649	0.97
19-Apr	70.2	16.11	0.97	4.042	0.97	0.97
	66.51	16.26	0.97	6.164	0.97	0.97
	65.12	15.72	0.97	6.833	0.97	0.97
22-Apr	99.58			3.72		
	101.2			2.499		
	103.3			2.767		
26-Apr	15.13	99.14	207.6	0.97	9.416	0.97
	13.51	97.46	209.8	0.97	8.387	0.97
	13.31	101.7	213	0.97	6.682	0.97
29-Apr	8.76	46.27	0.97	82.88	0.97	0.97
	8.45	45.18	0.97	86.08	0.97	0.97
	8.656	42.98	0.97	85.3	0.97	0.97
10-May	0.97	39.85	3.866			
	0.97	38.88	3.446			
	0.97	39.72	4.195			
17-May	41.74	15.4	0.97	0.97	0.97	0.97
	38.46	15.15	0.97	0.97	0.97	0.97
	38.81	15.81	0.97	0.97	0.97	0.97
25-May	23.98	25.78	0.97	0.97	13.96	0.97
	22.09	21.34	0.97	0.97	16.51	0.97
	22.56	22.98	0.97	0.97	16.26	0.97
31-May	33.78	4.144	0.97	0.97	0.97	0.97
	28.65	2.713	0.97	0.97	0.97	0.97
	31.83	1.542	0.97	0.97	0.97	0.97
07-Jun	2.472	26.34	0.97	11.01	0.97	0.97
	2.937	23.02	0.97	12.93	0.97	0.97
	2.635	27.26	0.97	13.03	0.97	0.97
14-Jun	22.31	5.082	0.97	0.97	0.97	0.97
	26.47	4.061	0.97	0.97	0.97	0.97
	22.43	4.554	0.97	0.97	0.97	0.97
21-Jun	0.97	8.452	0.97	2.792	0.97	0.97
	0.541	9.33	0.97	3.537	0.97	0.97
	1.738	6.712	0.97	4.466	0.97	0.97
28-Jun	22.35	10.99	0.97	3.954	0.97	0.97
	21.62	12.5	0.97	4.301	0.97	0.97
	21.07	7.933	0.97	7.137	0.97	0.97

Total Copper (µg/L)

Table C.22 Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	465.6	5746	969.6	89.2	1293.2	471.2
	465.8	5520	972.6	88.98	1305.8	469.6
	463.6	5516	972	89.96	1302.2	470.6
06-Jul	346.6	350.6	1717	142.12	114.26	534.4
	342	340.2	1799	136.46	111.42	541
	349.2	344.6	1821.8	140.24	110.18	537.8
09-Jul	303.3	971.8	552.2	70	138.64	41.78
	228.4	903	561.6	70	132.16	43.78
	237.8	914.8	567.6	70	131.36	47.26
13-Jul	22.68	355.2	132.84	70	15.06	70
	9.02	348.6	131.52	70	18.4	70
	15	351.2	128.62	70	15.44	70
16-Jul	82.66	377.8	367.6	70	70	70
	160.5	346.8	346.8	70	70	70
	154.76	365.4	387.2	70	70	70
20-Jul	70	76.54	61.46	70	70	70
	70	86.82	65.26	70	70	70
	70	582.6	54.1	70	70	70
23-Jul	418.4	349.8	648.4	100.32	124.28	155
	422	346.8	639.4	85.42	132.82	156.2
	423.8	331.4	632.8	102.36	108.54	158.42
27-Jul	247.1	160	64.42	70	70	70
	234.8	184.8	64.3	70	70	70
	249.1	169.2	64.79	70	70	70
30-Jul	2982	134.7	n/a	616.9	70	n/a
		150.2		626.6	70	
		154.9		657.3	70	
03-Aug	3666	145.82	307.6	679.2	91.46	95.3
	3300	146.48	309.2	687.8	91.5	96.24
	3456	147.12	306.2	648.4	91.88	96.5
06-Aug	848	292	357	165.84	94	104.68
	833	291.2	352	168.06	93.24	105.56
	833.8	293.4	343	169.24	93.42	103.22
10-Aug	347.6	189.6	151.5	81	70	70
	329.7	183	151	81.1	70	70
	328	188.5	149.2	81.97	70	70
13-Aug				96.2	70	153.44
				96.24	70	155.4
				98.8	70	151.38
17-Aug	526.4	117.62	754.6	70	70	191.94
	526.4	130.72	759	72.34	70	189.4
	521.4	102.7	784.4	71.42	70	190.04
20-Aug	782	70	70	181.94	70	70
	732.2	70	70	218.8	70	70
	737.6	70	70	230.8	70	70

Table C.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
24-Aug	332.6	60.56	70	70	70	70
	351.4	57.1	70	70	70	70
	327.2	40.22	70	70	70	70
27-Aug	260	19.52	70	85.63	70	70
	250	16.5	70	85.23	70	70
	254.8	41.78	70	86.47	70	70
31-Aug		20	70		70	70
		33.44	70		70	70
		30.46	70		70	70
03-Sep		92.46	70		70	70
		87.76	70		70	70
		85.18	70		70	70
14-Sep	34.34	299.6	348.8	70	70	147
	40.32	285.4	356.8	70	70	145.3
	43	296.4	342.4	70	43.44	146.4
17-Sep	136.24	263.2	164.9	70	103.5	70
	150.72	255.8	166	74.47	101.3	70
	168.82	246.2	163.5	73.94	103.4	70
21-Sep	112.12		43.82	70		70
	122.68		43.7	70		70
	132.56		42.4	70		70
24-Sep	138.6		26.31	70		70
	1386		26.15	70		70
	1386		26.1	70		70
28-Sep	61.5	339.8	81.23	70	171.2	70
	55.78	352.2	83.45	70	165.4	70
	54.36	352.8	83.18	70	170	70
01-Oct	265.4	65.34	96.02	83.2	70	70
	264.6	69.42	95.33	82.95	70	70
	273	67.9	98.61	84.34	70	70
05-Oct	131.99	70	70	70	85.88	70
	132.44	70	70	70	87.69	70
	135	70	70	70	87.53	70
07-Oct	328.6		109.8	70		70
	323.4		112.4	70		70
	324.2		111.9	70		70
12-Oct	98.72	297.1	191.8	70	70	70
	98.69	310	183.7	70	70	70
	99.56	297.3	190.5	70	70	70
15-Oct	70	70	4.789	70	70	70
	70	70	4.561	70	70	70
	70	70	4.331	70	70	70
19-Oct	70	70		70	70	70
	70	70		70	70	70
	70	403.6		70	70	70

Table C.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
22-Oct	1667	70		304.2	65.09	97.3
	1656	70		335.4	60.65	96.27
	1695	70		326.8	61.68	101.8
26-Oct	1048	129.72	275.8	184.5	94.57	82.44
	1050.2	132.28	275.9	185.4	94.25	81.47
	1061.4	132.86	284	184.8	93.8	81.17
29-Oct	715.3	283.8	346.1	3246	91.1	70
	762.3	280.8	339.2		91.39	70
	748.2	229.4	340.4		91.25	70
02-Nov				414.7	81.89	70
				399.6	81.88	70
				399	82.63	70
05-Nov	543.4	70	218.8	91.33	70	75.63
	543.4	70	211	92.23	70	74.92
	547.6	70	217	92.24	70	75.81
09-Nov		70	208.7		82.52	70
		70	207.1		81.84	70
		70	210.8		82.48	70
12-Nov	4060	1110	177.6	18760	70	70
	4080	1127	185.8	18240	70	70
	4060	1122	182.1	18400	70	70
16-Nov	2046	188.42	178.1	434.6	160.5	70
	2070	174.2	176.3	430.7	160.7	70
	2042	186.3	174.5	428.4	160.4	70
19-Nov	753	134.56	104.7	175.4	70	70
	743.8	130.16	106.3	172.8	70	70
	7360	130.46	103.2	177.8	70	70
23-Nov	994.6	105.64	157.3	166.2	170.3	70
	970.6	103.02	162.9	152.7	159.6	70
	980.4	99.38	168.5	164.9	141.6	70
30-Nov			18.19		70	70
			18.68		70	70
			18.3		70	70
03-Dec	2182	166.34	31.6	1095	70	70
	2166	155.38	32.15	1059	70	70
	2120	155.16	31.63	1111	70	70
07-Dec	314.4	155.08	70	74.49	81.91	84.32
	305.2	151.76	70	74.85	81.76	80.37
	306.8	155.16	70	74.58	81.62	80.01
01-Feb	434	149.9	109.3	76.35	70	70
	431.6	110.62	110.6	77.63	70	70
	416	138.86	110.9	75.97	70	70
04-Feb	3570	116.52	193.5	180.3	70	70
	3452	116.72	189.9	186.9	70	70
	3564	110.98	196.5	191.7	70	70

Table C.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
08-Feb	538.6	214.8	189.8	199.3	76.66	105.6
	580.2	216.1	217.5	194.4	77.37	109
	573	213	189.2	198.7	77.2	108.3
11-Feb		196.2	374		85.28	100.1
		194.4	396.4		86.5	101.7
		182.9	366.6		85.84	107.3
15-Feb	396.9	349.3	281.1	141.5	215.6	108.9
	418.7	372	285.4	135.8	217.1	105.6
	399.2	351.8	284.6	137.1	215.6	107.7
18-Feb	378.1	366.3	298.3	80.63	96.11	70
	368.3	364.5	297.7	78.04	96.58	70
	393.9	338.8	297.5	85.16	102.1	70
22-Feb	219	366.4	344.1	171.1	166.1	70
	220	387.5	356.1	174.8	147.8	70
	221.6	386.3	322.8	173	148.9	70
25-Feb	164.6	498.3	404.6	70	196.2	70
	180.9	477.3	436.9	70	196.7	70
	189.2	519.2	433.9	70	192.4	70
01-Mar	857.5	1215	426	106.1	847.7	184.5
	884.5	2430	423.8	110.3	856.5	161
	881.1	1875.4	420.1	112.4	902	187.7
04-Mar	634	1878.6	489	209	357.5	125.8
	583.7	702.6	514.9	195.3	345.4	127.9
	901	961.3	494.2	229.9	314.2	126.8
08-Mar	205.6	717.2		70	169.5	
	203	697.2		70	171.3	
	209.8	709		70	161.8	
11-Mar	710	252		95.59	75.92	
	778	255.8		97.77	75.39	
	732.2	264.6		97.61	75.04	
15-Mar	424.9	208.5	186.2	106.9	98.23	81.28
	398.1	209.6	173.2	100.6	106.6	81.07
	407.6	213.1	184.2	107.6	106.9	80.18
18-Mar	787.7	102.88	162.9	106.6	70	70
	753.8	97.12	157.2	109.4	70	70
	730.4	110.7	150.5	111.5	70	70
25-Mar	322	1774.6	2870	176.6	354.6	329.8
	381.2	1747	2752	175.7	355.9	294.8
	387	1688	2636	177.9	317.6	289
29-Mar	96.12	244.4	427	70	136.2	158.7
	104.04	266	462.4	70	126.1	148.2
	104.98	254.4	483.6	70	137.4	168.9
01-Apr				70	91	78.78
				70	91.17	81.66
				70	90.04	76.81

Table C.22 continued Raw data displaying the total copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	High Chloramines	Low Chloramines	Chlorine	High Chloramines	Low Chloramines	Chlorine
05-Apr	91.02	163.78	345.2	70	70	104.5
	91.2	163.24	355.8	70	70	109
	88.2	163.12	346.6	70	70	107.5
09-Apr	186.28	208.6		106.3	70	72.04
	192.76	205.2		105.7	70	71.71
	192.38	200.6		108.6	70	74.22
12-Apr	618.2	156.9	102.82	172.3	70	70
	633.2	152.82	101.08	176	70	70
	623	152.1	101.52	171.4	70	70
15-Apr	298.6	183.6	70	166.9	70	70
	313	188.8	70	168.2	70	70
	302.2	190.78	70	168	70	70
19-Apr	135.86	333.4	70	70	100.6	83.56
	134.5	327.2	70	70	101.3	84.65
	135	338.2	70	70	101.3	84.63
22-Apr	350.8			70		
	350.4			70		
	333.2			70		
26-Apr	216.6	1727.4	3992	70	400.1	178.4
	226.2	1750.4	4176	70	430.2	166.7
	225	1689.2	4134	70	419	144.5
29-Apr	3776	122.9	70		38.01	187.5
	4148	129.3	70		42.65	183.3
	4870	124.42	70		40.74	186.5
10-May	416.6	331.4	976.8			
	420.4	313.4	1105.2			
	381.6	325.4	1110.8			
17-May	370.2	43.86	100.2	190.3	19.24	
	376.8	40.74	104.24	191.4	18.98	
	376	39.74	104.22	190.1	17.47	
25-May	394.6	117.56	36.62	161.5	39.85	42.9
	410.6	116.8	35.42	160.8	39.7	44.54
	410.8	114.68	37.76	165.2	40.77	46.57
31-May	328.4	110.76	26.42	92.9	30.17	25.17
	331.6	111.58	23.94	92.1	29.17	26.28
	340.4	108.02	23	96.67	30.01	25.16
07-Jun	427.4	120.8	358.4	123.8	57.26	170.7
	352.6	123.02	350	119.8	54.64	171.7
	346.6	121.48	356.8	121.6	55.08	174.1
14-Jun	139.44	90.88	271.6	70	70	83.78
	139.3	90.68	265.8	70	70	87.69
	143.4	90.98	268	70	70	82.24
21-Jun	115.22	129.32	70	32.18	54.87	29.53
	115.16	128.56	70	31.83	54.33	27.92
	119	131.42	70	29.56	55.37	26.99
28-Jun	142.96	109.66	171.02	70	32.5	20.47
	132.2	116.98	175.62	70	32.23	32.39

Dissolved Copper (µg/L)

Table C.23 Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
02-Jul	279	5374	814.8	47.9	1118	385.8
	280.8	4194	815.8	44.1	1130.6	381.8
	281	4272	809	44.1	1147	377.2
06-Jul	205.4	220.6	1461.4	73.24	217.8	363.2
	210.4	212.8	1504.4	74.02	220.2	370.6
	208.6	212	1686.2	76.36	178.36	366
09-Jul	107.32	716.8	270	8.78	80.1	7.52
	97.96	828.2	257.8	7.52	80.24	6.96
	95.48	738	259.2	9.62	78.66	3.1
13-Jul	70	184.66	39.28	70	70	70
	70	168.62	38.22	70	70	70
	70	164.62	49.54	70	70	70
16-Jul	70	112.9	70	70	70	70
	70	7.52	70	70	70	70
	70	14.24	70	70	70	70
20-Jul	70	70	70	70	70	70
	70	70	70	70	70	70
	70	70	70	70	70	70
23-Jul	195.6	255.4	388.6	59.54	90.66	87.62
	478	250.6	388	55.16	97.2	82.92
	194.38	237.8	385.4	60.44	89.44	95.76
27-Jul	133	112.4	91.27	38.35	52.86	70
	137.8	112.2	93.55	37.86	59.48	70
	134.4	104.3	103.8	38.08	61.14	70
30-Jul	2323	66.7		524.5	35.13	
		73.61		479.7	35.58	
		75.07		521.2	35.58	
03-Aug	2820	99.54	193.82	590.2	70.86	70
	2796	99.12	193.66	594.4	70.8	70
	2818	99.9	194.84	589.6	71.04	70
06-Aug	661.2	165.24	218.6	125.76	67.04	72.26
	630.8	162.7	214	127.84	65.12	72.26
	671.8	162.5	213.2	128.98	66.6	70.88
10-Aug	109.2	169.1	80.88	74.3	35.23	70
	108.8	158.2	80.24	73.96	35.26	70
	108	156.9	79.06	73.59	34.86	70
13-Aug				80.86	113.46	129.5
				77.8	112.42	125.1
				80.96	112.22	130.38
17-Aug	1825.2	70	462.6	70	70	70
	1578.8	70	501.6	70	70	70
	1656	70	517.6	70	70	70
20-Aug	557	70	70	94.98	70	70
	472.8	70	70	150.32	70	70
	542.2	70	70	159.84	70	70

Table C.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
24-Aug	341.8	70	70	70	70	70
	349	70	70	70	70	70
	326.8	70	70	70	70	70
27-Aug	70	70	70	37.52	20.73	70
	70	70	70	37.27	21.29	70
	70	70	70	38.1	20.9	70
31-Aug		70	70		29.68	70
		70	70		28.58	70
		70	70		29.1	70
03-Sep		70	70		31.16	70
		70	70		30.75	70
		70	70		42.54	70
14-Sep	70	70	217	17.86	27.06	89.99
	70	70	214.4	16.8	26.52	89.12
	70	70	215.5	16.78	26.04	89.73
17-Sep	70	159.22	99.63	55.42	85.98	70
	70	150.68	90.82	54.97	86.43	70
	70	151.54	101.4	55.47	86.84	70
21-Sep	70		70	31.33		70
	79.94		70	31.29		70
	75.86		70	30.7		70
24-Sep	70		70	66.6		70
	70		70	67.34		70
	70		70	66.85		70
28-Sep	70	288.6	70	33.56	159.1	70
	70	299.8	70	33.39	166.6	70
	70	297	70	32.7	157.7	70
01-Oct	140.36	70	70	75.8	26.53	70
	130.26	70	70	75.33	26.38	70
	138.04	70	70	75.42	26.18	70
05-Oct	70	70	70	57.54	71.22	70
	70	70	70	57.73	66.11	70
	70	70	70	57.81	46.92	70
07-Oct	187.26		81.65	44.68		70
	205.6		81.48	44.45		70
	197.56		90.79	44.33		70
12-Oct	80.24	202.9	168.7	34.37	77.76	70
	80.96	204.7	162.5	37.05	72.7	70
	80.74	207.5	168.1	33.41	77.45	70
15-Oct	70	70	70	18.76	66.66	70
	70	70	70	17.14	77.43	70
	70	70	70	16.29	77.92	70
19-Oct	70	70		15.2	18.45	70
	70	70		14.71	18.74	70
	70	70		14.39	18.58	70

Table C.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
22-Oct	1554	70		306.9	54.33	95.42
	1507	70		302	54.61	92.98
	1562	70		300.4	54.7	94.77
26-Oct	898.4	84.48	210.3	161.6	93.66	80.15
	894.8	80.14	209	163.3	94.94	80.63
	883.8	79.56	208.9	163.5	95.02	80.41
29-Oct	505	140.24	304.6	3144	82.6	70
	507	134.46	309.4		79.16	70
	498	132.84	304		77.79	70
02-Nov				331.4	66.25	70
				332.7	66.16	70
				333	65.46	70
05-Nov	133	70	203	70	70	70
	140.24	70	201.2	70	70	70
	137.14	70	203.8	70	70	70
09-Nov		70	188.1		83.46	70
		70	191.1		85.48	70
		70	191.8		85.86	70
12-Nov	3800		150.1	929.5	70	70
	3760		146.5	912.4	70	70
	3680		145.6	923.6	70	70
16-Nov	1803.8	140.72	165.1	416	109.3	70
	1787.6	133.86	164.6	406.5	107.8	70
	1797.4	140.1	165.4	413.4	108.5	70
19-Nov	470	70	99.18	102.9	70	70
	454.8	70	97.43	104.4	70	70
	422.4	70	96.08	104.8	70	70
23-Nov	580.2	124.4	148.8	145.3	97.08	70
	511.8	55.78	147.1	148.1	98.63	70
	521.8	42.66	159.1	150	99.36	70
30-Nov			70		70	70
			70		70	70
			70		70	70
03-Dec	2100	119.84	70	995.6	70	70
	2200	124.34	70	942.9	70	70
	2196	123.1	70	947.9	70	70
07-Dec	136.32	135.7	260.9	70	84.19	74.03
	135.08	131.22	269.5	70	83.6	74.08
	132.1	128.22	270.3	70	84.29	74.9
01-Feb	120.94	19.48	96.38	70	70	70
	116.06	15.58	101	70	70	70
	114.8	195.42	99.3	70	70	70
04-Feb	3160	117.38	174.3	103.6	70	70
	3186	103.52	170.3	104.9	70	70
	3030	112.78	174.8	102.7	70	70

Table C.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
08-Feb	439.6	157.5	166.3	163.6	70	101
	422.1	185	179.9	135.9	70	103.5
	417.1	180.8	176.9	135.7	70	101.9
11-Feb		155.1	322.9		70	89.66
		160.4	274.4		70	90.28
		143.5	281.8		70	88.3
15-Feb	278.2	316.9	204.2	101.4	152.5	109.3
	283.2	315.3	204.5	102.6	151	106.2
	284.1	312.8	205.5	102	150.4	108.2
18-Feb	313	309.5	217.9	70.01	98.86	69.99
	300.4	326.2	216.6	70.92	99.73	70.09
	301.6	305.9	221.8	77.54	96.71	70
22-Feb	76.28	213	295.3	70	100.8	70
	75.63	218.8	278.8	70	101.2	70
	75.97	213.6	264.3	70	100.2	70
25-Feb	99.23	419	385.7	70	166.6	70
	93.68	421.2	388.7	70	148.6	70
	94.15	419.6	386.1	70	158	70
01-Mar	226.7	1622	301.4	72.93	331.1	145.2
	248.4	1501	301.9	73.29	310.6	154.3
	243.1	1338	300.5	72.12	290.7	148
04-Mar	1074	779.8	393.8	183	302.9	155.1
	1109	771	418.3	184.8	338.3	153.3
	1094	771.6	389.2	173.2	301.6	153.5
08-Mar	160.62	422		50.73	146.5	
	160.64	422.2		45.4	150.8	
	159.44	435.4		51.15	143.9	
11-Mar	279.2	157.26		97.9	55.97	
	270.2	156.58		97.67	60.99	
	274.4	158.92		91	57.72	
15-Mar	314.7	168.5	140.6	88.7	88.72	77.3
	312.3	171.2	144.1	90.3	89.2	79.19
	316.8	169.4	151.5	94.64	91.69	77
18-Mar	378.9	84.22	136.6	75.5	70	70
	418.5	83.81	136.6	83.43	70	70
	370.3	85.41	126.5	82.42	70	70
25-Mar	259.6	1573.8	3316	133.3	200	171.3
	261.4	1547.8	3216	144.9	218.9	162.6
	262.6	1489	2456	135.4	198.3	188.4
29-Mar	84.52	175.94	377.2	70	70	162.4
	89.64	176.94	397.8	70	70	174.6
	86.04	177.84	379.6	70	70	169.4
01-Apr				70	70	70
				70	70	70
				70	70	70

Table C.23 continued Raw data displaying the dissolved copper values after the long (24hr) and short (30min) stagnation time in the copper pipe racks using phosphate as a corrosion inhibitor. This data shows all three firing of the atomic adsorption measurements.

	Long (24hr) Stagnation Time			Short (30min) Stagnation Time		
Date	**High Chloramines**	**Low Chloramines**	**Chlorine**	**High Chloramines**	**Low Chloramines**	**Chlorine**
05-Apr	70	104.9	216.6	70	70	99.81
	70	104.86	214.6	70	70	101.3
	70	93.52	215.4	70	70	101.3
09-Apr	152.18	83.04		106.3	70	70
	146.2	87.46		91.26	70	70
	150.4	81.64		103.9	70	70
12-Apr	554	3140	98.12	164.4	70	70
	556	3004	83.42	163.9	70	70
	560.4	3196	80.88	161.9	70	70
15-Apr	285.2	89.76	70	154.2	70	70
	276.6	90.4	70	145.7	70	70
	279	93.16	70	146.7	70	70
19-Apr	88.54	153.16	70	70	85.01	66.41
	86.8	152.14	70	70	93.26	58
	84.08	151.58	70	70	83.01	57.98
22-Apr	356			70		
	344.6			70		
	344.4			70		
26-Apr	182.56		3710	70	344.5	200
	157.4		3348	70	316.4	189.2
	145.38		3678	70	311.3	165.7
29-Apr	2792	70	32.58	n/a	24.35	162.5
	2314	70	33.96	n/a	24.41	158.5
	2656	70	47.32	n/a	26.96	152.1
10-May	107.2	126.9	430.1			
	114.8	143.9	437			
	111	139.6	448.3			
17-May	368.2	76.66	56.26	207.1	39.41	23.33
	369.8	76.76	54.54	200.7	39.32	23.84
	363.6	76.96	55.86	199.6	37.75	17.26
25-May	325.4	105.96	38.68	141.3	32.62	50.05
	329.6	106.2	36.94	144	32.85	48.72
	346	105.8	35.26	131.9	33.01	50.56
31-May	185.86	67.16	7.802	87.24	25.39	23.71
	187.18	64.4	6.452	86.49	24.54	24.04
	186.86	65.56	6.066	86.35	25.24	23.88
07-Jun	267.8	102.98	297.2	90.89	48.54	140.2
	277.2	97.64	306	92.69	45.51	129
	276.8	105.58	294.8	98.6	46.64	141.1
14-Jun	79.48	143.1	325.4	70	70	72.25
	103.3	140.98	331.8	70	70	83.32
	102.79	146.44	323.6	70	70	80.83
21-Jun	52.38	86.62		15.58	42.71	3.539
	51.06	78.52		14.08	40.72	2.612
	54.36	83.4		14.6	37.28	2.818

APPENDIX D – Unintentional Consequences Data

Nitrification Data

The following data is the average data used to determine if nitrification was happening in the copper pipe racks

Table D.1 Nitrification data for high chloramines and sodium silicate

	High Chloramines using Sodium Silicate			
Unit as N (mg/L)	Influent of Pipe loop	Effluent of Pipe loop	24hr in Copper Racks	30min in Copper Racks
Nitrite	0.010439	0.011696	0.029497	0.02358
Nitrate	1.794997	0.808366	1.227431	2.570398
Ammonia	23.00874	14.06793	15.29917	14.27136
Total N	22.61178	9.476762	14.55905	13.52184

Table D.2 Nitrification data for low chloramines and sodium silicate

	Low Chloramines using Sodium Silicate			
Unit as N (mg/L)	Influent of Pipe loop	Effluent of Pipe loop	24hr in Copper Racks	30min in Copper Racks
Nitrite	0.004704	0.009421	0.033311	0.017113
Nitrate	0.364818	0.822336	0.322881	0.992265
Ammonia	7.672778	7.22037	8.937739	7.826519
Total N	6.641433	5.928905	6.467857	5.805476

Table D.3 Nitrification data for low chloramines and sodium silicate

	Low Chloramines using Sodium Silicate			
Unit as N (mg/L)	Influent of Pipe loop	Effluent of Pipe loop	24hr in Copper Racks	30min in Copper Racks
Nitrite	0.005783	0.006365	0.035685	0.020156
Nitrate	2.949419	4.695861	2.973961	1.202563
Ammonia	7.808111	6.427556	8.337778	8.097289
Total N	7.640276	5.908395	7.16281	6.368476

Disinfecting By products(DBPs)

Total Trihalomethane (THMs)

Total trihalomethane concentration measured in the influent and effluent of the pipe loops and after a long and short stagnation time are presented for each of the three sample dates (October 2009, December 2009, and April 2010).

Oct-09	**Influent of pipe loop**	**Effluent of pipe loop**	**24hr stagnation time in copper pipe racks**	**30min stagnation time in copper pipe racks**
High Chloramines Si	27.97	34.36	31.41	29.14
High Chloramines P	25.84	32.58	30.02	27.19
Low Chloramines Si	38.60	9.89	11.30	11.07
Low Chloramines P	29.31	25.67	25.66	28.41
Chlorine Si	27.98	59.09	97.95	80.78
Chlorine P	70.41	38.54	151.29	46.00

Dec-09	**Influent of pipe loop**	**Effluent of pipe loop**	**24hr stagnation time in copper pipe racks**	**30min stagnation time in copper pipe racks**
High Chloramines Si	23.26		16.24	17.10
High Chloramines P	17.60		25.15	24.80
Low Chloramines Si	20.25		11.97	10.85
Low Chloramines P	16.22		24.40	22.65
Chlorine Si	18.99		122.96	90.61
Chlorine P			49.85	28.04

Apr-09	**Influent of pipe loop**	**Effluent of pipe loop**	**24hr stagnation time in copper pipe racks**	**30min stagnation time in copper pipe racks**
High Chloramines Si			17.16	19.27
High Chloramines P			18.18	14.90
Low Chloramines Si			9.77	8.77
Low Chloramines P			19.10	17.75
Chlorine Si			48.87	43.11
Chlorine P			24.40	19.43

Total Haloacetic Acid (HAA)

Total haloacetic acid concentration measured in the influent and effluent of the pipe loops and after a long and short stagnation time are presented for each of the three sample dates (October 2009, December 2009, and April 2010)/

Oct-09	Influent of pipe loop	Effluent of pipe loop	24hr stagnation time in copper pipe racks	30min stagnation time in copper pipe racks
High Chloramines Si	12.20	22.00	36.55	43.31
High Chloramines P	28.14	16.90	50.96	22.62
Low Chloramines Si	21.26	22.93	37.48	28.18
Low Chloramines P	18.46	18.59	23.71	21.84
Chlorine Si	15.05	15.05	264.56	88.10
Chlorine P	43.94	43.94	246.12	110.06

Dec-09	Influent of pipe loop	Effluent of pipe loop	24hr stagnation time in copper pipe racks	30min stagnation time in copper pipe racks
High Chloramines Si	1.91	20.40	25.53	24.44
High Chloramines P	1.98	20.31	31.76	22.86
Low Chloramines Si	1.78	18.55	23.18	19.41
Low Chloramines P	1.52	15.93	17.30	19.09
Chlorine Si	27.28	37.62	67.70	47.45
Chlorine P	32.51	44.18	83.12	49.91

Apr-09	**Influent of pipe loop**	**Effluent of pipe loop**	**24hr stagnation time in copper pipe racks**	**30min stagnation time in copper pipe racks**
High Chloramines Si	20.11	16.56	21.81	20.42
High Chloramines P		27.50	32.96	22.38
Low Chloramines Si	18.19	13.39	15.67	15.73
Low Chloramines P	10.31	14.13	17.34	16.50
Chlorine Si	22.97	45.32	56.59	51.45
Chlorine P	32.96	7.04	9.64	9.10

APPENDIX E – Results of T-Tests

For all t-tests a 95% significance level (α=0.05) was used. Values that are α<0.025 between treatment groups are considered statistically different, due to two-tailed t-tests significance.

Table E.1 Results of t-tests comparing average total *lead* values at the copper pipe rack effluent using *sodium silicate* as corrosion inhibitor buffered with an acid/base.

Long Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		4.35079E-08	3.82925E-15
Low Chloramines			2.85418E-20
Chlorine			
Short Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.586388236	1.28661E-09
Low Chloramines			0.013099444
Chlorine			

Table E.2 Results of t-tests comparing average total *copper* values at the copper pipe rack effluent using *sodium silicate* as corrosion inhibitor buffered with an acid/base.

Long Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.00010412	0.00292024
Low Chloramines			0.00069982
Chlorine			
Short Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.0478525	0.23052782
Low Chloramines			0.01184859
Chlorine			

Table E.3 Results of t-tests comparing average total *lead* values at the copper pipe rack effluent using *sodium silicate* as corrosion inhibitor buffered with sodium silicate.

Long Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.138876345	1.15963E-07
Low Chloramines			1.55311E-14
Chlorine			
Short Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		1.64661E-08	0.002828619
Low Chloramines			4.04117E-20
Chlorine			

Table E.4 Results of t-tests comparing average total *copper* values at the copper pipe rack effluent using *sodium silicate* as corrosion inhibitor buffered with sodium silicate.

Long Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		6.0175E-38	4.0906E-16
Low Chloramines			5.8277E-12
Chlorine			
Short Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		5.4841E-28	1.8449E-14
Low Chloramines			2.4049E-11
Chlorine			

Table E.5 Results of t-tests comparing the *long vs short stagnation time* in the copper pipe racks with the average total lead values at the effluent of the copper pipe racks using *sodium silicate* as a corrosion inhibitor.

	Total Lead		
	High Chloramines	**Low Chloramines**	**Chlorine**
Buffered with an Acid/Base	1.18724E-14	6.45391E-14	3.12023E-09
Buffered with Sodium Silicate	1.1371E-09	1.97121E-16	9.84961E-12

Table E.6 Results of t-tests comparing average total lead from the copper pipe racks from when sodium silicate was buffered with an acid/base and when buffered with sodium silicate.

	Total Lead		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long Stagnation Time	6.14661E-12	1.7349E-12	0.000112792
Short Stagnation Time	1.03725E-08	0.068086094	0.036881907

Table E.7 Results of t-tests comparing the long and short stagnation time in the copper pipe racks with the average total copper values at the effluent of the copper pipe racks using sodium silicate as a corrosion inhibitor.

	Total Copper		
	High Chloramines	**Low Chloramines**	**Chlorine**
Buffered with an Acid/Base	6.53068E-05	1.39E-19	1.11E-07
Buffered with Sodium Silicate	4.09067E-05	6.33E-33	1.88E-11

Table E.8 Results of t-tests comparing average total *copper* from the copper pipe racks from when sodium silicate was buffered with an acid/base and when buffered with sodium silicate.

	Total Copper		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long Stagnation Time	1.09396E-06	5.17E-07	0.000169
Short Stagnation Time	0.000715	0.000715	0.006311

Table E.9 Results of t-tests comparing average total *lead* values at the copper pipe rack effluent using *phosphate* as corrosion

Long Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		3.52847E-10	2.01818E-14
Low Chloramines			3.52847E-10
Chlorine			
Short Stagnation Time Total Lead			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		5.86796E-10	4.00333E-16
Low Chloramines			1.79768E-05
Chlorine			

Table E.10 Results of t-tests comparing average total *copper* values at the copper pipe rack effluent using *phosphate* as corrosion inhibitor.

Long Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.000625	6.96435E-05
Low Chloramines			0.000625063
Chlorine			
Short Stagnation Time Total Copper			
p-values	**High Chloramines**	**Low Chloramines**	**Chlorine**
High Chloramines		0.050573	0.03442
Low Chloramines			0.071791
Chlorine			

Table E.11 Results of t-tests comparing the long vs short stagnation time in the copper pipe racks with the average total *lead* values at the effluent of the copper pipe racks using *phosphate* as a corrosion inhibitor.

	Total Lead		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long vs. short stagnation time	2.08672E-12	2.07E-19	0.003075

Table E.12 Results of t-tests comparing the long and short stagnation time in the *copper* pipe racks with the average total copper values at the effluent of the copper pipe racks using *phosphate* as a corrosion inhibitor.

	Total Copper		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long vs. short stagnation time	0.12822	3.24E-06	1.09232E-07

Table E.13 Results of t-tests comparing average total *lead* from the copper pipe racks from using *phosphate* and when sodium silicate was buffered with an acid/base.

	Total Lead		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long Stagnation Time	8.73278E-05	8.73278E-05	9.722E-07
Short Stagnation Time	0.027515153	0.021669941	6.22735E-14

Table E.14 Results of t-tests comparing average total *copper* from the copper pipe racks from using *phosphate* and when sodium silicate was buffered with an acid/base.

	Total Copper		
	High Chloramines	**Low Chloramines**	**Chlorine**
Long Stagnation Time	0.002465	0.01925	3.9213E-06
Short Stagnation Time	0.970156	0.000354	1.81E-12