IMPACT OF INTERFERING COMPOUNDS ON THE FERRIC CHLORIDE ARSENIC REMOVAL TREATMENT PROCESS

By

BENJAMIN HENRY WARE

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The members of the committee appointed to examine the thesis of BENJAMIN HENRY WARE find it satisfactory and recommend that it be accepted.

David R. Yonge, Ph.D., Chair

Richard J. Watts, Ph.D.

Marc Beutel, Ph.D.

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IMPACT OF INTERFERING COMPOUNDS ON THE FERRIC CHLORIDE

ARSENIC REMOVAL TREATMENT PROCESS

Abstract

by Benjamin Henry Ware, M.S.
Washington State University
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Chair: David R. Yonge

Since implementation of the 0.010 mg/L maximum contamination level drinking water standard for arsenic, many small public water suppliers have been struggling to remain in compliance. A popular treatment strategy is coagulation/flocculation using ferric chloride followed by filtration. The presence of phosphate and/or silicate in the source water, however, has been shown to decrease arsenic removal. The objective of this research was to evaluate arsenic removal and floc formation as a function of ferric chloride dose, silicate concentration and phosphate concentration. A synthetic groundwater, developed based on the average composition of major constituents found in Island County, WA groundwater was used in all experiments. Field treatment conditions were replicated using standard jar testing equipment to evaluate the impact of a range of silicate and phosphate concentrations on arsenic removal. Arsenic concentrations were determined by Inductively Coupled Plasma-Mass Spectrometry. In synthetic groundwater that contained no phosphate or silicate, arsenic concentrations in filtrate ranged from 0.004 to 0.002 mg/L (95 to 97 % removal) over the range of iron concentrations evaluated. Both phosphate and silicate decreased arsenic removal at low iron dosages, resulting in arsenic concentrations greater than 0.010 mg/L. However, higher iron dosages overcame the

interfering compounds effects, reducing arsenic concentrations to levels that were below the maximum contamination level.

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DEDICATION

This thesis is dedicated to my family who encouraged me
to work smart not hard.

INTRODUCTION

Arsenic is a naturally occurring constituent of groundwater with two common oxidation states. The reduced form is most often found in groundwater, arsenite (As(III) as AsO_3^{3-}), while the oxidized form, arsenate (As(V) as AsO_4^{3-}), predominates in surface waters (USEPA, 2000). Most waters usually contains a mixture of both As (III) and As(V), and the ratio depends on the redox condition of the given water. Depending on pH, As(V) exists as a weak acid with chemical formulas of AsO_4^{3-}, $HAsO_4^{2-}$, $H_2AsO_4^{-}$, or H_3AsO_4.

Drinking water containing elevated levels of arsenic is a significant threat to human health, resulting in both acute and chronic toxic effects. Arsenic attacks DNA ligase and polymerase that correct mutations in DNA, which increases the risk of cancer initiation, resulting in cancers of the bladder, kidney, liver, lung, and other organs (USEPA, 2000). Due to the increased health risk from arsenic exposure, the United States Environmental Protection Agency (USEPA) and the World Health Organization (WHO) reduced the maximum contamination level (MCL) of arsenic in drinking water from 50 to 10 µg/L effective in 2006.

Although there are several methods of removing soluble inorganic arsenic from solution, one of the most popular techniques, and the subject of this research, is chemical coagulation and flocculation using ferric chloride. Ferric chloride coagulation is an economical form of treatment and can exhibit high arsenic removal efficiencies, making ferric chloride advantageous for application in small public treatment systems. Ferric chloride ($FeCl_3 \cdot 6H_2O$) is an inorganic metal salt that can be purchased in solid or solution form. Once mixed with raw water it undergoes hydrolysis and forms ferric hydroxide floc. Arsenic forms inner sphere complexes with ferric hydroxide sites on amorphous ferric hydroxide floc that is then removed by gravity settling or direct filtration (Meng et al, 2000). Arsenic oxidation state, pH, and coagulate dose affects arsenic removal efficiency (Bilici Baskan et al, 2010). Arsenite adsorption onto iron hydroxides may only be 5% - 30% that of arsenate adsorptions, therefore, arsenite is normally oxidized to arsenate before ferric chloride treatment (Chwirka et al, 2004).

One difficulty in meeting the new arsenic MCL using ferric chloride treatment is the presence of interfering compounds in the raw groundwater. The presence of interfering compounds has been shown to allow soluble arsenic to pass through filters and into the water supply. Interfering compounds are also known to increase iron breakthrough in ferric chloride treatment systems (Meng et al, 2000). Iron breakthrough is defined as the amount of soluble iron that is not captured in the filter and remains in the treated water. The iron concentration in drinking water is a secondary water quality standard and should not be exceeded by the addition of ferric chloride. Arsenic and iron in treated water is both unsafe and aesthetically displeasing for human consumption. Compounds that interfere with ferric chloride treatment include phosphate and silicate and the mechanisms of interference for each compound are different.

Phosphate (PO_4^{3-}) is most commonly found in the earth's crust as the mineral apatite, and is released into groundwater from weathering of apatite or from anthropogenic sources such as detergents and fertilizer (Matthess, 1982). Due to phosphate's nearly identical structure and chemical properties relative to arsenate, phosphate replaces arsenate at iron floc binding sites and is a competitive inhibitor (Laky et al, 2011; Guan et al, 2009; Roberts et al, 2004). The findings of Laky et al, (2011) discovered that when phosphate concentrations increased from 0.5 to 1.0 mg/L, an additional 80 percent iron dose was required to lower arsenic concentrations below the MCL. In addition, if a ferrous salt is used for coagulation, phosphate has been shown to inhibit the formation of ferric hydroxide floc over a pH range of 7-9 by keeping floc surfaces negative and preventing the ferric hydroxide floc from growing (Guan et al, 2009).

Silicon species have been shown to effect arsenic removal by adsorbing onto floc particles, which increases the negative charge (zeta potential) of ferric hydroxide floc and thereby increasing repulsion forces between floc particles, sequestering floc polymerization (Ruiping et al, 2007; Pokrovski et al, 2003). Silicate (SiO_4^{4-}) naturally occurs in groundwater from the weathering of silicate minerals and typically exists in two forms: amorphous colloidal silica and soluble reactive silicate (Matthess, 1982). However, silicate is not stable in water as SiO_4^{4-} and hydrates to orthosilicic acid, H_4SiO_4 (Matthess, 1982; Krauskopf, 1956). Orthosilicic acid has such a high pKa ($pK_{a1} = 9.8$ and $pK_{a2} = 13.2$) that orthosilicic acid is stable as an uncharged, protonated weak acid under circa neutral pH conditions. Therefore, orthosilicic acid will hereafter be referred to as silicate and expressed as mg/L Si. Guan et al, (2009) found that the presence of 10 mg/L silicate had no observed effect on arsenic removal in the pH range of 4 to 5. However, in a 10 mg/L silicate solution, arsenic removal decreased by 5%, 18%, 53% and 42% at pH values of 6, 7, 8 and 9, respectively. At pH levels above 6, silicate significantly increases the solubility of iron, decreasing the potential for effective coagulation/flocculation (Guan et al, 2009).

The presence of calcium ions has been shown to reduce some of the negative effects silicate has on arsenic removal. In the absence of silicate, Smith et al, (2002) demonstrated that most arsenic was adsorbed to ferric hydroxide at a pH of 8.5. In water containing 18.7 mg/L silicate, the arsenic removal decreased to 48 percent. However, when 18.7 mg/L silicate and 10 mg/L calcium was present the arsenic removal increased to 84 percent. A possible mechanism for calcium increasing arsenic removal in the presence of silicate is it lowers the zeta potential toward the zero point of charge, thus enhancing floc formation (Ruiping et al, 2007).

It is clear that ferric hydroxide coprecipitation with arsenic can be an effective method of arsenic removal for small drinking water systems. However, studies indicate that if the raw water contains phosphate or silicate the arsenic removal may be decreased. Most studies have investigated the single effect of each interfering compound (Laky et al, 2011; Guan et al, 2009; Ruiping et al, 2007; Pokrovski et al, 2003). No studies were found that examined the combined interference of phosphate and silicate on ferric chloride coagulation treatment. Consequently, this research was focused on both the single and combined effects of phosphate and silicate on arsenate removal using a simulated groundwater.

MATERIALS AND METHODS

Chemicals. All experiments used analytical reagent grade chemicals. Chemicals included arsenate as $HAsNa_2O_4 \cdot 7H_2O$ (Aldrich Chemistry), ferric chloride as $FeCl_3 \cdot 6H_2O$ (Fisher Scientific), silicate as $Na_2SiO_3 \cdot 5H_2O$ (Fisher Scientific), and phosphate as KH_2PO_4 (J.T. Baker). Food grade NaCl (Morton Salt, Inc.) was used as an inert tracer to define the hydraulic characteristics of a field scale treatment system. All stock solutions were prepared using 18 MΩ deionized water.

Tracer Study. The Brutus Water System (Brutus) supplies drinking water to 28 homes in Island County, WA and removes arsenic from raw groundwater at an average flow of 14 gpm. The Brutus treatment system is composed of ferric chloride injection by a flow paced chemical pump, followed by a KOFLO™ 1 ½" PVC static mixer. The flow then enters through internal diffuser bars into the bottom of two 120 gallon Flexcon pressurized contact tanks in series and finally to a filtration unit (Figure 1). To accurately replicate the nominal (actual operating) hydraulic residence time of the field scale treatment system, an impulse input tracer study of the ferric chloride treatment process was completed on the Brutus Water System contact tanks. The nominal residence time gives a more accurate hydraulic residence time than the theoretical residence (volume/flow rate).

To perform the tracer study on the Brutus Water System, an Eco Testr EC Low Waterproof Pocket Tester conductivity meter was attached to the sampling port downstream of ferric hydroxide coagulation/flocculation unit. Background conductivity measurements were recorded. An injection pipe was then filled with 300 mL of 300 g/L NaCl solution (Figure 1). Water flow was redirected though the injection pipe to inject the saline tracer solution as an impulse. Time and water conductivity downstream of the tanks were recorded until conductivity returned to near background levels. Equation 1 was used to estimate the nominal residence time ($\bar{t}$) (Levenspiel, 1962).

$$\bar{t} \cong \frac{\sum t_i C_i \Delta t_i}{\sum C_i \Delta t_i} \quad (1)$$

where $t_i = discrete\ time$

$C_i = tracer\ concentration\ leaving\ system\ at\ t_i$

$\Delta t_i = time\ interval\ between\ t_i\ and\ t_{i-1}$

Synthetic groundwater. Synthetic groundwater was used in all testing, and was based on the average constituent concentrations of groundwater found in the arsenic affected areas of Island Co. Washington (USGS, 1968). The concentrations of constituents are summarized in Table 1. The synthetic groundwater was prepared by bubbling nanopure DI water with air overnight or until the pH reached approximately 5.5. To maximize the production of reactive silicate, solid $Na_2SiO_3 \cdot 5H_2O$ powder was added to 3 L of DI water to achieve final silicate concentrations of 10, 20 or 40 mg/L as Si. The $Na_2SiO_3 \cdot 5H_2O(s)$ was allowed to dissolve for 30 minutes. After dissolution, the solution pH was about 11. Afterwards 8 mL of Na_2CO_3 stock solution (90 g/L) was added, decreasing the solution pH to 9.5. A predetermined amount of HNO_3 was added that ultimately resulted in a final pH of 8.2 ± 0.1. The remaining minerals were then added to the solution to achieve the concentrations listed in Table 1. Phosphate concentrations and As(V) were added using 1 g/L stock solutions. The initial As(V) concentration in the synthetic groundwater was 0.075 mg/L. The synthetic groundwater was then bubbled with air for 24 hours, which allowed the pH to stabilize to the target value of 8.2.

Jar testing procedure. All tests were conducted at room temperature (~25 ℃), and were open to the atmosphere. Glassware was cleaned by soaking in 10 percent (v/v) HNO_3 and rinsed three times with deionized water. One liter of the synthetic groundwater was transferred into one liter circular Pyrex beakers and set into a standard gang stirrer (Phipps and Bird, PB - 700 JARTESTER) equipped with 1" x 3" rectangular paddles. During the coagulation/flocculation procedure, ferric chloride was added and flash mixed for 1 minute at 100 rpm yielding a mean velocity gradient (G) of $G = 106\ s^{-1}$, followed by 20 minutes of slow mixing (30 rpm; $G = 42\ s^{-1}$) and then allowed 10 minutes of quiescent settling. The G values were calculated using data supplied by (Jones et al, 1978).

Following the quiescent settling period, 200 mL of supernatant was collected 4 cm below the sample surface and was immediately vacuumed filtered through a 1.2 micron glass fiber filter (Wattman GFC) using Nalgene filter funnels. There was no attempt to control the pH in these experiments, therefore the final pH of the synthetic groundwater was recorded using a HACH HQ411d pH meter after the settling period. The floc formation character was evaluated qualitatively via visual inspection to assess settling rate, floc size and presence of suspended pin floc. The supernatant was then subjected to As, Fe, and PO_4^{3-} analysis.

Analytical methods. Arsenic concentration in the filtrate was analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), PO_4^{3-} concentrations were analyzed using stannous chloride method 4500 – P D (Standard Methods, 2005) and Fe concentrations were determined using HACH method 8008 in conjunction with a spectrophotometer set at a wave length of 510 nm.

Factorial Experimental Design. Arsenic removal under a range of iron doses (2, 4 and 6 mg/L as Fe), silicate (0, 10, 20, 40 mg/L as Si) and phosphate concentrations (0, 0.5, 1.0, 1.5 mg/L as PO_4^{3-}) was evaluated. In order to statistically quantify the effects of these factors and their concentrations, a two level, three factor experimental design was applied in the data analysis. Since the factorial design uses two concentrations (high and low) for each factor, multiple factorial analyses were performed in order to cover the entire range of factor concentrations used herein. The diagram in Figure 2 is an example of one factorial design. The main effect of each factor was defined as the average change in response (arsenic concentration) caused by the changing one factor from its low to its high level. A two factor interaction was defined as a combined effect of the factors on arsenic concentration. After all eight combinations of factor levels were evaluated via jar testing, each arsenic concentration response was designated y_1 through y_8. For example, y_4 is a response of arsenic concentration that resulted from Fe at its high level (+), Si at its low level (-) and PO_4^{3-} at its high level (+). Equations 2 through 8 were used to estimate both the main effects and interactions (Berthouex and Brown, 1994).

$$Main\ effect\ of\ Fe\ \left[As\frac{mg}{L}\right] = \frac{y_2+y_4+y_6+y_8}{4} - \frac{y_1+y_3+y_5+y_7}{4} \quad (2)$$

$$Main\ effect\ of\ PO_4^{3-}\left[As\frac{mg}{L}\right] = \frac{y_3+y_4+y_7+y_8}{4} - \frac{y_1+y_2+y_5+y_6}{4} \quad (3)$$

$$Main\ effect\ of\ Si\ [As\ mg/L] = \frac{y_5+y_6+y_7+y_8}{4} - \frac{y_1+y_2+y_3+y_4}{4} \quad (4)$$

$$Interaction\ of\ Fe\ and\ PO_4^{3-}\left[As\frac{mg}{L}\right] = \frac{y_1+y_4+y_5+y_8}{4} - \frac{y_2+y_3+y_6+y_7}{4} \quad (5)$$

$$Interaction\ of\ Fe\ and\ Si\ \left[As\frac{mg}{L}\right] = \frac{y_1+y_3+y_6+y_8}{4} - \frac{y_2+y_4+y_5+y_7}{4} \quad (6)$$

$$Interaction\ of\ PO_4^{3-}\ and\ Si\left[As\frac{mg}{L}\right] = \frac{y_1+y_2+y_7+y_8}{4} - \frac{y_3+y_4+y_5+y_6}{4} \quad (7)$$

$$Interaction\ of\ Fe, Si\ and\ PO_4^{3-}\ \left[As\frac{mg}{L}\right] = \frac{y_2+y_3+y_5+y_8}{4} - \frac{y_1+y_4+y_6+y_7}{4} \quad (8)$$

A normal probability plot of the main effects and interactions was made to determine if the main effects and interactions calculated were significant. If the effects are from randomly distributed errors then they will form a linear line on the normal probability plot (Berthouex and

Brown, 1994). If the data lie off the linear line, the effect or interactions are considered significant.

For example, Figure 3 shows a factorial design with indicated values of Fe dose, Si and PO_4^{3-} concentrations. To prepare a normal plot, the main effects and interactions were calculated using equations 2 through 8 and sorted in ascending order, shown in Table 2. In the normal probability plot, the normal order scores from Teichroew (1956) were plotted versus the sorted main effects and interactions (Figure 4). Once plotted the data is compared to a line of best fit and any points on the line are not significant (Fe- PO_4^{3-}, Fe-Si, and Fe- PO_4^{3-}-Si) and any points off the line are deemed significant (PO_4^{3-}, PO_4^{3-} -Si, and Si) shown in Figure 4. This study investigated three levels of Fe (2, 4, 6 mg/L), and four levels of Si (0, 10, 20, 40 mg/L) and PO_4^{3-} (0, 0.5, 1.0, 1.5 mg/L) as shown in Table 3. Therefore, arsenic removal was evaluated over 48 different factor level combinations.

The factorial design does not require replication of the experiments to ensure the precision of the data. However, triplicates tests were performed at selected conditions to determine the repeatability of the experiments and are noted in Table 3 as bold font. The triplicates selected were low Fe, low Si, low PO_4^{3-} and medium Fe, medium Si, medium PO_4^{3-} and high Fe, high Si, high PO_4^{3-}. To ensure that the experiments were reproducible, a second set of arsenic removal experiments were performed one month later with new stock solutions and new synthetic groundwater over the range of Fe (2, 4, 6 mg/L), PO_4^{3-} (0.5, 1.0, 1.5 mg/L) and a fixed Si concentration of 20 mg/L. These are the last italic entries in Table 3.

RESULTS AND DISCUSSION

Tracer Study. Based on data from the Brutus system tracer study shown in Figure 5, the two tanks in series treatment system in the field behaved similar to two ideal continuously stirred tank reactors (CSTR) in series. The treatment system does exhibit some minor dead zones in the tanks indicated by the longer tail section of the normalized conductivity values compared to the ideal CSTR curve (Figure 5). The existence of dead zones is not surprising because the pressurized tanks in the Brutus system are not mechanically stirred, but use an internal diffuser bar to distribute flow. The nominal (actual) residence time of the treatment system was 19.6 minutes and the theoretical residence time was 17.2 minutes. Despite the effect of dead zones the nominal residence time was within 14 % of the theoretical residence time, indicating that the tanks are close to ideal CSTR's.

Iron Breakthrough. Ferric chloride is an affordable coagulant that effectively removes arsenic from drinking water in the absence of interfering constituents, which was evident in this research. In synthetic groundwater that contained no phosphate or silicate the percent arsenic removal was 95, 96, and 97% for 2, 4, and 6 mg/L iron, respectively. An iron dose of 2 mg/L was sufficient to lower arsenic concentrations to below MCL standards, yielding a final arsenic concentration of 0.004 mg/L. No iron breakthrough was observed in this research as all concentrations were below the HACH 8008 method detection limit of 0.02 mg/L for all conditions studied. This finding is supported by Laky et al, (2011) who observed iron breakthrough of 0.015 mg/L iron following filtration through a 0.45 μm pore size membrane in the presence of 28 mg/L Si.

Phosphate interference. Since phosphate is a competitive inhibitor, it was expected that high arsenic removal efficiency could be maintained by increasing ferric chloride dose proportional to the phosphate concentration. No visual impact on floc formation was observed by the presence of phosphate. The results of singular phosphate interference are shown in Figure 6. When synthetic water was dosed with 2 mg/L iron and phosphate levels of 1.0 and 1.5 mg/L, the final arsenic concentration was 0.021 and 0.030 mg/L arsenic, respectively. An iron dose of 2 mg/L, with no phosphate present, resulted in 95 % arsenic removal, but in the presence of 1.0 and 1.5 mg/L phosphate the arsenic percent removal was reduced to 72 and 60 %, respectively. However, an iron dose of 4 mg/L (100% dose increase) removed arsenic to below the US EPA arsenic standard over the range of phosphate levels used in this study. These findings are similar to results from Laky et al, (2011) who stated that an 80 % increase in iron dose was needed to reach 0.010 mg/L arsenic in the presence of 1.2 mg/L phosphate.

Silicate interference. Silicate has been reported as a non-competitive inhibitor. Silicate was believed to not actively compete for binding sites, but act as a dispersant, inhibiting the formation of ferric hydroxide solids with a resulting increase in soluble arsenic concentrations (Guan et al, 2009; Pokrovski et al, 2003). The findings of Brandhuber, (2004) observed that smaller floc was formed as silicate concentration increased. The qualitative data from this study confirmed that smaller floc was formed in the presence of silicate. Floc formation was delayed by a few minutes longer in the presence of silicate when compared to the phosphate tests. The overall floc size was decreased and more pin floc was observed after the settling period.

The results of silicate as a single inhibitor are presented in Figure 7. At silicate concentrations of 20 and 40 mg/L (as Si), dosed with 2 mg/L iron, observed arsenic concentrations were 0.015 and 0.022 mg/L, respectively. At the lowest silicate concentration of 10 mg/L, all iron treatment doses removed arsenic to levels below 0.004 mg/L, or 95 percent removal. Guan et al, (2009) reported only 80 percent arsenic removal in the presence of 10 mg/L silicate and iron dose of 2.5 mg/L. Even lower arsenic removal (55 %) was found by Laky et al, (2011), who used similar low ranges of coagulant (Fe = 1.5 mg/L) and silicate (Si = 10 mg/L). This decrease in percent arsenic removal compared to this study could be due to the lack of Ca^{2+} ions in the Laky et al, (2011 and Guan et al, (2009) synthetic test water. The presence of divalent ions, specifically calcium and magnesium, aids in ferric hydroxide formation in the presence of silicate (Ruiping et al, 2007). Lytle et al, (2005) observed a 30 percent increase in arsenic removal in the presence of 80 mg/L calcium, while the synthetic Island County groundwater contained only 40 mg/L Ca^{2+}.

In synthetic groundwater containing silicate only, an iron dose of 4 mg/L was required to reduce final arsenic concentrations to below the MCL of 0.010 mg/L. The lower silicate interference found in this study could be explained not only by the presence of Ca^{2+} but by the final pH of synthetic groundwater after ferric chloride treatment. Researchers have shown that reducing pH decreases silicate interference with regard to arsenic removal. The final pH during jar testing ranged from 6.5 to 7.7 which was a similar pH range to Guan et al, (2009). Similarly, Holm, (2002) found that in water with 11 mg/L Si and 0.0395 mg/L As, reducing pH from 8 to 7, increased arsenic removal from 50 to 90 percent.

Combined phosphate and silicate interference. The combined effect that phosphate and silicate compounds have on arsenic removal adds a level of complexity that leaves a void of knowledge, warranting this research. Phosphate and silicate have two different theorized mechanisms of interference as previous stated, direct competition and inhibiting floc formation, respectively. The arsenic data displayed in Figure 8, over the range of silicate and phosphate concentrations studied at a fixed iron dose of 2 mg/L, showed 9 of the 12 phosphate and silicate level combinations had final arsenic concentrations above the MCL. The phosphate and silicate main effects and phosphate-silicate interaction were evaluated by factorial analysis between the 2 and 4 mg/L iron levels, shown in Table 4.

Contained in Table 4 are all 36 variations of phosphate and silicate levels over the 2 and 4 mg/L iron dose, including their statistical significance and average increase in arsenic response. The only conditions that had a significant phosphate-silicate interaction was an increase of phosphate from 0 to 0.5 mg/L and increase of silicate from 0 to 10 mg/L, which increased the arsenic concentration in the filtrate by an average of 0.003 mg/L (Equation 5). Although only one significant phosphate-silicate interaction was found, the main effects of phosphate and silicate were often determined to be significant at iron doses of 2 and 4 mg/L. For example, an increase of silicate from 0 to 10 mg/L and an increase of phosphate from 0 to 1.5 mg/L resulted in the main effect of phosphate increasing the arsenic concentration by an average of 0.017 mg/L (Equation 3). While increasing phosphate levels from 0 to 0.5 mg/L and increasing silicate from 0 to 40 mg/L, the main effect of silicate increased final arsenic concentration by an average of 0.011 mg/L (Equation 4). At all levels of silicate tested the increase of phosphate from 0 to 1.5 mg/L, resulted in a significant increase in final arsenic concentrations. Likewise, over the whole range of phosphate levels, an increase of 0 to 40 mg/L silicate resulted in a significantly increased final arsenic concentrations.

Arsenic concentration data shown in Figure 10, at a higher iron dose of 6 mg/L, overcame the combined interference and removed arsenic to below MCL. However, after completing factorial analysis between 4 and 6 mg/L iron dose many of the increases in phosphate and silicate concentration were statistically significant (Table 5). Although these main effects were statistically significant, the main effect of iron was large enough to lower the effects of phosphate and silicate and kept arsenic concentration below the MCL.

Triplicate data was taken to determine the repeatability of the experiments. The standard deviation values of the triplicate data in Table 2 are small and range from 0.000 to 0.0035 mg/L arsenic. Later a replicate set data over the range of iron (2, 4, 6 mg/L), phosphate (0.5, 1.0, 1.5 mg/L) at a fixed silicate concentration of 20 mg/L was performed to determine the reproducibility of the arsenic removal experiments. The largest deviation between the original and the replicated set of arsenic removal data was 0.002 mg/L arsenic (Figure 11).

CONCLUSIONS

This research was conducted to better understand the combined effect that interfering compounds have on traditional ferric chloride treatment for arsenic removal. By replicating the groundwater of Island County, Washington and controlling the concentrations of interfering compounds, their effect at low iron doses (e.g. 2 mg/L) can decrease arsenic removal from 97 to 59 percent. At a higher iron dose of 4 mg/L the interfering effects are significantly reduced (Figure 9). The only condition that resulted in arsenic concentrations greater than the MCL of 0.010 mg/L was 20 or 40 mg/L silicate combined with 1.5 mg/L phosphate at an iron dose of 4 mg/L. Although effects of phosphate and silicate were observed on arsenic concentration at an iron dose of 6 mg/L, all arsenic concentrations were significantly less than 0.010 mg/L. Consequently, over the range of concentrations studied, increasing iron dose can yield finished water that meets the 0.010 mg/L MCL.

FUTURE STUDIES

Based on the literature, humic substances have been reported to interfere with arsenic removal. Therefore future research topics include the effect humic and fulvic acids have on ferric chloride treatment. Additionally, the combined effects that humic acid with phosphate and silicate have on arsenic removal efficiency will yield a better understanding of naturally occurring interfering compounds in marginal groundwater sources. The presence of Ca^{2+} and Mg^{2+} in synthetic groundwater also merits further research because of their capacity to decrease silicate interference (García-Lara et al, 2010). Calcium or magnesium may also warrant use as coagulant aids in soft water systems.

REFERENCES

Bilici Baskan, M.; Pala, A.; Turkman, A., 2010. Arsenate Removal by Coagulation Using Iron Salts and Organic Polymers. *Ekoloji*, 19:74:69.

Berthouex, P.; Brown, L., 1994. *Statistics for Environmental Engineers.* CRC Press, Boca Raton, FL.

Brandhuber, P. Impact of the presence of silica on the treatment of arsenic on drinking water. Proc. 2004 AWWA WQTC.

Chwirka, J.; Colvin, C.; Gomez, J.; Mueller, P., 2004. Arsenic removal from drinking water using coagulation/microfiltration process. *Journal of American Water Works Association*, 96:3:106.

García-Lara, A.M.; Montero-Ocampo, C., 2010. Improvement of Arsenic Electro-Removal from Underground Water by Lowering the Interference of Other Ions. *Water Air Soil and Pollution*, 205:1-4:237.

Guan, X.; Dong, H.; Ma, J.; Jiang, L., 2009. Removal of arsenic from water: Effects of competing anions on As(III) removal in KMnO4–Fe(II) process. *Water Research,* 43:3891.

Holm, T., 2002. Effects of CO_3^{2-}/bicarbonate, Si, and2 PO_4^{3-} on Arsenic sorption to HFO. *Journal of American Water Works Association*, 94:4:174.

Jones, R.; Williams, R.; Moore, T., 1978. Development and Application of Design and Operation Procedures for Coagulation of Dredged Material Slurry and Containment Area Effluent. Environmental Laboratory U.S. Army Engineer Waterways Experiment Station, Technical Report D-78-54. 1-176.

Krauskopf, K., 1956. Dissolution and precipitation of silica at low temperatures. *Geochimica et Cosmochimica Acta*, 10:1-2:1.

Laky, D.; Licskó, I., 2011. Arsenic removal by ferric-chloride coagulation-effect of phosphate, bicarbonate and silicate. *Water Science & Technology*, 64:5:1046.

Levenspiel, O., 1962. *Chemical Reaction Engineering*, John Wiley and Sons, New York, N.Y.

Lytle, D.; Sorg, T.; Snoeyink, V., 2005. Optimizing arsenic removal during iron removal: Theoretical and practical considerations. *Journal of Water: Research & Technology–AQUA*, 54:8:545.

Matthess, G., 1982. *The Properties of Groundwater.* Trans. John C. Harvey, John Wiley and Sons, New York, N.Y.

Meng, X.; Bang, S.; Korfiatis, G., 2000. Effects of silicate, sulfate, and carbonate on arsenic removal by ferric chloride. *Water Resource* 34:4:1255.

Pokrovski, G.; Schott, J.; Farges, F.; Hazemann, J., 2003. Iron (III)-silica interactions in aqueous solution: Insights from X-ray absorption fine structure spectroscopy. *Geochimica et Cosmochimica Acta*, 67:19:3559.

Roberts, L.; Hug, S.; Ruettimann, T.; Billah, M.; Khan, A.; Rahman, M., 2004. Arsenic Removal with Iron(II) and Iron(III) in Waters with High Silicate and Phosphate Concentrations. *Environmental Science & Technology*, 38:1:307.

Ruiping, L,; Xing, L,; Shengji, X,; Yanling, Y,; Rongcheng, W,; Guibal, L., 2007. Calcium-enhanced ferric hydroxide co-precipitation of arsenic in the presence of silicate. *Water Environment Research*, 79:11:2260.

Standard Methods for the Examination of Water and Wastewater. 2005 (21th ed.). American Public Health, American Water Works Association, and Water Environment Federation, Washington.

Smith, S.; Ewards, M. The influence of water quality on arsenate sorption kinetics. Proc. 2002 AWWA WQTC.

Teichroew, D., 1956. Tables of Expected Values of Order Statistics and Products of Order Statistics for Samples of Size Twenty and Less from the Normal Distribution. *The Annals of Mathematical Statistics*, 27:2:410.

USEPA, 2000. "Technologies and Costs for Removal of Arsenic from Drinking Water." EPA 815-R-00-028 Retrieved from www.epa.gov/safewater

USGS, 1968. Groundwater Resources of Island County. Water Resources Division VanDenburgh, A. Water Supply Bulletin No. 25, 22-26

Table 1. Chemical and physico-chemical characteristics of synthetic and Island County groundwater.

	Synthetic Water		Natural Water	
pH	8.2 ± 0.1		8	
Conductivity [uS/cm]	1060		400	
Alkalinity[mg/L as $CaCO_3$]	125		136	
Inorganic Species	[mg/L]	[meq/L]	[mg/L]	[meq/L]
Cl^-	100	2.82	30	0.85
NO_3^-	1.3	0.02	1.3	0.02
SO_4^{2-}	20	0.42	20	0.42
CO_3^{2-}	136	4.54	140	4.66
	∑ =	**7.80**	∑ =	**5.95**
Na^+	105	4.56	60	2.61
K^+	3.3	0.08	3.3	0.08
Mg^{2+}	14.2	1.17	14.2	1.17
Ca^{2+}	40	1.99	40	1.99
	∑ =	**7.80**	∑ =	**5.85**

Table 2. An example of calculated values of main effects and interactions and ascending order sorted main effects and interactions to be plotted in normal probability plot.

Full Factorial Experiment Design 2^3 Factorial						
y_1 =	0.004	Effect or Interaction	Main Effect or Interaction Eqns 2-8 [As mg/L]	Sorted Effect or Interaction [As mg/L]		Normal Order Score
y_2 =	0.0025	Fe	-0.00638	Fe	-0.00638	-1.352
y_3 =	0.007	PO_4^{3-}	0.00338	Fe- PO_4^{3-}	-0.00363	-0.757
y_4 =	0	Si	0.00188	Fe-Si	-0.00213	-0.353
y_5 =	0.004	Fe- PO_4^{3-}	-0.00363	Fe- PO_4^{3-} -Si	-0.00088	0
y_6 =	0	Fe-Si	-0.00213	Si	0.00188	0.353
y_7 =	0.015	PO_4^{3-} -Si	0.00313	PO_4^{3-} -Si	0.00313	0.757
y_8 =	0.002	Fe- PO_4^{3-} -Si	-0.00088	PO_4^{3-}	0.00338	1.352

Table 3. Variations in concentrations of the three factors evaluated in this research and the resulting arsenic concentrations in filtrate.

Fe [mg/L]	Si [mg/L]	PO_4^{3-} [mg/L]	As [mg/L]	Initial pH	Final pH	
2	0	0	0.004	8.19	7.5	
4	**0**	**0**	**0.003**	**8.19**	**7.09**	As σ =
4	**0**	**0**	**0.003**	**8.19**	**7.09**	0.0000
4	**0**	**0**	**0.003**	**8.19**	**7.09**	
6	0	0	0.002	8.19	7.15	
2	10	0	0.004	8.09	-	
4	10	0	ND	8.09	-	
6	10	0	ND	8.09	-	
2	20	0	0.015	8.06	7.02	
4	20	0	0.008	8.06	6.79	As σ =
4	20	0	0.002	8.06	6.79	0.0035
4	20	0	0.002	8.06	6.79	
6	20	0	0.001	8.06	6.6	
2	40	0	0.022	8.16	7.63	
4	40	0	0.006	8.16	7.19	
6	40	0	0.002	8.16	6.95	
2	10	1.5	0.033	8.11	7.66	
4	10	1.5	0.01	8.11	7.46	
6	10	1.5	0.001	8.11	7.23	
2	10	1	0.03	8.13	7.63	
4	10	1	0.006	8.13	7.38	
6	10	1	ND	8.13	7.06	
2	20	0.5	0.024	8.21	7.67	
4	20	0.5	0.005	8.21	7.43	
6	20	0.5	0.001	8.21	7.2	
2	20	1	0.031	8.18	7.39	
4	**20**	**1**	**0.007**	**8.18**	**7.2**	As σ =
4	**20**	**1**	**0.007**	**8.18**	**7.17**	0.0006
4	**20**	**1**	**0.008**	**8.18**	**7.15**	
6	20	1	0.002	8.18	7.09	
2	20	1.5	0.037	8.19	7.32	
4	20	1.5	0.013	8.19	7.2	
6	20	1.5	0.003	8.19	7.05	
2	10	0.5	0.015	8.11	7.39	
Fe	Si	PO_4^{3-}	As	Initial	Final	

[mg/L]	[mg/L]	[mg/L]	[mg/L]	pH	pH	
4	10	0.5	0.002	8.11	7.14	
4	10	0.5	0.002	8.11	7.15	
6	10	0.5	ND	8.11	7.02	
2	40	0.5	0.023	8.05	7.31	
4	40	0.5	0.005	8.05	7.07	
6	40	0.5	0.002	8.05	6.92	
2	40	1	0.029	8.08	7.27	
4	40	1	0.008	8.08	7.07	
6	40	1	0.002	8.08	6.87	
2	40	1.5	0.037	8.08	7.01	
4	40	1.5	0.014	8.08	6.91	
6	**40**	**1.5**	**0.004**	**8.08**	**6.81**	As σ =
6	**40**	**1.5**	**0.004**	**8.08**	**6.81**	0.0000
6	**40**	**1.5**	**0.004**	**8.08**	**6.82**	
0	0	0	ND	-	-	
2	0	0.5	0.007	8.25	7.65	
4	0	0.5	ND	8.25	7.52	
6	0	0.5	ND	8.25	7.53	
2	0	1	0.021	8.25	7.55	
4	0	1	0.002	8.25	7.35	
4	0	1	0.002	8.24	7.81	
4	0	1	0.002	8.24	7.63	
6	0	1	ND	8.24	7.38	
2	0	1.5	0.03	8.25	7.55	
4	0	1.5	0.006	8.25	7.36	
6	0	1.5	0.001	8.25	7.17	
2	**10**	**0.5**	**0.019**	**8.22**	**7.4**	As σ =
2	**10**	**0.5**	**0.019**	**8.22**	**7.4**	0.0000
2	**10**	**0.5**	**0.019**	**8.22**	**7.4**	
2	*20*	*0.5*	*0.023*	*8.15*	*7.44*	
4	*20*	*0.5*	*0.004*	*8.15*	*7.32*	
6	*20*	*0.5*	*0.001*	*8.15*	*7.16*	
2	*20*	*1*	*0.032*	*8.12*	*7.47*	
4	*20*	*1*	*0.007*	*8.12*	*7.35*	*As σ =*
4	*20*	*1*	*0.009*	*8.12*	*7.35*	*0.0010*
4	*20*	*1*	*0.008*	*8.12*	*7.35*	
Fe [mg/L]	Si [mg/L]	PO_4^{3-}	As [mg/L]	Initial pH	Final pH	

		[mg/L]			
2	*20*	*1.5*	*0.039*	*8.13*	*7.11*
4	*20*	*1.5*	*0.014*	*8.13*	*7.09*
6	*20*	*1.5*	*0.003*	*8.13*	*6.99*

Table 4. The statistically significant average arsenic increases due to increases in phosphate and silicate concentrations at iron dosages of 2 and 4 mg/l.

	PO_4 [mg/L]		Si [mg/L]		PO_4 Main Effect		Si Main Effect		PO_4-Si Interaction	
Cube #	Low	High	Low	High	Significant	Average As [mg/L]	Significant	Average As [mg/L]	Significant	Average As [mg/L]
1	0	0.5	0	10	Yes	0.0034	Yes	0.0020	Yes	0.0031
2	0	0.5	10	20	Yes	0.0058	Yes	0.0068	No	-
3	0	0.5	20	40	Yes	0.0025	No	-	No	-
4	0.5	1	0	10	Yes	0.0088	Yes	0.0058	No	-
5	0.5	1	10	20	No	-	No	-	No	-
6	0.5	1	20	40	Yes	0.0046	No	-	No	-
7	1	1.5	0	10	Yes	0.0050	Yes	0.0050	No	-
8	1	1.5	10	20	No	-	No	-	No	-
9	1	1.5	20	40	Yes	0.0064	No	-	No	-
10	0	0.5	0	20	Yes	0.0026	Yes	0.0086	No	-
11	0	0.5	0	40	No	-	Yes	0.0106	No	-
12	0	0.5	10	40	No	-	Yes	0.0086	No	-
13	0.5	1	0	20	Yes	0.0063	No	-	No	-
14	0.5	1	0	40	Yes	0.0093	No	-	No	-
15	0.5	1	10	40	No	-	No	-	No	-
16	1	1.5	0	20	Yes	0.0062	Yes	0.0073	No	-
17	1	1.5	0	40	Yes	0.0073	Yes	0.0062	No	-
18	1	1.5	10	40	No	-	No	-	No	-
19	0	1	0	10	Yes	0.0121	No	-	No	-
20	0	1.5	0	10	Yes	0.0171	No	-	No	-
21	0.5	1.5	0	10	Yes	0.0138	No	-	No	-
22	0	1	10	20	Yes	0.0123	No	-	No	-
23	0	1.5	10	20	Yes	0.0175	No	-	No	-
24	0.5	1.5	10	20	Yes	0.0118	No	-	No	-
25	0	1	20	40	Yes	0.0071	Yes	0.0019	No	-
26	0	1.5	20	40	Yes	0.0135	No	-	No	-
27	0.5	1.5	20	40	Yes	0.0110	No	-	No	-
28	0	1	0	20	Yes	0.0090	No	-	No	-
29	0.5	1.5	0	20	Yes	0.0125	Yes	0.0090	No	-
30	0	1	10	40	Yes	0.0098	Yes	0.0056	No	-
31	0.5	1.5	10	40	Yes	0.0123	Yes	0.0048	No	-
32	0	1	0	40	Yes	0.0089	No	-	No	-
33	0.5	1.5	0	40	Yes	0.0130	Yes	0.0090	No	-
34	0	1.5	10	40	Yes	0.0155	No	-	No	-
35	0	1.5	0	20	Yes	0.0151	Yes	0.0066	No	-
36	0	1.5	0	40	Yes	0.0131	No	-	No	-

Table 5. The statistically significant average arsenic increases due to increases in phosphate and silicate concentrations at iron dosages of 2 and 4 mg/l.

	PO_4 [mg/L]		Si [mg/L]		PO_4 Main Effect		Si Main Effect	
Cube #	Low	High	Low	High	Significant	As(V) [mg/L]	Significant	As(V) [mg/L]
1	0	0.5	0	10	Yes	0.0017	No	-
2	0	0.5	10	20	Yes	0.0023	No	-
3	0	0.5	20	40	No	-	No	-
4	0.5	1	0	10	Yes	0.0015	Yes	0.0015
5	0.5	1	10	20	Yes	0.0018	Yes	0.0018
6	0.5	1	20	40	Yes	0.0018	No	-
7	1	1.5	0	10	Yes	0.0025	No	-
8	1	1.5	10	20	No	-	No	-
9	1	1.5	20	40	Yes	0.0036	No	-
10	0	0.5	0	20	Yes	0.0016	Yes	0.0014
11	0	0.5	0	40	No	-	Yes	0.0023
12	0	0.5	10	40	No	-	Yes	0.0030
13	0.5	1	0	20	No	-	No	-
14	0.5	1	0	40	No	-	Yes	0.0033
15	0.5	1	10	40	Yes	0.0020	Yes	0.0020
16	1	1.5	0	20	Yes	0.0029	Yes	0.0041
17	1	1.5	0	40	Yes	0.0040	Yes	0.0029
18	1	1.5	10	40	No	-	Yes	0.0028
19	0	1	0	10	No	-	No	-
20	0	1.5	0	10	Yes	0.0018	Yes	0.0014
21	0.5	1.5	0	10	Yes	0.0040	No	-
22	0	1	10	20	No	-	No	-
23	0	1.5	10	20	Yes	0.0055	No	-
24	0.5	1.5	10	20	Yes	0.0048	No	-
25	0	1	20	40	Yes	0.0016	Yes	0.0010
26	0	1.5	20	40	Yes	0.0053	No	-
27	0.5	1.5	20	40	Yes	0.0055	No	-
28	0	1	0	20	No	-	Yes	0.0019
29	0.5	1.5	0	20	No	-	Yes	0.0038
30	0	1	10	40	No	-	No	-
31	0.5	1.5	10	40	No	-	No	-
32	0	1	0	40	No	-	Yes	0.0028
33	0.5	1.5	0	40	Yes	0.0048	Yes	0.0043
34	0	1.5	10	40	Yes	0.0053	No	-
35	0	1.5	0	20	Yes	0.0034	Yes	0.0024
36	0	1.5	0	40	No	-	Yes	0.0036

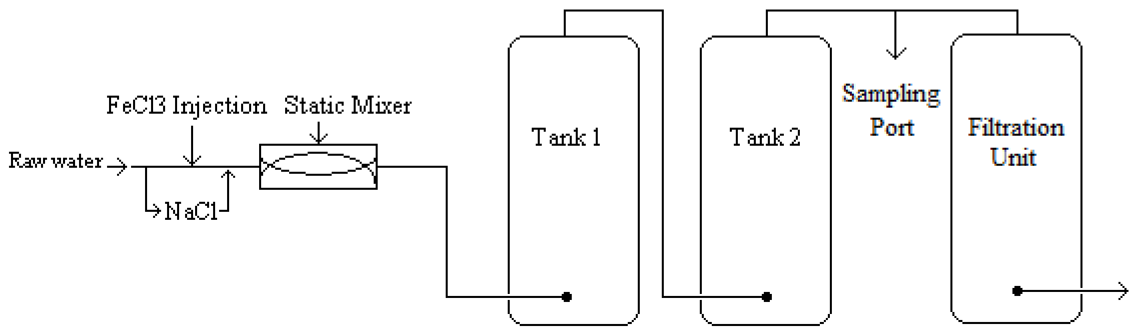

Figure 1. Schematic diagram of the Brutus Water System showing NaCl tracer injection loop.

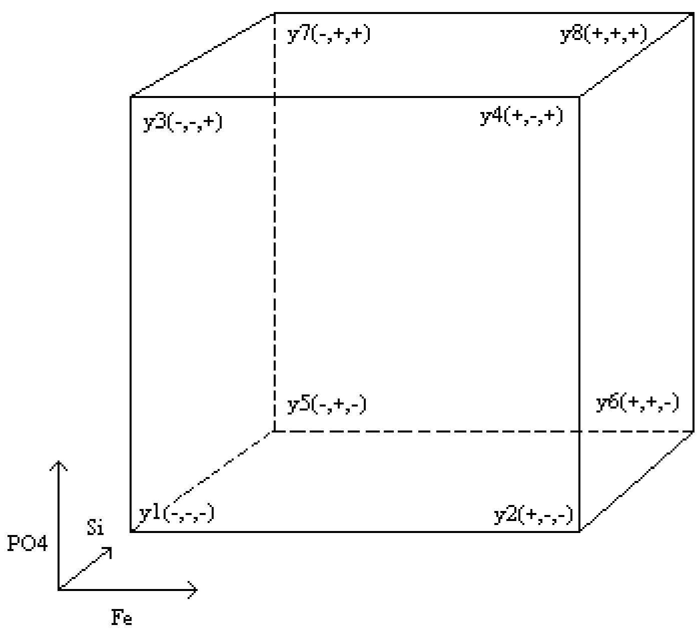

Figure 2. Cube plot of the two level, three factor experimental design. The three factors are Fe dose, silicate concentration, and phosphate concentration, shown here in high and low levels. The arsenic responses from the eight experimental conditions are labeled y_1 through y_8.

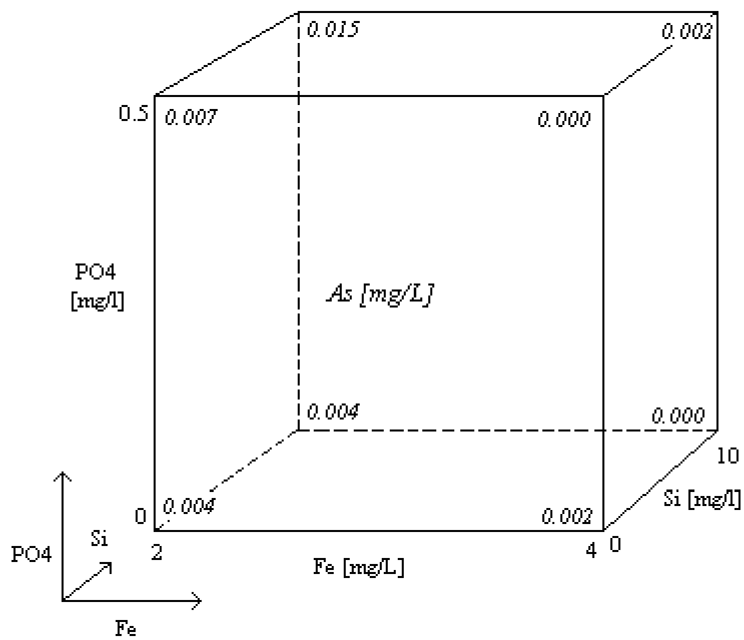

Figure 3. Example of a cube plot of eight experimental conditions. The three factors range from low to high levels, Fe dose (2-4 mg/L), silicate concentration (0-10 mg/L), and phosphate concentration (0-0.5 mg/L). The measured arsenic mg/L responses concentrations are shown in italics on the inside of the cube.

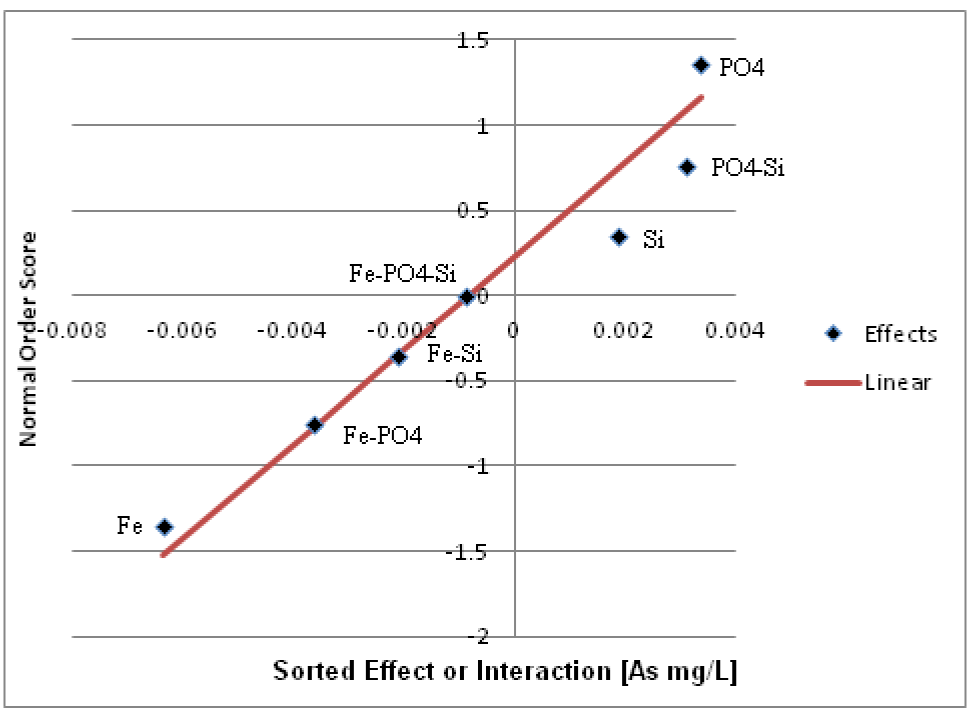

Figure 4. Normal probality plot of the normal order scores vs. the sorted main effects and interactions from Table 2 based on the arsenic responses shown in Figure 3.

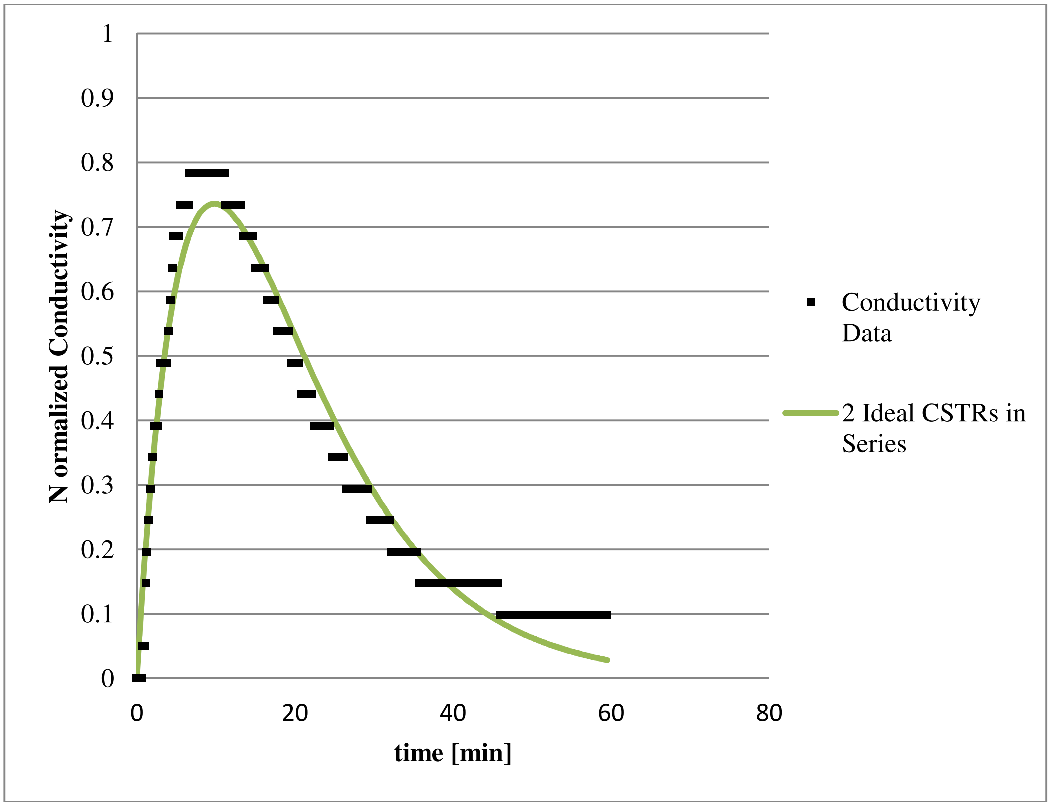

Figure 5. Normalized conductivity values from Brutus tracer study and two ideal CSTR's in series curve.

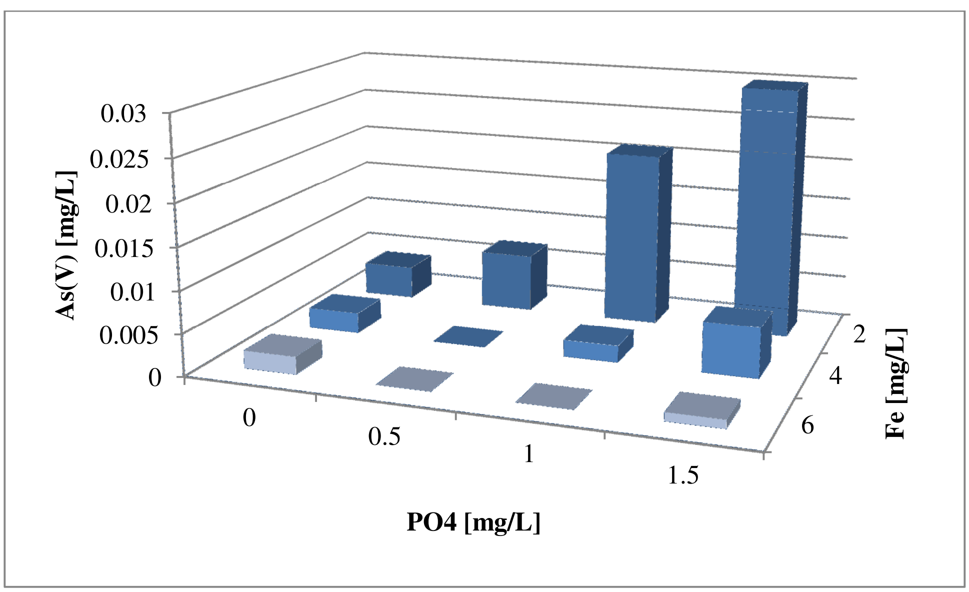

Figure 6. The effect of phosphate interference on arsenic removal over the range Fe doses studied.

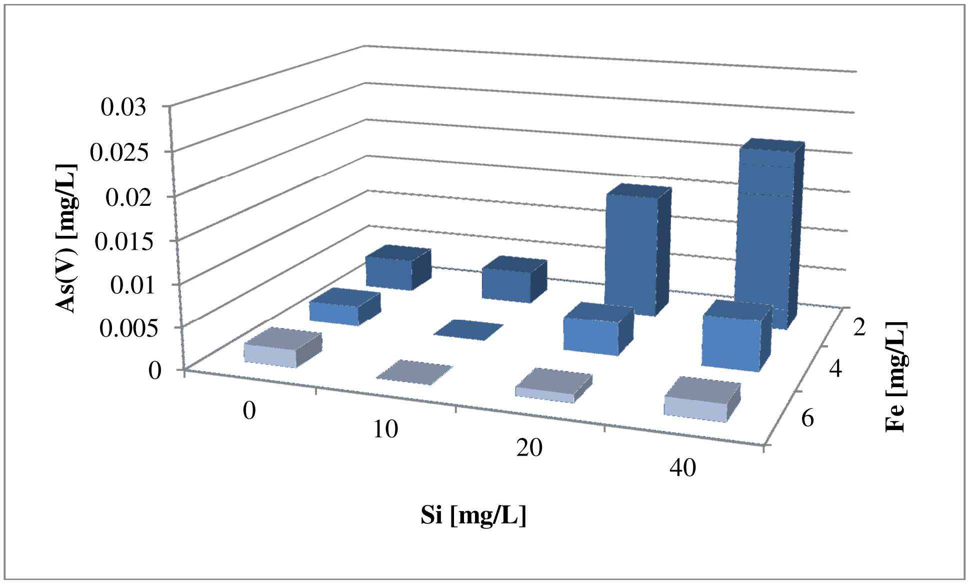

Figure 7. The effect of silicates interference on arsenic removal over the range of Fe doses studied.

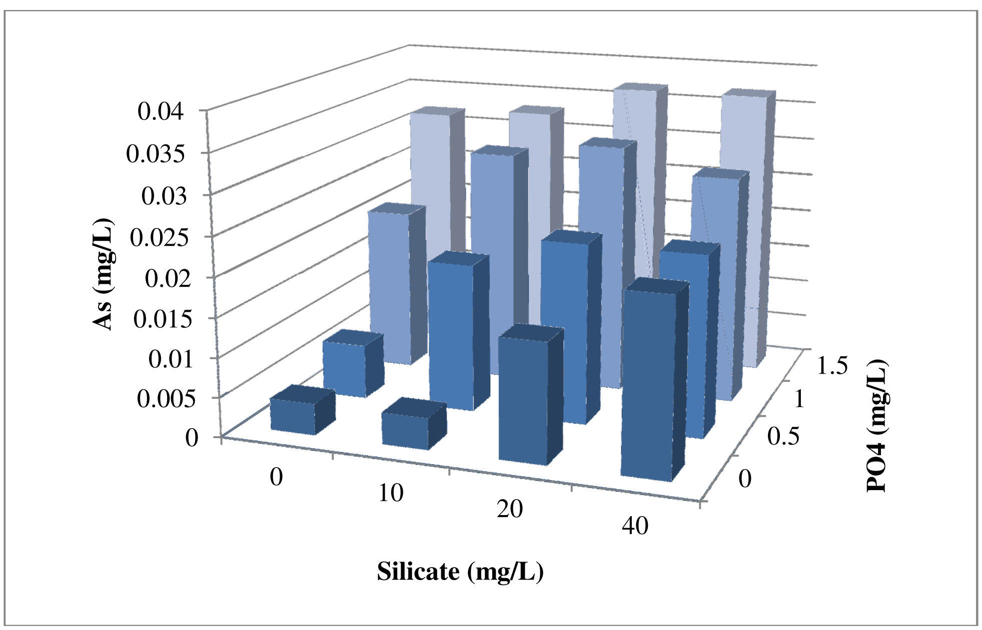

Figure 8. Arsenic concentrations in filtrate as a function of varying phosphate and silicate concentrations and a fixed dose of 2 mg/L Fe.

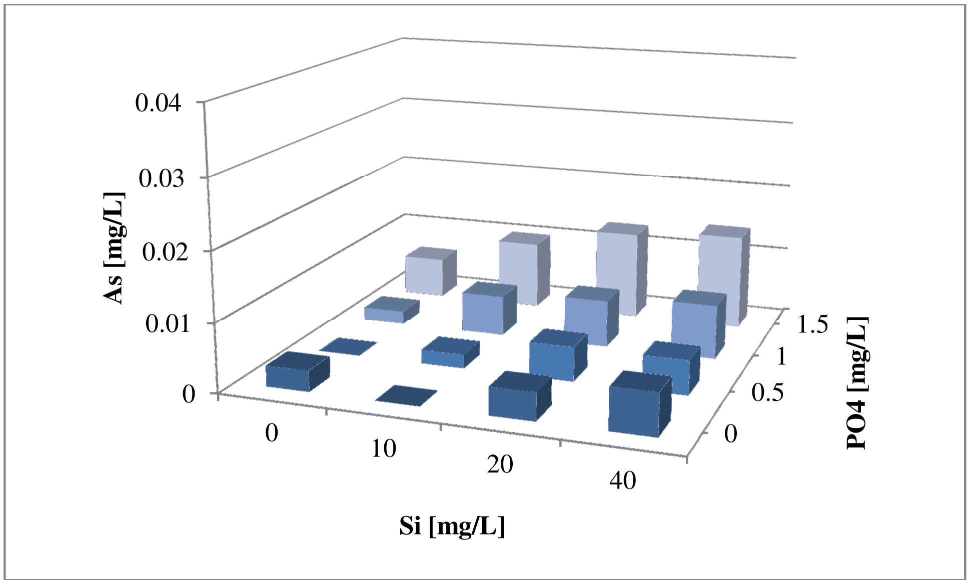

Figure 9. Arsenic concentrations in filtrate as a function of varying phosphate and silicate concentrations and a fixed dose of 4 mg/L Fe.

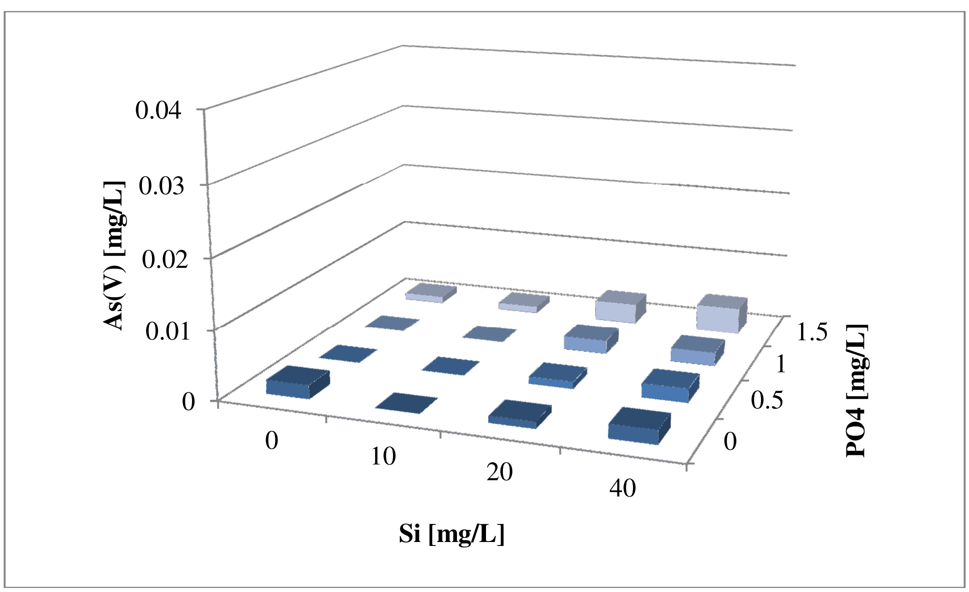

Figure 10. Arsenic concentrations in filtrate as a function of varying phosphate and silicate concentrations and a fixed dose of 6 mg/L Fe.

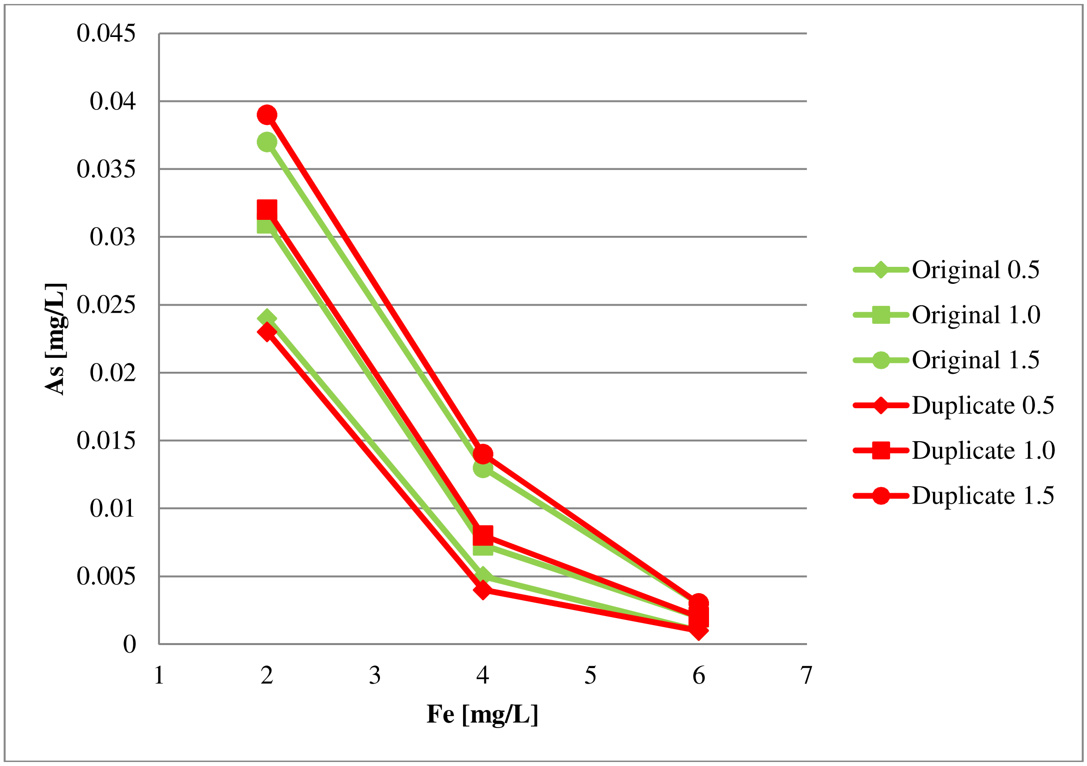

Figure 11. The original and replicate arsenic removal data, each pair was within 0.002 mg/L arsenic.

APPENDIX

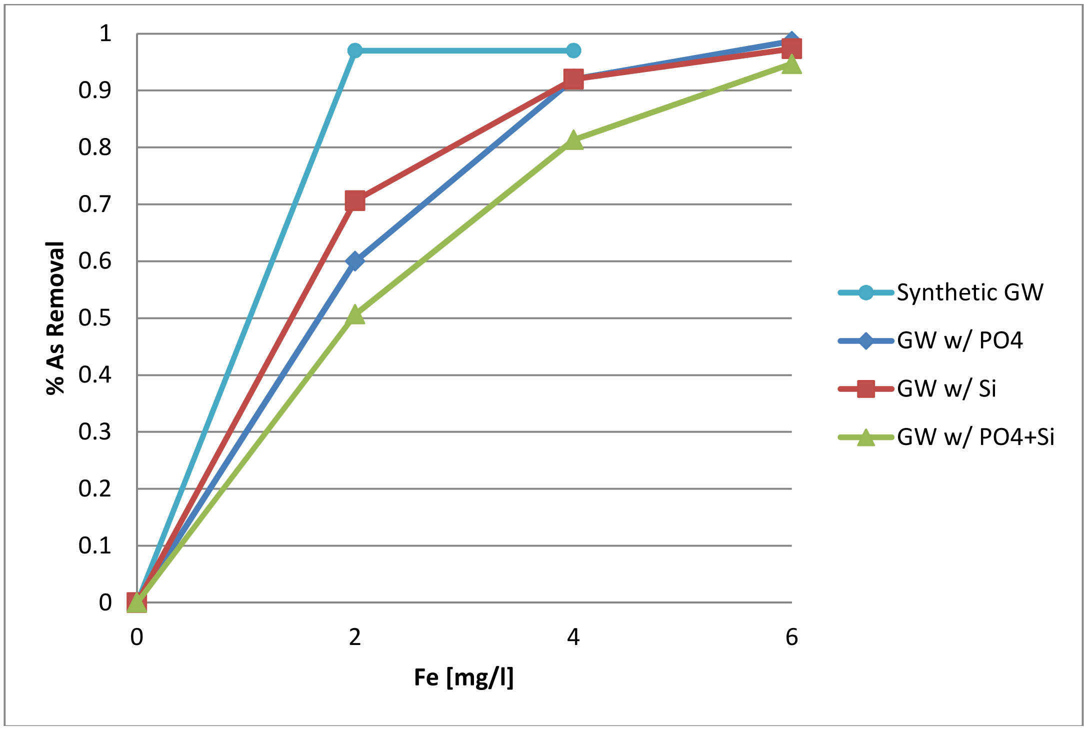

Figure 12. The percent removal of arsenic from synthetic groundwater containing varying interfering compounds, (PO_4^{3-} = 1.5 mg/L and Si = 40 mg/L).

Table 6. Arsenic and phosphate concentrations in filtrate and percent removals at fixed silicate concentration of 20 mg/L and varying iron doses and phosphate levels in synthetic groundwater.

Fe [mg/L]	PO4 [mg/L]	PO4 Filtrate [mg/L]	PO4 Filtrate [mg/L]	PO4 Filtrate [mg/L]	**Average PO4 [mg/L]**	STD Dev PO4 [mg/L]	**As [mg/L]**	**As % Removal**	**PO4 % Removal**
2	0.5	0.138	0.132	0.149	**0.14**	0.009	**0.019**	**0.747**	**0.72**
2	0.5	0.129	0.141	0.132	**0.134**	0.006	**0.019**	**0.747**	**0.732**
2	0.5	0.138	0.144	0.135	**0.139**	0.004	**0.019**	**0.747**	**0.722**
2	0.5	0.138	0.144	0.163	**0.148**	0.013	**0.023**	**0.693**	**0.704**
4	0.5	0.006	0.006	0.006	**0.006**	0	**0.004**	**0.947**	**0.988**
6	0.5	0.017	0.011	0.014	**0.014**	0.003	**0.001**	**0.987**	**0.972**
2	1	0.495	0.492	0.492	**0.493**	0.002	**0.032**	**0.573**	**0.507**
4	1	0.197	0.2	0.203	**0.2**	0.003	**0.007**	**0.907**	**0.8**
4	1	0.141	0.132	0.141	**0.138**	0.005	**0.009**	**0.88**	**0.862**
4	1	0.152	0.115	0.115	**0.128**	0.021	**0.008**	**0.893**	**0.872**
6	1	0.02	0.023	0.034	**0.025**	0.007	**0.002**	**0.973**	**0.975**
2	1.5	0.872	0.866	0.874	**0.871**	0.004	**0.039**	**0.48**	**0.42**
4	1.5	0.29	0.284	0.284	**0.286**	0.003	**0.014**	**0.813**	**0.809**
6	1.5	0.017	0.023	0.023	**0.021**	0.003	**0.003**	**0.96**	**0.986**

Table 7. Raw tracer study data conductivity and time

Test 1		Test 2		Test 3	
time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
0.000	0	0.000	0	0.000	0
0.083	0	0.083	0	0.083	0
0.167	0	0.167	0	0.167	0
0.250	0	0.250	0	0.250	0
0.333	0	0.333	0	0.333	0
0.417	0	0.417	0	0.417	0
0.500	0	0.500	0	0.500	0
0.583	0	0.583	0	0.583	0
0.667	0	0.667	0	0.666	0
0.750	0	0.750	0	0.750	10
0.833	10	0.833	10	0.833	10
0.917	20	0.917	20	0.916	10
1.000	20	1.000	30	1.000	10
1.083	20	1.083	40	1.083	10
1.167	20	1.167	60	1.166	30
1.250	30	1.250	60	1.250	40
1.333	40	1.333	60	1.333	40
1.417	40	1.417	60	1.416	50
1.500	40	1.500	60	1.499	50
1.583	40	1.583	60	1.583	50
1.667	50	1.667	60	1.666	60
1.750	60	1.750	60	1.749	60
1.833	60	1.833	60	1.833	60
1.917	70	1.917	60	1.916	70
2.000	80	2.000	60	1.999	70
2.083	80	2.083	60	2.083	70
2.167	80	2.167	70	2.166	80
2.250	80	2.250	70	2.249	80
2.333	80	2.333	70	2.332	80
2.417	80	2.417	70	2.416	80
2.500	80	2.500	70	2.499	80
2.583	80	2.583	80	2.582	80
2.667	80	2.667	90	2.666	80
2.750	90	2.750	100	2.749	80
2.833	100	2.833	100	2.832	90
2.917	100	2.917	100	2.916	90
3.000	100	3.000	100	2.999	100

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
3.167	100	3.167	110	3.165	100
3.250	100	3.250	120	3.249	100
3.333	100	3.333	120	3.332	100
3.417	110	3.417	120	3.415	100
3.500	110	3.500	120	3.499	100
3.583	110	3.583	120	3.582	100
3.667	110	3.667	120	3.665	100
3.750	120	3.750	120	3.749	100
3.833	120	3.833	120	3.832	100
3.917	120	3.917	120	3.915	100
4.000	120	4.000	120	3.998	110
4.083	120	4.083	130	4.082	110
4.167	120	4.167	130	4.165	110
4.250	120	4.250	130	4.248	120
4.333	120	4.333	140	4.332	120
4.416	120	4.416	140	4.415	120
4.500	130	4.500	140	4.498	130
4.583	130	4.583	140	4.582	130
4.666	130	4.666	140	4.665	140
4.750	140	4.750	140	4.748	140
4.833	140	4.833	140	4.831	140
4.916	140	4.916	150	4.915	140
5.000	140	5.000	150	4.998	140
5.083	140	5.083	150	5.081	140
5.166	140	5.166	150	5.165	140
5.250	140	5.250	150	5.248	140
5.333	140	5.333	150	5.331	140
5.416	140	5.416	150	5.415	140
5.500	140	5.500	150	5.498	150
5.583	150	5.583	150	5.581	150
5.666	150	5.666	150	5.664	150
5.750	150	5.750	150	5.748	150
5.833	150	5.833	160	5.831	150
5.916	150	5.916	160	5.914	150
6.000	150	6.000	160	5.998	150
6.083	150	6.083	160	6.081	150
6.166	150	6.166	160	6.164	150
6.250	160	6.250	160	6.248	150
6.333	160	6.333	160	6.331	150

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
6.583	160	6.583	160	6.581	150
6.666	160	6.666	160	6.664	160
6.750	160	6.750	160	6.747	160
6.833	160	6.833	160	6.831	160
6.916	160	6.916	160	6.914	160
7.000	160	7.000	160	6.997	160
7.083	160	7.083	160	7.081	160
7.166	160	7.166	160	7.164	160
7.250	160	7.250	160	7.247	160
7.333	160	7.333	160	7.330	160
7.416	160	7.416	160	7.414	160
7.500	160	7.500	160	7.497	160
7.583	160	7.583	170	7.580	160
7.666	160	7.666	170	7.664	160
7.750	160	7.750	170	7.747	160
7.833	160	7.833	170	7.830	160
7.916	160	7.916	170	7.914	160
8.000	160	8.000	170	7.997	160
8.083	160	8.083	170	8.080	160
8.166	160	8.166	170	8.163	160
8.250	160	8.250	170	8.247	160
8.333	160	8.333	170	8.330	160
8.416	160	8.416	170	8.413	160
8.500	160	8.500	170	8.497	160
8.583	160	8.583	170	8.580	160
8.666	160	8.666	170	8.663	160
8.750	160	8.750	170	8.747	160
8.833	160	8.833	170	8.830	160
8.916	160	8.916	170	8.913	160
9.000	160	9.000	170	8.996	160
9.083	160	9.083	170	9.080	160
9.166	160	9.166	170	9.163	160
9.250	160	9.250	170	9.246	160
9.333	160	9.333	170	9.330	160
9.416	160	9.416	170	9.413	160
9.500	160	9.500	170	9.496	160
9.583	160	9.583	170	9.580	160
9.666	160	9.666	170	9.663	160
9.750	160	9.750	170	9.746	160

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
9.916	160	9.916	170	9.913	160
10.000	160	10.000	170	9.996	160
10.083	160	10.083	170	10.079	160
10.166	160	10.166	170	10.163	160
10.250	160	10.250	170	10.246	160
10.333	160	10.333	170	10.329	160
10.416	160	10.416	170	10.413	160
10.500	160	10.500	170	10.496	160
10.583	160	10.583	160	10.579	160
10.666	160	10.666	160	10.662	160
10.750	160	10.750	160	10.746	160
10.833	160	10.833	160	10.829	160
10.916	160	10.916	160	10.912	160
11.000	160	11.000	160	10.996	160
11.083	160	11.083	160	11.079	160
11.166	160	11.166	160	11.162	160
11.250	160	11.250	160	11.246	150
11.333	160	11.333	160	11.329	150
11.416	160	11.416	160	11.412	150
11.500	160	11.500	160	11.495	150
11.583	160	11.583	160	11.579	150
11.666	160	11.666	160	11.662	150
11.750	150	11.750	160	11.745	150
11.833	150	11.833	160	11.829	150
11.916	150	11.916	160	11.912	150
12.000	150	12	160	11.995	150
13.750	140	12.25	150	12.079	150
14.083	140	12.5	150	12.162	150
14.167	140	12.75	150	12.245	150
14.750	140	13	150	12.328	150
15.00	140	13.25	150	12.412	150
15.25	140	13.5	150	12.495	150
15.50	140	13.75	150	12.745	150
15.75	130	14	150	12.995	150
16.00	130	14.25	140	13.245	150
16.25	130	14.5	140	13.495	140
16.50	130	14.75	140	13.745	140
16.75	120	15	140	13.995	140
17.00	120	15.25	140	14.245	140

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
17.50	120	15.75	130	14.745	140
17.75	120	16	130	14.995	130
18.00	120	16.25	130	15.245	130
18.25	110	16.5	130	15.495	130
18.50	110	16.75	130	15.745	130
18.75	110	17	120	15.995	130
19.00	110	17.25	120	16.245	130
19.25	110	17.5	120	16.495	120
19.50	110	17.75	120	16.745	120
19.75	110	18	120	16.995	120
20.00	100	18.25	120	17.245	120
20.25	100	18.5	110	17.495	120
20.50	100	18.75	110	17.745	110
20.75	100	19	110	17.995	110
21.00	100	19.25	110	18.245	110
21.25	90	19.5	110	18.495	110
21.50	90	19.75	100	18.745	110
21.75	90	20	100	18.995	110
22.00	90	20.25	100	19.245	110
22.25	90	20.5	100	19.495	100
22.50	90	20.75	100	19.745	100
22.75	90	21	100	19.995	100
23.00	80	21.25	100	20.245	100
23.25	80	21.5	90	20.495	100
23.50	80	21.75	90	20.745	90
23.75	80	22	90	20.995	90
24.00	80	22.25	90	21.245	90
24.25	80	22.5	90	21.495	90
24.50	80	22.75	90	21.745	90
24.75	80	23	80	21.995	90
25.00	80	23.25	80	22.245	90
25.25	70	23.5	80	22.495	80
25.50	70	23.75	80	22.745	80
25.75	70	24	80	22.995	80
26.00	70	24.25	80	23.245	80
26.25	70	24.5	80	23.495	80
26.50	70	24.75	70	23.745	80
26.75	60	25	70	23.995	80
27.00	60	25.25	70	24.245	80

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
27.50	60	25.75	70	24.745	70
27.75	60	26	70	24.995	70
28.00	60	26.25	70	25.245	70
28.25	60	26.5	70	25.495	70
28.50	60	26.75	70	25.745	70
28.75	60	27	70	25.995	70
29.00	60	27.25	60	26.245	70
29.25	50	27.5	60	26.495	60
29.50	50	27.75	60	26.745	60
29.75	50	28	60	26.995	60
30.00	50	28.25	60	27.245	60
30.25	50	28.5	60	27.495	60
30.50	50	28.75	60	27.745	60
30.75	50	29	60	27.995	60
31.00	50	29.25	60	28.245	60
31.25	50	29.5	60	28.495	60
31.50	50	29.75	50	28.745	60
31.75	50	30	50	28.995	60
32.00	50	30.25	50	29.245	60
32.25	50	30.5	50	29.495	50
32.50	40	30.75	50	29.745	50
32.75	40	31	50	29.995	50
33.00	40	31.25	50	30.245	50
33.25	40	31.5	50	30.495	50
33.50	40	31.75	50	30.745	50
33.75	40	32	50	30.995	50
34.00	40	32.25	50	31.245	50
34.25	40	32.5	50	31.495	50
34.50	40	32.75	50	31.745	50
34.75	40	33	50	31.995	50
35.00	40	33.25	50	32.245	40
35.25	40	33.5	50	32.495	40
35.50	40	33.75	40	32.745	40
35.75	40	34	40	32.995	40
36.00	40	34.25	40	33.245	40
36.25	40	34.5	40	33.495	40
36.50	40	34.75	40	33.745	40
36.75	40	35	40	33.995	40
37.00	40	35.25	40	34.245	40

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
37.50	40	35.75	40	34.745	40
37.75	40	36	40	34.995	40
38.00	40	36.25	40	35.245	40
38.25	40	36.5	40	35.495	40
38.50	30	36.75	40	35.745	30
38.75	30	37	40	35.995	30
39.00	30	37.25	40	36.245	30
39.25	30	37.5	40	36.495	30
39.50	30	37.75	40	36.745	30
39.75	30	38	40	36.995	30
40.00	30	38.25	40	37.245	30
40.25	30	38.5	40	37.495	30
40.50	30	38.75	40	37.745	30
40.75	30	39	40	37.995	30
41.00	30	39.25	40	38.245	30
41.25	30	39.5	40	38.495	30
41.50	30	39.75	40	38.745	30
41.75	30	40	30	38.995	30
42.00	30	40.25	30	39.245	30
42.25	30	40.5	30	39.495	30
42.50	30	40.75	30	39.745	30
42.75	30	41	30	39.995	30
43.00	30	41.25	30	40.245	30
43.25	30	41.5	30	40.495	30
43.50	30	41.75	30	40.745	30
43.75	30	42	30	40.995	30
44.00	30	42.25	30	41.245	30
44.25	30	42.5	30	41.495	30
44.50	30	42.75	30	41.745	30
44.75	30	43	30	41.995	30
45.00	30	43.25	30	42.245	30
45.25	30	43.5	30	42.495	30
45.50	30	43.75	30	42.745	30
45.75	30	44	30	42.995	30
46.00	30	44.25	30	43.245	30
46.25	30	44.5	30	43.495	30
46.50	30	44.75	30	43.745	30
46.75	30	45	30	43.995	30
47.00	30	45.25	30	44.245	30

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
47.25	30	45.5	30	44.495	30
47.50	30	45.75	30	44.745	30
47.75	30	46	30	44.995	30
48.00	30	46.25	30	45.245	30
48.25	30	46.5	30	45.495	30
48.50	30	46.75	30	45.745	30
48.75	30	47	30	45.995	20
49.00	30	47.25	30	46.245	20
49.25	30	47.5	30	46.495	20
49.50	30	47.75	30	46.745	20
49.75	30	48	30	46.995	20
50.00	30	48.25	30	47.245	20
50.25	30	48.5	30	47.495	20
50.50	30	48.75	30	47.745	20
50.75	30	49	30	47.995	20
51.00	30	49.25	30	48.245	20
51.25	30	49.5	30	48.495	20
51.50	30	49.75	30	48.745	20
51.75	30	50	30	48.995	20
52.00	30	50.25	30	49.245	20
52.25	30	50.5	30	49.495	20
52.50	30	50.75	30	49.745	20
52.75	30	51	30	49.995	20
53.00	30	51.25	30	50.245	20
53.25	30	51.5	30	50.495	20
53.50	30	51.75	30	50.745	20
53.75	30	52	30	50.995	20
54.00	30	52.25	30	51.245	20
54.25	30	52.5	30	51.495	20
54.50	30	52.75	30	51.745	20
54.75	30	53	30	51.995	20
55.00	30	53.25	30	52.245	20
55.25	30	53.5	30	52.495	20
55.50	30	53.75	30	52.745	20
55.75	30	54	30	52.995	20
56.00	30	54.25	30	53.245	20
56.25	30	54.5	30	53.495	20
56.50	30	54.75	30	53.745	20
56.75	30	55	30	53.995	20

time [min]	Cond. µS/cm	time [min]	Cond. µS/cm	time [min]	Cond. µS/cm
57.00	30	55.25	30	54.245	20
57.25	30	55.5	30	54.495	20
57.50	30	55.75	30	54.745	20
57.75	30	56	30	54.995	20
58.00	30	56.25	30	55.245	20
58.25	30	56.5	30	55.495	20
58.50	30	56.75	30	55.745	20
58.75	30	57	30	55.995	20
59.00	30	57.25	30	56.245	20
59.25	30	57.5	30	56.495	20
59.50	30	57.75	30	56.745	20
59.75	30	58	30	56.995	20
		58.25	30	57.245	20
		58.5	30	57.495	20
		58.75	30	57.745	20
		59	30	57.995	20
		59.25	30	58.245	20
				58.495	20
				58.745	20
				58.995	20
				59.245	20
				59.495	20

Table 8. E(Θ) and $\bar{t}$ calculation for Brutus Water System and E(Θ) of two ideal CSTRs in series.

time [min]		Cond. [μS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
0.0	0:00:00	0			0.00	0.000		0.000	0.000	0.000
0.1	0:00:05	0	0.0	0.0	0.00	0.000	0.0	0.000	0.000	0.017
0.2	0:00:10	0	0.0	0.0	0.01	0.000	0.0	0.000	0.000	0.033
0.2	0:00:15	0	0.0	0.0	0.01	0.000	0.0	0.000	0.000	0.050
0.3	0:00:20	0	0.0	0.0	0.02	0.000	0.0	0.000	0.000	0.066
0.4	0:00:25	0	0.0	0.0	0.02	0.000	0.0	0.000	0.000	0.081
0.5	0:00:30	0	0.0	0.0	0.03	0.000	0.0	0.000	0.000	0.097
0.6	0:00:35	0	0.0	0.0	0.03	0.000	0.0	0.000	0.000	0.112
0.7	0:00:40	0	0.0	0.0	0.03	0.000	0.0	0.000	0.000	0.127
0.7	0:00:45	10	0.4	0.3	0.04	0.049	149.0	0.049	0.000	0.141
0.8	0:00:50	10	0.8	0.7	0.04	0.049	296.7	0.098	0.001	0.156
0.9	0:00:55	10	0.8	0.7	0.05	0.049	294.1	0.147	0.001	0.170
1.0	0:01:00	10	0.8	0.8	0.05	0.049	291.5	0.196	0.001	0.184
1.1	0:01:05	10	0.8	0.9	0.06	0.049	288.9	0.245	0.002	0.197
1.2	0:01:10	30	1.7	1.9	0.06	0.147	571.4	0.391	0.003	0.211
1.2	0:01:15	40	2.9	3.5	0.06	0.196	992.5	0.587	0.004	0.224
1.3	0:01:20	40	3.3	4.3	0.07	0.196	1124.8	0.783	0.006	0.237
1.4	0:01:25	50	3.7	5.2	0.07	0.245	1253.4	1.027	0.007	0.249
1.5	0:01:30	50	4.2	6.1	0.08	0.245	1380.7	1.272	0.009	0.262
1.6	0:01:35	50	4.2	6.4	0.08	0.245	1368.1	1.516	0.011	0.274
1.7	0:01:40	60	4.6	7.5	0.08	0.293	1490.4	1.810	0.013	0.286
1.7	0:01:45	60	5.0	8.5	0.09	0.293	1611.6	2.103	0.015	0.298
1.8	0:01:50	60	5.0	9.0	0.09	0.293	1596.7	2.397	0.017	0.309
1.9	0:01:55	70	5.4	10.2	0.10	0.342	1713.1	2.739	0.020	0.321
2.0	0:02:00	70	5.8	11.4	0.10	0.342	1828.3	3.082	0.022	0.332
2.1	0:02:05	70	5.8	11.9	0.11	0.342	1811.1	3.424	0.025	0.343
2.2	0:02:10	80	6.2	13.3	0.11	0.391	1921.6	3.815	0.028	0.353
2.2	0:02:15	80	6.7	14.7	0.11	0.391	2030.9	4.207	0.030	0.364
2.3	0:02:20	80	6.7	15.3	0.12	0.391	2011.6	4.598	0.033	0.374
2.4	0:02:25	80	6.7	15.8	0.12	0.391	1992.3	4.989	0.036	0.384
2.5	0:02:30	80	6.7	16.4	0.13	0.391	1973.2	5.381	0.039	0.394
2.6	0:02:35	80	6.7	16.9	0.13	0.391	1954.1	5.772	0.042	0.404
2.7	0:02:40	80	6.7	17.5	0.14	0.391	1935.1	6.163	0.045	0.413
2.7	0:02:45	80	6.7	18.0	0.14	0.391	1916.3	6.555	0.047	0.423
2.8	0:02:50	90	7.1	19.8	0.14	0.440	2015.5	6.995	0.051	0.432
2.9	0:02:55	90	7.5	21.5	0.15	0.440	2113.7	7.435	0.054	0.441
3.0	0:03:00	100	7.9	23.4	0.15	0.489	2208.4	7.924	0.057	0.450
3.1	0:03:05	100	8.3	25.3	0.16	0.489	2302.1	8.413	0.061	0.458

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
3.2	0:03:15	100	8.3	26.7	0.17	0.489	2256.2	9.392	0.068	0.475
3.3	0:03:20	100	8.3	27.4	0.17	0.489	2233.4	9.881	0.071	0.483
3.4	0:03:25	100	8.3	28.1	0.17	0.489	2210.8	10.370	0.075	0.491
3.5	0:03:30	100	8.3	28.8	0.18	0.489	2188.2	10.859	0.078	0.499
3.6	0:03:35	100	8.3	29.5	0.18	0.489	2165.8	11.348	0.082	0.506
3.7	0:03:40	100	8.3	30.2	0.19	0.489	2143.5	11.837	0.085	0.514
3.7	0:03:45	100	8.3	30.9	0.19	0.489	2121.3	12.326	0.089	0.521
3.8	0:03:50	100	8.3	31.6	0.19	0.489	2099.2	12.816	0.093	0.528
3.9	0:03:55	100	8.3	32.3	0.20	0.489	2077.2	13.305	0.096	0.535
4.0	0:04:00	110	8.7	34.6	0.20	0.538	2157.6	13.843	0.100	0.542
4.1	0:04:05	110	9.2	37.0	0.21	0.538	2237.0	14.381	0.104	0.548
4.2	0:04:10	110	9.2	37.8	0.21	0.538	2213.2	14.919	0.108	0.555
4.2	0:04:15	120	9.6	40.3	0.22	0.587	2288.5	15.506	0.112	0.561
4.3	0:04:20	120	10.0	42.9	0.22	0.587	2362.9	16.093	0.116	0.567
4.4	0:04:25	120	10.0	43.7	0.22	0.587	2337.4	16.680	0.120	0.573
4.5	0:04:30	130	10.4	46.4	0.23	0.636	2407.8	17.316	0.125	0.579
4.6	0:04:35	130	10.8	49.2	0.23	0.636	2477.3	17.952	0.130	0.585
4.7	0:04:40	140	11.2	52.0	0.24	0.685	2543.8	18.636	0.135	0.590
4.7	0:04:45	140	11.7	54.9	0.24	0.685	2609.4	19.321	0.140	0.596
4.8	0:04:50	140	11.7	55.9	0.25	0.685	2580.4	20.006	0.144	0.601
4.9	0:04:55	140	11.7	56.8	0.25	0.685	2551.6	20.691	0.149	0.606
5.0	0:05:00	140	11.7	57.8	0.25	0.685	2522.9	21.376	0.154	0.612
5.1	0:05:05	140	11.7	58.8	0.26	0.685	2494.4	22.060	0.159	0.616
5.2	0:05:10	140	11.7	59.7	0.26	0.685	2466.1	22.745	0.164	0.621
5.2	0:05:15	140	11.7	60.7	0.27	0.685	2437.9	23.430	0.169	0.626
5.3	0:05:20	140	11.7	61.7	0.27	0.685	2409.9	24.115	0.174	0.631
5.4	0:05:25	140	11.7	62.7	0.28	0.685	2382.1	24.800	0.179	0.635
5.5	0:05:30	150	12.1	65.9	0.28	0.734	2438.0	25.533	0.184	0.639
5.6	0:05:35	150	12.5	69.2	0.28	0.734	2493.0	26.267	0.190	0.644
5.7	0:05:40	150	12.5	70.3	0.29	0.734	2463.7	27.001	0.195	0.648
5.7	0:05:45	150	12.5	71.3	0.29	0.734	2434.6	27.734	0.200	0.652
5.8	0:05:50	150	12.5	72.3	0.30	0.734	2405.6	28.468	0.206	0.655
5.9	0:05:55	150	12.5	73.4	0.30	0.734	2376.8	29.202	0.211	0.659
6.0	0:06:00	150	12.5	74.4	0.30	0.734	2348.2	29.936	0.216	0.663
6.1	0:06:05	150	12.5	75.5	0.31	0.734	2319.7	30.669	0.221	0.666
6.2	0:06:10	150	12.5	76.5	0.31	0.734	2291.5	31.403	0.227	0.670
6.2	0:06:15	150	12.5	77.5	0.32	0.734	2263.4	32.137	0.232	0.673
6.3	0:06:20	150	12.5	78.6	0.32	0.734	2235.4	32.870	0.237	0.676
6.4	0:06:25	150	12.5	79.6	0.33	0.734	2207.7	33.604	0.243	0.680

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
6.5	0:06:30	150	12.5	80.7	0.33	0.734	2180.1	34.338	0.248	0.683
6.6	0:06:35	150	12.5	81.7	0.33	0.734	2152.7	35.072	0.253	0.685
6.7	0:06:40	160	12.9	85.5	0.34	0.783	2195.8	35.854	0.259	0.688
6.7	0:06:45	160	13.3	89.4	0.34	0.783	2238.3	36.637	0.265	0.691
6.8	0:06:50	160	13.3	90.5	0.35	0.783	2209.6	37.419	0.270	0.694
6.9	0:06:55	160	13.3	91.6	0.35	0.783	2181.1	38.202	0.276	0.696
7.0	0:07:00	160	13.3	92.7	0.36	0.783	2152.8	38.985	0.282	0.699
7.1	0:07:05	160	13.3	93.8	0.36	0.783	2124.7	39.767	0.287	0.701
7.2	0:07:10	160	13.3	94.9	0.36	0.783	2096.7	40.550	0.293	0.703
7.2	0:07:15	160	13.3	96.0	0.37	0.783	2069.0	41.333	0.298	0.705
7.3	0:07:20	160	13.3	97.1	0.37	0.783	2041.4	42.115	0.304	0.707
7.4	0:07:25	160	13.3	98.3	0.38	0.783	2014.0	42.898	0.310	0.709
7.5	0:07:30	160	13.3	99.4	0.38	0.783	1986.8	43.681	0.315	0.711
7.6	0:07:35	160	13.3	100.5	0.39	0.783	1959.8	44.463	0.321	0.713
7.7	0:07:40	160	13.3	101.6	0.39	0.783	1932.9	45.246	0.327	0.715
7.7	0:07:45	160	13.3	102.7	0.39	0.783	1906.3	46.028	0.332	0.717
7.8	0:07:50	160	13.3	103.8	0.40	0.783	1879.8	46.811	0.338	0.718
7.9	0:07:55	160	13.3	104.9	0.40	0.783	1853.6	47.594	0.344	0.720
8.0	0:08:00	160	13.3	106.0	0.41	0.783	1827.5	48.376	0.349	0.721
8.1	0:08:05	160	13.3	107.1	0.41	0.783	1801.6	49.159	0.355	0.723
8.2	0:08:10	160	13.3	108.2	0.42	0.783	1775.8	49.942	0.361	0.724
8.2	0:08:15	160	13.3	109.4	0.42	0.783	1750.3	50.724	0.366	0.725
8.3	0:08:20	160	13.3	110.5	0.42	0.783	1724.9	51.507	0.372	0.726
8.4	0:08:25	160	13.3	111.6	0.43	0.783	1699.8	52.289	0.378	0.727
8.5	0:08:30	160	13.3	112.7	0.43	0.783	1674.8	53.072	0.383	0.728
8.6	0:08:35	160	13.3	113.8	0.44	0.783	1650.0	53.855	0.389	0.729
8.7	0:08:40	160	13.3	114.9	0.44	0.783	1625.4	54.637	0.395	0.730
8.7	0:08:45	160	13.3	116.0	0.44	0.783	1601.0	55.420	0.400	0.731
8.8	0:08:50	160	13.3	117.1	0.45	0.783	1576.7	56.203	0.406	0.732
8.9	0:08:55	160	13.3	118.2	0.45	0.783	1552.6	56.985	0.412	0.732
9.0	0:09:00	160	13.3	119.3	0.46	0.783	1528.8	57.768	0.417	0.733
9.1	0:09:05	160	13.3	120.5	0.46	0.783	1505.1	58.550	0.423	0.733
9.2	0:09:10	160	13.3	121.6	0.47	0.783	1481.6	59.333	0.428	0.734
9.2	0:09:15	160	13.3	122.7	0.47	0.783	1458.3	60.116	0.434	0.734
9.3	0:09:20	160	13.3	123.8	0.47	0.783	1435.1	60.898	0.440	0.735
9.4	0:09:25	160	13.3	124.9	0.48	0.783	1412.2	61.681	0.445	0.735
9.5	0:09:30	160	13.3	126.0	0.48	0.783	1389.4	62.464	0.451	0.735
9.6	0:09:35	160	13.3	127.1	0.49	0.783	1366.8	63.246	0.457	0.736
9.7	0:09:40	160	13.3	128.2	0.49	0.783	1344.4	64.029	0.462	0.736

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
9.7	0:09:45	160	13.3	129.3	0.50	0.783	1322.2	64.812	0.468	0.736
9.8	0:09:50	160	13.3	130.5	0.50	0.783	1300.2	65.594	0.474	0.736
9.9	0:09:55	160	13.3	131.6	0.50	0.783	1278.4	66.377	0.479	0.736
10.0	0:10:00	160	13.3	132.7	0.51	0.783	1256.7	67.159	0.485	0.736
10.1	0:10:05	160	13.3	133.8	0.51	0.783	1235.3	67.942	0.491	0.736
10.2	0:10:10	160	13.3	134.9	0.52	0.783	1214.0	68.725	0.496	0.735
10.2	0:10:15	160	13.3	136.0	0.52	0.783	1192.9	69.507	0.502	0.735
10.3	0:10:20	160	13.3	137.1	0.53	0.783	1172.0	70.290	0.508	0.735
10.4	0:10:25	160	13.3	138.2	0.53	0.783	1151.2	71.073	0.513	0.735
10.5	0:10:30	160	13.3	139.3	0.53	0.783	1130.7	71.855	0.519	0.734
10.6	0:10:35	160	13.3	140.4	0.54	0.783	1110.3	72.638	0.525	0.734
10.7	0:10:40	160	13.3	141.6	0.54	0.783	1090.2	73.420	0.530	0.733
10.7	0:10:45	160	13.3	142.7	0.55	0.783	1070.2	74.203	0.536	0.733
10.8	0:10:50	160	13.3	143.8	0.55	0.783	1050.4	74.986	0.542	0.732
10.9	0:10:55	160	13.3	144.9	0.55	0.783	1030.7	75.768	0.547	0.732
11.0	0:11:00	160	13.3	146.0	0.56	0.783	1011.3	76.551	0.553	0.731
11.1	0:11:05	160	13.3	147.1	0.56	0.783	992.1	77.334	0.558	0.730
11.2	0:11:10	160	13.3	148.2	0.57	0.783	973.0	78.116	0.564	0.730
11.2	0:11:15	150	12.9	144.6	0.57	0.734	924.6	78.850	0.569	0.729
11.3	0:11:20	150	12.5	141.0	0.58	0.734	877.0	79.584	0.575	0.728
11.4	0:11:25	150	12.5	142.1	0.58	0.734	859.6	80.317	0.580	0.727
11.5	0:11:30	150	12.5	143.1	0.58	0.734	842.4	81.051	0.585	0.726
11.6	0:11:35	150	12.5	144.2	0.59	0.734	825.4	81.785	0.591	0.725
11.7	0:11:40	150	12.5	145.2	0.59	0.734	808.6	82.519	0.596	0.724
11.7	0:11:45	150	12.5	146.2	0.60	0.734	791.9	83.252	0.601	0.724
11.8	0:11:50	150	12.5	147.3	0.60	0.734	775.4	83.986	0.606	0.722
11.9	0:11:55	150	12.5	148.3	0.61	0.734	759.1	84.720	0.612	0.721
12.0	0:12:00	150	12.5	149.4	0.61	0.734	743.0	85.453	0.617	0.720
12.1	0:12:05	150	12.5	150.4	0.61	0.734	727.0	86.187	0.622	0.719
12.2	0:12:10	150	12.5	151.4	0.62	0.734	711.2	86.921	0.628	0.718
12.2	0:12:15	150	12.5	152.5	0.62	0.734	695.6	87.655	0.633	0.717
12.3	0:12:20	150	12.5	153.5	0.63	0.734	680.2	88.388	0.638	0.716
12.4	0:12:25	150	12.5	154.6	0.63	0.734	664.9	89.122	0.644	0.714
12.5	0:12:30	150	12.5	155.6	0.64	0.734	649.8	89.856	0.649	0.713
12.7	0:12:45	150	37.5	473.3	0.65	0.734	1861.6	90.589	0.654	0.709
13.0	0:13:00	150	37.5	482.6	0.66	0.734	1731.9	91.323	0.659	0.705
13.2	0:13:15	150	37.5	492.0	0.67	0.734	1606.8	92.057	0.665	0.700
13.5	0:13:30	140	36.3	484.5	0.69	0.685	1438.9	92.742	0.670	0.696
13.7	0:13:45	140	35.0	476.7	0.70	0.685	1279.4	93.426	0.675	0.691

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
14.0	0:14:00	140	35.0	485.5	0.71	0.685	1175.8	94.111	0.680	0.686
14.2	0:14:15	140	35.0	494.2	0.72	0.685	1076.6	94.796	0.685	0.681
14.5	0:14:30	140	35.0	503.0	0.74	0.685	981.7	95.481	0.690	0.675
14.7	0:14:45	140	35.0	511.7	0.75	0.685	891.3	96.166	0.694	0.669
15.0	0:15:00	130	33.8	501.7	0.76	0.636	777.9	96.802	0.699	0.664
15.2	0:15:15	130	32.5	491.4	0.78	0.636	671.8	97.437	0.704	0.658
15.5	0:15:30	130	32.5	499.5	0.79	0.636	599.9	98.073	0.708	0.652
15.7	0:15:45	130	32.5	507.7	0.80	0.636	532.2	98.709	0.713	0.646
16.0	0:16:00	130	32.5	515.8	0.81	0.636	468.5	99.345	0.717	0.640
16.2	0:16:15	130	32.5	523.9	0.83	0.636	408.9	99.981	0.722	0.633
16.5	0:16:30	120	31.3	511.4	0.84	0.587	340.7	100.568	0.726	0.627
16.7	0:16:45	120	30.0	498.6	0.85	0.587	278.6	101.155	0.730	0.620
17.0	0:17:00	120	30.0	506.1	0.86	0.587	234.8	101.742	0.735	0.614
17.2	0:17:15	120	30.0	513.6	0.88	0.587	194.7	102.329	0.739	0.607
17.5	0:17:30	120	30.0	521.1	0.89	0.587	158.4	102.916	0.743	0.601
17.7	0:17:45	110	28.8	506.4	0.90	0.538	121.3	103.454	0.747	0.594
18.0	0:18:00	110	27.5	491.4	0.92	0.538	89.0	103.992	0.751	0.587
18.2	0:18:15	110	27.5	498.3	0.93	0.538	66.0	104.530	0.755	0.580
18.5	0:18:30	110	27.5	505.2	0.94	0.538	46.5	105.068	0.759	0.573
18.7	0:18:45	110	27.5	512.1	0.95	0.538	30.4	105.606	0.763	0.567
19.0	0:19:00	110	27.5	518.9	0.97	0.538	17.8	106.144	0.767	0.560
19.2	0:19:15	110	27.5	525.8	0.98	0.538	8.6	106.682	0.770	0.553
19.5	0:19:30	100	26.3	508.3	0.99	0.489	2.8	107.171	0.774	0.546
19.7	0:19:45	100	25.0	490.5	1.00	0.489	0.4	107.661	0.777	0.539
20.0	0:20:00	100	25.0	496.8	1.02	0.489	1.4	108.150	0.781	0.532
20.2	0:20:15	100	25.0	503.0	1.03	0.489	5.6	108.639	0.785	0.525
20.5	0:20:30	100	25.0	509.3	1.04	0.489	12.8	109.128	0.788	0.519
20.7	0:20:45	90	23.8	489.6	1.05	0.440	21.7	109.568	0.791	0.512
21.0	0:21:00	90	22.5	469.6	1.07	0.440	33.0	110.008	0.794	0.505
21.2	0:21:15	90	22.5	475.2	1.08	0.440	48.0	110.449	0.798	0.498
21.5	0:21:30	90	22.5	480.8	1.09	0.440	65.8	110.889	0.801	0.491
21.7	0:21:45	90	22.5	486.5	1.11	0.440	86.4	111.329	0.804	0.484
22.0	0:22:00	90	22.5	492.1	1.12	0.440	109.8	111.769	0.807	0.478
22.2	0:22:15	90	22.5	497.7	1.13	0.440	136.0	112.210	0.810	0.471
22.5	0:22:30	80	21.3	475.2	1.14	0.391	155.0	112.601	0.813	0.464
22.7	0:22:45	80	20.0	452.4	1.16	0.391	175.0	112.992	0.816	0.458
23.0	0:23:00	80	20.0	457.4	1.17	0.391	205.8	113.383	0.819	0.451
23.2	0:23:15	80	20.0	462.4	1.18	0.391	239.1	113.775	0.822	0.445
23.5	0:23:30	80	20.0	467.4	1.19	0.391	274.9	114.166	0.824	0.438

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
23.7	0:23:45	80	20.0	472.4	1.21	0.391	313.2	114.557	0.827	0.432
24.0	0:24:00	80	20.0	477.4	1.22	0.391	354.0	114.949	0.830	0.425
24.2	0:24:15	80	20.0	482.4	1.23	0.391	397.3	115.340	0.833	0.419
24.5	0:24:30	80	20.0	487.4	1.25	0.391	443.1	115.731	0.836	0.413
24.7	0:24:45	70	18.8	461.5	1.26	0.342	459.2	116.074	0.838	0.406
25.0	0:25:00	70	17.5	435.2	1.27	0.342	474.4	116.416	0.841	0.400
25.2	0:25:15	70	17.5	439.6	1.28	0.342	521.1	116.759	0.843	0.394
25.5	0:25:30	70	17.5	444.0	1.30	0.342	569.9	117.101	0.846	0.388
25.7	0:25:45	70	17.5	448.4	1.31	0.342	620.9	117.443	0.848	0.382
26.0	0:26:00	70	17.5	452.7	1.32	0.342	674.1	117.786	0.851	0.376
26.2	0:26:15	70	17.5	457.1	1.33	0.342	729.5	118.128	0.853	0.370
26.5	0:26:30	60	16.3	428.4	1.35	0.293	728.8	118.422	0.855	0.364
26.7	0:26:45	60	15.0	399.3	1.36	0.293	725.9	118.715	0.857	0.358
27.0	0:27:00	60	15.0	403.1	1.37	0.293	779.0	119.009	0.859	0.353
27.2	0:27:15	60	15.0	406.8	1.39	0.293	834.0	119.302	0.862	0.347
27.5	0:27:30	60	15.0	410.6	1.40	0.293	890.8	119.596	0.864	0.341
27.7	0:27:45	60	15.0	414.3	1.41	0.293	949.5	119.889	0.866	0.336
28.0	0:28:00	60	15.0	418.1	1.42	0.293	1010.1	120.183	0.868	0.330
28.2	0:28:15	60	15.0	421.8	1.44	0.293	1072.6	120.476	0.870	0.325
28.5	0:28:30	60	15.0	425.6	1.45	0.293	1137.0	120.770	0.872	0.320
28.7	0:28:45	60	15.0	429.3	1.46	0.293	1203.2	121.063	0.874	0.314
29.0	0:29:00	60	15.0	433.1	1.47	0.293	1271.3	121.357	0.876	0.309
29.2	0:29:15	60	15.0	436.8	1.49	0.293	1341.3	121.650	0.878	0.304
29.5	0:29:30	50	13.8	403.7	1.50	0.245	1292.3	121.895	0.880	0.299
29.7	0:29:45	50	12.5	370.3	1.51	0.245	1239.1	122.139	0.882	0.294
30.0	0:30:00	50	12.5	373.4	1.53	0.245	1302.1	122.384	0.884	0.289
30.2	0:30:15	50	12.5	376.5	1.54	0.245	1366.6	122.628	0.886	0.284
30.5	0:30:30	50	12.5	379.6	1.55	0.245	1432.7	122.873	0.887	0.279
30.7	0:30:45	50	12.5	382.8	1.56	0.245	1500.4	123.117	0.889	0.274
31.0	0:31:00	50	12.5	385.9	1.58	0.245	1569.7	123.362	0.891	0.270
31.2	0:31:15	50	12.5	389.0	1.59	0.245	1640.5	123.607	0.893	0.265
31.5	0:31:30	50	12.5	392.1	1.60	0.245	1712.9	123.851	0.894	0.260
31.7	0:31:45	50	12.5	395.3	1.61	0.245	1786.8	124.096	0.896	0.256
32.0	0:32:00	50	12.5	398.4	1.63	0.245	1862.3	124.340	0.898	0.251
32.2	0:32:15	40	11.2	361.2	1.64	0.196	1741.6	124.536	0.899	0.247
32.5	0:32:30	40	10.0	323.7	1.65	0.196	1614.4	124.732	0.901	0.243
32.7	0:32:45	40	10.0	326.2	1.67	0.196	1678.6	124.927	0.902	0.238
33.0	0:33:00	40	10.0	328.7	1.68	0.196	1744.0	125.123	0.904	0.234
33.2	0:33:15	40	10.0	331.2	1.69	0.196	1810.6	125.319	0.905	0.230

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
33.5	0:33:30	40	10.0	333.7	1.70	0.196	1878.5	125.514	0.906	0.226
33.7	0:33:45	40	10.0	336.2	1.72	0.196	1947.7	125.710	0.908	0.222
34.0	0:34:00	40	10.0	338.7	1.73	0.196	2018.1	125.906	0.909	0.218
34.2	0:34:15	40	10.0	341.2	1.74	0.196	2089.7	126.101	0.911	0.214
34.5	0:34:30	40	10.0	343.7	1.75	0.196	2162.6	126.297	0.912	0.210
34.7	0:34:45	40	10.0	346.2	1.77	0.196	2236.8	126.493	0.913	0.206
35.0	0:35:00	40	10.0	348.7	1.78	0.196	2312.2	126.688	0.915	0.203
35.2	0:35:15	40	10.0	351.2	1.79	0.196	2388.8	126.884	0.916	0.199
35.5	0:35:30	40	10.0	353.7	1.81	0.196	2466.7	127.080	0.918	0.195
35.7	0:35:45	30	8.8	311.5	1.82	0.147	2222.7	127.226	0.919	0.192
36.0	0:36:00	30	7.5	269.0	1.83	0.147	1969.7	127.373	0.920	0.188
36.2	0:36:15	30	7.5	270.9	1.84	0.147	2031.0	127.520	0.921	0.185
36.5	0:36:30	30	7.5	272.8	1.86	0.147	2093.1	127.666	0.922	0.181
36.7	0:36:45	30	7.5	274.7	1.87	0.147	2156.2	127.813	0.923	0.178
37.0	0:37:00	30	7.5	276.5	1.88	0.147	2220.3	127.960	0.924	0.175
37.2	0:37:15	30	7.5	278.4	1.89	0.147	2285.3	128.107	0.925	0.172
37.5	0:37:30	30	7.5	280.3	1.91	0.147	2351.2	128.253	0.926	0.168
37.7	0:37:45	30	7.5	282.2	1.92	0.147	2418.1	128.400	0.927	0.165
38.0	0:38:00	30	7.5	284.0	1.93	0.147	2485.9	128.547	0.928	0.162
38.2	0:38:15	30	7.5	285.9	1.94	0.147	2554.6	128.694	0.929	0.159
38.5	0:38:30	30	7.5	287.8	1.96	0.147	2624.3	128.840	0.930	0.156
38.7	0:38:45	30	7.5	289.7	1.97	0.147	2694.9	128.987	0.931	0.153
39.0	0:39:00	30	7.5	291.5	1.98	0.147	2766.5	129.134	0.933	0.150
39.2	0:39:15	30	7.5	293.4	2.00	0.147	2838.9	129.281	0.934	0.147
39.5	0:39:30	30	7.5	295.3	2.01	0.147	2912.4	129.427	0.935	0.145
39.7	0:39:45	30	7.5	297.2	2.02	0.147	2986.7	129.574	0.936	0.142
40.0	0:40:00	30	7.5	299.0	2.03	0.147	3062.0	129.721	0.937	0.139
40.2	0:40:15	30	7.5	300.9	2.05	0.147	3138.3	129.868	0.938	0.137
40.5	0:40:30	30	7.5	302.8	2.06	0.147	3215.4	130.014	0.939	0.134
40.7	0:40:45	30	7.5	304.7	2.07	0.147	3293.6	130.161	0.940	0.131
41.0	0:41:00	30	7.5	306.5	2.08	0.147	3372.6	130.308	0.941	0.129
41.2	0:41:15	30	7.5	308.4	2.10	0.147	3452.6	130.455	0.942	0.126
41.5	0:41:30	30	7.5	310.3	2.11	0.147	3533.5	130.601	0.943	0.124
41.7	0:41:45	30	7.5	312.2	2.12	0.147	3615.4	130.748	0.944	0.122
42.0	0:42:00	30	7.5	314.0	2.14	0.147	3698.2	130.895	0.945	0.119
42.2	0:42:15	30	7.5	315.9	2.15	0.147	3781.9	131.042	0.946	0.117
42.5	0:42:30	30	7.5	317.8	2.16	0.147	3866.6	131.188	0.947	0.115
42.7	0:42:45	30	7.5	319.7	2.17	0.147	3952.2	131.335	0.948	0.113
43.0	0:43:00	30	7.5	321.5	2.19	0.147	4038.8	131.482	0.949	0.110

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
43.2	0:43:15	30	7.5	323.4	2.20	0.147	4126.3	131.629	0.951	0.108
43.5	0:43:30	30	7.5	325.3	2.21	0.147	4214.7	131.775	0.952	0.106
43.7	0:43:45	30	7.5	327.2	2.22	0.147	4304.1	131.922	0.953	0.104
44.0	0:44:00	30	7.5	329.0	2.24	0.147	4394.4	132.069	0.954	0.102
44.2	0:44:15	30	7.5	330.9	2.25	0.147	4485.6	132.216	0.955	0.100
44.5	0:44:30	30	7.5	332.8	2.26	0.147	4577.8	132.362	0.956	0.098
44.7	0:44:45	30	7.5	334.7	2.28	0.147	4670.9	132.509	0.957	0.096
45.0	0:45:00	30	7.5	336.5	2.29	0.147	4764.9	132.656	0.958	0.094
45.2	0:45:15	30	7.5	338.4	2.30	0.147	4859.9	132.802	0.959	0.092
45.5	0:45:30	30	7.5	340.3	2.31	0.147	4955.8	132.949	0.960	0.091
45.7	0:45:45	30	7.5	342.2	2.33	0.147	5052.7	133.096	0.961	0.089
46.0	0:46:00	20	6.3	286.5	2.34	0.098	4283.9	133.194	0.962	0.087
46.2	0:46:15	20	5.0	230.6	2.35	0.098	3499.5	133.292	0.963	0.085
46.5	0:46:30	20	5.0	231.9	2.36	0.098	3566.0	133.389	0.963	0.084
46.7	0:46:45	20	5.0	233.1	2.38	0.098	3633.0	133.487	0.964	0.082
47.0	0:47:00	20	5.0	234.4	2.39	0.098	3700.7	133.585	0.965	0.080
47.2	0:47:15	20	5.0	235.6	2.40	0.098	3769.1	133.683	0.965	0.079
47.5	0:47:30	20	5.0	236.9	2.42	0.098	3838.0	133.781	0.966	0.077
47.7	0:47:45	20	5.0	238.1	2.43	0.098	3907.6	133.879	0.967	0.076
48.0	0:48:00	20	5.0	239.4	2.44	0.098	3977.8	133.976	0.968	0.074
48.2	0:48:15	20	5.0	240.6	2.45	0.098	4048.6	134.074	0.968	0.073
48.5	0:48:30	20	5.0	241.9	2.47	0.098	4120.1	134.172	0.969	0.071
48.7	0:48:45	20	5.0	243.1	2.48	0.098	4192.1	134.270	0.970	0.070
49.0	0:49:00	20	5.0	244.4	2.49	0.098	4264.8	134.368	0.970	0.068
49.2	0:49:15	20	5.0	245.6	2.50	0.098	4338.2	134.466	0.971	0.067
49.5	0:49:30	20	5.0	246.9	2.52	0.098	4412.1	134.563	0.972	0.066
49.7	0:49:45	20	5.0	248.1	2.53	0.098	4486.7	134.661	0.972	0.064
50.0	0:50:00	20	5.0	249.4	2.54	0.098	4561.9	134.759	0.973	0.063
50.2	0:50:15	20	5.0	250.6	2.56	0.098	4637.7	134.857	0.974	0.062
50.5	0:50:30	20	5.0	251.9	2.57	0.098	4714.2	134.955	0.975	0.060
50.7	0:50:45	20	5.0	253.1	2.58	0.098	4791.2	135.053	0.975	0.059
51.0	0:51:00	20	5.0	254.4	2.59	0.098	4868.9	135.150	0.976	0.058
51.2	0:51:15	20	5.0	255.6	2.61	0.098	4947.3	135.248	0.977	0.057
51.5	0:51:30	20	5.0	256.9	2.62	0.098	5026.2	135.346	0.977	0.056
51.7	0:51:45	20	5.0	258.1	2.63	0.098	5105.8	135.444	0.978	0.055
52.0	0:52:00	20	5.0	259.4	2.64	0.098	5186.0	135.542	0.979	0.053
52.2	0:52:15	20	5.0	260.6	2.66	0.098	5266.8	135.640	0.980	0.052
52.5	0:52:30	20	5.0	261.9	2.67	0.098	5348.3	135.737	0.980	0.051
52.7	0:52:45	20	5.0	263.1	2.68	0.098	5430.3	135.835	0.981	0.050

time [min]	time [min]	Cond. [µS/cm]	(Ci-1 + Ci)Δt/3	(Ci-1ti-1 + Citi)Δt/3	Θ	E(Θ)	term b		F(Θ)	E(Θ) n= 3
53.0	0:53:00	20	5.0	264.4	2.69	0.098	5513.0	135.933	0.982	0.049
53.2	0:53:15	20	5.0	265.6	2.71	0.098	5596.4	136.031	0.982	0.048
53.5	0:53:30	20	5.0	266.9	2.72	0.098	5680.3	136.129	0.983	0.047
53.7	0:53:45	20	5.0	268.1	2.73	0.098	5764.9	136.227	0.984	0.046
54.0	0:54:00	20	5.0	269.4	2.75	0.098	5850.1	136.324	0.984	0.045
54.2	0:54:15	20	5.0	270.6	2.76	0.098	5935.9	136.422	0.985	0.044
54.5	0:54:30	20	5.0	271.9	2.77	0.098	6022.4	136.520	0.986	0.043
54.7	0:54:45	20	5.0	273.1	2.78	0.098	6109.5	136.618	0.987	0.043
55.0	0:55:00	20	5.0	274.4	2.80	0.098	6197.2	136.716	0.987	0.042
55.2	0:55:15	20	5.0	275.6	2.81	0.098	6285.5	136.813	0.988	0.041
55.5	0:55:30	20	5.0	276.9	2.82	0.098	6374.4	136.911	0.989	0.040
55.7	0:55:45	20	5.0	278.1	2.83	0.098	6464.0	137.009	0.989	0.039
56.0	0:56:00	20	5.0	279.4	2.85	0.098	6554.2	137.107	0.990	0.038
56.2	0:56:15	20	5.0	280.6	2.86	0.098	6645.0	137.205	0.991	0.038
56.5	0:56:30	20	5.0	281.9	2.87	0.098	6736.5	137.303	0.992	0.037
56.7	0:56:45	20	5.0	283.1	2.89	0.098	6828.6	137.400	0.992	0.036
57.0	0:57:00	20	5.0	284.4	2.90	0.098	6921.3	137.498	0.993	0.035
57.2	0:57:15	20	5.0	285.6	2.91	0.098	7014.6	137.596	0.994	0.034
57.5	0:57:30	20	5.0	286.9	2.92	0.098	7108.5	137.694	0.994	0.034
57.7	0:57:45	20	5.0	288.1	2.94	0.098	7203.1	137.792	0.995	0.033
58.0	0:58:00	20	5.0	289.4	2.95	0.098	7298.3	137.890	0.996	0.032
58.2	0:58:15	20	5.0	290.6	2.96	0.098	7394.1	137.987	0.996	0.032
58.5	0:58:30	20	5.0	291.9	2.97	0.098	7490.6	138.085	0.997	0.031
58.7	0:58:45	20	5.0	293.1	2.99	0.098	7587.7	138.183	0.998	0.030
59.0	0:59:00	20	5.0	294.4	3.00	0.098	7685.4	138.281	0.999	0.030
59.2	0:59:15	20	5.0	295.6	3.01	0.098	7783.7	138.379	0.999	0.029
59.5	0:59:30	20	5.0	296.9	3.03	0.098	7882.6	138.477	1.000	0.029
			4020.0	79056.3			762094.1			
		$\bar{t}$	19.6	min.						
		C_n	204.4	uS/cm						
		σ^2	189.5	min^2						
		σ_t	13.7	min						