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March 2, 1998

Ms. Blanca Bayo
Director, Division of Records & Reporting
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida

RE: Application of United Water Florida Inc. For Increased Water and Wastewater Rates in Duval, Nassau and St. Johns Counties, Docket No. 960451-WS

Dear Ms. Bayo:

In accordance with the requirements in Order No. PSC-97-0618-FOF-WS, issued in Docket No. 960451-WS, enclosed is a report entitled "Update on the Effectiveness of Corrosion Control Systems at United Water Florida, February 1998" ("Update Report").

As set forth in the order, United Water Florida was required to provide the Florida Public Service Commission ("Commission") with data to update the Commission on the effectiveness of the corrosion control and hydrogen sulfide treatment programs after the equipment had been in place for several months and to specifically address the concerns of customers Bee, Gollor, and Emans. United Water Florida was to provide this report within six (6) months of the date of the order (i.e., May 30, 1997); however, the majority of the new equipment was installed subsequent to that date.

United Water Florida used a six (6) month sampling period of July through December, 1997 for lead and copper testing and to test the equipment after it had been in place for several months. United Water Florida compared the test results for July through December, 1997, with test results from July through December, 1992. Because United Water Florida was required to obtain testing results after the equipment had been in place for several months, a complete report could not be prepared and filed within six (6) months of the order. United Water Florida has now complied with the order, including an update after the equipment has been in place for several months. The Update Report specifically addresses the concerns of the three customers.

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Please file the enclosed Update Report in accordance with your standard procedures. If you have any questions or comments, please do not hesitate to call.

Sincerely yours,

Scott G. Schildberg

Scott G. Schildberg

SGS/msa
Enclosure
cc: Mr. David E. Chardavoyne
Mr. Walton F. Hill (w/o Enclosures)
Mr. Robert J. Iacullo (w/o Enclosures)
Mr. Munipalli Sambamurthi
Ms. Rosanne Gervasi
Mr. Harold McLean

ORIGINAL

United Water Florida
Order No. PSC-97-0618-FOF-WS
Docket No. 960451-WS

Update on the Effectiveness of Corrosion Control Systems at United Water Florida

February 1998

Todd D Mackey
2/4/98

Todd D. Mackey, P.E.
License # 32008

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United Water Florida
Order No. PSC-97-0618-FOF-WS
Docket No. 960451-WS

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A	Report - *Hydrogen Sulfide and Corrosion Control Study Jacksonville Suburban Utilities - Final report August 31,1994*
B	Acceptance of corrosion control study by DHRS, letter dated October 28,1994
C	Proposed Implementation Schedule, letter to DHRS, dated January 24, 1997

United Water Florida
Order No. PSC-97-0618-FOF-WS
Docket No. 960451-WS

Introduction:

United Water Florida (UWF) applied for rate relief in 1997 and during the hearing phase several customers had concerns relating to the corrosivity of the water. As a result, UWF was ordered to provide additional information to the Florida Public Service Commission (PSC). This information is summarized as follows;

- Update the PSC on the effectiveness of the corrosion control and hydrogen sulfide treatment programs after the equipment has been in place for several months.
- The utility shall specifically address the concerns of customers Bee, Goller, and Evans, who testified about the corrosiveness of the water.
- Provide data showing the results of treatment for hydrogen sulfide control and corrosive tendencies of the water.
- The utility shall provide this report within six months from the issuance date of this order.

Background Information:

In May of 1991, the National Primary Drinking Regulations (NPDWRs) for lead and copper were promulgated. The regulations established action levels for lead (0.015 mg/l) and copper (1.3 mg/l). The rule also established treatment techniques for lead and copper as follows;

Lead treatment techniques;

1. optimal corrosion control treatment
2. source water treatment
3. public education
4. lead service line replacement

Copper treatment techniques;

1. optimal corrosion control treatment
2. source water treatment

In order to establish compliance, the rule provided a monitoring schedule based upon system size (population) , small, medium, or large. The initial monitoring period required large systems to begin sampling in January of 1992 and was to include two samplings over a one year period. Samples were collected from sites deemed to be high risk locations. These sites would be homes with lead solder installed after 1992, lead pipes or lead service lines. The following Table I, provides a summary of the initial monitoring by system size and the number of required samples;

Table I
System Definition

System	Population	Start Date	Initial Base Monitoring
Large	> 50,000	January 1992	60 - 100
Medium	3,300 to 50,000	July 1992	40 - 60
Small	< 3,300	July 1993	10 - 20

Based upon the results of the monitoring, systems were directed to implement a corrosion control program or complete a corrosion control study to determine an effective control method. After acceptance by the Department of Environmental Protection and the Florida Department of Health and Rehabilitative Services, the chosen corrosion control method would be implemented and optimized. This schedule varied, depending upon the size of the system as indicated in the above table.

UWF has sixteen water systems that are classified as medium or small based upon the definition in the rule. The medium systems initiated monitoring for the period starting July 1992, and the small systems in July of 1993. The following Tables II & III summarizes the results of this sampling;

Table II
Medium Systems
Lead/Copper Monitoring Results

System	# of samples	Lead * (mg/l)	Copper * (mg/l)
Holly Oaks	49	<0.005	2.59
Marshview	48	<0.005	2.11
Ponte Vedra	45	<0.005	1.43
Royal Lakes	71	<0.005	1.95
San Jose	68	<0.005	2.62
Arlington Grid	75	0.010	4.71
Jax Heights Grid	61	<0.005	1.92

* Results at 90th Percentile

Table III
Small Systems
Lead/Copper Monitoring Results

System	# of Samples	Lead * (mg/l)	Copper * (mg/l)
Forest Brook	21	0.008	0.736
Hyde Grove	25	0.007	0.436
Lake Forest	23	0.007	0.108
Mag Gardens	26	<0.005	0.440
Nassau Jail	10	<0.005	0.063
Ortega Hills	25	0.019	0.202
Ponce de Leon	20	<0.005	0.716
St Johns North	20	<0.005	1.12
Venetia Terr.	21	0.007	0.088

* Results at 90th Percentile

From the above tables it can be determined that UWF meets the action level for lead but exceeds the action level for copper in all of the medium sized systems. The exceedence of the copper action level indicated a need to conduct a corrosion control study and make a recommendation to the Florida Department of Environmental Protection (DEP) and the Florida Department of Health and Rehabilitative Services (DHRS) designating an optimal corrosion control treatment.

Corrosion Control Studies :

UWF sought the assistance of the University of Florida (U F) in order to conduct the corrosion control study.

Initial studies had been conducted in 1991 by U F as a result of high copper levels in the wastewater residuals at the WWTP operated by UWF at its Holly Oaks system. The focus of the study was to determine the effect of hydrogen sulfide control and its effect on the disinfection residuals and corrosion in the distribution system. The study identified that the existing cascade aeration currently in service provided a sulfide reduction of 14% to 30%. It further stated that chlorine was effective in oxidizing the remaining sulfide to below detection limits (0.1 mg/l). It also determined that chlorine residuals leaving the treatment plants ranged from a trace to greater that 3.5 mg/l and that residuals with the distribution system varied from below detection limits to 0.9 mg/l. first draw samples within the distribution system were found to contain copper concentrations as high as 2.8 mg/l.

During the Spring and Summer of 1993, a study under the direction of Dr. Paul Chadik, was initiated that would identify an optimum corrosion control treatment.

This study was conducted at the Monument Road WTP investigating various physical treatment methods for removing sulfides. Primarily this study dealt with aeration methods and considered two forced-draft tower aerators; a packed tower aerator (PTA) and a slatted-tray aerator (STA).

During this study not only were physical aeration processes reviewed, the effect of pH on the aeration process was also investigated. The investigation found that both the STA and PTA processes provided increased sulfide removal rates when operating under similar influent pH and air/water ratios. It had been determined that the existing cascade tray aerator removed 14% to 30 % of the total sulfides in the raw water. The removal efficiencies of the STA and PTA were significantly higher than the cascade aerator. Under similar flow and pH conditions, the STA and PTA had removal efficiencies of 40% and 72 % respectively. Both of these systems increased the dissolved oxygen concentration from near zero to 5 to 6 mg/l. It was considered that high levels of dissolved oxygen may cause corrosion problems in the distribution system. The levels indicated are similar to the dissolved oxygen levels found currently with the cascade tray aerators. Low dissolved oxygen levels may lead to reversion of oxidized sulfur to sulfide in the distribution system causing taste and odor complaints as well as increased chlorine demand. It was concluded that the increased dissolved oxygen levels would not be a deterent to the use of a PTA or STA.

By adding an acid to lower the pH to 6.5, it was determined that the removal efficiencies of both systems could be improved. However due to the high alkalinity (135 mg/l) and buffering characteristic of the raw water, a large quantity of acid would be required. Approximately 50 mg/l of concentrated sulfuric acid or 95 mg/l of hydrochloric acid would be required to lower the pH by one pH unit. In addition, the pH would have to be increased with a strong base addition for corrosion control measures. It was concluded that since good hydrogen sulfide removal was accomplished without the addition of the acid/base and associated high cost, the adjustment of pH was not recommended.

The last phase of the studies conducted by U F reviewed the removal of sulfides by oxidation. Initially raw water was directed through a baffled tank with a hydraulic detention time of four hours. Sulfide removal efficiency without the addition of an oxidant was 69% for non-aerated water and 90% for aerated water by PTA. Removal of sulfide may have been by volatilization or oxidation by the dissolved oxygen present in the water, however the effect of mechanisms was not determined.

Oxidation of the sulfide by chlorine and hydrogen peroxide was also investigated. Sulfide removal by chlorination was rapid. In both non-aerated and aerated water, the sulfide removal occurred within one minute of contact time. However, turbidity formation was high (15 to 22 NTU) after chlorination of non-aerated water.

Chlorination of aerated water increased turbidity to above raw water levels but remained below 2.3 NTU for all doses up to 5.1 mg/l. At this level of chlorination, it was not possible to maintain a chlorine residual for the four hour detention time.

Similar to chlorine, hydrogen peroxide oxidation of non-aerated water caused excessive turbidity formation (30 to 40 NTU) after four hours of detention time.

The recommendations of the studies indicated that the Packed Tower Aeration system was more effective than the Slatted-Tray Aerator. Further, the storage of the aerated water with an appreciable dissolved oxygen concentration before chlorine application allowed the further oxidation of the remaining sulfide wihout excessive turbidity formation.

A third phase of study was completed by U F during the first half of 1994 that employed a corrosion control copper pipe loop. Six loops, of 1/2" Type L Copper tubing, each forty feet in length were utilized. Three corrosion inhibitors were evaluated in the study, an orthophosphate, polyphosphate and a blended phosphate product. During the loop studies various concentrations of inhibitor and aerated water were added to the five test loops. The sixth loop was a control loop where no treatment was added. It was concluded that the inhibitors did not work well in combination with the aerated water due to the elevated pH (8.0 to 8.5) and did not substantially reduce copper concentrations. It was recommended to not use a phosphate corrosion control inhibitor in conjunction with a PTA stripping at an elevated pH.

This study was submitted to the Department of Health and Rehabilitative Services (HRS) for the purpose of meeting the corrosion control study requirement of the Lead and Copper Rule. The HRS accepted the study as complete and approved the concept of raising the pH by either base addition or aeration.

A copy of the report *Hydrogen Sulfide and Corrosion Control Study, Jacksonville Suburban Utilities* is included in the appendix of this report.

UWF continued to research other aeration methods and in November of 1994 initiated a study with U F to evaluate the operation of vacuum spray stripping of hydrogen sulfide. The reason for this continued research was to find an alternative to PTA that would not have some of the potential operational problems, ie.algal and bacterial fouling of the packing.

Due to various operational problems with the pilot plant and the low removal efficiency, 51%, it was decided not to pursue this technology any further. UWF's primary corrosion control technology would be PTA.

Current Installations:

From the research conducted, the technology chosen to reduce the copper solubility was PTA. Seven medium sized systems within UWF would need to be upgraded with this technology in order to reduce the corrosivity of the water. Due to the time needed for design, permitting, construction and the capital expenditure requirements, UWF requested the PTAs be installed over a period of four years. In the interim, a chemical corrosion inhibitor system would be installed to reduce the corrossivity to meet the requirements of the Lead and Copper Rule. Table IV below shows the facilities and the type of corrosion control system installed as of the date of this report.

Table IV
Existing Corrosion Control Installations

Facility	System	Installed	Corrosion Inhibitor
Corona Road	Ponte Vedra	January 1997	Chemical System
St Johns North	St Johns North	November 1996	PTA
Alderman Park	Arlington	August 1997	Chemical System
Columbine	Arlington	August 1997	Chemical System
Elvia	Arlington	August 1997	Chemical System
Lake Lucina	Arlington	August 1997	Chemical System
University Park	Arlington	August 1997	Chemical System
Monument Road	Holly Oaks	June 1997	PTA
Queen Akers	Holly Oaks	May 1997	Chemical System
Green Forest	Jax Heights	August 1997	Chemical System
Oak Hill	Jax Heights	August 1997	Chemical System
Wheat Rd	Jax Heights	August 1997	Chemical System
Royal Lakes	Royal Lakes	May 1997	Chemical System
San Jose	San Jose	May 1997	Chemical System
Marshview	San Pablo	June 1997	Chemical System

Each chemical feed system is similar, consists of the following equipment;

2 - LMI Chemical Metering Pumps
2 - Eductors
2 - Booster Pumps
2 - Chemical storage tanks

Utilizing this feed system, two chemicals are added; C-5 a polyphosphate and C-15, a zinc orthophosphate. The average feed rate is approximately 5.0 mg/l for C-5 and 1.0 mg/l C-15 at each location.

The PTA can be described as a counter-current aeration device. The structure is approximately eight foot in diameter and the height varies depending upon treatment efficiency requirements. The tower contains a media to disburse the water and to provide multiple surfaces for the air to interact. A blower is provided for the air supply and a small wetwell is located at the base of the tower. The unit is constructed of NSF approved, UV protected PVC. Two pumps are available to transfer the treated water from the wetwell to the ground storage tank..

Results:

The improvements noted above have reduced the corrosivity of the water in each of the indicated systems. In every individual system, the improvements have brought the system into compliance with the Lead and Copper Rule. The following Table V shows the results of initial sampling of the seven medium sized systems in 1992 and the most recent sampling at the end of 1997 following installation of chemical corrosion control systems.

Table V
Copper Sampling Summary
Medium Systems
Results at 90th Percentile (mg/l)

System	July – Dec 1992	July – Dec 1997
Arlington Grid	4.71	Due 1998
Holly Oaks	2.59	0.952
Jax Heights	1.92	Due 1998
Ponte Vedra	1.43	0.827
Royal Lakes	1.95	1.11
San Pablo	2.11	1.21
San Jose	2.62	1.17

Copper action level = 1.3 mg/l

From the above table it can be determined that all the medium systems are in compliance with the Lead and Copper Rule. It should also be noted that the Royal Lakes, San Pablo and San Jose systems have only marginally met the requirements. PTAs are proposed for each of these locations in 1998. The impact of the PTAs can best be illustrated by looking at the results of copper sampling in the St Johns North system. Considered a small system, the 90th percentile results for the years 1994, 1995 and 1996 are 1.12,1.33 and 1.43 mg/l respectively. In November of 1996, UWF installed its first PTA at the St Johns North WTP. Sample results from the first and second half of 1997 indicate a drastic reduction in copper corrosion with 90th percentile copper levels of 0.269 and 0.245

mg/l. This represents approximately a 82% reduction from the 1996 levels. In fact none of the samples taken in 1997 exceeded the action level for copper. The installation of PTAs at the remaining medium sized systems are expected to have the same effect. A summary of the 1995, 1996 and 1997 results of sampling all sites further bears out the effectiveness of the PTA.

Table VI
Tap Sampling
St Johns North
(mg/l)

Site #	1995	1996	1st half 1997	2nd half 1997
21-01	0.714	0.817	0.127	0.103
21-03	-	0.168	0.027	0.020
21-04	1.27	0.896	0.043	-
21-07	0.627	0.634	0.085	0.084
21-08	0.972	1.410	0.146	0.245
21-10	1.05	0.939	0.371	0.293
21-13	0.877	1.08	0.189	0.196
21-14	1.56	1.46	0.202	0.038
21-15	0.845	1.73	0.137	0.157
21-16	1.14	-	0.174	-
21-17	0.755	0.994	0.011	0.028
21-18	0.205	1.43	0.295	0.267
21-19	0.63	0.667	0.119	-
21-20	0.917	0.786	0.127	0.115
21-23	-	1.33	0.107	0.13
21-25	0.84	0.33	0.045	-
21-26	1.114	1.24	0.163	0.192
21-27	0.694	1.19	0.162	0.18
21-29	1.010	0.771	0.144	0.112
21-30	1.06	0.542	0.269	0.187

Customer Inquiries:

At the beginning of this report it was mentioned that this information was requested as a result of concerns raised by three customers during the hearing phase of the previous rate proceedings. Specifically their concerns centered on the corrosive nature of the water as well as the poor taste and odor. The following customers were noted in the rate order;

1. Claire Bee
   4823 Marsh Hammock Dr. E.
   Jacksonville, Fl 32224

   (San Pablo Service Area)

2. Terry & Melissa Goller
   8059 Toulon Court
   Jacksonville, Fl 32277

   (Arlington Service Area)

3. Teri Emans
   2152 Forest Hollow Way
   Jacksonville, Fl. 32259

   (St Johns North Service Area)

The above customers testified during the last rate proceedings regarding the high level of corrosivity and the taste associated with hydrogen sulfide. They indicated the corrosive nature of the water was deteriorating faucets and and leaving "copper" rings in a pet water bowl.

From the data presented in Table V, the improvements made so far have significantly reduced the copper corrosivity of the finished water to all of the medium sized systems which includes the locations of the the above customers. To summarize, the chemical feed system for San Pablo has reduced the copper corrosion by approximately 43% as compared to the initial sampling in 1992. The installation of the PTA in the St Johns North Service Area has effected the largest reduction in copper corrosion of UWF's water systems of approximately 82%. The reduction in copper corrosion is a direct result of the effective removal of the sulfide in the raw groundwater. As mentioned earlier in this report, the PTA is removing in excess of 70% of the sulfides and the subsequent detention time in the storage tank and the addition of chlorine for disinfection is enhancing the treatment process to remove in excess of 90%of the sulfides. This high removal rate of sulfides not only reduces the corrosive nature of the water but also significantly improves the taste. It is for those reasons that UWF has proposed to DHRS to install PTA's at all of its medium sized systems for ultimate compliance with the Lead and Copper Rule. In order to allow for capital budgeting, UWF has proposed the folowing schedule which was accepted by HRS for the installation of the PTA's.

Table VII
Packed Tower Aerators
Future Implementation Schedule

Facility	System	Completion
Royal Lakes	Royal Lakes	November 1997
Elvia	Arlington Grid	November 1998
San Jose	San Jose	November 1998
Alderman Park	Arlington Grid	November 1999
Marshview	San Pablo	November 1999
Oak Hill	Jax Heights	November 2000

Conclusions :

United Water Florida has extensively studied the impact of hydrogen sulfide and its effect on the corrosivity of potable water. As a result of the studies, UWF has determined that the existing cascade tray aeration system that is commonly used to aerate for the removal of hydrogen sulfide throughout the region, is only about 30% effective in removing hydrogen sulfide. It was determined that the PTA's were more effective in removing hydrogen sulfide. Approximately 70% of the influent hydrogen sulfide was removed and when additional detention time is provided in the onsite ground storage tank, the removal efficiency exceeds 90%. The overall treatment impact is a large reduction in the corrosion rate of copper as well as a great improvement in the taste and odor of the finished water. The PTA was the most effective process for the removal of hydrogen sulfide and has been approved by the DHRS for installation in the medium sized water systems.

UWF has shown that of the three customers who raised concerns about the corrosivity of the water, the corrosion rate of copper has been significantly reduced in two of the affected water systems. The corrosivity of copper has been reduced approximately 43% in the San Pablo system and approximately 82% in the St Johns North Service Area. The sampling for the remaining Arlington Grid will be completed in March 1998 per the Lead and Copper Rule requirements. Currently a chemical feed system has been installed in this system to reduce the corrosivity of copper.

Lastly, UWF had submitted a proposed a construction schedule to the HRS for the implementation of PTA technology at each of the medium sized water systems. This schedule has been accepted and UWF is currently in the process of constructing PTA's accordingly.

Appendix A

HYDROGEN SULFIDE AND CORROSION CONTROL STUDY
JACKSONVILLE SUBURBAN UTILITIES

FINAL REPORT

August 31, 1994

prepared by:

Paul A. Chadik, Ph.D., P.E.
Department of Environmental Engineering Sciences
University of Florida

INTRODUCTION

Jacksonville Suburban Utilities (JSU) is a private utility company operating both water and wastewater facilities in ten noncontiguous areas in and around Jacksonville, Florida. In each of these service areas, water is pumped from deep wells in the Floridan Aquifer, aerated in small cascade aerators, chlorinated and stored in water storage tanks at the well sites before being pumped into the distribution system. Some service areas have a number of wells and treatment facilities that feed into a common distribution system, e.g. the Holly Oaks area is served by three treatment plants (Monument Road, Ft. Caroline Road, and Queen Akers).

In June 1991 JSU requested a study of a portion of its water supply system be performed by the University of Florida. The focus of the study was hydrogen sulfide control and its effect on disinfection residuals and corrosion in the distribution system. Phase I of this study was completed in October 1991 and is described in a report dated October 31, 1991 entitled Hydrogen Sulfide Study for Jacksonville Suburban Utilities Phase I: Water Quality Assessment.

The Phase I study focused on the Holly Oaks service area and the three water treatment plants that serve this area: Ft. Caroline Rd., Monument Rd., and Queen Akers. Sulfide concentrations in untreated well water pumped from the Floridan Aquifer ranged from 2.7 to 3.8 mg/L. Although these sulfide concentrations were reduced by only 14% to 30% by cascade aeration, chlorination was effective in oxidizing the remaining sulfide to below detection levels (0.1 mg/L) before the water entered the distribution system. Dissolved oxygen concentrations increased from virtually zero in the untreated well water to 5 mg/L before distribution. Free chlorine residuals leaving the treatment plants were found to vary from trace levels to greater than 3.5 mg/L. Free chlorine residuals in the distribution system were found to vary from below detection levels to 0.9 mg/L. First draw samples in the distribution system were found to contain copper concentrations as high as 2.8 mg/L.

In order to address the hydrogen sulfide problem as well as the excessive copper corrosion in the interior plumbing of residential homes, JSU commissioned the University of Florida to investigate various control technologies with laboratory and pilot plant studies. Three separate studies were conducted by graduate students at the University of Florida under the direction and supervision of the principal investigator. Project reports in partial fulfillment of the requirements for the Master of Engineering Degree were published. These graduate students and their report titles are listed below, and the reports are submitted as part of this final report of the project.

1. "Removal of Hydrogen Sulfide from Drinking Water by Packed-tower and Slatted-tray Aerators: A Pilot Study," by Ronald Olsen.
2. "Oxidation of Sulfide with Chlorine and Hydrogen Peroxide," by Michael Delate.

3. "Report on the Investigation of Copper Corrosion Control: A Flow-through Test Study," by Craig Langley.

This final report summarizes the results of these investigations and reports.

METHODS

The research project included both laboratory and pilot plant investigations. Laboratory bench-scale studies, conducted at the University of Florida Department of Environmental Engineer & Sciences, focused on the oxidation of sulfide. Laboratory analytical measurements for all phases of the research were also performed at the University of Florida facilities. A pilot plant for hydrogen sulfide control (both by air stripping and chemical oxidation) and copper corrosion control was constructed by JSU at their Monument Road Water Treatment Plant. A schematic diagram of the plant is provided in Figure 1.

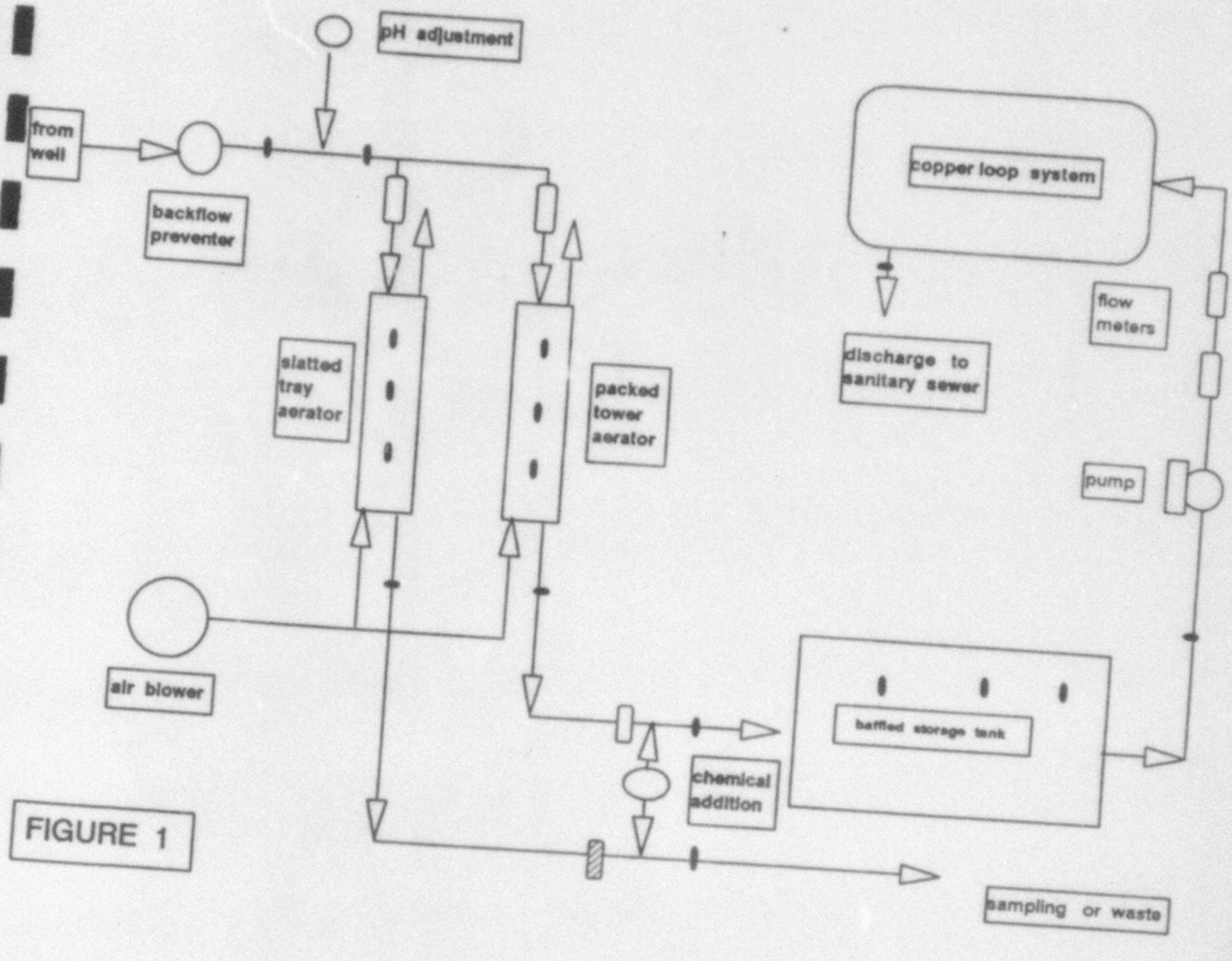
pH adjustment
from well
backflow preventer
slatted tray aerator
packed tower aerator
air blower
copper loop system
discharge to sanitary sewer
flow meters
pump
baffled storage tank
chemical addition
sampling or waste

FIGURE 1

Data from the pilot plant were collected intermittently (during specific experimental runs) from May, 1993 to August, 1993. Regular (weekly) monitoring of the corrosion loop portion of the pilot plant was performed from February, 1994 to August, 1994. During this latter period, the packed-tower aerator and oxidation/storage tank were also monitored with respect to selected water quality parameters.

Throughout the course of the project strict attention was given to accuracy and precision of results. All field and laboratory measurements were made according to either equipment instruction manuals or procedures outlined in Standard Methods. Field and laboratory instrumentation was calibrated daily or more often, and laboratory protocols included the development and validation of calibration curves, replicate analysis and blank analysis. Details of the monitoring method and analytical protocols can be found in the three reports that have been previously cited.

RESULTS

AERATION STUDY

The results of the aeration study indicated that hydrogen sulfide may be partially removed in a packed tower aerator (PTA) or a slatted-tray aerator (STA). The PTA provided better sulfide removal efficiencies than the STA particularly at the ambient pH (Table 1). The improved removal efficiency of the PTA as compared to the STA was in spite of the higher loading rate (Q/A) and the slightly higher pH in the PTA experimental run. Both of these factors would tend to decrease the sulfide removal efficiency. The results shown in Table 1 are representative; more detail may be found in the Olsen report.

Table 1. PTA and STA total sulfide removal efficiency at ambient pH

	G/L	Q/A	pH	Removal eff.
	ft^3/ft^3	gpm/ft^2		%
PTA	17	21.5	7.56	72
STA	19	9.0	7.40	40

As theory would predict, lowering the pH prior to aeration allowed better removal efficiencies in both the STA and the PTA under all air-to-water ratios. Because the alkalinity of the raw water is relatively high (135 mg/L as $CaCO_3$), about 50 mg/L of concentrated sulfuric acid or about 95 mg/L of concentrated hydrochloric acid would be required to lower the pH by one pH unit. Such a sulfuric acid dosage would appreciably increase the already substantial sulfate concentration of the raw water and the cost of either acid dosage would be significant. In addition, the pH would likely have to be increased with strong base addition for corrosion control purposes. Special facilities would be required to house the acid on site, and special handling would be required.

The PTA, STA and diffused aeration system increased the dissolved oxygen concentration of the water from near zero to between 5 and 6 mg/L. Increasing the dissolved oxygen concentration may exacerbate corrosion problems in the distribution system; however, low dissolved oxygen levels in the distribution system may lead to reversion of oxidized sulfur species to sulfide, thereby causing taste and odor problems and chlorine demand. Moreover, oxidation of the non-aerated raw water with chlorine produced high levels of turbidity as will be discussed in the oxidation portion of this report. It should be noted that the Phase 1 study found dissolved oxygen concentrations of between 5 and 6 mg/L as a result of the existing cascade aeration device which was found to remove between 23 and 30% of the total sulfide concentration at the Monument Rd. plant.

The PTA was operated intermittently during the initial phases of the research when volatilization and chemical oxidation were studied. During this initial period, the PTA and other appropriate processes were allowed to come to steady-state before samples were collected, but the systems were shut down for up to one week between certain sampling runs. During these shut-down periods, the packing dried, presumably inhibiting the growth of sulfide oxidizing bacteria. Accordingly, in the first phase of the research bacterial growth and fouling of the packing in the PTA was not observed.

During the second phase of the research, the corrosion control study, the PTA and the chlorination/storage processes were operated continuously. After approximately 4 months of operation considerable turbidity was found developing in the storage tank. Water was also found to be backing-up in the tower a few feet above the normal operating head. This latter hydraulic problem was subsequently found to be the result of a flow restriction in the static mixer between the PTA and the storage tank and unrelated to the bacterial growth in the PTA. At that time the PTA was temporarily taken out of service. Some packing was removed from the top of the PTA and from some of the sampling ports positioned at various depths in the PTA. A white slime was observed on most of the packing. Some of the packing contained a combination of white and dark slime. It should be noted that the PTA was originally constructed with a transparent window which was covered with an opaque plastic during the initial phase of the study. This plastic film was torn during an inspection of the packing at some time during the second phase and was not repaired. A luxuriant growth of green and brown material could be seen through the window after several months of continuous operation. This green and brown colored growth likely was a photosynthetic microorganism and should not be a problem with full-scale operation if light is excluded from the packing.

Samples were collected of the white slime on the packing and of the turbidity in the storage tank. Under microscopic examination, these appeared to be filamentous bacteria, perhaps *Beggiatoa* or *Thiothrix*. Granules of what appeared to be elemental sulfur appeared inside the filaments. Apparently, these bacteria began to grow on the packing using carbon dioxide as a carbon source and oxygen as an electron acceptor while oxidizing sulfide to sulfur in the PTA. During the initial phase of the study, the sulfide removal efficiency under ambient pH conditions was typically 65 to 75 %. In the second phase of the study when the bacterial growth developed, the sulfide concentration in the PTA effluent has been consistently below detection limits (0.1 mg/L) or essentially 100% removal efficiency.

Although the development of this bacteria enhances the sulfide removal in the PTA by catalyzing the oxidation of sulfide to sulfur, the resulting turbidity may prove to be a problem. Chlorine oxidation of sulfide also produces an elemental sulfur precipitate which results in an increase in turbidity in the effluent water. Apparently, the storage tanks have been retaining most of this turbidity in the past, but it is possible that colloidal sulfur is routinely leaving cascade aeration and chlorination facilities throughout Florida.

The turbidity (in the form of filamentous growth) appeared to be controlled if a chlorine residual was maintained in the storage tank. In the last two weeks of the study the microbial growth in the PTA increased above levels that were previously observed. Effluent from the PTA to the storage tank was highly turbid causing visibility in the storage tank to be reduced to only a few feet on the last site visit. Prior to this time, the bottom of the storage tank was always visible.

The formation of this turbidity is a cause for concern with regard to using PTA for hydrogen sulfide control at a full-scale treatment plant. Other plants in Florida have been using PTAs and other air stripping devices for hydrogen sulfide control. These utilities have also reported microbial growth but have not indicated that it has caused excessive turbidity problems. A central Florida utility tested the PTA concept with a pilot system but did not observe the growth to be a problem. This pilot system was not operated continuously for an extended period, so sufficient time for growth may not have been provided. The City of Cocoa observed the development of bacterial growth in their pilot PTAs and superchlorinated them with a recirculating chlorine solution every 6 months to control bacterial growth.

Measures to control the growth of the bacteria in the PTA may consist of allowing a drying period during normal operation. Providing two PTAs, each capable of handling the plant flow, would allow for alternate tower operation so that one PTA may be drying while the other is operating. Another option may be the continuous operation of the blower while water flow may be intermittent particularly during low flow conditions. Of course, routine cleaning of the packing will also control bacterial growth.

OXIDATION

A portion of the oxidation study focused on the removal of sulfide during storage without the addition of chlorine or hydrogen peroxide as oxidants. Water was allowed to flow through the pilot baffled storage tank with a mean hydraulic detention time of 4 hours. Removal of sulfide may have been by volatilization or oxidation by the dissolved oxygen present in the water, but the individual effect of each of these mechanisms was not determined. Sulfide removal efficiency without the addition of chlorine or peroxide was 69% (2.62 mg/L to 0.82 mg/L) using non-aerated well water and 90% (0.72 mg/L to 0.07 mg/L) using aerated water (passed through the PTA). There was evidence of significant oxygen consumption in the aerated water experiment which indicates that oxidation by oxygen was a factor in sulfide removal. A small increase in turbidity was found during these experiments but the final turbidity did not exceed 1 NTU.

Sulfide removal by chlorination was rapid. In both non-aerated and aerated water at mole ratios of chlorine to sulfide of greater than one, sulfide removal occurred within one minute of contact time. Turbidity formation was substantial (15 to 22 NTU) after chlorination of non-aerated water. Turbidity was found to increase above raw water turbidity levels when aerated water with a sulfide concentration of 0.7 mg/L was chlorinated, but the turbidity remained below 2.3 NTU for all chlorine doses (up to a mole ratio of chlorine to sulfide of 3.8 or a chlorine dose of 5.1 mg/L.) It should be noted that a chlorine residual could not be maintained for the four hour detention time at the chlorine doses employed in the field experiments.

Sulfide removal by oxidation with hydrogen peroxide was slower than chlorine oxidation in aerated water. Hydrogen peroxide oxidation of sulfide in non-aerated water caused excessive turbidity formation (30 to 40 NTU) after four hours of detention time in the storage tank.

Because hydrogen peroxide is twice as expensive as chlorine by weight, and the dosage of hydrogen peroxide required to remove sulfide remaining after packed tower aeration is twice the required dosage of chlorine, chlorine is clearly the less expensive of the two oxidants.

CORROSION CONTROL

The copper corrosion control loop study was performed using a cooper loop system shown in the schematic in Figure 2.

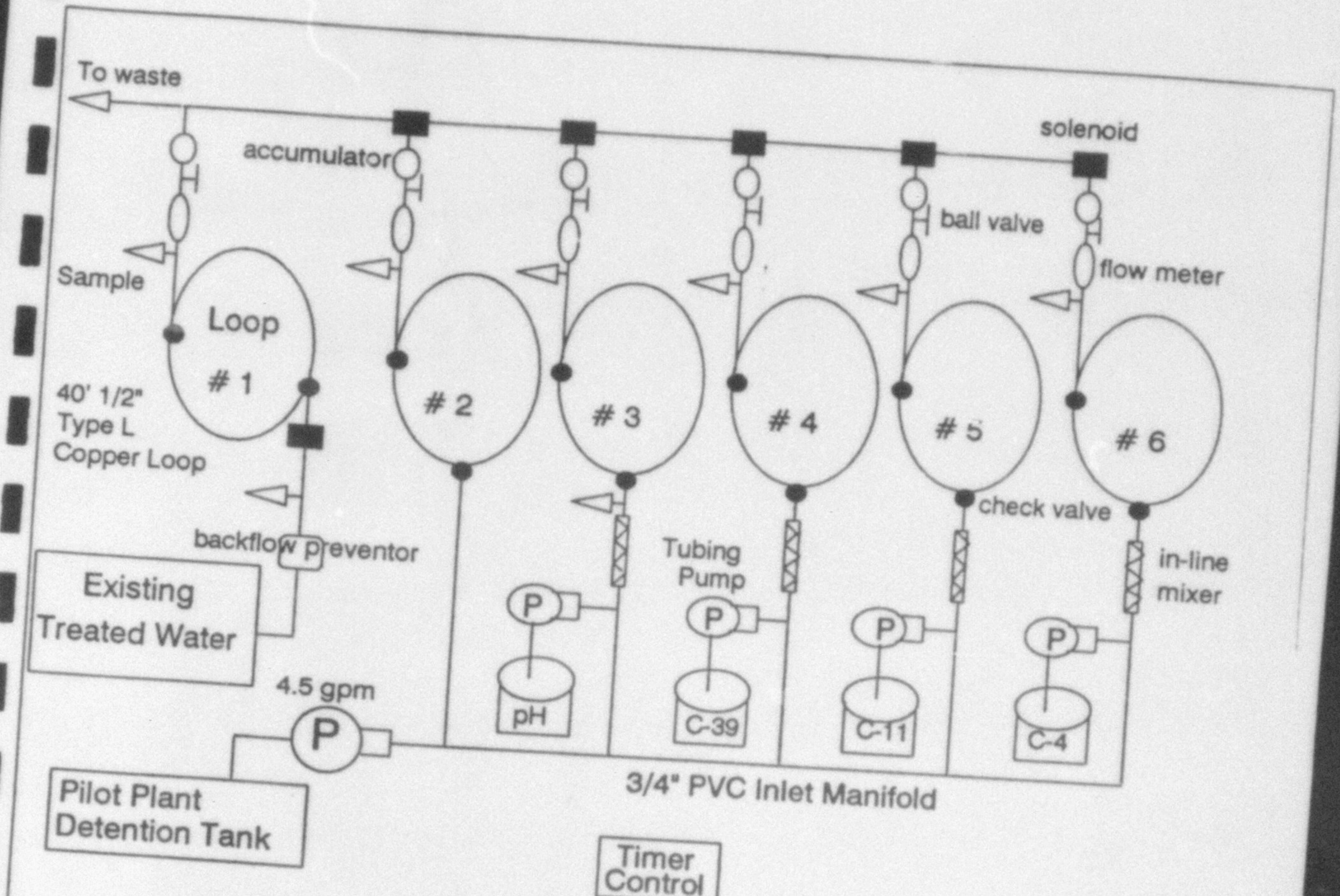
To waste
accumulator
solenoid
ball valve
flow meter
Sample
Loop
1
2
3
4
5
6
40' 1/2"
Type L
Copper Loop
check valve
backflow preventor
Tubing
Pump
in-line
mixer
Existing
Treated Water
P
P
P
P
P
pH
C-39
C-11
C-4
4.5 gpm
Pilot Plant
Detention Tank
3/4" PVC Inlet Manifold
Timer
Control

FIGURE 2

The loops were exposed to different water conditions:

Loop 1 - Water from the existing treatment system at the Monument Rd. Plant.

Loop 2 - Water from the pilot plant (stripped of hydrogen sulfide and carbon dioxide in the PTA, chlorinated, and stored for nominally 4 hours).

Loop 3 - Same as Loop 2. This loop was intended as a pH adjustment loop; however, the pH increased through the PTA to a value that provided a positive Langlier Index. Accordingly, the pH was not further adjusted.

Loop 4 - Pilot plant water with the addition of a polyphosphate inhibitor.

Loop 5 - Pilot plant water with the addition of an orthophosphate inhibitor.

Loop 6 - Pilot Plant water with the addition of a blended phosphate inhibitor.

The corrosion control study was conducted from February 6, 1994 to July 28, 1994, allowing the collection of data over a twenty-six week period.

The first draw, copper concentrations for the six loops are plotted versus time in Figure 3. The aberrant values obtained during weeks 9 through 11 were the result of a PTA malfunction. The copper concentration in Loop 1, the Monument Rd. plant control averaged about 1.5 mg/L over the last few weeks of the study. This value exceeds the action level of 1.3 mg/L in the Lead and Copper

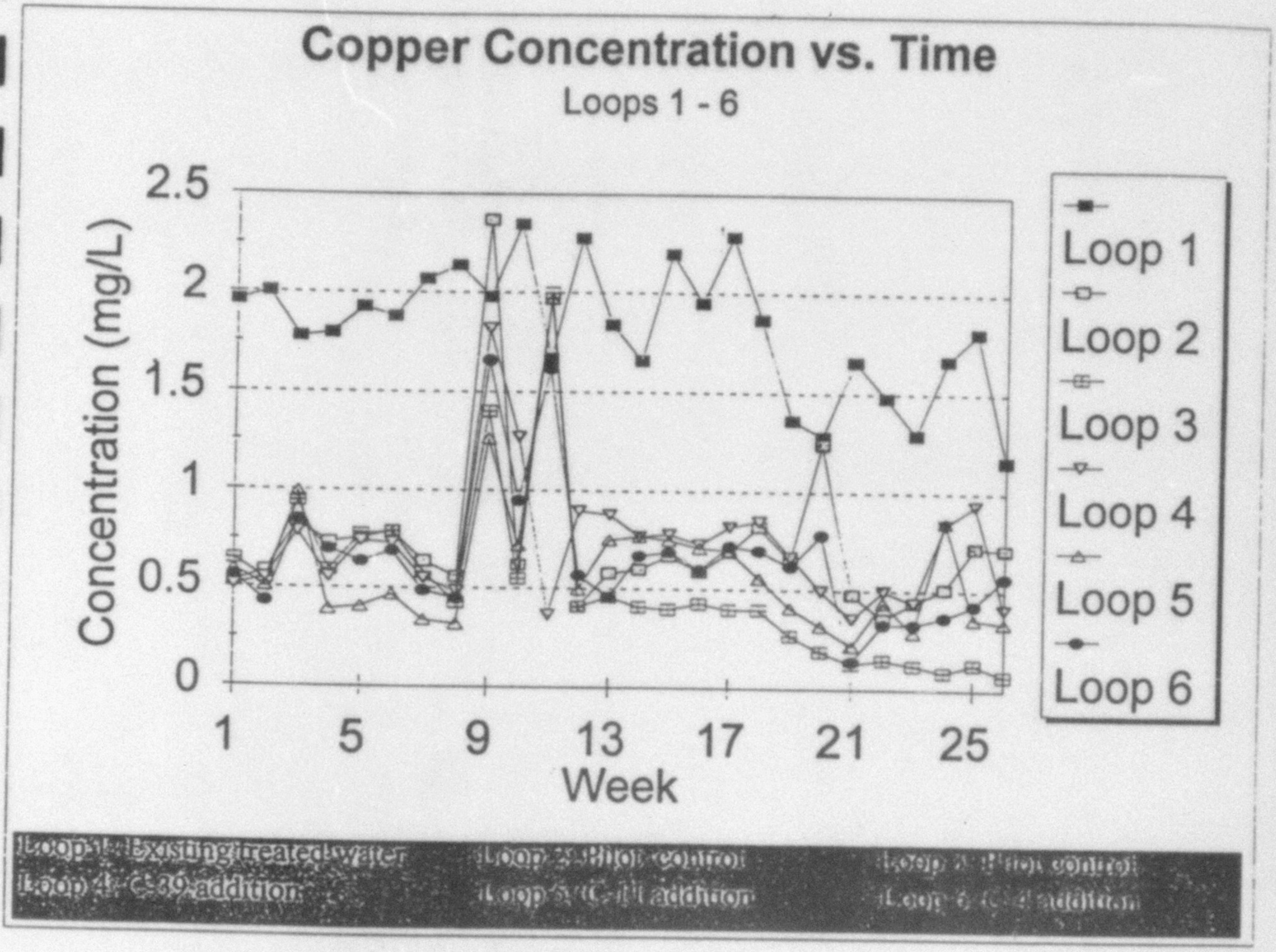

Figure 3. First draw copper concentrations for loops 1 - 6 vs time

Rule, and is near the average copper concentration found in the JSU Lead and Copper Rule Monitoring of 1.57 mg/L. With the exception of weeks 9 through 11, the average concentration for the loops 2 and 3, those receiving pilot plant water without any further chemical addition, was about 0.65 mg/L and 0.40 mg/L, respectively. The pilot plant water was considerably less corrosive to copper than the water treated in the existing Monument Rd. treatment plant.

Excluding, the three-week period when the PTA was inoperative, the average pH of the water treated in the pilot plant was 8.22 as compared to the existing treatment plant pH of 7.15. The increase in pH is the result of carbon dioxide removal, and, to a lesser extent, hydrogen sulfide removal in the PTA. The increase in pH was sufficient to alter the Langlier Index (LI) from -0.44 to +0.65 and change the calcium carbonate precipitation potential (CCPP) from -323 mg/L to 10 mg/L. This CCPP falls within the range recommended by EPA for producing a water that will inhibit corrosion through a protective coating of calcium carbonate. However, it is unlikely that the difference in the copper concentrations between loop 1 and loops 2 and 3, found from the beginning of this study, was the result of calcium carbonate deposition because some time is required before the deposition of the calcium carbonate scale can become effective. It is more likely, that the pH affected the electrochemical nature of corrosion by reducing the corrosion potential.

The trend of copper concentration decrease in Loop 3 from week 13 through week 26 was likely the result of a leaking solenoid on loop 3 that was only discovered in the final week of the study. The leakage was insufficient to produce a reading on the instantaneous flow meter but could be observed on the accumulator.

All inhibitors were fed at 1 mg/L as inhibitor in accordance with the manufacturer's recommendation. No one inhibitor caused a dramatic change in corrosion. As shown in Figure 3, there is little difference between these concentrations and those found in loops 2 and 3. Overall, of the three inhibitors, the zinc orthophosphate (C-11) produced the lowest copper concentrations in the test loops.

The dosage of C-11 was increased ten-fold and the concentrations of C-4 and C-39 were doubled during the last four weeks of the study. No significant difference in first-draw copper concentrations was noted when concentrations of copper before the increase in inhibitor dosage were compared to copper concentrations after the increase in dosage.

It should be noted that the three inhibitors in loops 4, 5 and 6 were used above the recommended pH range. The range of pH in the test loops fed by pilot plant water was 8.00 to 8.46. The optimum pH range for phosphate inhibitors is below 8.0. Operating outside the optimum pH range for the phosphate inhibitors may have had an adverse effect on their performance. On the other hand, the Monument Rd. Treatment Plant water in loop 1 was dosed with zinc polyphosphate inhibitor and had a pH range of 7.04 to 7.52 (a more favorable pH range for corrosion inhibition), yet copper concentrations in this loop were higher than all other loop copper concentrations.

SUMMARY AND RECOMMENDATIONS

In order to produce a potable water of high quality which satisfies federal and state regulations, an integrated design approach should be implemented, taking into consideration the effect of the treatment process on each important water quality parameter. The JSU supply, drawn from the Floridan Aquifer, contains elevated levels of hydrogen sulfide and carbon dioxide. It is desirable to reduce the concentrations of both of these compounds prior to distribution. The hydrogen sulfide produces offensive odor in water, exerts a chlorine demand and may cause pipe corrosion. Carbon dioxide is a weak acid and lowers the pH of water. Copper corrosion has been associated with low pH in this study as well as in previous research. JSU has been experiencing low chlorine residuals in the distribution system and elevated copper concentrations in first-draw samples from residences in their distribution system.

Hydrogen sulfide and carbon dioxide can be removed in an air stripping process. Total sulfide (the sum of hydrogen sulfide, H_2S, and bisulfide, HS^-) can be transformed to elemental sulfur and other oxidized forms of sulfur (such as sulfate, SO_4^{2-}) by using oxidants such as chlorine, hydrogen peroxide, ozone and even oxygen. Microbes may catalyze the oxidation when oxygen is the oxidant.

Air stripping has the advantage of removing the hydrogen sulfide from the water, but only the hydrogen sulfide portion of the total sulfide can be removed in this manner. Because carbon dioxide removal, as well as hydrogen sulfide removal, causes the pH to increase, the air stripping process causes the sulfide species distribution to shift to the non-volatile bisulfide. Accordingly, all of the sulfide may not be removed in the air stripping process. In the subject research only about 70% of the total sulfide was removed in the PTA. Adjustment of the pH prior to air stripping enables greater sulfide removal efficiencies, but, with the high alkalinity of the Floridan Aquifer water in the JSU service area, high dosages of acid would be required to substantially lower the pH. In addition, the lower pH would exacerbate copper corrosion in the distribution system. Accordingly, pH adjustment is not recommended since good hydrogen sulfide removal efficiencies may be obtained with the PTA at ambient pH and oxidation techniques are available to remove the remaining amount of sulfide.

Packed tower aeration achieves the greatest removal efficiencies for all volatile species as compared to other methods of air stripping. In this study the slatted tray aerator was found to be far less efficient at removing hydrogen sulfide. If PTAs replace the low efficiency cascade aerators at the JSU plants, increased concentrations of hydrogen sulfide in the air may be expected concomitant with increased efficiencies of hydrogen sulfide removal from the water. The total sulfide concentration of

2.0 to 2.5 mg/L at Monument Rd. Treatment Plant during the course of this study may not be high enough to produce severe odor problems, but the potential for neighborhood complaints exists. PTAs may be retrofitted with scrubbers or biofilters to remove hydrogen sulfide odors.

Oxidation of sulfides by chlorine, hydrogen peroxide and oxygen produce an insoluble colloidal elemental sulfur. This sulfur may increase turbidity levels in the distributed water but the turbidity may be reduced by removing some of the sulfide (in an air stripping process, for example) prior to the oxidation process. In this study both chlorine and hydrogen peroxide rapidly oxidized the sulfide, but caused excessive turbidity if the water was not subjected to air stripping before the oxidation step. Oxidation using chlorine was faster than hydrogen peroxide and chlorine, already in use at JSU facilities, is less costly than hydrogen peroxide.

Oxygen also oxidized the sulfide but at a much slower rate. Microbes may catalyze the oxidation of sulfide by oxygen, if microbial growth is allowed to develop. This catalytic effect was observed in the latter part of the research when microbial growth was observed in the pilot PTA and the sulfide removal efficiencies in the PTA approached 100% with a contact time of less than a minute. While microbial growth allows for greater sulfide removal efficiency, the growth produces turbidity in the form of string-like solids in the PTA and the storage tank. This solid is commonly found in all storage tanks and cascade aerators and presents a maintenance problem. In the last two weeks of the research, the microbial growth was extensive and the resulting turbidity was excessive. Although control of this microbial growth was not studied in this research, methods of control are available, such as periodic cleaning.

It appears that two sulfide removal mechanisms were active in sulfide removal in the PTA--volatile loss of hydrogen sulfide and oxidation of sulfide with oxygen catalyzed by microbial growth. Removal efficiencies are excellent but excessive turbidity may be produced. The turbidity may be controlled by controlling the microbial growth. This control may be achieved by cleaning the packing at regular intervals or, perhaps, by alternately loading two PTA systems and allowing the media to dry in between loadings. JSU personnel report that the cascade aerator at Monument Rd. develops more microbial growth than other aerators because the aerator surface is wet more often. In addition, during the initial testing of the PTA and oxidation system, when the PTA dried in between experimental runs, no microbial growth was noted.

In light of the above findings and the desire of JSU to lower the hydrogen sulfide concentration, the use of a PTA to enhance the hydrogen sulfide removal efficiency is recommended. Special consideration should be given to microbial growth and turbidity control in the full-scale implementation. Careful monitoring of the full-scale operation is important to gain further understanding of the process and to identify the best methods to minimize the problems described above.

The PTA effluent should be chlorinated to oxidize the sulfide remaining after air stripping and directed to a storage tank prior to distribution. Observations in the pilot plant operation indicated that microbial growth and turbidity formation in the storage tank were reduced if a free chlorine residual was maintained.

Consideration should be given to the Disinfection-disinfection by-product (D-DBP) Rule that will soon be promulgated by USEPA and enforced by the FDEP. The proposed rule will reduce the allowable concentration of trihalomethanes (THMs) to 80 ug/L and set the allowable concentration for haloacetic acids (HAAs) at 60 ug/L. A second phase of this regulation may reduce these concentrations by 50%. JSU has not had problems in the past meeting the current THM standard of 100 ug/L. THM formation increases as the pH increases. Since the PTA will increase the pH of the water, additional THM formation can be expected. It does not appear that the increase in pH will cause any problem with meeting the first phase of the new D-DBP rule. The lower concentration limits that may be required by the second phase of the rule may be difficult to achieve.

The copper test loop demonstration study indicated that the increase in pH provided by the PTA reduced the copper concentrations in the first-draw samples from the loop to an average value of 0.65 mg/L over the duration of the test. This concentration may be compared with the existing treatment plant water loop which maintained a copper concentration of about 2.0 mg/L during the first half of the study and 1.5 mg/L over the second half of the study. Accordingly, it appears that no additional corrosion control treatment of the aerated and chlorinated water is required to satisfy the Lead and Copper Rule action level for copper (1.3 mg/L).

Phosphate inhibitors used in this study included an orthophosphate, a polyphosphate and a blended phosphate product. At dosages of 1 mg/L as product they did not substantially reduce first-draw copper concentrations below copper concentrations achieved by simply increasing the pH as a result of carbon dioxide stripping in the PTA. Doubling the concentrations of the polyphosphate and blended phosphate inhibitors and increasing the concentration of the orthophosphate inhibitor by 10-fold did not substantially reduce the copper concentrations from these loops. It should be noted that the pH range (> 8.0) was above the normal recommended pH range for these inhibitors; use of the inhibitors at a lower pH may have provided better copper corrosion control. In light of these findings, the use of a phosphate corrosion control inhibitor at this time is not recommended if PTA stripping at ambient pH is employed.

Appendix B

SVM 1

HRS Duval County Public Health Unit
Environmental Health/Engineering Division
900 Building - Suite 300
900 University Boulevard North
Jacksonville, Florida 32211

HRS
STATE OF FLORIDA
DEPARTMENT OF HEALTH AND
REHABILITATIVE SERVICES
District Four

LAWTON CHILES, GOVERNOR

RECEIVED
NOV 03 1994
FLORIDA DISTRICT

October 28, 1994

Mr. Greg Hughes
Jacksonville Suburban Utilities Corp.
1400 Millcoe Road
P. O. Box 8004
Jacksonville, Florida 32239

Re: Corrosion Control Study
Arlington Grid - 2161326
Holly Oaks - 2160924
Jax Heights - 2160565
Royal Lakes - 2160980
San Jose - 2160995
San Pablo - 2160547

Dear Mr. Hughes:

Your corrosion control study for the above grids is considered complete after submission of the pilot study reports by the University of Florida. The concept of raising the pH to about 8.2 to reduce copper solubility by either improved aeration or by temporary base addition is approved. The October 6, 1994 letter from Mr. Manis gave a brief schedule for accomplishing the aeration upgrades. You are reminded that construction of the corrosion control options are due within two (2) years after approval, or by January 1, 1997 for any large systems. This may necessitate using base addition as a temporary measure until the aeration upgrades can be accomplished.

Please submit a more detailed schedule for: (a) permit application submissions; (b) dates for implementation of base addition or aeration upgrades to meet the above mentioned time frame.

It is our understanding that permit applications are to be submitted at the time of submittal of the corrosion control study or shortly after approval . Accordingly it is recommended that the permit applications be submitted within the next few months.

I believe this is self explanatory; however, please do not hesitate to contact me or Mr. Hamilton to discuss any questions or concerns you may have.

Sincerely,

Dr. T. James Tofflemire, P. E. I

ENVIRONMENTAL ENGINEERING SECTION

TJT/tkf

cc: Thomas R. Hamilton
Blanca Rodriguez

Appendix C

UnitedWater

United Water Florida
1400 Millcoe Road
PO Box 8004
Jacksonville, FL 32239-8004
telephone 904 721 4600
facsimile 904 721 4680

January 24, 1997

Mr. Thomas R. Hamilton, P.E.
Administrator
Environmental Engineering Division
Duval County Public Health Unit
900 University Blvd. North
Jacksonville, Florida 32211

RE: Corrosion Control Permits - Duval County
Arlington Grid - 216326, Holly Oaks Grid - 216094, Jax Heights Grid - 2160565, Royal Lakes - 2160980, San Jose - 2160995, San Pablo - 2160547.

Dear Mr. Hamilton:

United Water Florida proposed a tentative implementation schedule under letter to FDEP dated November 12, 1996, to install permanent packed tower aerators and install interim corrosion inhibitor feed systems at facilities exhibiting corrosion problems in St. Johns and Duval Counties.

A revised implementation schedule was submitted to your office on January 14, 1997 to address concerns about elevated copper levels during the interim period at all sites that exceeded the action level for copper in Duval County.

In response to our January 14, 1997 meeting between representatives of FDEP and UWF and subsequent conference call on January 23, 1997 with Blanca Rodriguez of FDEP, Tom Hamilton of HRS and Edgar Espinoza of UWF, United Water Florida is presenting the following mutually agreed upon implementation schedule to address corrosion control at all medium-sized water treatment plants in Duval County.

UWF IMPLEMENTATION SCHEDULE:

WTP Facility	**SYSTEM**	**Corrosion Inhibitor Feed System**	**Packed Tower Aerators**
Royal Lakes	Royal Lakes	March 31, 1997	November,1997
Alderman Park	Arlington	March 31, 1997	November, 1999
Columbine	Arlington	March 31, 1997	
Elvia	Arlington	March 31, 1997	November,1998
Lake Lucina	Arlington	March 31, 1997	
University Pk	Arlington	March 31, 1997	
Marshview	San Pablo	June 30, 1997	November,1999
San Jose	San Jose	UNDER CONSTRUCTION	November,1998
Queen Acres	Holly Oaks	June 30, 1997	
Monument Rd.	Holly Oaks	IN-PLACE NOW	March 31, 1997
Oak Hill	Jax Heights	September 30, 1997	November,2000
Green Forest	Jax Heights	September 30, 1997	
Wheat Rd.	Jax Heights	September 30, 1997	

The above schedule addresses the installation of interim corrosion inhibitor feed systems at grids with highest cooper levels as we discussed on January 23, 1997.

UWF believes that the time frames necessary for each facility are the minimum required to conduct the necessary design, permitting, purchase and installation of the equipment and chemicals for each water treatment plant. However, we are committed to make every effort to finish all the installations as early as possible.

Should you have any questions or comments, please do not hesitate to call me or our Mr. Edgar Espinoza at (904)721-4600. UWF appreciates your assistance and continued support in this matter.

Sincerely,

Edgar Espinoza for Gordon Grimes

Gordon Grimes, P.E.
Senior Project Engineer

cc: Blanca Rodriguez, FDEP
Munipalli Sambamurthi, UWF
Todd Mackey, UWF
Tom Cleveland, UW M&S
Edgar Espinoza, UWF