

APPENDIX K

WWTF EFFLUENT PERMIT LIMITS EVALUATION

WASTEWATER TREATMENT PLANT EFFLUENT PERMIT LIMITS EVALUATION

BACKGROUND

The City of Woodland (City) is located 20 miles north of Vancouver, Washington in both Clark and Cowlitz Counties, straddling the Lewis River. The City operates a Wastewater Treatment Plant (WWTP) that discharges effluent to the Lewis River.

This WWTP Effluent Permit Limit Evaluation (Evaluation) has been prepared as an appendix to the City's General Sewer Plan to re-evaluate if a reasonable potential exists for the City WWTP effluent to cause an exceedance of water quality standards and trigger a need for new permit limits or to implement WWTP capital or operating improvements. The Washington Department of Ecology (Ecology) has required completion of this Evaluation as a condition of approval of the General Sewer Plan.

The quality of effluent discharged by the City's WWTP is regulated by the City's National Pollutant Discharge Elimination System (NPDES) permit, issued by Ecology. The NPDES permit includes technology-based and water quality-based numeric effluent limitations, implemented to meet current standards and protect the receiving water. One of the steps to updating the NPDES permit is mixing zone modeling that provides a factor of dilution of the effluent from the WWTP into a receiving water body (Lewis River). Based on this dilution factor and a number of other variables including effluent and receiving water conditions, one can predict whether or not pollutants within the effluent will have a reasonable potential to cause an exceedance of water quality or human health standards in the receiving water.

A mixing zone study was completed for the Woodland WWTP in 1999 (and updated in 2005 and 2011) that calculated dilution factors based on effluent flows that were projected for the WWTP. Ecology determined that these dilution ratios of 5.26 : 1 for the acute condition and 74 : 1 for the chronic condition were appropriate when calculating the reasonable potential for pollutants to exceed water quality criteria and calculating permit limits for the City's most recent NPDES permit. In this evaluation, these dilution factors, along with water quality standards identified in the City's 2012 NPDES Permit Fact Sheet and recent effluent constituent data are used to calculate the reasonable potentials to exceed water quality standards. In addition, future permit limits are projected for pollutants with a reasonable potential to exceed water quality standards.

MIXING ZONE REGULATIONS

Mixing zones in rivers and streams are defined in WAC 173-201A-400 and are as follows:

- (7)(a) In rivers and streams, mixing zones, singularly or in combination with other mixing zones, shall comply with the most restrictive combination of the following:
 - i) Not extend in a downstream direction for a distance from the discharge port(s) greater than 300 feet plus the depth of water over the discharge port(s), or extend upstream for a distance of over 100 feet;
 - ii) Not utilize greater than 25 percent of the flow; and
 - iii) Not occupy greater than 25 percent of the width of the water body.

- 8) Acute criteria are based on numeric criteria and toxicity tests approved by the department, as generally guided under WAC 173-201A-240 (1) through (5), and shall be met as near to the point of discharge as practicably attainable. Compliance shall be determined by monitoring data or calibrated models approved by the department utilizing representative dilution ratios. A zone where acute criteria may be exceeded is allowed only if it can be demonstrated to the department's satisfaction the concentration of, and duration and frequency of exposure to the discharge, will not create a barrier to the migration or translocation of indigenous organisms to a degree that has the potential to cause damage to the ecosystem. A zone of acute criteria exceedance shall singularly or in combination with other such zones comply with the following maximum size requirements:
 - (a) In rivers and streams, a zone where acute criteria may be exceeded shall comply with the most restrictive combination of the following:
 - (i) Not extend beyond 10 percent of the distance towards the upstream and downstream boundaries of an authorized mixing zone, as measured independently from the discharge port(s);
 - (ii) Not utilize greater than 2.5 percent of the flow; and
 - (iii) Not occupy greater than 25 percent of the width of the water body.

DILUTION FACTORS

The City's 2012 NPDES Fact Sheet states the following regarding the mixing zone for Woodland's NPDES discharge.

CHRONIC

WAC 173-201A-400(7)(a) specifies that mixing zones must not extend in a downstream direction from the discharge ports for a distance greater than 300 feet plus the depth of water over the discharge ports or extend upstream for a distance of over 100 feet, not utilize greater than 25 percent of the flow, and not occupy greater than 25 percent of the width of the water body.

The horizontal distance of the chronic mixing zone is 302 feet downstream and 100 feet upstream. The mixing zone extends from the river bottom to the top of the water surface.

The approved General Sewer and Facility Plan estimated the chronic mixing zone ratio for the 2.0 MGD capacity SBR to be 27.5:1 (see page III-14, second paragraph). This is based on the flow volume restriction resulting from a discharge during peak decant rate (2.0 MGD times a peaking factor of 2.4 = 4.8 MGD). However, the chronic mixing zone ratio is designed to be protective of the highest 4-day average concentration anticipated during the term of the permit. It does not have to protect for the 1-hour maximum concentration as the acute mixing zone ratio does. For this facility, the flows are not anticipated to exceed .83 MGD over the maximum month. Therefore, the estimated chronic mixing zone ratio of 27.5:1 for the chronic mixing zone is rejected, and instead the program “rivplume” was used to estimate the chronic mixing zone at a flow of 0.84 MGD (maximum anticipated monthly flow average for the next permit cycle). **The resulting CMZR = 78:1, however the CMZR of the prior permit – 74:1 will be retained as it does not drive any lower limit.** For purposes of following permits (with higher flows) note that this program estimates the chronic mixing zone ratio at the design flow (2.0 MGD) to be 32.8:1

ACUTE

WAC 173-201A-400(8)(a) specifies that in rivers and streams a zone where acute toxics criteria may be exceeded must not extend beyond 10 percent of the distance towards the upstream and downstream boundaries of the chronic zone, not use greater than 2.5 percent of the flow and not occupy greater than 25 percent of the width of the water body.

The flow volume restriction resulted in a smaller chronic dilution factor than the distance downstream. The dilution factor below results from the volume restriction at the critical conditions. For acute WQ criteria, the critical condition for the river is the 7Q10 flow, and the critical condition for the POTW is the one-hour maximum flow.

The approved General Sewer Plan and Facility Plan estimates that the acute mixing zone or the future SBR will be 3.7:1. This value is rejected as overly conservative because the POTW is not close enough to its design capacity to use the maximum rated flow capacity for calculating the AMZR. Please see Appendix C for a tabulation of the mixing zone projections included in the approved plan.

The maximum daily flow during the last permit was 0.896 MGD (December, 2007). When increased by the annual flow increase of 4.8 percent/annum from the date of occurrence until 2014 (7 years), we estimate a peak day flow of 1.244 MGD. Multiplying this by the peaking factor for batch discharge (2.4) = 2.99 MGD for the peak hourly average flow. This is used to assess compliance with acute WQ criteria at the edge of the acute mixing zone (theoretical maximum mixing zone ratio using 2.5 percent of 7Q10 receiving water flows (789 cfs) = **5.26:1 (AMZR)**). The AMZR presumed in the last permit was 9:1, but was based on a steady state flow from a submerged biological contactor (SBC). The model “rivplume” predicted mixing at the Acute boundary of 6.9:1, and thus the statutory limit of 2.5 percent of receiving water flow was the more limiting (and therefore the applicable) criterion.

DISCUSSION

As noted in the above discussion in the 2012 Fact Sheet, the chronic dilution factor of 74:1 is considered valid up to a maximum month flow of 0.84 mgd. Based on the projections summarized in Table 5-12, this maximum month flow is not anticipated to be reached until approximately 2025. In addition, the fact sheet notes that the acute dilution factor of 5.26 : 1 is considered valid up to a peak day flow of 1.244 mgd, which is not projected to be reached until 2033.

Table 1 summarizes the dilution factors that are summarized in the City’s NPDES Permit fact sheet.

TABLE 1

City of Woodland Mixing Zone Dilution Factors

Criteria	Acute	Chronic
Aquatic Life	5.26:1	74:1
Human Health, Carcinogen		74:1
Human Health, Non-Carcinogen		140:1

Based on the 2012 Fact Sheet, and current conditions, these dilution factors are considered valid for the purposes of this analysis. The City understands that these dilution factors are based on limited data, and that there is a need to update the mixing zone analysis due to limitations with the river flow and water quality data used to develop the current dilution factors. It is understood, based on discussions with Ecology for this Evaluation, that completing a new mixing zone study, including a dye study and a revised reasonable potential evaluation, will likely be a condition of the City’s new NPDES Permit issued when the City’s existing permit expires in March 2017.

REASONABLE POTENTIAL ANALYSIS

A suite of Ecology spreadsheets was utilized to evaluate effluent and receiving water data in order to determine if a reasonable potential exists to exceed water quality standards. Effluent and receiving water data requires analysis and manipulation to match the input requirements of the various spreadsheets. The following sections describe the various spreadsheets, required input, source of the input values, and results.

WATER QUALITY STANDARDS

Since no river monitoring has been conducted since the NPDES Fact Sheet was issued, the water quality standards in the Fact Sheet could be considered valid for this analysis. However, per Department of Ecology input (attached), the water quality standards were re-calculated using 20 mg/L for river hardness (based on data in the Fact Sheet), and the assumption of mixed hardness at the mixing zone boundary. The water quality standards are summarized in Table 2. It is anticipated that new ambient monitoring will be completed as part of the future mixing zone study, allowing an update to the water quality standards.

TABLE 2

Water Quality Standards Applicable for the City of Woodland Mixing Zone

Criteria	Acute (µg/L)	Chronic (µg/L)
Ammonia	4,641	809
Copper	5.83	2.40
Zinc	43.71	22.37

The water quality standards calculated differ from those calculated in the Fact Sheet, which used 50 mg/L hardness for the copper reasonable potential, and did not use mixed hardness.

REASONABLE POTENTIAL EVALUATION

The Reasonable Potential to exceed water quality criteria was calculated from the “Reasonable Potential” spreadsheet in Ecology’s PermitCalc Excel workbook, which is the most recent version available on the Ecology website:

<http://www.ecy.wa.gov/programs/wq/permits/guidance.html>

Inputs

Required input values include copper, zinc, and ammonia ambient receiving water concentrations and the maximum effluent concentrations. Both ambient and effluent concentrations for copper and zinc came, in part, from a 2005 study conducted by Maul

Foster & Alongi, Inc. to develop necessary background information for future NPDES permitting. In addition, metals data has been collected quarterly beginning in April 2012 to the present. A total of 21 effluent samples were collected for each metal utilized for this analysis. The ambient receiving water values were the geometric mean of each respective metal from the Maul Foster & Alongi, Inc. dataset that included a total of seven samples. The effluent concentrations used were the 95th percentile maximum reported values, in keeping with State guidance. For copper, the 95th percentile concentration for the data set was 21.5 µg/L, and for zinc, it was 84.2 µg/L. (The maximum values for copper were 34.9 µg/L (April 4, 2012) and for zinc, 97.6 µg/L (April 4, 2012), both the first day sampling began.)

Other inputs into the workbook include dilution factors at the acute and chronic boundaries and the number of respective samples collected for copper, zinc, and ammonia.

Ammonia concentrations in the ambient receiving water were measured for the Maul Foster & Alongi, Inc. Report; however, all samples (eleven in total) were reported as less than 0.05 mg/L. Effluent ammonia data was not collected for that Report, but for this Evaluation, was obtained from the City's Discharge Monitoring Reports (DMRs). Data was reviewed for the last three years (May 2011 through August 2014). The values recorded in the DMRs were the Monthly Maximums of the Total Ammonia Weekly Grab samples and ranged from 0.1 mg/L to 12.5 mg/L. This data set recorded the maximum total ammonia on a weekly basis for forty months or 160 samples. The 12.5 mg/L sample occurred in May 2012 and was an anomaly among the samples; the next highest recorded sample was 0.81 mg/L. Note that the high ammonia value occurred outside the critical season and dilution likely would have been much higher. However, this value was used in the reasonable potential calculations.

Outputs

Table 3 summarizes the Reasonable Potential Analysis (RPA). The RPA shows that no reasonable potential exists for copper with the 95th percentile effluent concentration of 21.5 µg/L. A sensitivity analysis demonstrates that at a copper concentration of 27 µg/L, a reasonable potential would exist.

The RPA shows that no reasonable potential exists for zinc with the 95th percentile effluent concentration of 84.2 µg/L. A sensitivity analysis demonstrates that at a zinc concentration of 214 µg/L, which is higher than the maximum recorded effluent concentration, a reasonable potential would exist.

No limit for ammonia is required, despite the high maximum concentration of 12,500 µg/L. The next highest maximum concentration for ammonia was 810 µg/L (out of a total of 160 samples), a fifteen times reduction in the concentration. The Ecology Fact Sheet had predicted a limit for ammonia was necessary. This was based on a maximum effluent concentration of 27,000 µg/L. The last three years of Discharge Monitoring

Reports does not show a concentration exceeding 12,500 µg/L. A sensitivity analysis demonstrates that the concentration of ammonia that would require a limit is 24,500 µg/L.

PERMIT LIMIT CALCULATION SUMMARY

Permit Limits can be calculated from the “Reasonable Potential” spreadsheet in Ecology’s PermitCalc Excel workbook:

<http://www.ecy.wa.gov/programs/wq/permits/guidance.html>

Inputs into this spreadsheet would include the same as those input into the Reasonable Potential Calculation. However, because there was no reasonable potential, it was not necessary to calculate permit limits.

TABLE 3

Reasonable Potential Analysis

Instructions

Reasonable Potential Calculation

Facility	Woodland STP
Water Body Type	Freshwater
Rec. Water Hardness	Acute=32.1, Chronic=16.2 mg/L

Dilution Factors:		Acute	Chronic
Aquatic Life		5	74
Human Health Carcinogenic			
Human Health Non-Carcinogenic			

Pollutant, CAS No. & NPDES Application Ref. No.		AMMONIA, Criteria as Total NH3	COPPER - 744058 6M Hardness dependent	ZINC- 7440666 13M hardness dependent								
Effluent Data	# of Samples (n)	160	21	21								
	Coeff of Variation (Cv)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Effluent Concentration, ug/L (Max. or 95th Percentile)	12,500	21.5	84.2								
	Calculated 50th percentile Effluent Conc. (when n>10)		12									
Receiving Water Data	90th Percentile Conc., ug/L	20	0.9	4.1								
	Geo Mean, ug/L		0.9	4.1								
Water Quality Criteria	Aquatic Life Criteria, Acute ug/L	4,641	5,834.77	43.71								
	Chronic ug/L	809	2,398.46	22,374								
	WQ Criteria for Protection of Human Health, ug/L	-	1300	-								
	Metal Criteria Acute Translator, decimal	-	0.996	0.996								
Chronic	-	0.996	0.996									
Carcinogen?		N	N	N								

Aquatic Life Reasonable Potential

Effluent percentile value		0.950	0.950	0.950								
s	$s^2 = \ln(CV^2 + 1)$	0.555	0.555	0.555								
Pn	$Pn = (1 - \text{confidence level})^{1/n}$	0.981	0.867	0.867								
Multiplier		1.00	1.00	1.00								
Max concentration (ug/L) at edge of...	Acute	2,393	4,800	19,264								
	Chronic	189	1,177	5,178								
Reasonable Potential? Limit Required?		NO	NO	NO								

COMPLIANCE ALTERNATIVES AND RECOMMENDATIONS

The Permit Limit Evaluation demonstrates that limits are not required for copper, zinc or ammonia. However, these limits are based on limited data, and it is understood that a dye study and mixing zone evaluation will be required to be conducted in the next permit cycle. In that respect, it is possible that permit limits will be required in the future, particularly for copper, for which the concentration calculated at the edge of the mixing zone is about 1 µg/L (4.80 µg/L vs. 5.83 µg/L) below the water quality standard.

Looking forward, it is possible that completion of a mixing zone study will result in permit limits that necessitate reduction in effluent copper (and possibly zinc). Possible means for effluent copper reduction include (1) reduction of influent copper and zinc concentrations levels through source control measures and /or water system corrosion control augmentation, and (2) removal of copper and zinc in the wastewater treatment process through addition of specialized metal precipitants.

REDUCTION OF INFLUENT COPPER AND ZINC CONCENTRATIONS

A similar evaluation was conducted for WWTPs for the Cities of Puyallup, Sumner and Toppenish to determine the most optimal means to comply with stringent wastewater treatment plant effluent copper limits through bench and pilot testing of possible approaches. In both Sumner and Puyallup, a source evaluation determined that corrosion of domestic and commercial plumbing was the primary source of copper in wastewater entering the WWTPs.

PUYALLUP

For Puyallup, the City where the most extensive evaluation was conducted, the testing of compliance strategies with effluent copper limits included:

- Conducting a “pipe loop pilot study” to evaluate the efficacy of two potential drinking water corrosion control technologies to reduce copper and zinc concentrations discharged to the treatment plant via domestic sewage and to evaluate the impact of the different technologies on overall drinking water system quality.
- Evaluating the potential for enhanced metals removal within the treatment plant through bench testing using conventional, readily available chemicals such as ferric chloride and through the use of specialized polymers.

Results of the evaluation were published in *Evaluation of Compliance Strategies to Meet Stringent Effluent Copper Limits* (Swift, et al, WEFTEC 2006). A copy of this paper is included in Attachment 2. Based on the pipe loop pilot study, corrosion control in the drinking water system was projected to reduce, on average, WWTP influent copper by approximately 20%. The data provided an indication that pH adjustment would decrease

zinc release but this effect was highly variable. In the bench testing, use of specialized polymers was found to reduce WWTP effluent dissolved copper by 75 – 95% at optimal doses. The City selected the addition of specialized polymers in the wastewater treatment process to the mixed liquor entering the secondary clarifiers as the mean of achieving compliance with their effluent copper limits. Similar copper removals have been observed with full-scale operation at the Puyallup WWTP. However, no significant reduction in zinc concentrations were observed with the polymer addition.

SUMNER AND TOPPENISH

In Sumner and Toppenish, it was also concluded that precipitant addition was effective; however, re-evaluation of metal toxicity and seasonal dilution (including dynamic modeling at Sumner) resulted in a revised determination that no reasonable potential existed. Ultimately, no final permit limits were imposed. The re-evaluation of metal toxicity at Sumner and Toppenish was in part due to increasing state-of-the-art knowledge regarding factors that impact the aquatic toxicity of metal pollutants and the interactions between the aquatic environment and the metal pollutant.

Predicting the toxic effect that metals have in natural waters requires evaluating the speciation of the metals of concern. In addition to the ratio of dissolved to total metal, metal toxicity can be affected by pH, hardness, TSS, and the presence of other constituents in the water (potential “ligands”) that can bind to (“complex”) the metal and impact its toxicity. Typically, complexation (e.g., chelation), precipitation, and adsorption will reduce the toxicity of most metals. However, the federal and Washington state water quality standards are based on dissolved, uncomplexed metals (conservative assumptions) and thus may overestimate aquatic toxicity for some waters. The calculated water quality criteria may predict toxicity that is not observed in whole effluent toxicity (WET) testing or the environment.

The ratio of metals concentrations that actually produce toxicity at a specific site to that based on the default conservative assumptions is called a Water Effect Ratio (WER). Historically, WERs were determined by conducting a number of WET tests coupled with analytical chemistry. In 2003, new draft guidance was issued by EPA that utilizes a Biotic Ligand Model (BLM). The BLM is based on the premise that toxicity is related to metal bound to a biochemical site (e.g., fish gills, a biotic ligand) and that binding is related to total dissolved metal concentrations and complexing ligands in the water. The complexing ligands compete with the biotic ligand for metals and other cations in the water, thus reducing their capacity to bind at the biochemical site. Unlike the default calculations, the BLM explicitly accounts for individual water quality variables, is not linked to a particular correlation among these variables, and can address variables that were not a factor in the hardness relationship.

In the BLM, chemical speciation is simulated as an equilibrium system that includes complexation of inorganic ions and NOM (estimated by measurement of Dissolved Organic Carbon, DOC). Predictions of metal toxicity are made by assuming that the

dissolved metal LC50, which varies with water chemistry, is always associated with a fixed critical level of metal accumulation at the biotic ligand (e.g., fish gills).

On-site, flow through toxicity testing in 1997 (salmonids including *Oncorhynchus mykiss*, *Oncorhynchus kisutch*) and subsequent whole effluent toxicity testing (*Ceriodaphnia dubia*, *Pimephales promelas*) performed per the NPDES permit at least annually since 1997 have not revealed any evidence of effluent toxicity at Puyallup's WWTP, despite concentrations of copper that exceed the default water quality standards employed by EPA. These testing results suggest that the Puyallup WWTP effluent and the receiving water, the Puyallup River, may be more protective against copper toxicity than predicted based on the hardness-based equation used by EPA. This is likely due to differences in metal speciation (e.g., complexation with organic ligands) between the Puyallup receiving water / effluent and the default conditions that are used to determine the regulatory water quality standards by EPA.

Use of specialized precipitants may not be as effective for Woodland as for other WWTPs, due to the nature of the treatment process (SBR) which would require addition of precipitant to upstream of the SBR. Addition of precipitant directly to influent during testing in Puyallup and Sumner was found to be less effective and require additional dosage compared to addition to secondary clarification. However, given the relatively low cost of completing this bench testing and potential for success, it is recommended that that bench testing is considered.

For Sumner and Toppenish, it was concluded that, similar to Puyallup, the Biotic Ligand Model and dynamic dilution modeling would likely indicate that effluent copper limits could be increased significantly and be equally protective. It is expected that a similar conclusion would be reached in Woodland.

RECOMMENDATIONS FOR WOODLAND

Considering the significant long-term costs of complying with NPDES permit limits, it is recommended that the City conduct not only a new Mixing Zone Study, but, in addition, a more thorough evaluation of alternatives for avoiding and/or complying with permit limits. These alternatives include: (1.) chemical precipitation at the WWTP, (2.) drinking water pH adjustment, and (3.) copper toxicity be re-evaluated and site-specific metals criteria development through a Water Effects Ratio / Biotic Ligand Model evaluation. This evaluation could be conducted during the City's next NPDES Permit Cycle.

ATTACHMENT 1

ANALYTICAL DATA SUMMARY

Effluent	Date	Alkalinity (as CaCO3) (mg/l)	Hardness (as CaCO3) (mg/l)	Ammonia (as N) (mg/l) all Less Than	pH	Temp (°C)	Dissolved Oxygen (mg/l)	Copper (ug/l)	Zinc (ug/l)	# of effluent samples	Influent	Influent
											Copper (ug/l)	Zinc (ug/l)
	4/28/2005	151	78.4		7.13	19.52	4.64	21.5	67.3	1		
	6/24/2005	141	88		7.14	22.36	7.68					
	7/25/2005	155	95		7.76	23.02	9.38	8.4	73.7	2		
	8/25/2005	149	107		7.19	23.78	6.16					
	9/29/2005	150	108		7.23	22.54	7.06	10.1	57.5	3		
Duplicate	9/29/2005	152	108					10.8	61.9	4		
	2/17/2006	115	75		6.63	14.24	6.82	9.9	61.7	5		
	6/2/2006	152	108		7.09	20.71	7.43	19.8	62	6		
	7/26/2006	142	94		6.76	23.49	4.5					
	8/4/2006	132	97		7.06	23.39	6.94	11.9	71	7		
	9/29/2006	148	117		7.14	23.79	4.79					
	4/4/2012							34.9	97.6	8	74.1	140
	7/5/2012							12.8	61.4	9	100	135
	10/3/2012							12.3	78.1	10	147	157
	1/3/2013							13.7	56.6	11	98.9	155
	4/3/2013							17.9	84.2	12	120	160
	8/2/2013							12.8	73.9	13	144	181
	10/16/2013							14.4	52.9	14	102	136
	1/3/2014							14.7	68.2	15	136	163
	4/2/2014							15.5	69.5	16	77	137
	7/9/2014							12.2	78.7	17	147	178
	1/7/2015							11.8	63.7	18		
	4/2/2015							13.6	57.8	19		
	7/2/2015							11.8	70.4	20		
								10.9	68.6	21		
Mean												
90th percentile				7.28		23.78	4.63	14.4	68.4			
95th percentile								21.5	84.2			
CV								0.396	0.153			
Lowest Value		115	75					8.4	52.9			
Maximum								34.9	97.6			

ATTACHMENT 2

EVALUATION OF COMPLIANCE STRATEGIES TO MEET STRINGENT EFFLUENT COPPER LIMITS

(WEFTEC 2006 Proceedings)

EVALUATION OF COMPLIANCE STRATEGIES TO MEET STRINGENT EFFLUENT COPPER LIMITS

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ABSTRACT

The objective of this evaluation was to determine the optimal means for the City of Puyallup, Washington to comply with stringent wastewater treatment plant effluent copper limits through bench and pilot testing of possible approaches. A source evaluation determined that corrosion of domestic and commercial plumbing was the primary source of copper in wastewater entering Puyallup's Water Pollution Control Plant (WPCP).

Testing conducted to evaluate compliance strategies with effluent copper limits included:

- Conducting a "pipe loop pilot study" to evaluate the efficacy of two potential drinking water corrosion control technologies to reduce copper and zinc concentrations discharged to the treatment plant via domestic sewage and to evaluate the impact of the different technologies on overall drinking water system quality.
- Evaluating the potential for enhanced metals removal within the treatment plant through bench testing using conventional, readily available chemicals such as ferric chloride and through the use of specialized polymers.

Based on the pipe loop pilot study, corrosion control in the drinking water system was projected to reduce, on average, WPCP influent copper by approximately 20%. Use of specialized polymers was found to reduce WPCP effluent dissolved copper by 75 – 95% at optimal doses. The City selected the use of specialized polymers as the mean of achieving compliance with their effluent copper limits.

KEYWORDS

Copper, speciation, metals removal, corrosion control, precipitation, pipe loop study

INTRODUCTION

The City of Puyallup WPCP is a 14 MGD secondary activated sludge treatment plant, incorporating biological nitrogen removal and ultraviolet disinfection. The NPDES

effluent permit limits for the Puyallup WPCP for copper are 8.5 µg/L (micrograms per liter, or parts per billion) average monthly and 13.7 µg/L maximum daily. The permit requires the City to comply with the average monthly and maximum daily total copper effluent limitations on or before August 1, 2007. Until compliance with the effluent limitations is achieved, the NPDES permit requires the City to complete several tasks to determine the source(s) of copper in the wastewater treatment plant effluent and identify and implement opportunities to reduce effluent copper. Additionally, since zinc concentrations in effluent from the WPCP are within 30% of the level that would trigger permit limits for effluent zinc, voluntary determination of the source(s) of zinc in the wastewater treatment plant effluent and identification and implementation of opportunities to reduce effluent zinc are also being conducted concurrently. Presently, no chemicals are used to enhance metals removal.

In WPCP *effluent* collected with clean sampling techniques from 2002 –2004, reported copper ranged from 4.9 to 15.3 µg/L with an average value of approximately 9.5 µg/L. However, in 2005, the effluent copper concentration was considerably higher, averaging 15.5 µg/L. Hence, based on historical data, without reduction in copper levels, the City’s effluent copper is expected to exceed its monthly NPDES permit limit of 8.5 µg/L the majority of the year.

In 16 samples of WPCP *influent* collected in 2003 and 2004, copper concentrations ranged from 74 to 165 µg/L (an average of 100 µg/L). Percent removal of copper in the WPCP ranged from 86% to 94%. Reported “passive removal” of copper in other secondary WWTPs varies widely, from 25% to 90% for full-scale plants, 33% to 83% for pilot scale plants, and 24 to 35% in lab scale plants. (Boulay and Edwards, 2000) Hence, the Puyallup WPCP, as presently configured and operating, exhibits excellent copper removal.

In 49 samples of (WPCP) *effluent* collected with clean sampling techniques from 2002 – 2004, reported zinc ranged from 13.6 to 57.2 µg/L with an average value of approximately 35.1 µg/L. In 13 samples of WPCP *influent* taken in 2003 and 2004, zinc concentrations ranged from 84 to 233 µg/L (an average of 127 µg/L). Percent removal of zinc in the WPCP ranged from 58% to 79%. Reported “passive removal” of zinc in other full-scale secondary WWTPs varies widely, from 10% to 93% with an average removal rate of 55% (Sustainable Fisheries Foundation, 2004). Hence, the Puyallup WPCP, as presently configured and operating, exhibits above average zinc removal.

THE IMPACTS OF METAL SPECIATION

A metal in solution exists in a number of forms (species) in equilibrium. The distribution of the various species depends on conditions in the solution, including pH, oxidation-reduction potential, suspended solids concentration, hardness, temperature, and the concentration of potential complexing species (ligands). Solving simultaneous equations governing the equilibrium distribution of the possible species allows prediction of the relative proportion of species that will exist at equilibrium in a particular solution. Typical metal species in wastewater and freshwater receiving waters include the aquo ion

(coordinated with water molecules), hydroxo complexes, inorganic complexes (coordinated with chloride, fluoride, sulfate, etc.), complexes with simple organic ligands (coordinated with organic ligands, such as EDTA, ethylene diamine tetraacetic acid), complexes with polymeric organic ligands (e.g., humic acids, fulvic acids, or natural organic matter, NOM).

The speciation of dissolved copper in natural waters is dominated by interactions with dissolved organic matter (DOM) and the formation of relatively stable copper–DOM complexes. Studies show that in most natural waters typically 95–99 % of dissolved copper is organically complexed (EPA, 2003b).

The presence of the synthetic chelating agent EDTA (common in household products including food and detergents) in wastewater results in the formation of strong metal complexes that resist treatment. Equilibrium speciation models predict that complexes between copper and EDTA and zinc and EDTA are the dominant dissolved forms of these metals in wastewater treatment plant effluents with a pH above 7. Below pH 7, Zn^{+2} and copper complexed with biopolymers are thought to dominate. Variations in the relative concentrations of the complexing agents EDTA (especially), biopolymers and sulfur-containing ligands are thought to have a significant effect on metal speciation. (WERF, 2000)

The City’s effluent metal permit limits are based on projected aquatic toxicity in the receiving water, the Puyallup River. The aquatic toxicity of metal pollutants is a complicated phenomenon involving interactions between the aquatic environment and the metal pollutant. Predicting the toxic effect that metals have in natural waters requires evaluating the speciation of the metals of concern. In addition to the ratio of dissolved to total metal, metal toxicity can be affected by pH, hardness, TSS, and the presence of other constituents in the water (potential “ligands”) that can bind to (“complex”) the metal and impact its toxicity. Typically, complexation (e.g., chelation), precipitation, and adsorption will reduce the toxicity of most metals. However, the federal and Washington state water quality standards are based on dissolved, uncomplexed metals (conservative assumptions) and thus may overestimate aquatic toxicity for some waters. The calculated water quality criteria may predict toxicity that is not observed in whole effluent toxicity (WET) testing or the environment.

The ratio of metals concentrations that actually produce toxicity at a specific site to that based on the default conservative assumptions is called a Water Effect Ratio (WER). Historically, WERs were determined by conducting a number of WET tests coupled with analytical chemistry. In 2003, new draft guidance was issued by EPA that utilizes a Biotic Ligand Model (BLM). The BLM is based on the premise that toxicity is related to metal bound to a biochemical site (e.g., fish gills, a biotic ligand) and that binding is related to total dissolved metal concentrations and complexing ligands in the water. The complexing ligands compete with the biotic ligand for metals and other cations in the water, thus reducing their capacity to bind at the biochemical site. Unlike the default calculations, the BLM explicitly accounts for individual water quality variables, is not

linked to a particular correlation among these variables, and can address variables that were not a factor in the hardness relationship.

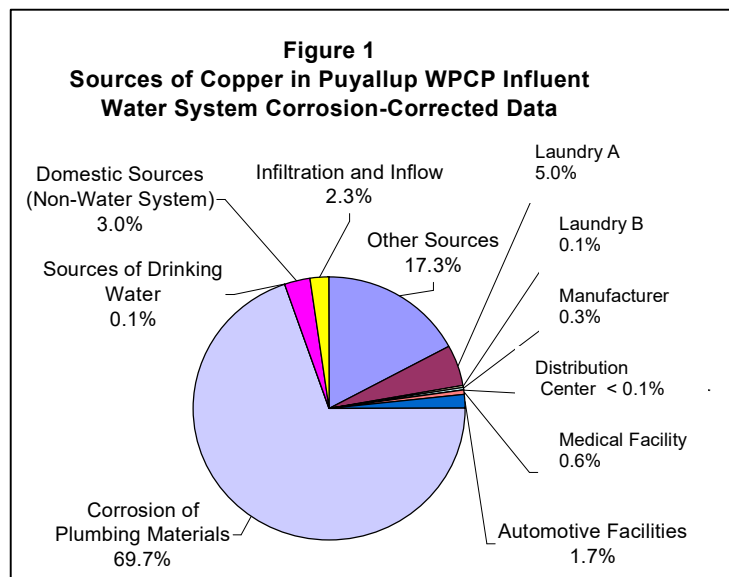
In the BLM, chemical speciation is simulated as an equilibrium system that includes complexation of inorganic ions and NOM (estimated by measurement of Dissolved Organic Carbon, DOC). Predictions of metal toxicity are made by assuming that the dissolved metal LC50, which varies with water chemistry, is always associated with a fixed critical level of metal accumulation at the biotic ligand (e.g., fish gills).

On-site, flow through toxicity testing in 1997 (salmonids including *Oncorhynchus mykiss*, *Oncorhynchus kisutch*) and subsequent whole effluent toxicity testing (*Ceriodaphnia dubia*, *Pimephales promelas*) performed per the NPDES permit at least annually since 1997 have not revealed any evidence of effluent toxicity at Puyallup's WPCP, despite concentrations of copper that exceed the default water quality standards employed by EPA. These testing results suggest that the Puyallup WPCP effluent and the receiving water, the Puyallup River, may be more protective against copper toxicity than predicted based on the hardness-based equation used by EPA. This is likely due to differences in metal speciation (e.g., complexation with organic ligands) between the Puyallup receiving water / effluent and the default conditions that are used to determine the regulatory water quality standards by EPA.

Although the Biotic Ligand Model and aforementioned toxicity testing suggests that Puyallup's effluent copper limits could be increased significantly through Water Effects Ratio testing and be equally protective of water quality, use of the Water Effects Ratio is not being pursued currently based on input from the regulatory agency involved (Van Genderen and Gensemer, 2005).

SOURCE EVALUATION

A copper / zinc source evaluation was conducted for Puyallup, including evaluation of water consumption data and analytical testing of samples from water system sources, the water distribution system, domestic sewage basins and several industries. Copper and zinc loadings in pounds per day from these sources were quantified based on measured or estimated flows and concentrations discharged. Figure 1 presents a summary of copper loading to the WPCP, based on analysis of sources. The majority of WPCP influent copper loading appears to originate from corrosion of domestic plumbing materials. The major sources of WPCP influent zinc were determined to be domestic and



commercial plumbing corrosion, domestic (non-water system) sources, and infiltration and inflow.

CORROSION CONTROL IN DRINKING WATER SYSTEMS

The City of Puyallup currently obtains its potable water from eight sources, one of which is Salmon Springs. Salmon Springs has a capacity of 1,200 gpm and provides approximately 40 percent of the City's average annual use. Salmon Springs was selected as the location for a corrosion control pilot study because it is the largest source for the City and any future changes to Salmon Springs might have a significant effect on WPCP influent metal levels.

Although the purpose of this pilot test was to investigate the potential for metals reduction at the WPCP, the corrosion control pilot study design was based on regulations for and information from the drinking water industry. Copper, lead, and zinc are regulated in drinking water by USEPA regulations administered through the Washington State Department of Health (DOH). Lead and copper are regulated through the Lead and Copper Rule (LCR), which is part of the Safe Drinking Water Act (SDWA). Zinc is regulated under SDWA as a secondary contaminant since it is considered an aesthetic rather than a health concern. The LCR mandates water quality sampling throughout the water purveyor's distribution system at the consumer's tap. The water samples are taken after a minimum of six hours of stagnation to simulate the first flush from the tap. The City of Puyallup drinking water meets all the regulations concerning copper, lead, and zinc concentrations.

The potable water industry, DOH, and the EPA have compiled extensive amounts of data on lead and copper issues in drinking water under the LCR. The USEPA published the *Revised Guidance Manual for Selecting Lead and Copper Control Strategies* in 2003. The Guidance Manual recommends pH adjustment as the most effective method for reducing copper in systems with source waters similar to Salmon Springs. The pH adjustment methods recommended in the Guidance Manual are aeration, caustic soda addition, potash addition, and soda ash addition. Although the emphasis of the pilot test was the reduction of copper in the WPCP influent rather than at the consumer's tap, the existing information on lead and copper pilot studies for the LCR was used to design the Puyallup pilot test described in this report. The manual targets compliance with the 1,300 µg/L drinking water Action Level (AL) for 90th percentile of stagnant water samples. Testing of stagnant Puyallup tap water for compliance with the Lead and Copper Rule (LCR) showed 90th percentile copper testing results of 740 µg/L in July 1999 and 840 µg/L in June 2002 (based on 30 samples tested). Subsequent additional testing showed an average stagnant tap water concentration of 444 µg/L.

Because the 1,300 µg/L AL is more than 100 times higher than the City's monthly NPDES wastewater effluent limit, the EPA guidance for control of metals in drinking water is not directly relevant to Puyallup's WPCP effluent. However, the general concepts for reducing corrosion are applicable. Copper entering drinking water from household plumbing materials such as pipes, and brass or bronze fittings, can be

controlled by changing water quality characteristics. The water quality factors that have the greatest effect on copper corrosion are pH, dissolved inorganic carbon (DIC), orthophosphate concentration, and alkalinity. Dissolved oxygen and/or chlorine residual are also important considerations. There are other factors that affect the corrosion of copper (temperature, plumbing materials used, etc.), but they cannot be easily altered by a water system and have a lesser effect on corrosion (EPA, 2003).

Any increase in drinking water pH within the pH range of 5 to 8 generally results in some measurable decrease in copper levels. At the higher pH levels, there is less tendency for copper in plumbing materials to dissolve and enter drinking water. The pH of water can vary significantly as water moves through the distribution system. At a constant pH, as the DIC increases, copper levels should increase. The effect of DIC is not as strong as the effect of pH until high levels of DIC (> 30 mg/L) are reached, when pH adjustment stops being an effective treatment. (EPA, 2003)

Issac, et al (1997) compared copper and lead in drinking water, sewage, wastewater treatment plant (WWTP) influent and WWTP effluent in four communities. Data from the study indicate that minimizing influent concentrations of copper and lead to a WWTP is an important control factor since at a constant removal efficiency, the higher their concentrations in the influent, the higher they will be in the effluent. Isaac concluded that corrosive drinking water contributes substantially to exceeding receiving water quality standards for copper, especially where dilution of wastewater effluents is low, and recommended corrosion reduction efforts in water supply systems.

Table 1 provides a comparison of copper concentrations in the City of Puyallup's drinking water and WWTP influent and effluent with concentrations in other communities. In evaluating the Puyallup data along with that from the other communities, the following observations are provided:

1. Puyallup's drinking water, WPCP influent and WPCP effluent copper concentrations are in the middle of the range of values seen among the municipalities.
2. The Massachusetts facilities reported by Isaac (1997) had low drinking water alkalinity, low drinking water pH and generally high WWTP effluent copper. The authors found a correlation between influent and effluent copper and concluded that corrosion control should be implemented since "the higher the concentrations in the influent, the higher they will be in the effluent." However, the observed correlation between influent and effluent copper concentrations was weak ($R^2 = 0.576$). For instance, for the range of influent copper concentrations of 130 - 180 $\mu\text{g/L}$, effluent copper concentrations varied widely (from 10 to 70 $\mu\text{g/L}$). The effluent copper data may be flawed, since the data was not obtained with the now current state-of-the-art ICP-MS methodology, although the authors noted that "as many of the 'clean techniques' as practical were used." In a personal communication, the City of La Porte, Indiana, reported a similar lack of correlation between influent and effluent copper concentrations after

implementing water system corrosion control. Despite the lack of correlation, their compliance with their NPDES effluent copper limit has improved. As with the Massachusetts data, La Porte was not using all of the current “clean” techniques for sampling and analysis.

3. Implementing corrosion control through the addition of an alkaline chemical, such as caustic soda, lime, sodium bicarbonate, or an inhibitor, such as orthophosphate, to Puyallup’s drinking water to control pH could lower the corrosivity of the City’s drinking water supply and the levels of copper in the City’s WPCP influent. The amount of reduction attained through implementation of corrosion control measures is unclear; implementation in similar drinking water systems typically results in a copper reduction of 30 -70%. However, the effect corrosion control would have on the copper concentration in the Puyallup WPCP effluent is unclear, since, based on the data obtained to date, there is not a clear correlation between Puyallup WPCP influent copper and WPCP effluent copper levels. (Note: the lack of correlation may be influenced by copper in recycle streams. Boulay and Edwards (1999) found that total copper in Return Activated Sludge, 1200 µg/L, was 17 times that in the influent, 69 µg/L, in the Boulder, Colorado WWTP. Puyallup’s Mixed Liquor contains total copper averaging 1670 µg/L, also about 17 times the average influent – 100 µg/L.)

The *Revised Guidance Manual for Selecting Lead and Copper Control Strategies* (EPA, 2003) states that “many wastewater utilities have found that preventing metals from getting into the wastewater stream has proven more cost-effective than trying to remove them. Some wastewater utilities have gone so far as to provide some of the funding to their water utility to support corrosion control efforts rather than construct improved metals removal treatment at the wastewater treatment plant.” Per discussion with the author of the Revised Guidance Manual, the only municipalities she was aware of where corrosion control had been implemented for the purpose of reducing WWTP effluent copper were Mars Hill, Maine and Chicopee, Massachusetts. Per discussion with Mars Hill, Maine, the City implemented corrosion control due to the Lead and Copper Rule, not WWTP compliance concerns. Per discussion with Laurie Goff, City of Chicopee Pretreatment Coordinator, Chicopee actually implemented corrosion control for their drinking water system to reduce copper and zinc concentrations in WWTP biosolids.

The Chicopee Water Pollution Control Division decided to regulate the drinking water supply as an industrial discharge with maximum daily average concentrations of 0.28 mg/L copper and 0.05 mg/L zinc. As shown in Table 2, implementation of a sodium carbonate / sodium bicarbonate corrosion control system for the Chicopee drinking water supply system resulted in approximately a three-fold reduction in copper to both the WWTP influent and effluent. Use of a sequestering agent (zinc polyphosphate), which was tried for control of iron precipitation prior to the use of sodium carbonate / sodium bicarbonate, slightly increased copper levels in WWTP influent and effluent.

TABLE 1
Comparison of Drinking Water and WWTP Copper in Puyallup with Other Municipalities

City	Drinking Water			Domestic Wastewater	WWTP			Tertiary Treatment Reference	
	First Draw Tapwater Standing More than 6 hours	Drinking Water Alkalinity	Drinking Water pH Range	Domestic Wastewater	WWTP Influent	Secondary Effluent	WWTP Effluent		
	Mean Cu µg/L	as CaCO ₃ mg/L		Mean Cu µg/L	Mean Cu µg/L	Mean Cu µg/L	Mean Cu µg/L		
Puyallup, WA	444	55	7.1-7.2	111	100	9.46	9.46	None	1
Grand Rapids, MI	N/A	N/A	N/A	N/A	66.9	6.0	6.0	None	2
San Jose, CA	N/A	N/A	N/A	N/A	82.5	N/A	4.4	Filtration	2
N.Tonawanda, NY	N/A	N/A	N/A	N/A	63.4	3.7	3.7	None	2
Lansing, MI	N/A	N/A	N/A	N/A	47.2	6.1	2.8	Filtration	2
Clinton, MA	240	6.8	6.1 - 6.8	~60	~90	N/A	~5	None	3
Gardner, MA	1430	6.3	6.0 - 6.3	~150	~400	N/A	~50	None	3
Fall River, MA	31.9	7.6	6.9 - 8.9	~130	~150	N/A	~40	None	3
New Bedford, MA	73.7	1.7	4.7 - 5.7	~50	~120	N/A	~90	None	3
South Carolina City	N/A	N/A	N/A	N/A	108	N/A	11	None	4

- 1) Gray & Osborne, 2005
- 2) WERE, 2005
- 3) Isaac et al, 1997
- 4) Kobylinski, et al, 2003
- 5) N/A = Not Available

Contrary to the Chicopee experience, Salkind et al (1996) studied the effect of phosphates used for drinking water corrosion control on WWTP effluent and sludge and found that orthophosphate (PO₄) reduces lead solubility in low and high alkaline water but that zinc orthophosphate also controls other corrosion materials such as iron, steel, and copper. Presumably, the zinc accelerates the rate at which a protective film is formed within the pipe and decreases the amount of phosphate required. However, based on their analysis, the addition of corrosion control chemicals to meet the requirements of the LCR adds 23% of the zinc and 5.2% of the phosphate to the WWTP load of these chemicals.

TABLE 2
Average Concentrations of WWTP Influent and Effluent Copper
Before and After Implementation of Corrosion Control at the City of Chicopee, MA
WWTP

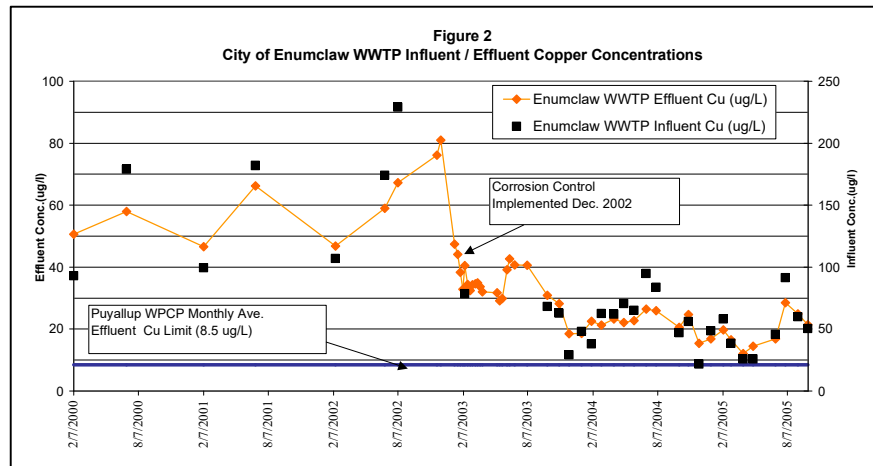
	WWTP Influent			WWTP Effluent		
	Before Corrosion Control	After Corrosion Control	Reduction Factor	Before Corrosion Control	After Corrosion Control	Reduction Factor
	µg/L	µg/L		µg/L	µg/L	
Mean	197	70	2.83	70	21	3.39
Maximum	330	200		120	120	

According to limited information provided in a paper by Schock (1999), an American Waterworks Research Foundation (AWWARF) study regarding corrosion control at Bellingham, Washington, indicated that after implementation of corrosion control in the drinking water system, WWTP effluent copper was reduced from approximately 90 µg/L to approximately 30 µg/L, and effluent zinc was reduced from approximately 160 µg/L to approximately 60 µg/L. No data is provided in the paper regarding the date of implementation or the corrosion control chemical used.

The City of La Porte, Indiana, implemented corrosion control in September 2003, for the purpose of achieving compliance with an effluent copper limitation of 24 µg/L. La Porte uses an orthophosphate product that is fed at both of their water treatment plants and have generally achieved compliance with their effluent limitation, although they find their WWTP *influent* copper concentration (100 µg/L) continues to be about the same as before feeding orthophosphate. WWTP *effluent* copper concentrations, however, averaged 32 - 33 µg/L prior to the implementation of corrosion control, and average 18 µg/L after implementation. La Porte is the only City this study determined is practicing corrosion control in the water distribution system solely in order to meet a WWTP effluent wastewater limitation for copper. However, due to administrative orders from EPA to address WWTP effluent copper, as of late 2005, three facilities in New England are reportedly conducting intensive copper optimization studies and are considering implementing corrosion control in their respective water distribution systems.

The City of Enumclaw, Washington implemented corrosion control with sodium hydroxide for compliance with the LCR in December 2002. WWTP influent and effluent copper concentrations are summarized in Figure 2. WWTP influent copper concentrations decreased an average of 63% after implementation of corrosion control from an average of 152 µg/L to an average of 56 µg/L. WWTP effluent copper concentrations decreased an average of 48% after implementation of corrosion control from an average of 58 µg/L to an average of 30 µg/L. As shown in Figure 2, copper concentrations in the Enumclaw WWTP effluent exceeded the Puyallup WPCP effluent limits even after the implementation of corrosion control.

It is noted that all of the above examples involved significantly higher effluent copper levels than observed at the Puyallup WPCP; hence, caution should be exercised in applying results from these other facilities to Puyallup. At the lower concentrations observed at the Puyallup WPCP, it is possible that speciation and solubility may reduce the removal efficiency of copper at the WPCP.



Methods of Corrosion Control in Drinking Water Systems

Aeration and caustic soda addition were chosen for a corrosion control pilot study based on previous success with similar facilities. The two methods are commonly employed in water systems in Washington State for pH adjustment and are both effective methods. Other types of chemical addition are used for pH adjustment but caustic soda addition is generally the most efficient and cost-effective for this type of facility.

Aeration, also called air stripping, is a process where water is cascaded down through a rising column of air. The interaction of the air and water serves to remove dissolved gases in the water such as carbon dioxide. Dissolved carbon dioxide in the water forms carbonic acid and depresses pH. Consequently, the removal of carbon dioxide by aeration will elevate pH.

Chemical addition raises pH through the addition of a base, in this case caustic soda (NaOH). The base neutralizes the carbonic acid and converts it to bicarbonate or, if enough base is added, carbonate.

Source Water Quality

A summary of inorganic water quality test results for Salmon Springs prior to the pilot study is shown in Table 3.

TABLE 3
Inorganic Water Quality for Salmon Springs

Parameter	MCL ¹	August 2005	April 1999	January 2003	January 2003
pH	6-9	7.3	NA ³	NA	NA
Manganese (mg/L)	0.05 ²	NA	<0.03	NA	NA
Iron (mg/L)	0.3 ²	NA	<0.01	NA	NA
Alkalinity (mg/L as CaCO ₃)	None	40	NA	NA	NA
Dissolved CO ₂ (mg/L)	None	2.5 ⁴	NA	NA	NA
Copper (mg/L)	1.3	NA	NA	0.00017	0.00025
Zinc (mg/L)	None	NA	NA	0.00034	0.00020

1. Maximum Contaminant Level, or Action Level for Copper
2. Secondary standard
3. NA – not analyzed or data not available
4. Calculated

The raw water quality data in Table 3 indicate that the spring water contains a small amount of dissolved carbon dioxide. Dissolved carbon dioxide reacts with water to form carbonic acid, which lowers pH. A raw water sample taken at Salmon Springs in August 2005 had a pH of 7.3; however, other samples taken indicated that the more typical pH range is closer to 7.0.

The upper limit of pH that can be achieved by removing carbon dioxide through aeration is dependent upon the amount of carbon dioxide in the atmosphere. Normal air contains 0.04 percent carbon dioxide. In an aeration system, carbon dioxide is removed from the water and the equilibrium of the carbon dioxide in the air and in the water, as determined by solubility characteristics, will determine the upper pH limit. In general, the carbon dioxide equilibrium value in water is approximately 0.5 mg/L. For water with an alkalinity of 40 mg/l as CaCO₃, the equilibrium pH will be approximately 8.1. It is possible, therefore, that the pH of Salmon Springs water can be raised using aeration.

As shown in Table 3, no iron or manganese has been detected in Salmon Springs water. A lack of iron and manganese is desirable for an aeration system since dissolved iron can precipitate in an aeration system and clog packed tower media.

Copper data taken in 2003 indicate that copper in Salmon Springs water is present at levels below 1 µg/L. This indicates that raw water from Salmon Springs is not a significant source of copper relative to the levels observed in WPCP influent as described above.

ENHANCEMENT OF WWTP METALS REMOVAL

Speciation of metals impacts trace metal removal in wastewater treatment processes. As described above, the speciation of metals in water is a function of the pH, oxidation-reduction potential and concentration of other inorganic and organic constituents in solution. Typically, in municipal wastewater treatment plants, removal rates for particulate metals substantially exceed that for dissolved metals. The synthetic chelating agent EDTA in wastewater results in the formation of strong dissolved metal complexes that resist removal by treatment processes.

Historically, metal speciation (e.g., complexation) was determined by indirect methods due to a lack of direct analytical techniques. Recently, a method has been developed using HPLC (High Performance Liquid Chromatography) with post column reaction and UV detection for direct quantification of EDTA-metal complexes (WERF, 2005). Unfortunately, copper-EDTA complexes are difficult to quantify throughout the treatment train because dissolved copper often is present at concentrations close to the method detection limit (4.4 µg/L) for the copper-EDTA complex. Using this approach, Sedlak (WERF, 2005) found substantial variation in the amount of copper-EDTA complexes as a percentage of total dissolved copper (0 - 80%) entering four WWTPs. Sedlak confirmed the predicted important role of pH in the speciation of metals throughout the WWTP treatment train, with lower concentrations of EDTA-complexed copper and zinc present at lower pH due to a shift to iron – EDTA complexes.

Impacts of WWTP Design And Operational Parameters

Boulay and Edwards (2000) concluded that a large number of variables might be influential in the copper removals reported, including differences in process configurations within different WWTPs. For example, some plants that achieve very high removal efficiencies treat their sludge by direct vacuum filtration and sludge incineration rather than digestion. The process of sludge digestion concentrates some of the copper into a digester supernatant that recycled back to the headworks of the WWTP. Metals concentrations in supernatants have been noted to be 10-300 times more concentrated than the influent metals concentration. In other words, at plants that employ sludge digestion, the copper is removed from the water in the waste solids, but a significant portion is returned. Vacuum filtration and sludge incineration processes do not employ a digestion step, and therefore, do not recycle as much of the metals. Heart, et al (1994) noted that the plants that had the highest overall copper removal had minimal recycle streams from solids handling processes (Boulay and Edwards, 2000).

Sidestream flows at the Puyallup WPCP consist primarily of gravity thickener overflow resulting from concentrating primary sludge, centrate discharge from a centrifuge thickening waste activated sludge, and filtrate resulting from belt press dewatering of anaerobically digested sludge. Based on mass balance testing, these combined waste streams, discharged directly to aeration basin inlet, contribute between 16% - 27% of the total copper loading to aeration and between 6% - 10% of the dissolved copper loading. Total zinc loading ranged between 17% - 64% of aeration loading and dissolved zinc was

about 8%. The highest loadings were typically incurred when digested sludge was being dewatered.

Although the dissolved metals contribution from the sidestream flows is relatively low, the total metals contribution of copper and zinc to aeration is significant offering opportunities for changes in speciation during secondary treatment. Consequently, these flows were recently re-routed to the headworks where settling and capture of the metals bearing particulates may occur.

Other research has emphasized the importance of optimizing secondary treatment. A recent study by Edwards tracked the fate of copper as it traveled through a wastewater plant in Boulder, Colorado. Although a significant portion of copper was removed during primary settling processes, most copper was removed through adsorption to microbial flocs (particulate biomass) used in the activated sludge process. Because the biomass was recycled continually to treat the sewage, particulate copper levels built up in this stage of treatment to the milligram per liter level. (Boulay and Edwards, 2000).

Examining the literature on copper removal at various stages of wastewater treatment reveals the percentage of copper removal during primary treatment varies from 20-45% while the removal during secondary treatment varies from 40-80%. This performance is probably because primary treatment processes can only remove particulate copper, whereas secondary treatment allows soluble copper uptake into the biomass of growing microorganisms (Boulay and Edwards, 2000). Based on mass balance testing, Puyallup typically removes between 25% - 41% of the primary clarifier copper loading.

Many approaches have been noted to improve copper removal in wastewater treatment. One researcher found that copper removal could be enhanced by minimizing the mixed liquor concentration in order to maximize biological growth and uptake of copper. Others have reported that, under ideal conditions, percent metal removal has been found to increase linearly with sludge age (although Heart, et al, found that optimal copper removal occurred at a sludge age of 6 to 12 days.) Other suggestions for more effective copper removal in WWTPs have been made including a recommendation of an approximate 15-day sludge age (Boulay and Edwards, 2000). Based on charting three years of effluent copper data and sludge age, Puyallup found a strong correlation between the effect of sludge age and copper removal. In Puyallup's case, a sludge age (calculated on the basis of oxic zones only) of about 7 or 8 days appears optimum.

The City of Palo Alto modified their effluent filter backwash procedures by ceasing pre-chlorination before backwashing, since the chlorine was apparently solubilizing the copper. One researcher found that co-precipitation of copper by ferric coagulation could improve copper removal substantially. This result was further confirmed by a survey of 20 wastewater treatment plants, which revealed that many of the plants using ferric chloride coagulation achieved superior copper removal (City of Palo Alto, 1994). However, recent testing conducted by Sedlak failed to support the impact of ferric chloride (WERF, 2005).

Potential WPCP Copper Removal Technologies

Filtration

In an activated sludge process, the majority of the particulate copper in the biomass is settled from the water in secondary clarifiers, leaving behind relatively clean secondary effluent for discharge to the environment. However, since solid-liquid separation in an activated sludge system does not occur with 100% efficiency, some particulate copper will be discharged. In the case of the Boulder WWTP, the particulate copper concentration entering the secondary clarifiers is about 1,200 µg/L. If the solid liquid separation is 99% effective, then 12 µg/L of particulate copper will be discharged from the secondary clarifier. However, if the separation is only 95% efficient, then 60 µg/L of particulate copper will be discharged. Effluent copper concentrations can be strongly dependent on settling efficiency in the secondary clarifiers (Boulay and Edwards, 2000).

Some studies have found that most of the copper in wastewater effluent is in a soluble form (passes through a 0.45 µm pore size filter) and suggests treatment efforts be targeted on the soluble copper (Boulay and Edwards, 2000). In contrast, another study concluded that between 30 and 80% of the copper in the wastewater effluent at the Boulder, Colorado WWTP was particulate, based on 0.45 micron pore size filtration (Edwards et al., 1996). The variability noted in the Edwards study support the notion that effluent copper is highly dependent on the sludge settling process, water quality and other factors. In support of this assertion, some researchers found that when activated sludge is diluted, bacterial flocs sometimes quickly release soluble extracellular polymeric substances (EPS) in the wastewater. Since soluble EPS can bind soluble species such as copper, an increase in soluble EPS could result in an increase in soluble copper in the wastewater effluent. Future research should determine whether heavy rain events increase soluble copper concentrations via this mechanism (Boulay and Edwards, 2000).

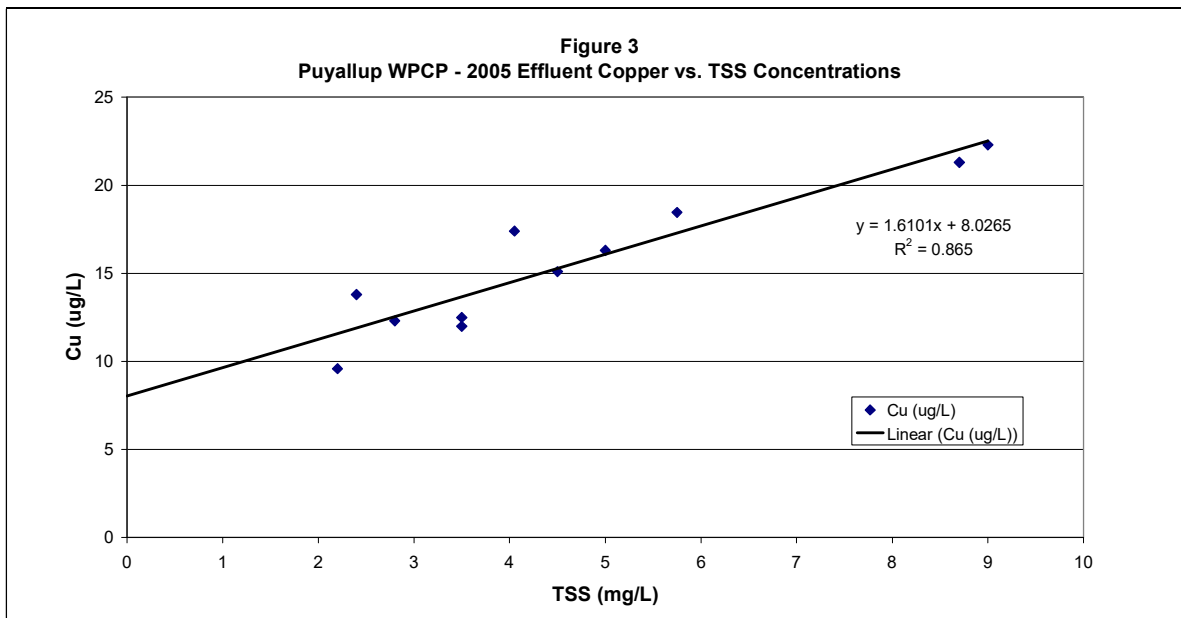
One way to improve the liquid – solids settling process is through filtration, which could be effected through cloth, membrane or granular media. However, Heart, et al, (1994) noted that plants without filtration achieved approximately the same average copper removals compared to plants with filtration (79 percent versus 81 percent average total copper removal). For the Puyallup WPCP, the majority of *influent* zinc and copper is usually present in particulate form, but, in the *effluent*, the majority of the remaining copper (72-74%) and zinc (87-95%) are present in the dissolved form, as shown in Table 4. Hence, based on the existing data, filtration would only remove 26 - 28% of the copper and 5 – 13% of the zinc, at the most.

As shown in Figure 3, 2005 effluent copper concentrations appeared to correlate with effluent TSS concentrations, and to changes in the settlability of the mixed liquor. These data suggest the possibility that removal of effluent suspended solids by effluent filtration may be effective at reducing the effluent copper concentrations. However, frequently (three out of eight samples) the concentration of *dissolved copper alone* is in exceedance of the City's NPDES monthly permit limit, suggesting that filtration might not be effective in achieving compliance.

TABLE 4
Dissolved and Total Puyallup WPCP Effluent Metals

Sample Date	WPCP Effluent Copper			WPCP Effluent Zinc		
	Total	Dissolved	% Dissolved	Total	Dissolved	% Dissolved
3/25-26/03	5.7	4.1	72%	18.9	16.4	87%
4/21-22/03	9.4	6.8	72%	40.1	35.5	89%
5/5-6/03	8.1	6.0	74%	36.6	34.8	95%
5/4-5/5/04	10.8	10.8	100%	-	-	-
6/7/-6/8/04	13.4	11.9	89%	32.4	-	-
7/14-7/15/04	10.3	8.4	82%	-	-	-
8/3-8/4/04	11.8	10.2	86%	-	-	-
Average	9.9	8.3	82%	32	28.9	90%

Additionally, in-situ composite sampling of mixed liquor was conducted in Puyallup using a modular membrane filter with a nominal pore diameter of 0.04 µm. As would be expected, the mixed liquor composite was free of suspended solids and thus free of particle-borne copper or zinc. Nonetheless, the filtered samples still contained copper and zinc concentrations similar to the concentrations found in the final effluent composite sample indicating that filtration would not facilitate compliance with Puyallup’s effluent copper limitation at this point in time.



Ferric Chloride

Sedlak (2000, 2005) reported that attempts to improve metal removal are often unsuccessful because a significant fraction of the cationic metals are complexed by the synthetic chelating agent ethylenediamine tetraacetic acid (EDTA). To identify practical approaches for improving metal removal, an analytical method for measuring metal-EDTA complexes was used to survey metal speciation at a series of wastewater treatment plants. Following these analyses, bench-scale experiments were conducted. The survey data indicated that pollutant metal-EDTA complexes account for a significant fraction of the dissolved metals in wastewater. The bench-scale studies indicated that ferric chloride addition improves the removal of Cu and Zn by approximately 20%.

To test the results of the bench-scale experiments, a full-scale experiment was conducted by Sedlak by interrupting chemical addition at a municipal wastewater treatment plant that normally adds ferric chloride during primary treatment. Results indicated that ferric chloride addition had a slight impact on metal speciation but no effect on metals removal. The lack of an effect was attributed to changes in metal speciation that occurred during primary treatment irrespective of ferric chloride addition.

It should be noted that use of ferric chloride at the Puyallup WPCP would be expected to negatively impact the performance of the existing ultraviolet disinfection system through reduction of effluent transmittance, coating of ultraviolet lamp sleeves, and the presence of iron precipitates in bacterial flocs reducing the ability to disinfect particle-associated coliform.

Sequestering, Precipitation and Adsorption Agents

Gerhardt, et al (2002) reported results from testing the use of chemical addition to enhance copper removal in the University of California, Davis (UCD) wastewater treatment plant (WWTP). Wastewater from the headworks and oxidation ditch were treated with ferric chloride and two organic precipitants in jar tests. Ferric chloride had little effect on residual dissolved copper, while the organic precipitants reduced it below 10 µg/L. In the testing, MR2405 from Betz Dearborn (now G.E. Infrastructure) outperformed Ondeo-Nalco 8702. In a full-scale trial, a dose of 8 ppm to 13 ppm of Betz Dearborn MR-2405 effected a mean reduction in dissolved copper concentration of 2 µg/L, sufficient to maintain compliance with the WWTP's 13 µg/L water quality-based effluent limit for copper. Full-scale implementation required no additional solids separation or handling equipment.

According to the manufacturer, the Betz polymer, whose active ingredient is trithiocarbonate, has an LC50 (lethal concentration to 50% of exposed organisms) for rainbow trout of 8 mg/L and a no effect level of 3 mg/L. (Note: per discussion with the manufacturer, these toxicity thresholds apply only to concentrations of unsequestered, unreacted, polymer.) To avoid overfeeding the polymer, daily rapid-turnaround analysis of copper was used at the UCD WWTP to set the correct dosing rate at the Davis WWTP. G.E. recommended that Puyallup procure analytical instrumentation for rapid analysis of

copper. Costs for such instrumentation for this application range from \$40,000 (atomic absorption), to \$60,000 (ICP), to \$120,000 (ICP-MS). Additionally, because of testing complexity, Puyallup would need to hire an analyst experienced with these testing methods and instruments. However, recent testing showed substantial variation in mixed liquor dissolved copper concentrations in 30 minutes; thus, the utility of daily analytical testing is in question when concentrations vary significantly within 30 minutes.

Per discussion with the UC Davis WWTP operator, use of the Betz MR 2405 at the Davis WWTP in recent years resulted in a reduction of effluent copper from an average of approximately 13 µg/L to an average of 6 – 7 µg/L. During the two-year period that the MR-2405 was used, eight quarterly whole effluent toxicity tests were passed for rainbow trout, *Ceriodaphnia dubia*, fathead minnows, and algae, with no significant toxicity in 100% effluent. Procuring an atomic absorption analyzer allowed them to research copper sources, and ultimately copper sulfate, used to kill fungus, was determined to be the major source. After this source was eliminated, effluent copper has been below detection limits (0.5 µg/L), without feeding MR-2405, so use of MR-2405 has been eliminated.

Other Technologies

Kobylinski, et al conducted bench testing on metals removal using a number of different technologies for a WWTP in South Carolina, including:

1. 0.45 um filtration (to simulate sand filtration)
2. 0.1 um filtration (to simulate microfiltration)
3. Hydroxide precipitation
4. Sulfide precipitation
5. Alum Coagulation / Flocculation
6. Ion exchange and Adsorbent Resins
7. Activated carbon

The only technology that provided acceptable results was activated carbon, which provided 67 - 96% removal of copper and 83 - 93% removal of zinc from secondary effluent. (Kobylinski, 2003). (However, use of activated carbon was found to have prohibitive operating costs.) The methodology employed provided some degree of speciation analysis. Activated carbon treatment typically is more successful for non-polar constituents; filtration is typically more successful with particulate constituents; the other technologies are typically more successful with ionic constituents. The fact that activated carbon was more successful than the other technologies may indicate that the metals are present in a dissolved form complexed with organic ligands (e.g., chelates, such as EDTA). Such complexes are typically expensive to remove. The fact that the South Carolina WWTP was passing toxicity tests, yet had concentrations of metals that predicted toxicity based on EPA criteria, was taken by regulators to indicate that the copper was likely complexed and not likely bioavailable.

CORROSION CONTROL PILOT TEST

Materials And Methods

The corrosion control pilot study at Puyallup was conducted from September through November 2005. The main goals of the pilot study were:

- To ascertain Salmon Springs pH and alkalinity.
- To determine the feasibility of increasing pH through aeration and caustic soda addition.
- To ascertain the effect of increased pH on copper, lead, and zinc corrosion and metal release from the test plumbing materials.
- To determine the effect of increased pH on disinfection byproduct formation.

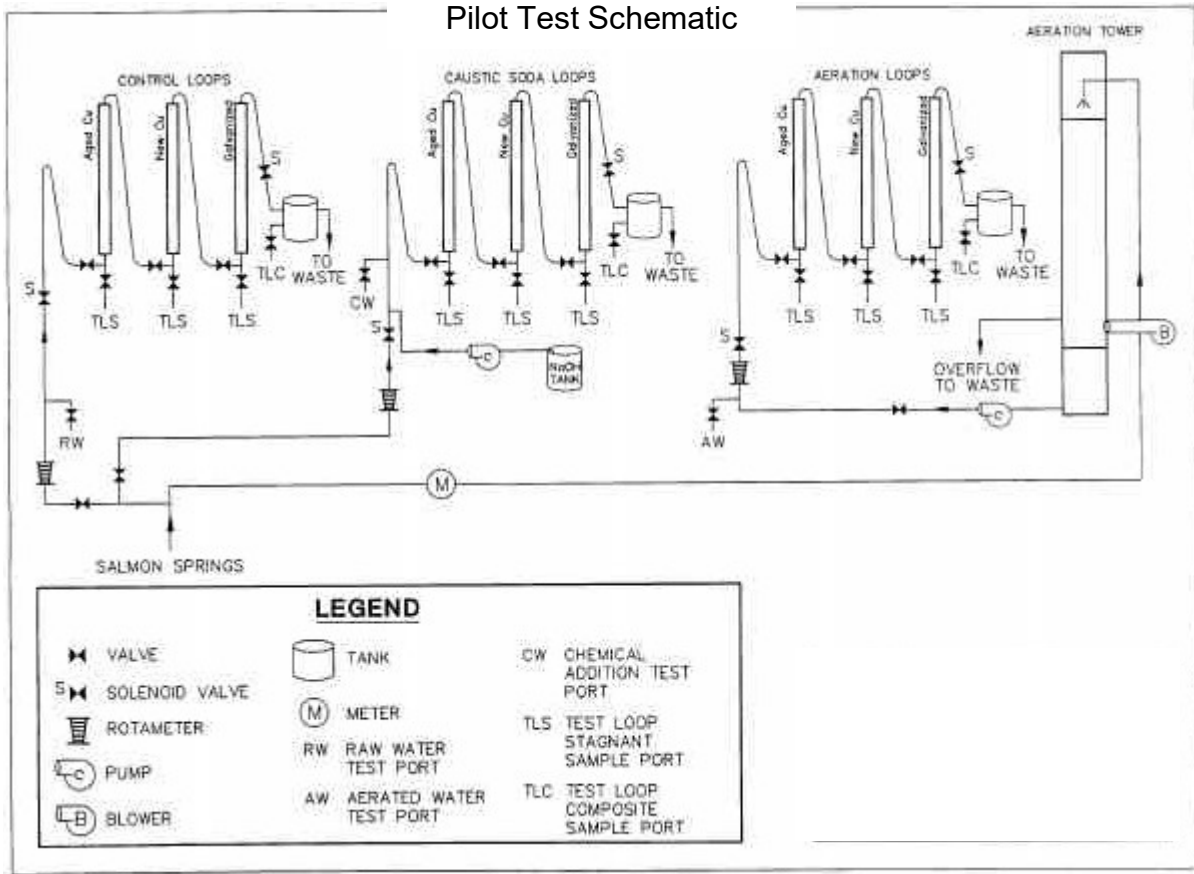
The corrosion control pilot system apparatus was a flow-through pipe loop arrangement made with standard household plumbing materials including loops of the following pipe materials:

- New copper pipe,
- Old copper pipe that was taken from the Puyallup system, and
- Galvanized piping.

Figure 4 shows a schematic diagram of the pilot system. Each test apparatus had one pipe loop of each pipe material arranged in series. One test apparatus was used for each test water: (1.) untreated raw Salmon Springs (a control), (2.) aerated Salmon Springs, and (3.) Salmon Springs with caustic soda addition. The flow from each test apparatus was directed into a plastic barrel to provide a composite of both stagnant and flowing water from the various pipe materials. A timer controlled the flow through each apparatus by alternating periods of flow and stagnation to simulate household use. Water samples were taken weekly from each of the pipe loops and the composite barrel to compare the three test water conditions.

The pilot study protocol was patterned after similar pilot studies conducted to assist water purveyors in complying with the Lead and Copper Rule (LCR), a part of the Surface Water Treatment Rule (SWTR). The pilot study protocol was designed to mimic techniques for sampling stagnant tap water under the LCR.

Figure 4
Pilot Test Schematic



A photo of the apparatus for the Control and Sodium Hydroxide-treated waters is included as Figure 5. A separate test apparatus with the three pipe loop sections was constructed for each test water. A sample tap was provided for each pipe loop. The flow from each test apparatus was captured in a 30-gallon plastic container with an overflow. The water in the container represented a composite of the water from the three different pipe loops. The flow of test water for each test apparatus was set at 1 gpm to simulate household flow.

A discussion of the two pH adjustment methods is included below.

FIGURE 5
Pipe Loop Apparatus for Corrosion Control Pilot Test



Aeration

The aeration system consisted of a packed tower system. Water was directed from a tap in the vault to the tower installed outside of the Salmon Springs chlorination facility. The water entered the tower at the top and cascaded through the tower packing. Air was directed up through the tower countercurrent to the water flow using an electric blower. The water was collected in a sump in the bottom of the aeration tower and pumped to the pipe exposure loop apparatus located in the chlorination building. The excess water from the sump was directed to waste.

A summary of the aeration pilot unit characteristics is shown in Table 5. A photo of the aeration tower is included as Figure 6.

FIGURE 6
Aeration Tower for Corrosion
Control Pilot Test



TABLE 5
Physical Characteristics of Aeration Pilot Unit

Parameter	Value
Aeration System Type	Packed Tower
Material	PVC Pipe
Diameter	8 inches
Height	25 feet
Packing Height	15 feet
Flow rate	5 gpm
Packing Type	2-inch Lanpac
Hydraulic Loading	14 gpm/sq. ft.
Air/Water Ratio	425:1
pH after Aeration	8.1

Caustic Soda Addition

Caustic soda (sodium hydroxide) solution was added to adjust pH. The addition point was just upstream of the pipe loop apparatus using a mixing reservoir. The design parameters for the caustic soda addition are shown in Table 6.

TABLE 6
Physical Characteristics of Caustic Feed Pilot Unit

Parameter	Value
Chemical Addition Type	Caustic Soda
Solution Strength	~3 percent
Chemical Feed Pump Type	Peristaltic
Target pH	8.1
Anticipated Target Dose	5 mg/L

Pilot Operation

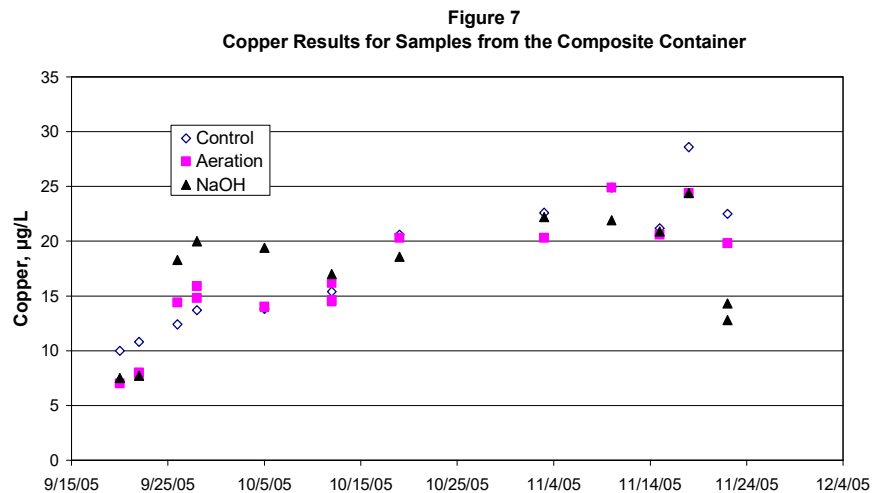
Pilot plant operation began during September 2005. The pilot study was concluded at the end of November 2005. A timer was used to control the flow through pilot system to simulate a household water use schedule. The timer allowed flow through the system for 20 minutes every three hours with one 8 hour 40 minute stagnation period each day. In addition to operating the solenoid valves to allow flow, the timer controlled the aeration tower blower, sump pump, and the caustic soda feed.

Sample Collection And Analysis

All sampling for trace metals was conducted by staff trained in the use of clean sampling techniques. In general, samples were taken with “clean-hands, dirty-hands” sampling techniques adapted from *EPA Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Levels* (EPA 1996).

Results

The pilot study data indicated that pH adjustment appeared to decrease copper release although not in all cases. Composite concentrations are summarized in Figure 7 and average concentrations for all test waters are summarized in Table 7.



Data for the new copper loops indicated that both aeration and caustic soda addition reduced copper release to stagnant water. The data indicated that aeration reduced copper release in old copper plumbing, but that caustic soda did not. The opposite effect was noted for galvanized plumbing with copper levels from the aerated water being much higher than the other two water conditions, although the copper concentrations from the galvanized plumbing were significantly lower than for the copper plumbing materials. Both samples from the composite barrel and samples taken under flowing conditions for each apparatus showed a reduction with pH adjustment. An overall assessment of the pilot data indicated that pH increase reduced copper release approximately 20 percent, when applicable corrections were applied for copper in untreated control samples.

TABLE 7
Average Copper Concentrations for Pilot Test

Water Quality	New Copper Column Copper Conc., µg/L	Old Copper Column Copper Conc., µg/L	Galvanized Column Copper Conc., µg/L	Composite Copper Conc., µg/L
Raw Water	2,795	1,206	9.7	18.7
Aerated Water	1,930	661	48.5	17.4
Caustic Addition	1,217	1,259	6.6	17.5

The pilot study water samples were also analyzed for lead to ascertain any potential effect from pH adjustment. The levels of lead in all the samples were very low, both in relation to the detection limits of the analytical methods and the regulatory limits of the LCR. The results of the lead analysis data did not provide any clear trends for the effect of pH adjustment on lead corrosion. Consequently, the data for lead corrosion and release were deemed inconclusive.

The data provided an indication that pH adjustment would decrease zinc release but this effect was not definitively quantified. pH adjustment appeared to decrease zinc from the new copper column but not in the old copper column. Both aeration and caustic soda addition had levels of zinc higher than the samples from raw water. However, there was a distinct trend for both, but especially for aeration, that showed high levels of zinc during the first portion of the pilot study but low levels relative to raw water during the latter half of the study (suggesting surface passivation). The composite samples indicated an approximately 25 percent reduction in zinc release for both types of pH adjustment.

PUYALLUP WPCP EFFLUENT AND MIXED LIQUOR TESTING

Bench testing of the addition of chemicals to enhance WPCP metals removal was conducted using chemical addition and filtration in two phases - Phase 1 on September 7, 2005 and Phase 2 on November 20, 2005.

Phase 1 Testing - September 7, 2005

Materials and Methods

1. Mixed Liquor was taken from the final clarifier splitter box that distributes mixed liquor to the clarifiers at 9:55 am and 10:30 am.
2. Final effluent samples were treated with powdered activated carbon or alum. Mixed liquor samples were treated with Nalco 8702, Betz MR-2405, or ferric chloride.
3. 1000 mL samples were mixed with a Phipps Bird gang stirrer (6-paddle) at 50 rpm. The samples treated with the Betz and Nalco polymers were mixed for two minutes, while the samples treated with aluminum sulfate, powdered activated carbon, and ferric chloride were each mixed for ten minutes. The stirrers were covered with plastic zip-lock bags to prevent metals contamination.

Results

Results of the testing are summarized in Table 8, and shown graphically (for dissolved copper only) in Figure 8. Greater than 80% removal of dissolved copper was observed for the mixed liquor samples treated with 50 mg/L Nalco 8702 and the samples treated with 10, 15 and 20 mg/L Betz MR-2405. No sample showed greater than a 41% removal of dissolved zinc. The two samples of untreated mixed liquor taken 35 minutes apart showed a significant, unexpected difference in dissolved copper concentration (9.8 $\mu\text{g/L}$ and 24.8 $\mu\text{g/L}$). 9.8 $\mu\text{g/L}$ is, however, more consistent with 24-hour composite samples taken during subsequent mass balance testing.

Figure 8
Precipitant Testing on Puyallup WPCP Mixed Liquor
Phase 1

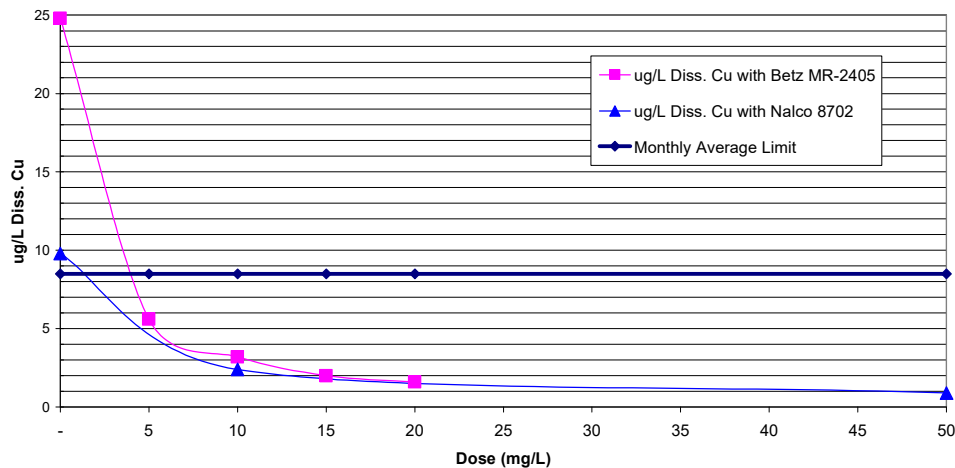


TABLE 8
Results of Phase 1 Jar Testing
WPCP Copper Removal Technologies

Feed	Feed Cu Conc (Diss., µg/L)	Feed Zn Conc (Diss., µg/L)	Sample	Copper Conc (Diss., µg/L)	Zinc Conc (Diss., µg/L)	Copper Percent Removal	Zinc Percent Removal
Blank Control			Filter Blank 0.45	0.2	ND		
Blank Control			Filter Blank 0.7	1.2	5.4		
Sec. Effluent			Sec. Effluent	14.2	38.2		
Sec. Effluent			Sec. Effluent W/0.7 filt.	13	125		
Sec. Effluent			Sec. Effluent W/0.45 filt.	13.2	39		
Mixed Liquor-1	9.8	183	Nalco 8702 0 ppm	9.8	183		
Mixed Liquor-1	9.8	183	Nalco 8702 10 ppm	2.4	134	76%	27%
Mixed Liquor-1	9.8	183	Nalco 8702 50 ppm	0.9	108	91%	41%
Mixed Liquor-1	9.8	183	FeCl ₃ DI 40 ppm	9.5	115		
Mixed Liquor-1	9.8	183	FeCl ₃ 20 ppm	10.7	123	-9%	33%
Mixed Liquor-1	9.8	183	FeCl ₃ 40 ppm	4.5	185	54%	-1%
Mixed Liquor-2	24.8	234	Betz MR-2405 0 ppm	24.8	234		
Mixed Liquor-2	24.8	234	Betz MR -2405 5 ppm	5.6	189	77%	19%
Mixed Liquor-2	24.8	234	Betz MR-2405 10 ppm	3.6	173	85%	26%
Mixed Liquor-2	24.8	234	Betz MR-2405 10 ppm Dup	2.8	174	89%	26%
Mixed Liquor-2	24.8	234	Betz MR-2405 15 ppm	2	172	92%	26%
Mixed Liquor-2	24.8	234	Betz MR-2405 20 ppm	1.6	178	94%	24%
Distilled Water	0.2	0	Powd. Act Carbon Control 100 ppm	0.2	ND		
Sec. Effluent	13.2	39	Powd. Act. Carbon 100 ppm	7	32.8	47%	16%
Distilled Water	0.2	0	Alum DI 40 ppm	0.7	116		
Sec. Effluent	13.2	39	Alum 20 ppm	12.2	99.6	8%	-155%
Sec. Effluent	13.2	39	Alum 40 ppm	11.8	106	11%	-172%

Phase 2 Testing - November 20, 2005

Materials and Methods

1. 40 liters of Mixed Liquor (ML) was taken from the final clarifier splitter box that distributes mixed liquor to the clarifiers. The ML was put into two carboys and aerated and mixed with a magnetic stirrer.
2. Mixed liquor samples were treated with Nalco 8702, Betz MR-2405, or polyaluminum chloride.
3. 3000 mL samples were mixed with a Phipps Bird gang stirrer (6-paddle) at 50 rpm in three 1000 mL beakers. Each beaker tested contained 500 mL from each of the two carboys. All samples were treated with either the Betz and Nalco polymers or polyaluminum

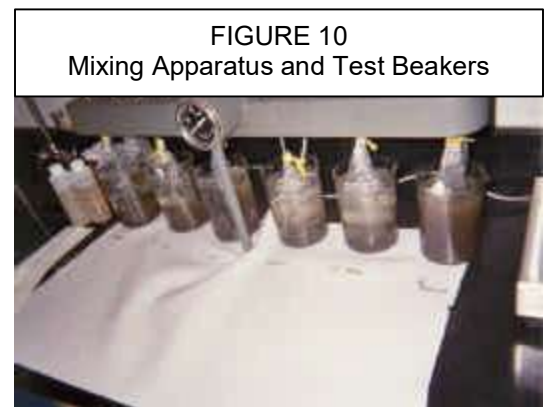


chloride and were mixed for five minutes and allowed to settle. The stirrers were double -wrapped with plastic zip-lock bags to prevent metals contamination.

Results

Results of the testing are summarized in Table 9. Figures 9 and 10 show photographs of the testing conducted. Removals of dissolved copper with the Betz and Nalco polymers were not as good as seen with the previous testing; maximal removals were 75% in the sample treated with 10 mg/L Betz and 54% in the sample treated with 25 mg/L Nalco. However, copper concentrations in untreated samples were significantly lower than observed in Phase 1, and dissolved copper concentrations in treated samples were well below permit limits. Significantly poorer removals were observed for *total* copper than for *dissolved* copper, suggesting poor settling of the precipitate in the testing apparatus.

Due to concerns regarding the aquatic toxicity of the polymers, whole effluent toxicity of the samples treated with the Betz and Nalco polymers was assessed. Due to limitations in sample volume, only chronic toxicity to *Ceriodaphnia dubia* was tested. Rather than the standard dilution series, each bench test sample was assessed for toxicity. Significant toxicity was observed to *Ceriodaphnia dubia* reproduction only in samples treated with >10 mg/L Nalco 8702 compared to the untreated samples.



Puyallup WPCP Recycle Stream Testing

Sidestream flows at the Puyallup WPCP consist primarily of gravity thickener overflow resulting from concentrating primary sludge, centrate discharge from a centrifuge thickening waste activated sludge, and filtrate resulting from belt press dewatering of anaerobically digested sludge. Analysis of the belt press filtrate in September 2005 showed total copper concentrations of 156, 111, and 143 $\mu\text{g/L}$ and a dissolved copper concentration of 5.1 $\mu\text{g/L}$. Analysis of the belt press filtrate in September 2005 showed total zinc concentrations of 170, 128, and 167 $\mu\text{g/L}$ and a dissolved zinc concentration of 38.2 $\mu\text{g/L}$. Subsequent mass balance testing in 2006 indicates that these combined waste streams, discharged directly to aeration basin inlet, contribute between 16% - 27% of the total copper loading to the aeration basins and between 6% - 10% of the dissolved copper loading. Total zinc loading ranged between 17% - 64% of aeration basin loading and dissolved zinc was about 8%. These flows were subsequently re-routed to the headworks.

CONCLUSIONS

Corrosion Control

The following conclusions can be drawn from the data presented in this report.

- Both aeration and caustic soda addition are effective techniques for pH adjustment for Salmon Springs. Salmon Springs raw water average pH during the pilot study was 7.1. The maximum pH that was achieved for aeration during the pilot was 8.1. The target pH for caustic soda addition was 8.1 to match the performance of aeration. Variability in either the chemical feed or in the raw water pH created variability in the pH of the water with caustic soda addition, which averaged 7.7 over the pilot period.
- The pH elevation appears to decrease copper release but the release was not easily quantified from the data. The data indicate that adjusting Salmon Springs water pH was effective in reducing average copper release in the experimental test apparatus by approximately 20 percent. Both aeration and caustic soda addition proved equally effective in decreasing copper release but the average measured pH with caustic soda addition was 7.7 while for aeration it was 8.1.
- The effect of pH adjustment on lead and zinc reduction was not clear from the pilot study data. The levels of lead were very low and the differences among the three test waters were not significant. The data did indicate a possible reduction in zinc because significant reductions in zinc were noted in both the composite and flowing samples for both pH adjustment methods, but the results from the galvanized column, the single largest contributor of zinc, showed an opposite average effect. There was a trend with the samples from the galvanized column that indicated that, after an initial period of high zinc release, the levels of zinc released with pH adjustment, especially aeration, were lower than with raw water. If this trend were to continue over a longer exposure, it is likely that pH adjustment would prove to lower zinc release.
- THM testing indicated that pH addition would increase THM levels above their current levels. The pilot study showed a total THM concentration of 2.5, 3.8, and 3.2 µg/L for the untreated water, aerated raw water, and raw water with caustic soda addition, respectively (all below the regulatory standard of 80 µg/L).

It is difficult to extrapolate the results of the pilot test to predict exactly how full-scale implementation of corrosion control in the drinking water system would affect effluent copper levels at the Puyallup WPCP. The impact would depend on:

- The number of drinking water sources at which corrosion control treatment was implemented,
- The relative corrosivity of the drinking water sources where corrosion control was implemented,
- The nature of the metal-bearing materials releasing copper during full-scale implementation versus the metal pipes tested in the pilot test (i.e. the age of the basin served by the source and the types of plumbing materials commonly used at that time and predominant in the basin).

TABLE 9
Precipitant Testing on Puyallup Mixed Liquor – Phase 2

Sample	Cu ug/L	Cu % removal	Al ug/L	As ug/L	Cd ug/L	Cr ug/L	Pb ug/L	Ni ug/L	Se ug/L	Zn ug/L	Hg ng/L
Mixed Liquor Blank	<0.1		<2	<0.5	<0.02	<0.2	<0.02	<0.2	<2	<0.5	<1
Total Mixed Liquor 0 PPM	10.8		20.6	0.9	0.08	0.7	0.3	2.3	<2	37.6	6.1
Total Mixed Liquor Betz 5 PPM	7.6	30%	32.6	0.9	0.07	0.5	0.38	2.1	<2	39	6.9
Total Mixed Liquor Betz 8 PPM	9.5	12%	54.6	1	0.08	0.5	0.49	2.1	<2	41	5.6
Total Mixed Liquor Betz 10 PPM	8.7	19%	49.7	0.9	0.08	0.9	0.43	2.2	<2	39	7.6
Total Mixed Liquor Betz 25 PPM	9.8	9%	70.9	0.9	0.07	0.7	0.45	1.9	<2	39.7	5.2
Dissolved Mixed Liquor 0 PPM	5.6		7.7	1.4	0.08	0.4	0.18	2.3	<2	37.7	
Dissolved Mixed Liquor Betz 5 PPM	2.5	55%	7	1.4	0.04	0.4	0.18	2.1	<2	33.6	
Dissolved Mixed Liquor Betz 8 PPM	2.5	55%	15.7	0.8	0.06	0.4	0.17	1.9	<2	30.3	
Dissolved Mixed Liquor Betz 10 PPM	1.4	75%	13.6	0.8	0.05	0.5	0.15	1.9	<2	27.2	
Dissolved Mixed Liquor Betz 25 PPM	3.6	36%	35	0.8	0.05	0.4	0.14	1.7	<2	28.9	
Total Mixed Liquor 0 PPM	10.8		20.6	0.9	0.08	0.7	0.3	2.3	<2	37.6	6.1
Total Mixed Liquor Nalco 5 PPM	8.8	19%	54.7	1	0.09	0.5	0.39	2.3	<2	43.5	4.6
Total Mixed Liquor Nalco 8 PPM	17.2	-59%	132	1.1	0.12	0.8	0.9	2.5	<2	49.9	5.4
Total Mixed Liquor Nalco 10 PPM	8.9	18%	71.4	1	0.1	0.5	0.44	2.3	<2	41.4	5.7
Total Mixed Liquor Nalco 25 PPM	9.4	13%	73.5	1	0.09	0.5	0.41	2.2	<2	41	6.7
Dissolved Mixed Liquor 0 PPM	5.6		7.7	1.4	0.08	0.4	0.18	2.3	<2	37.7	
Dissolved Mixed Liquor Nalco 5 PPM	3.3	41%	29.9	0.9	0.06	0.4	0.18	2	<2	33.5	
Dissolved Mixed Liquor Nalco 8 PPM	3.6	36%	38.8	0.8	0.07	0.4	0.18	2.1	<2	34.1	
Dissolved Mixed Liquor Nalco 10 PPM	2.8	50%	37.2	0.9	0.06	0.4	0.17	1.8	<2	32.3	
Dissolved Mixed Liquor Nalco 25 PPM	2.6	54%	41.2	0.9	0.05	0.5	0.15	1.9	<2	29.6	
Total Mixed Liquor PAC 0 PPM	10.8		20.6	0.9	0.08	0.7	0.3	2.3	<2	37.6	6.1
Total Mixed Liquor PAC 1:1000	6.6		10,300	0.5	0.08	0.5	0.13	3.4	<2	83.6	2.9
Total Mixed Liquor PAC 1:100	31.5		599,000	<5	0.6	3.5	0.84	10	<20	220	1.2
Blank Control PAC 1:100	5.5		650,000	<5	<0.2	3.5	1.41	4.5	<20	<5	

- Changes in copper release that may occur beyond the three months evaluated in this pilot test,
- The impact of the specific corrosion control method employed on copper speciation within the WPCP and thus its impact on removal processes in the WPCP.

For example, if pH adjustment were installed at Salmon Springs, a simple approximation of its effect would be to assume a 20 percent reduction in copper over 44 percent of the distribution system since Salmon Springs accounted for approximately 44 percent of source water to Puyallup in 2005. As described earlier in the Source Evaluation, drinking water corrosion was estimated to contribute seventy percent of the copper loading to the WPCP, so a twenty percent reduction in copper from Salmon Springs would equate to only a six percent ($0.20 \times 0.44 \times 0.70$) reduction in overall copper influent loading at the WPCP.

There is no guarantee that a six percent reduction in influent copper loading to the WPCP will lead to a similar six percent reduction in effluent copper loading. Given the fact that the concentrations of copper in WPCP effluent are already quite low, the concentrations of complexing ligands such as EDTA may be in stoichiometric excess of copper concentrations, and thus, without use of a stronger complexing agent than EDTA as a WPCP treatment agent, the reduction in influent copper may not be reflected in a similar reduction in effluent copper. Certainly other WWTPs (e.g., Enumclaw, Washington and LaPorte, Indiana) have observed WWTP effluent concentrations reduced significantly after implementation of drinking water corrosion control. However, Enumclaw and LaPorte WWTP effluent concentrations *after* implementation of corrosion control significantly exceed Puyallup WPCP NPDES permit limits for effluent copper.

Even if corrosion control treatment were installed at the City's three largest sources, the anticipated 20 percent reduction of copper in drinking water is not enough to facilitate the necessary reduction in effluent copper to comply with the NPDES permit limits. A nearly 50 percent reduction in effluent copper concentrations is required to reduce current levels, averaging nearly 16 µg/L, to below the monthly average limit of 8.5 µg/L.

Enhancement of WPCP Copper Removal

The majority of Puyallup's effluent copper is present as dissolved copper. Precipitation with Betz MR-2405 has shown to be the most effective treatment technology in testing conducted to date, with 75 - 95% removal of dissolved copper at optimal doses. Based on measurements of dissolved copper, the copper concentrations were reduced to well below the permit limits in both tests. However, the measurements of *total* copper in the supernatant conducted in Phase 2 did not show a similar substantial reduction as *dissolved* copper. This result indicates that the copper has precipitated (formed a solid) but not settled. Hence, subsequent testing adding flocculants (chemicals that cause solids to settle) has been conducted (results pending).

In the sample treated with powdered activated carbon in the Phase 1 testing, 47% removal of dissolved copper was observed. Activated carbon treatment typically is more successful for non-polar constituents. The fact that activated carbon was moderately successful in removing dissolved copper may indicate that a portion of copper is present in a dissolved form complexed with organic ligands (e.g., chelates, such as EDTA), as expected. The poor removal of dissolved copper observed with conventional coagulants such as alum and polyaluminum chloride suggests that the majority of copper that passes through the 0.45-micron filter used for filtration is likely not colloidal, but truly dissolved.

As shown in Table 9, although removal of dissolved copper was substantial, removal of other metals, including zinc, was not significant with the treatment chemicals employed in Phase 2 testing. This confirmed that, as anticipated, the Betz and Nalco polymers used have a high affinity for copper, and a substantially smaller affinity for other metals.

Puyallup has just completed Phase 3 (May 2006) bench testing using 30-gallon cone-bottom tanks to generate sufficient sample volumes for expanded toxicity testing and process optimization. Analytical results are pending. The City will move forward with a “full-scale pilot test” of the polymers, dosed into the flow into one of the WPCP’s secondary clarifiers, pending successful completion of the Phase 3 bench testing. Metals removal will be quantified against that in the untreated control” clarifier.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the following people for their assistance with this project: Aaron Pease and Mallory Taylor at Gray and Osborne; Allan Maas, Matthew DeBoer, Bob Gensemer and Eric Van Genderen at Parametrix; Ed Wallace at Columbia Analytical Services; Michael Brenner and Mikel Goldblatt at G.E. Infrastructure; and Doug MacClean, Craig Hale and Chuck White at the City of Puyallup.

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ATTACHMENT 3

COMMUNICATION WITH ECOLOGY

Jay Swift

From: Knight, David J. (SWRO) (ECY) [dakn461@ECY.WA.GOV]
Sent: Wednesday, February 10, 2016 9:45 AM
To: Jay Swift
Subject: RE: Woodland Reasonable Potential Analy
Attachments: 2005_Data_in_PermitCalcJanuary9-2014.xlsm

Jay, the data in the body of the fact sheet has much good information useful for calculating the hardness specific WQ Criteria for copper and zinc. I would ask you input the information there into Ecology's current model, and where better data is available, use it.

I observed from the fact sheet that the following values are provided:

Mixing Zone Ratios 5.26 (AMZR) and 74 (CMZR)

Fact sheet table 3: "Wastewater Characterization" shows ambient copper at 0.9 ug/L zinc at 4.1 ug/L, effluent copper and zinc maximums of 21.5 ug/L and 73.7 ug/L respectively. The second half of table 3 "Ambient Background Data" on the next page of the fact sheet states that the range of hardness is 15-18 mg/L. For ammonia, the ambient concentration is given as 20 ug/L, and a maximum effluent value of 27,000 ug/L was used on page 49.

Putting these into our current spreadsheet yields the following results (without using mixed hardness):

Copper: Acute Criteria, 3.73 ug/L, **Chronic Criteria 2.869 ug/L**
Zinc: Acute Criteria, 29.3 ug/L, **Chronic Criteria 26.7 ug/L**
Ammonia-N Criteria: **4.64 mg/L** (acute criteria), **0.81 mg/L** (chronic criteria)

These appear to trigger limits if effluent ammonia is as high as 13 mg/L, if Copper is as high as 6 ug/L, and Zinc is as high as 60 ug/L.

However, using an effluent hardness of 105, ambient hardness of 15 (low end of observed range), and mixed hardness for the calculation of criteria yields higher criteria for copper and zinc at the edge of the acute mixing zone:

Copper: **Acute Criteria, 5.8 ug/L**, Chronic Criteria 2.4 ug/L
Zinc: **Acute Criteria, 43.7 ug/L**, Chronic Criteria 22.4 ug/L

Using a value of 20 mg/L for hardness is less restrictive than actual mixed hardness at the chronic boundary when ambient hardness is below 20, and it is an appropriate approach. The appropriately less restrictive of allowable standards are underlined above.

Does this answer your question #1?

With respect to question #2, the answer is yes.

Dave Knight

From: Jay Swift [mailto:jswift@g-o.com]
Sent: Tuesday, February 09, 2016 3:09 PM
To: Knight, David J. (SWRO) (ECY) <dakn461@ECY.WA.GOV>
Subject: RE: Woodland Reasonable Potential Analy

Dave

Thank you for discussing the City of Woodland General Sewer Plan with me on Friday. Per our discussion, I am re-sending this previous email, along with a summary of the pertinent questions. Here is that summary:

1. Is it ok to use the water quality standards identified in the City's 2012 NPDES Permit Fact Sheet (as we have done) to complete the analysis in the General Sewer Plan?

Following approval of the General Sewer Plan, it is assumed that an assessment of potential to violate water quality standards would be re-examined within the next permit cycle, when a mixing zone study would be required. By waiting until completion of the mixing zone study, during which more ambient data is obtained and flows and mixing are better understood, permit limits can be accurately projected and compliance/treatment methods, if necessary, can be appropriately targeted.

2. Should we add additional discussion of the ability of the WWTP to nitrify to avoid a reasonable potential at future flows and loadings?

Thanks

Jay

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From: Jay Swift [<mailto:jswift@g-o.com>]
Sent: Monday, October 26, 2015 9:59 AM
To: 'Knight, David J. (SWRO) (ECY)'
Cc: 'Zentner, Greg (ECY)'; 'Ken Alexander'; 'Bart Stepp'
Subject: RE: Woodland Reasonable Potential Analy

Dave

Thanks for your thoughts on the Woodland GSP and the revised version of Appendix K - WWTF EFFLUENT PERMIT LIMITS EVALUATION we sent to you . Responses are below in green font.

Thanks

Jay

=====

Jay, it would help me if you documented the decisions on the variables that go into some of the calculations. For example, in one table you show metals criteria based on a hardness which I back calculated to be 20 mg/L, whereas in the next table (limits for copper) you show criteria which are based on a receiving water hardness of 50 mg/L. In the permit fact sheet there is a table of river data which notes that receiving water hardness data shows it to be at 11 mg/L.

Is there better data on receiving water hardness that you are using? Could you talk about what hardness values you used and why?

We do cite the basis for the acute and chronic water quality standards/criteria use in the evaluation. See citation from page 1 in our evaluation below...

“A mixing zone study was completed for the Woodland WWTP in 1999 (and updated in 2005 and 2011) that calculated dilution factors based on effluent flows that were projected for the WWTP. Ecology determined that these dilution ratios of 5.26 : 1 for the acute condition and 74 : 1 for the chronic condition were appropriate when calculating the reasonable potential for pollutants to exceed water quality criteria and calculating permit limits for the City’s most recent NPDES permit. In this evaluation, these dilution factors, along with water quality standards identified in the City’s 2012 NPDES Permit Fact Sheet and recent effluent constituent data are used to calculate the reasonable potentials to exceed water quality standards.”

To my knowledge, no new receiving water hardness data has been obtained since the 2012 Permit and Fact Sheet came out (which is based on 2005-2006 data). Since there is no new data, we did not re-derive water quality standards (WQS); we used what was in the fact sheet. Below is what page 48 of the fact sheet shows.

*FACT SHEET FOR NPDES PERMIT WA0020401
CITY OF WOODLAND WASTEWATER TREATMENT PLANT*

Pollutant, CAS No. & Application Ref. No.	Water Quality Criteria		Human Health Fresh	Taste	Me Trans Ac
	acute	chronic			
ANTIMONY (INORGANIC) 7440360 1M			14		1.
ARSENIC (dissolved) 7440382 2M	360	190			1.
COPPER - 744058 6M Hardness dependent	8.86	6.28		1000.00	0.5
CADMIUM - 7440439 4M Hardness dep.	0.65	0.31			0.
LEAD - 7439921 7M Dependent on hardness	30.14	1.17			0.
MERCURY 7439976 8M	2.10	0.012	0.14		0.
NICKEL - 7440020 9M - Hardness dep	362.70	40.28	610		0.5
SELENIUM 7782492 10M	20	5	170.00		1.
SILVER - 7740224 11M Hardness dep.	1.05	NA			0.
THALLIUM 7440280 12M		2	1.70		1.
ZINC- 7440666 13M Hardness dep.	29.27	26.72		5000.00	0.1

Receiving water studies found that the hardness was below 20 at the 10th percentile value. Therefore, a val
The WQ criteria formulas are not to be extrapolated beyond the hardnesses for which they were developed

Agreed, from back-calculating, it does appear that the fact sheet used different hardness values for zinc (20 mg/L) than they did for copper (50 mg/L) in deriving the WQS. Do you know why?

We could certainly re-derive the WQS. However, to my knowledge there is no new hardness data obtained since the Permit and Fact Sheet were issued to justify re-deriving the WQS. If we were to derive them using a hardness of 20 mg/L, and used the dilution factors in the fact sheet, we would show limits that could not be consistently met. See the table below.

I think it is appropriate to wait until we get new mixing ratios and ambient data to re-evaluate the WQS; otherwise, all we are doing is correcting the hardness-based calculations in the Fact Sheet, using the same data set available when the fact sheet was developed, which we certainly could do if you wish. However, as it drives the permit limit and treatment analysis, it would be better to wait until more ambient data is obtained and the mixing zone study is completed, so that the permit limits are known and compliance/treatment methods, if necessary, can be appropriately targeted.

You also use a COV in the calculations worksheet that is the default of 0.6 rather than calculating the actual COV (coefficient of variation is the standards deviation divided by the mean for the data set). If you aren't using the highest value (which isn't required when you have 20 or more data points), you should use the data set specific COV.

The table below shows a new analysis using the calculated COV.

Dilution (Dil'n) factor is the inverse of the percent effluent concentration at the edge of the acute or chronic mixing zone.							
Permit Limit Calculation Summary							
	Acute Dil'n Factor	Chronic Dil'n Factor	Metal Criteria Translator	Metal Criteria Translator	Ambient Concentration	Water Quality Standard Acute	Water Quality Standard Chronic
PARAMETER			Acute	Chronic	ug/L	ug/L	ug/L
COPPER - 744058 6M Hardness dependent	5.26	74.00	0.996	0.996	0.6600	3.7350	2.8692
ZINC- 7440666 13M hardness dependent	5.26	74.00	0.996	0.996	2.1300	29.27	26.72
COPPER - 744058 6M Hardness dependent	5.26	74.00	0.996	0.996	0.6600	8.8559	6.2777
ZINC- 7440666 13M hardness dependent	5.26	74.00	0.996	0.996	2.1300	63.61	58.09
COPPER - 744058 6M Hardness dependent	5.26	74.00	0.996	0.996	0.6600	3.7350	2.8692
ZINC- 7440666 13M hardness dependent	5.26	74.00	0.996	0.996	2.1300	29.27	26.72
COPPER - 744058 6M Hardness dependent	5.26	74.00	0.996	0.996	0.6600	8.8559	6.2777
ZINC- 7440666 13M hardness dependent	5.26	74.00	0.996	0.996	2.1300	63.61	58.09

Also, including the data set would be useful (actual values and dates they are from) for at least copper and zinc.

The data set was included in Attachment 1 of the revised Appendix K - WWTF EFFLUENT PERMIT LIMITS EVALUATION we had sent you.

Ecology hasn't used this spreadsheet for a couple years, instead we use "PermitCalc" now although most of the calculations haven't changed.

I checked the calcs with the new spreadsheet and got the same results.

The key data needed to calculate appropriate ammonia criteria include background pH, temperature, and receiving water ammonia concentrations. It would be good to address what data we have, and include it in the analysis. Is there any better data available? Where does it come from?

To my knowledge, there is no new data to add to that in the fact sheet.

There's a lot of text about whether POTWs can meet low copper and zinc limits that isn't really site specific to Woodland. My experience in reviewing POTW data is that lower metals levels are generally obtained with effluents that are of higher pH (7.0 or above) and lower TSS. Features to increase effluent pH and buffering (carbonate addition) and lower effluent TSS (e.g. obtained with effluent filters) are not so cost prohibitive as the text you included would seem to imply.

Given that it is understood that (1) the City will conduct a mixing zone/receiving water study within the next permit cycle, and (2) in your emails you have raised significant questions about effluent mixing that cannot be answered without a mixing zone study, it doesn't seem appropriate to get into a detailed, site-specific evaluation of means to ensure compliance with potential metals limits for Woodland. In theory, we could do a what/if analysis... If there are no limits, we don't do anything, if the limits are in a high range, we do this (however, what we do will depend on whether the metals are present in dissolved or particulate form), if the limits are in a lower range, we do something else (however, what we do will depend on whether the metals are present in dissolved or particulate form). However, this analysis is best done when the limits are known. It seems like a general discussion of means of compliance (as provided in the revised Appendix K - WWTF EFFLUENT PERMIT LIMITS EVALUATION we had sent you) is appropriate given the uncertainty over the necessity and magnitude of permit limits, and the understanding that this will be looked at in detail in the next Permit cycle. With this approach, it is understood that the City will issue a Compliance Evaluation or small amendment to its GSP when the Receiving Water /Mixing Zone Study is completed (if a GSP amendment, it is assumed it will be limited to compliance with any new limits that come out of the Mixing Zone Study).

With respect to limits, the need for treatment is key to address. The City may not have a "reasonable potential" for exceeding ammonia limits because they have been consistently treating ammonia to low levels, but what assurance does Ecology have that such treatment will continue absent a limit? Where treatment is necessary to meet the limit, EPA does not allow industries to forego sampling to assure that appropriate limits for that pollutant are met (See EPA Pretreatment Streamlining Rule revisions of 2005). In similar vein, it is best for GSP's to anticipate that limits would be applicable for any pollutant for which treatment is not incidental. In this case, the POTW can be operated in a manner which removes ammonia, or in a manner in which it doesn't. Therefore, the GSP should presume that limits would be appropriate to assure compliance regardless of whether there is any present intention to discontinue such treatment. This assures that the sizing of components (which is different depending on the level of nitrification provided) meets the needs for achieving the limits which would be appropriate to the discharge. The GSP is a planning document, not a permitting document.

We could certainly add a discussion of the ability of the WWTP to nitrify to avoid a reasonable potential at future flows and loadings. Is that what you are looking for?

Does this help?

It is helpful to sort this out before we re-submit the GSP.

Dave

From: Jay Swift [<mailto:jswift@g-o.com>]
Sent: Tuesday, October 20, 2015 12:07 PM
To: Knight, David J. (SWRO) (ECY) <dakn461@ECY.WA.GOV>
Subject: Woodland Reasonable Potential Analy

Dave

Attached is a revised version of Appendix K - WWTF EFFLUENT PERMIT LIMITS EVALUATION for the Woodland General Sewer Plan (GSP). This evaluation has been revised per our recent discussions.

Would it be possible for you to take a look at this in advance of us submitting the full revised General Sewer Plan? Following your review, we will incorporate the findings from this analysis into the GSP WWTP chapter.

Thanks

Jay

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