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M E M O R A N D U M
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To: Frank Monahan

Through: Dick Cunningham

From: Bill Yake

Subject: Tacoma Central (#1) Sewage Treatment Plant Class II (Priority Pollutants) Surveys: August 25-26, 1981, and February 16-17, 1982

INTRODUCTION

Two source/receiving water studies were conducted at the Tacoma Central Sewage Treatment Plant (STP). These surveys were conducted on August 25-26, 1981, and February 16-17, 1982, and reflect dry (low plant flow) and storm (high plant flow) conditions, respectively. In addition to the results of these two major studies, an effluent sample was collected on July 28, 1981, and the results from this sample are also reported. These studies are part of a series of source-oriented surveys conducted cooperatively by the Washington State Department of Ecology (WDOE) and Region 10 of the federal Environmental Protection Agency (EPA). The focus of these surveys is to identify and quantify priority pollutants in wastewater discharges and the impact of these discharges on adjacent surface waters and sediments in and near Commencement Bay.

Participants in the Tacoma Central STP surveys included Jim Hileman (EPA, Region 10), Bill Yake and Dale Norton (WDOE, Water Quality Investigations Section), and Ken Mauermann (WDOE, Southwest Regional Office). The City of Tacoma was represented by Dave Hufford. The studies of the receiving waters and sediments were conducted by Art Johnson and Shirley Prescott (WDOE, Water Quality Investigations Section). The results of these receiving water studies are published in a separate report (Johnson and Prescott, 1982).

Setting

The Tacoma Central (#1) STP is located on the south side of the Puyallup River at approximately river mile 1.6 (see Figure 1). This primary treatment plant serves a population of 115,000 and numerous industries. The original plant was completed in 1952. An upgrade of the existing

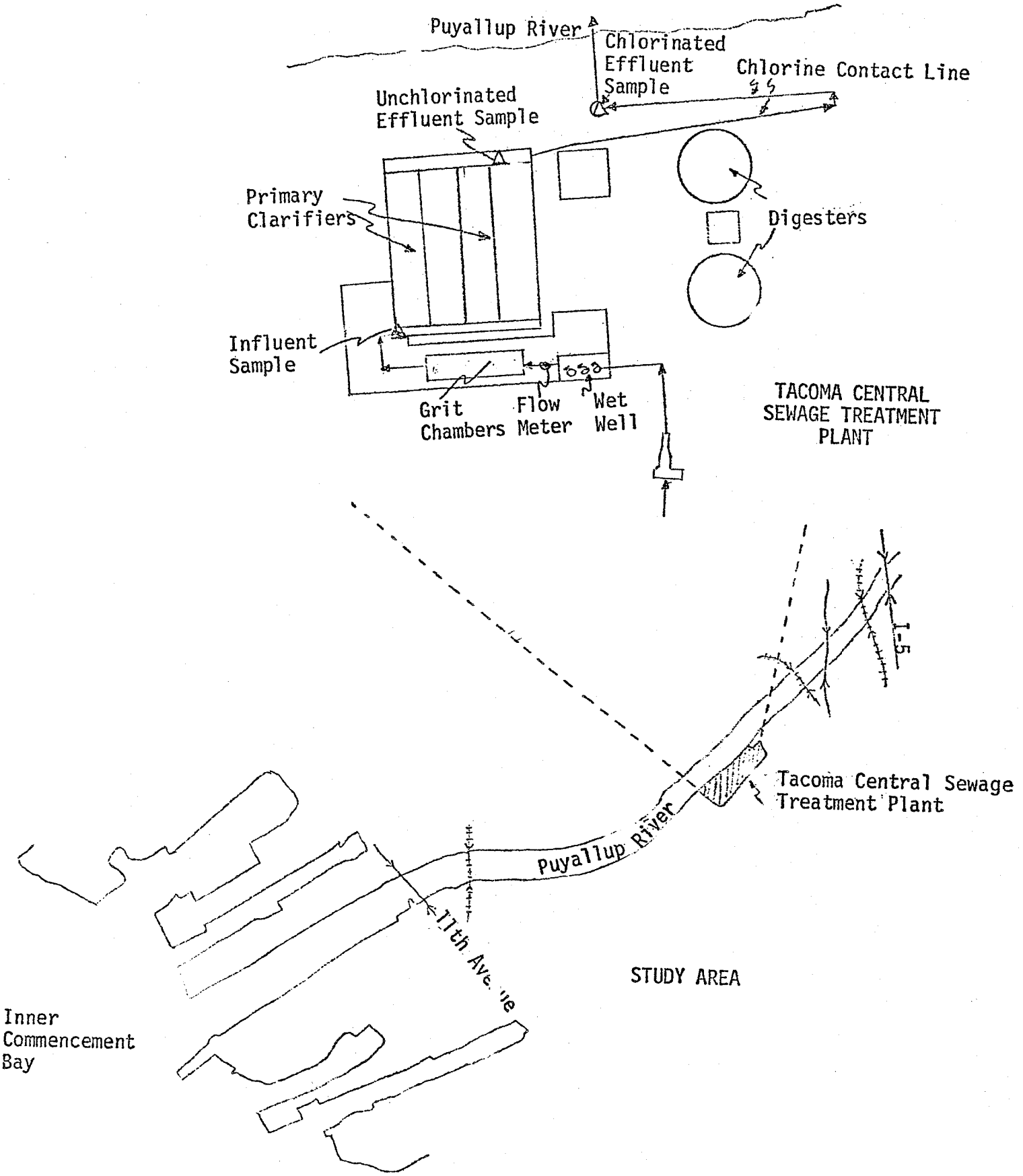

Figure 1. Study area: Puyallup River and Tacoma Central Sewage Treatment Plant.

facility has been in progress for the past several years and was formally completed in March 1982 when the City of Tacoma accepted the upgraded plant. The plant has a dry-weather design flow of 28 MGD and a peak wet-weather design flow of 78 MGD.

Treatment plant layout is given in Figure 1. Wastewater is pumped from an influent wet well to grit chambers. It then flows by gravity to four rectangular primary clarifiers operated in parallel. After clarification, wastewater is chlorinated and routed through a buried pipe which serves as a contact chamber. Effluent is discharged to the Puyallup River through a single outfall pipe on the south bank. Depending on river flow and tide conditions, this outfall can be either exposed or submerged.

If flow to the plant exceeds its maximum 78 MGD capacity, excess flow can back up into the sewer system and ultimately overflow a weir, carrying the bypassed sewage to the Cleveland Avenue pump station, from which it is discharged to the Puyallup River.

Plant flow is measured by a magnetic flow meter located on the discharge line from the influent pump station.

Sampling Design

Influent and effluent wastewater samples were collected during both surveys. Sample locations, times, and types (composite or grab) for each survey are summarized in Tables 1A and 1B. Laboratories responsible for each of the analyses are summarized in Table 2.

Table 2. Laboratories providing analyses.

Constituents	Responsible Agency	Dates	Laboratory
Oil & grease, phenolics, nutrients, BOD, COD, solids, fecal coliform, metals, turbidity, conductivity, pH	WDOE	8/81 & 2/82	WDOE, Tumwater, WA
Daphnid and oyster larvae bioassays	EPA	8/81	EPA, Manchester, WA
Sediment (amphipod) bioassays	EPA	8/81	EPA, Newport, OR
Organic priority pollutants	EPA	8/81 & 2/82	California Analytical Laboratories, Sacramento, CA
Organic priority pollutants	EPA	7/81	Science Applications, Inc.

Table 1A. Sample times and location, August 25-26, 1981.

24-hour Composite Samples

Sample	Installation Date (Time)	Location
Influent	8/25/81 (1040)	Channel after grit chamber, immediately prior to primary clarifiers
Unchlorinated Effluent	8/25/81 (1035)	Channel immediately downstream of primary clarifiers
Chlorinated Effluent	8/25/81 (0940)	Collection well inside fence, immediately prior to discharge

Grab Samples

Sample	Collection Date (Time)	Laboratory Analysis
Influent	8/25/81 (1010)	Oils & grease; phenols
Unchlorinated Effluent	8/25/81 (1040)	Oils & grease; phenols
	8/25/81 (1130)	Oils & grease
Chlorinated Effluent	8/25/81 (0945)	Fecal coliform; oils & grease; phenols
	8/26/81 (0940)	Fecal coliform

Field Analyses

Location	Sample Date (Time)	Field Analyses
Influent	8/25/81 (1010)	pH; temperature; conductivity
	8/26/81 (1040)	pH; temperature; conductivity
Unchlorinated Effluent	8/25/81 (1035)	pH; temperature; conductivity
	8/26/81 (1100)	pH; temperature; conductivity
	8/25-26/81 (Comp)	pH
Chlorinated Effluent	8/25/81 (0910)	pH; temp.; cond.; D.O.; TCR
	8/25/81 (0945)	TCR
	8/25/81 (1220)	TCR; D.O.
	8/26/81 (0915)	pH; temp.; cond.; D.O.; TCR
	8/26/81 (0940)	TCR

Table 1B. Sample times and location, February 16-17, 1982.

24-hour Composite Samples

Sample	Installation Date (Time)	Location
Influent	2/16/82 (1200)	In channel downstream of grit chambers
Chlorinated Effluent	2/16/82 (1230)	Collection well inside fence, immediately prior to discharge

Grab Samples

Sample	Collection Date (Time)	Laboratory Analysis
Influent	2/17/82 (1030)	Cyanide; recoverable phenolics
Chlorinated Effluent	2/16/82 (1235)	Fecal coliform
	2/17/82 (1000)	Fecal coliform; cyanide; recoverable phenolics

Field Analyses

Location	Sample Date (Time)	Field Analyses
Influent	2/16/82 (1300)	pH; temperature; conductivity
	2/16/82 (1030)	pH; temperature; conductivity
Chlorinated Effluent	2/16/82 (1235)	pH; temp.; cond.; D.O.; TCR
	2/17/82 (1000)	pH; temp.; cond.; TCR

Most laboratory analyses for conventional and priority pollutants, as well as bioassays, were performed on composite samples of wastewater collected before and after primary treatment. Portable ISCO samplers were provided by U.S. Environmental Protection Agency (EPA) Region 10 to collected these samples. The samplers and sample bottles were cleaned according to EPA priority pollutant protocol. Laboratory and field blanks were obtained for each sampler to detect possible contamination. Treatment plant personnel also collected composite samples of influent and unchlorinated effluent for conventional pollutant analyses. During the first (August 25) survey, all composite samples were split to provide comparison of BOD, suspended solids, COD, pH, and metals results from the WDOE and the treatment plant laboratories. During the second (February 16) survey, the treatment plant composites were split for comparison of BOD, COD, and suspended solids results only.

Grab samples were obtained for oils and grease, phenols, and fecal coliform analyses; while chlorine residual, dissolved oxygen, temperature, and pH were determined in the field.

Organic pollutant analytical results from California Analytical Laboratories and Science Applications, Inc. were reviewed by Joseph Blazevich (EPA, Manchester). The data reported here are those which met the quality assurance criteria of the EPA reviewer.

As indicated earlier, flow is measured by a magnetic flow meter on the discharge pipe from the influent wet well. At the time of the first (August, 1981) survey, neither the script chart nor the totalizer had been installed. Therefore, instantaneous flow was read and recorded hourly from the flow meter dial. A 24-hour flow was obtained by averaging these flows for the sampling period.

RESULTS AND DISCUSSION

The following section discusses results and observations in four general categories: (1) compliance with effluent limitations; (2) laboratory procedures and comparison of split sample results; (3) specific priority and other pollutants; and (4) bioassay results.

Compliance with Effluent Limitations

The permit status of the Tacoma Central STP is somewhat involved. The most recent full permit (#WA-003708-7) contained interim permit limits (Section S1) and final permit limits (Section S2). In general terms, the interim limits apply to primary treatment while the final limits assume secondary treatment. This permit expired October 9, 1979.

A permit extension letter was sent to Tacoma on October 22, 1979, and subsequently an Order (Docket No. DE-80-317) was issued to the city on June 24, 1980, which specified: "Effluent limits specified in condition S1 of the permit will be complied with until March 1, 1982. New effluent limitations will be established when sufficient data has (sic) been obtained on the upgraded primary facility."

Thus, with one apparent exception, the S1 permit limits applied during the surveys. The one exception is the chlorine residual limitation. In a letter dated August 18, 1980, the chlorine residual limit was apparently waived. The letter states "...we will accept your use of MPN's [fecal coliform counts] as a means for determining if adequate disinfection is occurring."

It should be noted that the S1 permit conditions do not set fecal coliform limits and that the August 18, 1980, letter makes no mention of fecal coliform limits. Now that the upgrade is complete and redrafting the permit is necessary, it would be useful to incorporate appropriate fecal coliform limits into the new permit. This will be discussed later in this section.

Both surveys were conducted prior to formal completion of the plant upgrade; thus the results here may not fully represent the current capabilities of the plant. In general, however, it did not appear that plant operation during the surveys was significantly hampered by on-going upgrade activities. One possible exception to this was the initial failure of the chlorine residual probes in the effuent sampling well. Because these probes were not working, effluent residual chlorine had to be measured manually and plant personnel had to manually adjust the chlorine feed. This resulted in some low chlorine residuals during the first survey. During the first survey, rehabilitation work was being conducted on the sedimentation (primary clarifier) tanks. This probably had little effect on plant efficiency as plant flow was low and operational clarifiers provided adequate capacity for this low flow.

Table 3 summarizes the results of effluent monitoring during the two surveys and compares these results to the permit limitations in effect during the survey. Tables 4A and 4B report all conventional pollutant results for the two surveys.

Based on Table 3, Tacoma Central STP performance with respect to permit limits can be summarized as follows:

1. Measured pH values all fell within the permitted range.

2. Effluent BOD concentration exceeded the monthly average permit limit during the low-flow survey while effluent BOD loading exceeded the monthly average permit limit during the high-flow survey.

3. Suspended solids results were similar to BOD results in that effluent suspended solids concentrations exceeded the monthly average permit loading during the low-flow survey while effluent suspended solids loading exceeded both the weekly and monthly average permit during the high-flow survey.

Table 3. Permit compliance, Tacoma Central STP.

Parameter (units)	Final (Chlorinated) Effluent Values		Permit Requirements	
	Aug. 25-26, 1981	Feb. 16-17, 1982	Weekly Average	Monthly Average
Flow (MGD)	16.5	71.8	--	50
BOD (mg/L)	250	120	295	234
(lbs/day)	34,000	72,000	78,000	52,000
Suspended Solids (mg/L)	170	81	255	123
(lbs/day)	23,000	49,000	45,000	30,000
Total Chlorine Resid. (mg/L)	0.2* <0.1* 0.2*	1.2* 1.2*	$\geq$0.5†	
pH (Standard Units)	6.2* 6.6* 7.3	6.9* 6.8* 7.2	6.0 - 9.0	

†Permit states: "...shall be maintained at a minimum level of 0.5 mg/L"; however, this requirement apparently waived at time of inspection. See text.

*Grab sample, field analysis.

In reviewing the data available from these surveys and recent discharges monitoring reports (DMRs), several important points have been noted:

1. A large and variable portion of the plant's BOD loading appears to be from industrial sources. The plant serves a population of about 115,000 people. Based on the standard loading of 0.17 lb. of BOD_5 per capita day, this would result in a load to the plant of about 20,000 lbs/day. Based on DMR data from August 1981 to March 1982, monthly average BOD_5 loading to the plant ranged from approximately 35,000 to 78,000 lbs/day. It therefore appears that industrial BOD_5 can make up approximately 45 to 75 percent of the plant's BOD load.

Table 4A. Tacoma Central STP, conventional pollutant results, August 25-26, 1981.

Parameter	Influent WDOE/EPA Samples	Influent STP Samples	Unchlorinated Effluent WDOE/EPA Samples	Unchlorinated Effluent STP Samples	Chlorinated Effluent WDOE/EPA Samples
Flow (MGD)	16.5	16.5	16.5	16.5	16.5
BOD_5 (mg/L)	†	†	†	†	250
(lbs/day)	†	†	†	†	34,000
TSS (mg/L)	610	530	130	140	170
(lbs/day)	84,000	73,000	18,000	19,000	23,000
Cond. (μmhos/cm)	1,220	1,260	1,230	1,240	1,240
pH (S.U.)	7.2	7.0	7.2	7.2	7.3
	6.5**		6.9††		
	7.0**		6.3**		6.2**
			6.8**		6.6**
Temperature (°C)	21.1**		21.4**		21.2**
	22.2**		22.0**		21.4**
Dissolved Oxygen (mg/L)					3.2**
					1.8**
					2.9**
					1.5**
Tot. Chl. Res. (mg/L)					0.2**
					0.2**
F. Coli. (#/100 ml)					2,600
					11,400
Turbidity (NTU)	300	240	149	147	168
Total Solids (mg/L)	1,300	1,300	920	920	930
TNVS (mg/L)	720	730	640	640	620
TSS (mg/L)	610	530	130	140	170
TNVSS (mg/L)	140	88	20	27	35
NH_3-N (mg/L)	21		20		22
NO_2-N (mg/L)	<.125		<.1		<.1
NO_3-N (mg/L)	<.125		<.1		<.1
O-PO_4-P (mg/L)	7.0		5.2		5.6
T-PO_4-P (mg/L)	10.5		8.0		9.15
PBI (mg/L)	150				150
Recoverable Phenolics	1.7*		0.28*		0.45*
	.17		0.16		0.22
Oil & Grease (mg/L)	58*		12*		27*
	18*		16*		26*
COD (mg/L)	820	1,000	540	600	590

* = Grab sample, lab analysis
** = Grab sample, field analysis
† = BOD results rejected, analyses questionable
†† = Composite sample, field analysis

Table 4B. Tacoma Central STP conventional pollutant results February 16-17, 1982.

Parameter	Influent		Effluent	
	WDOE Comp.	STP Comp.	WDOE Comp.	STP Comp.
Flow (MGD)	71.8		71.8	
BOD (mg/L)	140	140	120	120
(lbs/day)	84,000	84,000	72,000	72,000
TSS (mg/L)	120	140	81	78
(lbs/day)	72,000	84,000	49,000	47,000
COD (mg/L)	260	260	260	200
pH (S.U.)	7.2	7.0	7.2	7.5
	6.9**		6.9**	
	6.7**		6.8**	
Temperature (°C)	11.9*		11.7*	
	11.1*		10.7*	
Dissolved Oxygen (mg/L)			9.2*	
Spec. Cond. (μmhos/cm)	498		480	
	610**		690**	
	450**		420**	
Turbidity (NTU)	58		57	
Total Solids (mg/L)	480		420	
TNVS (mg/L)	250		250	
Sus. Solids (mg/L)	120	140	81	78
NVSS (mg/L)	24		20	
NH_3-N (mg/L)	4.5		4.4	
NO_2-N (mg/L)	<0.1		<0.1	
NO_3-N (mg/L)	3.2		2.7	
O-PO_4-P (mg/L)	1.3		1.3	
T-PO_4-P (mg/L)	2.6		2.7	
Recoverable Phenolics (mg/L)	.078*		.067*	
Fecal Coliform (#/100 ml)			2,200*[1]	
			480*[2]	
Total Chlorine Res. (mg/L)			1.2*[1]	
			1.2*[2]	

* = Grab sample
** = Grab sample, field analysis

[1]February 16, 1982 at 1235 hours.
[2]February 17, 1982 at 1000 hours.

2. Both suspended solids and BOD loading are highly variable. The variations in monthly average BOD load have been noted above. During the same time period, monthly average influent suspended solids loads varied from approximately 43,000 to 64,000 lbs/day. Daily variations in both parameters are more extreme than monthly variations.

3. The effect of flow on the plant's ability to meet current permit limits is reflected in the survey results. During the low-flow (16.5 MGD) survey, BOD removal efficiency was 43 percent (based on STP laboratory data) and suspended solids removal efficiency was 77 percent. During the high-flow (71.8 MGD) survey, BOD removal efficiency fell to 14 percent and suspended solids removal efficiency dropped to 33 percent. Comparison of WDOE treatment plant design criteria (WDOE, 1978) to conditions at the Tacoma Central treatment plant helps explain this steep drop in efficiency at high flows. Pertinent Tacoma STP sizing data (Krolikowski, 1982) include a total primary clarifier surface area of 26,800 ft^2 and a total weir length of 2,148 linear feet. The criteria (WDOE, 1978) for primary clarifiers not preceding secondary treatment state that the overflow rate should not exceed 2,000 gpd/ft^2 at peak design flow. This rate is exceeded whenever flows at the plant exceed 53 MGD. It should be noted that design at Tacoma Central has been premised on the assumption that the plant will eventually be upgraded to secondary treatment. When secondary treatment is provided, the clarifiers will meet the peak overflow rate criterion for primary clarifiers followed by secondary treatment. The weir loading criterion states that "Loadings should not exceed 15,000 gpd/li. ft." This criterion is exceeded whenever the plant flows exceed 32 MGD.

As noted previously, there are currently no fecal coliform limits in Tacoma Central's permit. Table 5 summarizes fecal coliform results obtained during the two surveys.

Part of the plant upgrade included installing some of the piping that is to be eventually used when the plant is upgraded to secondary treatment. In the interim, this piping will be used as a chlorine contact chamber. This interim contact chamber does not meet all of the detention time criteria for disinfection but is a substantial improvement over the pre-upgrade disinfection system. The volume of the present contact chamber is 317,000 gallons and provides contact times noted in Table 6.

Table 5. Fecal coliform results.

Date	Time	Sampled by: Receiving Water Team	Sampled by: Facility Survey Team	Total Chlorine Residual (mg/L)	Fecal Coliform Count (col/100 mls)
8/25/81	0945		X	0.2	2,600
8/26/81	0830	X			176 est.
	0940		X	0.2	11,400
	1055	X		<0.1	100 est.
	1250	X			180
	1450	X		<0.1	500 est.
	1645	X			330 est.
	1845	X			530
2/16/82	1235		X	1.2	2,200
2/17/82	1000		X	1.2	480

Table 6. Chlorine contact time versus flow.

Flow (MGD)	Contact Time
10	46 minutes
15	30 minutes
20	23 minutes
30	15 minutes
50	9 minutes
78	6 minutes

Because of the interrelationships among chlorine residual concentrations, contact time, and disinfection efficiency, it would probably be valuable to have Tacoma Central personnel record these simultaneous values for several months. Prior to this, however, problems with the fecal coliform analytical procedure should be corrected (see Review of Laboratory Procedures). Using these data (which would define the disinfection efficiency for the present system) along with receiving water goals for fecal coliform and chlorine residual concentrations, appropriate permit limits could be set. Although the data in Table 5 are limited, it appears that the present system is capable of adequate

disinfection at fairly low chlorine residuals as long as plant flows are low to moderate. Higher chlorine residuals may be required when high plant flows result in low contact time. The goal of interim studies and final permit limitations should be to achieve adequate disinfection with minimum chlorine residual concentrations.

Laboratory Procedures and Comparison of Split Sample Results

Laboratory procedures for BOD, suspended solids, and fecal coliforms were reviewed with laboratory personnel during the August 1981 survey. In addition, a number of composite samples collected by both the WDOE personnel and STP personnel were split for analysis by both the WDOE Tumwater laboratory and the STP laboratory. The results of these split sample analyses are summarized in Table 7. Results of laboratory procedure reviews and split sample results are discussed below by constituent:

BOD5 - Because WDOE results for most of the 8/25-26/81 BOD samples were rejected, only two split sample results are available for comparison. Of these, one compares well (125 vs. 120) while on the other the STP laboratory recorded a substantially higher value than the WDOE laboratory (200 vs. 140). Based on the COD values for this sample, the STP value appears to be high while the WDOE value appears realistic.

The BOD procedure used by the treatment plant laboratory appeared to be generally quite good. However, several recommendations were made which may improve the reliability of the BOD data:

1. The pH of the influent and effluent samples should be checked. If pH values are outside the 6.5 to 8.5 range, the samples should be neutralized and seeded. Evidently sample pH is now being checked and samples neutralized if necessary. Seeding has not been instituted, but will be.

2. The PAO used for the dissolved oxygen titration should be checked to confirm its normality. Normality should be determined when a new batch is prepared and checked weekly thereafter. This involves titrating against a known bi-iodate standard as described in Standard Methods (APHA, 1980).

3. Initial dilution water dissolved oxygen (D.O.) concentrations were somewhat low (7 to 8 mg/L). These concentrations should approach saturation: 9.2 mg/L at 20°C. Dilution water is neither aged nor aerated. This is probably responsible for the low initial D.O. values. Aging and/or aeration of dilution water is recommended.

Table 7. Comparison of laboratory results.

	August 25-26, 1981										February 16-17, 1982					
	Influent				Unchlor. Effluent				Chlor. Effluent		Influent			Unchlor. Effluent		Chlor. Effluent
	WDOE Composite		STP Composite		WDOE Composite		STP Composite		WDOE Composite		WDOE Composite	STP Composite		STP Composite		WDOE Composite
	WDOE Lab	STP Lab	WDOE Lab	STP Lab	WDOE Lab	STP Lab	WDOE Lab	STP Lab	WDOE Lab	STP Lab	WDOE Lab	WDOE Lab	STP Lab	WDOE Lab	STP Lab	WDOE Lab
BOD (mg/L)	*	330	*	280	*	195	*	160	250	--	140	140	200	120	125	120
Susp. Solids (mg/L)	610	584	530	441	130	137	140	133	170	--	120	140	134	81	66	78
COD (mg/L)	820	892	1000	833	540	493	600	508	590	--	260	260	275	260	315	200
pH (S.U.)	7.2	7.2	7.0	--	7.2	--	7.2	7.0	7.3	--	7.2	7.0	--	7.2	--	7.5
T-As (µg/L)	19	85.4	--	79.8	7	67.8	--	62.3	12	57.1	23	--	<6	--	<6	23
T-Cd (µg/L)	1.5	26	--	16	0.7	2.1	--	5.7	2.0	2.3	3	--	22	--	28	1
T-Cr (µg/L)	116	110	--	75	42	84	--	63	76	65	<10	--	--	--	--	<10
T-Cu (µg/L)	100	204	--	270	37	93	--	109	53	126	50	--	57	--	68	50
T-Hg (µg/L)	--	7.2	--	3.1	--	2.3	--	1.1	--	2.3	<0.2	--	--	--	--	<0.2
T-Ni (µg/L)	100	68	--	44	59	60	--	35	59	76	60	--	--	--	--	170
T-Pb (µg/L)	96	200	--	109	29	131	--	152	39	75	70	--	--	--	--	80
T-Zn (µg/L)	640	830	--	581	210	368	--	564	340	275	110	--	358	--	336	130

*BODs rejected, questionable results.
-- = None detected.

Suspended Solids - Split-sample agreement for suspended solids is generally good although STP results are somewhat lower than WDOE results for five out of six of the split samples. Agreement was within ±20 percent in all cases and much closer in most cases.

Review of laboratory procedures resulted in only one recommendation. The laboratory was using Whatman GF/C filter papers. It was recommended that the laboratory switch to a filter specifically approved by Standard Methods. The laboratory has subsequently switched to an approved filter (Whatman 940 A/H).

Fecal Coliform - Review of laboratory procedures for fecal coliform revealed several procedural errors which should be addressed:

1. The incubator temperature was at 46°C rather than the required 44.5 ± 0.2°C. A log should be maintained which records both temperature and incubator setting on at least a daily basis. Both temperatures should be maintained within the 44.3 to 44.7°C range.

2. It appeared that the operator responsible for the test was using distilled water rather than sterilized dilution water to rinse down the filter. This has apparently been remedied.

3. It also appeared that the very small blue specks on the filter were being counted as colonies. These are not fecal coliforms but packets or single insect eggs and should not be counted.

4. Some results were being reported as TNTC (too numerous to count). DMRs should report these counts as "greater than" values, using the procedure described in the WDOE procedures manual (Woodward, 1977).

5. In reviewing recent fecal coliform results reported on the DMRs, it appears that despite recent decreases in effluent fecal coliform counts, only 1 ml of sample is being filtered for analysis. Sample volumes should be chosen which are expected to yield the recommended 20 to 60 colonies per filter. If counts are variable, several volumes or dilutions should be used so that at least one will yield this recommended range of colonies per filter. Initially, volumes of 50, 15, and 5 mls should yield accurate counts under normal operating conditions.

Other Constituents - Laboratory procedures for other constituents were not reviewed in detail. Brief comments regarding split-sample results and other observations are noted below.

pH - Split-sample results showed good comparison.

COD - Split-sample results agreed within ± 17 percent.

Metals - Split samples were run by both laboratories for total (digested) metals. Although agreement for certain metals in certain samples was good, results were often erratic with STP laboratory results being generally higher than WDOE laboratory results. The reason for these discrepancies is unknown.

Specific Priority and Other Pollutants

The results of pollutant analyses are summarized in the following tables: Conventional pollutant concentrations - Tables 4A and 4B; priority pollutant concentrations - Tables 8A, 8B, and 8C; tentatively identified organic compounds - Tables 12A, 12B, and 12C (pages 27, 28, and 29; and priority pollutant loadings - Table 16, (page 41).

Priority Pollutants

A total of seven samples from the Tacoma Central STP were analyzed for priority pollutants. Twenty-four-hour composite samples of influent and chlorinated effluent, as well as grab samples of digested sludge were collected for analysis during both the low-flow (August 1981) and high-flow (February 1982) surveys. In addition, a four-hour grab composite of chlorinated effluent was obtained on July 28, 1981. Table 8A summarizes the analytical results for each of these samples, plus a grab sample of chlorinated effluent obtained by EPA (September 30, 1980). Priority pollutant results obtained for all source and receiving environment samples during the low- and high-flow surveys are summarized in Tables 8B and 8C.

A total of 46 priority pollutants were detected in one or more wastewater or sludge samples from the Tacoma plant. Forty-three of these were detected in influent or effluent wastewater samples. Twenty priority pollutants were detected in the sludge samples. The detection of fewer organic priority pollutants in the sludge samples is probably due to the difficulties associated with extracting many of these compounds from the organic sludge matrix.

Table 8A. Priority pollutar - Tacoma Central STP (units: water (µg/L), sludge (µg/Kg d.w.)).

Parameter	Influent (µg/L) WDOE 8/25-26/81	Influent (µg/L) WDOE 2/16-17/82	Effluent (µg/L) EPA 9/23/80	Effluent (µg/L) WDOE 7/28/81	Effluent (µg/L) WDOE 8/25-26/81	Effluent (µg/L) WDOE 2/16-17/82	Sludge (µg/Kg d.w.) WDOE 8/26/81	Sludge (µg/Kg d.w.) WDOE 2/17/82
Flow (MGD)	16.5	71.8	?	?	16.5	71.8		
% Solids							9.2%	7.1%
Metals								
Arsenic - Total	19	23	10	<1	12	23	22,000	23,000
Cadmium - Total	1.5	3	7.9	10	2.0	1	21,000	14,000
Chromium - Total	116	<10	34	57	76	<10	160,000	74,000
Copper - Total	100	50	35	50	53	50	520,000	500,000
Lead - Total	96	70	45	<100	39	80	610,000	480,000
Mercury - Total	1.3	<0.2	0.63	<0.2	0.63	<0.2		6,300
Nickel - Total	100	60	33	39	59	170	100,000	79,000
Zinc - Total	640	110	150	150	340	130	1,800,000	1,600,0[illegible]
Volatiles								
Methylene chloride	*	*	7	*	*	*	--	--
Chloroform	7.5	7.3	21	18	16	8	--	--
Bromodichloromethane	--	--	0.8	3.2	--	--	--	--
Chloroethane	--	--	2	--	--	--	--	--
1,1-dichloroethane	2.4	--	0.2	--	1.1	--	--	--
1,1,1-trichloroethane	2.1	2	1.3	--	1.1	1	--	--
1,1,2,2-tetrachloroethane	--	--	1.1	--	--	--	--	--
1,2-trans-dichloroethylene	--	--	1	--	--	--	--	420
Trichloroethylene	12	--	6	--	10	--	--	
Tetrachloroethylene	2.8	12	5.2	2.6	2.3	110	--	--
Benzene	--	--	0.5	63	--	3	T	--
Chlorobenzene	--	--	--	--	--	--	3,100	--
Ethylbenzene	--	--	2	2	--	--	1,170	700
Toluene	3.4	3	13	10	--	8	1,170	--
Base Neutral Extractables								
Napthalene	6.8	3.8	1	2.5	4.5	4.9	3,370	--
Anthracene/phenanthrene	--	--	1	0.7	--	--	3,900	--
Fluoranthene	--	--	--	--	--	--	2,280	T
Pyrene	--	--	1	--	--	--	2,200	T
1,2-dichlorobenzene	7.3	--	5	--	5.6	--	--	--
1,4-dichlorobenzene	4.2	--		--	3.3	--	--	--
1,3-dichlorobenzene	--	--	--	3.6	--	--	--	--
Di-ethyl phthalate	1.2	--	7	*	--	--	--	--
Di-n-butyl phthalate	8.5	1	3	--	--	--	--	--
Di-n-octyl phthalate	--	--	4.1	--	2.1	--	--	--
Bis(2-ethyl hexyl) phthalate	58	--	7	17	25	--	--	--
Butyl benzyl phthalate	10	--	--	21	--	--	--	--
Acid Extractables								
Phenol	20	2.7	30	27	34	18	1,200	T
2-chlorophenol	1.5	3.9	19	--	8.2	5.7	--	--
2,4-dichlorophenol	1.9	69	15	--	4.5	8.5	--	--
2,4,6-trichlorophenol	5.0	8.4	62	--	5.3	11	--	--
Pentachlorophenol	--	18	4	T(<40)	--	24	--	--
2,4-dimethylphenol	--	--	--	5.1	3.9	--	--	--
Pesticides								
4,4'-DDT	--	--	.033	--	--	--	--	--
4,4'-DDD	--	--	.020	--	--	--	--	--
α-BHC	--	0.36	.018	--	--	--	--	170
Δ-BHC	--	--	--	--	--	0.1	--	--
γ-BHC (Lindane)	--	0.36	.057	--	--	--	--	--
PCB-1260	--	--	--	--	--	--	--	980
Cyanide	20	70			18	85		

* = Present, but also present in blanks.
-- = None detected.
T = Trace; compound present, concentration less than limit of quantification.

Table 8B. Tacoma Central STP and receiving environment - priority pollutants - August 25-26, 1981 (units: water [µg/L], sludge and sediments [µg/Kg d.w.]).

Parameter	Puyallup River Above STP		Tacoma Central STP			Puyallup River				
						Flood Tide Near STP Discharge	Below STP		Near Mouth	
	Water	Sediment	Influent	Effluent	Sludge	Water	Water	Sediment	Water	Sediment
% Solids		30.5%			9.2%			35.3%		23.9%
Metals										
Arsenic - Total	4	9,400	19	12	22,000	8	18	8,000	11	5,400
Cadmium - Total	<5	190	1.5	2.0	21,000	<5	<5	560	<5	170
Chromium - Total	<10	4,600	116	76	160,000	<10	<10	7,900	<10	3,800
Copper - Total	<10	20,000	100	53	520,000	30	<10	28,000	20	16,000
Lead - Total	<20	5,800	96	39	610,000	<20	<20	12,000	<20	3,400
Mercury - Total	0.2	890	1.3	0.63		0.32	0.44	280	<0.2	90
Nickel - Total	<10	9,700	100	59	100,000	<10	<10	12,000	<10	8,100
Zinc - Total	28	14,000	640	340	1,800,000	140	370	42,000	15	13,000
Volatiles										
Chloroform	--	--	7.5	16	--	5.6	--	--	--	--
1,1,1-trichloroethane	--	--	2.1	1.1	--	--	--	--	--	--
Trichloroethylene	--	--	12	10	--	8.6	--	--	--	--
Tetrachloroethylene	--	--	2.8	2.3	--	1.4	--	--	--	--
Toluene	--	--	3.4	--	1,170	--	--	7,900	--	--
Benzene	--	--	--	--	T	--	--	--	--	--
Ethylbenzene	--	--	--	--	1,170	--	--	--	--	--
Chlorobenzene	--	--	--	--	3,090	--	--	--	--	--
1,2-dichlorobenzene	--	--	7.3	5.6	--	4.2	--	--	--	--
1,4-dichlorobenzene	--	--	4.2	3.3	1,600	2.1	--	--	--	--
Base Neutral Extractables										
Fluoranthene	--	--	--	--	2,300	--	--	--	--	--
Naphthalene	--	--	6.8	4.5	3,400	1.9	--	--	--	--
Anthracene/phenanth...	--	--	--	--	3,900	--	--	--	--	--
Fluorene	--	--	--	--	1,600	--	--	--	--	--
Pyrene	--	--	--	--	2,200	--	--	--	--	--
Bis(2-ethylhexyl) phthalate	--	--	58	25	98,000	--	--	3,100	--	--
Butyl benzl phthalate	--	--	10	--	8,400	--	--	--	--	--
Di-n-butyl phthalate	--	T	8.5	--	8,300	--	--	--	--	T
Di-n-octyl phthalate	--	--	4.1	2.1	3,900	--	--	T	--	--
Diethyl phthalate	--	--	1.2	--	--	--	--	--	--	--
Acid Extractables										
Phenol		T	20	34	1,200	80	--	310	--	T
2-chlorophenol		--	1.5	8.2	--	1.1	--	--	--	--
2,4-dichlorophenol	-	--	1.9	4.5	--	T	--	--	--	--
2,4,6-trichlorophenol	--	--	5	5.3	--	5.7	--	--	--	--
2,4-dimethylphenol	--	--	--	3.9	--	--	--	--	--	--

T = Trace; less than limit of quantification.

-- = None detected.

Table 8C. Tacoma Central STP and receiving environment - priority pollutants - February 16-17, 1982 (units: water [µg/L], sludge [µg/Kg d.w.]).

Parameter	Puyallup R. above. Cleveland Avenue	Cleveland Avenue Pump Station	Tacoma Central STP Influent	Tacoma Central STP Effluent	Tacoma Central STP Sludge	Puyallup R. at 11th St. Bridge
Metals						
Arsenic - Total	<2	32	23	23	23,000	5
Dissolved			27	27		
Cadmium - Total	<5	<5	3	1	14,000	<5
Dissolved			<1	<1		
Chromium - Total	<20	<20	<10	<10	74,000	<20
Dissolved			<10	<10		
Copper - Total	20	220	50	50	500,000	20
Dissolved			<10	<10		
Lead - Total	4	200	70	80	480,000	4
Dissolved			56	39		
Mercury - Total	<0.2	<0.2	<0.2	<0.2	6,300	<0.2
Nickel - Total	<5	9	60	170	79,000	8
Dissolved			52	96		
Zinc - Total	35	220	110	130	1,600,000	50
Dissolved			42	52		
Volatiles						
Chloroform	--	--	7.3	8	--	--
1,1,1-trichloroethane	--	--	2	1	--	--
Tetrachloroethylene	--	--	12	110	--	--
Benzene	--	--	--	3	--	--
1,2-dichlorobenzene	--	3.5	--	--	--	--
Ethylbenzene	--	--	--	--	700	--
Toluene	--	--	3	8	--	--
Base Neutral Extractables						
Napthalene	--	--	3.8	4.9	--	--
Fluoranthene	--	--	--	--	T	--
Pyrene	--	--	--	--	T	--
Di-n-butyl phthalate	--	--	1	--	--	--
Acid Extractables						
Phenol	--	--	2.7	18	T	--
2-chlorophenol	--	--	3.9	5.7	--	--
2,4-dichlorophenol	--	--	69	8.5	--	--
2,4,6-trichlorophenol	--	--	8.4	11	--	--
Pentachlorophenol	--	--	18	24	--	--
Pesticides						
4,4'-DDE	--	--	--	--	170	--
α-BHC	--	--	0.36	--	--	--
γ-BHC	--	--	0.36	--	--	--
Δ-BHC	--	--	--	0.1	--	--
PCB-1260	--	--	--	--	980	--
Cyanide	8	8	70	85		5
Percent Solids					7.1%	

-- = None detected.
T = Trace; less than limit of quantification.

A wider range of priority pollutants was isolated in Tacoma Central STP wastewaters than in any of the sources previously sampled in the Commencement Bay studies. This result is not unexpected as nearly all of the pollutants identified have previously been reported in municipal wastewaters (EPA, 1980). EPA (1980) has reported priority pollutant data for 20 municipal sewage treatment plants throughout the United States. For each pollutant, they report the range of concentrations and frequency with which each was detected in plant influents. Table 9 compares these values with equivalent values for Tacoma Central STP wastewater samples. In the case of most priority pollutants, concentrations at the Tacoma plant appear to be similar to influent concentrations at other municipal facilities. The exceptions to this general observation are the chlorinated phenols which are present in substantially higher concentrations than those observed at other facilities; and possibly arsenic which appeared to be more consistently present in Tacoma wastewaters. Reichhold Chemicals is the major known source of potential chlorinated phenol loads to the Tacoma Central plant.

It should be noted that although the metals concentrations noted in wastewater samples do not appear unusually high when compared to EPA's data for treatment plants throughout the country, sludge metals concentrations noted at the Tacoma plant do indicate that, in general, metals concentrations at the Tacoma facility may be higher than concentrations at most Washington State treatment plants. This will be discussed in more detail later.

Tables 10A, 10B, and 10C compare the concentrations of priority pollutants observed in Tacoma Central effluent during each of the three sampling periods to EPA receiving water criteria for these pollutants. The "sample-to-criteria ratios" represent the approximate dilution ratios which would be required to meet these criteria if the effluent was diluted with uncontaminated surface waters. In general, some metals, cyanide, the phthalate esters, and (in one case) pentachlorophenol, were found in high enough concentrations to require dilution to meet the EPA criteria for acute and/or chronic toxicity to aquatic life. Cadmium, lead, nickel, mercury, and cyanide concentrations were found (during at least one sampling period) at concentrations which would require at least a 20:1 dilution ratio to meet the chronic aquatic toxicity criterion. The concentations of pollutants actually found in the receiving water (the Puyallup River) are discussed in detail by Johnson and Prescott (1982).

The "carcinogenic risk criteria" based on human consumption of fish from contaminated waters were exceeded (during at least one sampling period) for arsenic, anthracene/phenanthrene, tetrachloroethylene, benzene, 2,4,6-trichlorophenol, and chloroform. The degree to which effluent concentrations exceeded criteria were substantial for arsenic (690 to 1300 x) and anthracene/phenanthrene (80 x); all others were marginal.

Table 9. Comparison of priority pollutants detected at Tacoma Central STP to those detected at other treatment plants.[1]

Priority Pollutant	Influent Samples from 20 Municipal Plants Reported by EPA[1]		Influent and Effluent Samples from Tacoma Central STP	
	% of Time Pollutant Detected in Samples	Concentration Range (µg/L)	% of Time Pollutant Detected in Samples	Concentration Range (µg/L)
Zinc	100	23-7680	100	130-640
Copper	100	34-1190	100	35-100
Cyanide	99	3-2500	100	18-85
Chromium	99	8-2380	67	<10-116
Toluene	98	2-500	83	3-13
Tetrachloroethylene	97	2-1100	100	2.8-110
Chloroform	96	1-430	100	7.3-21
Trichloroethylene	95	1-860	50	6-12
Bis(2-ethylhexyl) phthalate	94	2-390	67	7-58
1,1,1-trichloroethane	91	1-1600	83	1-2.1
Nickel	87	11-1930	100	33-170
Ethylbenzene	86	1-448	33	2
Phenol	83	1-380	100	2.7-34
Lead	79	16-935	100	39-96
Cadmium	71	1-1800	67	1.5-10
Mercury	70	0.2-3.9	50	0.63-1.3
Benzene	68	1-1560	50	0.5-63
Di-n-butyl phthalate	63	1-105	50	1-8.5
Di-ethyl phthalate	62	1-33	40	1.2-7
Butylbenzyl phthalate	59	2-140	33	10-21
1,2-trans-dichloroethylene	58	1-97	17	1
Naphthalane	55	1-150	100	1-6.8
1,1-dichloroethane	40	1-24	50	0.2-2.4
1,2-dichlorobenzene	30	2-440	50	5-7.3
*Pentachlorophenol	27	2-94	67	4-24
Anthracene/phenanthrene	27	1-93	33	0.7-1
γ-BHC	23	.02-0.5	33	.06-0.4
1,4-dichlorobenzene	23	2-200	50	3.3-5
*Arsenic	16	2-80	83	10-23
Bromodichloromethane	10	1-4	33	0.8-3.2
Pyrene	9	5-84	17	1
2,4-dimethyl phenol	9	1-55	33	3.9-5.1
1,3-dichlorobenzene	9	3-92	17	3.6
Di-n-octyl phthalate	8	5-210	33	2.1-4.1
1,1,2,2-tetrachloroethane	5	3-52	17	1.1
*2,4,6-trichlorophenol	5	1-6	83	5-62
α-BHC	5	.05-3	33	.02-.36
*2,4-dichlorophenol	5	1-12	83	1.9-69
*2-chlorophenol	5	1-5	83	1.5-19
4,4'-DDD	1	0.31-0.77	17	.02
Δ-BHC	1	0.5	17	0.1
4,4'-DDT	0		17	.033

*Priority pollutants which appear to be relatively more prevalent in Tacoma Central STP wastewaters.

[1]Data from EPA (1980).

Table 10A. Comparison of Tacoma Central effluent priority pollutant concentrations (July 28, 1981) to EPA receiving water criteria (all concentrations in µg/L).

Priority Pollutant	Effluent Conc. (µg/L)	Water Quality Criteria: Aquatic Life: Freshwater: Criteria: Acute	Freshwater: Criteria: Chronic	Freshwater: Sample/Criteria Ratio: Acute	Freshwater: Sample/Criteria Ratio: Chronic	Saltwater: Criteria: Acute	Saltwater: Criteria: Chronic	Saltwater: Sample/Criteria Ratio: Acute	Saltwater: Sample/Criteria Ratio: Chronic	Human Health Food (Fish) Intake*: Criteria	Human Health Food (Fish) Intake*: Sample/Criteria Ratio
Cadmium	10	1.5(1)	.012(1)	/6.7/	/833/	59	4.5	0.17	/2.2/	**	--
Chromium	57	2200(1,2)	44(2)	0.03	/1.3/	10,300(2)	**	6×10^{-3}	--	3.4×10^{6}(3)	1.7×10^{-5}
Copper	50	12(1)	5.6	/4.1/	/8.9/	23	4.0	/2.2/	/12.5/	**	--
Nickel	39	1100(1)	56(1)	0.04	0.9	140	7.1	0.36	/7.0/	100(3)	0.50
Zinc	150	180(1)	47(1)	0.83	/3.2/	170	58	0.88	/2.6/	**	--
Chloroform	18	28,900	1,240	6.2×10^{-4}	.015	**	**	--	--	15.7	/1.1/
Bromodichloromethane	3.2	11,000	**	2.9×10^{-4}	--	12,000	6,400	2.7×10^{-4}	5×10^{-4}	15.7	0.2
Tetrachloroethylene	2.6	5,280	840	4.9×10^{-4}	3.1×10^{-3}	10,200	450	2.5×10^{-4}	6×10^{-3}	8.85	0.3
Benzene	63	5,300	**	.012	--	5,100	700	.012	.09	40	/1.6/
Ethyl benzene	2	32,000	**	6.3×10^{-5}	--	430	**	4.6×10^{-5}	--	3,280(3)	6.1×10^{-4}
Toluene	10	17,500	**	5.7×10^{-4}	--	6,300	5,000	1.6×10^{-3}	2×10^{-3}	4.24×10^{5}(3)	2.4×10^{-6}
Napthalene	2.5	2,300	620	1.1×10^{-3}	4×10^{-3}	2,350	**	1.1×10^{-3}	--	**	--
Anthracene/phenanthrene	0.7	**	**	--	--	300	**	2.3×10^{-3}	--	.0311	/80/
1,3-dichlorobenzene	3.6	1,120	763	3.2×10^{-3}	4.7×10^{-3}	1,970	**	1.8×10^{-3}	--	2,600(3)	1.4×10^{-3}
Bis(2-ethyl hexyl) phthalate	17	940	3	.018	/5.7/	2,944	3.4(4)	5.8×10^{-3}	/5.0/	50,000(3)	3.4×10^{-4}
Butyl benzl phthalate	21	940	3	.022	/7/	2,944	3.4(4)	7.1×10^{-3}	/6.2/	**	--
Phenol	27	10,200	2,560	2.6×10^{-3}	.011	5,800	**	4.7×10^{-3}	--	**	--
2,4-dimethyl phenol	5.1	2,120	**	2.4×10^{-3}	--	**	**	--	--	**	--

(1) Based on total hardness of 50 mg/L as $CaCO_3$.

(2) Criteria for trivalent chromium.

(3) Based on toxicity rather than carcinogenic risk.

(4) Based on toxicity to one form of algae.

-- = None detected.

/ / = Sample/criteria ratio >1.

*These criteria assume human consumption of fish from waters with pollutant concentrations as noted. Concentrations are those which EPA calculates would result in one (1) additional cancer per 10^6 exposures.

**No criterion presently available.

Table 10B. Comparison of Tacoma Central effluent priority pollutant concentrations (Aug. 25-26, 1981) to EPA receiving water criteria (all concentrations in µg/L).

Priority Pollutant	Effluent Load (lbs/day)	Effluent Conc. (µg/L)	Water Quality Criteria: Aquatic Life: Freshwater: Criteria: Acute	Freshwater: Criteria: Chronic	Freshwater: Sample/Criteria Ratio: Acute	Freshwater: Sample/Criteria Ratio: Chronic	Saltwater: Criteria: Acute	Saltwater: Criteria: Chronic	Saltwater: Sample/Criteria Ratio: Acute	Saltwater: Sample/Criteria Ratio: Chronic	Human Health Food (Fish) Intake*: Criteria	Human Health Food (Fish) Intake*: Sample/Criteria Ratio
Arsenic	1.7	12	440(1)	40(1)	.03	0.30	508(1)	**	.02	--	.0175	/690/
Cadmium	0.28	2.0	1.5(2)	.012(2)	/1.3/	/170/	59	4.5	.03	0.44	**	--
Chromium	10.5	76	2200(2,3)	44(3)	.03	/1.7/	10,300(3)	**	.01	--	3.4×10^{6}(6)	2.2×10^{-5}
Copper	7.3	53	12(2)	5.6	/4.4/	/9.5/	23	4.0	/2.3/	/13/	**	--
Mercury	.087	.63	.0017	.00057	/370/	/1100/	3.7	.025	0.17	/25/	.146(6)	/4.3/
Nickel	8.1	59	1100(2)	56(2)	.05	/1.1/	140	7.1	.42	/8.3/	100(6)	0.59
Lead	5.4	39	74(2)	0.75(2)	.53	/52/	668	25	.06	/1.6/	**	--
Zinc	47	340	180(2)	47(2)	/1.9/	/7.2/	170	58	/2.0/	/5.9/	**	--
Chloroform	2.2	16	28,900	1240	5.5×10^{-4}	.01	**	**	--	**	15.7	/1.02/
1,1-dichloroethane	0.15	1.1	118,000(4)	20,000(4)	1×10^{-5}	5.5×10^{-5}	113,000(4)	**	1×10^{-5}	--	24.3(4)	.05
1,1,1-trichloroethane	0.15	1.1	18,000	**	6×10^{-5}	--	113,000	**	1×10^{-5}	--	1.03×10^{6}(6)	1×10^{-6}
Trichloroethylene	1.4	10	45,000	**	2×10^{-4}	--	2000	**	.005	--	80.7	0.12
Tetrachloroethylene	0.32	2.3	5280	840	4×10^{-4}	.003	10,200	450	2×10^{-4}	.005	8.85	0.26
Napthalene	0.62	4.5	2300	620	.002	.007	2350	**	.002	--	**	--
1,2-dichlorobenzene	0.77	5.6	1120	763	.005	.007	1970	**	.003	--	2600(6)	.002
1,4-dichlorobenzene	0.45	3.3	1120	763	.003	.004	1970	**	.002	--	2600(6)	.001
Bis(2-ethyl hexyl) phthalate	3.4	25	940	3	.03	/8.3/	2944	3.4	.008	/7.4/	50,000(6)	5×10^{-4}
Di-n-octyl phthalate	0.29	2.1	940	3	.002	0.7	2944	3.4	.001	0.6	**	--
Phenol	4.7	34	10,200	2560	.003	.01	5800	**	.006	--	**	--
2-chlorophenol	1.1	8.2	4380	2000(5)	.002	.004	**	**	--	--	**	--
2,4-dichlorophenol	0.62	4.5	2020	365	.002	.01	**	**	--	--	3090(6)	.001
2,4,6-trichlorophenol	0.73	5.3	**	970	--	.005	**	**	--	--	3.6	/1.5/
2,4-dimethyl phenol	0.54	3.9	2120	**	.002	--	**	**	--	--	**	--
Cyanide	2.5	18	52	3.5	0.4	/5.1/	30	2.0	0.60	/9.0/	**	--

(1) Criteria for trivalent inorganic arsenic.
(2) Based on total hardness of 50 mg/L as $CaCO_3$.
(3) Criteria for trivalent chromium.
(4) Criteria for 1,2-dichloroethane.
(5) Criteria for "flavor impairment".
(6) Based on toxicity rather than carcinogenic risk.

/ / = Sample/criteria ratio >1.

* = These criteria assume human consumption of fish from waters with pollutant concentrations as noted. Concentrations are those which EPA calculates would result in one (1) additional cancer per 10^6 exposures.

** = No criterion presently available.

Table 10C. Comparison of Tacoma Central effluent priority pollutant concentrations (February 16-17, 1982) to EPA receiving water criteria (all concentrations in µg/L).

Priority Pollutant	Effluent Load (lbs/day)	Effluent Conc. (µg/L)	Water Quality Criteria: Aquatic Life: Freshwater: Criteria: Acute	Freshwater: Criteria: Chronic	Freshwater: Sample/Criteria Ratio: Acute	Freshwater: Sample/Criteria Ratio: Chronic	Saltwater: Criteria: Acute	Saltwater: Criteria: Chronic	Saltwater: Sample/Criteria Ratio: Acute	Saltwater: Sample/Criteria Ratio: Chronic	Human Health Food (Fish) Intake*: Criteria	Human Health Food (Fish) Intake*: Sample/Criteria Ratio
Arsenic	14	23	440(1)	40(1)	.05	0.58	508(1)	**	.05	--	.0175	/1300/
Cadmium	0.6	1	1.5(2)	.012(2)	.67	/83/	59	4.5	.02	.22	**	--
Copper	30	50	12(2)	5.6	/4.2/	/5.4/	23	4.0	/1.3/	/7.5/	**	--
Nickel	102	170	1100(2)	56(2)	.15	/3.0/	140	7.1	/1.2/	/24/	100(4)	/1.7/
Lead	48	80	74	0.75(2)	/1.1/	/110/	668	25	.12	/3.2/	**	--
Zinc	31	52	180	47	.29	/1.1/	170	58	.31	0.9	**	--
Chloroform	4.8	8	28,900	1240	2.8×10^{-4}	.01	**	**	--	--	15.7	0.5
1,1,1-trichloroethane	0.6	1	18,000	**	5.6×10^{-5}	--	113,000	**	8.8×10^{-6}	--	1.03×10^{6}(4)	9.7×10^{-7}
Tetrachloroethylene	66	110	5280	840	.02	.13	10,200	450	.01	0.24	8.85	/12/
Benzene	1.8	3	5300	**	5.6×10^{-4}	--	5100	700	5.9×10^{-4}	4.3×10^{-3}	40	.08
Toluene	4.8	8	17,500	**	4.6×10^{-4}	--	6300	**	1.3×10^{-3}	--	4.24×10^{5}(4)	1.9×10^{-5}
Napthalene	2.9	4.9	2300	620	2.1×10^{-3}	.01	2350	**	2.1×10^{-3}	--	**	--
Phenol	11	18	10,200	2560	1.8×10^{-3}	7.1×10^{-3}	5800	**	3.1×10^{-3}	--	**	--
2-chlorophenol	3.4	5.7	4380	2000(3)	1.3×10^{-3}	2.9×10^{-3}	**	**	--	--	**	--
2,4-dichlorophenol	5.1	8.5	2020	365	4.2×10^{-3}	.023	**	**	--	--	3090(4)	2.7×10^{-3}
2,4,6-trichlorophenol	6.6	11	**	970	--	.01	**	**	--	--	36	.31
Pentachlorophenol	14	24	55	3.2	.44	/7.5/	53	34	.45	.71	**	--
Δ-BHC	.06	0.1	100	**	1×10^{-3}	--	.34	**	.29	--	**	--
Cyanide	51	85	52	3.5	/1.6/	/24/	30	2.0	/2.8/	/43/	**	--

(1) Criteria for trivalent inorganic arsenic.
(2) Based on total hardness of 50 mg/L as $CaCO_3$
(3) Criteria for "flavor impairment".
(4) Criteria based on toxicity rather than carcinogenic risk.

/ / = Sample/criteria ratio >1.

* = These criteria assume human consumption of fish from waters with pollutant concentrations as noted. Concentrations are those which EPA calculates would result in one (1) additional cancer per 10^6 exposures.

** = No criterion presently available.

Priority pollutant loadings for each of the sampling periods are summarized in Table 16, page 41. The loads for each of the sampling periods are averaged to provide an estimate of the average load of each of the priority pollutants from the Tacoma Central plant. It should be noted that in some cases extreme ranges in loadings for certain priority pollutants were noted when different sampling periods are compared (tetrachloroethylene - 0.32 to 66 lbs/day; nickel - 5.5 to 102 lbs/day; and arsenic - <0.14 to 14 lbs/day). It may be significant that in the case of each of these pollutants the highest loading occurred during the high-flow sampling period. In fact, the highest loading for each of the metals, the chlorinated phenols, and cyanide also occurred during the high-flow sampling period. This phenomenon has been noted previously for metals. In a study of 20 municipal plants, EPA (1980) concluded: "Heavy rainfall increased metallic priority pollutant mass loading at POTW's with combined sewer collection systems." The potential for short-term (slug) loads of pollutants in a system like Tacoma Central with numerous industrial connections is substantial. Thus, a continuing sampling and analysis effort would probably substantially improve estimates of the average and extreme concentrations and loadings of priority pollutants in Tacoma Central STP's wastewaters.

Based on only two sampling periods, it is difficult to assess the efficiency of the plant in removing priority pollutants. However, the primary treatment provided by the plant does not appear to remove most priority pollutants very efficiently (Tables 8A, 8B, and 8C). Efficiency certainly does not approach the average efficiency reported by EPA for secondary treatment plants (76 percent reduction of total priority pollutant metals, 85 percent reduction of total volatile priority pollutants, and 70 percent reduction of total acid-base-neutral priority pollutants).

Table 11 summarizes the sludge metals data for the August and May surveys and compares these values to sludge metals concentrations at other Washington State plants. Although comparable data are not available for arsenic and mercury, data for the other metals suggest that metals concentrations at the Tacoma Central facility are higher than average. This is particularly true for cadmium, chromium, nickel, and lead.

Tentatively Identified Compounds

In addition to the priority organic pollutants, other organic compounds isolated in the samples were "tentatively identified" by computer matching of mass spectra with records in the EPA-NIH data bank. These tentative identifications were then reviewed by Joseph Blazevich (EPA, Manchester). Only those identifications with which the EPA reviewer concurred were accepted. In some cases the contract

laboratory provided estimated concentrations for "tentatively identified" compounds. If so, these estimates are reported here. Tables 12A, 12B, and 12C summarize the data for the "tentatively identified" compounds.

Table 11. Tacoma Central - sludge metals (mg/Kg d.w.).

Sample Location		Date	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Tacoma Central		8/25/81	22	21	160	520	--	100	610	1800
Tacoma Central		2/17/82	23	14	74	500	6.3	79	480	1600
19	Statewide Primary Plants	Geometric Mean	--	6.9	57	430	--	49	320	1300
		Geo. Mean ± 1 S.D.*	--	3.7-13	23-140	220-850	--	26-94	160-670	660-250
16	Statewide Activated Sludge Plants	Geometric Mean	--	6.9	81	330	--	18	240	1200
		Geo. Mean ± 1 S.D.*	--	1.7-28	42-150	170-610	--	2.7-115	110-520	620-230
12	Statewide Trickling Filter or RBC Plants	Geometric Mean	--	5.1	37	490	--	32	340	1600
		Geo. Mean ± 1 S.D.*	--	0.7-37	6.6-200	170-1500	--	24-43	180-630	1100-2200

-- = No data.
* = Standard deviation.

A brief summary of available and pertinent information on these compounds or groups of compounds follows:

Alkanes - A total of ten straight chain and branched paraffins were identified in the treatment plant effluent sample collected on July 28, 1981. The number of carbons in these alkanes ranged from 9 to 36 and included compounds associated with the gasoline, kerosene, diesel, light lubricant, and paraffin wax fractions of petroleum. All estimated concentrations were less than 20 µg/L. Many of these compounds are typically associated with municipal wastewater and may originate from highway runoff, combustion of petroleum products, and general use of petroleum oils and tars. The fact that these compounds were only isolated in the July 28 sample may be more a function of the laboratory analysis than changes in the quality of the wastewaters. It also may be a function of the sampling technique. The July 28 sample was collected directly into the one-gallon, glass container used to send the sample to the laboratory.

There are no alkanes included in EPA's list of priority pollutants. The concentrations of these substances noted in the effluent, particularly because they are low, probably do not represent a major concern.

Table 12A. Tacoma Central - tentatively identified compounds, August 25-26, 1981.

	Puyallup River Above STP		Tacoma Central STP			Puyallup River				
						Flood Tide Near STP Discharge	Below STP Discharge		Near Mouth	
	Water	Sediment	Influent	Effluent	Sludge	Water	Water	Sediment	Water	Sediment
Decanoic acid	--	--	--	--	--	--	--	TI	--	--
Dodecanoic acid	--	--	TI	--	--	TI	--	TI	--	--
Tridecanoic acid	--	--	TI	TI	--	TI	--	TI	--	--
Tetradecanoic acid	--	--	TI	TI	--	TI	--	TI	--	--
Pentadecanoic acid	--	--	TI	TI	--	TI	--	TI	--	--
Heptadecanoic acid	--	--	--	TI	--	TI	--	--	--	--
Octadecanoic acid	--	--	TI	--	--	TI	--	--	--	TI
Methyltetradecanoate	--	--	--	--	--	--	--	TI	--	--
Methylhexadecanoate	--	--	--	--	--	--	--	TI	--	TI
Butenoic acid	--	--	TI	--	--	--	--	--	--	--
Propanoic acid	--	--	TI	--	--	--	--	--	--	--
Benzene acetic acid	--	--	TI	--	--	TI	--	TI	--	--
2-methylbenzoic acid	--	--	--	--	--	TI	--	--	--	--
4-methylbenzoic acid	--	--	TI	--	--	--	--	--	--	--
2-methyl phenol	--	--	--	--	--	--	--	TI	--	--
α,α,4-trimethyl-(S)3-cyclohexene-1-methanol	--	--	TI	TI	--	TI	--	--	--	--
3,3,3-trichloro-1-propene	--	--	--	--	--	TI	--	--	--	--
1,2-dimethylbenzene	--	--	--	TI	--	--	--	--	--	--
1,2,4-trimethylbenzene	--	--	--	TI	--	--	--	--	--	--
1,2,4,5-tetramethylbenzene	--	--	--	--	TI	--	--	--	--	--
3α,5α-cholestan-3-ol	--	--	--	--	--	--	--	TI	--	--

TI = Compound tentatively identified in sample.
-- = Non detected.

Table 12B. Tentatively identified compounds, February 16-17, 1982.

	Puyallup R. above Lift Station	Tacoma Central STP			Puyallup R. at 11th Street
		Influent	Effluent	Sludge	
	(µg/L)	(µg/L)	(µg/L)	(µg/Kg d.w.)	(µg/L)
Benzoic acid	--	--	20 est.	--	--
Dodecanoic acid	--	27 est.	40 est.	--	--
Tetradecanoic acid	--	20	30 est.	940 est.	--
Pentadecanoic acid	--	--	--	940 est.	--
Hexadecanoic acid	--	110 est.	300 est.	3500 est.	--
9-hexadecanoic acid	--	--	70 est.	--	--
Octadecanoic acid	--	20 est.	--	--	--
α,α,α-trimethyl-3-cyclohexene-1-methanol	--	26 est.	20 est.	--	--
4-chloro-trans-cyclohexanol	--	30 est.	--	--	--
3-hexen-2-one	--	--	--	51,000 est.	--
3,7-dihydro-3,7-IH-purine-2,6-dione	--	9 est.	10 est.	--	--
4-(1,1-dimethylethyl)phenol	--	15 est.	20 est.	--	--
Dibenzothiophene	--	10m	--	--	--

Est. = Estimated concentration.
m = Compound detected; concentration less than value given (below level of quantification).
-- = None detected.

Table 12C. Summary of tentatively identified compounds - Tacoma Central STP.

Constituent	Influent 8/25-26/81 (µg/L)	Influent 2/16-17/82 (µg/L)	Effluent 7/28/81 (µg/L)	Effluent 8/25-26/81 (µg/L)	Effluent 2/16-17/82 (µg/L)	Sludge 8/26/81 (µg/Kg d.w.)	Sludge 2/17/81 (µg/Kg d.w.)
2,2,3,4-tetramethyl pentane			11 est.				
2-methyl-5-ethyl heptane			2.7 est.				
2,6-dimethyl octane			19 est.				
2-methyl nonane			4 est.				
Undecane			36 est.				
2,6,11-trimethyldodecane			2.9 est.				
Hexadecane			7.4 est.				
Eicosane			14 est.				
Pentacosane			7.8 est.				
Hexatricontane			7.1 est.				
(1-methylethyl)-cyclohexane			20 est.				
1-methyl-3-propylbenzene			22 est.				
1,2-dimethylbenzene				TI			
1,3-dimethylbenzene			21 est.				
1,2,3-trimethylbenzene			42 est.				
1,2,4-trimethylbenzene			90 est.	TI			
1,2,3,5-tetramethylbenzene			14 est.				
1,2,4,5-tetramethylbenzene						TI	
1-ethyl-2-methylbenzene			7.7 est.				
Dibenzothiophene		10m					
Propanoic acid	TI						
Butanoic acid	TI						
Pentanoic acid			7.9 est.				
4-methyl pentanoic acid			17 est.				
Hexanoic acid			30 est.				
2-methylhexanoic acid			2.3 est.				
Octanoic acid			23 est.				
Nonanoic acid			8.5 est.				
Decanoic acid			15 est.				
Dodecanoic acid	TI	27 est.			40 est.		
Tridecanoic acid	TI			TI			
Tetradecanoic acid	TI	20 est.	38 est.	TI	30 est.		940 est.
Pentadecanoic acid	TI			TI			940 est.
Hexadecanoic acid		110 est.			300 est.		3500 est.
9-hexadecanoic acid			19 est.				
Heptadecanoic acid				TI			
Octadecanoic acid	TI	20 est.					
Benzoic acid			12 est.		20 est.		
4-methylbenzoic acid	TI						
Benzene acidic acid	TI		11 est.				
Benzene propanoic acid			11 est.				
Phosphoric acid, tributyl ester			4.9 est.				
α,α,4-trimethyl-,(S)-3-cyclohexane-1-methanol (terpineol)	TI	26 est.	60 est.	TI	20 est.		
2-butoxyethanol			17 est.				
2-(2-butoxyethoxy)-2-ethoxyethanol			4.3 est.				
1-ethyl-1-hexanol			20 est.				
4-chloro-trans-cyclohexanol		30 est.					
2-propyl-1-heptanol			46 est.				
3,7-dimethyl-1-octanol			44 est.				
1-dodecanol			5.3 est.				
4-methyl phenol			19 est.				
2-methoxy phenol			5 est.				
4-(1,1-dimethylethyl)phenol		15 est.			20 est.		
4-(1,1,3,3-tetramethylbutyl)phenol			1.4 est.				
[1,1'-biphenyl]-2-ol			2.7 est.				
1-(methylphenyl) ethanone			12 est.				
1-(4-hydroxy-3-methoxy-phenyl)ethanone			1.6 est.				
3-hexen-2-one							51,00 est.
Piperidinone			3.2 est.				
1,3,7-trimethyl-3,7-dihydro-1-H-purine-2,6-dione (caffiene)			15 est.				
Nonanamide			7.1 est.				

Est. = Estimated concentration.
TI = Tentatively identified.
m = Compound detected; concentration less than value given (below level of quantification).

Alkylated Aromatics - Eight alkyl-substituted benzenes were noted during the three sampling periods in either the wastewater stream or the sludge at the Tacoma Central plant. These compounds included two isomers of xylene (dimethylbenzene), 2 trimethylbenzene isomers, 2 tetramethylbenzene isomers, a methylpropylbenzene isomer, and an ethylmethylbenzene isomer. In addition to benzene itself, there are two alkyl-substituted benzenes (ethylbenzene and toluene) which are designated as priority pollutants. These three priority pollutants were also found, at various times, in the wastewater stream.

The probable source of these compounds is not clear although many of them are prevalent in higher octane gasoline and aviation fuel. A number of these compounds are also used in the organic synthesis of such materials as dyes, insecticides, pharmaceuticals, plasticizers, polymers, and fibers. For those which have toxicity data available, toxicity to marine organisms appears generally in the 1 to 20 mg/L range (Neff, 1979). The relatively low concentrations estimated in the effluent (5 to 100 µg/L) probably do not represent a significant problem with respect to toxicity to aquatic organisms.

Dibenzothiophene - Dibenzothiophene is a three-ring, heteroaromatic hydrocarbon containing two benzene rings joined by a five-member ring containing a sulfur atom. It was one of the compounds quantified in sediment and marine organism tissue by the National Oceanic and Atmospheric Administration (NOAA) (Malins, *et al.*, 1982). Concentrations of this compound were somewhat elevated in certain Commencement Bay sediments. The compound was noted at less than 10 µg/L in the Tacoma Central influent sample obtained during the high-flow (February, 1982) sampling. Dibenzothiophene appears to be a byproduct of burning coal (Lee, *et al.*, 1977) as well as a component of crude oil (O'Conner and Stanford, 1979). Neff (1979) reports the results of two 96-hour toxicity tests for dibenzothiophene. The LC_{50} for grass shrimp was 280 µg/L; that for sheepshead minnow was 3,180 µg/L. The single low-level value detected in plant influent probably does not represent a problem.

Carboxylic Acids - A number of aliphatic and aromatic acids were identified in one or more wastewater and sludge samples from the Tacoma Central plant. The erratic identification of many of these compounds (for instance,

the fact that the 5- to 10-carbon aliphatic acids were identified only in the July 1981 sample) is probably more a function of different testing and reporting protocols at different EPA contract laboratories than an indication of substantial variations in wastewater constituents.

Aliphatic Acids - Seventeen aliphatic (straight chain) acids were identified in Tacoma Central STP samples. These ranged from 3- to 18-carbon acids and included a number of naturally occurring fatty acids. These compounds generally have little or no toxicity associated with them and most occur in natural fats, oils, and waxes. Verschueren (1977) gives typical concentrations for five of these aliphatic acids in domestic sewage or sewage effluents. Concentrations for three of these compounds (hexadecanoic, octadecanoic, and hexanoic acid) were estimated in at least one Tacoma Central wastewater sample. For these three compounds, agreement is good between values reported in Tacoma Central wastewaters and Verschueren's values. It appears that the presence of these aliphatic acids is common in domestic sewage. Linden, *et al.* (1979) tested the toxicity of a technical mixture of C_6-C_{10} acids called "Hager Blue". The 96-hour LC_{50} values for this mixture were 800 to 1,000 mg/L for the bleak (a brackish water fish, *Alburnus aburnus*) and 1,150 mg/L for *Nitocra spinipes* (a brackish water harpacticoid). The sum of the estimated concentrations for C_6-C_{10} aliphatic acids during the July 1981 survey was about 100 µg/L or approximately .01 percent of the acute toxicity values given above. Domestic sources of these compounds include animal and vegetable fats, soaps, detergents, cosmetics, and food additives, while industrial uses include lube oils, dispersing agents, ore separators, and synthesis of a wide range of organic compounds.

Aromatic Acids - Four benzene-based acids were identified in wastewater samples (benzoic acid, 4-methylbenzoic acid, benzene acetic acid, and benzene propanoic acid). No information was found on the latter two compounds.

Benzoic Acid - Benzoic acid is a germicide and food preservative allowed in concentrations up to 0.1 percent if foods (Hawley, 1981). Toxicity to fish has been reported in the 100 to 300 mg/L range (Verschueren, 1977), far above the concentration (10 to 12 µg/L) reported in the treatment plant's effluent.

4-methylbenzoic acid (para-toluic acid) - This chemical is used in agricultural chemicals and as an animal food supplement and has an acute oral LD_{50} of .4 to 3.2 g/Kg (Verschueren, 1977). No information was found regarding aquatic toxicity.

Phosphoric acid, tributyl ester (Tributyl phosphate) - This compound is used as a heat exchange medium, anti-foam agent, plasticizer, solvent for nitrocellulose and cellulose acetate, and as a solvent for extraction of metal ions from solutions of reactor products (Hawley, 1971). Verschueren (1977) reports the maximum allowable concentration (Germany) in drinking water is 10 µg/L. This compound was detected at an estimated concentration of 4.9 µg/L in the July 1981 effluent sample.

Alcohol-based Hydrocarbons

Four of the alcohol-based compounds tentatively identified in Tacoma Central STP wastewaters are relatively simple, straight- or branched-chain alcohols: 1 ethyl-hexanol; 2 propyl-1-heptanol; 3,7-dimethyl-1-octanol; and 1-dodecanol.

1-ethyl-hexanol - This chemical has a number of uses including PVC resin plasticizer, defoaming agent, and as a solvent for a wide range of materials including nitrocellulose, paints, inks, plasticizers, lubricants, and dry cleaning. No information was found regarding aquatic toxicity, but NIOSH (1980) reports relatively low toxicities when this compound is administered to rats and mice.

2-propyl-1-heptanol - Little information was found on this chemical. NIOSH (1980) reports a low toxicity to rats.

3,7-dimethyl-1-octanol (tetrahydrogeraniol) - This chemical is used in perfumes and as a flavoring agent. No relevant information regarding its toxic effects was found.

1-dodecanol (lauryl alchohol) - This chemical is used in synthetic detergents, lube additives, pharmaceuticals, rubber, textiles, perfumes, and flavoring

agents. NIOSH (1980) notes that in at least one test, it appeared to be carcinogenic. Linden, *et al.* (1979) report that 1-dodecanol had a 96-hour LC_{50} of 0.9 mg/L for the brackish water harpacticoid (*Nitocra spinipes*). This concentration is about 170 times the concentration (5.3 µg/L) estimated in the effluent collected during the July 1981 survey.

Two of the compounds included in this section are of the gycol ester family. Little information was available on 2-(2-butyxy ethoxy)-2-ethoxy ethanol except that NIOSH (1980) reported a relatively low toxicity to rats and mice. 2-butoxy ethanol (also known as butyl cellusolve or ethylene glycol monobutyl ether) is used as a solvent for nitrocellulose resins, lacquers, enamels, dry cleaning compounds, and varnish removers, as well as an emulsifier. Verschueren (1977) reports that inhibition of algal cell multiplition begins at 35 mg/L and the 48-hour LC_{50} to brown shrimp (*Grangon crangon*) is 800 mg/L while the 96-hour LC_{50} to goldfish is 775 mg/L. Dawson (1977) reports 96-hour LC_{50}s of 1,490 mg/L for bluegills (*Lepomis macrochirus*) and 1,250 mg/L for tidewater silversides (*Menidia beryllina*). The estimated effluent concentration of this chemical (17 µg/L) is a small fraction (.001 to .05 percent) of levels reported to cause aquatic toxicity.

Of the remaining two alchohol-based compounds, one is 4-chloro-trans-cyclohexanol. This compound was estimated at 30 µg/L in the effluent during the high-flow study. As a chlorinated compound, it may warrant further attention. No information could be located regarding this chemical although both chlorinated and brominated cyclohexanols were identified in seep samples collected during the Pennwalt Corporation source survey (Yake, 1981).

The final compound of this group is α,α,4-trimethyl-(5)3-cyclohexene-1-methanol (terpineol). It is found naturally in forest runoff (Verschueren, 1977) and is a constituent of various plant oils. It is used in soaps, perfumes, medicines, and flavoring agents and as a solvent, disinfectant, and antioxident.

Phenolic Compounds

Five non-priority phenolic compounds (inluding two cresols) were tentatively identified in the 1 to 20 µg/L range in wastewater samples:

Cresols - The cresols are methyl phenols originating from natural sources including leaching from wood, coal, and petroleum. Man-made sources include petroleum refining, coal tar refining, organic chemical manufacturing, wood processing, auto exhaust, and runoff from asphalt. Two cresols were tentatively identified in the July 1981 effluent sample at low concentrations:

4-methyl phenol (*p*-cresol) - Verschueren (1977) reports 24-hour LC_{50} values for several types of fish. These values range from 4 mg/L for "trout" embryos to 21 mg/L for carp. These values are 200 to 1,000 times higher than the concentration estimated in the effluent.

2-methyl phenol (*o*-cresol) - Verschueren (1977) reports 24- to 96-hour TLm values for several types of fish. These values range from 2 mg/L for "trout" embryos to 50 mg/L for guppies. Inhibition of cell multiplications for algae *Microcystis aerogenosa* begins at 6.8 mg/L. These values are 400 to 10,000 times higher than the concentrations estimated in the effluent.

Other phenolics tentatively identified in wastewater samples included:

4-(1,1-dimethyl ethyl) phenol [*p-tert*-butyl phenol] -This chemical is used as an intermediate in the manufacture of varnish and lacquer resins, in motor oil additives, and as a soap antioxidant. Verschueren (1977) toxicities to *Daphnia* and the algae *Scenedesmus* in the 8 to 10 mg/L range. This author also notes that at approximately 30 µg/L, this compound causes an adverse taste in fish. During high-flow survey concentrations of 4-(1,1-dimethylethyl)phenol were estimated at 15 µg/L in the influent and 20 µg/L in the effluent. After dilution with river water, in-stream concentrations would be well below the values reported by Verschueren.

4-(1,1,3,3-tetramethylbutyl)phenol - The Merck Index (Windholz, 1976) notes that this chemical is used as a polymer with formaldehyde and oxirane as a non-ionic detergent which reduces surface tension. NIOSH (1980) notes a study which reported possible tumorogenic activity when applied to the skin of mice. It was noted at a very low estimated concentration of 1.4 µg/L in the July 1981 effluent sample.

[1,1'-biphenyl]-2-ol(AKA: 2-biphenylol, 2-phenylphenol, Dowcide 1) - This compound is used as a germicide and fungicide. Verschueren (1977) reports that it imparts an adverse taste to fish at 1 mg/L. It was noted at an estimated concentration of 2.7 µg/L in the July 1981 effluent sample.

Other Tentatively Identified Compounds

Several additional organic chemicals were tentatively identified in wastewater or sludge samples. Of these, no relevant information could be located regarding 1-(methylphenyl)ethane; 1-(4-hydroxy-3-methoxyphenyl)ethane (AKA: apocynin, acelovanillane); piperidinone; and nonanamide. There was also little information located regarding 3-hexen-2-one which was tentatively identified at a relatively substantial concentration in the February 1981 sludge sample. The *Condensed Chemical Dictionary* (Hawley, 1971) did, however, note that a closely related compound (5-hexen-2-one or alkyl acetone) is "probably highly toxic" and is used in fungicides and insecticides.

The final tentatively identified compound is 1,3,7-trimethyl-3,7-dihydro-1-H-purene-2,6-dione or caffiene. Caffiene occurs in tea, coffee, and maté leaves as well as cola nuts, and is a central nervous system stimulant. Caffiene is moderately toxic, but no information was located regarding aquatic toxicity. NIOSH (1980) notes reports which indicate that caffiene causes teratogenic effects in rats and mice. Mutagenic activity based on chromosomal observations in cultures of human cells is also reported. Caffiene was tentatively identified at an estimated concentration of 15 µg/L in the July 1981 effluent sample.

Bioassay Results

Bioassays were performed on both wastewater and receiving water samples collected during the July and August 1981 surveys. Oyster larvae and daphnid bioassays were used to assess these samples. The results of these tests are summarized in this section.

Oyster larvae and daphnid bioassays were conducted at the EPA laboratory in Manchester, Washington. The results of these tests were reported in detail in two memoranda (Cummins, 1982a and 1982b) to James Hileman (Region X, EPA). The results of these tests have been abstracted here. The reader is directed to the original memoranda for the full details of the tests.

Memo to Frank Monahan
Tacoma Central (#1) Sewage Treatment Plant Class II (Priority Pollutants)
Surveys: August 25-26, 1981, and February 16-17, 1982

The daphnid acute bioassays were performed by exposing daphnids for 48 hours to 100 percent concentrations of wastewater and receiving water samples. The results are summarized in Table 13.

Table 13. Results of daphnid bioassays.

Sample Location	Date	Percent Mortality
Tacoma Central STP Influent	8/81	100%
Tacoma Central STP Effluent	8/81	100%
Tacoma Central STP Effluent	7/81	50%
Puyallup River nr. STP Outfall - Flood Tide	8/81	20%
Puyallup River below STP Outfall	8/81	5%
Puyallup River below STP Outfall	7/81	10%
Puyallup River at Mouth	8/81	5%
Puyallup River above STP	8/81	0%
Puyallup River above STP	7/81	10%

In general, wastewater samples showed the highest mortalities, while background (upstream) samples exhibited the lowest mortalities. Cummins (1982a, b) notes that low dissolved oxygen levels in the Tacoma Central STP wastewater samples were believed to have been at least partly responsible for the high daphnid mortality. Nonetheless, the elevated mortality (20 percent) in the Puyallup River flood tide sample (which contained a relatively high percentage of STP effluent) and the results of the oyster larvae bioassays, while not directly comparable, suggest that other factors may bear some responsibility for daphnid mortality in the wastewater samples. Although isolating the causes of elevated mortality in complex wastewater samples containing numerous chemical compounds is generally not possible, based on comparison of pollutant concentrations with available criteria, these pollutants which may bear some responsibility are mercury (up to 370 times EPA acute criterion), cadmium (1 to 7 times EPA acute criterion), copper (4 to 8 times EPA acute criterion), and un-ionized ammonia (10 to 20 times EPA acute criterion).

The oyster larvae bioassay involves seeding oyster embryos to a test solution. In this case, the test solutions were water and wastewater samples diluted from original strength to .02% to 20% strength with uncontaminated sea water. After 48 hours, larvae with normal and abnormal shell development are counted. Percent mortality and abnormality are then calculated. Control tests are conducted simultaneously; mortality and abnormality results can then be corrected to yield net values.

Tables 14A and 14B summarize the results of these tests. Although only the August 1981 effluent sample displayed substantially elevated mortality, all wastewater samples resulted in 99 to 100 percent net abnormalities at the 20 percent sample dilution level. The receiving water sample collected from the Puyallup River at flood tide also resulted in high abnormalities (100 percent) at the 20 percent dilution. As noted previously, this sample was obtained as effluent pooled near the discharge point and thus contained a substantial percentage of effluent. The results of the oyster larvae bioassays roughly parallel those of the daphnid bioassays. The effect of specific chemical species on normal oyster larvae shell development has not been well researched. The specific causitive agent(s) cannot presently be determined. The results indicate, however, that primary treatment may not significantly alter the effect of wastewater on oyster larvae.

CONCLUSIONS AND RECOMMENDATIONS

Conventional Pollutants

Tacoma Central STP wastewaters were sampled during two 24-hour periods for conventional pollutants. These pollutants include those addressed by the plant's NPDES permit. One survey was conducted during a period of low river and treatment plant flow (8/25-26/81); the other during a period of high river and treatment plant flow (2/16-17/82). The effluent loadings for selected conventional pollutants during these two time periods are given in Table 15.

Table 15. Conventional pollutant effluent loadings during Tacoma Central STP surveys.

Survey Dates:	Low Flow 8/25-26/81	High Flow 2/16-17/82
Parameter		
Flow (MGD)	16.5	71.8
BOD_5 (lbs/day)	34,000	72,000
Suspended Solids (lbs/day)	23,000	49,000
Ammonia as N (lbs/day)	3,000	2,600
Nitrate as N (lbs/day)	<14	1,600
Total Inorganic Nitrogen (lbs/day)	3,000	4,300
Total Phosphate as P (lbs/day)	1,260	1,600
Oil and Grease (lbs/day)	3,600	--

Table 14A. Oyster larvae bioassay test results (July, 1981).

Percent Sample	Puyallup River above STP Outfall	Treatment Plant Effluent	Puyallup River below STP at 11th St. Bridge
	Mean Net Mortality - Expressed as Percent		
20%	29.1%	17.9%	8.5%
2%	0.9%	0*	0*
0.2%	(a)	0*	(a)
0.02%	(a)	0*	(a)
	Mean Weighted Net Abnormality - Expressed as Percent		
20%	5.9%	99.7%	6.5%
2%	1.6%	7.4%	0.8%
0.2%	(a)	4.9%	(a)
0.02%	(a)	?.8%	(a)

* = Larval mortality or abnormality less than 0% based on control responses.
(a) = Counts were not made on these replicates because only negligible effects were observed in the next lower dilution.

Table 14B. Oyster larvae bioassay test results (August, 1981).

Mean Net Mortality - Expressed as Percent

Percent Sample	Puyallup River above STP Outfall	Treatment Plant Influent	Treatment Plant Effluent	Puyallup River near STP Outfall - Flood Tide	Puyallup River below STP	Puyallup River at Mouth
20%	3.6%	2.8%	43.4%	10.0%	0*	0*
2%	0*	10.0%	0*	8.4%	0*	9.2%
0.2%	0*	2.8%	(a)	5.6%	0*	0*
0.02%	7.6%	1.2%	(a)	(a)	(a)	0.8%

Mean Weighted Net Abnormality - Expressed as Percent

Percent Sample	Puyallup River above STP Outfall	Treatment Plant Influent	Treatment Plant Effluent	Puyallup River near STP Outfall - Flood Tide	Puyallup River below STP	Puyallup River at Mouth
20%	12.6%	100%	100%	100%	14.0%	19.1%
2%	0.8%	9.9%	0*	0*	1.5%	1.9%
0.2%	0*	0.4%	(a)	0*	0*	1.4%
0.02%	0*	0*	(a)	(a)	(a)	0.4%

* = Larval mortality or abnormality less than 0% based on control responses.
(a) = Counts were not made on these replicates because only negligible effects were observed in the next lower dilution.

The effects of these wastewater constituents on the Puyallup River and Commencement Bay are discussed in the receiving water report (Johnson and Prescott, 1982).

Permit Compliance

Based on data from the two surveys:

1. Measured pH values all fell within the permitted range.

2. Effluent BOD concentration exceeded the monthly average permit limit during the low-flow survey, while effluent BOD loading exceeded the monthly average permit limit during the high-flow survey.

3. Suspended solids results were similar to BOD results in that effluent suspended solids concentrations exceeded the monthly average permit limit during the low-flow survey, while effluent suspended solids loading exceeded both the weekly and monthly average permit limits during the high-flow survey.

As discussed in detail in the text, BOD and suspended solids loadings to the plant are highly variable on both a daily and seasonal basis, with storm flows and industrial discharges apparently responsible for much of this variability. The treatment efficiency of the plant is adversely affected by high (storm) flows with clarifier overflow and weir loading criteria for primary plants being exceeded at 53 and 32 MGD, respectively.

Permit Status

The permit currently contains no limits for fecal coliforms or residual chlorine. The effectiveness of the new chlorine contact structure should be assessed and used in concert with available receiving water data to determine appropriate permit limits for both of these parameters.

Laboratory Procedures

This memorandum notes several recommended modifications in laboratory procedure at the Tacoma Central STP laboratory. These recommendations should be implemented.

Priority Pollutants

Table 16 summarizes the priority pollutant loadings from three sets of Tacoma Central STP effluent samples. The final column provides an estimated average load for each of the priority pollutants based on the three sets of samples.

Table 16. Effluent priority pollutant loading (lbs/day) - Tacoma Central STP.

Constituent	Dry Weather 7/28/81*	Dry Weather 8/25-26/81	Wet Weather 2/16-17/82	Estimated Average Load
Zinc	(21)*	47	78	49
Nickel	(5.5)*	8.1	102	39
Cyanide		2.5	51	(27)
Tetrachloroethylene	(0.37)*	0.32	66	22
Lead	(<14)*	5.4	48	(20)
Copper	(7.1)*	7.3	30	15
Chromium	(8.1)*	10.5	--	(7.2)
Phenol	(3.8)*	4.7	11	6.5
Pentachlorophenol	(<5.7)*	--	14	5.6
Arsenic	(<0.14)*	1.7	14	5.3
Benzene	(8.9)*	--	1.8	(3.6)
Chloroform	(2.6)*	2.2	4.7	3.2
2,4,6-trichlorophenol	--	0.73	6.6	(2.5)
Toluene	(1.4)*	--	4.7	(2.0)
2,4-dichlorophenol	--	0.62	5.0	(1.9)
Bis(2-ethylhexyl) phthalate	(2.4)*	3.4	--	(1.9)
2-chlorophenol	--	1.1	3.4	(1.5)
Napthalene	(0.35)*	0.62	2.9	1.3
Cadmium	(1.4)*	1.4	0.6	1.1
Butylbenzyl phthalate	(3.0)*	--	--	(1.0)
Trichloroethylene	(0.62)*	1.4	--	(0.7)
2,4-dimethyl phenol	(0.72)*	0.54	--	(0.42)
1,4-dichlorobenzene	--	0.77	--	(0.26)
1,1,1-trichloroethane	--	0.15	0.6	(0.25)
1,3-dichlorobenzene	(0.51)*	--	--	(0.17)
1,2-dichlorobenzene	--	0.45	--	(0.15)
Dichlorobromomethane	(0.45)*	--	--	(0.15)
Di-n-octyl phthalate	--	0.29	--	(0.10)
Ethyl benzene	(0.28)*	--	--	(0.09)
1,1-dichloroethane	--	0.15	--	(0.05)
Mercury	(<.028)	0.087	<0.12	(0.05)
Phenanthrene/anthracene	(0.10)*	--	--	(0.03)
Δ-BHC	--	--	.06	(0.02)

* = Grab composite sample; flow based on conservative rough estimate of 17 MGD.
-- = None detected.
( ) = Estimated value (in case of averages: 1 or 2 values below detection limits).

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Based on the data generated during these surveys and comparison of these data with values from other treatment plants throughout the United States, the following general observations can be made:

1. The wide range of priority pollutants found in Tacoma Central's wastewaters is generally typical of municipal wastewaters. Likewise, the concentrations reported are generally typical. The primary exception to this generalization appears to be the chlorinated phenols which are present in substantially higher concentrations than those observed in wastewaters from other municipalities.

2. Although metals concentrations at Tacoma Central do not appear to be unusually high when compared to wastewaters from other major cities throughout the country, they are elevated when compared to sludge concentrations at most other Washington towns and cities. This is particularly true for chromium, cadmium, nickel, and lead. Arsenic is probably also elevated; however, data are not available for arsenic concentrations in other Washington State wastewaters and sludges. Effluent mercury concentrations measured during the low-flow survey are well above EPA receiving water criteria.

3. Effluent loads for metals and several other priority pollutants (cyanide, tetrachloroethylene, and the chlorinated phenols) were substantially higher during the storm flow sampling period. Elevation of metals in wastewaters during storm flows in cities with combined sewer systems has been previously documented.

4. Many of the priority pollutants detected were only detected in one or two of the three periods. Concentrations often varied substantially from one sampling period to another. Because a large portion of Tacoma's wastewater flow is from industrial sources, the potential for slug loads of specific pollutants from spills, upsets, or batch processes is substantial. A continuing program of wastewater analysis would provide a much more comprehensive and complete knowledge of pollutant concentrations and effluent loadings.

5. Concentrations of priority pollutants in the effluent are generally low enough that they would not exceed EPA in-stream criteria for the protection of aquatic and marine life after the effluent is fully mixed with the Puyallup River/Estuary. Possible exceptions to this generalization may be mercury, cadmium, and lead. Factors which may hinder ideal dilution include the absence of an effluent diffuser and effluent pooling caused when low river flow and high tidal conditions coincide.

6. Based on data available, the primary treatment process employed at the Tacoma Central plant does not appear to be very effective in reducing priority pollutant concentrations in the wastewater stream. Available literature suggests that secondary treatment would be much more effective.

Other Organic (Tentatively Identified) Compounds

A wide range of non-priority organic compounds was tentatively identified in wastewater and sludge samples from the Tacoma Central plant. Many of these compounds are normal constituents of municipal wastewater. Although some information is available on the environmental effects of certain of these compounds, criteria are generally sparse and it is difficult in many cases to assess the significance of the data on tentatively identified organic compounds.

Bioassays

Daphnid and oyster larvae bioassays indicated that the wastewaters were toxic to these organisms. Twenty percent solutions of wastewater produced a high incidence of abnormal shell development in oyster larvae while two percent solutions showed little effect. Samples of receiving water collected above and below the discharge did not generally display substantial toxicity based on these bioassay results. The exception to this was the Puyallup River sample collected from an area near the discharge where effluent was pooling during high tide.

WEY:cp

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LABORATORY PROCEDURAL SURVEY

Discharger: Tacoma Central (#1) STP

NPDES Permit Number: WA-003708-7

Date: 8/25/81

Industrial/Municipal Representatives Present: Dave Hufford, Laura Clark, Bob McElroy

Agency Representatives Present: Bill Yake, Dale Norton

I. COMPOSITE SAMPLES

A. Collection and Handling

1. Are samples collected via automatic or manual compositing method? Automatic, Model? Manning

a. If automatic, are samples portable X or permanently installed ____?

Comments/problems Old Locations: Influent - in grit chamber, Effluent in channel from #1 Clarifier. New Locations: Influent - behind large rag rung, Effluents - unchlorinated effluent from both clarifiers.

2. What is the frequency of collecting composite samples? 4 days/wk. for BOD, 5 days/wk. for Suspended solids

3. Are composites collected at a location where homogeneous conditions exist?

a. Influent? Present location quiescent

b. Final Effluent? Present location only picks up 1 clarifier

c. Other (specify)? ____

4. What is the time span for compositing period? 24 hr.

Sample aliquot? 150 ml mls per 10 to 30 mins is minutes

5. Is composite sample f. or time proportional? ~ ε

6. Is final effluent comp site collected from a chlorinated or non-chlorinated source? non-chlorinated

7. Are composites refrigerate during collection? Presently - used
Future - will be refrigerated

8. How long are samples held prior to analyses? During inc. BOD set ups
1 hr. after collection, Sample taken on Sunday held to Monday before set-up

9. Under what condition are samples held prior to analyses?

   a. Refrigeration? BOD aliquot refrigerated

   b. Frozen? _____

   c. Other (specify)? _____

10. What is the approximate sample temperature at the time of analysis? Approaches Room Temp.

11. Are compositor bottles and sampling lines cleaned periodically? Yes

   a. Frequency? Bottles daily, Lines weekly

   b. Method? Soap, water, chlorine solution

12. Does compositor have a flushing cycle? Yes

   a. Before drawing sample? Yes

   b. After drawing sample? Yes

13. Is composite sample thoroughly mixed immediately prior to withdrawing sample? Yes

Recommendations:

II. BIOCHEMICAL OXYGEN DEMAND CHECKLIST

A. Technique

1. What analysis technique is utilized in determining BOD_5?

a. Standard Methods? X _ Edition? 14th/15th

b. EPA? _____

c. A.S.T.M.? _____

d. Other (specify)? _____

B. Seed Material

1. Is seed material used in determining BOD? Not with STP samples.

2. Where is seed material obtained? N/A

_____

3. How long is a batch of seed kept? N/A _____

and under what conditions? (temperature, dark) N/A

_____

4. How is seed material prepared for use in the BOD test? N/A

_____

Recommendations:

_____

_____

_____

_____

_____

_____

_____

C. Reagent Water

1. Reagent water utilized in preparing diultion water is:

   a. Distilled? X present still is metal, still in new lab. - glass.

   b. Deionized? _____

   c. Tap _____, chlorinated _____ non-chlorinated _____

   d. Other (specify)? _____

2. Is reagent water aged prior to use? Not really _____ _____

   How long? _____, under what conditions? Distilled water is generated for about 12 hrs. prior to use.

Recommendations:

_____ _____

_____ _____ _____

_____

_____

_____

D. Dilution Water

1. Are the four (4) nutrient buffers added to the reagent water? Yes. Pow buffer added directly to BOD dilution (test bottle)

   a. 1 mls of each nutrient buffer per 1000mls. mls of reagent water

2. When is phosphate buffer added (in relation to setting up BOD test)? 5-6 drops added directly to BOD bottle (sample dil ...)

3. How often is dilution water prepared? Prior to each test
   Maximum age of dilution water at the time test is set up.
   Unless, probably 12-24 hrs.

4. Under what conditions is dilution water kept? Kept in incubator at 20°c, not aerated

5. What is temperature of dilution water at time of setup? 20°C

Recommendations:

E. Test Procedure

1. How often are BOD's being set up? 4 days/wk.

   What is maximum holding time of sample subsequent t end of composite period? 1 day (Sunday → Monday only)

2. If sample to be tested has been previously frozen, is it reseeded? N/A How? _____

3. Does sample to be tested contain residual chlorine? No
   If yes, is sample

   a. Dechlorinated? N/A

      How? _____

   b. Reseeded? N/A

      How? _____

4. Is pH of sample between 6.5 and 8.5? Not check w/ Region to STP inf/eff samples.

   If no, is sample pH adjusted and sample reseeded? No

5. How is pH measured? Orion probe, Corning meter

   a. Frequency of calibration? Daily

   b. Buffers used? pH 4 & 7

6. Is final effluent sample toxic? Not believed to be toxic to BOD test.

7. Is the five (5) day DO depletion of the dilution water (blank) determined? Yes, normal range? 0.0 – 0.2 mg/l

8. What is the range of initial (zero day) DO in dilution water blank? 7.0 – 7.2 mg/l - too low, due to lack of aeration

9. How much seed is used in preparing the seeded dilution water? N/A

10. Is five (5) day DO depletion of seeded blank determined? N/A
If yes, is five (5) day DO depletion of seeded blank approximately 0.5 mg/l greater than that of the dilution water blank? N/A

11. Is BOD of seed determined? N/A

12. Does BOD calculation account for five (5) day DO depletion of

a. Seeded dilution water? N/A

How?

b. Dilution water blank? No. Discounted

How?

13. In calculating the five (5) day DO depletion of the sample dilution, is the initial (zero day) DO obtained from

a. Sample dilution? Yes.

b. Dilution water blank?

14. How is the BOD_5 calculated for a given sample dilution which has resulted in a five (5) day DO depletion of less than 2.0 ppm or has a residual (final) DO of less than 1.0 ppm? ok.

15. Is liter dilution method or bottle dilution method utilized in preparation of

a. Seeded dilution water? N/A

b. Sample dilutions? Yes

16. Are samples and controls incubated for five (5) days at 20°C ± 1°C and in the dark? Yes

17. How is incubator temperature regulated? against Mercury thermometer

18. Is the incubator temperature gage checked for accuracy? Yes

    a. If yes, how? ASTM thermometer

    b. Frequency? _____

19. Is a log of recorded incubator temperatures maintained? Script Chart

    a. If yes, how often is the incubator temperature monitored/checked? _____

20. By what method are dissolved oxygen concentrations determined?

    Probe X (YSI) Winkler _____ Other _____

    a. If by probe:

        1. What method of calibration is in use? Winkler

        2. What is the frequency of calibration? Daily

    b. If by Winkler:

        1. Is sodium thiosulfate or PAO used as titrant? _____

        2. How is standardization of titrant accomplished? _____

        Not Standardized

        3. What is the frequency of standardization? _____

Recommendations:

1) Age (& or Aerate) dilution water long enough to reach D.O. saturation (8.0-8.4 mg/l).

2) Standardize Winkler titrant. (PAO or this?)

F. Calculating Final Biochemical Oxygen Demand Values Washington State Department of Ecology

1. Correction Factors

a. Dilution factor:

$$= \frac{\text{total dilution volume (ml)}}{\text{volume of sample diluted (ml)}}$$

b. Seed correction:

$$= \frac{(\text{BOD of Seed})(\text{ml of seed in 1 liter dilution water})}{1000}$$

c. F factor ∿ a minor correction for the amount of seed in the seeded reagent versus the amount of seed in the sample dilution:

$$F = \frac{[\text{total dilution volume (ml)}] - [\text{volume of sample diluted ml}]}{\text{Total dilution volume, ml}}$$

2. Final BOD Calculations

a. For seed reagent:

(seed reagent depletion-dilution water blank depletion) x D.F.

b. For seeded sample:

(sample dilution depletion-dilution water blank depletion-scf) x D.F.

c. For unseeded sample:

(sample dilution depletion-dilution water blank depletion) x D.F.

3. Industry/Municipality Final Calculations

$$\frac{D.O._o - D.O._s}{D.F.} =$$

Recommendations:

III. TOTAL SUSPENDED SOLIDS CHECKLIST

A. Technique

1. What analysis technique is utilized in determining total susnended solids?

a. Standard Methods? X Edition 14th/15th

b. EPA? _____

c. A.S.T.M.? _____

d. Other (specify)? _____

B. Test Procedure

1. What type of filter paper is utilized:

a. Reeve Angel 934 AH? _____

b. Gelman A/E? _____

c. Other (specify)? Whatman GF/C

d. Size? _____

2. What type of filtering apparatus is used? Buchner Funnel

3. Are filter papers prewashed prior to analysis? Yes

a. If yes, are filters then dried for a minimum of one hour Yes at 103°C-105°C Yes ?

b. Are filters allowed to cool in a dessicator prior to weighing? Yes

4. How are filters stored prior to use? in Dessicator, 1 to 2 wk.

5. What is the average and minimum volume filtered? influent 100-150ml, effluent 200-250ml

6. How is sample volume selected?

   a. Ease of filtration? X, try for 2-4 minute filtering time

   b. Ease of calculation? _____

   c. Grams per unit surface area? _____

   d. Other (specify)? _____

7. What is the average filtering time (assume sample is from final effluent)? 2 to 4 minutes

8. How does analyst proceed with the test when the filter clogs at partial filtration? Start over

9. If less than 50 milliliters can be filtered at a time, are duplicate or triplicate sampe volumes filtered? Not a problem

10. Is sample measuring container; i.e., graduated cylinder, rinsed following sample filtration and the resulting washwater filtered with the sample? Yes, several times

11. Is filter funnel washed down following sample filtration? Yes

12. Following filtration, is filter dryed for one (1) hour, cooled in a desscator, and then reweighed? Yes, actually several hrs.

13. Subsequent to initial reweighing of the filter, is the drying cycle repeated until a constant filter weight is obtained or until weight loss is less than 0.5 mg? No

14. Is a filter aid such as cellite used? No.

a. If yes, explain: _____

Recommendations:

1) Switch filter papers after GF/c runs out.

C. Calculating Total Suspended Solids Values Washington State Department of Ecology

A. $mg/l\ TSS = \frac{A-B}{C} \times 10^6$

1. Where: A = final weight of filter and residue (grams)

B = initial weight of filter (grams)

C = Milliliters of sample filtered

2. Industry/Municipality Calculations

$$\frac{A_{(mg)} - B_{(mg)}}{C_{(ml)}} \times 1000$$

OK