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A Study of Municipal Wastewater Toxicity, Penticton Water Quality Control Centre, July, 1976

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A STUDY OF MUNICIPAL WASTEWATER TOXICITY, PENTICTON WATER QUALITY CONTROL CENTER, JULY, 1976

by

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ABSTRACT

A wastewater toxicity study of the Penticton Water Quality Control Center was conducted by the author in conjunction with personnel of the Environmental Protection Service, Pacific Region.

The objectives of this study, conducted from July 19-23, 1976, were as follows:

1) to determine the extent of toxicity removal achieved by the sewage treatment plant,
2) to determine the effect of chlorination on the toxicity of the effluent,
3) to relate the toxicity of the influent and the effluent to the concentrations of certain known toxic substances,
4) to determine the degree of disinfection achieved by tertiary treatment, and
5) to determine the incidence and the extent of removal of polychlorinated biphenyls.

The study also included the collection of information concerning such factors as plant design and actual loading, chlorine dosage and residual, and the extent of sewer line infiltration. This information was collected to assist in interpreting data gathered for the objectives listed above.

This report contains the results of bioassay determinations, chemical analyses and bacteriological analyses of samples collected during the survey at various treatment plant locations.

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LIST OF ABBREVIATIONS

BOD_5	5 day biochemical oxygen demand
cc	cubic centimetres
CL_2	chlorine
DO	dissolved oxygen
ft	feet
GLC	gas liquid chromatography
g/ℓ	grams per liter
hr	hour(s)
Imp gal	Imperial gallons
Imp MGD	million Imperial gallons per day
ℓ	liter(s)
mg/ℓ	milligrams per liter
mℓ	milliliters
MPN	most probable number
MLSS	mixed liquor suspended solids
ppm	parts per million
ppb	parts per billion
Tc	toxicity concentration
TU	toxic units
μg/ℓ	micrograms per liter
WQCC	water quality control center

CONCLUSIONS

Based on data collected at the Penticton Water Quality Control Center from July 19 to 23, 1976 the following conclusions can be made:

1) Activated sludge sewage treatment was responsible for a reduction in the average toxicity concentration from 1.63 toxic units in the raw sewage to 1.15 toxic units in the secondary effluent.

2) Chlorination of the secondary effluent was responsible for an increase in the average toxicity concentration of the final effluent to 2.59 toxic units. This represents a 58.9% increase based on the raw sewage samples and a 125.2% increase based on the secondary effluent samples.

3) The toxic wastewater constituents which were examined in this study and deemed responsible for the bioassay results were:

   i) un-ionized ammonia,

   ii) anionic sufactants,

   iii) compounds formed by chlorination,

   iv) dissolved copper and zinc, and

   v) cyanides.

4) The polychlorinated biphenyls concentrations as reported in Appendix I were all significantly low. The treatment plant was responsible for a 69% reduction of the raw sewage PCB level.

1 INTRODUCTION

The City of Penticton, located in the Okanagan Valley between Lake Okanagan and Lake Skaha, had an estimated poulation of 21,017 in 1976 (1). The actual population increases dramatically during the summer months due to the influx of tourists to the area. All sewage from the city is treated by the Penticton Water Quality Control Center. The sanitary and storm sewer systems are completely separate; storm water is discharged to the Okanagan River channel. Economic activity is concentrated in the tourism, recreation, food processing and service industries. The major industries discharging wastewater to the sanitary sewer system are:

Canadian Canners Limited, primarily a fruit processing and canning operation that operates most of the year. The strength and volume of wastewater discharge varies with the type of fruit being processed and the level of plant activity. During the study period the plant was processing strawberries and cherries.

Casabello Wines Limited, a winery which operates year round but discharges wastewater intermittently according to the season and the operation being conducted. There was no discharge from the winery during the survey period.

The survey consisted of the following programs:

1) a 4 day composite sampling program,
2) a 12 hour grab sampling program,
3) a 24 hour chlorine residual monitoring program,
4) a bacteriological sampling program, and;
5) general plant operation data collection.

The objectives of this study, conducted from July 19-23, 1976, were as follows:

1) to determine the extent of toxicity removal achieved by the sewage treatment plant;
2) to determine the effect of chlorination on the toxicity of the effluent;
3) to relate the toxicity of the influent and the effluent to the concentrations of certain known toxic substances,
4) to determine the degree of disinfection achieved by tertiary treatment, and
5) to determine the incidence and the extent of removal of polychlorinated biphenyls.

Additional municipal wastewater toxicity studies were conducted at other locations in the Pacific Region during 1976. These surveys were conducted to collect information regarding the ability of various types of sewage treatment systems to remove or reduce wastewater toxicity and to establish the toxicity concentrations involved with each case.

1.1 Penticton Water Quality Control Center, Plant Description

The Penticton WQCC is a conventional activated sludge sewage treatment plant with the addition of phosphorous removal using iron salts. The treatment components include headworks, an aerated grit tank, 3 primary sedimentation tanks, 4 aeration tanks, 3 secondary sedimentation tanks, a chlorine contact tank and 2 final polishing clarifiers. Primary sludge and waste activated sludge are digested in a two stage anaerobic digester, and the final digested sludge is dried on sludge drying beds. The phosphorous removal facilities include a waste pickling liquor storage tank and a metering pump. A simplified flow sheet including sample point locations is presented in Figure 1. The sampling points are described in more detail in section 2.1 of this report. Pickling liquor, which mainly consists of a 30% solution of ferrous chloride ($FeCl_2$), is metered at 800 $m\ell$/min to the aeration tank as indicated in Figure 1. Pickling

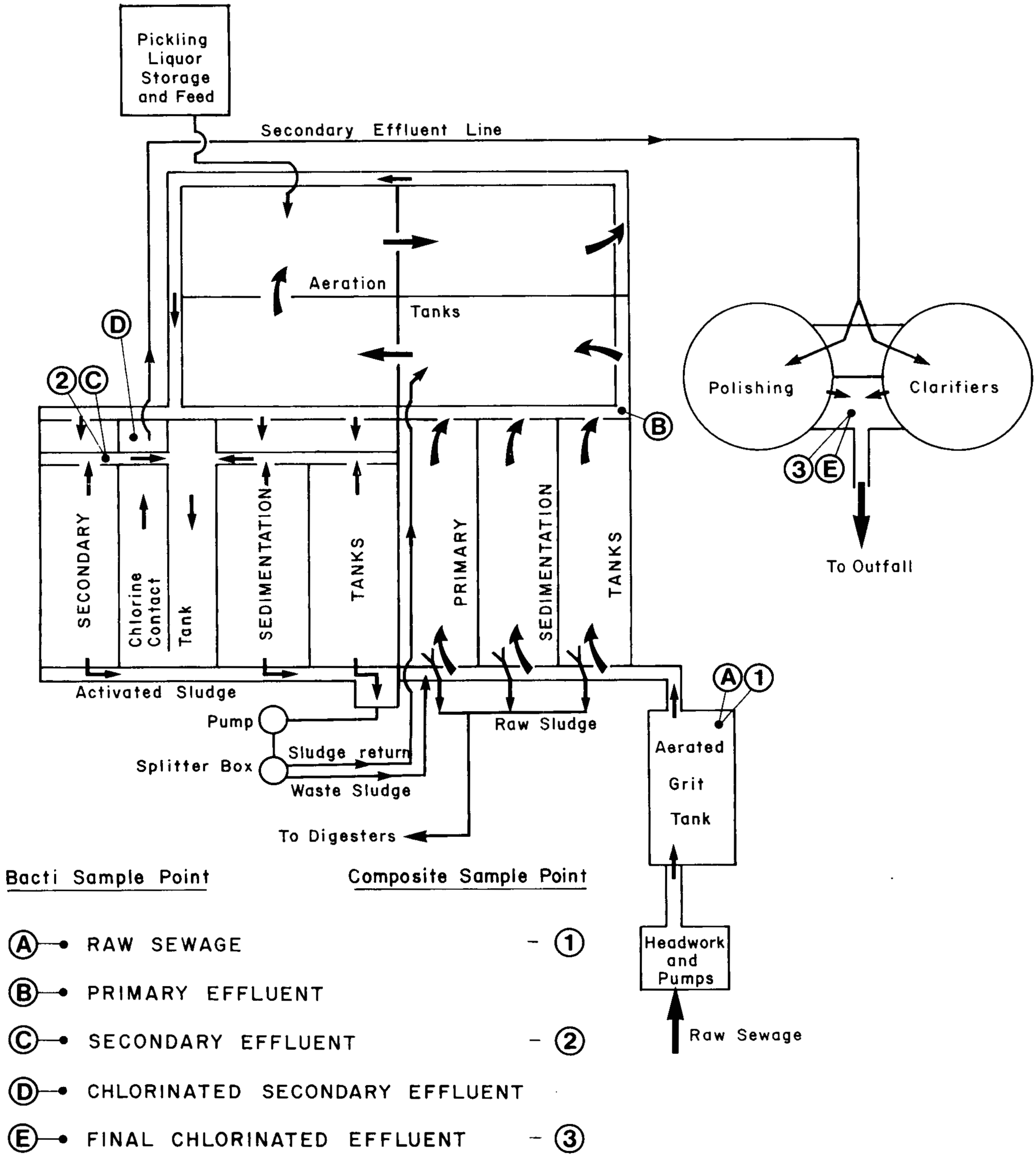

FIGURE I CITY OF PENTICTON WATER QUALITY CONTROL CENTER SIMPLIFIED FLOW DIAGRAM AND SAMPLE POINT LOCATION.

TABLE 1 OPERATIONAL CHARACTERISTICS OF PENTICTON WATER QUALITY CONTROL CENTER

Type of Treatment: Conventional Activated Sludge plus Phosphorous Removal and Polishing Clarifier

Treatment Components:
1) Barminutor (1)
2) Raw Sewage Pumps (3) Parallel
3) Aerated Grit Tank (1)
4) Primary Sedimentation Tanks (3) Parallel
5) Aeration Tanks (4) Series
6) Secondary Sedimentation Tanks (3) Parallel
7) Chlorine Contact Tank (1)
8) Polishing Clarifier (2) Parallel

Design Dry Weather Flow = 1.83 Imp MGD

Average Flow (July 1975 - July 1976) = 1.54 Imp MGD
Average Flow (July 1976) = 1.69 Imp MGD

Raw Sewage Average BOD_5 = 240 mg/ℓ
NFR = 180

Primary Effluent Average BOD_5 = 192 (est.)
NFR = 65

Average Mixed Liquor Suspended Solids = 1223 (July 1976)

Aeration Tank Volume = 400,000 Imp gal
= 64,100 cu ft

Food to Microorganisms Ratio F/M = 0.66 lb BOD_5/day lb MLSS

Volumetric Loading = 50 lb BOD_5/1000 cu ft

Secondary Sedimentation Tank Overflow = 620 gal/ft^2/day

Average Retention Times (July 1976)

Primary Sedimentation	= 1.9 hr
Aeration Tank	= 4.4 hr (30% return sludge flow)
Secondary Sedimentation	= 1.9 hr (30% return sludge flow)
Chlorine Contact Tank	= 0.5 hr
Polishing Clarifier	= 3.5 hr
Total Retention	12.2 hr

Sludge Digestion Components
1) Primary Anaerobic Digester 50,900 cu ft
2) Secondary Anaerobic Digester 50,900 cu ft
3) Sludge Drying Beds 234,000 gal capacity

Chlorinator - Flow Proportional, checked twice daily

Point of Discharge - Okanagan River Channel, adjacent to plant

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liquor is a by-product of the metal finishing industry supplied by Tree Island Steel, New Westminster. At the design dry weather flow of 1.83 Imp MGD the aeration tank has a hydraulic retention time of 4.0 hours. Oxygen and mixing are supplied by both submerged air diffusers and mechanical surface aerators. The general operation characteristics of the Penticton WQCC are outlined in Table 1.

1.1.1 Phosphorous Removal. The precise mechanisms responsible for the removal of phosphorous from wastewater by iron salts addition are complex and beyond the scope of this survey. The coagulation and precipitation of soluble phosphate is dependent on pH, temperature hardness and alkalinity. In general the ferrous ion in the presence of oxygen converts to the ferric ion as follows:

$$2Fe^{2+} + \frac{1}{2}O_2 + 2H^+ \longrightarrow 2Fe^{3+} + H_2O$$

The ferric ion then combines with the phosphate ion to form a precipitate

$$Fe^{3+} + PO_4^{3-} \longrightarrow FePO_4 \downarrow$$

The dissolved oxygen in the mixed liquor is responsible for converting the iron salts to the ferric ion.

The metal analysis results from a pickling liquor sampling program conducted by the City of Penticton prior to October, 1975 is presented in Table 2(2).

1.1.2 Plant Operation. Long term performance data provided by the Penticton WQCC is given to Table 3. This data represents the monthly averages of 4-24 hour composite samples taken from the influent and effluent. Based on this information the treatment plan accomplished a 96% overall reduction in BOD_5, a 91% reduction in NFR and a 89% reduction in Total Phosphate over a one year period. Figure 2 illustrates the chlorine dosages, final effluent dissolved oxygen and pH, and daily flow readings for the month of July, 1976 prior to and including the survey period. Final effluent DO's and pH readings represent the values which were obtained daily by the operator and reported. The values for chlorine dosage and daily flow however, which were reported on a particular day, represent the 24 hour period commencing mid morning the previous day. Appendix IV lists all the data plotted in Figure 2 plus daily mixed liquor pH, NFR, settleable solids and sludge volume index (SVI) readings for the month of July prior to and including the survey period.

TABLE 2 PENTICTON WQCC SPENT PICKLE LIQUOR ANALYSIS* (2)

Metal	Average Concentration ppm	Range ppm
Cu	21	50-0
Fe	11.4×10^4	16.6×10^4-9×10^4
Ni	15	44-0
Pb	8	21-0
Zn	32	-
Al	130	300-20
Mn	423	824-200
Cr	68	215-17
Mg	160	200-130
Mo	8	30-0
Ti	15	30-10

*Results represent five samples taken from separate shipments prior to October, 1975.

Note: Other elements and compounds were analyzed for but were not found in significant quantities.

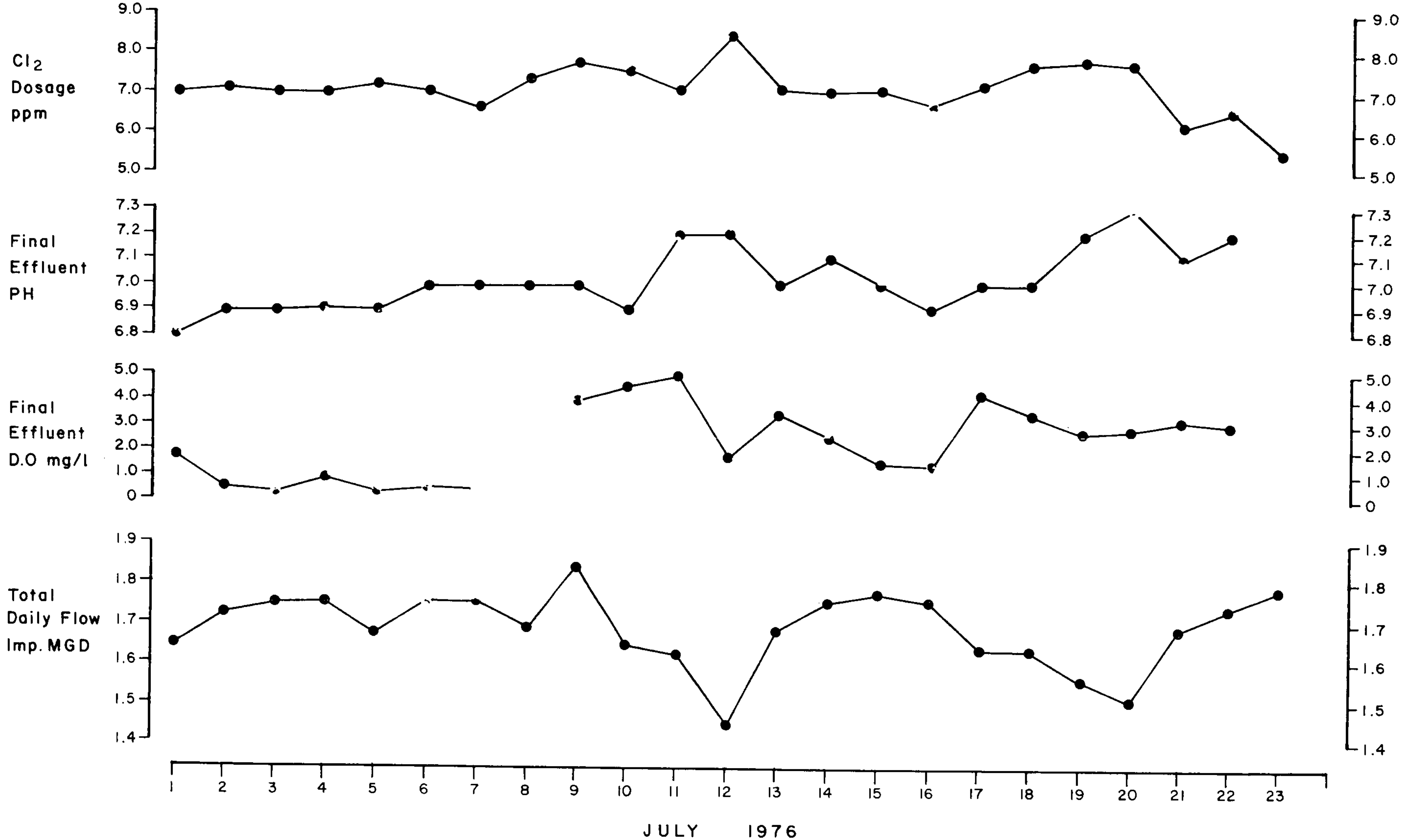

FIGURE 2 CITY OF PENTICTON WQCC PLANT PERFORMANCE DATA

TABLE 3 TREATMENT PLANT PERFORMANCE DATA - AUGUST, 1975 TO JULY, 1976

	Influent						Effluent				
Month	pH 0-14	Temp. ^{o}C	BOD mg/ℓ	COD mg/ℓ	NFR mg/ℓ	TPO_4 mg/ℓ P	pH 0-14	BOD mg/ℓ	COD mg/ℓ	NFR mg/ℓ	TPO_4 mg/ℓ P
August, 1975	7.30	21.1	213	368	198	5.7	7.0	7	25	8	0.65
September	7.00	20.0	265	440	219	5.7	6.7	10	25	15	0.40
October	7.10	18.0	370	557	200	5.4	6.9	10	36	16	0.27
November	7.20	16.0	317	615	196	6.6	8.1	34	78	38	0.64
December	7.50	12.0	252	385	150	6.1	7.4	21	54	20	0.96
January, 1976	7.70	11.0	208	385	151	6.1	7.2	7	28	10	0.61
February	7.70	11.2	215	305	182	7.0	7.0	5	20	6	0.48
March	7.60	11.0	225	315	152	5.7	7.4	5	26	6	0.44
April	7.50	13.7	205	362	170	5.8	7.3	7	35	19	0.98
May	7.20	16.5	197	274	190	6.2	7.1	6	36	16	0.52
June	7.20	17.6	203	412	163	5.3	7.0	7	26	21	0.80
July	7.20	19.3	220	333	177	5.4	7.2	5	20	12	0.83
Average	7.35	15.6	241	396	179	5.9	7.2	10	34	16	0.63

2 PROCEDURES AND METHODS

2.1 Sampling Program

The time proportional 24 hour composite samples were collected at three treatment plant locations as follows:

1) The raw sewage sample was taken from the aerated grit tank in a well mixed area near the overflow weir. Approximate 250 mℓ samples were taken every 2.5 minutes using a Markland Model 2101-Spec. Duckbill sampler.

2) The secondary effluent sample was taken from the secondary sedimentation tank overflow channel prior to the chlorine contact tank. Approximate 1.1 ℓ samples were taken every 10 minutes using an Eagle Signal timer assembly and a submersible pump.

3) The final chlorinated effluent sample was taken from the combined overflow of the polishing clarifiers located after the chlorine contact tank. Approximate 1.1 ℓ samples were taken every 10 minutes using an Eagle Signal timer assembly and a submersible pump.

The composite sample aliquots were collected in 45 gallon polyethylene barrels. The 24 hour composite sampling program commenced at 0600 hr. July 19 and ended at 0600 hr. July 23.

The raw sewage and final effluent grab samples were taken from the same locations as the composites. The grab samples were collected every 2 hours on July 21 from 0630 hr. to 1830 hr.

The grab samples for bacteriological analysis were collected at the following locations:

A Raw Sewage
B Primary Effluent, primary sedimentation tank overflow
C Secondary Effluent, prior to chlorination
D Chlorinated Secondary Effluent, chlorine contact tank overflow
E Final Chlorinated Effluent, polishing clarifier overflow

Samples for bacteriological analysis were collected in sterile 170 cc wide mouth bottles and analyzed by the Water Bacteriology staff in the EPS mobile laboratory located on site during the survey.

All sample point locations are illustrated in Figure 1.

2.2 Analyses

Table 4 lists the analytical parameters for the 24 hour composite sampling program. Table 5 lists the analytical parameters for the grab sampling program.

The contents of each composite sample barrel were well mixed prior to sample division. The samples for chemical analysis including metals were divided into sample bottles and preserved as outlined in the Environment Canada Pollution Sampling Handbook. Samples for bio-assay analysis were placed in 4-5 gal. plastic jerry cans. All samples were shipped by air within one hour to the Environment Canada laboratory facilities. Sample analysis for all parameters except metals and PCB's commenced within 6 hours of completion of each sampling day. Grab samples collected on July 21 were separated into the proper container, preserved as required and stored at $4^{o}C$ before being shipped on July 22 at 0830 hr. with the 24 hour composite samples.

2.2.1 Chemical Analyses. The chemical parameters including metals as listed in Tables 4 and 5 were analyzed as described in the Environment Canada Pacific Region Laboratory Manual.

2.2.2 Bacteriological Analyses. The total confirmed coliform MPN per 100 mℓ and fecal coliform MPN/100 mℓ were determined as described in Section 908A and 908C of the 14th Edition of Standard Methods for the Examination of Water & Wastewater.

2.2.3 Polychlorinated Biphenyls Analysis (PCB). Samples for PCB were collected in one gallon amber glass bottles containing 50 mℓ hexane as a preservative. Basically the analysis involves acetone: hexane extraction, filtration, purification and electron capture GLC analysis. The detection limit for a one gallon sample is approximately 0.005 ppb.

TABLE 4 ANALYTICAL PARAMETERS - 24 HOUR COMPOSITE SAMPLING PROGRAM

Parameter	Abbreviation	Units
Total Phosphate	TPO_4	mg/ℓ P
Ammonia	NH_3	mg/ℓ N
Nitrate	NO_3	mg/ℓ N
Nitrite	NO_2	mg/ℓ N
Total Alkalinity	-	mg/ℓ Ca CO_3
Chemical Oxygen Demand	COD	mg/ℓ
Total Organic Carbon	TOC	mg/ℓ C
pH	-	0-14 pH units
Non Filterable Residue	NFR	mg/ℓ
Anionic Surfactants	-	mg/ℓ LAS
Total Residue	TR	mg/ℓ
Cyanide	CN	mg/ℓ
Phenol	-	mg/ℓ
Oil & Grease	-	mg/ℓ
Poly Chlorinated Biphenyls	PCB	ppb
Bioassay	LC_{50}	%
<u>Metals</u>		
Total Mercury	Hg	µg/ℓ
Copper, Total & Dissolved	Cu	mg/ℓ
Iron, Total & Dissolved	Fe	mg/ℓ
Nickel, Total & Dissolved	Ni	mg/ℓ
Lead, Total & Dissolved	Pb	mg/ℓ
Zinc, Total & Dissolved	Zn	mg/ℓ
Aluminum, Total & Dissolved	Al	mg/ℓ
Cadmium, Total & Dissolved	Cd	mg/ℓ
Manganese, Total & Dissolved	Mn	mg/ℓ
Chromium, Total & Dissolved	Cr	mg/ℓ

TABLE 5 ANALYTICAL PARAMETERS - GRAB SAMPLING PROGRAM

Parameter	Abbreviation	Units
Total Phosphate	TPO_4	mg/ℓ P
Ammonia	NH_3	mg/ℓ N
Nitrate	NO_3	mg/ℓ N
Nitrite	NO_2	mg/ℓ N
Non Filterable Residue	NFR	mg/ℓ
Chemical Oxygen Demand	COD	mg/ℓ
Anionic Surfactants	-	mg/ℓ LAS
Total Residue	TR	mg/ℓ
Total Organic Carbon	TOC	mg/ℓ C
<u>Metals</u>		
Copper, Total & Dissolved	Cu	mg/ℓ
Iron, Total & Dissolved	Fe	mg/ℓ
Nickel, Total & Dissolved	Ni	mg/ℓ
Lead, Total & Dissolved	Pb	mg/ℓ
Zinc, Total & Dissolved	Zn	mg/ℓ
Manganese, Total & Dissolved	Mn	mg/ℓ
Chromium, Total & Dissolved	Cr	mg/ℓ

2.2.4 Bioassay Determination (96 hour LC_{50}). The static fish bioassay test gives an approximate numerical value to the biological toxicity of a wastewater. It is defined as the concentration of a measureable lethal agent (in this case wastewater) required to kill the 50th percentile in a group of test organisms over a period of 96 hours.

The static bioassay test consists of a series of 30 ℓ glass vessels containing different sample dilutions with 6-9 Rainbow Trout (Salmo gairdneri) per test vessel. The test vessels were placed in a controlled environment room with the temperature maintained at 13.0 $\pm$ 1.0^{o} C and a photo period limited to 16 hours per 24 hours. The bioassay test procedures calls for samples with pH values below 6.0 or above 8.0 to be neutralized to a pH of 7; however pH adjustment was not required for any of the samples collected. All samples were aerated prior to the test and continuously, for the 96 hour period. Pre-test aeration times are listed with the test results in Table 6. The fish loading density in each vessel was 0.5 g/ℓ. The percent mortality and percent dilution were plotted on semi log paper to establish an LC_{50} value.

2.3 Chlorine Residual Monitoring

The chlorine residual monitoring program consisted of grab sampling the final chlorinated effluent (polishing clarifier overflow), every hour for 24 hours from 1200 hr July 19 to 1200 hr July 20 and determining the total residual chlorine concentration (TRC).

The determination of TRC was done using a Wallace & Tiernan Amperometric Titrator series A-790013. The fundamental procedure used is a Back Titration method involving the neutralization of an oxidizing agent (free iodine) with a reducing agent (phenylarsine oxide solution) of known strength, in the presence of potassium iodide.

Total residual chlorine as determined by the amperometric Back Titration method determines the concentration of compounds in the wastewater containing active chlorine which consist of monochloramines, dichloramines and hypochlorous acid.

3 RESULTS

3.1 Bioassay

The static fish bioassay results obtained from the 24 hour composite samples are outlined in Table 6. The results are expressed as both a 96 hour LC_{50} as defined earlier and a toxicity concentration Tc. The toxicity concentration, Tc, expressed in toxic units, Tu, can be derived as follows:

$$TC = \frac{100\%}{96 \text{ hr } LC_{50(\%)}}$$

A Tc value can also be calculated when considering wastewater that produces less than 50 percent mortality at the 100% concentration. The actual Tc value in this case is determined by plotting the percent mortality of test fish versus the Tc values for the various test dilutions of wastewater in which the undiluted wastewater has a Tc value greater than 1.

3.2 Chemical Analyses Non Metals

The chemical analysis non-metal results obtained from the 24 hour composite samples are listed in Appendix I. A comparison of these results and the treatment level involved with each sample is illustrated in Figure 3a and 3b. The values plotted in this comparison represent the mean value from the 4-24 hour composite samples. The chemical analysis non-metal results obtained from the grab sampling program are outlined in Appendix II.

3.3 Chemical Analyses Metals

The results of the metal analyses including total and dissolved for the 24 hour composite sampling program are presented in Appendix I. The same results for the grab sampling program are given in Appendix II.

3.4 Bacteriological Results

Appendix III list the individual bacteriological results for samples taken during the survey.

A plot of the mean total confirmed coliform and fecal coliform MPN/100 mℓ values obtained from the various treatment plant

TABLE 6 PENTICTON WQCC COMPOSITE SAMPLE BIOASSAY RESULTS

Sample Point	Parameter	Unit	Date July 20	July 21	July 22	July 23	Average
Raw Sewage	Pre-test Aeration	hr	24	24	24	25	
	LC_{50}	%	65	61	57	63	61.5
	Tc	Tu	1.54	1.64	1.75	1.59	1.63
Secondary Effluent	Pre-test Aeration	hr	24	24	24	25	
	LC_{50}	%	87	99	78	87	87.8
	Tc	Tu	1.15	1.01	1.28	1.15	1.15
Final Chlorinated Effluent	Pre-test Aeration	hr	24	24	24	25	
	LC_{50}	%	51	<32*	31	49	40.5
	Tc	Tu	1.96	>3.13	3.23	2.04	2.59

*96 hr LC_{50} could not be determined. Mortality was 78% at the lowest concentration (32% v/v) after 96 hr.

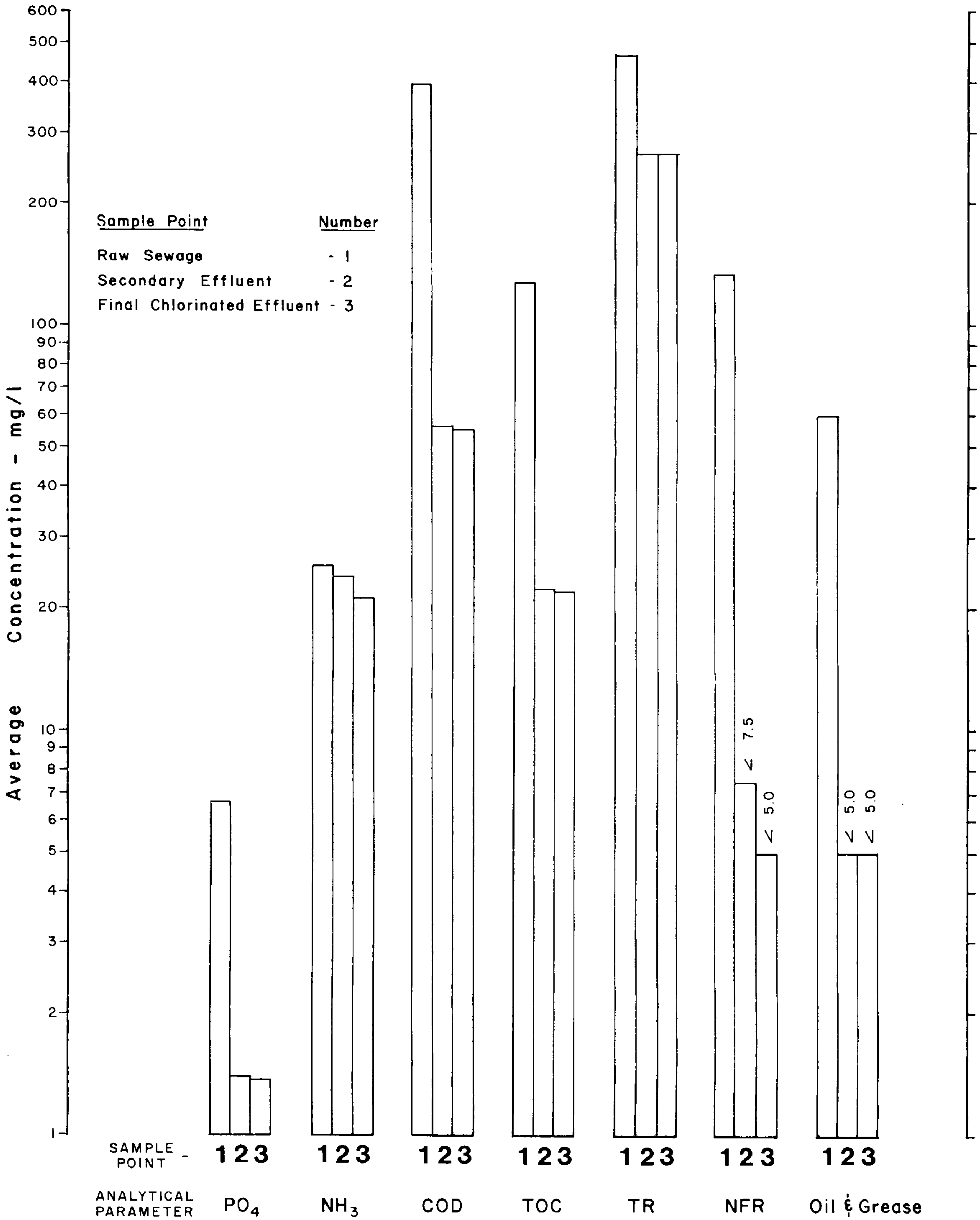

FIGURE 3a COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL.

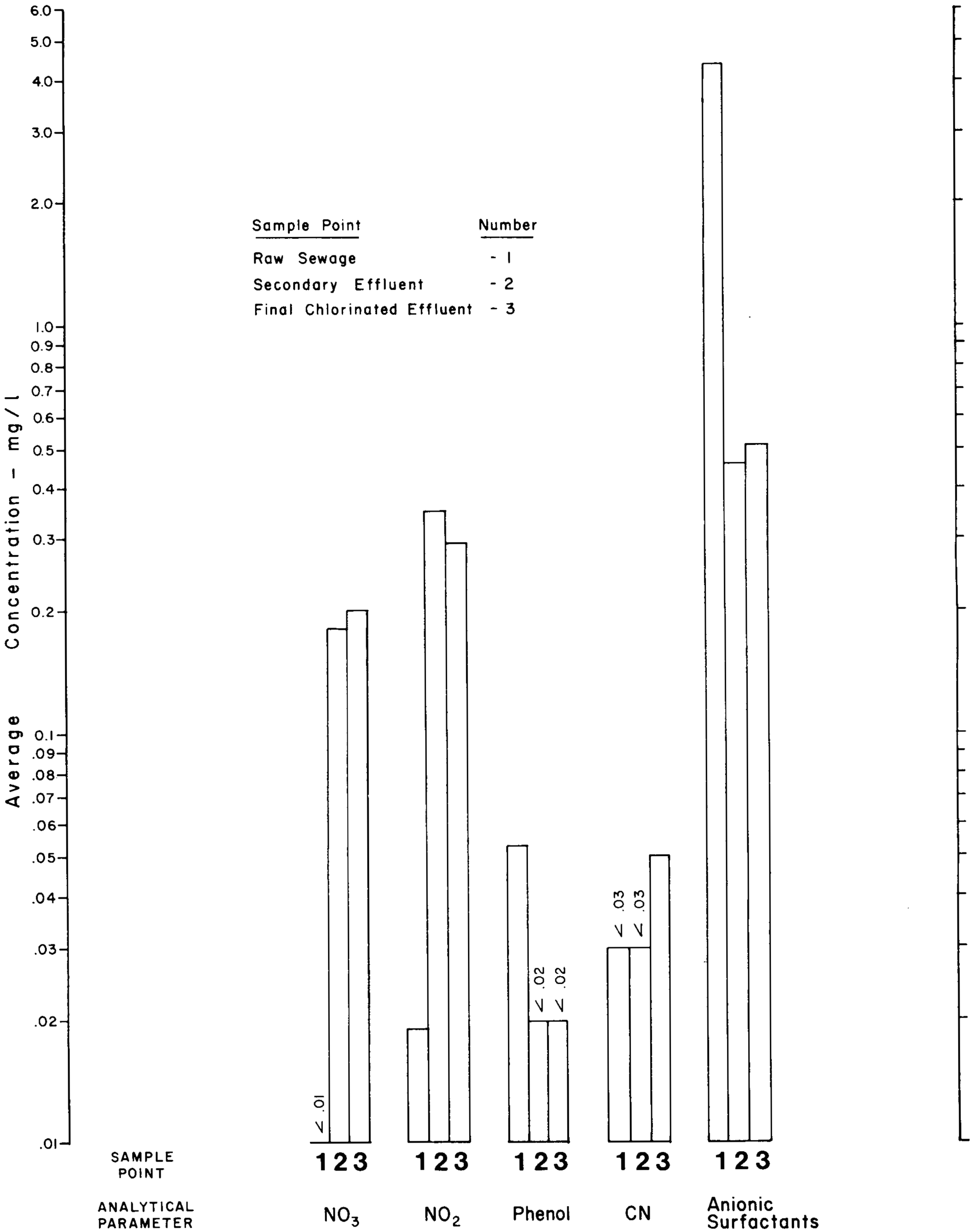

FIGURE 3b COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL.

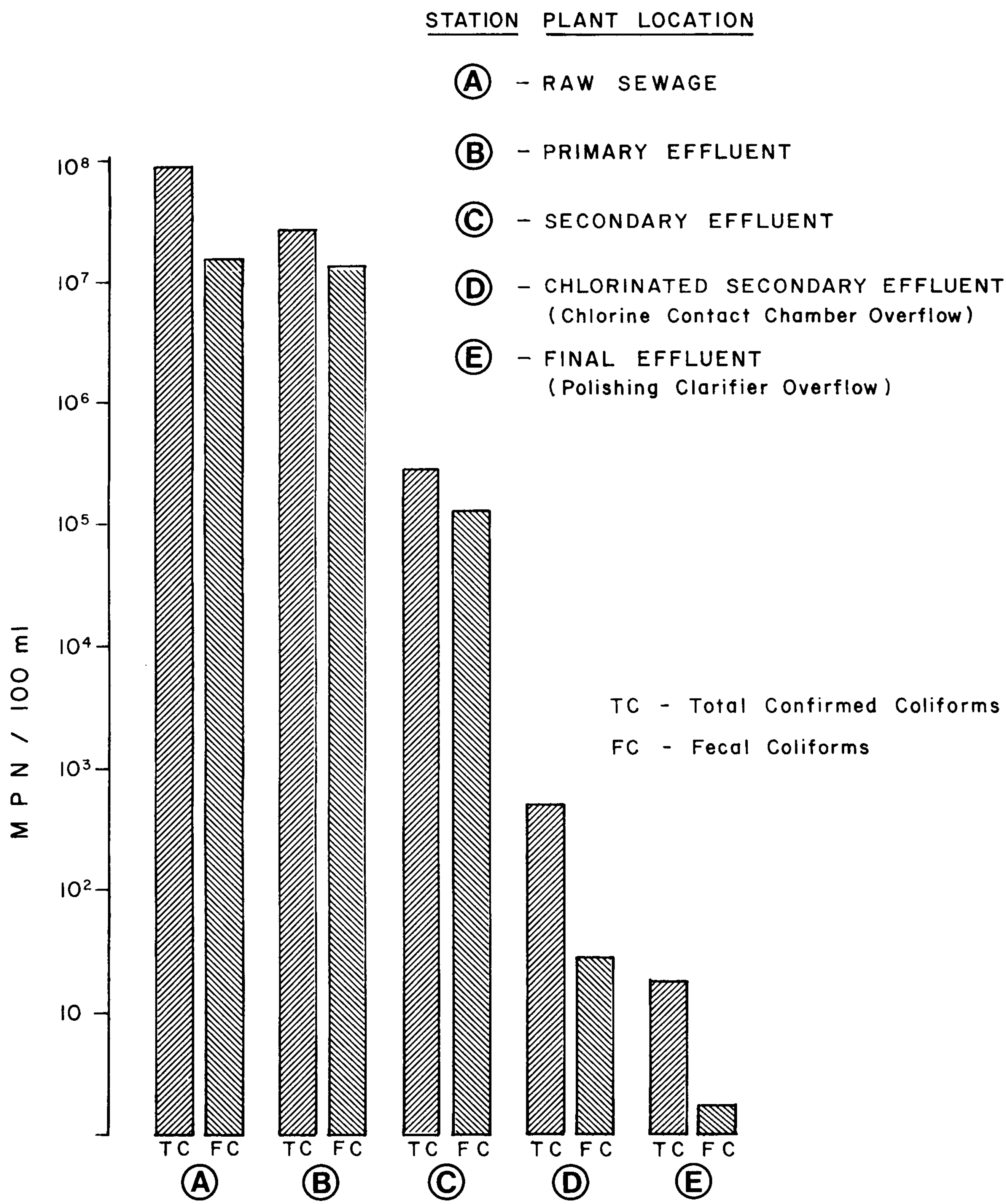

FIGURE 4 PENTICTON WQCC - MEAN TOTAL AND FECAL COLIFORM CONCENTRATIONS vs. TREATMENT LEVEL

locations is illustrated in Figure 4. The raw sewage mean fecal coliform MPN/100 mℓ was 1.9 X 10^7. After primary treatment the mean fecal coliform value dropped to 1.7 X 10^7. Secondary treatment which includes phosphorous removal further reduces the mean fecal coliform value to 1.1 X 10^5. Chlorine addition and 30 minutes of contact in the chlorine contact chamber lowers the mean fecal coliform level to 44 and finally 3.3 hours of residence time in the polishing clarifier reduces the mean fecal coliform to 2.3.

3.5 Chlorine Residual Monitoring Results

The results of the 24 hour chlorine residual monitoring program are illustrated in Figure 5. The TRC had a range of 0.80-3.48 mg/ℓ and a mean of 1.80 mg/ℓ.

3.6 Polychlorinated Biphenyls Results

The results of the PCB analysis for the 24 hour composite sampling program are listed in Appendix I. All levels encountered are significantly low. The treatment plant is responsible for a 69% reduction in PCB levels from influent to effluent.

3.7 Daily Flowrates, Chlorine Dosages and Precipitation

Daily flowrates and chlorine dosages for a one year period, July 1, 1975 to June 30, 1976, for the Penticton WQCC have been plotted in Appendix V. In addition total daily precipitation data has been provided. This data would tend to indicate the absence of an infiltration/inflow problem in the sewer system. In general, flows tend to peak during the summer months and drop during the late fall, winter and spring. The mean annual precipitation (1941-1970) for Penticton is 296.2 mm. Figure 6 illustrates the actual flow readings taken every three hours for a one week period from 0900 hr July 16 to 0900 July 23. This shows a typical diurnal pattern with peaks at 1100 hr of 2.4-2.5 Imp MGD and lows of 0.6-0.7 Imp MGD at 0600 hr.

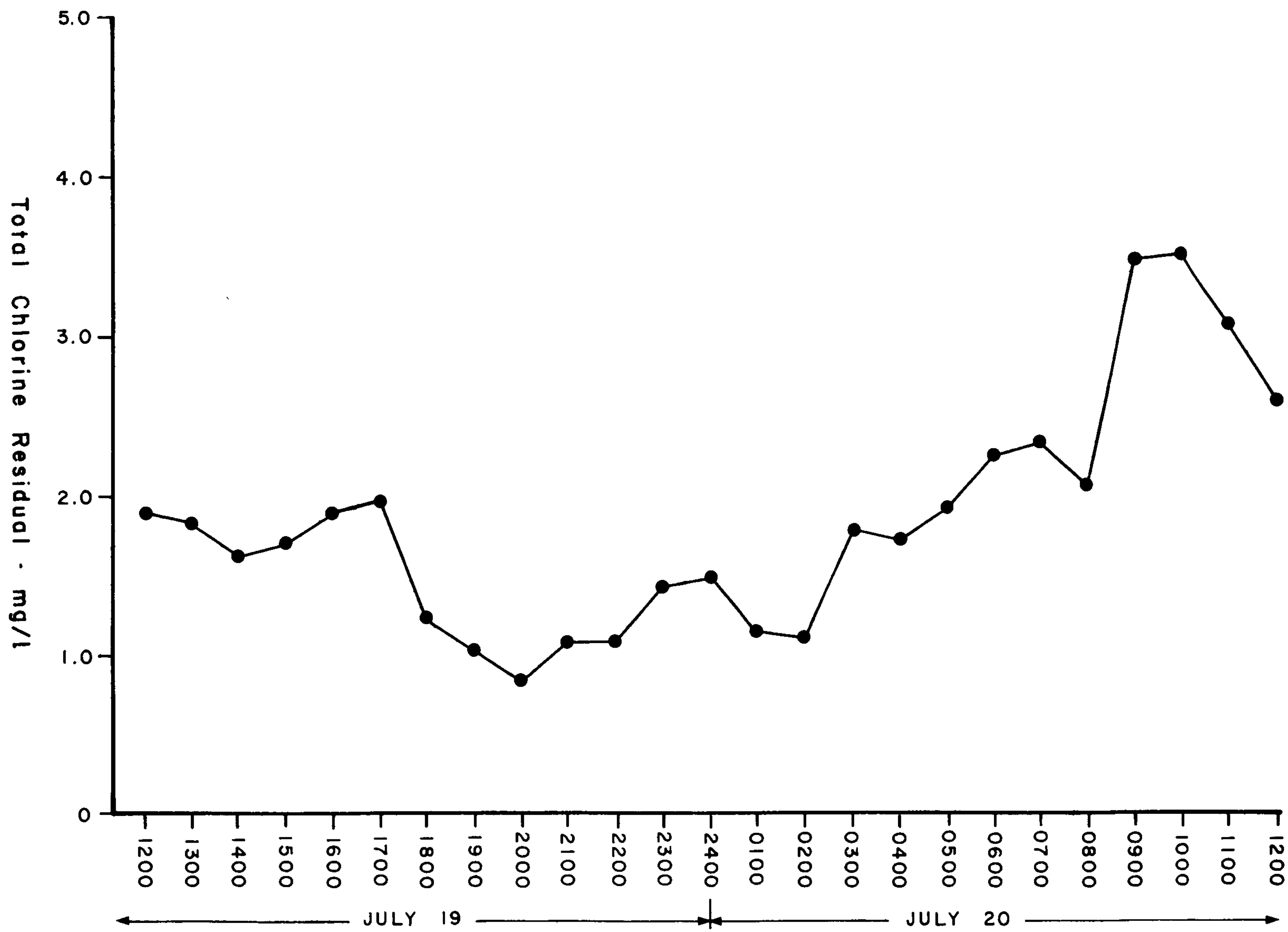

FIGURE 5 24 HOUR CHLORINE RESIDUAL MONITORING PROGRAM

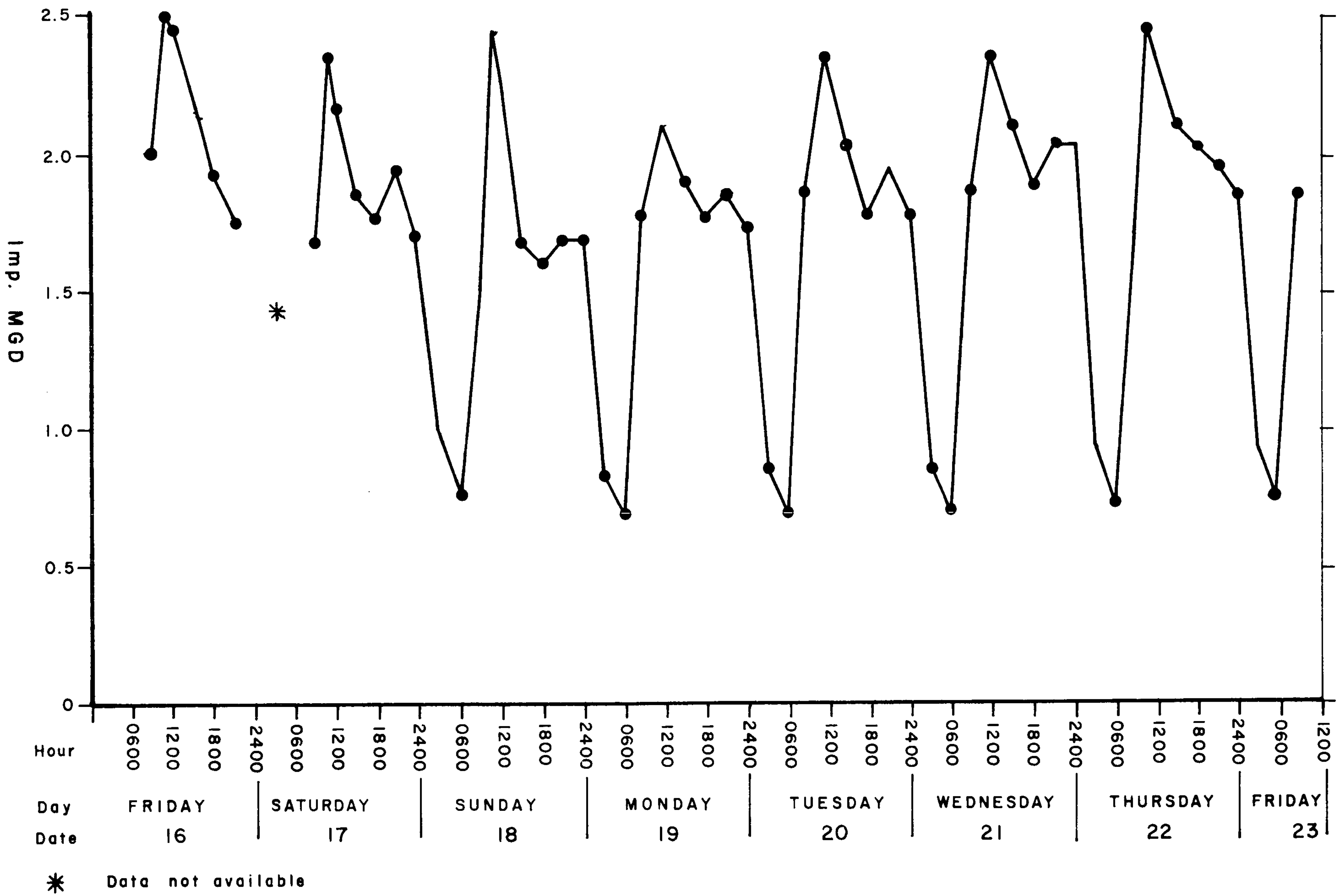

FIGURE 6 CITY OF PENTICTON WQCC, FLOWRATES JULY 16 - 23, 1976

3.8 Metals Analyses Summary

In addition to the metal analyses conducted during the survey on the composite samples, metal determinations were also carried out on

1) aeration mixed liquor,
2) the waste pickling liquor,
3) the primary digester sludge, and
4) the municipal water supply.

The results of these analyses are presented in Table 7. As indicated, pickling liquor contains relatively high concentrations of copper, iron, nickel, zinc, aluminum, manganese and chromium. The results indicate that there is no significant carry over of these metals into the final effluent. Instead the metals tend to accumulate in the digester sludge. The municipal water supply sample was provided for background information.

TABLE 7 METAL ANALYSIS SUMMARY

Sample Point Designation:

Raw Sewage	A
Final Effluent	B
Aeration Mixed Liquor	C
Waste Pickling Liquor	D
Primary Digested Sludge	E
Municipal Water Supply	F

Metal	A[1] mg/ℓ	B[1] mg/ℓ	C[2] mg/ℓ	D[2] mg/ℓ	E[2] mg/ℓ	F[2] mg/ℓ
Cu	0.20	0.02	1.3	33	80	0.06
Fe	1.6	0.45	110	1.3×10^5	3.1×10^3	0.59
Ni	<0.05	<0.05	<0.05	23	0.88	<0.05
Pb	0.03	<0.02	0.07	<2.0	<0.08	<0.02
Zn	0.21	0.16	0.69	44	47	0.03
Al	0.58	<0.3	3.2	370	360	0.3
Cd	<0.01	<0.01	<0.01	<1.0	0.36	<0.01
Mn	0.07	0.07	0.5	620	20	<0.03
Cr	<0.02	<0.02	0.04	13	3.3	<0.02
Hg[3]	<0.23	<0.20	-	-	-	0.48

[1]Average of four - 24 hr composite samples.

[2]Result of one grab sample only.

[3]Units μg/ℓ.

4 DISCUSSION

4.1 Bioassay Evaluation

Municipal wastewaters in general contain a wide variety of chemical constituents readily known to be toxic to fish. The most common constituents exerting toxicity include ammonia, cyanide, sulfides, chlorine and chloramine, phenols, surfactants and several heavy metals which include copper, zinc, chromium and nickel. Other factors such as temperature, pH, hardness, alkalinity and dissolved oxygen tend to modify the toxicity produced by various chemical constitutents. However as outlined earlier the bioassay test conditions are controlled so that pH, temperature and dissolved oxygen do not themselves exert toxicity. The chemical analyses results for the individual composite samples were examined with reference to the literature to determine those factors responsible for toxicity. Following is a discussion of those factors deemed responsible for the bioassay results encountered in the survey.

4.1.1 Ammonia Toxicity. The common sources of ammonia in wastewater are:

1) urine, which contains urea (H_2NCOH_2N) which in turn readily hydrolizes to ammonia,
2) organic matter containing protein and amino acids which decomposes under bacterial action yielding ammonia,
3) chemical plants and cleaning establishments which release ammonia to the sewer system, and
4) household cleaning agents.

The toxicity of ammonia and ammonium salts to fish is directly related to the amount of un-ionized ammonia in solution. Ammonia establishes a pH dependent equilbrium in solution as follows:

$$NH_3 + nH_2O \rightleftharpoons NH_3 \cdot nH_2O \rightleftharpoons NH_4^+ + OH^- + (n-1)H_2O$$

Emmerson, et al (3) have outlined a set of equilibrium calculations for determining the un-ionized ammonia in solution under varying conditions of pH and temperature. The un-ionized ammonia concentrations for the 24 hour composite samples have been calculated according to this set of equations and are reported in Table 8. In addition, this

TABLE 8 COMPARISON OF ANALYTICAL AND BIOASSAY RESULTS

Sample Points	Date	LC_{50}	Tc	NH_3	*Un-ionized NH_3	Diss. Cu	Diss. Zn	CN^-	Alkalinity	Anionic Surfactants
	July	%	Tu	mg/ℓ N	mg/ℓ N	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ $CaCO_3$	mg/ℓ LAS
Raw Sewage	20	65	1.50	21	0.24	0.11	0.17	<0.03	181	4.80
	21	61	1.60	29	0.42	0.09	0.09	<0.03	176	4.00
	22	57	1.75	22	0.32	0.08	0.20	<0.03	184	4.30
	23	63	1.59	30	0.18	0.13	0.23	<0.03	199	4.20
Secondary Effluent	20	87	1.15	21	0.12	0.03	0.19	<0.03	140	0.70
	21	99	1.00	26	0.24	0.03	0.10	<0.03	147	0.37
	22	78	1.28	22	0.16	0.03	0.20	<0.03	154	0.44
	23	87	1.15	27	0.20	0.02	0.18	<0.03	142	0.34
Final Chlorinated Effluent	20	51	1.96	21	0.12	0.03	0.18	0.05	138	0.70
	21	<32	3.13	23	0.17	0.01	0.10	0.03	144	0.36
	22	31	3.22	17	0.16	0.02	0.12	0.07	145	0.44
	23	49	2.04	24	0.14	0.02	0.37	0.05	138	0.54

*According to Emmerson, et al (3).

table lists the bioassay results and the major toxic constituents involved for each composite sample.

Mayo, et al (4) state that 0.006 mg/ℓ N un-ionized ammonia may be considered to be the desirable upper level for extended fish exposure. A level of 0.025 mg/ℓ un-ionized ammonia has been stated as the maximum that fish can tolerate (5). Lloyd and Orr (6) reported that 0.44 mg/ℓ un-ionized ammonia caused 100% mortality of Salmo gairdneri in 96 hours.

The un-ionized ammonia levels reported in Table 8 fall within the 0.025-0.44 m g/ℓ range and therefore would be expected to contribute significantly to wastewater toxicity. However, as pointed out by Esvelt, Kaufman & Selleck (7) it should be noted that factors in addition to un-ionized ammonia may be associated with the toxicity of ammonia. A full discussion of these factors is beyond the scope of this report.

4.1.2 Copper and Zinc Toxicity. The toxicity of copper to aquatic organisms is normally associated with the dissolved copper concentration. Copper in wastewater can originate from industrial sources or from the corrosion of copper pipes. Increasing water hardness tends to decrease copper toxicity. In addition copper tends to act synergistically when present with zinc, cadmium, mercury and lead. The threshold 96 hr LC_{50} of copper for rainbow trout was reported to be 0.044 mg/ℓ in soft water (8) increasing to 0.5 mg/ℓ in very hard water (9). Relationships between water hardness, and lethal toxicity for copper, lead and zinc have been established by Brown (10) and Lloyd and Herbert (11). Using these references, the levels of dissolved copper found in Table 8, especially the raw sewage samples, could be expected to increase toxicity. The levels of zinc encountered in the sewage samples are not significantly high but could be excpected to act synergistically with copper.

4.1.3 Cyanide Toxicity. Cyanides occur in water as cyanide ion (CN^-), as undissociated hydrogen cyanide and in complexes with other constituents. Cyanides are generally associated with metal processing wastes and some household cleanrs. Hydrogen cyanide rather than cyanide ion seems to produce toxicity. Hydrogen cyanide dissociates to cyanide ion and hydronium ion and has a dissociation constant of 4.93×10^{-10} at $25^{o}C$. Nickel complexes cyanide to make it less toxic whereas copper and cadmium complexes are exceedingly toxic (12).

Brown (10) determined a 48 hr LC_{50} for rainbow trout of 0.01 mg/ℓ for CN. In reference to Table 8, the cyanide concentration in the final effluent samples is sufficient to exert a toxic influence on the bioassay test. Due to the fact that the cyanide analysis detection limit is 0.03 mg/ℓ it is difficult to determine the degree of cyanide toxicity present in the raw sewage and secondary effluent samples.

4.1.4. Surfactant Toxicity. Detergents are a common component of sewage and industrial effluents, derived in largest amounts from household cleaning agents. Surfactants can be divided as being either anionic, cationic or non-ionic. In current detergent formulas, the primary toxic active agent is LAS, (linear alkylate sulfonates) an anionic surfactant. The surfactant analysis conducted during this survey was carried out specifically for LAS.

The toxicity of LAS tends to increase in hard water, and increase as the carbon chain length increases (7).

Thatcher and Santner (13) found 96 hr LC_{50} values for LAS of 3.3-6.4 mg/ℓ for five species of fish. Dolan and Hendricks determined an LC_{50} of 5.9 mg/ℓ LAS for bluegill sunfish (14). The anionic surfactant concentrations for the raw sewage samples as outlined in Table 8 would be expected to contribute to wastewater toxicity.

4.1.5 Chlorine Toxicity. The toxicity of chlorine and other chlorinated compounds such as chloramines and chlorinated hydrocarbons has been thoroughly documented in the literature. Martens and Servizi (15) observed that the toxicity of primary treated sewage to sockeye salmon was increased several fold whenever chlorine residuals were detected in the effluent. In field studies, residual chlorine levels above 0.02 mg/ℓ were found likely to be toxic to rainbow trout and sockeye salmon using in stream bioassay techniques (15).

The toxicity of chlorinated wastewater does not depend directly on the amount of chlorine added but on the concentration of residual chlorine remaining (16). Residual chlorine is commonly understood to mean the total concentration of compounds containing active chlorine which remain after free chlorine addition. These compounds consist of monochloramines, dichloramines and hypochlorous acid. In addition chlorine may combine with a variety of compounds in wastewater including cyanide, phenols and alkyl sulfonate, which are not detectable by the amperometric technique.

Residual chlorine is known to decrease with time owing to reaction with substances in sewage. Martens and Servizi (15) reported in a test of chlorinated primary sewage that the residual chlorine decreased significantly from 2.6 mg/ℓ during the first 10 hr but assumed a virtually constant value of 0.2 mg/ℓ which persisted beyond 50 hr.

During the 24 hr chlorine residual monitoring program carried out during the Penticton study the TRC averaged 1.80 mg/ℓ and had a range of 0.80-3.48 mg/ℓ.

The 24 hr composite samples collected for bioassay determination would be expected to exhibit lower residuals than reported above, from the monitoring program, and it could also be assumed that the chlorine residual in a particular sample would tend to decrease with time to a very low or non detectable level. During this study, tests performed on the composite samples prior to the bioassay determination indicated the absence of a detectable chlorine residual. The bioassay results indicate however, that there is a significant increase in toxicity which is associated with chlorination even though by the time the bioassay determination commenced the chlorine residual had reached non detectable levels.

4.2 Bioassay Summary

A comparison of the toxicity concentrations, Tc, of the 24 hour composite samples obtained from the three treatment plant locations appears in Figure 7.

The raw sewage exhibited a mean 96 hr LC_{50} of 61.5% (Tc = 1.63). Most of the toxicity associated with the raw sewage would be attributable to the un-ionized ammonia content (0.29 mg/ℓ N) and the anionic surfactant concentration (4.33 mg/ℓ LAS); in addition some influence would be exerted by the dissolved copper and zinc content.

The secondary effluent exhibited a mean 96 hr LC_{50} of 87.8% (Tc = 1.15). This represents a 29.4% reduction of the raw sewage toxicity. Activated sludge sewage treatment was responsible for a drop in the average un-ionized ammonia content to 0.18 mg/ℓ N and in the average anionic surfactant level to 0.46 mg/ℓ LAS. This results in a corresponding drop in toxicity. In addition there is some reduction in the dissolved copper level.

The final chlorinated effluent exhibited a mean 96 hr LC_{50} of 40.5% (Tc = 2.59). Since there are only slight differences in the analytical results between the secondary effluent and final chlorinated effluent samples it would appear that chlorination is responsible for an increase in the toxicity concentration of 1.44 TU. However the precise compounds responsible for chlorine induced toxicity have not been determined. Also of interest is the fact that cyanide levels increase in the final effluent as compared to the raw sewage and secondary effluent. As mentioned earlier this cyanide level could be expected to exert a toxic influence on the bioassay test. Possible explanations are:

1) compounds produced by chlorination are being read as cyanides in the cyanide analysis,

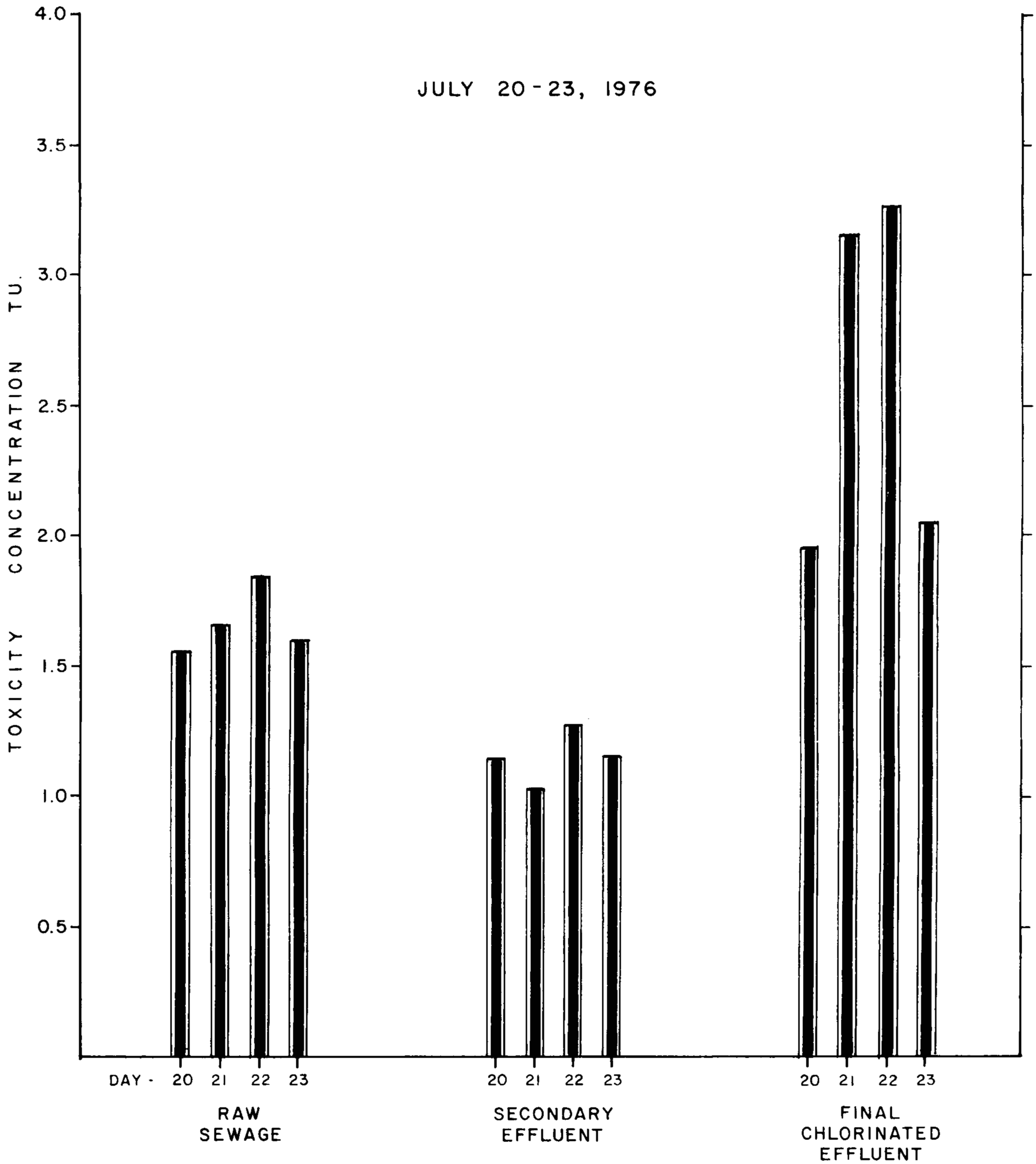

FIGURE 7 PENTICTON WQCC BIOASSAY RESULTS, TOXICITY CONCENTRATIONS

2) compounds, such as sulfides, fatty acids and urea which interfere with the cyanide analysis, are being destroyed by chlorination, and
3) cyanide ions are being released from an organo-cyanide complex by chlorination. The colorimetric method does not reveal the presence of some organo-cyanide complexes.

4.3 Disinfection

One objective of this study was to determine the degree of disinfection achieved by tertiary treatment. However due to the plant configuration the tertiary aspect (in this case phosphorous removal) cannot be delineated from the activated sludge process, since phosphorous removal is accomplished by the addition of iron salts to the aeration tanks. The results of the bacteriological monitoring program are listed in Appendix III and illustrated in Figure 4. Metcalf and Eddy (17) state that activated sludge sewage treatment in general is capable of a 90-98% reduction in bacterial levels. In the case of the Penticton treatment plant activated sludge sewage treatment which includes phosphorous removal accomplished a 99.35% reduction of the primary effluent fecal coliform concentration. However it should be noted that the actual mean fecal coliform concentration at this point was 1.1×10^5 MPN/100 mℓ, a level which would require disinfection prior to discharge.

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APPENDIX I

PENTICTON WQCC COMPOSITE SAMPLE ANALYTICAL RESULTS

a. Non Metals

b. Metals

APPENDIX I PENTICTON WQCC COMPOSITE SAMPLE ANALYTICAL RESULTS

a. Non Metals

Sampling Point	Number
Raw Sewage	1
Secondary Effluent	2
Chlorinated Final Effluent	3

Analytical Parameter	Sampling Point	Date			
		July 20	July 21	July 22	July 23
TPO_4 mg/ℓ P	1	7.6	5.6	5.2	8.3
	2	1.4	1.3	1.5	1.4
	3	1.2	1.3	1.5	1.5
NH_3 mg/ℓ N	1	21	29	22	30
	2	21	26	22	27
	3	21	23	17	24
NO_3 mg/ℓ N	1	<0.01	<0.01	<0.01	<0.01
	2	0.28	0.12	0.15	0.16
	3	0.19	0.20	0.19	0.22
NO_2 mg/ℓ N	1	0.02	0.02	0.015	0.02
	2	0.34	0.38	0.35	0.31
	3	0.31	0.30	0.31	0.25
Alkalinity mg/ℓ $CaCO_3$	1	181	176	184	199
	2	140	147	154	142
	3	138	144	145	138
COD mg/ℓ	1	390	340	350	500
	2	61	64	40	59
	3	65	40	43	71
TOC	1	122.0	126.0	123.0	132
	2	26.0	22.0	19.0	22.0
	3	26.0	22.0	20.0	18.0
pH	1	7.7	7.8	7.8	7.4
	2	7.4	7.6	7.5	7.5
	3	7.4	7.5	7.6	7.4
NFR mg/ℓ	1	77	110	160	190
	2	7.5	<5	<5	<5
	3	<5	<5	<5	<5
Anionic Surfactants mg/ℓ LAS	1	4.8	4.0	4.3	4.2
	2	0.7	0.37	0.44	0.34
	3	0.7	0.36	0.44	0.54
TR mg/ℓ	1	440	418	480	520
	2	280	280	260	240
	3	280	260	260	260
CN mg/ℓ	1	<0.03	<0.03	<0.03	<0.03
	2	<0.03	<0.03	<0.03	<0.03
	3	0.05	0.03	0.07	0.05
Phenol mg/ℓ	1	.07	.05	.04	.05
	2	<.02	<.02	<.02	<.02
	3	<.02	<.02	<.02	<.02
Oil & Grease mg/ℓ	1	56	43	83	55
	2	<5	<5	<5	<5
	3	<5	5	<5	<5
PCB ppb	1	0.039	0.043	0.057	0.052
	2	0.040	0.007	0.017	0.011
	3	0.020	0.013	0.011	0.015

APPENDIX I PENTICTON WQCC COMPOSITE SAMPLE

ANALYTICAL RESULTS

b. Metals

Sampling Point	Number
Raw Sewage	1
Secondary Effluent	2
Chlorinated Final Effluent	3

Analytical	Parameter	Sampling Point	Date July 20	July 21	July 22	July 23
Zn	Total	1	0.27	0.18	0.5	0.22
mg/ℓ		2	0.29	0.12	0.11	0.09
		3	0.28	0.11	0.10	0.13
Zn	Dissolved	1	0.17	0.09	0.20	0.23
		2	0.19	0.10	0.20	0.18
		3	0.18	0.10	0.12	0.37
Al	Total	1	0.6	0.6	0.5	0.5
		2	<0.3	<0.3	<0.3	<0.3
		3	<0.3	<0.3	<0.3	<0.3
Al	Dissolved	1	<0.3	<0.3	<0.3	<0.3
		2	<0.3	<0.3	<0.3	<0.3
		3	<0.3	<0.3	<0.3	<0.3
Cd	Total	1	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01
Cd	Dissolved	1	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01
Mn	Total	1	0.06	0.06	0.06	0.08
		2	0.07	0.05	0.07	0.05
		3	0.08	0.06	0.08	0.07
Mn	Dissolved	1	0.06	0.05	0.05	0.05
		2	0.09	0.05	0.06	0.05
		3	0.09	0.07	0.08	0.07
Cr	Total	1	0.03	0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Cr	Dissolved	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Hg	Total	1	0.23	0.20	0.27	<0.20
µg/ℓ		2	<0.20	1.9	<0.20	0.20
		3	<0.20	<0.20	<0.20	<0.20
Cu	Total	1	0.23	0.16	0.18	0.22
mg/ℓ		2	0.03	0.02	0.02	0.02
		3	0.03	0.02	0.02	0.02
Cu	Dissolved	1	0.11	0.09	0.08	0.13
		2	0.03	0.03	0.03	0.02
		3	0.03	0.01	0.02	0.02
Fe	Total	1	2.1	1.2	1.4	1.7
		2	0.66	0.22	0.34	0.28
		3	0.91	0.29	0.32	0.29
Fe	Dissolved	1	0.78	0.57	0.63	1.0
		2	0.35	0.10	0.15	0.12
		3	0.46	0.16	0.19	0.16
Ni	Total	1	<0.05	<0.05	<0.05	<0.05
		2	<0.05	<0.05	<0.05	<0.05
		3	<0.05	<0.05	<0.05	<0.05
Ni	Dissolved	1	<0.05	<0.05	<0.05	<0.05
		2	<0.05	<0.05	<0.05	<0.05
		3	<0.05	<0.05	<0.05	<0.05
Pb	Total	1	0.04	0.03	0.02	0.03
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02
Pb	Dissolved	1	<0.02	<0.02	<0.02	<0.02
		2	<0.02	<0.02	<0.02	<0.02
		3	<0.02	<0.02	<0.02	<0.02

APPENDIX II

PENTICTON WQCC GRAB SAMPLE
ANALYTICAL RESULTS

a. Non Metals

b. Metals

APPENDIX II PENTICTON WQCC GRAB SAMPLE ANALYTICAL RESULTS, JUNE 21, 1976

a. Non Metals

Sampling Point	Number
Raw Sewage	1
Final Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Time (hr)						
		0630	0830	1030	1230	1430	1630	1830
TPO_4	1	2.1	9.8	9.8	8.8	7.6	7.4	6.5
mg/ℓ P	3	1.4	1.3	1.1	0.8	1.3	1.6	1.6
NH_3	1	16	52	38	23	44	29	25
mg/ℓ N	3	26	22	23	26	35	30	32
NO_3	1	<.01	<.01	<.01	<.01	<.01	<.01	<.01
mg/ℓ N	3	.28	.27	.12	.55	.36	.35	.54
NO_2	1	.007	.019	.025	.033	.028	.032	.025
mg/ℓ N	3	.22	.24	.41	.85	.64	.42	.31
NFR	1	22	290	150	180	190	170	150
mg/ℓ	3	<5	16	<5	<5	<5	<5	<5
COD	1	150	930	510	810	500	480	430
mg/ℓ	3	43	47	36	36	32	40	40
Anionic Surfactants	1	0.88	0.88	3.3	5.8	9.3	7.4	5.5
mg/ℓ LAS	3	0.34	0.35	0.25	0.17	0.17	0.20	0.28
TR	1	230	600	500	540	700	500	450
mg/ℓ	3	270	260	250	240	230	240	270
TOC	1	49.0	152	226	188	148	146	134
mg/ℓ C	3	20.0	20	20	13	16	20	20

APPENDIX II PENTICTON WQCC GRAB SAMPLE ANALYTICAL RESULTS, JUNE 21, 1976

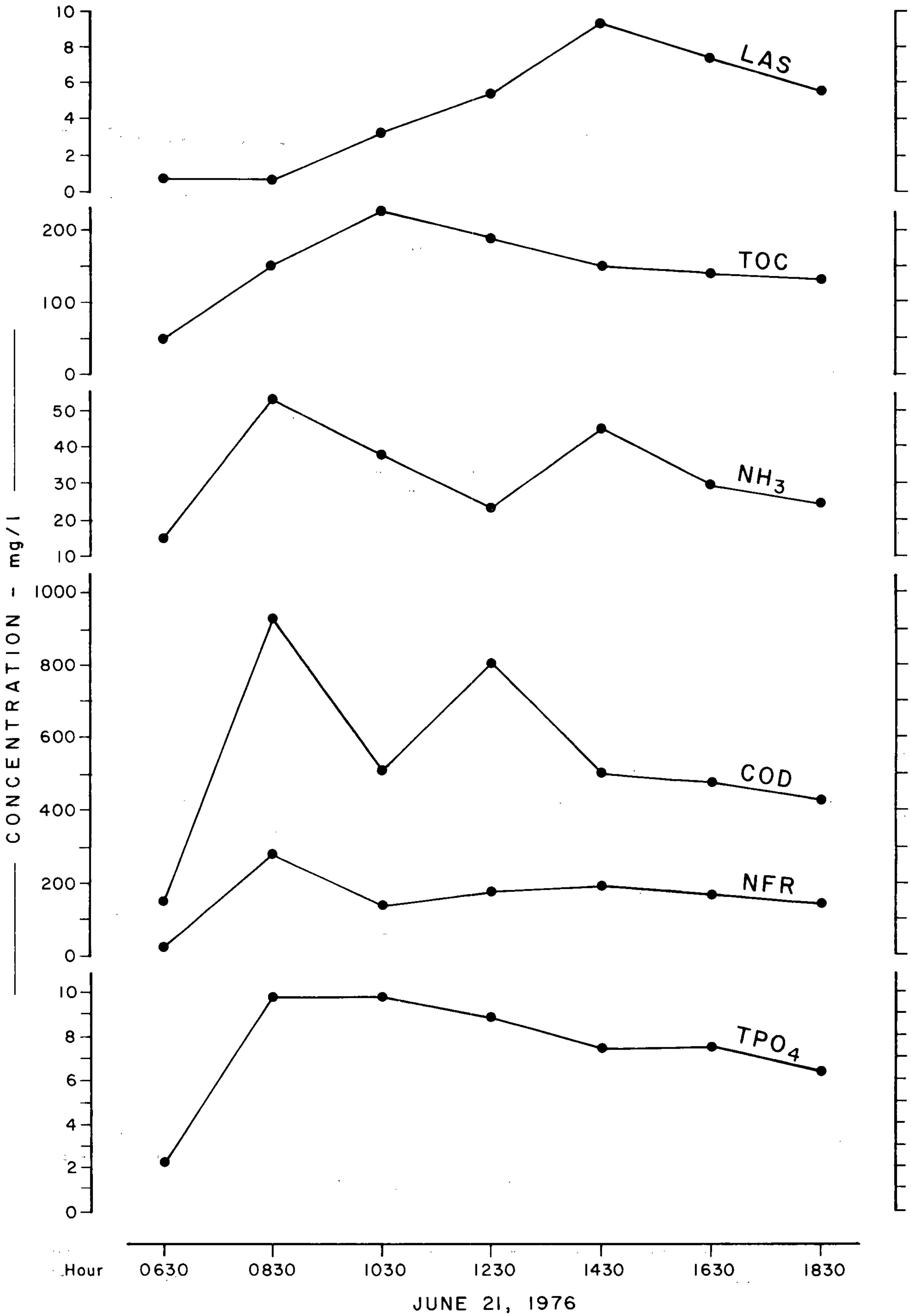
b. Metals

Sampling Point	Number
Raw Sewage	1
Final Chlorinated Effluent	3

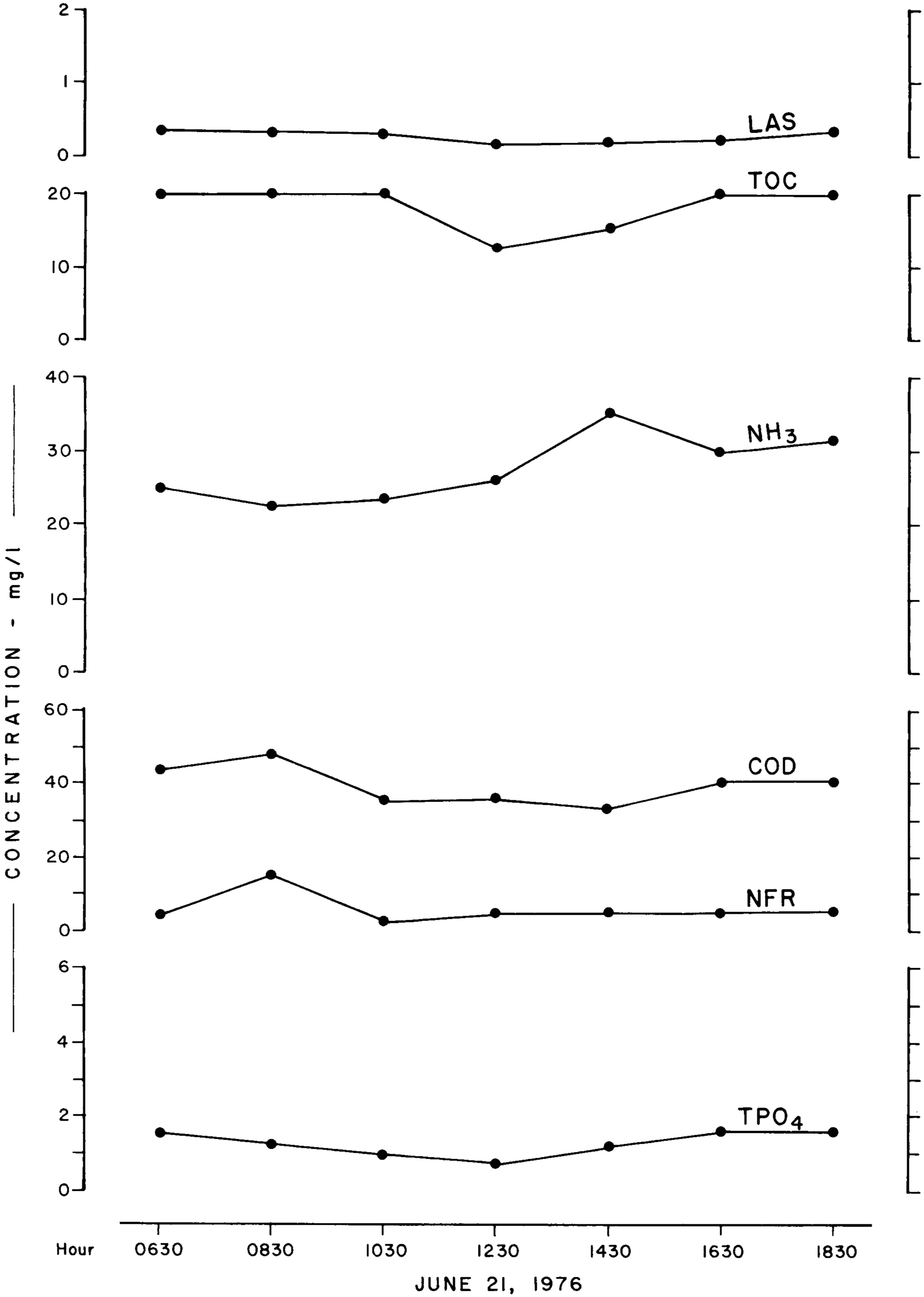
Analytical Parameter	Sampling Point	Time (hr)						
		0630	0830	1030	1230	1430	1630	1830
Cu T[1]	1	0.08	0.26	0.27	0.27	0.22	0.21	0.23
	3	0.02	0.03	0.02	0.02	0.02	0.03	0.02
Cu D[2]	1	0.04	0.09	0.11	0.12	0.09	0.12	0.12
	3	0.01	0.02	0.02	0.01	0.02	0.02	0.02
Fe T	1	1.6	2.1	2.4	2.0	2.3	1.8	1.5
	3	0.39	0.65	0.34	0.32	0.28	0.35	0.42
Fe D	1	0.93	0.60	0.49	0.68	0.50	0.78	0.75
	3	0.14	0.11	0.07	0.05	0.06	0.14	0.21
Ni T	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ni D	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb T	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pb D	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zn T	1	0.09	0.26	0.28	0.29	0.24	0.25	0.20
	3	0.07	0.10	0.06	0.06	0.09	0.09	0.10
Zn D	1	0.09	0.14	0.15	0.18	0.12	0.20	0.39
	3	0.11	0.12	0.15	0.08	0.09	0.12	0.13
Mn T	1	0.07	0.07	0.11	0.08	0.07	0.08	0.09
	3	0.07	0.08	0.06	0.07	0.08	0.07	0.09
Mn D	1	0.07	0.05	0.04	0.06	0.03	0.05	0.06
	3	0.08	0.07	0.07	0.07	0.07	0.07	0.08
Cr T	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cr D	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

[1]T Total

[2]D Dissolved



PENTICTON WQCC GRAB SAMPLING PROGRAM - RAW SEWAGE



PENTICTON WQCC GRAB SAMPLING PROGRAM - FINAL EFFLUENT

APPENDIX III

PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station A	Raw Sewage
Sample Station B	Primary Effluent
Sample Station C	Secondary Effluent
Sample Station D	Chlorinated Secondary Effluent
Sample Station E	Final Effluent

APPENDIX III   PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station A   Raw Sewage

	July 19		July 20		July 21		July 22	
Time	*TC	+FC	TC	FC	TC	FC	TC	FC
0700	-	-	-	-	$3.3x10^7$	$5.0x10^6$	$3.5x10^7$	$7.0x10^6$
0800	-	-	-	-	$1.3x10^8$	$1.7x10^7$	-	-
0900	$9.2x10^7$	$3.5x10^7$	-	-	$7.9x10^7$	$2.2x10^7$	$4.0x10^7$	$3.3x10^7$
1000	-	-	$5.4x10^7$	$1.7x10^7$	$3.5x10^8$	$7.0x10^7$	$5.4x10^7$	$1.3x10^7$
1100	-	-	$9.2x10^7$	$7.0x10^6$	$1.7x10^8$	$1.3x10^7$	$1.1x10^8$	$2.1x10^7$
1200	-	-	-	-	$1.1x10^8$	$7.0x10^6$	-	-
1300	-	-	-	-	$1.1x10^8$	$1.7x10^7$	-	-
1400	-	-	-	-	$2.4x10^7$	$7.9x10^6$	-	-
1500	-	-	-	-	-	-	-	-
1600	$3.5x10^7$	$7.9x10^6$	-	-	-	-	-	-

Raw Sewage Mean Total Confirmed Coliforms - $9.5x10^7$ MPN/100 mℓ
Raw Sewage Mean Fecal Coliforms - $1.9x10^7$ MPN/100 mℓ

*TC - Total Confirmed Coliforms

+FC - Fecal Coliforms

APPENDIX III PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station B Primary Effluent

	July 19		July 20		July 21		July 22	
Time	*TC	+FC	TC	FC	TC	FC	TC	FC
0700	-	-	-	-	-	-	2.2×10^7	7.9×10^6
0800	-	-	-	-	-	-	3.5×10^7	1.3×10^7
0900	-	-	-	-	-	-	1.6×10^8	3.5×10^7
1000	-	-	-	-	-	-	3.5×10^7	7.9×10^6
1100	-	-	-	-	-	-	2.4×10^7	1.3×10^7
1200	-	-	-	-	-	-	3.5×10^7	1.3×10^7
1300	-	-	-	-	-	-	2.4×10^7	7.9×10^6
1400	-	-	-	-	-	-	1.7×10^7	4.9×10^6

Primary Effluent Mean Total Confirmed Coliforms - 4.1×10^7 MPN/100 mℓ

Primary Effluent Mean Fecal Coliforms - 1.3×10^7 MPN/100 mℓ

*TC - Total Confirmed Coliforms

+FC - Fecal Coliforms

APPENDIX III PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station C Secondary Effluent

	July 19		July 20		July 21		July 22	
Time	*TC	+FC	TC	FC	TC	FC	TC	FC
0700	-	-	$1.6x10^5$	$1.7x10^4$	$1.7x10^5$	$5.0x10^3$	$2.4x10^5$	$4.9x10^4$
0800	-	-	$5.4x10^5$	$3.3x10^4$	$9.2x10^4$	$3.3x10^3$	$3.5x10^5$	$4.9x10^4$
0900	$1.7x10^5$	$5.0x10^3$	$1.6x10^5$	$7.9x10^3$	$9.4x10^4$	$8.0x10^3$	$1.6x10^6$	$1.4x10^4$
1000	$4.9x10^4$	$5.0x10^3$	$2.4x10^5$	$5.0x10^3$	$3.3x10^4$	<2000	-	-
1100	$3.5x10^5$	$2.7x10^4$	$5.4x10^4$	$2.2x10^4$	$1.1x10^5$	$1.1x10^5$	$1.3x10^5$	$2.3x10^4$
1200	$3.5x10^5$	$2.4x10^5$	$5.4x10^4$	$3.5x10^4$	$1.7x10^5$	$1.2x10^4$	$1.4x10^5$	$3.3x10^4$
1300	$5.4x10^5$	$7.0x10^4$	$2.2x10^5$	$4.6x10^4$	$5.4x10^5$	$2.1x10^4$	$9.2x10^5$	$2.4x10^5$
1400	$1.6x10^6$	$9.2x10^5$	$9.2x10^5$	$1.7x10^5$	$5.4x10^5$	$7.0x10^9$	$9.2x10^5$	$2.4x10^5$
1500	$5.4x10^5$	$1.7x10^5$	-	-	-	-	-	-
1600	$2.4x10^6$	$7.9x10^5$	-	-	-	-	-	-

Secondary Effluent Mean Total Confirmed Coliforms - $4.65x10^5$ MPN/100 mℓ

Secondary Effluent Mean Fecal Coliforms - $1.1x10^5$ MPN/100 mℓ

*TC - Total Confirmed Coliforms

+FC - Fecal Coliforms

APPENDIX III PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station D Chlorinated Secondary Effluent

	July 19		July 20		July 21		July 22	
Time	*TC	+FC	TC	FC	TC	FC	TC	FC
0700	-	-	<2	<2	240	5	-	-
0800	-	-	49	2	33	2	-	-
0900	50	<20	46	7	220	21	-	-
1000	490	<20	1600	46	540	33	240	49
1100	460	20	1600	79	1400	120	2200	110
1200	790	20	3500	140	1300	90	-	-
1300	490	20	240	79	1100	110	-	-
1400	700	80	350	17	490	20	-	-
1500	110	<20	-	-	-	-	-	-
1600	80	<20	-	-	-	-	-	-

Chlorinated Secondary Effluent Mean Total Confirmed Coliforms - 705 MPN/100 mℓ

Chlorinated Secondary Effluent Mean Fecal Coliforms - 44 MPN/100 mℓ

*TC - Total Confirmed Coliforms

+FC - Fecal Coliforms

APPENDIX III PENTICTON WQCC BACTERIOLOGICAL SAMPLING RESULTS

Sample Station E Final Effluent

	July 19		July 20		July 21		July 22	
Time	*TC	+FC	TC	FC	TC	FC	TC	FC
0700	-	-	<2	<2	23	<2	-	-
0800	-	-	130	<2	-	-	-	-
0900	2	2	8	5	-	-	-	-
1000	<2	<2	8	<2	-	-	13	<2
1100	49	2	2	2	-	-	21	<2
1200	22	<2	13	2	-	-	-	-
1300	33	<2	2	<2	-	-	-	-
1400	17	4	49	2	33	2	-	-
1500	79	<2	-	-	-	-	-	-
1600	23	<2	-	-	-	-	-	-

Final Effluent Mean Total Confirmed Coliforms - 27

Final Effluent Mean Fecal Coliforms - 2.3

*TC - Total Confirmed Coliforms

+FC - Fecal Coliforms

APPENDIX IV

PENTICTON WQCC OPERATING DATA

JULY 1-23, 1976

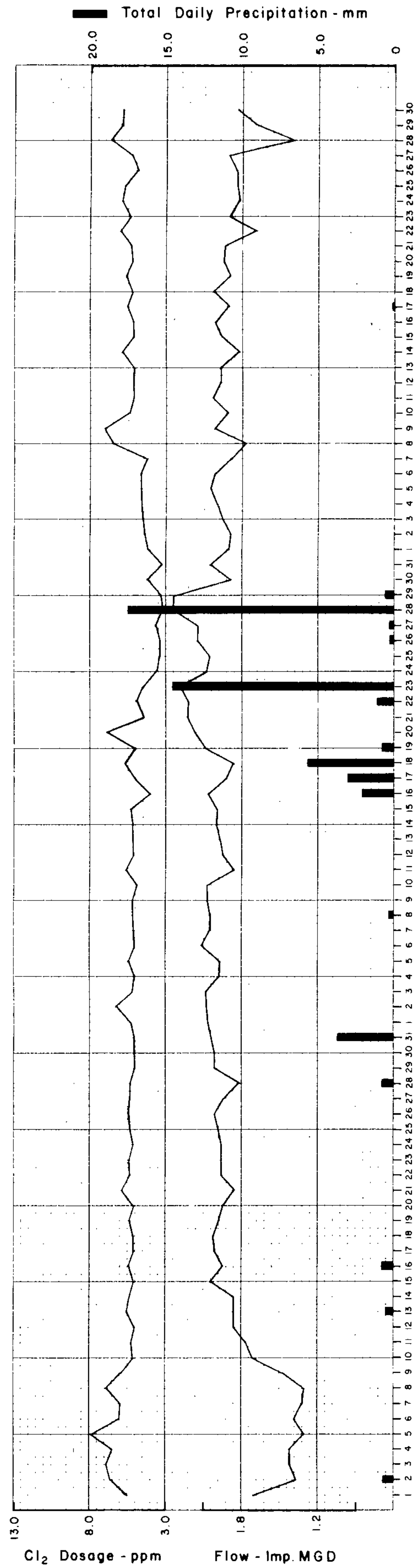
APPENDIX IV PENTICTON WQCC OPERATING DATA - JULY 1-23, 1976

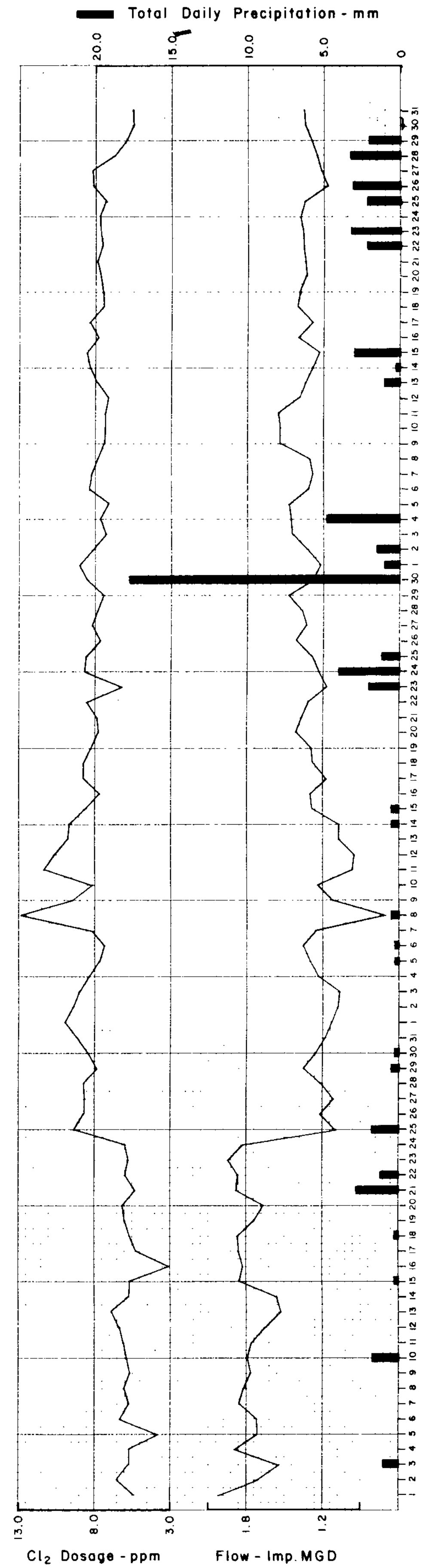
Date	Mixed Liquor				Final Effluent		Total Flow	Chlorine Consumption	
July 1976	pH	Suspended Solids mg/ℓ	Settleable Solids %	SVI	pH	DO mg/ℓ O_2	Imp MGD	lb/day	Dosage ppm
1	6.9	1045	18.5	177	6.8	1.6	1.65	115	7.0
2	7.0	1261	23.5	186	6.9	0.5	1.72	122	7.1
3	7.0	1477	35.0	237	6.9	0.4	1.74	122	7.0
4	7.0	1431	27.5	192	6.9	0.9	1.75	122	7.0
5	7.0	1503	27.0	180	6.9	0.4	1.68	121	7.2
6	7.1	1277	31.0	243	7.0	0.6	1.75	125	7.1
7	7.1	1057	20.5	194	7.0	0.5	1.76	119	6.8
8	8.0	1193	19.0	159	7.0	-	1.69	125	7.4
9	7.3	1143	17.0	148	7.0	3.9	1.83	143	7.8
10	7.1	1116	21.5	193	6.9	4.7	1.64	124	7.6
11	7.4	1237	23.0	186	7.2	5.0	1.62	115	7.1
12	7.1	1207	26.0	215	7.2	1.8	1.48	125	8.4
13	7.2	1158	34.0	293	7.0	3.4	1.68	119	7.1
14	7.2	1214	54.0	445	7.1	2.5	1.74	121	7.0
15	7.1	1224	86.5	707	7.0	1.6	1.78	125	7.0
16	7.1	1175	57.0	485	6.9	1.5	1.75	117	6.7
17	7.3	1238	51.0	412	7.0	4.2	1.63	118	7.2
18	8.0	1194	28.0	234	7.0	3.5	1.63	125	7.7
19	7.4	1045	23.5	225	7.2	2.6	1.57	123	7.8
20	7.5	1232	27.0	219	7.3	2.8	1.52	117	7.7
21	7.5	1191	53.0	445	7.1	3.3	1.69	106	6.3
22	7.3	1278	74.0	579	7.2	3.2	1.74	113	6.5
23	-	-	-	-	-	-	1.78	100	5.6
Average	7.2	1223	35.3	289	7.0	2.3	1.69		7.1

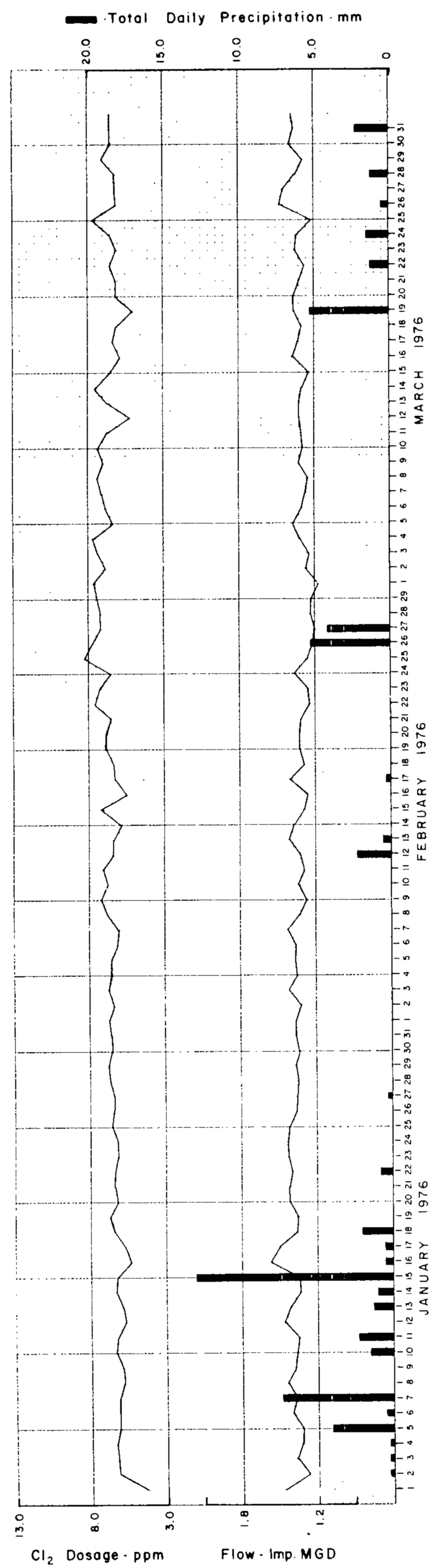
APPENDIX V

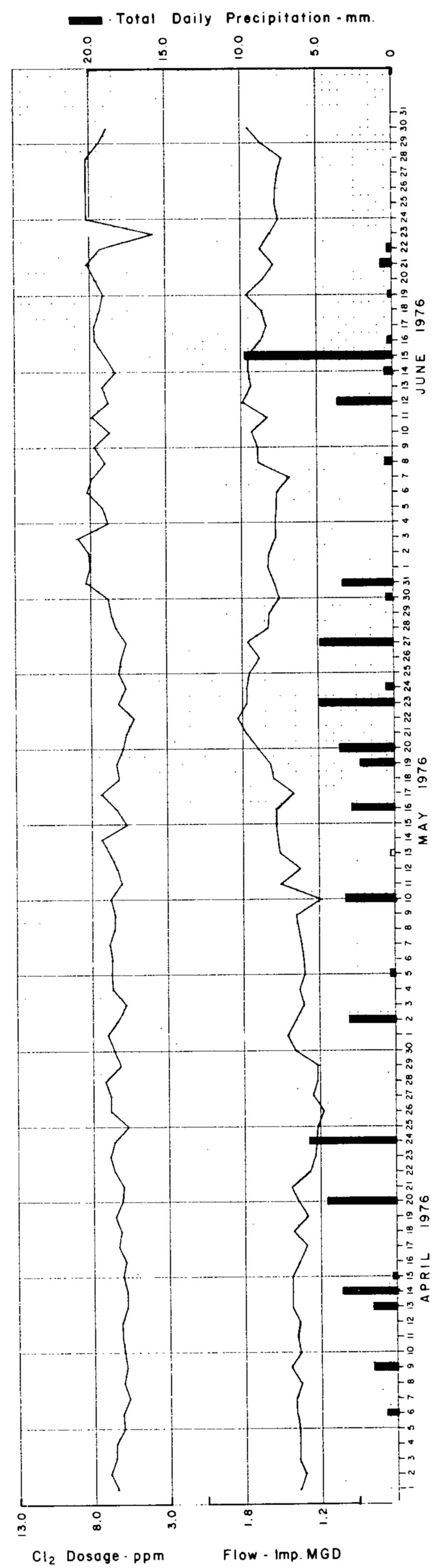
PENTICTON WQCC, DAILY FLOWS, CHLORINE DOSAGES AND PRECIPITATION

July 1, 1975 - June 30, 1976


Total Daily Precipitation - mm
20.0
15.0
10.0
5.0
0
JULY 1975
AUGUST 1975
SEPTEMBER 1975
13.0
8.0
3.0
1.8
1.2
Cl$_2$ Dosage - ppm
Flow - Imp. MGD


Total Daily Precipitation - mm
20.0
15.0
10.0
5.0
0
OCTOBER 1975
NOVEMBER 1975
DECEMBER 1975
13.0
8.0
3.0
1.8
1.2
Cl$_2$ Dosage - ppm
Flow - Imp. MGD


Total Daily Precipitation - mm
20.0
15.0
10.0
5.0
0
JANUARY 1976
FEBRUARY 1976
MARCH 1976
13.0
8.0
3.0
1.8
1.2
Cl_2 Dosage - ppm
Flow - Imp. MGD


Total Daily Precipitation - mm.
20.0
15.0
10.0
5.0
0
APRIL 1976
MAY 1976
JUNE 1976
13.0
8.0
3.0
1.8
1.2
Cl_2 Dosage - ppm
Flow - Imp. MGD