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A Study of Municipal Wastewater Toxicity, Iona Island Sewage Treatment Plant, August, 1976

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A STUDY OF MUNICIPAL WASTEWATER TOXICITY, IONA ISLAND SEWAGE TREATMENT PLANT, AUGUST, 1976

by

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ABSTRACT

A wastewater toxicity study of the Iona Island Sewage Treatment Plant was conducted by the author in conjunction with personnel from the Environmental Protection Service, Pacific Region.

The objectives of this study, conducted from August 16 to 20, 1976, were as follows:

1. to determine the extent of toxicity removal achieved by the sewage treatment plant, i.e. primary treatment;
2. to determine the effect of chlorination on the toxicity of the effluent;
3. to relate the toxicity of the influent, primary effluent and chlorinated effluent to the concentrations of certain known toxic substances, and;
4. 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 and chlorine dosage. This information was collected to assist in interpreting data gathered for the objectives listed above.

This report contains the results of bioassay determinations and chemical 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
CFS	cubic feet per second
COD	chemical oxygen demand
ft	feet
GLC	gas liquid chromatography
hr	hour(s)
Imp MGD	million imperial gallons per day
l	liter(s)
LAS	linear alkylate sulfonate
LC_{50}	50th percentile lethal concentration
lb/day/cap	pounds per day per capita
mg/l	milligrams per liter
ml	milliliter(s)
mm	millimeter
NFR	non filterable residue
PCB	polychlorinated biphenyls
ppb	parts per billion
ppm	parts per million
Tc	toxicity concentration
TRC	total residual chlorine
TU	toxic unit
$\mu g/l$	micrograms per liter

CONCLUSIONS

Based on data collected at the Iona Island Sewage Treatment Plant from August 16 to 20, 1976, the following conclusions can be made:

1) Primary treatment did not reduce raw sewage toxicity. The mean toxicity concentrations, Tc, were 1.46 and 1.45 TU for the raw sewage and primary effluent samples respectively. (Results obtained on August 20 were ignored due to the high degree of dilution of the sewage with stormwater).

2) Chlorination of the primary effluent was responsible for an increase in the mean toxicity concentration of the chlorinated effluent to 1.99 TU. (Results obtained on August 19 and 20 were ignored due to the delay in starting the bioassay tests).

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

   (i) un-ionized ammonia
   (ii) anionic surfactants, and
   (iii) compounds formed by chlorination

4) The average raw sewage PCB concentration was 0.14 ppb. The treatment plant reduced PCB levels an average of 42%. All PCB concentrations were low.

5) In general the results obtained from the bioassay determinations are not definitive and can only be used to indicate trends.

1. INTRODUCTION

The Iona Island Sewage Treatment Plant is operated by the Greater Vancouver Sewerage and Drainage District and treats sewage from the Vancouver Sewerage Area which includes the City of Vancouver, a portion of the Municipality of Burnaby, and Sea Island. The collection area of the Iona Island STP has been estimated at 35,600 acres, with a contributory population of 459,000. The collection area is serviced primarily by a combined sanitary and storm sewer system. The Iona Island STP treats domestic, commercial and industrial wastewater. A complete list of the major industrial contributors to the sewer system is unavailable. The major types of industries located within the area serviced by Iona Island STP include:

1) Lumber, Treated and Laminated;
2) Metal, Fabricating and Finishing;
3) Food Processing;
4) Secondary Industries; and
5) Service Related

A report dealing with an Inventory of Toxic and Hazardous Waste Generation within the City of Vancouver being prepared by the Environmental Protection Service and the City of Vancouver will be published in December, 1977. This report will provide background information concerning the major industrial contributors to the sewerage systems in the City of Vancouver plus the toxic constituents involved with each industry. In addition, a report has recently been published by the Westwater Research Centre, University of British Columbia, titled "Toxic Substances in The Wastewater from a Metropolitan Area," which deals with the heavy metal concentrations found in wastewater from residential, industrial and mixed areas within the GVRD (1). Reference should also be made to a report by Tanner, Trasolini and Nemeth (2) which deals with the wastewater characteristics of GVRD treatment plants and major sewers.

The present 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, and;
4) general plant operation data collection.

The objectives of this study, conducted from August 16 to 20, 1976, were as follows:

1) to determine the extent of toxicity removal achieved by the sewage treatment plant, i.e. primary treatment;
2) to determine the effect of chlorination on the toxicity of the effluent;
3) to relate the toxicity of the influent, primary effluent and chlorinated effluent to the concentrations of certain known toxic substances, and;
4) 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 in each case.

1.1 Iona Island Sewage Treatment Plant Description

The Iona Island STP is a primary sedimentation treatment plant with a design dry weather flowrate of 130 CFS (70 Imp MGD). The treatment components include two comminuting units, four bar screens, six raw sewage pumps, six grit chambers, ten pre-aeration tanks, ten sedimentation tanks and a chlorine contact tank. A flow diagram showing sample point locations is presented in Figure 1. At the design dry weather flow of 130 CFS the treatment plant has a total hydraulic retention time of 3.35 hours. The general operating characteristics of the Iona Island STP are outlined in Table 1. The primary sludge is thickened in a sludge thickener and pumped to two single stage anaerobic digesters. The final digested sludge is pumped to sludge lagoons.

1.1.1 Plant Performance

Long term performance data provided by GVS & DD is given in Table 2. This data represents the monthly averages of composite samples taken from the influent and effluent over a one year period. Based on this information, the treatment plant accomplished a 27% overall reduction in BOD_5, a 59% reduction in NFR and a 27% reduction in COD. Table 3 lists the treatment plant data collected by Iona Island STP personnel during the survey period.

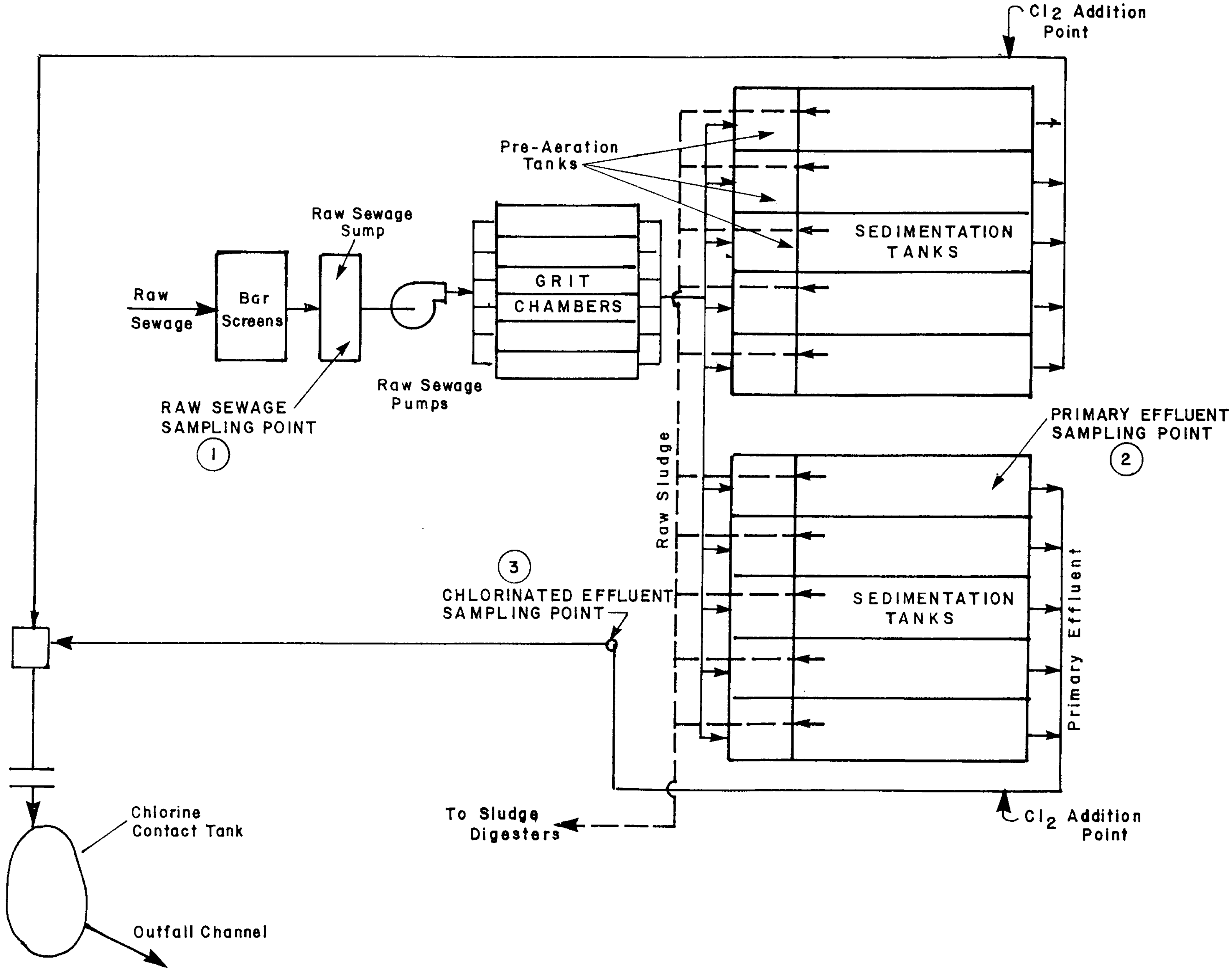

FIGURE I IONA ISLAND STP FLOW DIAGRAM AND SAMPLE POINT LOCATIONS

Table 1

OPERATIONAL CHARACTERISTICS OF IONA ISLAND STP

Type of Treatment - Primary Sedimentation

Treatment Components:

1) Comminuting Units (2) Parallel
2) Bar Screens (4) Parallel
3) Raw Sewage (6) Parallel
4) Grit Chambers (6) Parallel
5) Pre-Aeration Tanks (10) Parallel
6) Sedimentation Tanks (10) Parallel
7) Chlorine Contact Tank (1)

Average Dry Weather Flow	=	130 CFS
Peak Dry Weather Flow	=	200 CFS
Peak Wet Weather Flow	=	625 CFS

Average Daily Flow (September 1975 to August 1976)	=	155 CFS
Average Daily Flow August 1976	=	109.6 CFS
Peak Daily Flow October 29, 1975	=	391 CFS
Peak Instanteous Flowrate December 24, 1975	=	490 CFS

Detention Times at DWF

Grit Chambers	=	0.20 hr
Pre-Aeration Tanks	=	0.55 hr
Primary Sedimentation Tanks	=	1.60 hr
Chlorine Contact Tank	=	1.0 hr
Total		3.35 hr

Sedimentation Tank Overflow (at DWF) = 857 gal/ft/day.

Raw Sewage Average	BOD	=	133 mg/l
	NFR	=	118 mg/l
	COD	=	230 mg/l

Effluent Average	BOD	=	97 mg/l
	NFR	=	48 mg/l
	COD	=	167 mg/l

Sludge Treatment Components

1) Raw Sludge Pumps 6 Parallel
2) Sludge Thickener 1
3) Disintegrators 2 Parallel
4) Thickened Sludge Pumps 2 Parallel
5) Primary Anaerobic Digesters 2 Parallel
6) Sludge Lagoons 4

TABLE 2

IONA ISLAND TREATMENT PLANT PERFORMANCE DATA - SEPTEMBER, 1975 TO AUGUST, 1976

	Average Flow	Influent							Effluent							
Month	Imp MGD	pH 0-14	Temp °C	DO mg/l	TR mg/l	NFR mg/l	BOD mg/l	COD mg/l	pH 0-14	Temp °C	DO mg/l	TR mg/l	NFR mg/l	BOD mg/l	COD mg/l	Coliform MPN per 100 ml.
Sept, 1975	48.4	7.0	18	<.1	413	178	186	338	6.8	18	3.9	284	48	111	180	3300
October	105.9	6.7	16	3.0	304	105	114	200	6.7	15	5.8	236	45	82	135	9300
November	122.8	7.0	13	4.7	249	79	100	150	7.1	13	6.5	202	39	78	105	9300000
December	116.4	7.1	11	4.8	322	80	92	194	7.1	10	7.1	267	47	77	147	9300000
Jan, 1976	116.7	7.3	10	6.6	239	74	89	157	7.3	10	8.0	201	43	67	118	4300000
February	97.2	7.1	11	5.4	255	90	96	179	7.0	10	7.0	210	48	83	141	4300000
March	79.2	7.4	12	2.9	390	112	135	222	7.3	11	5.9	333	56	96	163	4300000
April	80.2	7.3	14	2.9	320	109	131	184	7.2	13	5.0	267	56	98	266	4300000
May	62.6	7.5	15	0.9	377	143	189	282	7.1	15	5.3	295	49	116	197	2300
June	66.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
July	50.5	7.6	18	0.3	396	170	172	325	7.2	18	4.1	280	50	140	196	2300
August	59.2	7.5	18	0.9	351	158	161	303	7.1	19	4.3	252	44	122	185	750
Average	83.8	7.2	14	3.0	328	118	133	230	7.1	14	5.7	257	48	97	167	3256177

TABLE 3

IONA ISLAND STP OPERATING DATA

AUGUST 16 - 20, 1976

Date	Total Daily Flow	Influent				Effluent				Chlorine		Coliform
August 1976	Imp MGD	NFR mg/l	TR mg/l	COD mg/l	DO mg/l	NFR mg/l	TR mg/l	COD mg/l	DO mg/l	Dosage ppm	Residual ppm	per 100 ml. in Effluent
16	87.2	120	249	198	7.0	48	120	123	8.1	5.7	2.80	230
17	49.8	40	333	259	0.4	41	274	185	4.5	6.8	1.75	430
18	49.8	166	416	329	0.1	65	275	214	3.6	6.2	1.15	15000
19	118.4	116	242	171	3.6	57	170	131	5.6	2.6	2.10	110000
20	60.4	125	275	-	1.3	40	177	-	5.8	5.3	1.20	240000
Average	73.1	113	303	239	2.4	50	203	163	5.9	5.3	1.80	73132

2. PROCEDURES AND METHODS

2.1 Sampling Program

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

1. The raw sewage sample was taken from the raw sewage sump, prior to the grit chambers. Approximate 250 ml samples were taken every 2.5 minutes using a Markland Model 2101 - Spec. Duckbill sampler.
2. The primary effluent sample was taken from the overflow channel of one sedimentation tank as shown in Figure 1. Approximate 1.1 l samples were taken every 10 minutes using an Eagle signal timer assembly and a submersible pump.
3. The chlorinted effluent sample was taken from the south effluent channel as shown in Figure 1. Approximate 1.1 l samples were taken every 10 minutes using an Eagle signal timer assembly and a submersible pump.
4. The composite sample aliquots were collected in 45 gallon polyethylene barrels. The 24 hour composite sampling program commenced at 0900 hr August 16 and ended at 0900 hr August 20, 1977.

The raw sewage and chlorinated effluent grab samples were taken from the same locations as the composites. The grab samples were collected every 2 hours on August 18, 1976 from 0830 to 2030 hr.

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.

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 $CaCo_3$
Chemical Oxygen Demand	COD	mg/l
Total Organic Carbon	TOC	mg/l C
pH	-	0-14 pH
Non Filterable Residue	NFR	mg/l
Anionic Surfactants	-	mg/l LAS
Total Residue	TR	mg/l
Cyanide	CN	mg/l
Phenol	-	mg/l
Oil and Grease	-	mg/l
Polychlorinated Biphenyls	PCB	ppb
Bioassay	LC_{50}	%
<u>Metals</u>		
Total Mercury	Hg	µg/l
Copper, Total and Dissolved	Cu	mg/l
Iron, Total and Dissolved	Fe	mg/l
Nickel, Total and Dissolved	Ni	mg/l
Lead, Total and Dissolved	Pb	mg/l
Zinc, Total and Dissolved	Zn	mg/l
Aluminum, Total and Dissolved	Al	mg/l
Cadmium, Total and Dissolved	Cd	mg/l
Manganese, Total and Dissolved	Mn	mg/l
Chromium, Total and 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
Cyanide	CN	mg/l
Phenol	-	mg/l
Oil and Grease	-	mg/l
pH	-	0-14 pH
<u>Metals</u>		
Copper, Total and Dissolved	Cu	mg/l
Iron, Total and Dissolved	Fe	mg/l
Nickel, Total and Dissolved	Ni	mg/l
Lead, Total and Dissolved	Pb	mg/l
Zinc, Total and Dissolved	Zn	mg/l
Aluminum, Total and Dissolved	Al	mg/l
Cadmium, Total and Dissolved	Cd	mg/l
Manganese, Total and Dissolved	Mn	mg/l
Chromium, Total and Dissolved	Cr	mg/l

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 bioassay analysis were placed in four 5 gallon plastic jerry cans. All samples were delivered within 2 hours to the Environment Canada laboratory facilities. Sample analysis for all parameters except metals and PCB commenced within 4 hours of completion of each sampling day. Grab samples collected on August 18 were separated into the proper container, preserved as required and stored at 4^{o}C before being delivered on August 19 at 1100 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 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.

2.2.3 Bioassay Determination (96 hour LC_{50})

The static fish bioassay test gives an approximate numerical value to the biological toxicity of 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 liter 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 14.5 $\pm$ 1.0^{0}C and a photo period limited to 16 hours per 24 hours. The bioassay test procedure 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. The fish loading density in each vessel was 0.6 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 chlorinated effluent (Sample point No. 3) every hour for 24 hours from 1400 hr August 16 to 1400 hr August 17 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 determined the concentration of compounds in the wastewater containing active chlorine which consist of monochloramines, dichloramines and hypochlorous acid.

3 RESULTS

3.1 Bioassay Results

The static fish bioassay results obtained from the 24 hour composite samples are included 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 (expressed in toxic units, TU) can be calculated for effluent discharges as follows:

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

Therefore, a Tc of unity is equivalent to an LC_{50} of 100%. The toxicity concentration concept becomes useful when comparing effluents that produces less than 50 percent mortality at the 100% concentration in the bioassay test. A Tc value in this case can be determined by plotting the percent mortality of test fish versus the Tc values for the various test dilutions.

3.2 Chemical Analyses Non Metals - Results

The chemical analysis non-metals 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 Figures 2 and 3. The values plotted in this comparison represent the mean value from the four 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 - Results

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

3.4 Chlorine Residual Monitoring Results

The results of the 24 hour chlorine residual monitoring program are illustrated in Figure 4. The compound loop residual chlorine control system maintained a TRC within a range of 0.09 to 1.54 mg/l and with a mean of 0.85 mg/l. It should be noted that the TRC sample was taken from sample point number 3, a point in the effluent channel prior to the chlorine contact tank.

TABLE 6 IONA ISLAND STP COMPOSITE SAMPLE BIOASSAY RESULTS

Sample Point	Parameter	Unit	Date			
			August 17	August 18	August 19	August 20
Raw Sewage	LC_{50}	%	81.5	62.5	65	NT[1]
	Tc	TU	1.23	1.60	1.54	-
Primary Effluent	LC_{50}	%	48.5	86.5	89	NT
	Tc	TU	2.06	1.16	1.12	-
Final Chlorinated Effluent	LC_{50}	%	44	58.5	NT	NT
	Tc	TU	2.27	1.71	-	-

1 NT Non Toxic

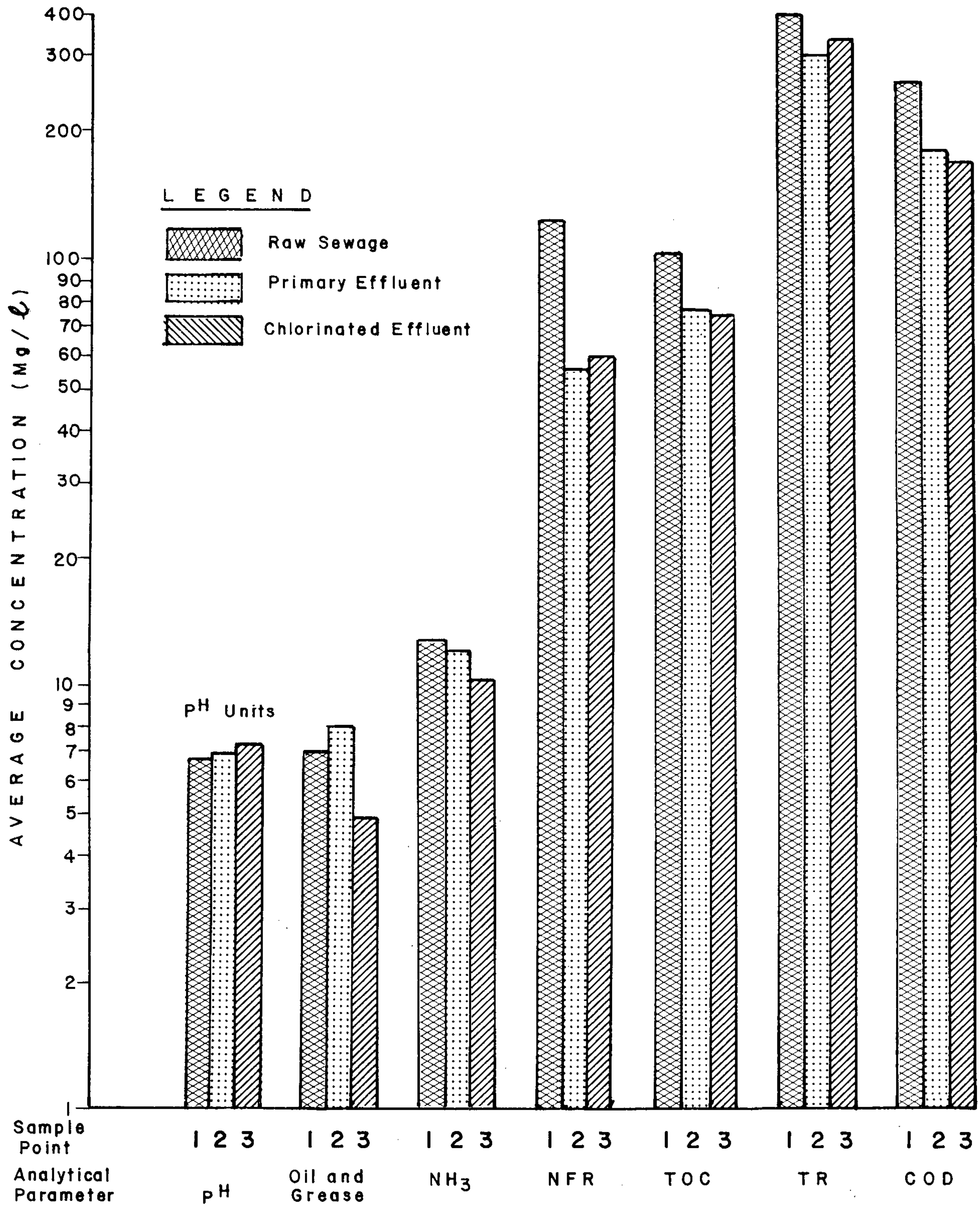

FIGURE 2 COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL

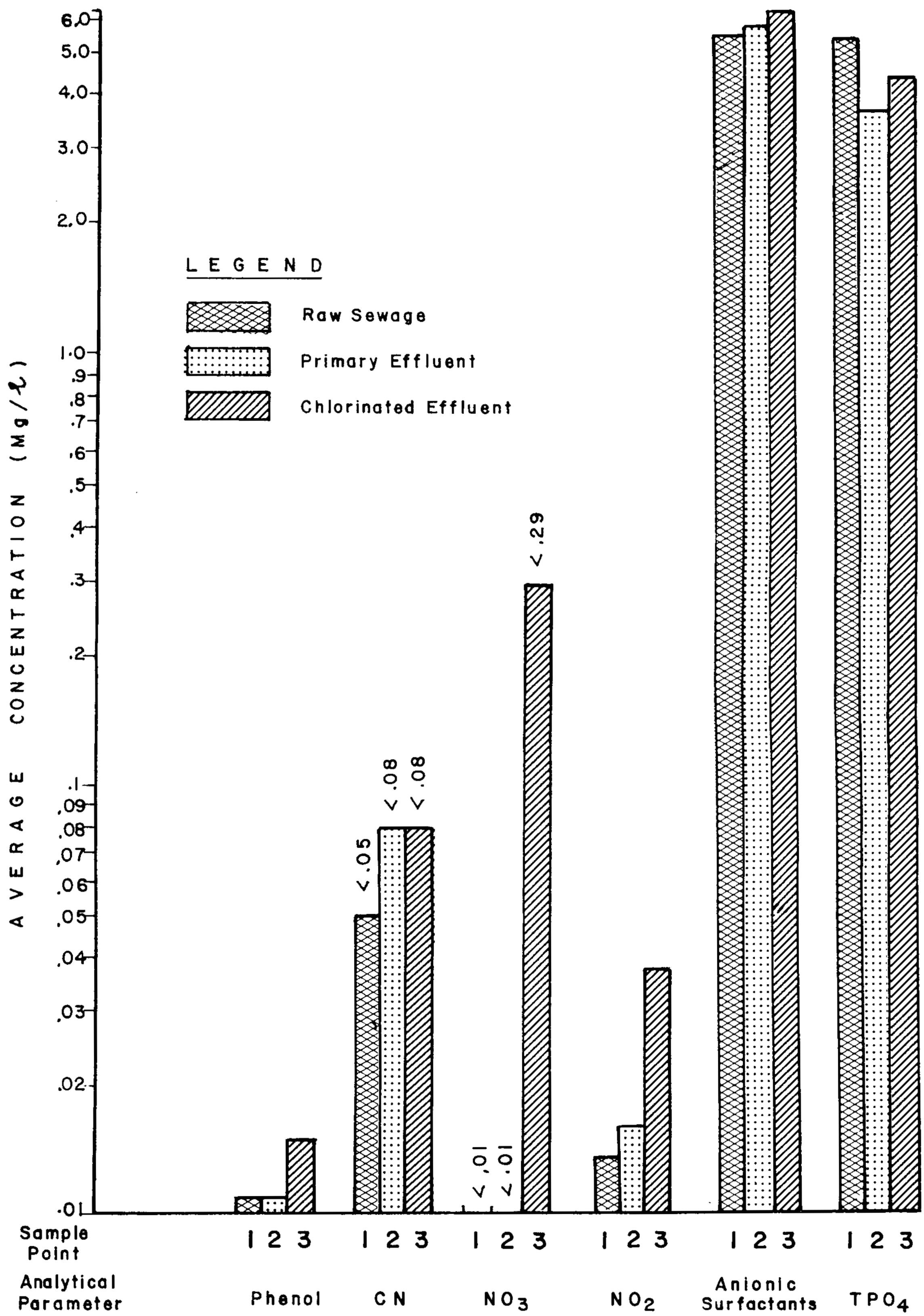

FIGURE 3 COMPARISON OF ANALYTICAL RESULTS AND TREATMENT LEVEL (cont'd)

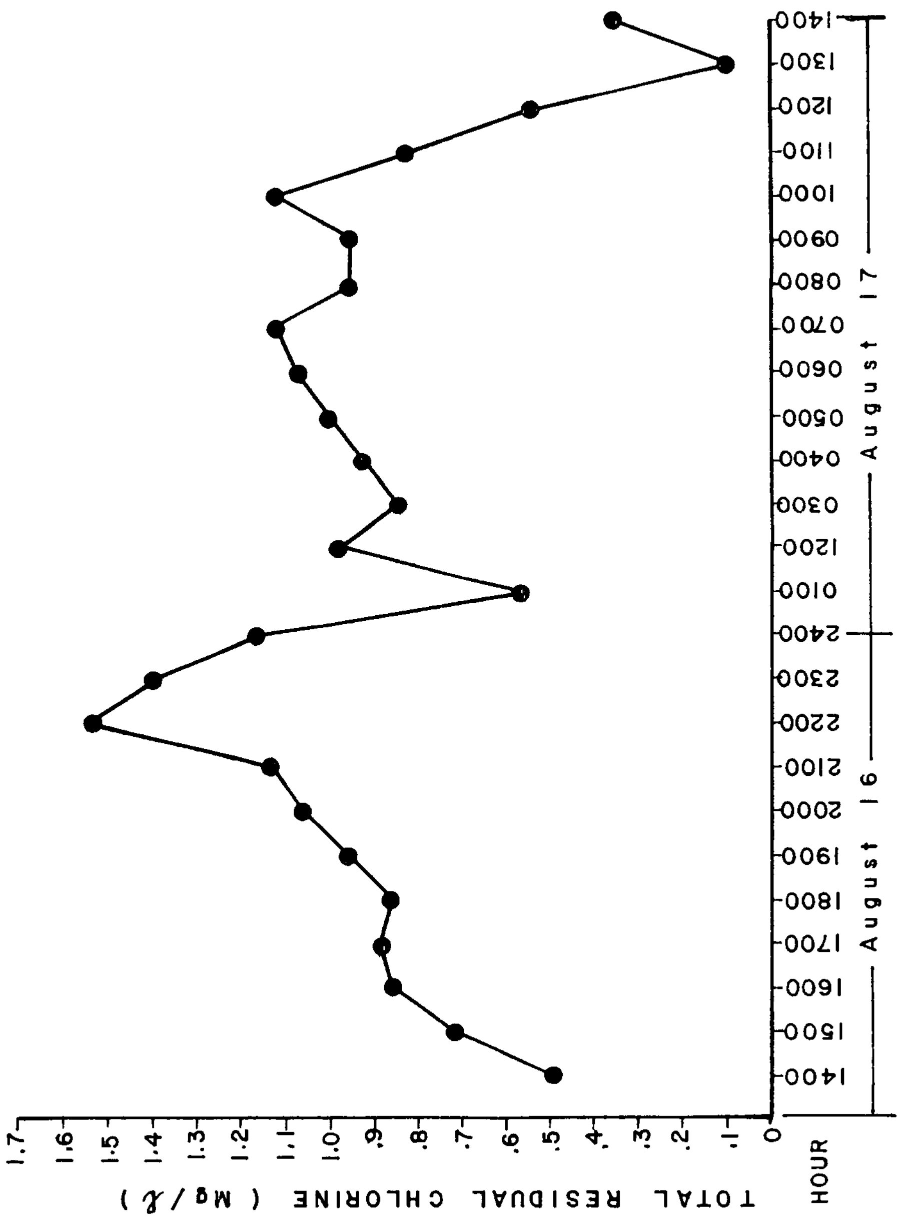

FIGURE 4 24-HOUR RESIDUAL CHLORINE MONITORING PROGRAM

3.5 POLYCHLORINATED BIPHENYLS RESULTS

The results of the PCB analyses for the 24 hour composite sample program are listed in Appendix I. The raw sewage mean PCB concentration was 0.14 ppb while the mean effluent concentration was 0.08 ppb, representing a 43% reduction. A digester sludge sample had a PCB concentration of 1.1 ppm.

3.6 DAILY FLOWRATES, CHLORINE DOSAGES AND PRECIPITATION

Daily flowrates and chlorine dosages for a one year period from September 1, 1975 to August 31, 1976 have been plotted in Appendix IV. Chlorine addition was not carried out from October 31, 1975 to April 30, 1976. Daily precipitation data has also been included.

The plot indicated that flows increase significantly due to precipitation, as would be expected from a combined sewer system. For example, during the month of September 1975 the total precipitaion received was 0.25 mm and the average daily flow was 48.4 Imp MGD; this contrasts with the month of January 1976 when the total precipitation received was 179 mm and the average daily flow was 116.7 Imp MGD.

Figure 5 illustrates the instantaneous flow readings taken from the flow recorder chart every two hours from 0000 hr August 16 to 1200 hr August 21, 1976. This plot also illustrates the influence of precipitation on flowrate; the total precipitation on August 16 was 16.3 mm and the total precipitation on August 19 was 24.6 mm. The peak flow during the period was 370 CFS at 1400 hr August 16 and the low flow was 50 CFS at 0800 hr August 19.

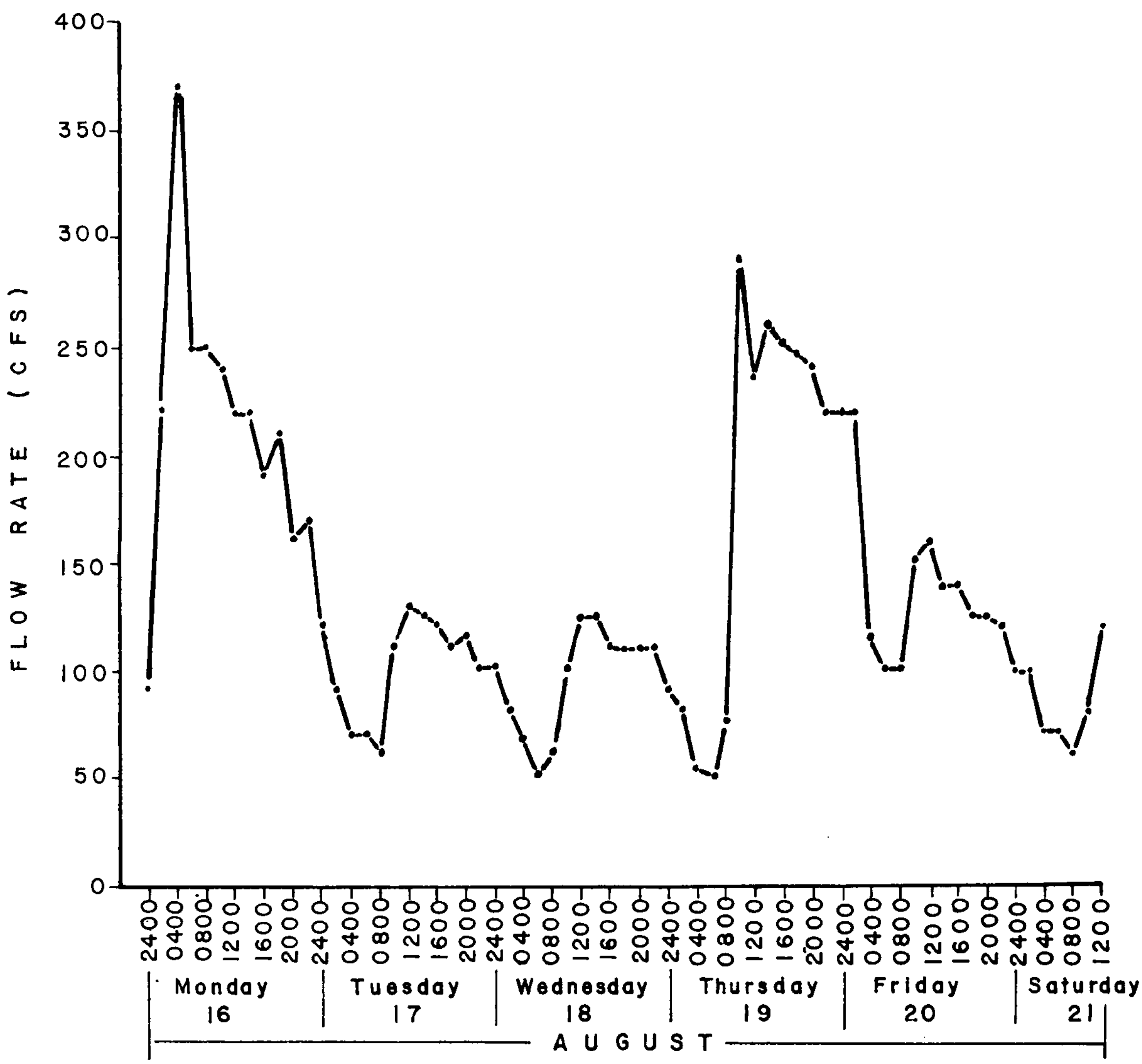

FIGURE 5 IONA ISLAND STP FLOWRATES
August 16 - 21, 1976

3.7 METAL ANALYSES SUMMARY

In addition to the metal analyses conducted during the survey on the composite samples, metal determinations were also conducted on primary digester sludge. Municipal water supply metal analyses data was provided by the Greater Vancouver Water District. A summary of the metal analyses is presented in Table 7. The results indicate a significant metal concentration increase in the raw sewage samples compared to the municipal water supply, a slight decrease in metal content of the effluent following primary treatment and a subsequent accumulation of metal in the digester sludge.

3.8 SEWAGE TREATMENT PLANT LOADINGS

As mentioned previously, the sewer system discharging to the Iona Island STP collects both sanitary sewage and stormwater. For comparative purposes the composite sample results collected during the survey have been converted to loadings and are presented in Appendix III. The calculations were based on the daily flows observed during the survey and a contributory population estimate of 459,000.

The results obtained from a similar wastewater toxicity study carried out at the Penticton Water Quality Control Centre (3) during July, 1976 have been converted to loadings per capita and are presented for comparison with the Iona Island STP loadings per capita data in Table 8. The comparison indicates that, in general, loadings of nutrients, solids, and metals on a per capita basis are higher for the Iona Island STP than the Penticton WQCC, probably due to the influence of industrial discharges on the Iona Island STP raw sewage. The industrial discharges in Penticton are mainly from food processors.

TABLE 7 METAL ANALYSES SUMMARY

Metal	Raw Sewage[1] mg/l	Effluent[1] mg/l	Digester Sludge mg/l	Municipal[2] Water Supply mg/l
Cu	0.16	0.09	38	<0.01
Fe	1.09	0.74	560	0.16
Ni	<0.05	<0.05	-	<0.005
Pb	0.08	0.03	24	<0.005
Zn	0.24	0.16	29	<0.005
Al	0.75	0.40	740	-
Cd	<0.01	<0.01	0.36	<0.001
Mn	0.07	0.05	12	0.005
Cr	0.04	0.04	330	<0.005
Hg[3]	<0.23	<0.20	-	< 0.5
TR	358	268	29000	17.5
TVR	-	-	16000	8.9

1 - Average of four - 24 hour composite samples

2 - Results supplied by Greater Vancouver Water District
Represents average of Capilano, Seymour, and Coquitlam systems

3 - Units µg/l

TABLE 8 COMPARISON OF RAW SEWAGE LOADINGS
VANCOUVER & PENTICTON, B.C.

Parameter	Units	Penticton WQCC	Iona STP
TPO_4	lb/day/10^5cap	537	784
NH_3	lb/day/10^5cap	2052	1474
NFR	lb/day/cap	0.11	0.20
COD	lb/day/cap	0.32	0.38
TOC	lb/day/cap	0.10	0.14
CuT[1]	lb/day/10^5cap	16.2	19.5
ZnT	lb/day/10^5cap	23.3	32.3
PbT	lb/day/10^5cap	2.4	11.3
FeT	lb/day/10^5cap	128	149.5

1 CuT - Total Copper

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 constituents. However, as outlined earlier, the bioassay test conditons are controlled so that pH, temperature and dissolved oxygen do not themselves affect 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 hydrolyzes 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 equilibrium 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 (4) have outlined a set of equilibrium calculations for determing 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 9. In addition, this table lists the bioassay results and the major toxic constituents involved for each composite sample.

Mayo, et al (5) 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 (6). Lloyd and Orr (7) 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 9 for August 17, 18, 19 were in the range of 0.025 mg/l and therefore would be expected to contribute marginally to wastewater toxicity. However, as pointed out by Esvelt, Kaufman and Selleck (8) 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 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 (9). 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

TABLE 9 COMPARISON OF ANALYTICAL AND BIOASSAY RESULTS

Sample Points	Collection Date	LC_{50}	Tc	NH_3	Un-ionized NH_3	pH	Anionic Surfactants	Alkalinity	Start Date Bioassay Test
	August	%	TU	mg/l N	mg/l N		mg/l LAS	mg/l LAS	August
Raw Sewage	17	81.5	1.23	15	0.032	6.9	1.5	72	17
	18	62.5	1.60	11	0.029	7.0	2.6	93	18
	19	65	1.54	11	0.023	6.9	2.6	84	20
	20	NT[1]	-	2.4	0.004	6.8	1.9	38	22
Primary Effluent	17	48.5	2.06	10	0.021	6.9	0.57	62	17
	18	86.5	1.16	11	0.023	6.9	1.1	85	18
	19	89	1.12	12	0.025	6.9	0.97	100	22
	20	NT	-	4.4	0.009	6.9	0.49	50	22
Chlorinated Effluent	17	44	2.27	10	0.033	7.1	1.0	54	17
	18	58.5	1.71	11	0.036	7.1	1.1	79	18
	19	NT	-	12	0.031	7.0	0.93	90	22
	20	NT	-	3.6	0.012	7.1	0.63	40	22

1 NT Non-Toxic

as the carbon chain length increases (8).

Thatcher and Santner (10) found 96 hour 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 (11). The anionic surfactant concentrations as reported in Table 9 could be expected to contribute to wastewater toxicity. However, the degree of influence cannot be readily determined.

4.1.3 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 (10) 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-situ bioassay techniques (12).

The toxicity of chlorinated wastewater does not depend directly on the amount of chlorine added but on the concentration of residual chlorine remaining (13). 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. Marten and Servizi (12) 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.

The bioassay test start dates are listed with the results in Table 9. For chlorinated samples collected on August 17 and 18 the bioassay tests started the same day. Whereas, for chlorinated samples collected on August 19 and 20, the bioassay tests commenced 3 and 2 days later respectively.

Therefore, it can be assumed that the samples collected on August 19 and 20 would not exhibit chlorine induced toxicity.

If the samples collected on August 17 and 18 are considered separately the average toxicity concentrations would be; raw sewage Tc = 1.42, primary effluent Tc = 1.61 and chlorinated effluent Tc = 1.99. This information would tend to indicate an increase in toxicity due to chlorination.

4.2 Bioassay Summary

The results obtained from the bioassay determinations are not definitive and therefore, can only be used to indicate trends.

All samples collected on August 20 were non-toxic due to the high degree of dilution of the sewage with stormwater. (Total precipitation for August 19 was 24.6 mm and the plant daily flow was 118.4 Imp MGD).

Of the remaining samples, un-ionized ammonia and surfactant concentrations were low by comparison to sewage from a separate sanitary system. In addition, parameters other than those investigated during the sampling program may have been responsible for wastewater toxicity.

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APPENDIX I

IONA ISLAND STP

COMPOSITE SAMPLE ANALYTICAL RESULTS

a) NON METALS

b) METALS

APPENDIX I IONA ISLAND COMPOSITE SAMPLE ANALYTICAL RESULTS

(a) Non-Metals

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Date			
		Aug 17	Aug 18	Aug 19	Aug 20
TPO_4	1	4.0	5.10	7.9	1.6
mg/l P	2	3.4	3.50	3.6	1.7
	3	3.5	3.15	3.3	1.2
NH_3	1	15	11	11	2.4
mg/l N	2	10	11	12	4.4
	3	10	11	12	3.6
NO_3	1	$<$0.01	$<$0.01	$<$0.01	$<$0.01
mg/l N	2	$<$0.01	$<$0.01	$<$0.01	$<$0.01
	3	0.20	$<$0.01	$<$0.01	0.42
NO_2	1	.008	.012	.01	$<$0.005
mg/l N	2	.009	.014	.019	.005
	3	.036	.038	.035	.035
Alkalinity	1	72	93	84	38
mg/l $CaCO_3$	2	62	85	100	50
	3	54	79	90	40
COD	1	260	340	210	250
mg/l	2	120	210	130	300
	3	140	190	350	290

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pH	1	6.9	7.0	6.9	6.8
	2	6.9	6.9	6.9	6.9
	3	7.1	7.1	7.0	7.1
NFR	1	160	210	98	110
mg/l	2	46	59	81	59
	3	44	50	61	30
Anionic	1	1.5	2.6	2.6	1.9
Surfactants	2	0.57	1.1	0.97	0.49
mg/l LAS	3	1.0	1.1	0.93	0.63
TR	1	400	410	340	280
mg/l	2	210	310	360	180
	3	240	320	330	180
CN	1	$<$0.03	0.05	$<$0.03	$<$0.03
mg/l	2	$<$0.03	0.05	0.04	$<$0.03
	3	0.05	0.05	$<$0.03	0.04
Phenol	1	0.019	0.007	.030	$<$0.02
mg/l	2	0.012	0.004	.030	$<$0.02
	3	0.010	0.021	.025	$<$0.02
Oil & Grease	1	36	2.8	80	32
mg/l	2	8.9	5.0	57	15
	3	50	4.6	37	130
TOC	1	116.0	134.0	86.0	46.0
mg/l	2	40.0	62.0	86.0	24.0
	3	42.0	53.0	80.0	32.0

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PCB	1	0.150	0.110	0.120	0.190
ppb	2	0.110	0.080	0.100	0.068
	3	0.100	0.064	0.092	0.068

APPENDIX I IONA ISLAND STP COMPOSITE SAMPLE ANALYTICAL RESULTS

(b) Metals

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Date			
		Aug 17	Aug 18	Aug 19	Aug 20
Pb T[1]	1	0.12	0.05	0.04	0.12
mg/l	2	0.04	0.05	0.02	0.11
	3	0.05	0.03	0.03	0.08
Pb D[2]	1	0.02	<0.02	<0.02	0.04
mg/l	2	0.03	0.02	0.02	0.05
	3	<0.02	<0.02	0.02	0.05
Cu T	1	0.15	0.23	0.11	0.07
	2	0.08	0.13	0.09	0.08
	3	0.07	0.12	0.11	0.06
Cu D	1	0.03	0.05	0.05	0.03
	2	0.03	0.02	0.05	0.04
	3	0.07	0.11	0.07	0.05
Zn T	1	0.37	0.27	0.15	0.16
	2	0.15	0.25	0.16	0.17
	3	0.18	0.21	0.13	0.11

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Zn	D	1	-3	0.13	-	0.08
		2	-	0.17	-	0.09
		3	-	0.14	-	0.08
Fe	T	1	1.5	1.4	0.75	0.70
		2	0.91	1.1	0.65	0.84
		3	0.92	0.85	0.65	0.52
Fe	D	1	0.32	0.44	0.44	0.34
		2	0.33	0.52	0.48	0.36
		3	0.29	0.38	0.34	0.45
Cd	T	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	D	1	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	-
		3	<0.01	<0.01	<0.01	-
Ni	T	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	D	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
Mn	T	1	0.08	0.08	0.05	0.06
		2	0.06	0.06	0.06	0.04
		3	0.06	0.05	0.06	0.04
Mn	D	1	0.04	0.05	0.04	0.05
		2	0.04	0.06	0.05	<0.03
		3	0.04	0.06	0.05	0.04

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Al T	1	1.1	1.2	0.3	0.4
	2	0.5	0.6	0.3	0.6
	3	0.6	0.4	0.3	0.3
Al D	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
Cr T	1	0.05	0.05	0.03	0.02
	2	0.03	0.05	0.04	0.02
	3	0.04	0.05	0.03	0.02
Cr D	1	0.02	0.02	0.03	<0.02
	2	0.02	0.02	0.03	<0.02
	3	<0.02	<0.02	0.02	<0.02
Hg T	1	<0.20	0.24	0.27	0.20
ug/l	2	<0.20	0.20	0.27	0.23
	3	<0.20	<0.20	<0.20	<0.20

T[1] Total

D[2] Dissolved

-3 Data unreliable

APPENDIX II

IONA ISLAND STP

GRAB SAMPLE ANALYTICAL RESULTS

a) NON-METALS

b) METALS

APPENDIX II　　IONA ISLAND STP　　GRAB SAMPLE ANALYTICAL RESULTS

(a) Non-Metals　　August 18, 1976

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Time (hr.) 0830	1030	1230	1430	1630	1830	2030
TPO_4	1	9.5	4.2	3.9	8.0	3.4	3.6	3.5
mg/l P	2	4.5	3.9	3.9	4.0	3.9	3.8	3.4
	3	3.9	4.1	3.4	3.3	3.5	3.6	9.0
NH_3	1	17	18	9.2	11	12	12	9.8
mg/l N	2	14	16	10	9.6	12	12	12
	3	10	12	11	11	10	10	8.6
NO_3	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
mg/l N	2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	3	0.53	0.37	<0.01	<0.01	0.54	0.28	0.28
NO_2	1	.015	.016	.013	.015	.014	.011	.015
mg/l N	2	.015	.017	.017	.017	.018	.016	.010
	3	.091	.043	.017	.017	.055	.021	.021
NFR	1	230	130	110	110	100	87	95
mg/l	2	63	52	50	56	63	65	45
	3	65	89	59	58	54	59	53

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COD	1	200	280	210	280	310	230	290
mg/l	2	88	120	120	130	280	310	210
	3	76	100	180	180	210	260	230
Anionic	1	2.6	5.2	14	1.4	1.4	3.0	10
Surfactants	2	1.5	4.8	1.2	1.2	1.2	3.6	16
mg/l LAS	3	1.8	4.0	1.2	1.3	1.4	17	17
TR	1	620	460	290	300	300	310	340
mg/l	2	270	350	320	310	310	270	260
	3	290	370	340	330	330	290	320
CN	1	0.05	0.10	<0.03	0.05	0.07	<0.03	<0.03
mg/l	2	<0.03	0.27	0.07	0.07	0.07	<0.03	<0.03
	3	<0.03	0.27	0.07	0.07	0.07	<0.03	<0.03
Phenol	1	.023	.015	.017	.002	.003	.011	.002
mg/l	2	.002	.027	.002	.002	.034	.005	.002
	3	.004	.027	.005	.004	.053	.009	.002
Oil & Grease	1	6.6	5.4	5.6	6.4	14.4	7.6	4.4
mg/l	2	10.4	7.4	3.0	7.2	5.6	9.4	11.4
	3	7.4	6.4	3.8	4.2	2.8	3.6	5.0
pH	1	7.0	6.7	6.8	6.8	6.9	6.9	6.8
	2	6.9	7.1	7.0	7.0	7.0	6.7	6.6
	3	7.2	7.1	7.1	7.1	7.1	6.9	6.9
TOC	1	117.0	150.0	92.0	96.0	132.0	70.0	89.0
mg/l	2	70.0	71.0	72.0	84.0	73.0	82.0	72.0
	3	74.0	80.0	70.0	72.0	74.0	73.0	76.0

APPENDIX II IONA ISLAND STP GRAB SAMPLE ANALYTICAL RESULTS

(b) Metals August 18, 1976

Sampling Point	Number
Raw Sewage	1
Primary Effluent	2
Chlorinated Effluent	3

Analytical Parameter	Sampling Point	Time (hr.)						
		0830	1030	1230	1430	1630	1830	2030
Cu T[1]	1	0.18	0.18	0.17	0.14	0.10	0.72	0.17
mg/l	2	0.12	0.14	0.12	0.13	0.12	0.15	0.43
	3	0.11	0.14	0.14	0.13	0.12	0.14	0.35
Cu D[2]	1	0.02	0.04	0.04	0.05	0.05	0.26	0.40
mg/l	2	0.02	0.03	0.01	0.02	0.01	0.02	0.08
	3	0.04	0.03	0.01	0.04	0.10	0.11	0.25
Zn T	1	0.20	0.33	0.17	0.13	0.14	0.14	0.13
	2	0.19	0.25	0.35	0.23	0.24	0.35	0.28
	3	0.17	0.28	0.21	0.20	0.25	0.32	0.28
Zn D	1	0.13	0.20	0.10	0.07	0.10	0.08	0.08
	2	0.12	0.12	0.12	0.12	0.16	0.22	0.22
	3	0.12	0.15	0.12	0.14	0.13	0.24	0.18

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Pb T	1	0.04	0.06	1.2	0.04	0.02	0.03	0.02
	2	<0.02	0.06	0.04	0.03	0.05	0.03	0.02
	3	0.04	0.04	0.04	0.09	0.07	0.02	0.02
Pb D	1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
	3	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.02
Fe T	1	1.4	1.5	1.3	0.90	0.72	1.1	0.72
	2	0.86	1.2	1.0	1.3	1.0	1.1	0.97
	3	0.75	1.1	0.76	1.0	0.78	0.80	0.86
Fe D	1	0.49	0.56	0.42	0.64	0.46	0.45	0.45
	2	0.44	0.50	0.46	0.45	0.54	0.58	0.51
	3	0.33	0.53	0.36	0.43	0.33	0.39	0.38
Mn T	1	0.09	0.09	0.08	0.08	0.08	0.07	0.08
	2	0.07	0.08	0.08	0.08	0.07	0.08	0.08
	3	0.09	0.08	0.07	0.07	0.08	0.07	0.07
Mn D	1	0.06	0.06	0.07	0.06	0.07	0.06	0.06
	2	0.06	0.06	0.06	0.05	0.06	0.05	0.06
	3	0.06	0.06	0.06	0.8	0.06	0.08	0.06
Ni T	1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	2	<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
	2	<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

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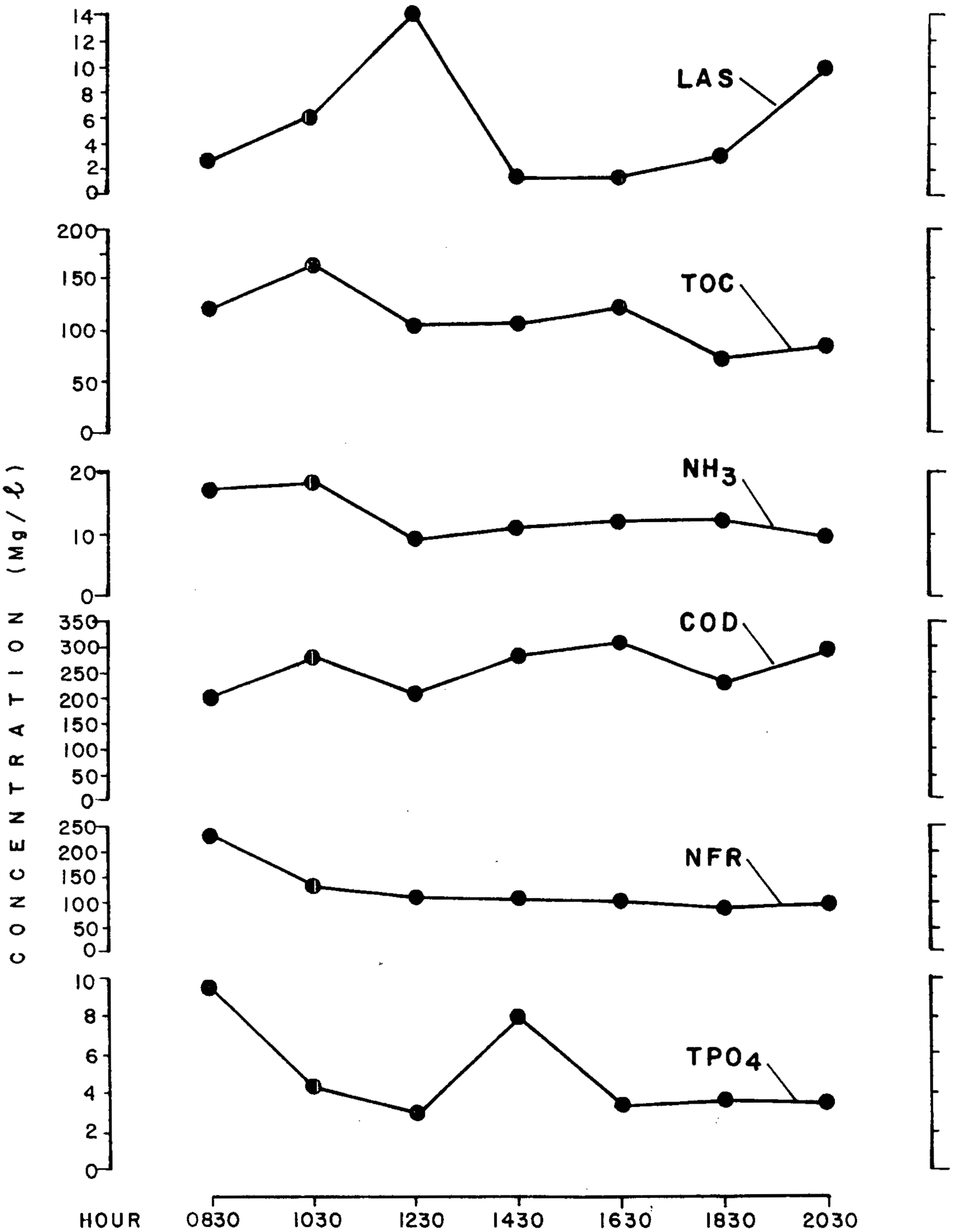
cont'd

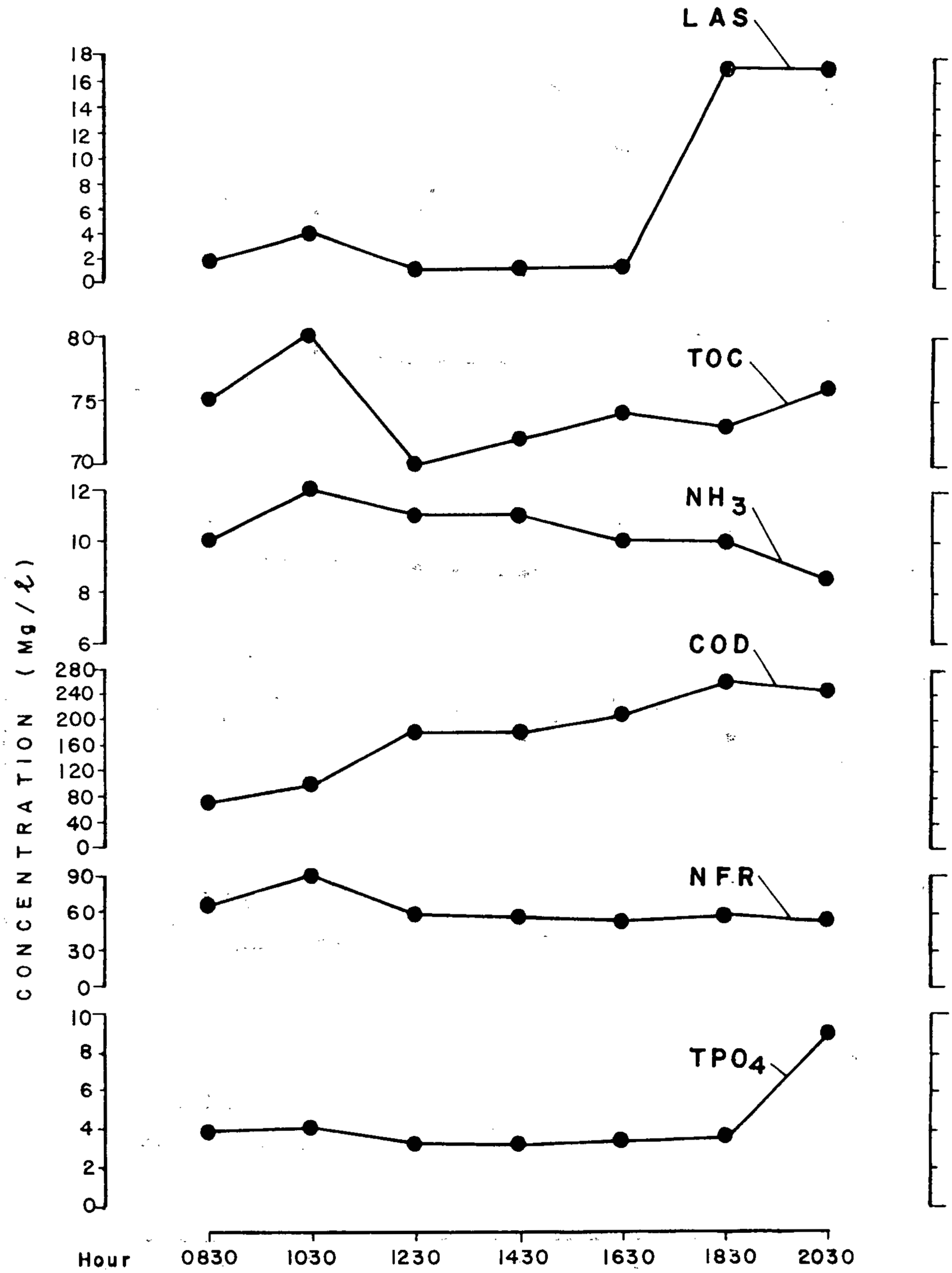
Cd	T	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cd	D	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	T	1	0.06	0.05	0.05	0.04	0.03	0.02	0.03
		2	0.03	0.05	0.03	0.04	0.03	0.03	0.02
		3	0.03	0.05	0.03	0.04	0.03	0.03	0.03
Cr	D	1	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
		2	<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
Al	T	1	0.6	0.8	0.8	0.5	<0.3	0.6	0.4
		2	0.6	0.6	1.0	1.1	1.0	0.6	0.5
		3	0.7	0.6	1.1	1.2	1.1	0.6	0.4
Al	D	1	<0.3	<0.3	<0.3	0.4	<0.3	0.3	<0.3
		2	<0.3	<0.3	0.4	0.4	<0.3	<0.3	<0.3
		3	<0.3	<0.3	0.4	0.5	0.4	<0.3	0.3

T[1] Total

D[2] Dissolved



IONA WQCC GRAB SAMPLING PROGRAM-
RAW SEWAGE - August 18, 1976



IONA WQCC GRAB SAMPLING PROGRAM - CHLORINATED EFFLUENT - August 18, 1976

APPENDIX III

SEWAGE TREATMENT PLANT LOADINGS

a) NON-METALS

b) METALS

IONA ISLAND STP LOADINGS

(a) Non-Metals — 24 Hour Composite Results

1 - Raw Sewage

3 - Chlorinated Effluent

Analytical Parameter	Sample Point	Loading Parameter	Date: Aug 17	Aug 18	Aug 19	Aug 20
TPO_4	1	lb/day	2095	2579	8754	969
		lb/day/10^5cap	456	562	1907	211
	3	lb/day	1833	1593	3656	727
		lb/day/10^5 cap	399	347	797	158
NH_3	1	lb/day	7854	5562	12188	1454
		lb/day/10^5cap	1711	1212	2655	317
	3	lb/day	5236	5562	13296	2181
		lb/day/10^5cap	1140	1212	2897	475
NFR	1	lb/day	8.38×10^4	10.6×10^4	10.8×10^4	6.66×10^4
		lb/day/cap	0.18	0.23	0.24	0.15
	3	lb/day	2.30×10^4	2.53×10^4	6.76×10^4	1.82×10^4
		lb/day/cap	0.05	0.06	0.15	0.04

...cont'd

COD	1	lb/day	1.36×10^5	1.71×10^5	2.32×10^5	$1.51 \times$
		lb/day/cap	0.30	0.37	0.51	0.33
	3	lb/day	7.33×10^4	9.61×10^4	-	1.75×10^5
		lb/day/cap	0.16	0.21	-	0.38
TOC	1	lb/day	6.07×10^4	6.78×10^4	9.53×10^4	2.79×10^4
		lb/day/cap	0.13	0.15	0.21	0.06
	3	lb/day	2.20×10^4	2.68×10^4	8.86×10^4	1.94×10^4
		lb/day/cap	0.05	0.06	0.19	0.04
Anionic	1	lb/day	785	1315	2881	1151
Surfactants		lb/day/10^5 cap	171	286	628	251
	3	lb/day	524	556	1030	382
		lb/day/10^5 cap	114	121	224	83

IONA ISLAND STP LOADINGS

(b) Metal

1 - Raw Sewage

3 - Chlorinated Effluent

Metal	Sample Point	Loading Parameter	Date: Aug 17	Aug 18	Aug 19	Aug 20
Cu T	1	lb/day	79	116	122	42
		lb/day/10^5cap	17	25	27	9
	3	lb/day	37	61	122	36
		lb/day/10^5cap	8	13	27	8
Zn T	1	lb/day	194	137	166	97
		lb/day/10^5cap	42	30	36	21
	3	lb/day	94	106	144	67
		lb/day/10^5cap	20	23	31	15
Fe T	1	lb/day	785	708	831	424
		lb/day/10^5cap	171	154	181	92
	3	lb/day	482	430	720	315
		lb/day/10^5cap	105	94	157	69

cont'd

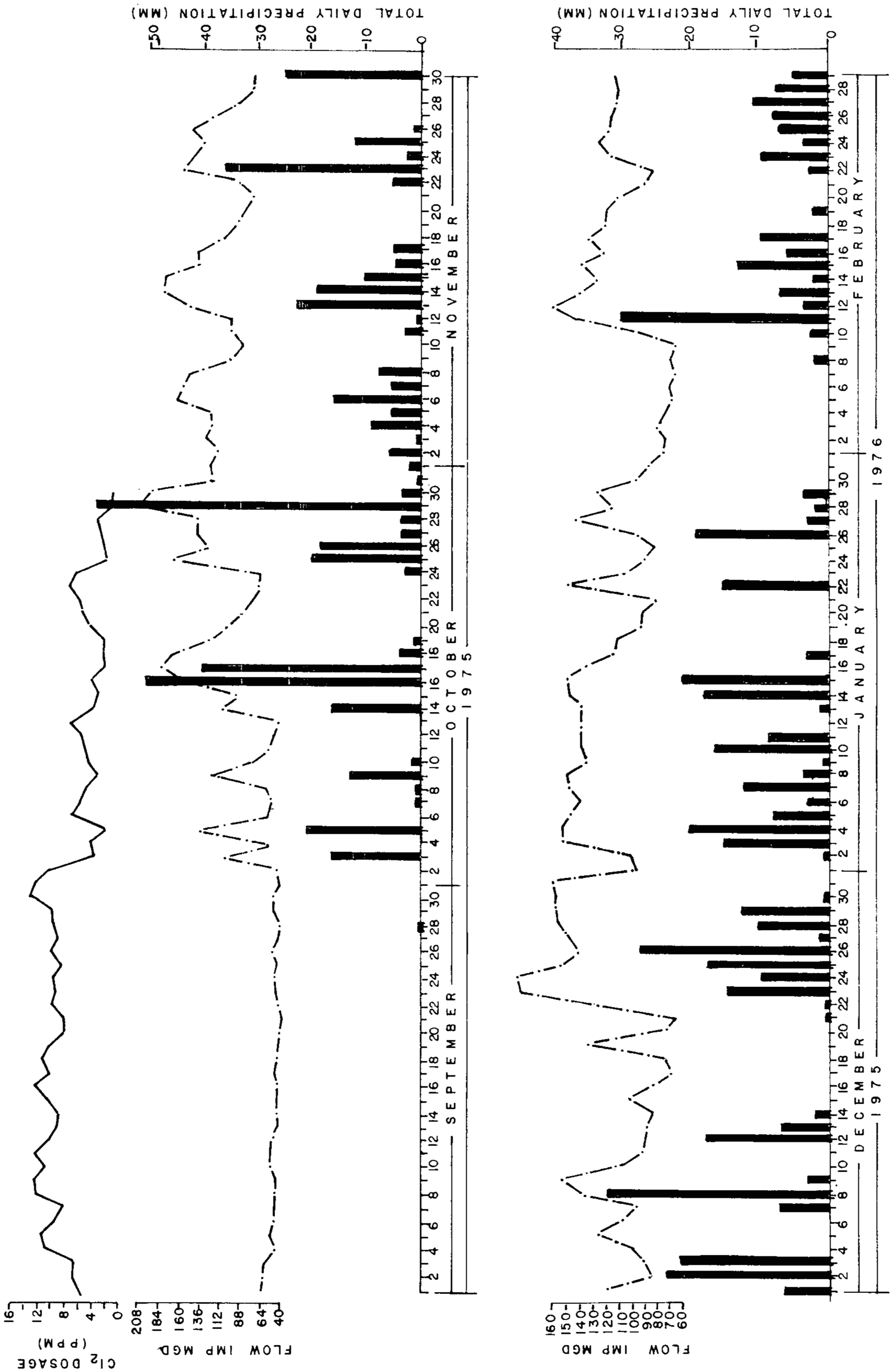
Pb T	1	lb/day	63	25	44	72
		lb/day/10^5cap	14	5	10	16
	3	lb/day	26	15	33	49
		lb/day/10^5cap	6	3	7	11
Mn T	1	lb/day	42	41	55	36
		lb/day/10^5cap	9	9	12	8
	3	lb/day	31	25	67	24
		lb/day/10^5cap	7	5	15	5
Cr T	1	lb/day	26	25	33	12
		lb/day/10^5cap	6	5	7	3
	3	lb/day	21	25	33	12
		lb/day/10^5cap	5	5	7	3

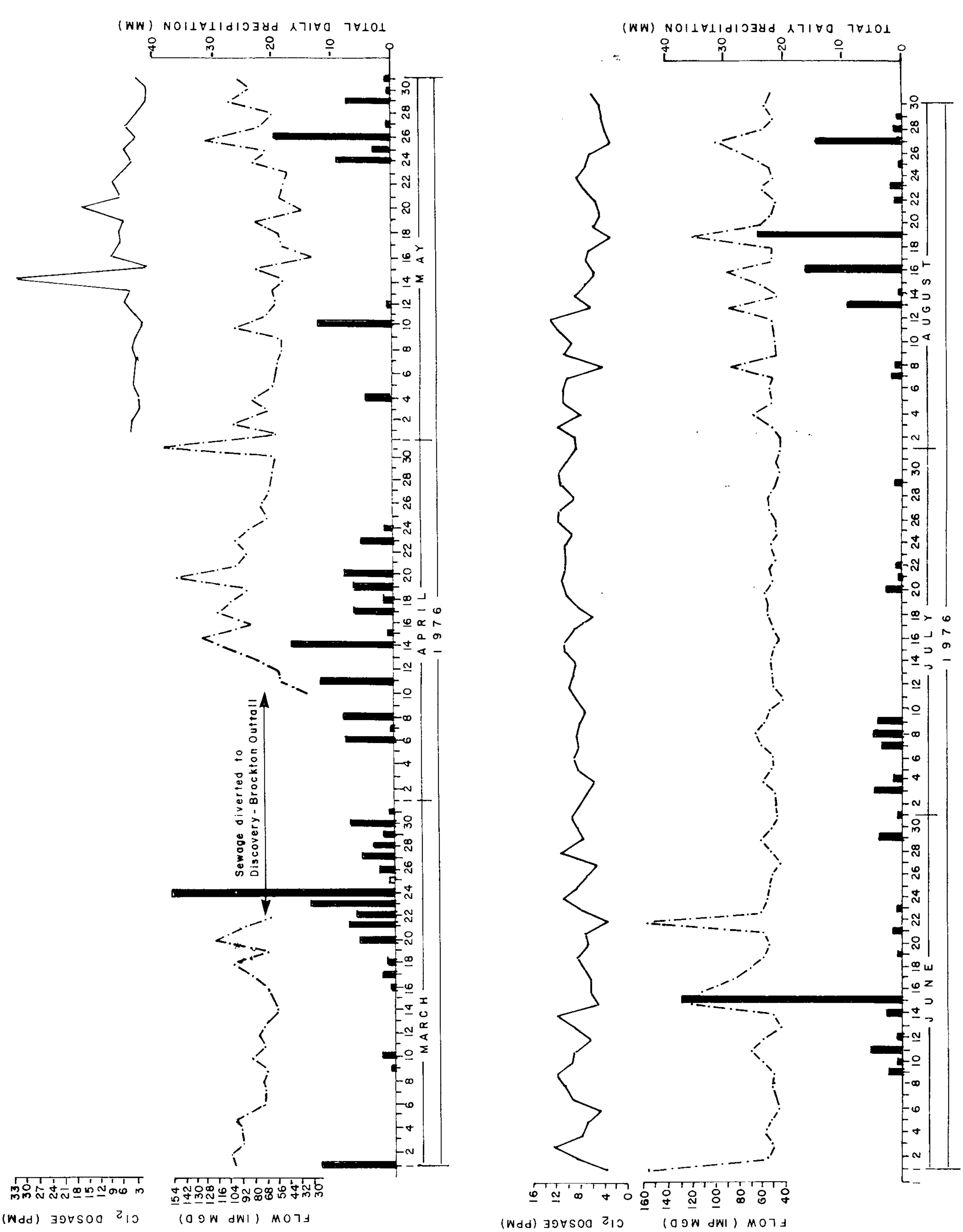
APPENDIX IV

IONA ISLAND STP, DAILY FLOWS,

CHLORINE DOSAGES AND PRECIPITATION

SEPTEMBER 1, 1975 TO AUGUST 31, 1976


TOTAL DAILY PRECIPITATION (MM)
FLOW IMP MGD
Cl_2 DOSAGE (PPM)
SEPTEMBER
OCTOBER
1975
NOVEMBER
DECEMBER
1975
JANUARY
1976
FEBRUARY


TOTAL DAILY PRECIPITATION (MM)
FLOW (IMP MGD)
Cl2 DOSAGE (PPM)
Sewage diverted to Discovery - Brockton Outfall
MARCH
APRIL
MAY
1976
JUNE
JULY
AUGUST
1976