Characteristics of Effluents from Large Municipal Wastewater Treatment Facilities in 1995

Valerie Raco-Rands

ABSTRACT

The marine environment of the Southern California Bight (SCB) is used for a variety of recreational, commercial, municipal, and industrial purposes, each of which contributes varying amounts of contaminants to the ocean. This study summarizes constituent concentrations of effluents and constituent mass emissions of the large municipal wastewater facilities in 1995 and describes trends that have occurred in constituent emissions from these facilities over the past 24 years. Mass emissions were calculated from monthly measurements of flow and constituent concentrations for 1995. Sixty-seven percent of the constituents discharged into the SCB have declined more than 70% since 1971. Cyanide, which declined by six metric tons, was the only constituent for which combined mass emissions changed significantly between 1994 and 1995.

INTRODUCTION

Coastal southern California is one of the most densely populated areas on the west coast of North America. The human population of the area utilizes the marine environment for a number of recreational, commercial, municipal, and industrial uses. These uses contribute a variety of contaminants to coastal waters, which in excessive amounts can cause environmental damage. To identify the most important sources of contamination, inputs of contaminants from different sources are measured. These measurements provide a basis for developing emission control strategies and, when measured over time, for assessing the effectiveness of these control strategies.

Historically, municipal wastewater has been one of the major sources of contaminants to the marine environment of the SCB (SCCWRP 1973). In 1994, effluents from the Hyperion Treatment Plant (HTP) operated by the City of Los Angeles; the Joint Water Pollution Control Plant (JWPCP) operated by the County Sanitation Districts of Los Angeles County (CSDLAC); Wastewater Treatment Plants 1 and 2 operated by the County Sanitation Districts of Orange County (CSDOC); and Point Loma Wastewater Treatment Plant (PLWTP) operated by the City of San Diego comprised 89% of the municipal wastewater discharged directly into the SCB (Figure 1) (Raco-Rands 1996). For at least two decades, these agencies have routinely measured the characteristics of their effluents.

Although constituent concentrations are summarized in the monitoring reports produced by these agencies, not all of the agencies estimate mass loadings. Among those that do, differences exist in the estimation methods used. Since 1973, Southern California Coastal Water Research Project (SCCWRP) has regularly summarized and compared effluent constituent concentrations and mass emissions among these facilities (Raco-Rands 1996, SCCWRP 1973, 1990). In this report, we continue our comparison from previous years by summarizing the concentrations of effluent constituents and estimating mass emissions for these four wastewater treatment facilities in 1995. Trends in mass emissions of constituents from 1971 to 1995 are also discussed.

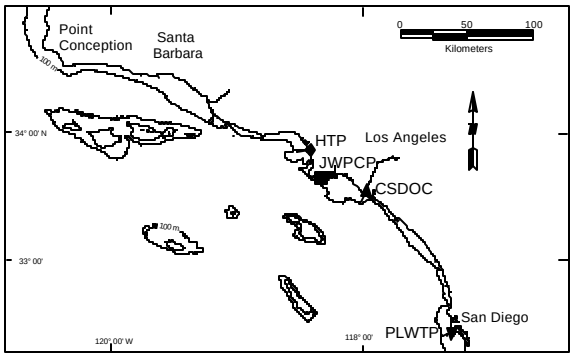


FIGURE 1. Locations of the four largest municipal wastewater facilities that discharge into the Southern California Bight: Hyperion Treatment Plant (HTP, City of Los Angeles); Joint Water Pollution Control Plant (JWPCP, County Sanitation Districts of Los Angeles County); County Sanitation Districts of Orange County (CSDOC); and Point Loma Wastewater Treatment Plant (PLWTP, City of San Diego).

MATERIALS AND METHODS

Effluent data was obtained from each discharge agency under the National Pollutant Discharge Elimination System permits from the Los Angeles, Santa Ana, and San Diego regions of the California Regional Water Quality Control Board (CRWQCB).

The large municipal wastewater treatment plants measured constituents at the following frequencies: (1) general constituents (e.g., suspended solids, BOD, oil and grease, ammonia-N, etc.) — seven times per month to once per day; (2) toxicity — once per month to once per week; (3) metals — once per month to seven times per month; and (4) organics — once per quarter to once per week (Table 1).

In general, the facilities used different analytical methods (Table 2). Reporting limits also varied by as much as 50 times among the agencies (Table 3).

Two types of assessments were performed. First, annual mean concentrations were calculated using zeroes for months when constituent concentrations were below reporting limits. However, the annual mean was reported even if it was below the reporting limit. (This method may differ from methods used by the agencies for compliance reporting to the CRWQCB and Environmental Protection Agency (EPA)). Second, annual contaminant mass emissions were estimated from the product of the mean daily flow, constituent concentration, and the number of days in month *i*. These emissions were summed over all months to obtain the annual estimate:

$$ME = \sum_{i=1}^{12} (F_i C_i D_i)$$

Where

F_i = mean daily flow in month *i*; C_i = constituent concentration in month *i*, or annual mean concentration (for months not measured); and D_i = number of days in month *i*.

TABLE 1. Frequency of constituent measurements in effluents from the largest municipal wastewater treatment facilities in southern California in 1995.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids	1/Day	1/Day	1/Day	1/Day
Settleable solids	6/Day	3/Day	1/Day	1/Day
BOD	1/Day	1/Day	1/Day	1/Day
Oil and grease	1/Week	1/Day	7/Month	1/Day
Nitrate-N	1/Month	1/Month	NA	1/Week
Nitrite-N	1/Month	1/Month	NA	NA
Ammonia-N	1/Month	1/Month	7/Month	1/Week
Organic N	1/Month	1/Month	NA	NA
Phosphate	NA	1/Month	NA	1/Week
Total phosphorus	1/Month	NA	NA	NA
Cyanide	1/Month	1/Month	1/Month	1/Week
Turbidity	1/Day	1/Day	7/Month	1/Day
Acute toxicity				
Pimephales promelas	1/Month	1/Month	1/Month	1/Week
Chronic toxicity				
Haliotis rufescens	1/Month	NA	NA	1/Month
Macrocystis pyrifera				
Germ tube length	1/Year	1/Month	NA	1/Month
Germination	1/Year	1/Month	NA	1/Month
Arsenic	1/Month	1/Month	1/Month	1/Week
Cadmium	1/Month	1/Month	7/Month	1/Week
Chromium	1/Month	1/Month	7/Month	1/Week
Copper	1/Month	1/Month	7/Month	1/Week
Lead	1/Month	1/Month	7/Month	1/Week
Mercury	1/Month	1/Month	1/Month	1/Week
Nickel	1/Month	1/Month	7/Month	1/Week
Selenium	1/Month	1/Month	1/Month	1/Week
Silver	1/Month	1/Month	7/Month	1/Week
Zinc	1/Month	1/Month	7/Month	1/Week
Phenols	NA	1/Month	1/Month	NA
Chlorinated phenols	Quarterly	1/Month	1/Month	1/Week
Nonchlorinated phenols	Quarterly	Quarterly	1/Month	1/Week
Total DDT	Quarterly	1/Month	1/Month	1/Week
Total PCB	Quarterly	1/Month	7/Month	1/Week

HTP = Hyperion Treatment Plant, City of Los Angeles.
JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County.
CSDOC = County Sanitation Districts of Orange County.
PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.
BOD = Biochemical oxygen demand.
NA = Not analyzed.

TABLE 2. Analytical methods used for measuring constituent levels in effluents of the largest municipal wastewater treatment facilities in southern California in 1995.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids	2540D([a])	2540D(b)	160.2(c)	160.2(c)
Settleable solids	2540F(a)	2540F(b)	2540F(b)	160.5(c)
BOD	5210B(a)	5210B(b)	5210B(b)	5210B(b)
Oil and grease	5520B(a)	5520B(b)	413.1(c)	5520B(b)
Nitrate-N	4500-NO_3E(a)	4500-NO_3E(a)	NA	4110B(b)
Nitrite-N	4500-NO_2B(a)	4500-NO_2B(b)	NA	NA
Ammonia-N	4500-NH_3B, & E(a)	4500-NH_3 B, & E(b)	350.1(c)	4500-NH_3 F(b)
Organic N	4500-N-$_{org}$B(a)	4500-N-$_{org}$B(b)	NA	NA
Phosphate	NA	4500-P B.5 & E(b)	NA	4110B(b)
Total phosphorus	4500-P B & E(a)	NA	NA	NA
Cyanide	335.2(c)	4500-CN C &E(b)	335.2(c)	4500-CN G(b)
Turbidity	2130B(a)	2130B(b)	180.1(c)	2130B(b)
Acute toxicity				
Pimephales promelas	(d)	(e)	(e)	(d)
Chronic toxicity				
Haliotis rufescens	(f)	NA	NA	(f)
Macrocystis pyrifera				
Germ tube length	(f)	(f)	NA	(f)
Germination	(f)	(f)	NA	(f)
Trace metals				
Digestion				
Arsenic, selenium	3114B(a)	3114B(b)	200(c)	3114B(b)
Cadmium, chromium, nickel, silver	3030E(a)	3030H(b)	200(c)	200.7(c)
Copper, zinc	3030E(a)	3030H(b)	200.7(c)	200.7(c)
Lead	3030E(a)	3030H(b)	200(c)	3030F(b)
Mercury	3112B(a)	3112B(b)	245.1(c)	3112B(b)
Analysis				
Arsenic	3114B(a)	3114B(b)	204.2(c)	3114B(b)
Cadmium	3120(a)	3111B(b)	213.2(c)	200.7(c)
Chromium	3120(a)	218.1(c)	218.2(c)	200.7(c)
Copper, zinc	3120(a)	3111B(b)	200.7(c)	200.7(c)
Lead	3113(a)	3111B(b)	239.2(c)	3111B(b)
Mercury	3112B(a)	3112B(b)	245.1(c)	3112B(b)
Nickel	3120(a)	3111B(b)	249.2(c)	200.7(c)
Selenium	3114B(a)	3114B(b)	270.2(c)	3114B(b)
Silver	3113B(a)	3111B(b)	272.2(c)	200.7(c)
Phenols	NA	420.2(c)	420.2(c)	NA
Chlorinated phenols	625(g)	625(h)	625(h)	625(g)
Nonchlorinated phenols	625(g)	625(h)	625(h)	625(g)
Total DDT	608(g)	6630B(h)	608(h)	608(g)
Total PCB	608(g)	6630B(h)	608(h)	608(g)

[a]Letter in parentheses refers to reference list at the end of the table.

References

(a) Clesceri, L., A.E. Greenberg, and R.R. Trussell. 1989.
(b) Greenberg, A.E., L.S. Clesceri, and A.D. Eaton. 1992.
(c) U.S. EPA. 1983.
(d) U.S. EPA. 1985.
(e) Kopperdahl, F.R. 1976.
(f) Anderson, B.S., J.W. Hunt, S.L. Turpen, A.R. Coulon, M. Martin, D.L. McKeown, and F.H. Palmer. 1990.
(g) U.S. EPA. 1992.
(h) U.S. EPA. 1984.

TABLE 3. Reporting limits of constituents in effluent from the largest municipal wastewater treatment facilities in southern California in 1995.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids (mg/L)	1	3.8	4	0.6
Settleable solids (ml/L)	0.1	0.1	0.1	0.1
BOD (mg/L)	2	1.5	40	2
Oil and grease (mg/L)	1	0.7	5.0	ND
Nitrate-N (mg/L)	0.01	0.05	NA	0.03
Nitrite-N (mg/L)	0.1	NR	NA	NA
Ammonia-N (mg/L)	0.1	NR	1	1.6
Organic N (mg/L)	0.1	NR	NA	NA
Phosphate (mg/L)	NA	NR	NA	0.05
Total phosphorus (mg/L)	0.1	NA	NA	NA
Cyanide (µg/L)	9-10	5	5	2
Turbidity (NTU)	0.1	0.9	0.05	ND
Chronic toxicity (TUc)				
Haliotis rufescens	NR	NA	NA	37-64
Macrocystis pyrifera				
Germ tube length	NR	16.7	NA	18-64
Germination	NR	16.7	NA	18-64
Arsenic (µg/L)	1	0.4	1	0.18
Cadmium (µg/L)	2-4	1	0.1	1
Chromium (µg/L)	4	10	1	5
Copper (µg/L)	10	3	1	4
Lead (µg/L)	3-6	8	1	18
Mercury (µg/L)	0.3	0.5-1	0.2	0.3
Nickel (µg/L)	5	3	1	14
Selenium (µg/L)	1	0.7	1	0.4
Silver (µg/L)	0.4	5	1	6.6
Zinc (µg/L)	10	5	1	4
Phenols	NA	200	5	NA
Chlorinated phenols (µg/L)				
2-Chlorophenol	1-2	2-3	5	3.6
2,4-Dichlorophenol	1-3	2-3	6.9	6.1
4-Chloro-3-methylphenol	1-2	2-3	5.1	3.6
2,4,6-Trichlorophenol	1-3	2-3	6.5	3.4
Pentachlorophenol	7	16-26	3.3	1.6
Nonchlorinated phenols (µg/L)				
Phenol	1	2	2.6	1.8
2-Nitrophenol	1-2	3	3.5	4.5
2,4-Dimethylphenol	1-5	8	3.9	4.6
2,4-Dinitrophenol	34-100	19	4.1	3.3
4-Nitrophenol	2-6	18	11	6.1
4,6-Dinitro-2-methylphenol	7-8	2	6.1	3
Total DDT (µg/L)				
o,p'-DDD	0.006	0.01-0.02	0.02	0.02
p,p'-DDD	0.003	0.01-0.02	0.04	0.03
o,p'-DDE	0.004	0.03	0.02	0.04
p,p'-DDE	0.003	0.01	0.01	0.02
o,p'-DDT	0.004	0.02	0.01	0.02
p,p'-DDT	0.013	0.01-0.02	0.04	0.02
Total PCB (µg/L)				
PCB-1016	0.046	0.5	0.30	0.6
PCB-1221	0.034	0.8	0.30	ND
PCB-1232	0.033	0.5	0.30	ND
PCB-1242	0.04	0.9	0.30	0.07
PCB-1248	0.057	0.08	0.30	ND
PCB-1254	0.025	0.4	0.30	ND
PCB-1260	0.065	0.1	0.30	0.3

NA = Not analyzed.
ND = Not determined.
NR = Not reported.
NTU =Nephelometric turbidity units.
TUa = (toxic units acute) = 100/96hr LC50 (percent waste giving 50% survival). If greater than 50% survival: TUa= Log (100-percentage survival in 100% waste)/1.7.
TUc (toxic units chronic) = 100/No Observed Effect Level (maximum percent effluent that causes no observable effect).

Months with constituent concentrations below reporting limits were considered to have zero mass emissions. However, if the constituent was above the reporting limit in one or more months, the mass emissions for the month(s) were calculated, summed across all months, and included in the table of mass emissions. If a constituent concentration was not analyzed for a certain month or had unacceptable results, the annual mean concentration was used to calculate mass emissions for that month.

Prior to 1990, effluent data mass emission estimates were based on annual mean values. Effluent data mass emission estimates for 1990 to 1993 were based on monthly flow and constituent concentration values (SCCWRP 1992, 1994, 1995). In reports of the 1990 to 1992 data, annual mass emissions were reported as zero when annual mean constituent concentrations were below method detection limits. This method was used even though measurable concentrations, and thus measurable discharges, were present in some months. To accommodate these measurable discharges, the method was eventually changed. Beginning with SCCWRP (1995), 1990 to 1993 mass emissions were calculated for all months with measurable concentrations even when annual mean constituent concentrations were below detection limits.

Effluent flow, mass emissions, and toxicity differences between 1994 and 1995 were tested for significance using either the t-test or the Mann-Whitney test. T-tests were performed when all monthly concentrations were detectable and the data was normally distributed. Mann-Whitney tests were performed when the data were not normally distributed. Mann-Whitney tests were also performed when nondetectable monthly concentrations were present (these values were converted to zeroes).

A linear regression was performed on the acute toxicity results from 1990 to 1995 to determine whether there was a significant increase or decrease of toxicity units over time.

RESULTS

1995 Effluents

In 1995, daily flow rates varied among the dischargers by an approximate factor of two. The percent of secondary treated water ranged from zero (PLWTP) to 57% (JWPCP) (Table 4).

General constituents, acute toxicity, and arsenic, copper, and zinc were usually detectable for the four facilities in 100% of the samples (Table 5). Mercury was detected from zero to 8%. The remaining metals were detected from zero to 100%. Of the phenolic compounds, phenol (EPA method 625) was detected by all of the facilities with an average frequency rate of 96%. The remaining phenolic compounds were detectable with an average frequency rate of 4%. Detectable levels of monthly concentrations of DDT were reported by HTP (50%) and JWPCP (42%). All monthly and annual mean concentrations of PCBs were below reporting limits for all dischargers.

The concentrations of effluent constituents usually varied by a factor of more than one to two among the four municipal wastewater treatment plants (Table 6). As with the 1994 study, a few constituents (selenium, total phenols, and nonchlorinated phenols) varied by more than an order of magnitude. Differences among the effluents were attributed to the types of wastes (domestic and industrial), the source control, the volume of water removed for reclamation and inland discharge, and the efficiency and degree of treatment (advanced primary or secondary).

TABLE 4. Flow rate of municipal wastewater discharged to the ocean by the largest municipal wastewater treatment facilities in southern California in 1994 and 1995.

			1994			1995		
Treatment Plant	Length of Outfall from Shore (m)	Depth of Discharge (m)	Advanced Primary (mgd)	Secondary (mgd)	Total Flow (mgd)	Advanced Primary (mgd)	Secondary (mgd)	Total Flow (mgd)
HTP	8,300	57	167	161	329	202	145	347
JWPCP	2,800/3,600	60	141	187	328	144	188	332
CSDOC	7,250	60	120	113	240[a]	118	121	239[a]
PLWTP	7,285	93	172	0	172	188	0	188
Total			600	461	1,069	652	454	1,106

[a]Includes 6 mgd for 1994 and 1.6 mgd for 1995 from construction groundwater dewatering from construction sites at Plant 1 and Plant 2.
mgd=million gallons per day (1 mgd = 3,785,000 L/day).

TABLE 5. Percent of detectable monthly constituent measurements in effluent from the largest municipal wastewater treatment facilities in southern California in 1995.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids	100	100	100	100
Settleable solids	0	100	100	92
BOD	100	100	100	100
Oil and grease	100	100	100	100
Nitrate-N	92	100	NA	100
Nitrite-N	NR	100	NA	NA
Ammonia-N	100	100	100	100
Organic N	100	100	NA	NA
Phosphate	NA	100	NA	100
Total phosphorus	100	NA	NA	NA
Cyanide	25	58	17	100
Turbidity	100	100	100	100
Acute toxicity				
Pimephales promelas	100	83	92	100
Chronic toxicity				
Haliotis rufescens	100	NA	NA	8
Macrocystis pyrifera				
Germ tube length	NR	25	NA	33
Germination	NR	8	NA	42
Arsenic	100	100	83	100
Cadmium	8	25	100	33
Chromium	50	67	100	8
Copper	100	100	100	100
Lead	25	0	100	17
Mercury	8	0	0	8
Nickel	100	100	100	8
Selenium	33	100	75	100
Silver	100	92	100	0
Zinc	100	100	100	100
Phenols	NA	100	92	NA
Chlorinated phenols				
2-Chlorophenol	0	25	0	0
2,4-Dichlorophenol	0	17	0	0
4-Chloro-3-methylphenol	0	0	0	0
2,4,6-Trichlorophenol	0	50	0	0
Pentachlorophenol	0	0	0	0
Nonchlorinated phenols				
Phenol	100	100	83	100
2-Nitrophenol	0	0	0	0
2,4-Dimethylphenol	0	75	0	0
2,4-Dinitrophenol	0	0	0	0
4-Nitrophenol	0	0	0	0
4,6-Dinitro-2-methylphenol	0	0	0	0
Total DDT				
o,p'-DDD	0	0	0	0
p,p'-DDD	0	0	0	0
o,p'-DDE	0	0	0	0
p,p'-DDE	50	42	0	0
o,p'-DDT	0	0	0	0
p,p'-DDT	0	0	0	0
Total PCB				
PCB-1016	0	0	0	0
PCB-1221	0	0	0	0
PCB-1232	0	0	0	0
PCB-1242	0	0	0	0
PCB-1248	0	0	0	0
PCB-1254	0	0	0	0
PCB-1260	0	0	0	0

NA = Not analyzed.
NR = Not reported.

TABLE 6. Means and coefficients of variation (CV) of annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in southern California in 1995.

	HTP		JWPCP		CSDOC		PLWTP	
Constituent	Mean[a]	CV (%)	Mean[a]	CV (%)	Mean[a]	CV (%)	Mean[a]	CV (%)
Flow (mgd)	347	3	332	3	239	5	188	6
Flow (million L/day)	1,313	3	1257	3	905	5	712	6
Suspended solids (mg/L)	34	13	70	8	42	8	43	8
Settleable solids (ml/L)	<0.1	-[b]	0.2	36	0.5	22	0.2	83
BOD (mg/L)	85	18	98	6	76	9	107	8
Oil and grease (mg/L)	12	15	12.4	8	13.4	9	13.4	14
Nitrate-N (mg/L)	0.11	71	0.37	45	NA	-	0.18[c]	28
Nitrite-N (mg/L)	NR	-	0.3	53	NA	-	NA	-
Ammonia-N (mg/L)	25.3	10	33.9	10	23	4	24.2	11
Organic N (mg/L)	5.98	34	6.44	9	NA	-	NA	-
Phosphate (mg/L)	NA	-	3.51	9	NA	-	0.8[c]	66
Total phosphorus (mg/L)	3.83	11	NA	-	NA	-	NA	-
Cyanide (µg/L)	4	197	7	93	1.8	252	2.3	51
Turbidity (NTU)	30	15	59	11	39	7	37	8
Acute toxicity (TUa)								
Pimephales promelas	1.6	18	0.87	54	0.93	46	1.2	20
Chronic toxicity (TUc)								
Haliotis rufescens	47	42	NA	-	NA	-	10	332
Macrocystis pyrifera								
Germ tube length	NR	-	20	234	NA	-	51	152
Germination	NR	-	4.2	346	NA	-	66	162
Arsenic (µg/L)	6	66	3	20	2	60	1.1	17
Cadmium (µg/L)	1	346	0.3	181	0.6	31	0.3	156
Chromium (µg/L)	3	117	8.3	77	4	29	0.7	346
Copper (µg/L)	39	14	23	13	35	17	44	42
Lead (µg/L)	1	222	<8	-	2	21	4.3	241
Mercury (µg/L)	0.03	346	<1[d]	-	<0.2	-	0.04	346
Nickel (µg/L)	17	67	35	21	17	30	0.3	346
Selenium (µg/L)	0.4	161	15	9	1	91	1.26	19
Silver (µg/L)	5.2	42	5	33	2	27	<6.6	-
Zinc (µg/L)	56	29	76	24	37	18	46	61
Phenols (µg/L)	NA	-	333	26	29	59	NA	-
Chlorinated	<7[d]	-	6	152	<6.9[d]	-	<6.1[d]	-
Nonchlorinated	13	122	183	69	3.1	52	13.5	30
Total DDT (µg/L)	0.003	120	0.004	124	<0.04[d]	-	<0.04[d]	-
Total PCB (µg/L)	<0.065[d]	-	<0.9[d]	-	<0.3	-	<0.6[d]	-

[a]The number of significant figures are those reported by the agencies.
[b]Dash=Not applicable.
[c]Only soluble forms of phosphate and nitrate were analyzed.
[d]Maximum of the range of detection limits reported.
NA = Not analyzed.
NR = Not reported.

The monthly concentrations of 86% of the constituents had coefficients of variation (CVs) less than 50% (Table 6). (Constituents that had any monthly concentrations below reporting limits were not included in this inventory because they were treated as zero in the CV calculations, which makes the CVs appear more variable than they actually were.) The majority of mass emissions (79%) varied by less than a factor of 10 among the facilities (Table 7).

Comparison of 1994 and 1995 Effluents

The combined daily flow volume of effluent discharged from the four largest municipal wastewater treatment facilities in southern California did not change significantly from 1994 to 1995 (Table 8). Daily flow increased significantly at HTP (5%) and at PLWTP (9%). The volume of combined effluent receiving secondary treatment decreased slightly from 43% in 1994 to 41% in 1995 (Table 4).

From 1994 to 1995, 37% of the annual mean concentrations of effluent constituents showed no change, while 33% decreased and 30% increased. Effluent acute toxicity to fathead minnows (*Pimephales promelas)* did not change significantly (Table 8) at any of the facilities. Annual mean concentrations of total DDT and PCBs were below reporting limits for both years.

TABLE 7. Estimated constituent mass emissions from the largest municipal wastewater treatment facilities in southern California in 1995.

Constituent	HTP	JWPCP	CSDOC	PLWTP	Total
Flow [a] ($L \times 10^9$)	480	459	330	260	1,529
Suspended solids (mt)	16,350	32,241	13,787	11,085	73,463
BOD (mt)	40,444	44,875	24,900	27,780	137,999
Oil and grease (mt)	5,635	5,676	4,412	3,475	19,198
Nitrate-N (mt)	50	169	NA	46	265
Nitrite-N (mt)	NR	127	NA	NA	127
Ammonia-N (mt)	12,132	15,509	7,413	6,283	41,337
Organic N (mt)	2,873	2,948	NA	NA	5,821
Phosphate (mt)	NA	1,609	NA	193	1,802
Total phosphorus (mt)	1,841	NA	NA	NA	1,841
Cyanide (mt)	2.0	3.2	0.7	0.6	6.5
Arsenic (mt)	2.7	1.4	0.6	0.3	5.0
Cadmium (mt)	0.6	0.1	0.2	0.08	1.0
Chromium (mt)	1.6	3.8	1.4	0.2	7.0
Copper (mt)	19	10	12	12	53
Lead (mt)	0.6	nd	0.7	1.1	2.4
Mercury (mt)	0.012	nd	nd	0.01	0.02
Nickel (mt)	8.0	16	5.7	0.09	30
Selenium (mt)	0.2	6.9	0.4	0.3	7.8
Silver (mt)	2.5	2.3	0.6	nd	5.4
Zinc (mt)	27	35	12	12	86
Phenols (mt)	NA	153	9.6	NA	163
Chlorinated	nd	2.8	nd	nd	2.8
Nonchlorinated	6.3	84	1.0	3.5	95
Total DDT (kg)	1.2	1.9	nd	nd	3.1
Total PCB (kg)	nd	nd	nd	nd	-

[a] Annual flow volumes were the sum of mean daily flow per month times the number of days in each month.
mt = Metric tons.
NA = Not analyzed.
NR = Not reported.
nd = Not detected.

Of the combined mass emissions of constituents tested for significant changes, only cyanide changed significantly (decreased) from 1994 to 1995 (Table 8). Sixteen percent of constituent mass emissions at the individual plants changed significantly during this period. Of the constituent mass emissions that showed significant changes, the majority (56%) either decreased or increased less than 25%. Cyanide at HTP, phenols at JWPCP, ammonia-N at CSDOC and arsenic at PLWTP decreased significantly from 1994 to 1995.

DISCUSSION

One goal of this study is to analyze annual mean concentrations and mass emissions reported by each agency and compare this data among the facilities. Conducting an accurate comparison requires that the reporting agencies use compatibile methodology with similar standards for accuracy and reporting limits. Most constituents (72%) met these requirements; however, 28% of the constituents had more than a two-fold difference in reporting limits accompanied by a two-fold difference in the percent of detectable concentrations. For these constituents, it is impossible to differentiate whether the nondetectable results are from cleaner effluents or from higher reporting limits.

Effluent Trends, 1971-1995

The combined flow from the four largest municipal wastewater treatment facilities increased 19% from 1971 (SCCWRP 1973) to 1995 (Table 9; Figure 2), for a mean annual increase of 0.8%. During this time, the volume of wastewater discharged by PLWTP, CSDOC, and HTP increased 104, 84, and 4%, respectively, while the volume discharged by JWPCP decreased 11%. Population growth patterns, industry type and number, water reclamation, and inland discharge accounted for the differences among these agencies. Specifically, since 1970, Los Angeles County has grown by approximately two million people, and Orange County and San Diego County each have grown by approximately one million (SCCWRP 1973, California Department of Finance 1996). Although Los Angeles County has grown by approximately two million people, flow has only increased 4% at HTP and JWPCP flow has

TABLE 8. Results of significance tests for comparisons of effluent flow, toxicity, and constituent mass emission values between 1994[a] and 1995.

Constituent	Test Used	P value	1994 Mass Emissions	Difference Between 1994-1995	Percent Change	Significantly Higher Year
Combined Discharge						
Flow (mgd)	Mann-Whitney	0.1478	1,069	37	3	-
Acute toxicity (TUa)	Mann-Whitney	0.4637	4.8	-0.2	-4	-
Suspended solids (mt)	Mann-Whitney	0.3852	68,126	5,337	8	-
BOD (mt)	Mann-Whitney	0.3280	132,257	5,742	4	-
Oil and grease (mt)	t-test	0.4313	18,534	664	4	-
Ammonia-N (mt)	Mann-Whitney	0.9795	41,106	231	1	-
Cyanide (mt)	Mann-Whitney	0.0427	12	-5.5	-46	1994
Arsenic (mt)	Mann-Whitney	0.8748	4.0	1.0	25	-
Cadmium (mt)	Mann-Whitney	0.6466	0.7	0.3	43	-
Chromium (mt)	Mann-Whitney	0.8088	6.7	0.3	4	-
Copper (mt)	Mann-Whitney	0.1584	49	4	8	-
Lead (mt)	Mann-Whitney	0.5695	1.3	1.1	85	-
Mercury (mt)	Mann-Whitney	0.5103	0.03	-0.01	-33	-
Nickel (mt)	Mann-Whitney	0.5927	28	2	7	-
Selenium (mt)	Mann-Whitney	0.3772	7.4	0.4	5	-
Silver (mt)	Mann-Whitney	0.5901	5.7	-0.3	-5	-
Zinc (mt)	Mann-Whitney	0.1478	72	14	19	-
Chlorinated phenols (mt)	Mann-Whitney	0.7520	2.1	0.7	33	-
Nonchlorinated phenols (mt)	Mann-Whitney	0.0844	72	23	32	-
DDT (kg)	Mann-Whitney	0.8978	7.9	-4.8	-61	-
PCB (kg)	-	-	-	-	-	All nds
HTP						
Flow (mgd)	Mann-Whitney	<0.0001	329	18	5	1995
Acute toxicity (TUa)	Mann-Whitney	0.3112	1.5	0.1	7	-
Suspended solids (mt)	t-test	0.0066	13,471	2,879	21	1995
BOD (mt)	t-test	0.1450	37,009	3,435	9	-
Oil and grease (mt)	Mann-Whitney	0.1939	5,371	264	5	-
Nitrate-N (mt)	Mann-Whitney	0.2602	78	-28	-36	-
Ammonia-N (mt)	t-test	0.0899	11,334	798	7	-
Organic-N (mt)	Mann-Whitney	0.1260	2,526	347	14	-
Total phosphorus (mt)	t-test	0.8215	1,821	20	1	-
Cyanide (mt)	Mann-Whitney	0.0278	6.7	-4.7	-70	1994
Arsenic (mt)	Mann-Whitney	0.1124	1.8	0.9	50	-
Cadmium (mt)	Mann-Whitney	1.0000	0.2	0.4	200	-
Chromium (mt)	Mann-Whitney	0.1548	0.6	1.0	167	-
Copper (mt)	t-test	0.0099	16	3	19	1995
Lead (mt)	Mann-Whitney	0.3058	All nds	0.6	0	-
Mercury (mt)	Mann-Whitney	1.0000	0.008	0.004	50	-
Nickel (mt)	Mann-Whitney	0.0141	5.1	2.9	57	1995
Selenium (mt)	Mann-Whitney	0.3075	0.04	0.16	400	-
Silver (mt)	t-test	0.8993	2.4	0.1	4	-
Zinc (mt)	t-test	0.0383	21	6	29	1995
Chlorinated phenols (mt)	Mann-Whitney	-	-	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	<0.0001	1.4	4.9	350	1995
DDT (kg)	Mann-Whitney	0.3405	4.8	-3.6	-75	-
PCB (kg)	-	-	-	-	-	All nds
JWPCP						
Flow (mgd)	t-test	0.2808	328	4	1	-
Acute toxicity (TUa)	Mann-Whitney	0.1842	1.06	-0.19	-18	-
Suspended solids (mt)	t-test	0.0130	29,068	3,173	10.9	1995
BOD (mt)	Mann-Whitney	0.8399	44,776	99	0.2	-
Oil and grease (mt)	t-test	0.0194	5,254	422	8	1995
Nitrate-N (mt)	Mann-Whitney	0.1260	118	51	43	-
Nitrite-N (mt)	Mann-Whitney	<0.0001	20	107	535	1995
Ammonia-N (mt)	t-test	0.4640	15,925	-416	-3	-
Organic-N (mt)	t-test	0.8840	2,963	-15	-0.5	-
Total phosphate (mt)	t-test	0.7832	1,627	-18	-1	-
Cyanide (mt)	Mann-Whitney	0.8173	3.8	-0.6	-16	-
Arsenic (mt)	-	-	1.4	0	0	-
Cadmium (mt)	Mann-Whitney	0.8841	0.2	-0.1	-50	-
Chromium (mt)	Mann-Whitney	0.9770	4.1	-0.3	-7	-
Copper (mt)	-	-	10	0	0	-

TABLE 8. (continued)

Constituent	Test Used	P value	1994 Mass Emissions	Difference Between 1994-1995	Percent Change	Significantly Higher Year
Lead (mt)	Mann-Whitney	0.5000	16	-0.6	-100	-
Mercury (mt)	-	-	-	-	-	All nds
Nickel (mt)	-	-	16	0	0	-
Selenium (mt)	t-test	0.4865	6.7	0.2	3	-
Silver (mt)	Mann-Whitney	0.1749	2.6	-0.3	-12	-
Zinc (mt)	t-test	0.6118	33	2	6	-
Phenols (mt)	Mann-Whitney	0.0014	230	-77	-34	1994
Chlorinated phenols (mt)	Mann-Whitney	0.6859	2.1	0.7	33	-
Nonchlorinated phenols (mt)	Mann-Whitney	0.1124	66	18	27	-
DDT (kg)	Mann-Whitney	0.8391	2.9	-1.0	-35	-
PCB (kg)	-	-	-	-	-	All nds
CSDOC						
Flow (mgd)	Mann-Whitney	0.1410	240	-1	-0.4	-
Acute toxicity (TUa)	t-test	0.9165	0.94	-0.01	-1	-
Suspended solids (mt)	t-test	0.0779	14,712	-925	-6.3	-
BOD (mt)	t-test	0.0219	23,396	1,504	6.4	1995
Oil and grease (mt)	t-test	0.9688	4,418	-6	-0.1	-
Ammonia-N (mt)	t-test	0.0366	7,754	-341	-4.4	1994
Cyanide (mt)	Mann-Whitney	0.7036	0.2	0.5	250	-
Arsenic (mt)	Mann-Whitney	0.8852	0.4	0.2	50	-
Cadmium (mt)	-	-	0.2	0	0	-
Chromium (mt)	Mann-Whitney	0.6232	1.6	-0.2	-13	-
Copper (mt)	t-test	0.0013	9.2	2.8	30	1995
Lead (mt)	-	-	0.7	0	0	-
Mercury (mt)	-	-	-	-	-	All nds
Nickel (mt)	Mann-Whitney	0.0781	5.8	-0.1	-2	-
Selenium (mt)	-	-	0.4	0	0	-
Silver (mt)	Mann-Whitney	0.7507	0.7	-0.1	-14	-
Zinc (mt)	-	-	12	0	0	-
Phenols (mt)	-	-	9.6	0	0	-
Chlorinated phenols (mt)	-	-	-	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	0.5442	1.2	-0.2	-17	-
DDT (kg)	Mann-Whitney	0.7465	0.2	-0.2	-100	-
PCB (kg)	-	-	-	-	-	All nds
PLWTP						
Flow (mgd)	t-test	<0.0001	172	16	9	1995
Acute toxicity (TUa)	t-test	0.0992	1.3	-0.1	-8	-
Suspended solids (mt)	t-test	0.5098	10,875	210	2	-
BOD (mt)	t-test	0.2740	27,076	704	3	-
Oil and grease (mt)	t-test	0.9160	3,491	-16	-0.5	-
Nitrate-N (mt)	Mann-Whitney	<0.0001	15	31	207	1995
Ammonia-N (mt)	t-test	0.3528	6,093	190	3	-
Phosphate (mt)	t-test	0.8041	202	-9	-5	-
Cyanide (mt)	t-test	0.0965	0.9	-0.3	-33	-
Arsenic (mt)	Mann-Whitney	0.0020	0.4	-0.1	-25	1994
Cadmium (mt)	Mann-Whitney	0.6623	0.07	0.01	14	-
Chromium (mt)	Mann-Whitney	0.7475	0.4	-0.2	-50	-
Copper (mt)	Mann-Whitney	0.7950	14	-2	-14	-
Lead (mt)	Mann-Whitney	0.5000	All nds	1.1	100	-
Mercury (mt)	Mann-Whitney	0.2214	0.02	-0.01	-50	-
Nickel (mt)	Mann-Whitney	0.2807	0.6	-0.51	-85	-
Selenium (mt)	-	-	0.3	0	0	-
Silver (mt)	-	-	-	-	-	All nds
Zinc (mt)	Mann-Whitney	0.0166	6.2	5.8	94	1995
Chlorinated phenols (mt)	-	-	All nds	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	0.4357	3.1	0.4	13	-
DDT (kg)	-	-	All nds	-	-	All nds
PCB (kg)	-	-	All nds	-	-	All nds

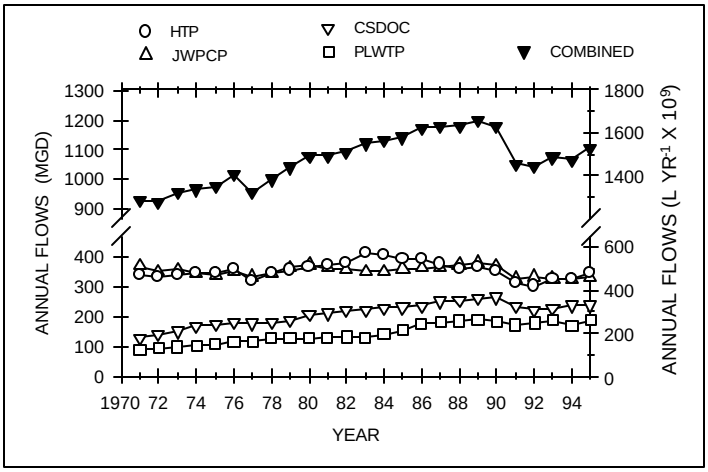
[a]Raco-Rands (1996).
All nds = All nondetectable quantities.

TABLE 9. Estimated combined constituent mass emissions for HTP, JWPCP, CSDOC, and PLWTP from 1971 through 1995.

Constituent	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Flow (L x 10^9)	1,284	1,278	1,319	1,336	1,346	1,406	1,319	1,382	1,438	1,493	1,492
Flow (mgd)	930	922	954	967	975	1,015	955	1,001	1,041	1,078	1,080
Suspended solids[a] (mt x 10^3)	294	287	292	271	285	286	242	254	244	232	225
BOD[b] (mt x 10^3)	283	250	227	234	234	256	242	234	242	255	261
Oil and grease (mt x 10^3)	62	61	61	55	57	59	49	49	45	38	37
NH3-N (mt x 10^3)	55	40	46	39	36	37	40	39	41	41	41
Total P[c] (mt x 10^3)	34	36	39	38	11	23	11	10	10	10	9.5
MBAS (mt x 10^3)	0.5	6.3	5.9	6.8	6.1	6.1	5.4	5.8	6.3	6.4	5.6
Cyanide(mt)	188	238	244	303	251	401	213	176	145	116	98
Arsenic (mt)	3[e]	18	16	18	12	11	12	15	15	11	12
Cadmium (mt)	52	34	49	55	51	44	41	44	43	39	32
Chromium (mt)	667	675	694	690	579	592	368	279	239	275	187
Copper (mt)	535	486	508	576	510	506	402	416	361	335	337
Lead (mt)	226	252	180	199	198	189	150	216	224	175	130
Mercury (mt)	2.9	2.6	3.1	1.8	2.2	2.5	2.6	1.9	2.6	1.8	1.8
Nickel (mt)	326	262	318	315	282	302	262	318	256	224	167
Selenium (mt)	12	11	16	18	11	22	22	23	7.9	11	15
Silver (mt)	15	22	29	22	25	20	34	32	43	30	28
Zinc (mt)	1,834	1,201	1,189	1,324	1,087	1,061	834	833	7,287	729	538
DDT[f] (kg)	21,527	6,558	3,818	1,562	1,158	1,633	855	1,121	839	671	480
PCB[f] (kg)	8,730	9,830	3,389	5,421	3,065	3,492	2,183	2,540	1,170	1,127	1,252

[a] Solids from HTP's 7-mile outfall are total solids.
[b] Hyperion's 7-mile outfall not included.
MBAS = methylene blue active substances.
[c] Sum of soluble phosphate (PLWTP) and total phosphorus (HTP and JWPCP).
[d] Analyses discontinued.

FIGURE 2. Combined effluent flow and individual effluent flows from the four largest municipal wastewater treatment facilities in southern California (MGD = millions of gallons per day, L = liters).



decreased 11% due in part to CSDLAC and the City of Los Angeles expanding their upstream treatment and reclamation facilities. CSDLAC reclaimed 190 million gallons per day (mgd) of water in 1995, double the amount reclaimed 14 years ago (95 mgd). The City of Los Angeles has increased the volume of effluent discharged into the Los Angeles River by the Los Angeles-Glendale and Donald C. Tillman Water Reclamation Plants from 25 mgd in 1985 to 69 mgd in 1995 (City of Los Angeles 1996 a,b).

Despite increases in population and increases in the volume of wastewater discharged during the past 25 years, the mass emissions of most effluent constituents have decreased (Table 9). These reductions in contaminant mass emissions are the result of increased source control, land disposal of sludge, improved sludge and primary treatment, and increased secondary treatment. The combined mass emissions of suspended solids, oil and grease, and biochemical oxygen demand (BOD) have decreased 75, 69, and 51%, respectively (Figure 3-5). The decline in JWPCP solids emissions between 1971 (SCCWRP 1973) and 1995 accounted for 70% of this reduction. Termination of sludge discharge from the HTP 7-mile outfall in November 1987 accounted for a 40% reduction in combined solids emissions from 1987 to 1988. Reductions by JWPCP from 1971 (SCCWRP 1973) to 1995 accounted for approximately 70% of the decline in oil and grease emissions.

The combined mass emissions of trace metals decreased 95% from 1971 to 1995 (Table 9, Figure 6). Reductions of individual metals averaged 86% (arsenic excluded). Arsenic was reported only by HTP in 1971. The greatest reductions were for chromium, mercury, and lead (all 99%), followed by cadmium (98%), zinc (95%), nickel (91%), copper (90%), silver (64%), and selenium (35%). From 1972 to 1995, arsenic declined 72%. Several factors affected the decline of combined mass emssions of trace

1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1,511	1,549	1,565	1,579	1,623	1,629	1,632	1,656	1,627	1,455	1,440	1,485	1,474	1,529
1,094	1,122	1,129	1,143	1,175	1,179	1,178	1,199	1,178	1,053	1,039	1,075	1,069	1,106
227	245	198	205	185	149	97	83	80	79	79	75	68	73
266	252	230	254	182	167	169	161	159	139	135	136	132	138
37	36	30	34	29	26	25	23	22	19	19	18	19	19
42	40	40	43	45	44	44	45	46	44	42	41	41	41
9.0	9.0	9.2	8.5	11	9.0	7.1	6.9	7.1	6.7	5.9	4.3	3.7	3.6
5.7	5.2	4.6	4.3	4.8	4.6	3.4	3.3	3.5	3.5	3.2	-[d]	-[d]	-[d]
77	46	39	26	22	27	26	10	13	16	18	14	12	6.5
8	10	18	16	12	12	8.9	7.4	8.2	5.4	5.5	5.2	4.0	5.0
21	23	16	16	14	9.0	3.4	1.9	1.3	1.1	0.5	0.6	0.7	1.0
203	163	140	110	88	57	29	22	14	10	11	6.8	6.7	7.0
284	272	251	239	202	125	76	68	59	47	48	45	49	53
122	98	87	118	105	61	50	27	8.0	2.5	3.4	1.8	1.3	2.4
1.2	1.1	0.9	0.9	0.7	0.4	0.4	0.4	0.2	0.2	0.03	0.02	0.03	0.02
168	163	133	118	127	76	63	54	40	33	31	31	28	30
6.4	6.5	6.5	5.8	8.2	7.2	6.7	7.6	7.3	7.0	7.2	6.6	7.4	7.8
25	26	24	26	22	15	11	11	9.4	7.9	6.9	6.0	5.7	5.4
545	497	369	375	336	261	151	146	115	125	98	82	72	86
290	223	310	48	51	53	26	20	17	6.4	13	9.2	7.9	3.1
785	628	1,209	46	37	5	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]

[e] Only HTP data was available.
[f] Estimates for 1971 through 1975 were based on Southern California Coastal Water Research Project analyses of effluents; estimates for years after 1975 were based on discharger data.
[g] Concentrations were below method detection limits.

FIGURE 3. Combined suspended solids emissions and individual suspended solids from the four largest municipal wastewater treatment facilities in southern California (MT = metric tons).

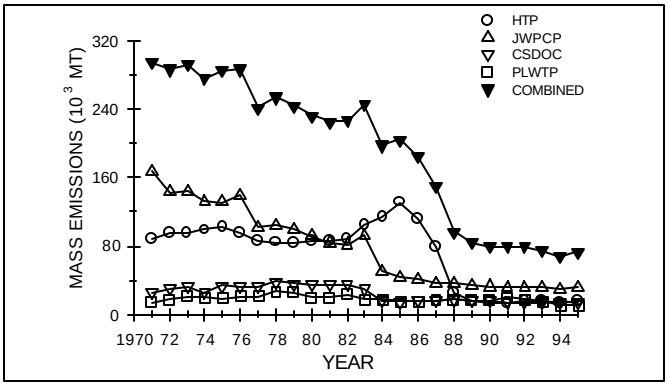


FIGURE 4. Combined oil and grease emissions and individual oil and grease from the four largest municipal wastewater treatment facilities in southern California.

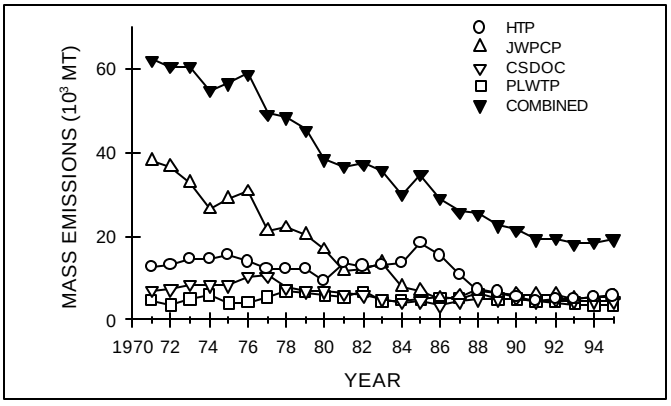
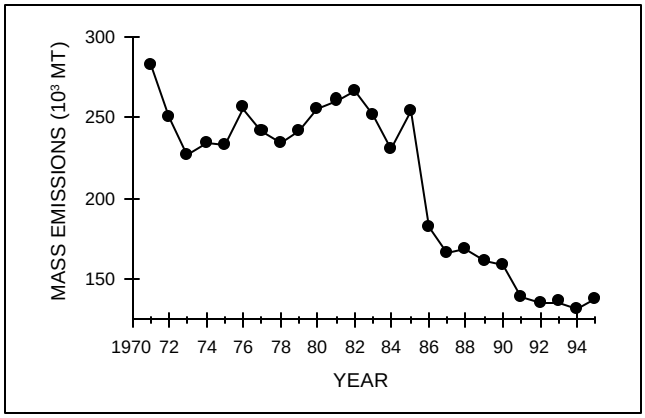
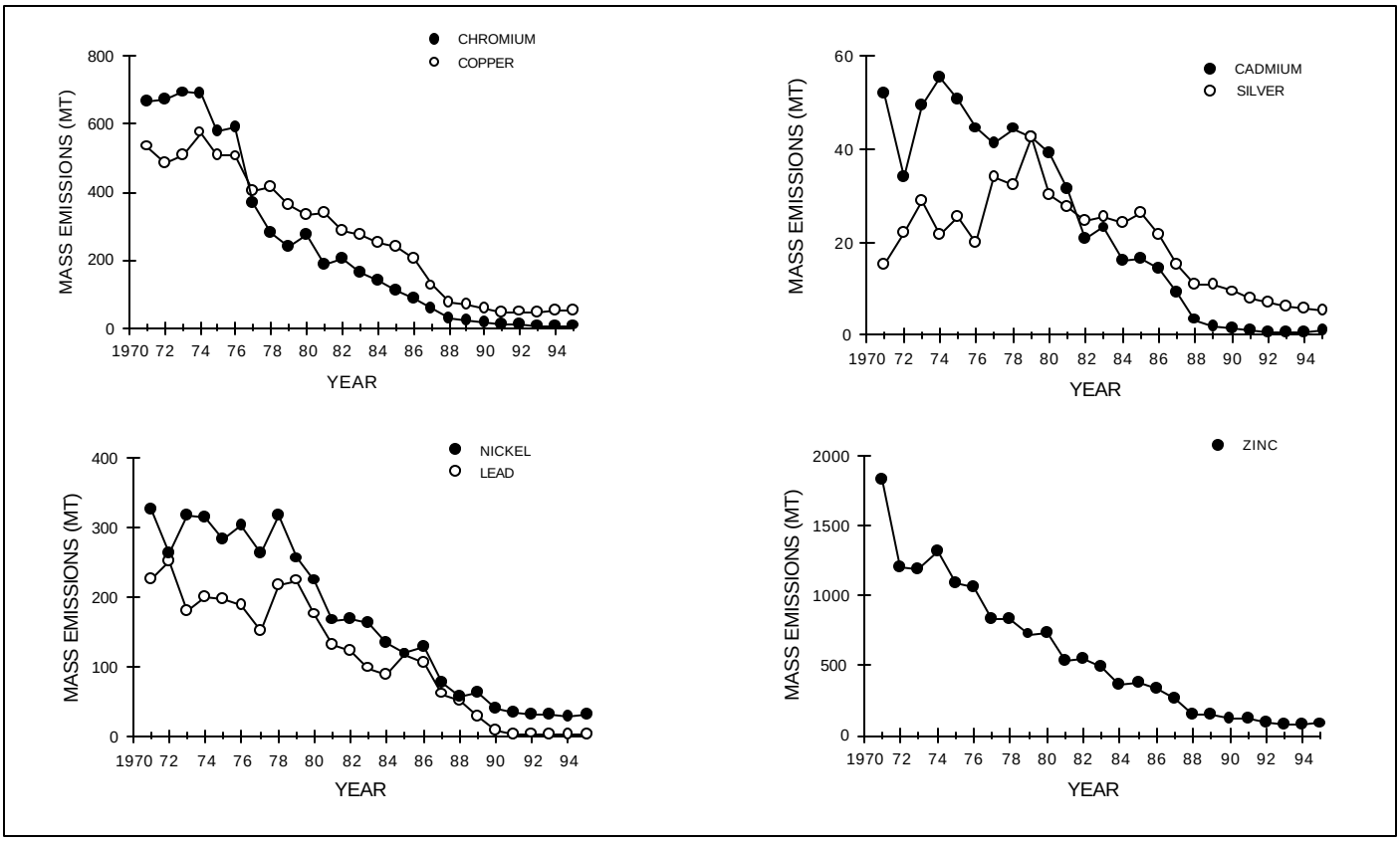


FIGURE 5. Combined mass emission of biochemical oxygen demand from the four largest municipal wastewater treatment facilities southern California.



metals during this period. From 1987 to 1988, the combined mass emissions of trace metals declined 36%; the termination of sludge discharge from the HTP 7-mile outfall accounted for approximately 60% of this reduction. From 1989 to 1991, combined metals emissions decreased 31%; however, lead decreased 91%. Some of the decrease in lead emissions can be attributed to a change in methods used by HTP and CSDOC. Both of these agencies replaced the flame atomic absorption spectrophotometer (AAS) with the graphite furnace AAS, which has less sample matrix interference. Matrix interference causes some of the matrix to appear as lead, resulting in an overestimation of lead concentration.

FIGURE 6. Combined mass emissions of trace metals from the four largest wastewater treatment facilities in southern California.



The combined mass emissions of chlorinated hydrocarbons decreased more than 99% from 1971 to 1995 (Table 9, Figure 7). Montrose Chemical Corporation, the largest manufacturer of DDT in the world and the only manufacturer in California, discharged DDT wastes into the JWPCP sewer system from 1947 to 1971 (Chartrand 1988). Residual sediment in the sewer system was the principal source of DDT in JWPCP effluent after that time (Schafer 1989). Annual mean concentrations of DDT were below reporting limits in 1995; however, JWPCP (as well as HTP) still have measurable amounts of DDT in their effluents during some months.

From 1990 to 1995, acute toxicity has significantly increased at CSDOC and significantly decreased at JWPCP, but has not significantly changed at HTP or PLWTP (Figure 8). Toxicity levels cannot be compared before 1990 because toxicity tests were either unreliable or used different species or methods.

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FIGURE 7. Combined mass emissions of DDT and PCB from the four largest wastewater treatment facilities in southern California (BRL = below reporting limits).

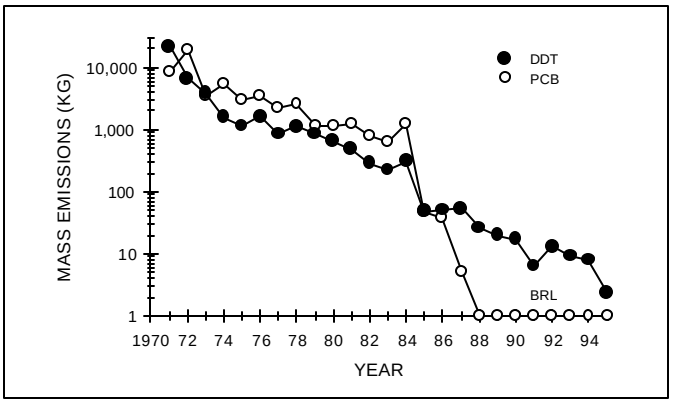
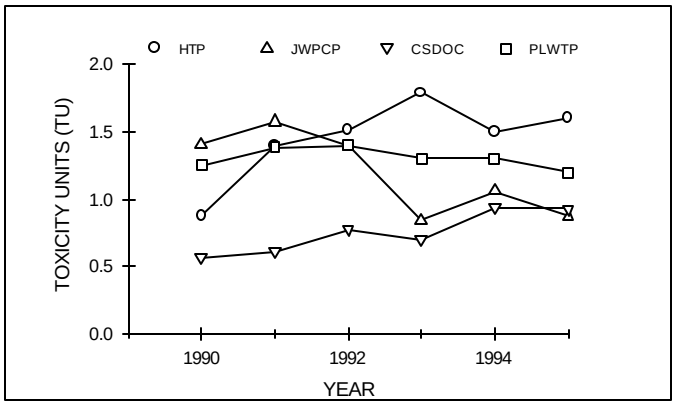


FIGURE 8. Effluent acute toxicity to fathead minnows (*Pimephales promelas)* at the four largest wastewater treatment facilities in southern California.



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