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Characteristics of Effluents from Large Municipal Wastewater Treatment Facilities in 1996

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 from the large municipal wastewater facilities in 1996 and describes trends that have occurred in constituent emissions from these facilities over the past 25 years. Mass emissions were estimated from monthly measurements of flow and constituent concentrations for 1996. Seventy-two percent of the constituents discharged into the SCB have declined more than 70% since 1971. Cyanide, which increased by 3.5 metric tons (mt) between 1995 and 1996, was the only constituent during this period for which combined mass emissions changed significantly.

INTRODUCTION

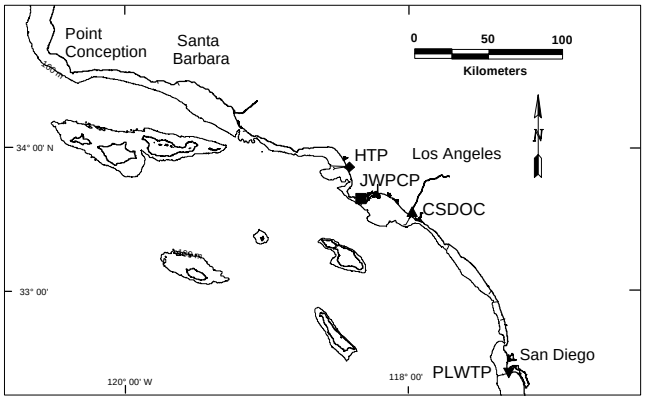
Coastal southern California is one of the most densely populated areas in the nation. The human population of the area utilizes the marine environment for a number of recreational, commercial, municipal, and industrial uses. These uses produce a variety of impacts including an influx of pollutants that can cause environmental damage.

Since pollutants are discharged into the ocean from a variety of sources, inputs from these different sources are measured to identify the most important sources of contaminants. Measurements of pollutant inputs also 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 discharged into the marine environment of the SCB (SCCWRP 1973). In 1995, effluents from the following facilities comprised 89% of the municipal wastewater discharged directly into the SCB: Hyperion Treatment Plant (HTP) operated by the City of Los Angeles; the Joint Water Pollution Control Plant (JWPCP) operated by the Los Angeles County Sanitation District (LACSD); Wastewater Treatment Plant No. 2 operated by the Orange County Sanitation District (OCSD); and Point Loma Wastewater Treatment Plant (PLWTP) operated by the City of San Diego (Figure 1) (Raco-Rands 1997a). 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 analysis from previous years by summarizing the concentrations of effluent constituents and estimating mass emissions for these four wastewater treatment facilities in 1996. Trends in mass emissions of constituents from 1971 to 1996 are also described and 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); Orange County Sanitation District (OCSD); and Point Loma Wastewater Treatment Plant (PLWTP, City of San Diego).



METHODS

Effluent data were obtained from each discharging agency under the National Pollutant Discharge Elimination System (NPDES) permits from the Los Angeles, Santa Ana, and San Diego regions of the California Regional Water Quality Control Board (CRWQCB). Population data were obtained from the State of California (1998).

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

Seventy-four percent of the constituents were analyzed by all of the facilities. Of those, 48% were analyzed using different methods (Table 2); 23% were analyzed using the same method or similar methods (but different reference sources); and 3% were analyzed using the same method but different reagents or procedures within the method. Reporting limits varied by as much as 769 times among the agencies (Table 3).

Two types of assessments were performed. First, annual mean concentrations were calculated by averaging monthly concentrations recorded throughout the year. Zeros were assigned for months with constituent concentrations below reporting limits. Annual mean concentrations were reported even if they were below reporting limits. (This method may differ from methods used by the agencies for compliance reporting to the CRWQCB and the 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 each month. 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*.

Single constituent concentration measurements below reporting limits were converted to zero for mass emission calculations. If multiple samples per month were measured, monthly averages were used to calculate mass

TABLE 1. Frequency of constituent measurements in effluents from the largest municipal wastewater treatment facilities in southern California in 1996.

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	1/Day	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	5/Year (Quarterly)[a]	1/Month	1/Week
Total DDT	Quarterly	1/Month	1/Month	1/Week
Total PCB	Quarterly	1/Month	7/Month	1/Week
PAHs	Quarterly	Quarterly	1/Month	1/Month

[a]Frequency in parentheses is required amount in permit.
HTP = Hyperion Treatment Plant, City of Los Angeles.
JWPCP = Joint Water Pollution Control Plant, Los Angeles County Sanitation District
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 1996.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids	2540D(a[a])	2540D(b)	160.2(c)	2540D(b)
Settleable solids	2540F(a)	2540F(b)	2540F(b)	2540F(b)
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(b)	NA	4110B(b)
Nitrite-N	4500-NO_2B(a)	4500-NO_2B(b)	NA	NA
Ammonia-N	4500-NH_3 B, & E(a)	4500-NH_3 B, & E(b)	350.1(c)	4500-NH_3 F(b)
Organic N	4500-N-orgB(a)	4500-N-orgB(b)& NH_3E(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 E(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)	3030G(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	420.1(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(b)	608(h)	608(g)
Total PCB	608(g)	6630B(b)	608(h)	608(g)
PAHs	625(g)	625 & 610(h)	625(h)	625(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.
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(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 effluents from the largest municipal wastewater teatment facilities in southern California in 1996.

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	ND
Nitrate-N (mg/L)	0.01	0.05	NA	0.007
Nitrite-N (mg/L)	0.1	0.01	NA	NA
Ammonia-N (mg/L)	0.1	0.1	1	1.6
Organic N (mg/L)	0.1	0.1	NA	NA
Phosphate (mg/L)	NA	0.08	NA	0.05
Total phosphorus (mg/L)	0.1	NA	NA	NA
Cyanide (µg/L)	4, 9	5	5	2
Turbidity (NTU)	0.1	0.9	0.05	ND
Chronic toxicity (TUc)[a]				
Haliotis rufescens	15	NA	NA	37-64
Macrocystis pyrifera				
Germ tube length	NR	16.7	NA	NR
Germination	NR	16.7	NA	NR
Arsenic (µg/L)	1	0.4	1	0.18
Cadmium (µg/L)	2	1	0.1	1
Chromium (µg/L)	4	10	1	5
Copper (µg/L)	10	3	1	4
Lead (µg/L)	3	8	1	18
Mercury (µg/L)	0.3	0.5	0.2	0.27
Nickel (µg/L)	4, 5	3	2	14
Selenium (µg/L)	1	0.7	1	0.4
Silver (µg/L)	0.4	5	1	6.6
Zinc (µg/L)	10	5	2	4
Phenols[b] (µg/L)	NA	NR	5	NA
Chlorinated phenols[c] (µg/L)				
2-Chlorophenol	1	2	5	3.6
2,4-Dichlorophenol	1	2	6.9	6.1
4-Chloro-3-methylphenol	1	2	5.1	3.6
2,4,6-Trichlorophenol	1	2	6.5	3.4
Pentachlorophenol	7	16	3.3	1.6
Nonchlorinated phenols[b] (µg/L)				
Phenol	1	2	2.6	1.8
2-Nitrophenol	1	3	3.5	4.5
2,4-Dimethylphenol	1	8	3.9	4.6
2,4-Dinitrophenol	34	19	4.1	3.3
4-Nitrophenol	6	18	11	6.1
4,6-Dinitro-2-methylphenol	8	2	6.1	3
Total DDT (µg/L)				
o,p'-DDD	0.006	0.02	0.02	0.02
p,p'-DDD	0.003	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	0.02	0.04	0.02
Total PCB (µg/L)				
PCB-1016	0.046	0.5	0.3	0.6
PCB-1221	0.034	0.8	0.3	ND
PCB-1232	0.033	0.5	0.3	ND
PCB-1242	0.04	0.9	0.3	0.07
PCB-1248	0.057	0.08	0.3	ND
PCB-1254	0.025	0.4	0.3	ND
PCB-1260	0.065	0.1	0.3	0.3
PAHs (µg/L)				
Acenaphthene	1	2	8.4	1.2
Acenaphthylene	1	2	7.4	0.9
Anthracene	1	0.018, 0.024	5.7	1.2
Benzo(A)Anthracene	1	0.023	9.8	1.2
Benzo(A)Pyrene	1	0.031	2.6	7.4
Benzo(B)Fluoranthene	1	0.014	2.8	0.8

Table 3 continued.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Benzo(G,H, I)Perylene	1	0.013	10	7
Benzo(K)Fluoranthene	1	0.008	1.7	1
Chrysene	1	0.091	2.9	1.4
Dibenzo(A,H)Anthracene	1	0.023, 0.079	10	7.8
Fluoranthene	1	2	5.7	1.3
Fluorene	1	0.079	8	1.1
Indeno(1,2,3-C,D)Pyrene	1	0.014	10	7.4
Naphthalene	1	3	4.6	1.6
Phenanthrene	1	0.31	6.7	0.9
Pyrene	1	0.068	5.1	1.5

[a] Lowest concentration of effluent tested.
[b] Colorimetric method.
[c] Gas chromatography/mass spectrometry (GC/MS) method.
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.

emissions, even if that monthly average was below the reporting limit. Some months had no measurements for individual constituents or the measurement was considered unreliable (determined by the discharger). In this case, the annual average was applied to that month to calculate mass emissions, even if the annual average was below reporting limits.

Prior to 1990, effluent data mass emission estimates were based on annual mean values. Effluent data mass emission estimates for 1990 to 1995 were based on monthly flow and constituent concentration values (Raco-Rands 1996, 1997b; 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 reporting 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 changed. Beginning with SCCWRP (1995), 1990 to 1993 mass emissions were calculated for all months with measurable concentrations.

Effluent flow, mass emissions, and toxicity differences between 1995 and 1996 were tested for significance using the t-test or the Mann-Whitney test. A t-test was performed when all monthly concentrations were detectable and the data were normally distributed, otherwise a Mann-Whitney test was performed. Acute toxicity results from 1990 to 1996 were tested using a linear regression to determine whether a significant increase or decrease of toxicity units occurred over time.

RESULTS

1996 Effluents

In 1996, mean daily flow rates varied by an average factor of two among the four largest dischargers . The level of secondary treated effluent ranged from zero (PLWTP) to 59% (JWPCP) of the average daily flow rate. (Table 4).

General constituents were detectable in an average of 97% of the monthly measurements among all of the facilities (Table 5). Trace metals were detectable in an average of 65% of the monthly measurements among all of the facilities. Mercury had the lowest frequency of detection for any metal among all of the facilities at 4%. The chlorinated phenols group was detectable in an average of 20% of the monthly measurements across all of the facilities. Individual chlorinated phenolic compounds were detectable in an average of 5% of the monthly measurements. The nonchlorinated phenols group was detectable in an average of 96% of the monthly measurements among all of the facilities. The individual compound phenol was above detectable limits at a much higher average frequency ((96%) of the monthly measurements among all of the facilities) than the remaining nonchlorinated phenolic compounds (0 to 25%). Total DDTs were detectable in an average of 8% of monthly measurements among all of the facilities. Individual isomers were detectable in an average of 1% of the monthly measurements among all of the facilities. The PCBs were nondetectable for all four facilities. The PAH group was detectable in an average of 4% of the

TABLE 4. Flow rate of municipal wastewater discharged into the ocean by the largest municipal wastewater treatment facilities in southern California in 1995 and 1996.

Treatment Plant	Length of Outfall from Shore (m)	Depth of Discharge (m)	1995 Advanced Primary (mgd)	1995 Secondary (mgd)	1995 Total Flow (mgd)	1996 Advanced Primary (mgd)	1996 Secondary (mgd)	1996 Total Flow (mgd)
HTP	8,300	57	202	145	347	161	196	357
JWPCP	2,800/3,600	60	144	188	332	137	194	331
CSDOC	7,250	60	118	121	239[a]	120	116	236[a]
PLWTP	7,285	93	188	0	188	179	0	179
Total			652	454	1,106	597	506	1,103

[a]Includes 1.6 mgd for 1995 and 0.11 mgd for 1996 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 months with detectable constituent measurements in effluents from the largest municipal wastewater treatment facilities in southern California in 1996.

Constituent	HTP	JWPCP	CSDOC	PLWTP
Suspended solids	100	100	100	100
Settleable solids	100	100	100	100
BOD	100	100	100	100
Oil and grease	100	100	100	100
Nitrate-N	100	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	92
Total phosphorus	100	NA	NA	NA
Cyanide	75	100	8	100
Turbidity	100	100	100	100
Acute toxicity				
Pimephales promelas	100	83	92	100
Chronic toxicity				
Haliotis rufescens	92	NA	NA	100
Macrocystis pyrifera				
Germ tube length	NR	50	NA	100
Germination	NR	25	NA	100
Arsenic	100	100	100	100
Cadmium	0	25	100	58
Chromium	25	67	100	17
Copper	100	100	100	100
Lead	8	0	92	17
Mercury	8	0	8	0
Nickel	100	100	100	25
Selenium	0	100	75	100
Silver	100	92	100	0
Zinc	100	100	100	100
Phenols (Colorimetric method)	NA	100	100	NA
Chlorinated phenols (GC/MS method)				
2-Chlorophenol	0	25	0	0
2,4-Dichlorophenol	0	0	0	0
4-Chloro-3-methylphenol	0	0	0	0
2,4,6-Trichlorophenol	0	75	0	0
Pentachlorophenol	0	0	0	0
Nonchlorinated phenols (GC/MS method)				
Phenol	100	100	83	100
2-Nitrophenol	0	0	0	0
2,4-Dimethylphenol	0	100	0	0

Table 5 continued.

Constituent	HTP	JWPCP	CSDOC	PLWTP
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	8
p,p'-DDD	0	0	0	0
o,p'-DDE	0	0	0	0
p,p'-DDE	0	25	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
PAHs				
Acenaphthene	0	0	0	0
Acenaphthylene	0	0	0	0
Anthracene	0	0	0	0
Benzo(A)Anthracene	0	0	0	0
Benzo(A)Pyrene	0	0	0	0
Benzo(B)Fluoranthene	0	0	0	0
Benzo(G,H, I)Perylene	0	0	0	0
Benzo(K)Fluoranthene	0	0	0	0
Chrysene	0	0	0	0
Dibenzo(A,H)Anthracene	0	0	0	0
Fluoranthene	0	0	0	0
Fluorene	0	0	0	0
Indeno(1,2,3-C,D)Pyrene	0	0	0	0
Naphthalene	0	0	0	17
Phenanthrene	0	0	0	0
Pyrene	0	0	0	0

GC/MS = Gas chromatography/mass spectrometry.

monthly measurements among all of the facilities. Individual PAH compounds were detectable in an average of 0.3% of the monthly measurements among all of the facilities.

The concentrations of effluent constituents usually varied by a factor of two or less among the four municipal wastewater treatment plants (Table 6). Nonchlorinated phenols demonstrated the widest range of concentration, varying by a factor of 40. Differences in effluent concentrations 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 methods and processes (advanced primary or secondary).

The monthly concentrations for 72% of the constituents had coefficients of variation (CVs) less than 50% (Table 6). The majority (72%) of the mass emissions of constituents across the four facilities varied by a factor of less than 10 (Table 7).

Comparison of 1995 and 1996 Effluents

The combined daily flow rate of effluent from the four largest municipal wastewater treatment facilities in southern California did not change significantly from 1995 to 1996 (Table 8). However, the daily flow rate decreased significantly (5%) at PLWTP as the result of a 43% decrease in rainfall from 1995 to 1996 (City of San Diego 1997). This decrease is much larger than decreases in rainfall measured in the Los Angeles and Santa Ana areas (25 and 24%, respectively). The daily flow rate of combined effluent receiving secondary treatment significantly increased among all of the agencies from 41% in 1995 to 46% in 1996 (Table 4).

Of the combined constituent mass emissions tested across all facilities for significant changes from 1995 to 1996, only cyanide changed significantly (increasing from 6.5 mt in 1995 to 10 mt in 1996) (Table 8). However, the 1996 cyanide level of 10 mt is still lower than the 1994 cyanide level, which was 12 mt. Twenty percent of constituent mass emissions at the individual

TABLE 6. Means and coefficients of variation (CVs) of annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in southern California in 1996.

	HTP		JWPCP		CSDOC		PLWTP	
Constituent	Mean[a]	CV (%)	Mean[a]	CV (%)	Mean[a]	CV (%)	Mean[a]	CV (%)
Flow (mgd)	357	3	331	2	236	2	179	2
Flow (million L/day)	1,350	3	1,252	2	895	2	677	2
Suspended solids (mg/L)	27	8	66	7	48	7	43	6
Settleable solids (mL/L)	0.03	49	0.16	30	0.5	24	0.2	38
BOD (mg/L)	61	9	93	5	75	9	119	4
Oil and grease (mg/L)	9	16	12	10	14.6	13	12	21
Nitrate-N (mg/L)	0.163	66	0.36	85	NA	-[b]	0.20[c]	71
Nitrite-N (mg/L)	NR	-	0.23	72	NA	-	NA	-
Ammonia-N (mg/L)	26.4	7	30	5	23	3	26.8	4
Organic-N (mg/L)	4.76	9	6.25	10	NA	-	NA	-
Phosphate (mg/L)	NA	-	3.37	16	NA	-	0.4[c]	54
Total phosphorus (mg/L)	3.71	8	NA	-	NA	-	NA	-
Cyanide (µg/L)	7	79	11	54	0.5	346	4.8	61
Turbidity (NTU)	23	13	52	6	38	7	41	8
Acute toxicity (TUa)								
Pimephales promelas	1.0	37	0.81	58	0.87	33	1.2	24
Chronic toxicity (TUc)								
Haliotis rufescens	30	44	NA	-	NA	-	64	0
Macrocystis pyrifera								
Germ tube length	NR	-	28	158	NA	-	103	61
Germination	NR	-	7.0	181	NA	-	100	53
Arsenic (µg/L)	4	40	2.6	16	2	30	1.33	26
Cadmium (µg/L)	<2	0	0.3	181	0.4	36	0.8	137
Chromium (µg/L)	1	201	9.5	87	4	17	0.4	279
Copper (µg/L)	33	16	24	21	34	15	44	29
Lead (µg/L)	0.2	346	<8	0	2	42	3	255
Mercury (µg/L)	0.03	346	<0.5[d]	0	0.07	346	<0.27	0
Nickel (µg/L)	10	36	47	18	20	10	2	192
Selenium (µg/L)	<1	0	15	14	1	76	1.15	17
Silver (µg/L)	3.6	29	5	33	2	18	<6.6	0
Zinc (µg/L)	46	22	78	49	42	46	76	83
Phenols (µg/L)	NA	-	275	19	41	22	NA	-
Chlorinated	<7[d]	0	7	70	<6.9[d]	0	<6.1[d]	0
Nonchlorinated	2.9	55	115	22	3.8	58	18.0	8
Total DDT (µg/L)	<0.013	0	0.003	181	<0.04[d]	0	0.001	346
Total PCB (µg/L)	<0.065[d]	0	<0.9[d]	0	<0.3	0	<0.6[d]	0
PAHs (µg/L)	<1	0	<3	0	<10	0	0.63	270

[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 reporting limit.
NA = Not analyzed.
NR = Not reported.

TABLE 7. Estimated constituent mass emissions from the largest municipal wastewater treatment facilities in southern California in 1996.

Constituent	HTP	JWPCP	CSDOC	PLWTP	Total
Flow[a] (L x 10^9)	494	458	327	248	1,527
Suspended solids (mt)	13,308	30,052	15,867	10,713	69,940
BOD (mt)	30,299	42,452	24,486	29,412	126,649
Oil and grease (mt)	4,446	5,432	4,788	2,926	17,592
Nitrate-N (mt)	81	167	NA	50	298
Nitrite-N (mt)	NR	104	NA	NA	104
Ammonia-N (mt)	13,063	13,753	7,531	6,632	40,979
Organic-N (mt)	2,355	2,862	NA	NA	5,217
Phosphate (mt)	NA	1,544	NA	110	1,654
Total phosphorus (mt)	1,832	NA	NA	NA	1,832
Cyanide (mt)	3.7	5.2	0.17	1.2	10

Table 7 continued.

Constituent	HTP	JWPCP	CSDOC	PLWTP	Total
Arsenic (mt)	2.2	1.2	0.55	0.33	4.3
Cadmium (mt)	nd	0.11	0.11	0.19	0.4
Chromium (mt)	0.71	4.3	1.4	0.10	6.5
Copper (mt)	16	11	11	11	49
Lead (mt)	0.09	nd	0.52	0.62	1.2
Mercury (mt)	0.01	nd	0.02	nd	0.03
Nickel (mt)	4.8	22	6.6	0.42	34
Selenium (mt)	nd	6.6	0.47	0.28	7.4
Silver (mt)	1.8	2.4	0.71	nd	4.9
Zinc (mt)	22	36	14	19	91
Phenols (mt)	NA	126	13	NA	139
Chlorinated	nd	3	nd	nd	3.0
Nonchlorinated	1.4	53	1.2	4.5	60
Total DDT (kg)	nd	1.1	nd	0.25	1.4
Total PCB (kg)	nd	nd	nd	nd	-
PAHs (kg)	nd	nd	nd	161	161

[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.

TABLE 8. Results of significance tests for comparisons of effluent flow, toxicity, and constituent mass emission values between 1995[a] and 1996.

Constituent	Test Used	P value	1995 Mass Emissions	1996 Mass Emissions	Difference Between 1995-1996	Percent Change	Significantly Higher Year
Combined Discharge							
Flow (mgd)	Mann-Whitney	0.9387	1,106	1,103	-3.0	-0.3	-
Acute toxicity (TUa)	Mann-Whitney	0.0622	1.1[b]	1.02[b]	-0.08	-7	-
Suspended solids (mt)	Mann-Whitney	0.5072	73,463	69,940	-3,523.0	-5	-
BOD (mt)	Mann-Whitney	0.3974	137,999	126,649	-11,350.0	-8	-
Oil and grease (mt)	t-test	0.0745	19,198	17,592	-1,606.0	-8	-
Ammonia-N (mt)	Mann-Whitney	0.8690	41,337	40,979	-358.0	-1	-
Cyanide (mt)	Mann-Whitney	0.0314	6.5	10	3.5	54	1996
Arsenic (mt)	Mann-Whitney	0.9212	5.0	4.3	-0.7	-14	-
Cadmium (mt)	Mann-Whitney	0.8116	1.0	0.4	-0.6	-60	-
Chromium (mt)	Mann-Whitney	0.5188	7.0	6.5	-0.5	-7	-
Copper (mt)	Mann-Whitney	0.6157	53	49	-4.0	-8	-
Lead (mt)	Mann-Whitney	0.4697	2.4	1.2	-1.2	-50	-
Mercury (mt)	Mann-Whitney	0.9971	0.02	0.03	0.01	50	-
Nickel (mt)	Mann-Whitney	0.8575	30	34	4.0	13	-
Selenium (mt)	Mann-Whitney	0.3520	7.8	7.4	-0.4	-5	-
Silver (mt)	Mann-Whitney	0.8748	5.4	4.9	-0.5	-9	-
Zinc (mt)	Mann-Whitney	0.8633	86	91	5.0	6	-
Chlorinated phenols (mt)	Mann-Whitney	0.6969	2.8	3.0	0.2	7	-
Nonchlorinated phenols (mt)	Mann-Whitney	0.1499	95	60	-35.0	-37	-
DDT (kg)	Mann-Whitney	0.0724	3.1	1.4	-1.7	-55	-
PCB (kg)	-	-	-	-	-	-	All nds
HTP							
Flow (mgd)	t-test	0.0507	347	357	10.0	3	-
Acute toxicity (TUa)	t-test	0.0002	1.6	1.0	-0.6	-38	1995
Suspended solids (mt)	t-test	0.0008	16,350	13,308	-3,042.0	-19	1995
BOD (mt)	Mann-Whitney	<0.0001	40,444	30,299	-10,145.0	-25	1995
Oil and grease (mt)	t-test	0.0016	5,635	4,446	-1,189.0	-21	1995
Nitrate-N (mt)	Mann-Whitney	0.1260	50	81	31.0	62	-
Ammonia-N (mt)	t-test	0.0564	12,132	13,063	931.0	8	-

Table 8 continues.

Constituent	Test Used	P value	1995 Mass Emissions	1996 Mass Emissions	Difference Between 1995-1996	Percent Change	Significantly Higher Year
Organic N (mt)	Mann-Whitney	0.1939	2,873	2,355	-518.0	-18	-
Total phosphorus (mt)	t-test	0.9177	1,841	1,832	-9.0	-0.5	-
Cyanide (mt)	Mann-Whitney	0.1181	2.0	3.7	1.7	85	
Arsenic (mt)	Mann-Whitney	0.3708	2.7	2.2	-0.5	-19	-
Cadmium (mt)	Mann-Whitney	0.7465	0.62	nd	-	-	-
Chromium (mt)	Mann-Whitney	0.2123	1.6	0.71	-0.9	-56	-
Copper (mt)	t-test	0.0219[c]	19	16	-3.0	-16	1995
Lead (mt)	Mann-Whitney	0.4476	0.65	0.09	-0.6	-86	-
Mercury (mt)	Mann-Whitney	1.0000	0.012	0.01	0.0	-17	-
Nickel (mt)	Mann-Whitney	0.0094	8.0	4.8	-3.2	-40	1995
Selenium (mt)	Mann-Whitney	0.1698	0.19	nd	-	-	-
Silver (mt)	t-test	0.0531	2.5	1.8	-0.7	-28	-
Zinc (mt)	t-test	0.1106	27	22	-5.0	-19	-
Chlorinated phenols (mt)	-	-	nd	nd	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	<0.0001	6.3	1.4	-4.9	-78	1995
DDT (kg)	Mann-Whitney	<0.0001	1.2	nd	-	-	1995
PCB (kg)	-	-	nd	nd	-	-	All nds
JWPCP							
Flow (mgd)	Mann-Whitney	0.931	332	331	-1.0	-0.3	-
Acute toxicity (TUa)	Mann-Whitney	0.7508	0.87	0.81	-0.1	-7	-
Suspended solids (mt)	t-test	0.0891	32,241	30,052	-2,189.0	-7	-
BOD (mt)	t-test	0.0313[c]	44,875	42,452	-2,423.0	-5	1995
Oil and grease (mt)	t-test	0.1656	5,676	5,432	-244.0	-4	-
Nitrate-N (mt)	Mann-Whitney	0.4025	169	167	-2.0	-1	-
Nitrite-N (mt)	Mann-Whitney	0.4357	127	104	-23.0	-18	-
Ammonia-N (mt)	Mann-Whitney	0.0029	15,509	13,753	-1,756.0	-11	1995
Organic N (mt)	t-test	0.4343	2,948	2,862	-86.0	-3	-
Total phosphate (mt)	t-test	0.4565	1,609	1,544	-65.0	-4	-
Cyanide (mt)	Mann-Whitney	0.3122	3.2	5.2	2.0	63	-
Arsenic (mt)	t-test	0.0523	1.4	1.2	-0.2	-14	-
Cadmium (mt)	Mann-Whitney	1.0000	0.11	0.11	0.0	0	-
Chromium (mt)	Mann-Whitney	0.8852	3.8	4.3	0.5	13	-
Copper (mt)	t-test	0.4191	10	11	1.0	10	-
Lead (mt)	-	-	nd	nd	-	-	All nds
Mercury (mt)	-	-	nd	nd	-	-	All nds
Nickel (mt)	t-test	0.0010	16	22	6.0	38	1996
Selenium (mt)	t-test	0.4600	6.9	6.6	-0.3	-4	-
Silver (mt)	Mann-Whitney	0.3263	2.3	2.4	0.1	4	-
Zinc (mt)	t-test	0.8859	35	36	1.0	3	-
Phenols (mt)	t-test	0.0620	153	126	-27.0	-18	-
Chlorinated phenols (mt)	Mann-Whitney	0.3260	2.8	3.0	0.2	7	-
Nonchlorinated phenols (mt)	Mann-Whitney	0.0029	84	53	-31.0	-37	1995
DDT (kg)	Mann-Whitney	0.5614	1.9	1.1	-0.8	-42	-
PCB (kg)	-	-	nd	nd	-	-	All nds
CSDOC							
Flow (mgd)	Mann-Whitney	0.7950	239	236	-3.0	-1	-
Acute toxicity (TUa)	Mann-Whitney	0.9310	0.93	0.87	-0.1	-6	-
Suspended solids (mt)	Mann-Whitney	0.0017	13,787	15,867	2,080.0	15	1996
BOD (mt)	t-test	0.5979	24,900	24,486	-414.0	-2	-
Oil and grease (mt)	t-test	0.0965	4,412	4,788	376.0	9	-
Ammonia-N (mt)	t-test	0.3424	7,413	7,531	118.0	2	-
Cyanide (mt)	Mann-Whitney	0.7036	0.68	0.17	-0.5	-75	-
Arsenic (mt)	Mann-Whitney	0.7950	0.57	0.55	0.0	-4	-
Cadmium (mt)	t-test	0.0013	0.20	0.11	-0.1	-45	1995
Chromium (mt)	Mann-Whitney	0.8399	1.4	1.4	0.0	0	-
Copper (mt)	t-test	0.5134	12	11	-1.0	-8	-
Lead (mt)	Mann-Whitney	0.2145	0.66	0.52	-0.1	-21	-
Mercury (mt)	Mann-Whitney	0.7465	nd	0.02	-	-	-
Nickel (mt)	t-test	0.2201	5.7	6.6	0.9	16	-
Selenium (mt)	Mann-Whitney	0.6441	0.41	0.47	0.1	15	-
Silver (mt)	Mann-Whitney	0.1572	0.63	0.71	0.1	13	-
Zinc (mt)	Mann-Whitney	0.5834	12	14	2.0	17	-
Phenols (mt)	Mann-Whitney	0.0606	9.6	13	3.4	35	-

Table 8 continued.

Constituent	Test Used	P value	1995 Mass Emissions	1996 Mass Emissions	Difference Between 1995-1996	Percent Change	Significantly Higher Year
Chlorinated phenols (mt)	-	-	nd	nd	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	0.3123	1.0	1.2	0.2	20	-
DDT (kg)	-	-	nd	nd	-	-	All nds
PCB (kg)	-	-	nd	nd	-	-	All nds
PLWTP							
Flow (mgd)	Mann-Whitney	0.0051	188	179	-9.0	-5	1995
Acute toxicity (TUa)	Mann-Whitney	0.6030	1.2	1.2	0.0	0	-
Suspended solids (mt)	t-test	0.1935	11,085	10,713	-372.0	-3	-
BOD (mt)	t-test	0.0032	27,780	29,412	1,632.0	6	1996
Oil and grease (mt)	t-test	0.0191[c]	3,475	2,926	-549.0	-16	1995
Nitrate-N (mt)	t-test	0.7424	46	50	4.0	9	-
Ammonia-N (mt)	t-test	0.1021	6,283	6,632	349.0	6	-
Phosphate (mt)	Mann-Whitney	0.0606	193	110	-83.0	-43	-
Cyanide (mt)	Mann-Whitney	0.0351	0.59	1.2	0.6	103	1996
Arsenic (mt)	t-test	0.0985	0.28	0.33	0.1	18	-
Cadmium (mt)	Mann-Whitney	0.3108	0.08	0.19	0.1	138	-
Chromium (mt)	Mann-Whitney	0.7923	0.17	0.10	-0.1	-41	-
Copper (mt)	Mann-Whitney	0.9310	12	11	-1.0	-8	-
Lead (mt)	Mann-Whitney	0.9767	1.1	0.62	-0.5	-44	-
Mercury (mt)	Mann-Whitney	0.7465	0.01	nd	-	-	-
Nickel (mt)	Mann-Whitney	0.4833	0.09	0.42	0.3	367	-
Selenium (mt)	t-test	0.1009	0.33	0.28	-0.1	-15	-
Silver (mt)	-	-	nd	nd	-	-	All nds
Zinc (mt)	Mann-Whitney	0.5444	12	19	7.0	58	-
Chlorinated phenols (mt)	-	-	nd	nd	-	-	All nds
Nonchlorinated phenols (mt)	Mann-Whitney	0.0262	3.5	4.5	1.0	29	1996
DDT (kg)	Mann-Whitney	0.7465	nd	0.25	-	-	-
PCB (kg)	-	-	nd	nd	-	-	All nds

[a] Raco-Rands (1997b).
[b] Median of all monthly values.
[c] Power of performed test is below the desired power of 0.800. Results should be viewed cautiously.
All nds = All nondetectable quantities.

facilities changed significantly from 1995 to 1996. Of the constituent mass emissions that showed significant changes, the majority of constituents (74%) decreased. The constituents that significantly increased were nickel at JWPCP (38%); suspended solids at OCSD (15%); and BOD (6%), cyanide (103%), and nonchlorinated phenols (29%) at PLWTP. Of the acute toxicity tests performed, only the toxicity at HTP changed significantly (decreasing 7%).

DISCUSSION

The goals of this study were (1) to calculate annual mean concentrations and mass emissions using monthly concentrations and flows reported by each agency and (2) to compare the resulting data among the facilities. Conducting an accurate comparison requires that the reporting agencies use compatible methodology with similar standards for accuracy and reporting limits. The agencies met these requirements for most of the constituents (80%); however, 20% of the constituents had reporting limits that varied by a factor of two or more, accompanied by a two-fold or more difference in the percent of detectable concentrations reported. For these constituents, it is impossible to differentiate whether the nondetectable measurements result from cleaner effluents or from higher reporting limits.

Effluent Trends, 1971-1996

The combined flow from the four largest municipal wastewater treatment facilities increased 19% from 1971 (SCCWRP 1973) to 1996 (Table 9; Figure 2), for a mean annual increase of 0.8%. During this time, the volume of wastewater discharged by PLWTP, OCSD, and HTP increased 99, 82, and 7%, respectively, while the volume discharged by JWPCP decreased 11%. Population growth patterns, regional industry types and numbers, and the presence or absence of water reclamation programs and inland discharge sources 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 people (SCCWRP 1973, State of California 1998). Although the population of Los Angeles County has grown by 34%, flow has increased only 7% at HTP and has decreased by 11% at JWPCP, due, in part, to the LACSD and the City of Los Angeles expanding their upstream treatment and reclamation facilities. The LACSD reclaimed 188 million gallons per day (mgd) of water in 1996, almost twice the amount reclaimed 15 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 67 mgd in 1996 (City of Los Angeles 1997 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 biosolids, improved sludge dewatering and primary treatment methods, and increased secondary treatment processes. The combined mass emissions of suspended solids, oil and grease, and BOD have decreased 76, 71, and 55%, respectively (Figure 3-5). The decline in JWPCP solids emissions between 1971 and 1996 accounted for 69% 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 to 1996 accounted for approximately 68% of the decline in combined oil and grease emissions.

The combined mass emissions of trace metals decreased 95% from 1971 to 1996 (Table 9, Figure 6). Reductions of individual metals averaged 86% (arsenic was excluded since it was only reported by HTP in 1971). The largest reductions were for cadmium, chromium, lead, and mercury (all 99%), followed by zinc (95%), copper (91%), nickel (90%), silver (67%), and selenium (38%). From 1972 to 1996, arsenic levels decreased 76%.

Several factors affected the combined mass emissions of trace metals during this period. One factor was the termination of sludge discharge from the HTP 7-mile outfall in 1987. From 1987 to 1988, the combined mass emissions of trace metals declined 36%; the termination of the 7-mile outfall accounted for 60% of this reduction. Another factor was the change in the analytical method used by HTP and OCSD to evaluate trace metals emissions. From 1989 to 1991, combined metals emissions decreased 31%, while lead decreased 91%. During this period, both 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.

The combined mass emissions of chlorinated hydrocarbons among all of the facilities decreased more than 99% from 1971 to 1996 (Table 9, Figure 7). Historically, Montrose Chemical Corporation was the largest source of chlorinated hydrocarbons in the SCB, discharging 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 at JWPCP were below reporting limits in 1996, even though measurable amounts of DDT were detected in its effluents for three months.

From 1990 to 1996, acute toxicity has increased significantly at OCSD and decreased significantly at JWPCP, but has not changed significantly 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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ACKNOWLEDGMENTS

The author thanks the staff of the Hyperion Wastewater Treatment Plant, County Sanitation Districts of Los Angeles County, Orange County Sanitation District, and Point Loma Wastewater Treatment Plant for providing effluent data and reviewing this report.

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).

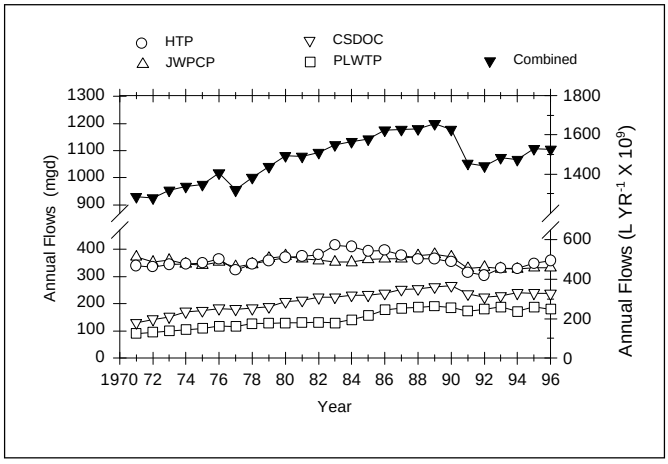


FIGURE 3. Combined suspended solids emissions and individual suspended solids from the four largest municipal wastewater treatment facilities in southern California (mt = Metric tons).

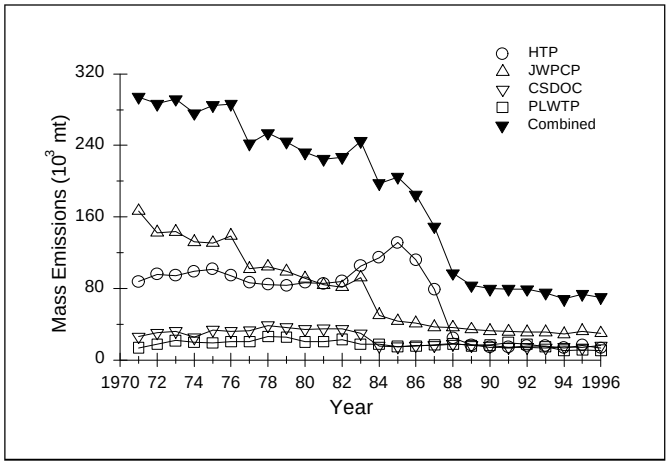


FIGURE 4. Combined oil and grease emissions and individual oil and grease from the four largest municipal wastewater treatment facilities in southern California.

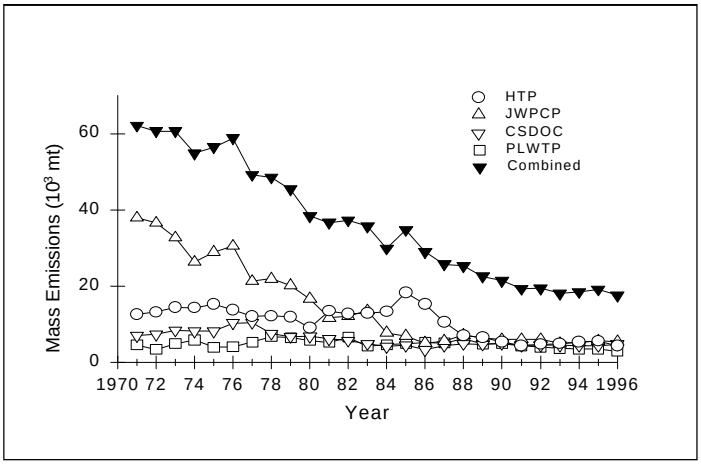


FIGURE 5. Combined mass emissions of biochemical oxygen demand from the four largest municipal wastewater treatment facilities in southern California.

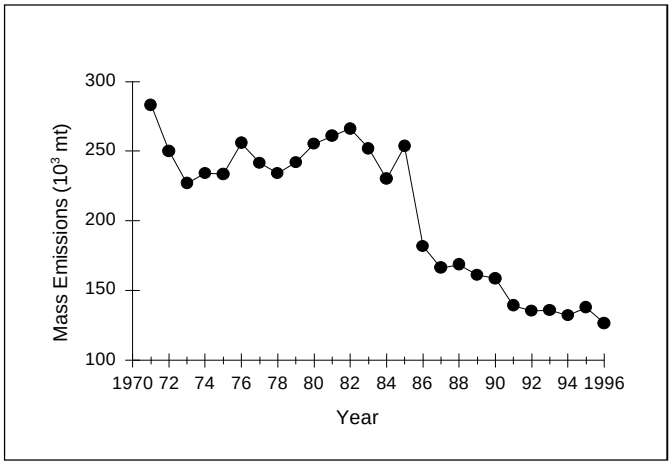
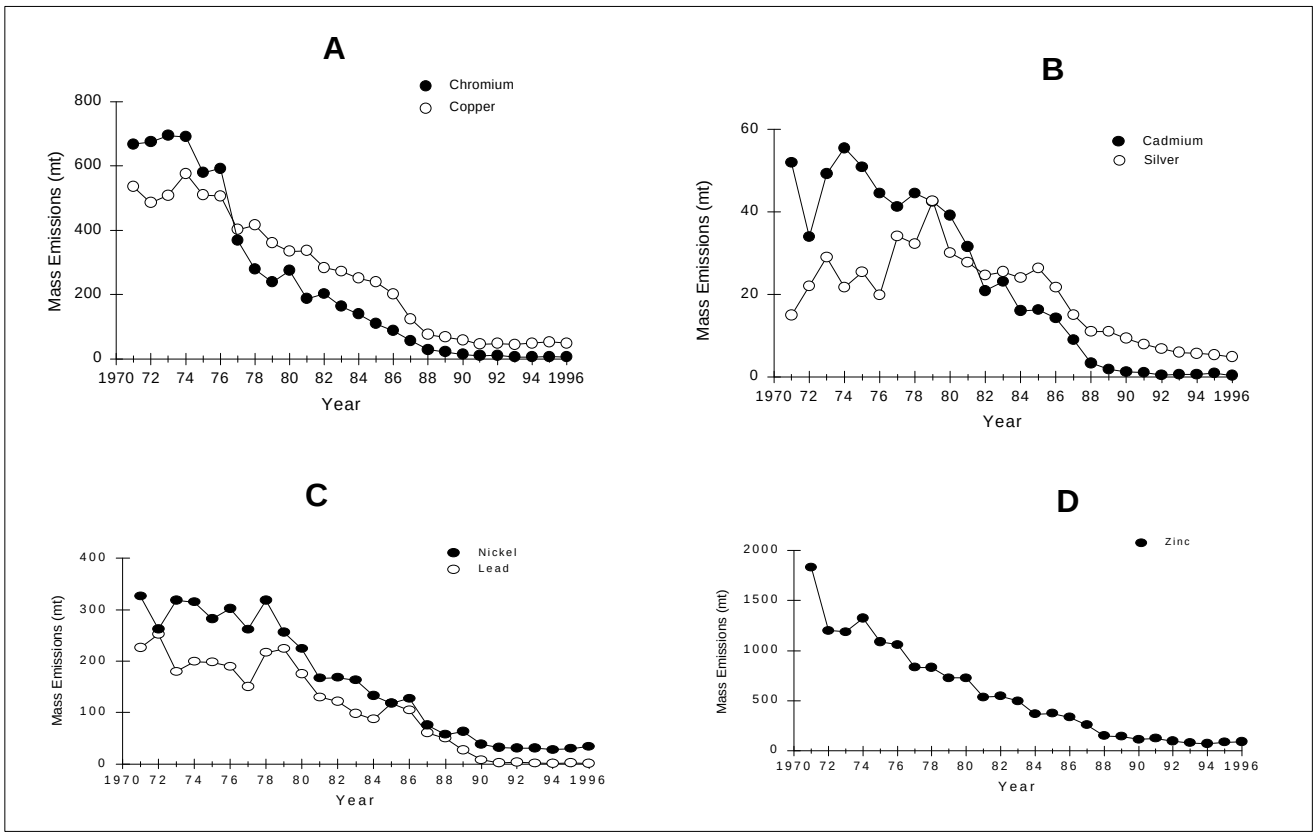


TABLE 9. Estimated combined constituent mass emissions for HTP, JWPCP, CSDOC, and PLWTP from 1971 through 1996.

Constituent	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
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	1,511
Flow (mgd)	930	922	954	967	975	1,015	955	1,001	1,041	1,078	1,080	1,094
Suspended solids[a] (mt x 10^3)	294	287	292	271	285	286	242	254	244	232	225	227
BOD[b] (mt x 10^3)	283	250	227	234	234	256	242	234	242	255	261	266
Oil and grease (mt x 10^3)	62	61	61	55	57	59	49	49	45	38	37	37
NH_3-N (mt x 10^3)	55	40	46	39	36	37	40	39	41	41	41	42
Total P[c] (mt x 10^3)	34	36	39	38	11	23	11	10	10	10	9.5	9.0
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	5.7
Cyanide (mt)	188	238	244	303	251	401	213	176	145	116	98	77
Arsenic (mt)	3[e]	18	16	18	12	11	12	15	15	11	12	8.0
Cadmium (mt)	52	34	49	55	51	44	41	44	43	39	32	21
Chromium (mt)	667	675	694	690	579	592	368	279	239	275	187	203
Copper (mt)	535	486	508	576	510	506	402	416	361	335	337	284
Lead (mt)	226	252	180	199	198	189	150	216	224	175	130	122
Mercury (mt)	2.9	2.6	3.1	1.8	2.2	2.5	2.6	1.9	2.6	1.8	1.8	1.2
Nickel (mt)	326	262	318	315	282	302	262	318	256	224	167	168
Selenium (mt)	12	11	16	18	11	22	22	23	7.9	11	15	6.4
Silver (mt)	15	22	29	22	25	20	34	32	43	30	28	25
Zinc (mt)	1,834	1,201	1,189	1,324	1,087	1,061	834	833	7,287	729	538	545
DDT[f] (kg)	21,527	6,558	3,818	1,562	1,158	1,633	855	1,121	839	671	480	290
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	785

[a]Solids from HTP's 7-mile outfall are total solids.
[b]Hyperion's 7-mile outfall is not included.
[c]Sum of soluble phosphate (PLWTP) and total phosphorus (HTP and JWPCP).
[d]Analyses discontinued.
[e]Only HTP data were available.

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



1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
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	1,527
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	1,103
245	198	205	185	149	97	83	80	79	79	75	68	73	70
252	230	254	182	167	169	161	159	139	135	136	132	138	127
36	30	34	29	26	25	23	22	19	19	18	19	19	18
40	40	43	45	44	44	45	46	44	42	41	41	41	41
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	3.5
5.2	4.6	4.3	4.8	4.6	3.4	3.3	3.5	3.5	3.2	-[d]	-[d]	-[d]	-[d]
46	39	26	22	27	26	10	13	16	18	14	12	6.5	10
10	18	16	12	12	8.9	7.4	8.2	5.4	5.5	5.2	4.0	5.0	4.3
23	16	16	14	9.0	3.4	1.9	1.3	1.1	0.5	0.6	0.7	1.0	0.4
163	140	110	88	57	29	22	14	10	11	6.8	6.7	7.0	6.5
272	251	239	202	125	76	68	59	47	48	45	49	53	49
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	0.03
163	133	118	127	76	63	54	40	33	31	31	28	30	34
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	7.4
26	24	26	22	15	11	11	9.4	7.9	6.9	6.0	5.7	5.4	4.9
497	369	375	336	261	151	146	115	125	98	82	72	86	91
223	310	48	51	53	26	20	17	6.4	13	9.2	7.9	3.1	1.4
628	1,209	46	37	5	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]

[f]Estimates for 1973 through 1975 were based on Southern California Coastal Water Research Project, Bodega Bay Marine Laboratories, and University of Washington analyses, except for DDT estimates for JWPCP were based on JWPCP's own analyses. Estimates for remaining years are based on discharger data.

[g]Concentrations were below method detection limits.

MBAS = Methylene blue active substances.

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

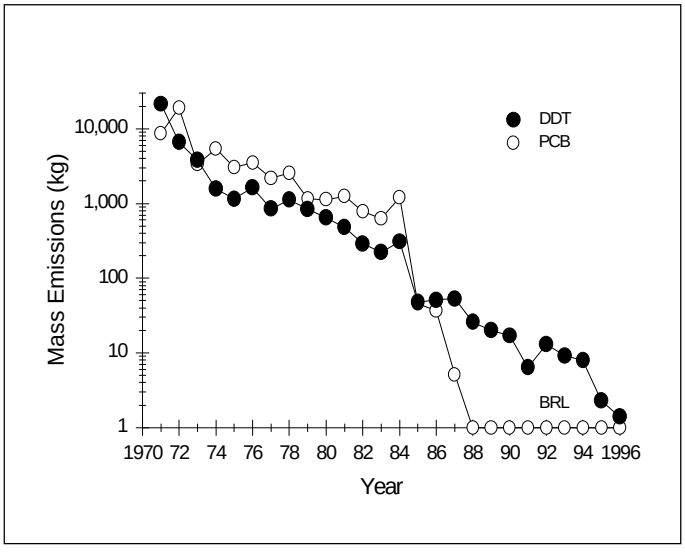


FIGURE 8. Effluent acute toxicity to fathead minnows (*Pimephales promelas)* at the four largest wastewater treatment facilities in southern California.