Characteristics of Effluents from Large Municipal Wastewater Treatment Facilities in 1994

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Effluents from the Hyperion Treatment Plant (HTP) of the City of Los Angeles, the Joint Water Pollution Control Plant (JWPCP) of County Sanitation Districts of Los Angeles County (CSDLAC), Wastewater Treatment Plants 1 and 2 of County Sanitation Districts of Orange County (CSDOC), and Point Loma Wastewater Treatment Plant (PLWTP) of the City of San Diego comprise 90% of municipal wastewater discharged directly to the Southern California Bight (Figure 1). Until 1993, the four largest agencies discharged municipal wastewater via outfalls into the ocean at a depth of about 60 m (Table 1). However, since November 24, 1993, PLWTP has discharged from an extended outfall at a depth of 93 m. These agencies have routinely measured the characteristics of their effluents for at least two decades. Each year during this period, the Southern California Coastal Water Research Project (SCCWRP) has summarized these measurements and reported on discharge and constituent trends. In this report, we summarize the concentrations of effluent constituents and estimate the mass emissions for these four agencies for 1994; we also discuss trends in the mass emissions of contaminants from 1971 to 1994.

MATERIALS AND METHODS

We obtained the effluent data that are reported monthly and annually by each discharge agency under National Pollutant Discharge Elimination System permits from the Los Angeles, Santa Ana, and San Diego Regions of the California Regional Water Quality Control Board.

Annual contaminant mass emissions were estimated from the product of mean daily flow, constituent concentration, and the number of days in each month; these were summed over all months to obtain the annual estimate (Appendix 1). Monthly constituent concentrations below method detection limits were treated as zeros in calculations of annual mean constituent concentrations. However, where annual mean concentrations were below detection limits, they were reported as less than the detection limits rather than as zeros.

Effluent data mass emission estimates for 1990-1993 were based on monthly values of flow and constituent concentrations (SCCWRP 1992, 1994, 1995). Prior to 1990, effluent data mass emission estimates were based on annual values. In reports of the 1990-1992 data, annual mass emissions were reported as zero where annual mean constituent concentrations were below method detection limits, even though there may have been measurable concentrations, and hence measurable discharges, in some months. Because these measurable discharges were neglected by this method, it has been changed. Beginning with SCCWRP (1995), 1990-93 mass emissions were calculated from all months with measurable concentrations even though annual mean constituent concentrations may have been below detection limits. If a constituent concentration was not analyzed for a certain month or had unacceptable results, the annual mean concentration was used in calculating mass for that month. Months with concentra-

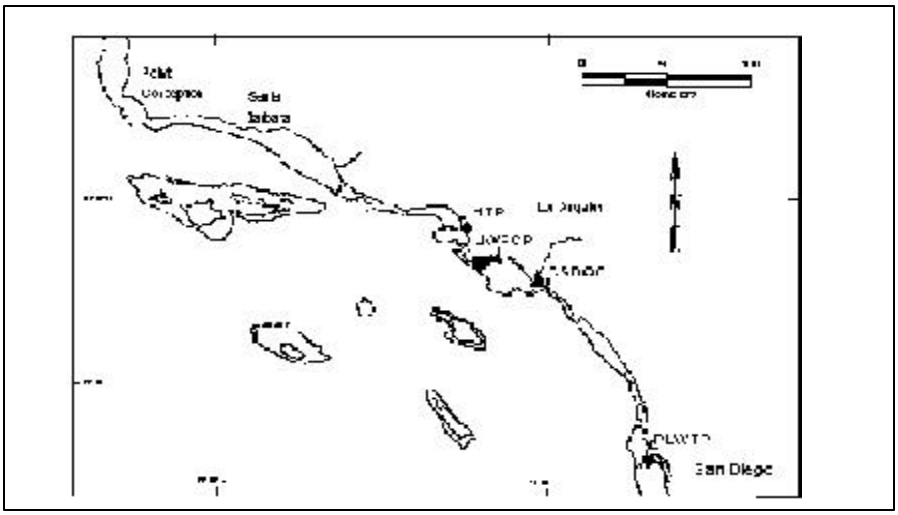

FIGURE 1. Locations of the four largest municipal wastewater facilities that discharge into the Southern California Bight: Hyperion Wastewater Treatment Plant (HTP; City of Los Angeles), Joint Water Pollution Control Plant (JWPCP; County Sanitation Districts of Los Angeles County), County Sanitation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

tions below detection limits were considered to have zero mass emissions.

RESULTS

Daily flow rates varied among the dischargers by a factor of about two in 1994. The amount of secondary treated water ranged from zero (PLWTP) to 57% (JWPCP)
(Table 1).

The concentrations of effluent constituents generally varied by a factor of two among the four municipal wastewater treatment plants (Table 2). As with last year, the same few constituents (selenium, total phenols, and nonchlorinated phenols) varied by more than an order of magnitude. Differences among the effluents were due to the type of wastes (domestic and industrial), source control, volume of water removed for reclamation and inland discharge, and the efficiency and degree of treatment (advanced primary or secondary).

The monthly concentrations of some constituents varied substantially at individual treatment plants (Table 2). Nineteen percent of the mean monthly constituent concentrations above detection limits had coefficients of variation higher than 50%. The highest coefficient of variation of 121 for selenium was due to a high proportion of monthly contaminant concentrations below detection limits.

Detectable levels of monthly concentrations of DDT were reported by HTP (two months), JWPCP (four months), and CSDOC (one month). However, because most of the concentrations were near detection limits the annual mean concentrations of DDT were below detection limits. Monthly and annual mean concentrations of PCBs were below detection limits for all dischargers.

Effluent mass emissions from the four dischargers were somewhat related to flow (Table 3); the average rank correlation (r_s) (Mosteller and Rourke 1973) between constituent mass emissions and flow for the four treatment plants was 0.42. HTP and JWPCP had the highest and most similar flows (454 versus 452 x 10^9 L, respectively). Sixty-two percent of HTP and 92% of JWPCP constituents discharged were the highest or second to highest in mass. CSDOC had the third highest flow with 38% of its constituents being similarly rated. PLWTP had the lowest flow with 54% of its constituents being the lowest in mass.

DISCUSSION

Comparison of 1993 and 1994 Effluents

The combined daily volume of effluent discharged from the four largest municipal wastewater treatment facilities in Southern California did not change significantly from 1993 to 1994 (Table 1; Appendix 2). Daily flow significantly increased at CSDOC (5%, groundwater discharge not included) but significantly decreased at PLWTP (9%) (Table 4). The proportion of combined effluent receiving secondary treatment decreased slightly from 44% in 1993 to 43% in 1994 (Table 1).

From 1993 to 1994, the majority (49%) of the concentrations of effluent constituents declined, 24% were unchanged, and 27% increased (SCCWRP 1995). The majority (47%) of metal concentrations decreased, 33% stayed the same, and 20% increased. CSDOC had the

TABLE 1. Volume of municipal wastewater discharged to the ocean by the largest municipal wastewater treatment facilities in Southern California in 1993 and 1994.

			1993			1994		
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	164	166	330	167	161	329
JWPCP	2,800/3,600	60	133	195	328	141	187	328
CSDOC	7,250	60	112[a]	113	229[b]	120	113	240[b]
PLWTP	3,600/7,285[c]	60/93[d]	188	0	188	172	0	172
Total			597	474	1075	600	461	1069

[a] Revised number from SCCWRP (1995).
[b] Includes 4 mgd for 1993 and 6 mgd for 1994 from construction groundwater dewatering from construction sites at Plant 1 and Plant 2.
[c] Length was 3,600m prior to November 24,1993, but 7,285m after this date.
[d] Discharge depth was 60m prior to November 24, 1993, but 93m after this date.
mgd=million gallons per day (1 mgd = 3,785,000 L/day).
HTP=Hyperion Treatment Plant, Department of 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, Metropolitan Wastewater Department, City of San Diego.

greatest number of metal concentrations (six out of 10) that decreased. Effluent acute toxicity to fathead minnows (*Pimephales promelas*) at HTP decreased significantly while acute toxicity at the other facilities did not change significantly (Appendix 2). Annual mean concentrations of total DDT and PCBs were below detection limits in both years.

Of the combined mass emissions of constituents tested for significant changes, none changed significantly from 1993 to 1994 (Appendix 2). The majority of constituent mass emissions at the individual plants tested did not change significantly during this period. Of the constituents that showed significant changes, the majority of constituent mass emissions decreased (Table 4). Only copper at HTP and flow and suspended solids at CSDOC increased significantly from 1993 to 1994. Constituents that had concentrations below detection limits were not tested.

The combined emissions of DDT decreased 14% from 1993 to 1994 (Table 5) (SCCWRP 1995). For both years, the annual mean concentrations were below method

TABLE 2. Means and coefficients of variation (CV) of annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in Southern California in 1994.

	HTP		JWPCP		CSDOC		PLWTP	
Constituent	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)
Flow (mgd)	329	2	328	2	240	2	172	3
Flow (million L/day)	1245	2	1241	2	908	2	651	3
Suspended solids (mg/L)	30	16	64	6	44	7	46	6
Settleable solids (ml/L)	<0.1	-	0.1	36	0.4	28	0.1	98
BOD (mg/L)	82	10	99	3	71	4	114	6
Oil and grease (mg/L)	12	21	11.6	8	13.4	9	14.7	11
Nitrate-N (mg/L)	0.17	73	0.26	26	-	-	0.06[b]	73
Nitrite-N (mg/L)	-	-	0.05	22	-	-	-	-
Ammonia-N (mg/L)	25.0	9	35.2	8	23	4	25.7	6
Organic N (mg/L)	5.56	13	6.56	9	-	-	-	-
Phosphate (mg/L)[b]	-	-	-	-	-	-	0.9	28
Total phosphorus (mg/L)	4.02	13	3.59	7	-	-	-	-
Cyanide (µg/L)	15	81	9	50	<10[c]	-	4.0	65
Turbidity NTU	28	11	55	7	39	3	48	12
Toxicity TUa	1.5	6	1.06	35	0.94	31	1.3	10
Silver (µg/L)	5.4	36	6	12	2	18	<6.6	-
Arsenic (µg/L)	4	58	3	14	1	67	1.7	31
Cadmium (µg/L)	<2[c]	-	<1	-	0.6	35	<1	-
Chromium (µg/L)	<4[c]	-	9	61	5	17	<5	-
Copper (µg/L)	35	12	23	14	28	12	58	55
Mercury (µg/L)	<0.3[c]	-	<5	-	<0.3[c]	-	<0.27	-
Nickel (µg/L)	11	59	36	34	18	13	<14	-
Lead (µg/L)	<3[c]	-	<8	-	2	21	<18	-
Selenium (µg/L)	<1	-	15	13	1	121	1.4	27
Zinc (µg/L)	46	22	73	28	38	12	26	25
Phenols (µg/L)[d]	-	-	511	34	29	77	-	-
Chlorinated[e]	<7[c]	-	<160[c]	-	<6.9[c]	-	<6.1[c]	-
Nonchlorinated[e]	2.99	81	147	58	3.7	94	13.0	30
Total DDT (µg/L)	<0.013[c]	-	<0.03[c]	-	<0.04[c]	-	<0.04[c]	-
Total PCB[f] (µg/L)	<0.065[c]	-	<0.9[c]	-	<0.5[c]	-	<0.6[c,f,g]	-

[a]The number of significant figures are those reported by the agencies.
[b]Only soluble forms of phosphate and nitrate were analyzed.
[c]Maximum of the range of detection limits reported.
[d]EPA method 420.2 (Colorimetric method).
[e]EPA method 604 or 625 (GC/MS method).
[f]Total PCB= PCB 1016, 1221, 1232, 1242, 1248, 1254, and 1260.
[g]PCB 1221, 1232, 1248, and 1254 detection limits were not determined.
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.
mgd=million gallons per day (1 mgd = 3,785,000 L/day).
NTU=nephelometric turbidity units.
TUa (toxic units acute)= 100/96 hr LC 50 (lethal concentration for 50%).

detection limits; nevertheless there were still monthly concentrations that were measurable and these contributed to the mass emissions. The four dischargers all had monthly concentrations of PCBs below detection limits in 1993 and 1994.

Effluent Trends, 1971-1994

The combined flow from the four largest municipal wastewater treatment facilities increased 15% from 1971 (SCCWRP 1973) to 1994 (Table 5; Figure 2), for a mean annual increase of 0.7% (sd=3.4, n=23). During this time, the volume of wastewater discharged by CSDOC and PLWTP nearly doubled while the volume discharged by JWPCP decreased 12% and the volume discharged by HTP decreased 2%. Population growth patterns, industry type and number, water reclamation, and inland discharge accounted for differences among the agencies. Los Angeles County has grown by approximately two million people since 1970, Orange County and San Diego County each have grown by approximately one million (SCCWRP 1973, California Department of Finance 1995). However, CSDLAC and the City of Los Angeles have expanded their upstream treatment and reclamation facilities. CSDLAC reclaimed 181 mgd of water in 1994—nearly double the amount reclaimed 13 years ago (95 mgd). The volume of effluent discharged to the Los Angeles River by the Los Angeles-Glendale and Donald C. Tillman Water Reclamation Plants increased from 25 mgd in 1985 to 66 mgd in 1994 (City of Los Angeles 1995a, b).

The annual combined volume of effluent discharged decreased for the fourth time in 1994 since 1989 (Table 5). The lower volumes discharged from 1990 to 1992 may be the result of water conservation during the drought, in-

TABLE 3. Estimated constituent mass emissions from the largest municipal wastewater treatment facilities in Southern California in 1994.

Constituent	HTP	JWPCP	CSDOC	PLWTP	Total
Flow[a] ($L \times 10^9$)	454	452	331	237	1,474
Suspended solids (mt)	13,471	29,068	14,712	10,875	68,126
BOD (mt)	37,009	44,776	23,396	27,076	132,257
Oil and grease (mt)	5,371	5,254	4,418	3,491	18,534
Nitrate-N (mt)	78	118	-	15	211
Nitrite-N (mt)	-	20	-	-	20
Ammonia-N (mt)	11,334	15,925	7,754	6,093	41,106
Organic N (mt)	2,526	2,963	-	-	5,489
Phosphate (mt)	-	-	-	202	202
Total phosphorus (mt)	1,821	1,627	-	-	3,448
Cyanide (mt)	6.7	3.8	0.2	0.9	12
Silver (mt)	2.4	2.6	0.7	-	5.7
Arsenic (mt)	1.8	1.4	0.4	0.4	4.0
Cadmium (mt)	0.2	0.2	0.2	0.07	0.7
Chromium (mt)	0.6	4.1	1.6	0.4	6.7
Copper (mt)	16	10	9.2	14	49
Mercury (mt)	0.008	-	-	0.02	0.03
Nickel (mt)	5.1	16	5.8	0.6	28
Lead (mt)	-	0.6	0.7	-	1.3
Selenium (mt)	0.04	6.7	0.4	0.3	7.4
Zinc (mt)	21	33	12	6.2	72
Phenols[b] (mt)	-	230	9.6	-	240
Chlorinated[c]	-	2.1	-	-	2.1
Nonchlorinated[c]	1.4	66	1.2	3.1	72
Total DDT (kg)	4.8	2.9	0.2	-	7.9
Total PCB[d] (kg)	-	-	-	-	-

[a]Annual flow volumes were the sum of mean daily flow per month times the number of days in each month.
[b]EPA method 420.2 (Colorimetric method).
[c]EPA method 604 or 625 (GCMS method).
[d]Total PCB = PCB 1016, 1221, 1232, 1242, 1248, 1254, and 1260.
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.
mt =metric tons.

creased water reclamation, or a decline in manufacturing, especially in the defense industry.

Despite increases in population and the volume of wastewater discharged during the past 24 years, the mass emissions of most effluent constituents have declined (Table 5). The combined mass emissions of suspended solids, oil and grease, and biochemical oxygen demand (BOD) have decreased 77%, 69%, and 53% respectively (Figures 3-5). The decline in JWPCP solids emissions between 1971 (SCCWRP 1973) and 1994 accounted for 69% of this reduction. Termination of sludge discharge from the HTP 7-mile outfall (November 1987) accounted for a 40% reduction in combined solids emissions from 1987 to 1988. Most of the decline in BOD occurred after 1985. Reductions by JWPCP from 1971 (SCCWRP 1973) to 1994 accounted for about 70% of the decline in oil and grease.

The combined mass emission of trace metals declined 95% from 1971 to 1994 (Table 5; Figure 6). Declines of individual metals averaged 86% (sd=22, n=9, arsenic excluded). Arsenic was reported only by HTP in 1971. The greatest reductions were for cadmium, chromium, mercury, and lead (all 99%), followed by zinc (96%), copper (91%), and nickel (91%). From 1972 to 1994, arsenic declined 78%. The combined mass emissions of trace metals declined 36% from 1987 to 1988; the termination of sludge discharge from the HTP 7-mile outfall accounted for about 60% of the decline. From 1989 to 1991, combined metal emissions decreased 31%; however, lead decreased 91%. Some of the lead decline is due to the change in methods by HTP and CSDOC from flame atomic absorption spectrophotometry (AAS) to 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 emissions of chlorinated hydrocarbons declined more than 99% from 1971 to 1994 (Table 5; Figure 7). Montrose Chemical Corporation, the largest

TABLE 4. Flow, toxicity, and constituent mass emissions from the largest municipal wastewater treatment facilities in Southern California with significant changes from 1993 to 1994.

Constituent	Test Used	P value	Significance	Significantly Higher Year
HTP				
Toxicity	Mann-Whitney	0.0165	*	1993
Copper	t-test	0.0265	*	1994
JWPCP				
Suspended solids	t-test	0.0443	*	1993
Nitrite-N	Mann-Whitney	0.0301	*	1993
Total phosphorus	t-test	0.0014	**	1993
CSDOC				
Flow	Mann-Whitney	0.0051	**	1994
Suspended solids	t-test	0.0475	*	1994
BOD	t-test	0.0393	*	1993
Copper	Mann-Whitney	0.0325	*	1993
Zinc	Mann-Whitney	0.0402	*	1993
PLWTP				
Flow	Mann-Whitney	0.0015	**	1993
BOD	t-test	0.0273	*	1993
Ammonia-N	t-test	0.0002	**	1993
Phosphate	Mann-Whitney	0.0056	**	1993
Arsenic	Mann-Whitney	0.0042	**	1993
Zinc	Mann-Whitney	0.0120	*	1993

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.
* = significant at $p \leq 0.05$.
** = significant at $p \leq 0.01$.

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. Annual mean concentrations of DDT were below detection limits in 1994; however, JWPCP (as well as HTP and CSDOC) still have measurable amounts of DDT in their effluents in some months.

Acute toxicity has significantly increased from 1990 to 1994 at HTP and CSDOC, stayed the same at Point Loma and decreased significantly at JWPCP (Figure 8). Data before 1990 was either unreliable or resulted from tests using different species or methods.

Recent declines in constituent concentrations and mass emissions were the result of improved primary treatment, increased secondary treatment, and improved source control (the most important factor). As a consequence, the number of reported analytes with concentrations below detection limits continued to increase. If detection limits of the recommended techniques were below discharge NPDES permit requirements, the constituents were in compliance. However, results below detection limits complicated the assessment of total and long-term trends of mass emissions into the Southern California Bight.

The interpretation of long-term trends was also hindered somewhat by the questionable reliability of trace contaminant analyses (particularly organic) in the early years of monitoring programs. Analytical methods for quantifying chlorinated hydrocarbons evolved in the 1970s and techniques had not yet been standardized among laboratories. The older data reported herein were the best available for past discharges, but better methods are used today. The accuracy and precision of contaminant analyses have improved over the years because of advancements in methods and instruments, and because of intercalibration among laboratories.

CONCLUSIONS

The quality of municipal wastewaters discharged to the Southern California Bight has improved significantly over the past two decades. Decreases in contaminant mass emissions are the result of increased source control and land disposal of biosolids, improved sludge and primary treatment, and increased secondary treatment. In the future, rates of improvement in mass emissions from the major municipal wastewater treatment facilities are not likely to be as great as in the past. Nominal reductions will occur due to planned increases in the volume of wastewater receiving secondary treatment, increased inland reclamation of water, and more effective source control.

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ACKNOWLEDGMENTS

The author thanks the Hyperion Wastewater Treatment Plant, County Sanitation Districts of Los Angeles County, County Sanitation

TABLE 5. Estimated combined constituent mass emissions for Hyperion Treatment Plant (HTP; City of Los Angeles), Districts of Orange County (CSDOC), and Point Loma Wastewater Treatment Plant (PLWTP; City of San Diego) from 1971

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
Silver (mt)	15	22	29	22	25	20	34	32	43	30	28
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
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
Lead (mt)	226	252	180	199	198	189	150	216	224	175	130
Selenium (mt)	12	11	16	18	11	22	22	23	7.9	11	15
Zinc (mt)	1,834	1,201	1,189	1,324	1,087	1,061	834	833	7287	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 7-mile outfall are total solids.
[b] Hyperion 7-mile outfall not included.
BOD = biochemical oxygen demand.
MBAS = methylene blue active substances.
mgd=million gallons per day (1 mgd = 3,785,000 L/day).
mt=metric tons.

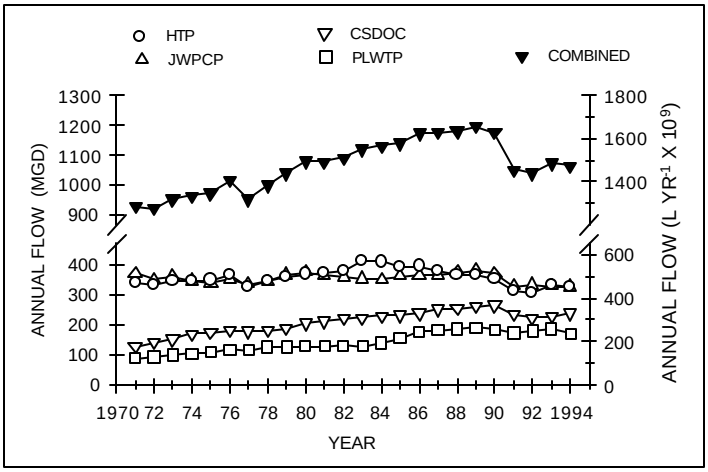

FIGURE 2. Combined effluent flow and individual effluent flows from the four largest municipal wastewater treatment facilities in Southern California (MGD = millions of gallons per day, L = liters). HTP = Hyperion Treatment Plant, City of Los Angeles, JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County, CSDOC = County Santation District of Orange County, PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.

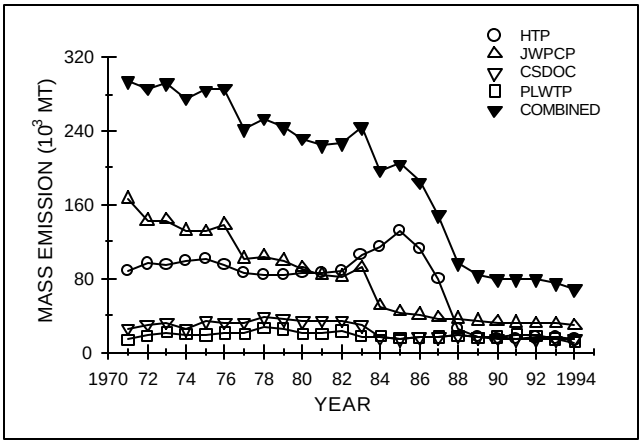

FIGURE 3. Combined suspended solids emissions and individual suspended solids from the four largest municipal wastewater treatment facilities in Southern California (MT = metric tons). HTP = Hyperion Treatment Plant, City of Los Angeles, JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County, CSDOC = County Santation District of Orange County, PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.

Joint Water Pollution Control Plant (JWPCP; County Sanitation Districts of Los Angeles County), County Sanitation through 1994.

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

[c] Sum of soluble phosphate (PLWTP) and total phosphorus (HTP and JWPCP).
[d] Analyses discontinued.
[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.

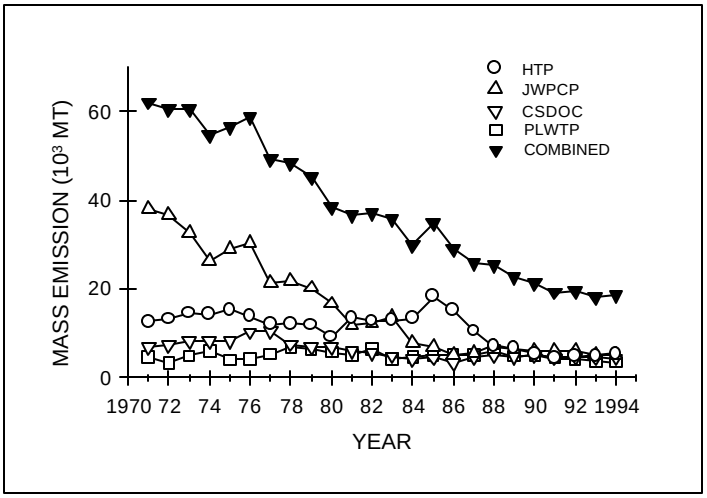

FIGURE 4. Combined oil and grease emissions and individual oil and grease from the four largest municipal wastewater treatment facilities in Southern California (MT = metric tons). HTP = Hyperion Treatment Plant, City of Los Angeles, JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County, CSDOC = County Santation District of Orange County, PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.

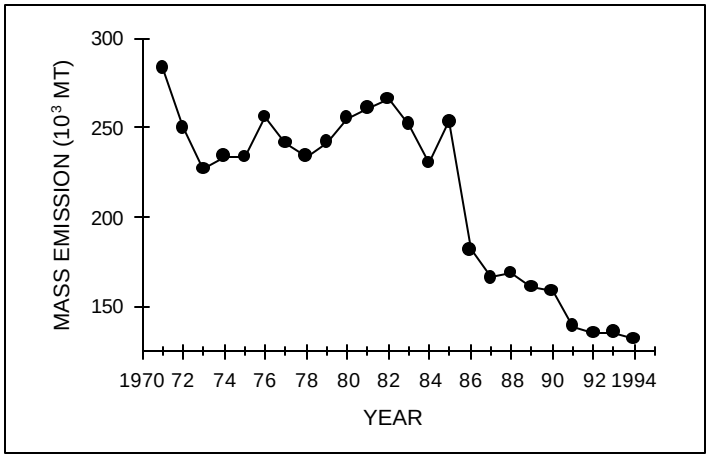

FIGURE 5. Combined mass emission of biochemical oxygen demand from the four largest municipal wastewater treatment facilities in Southern California (MT = metric tons).

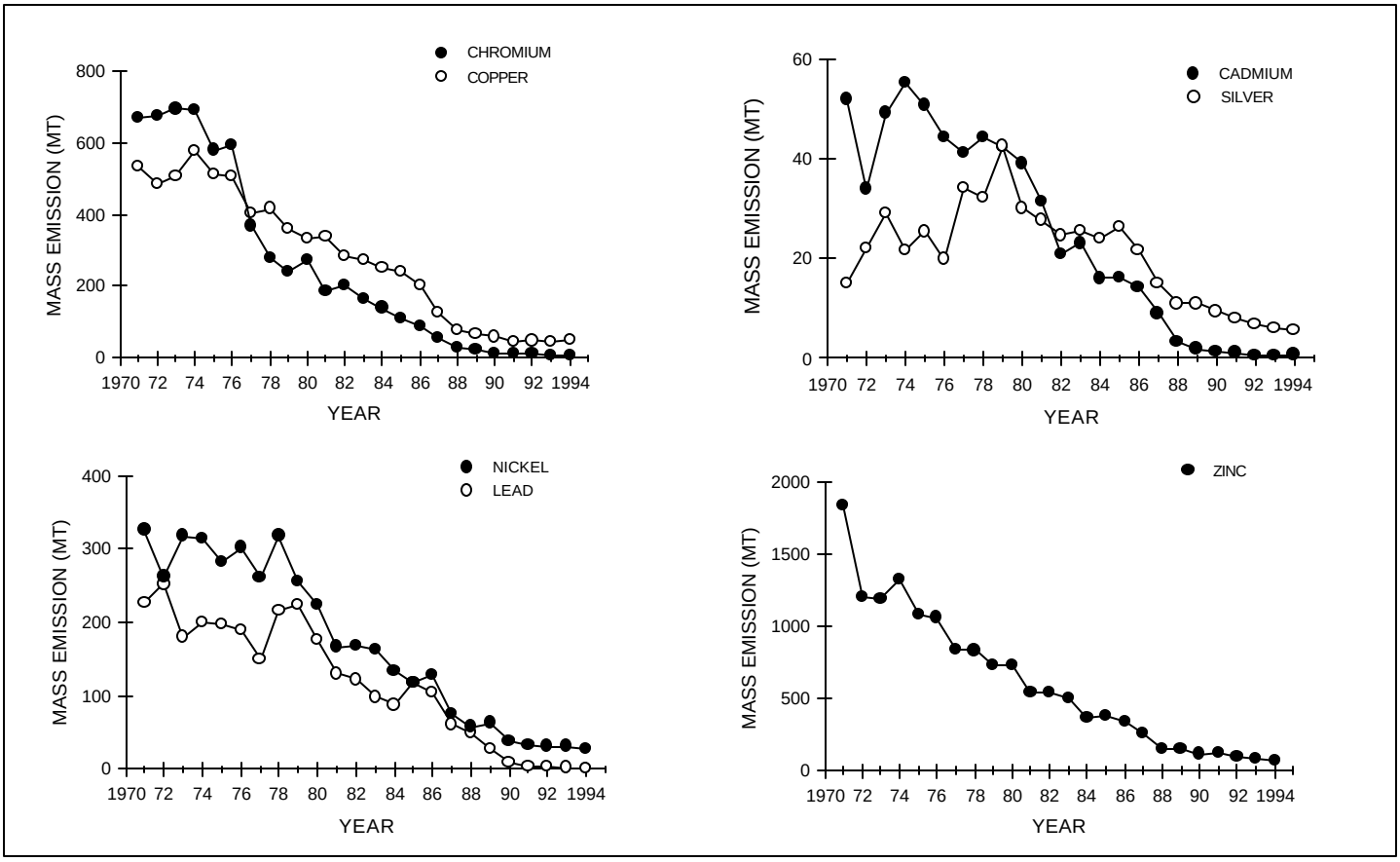

FIGURE 6. Combined mass emissions of trace metals from the four largest wastewater treatment facilities in Southern California (MT = metric tons).

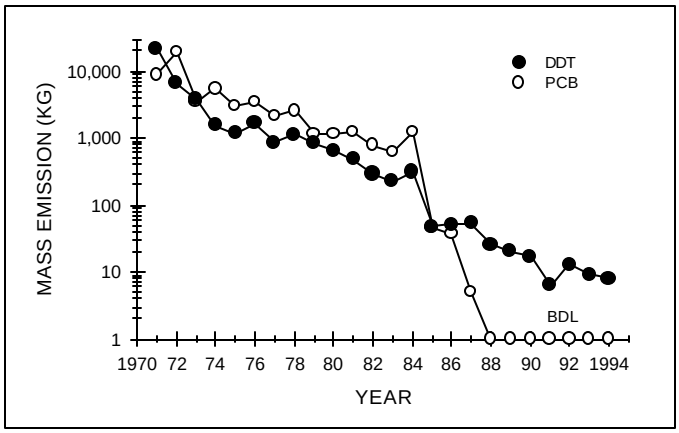

FIGURE 7. Combined mass emissions of DDT and PCB from the four largest wastewater treatment facilities in Southern California (BDL = below detection limits).

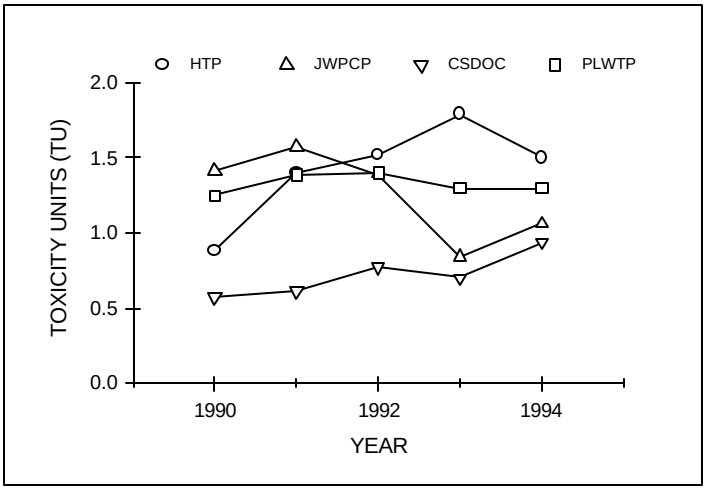

FIGURE 8. Effluent acute toxicity to fathead minnows (*Pimephales promelas)* at the four largest wastewater treatment facilities in Southern California. HTP = Hyperion Treatment Plant, City of Los Angeles, JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County, CSDOC = County Santation District of Orange County, PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.

Districts of Orange County, and Point Loma Wastewater Treatment Plant for providing effluent data and reviewing this report. She also thanks M. James Allen (SCCWRP) for comments on the manuscript.

APPENDIX 1.

Mass Emission Estimation

Annual constituent mass emissions (ME) were estimated as follows:

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

where

F_i = mean daily flow in month i;
C_i = constituent concentration in month i; and
D_i = number of days in month i.

This method, which was first used for 1990 effluent data (SCCWRP 1992), differs from previous SCCWRP reports where mass emissions were estimated by the product of total annual flow and mean annual constituent concentration (e.g., SCCWRP 1990). Estimates by the two methods differ by <1%; therefore, the historic mass emission data have not been recalculated.

Monthly constituent concentrations below detection limits were treated as zeros in the calculation of annual mean concentrations. If the annual mean was below the detection limit, it was reported as less than the detection limit in the table of concentrations (Table 2). Months with constituent concentrations below detection limits were considered to have zero mass emissions. However, if the constituent was above the detection limit in one or more months, the mass emission for the month(s) was calculated, summed across all months, and included in the table of mass emissions (Table 3). If a constituent concentration was not analyzed for a certain month or had unacceptable results, the annual mean concentration was used in calculating mass for that month.

APPENDIX 2.

Results of significance tests for comparisons of effluent flow, toxicity, and constituent mass emission values of large municipal wastewater facilities in Southern California between 1993 and 1994.

Constituent	Test Used	P value	Significance	Significantly Higher Year
Combined Discharge				
Flow	Mann-Whitney	0.8777	n.s.	-
Suspended solids	Mann-Whitney	0.3502	n.s.	-
BOD	Mann-Whitney	0.4979	n.s.	-
Oil and grease	t-test	0.6074	n.s.	-
Ammonia-N	Mann-Whitney	0.8690	n.s.	-
Copper	Mann-Whitney	0.6131	n.s.	-
Zinc	Mann-Whitney	0.3102	n.s.	-
HTP				
Flow	Mann-Whitney	0.5637	n.s.	-
Toxicity	Mann-Whitney	0.0165	*	1993
Suspended solids	Mann-Whitney	0.2145	n.s.	-
BOD	t-test	0.8138	n.s.	-
Oil and grease	Mann-Whitney	0.3556	n.s.	-
Nitrate-N	t-test	1.0000	n.s.	-
Ammonia-N	Mann-Whitney	0.0885	n.s.	-
Organic-N	t-test	0.9110	n.s.	-
Total phosphorus	t-test	0.0874	n.s.	-
Silver	t-test	0.8751	n.s.	-
Copper	t-test	0.0265	*	1994
Nickel	Mann-Whitney	0.9079	n.s.	-
Zinc	t-test	0.1337	n.s.	-
JWPCP				
Flow	t-test	0.8169	n.s.	-
Toxicity	t-test	0.2789	n.s.	-
Suspended solids	t-test	0.0443	*	1993
BOD	Mann-Whitney	0.1939	n.s.	-
Oil and grease	t-test	0.2693	n.s.	-
Nitrate-N	t-test	0.3991	n.s.	-
Nitrite-N	Mann-Whitney	0.0301	*	1993
Ammonia-N	t-test	0.8917	n.s.	-
Organic-N	t-test	0.9599	n.s.	-
Total phosphorus	t-test	0.0014	**	1993
Silver	Mann-Whitney	0.4188	n.s.	-
Copper	t-test	0.4622	n.s.	-
Selenium	t-test	0.0786	n.s.	-
Zinc	Mann-Whitney	0.2145	n.s.	-

Appendix 2 continued.

Constituent	Test Used	P value	Significance	Significantly Higher Year
CSDOC				
Flow	Mann-Whitney	0.0051	**	1994
Toxicity	t-test	0.1088	n.s.	-
Suspended solids	t-test	0.0475	*	1994
BOD	t-test	0.0393	*	1993
Oil and grease	t-test	0.7491	n.s.	-
Ammonia-N	t-test	0.1881	n.s.	-
Silver	t-test	0.2184	n.s.	-
Cadmium	Mann-Whitney	0.2030	n.s.	-
Chromium	Mann-Whitney	0.7490	n.s.	-
Copper	Mann-Whitney	0.0325	*	1993
Nickel	Mann-Whitney	0.0934	n.s.	-
Zinc	Mann-Whitney	0.0402	*	1993
PLWTP				
Flow	Mann-Whitney	0.0015	**	1993
Toxicity	Mann-Whitney	0.9769	n.s.	-
Suspended solids	Mann-Whitney	0.9310	n.s.	-
BOD	t-test	0.0273	*	1993
Oil and grease	t-test	0.4113	n.s.	-
Cyanide	t-test	0.4313	n.s.	-
Nitrate-N	Mann-Whitney	0.3263	n.s.	-
Ammonia-N	t-test	0.0002	**	1993
Phosphate	Mann-Whitney	0.0056	**	1993
Arsenic	Mann-Whitney	0.0042	**	1993
Copper	Mann-Whitney	0.0733	n.s.	-
Selenium	t-test	0.2381	n.s.	-
Zinc	Mann-Whitney	0.0120	*	1993

n.s. = not significant.
* = significant at $p \leq 0.05$.
** = signifcant at $p \leq 0.01$.
BOD=biochemical oxygen demand.
HTP = Hyperion Treatment Plant, City of Los Angeles.
JWPCP = Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County.
CSDOC = County Santation Districts of Orange County.
PLWTP = Point Loma Wastewater Treatment Plant, City of San Diego.