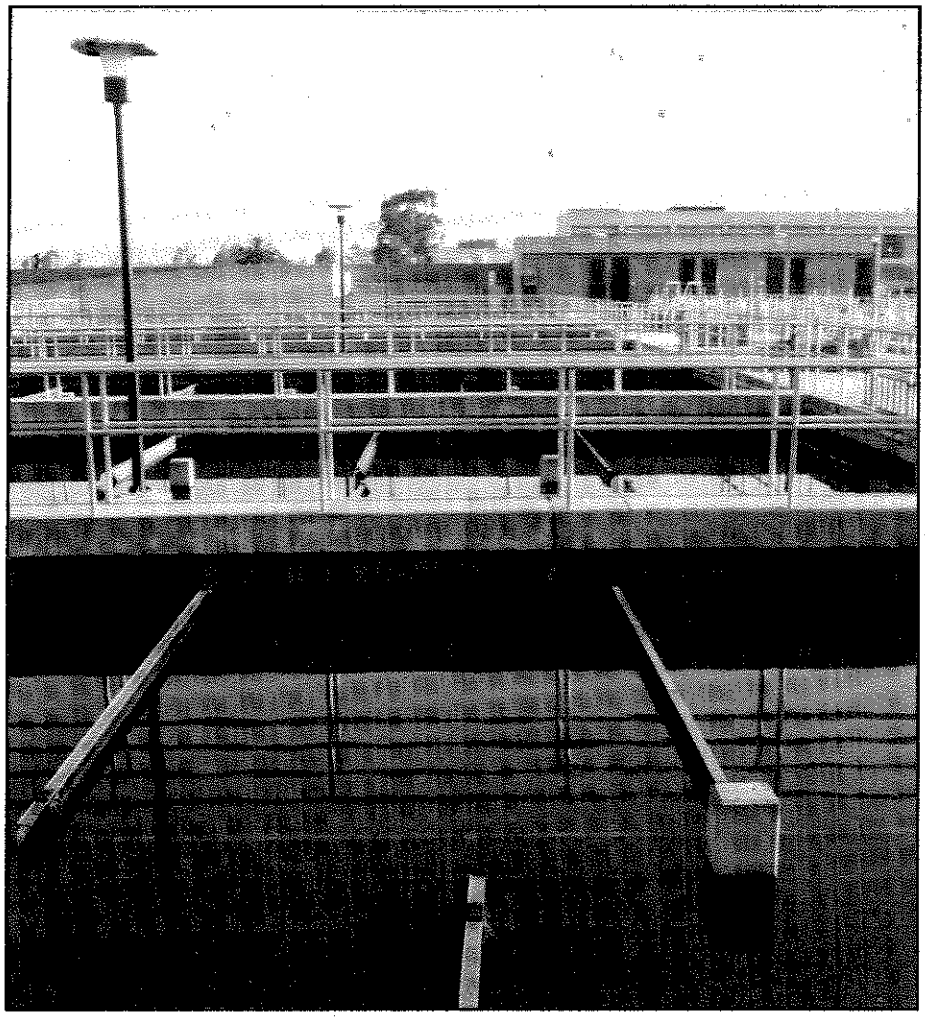
Characteristics of Effluents from Large Municipal Wastewater Treatment Facilities in 1990 and 1991

In this report, we summarize concentrations of effluent constituents and estimates of effluent mass emissions for Hyperion Wastewater Treatment Plant (City of Los Angeles), Joint Water Pollution Control Plant (JWPCP, County Sanitation Districts of Los Angeles County), County Sanitation Districts of Orange County Wastewater (CSDOC) Treatment Plants 1 and 2, and Point Loma Sewage Treatment Plant (City of San Diego) for 1990 and 1991 (Figure 1). Effluents from these facilities composed 90% of municipal effluents discharged directly to the Southern California Bight.

The discharge agencies have measured the constituents featured in this report for at least two decades. Long-term trends in the mass emission of contaminants to the Southern California Bight (SCB) are also discussed.



County Sanitation Districts of Orange County Plant No.1

Materials and Methods

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

Annual contaminant mass emissions were estimated from the product of mean daily flow in month *i*, constituent concentration in month *i*, and the number of days in the month; these were summed over all months to obtain the annual estimate (Appendix 1). This method differs from that used in previous SCCWRP reports where we estimated mass emissions by the product of total annual flow and mean annual constituent concentration (e.g., SCCWRP 1990). Estimates by the two methods differed by <1% (Appendix 1), so the historic mass emission data have not been recalculated. Constituent concentrations below detection limits were treated as zeros in both estimation methods.

Results

The combined daily volume of effluent discharged from the four largest municipal wastewater treatment facilities in Southern California declined by 12% from 1989 to 1991 (Table 1; Figure 2); declines at individual treatment facilities ranged from 10-14%. Most of the declines occurred from 1990 to 1991. The amount of effluent receiving secondary treatment increased from 43% of the combined emissions in 1989 to 47% in 1991 (Table 1). The greatest increase occurred at Hyperion where 48% of the flow received secondary treatment in 1989 and 58% received secondary treatment in 1991.

The concentrations of effluent constituents generally varied by about a factor of two among the four municipal wastewater treatment plants; a few constituents, such as selenium, varied by an order of magnitude (Tables 2a,b).

Figure 1.
Map of the Southern California Bight showing the location of the four largest municipal wastewater dischargers: Hyperion Wastewater Treatment Plan (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 Sewage Treatment Plant (City of San Diego).

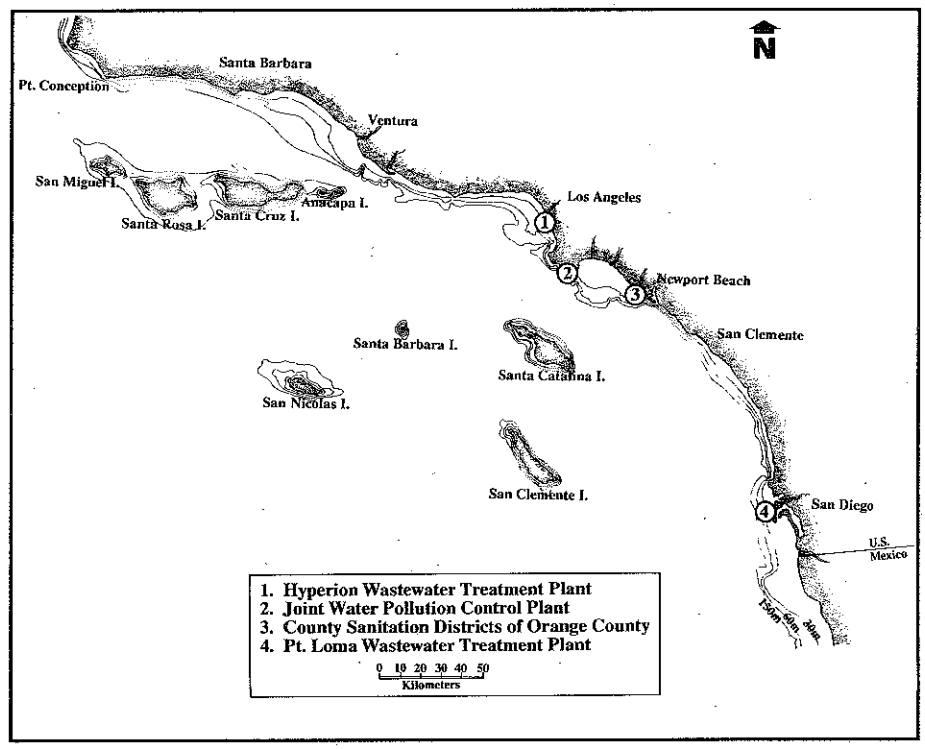


Table 1.
Volume of municipal wastewater discharged to the ocean from 1989 to 1991 from the largest treatment facilities in Southern California. Secondary is the volume of effluent receiving secondary treatment.

	1989		1990		1991			
	Secondary Flow (mgd[a])	Total Flow (mgd)	Secondary Flow (mgd)	Total Flow (mgd)	Secondary Flow (mgd)	Total Flow (mgd)	Distance of Discharge from Shore (m)	Depth of Discharge (m)
Hyperion[b]	177	365	185	354	182	315	8,300	57
JWPCP[c]	208	382	204	372	193	330	2,400/3,660	60
CSDOC[d]	134	261	128	266	116	235	7,250	60
Point Loma[e]	0	191	0	186	0	173	3,600	60
Total	519	1199	517	1178	491	1053		

[a]mgd=million gallons per day; 1 mgd = 3,785,000 L/day
[b]City of Los Angeles
[c]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County
[d]County Sanitation Districts of Orange County
[e]City of San Diego

The differences among the effluents are due to the type of wastes (domestic and industrial), source control, volume of water removed for reclamation and inland discharge, and efficiency and degree of treatment (advanced primary or secondary).

The concentrations of some constituents varied substantially among months at individual treatment plants (Tables 2a,b). Nearly one-quarter of the mean monthly constituent concentrations had coefficients of variation greater than 50%. Coefficients of variation higher than 100% generally were due to a high

Table 2a.

Mean annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in Southern California in 1990. CV=coefficient of variation.

	Hyperion[a]		JWPCP[b]		CSDOC[c]		Point Loma[d]	
	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)
Flow (mgd)[e]	354	2	372	2	266	1	186	5
Suspended solids (mg/L)	30	11	63	8	44	5	65	14
Settlable solids (ml/L)	0.3	32	0.1	36	0.43	27	0.5	59
BOD (mg/L)	93	9	106	6	70	6	129	7
Oil and grease (mg/L)	11	12	11.8	6	13.7	10	19.2	11
NO_3-N (mg/L)	0.28	34	0.15	87	-	-	-	-
NO_2-N (mg/L)	-	-	0.56	154	-	-	-	-
NH_3-N (mg/L)	22	9	36.6	7	24	5	28.3	6
Organic N (mg/L)	5.4	17	7.4	12	-	-	-	-
PO_4-P[f] (mg/L)	-	-	-	-	-	-	3.8	44
Total phosphorus (mg/L)	5.0	13	7.2	13	-	-	-	-
MBAS[g] (mg/L)	-	-	3.9	14	-	-	5.8	19
Cyanide (mg/L)	0.013	79	0.01	80	<0.02	-	0.003	19
Phenols (µg/L)								
Non-chlorinated	4.0	86	-	-	4	92	5.8	25
Chlorinated	nd[k]	-	37	84	2.1	346	<2.7-<3.6	-
Turbidity NTU[h]	31	9	43	7	30	9	69	13
Toxicity TU[i]	0.88	57	1.41	21	0.57	49	1.25	17
Silver (µg/L)	6	39	8	13	7	18	<10	-
Arsenic (µg/L)	4	19	9	79	1.9	9	3.7	30
Cadmium (µg/L)	0.7	185	1	50	1.1	32	<5	-
Chromium (µg/L)	6	60	18	37	6.5	14	<50	-
Copper (µg/L)	38	25	31	14	45	8	32	17
Mercury (µg/L)	0.2	57	0.3	79	0.12	89	<0.5	-
Nickel (µg/L)	16	35	43	20	23	19	3.8	346
Lead (µg/L)	3	55	8	190	3.3	35	6.5	346
Selenium (µg/L)	nd	-	13	21	0.9	33	1.2	53
Zinc (µg/L)	69	15	87	22	55	18	67	26
Total DDT (µg/L)	<0.01-<0.05	-	0.02	57	<0.004-<0.05	-	0.021	275
Total PCB[j] (µg/L)	<0.02	-	<0.1-<0.9	-	<0.3-<0.5	-	nd	-

[a]City of Los Angeles

[b]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County

[c]Plants 1 and 2, County Sanitation Districts of Orange County

[d]City of San Diego

[e]mgd=million gallons per day; 1 mgd=3,785,000 L/day

[f]soluble PO_4-P

[g]MBAS=methylene blue active substances

[h]NTU=nephelometric turbidity units

[i]TU=toxicity units acute = 100/(96 hr LC 50%)

[j]Total PCB=Aroclors 1016+1221+1232+1242+1248+1254+1260; JWPCP: Total PCB=Aroclors 1242+254+1260

[k]nd=not detectable and detection limit not reported

proportion of monthly contaminant concentrations below detection limits.

Effluent mass emissions from the four dischargers were generally related to flow (Tables 3a,b); the average rank correlation (r_s) among constituent mass emissions for the four treatment plants was 0.62 in 1990 and 0.44 in 1991. The JWPCP had the highest flow and generally the highest constituent mass emissions. It was followed by Hyperion, County Sanitation Districts of Orange County, and Point Loma.

From 1989 to 1991, the combined emissions of suspended

Table 2b.

Mean annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in Southern California in 1991. CV=coefficient of variation.

	Hyperion[a]		JWPCP[b]		CSDOC[c]		Point Loma[d]	
	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)	Mean	CV(%)
Flow (mgd)[e]	315	5	330	4	235	10	173	6
Suspended solids (mg/L)	33	10	70	9	44	5	81	8
Settlable solids (ml/L)	0.3	23	0.2	42	0.5	18	0.6	50
BOD (mg/L)	83	12	103	8	71	5	140	8
Oil and grease (mg/L)	10	17	13.4	7	13.8	15	18.4	12
NO_3-N (mg/L)	0.328	63	0.22	51	-	-	-	-
NO_2-N (mg/L)	-	-	0.25	47	-	-	-	-
NH_3-N (mg/L)	25.8	6	37.8	8	25	4	30.0	9
Organic N (mg/L)	5.5	10	7.87	10	-	-	-	-
PO_4-P (mg/L)[f]	-	-	-	-	-	-	4.3	50
Total phosphorus (mg/L)	4.75	12	7.87	13	-	-	-	-
MBAS[g] (mg/L)	-	-	4.4	25	-	-	6.5	22
Cyanide (mg/L)	0.022	76	0.01	62	<0.02	-	0.006	59
Phenols (µg/L)								
Non-chlorinated	2.11	151	-	-	6.0	67	4.6	55
Chlorinated	<1-<3	-	24	99	<0.2-<3	-	<2.7-<3.6	-
Turbidity NTU[h]	37	26	43	9	37	8	80	15
Toxicity TU[i]	1.40	23	1.58	15	0.61	48	1.38	10
Silver (µg/L)	5.7	53	8	18	6	29	<10	-
Arsenic (µg/L)	5	17	4	11	2	21	3.2	31
Cadmium (µg/L)	<1	-	<1	-	1.2	71	<5	-
Chromium (µg/L)	4	57	15	44	6	34	<50	-
Copper (µg/L)	31	24	29	22	38	18	30	17
Mercury (µg/L)	0.2	74	<0.5	-	0.3	216	<0.5	-
Nickel (µg/L)	17	42	38	17	24	10	<40	-
Lead (µg/L)	2	83	<8	-	2	35	<50	-
Selenium (µg/L)	<1	-	14.2	15	<1	-	1.4	21
Zinc (µg/L)	113	110	92	26	48	22	79	35
Total DDT (µg/L)	<0.03	-	<0.01-<0.03	-	<0.02	-	<0.02-<0.04	-
Total PCB[j] (µg/L)	<0.02	-	<0.01-<0.9	-	<0.5	-	nd[k]	-

[a]City of Los Angeles
[b]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County
[c]County Sanitation Districts of Orange County
[d]City of San Diego
[e]mgd=million gallons per day; 1 mgd=3,785,000 L/day
[f]soluble PO_4-P
[g]MBAS=methylene blue active substances
[h]NTU=nephelometric turbidity units
[i]TU=toxicity units acute = 100/(96 hr LC 50%)
[j]Total PCB=Aroclors 1016+1221+1232+1242+1248+1254+1260; JWPCP: Total PCB=Aroclors 1242+254+1260
[k]nd=not detectable and detection limit not reported

solids declined 5%, BOD declined 14%, and oil and grease declined 15% (Table 4). The discharge of suspended solids decreased 15% at Hyperion and CSDOC, and 8% at JWPCP, but it increased 22% at Point Loma. The discharge of BOD decreased 21% at Hyperion, 19% at JWPCP, and 14% at CSDOC, but it increased 7% at Point Loma. The discharge of oil and grease decreased by 33% at Hyperion, 10% at Point Loma, 6% at CSDOC, and 5% at JWPCP. [Data for 1989 are from SCCWRP (1990).]

From 1989 to 1991, their were substantial declines in the combined emissions of several trace metals (Table 4). The combined emissions of lead declined 95%, cadmium declined 79%, chromium declined 55%, and mercury declined 50%. The combined emissions of nickel declined 39%, copper declined 31%, and silver and arsenic declined 27%. The combined emissions of zinc declined 14% and selenium declined 11%. [Data for 1989 are from SCCWRP (1990).]

Effluent concentrations of DDT and PCB were below

Table 3a.

Estimated mass emissions from the largest municipal wastewater treatment facilities in Southern California in 1990.

	Hyperion[a]	JWPCP[b]	CSDOC[c]	Point Loma[d]
Flow (L x 10^9)	489	513	367	256
Suspended solids (mt[e])	14,435	32,578	16,001	16,700
BOD (mt)	45,520	54,434	25,616	33,147
Oil and grease (mt)	5,418	6,076	5,027	4,937
NO_3-N (mt)	137	76	-	-
NO_2-N (mt)	-	288	-	-
NH_3-N (mt)	10,911	18,799	8,711	7,264
Organic N (mt)	2,635	3,773	-	-
PO_4-P (mt)	-	-	-	962
Total phosphorus (mt)	2,456	3,706	-	-
MBAS[f] (mt)	-	2,017	-	1,485
Cyanide (mt)	6.6	6.0	-	0.84
Phenols (mt)				
Non-chlorinated	1.9	-	1.6	1.5
Chlorinated	-	19	0.75	-
Silver (mt)	3.0	3.9	2.5	-
Arsenic (mt)	2.0	4.6	0.66	0.94
Cadmium (mt)	0.34	0.64	0.41	-
Chromium (mt)	3.1	9.0	2.4	-
Copper (mt)	19	16	16	8.2
Mercury (mt)	0.077	0.13	0.043	-
Nickel (mt)	8.0	22	8.5	1.1
Lead (mt)	1.2	4.0	1.2	1.6
Selenium (mt)	-	6.6	0.34	0.32
Zinc (mt)	34	44	20	17
Total DDT (kg)	-	12	-	5.4
Total PCB[g] (kg)	-	-	-	-

[a]City of Los Angeles

[b]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County

[c]County Sanitation Districts of Orange County

[d]City of San Diego

[e]mt=metric tons

[f]MBAS=methylene blue active substances

[g]Total PCB=Aroclors 1016+1221+1232+1242+1248+1254+1260; JWPCP: Total PCB=Aroclors 1242+1254+1260

method detection limits in 1991. Based on detectable concentrations, the estimated mass emission of DDT declined 40% from 1989 to 1990.

Discussion

The annual combined volume of effluent discharged has declined only five times since 1971 (Table 4). The lower volumes discharged in 1990 and 1991 may be the result of water conservation efforts during the drought. The concentrations of most effluent constituents declined from 1989 to 1991. The greatest change was in lead — effluent concentrations declined 92% at Hyperion and 86% at CSDOC.

Declines in constituent concentrations and mass emissions are the result of improved primary treatment, increased secondary treatment, and improved source control (the most important factor). As a consequence, the number of reported analyses with masses below detection limits (BDL) continues to increase. Some contaminant measurements are consistently below detection limits. If detection limits of the recommended techniques are

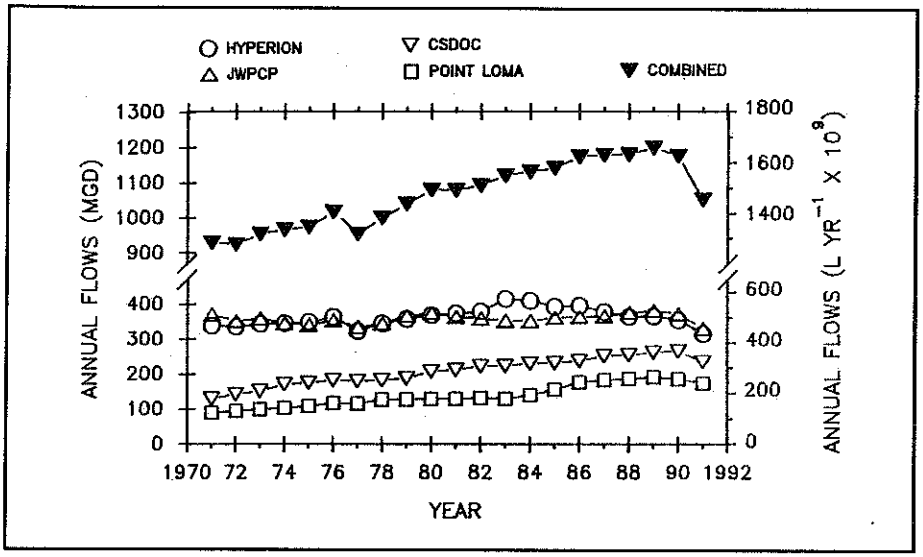
Table 3b.
Estimated mass emissions from the largest municipal wastewater treatment facilities in Southern California in 1991.

	Hyperion[a]	JWPCP[b]	CSDOC[c]	Point Loma[d]
Flow (L x 10^9)	435	455	325	239
Suspended solids (mt[e])	14,170	31,715	14,120	19,353
BOD (mt)	36,037	46,683	23,090	33,464
Oil and grease (mt)	4,390	6,076	4,481	4,393
NO_3-N (mt)	144	99	-	-
NO_2-N (mt)	-	113	-	-
NH_3-N (mt)	11,229	17,190	8,025	7,189
Organic N (mt)	2,394	3,578	-	-
PO_4-P (mt)	-	-	-	1,025
Total phosphorus (mt)	2,065	3,585	-	-
MBAS[f] (mt)	-	1,991	-	1,546
Cyanide (mt)	9.4	5.0	-	1.43
Phenols (mt)				
Non-chlorinated	0.95	-	2.0	1.1
Chlorinated	-	11	-	-
Silver (mt)	2.5	3.6	1.8	-
Arsenic (mt)	2.0	1.8	0.79	0.77
Cadmium (mt)	-	-	0.40	-
Chromium (mt)	1.8	6.6	2.0	-
Copper (mt)	13	13	13	7.3
Mercury (mt)	0.076	-	0.082	-
Nickel (mt)	7.6	17	7.7	-
Lead (mt)	0.70	-	0.68	-
Selenium (mt)	-	6.5	-	0.33
Zinc (mt)	49	42	16	19
Total DDT (kg)	-	-	-	-
Total PCB[g] (kg)	-	-	-	-

[a]City of Los Angeles
[b]Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County
[c]County Sanitation Districts of Orange County
[d]City of San Diego
[e]mt=metric tons
[f]MBAS=methylene blue active substances
[g]Total PCB=Aroclors 1016+1221+1232+1242+1248+1254+1260; JWPCP: Total PCB=Aroclors 1242+1254+1260

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).



below discharge permit requirements, then BDL results are in compliance. However, BDL results complicate mass emissions estimates. We reported detection limits in the table of concentrations (Tables 2a,b) and treated BDL results as zeros for the estimates of mass emissions (Tables 3a,b).

The combined flow from the four largest facilities increased 27% between 1971 and 1990 as a result of population increases (Figure 2). This is a mean annual increase of 1.3% (sd=2.5, n=19). During this time, the volume of wastewater discharged by CSDOC and Point Loma doubled while the volume discharged by

Table 4.

Combined mass emissions from City of Los Angeles Hyperion Treatment Plant, County Sanitation Districts of Los Angeles County Joint Water Pollution Control Plant, County Sanitation Districts of Orange County Wastewater Treatment Plants 1 and 2, and City of San Diego Point Loma Sewage Treatment Plant from 1971 through 1991.

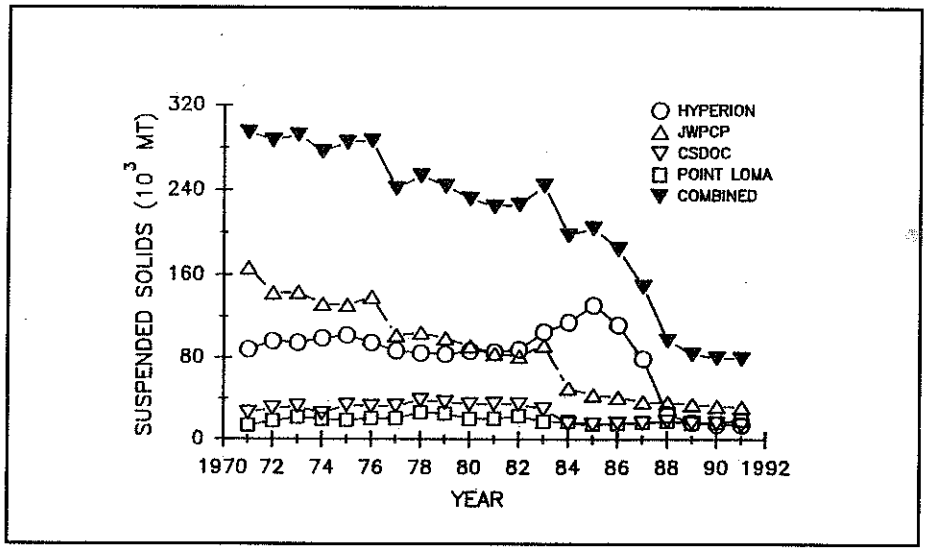
	1971	1972	1973	1974	1975	1976	1977	1978	1979
Flow (L x 10^9)	1,284	1,278	1,319	1,336	1,346	1,406	1,319	1,382	1,438
Flow (mgd[a])	930	922	954	967	975	1,015	955	1,001	1,041
Suspended solids[b](mt[c])	294,000	286,500	291,700	270,900	284,900	286,400	241,800	253,800	243,900
BOD (mt)	283,100	250,300	226,800	233,900	233,500	255,900	241,500	234,200	241,900
Oil and grease (mt)	62,312	60,700	60,700	54,800	56,500	58,800	49,200	48,500	45,400
NH_3-N (mt)	54,500	40,100	45,900	38,900	36,300	37,000	40,000	38,900	41,100
Total P[d](mt)	33,500	36,300	39,200	37,700	11,000	22,800	10,600	10,100	10,000
MBAS[e] (mt)	6,500	6,300	5,900	6,800	6,100	6,100	5,400	5,800	6,300
Cyanide (mt)	188	238	244	303	251	401	213	176	145
Silver (mt)	15	22	29	22	25	20	34	32	43
Arsenic (mt)	3[f]	18	16	18	12	11	12	15	15
Cadmium (mt)	52	34	49	55	51	44	41	44	43
Chromium (mt)	667	675	694	690	579	592	368	279	239
Copper (mt)	535	486	508	576	510	506	402	416	361
Mercury (mt)	2.9	2.6	3.1	1.8	2.2	2.5	2.6	1.9	2.6
Nickel (mt)	326	262	318	315	282	302	262	318	256
Lead (mt)	226	252	180	199	198	189	150	216	224
Selenium (mt)	12	11	16	18	11	22	22	23	7.9
Zinc (mt)	1,834	1,201	1,189	1,324	1,087	1,061	834	833	728
DDT[g] (kg)	21,527	6,558	3,818	1,562	1,158	1,633	855	1,121	839
PCB[g] (kg)	8,730	9,830	3,389	5,421	3,065	3,492	2,183	2,540	1,170

[a]mgd=million gallons per day; 1 mgd=3,785,000 L/day
[b]solids for Hyperion 7-mile outfall are total solids
[c]mt=metric tons
[d]City of San Diego measures only soluble PO_4P

JWPCP and Hyperion increased only slightly (Figure 2). Population growth patterns, water reclamation, and inland discharge account for differences among the districts. Orange and San Diego counties have grown faster than Los Angeles County. Los Angeles County and the City of Los Angeles expanded their upstream treatment and reclamation facilities. The County reclaimed 155 mgd of water in 1990 — double the amount reclaimed 10 years ago. The volume of effluent discharged to the Los Angeles River by the Los Angeles-Glendale and Donald C. Tillman water reclamation plants

Figure 3.

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



1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1,493	1,492	1,511	1,549	1,565	1,579	1,623	1,629	1,632	1,656	1,627	1,455
1,078	1,080	1,094	1,122	1,129	1,143	1,175	1,179	1,178	1,199	1,178	1,053
232,100	224,900	226,800	244,600	197,700	204,500	184,900	149,100	97,000	83,400	79,700	79,400
255,100	260,900	266,100	251,800	230,100	253,500	181,900	166,500	168,800	161,100	159,000	139,300
38,400	36,700	37,300	35,700	30,000	34,300	29,000	25,800	25,300	22,600	21,500	19,300
41,200	40,500	41,500	39,800	40,400	42,500	45,000	44,300	44,300	45,100	45,700	43,600
10,000	9,500	9,000	9,000	9,200	8,500	10,900	9,000	7,100	6,900	7,100	6,700
6,400	5,600	5,700	5,200	4,600	4,300	4,800	4,600	3,400	3,300	3,500	3,500
116	98	77	46	39	26	22	27	26	10	13	16
30	28	25	26	24	26	22	15	11	11	9	8
11	12	8	10	18	16	12	12	8.9	7.4	8.2	5.4
39	32	21	23	16	16	14	9.0	3.4	1.9	1.0	0.4
275	187	203	163	140	110	88	57	29	22	14	10
335	337	284	272	251	239	202	125	76	68	59	47
1.8	1.8	1.2	1.1	0.9	0.9	0.7	0.4	0.4	0.4	0.2	0.2
224	167	168	163	133	118	127	76	63	54	40	33
175	130	122	98	87	118	105	61	50	27	6.4	1.4
11	15	6.4	6.5	6.5	5.8	8.2	7.2	6.7	7.6	7.3	6.8
729	538	545	497	369	375	336	261	151	146	115	125
671	480	290	223	310	48	51	53	26	20	12	-[h]
1,127	1,252	785	628	1,209	46	37	5	-[h]	-[h]	-[h]	-

[e]Hyperion 7-mile outfall not included

[f]only Hyperion data were available

[g]estimates for 1971-75 are based on SCCWRP analyses of effluents; estimates estimates for 1976-91 are based on discharger data

[h]concentrations were below detection limits

increased from 25 mgd in 1985 to 55 mgd in 1990.

Despite increases in population and the volume of wastewater discharged over the past two decades, the mass emissions of most effluent constituents have declined (Table 4). The combined annual mass emission of suspended solids has decreased 73%, BOD has decreased 51%, and oil and grease has decreased 69% (Figures 3, 4, and 5). The decline in JWPCP solids emissions between 1971 and 1989 accounts for 65% of the reduction. Termination of sludge discharge from the Hyperion 7-mile outfall (October 1987) accounts for a 40% reduction in combined emissions from 1987 to 1988. Most of the decline in BOD occurred after 1985. Reductions by JWPCP account for about 75% of the decline in oil and grease.

The combined mass emission of trace metals declined 94% from 1971 to 1991 (Table 4; Figure 6). Declines of individual metals averaged 84% (sd=19%, n=10). The greatest reductions were for chromium (99%), cadmium (99%), lead (99%), zinc (93%), mercury (93%), copper (91%), nickel (90%), and selenium (43%). From 1972 to 1990, arsenic declined 70% and silver declined 64%. The combined mass emissions of trace metals declined 36% from 1987 to 1988; termination of sludge discharge from the Hyperion 7-mile outfall accounted for about 60% of this decline.

The combined emissions of chlorinated hydrocarbons declined more than 99% from 1971 to 1990 (Table 4; Figure 7). Montrose Chemical Corporation, the largest manufacturer of DDT in the world and the only manufacturer in California, discharged DDT wastes into the Los Angeles County sewer system from 1947 to 1971. Residual waste in the sanitation system was the principal source of DDT in JWPCP effluent after that time. Concentrations of DDT in JWPCP effluent are now below detection limits (tens of pg/l).

The interpretation of long-term trends is hindered somewhat by the reliability of trace contaminant analyses, especially trace organic analyses, in early monitoring programs. Analytical methods for quantifying chlorinated hydrocarbons evolved during the 1970s and techniques were not standardized among laboratories. The older data reported herein are the best available for past discharges, but the old methods are unacceptable 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.

Figure 4.
Combined mass emission of biological oxygen demand from the four largest municipal wastewater treatment facilities (MT = metric tons).

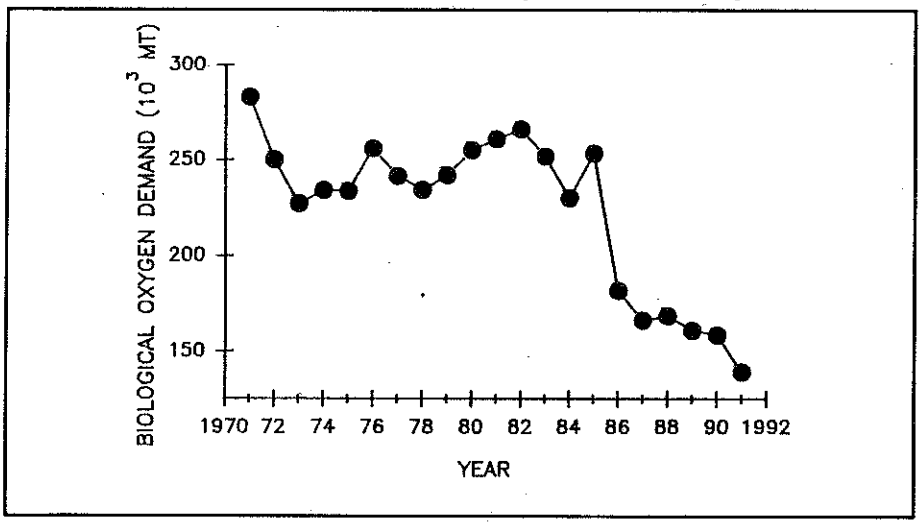


Figure 5.
Combined oil and grease emissions and individual oil and grease from the four largest municipal wastewater treatment facilities (MT = metric tons).

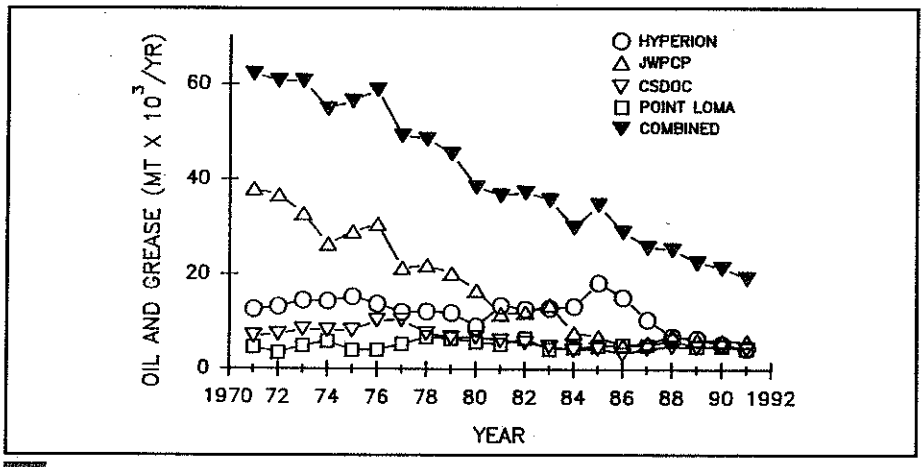
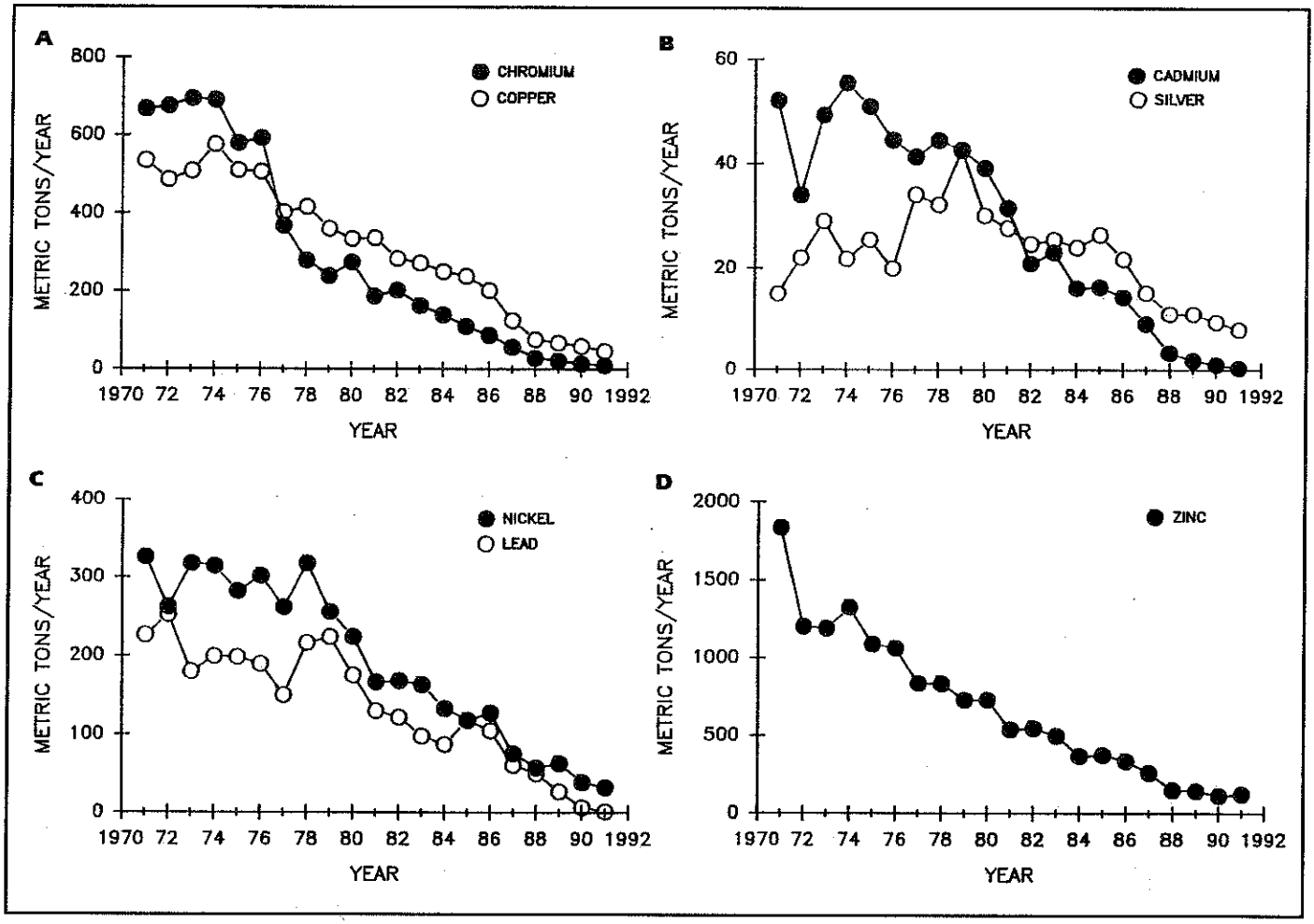


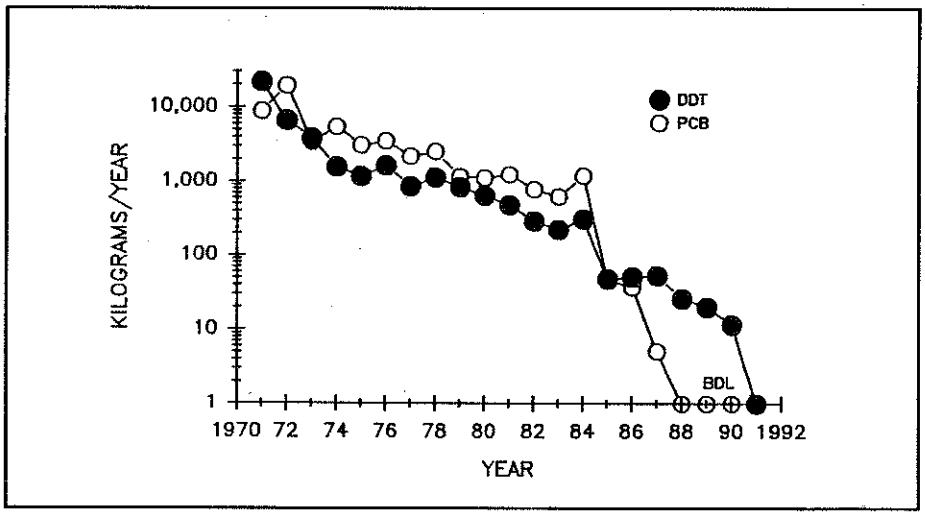
Figure 6.
Combined mass emissions of trace metals from the four largest municipal wastewater treatment facilities.



Conclusions

The quality of municipal wastewaters discharged to the Southern California Bight today is significantly better than the quality of wastewaters discharged in 1971. Decreases in contaminant mass emissions are due to increased source control and land disposal of sludge, improved sludge and primary treatment, and increased secondary treatment. Further reductions in mass emissions on a comparable scale are not possible. Nominal reductions

Figure 7.
Combined mass emissions of chlorinated hydrocarbons from the four largest municipal wastewater treatment facilities (BDL = below detection limits).



will occur due to planned increases in the volume of wastewater receiving secondary treatment, increased inland reclamation of water, and more effective source control.■

Literature Cited

•SCCWRP. 1990. Characteristics of effluents from large municipal wastewater treatment plants in 1989. pp. 8-15, *In:* Southern California Coastal Water Research Project, Annual Report 1989-90. J.N. Cross (ed.). Southern California Coastal Water Research Project, Long Beach.

Appendix 1.

Annual mass emissions (ME) of contaminants were estimated from:

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

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*.

Historically, mass emissions were estimated from:

$$ME = \sum F_t C_m \qquad (2)$$

where:
$\sum F_t$ = total annual flow, and
C_m = mean monthly constituent concentration.

We estimated mass emissions for 1990 and 1991 by both methods. Estimates by (2) were similar to estimates by (1); the mean difference in 1990 was -0.09% (sd=1.55, n=71, min=0%, max=-10.5%) and the median difference was 0.08%. The maximum difference occurred for estimates of nickel emissions from Point Loma. Without this datum, the mean difference was 0.06% (sd=0.61, n=70, min=0%, max=-3.0%) and the median difference was 0.10%.

Method (2) was slightly, but significantly, positively biased. Nearly 70% of the 1990 estimates were higher by (2) than by (1), more than would be expected by chance alone (normal approximation to binomial test, $Z=3.04$, $0.002<p<0.005$). Estimates by (1) were more accurate, and therefore less biased, than (2). Method (1) also allowed us to examine monthly variability in constituent concentrations (Tables 2a,b).

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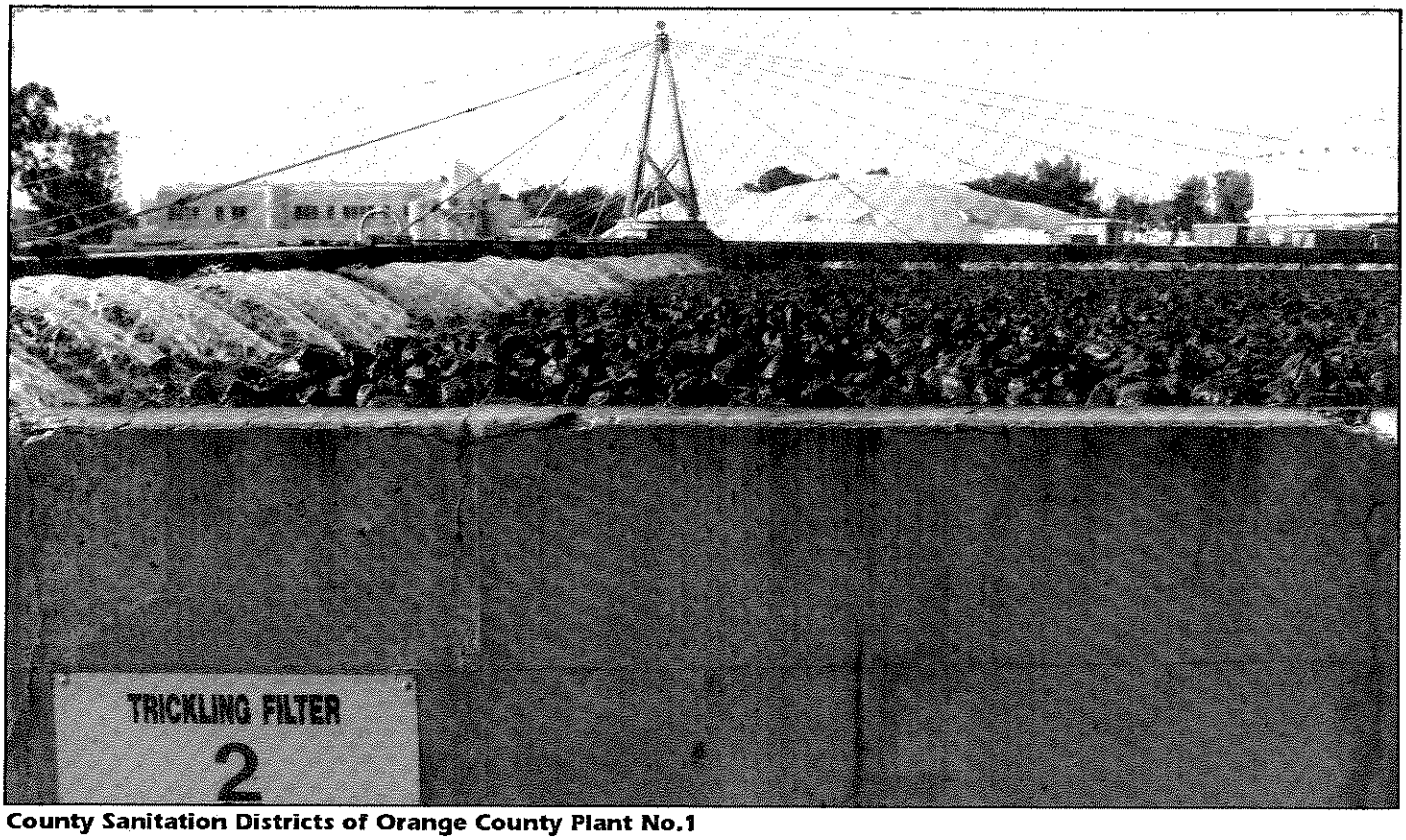

County Sanitation Districts of Orange County Plant No.1