Effluent discharges to the Southern California Bight from industrial facilities in 2005

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Abstract

Industrial facilities represent a diverse class of point source dischargers to the Southern California Bight (SCB). Industrial effluent characteristics have been analyzed periodically since 1971 to estimate total contaminant loading, to evaluate discharge trends, and to facilitate comparisons between pollutant sources within the SCB. This study continues the assessment of industrial effluent by analyzing discharges from 2005. Five industrial facilities, including a petroleum refinery, a chemical plant, a salt processing plant, and two research and public aquaria, discharged directly to the SCB in 2005. Total effluent volume, contaminant mass emissions, and annual average concentrations were calculated and compared to the previous assessments of discharges. Industrial emissions were also compared to the largest point source of contaminants to the SCB, large publicly owned treatment works (POTWs). Total effluent volume from industrial facilities was 13.3 L x 10^9 in 2005 compared to 1,453 L x 10^9 from large POTWs. The number of discharging industrial facilities and their combined effluent volume has decreased by more than 90% since 1971. Mass emissions of most constituents have also decreased, with all general constituent loads down at least 98% since 1971 and most metals loads below 1995 levels. Although the long-term trend in mass emissions has decreased, discharge volume and loads of many constituents were higher in 2005 than in 2000. The increased contaminant loading observed in 2005 was influenced by three factors: 1) increased monitoring and reporting requirements, 2) increased flow volume, and 3) higher constituent concentrations at individual facilities. Although mass emissions from industrial facilities increased in 2005, they remain a relatively minor source of contaminants to the SCB compared to large POTWs; effluent volume and contaminant mass from all industrial facilities constitutes generally less than 1% of the combined loading from all major point source discharges.

Introduction

The SCB is an important ecological, recreational, and economic resource adjacent to one of the most densely populated coastal regions in the United States (Crossett *et al*. 2004). The five coastal counties bordering the SCB are home to over 16 million people and 60 major point sources of contaminant discharge to the coastal ocean (US Census Bureau 2000; Lyon and Stein 2009). Since 1971, the Southern California Coastal Water Research Project (SCCWRP) has been compiling and analyzing effluent data from all major point-source dischargers to the coastal waters of the SCB. These discharge data are used to calculate total mass emission estimates for selected contaminants. Mass emission estimates can be used by environmental resource managers to assess total pollutant loading to the SCB, to predict the relative impact of a particular source, and to evaluate the long-term effects of management actions.

Point source discharges to the SCB include municipal wastewater treatment plants or POTWs, power generating stations, offshore oil platforms, and industrial facilities. The industrial discharger class is comprised of diverse facilities that don't fit the other common categories and can vary from year to year. Regional assessments of industrial facility discharges have been conducted periodically by SCCWRP since 1971 (SCCWRP 1973, Raco-Rands 1999, Steinberger and Schiff 2003). The most recent assessment of discharges from 2000 identified seven actively discharging industrial facilities (Steinberger and Schiff 2003), compared to five actively discharging facilities in 2005. Two of the petroleum-related facilities included in 2000 have diverted their treated waste effluent to the sanitary sewer system and ceased discharge to surface waters prior to 2005.

Effluent discharges and associated compliance monitoring requirements for each facility are stipulated by their National Pollutant Discharge

Elimination System (NPDES) permit (Appendix I). Although each facility is required to monitor its effluent flow and chemistry, the specific constituents and minimum analysis frequencies vary by facility (Appendix II). NPDES permits also do not require integration of data from multiple dischargers or classes of dischargers to assess the cumulative impact to a water body. This poses a challenge to environmental resource managers who need to evaluate pollutant loads and trends from all sources on a regional or larger scale.

The goal of this study was to characterize effluent from industrial facilities in 2005. To achieve this objective, flow and chemistry data from industrial facilities discharging directly to the SCB were compiled and standardized to allow calculation of cumulative mass emission estimates for the entire SCB and average constituent concentrations for each facility. To assess historical trends, we then compared these effluent data to results from previous assessments of industrial discharges for 1971, 1995, and 2000. Industrial effluent characteristics were also compared to large POTW discharges to assess their relative regional significance.

METHODS

Industrial facilities included in this assessment were selected based on receiving water and waste discharge types. Facilities that discharge directly to the coastal ocean or to bays, harbors, or channels within the tidal prism of the SCB were included. Discharges to freshwater rivers and channels were excluded to avoid duplicating or confounding estimates of contaminant loading from non-point source runoff estimates. Discharges of process water, cooling water, aquarium water, and in-plant waste streams were included, while facilities that discharged only stormwater were excluded.

Five industrial facilities discharged to the coastal waters of the SCB in 2005, including a petroleum refinery, a chemical production plant, a salt processing plant, and two marine research and public display aquaria (Table 1; Figure 1). Chevron El Segundo was the only petroleum refinery that discharged treated effluent to surface waters of the SCB in 2005. Waste streams were treated on site through two independent treatment systems: 1) Cooling water, condensate, low volume wastes, and stormwater within the facility were treated by chemically enhanced primary treatment prior to discharge; 2)

Table 1. Flow rates and receiving waters of industrial discharges in 2005. "--" = facility has only one outfall.

Facility	Outfall	Effluent Flow (mgd)	Receiving Water
Chevron El Segundo	--	**6.10**	Santa Monica Bay
US Borax	--	**0.13**	Los Angeles Harbor
Morton Salt Long Beach	--	**0.01**	Long Beach Harbor
Scripps Institution of Oceanography	001	0.41	San Diego Marine Life Refuge (ASBS 31)
	003	0.05	
	004a	0.02	
	004b	0.03	
	Combined	***0.51***	
Sea World	001 (East)	1.09	Mission Bay
	002 (West)	1.81	
	Combined	***2.90***	
TOTAL		**9.65**	

Petroleum process water was treated first by chemically enhanced primary treatment followed by secondary (biological) treatment prior to discharge. Both treatment systems discharged to the Santa Monica Bay via a 3500-foot outfall pipe. The US Borax chemical plant discharged single-pass non-contact cooling water to the Los Angeles Harbor. All chemical process water was diverted to the sanitary sewer system. Discharge of cooling water occurred only during March, April, and May of 2005, for a total of 36 days. The plant's production operations were transferred to another facility in Europe and discharge ceased in May 2005. Morton Salt processing plant discharged untreated process water to the Long Beach Harbor. The plant used water spray as an air scrubber to control salt dust within its plant. The Scripps Institution of Oceanography discharged seawater circulated through its research and public display aquaria via four outfalls. Outfalls 001 and 003 discharged the circulated aquaria seawater that constituted the majority of the volume, while Outfall 004a discharged intake and settling tank overflow, and Outfall 004b discharged backwash from the sand filter system. The seawater intake and the outfalls are located within the San Diego Marine Life Refuge, which is designated by the State Water Resources Control Board as an Area of Special Biological Significance (ASBS). The Sea World aquatic park discharged circulated seawater from exhibit pools, intermittent flows from pool draining and cleaning

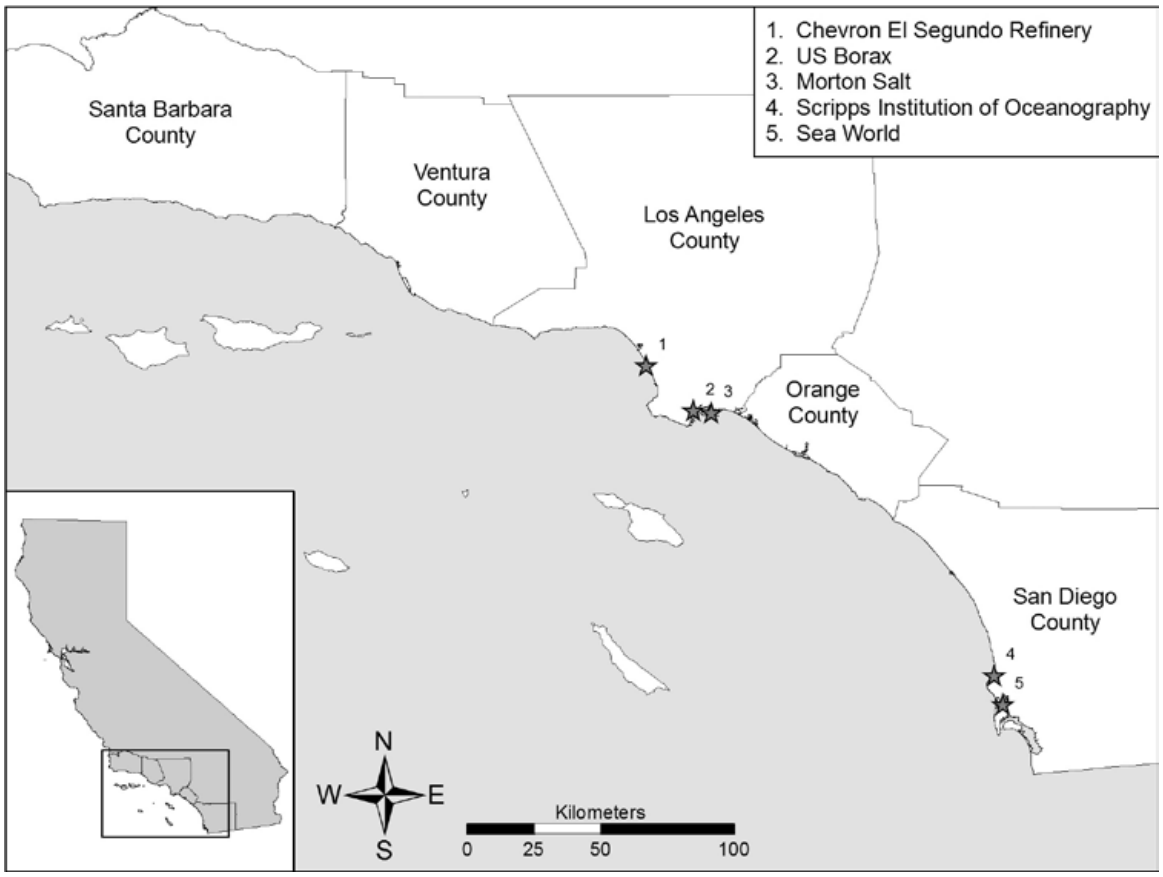

Figure 1. Locations of the industrial facilities discharging to the SCB in 2005.

operations, landscape irrigation runoff, and facility wash down water. The seawater intake and two discharge outfalls are located in Mission Bay. The assessment of industrial discharges in 2000 included only discharges from the adjacent Hubbs Seaworld Research Institute, not the larger Sea World aquatic park itself, resulting in a 10-fold increase in the discharge volume attributed to Sea World between 2000 and 2005.

Annual mass emissions data for the industrial facilities were compiled from effluent flow and chemistry data provided in each facility's monthly, quarterly, and annual discharge monitoring reports, which were obtained from the California Regional Water Quality Control Boards. Constituents included in this assessment were selected based on the availability of data and on the known influence of these constituents in the marine environment. General constituents included solids, biochemical oxygen demand (BOD), oil and grease, ammonia, and cyanide. Selected metals, phenols, dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCB), and polycyclic aromatic hydrocarbons (PAH) were also analyzed.

Constituent concentration data were standardized to monthly time steps. For constituents analyzed more than once per month, the arithmetic mean of all results in a given month was calculated. Where the frequency of constituent analysis was less than monthly or data for a given month were not available, the arithmetic mean of available data within the given year was calculated and used to populate months for which no data existed. The monthly flow and concentration data were then used to calculate annual discharge volumes and constituent mass emissions for each facility. Constituent concentrations below the minimum reporting level (RL) were assigned a value of zero for calculating mass emission estimates.

The annual discharge volume (V) for each facility was calculated from the sum of the monthly effluent volumes:

$$V = \sum_{i=1}^{12} uF_iD_i$$

where F_i was the mean daily flow for the

month i, D_i was the number of days that discharge occurred during the month i, and u was the unit conversion factor for calculating the volume in liters.

Mass emission estimates (ME) were calculated from the product of the mean daily flow, the monthly constituent concentration, the number of days in the given month, and a unit conversion factor. These estimates were calculated for each constituent for each month, and then summed over all months in the year to obtain an annual estimate:

$$ME = \sum_{i=1}^{12} uF_iC_iD_i$$

where C_i was the reported constituent concentration for the month i, and u was the appropriate unit conversion factor for calculating the ME in metric tons, kilograms, or liters.

Annual average flow-weighted concentrations (FWC) were calculated by dividing the annual ME for a given constituent by the total annual effluent volume (V).

$$FWC = u\frac{ME}{V}$$

where u was the unit conversion factor for reporting the FWC in the appropriate concentration units.

This approach for calculating FWC occasionally resulted in estimates below the RL for constituents that had one or more non-detected results. In these cases, the FWC was reported as calculated. Constituents that were consistently not detected resulted in FWC of zero, and were reported as less than the RL. When more than one RL was used for a given constituent during the year, the greatest RL was reported.

Historical trends in mass emissions from industrial facilities were analyzed by comparing results from 2005 to results of previous assessments from 1971, 1995, and 2000 reported by Steinberger and Schiff (2003). Industrial discharges were also compared to large POTW effluent characteristics in order to determine the relative contribution of industrial facilities to the cumulative impact from the primary point source of contaminants. The most recent quality assured large POTW effluent data from 2004 were obtained from Lyon *et al*. (2006) for the comparison.

RESULTS

Industrial Discharges in 2005

Combined daily effluent flow from the five industrial facilities in 2005 was 9.6 mgd (Table 1). Flows from individual facilities ranged from 0.01 mgd (Morton Salt) to 6.1 mgd (Chevron El Segundo). These daily flow rates resulted in an annual effluent volume of 13.3 L x 10^9, which represents a 7% increase from the total annual volume in 2000 (Table 2; Steinberger and Schiff 2003). Chevron El Segundo discharged 63% of the total industrial volume in 2005 (Figure 2). Sea World was the second largest discharge source with 30% of the volume, and the remaining three facilities combined discharged only 7% of the total annual effluent volume.

Total mass emissions from industrial facilities in 2005 included 114 mt of suspended solids and 146 L x 10^3 of settleable solids (Table 2). Industrial facilities also discharged 22 mt of oil/grease and 20 mt of ammonia-N. Combined metals emissions from industrial facilities totaled 1.6 mt, with selenium, zinc, and copper providing 65, 18, and 8% of the total metals load, respectively. Non-chlorinated phenols were detected only in Chevron El Segundo refinery effluent, resulting in mass emissions of 305 kg. No chlorinated phenols, DDTs, PAHs, or PCBs were detected in effluent from any industrial facility in 2005.

The highest average constituent concentrations were distributed among the facilities depending on the constituent. The Chevron El Segundo refinery discharged the highest average concentrations of ammonia-N, arsenic, mercury, selenium, and the only detected concentrations of non-chlorinated phenols (Table 3). The Chevron El Segundo effluent also produced the highest chronic toxicity levels among industrial facilities. Morton Salt effluent contained the highest concentrations of suspended solids, turbidity, nickel, silver, and zinc, and resulted in the highest acute toxicity level. Scripps Institution of Oceanography had the greatest concentration of settleable solids, cadmium, chromium, and lead. Sea World effluent contained the highest concentrations of oil/grease and copper.

Wide variation in average concentrations produced constituent loads from facilities that were dis-

Table 2. Estimated constituent mass emissions from industrial dischargers in 2005. "--" = constituent was not analyzed or data were not available. nd = not detected.

Constituent	Chevron El Segundo	US Borax	Morton Salt Long Beach	Scripps Institution of Oceanography					Sea World			TOTAL
				001	003	004a	004b	*Combined*	001	002	*Combined*	
Volume (L x 10^9)	8.4	0.18	0.02	0.57	0.08	0.03	0.04	*0.71*	1.5	2.5	*4.0*	**13.3**
Suspended Solids (mt)	79	0.58	0.9	3.8	0.16	0.004	1.8	*5.7*	1.9	26	*28*	**114**
Settleable Solids (L x 10^3)	nd	nd	nd	nd	nd	nd	11.7	*11.7*	50	84	*134*	**146**
BOD (mt)	--	8.4	nd	--	--	--	--	--	--	--	--	**8.4**
CBOD (mt)	59	--	--	--	--	--	--	--	--	--	--	**59**
Oil/Grease (mt)	7.4	0.06	0.03	nd	0.02	nd	0.01	*0.03*	7.3	7.6	*15*	**22**
Ammonia-N (mt)	19	--	--	0.003	0.001	0.002	0.001	*0.007*	0.15	0.25	*0.40*	**20**
Cyanide (kg)	nd	nd	nd	0.17	0.02	0.006	0.007	*0.20*	--	--	--	**0.20**
Arsenic (kg)	61	0.26	nd	0.84	0.12	0.04	0.09	*1.1*	--	--	--	**63**
Cadmium (kg)	nd	nd	--	0.02	0.002	0.001	0.004	*0.03*	--	--	--	**0.03**
Chromium (kg)	5.2	nd	nd	0.43	0.04	0.01	0.12	*0.61*	--	--	--	**5.8**
Copper (kg)	58	nd	nd	2.8	0.22	0.01	0.05	*3.1*	18	52	*70*	**131**
Lead (kg)	0.75	0.04	nd	1.1	0.05	<0.001	0.02	*1.1*	--	--	--	**1.9**
Mercury (kg)	0.17	nd	nd	0.002	<0.001	<0.001	<0.001	*0.002*	--	--	--	**0.18**
Nickel (kg)	59	nd	0.35	0.26	0.03	0.01	0.05	*0.35*	--	--	--	**59**
Selenium (kg)	1,035	nd	nd	0.005	0.003	<0.001	0.003	*0.01*	--	--	--	**1,035**
Silver (kg)	nd	nd	0.24	0.09	0.009	0.005	0.006	*0.11*	nd	nd	*nd*	**0.35**
Zinc (kg)	280	0.60	1.1	4.8	0.44	0.05	0.23	*5.5*	--	--	--	**287**
Combined Metals (kg)	1,499	0.90	1.7	10.3	0.92	0.14	0.57	11.9	18	52	70	**1,583**
Non-chlorinated Phenols (kg)	305	nd	nd	nd	nd	nd	nd	*nd*	--	--	--	**305**
Chlorinated Phenols (kg)	nd	nd	nd	nd	nd	nd	nd	*nd*	--	--	--	**nd**
Total DDT (kg)	nd	nd	nd	nd	nd	nd	nd	*nd*	--	--	--	**nd**
Total PAH (kg)	nd	nd	nd	--	--	--	--	--	--	--	--	**nd**
Total PCB (kg)	nd	nd	nd	--	--	--	--	--	--	--	--	**nd**

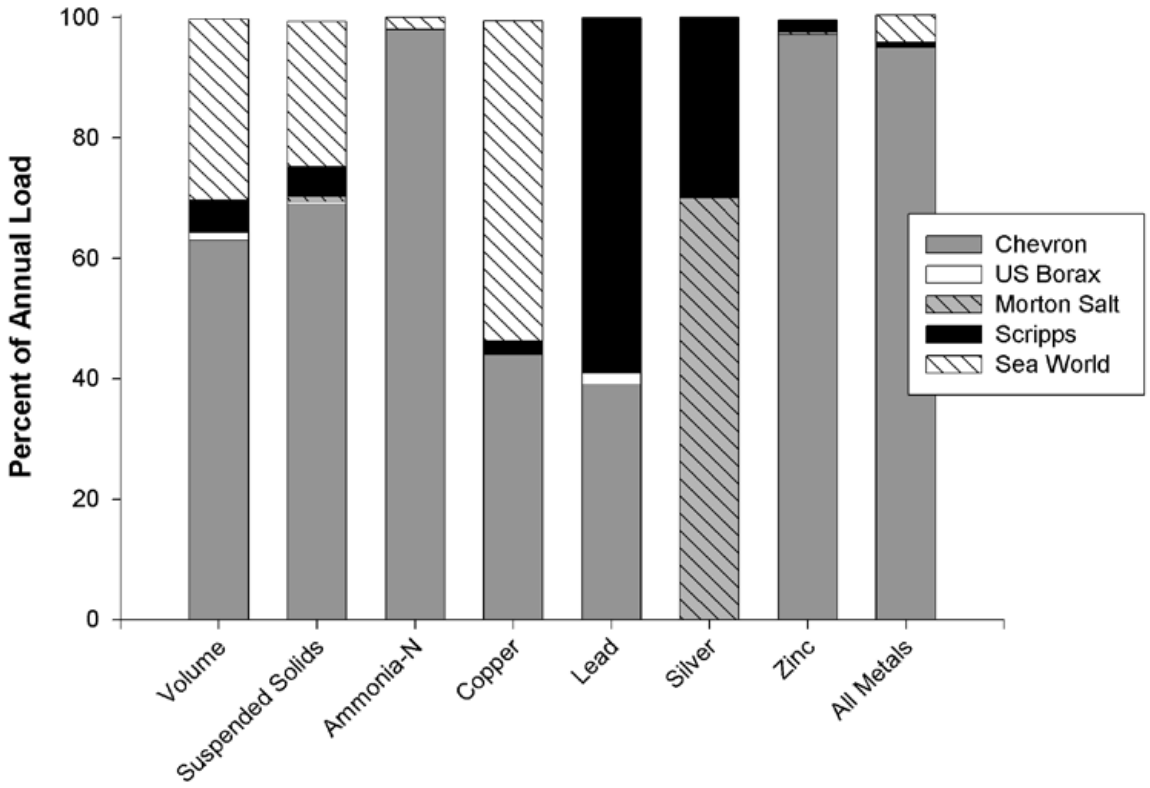

Figure 2. Relative contribution of selected constituents from industrial facilities in 2005.

proportionate to their volume contribution. The Chevron El Segundo refinery contributed less than two thirds of the total discharge volume, but accounted for 95% of the combined metals load, and greater than 95% of the ammonia-N, arsenic, mercury, nickel, selenium, and zinc loads (Figure 2). Sea World contributed 30% of the total volume, but accounted for 92% of the settleable solids, 67% of the oil/grease, and 53% of the copper load. Morton Salt contributed less than 1% of the total volume, but accounted for 70% of the total silver load. Scripps effluent contained the only detectable levels of cyanide and cadmium, and contributed disproportionately large amounts of chromium, lead, and zinc, with 11, 59, and 30% of the total loads, relative to its 5% of combined volume.

Trends in Industrial Discharges

Since 1971, the number of discharging industrial facilities and their combined annual effluent volume have both decreased more than 90%, from 96 facilities and 185 L x 10^9 to just 5 facilities and 13.3 L x 10^9 (Figure 3; Table 4). Each of the constituent loads for which 1971 data were available, including suspended solids, oil/grease, ammonia-N, and non-chlorinated phenols, decreased by at least 98% during the same time period (Figure 4). Combined metals loads, which were not assessed in 1971, decreased 29% from 1995 to 2005. Most individual metals emissions also decreased during this period, from 13% (silver) to 99% (cadmium). The exceptions were copper, mercury, and selenium loads, which increased by 191, 157, and 64%, respectively, from 1995 to 2005 (Table 4).

Despite the long-term general trend of decreasing mass emissions, and the continued reduction in the number of discharging facilities, total volume and mass loads of most constituents were greater in 2005 than in 2000 (Table 4). Significant increases in contaminant loads were observed in suspended and settleable solids, oil/grease, non-chlorinated phenols, and most metals. Ammonia-N and arsenic were among the few constituent mass emissions that decreased from 2000 to 2005. The greatest increases in average concentrations were observed in suspended solids, turbidity, copper, nickel, and selenium.

Industrial vs. Large POTW Discharges

Effluent from large POTW facilities has historically been the most dominant point source of contaminants to the SCB (Lyon and Stein 2009). Compared to large POTW effluent, the discharge

Table 3. Annual average flow-weighted constituent concentrations in effluent from industrial dischargers in 2005. "--" = constituent was not analyzed or data were not available. nd = measurement below detection level, or RL/MDL not provided or not found. < = less than the reporting level; if more than one RL was used during the year, the highest was reported here.

Constituent	Chevron El Segundo	US Borax	Morton Salt Long Beach	Scripps Institution of Oceanography					Sea World			Overall Average
				001	003	004a	004b	*Average*	001	002	*Average*	
Suspended Solids (mg/L)	9.4	3.3	62	6.6	2.1	0.15	51	*15*	1.3	10.3	*5.8*	**16**
Settleable Solids (mL/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.34	*0.08*	0.03	0.03	*0.03*	**0.04**
BOD (mg/L)	--	48	<5	--	--	--	--	--	--	--	--	**24**
CBOD (mg/L)	7.0	--	--	--	--	--	--	--	--	--	--	**7.0**
Oil/grease (mg/L)	0.88	0.34	1.9	<5	0.21	<5	0.34	*0.14*	4.9	3.050	*4.0*	**1.3**
Ammonia-N (mg/L)	2.3	--	--	0.006	0.01	0.09	0.02	*0.03*	0.10	0.100	*0.10*	**0.38**
Cyanide (mg/L)	<0.025	<0.02	<0.05	<0.005	<0.005	<0.005	<0.005	<0.005	--	--	--	**nd**
Turbidity (NTU)	9.8	3.9	31	2.2	2.0	0.65	17	*5.6*	2.2	1.377	*1.8*	**7.9**
Acute Toxicity (TUa)	0.15	0.0	1.0	0.48	0.48	--	0.84	*0.60*	0.77	0.440	*0.61*	**0.52**
Chronic Toxicity (TUc)	10.6	1.0	--	8.5	8.0	--	10.0	*8.8*	--	--	--	**7.6**
Arsenic (µg/L)	7.3	1.5	<10	1.5	1.6	1.5	2.5	*1.8*	--	--	--	**2.3**
Cadmium (µg/L)	<1	<0.25	--	0.04	0.03	0.03	0.12	*0.05*	--	--	--	**0.04**
Chromium (µg/L)	0.62	<0.5	<10	0.76	0.59	0.49	3.5	*1.3*	--	--	--	**0.85**
Copper (µg/L)	6.9	<0.5	<10	4.9	3.0	0.49	1.3	*2.4*	12	20.600	*16*	**5.5**
Lead (µg/L)	0.09	0.21	<5	1.9	0.63	0.02	0.65	*0.79*	--	--	--	**0.50**
Mercury (µg/L)	0.02	<0.5	<2	0.003	0.002	0.003	0.002	*0.002*	--	--	--	**0.004**
Nickel (µg/L)	7.0	<1	23	0.45	0.35	0.34	1.5	*0.66*	--	--	--	**4.7**
Selenium (µg/L)	123	<2	<10	0.009	0.04	0.007	0.07	*0.03*	--	--	--	**18**
Silver (µg/L)	<1	<0.25	16	0.15	0.13	0.19	0.16	*0.16*	<5	<5.000	*<5*	**1.8**
Zinc (µg/L)	33	3.4	71	8.4	5.9	1.9	6.7	*5.7*	--	--	--	**19**
Non-chlorinated Phenols (µg/L)	36	<1	<1	<0.2	<0.2	<0.2	<0.2	<0.2	--	--	--	**5.2**
Chlorinated Phenols (µg/L)	<95	<1	<1	<0.2	<0.2	<0.2	<0.2	<0.2	--	--	--	**nd**
Total DDT (µg/L)	<0.6	<0.04	<0.1	<0.005	<0.005	<0.005	<0.005	<0.005	--	--	--	**nd**
Total PAH (µg/L)	<142.5	<1	<10	--	--	--	--	--	--	--	--	**nd**
Total PCB (µg/L)	<3.5	<0.5	<0.65	--	--	--	--	--	--	--	--	**nd**

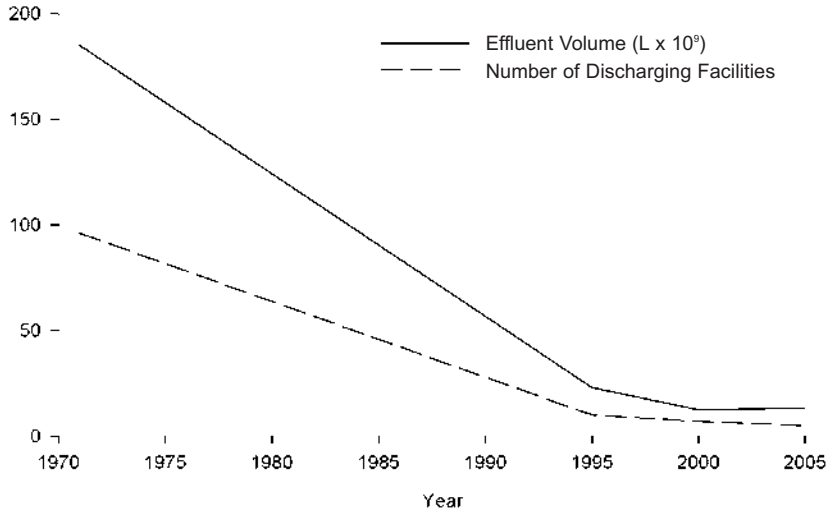

Figure 3. Combined effluent flow from industrial facilities between 1971 and 2005.

Table 4. Historical mass emissions of selected constituents from industrial dischargers combined, and the percent changes for selected years. "--" = constituent was not analyzed or data were not available. nc = no change. nd = not detected.

Constituent	Mass Emissions				Percent Change		
	1971[a]	1995[b]	2000[c]	2005	1971-2005	1995-2005	2000-2005
Number of Facilities	96	10	7	5	-95%	-50%	-29%
Effluent Volume (L x 10^9)	185	23	12.4	13.3	-93%	-42%	7%
% from Petroleum	81	77	83	63	-22%	-18%	-24%
Suspended Solids (mt)	6,206	312	7.5	114	-98%	-63%	1420%
Settleable Solids (L x 10^3)	--	nd	9.2	146	--	100%	1487%
BOD (mt)	1,342	41	20	8.4	-99%	-80%	-59%
CBOD (mt)	--	137	nd	59	--	-57%	100%
Oil/Grease (mt)	1,789	90	4.2	22	-99%	-76%	424%
Ammonia-N (mt)	1,206	57	22	20	-98%	-65%	-9%
Cyanide (kg)	--	nd	nd	0.20	--	100%	100%
Arsenic (kg)	--	235	218	63	--	-73%	-71%
Cadmium (kg)	--	4.3	0.02	0.03	--	-99%	50%
Chromium (kg)	--	96	1.3	5.8	--	-94%	346%
Copper (kg)	--	45	24	131	--	191%	446%
Lead (kg)	--	16	1.1	1.9	--	-88%	73%
Mercury (kg)	--	0.07	nd	0.18	--	157%	100%
Nickel (kg)	--	134	18	59	--	-56%	228%
Selenium (kg)	--	631	933	1,035	--	64%	11%
Silver (kg)	--	0.40	0.20	0.35	--	-13%	75%
Zinc (kg)	--	1,068	57	287	--	-73%	404%
Combined Metals (kg)	--	2,230	1,253	1,583	--	-29%	26%
Non-chlorinated Phenols (kg)	20,000	nd	4.2	305	-98%	100%	7162%
Chlorinated Phenols (kg)	--	nd	nd	nd		nc	nc
Total DDT (kg)	--	nd	nd	nd	--	nc	nc
Total PAH (kg)	--	--	nd	nd		nc	nc
Total PCB (kg)	--	nd	nd	nd	--	nc	nc

[a] *Reproduced from SCCWRP (1973)*

[b] *Reproduced from Raco-Rands (1999)*

[c] *Reproduced from Steinberger and Schiff (2003)*

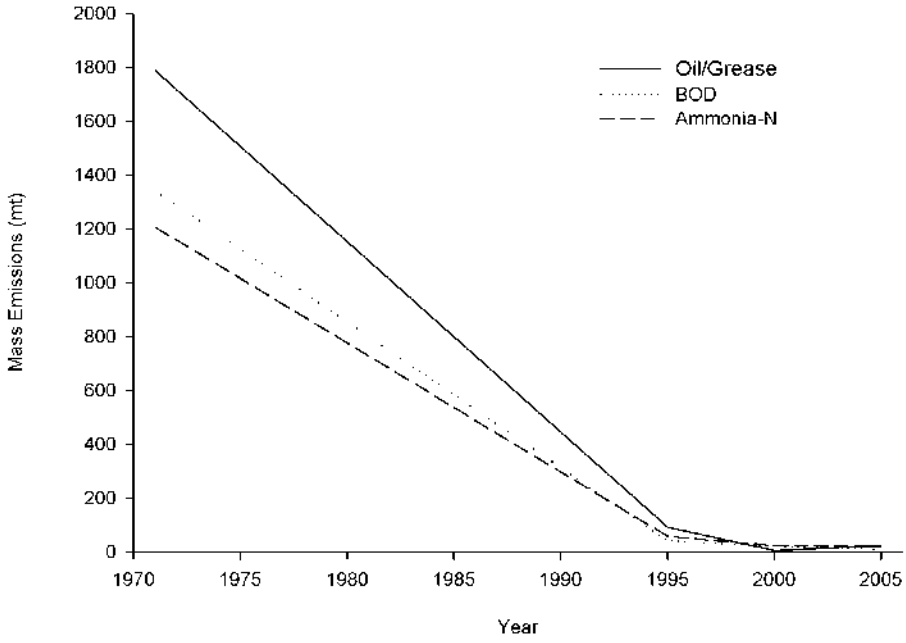

Figure 4. Cumulative mass emissions of selected general constituents from industrial facilities between 1971 and 2005.

from industrial facilities in 2005 would account for only 0.9% of the total combined effluent volume. Most constituent load contributions from industrial facilities were even lower than the 0.9% volume contribution (Table 5). Of the constituents common to both large POTWs and industrial facilities, only arsenic, mercury, selenium, and non-chlorinated phenols loads constituted relative contributions greater than 1% of the combined mass, ranging from 1.8% (mercury) to 15% (selenium).

Discussion

Since 1971 and the implementation of the Clean Water Act, the number of discharging industrial facilities and the volume of industrial effluent have dramatically decreased. More stringent regulatory limits have driven facilities with significant concentrations of priority contaminants to either invest in increasing treatment capabilities or to divert their effluent to POTWs for further treatment. The diversion of former ocean discharges from petroleum-related industrial facilities to the sanitary sewer system ensures that the most significant sources of industrial contaminant discharge (Steinberger and Schiff 2003) receive the highest level of treatment available before discharge. Unlike sources such as POTWs that are likely to continue increasing discharge volume in response to future population growth, industrial facilities seem more likely to decrease over time in response to regulation.

Industrial facilities continue to be a relatively minor source of contaminants to the SCB compared to large POTW discharges and non-point source runoff (Lyon and Stein 2009). Although effluent quality from large POTWs has been continually improving, they remain the primary point source of contaminants to the SCB (Steinberger and Stein 2004, Lyon *et al*. 2006, Lyon and Stein 2009). Mass emissions from industrial sources have followed a pattern similar to large POTWs, with drastic reductions of mass emissions since the 1970s. Even with the increase in 2005 mass emissions, industrial discharges contribute only a small fraction of the contaminant loading from point sources to the SCB.

The increases in industrial mass emissions observed in 2005 were likely caused by a combination of three factors: increased reporting requirements, increased discharge volume, and increased constituent concentrations. Increased monitoring and reporting requirements resulted in detected concentrations of many constituents that were not analyzed in 2000. This primarily affected metal loads; four of the five facilities were not required to analyze metals in 2000, and all had detectable concentrations for at least one metal in 2005. Increased constituent loads were also influenced by detected values of constituents whose concentrations were

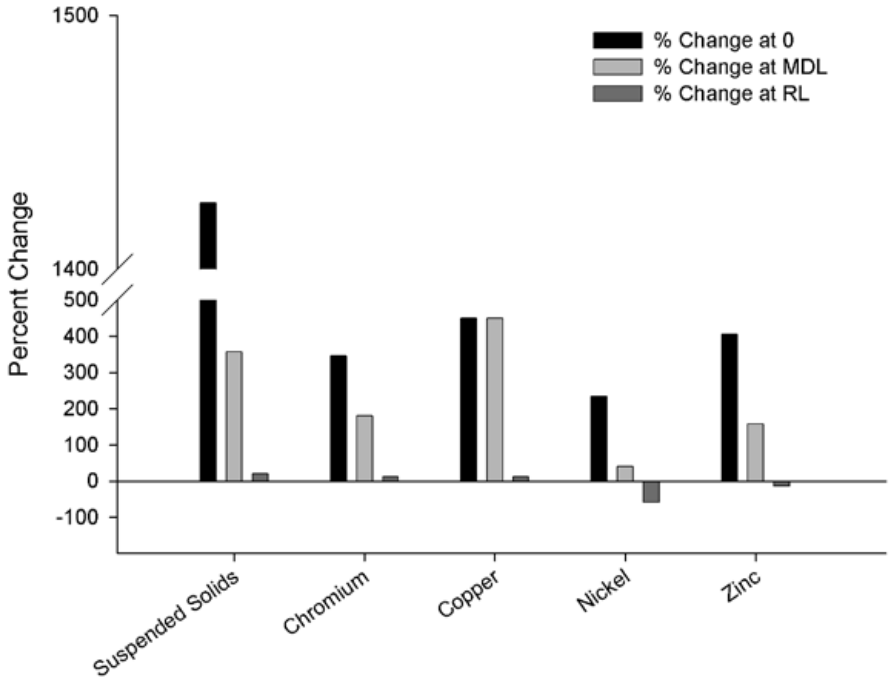

Figure 5. Percent change in mass emissions of selected constituents from the Chevron Refinery between 2000 and 2005 based on <RL results assigned values of 0, minimum detection limit (MDL), and reporting limit (RL).

Table 5. Estimated constituent mass emissions from industrial dischargers in 2005 compared to the most recent published large POTW emissions estimates from 2004. "—" = constituent was not analyzed or data were not available. nd = not detected.

Constituent	Combined Industrial Dischargers 2005	Combined Large POTWs 2004[a]	Relative Contribution from Industrial Dischargers
Volume (L x 10^6)	13.3	1,452.5	0.91%
Suspended Solids (mt)	114	37,451	0.30%
Settleable Solids (L x 10^3)	146	250,250	0.06%
BOD (mt)	8.4	54,261.9	0.02%
CBOD (mt)	59	--	100%
Oil/grease (mt)	22	7,267	0.30%
Ammonia-N (mt)	20	45,556	0.04%
Cyanide (kg)	0.20	3,559.96	0.01%
Arsenic (kg)	63	2,815	2.2%
Cadmium (kg)	0.03	266.87	0.01%
Chromium (kg)	5.8	2,158.4	0.27%
Copper (kg)	131	34,878	0.37%
Lead (kg)	1.9	2,129.9	0.09%
Mercury (kg)	0.18	10	1.8%
Nickel (kg)	59	25,328	0.23%
Selenium (kg)	1,035	5,787	15%
Silver (kg)	0.35	1,169.43	0.03%
Zinc (kg)	287	31,686	0.90%
Combined Metals (kg)	1,583	106,228	1.5%
Phenols (kg)	305	7,309	4.0%
Total DDT (kg)	nd	0.13	0%
Total PAH (kg)	nd	71	0%
Total PCB (kg)	nd	nd	nd

[a] *Reproduced from Lyon et al. (2006)*

below the RL in 2000. These constituent concentrations were counted as zero in 2000. Between 2000 and 2005, new requirements were issued that resulted in lower RLs and the requirement to report concentrations between the method detection limit (MDL) and the RL. These new requirements resulted in values being reported in 2005 for constituents that may have been present, but not reported in 2000. As a result, the increase in 2005 load estimates may be an artifact of the change in reporting. This scenario primarily affected suspended solids and metals from the Chevron refinery. The effect of the 2000 RLs on increases in Chevron mass emissions were analyzed by comparing the 2005 loads to a range of load estimates for 2000. The original load estimates for 2000 were determined by assigning a value of 0 for all results less than the RL. Middle and upper load estimates were then calculated by assigning the value of the 2000 MDL or RL, respectively, for all results less than the RL. The original suspended solids load estimate for 2000 was 7.5 mt, but if the actual concentration was between the MDL and RL, the total load could have been between 25 and 95 mt in 2000. This would greatly reduce the percent increase observed in the Chevron El Segundo refinery's suspended solids load for 2005 (Figure 5). The same pattern applies to chromium and copper, while nickel and zinc loads may have actually decreased from 2000 to 2005.

Another factor influencing the increase in mass emissions in 2005 was increased effluent volume. Although the number of discharging facilities decreased from seven in 2000 to five in 2005; overall effluent volume increased by 7%. This was primarily due to the greater volume discharged by the Sea World aquatic park compared to the Sea World research institute effluent included in the assessment of industrial discharges in 2000. Discharge from the entire facility resulted in a nearly 10-fold effective increase in effluent volume and significantly increased loads of solids, ammonia-N, and copper.

The final contributor to increased contaminant loads in 2005 was higher constituent concentrations. Annual average concentrations of several metals in Chevron El Segundo effluent, as well as suspended solids in effluent from Morton Salt and Sea World, were higher in 2005 than in 2000, though all were still below permit limits.

It is important to note that many industrial facilities may continue to discharge effluent to inland water bodies such as rivers that ultimately flow to the coastal ocean. These inputs are not included in the present study's assessments of direct ocean discharges. Effluent from the inland industrial facilities is not addressed in this assessment because the discharges are mixed with other watershed-based flows prior to reaching the ocean, confounding the ultimate impact of the discharges on the coastal ocean. Further, assessing the effluent from inland facilities along with the ocean discharging facilities would introduce the potential for duplicate reporting of the contaminants discharged from the inland facilities as their contributions are already included in analyses of runoff from the rivers they discharge into. A framework for compiling and analyzing regional runoff data to produce non-point source mass emission estimates is being initiated by SCCWRP and the southern California Stormwater Monitoring Coalition.

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Appendix I. Industrial facilities with discharges to the SCB in 2005.

Facilities	NPDES Permit	County	RWQCB Region	Facility Type	Effluent Types
Chevron El Segundo	CA0000337	Los Angeles	Los Angeles	Petroleum Refinery	Process water, cooling water, condensate, low volume wastes, stormwater
US Borax	CA0000787	Los Angeles	Los Angeles	Chemical Production Plant	Non-contact cooling water
Morton Salt Long Beach	CA0061476	Los Angeles	Los Angeles	Salt Processing Plant	Air scrubber process water
Scripps Institution of Oceanography	CA0107239	San Diego	San Diego	Research & Public Aquarium	Circulated seawater
Sea World	CA0107336	San Diego	San Diego	Public Aquarium & Aquatic Amusement Park	Circulated seawater, pool draining and cleaning water, facility washdown water, irrigation runoff

Appendix II. Frequency of constituent analyses by industrial facilities in 2005. "--" = not applicable. na = not analyzed.

Constituent	Chevron El Segundo	US Borax	Morton Salt Long Beach	Scripps Institution of Oceanography	Sea World
Suspended Solids	Weekly	Quarterly	Quarterly	Monthly	Quarterly
Settleable Solids	Monthly	Quarterly	Quarterly	Monthly	Quarterly
BOD	na	Quarterly	Semiannually	na	na
CBOD	Weekly	na	na	na	na
Oil/Grease	Weekly	Quarterly	Quarterly	Monthly	Semiannually
Ammonia-N	Weekly	na	na	Monthly	Semiannually
Cyanide	Monthly	Annually	Annually	Monthly	na
Turbidity	Monthly	Quarterly	Quarterly	Monthly	Semiannually
Acute Toxicity	--	--	--	--	--
Atherinops affinis (survival)	--	Quarterly	--	Quarterly	Annually
Pimephales promelas (survival)	Monthly	--	Annually	--	--
Chronic Toxicity	--	--	na	--	1 / 5 years
Atherinops affinis (growth)	--	--	--	Quarterly	--
Atherinops affinis (survival)	--	--	--	Quarterly	--
Dendraster excentricus (fertilization)	Monthly	--	--	Quarterly	--
Haliotis rufescens (development)	--	Annually	--	--	--
Macrocystis pyrifera (germination)	--	--	--	Quarterly	--
Macrocystis pyrifera (growth)	--	--	--	Quarterly	--
Strongylocentrotus purpuratus (fertilization)	Monthly	--	--	Quarterly	--
Arsenic	Monthly	Annually	Annually	Monthly	na
Cadmium	Monthly	Annually	na	Monthly	na
Chromium	Monthly	Annually	Annually	Monthly	na
Copper	Monthly	Quarterly	Annually	Monthly	Semiannually
Lead	Monthly	Quarterly	Annually	Monthly	na
Mercury	Monthly	Annually	Annually	Monthly	na
Nickel	Monthly	Annually	Annually	Monthly	na
Selenium	Monthly	Annually	Annually	Monthly	na
Silver	Monthly	Annually	Annually	Monthly	Semiannually
Zinc	Monthly	Quarterly	Annually	Monthly	na
Non-chlorinated Phenols	Monthly	Annually	Annually	Monthly	na
Chlorinated Phenols	Quarterly	Annually	Annually	Monthly	na
Total DDT	Annually	Quarterly	Annually	Monthly	na
Total PAH	Quarterly	Annually	Annually	na	na
Total PCB	Annually	Quarterly	Annually	na	na

Appendix III. Analytical methods used for constituent analyses by industrial facilities and/or contract laboratories in 2005. nf = not found. "--" = not applicable. na = not analyzed.

Constituent	Chevron El Segundo	US Borax	Morton Salt Long Beach	Scripps Institution of Oceanography	Sea World
Suspended Solids	EPA 160.2	EPA 160.2	EPA 160.2	SM 2540 D	EPA 160.2
Settleable Solids	EPA 160.5	EPA 160.5	EPA 160.5	SM 2540 F	EPA 160.5
BOD	na	SM 5210 B	EPA 405.1	na	na
CBOD	SM 5210 B	na	na	na	na
Oil/Grease	EPA 1664 A	EPA 1664 A	EPA 1664 A	EPA 1664 A	EPA 1664 A
Ammonia-N	SM 4500-NH3	na	na	SM 4500-NH3	EPA 350.2
Cyanide	EPA 335.2	EPA 9010	EPA 335.2	SM 4500-CN	na
Turbidity	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1	EPA 180.1
Acute Toxicity	--	--	--	--	--
Atherinops affinis (survival)	--	EPA/600/4-90/027F	--	EPA-821-R-02-012	EPA-821-R-02-012
Pimephales promelas (survival)	EPA/600/4-85/013	--	EPA 2000.0	--	--
Chronic Toxicity	--	--	na	--	nf
Atherinops affinis (growth)	--	--	--	EPA 600/R-95/136	--
Atherinops affinis (survival)	--	--	--	EPA 600/R-95/136	--
Dendraster excentricus (fertilization)	EPA/600/R-95/136	--	--	EPA 600/R-95/136	--
Haliotis rufescens (development)	--	EPA/600/R-95/136	--	--	--
Macrocystis pyrifera (germination)	--	--	--	EPA 600/R-95/136	--
Macrocystis pyrifera (growth)	--	--	--	EPA 600/R-95/136	--
Strongylocentrotus purpuratus (fertilization)	EPA/600/R-95/136	--	--	EPA 600/R-95/136	--
Arsenic	EPA 206.2	SOP 7040	EPA 6010 B	EPA 1640	na
Cadmium	EPA 213.2	SOP 7040	na	EPA 1640	na
Chromium	EPA 218.2	SOP 7040	EPA 6010 B	EPA 1640	na
Copper	EPA 220.2	SOP 7040	EPA 6010 B	EPA 1640	EPA 1610 B
Lead	EPA 239.2	SOP 7040	EPA 6010 B	EPA 1640	na
Mercury	EPA 245.1	SOP 7040	EPA 6010 B	EPA 1640	na
Nickel	EPA 249.2	SOP 7040	EPA 6010 B	EPA 1640	na
Selenium	EPA 270.2	SOP 7040	EPA 6010 B	EPA 1640	na
Silver	EPA 272.2	SOP 7040	EPA 6010 B	EPA 1640	EPA 1610 B
Zinc	EPA 200.7	SOP 7040	EPA 6010 B	EPA 1640	na
Non-chlorinated Phenols	SM 510	EPA 625	EPA 625	EPA 625	na
Chlorinated Phenols	EPA 625	EPA 625	EPA 625	EPA 625	na
Total DDT	EPA 608	EPA 608	EPA 608	EPA 625	na
Total PAH	EPA 625	EPA 625	EPA 625	na	na
Total PCB	EPA 608	EPA 608	EPA 608	na	na

Appendix IV. Reporting limits used for constituent analyses by industrial facilities and/or contract laboratories in 2005. nf = not found. "--" = not applicable. na = not analyzed.

Constituent	Units	Chevron El Segundo	US Borax	Morton Salt Long Beach	Scripps Institution of Oceanography	Sea World
Suspended Solids	mg/L	10	1	10	0.5	1
Settleable Solids	mL/L	0.1	0.1	0.1	0.1	0.1
BOD	mg/L	na	0.8	5	na	na
CBOD	mg/L	2	na	na	na	na
Oil/Grease	mg/L	5	0.3	5	5	1
Ammonia-N	mg/L	0.5	na	na	0.05	0.1
Cyanide	mg/L	0.025	0.02	0.05	0.005	na
Turbidity	NTU	1	0.1	1	2	0.5
Acute Toxicity	TUa	--	--	--	--	--
Atherinops affinis (survival)	TUa	--	0	--	nf	nf
Pimephales promelas (survival)	TUa	0	--	nf	--	--
Chronic Toxicity	TUc	--	--	na	--	nf
Atherinops affinis (growth)	TUc	--	--	--	nf	--
Atherinops affinis (survival)	TUc	--	--	--	nf	--
Dendraster excentricus (fertilization)	TUc	10	--	--	nf	--
Haliotis rufescens (development)	TUc	--	nf	--	--	--
Macrocystis pyrifera (germination)	TUc	--	--	--	nf	--
Macrocystis pyrifera (growth)	TUc	--	--	--	nf	--
Strongylocentrotus purpuratus (fertilization)	TUc	10	--	--	nf	--
Arsenic	µg/L	1	2	10	0.015	na
Cadmium	µg/L	1	0.25	na	0.01	na
Chromium	µg/L	2	0.5	10	0.01	na
Copper	µg/L	2	0.5	10	0.01	5
Lead	µg/L	1	0.5	5	0.01	na
Mercury	µg/L	0.2	0.5	2	0.01	na
Nickel	µg/L	2	1	10	0.01	na
Selenium	µg/L	2	2	10	0.015	na
Silver	µg/L	1	0.25	10	0.01	5
Zinc	µg/L	20	1	10	0.01	na
Non-chlorinated Phenols	µg/L	100	1	1	0.2	na
Chlorinated Phenols	µg/L	95	1	1	0.2	na
Total DDT	µg/L	0.6	0.04	0.1	0.005	na
Total PAH	µg/L	142.5	1	10	na	na
Total PCB	µg/L	3.5	0.5	0.65	na	na