Characteristics of effluents from power generating stations in the Southern California Bight in 2000

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ABSTRACT - There are 13 power generating stations (PGSs) in southern California, and their effluent constitutes a source of contaminants to the Southern California Bight (SCB). To determine the relative contribution of PGS effluent to total mass emissions to the SCB, this study evaluated PGS discharges to the SCB in 2000 and compared them to emissions from large municipal wastewater treatment facilities (POTWs). Data regarding PGS discharges were obtained from compliance monitoring reports, and were used to quantify discharges to the SCB in terms of overall annual volumes, constituent mass emissions, and average concentrations. The PGSs discharged 20 billion liters of wastes in 2000, which contained relatively high quantities of oil and grease, suspended solids, and ammonia-N. However, compared to large POTWs, PGSs were a minor source of contaminants to the SCB.

INTRODUCTION

There are 13 power generating stations (PGSs) operating within the SCB (Figure 1; Table 1). Twelve of these facilities are conventional thermal power plants that use coal or natural gas to produce electricity; one plant, the San Onofre Nuclear Generating Station (SONGS), utilizes nuclear energy to generate electricity. The PGSs discharge a variety of waste streams to the coastal ocean such as sanitary wastes, metal cleaning wastes, and other low-volume wastes. These in-plant wastes are not treated, but are generally discharged into the cooling water waste stream (seawater that is used to cool heat generating components in the plant) before discharge to receiving waters (Figure 2). This combined waste stream of in-plant wastes and cooling water may contain contaminants such as metals, nutrients, and suspended solids that are harmful to the marine environment.

Discharges from PGSs are regulated by a number of different state and federal agencies, including the Regional Water Quality Control Boards (RWQCB) and the California Environmental Protection Agency. Monitoring and reporting of power plant discharges is required by the Clean Water Act, Section 402 under National Pollution Discharge Elimination System (NPDES) permits. Permit requirements include the frequent monitoring and reporting of discharges for a suite of contaminants such as metals, organics, and general constituents (i.e., suspended solids, oil, and grease). However, NPDES monitoring does not include an assessment of the annual and long-term contribution of contaminants from PGSs. For environmental managers to make sound decisions regarding southern California's coastal resources, it is important to quantify the contribution of PGSs to overall contaminant loading in the region relative to other discharges.

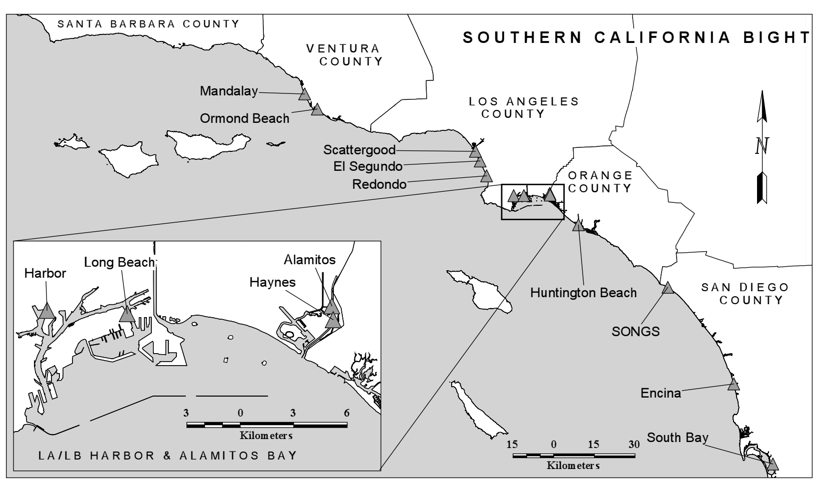

Figure 1. Locations of power generating stations in the Southern California Bight (SCB).

Table 1. Power generating stations in the SCB in 2000.

Facility	NPDES Permit Number	County	Receiving Waters	Operator
Alamitos Generating Station	CA0001139	Los Angeles	San Gabriel River	AES Pacific
El Segundo Generating Station	CA0001147	Los Angeles	Santa Monica Bay	NRG Energy/Destec Energy, Inc.
Encina Power Plant	CA0001350	San Diego	San Diego Coastal	Cabrillo Power I LCC
Harbor Generating Station	CA0000361	Los Angeles	Los Angeles Harbor	City of Los Angeles Department of Water and Power
Haynes Generating Station	CA0000353	Los Angeles	San Gabriel River	City of Los Angeles Department of Water and Power
Huntington Beach Generating Station	CA0001163	Orange	Orange County Coastal	AES Pacific
Long Beach Generating Station	CA0001171	Los Angeles	Long Beach Harbor	Southern California Edison
Mandalay Generating Station	CA0001180	Ventura	Ventura Coastal	Houston Industries Power Generations, Inc.
Ormond Beach Generating Station	CA0001198	Ventura	Ventura Coastal	Southern California Edison
Redondo Generating Station	CA0001201	Los Angeles	Santa Monica Bay	AES Pacific
San Onofre Nuclear Generating Station (001)	CA0001228	San Diego	San Diego Coastal	Southern California Edison
San Onofre Nuclear Generating Station (002)	CA0108073	San Diego	San Diego Coastal	Southern California Edison
San Onofre Nuclear Generating Station (003)	CA0108181	San Diego	San Diego Coastal	Southern California Edison
Scattergood Generating Station	CA0000370	Los Angeles	Santa Monica Bay	City of Los Angeles Department of Water and Power
South Bay Power Plant	CA0001368	San Diego	San Diego Bay	San Diego Gas and Electric Company

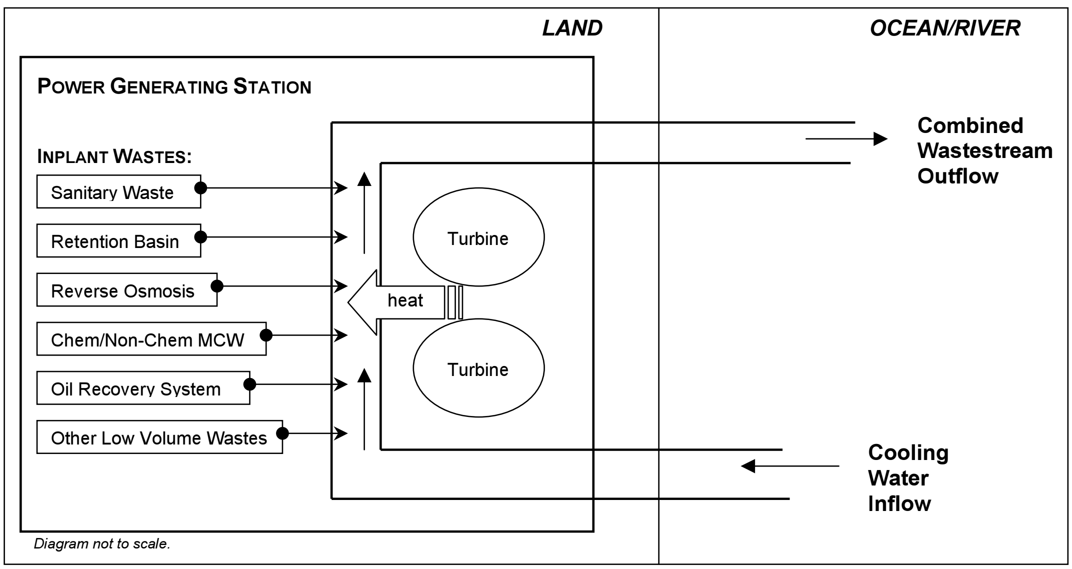

Figure 2. Simple schematic diagram of wastestream discharges from power generating stations.

PGS discharges in 2000 from the 13 facilities operating in southern California were characterized in terms of total annual discharge volumes, constituent mass emissions, and constituent concentrations. PGS discharges were also compared to effluents from large municipal wastewater treatment facilities (POTWs) in 2000. Since large POTWs are historically the most significant source of constituent emissions to the SCB (Steinberger and Schiff 2003), this latter assessment allowed us to gauge the relative significance of PGS discharges to the SCB.

METHODS

Data for PGS discharges in 2000 were obtained directly from monthly, quarterly, and annual discharge monitoring reports (DMRs) submitted by the individual facilities to the respective regional water quality control board (San Diego, Los Angeles, or Santa Ana) in compliance with NPDES permit requirements. Information also was obtained directly from the discharging agencies when necessary.

For 3 of the 13 facilities (Huntington, Scattergood, and South Bay), DMRs for certain months could not be found, resulting in data gaps for various portions of the year. When data existed for at least a part of the year, the arithmetic mean value of the available data was used to populate months in which no data existed, operating on the assumption that discharges were continuous throughout the year and constituent concentrations during the year were not highly variable. This interpolation was necessary for approximately 10% of the constituent values at the three facilities for which data were missing.

The in-plant and combined waste streams were evaluated in terms of volume, constituent mass emissions (MEs), and annual average flow-weighted constituent concentrations (FWCs). In-plant waste streams varied from one facility to the next, but included such discharges as boiler blowdown wastes, chemical and non-chemical metal cleaning wastes, sanitary wastes, and retention basin wastes (Table 2; Figure 2). Characterization of the total in-plant waste stream used data provided by the facilities for the individual waste streams. Characterization of the combined waste stream used data from chemical analyses of the cooling water discharges after injection of the in-plant waste streams.

Monthly discharge volumes for the combined and in-plant waste streams were calculated from monthly flow values reported by the individual facilities, then summed over all months in the year (i = 1-12) to obtain the total annual discharge volume (V):

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

where, F was the monthly flow, T was the number of days in the given month, and u was the unit conversion factor for reporting discharge volumes in liters (L).

Annual constituent MEs were calculated from the reported monthly constituent concentrations and the average monthly flows for the given waste

Table 2. Inplant waste types discharged by power-generating stations in 2000.

Facility	In-plant Wastes
Alamitos	Sanitary Waste, Low Volume Waste, MCW
El Segundo	Chemical and Non-chemical MCW, Retention Basin, Sanitary Waste
Encina	Low Volume Waste, MCW
Harbor	MCW[a], Makeup Demineralizer[b], Reverse Osmosis[b]
Haynes	Chemical MCW, Reverse Osmosis, Sanitary Waste, Settling Basin
Huntington	Retention Basin, Cooling Water[c]
Long Beach	Oil Recovery System, Retention Basin
Mandalay	Low Volume Waste, MCW
Ormond Beach	Low Volume Waste, MCW
Redondo Beach	MCW, Retention Basin, Yard Drains, and Dewatering Pumps
Scattergood	Chemical and Non-chemical MCW, Cooling Tower Blowdown, Rainfall Runoff, Reverse Osmosis, Settling Basin
South Bay	na
SONGS-001	MCW, Plant Drains, Radwaste System, Sanitary Waste, Steam Generator, Building Sumps
SONGS-002	Condenser Hotwell, Full Flow Condenser, Intake Sump, Low Volume Waste, Makeup Demineralizer, MCW, Radwaste System, Steam Generator, Blowdown Processing, Building Sumps
SONGS-003	Condenser Hotwell, Full Flow Condenser, Intake Sump, Low Volume Waste, Makeup Demineralizer, MCW, Radwaste System, Steam Generator

[a] No discharge of this waste stream in 2000.

[c] Not an in-plant waste.
MCW = Metal cleaning wastes; may be either chemical, non-chemical, or both, when not specified.
Low Volume Waste = May be a combination of a number of unspecified waste streams (i.e., retention basin, reverse osmosis)
na = Not analyzed; only combined discharge analyzed at South Bay in 2000.

stream, then summed over all months to obtain the annual constituent MEs:

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

where, F was the monthly flow for a given discharge type, C was the constituent concentration reported by the platforms, T was the number of days in the given month, and y was the unit conversion factor for reporting the estimated MEs in metric tons (mt). For ME calculations, non-detectable analytical results were assigned a value of zero.

The FWCs were calculated using the estimated annual MEs normalized by the annual discharge volumes from each facility:

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

Total discharge volumes and MEs calculated for in-plant waste streams in 2000 were compared to a previous assessment conducted in 1994 (Raco-Rands 1996) to assess trends in PGS discharges between 1994 and 2000.

Total volumes and MEs from all PGSs combined were compared to total discharges from large POTWs (discharge >100 mgd) in 2000, to assess the relative contribution of PGS discharges to overall emissions in the SCB. Annual volumes and MEs for large POTWs in 1994 and 2000 were taken from Steinberger and Schiff (2003). Discharge volumes and constituent MEs from the two sources were compared in terms of the relative percent difference (RPD) between estimates for each of the sources:

$$RPD = \frac{(LP - PP)}{(LP + PP)/2}100$$

where LP was the estimate under comparison for large POTWs, and PP was the respective estimate for power plants. A negative value for the RPD in this comparison indicated that the estimate for PGSs was higher.

RESULTS

Power Generating Station Discharges in 2000

In-plant wastes

Twenty billion liters of in-plant wastes were injected into the cooling water waste streams of PGSs in 2000 (Table 3). Almost 81% of the total in-plant waste stream volume was discharged by SONGS. The total in-plant waste stream from all PGSs combined contained 94 mt of suspended solids and almost 18 billion liters of settleable solids. Long Beach and SONGS combined accounted for 86% of

Table 3. Estimated constituent mass emissions from in-plant wastestream discharges to the SCB from individual power generating stations [a,b,c] in 2000.

Grouping Level	Units	Alamitos	El Segundo	Encina	Haynes	Huntington	Long Beach	Mandalay	Ormond Beach	Redondo	Scattergood	SONGS	TOTAL
Volume	L x 10^9	0.11	0.22	0.14	0.31	0.15	1.99	0.11	0.56	0.00	0.15	16	20
Total Suspended Solids	mt	1.2	3.3	0.17	1.5	1.2	20	0.42	3.3	0.01	1.9	61	94
Settleable Solids	L x 10^6	--	nd	--	--	--	--	--	--	--	--	18	18
Settleable Solids	kg	0.46	--	--	--	--	nd	--	--	--	--	--	0.46
Ammonia-N	mt	--	--	nd	--	--	--	--	--	--	--	2.4	2.4
BOD	mt	0.13	0.01	--	--	--	nd	--	--	--	--	--	0
Oil/Grease	mt	0.42	0.61	0.21	0.09	0.26	1.5	0.25	1.3	0.005	0.17	46	51
Cyanide	kg	--	--	nd	--	--	--	--	--	--	--	nd	nd
Arsenic	kg	--	nd	0.04	--	--	nd	--	--	--	--	nd	0.04
Cadmium	kg	--	nd	nd	--	--	nd	--	--	--	--	nd	nd
Total Chromium	kg	--	0.01	0.23	--	--	nd	--	--	--	0.19	2.9	3.3
Chromium,III	kg	--	--	0.23	--	--	--	--	--	--	--	nd	0.23
Chromium,VI	kg	--	nd	--	--	--	--	--	--	--	--	2.9	2.9
Copper	kg	--	1.2	2.4	--	--	--	--	--	--	--	12	16
Iron	kg	--	59	--	--	--	--	--	--	--	--	nd	59
Lead	kg	--	nd	0.23	--	--	0.003	--	--	--	--	nd	0.23
Mercury	kg	--	nd	nd	--	--	--	--	--	--	--	nd	nd
Nickel	kg	--	0.78	0.34	--	--	--	--	--	--	--	nd	1.1
Selenium	kg	--	nd	nd	--	--	--	--	--	--	--	nd	nd
Silver	kg	--	nd	nd	--	--	--	--	--	--	--	nd	nd
Zinc	kg	--	0.15	nd	--	--	--	--	--	--	0.45	27	28

[a] South Bay did not analyze in-plant waste streams in 2000.
[b] Constituent mass emissions for in-plant waste streams could not be calculated for Harbor in 2000, since necessary data are not available.
[c] In-plant waste stream volume for Harbor in 2000 was 0.14 L x 10^9.
Dash = Not Analyzed.
nd = Not detected.

the total suspended solids contribution, and SONGS alone accounted for 90% of the oil/grease contribution with a discharge of 46 mt. Only four facilities analyzed for settleable solids and SONGS was the most significant discharger of this constituent. Metals were only analyzed by four facilities; among these facilities, only copper, chromium, and zinc were detected in appreciable quantities. Estimates for organic compounds, such as total phenols, PCBs and DDTs, were calculated, though not included in the results since the estimates were consistently below detection levels.

In terms of annual average constituent concentrations, the highest concentrations of suspended solids in the in-plant waste stream were discharged by El Segundo (14.8 mg/L), Scattergood (12.2 mg/L), Alamitos (10.6 mg/L), and Long Beach (9.9 mg/L) (Table 4). Although SONGS had the highest mass emissions of suspended solids, this facility had one of the lowest concentrations of suspended solids in its in-plant waste stream. The concentration of settleable solids in SONGS in-plant waste stream was also much lower than most standard detection levels for this constituent. The highest concentrations of oil/grease were found in the in-plant waste streams of Alamitos (3.6 mg/L) and SONGS (2.9 mg/L), though these concentrations were much lower than concentrations usually found in large POTW waste streams (Steinberger and Schiff 2003). Concentrations of metals in in-plant waste streams varied among the facilities that analyzed for these compounds.

Combined Wastes

The total volume of effluents, cooling water, and in-plant wastes discharged by PGSs in 2000 was 9,837 billion liters (Table 5). The SONGS facility accounted for almost 33% of this total volume; each of the other 14 facilities individually accounted for no more than 12% of the total volume in 2000. Though only two facilities analyzed the combined waste stream for suspended solids (Encina and South Bay), a total of 8,626 mt were discharged in 2000. Despite a notable quantity of settleable solids in the in-plant waste stream, settleable solids were not detected in the combined waste stream at SONGS, and were not analyzed by any other facility. In 2000, only South Bay and Encina analyzed the combined waste stream for oil/grease; these two facilities combined discharged 1,671 mt of oil/grease in the combined waste stream, almost 55% of which was contributed by Encina.

The concentrations of most constituents in the combined waste stream were relatively low (Table 6). Residual chlorine was detected in the effluents of nearly all of the facilities that analyzed for this constituent. Concentrations of oil/grease, analyzed by only South Bay and Encina, were estimated at 1.1 mg/L for both facilities. The larger overall load of oil/grease delivered by Encina was a result of the greater discharge volume from this facility. Metals were most often not detected in the combined waste stream of PGSs, with the exception of the Haynes facility, which detected 5 of the 10 metals included in this assessment.

Acute and chronic toxicity bioassays were conducted on effluents from the combined waste stream for most facilities, though toxicity was not tested on any in-plant waste streams (Table 6). Acute toxicity was tested by Encina, Huntington, SONGS, and South Bay using the species *Atherinops affinis* (topsmelt), *Haliotis rufescens* (red abalone), or *Menidia beryllina* (silversides). Encina tested acute toxicity using all three of these species. Acute toxicity levels ranged from non-detectable levels to 3.5 TUa.

Chronic toxicity bioassays were conducted by all of the PGSs using either *Atherinops affinis*, *Haliotis rufescens*, *Macrocystis pyrifera* (giant kelp), or *Menidia beryllina*. Chronic toxicities in combined waste streams ranged from non-detectable levels to 8.5 TUc at the SONGS facility; the species used for SONGS toxicity bioassays was not indicated in the discharge monitoring data.

Power Generating Stations vs. Large POTWs

The total discharge volume of the combined waste stream from PGSs in 2000 was almost seven times higher than the total effluent volume discharged by large POTWs (Table 7). Despite having a lower overall discharge volume, large POTWs discharged over seven times more suspended solids and almost nine times more oil/grease than PGSs. Large POTWs contributed more metals to the SCB; however, the combined waste stream of PGSs contained greater quantities of arsenic, cadmium, total chromium, and zinc than did large POTW effluents (Table 7).

Comparison of large POTW effluents to the in-plant waste stream from PGSs revealed that constituent mass emissions in large POTW effluents eclipse constituent loads in in-plant waste from PGSs (Table 7). The RPDs for this comparison ranged from 89-100%.

Table 4. Annual average flow-weighted constituent concentrations and coefficients of variation (CV) for in-plant wastestreams discharged by power generating stations to the SCB in 2000. Estimates below the detection level were reported as less than the RL used in 2000, if multiple RLs were used in the year the greatest RL was reported here.

GroupingLevel	Units	Alamitos		El Segundo		Encina		Haynes		Huntington		Long Beach		Mandalay		Ormond Beach		Redondo		Scattergood		SONGS	
		Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Total Suspended Solids	mg/L	10.6	44	14.8	41.0	1.2	110	5.0	89	8.2	52	9.9	51.0	3.7	78	5.9	82	2.8	127	12.2	123	3.9	53
Settleable Solids	ml/L	--	--	nd	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.001	156
Settleable Solids	mg/L	0.004	148	--	--	--	--	--	--	--	--	nd	na	--	--	--	--	--	--	--	--	--	
Turbidity	NTU	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.02	68
Ammonia-N	mg/L	--	--	--	--	< 0.028	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.15	103
BOD	mg/L	1.1	65	0.05	133	--	--	--	--	--	--	< 1	na	--	--	--	--	--	--	--	--	--	
Oil/grease	mg/L	3.6	68	2.8	131	1.5	52	0.30	154	1.7	65	0.76	235	2.2	14	2.4	23	1.9	145	1.1	43	2.9	56
Cyanide	ug/L	--	--	--	--	< 0.005	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 20	na
Arsenic	ug/L	--	--	< 15	na	0.30	141	--	--	--	--	< 0.015	na	--	--	--	--	--	--	--	--	< 20	na
Cadmium	ug/L	--	--	< 5	na	< 0.5	na	--	--	--	--	< 0.005	na	--	--	--	--	--	--	--	--	< 5	na
Chromium	ug/L	--	--	0.04	--(1)	1.6	9	--	--	--	--	< 0.005	na	--	--	--	--	--	--	1.2	154	--	
Chromium,III	ug/L	--	--	--	--	1.6	9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 10	na
Chromium,VI	ug/L	--	--	< 7	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.18	141
Copper	ug/L	--	--	5.4	141	17	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.76	141
Iron	ug/L	--	--	265	136	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 200	na
Lead	ug/L	--	--	< 10	na	1.6	141	--	--	--	--	0.001	--(1)	--	--	--	--	--	--	--	--	< 20	na
Mercury	ug/L	--	--	< 0.5	na	< 0.2	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 1	na
Nickel	ug/L	--	--	3.5	--(1)	2.4	141	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 20	na
Selenium	ug/L	--	--	< 15	na	< 50	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 20	na
Silver	ug/L	--	--	< 5	na	< 0.5	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 20	na
Zinc	ug/L	--	--	0.68	--(1)	< 10	na	--	--	--	--	--	--	--	--	--	--	--	--	2.9	197	1.7	3

nd = Not detected; reporting limit/method detection limit not provided.
na = Not applicable, estimate below detection levels.
Dash = Not analyzed, or not enough information reported by facility to calculate an estimate.
--(1) = Only one analysis conducted during year, CV not applicable.

Table 5. Estimated constituent mass emissions from combined wastestream discharges to the SCB from individual power generating stations [a,b] in 2000.

Constituent	Units	Alamitos	El Segundo	Encina	Haynes	Long Beach	Mandalay	Ormond Beach	Redondo	Scattergood	SONGS	South Bay	**TOTAL**
Volume	L x 10^9	1,146	570	796	1,011	138	351	675	913	351	3,215	672	9,837
Total Suspended Solids	mt	--	--	3,696	--	--	--	--	--	--	--	4,930	8,626
Settleable Solids	L	--	--	--	--	--	--	--	--	--	nd	--	nd
Ammonia-N	mt	nd	nd	--	--	--	nd	0.09	nd	--	7,681	nd	7,681
Nitrate-N	mt	nd	nd	--	--	--	0.17	nd	93	--	--	--	93
Oil/Grease	mt	--	--	912	--	--	--	--	--	--	--	759	1,671
Residual Chlorine	mt	71	48	nd	--	7.1	67	101	67	--	26	22	408
Cyanide	mt	--	--	--	--	--	--	--	--	--	nd	nd	nd
Arsenic	mt	nd	nd	1.5	5.5	--	nd	nd	nd	nd	1.5	1.7	4.8
Cadmium	mt	nd	nd	nd	2.4	--	nd	nd	nd	1.2	nd	nd	1.2
Chromium	mt	5.9	3.0	nd	--	--	--	3.0	nd	--	--	0.94	13
Chromium,III	mt	--	--	--	--	--	1.8	--	--	nd	--	--	1.8
Chromium,VI	mt	2.2	--	--	5.1	--	nd	nd	nd	nd	nd	--	2.2
Copper	mt	2.7	1.2	nd	nd	--	1.3	nd	nd	nd	nd	nd	5.2
Lead	mt	nd	nd	nd	1.7	--	nd	nd	nd	nd	nd	nd	nd
Mercury	mt	nd	nd	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Nickel	mt	nd	nd	nd	nd	--	nd	nd	nd	nd	nd	nd	nd
Selenium	mt	nd	nd	--	--	--	nd	nd	nd	nd	nd		nd
Silver	mt	nd	nd	--	nd	--	nd	nd	nd	nd	nd	nd	nd
Zinc	mt	21	14	nd	20	--	7.0	8.0	nd	5.6	36	nd	93

[a] Harbor and Huntington only analyzed toxicity in the combined waste stream; toxicity data not applicable to mass emission estimates.

[b] Discharge volumes of the combined waste stream from Harbor and Huntigton in 2000 were 93 and 227 L x 10^9, respectively.

Dash = Not analyzed.

nd = Not detected.

Table 6. Annual average flow-weighted constituent concentrations and coefficients of variation (CV) in the combined wastestream discharged by power generating stations to the SCB in 2000. Estimates below the detection level were reported as less than the RL used in 2000. If multiple RLs were used in the year, the greatest RL was reported here.

		Alamitos		El Segundo		Encina		Harbor		Haynes		Huntington		Long Beach		Mandalay		Ormond Beach		Redondo		Scattergood		SONGS		South Bay	
Constituent	Units	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)	mean	CV(%)
Total Suspended Solids	mg/L	--	--	--	--	4.6	115	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.3	66.0
Settleable Solids	ml/L	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 0.1	na	--	--
Turbidity	NTU	--	--	--	--	0.6	107	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3.6	47	--	--
Oil/Grease	mg/L	--	--	--	--	1.1	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.1	42.0
Residual Chlorine	mg/L	0.06	39	0.08	60.00	< 0.2	na	--	--	--	--	--	--	0.05	81.00	0.19	4.00	0.15	44	0.07	115	--	--	0.01	84.00	0.03	76.00
Ammonia-N	mg/L	< 0.05	na	< 0.05	na	--	--	--	--	--	--	--	--	--	--	< 0.05	na	0.0001	0	< 0.05	na	--	--	2.4	2.0	< 0.028	na
Nitrate-N	mg/L	< 0.05	na	< 0.05	na	--	--	--	--	--	--	--	--	--	--	0.0005	--(1)	< 0.0005	na	0.10	--(1)	--	--	--	--	--	--
Cyanide	ug/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	< 20	na	< 5	na
Arsenic	ug/L	< 20	na	< 0.015	na	1.9	7	--	--	5.4	49	--	--	--	--	< 20	na	< 15	na	< 20	na	< 5	na	0.47	173	2.6	--(1)
Cadmium	ug/L	< 3	na	< 5	na	< 0.5	na	--	--	2.3	35	--	--	--	--	< 3	na	< 5	na	< 3	na	3.4	--(1)	< 5	na	< 0.5	na
Chromium	ug/L	5.1	141	5.3	173.0	< 0.5	na	--	--	--	--	--	--	--	--	--	--	4.5	141	< 20	na	--	--	--	--	1.4	--(1)
Chromium, III	ug/L	--	--	--	--	--	--	--	--	--	--	--	--	--	--	5.0	141	--		--	--	< 5	na	--	--	--	--
Chromium,VI	ug/L	2.0	141	--	--	--	--	--	--	5.1	141	--	--	--	--	< 7	na	< 7	na	< 7	na	< 10	na	< 10	na	--	--
Copper	ug/L	2.4	141	2.0	173.0	< 2.5	na	--	--	< 5	na	--	--	--	--	3.8	141	< 5	na	< 5	na	< 5	na	< 30	na	< 2.5	na
Lead	ug/L	< 7	na	< 10	na	< 2.5	na	--	--	1.7	141	--	--	--	--	< 7	na	< 10	na	< 7	na	< 5	na	< 20	na	< 2.5	na
Mercury	ug/L	< 1	na	< 0.5	na	< 0.2	na	--	--	< 0.2	na	--	--	--	--	< 0.1	na	< 0.5	na	< 0.1	na	< 0.2	na	< 1	na	< 0.5	na
Nickel	ug/L	< 15	na	< 5	na	< 5	na	--	--	< 5	na	--	--	--	--	< 15	na	< 5	na	< 15	na	< 5	na	< 20	na	< 2.5	na
Selenium	ug/L	< 50	na	< 15	na	--	--	--	--	--	--	--	--	--	--	< 50	na	< 15	na	< 50	na	< 5	na	< 20	na	--	--
Silver	ug/L	< 2	na	< 5	na	--	--	--	--	< 5	na	--	--	--	--	< 2	na	< 5	na	< 2	na	< 5	na	< 20	na	< 0.5	na
Zinc	ug/L	19	141	25	93	< 10	na	--	--	20	41	--	--	--	--	20	141	12	141	< 50	na	16	--(1)	11	87	< 10	na
Acute Toxicity	TUa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Atherinops affinis (survival)	TUa	--	--	--	--	1.4	59	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.43	81	--	--
Haliotis rufescens (survival)	TUa	--	--	--	--	3.5	29	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Menidia beryllina (survival)	TUa	--	--	--	--	0.34	141	--	--	--	--	< 1.0	na	--	--	--	--	--	--	--	--	--	--	--	--	0.58	16.00
Chronic Toxicity	TUc	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.5	38	--	--	--	--	--	--	8.5	--(1)	--	--
Atherinops affinis (growth)	TUc	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 1.0	na	--	--
Haliotis rufescens [a]	TUc	--	--	--	--	--	--	1.0	0	--	--	< 1.0	na	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Haliotis rufescens (development)	TUc	--	--	0.49	121.00	--	--	--	--	--	--	--	--	1.0	0.0	1.3	43	--	--	--	--	< 1.0	na	--	--	--	--
Haliotis rufescens (normality)	TUc	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 3.125	na	--	--
Haliotis rufescens (survival)	TUc	--	--	--	--	--	--	--	--	1.0	18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Macrocystis pyrifera (germ tube length)	TUc	1.0	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	< 3.125	na	nd	na
Macrocystis pyrifera (germination)	TUc	1.0	0	--	--	4.6	56	--	--	--	--	--	--	--	--	1.0	0	--	--	--	--	--	--	1.3	173	nd	na
Macrocystis pyrifera (growth)	TUc	--	--	--	--	33	--(1)	--	--	--	--	--	--	--	--	1.0	0	--	--	--	--	--	--	< 3.125	na	--	--
Menidia beryllina (growth)	TUc	--	--	0.19	--(1)	--	--	--	--	--	--	--	--	1.0	--(1)	1.0	0	1.0	0	--	--	--	--	--	--	--	--
Menidia beryllina (survival)	TUc	--	--	0.19	--(1)	--	--	--	--	--	--	--	--	1.0	--(1)	5.0	85	1.0	0	--	--	--	--	--	--	--	--

[a] Specific chronic toxicity test not indicated.
nd = Not detected; reporting limit/method detection limit not provided.
na = Not applicable, estimate below detection levels.
Dash = Not analyzed/not applicable.
(1) = Only one analysis conducted during year, CV not applicable

Table 7. Volume and constituent mass emissions totals for the combined and in-plant waste streams for power generating stations (PGS) and for large POTWs in 2000; and the relative percent difference (RPD) between the volume and estimated constituent mass emissions for the PGS combined waste stream and in-plant waste stream versus large POTW effluents.

Constituent	Units	PGS Combined TOTAL	PGS In-plant TOTAL	Large POTW TOTAL	RPD Combined vs. Large POTW	RPD Inplant vs. Large POTW
Volume	L x 10^9	9,837	20	1,489	-74	97
Total Suspended Solids	mt	8,626	37	64,631	76	100
Settleable Solids	L x 10^6	nd	18	308	100	89
Ammonia-N	mt	7,681	2.4	42,567	69	100
Nitrate-N	mt	93	--	279	50	--
Oil/Grease	mt	1,671	8.0	14,840	80	100
Residual Chlorine	mt	408	--	--	--	--
Cyanide	mt	nd	nd	9.2	100	100
Arsenic	mt	4.8	0.00004	3.4	-17	100
Cadmium	mt	1.2	nd	0.08	-87	100
Chromium	mt	13	0.003	4.8	-46	100
Chromium,III	mt	1.8	0.0002	--	--	--
Chromium,VI	mt	2.2	0.003	--	--	--
Copper	mt	5.2	0.016	51	81	100
Lead	mt	nd	0.0002	0.6	100	100
Mercury	mt	nd	nd	0.02	100	100
Nickel	mt	nd	0.001	32	100	100
Selenium	mt	nd	nd	8.5	100	100
Silver	mt	nd	nd	4.1	100	100
Zinc	mt	93	0.028	66	-17	100

Dash = Not analyzed/not included in assessment.
nd = Not detected.

Discussion

Mass emissions to the SCB from large POTWs are greater than those from PGSs. However, estimating the magnitude of this difference is complicated by two competing factors. First, estimates of mass emissions from PGSs may underestimate the true load, since constituent analyses among the facilities were dissimilar. For example, oil/grease in the combined waste stream was only analyzed by two facilities. Had all of the facilities measured this constituent and obtained approximately the same results as the two facilities that did, the overall mass emission estimate for oil/grease would have been almost seven times higher. In this case, emissions from POTWs would have only been twice those of PGSs, as opposed to the nine-fold difference we estimated.

In contrast to our potential underestimation of mass emissions associated with lack of reporting from some PGSs, we may have dramatically overestimated mass emissions by not accounting for constituent concentrations in influent cooling water. Because the PGSs do not monitor the intake waters (i.e., influent seawater used as cooling water), it was not possible to assess accurately contributions from the overall waste streams from the facilities. The contrast between loading estimates for in-plant wastes versus the combined waste stream highlighted the possibility that cooling water circulated through the plant was already high in several contaminants prior to intake at the PGS. For example, 94 mt of total suspended solids were discharged via the in-plant waste stream, compared to over 8,000 mt discharged in the combined waste stream. Without adequate intake monitoring, the exact source of contamination is uncertain. Based on comparison of the in-plant waste stream to large POTW effluents, PGSs were a minor source of constituent mass emissions to the SCB in 2000. On the other hand, based on comparison of the combined waste stream to large

POTW effluents, PGSs were more comparable in terms of a few metals and overall discharge volumes. Considering both the potential underestimation associated with some plants not reporting emissions on all constituents and the potential much larger overestimation associated with the lack of data on constituent concentrations in influent cooling water, large POTWs were still a substantially larger source of nutrients and general constituents (i.e., suspended solids, oil/grease, and ammonia-N) to the SCB. Nevertheless, influent monitoring by the PGSs would improve the ability to assess their contribution to the SCB accurately.

The PGSs varied widely in the constituents and waste streams that were analyzed, complicating efforts to extract trends over time from discharge information. Variability in monitoring and reporting between the two years and inconsistencies between facilities from year to year resulted in unacceptable levels of uncertainty in interannual data. However, because mass emissions from POTWs are so much higher than those of PGSs, the level of uncertainty in the estimates of PGS emissions would have not changed our conclusions regarding the significance of PGSs relative to large POTWs. Consistent with previous studies, PGSs are a minor source of contaminants to the SCB relative to large POTWs (Raco-Rands 1996, 1997)

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