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Deirdre McDermott-Ehrlich
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CHEMICAL STUDIES OF OFFSHORE OIL PLATFORMS IN THE SANTA BARBARA CHANNEL

Deirdre McDermott-Ehrlich[1,3], David R. Young[1], George V. Alexander[2], Tsu-Kai Jan[1], and G. Patrick Hershelman[1]

[1]Southern California Coastal Water Research Project
1500 East Imperial Highway
El Segundo, California 90245

[2]Laboratory of Nuclear Medicine and Radiation Biology
University of California
Los Angeles, California 90024

Current Address: [3]Lockheed Center for Marine Research
6350 Yarrow Drive, Suite A
Carlsbad, California 92008

Abstract

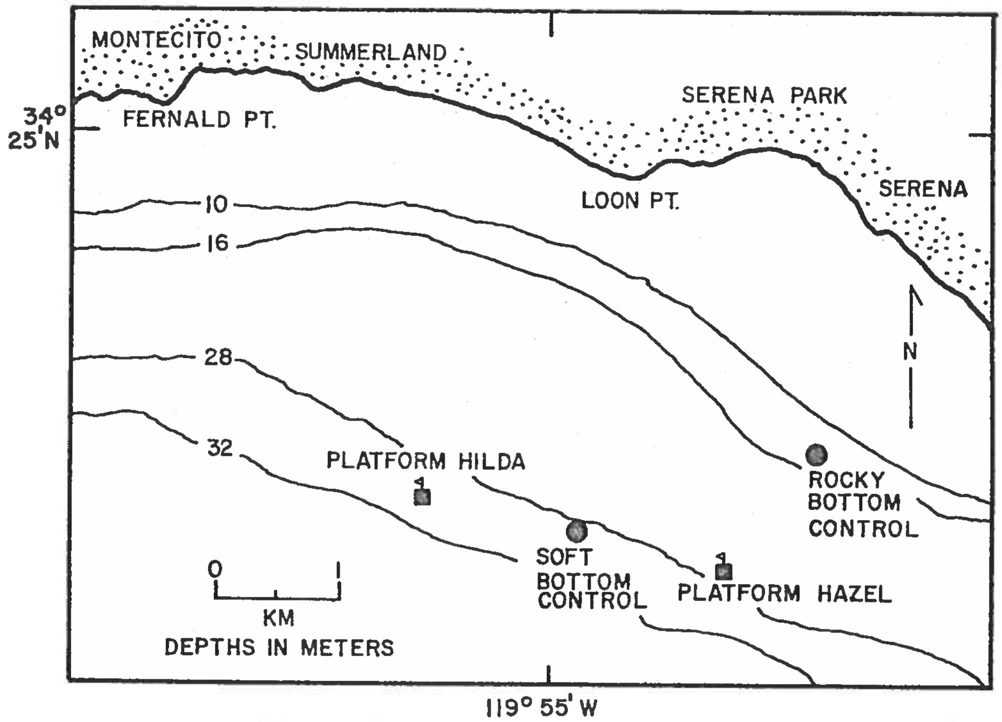
A series of field surveys were conducted during 1975 to document the diversity, health, and abundance of marine life around oil platforms Hazel and Hilda in the Santa Barbara Channel, California. This paper discusses the results of the chemical studies performed. Sediments collected in the vicinity of and directly below the platforms were analyzed for their hexane extractable materials, volatile solids, copper, zinc, and petroleum hydrocarbon content. The levels of the first four items appeared normal in most samples; however, immediately below the platforms, values for all four were elevated. The petroleum hydrocarbon content of all samples was higher than values obtained in areas with no natural seeps. Tissues of two fish species (*Sebastes auriculatus* and *S. vexillaris*) and two invertebrates (*Cancer anthonyi* and *Mytilus californianus*) were analyzed for trace metal (Ag, Cd, Cr, Cu, Fe, Mo, Ni, Pb, Si, V and Zn) and petroleum hydrocarbon levels. There were no enhanced trace element levels in the animals collected from the platforms when compared with those from control sites. Similarly, no detectable amounts of petroleum hydrocarbons were observed in any of the animal specimens analyzed.

Introduction

A series of field surveys of the marine life around two oil platforms, "Hazel" and "Hilda", in the Santa Barbara Channel were conducted during 1975. As part of an effort to determine if the drilling and oil production operations at the platforms have had an effect on these organisms, we conducted chemical analyses of the nearby sediments and of the tissues of several marine animals found in the area.

The platforms, which were installed in the late 1950's by Standard Oil Company, are about 2.5 km apart and located about 3 km offshore in 30 m of water (Figure 1). Each platform is about 30 m square and sits on legs of steel tubing in a pile of cuttings (rock chips and mud brought up in well drilling), which is now covered by a deep mantle of mussel and other shells from the tower. About 25 wells have been drilled from each platform, and the eight wells still in operation at Hazel and the seven at Hilda now produce around 600 barrels of oil per day.

Figure 1. Location of Oil Platforms Hazel and Hilda and control sites in the Santa Barbara Channel, California.



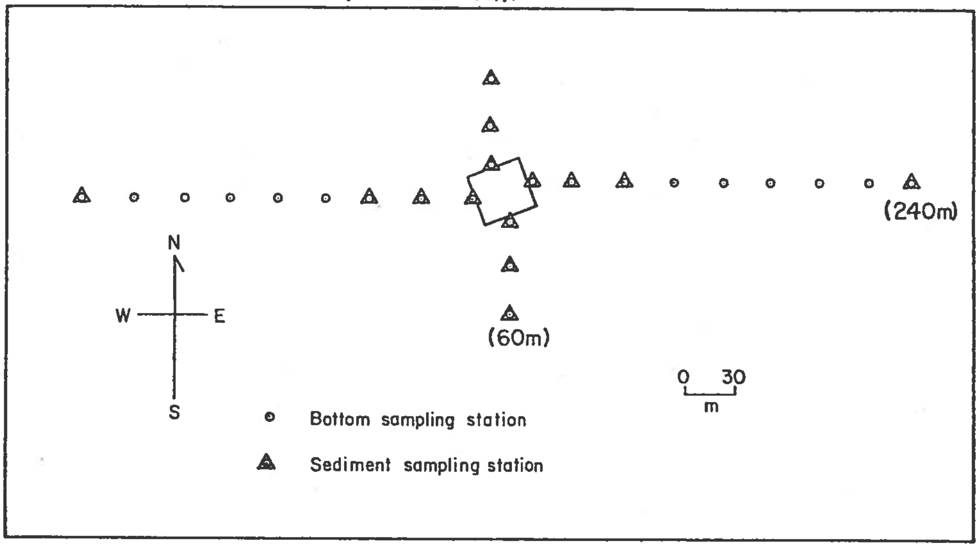
For this study, animals and sediments were collected at 14 sites within 0 to 240 m of each platform. Samples were also taken at two control sites at the same water depth, one rocky and one with a soft sandy bottom (Figure 1).

Sample Collection and Storage

Sediment grab samples were taken around the platforms according to the station and transect plan shown in Figure 2. The grabs were taken using a Van Veen grab that had been modified so that the top could be removed to subsample the undisturbed surface sediment to take a subcore for trace metal, hexane extractable materials (HEM), volatile solids, and petroleum hydrocarbon (PHC) measurements. After the subcores were taken, the sediment samples for trace metals, HEM and volatile solids analyses were stored in polyethylene vials and those for PHC measurements were stored in kiln-fired (550°C) glass bottles with foil-lined caps. All sediment samples were immediately frozen and kept frozen until analysis.

Samples of fish and invertebrates were collected from both towers and control areas for laboratory analysis of PHC and trace metal levels. Hook and line gear was used to capture white belly rockfish (Sebastes vexillaris) and the brown rockfish (S. auriculatus) from Hazel, Hilda, and the hard bottom control area. These species were not present at the soft bottom control site. California mussels (Mytilus californianus) were collected from the two platforms and yellow rock crabs (Cancer anthonyi) were collected from all four stations.

Figure 2. Schematic station plan for bottom sampling around platforms Hazel and Hilda, Santa Barbara Channel, California. Each platform is approximately 30x30m and not oriented to true north. Stations are oriented to magnetic compass directions and spaced at 30m intervals to 60m (North and South) or 240m (East and West).



The fish and invertebrates were packaged in plastic bags for the trace metals analysis and in aluminum foil for the PHC analysis. These specimens were then immediately frozen and kept frozen until dissection for the analyses.

Methodologies for Chemical Analyses

Trace Metal Analyses: Tissue Samples. The tissue samples were first freeze-dried and then they were stored in polystyrene vials until analysis. Graphite electrodes were packed with 10 ± 2 mg of dried tissue and analyzed directly by an optical emission spectrographic procedure (1) capable of the simultaneous determination of 25 elements frequently present in these tissues (Ag, Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Si, Sn, Sr, Ti, V, Zn).

Trace Metal Analyses: Sediment Samples. Approximately 2 g of wet sediment was weighed into a 150-ml beaker. The sample was digested with 1:1 nitric acid solution on a hot plate until the solution became clear. Then 20 ml of deionized water and about 20 drops of concentrated HCl were added to the residue and the mixture was boiled for 20 minutes and allowed to cool. The sample was filtered through a Whatman #40 filter paper to remove any residues and was diluted to 100 ml. The digested sample was aspirated into an air-acetylene flame and the concentrations of trace metals was determined against standards. A Varian-Techtron atomic absorption spectrophotometer model AA-6 was used for determination of copper and zinc.

Volatile Solids. Volatile solids were measured by a method modified from Standard Methods (2). One-gram of wet sediment was placed in a tared beaker and dried to constant weight at 80°C for 24 hours. After cooling, the beaker was placed in a mufflefurnace at 550°C for 1 hr, cooled and reweighed. The weight differences was expressed as percent volatile matter on a dry weight basis. A correction for volatile salts was made by subtracting (0.035 x % water x 0.14) from the original difference.

Hexane Extractable Materials (HEM). HEM was analyzed by drying 20 g sediment at 80°C to constant weight (24 hr), placing the material in a soxlet thimble and extracting in condensers with hexane for 3 hr (boiling). The hexane was roto-evaporated and the flash weighed. The difference between tare and final weight was expressed as HEM in mg/kg dry weight.

Petroleum Hydrocarbon Analyses: Tissue Samples. The tissue samples were digested with caustic, extracted with ether, and the ether extracts cleaned up and fractionated by silica gel chromatography. Three hydrocarbon fractions were obtained, a paraffin hydrocarbon fraction (Fraction 1) and two aromatic hydrocarbon fractions (Fractions 2 and 3). The monoaromatic and most of the diaromatic hydrocarbons occurred in Fraction 2. Most of the 3-to 7-ring polycyclic aromatic hydrocarbons occurred in Fraction 3. Biogenic olefinic hydrocarbons also occurred in Fractions 2 and 3. The biogenic hydrocarbons could generally be distinguished from petroleum hydrocarbons by their GC distribution pattern.

Petroleum Hydrocarbon Analyses: Sediment Samples. The sediment samples were extracted with carbon tetrachloride and the extract analyzed by a procedure similar to that used for the tissue samples. Elemental sulfur, frequently present in sediment samples, interferes with the analyses and was therefore removed by treatment of the extract with freshly activated electrolytic copper. In addition to the gas chromatographic (GC) analysis of the sediment samples, the carbon tetrachloride extracts were analyzed by infrared (IR) spectrometry by measuring the methylene absorption to determine the "total carbon tetrachloride extractable organic matter". This method, unlike the GC procedure, measures all petroleum components including the asphaltenes. Since the extract also contains any fatty materials present in the sediment as well as hydrocarbons, an indication of the proportion of non-hydrocarbon material present was determined by also measuring the carbonyl absorption. The total carbon tetrachloride extractable organic matter was also determined gravimetrically by evaporating the solvent from an aliquot of the extract and weighing the residue on a microbalance. Similarly, the residue from each of the three silica gel fractions were weighed as a check on the total hydrocarbon values found by GC analysis.

Chemical Levels in Sediments

Sediment samples from all collection sites around each platform (Figure 2) were analyzed for copper, zinc, volatile solids, and hexane extractable materials. The median values for these substances were similar to the average coastal background levels and well below levels in sediments contaminated by the discharge of municipal wastewaters (Table 1). In the cuttings piles immediately below the platforms, however, all four materials were elevated: the most obvious increases occurred for zinc (1,500 mg/kg compared to a median of 61 mg/kg) and hexane extractables (4,400 mg/kg compared to a median of 665 mg/kg) at site West-1 under platform Hazel. The high zinc level may have resulted from sediment contamination by metal flakes from the platform or from the metal debris scattered around the tower. Likewise, the high hexane extractable material

Table I. Median values of chemical parameters measured in sediments collected from various coastal sites, 1975.

Collection Site	Volatile Solids (%)	Hexane Extractable Materials (mg/dry kg)	Copper (mg/dry kg)	Zinc (mg/dry kg)
Coastal background	3 to 5	~1,000	16	63
Oil platforms (Santa Barbara Channel)				
Hazel	3.9	665	12	61
Hilda	4.8	-	14	68
Soft Control	3.3	470	9.8	61
Santa Monica Bay, end of 7-mile outfall	40	25,600	1,000	2,000

may have been due to inclusion of animals in the sample or may reflect a high fallout of fecal material from the biota of the structure. In any case, such anomalous values were limited to the biological and cuttings debris piled under the towers.

Petroleum hydrocarbons were analyzed from sediment samples taken along the east transect of each platform and at the soft-bottom control site. The near-platform samples tended to have higher values than the control sample (Table 2). The infrared analysis (IR) indicated that the extractable material was primarily petroleum hydrocarbon in nature; this analysis also showed that a considerable amount of aromatic hydrocarbon was present which may explain why the IR values were significantly lower than gravimetric values. The agreement, however, between the IR and gravimetric values was quite satisfactory.

The total hydrocarbon values determined by the IR and gravimetric methods were four to ten times higher than the gas chromatography (GC) results (Table 2). This difference is typical for highly weathered natural seeps and oils; unlike the IR and gravimetric methods, the gas chromatograph is not sensitive to asphaltenes and polar components, which are important constituents of such oils. In addition, higher molecular weight components (above carbon 35) are not detected in analysis by GC. The GC fingerprints for the oil platform sediments showed a broad envelope with no significant individual peaks; this is also typical of a highly weathered oil and of the hydrocarbons from the sediments of Coal Oil Point, the nearby site of a natural oil seep.

The petroleum hydrocarbon content of all sediment samples collected was higher than values observed in areas with no natural seeps. While the platform levels were higher than the level measured at the control site, the GC fingerprints for all samples were indicative of highly weathered oil indicating no present day contamination of the sediments.

Table 2. Hydrocarbon concentrations (mg/l) in sediments collected near oil platforms and at a soft control site, Santa Barbara Channel, spring 1975.

	Type of Analysis		
Station*	Infrared**	Gravimetric	Gas Chromatography
Hazel			
Station 1	730	1,200	125
Station 2	620	1,050	170
Station 3	630	1,230	165
Hilda			
Station 1	980	1,870	135
Station 2	1,230	1,670	165
Station 3	660	1,200	265
Soft Control	550	980	150

* Station 1 is located just under the eastern edge of each platform; Stations 2 and 3 are 30 and 60 meters east (the direction of the prevailing currents).

** Absorption at 2,920 cm^{-1}.

Chemical Levels in Marine Animals

The tissues of marine animals collected near and away from the oil platforms were checked for trace metal and petroleum hydrocarbon levels. The analyses involved four species--the brown rockfish (*Sebastes auriculatus*), the white belly rockfish (*Sebastes vexillaris*), the yellow rock crab (*Cancer anthonyi*), and an intertidal mussel (*Mytilus californianus*). Up to eight specimens of each species were collected at each platform and at the rocky control station. Predictaby, the rockfishes and mussels were not present at the soft-bottom control station; however crabs were taken at this site.

Trace Metals. Three tissues (muscle, liver, and kidney) were excised from the rockfish and analyzed for their levels of 25 trace elements. From these results, 11 elements of interest were selected for statistical analysis and comparison: silver, cadmium, chromium, copper, iron, molybdenum, nickel, lead, silicon, vanadium, and zinc. The Wilcoxon rank-sum test (a non-parametric statistical method comparable to the parametric Student-t Test) was utilized to determine if there were any statistically significant species differences in the levels of six of these metals (Ag, Cr, Cu, Fe, Si, Zn) in the brown rockfish and the white belly rockfish. (The remaining five elements could not be used for this comparison since the values measured were generally less than the lower limit of detection.) Each tissue from the rockfish was analyzed for species differences on an individual station basis to eliminate possible station variations. Two of the results for the 54 statistical tests run (six metals in three tissues of specimens from three locations) were statistically significant: Kidney tissue from brown rockfish taken near Hazel had a higher concentration of iron than kidney tissue from white belly rockfish from the same location and kidneys of white belly rockfish from the rocky control station had higher levels of zinc than those of brown rockfish from this site. When performing 54 tests, however, one would expect up to three statistically significant differences to appear as the random result of multiple testing. We therefore concluded that there was no significant difference between the trace element levels in the two species of rockfish and combined the rockfish results for each tissue. These data appear in Tables 3, 4 and 5.

The Wilcoxon rank-sum test was again used on the rockfish data to determine if the trace metal values varied significantly with location. Again, 54 statistical tests were performed; however, in this case, no statistically significant differences were observed for silver, chromium, copper, iron, silicon or zinc. No statistical comparisons could be performed with the results for cadmium, molybdenum, nickel, lead, and vanadium. A review of the median lower limit of detection values (the lower limit of detection values were based on sample weight; therefore, each sample could have a different lower limit) and ranges shown in Tables 3, 4, and 5, indicated that the values were generally quite comparable.

Table 3. Median trace element concentrations (mg/dry kg) in muscle tissue of rockfish (<u>Sebastes auriculatus</u> and <u>Sebastes vexillaris</u>) collected near the oil platforms and a control site, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=12) Median	Hazel (n=12) Range	Hilda (n=12) Median	Hilda (n=12) Range	Rocky Control (n=12) Median	Rocky Control (n=12) Range
Silver	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND-<7.7	ND	ND-<7.7	<5.2	ND-<6.8
Chromium	ND	ND-1.1	ND	ND-2.6	ND	ND-1.2
Copper	ND	ND	ND	ND-0.5	ND	ND-1.1
Iron	4.4	ND-9.1	7.2	ND-27.0	8.5	ND-22.8
Molybdenum	<0.5	<0.6	<0.5	ND-<0.6	ND	ND-1.2
Nickel	<4.6	ND-<7.7	<4.7	<5.9	<3.9	<3.3
Lead	<2.5	<2.9	<2.3	<2.9	<1.9	<2.0
Silicon	7.4	4.0-25.7	6.3	4.1-14.5	5.4	<2.0-35.5
Vanadium	<2.5	ND-<3.0	<2.2	ND-<2.9	<1.9	ND-<2.3
Zinc	12.9	<11.9-44.0	10.0	<11.1-27.9	13.0	<11.6-22.6

ND: Not Detected

Table 4. Median trace element concentrations (mg/dry kg) in liver tissue of rockfish (Sebastes auriculatus and Sebastes vexillaris) collected near the oil platforms and a control site, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=14) Median	Hazel (n=14) Range	Hilda (n=11) Median	Hilda (n=11) Range	Rocky Control (n=12) Median	Rocky Control (n=12) Range
Silver	0.6	ND-4.4	0.4	ND-1.0	0.6	ND-1.5
Cadmium	<6.7	ND-5.1	<4.7	<10.0	<3.8	ND-<10.4
Chromium	ND	ND-1.0	<0.2	ND-10.6	ND	ND-8.0
Copper	7.4	1.8-121.0	5.2	2.3-16.7	7.4	1.5-17.9
Iron	333.0	91.8-3,540.0	249.0	80.5-1,060.0	309.0	59.1-799.0
Molybdenum	<0.4	ND-0.4	<0.2	ND-<0.3	<0.2	ND-<0.5
Nickel	<4.4	<9.1	<2.8	ND-5.4	<3.1	<1.4-3.0
Lead	<1.5	ND-1.8	ND	ND-<2.2	ND	ND-<2.4
Silicon	5.8	<3.2-280.0	5.3	ND-12.5	4.0	<1.4-18.6
Vanadium	<6.8	ND-5.8	<1.6	<0.9-3.8	<1.4	<0.7-3.8
Zinc	48.4	26.6-283.0	41.9	25.8-70.0	45.2	24.6-77.5

ND: Not Detected

Two tissues (muscle and gonad) were excised from the yellow rock crab and analyzed for their trace element content. These results are presented in Tables 6 and 7. There were too few data points from Hilda and the rocky control to do statistical comparisons between each location sampled. The Wilcoxon rank-sum test was utilized, however, to compare the silver, chromium, copper, iron, silicon, and zinc levels in tissues of crabs collected from platform Hazel and the soft control site. The results indicated that there were no statistically significant differences between these trace metal levels in gonadal or muscle tissue from crabs collected at these sites. As with the rockfish, a review of the median lower limit of detection values and ranges for cadmium, molybdenum, nickel, lead, and vanadium (Tables 6 and 7) indicated that the levels were generally comparable for the four sampling sites.

The whole soft tissues of mussels collected from the oil platforms were analyzed for their trace element content (Table 8); no control samples were available. Coastal values from mussels collected from Pt. Sal, California during January 1976 were utilized to compare these data. The values for cadmium, chromium, copper, nickel, lead, vanadium, and zinc were comparable. The median coastal value for silver was 2 to 3 times less than the median values for the platforms; the ranges, however, were similar. The median coastal values for iron, molybdenum, and silicon were 3 to 8 times greater than the platform values. Since whole soft tissues were used in these analyses, the inclusion of sediments in the

Table 5. Median trace element concentrations (mg/dry kg) in kidney tissue of rockfish (Sebastes auriculatus and Sebastes vexillaris) collected near the oil platforms and a control site, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=13) Median	Hazel (n=13) Range	Hilda (n=11) Median	Hilda (n=11) Range	Rocky Control (n=11) Median	Rocky Control (n=11) Range
Silver	0.5	ND-1.1	0.9	0.4-1.4	0.8	ND-1.2
Cadmium	<4.2	ND-<11.6	ND	ND-<10.0	<0.4	ND-<10.4
Chromium	ND	ND-0.7	ND	ND-1.9	ND	ND-5.9
Copper	3.3	1.3-9.0	3.1	0.8-5.6	3.8	0.6-5.1
Iron	601.0	288.0-1,060.0	677.0	276.0-1,220.0	533.0	388.0-817.0
Molybdenum	<0.3	ND-<0.4	<0.6	ND-<0.6	<0.4	ND-<0.6
Nickel	<4.2	ND-<7.7	<5.1	ND-<6.7	<6.1	<3.2-7.5
Lead	ND	ND-<2.9	<2.1	ND-<3.3	<3.0	ND-<3.3
Silicon	6.9	4.7-11.8	10.7	ND-24.5	5.1	3.3-58.5
Vanadium	<2.6	<1.4-4.3	<3.0	ND-3.8	<3.2	<3.3
Zinc	66.3	47.7-89.7	62.5	49.3-75.4	68.7	50.1-120.0

ND: Not Detected

digestive gland of the coastal mussels could account for the differences. These results indicate no trace metal contamination of the oil platform mussels.

Petroleum Hydrocarbons. The hydrocarbon content of tissue samples determined by gas chromatographic (GC) analysis showed no detectable petroleum hydrocarbons in the mussels and crabs regardless of collection site (Table 9). The GC fingerprints showed no indication of any petroleum hydrocarbons in the rockfish: All of the peaks can be reasonably attributed to biogenic hydrocarbons. One component in the rockfish, tentatively identified as squalene on the basis of GC retention time, accounts for over one-half of the total hydrocarbon content. Squalene is a natural lipid common to many marine organisms, especially fish.

Because of the overwhelming quantity of biogenic hydrocarbons found in the rockfish, it would not be possible to detect trace amounts of petroleum hydrocarbons. Since mussels are generally good accumulators of petroleum hydrocarbons and no detectable amounts of petroleum hydrocarbons were found in the mussles (Table 9), it is unlikely that the rockfish from the same site would contain significant amounts of petroleum hydrocarbons.

Table 6. Median trace element concentrations (mg/dry kg) in the whole soft tissues of intertidal mussels (Mytilus californianus) collected near the oil platforms, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=5) Median	Range	Hilda (n=6) Median	Range	Coastal* (n=12) Median	Range
Silver	2.1	0.7-4.8	1.6	0.9-4.8	0.7	0.5-5.3
Cadmium	<5.0	ND-<6.5	<5.8	ND-8.1	<2.9	<3.1
Chromium	5.9	4.1-23.8	12.6	2.7-70.8	5.5	2.7-58.9
Copper	4.0	3.3-6.8	6.2	3.5-11.1	7.6	6.0-16.8
Iron	76.4	53.1-514.0	97.2	35.6-151.0	300.0	189.0-422.0
Molybdenum	0.5	<0.4-0.9	<0.3	<0.3-0.5	1.7	0.9-1.6
Nickel	<4.2	<2.9-4.4	<4.2	<3.1-7.5	3.0	<1.8-4.7
Lead	<1.9	ND-<2.2	<1.6	ND-2.1	ND	ND-<0.9
Silicon	243.0	115.0-2,100.0	489.0	233.0-915.0	2,095.0	708.0-5,990.0
Vanadium	<1.9	ND-<2.2	<1.6	ND-<2.1	1.1	<0.9-1.6
Zinc	53.6	23.3-68.7	61.0	20.7-105.0	59.0	30.0-95.0

ND: Not Detected

*Coastal values are for mussels collected from Pt. Sal, California, January 1976.

Table 7. Median trace element concentrations (mg/dry kg) in muscle tissue of the yellow rock crab (Cancer anthonyi) collected near the oil platforms and two control sites, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=6) Median	Range	Hilda (n=2) Median	Range	Rocky Control (n=4) Median	Range	Soft Control (n=9) Median	Range
Silver	3.9	2.4-6.7	1.4	1.3-1.6	1.9	ND-3.2	3.5	2.7-7.9
Cadmium	2.1	<5.2	<5.9	<7.0	<3.6	ND-<6.5	<5.2	<3.5-12.0
Chromium	0.6	ND-3.8	ND	ND	<0.4	ND-3.4	1.1	ND-7.3
Copper	41.4	32.4-58.5	32.9	29.8-36.0	35.0	14.1-53.4	41.0	23.6-126.0
Iron	21.8	7.7-113.0	21.0	11.7-30.4	15.4	10.8-28.1	22.0	12.5-67.6
Molybdenum	<0.3	<0.4	<0.4	<0.5	<0.3	ND-<0.4	<0.3	ND-<0.3
Nickel	<2.8	<3.5	<3.9	<4.7	<4.0	<2.4-3.0	<3.1	<2.4-3.3
Lead	<1.4	<1.8	<1.8	<2.3	<1.5	<2.2	<1.4	ND-<1.7
Silicon	64.8	11.0-401.0	63.4	19.7-107.0	45.7	8.0-89.3	96.7	4.4-431.0
Vanadium	<1.2	ND-<1.8	<1.8	<2.3	<1.4	ND-<2.2	ND	ND-<1.7
Zinc	65.2	40.2-96.6	82.1	77.2-87.0	72.4	67.0-79.2	87.6	45.4-119.0

ND: Not Detected

Table 8. Median trace element concentrations (mg/dry kg) in gonadal tissue of the yellow rock crab (Cancer anthonyi) collected near the oil platforms and two control sites, Santa Barbara Channel, Spring 1975.

Trace Element	Hazel (n=4) Median	Hazel (n=4) Range	Hilda (n=2) Median	Hilda (n=2) Range	Rocky Control (n=4) Median	Rocky Control (n=4) Range	Soft Control (n=8) Median	Soft Control (n=8) Range
Silver	4.2	3.6-9.9	3.6	1.8-5.3	1.6	1.5-2.1	6.4	1.5-12.5
Cadmium	5.2	3.9-8.1	4.8	4.5-5.2	<5.4	<2.6-8.0	6.0	<2.5-10.
Chromium	1.2	0.7-1.7	<0.7	ND-0.7	2.4	0.6-7.0	3.0	ND-7.3
Copper	35.9	23.7-60.3	42.6	14.1-71.0	17.3	13.4-33.1	45.4	10.4-135.0
Iron	53.9	34.5-81.4	73.3	46.6-100.0	61.5	35.2-94.4	45.0	4.6 -89.7
Molybdenum	<0.2	<0.1-0.2	<0.3	<0.3	<0.2	<0.2-0.5	<0.2	<0.3
Nickel	<2.8	<1.4-3.5	3.6	3.5-3.6	<3.8	<1.7-5.8	2.4	<2.0-9.9
Lead	<0.7	<1.6	<1.4	<1.4	<1.2	<1.6	<1.1	ND-<1.6
Silicon	7.7	3.3-15.8	9.8	9.1-10.5	6.2	2.5-8.2	9.4	4.0-54.0
Vanadium	<1.0	<1.6	<1.4	<1.4-1.4	<1.0	ND-<1.4	<1.1	ND-<1.6
Zinc	70.6	38.2-110.0	90.1	88.7-91.5	101.7	89.7-141.0	91.2	60.4-219.0

ND Not Detected

Table 9. Hydrocarbon concentrations (mg/wet kg) in tissues of marine organisms collected near the oil platforms and control sites, Santa Barbara Channel, spring 1975.

Tissue	Hazel	Hilda	Rocky Control	Soft Control
White belly rockfish liver	320	270	580	-*
Brown rockfish liver	420	1,000	1,100	-
Mussel whole soft tissues	<5**	<5**	-	-
Crab muscle	<5**	<5**	<5**	<5**

* No samples obtained.

** Limit of detection.

Summary

Levels of copper, zinc, hexane extractable materials, and volatile solids in sediments around the oil platforms were similar to average coastal background levels and were well below levels observed in sediments contaminated by the largest discharges of municipal wastewaters in southern California.

The petroleum hydrocarbon content of all sediment samples collected was higher than values observed in areas with no natural seeps. The platform levels were higher than the level measured at the soft control site; however, the gas chromatographic fingerprints for all samples were indicative of highly weathered oil, indicating no recent contamination of the sediments.

No statistically significant differences in the 11 trace elements studied were observed for the rockfish and crabs collected from the oil platforms and the control sites. Similarly, no trace metal contamination of the oil platform mussels was observed when compared with coastal mussels. No detectable amount of petroleum hydrocarbons were observed in any of the animals analyzed.

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