

Using Linear Alkylbenzenes to Trace Sewage-derived Organic Materials off San Diego, California

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Since the mid-1960s, linear alkylbenzene sulfonates (LASs) have been widely used as surfactants in the manufacture of detergents (Myers 1992). LASs are synthesized from benzene via a two-step process (Hinds 1976): Friedel-Crafts alkylation of benzene with either chloroalkane or alkene with the total number of carbons ranging from 10 to 14 to produce linear alkylbenzene (LAB), followed by sulfonation of LAB at the phenyl ring using either H_2SO_4 or SO_3 . Rearrangements taking place in the alkylation step yield an isomeric mixture of LABs for each alkyl group. Due to incomplete sulfonation, small amounts (1-3%) of unreacted LABs are carried into detergents (Glendhill *et al.* 1991) and into the aquatic environment via discharges of treated sewage. The presence of LABs have been found in various environmental media, including municipal wastewater effluent (Eganhouse *et al.* 1983), sediment-trap particulates (Crisp *et al.* 1979), riverine and marine sediments (Ishiwatari *et al.* 1983, Murray *et al.* 1987, Eganhouse and Kaplan 1988, Chalaux *et al.* 1992, Raymundo and Preston 1992, Chalaux *et al.* 1995), and marine organisms (Albaigés *et al.* 1987, Serrazanetti *et al.* 1994). Although LABs do not pose severe adverse effects to many marine species (Glendhill *et al.* 1991), LABs are useful tracers of domestic waste inputs in the environment (Eganhouse *et al.* 1983, Takada and Ishiwatari 1987, Eganhouse *et al.* 1988, Takada and Ishiwatari 1991), due to their limited sources.

In the two previous articles (*Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* and *Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California*, this annual report), we examined the distributions and sources of polycyclic aromatic hydrocarbons (PAHs) and aliphatic hydrocarbons (AHs) in the coastal marine environment off San Diego. The compositional patterns of these hydrocarbon compounds were qualitatively useful in differentiating several sources of contaminant inputs, such as petrochemical products, biogenic residues, and combustion-induced remains. In this article, we will present the results from

LAB measurements in the same samples as described in the previous articles. The objectives are (1) to assess the spread of domestic wastes discharged from the outfall of the Point Loma Wastewater Treatment Plant (PLWTP) and (2) to gain insights into the mechanisms for the transport and fate of sewage-derived organic materials.

MATERIALS AND METHODS

Definitions and Sample Collection

In this article, LABs are often labeled as $\text{C}_i\text{-LAB-}n$, where i denotes the number of carbons in the alkyl chain and n is the position number of the phenyl ring (e.g., 1 indicates the terminal position of the alkyl chain). The isomeric distribution of C_{12} -LABs may provide valuable information related to the degree of biodegradation of LABs in the environment (Takada and Ishiwatari 1990). Specifically, the ratio of the concentrations of internal and external isomers, designated as I/E, is defined as:

$$\text{I/E} = \frac{\sum (\text{C}_{12}\text{-LAB-6} + \text{C}_{12}\text{-LAB-5})}{\sum (\text{C}_{12}\text{-LAB-4} + \text{C}_{12}\text{-LAB-3} + \text{C}_{12}\text{-LAB-2})}$$

A high I/E value indicates a high degree of LAB biodegradation, due to the selective biodegradation of the external isomers relative to the internal isomers (Takada and Ishiwatari 1990).

A detailed description of the study site, abbreviations for sampling locations, sample collection, and sample extraction is given in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* in this annual report.

Materials

Individual LAB standards, including C_{10} -LAB-1, C_{12} -LAB-1, and C_{13} -LAB-1, were purchased from Aldrich (St. Louis, MO) and C_{14} -LAB-1 from Pfaltz and Bauer (Westbury, CT). A mixture of LABs used as calibration standard, whose composition was determined previously (SCCWRP 1995), was provided by Dr. Robert Bowen (Science Applications International Corporation, Narragansett, RI). The surrogate standard, phenanthrene-

d_{10} , and two internal standards, 2-fluorobiphenyl and p-terphenyl- d_{14} , were obtained from Ultra Scientific, Inc. (North Kingstown, RI). Ultra resi-analyzed grade hexane and methylene chloride were purchased from J.T. Baker Inc. (Phillisburg, NJ). All standard solutions were prepared in hexane.

Instrumental Analysis

Individual LAB compounds were identified based on their retention times and fragmentation patterns using a Hewlett-Packard (HP) gas chromatograph/mass spectrometer (GC/MS). The detailed experimental parameters and procedures were identical to those used for measurements of PAHs. The molecular ion used for quantitation was m/z 105 for Ci-LAB-2 ($I=10$ to 14) and m/z 91 for the other LAB compounds. Since the LAB mixture contains only C_{11} -LAB to C_{14} -LAB components, quantitation of C_{10} -LAB- n ($n=2$ to 5) was done using the relative response factor of C_{11} -LAB-6.

The quantitation limit was 40 ng/g for solid samples based on 1 g of dry sample and 50 ng/L for aqueous samples based on 1 L of sample volume. These values were slightly higher than the Method Detection Limits determined using the procedure described elsewhere (Clesceri *et al.* 1989), so they were always achievable under any circumstances.

All the samples were spiked with the surrogate standard at 2 $\mu\text{g/mL}$ in the samples prior to extraction. The internal standards were spiked into the final extracts before instrument analysis. The mean \pm 1 standard deviation of the surrogate standard recoveries (%) in 31 field samples were 77 ± 13 . No correction was made for the concentrations of LABs in the samples.

The LAB concentrations are expressed in ng/g dry sample weight and ng/g total organic carbon (TOC) for solid samples and ng/L for aqueous samples. The TOC normalized concentration is defined as the dry weight based concentration divided by TOC content and more closely describes the partitioning of hydrophobic organics in particles. Since aqueous samples were not analyzed for TOC, no TOC normalized concentrations were obtained for these samples. For the Point Loma Wastewater Treatment Plant (PLWTP) effluent, Tijuana River (TJR) runoff, and microlayer, the concentrations of the particulate fractions are also presented in ng/L based on the aqueous volumes. The general characteristics of the LAB assem-

blages obtained in these samples (Table 1) are described below.

RESULTS

PLWTP Wastewater Effluent

As expected, the LAB contents in the PLWTP wastewater effluent samples were the highest among all the field samples and as high as 2,760 ng/L for the particulate sample collected in June 1994. The TOC normalized concentrations for the particulate samples were also high (99,600 ng/g in January and 281,000 ng/g in June). The large difference between the particulate concentrations (34,200 ng/g dry in January and 100,000 ng/g dry in June) was discussed previously and attributed to different samples used for total suspended solid (TSS) and organics measurements (*Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California*, this annual report). The average LAB concentration in the PLWTP effluent (both dissolved and particulate) was 3,010 ng/L in 1994.

The distributional patterns of individual LABs detected in the PLWTP effluents did not exhibit significant temporal variation or variation between filtrate and particulate fractions (Figures 1a-1d). They all showed predominant components in the range of C_{11} to C_{13} . In addition, the I/E ratios were all less than 1 (from 0.77 to 0.87; Table 1).

TJR Runoff

The TJR runoff samples contained significantly lower LAB concentrations compared to the PLWTP effluent. In addition, the LAB concentrations in the runoff filtrates were all below the detection limits. The particulate LAB concentration based on the aqueous volume was an order of magnitude greater in the January (714 ng/L) sample compared to June (57.4 ng/L) sample (Table 1). However, the dry weight based concentrations were comparable (8,110 ng/g in January and 3,830 ng/g in June), again reflecting the large variation in TSS measurements.

The I/E ratios (5.8 in January and 2.6 in June) calculated from the LAB compositions in the particulate samples (Figs. 1e and 1f) were substantially higher than unity. This suggests that LAB compounds in TJR runoff were subject to biodegradation.

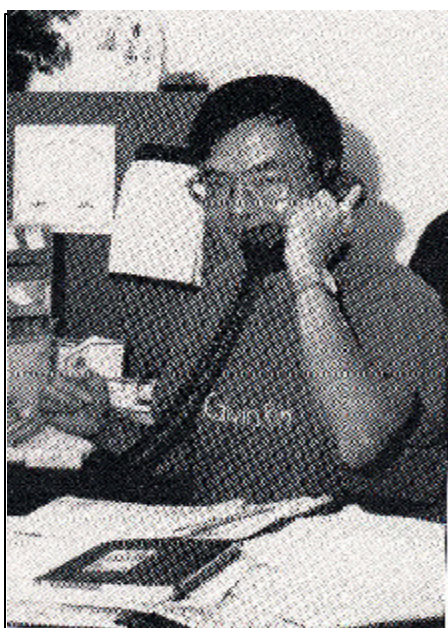


TABLE 1. Linear alkylbenzene (LAB) concentrations in effluent, runoff, microlayer, sediment, and water-column particulate samples from the San Diego coast, California.

Sample Type	Total LABs (dry wt based) ^a		Total LABs (TOC based) ^b		I/E Ratio ^c	
	1/94	6/94	1/94	6/94	1/94	6/94
PLWTP Effluent						
Filtrates	705	635	—	—	0.87	0.77
Particulates	34200 (1920)	100000 (2760)	99600	281000	0.85	0.78
Tijuana River Runoff						
Filtrates	ND	ND	—	—	na	na
Particulates	8110 (714)	3830 (57.4)	79600	46900	5.8	2.6
Microlayer						
A-17 Filtrates	NA	ND	—	—	NA	na
A-17 Particulates	NA	ND	NA	ND	NA	na
R-61 Filtrates	NA	ND	—	—	NA	na
R-61 Particulates	NA	ND	NA	ND	NA	na
MTJR Filtrates	NA	ND	—	—	NA	na
MTJR Particulates	NA	821 (23.0)	NA	8290	NA	na
SDB Filtrates	NA	ND	—	—	NA	na
SDB Particulates	NA	ND	NA	ND	NA	na
Sediments						
A-17	35.3	39.2	6540	7640	1.6	2.3
R-61	ND	ND	ND	ND	na	na
MTJR	ND	ND	ND	ND	na	na
SDB	1.61	ND	196	ND	na	na
Sediment Trap Particulates						
A-17 (1 m)	35.9	** d	1900	**	4.2	**
A-17 (5 m)	24.8	10.9	1110	371	4.4	na
R-61 (1 m)	ND	10.3	ND	403	na	na
R-61 (5 m)	5.09	60.4	187	1880	na	2.3

^aIn ng/g dry weight for solid samples and ng/L for aqueous samples; the numbers in parentheses are concentrations based on the aqueous volumes.

^bIn ng/g total organic carbon (TOC) for solid samples; TOC was not measured for aqueous samples.

^cI/E Ratio = ratio of internal and external isomers.

^dA-17 1-m traps were not recovered in June 1994.

ND=not detectable.

na=not applicable since the LABs to calculate I/E were not detectable.

NA=not analyzed; see text for reasons.

Microlayer

None of the filtrate samples exhibited detectable levels for LABs. Only the microlayer particulates from the mouth of Tijuana River (MTJR) contained two LABs above the detection limits (Figure 1g). The total LAB concentration in this sample was 23.0 ng/L. The I/E ratio for this sample, however, could not be calculated due to the absence of several phenyl dodecanes (Figure 1g).

Sediments

All the sediments contained significantly lower LAB concentrations than those of the PLWTP effluent and TJR runoff particulates on a particle dry weight basis (Table 1). Samples collected at stations R-61 (reference station) and MTJR in both January and June 1994 contained no detectable LABs. Substantially low total LAB concentration (1.61 ng/g dry weight) was detected in the San Diego Bay (SDB) sediments collected in January. In contrast, the A-17 (outfall station) sediments contained the highest

amounts of LABs (35.3 ng/g in January and 39.2 ng/g in June) as compared to those from other stations. The low LAB concentrations in the MTJR sediments were consistent with the low PAH and AH concentrations in the same samples (*Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* and *Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California*, this annual report).

The LAB contents were too low in the R-61, MTJR, and SDB sediments to calculate I/E ratios. The I/E ratios for the A-17 sediments collected in January and June, calculated from their LAB compositions (Figs. 2a and 2b), were 1.6 and 2.3, respectively.

Sediment Trap Particulates

The LAB concentrations in the A-17 sediment trap particulates were similar to those in the A-17 sediments. In contrast, R-61 trap particulates contained detectable LABs while the sediments contained none. In addition, the

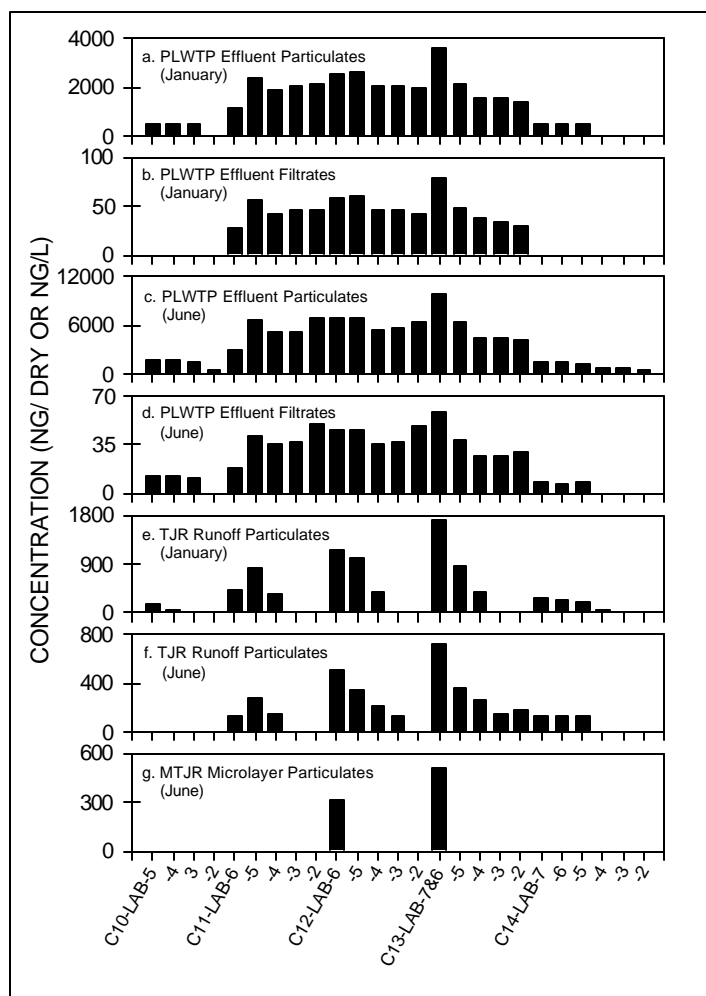


FIGURE 1. Compositions of linear alkylbenzenes (LABs) in the Point Loma Wastewater Treatment Plant (PLWTP) effluent, Tijuana River (TJR) runoff, and mouth of Tijuana River (MTJR) microlayer samples (ng/g dry weight for particulates and ng/L for filtrates).

total LAB concentration collected in June from the R-61 sediment trap at 5 m was higher than those found in the A-17 sediment samples. The trap particulates collected in January from A-17 contained higher LAB concentrations than those collected in June. The coeluting C₁₃-LAB-7 and C₁₃-LAB-6 were the only detectable LABs in the sediment trap samples collected in June at A-17 (5 m) and R-61 (1 m) and in January at R-61 (5 m). The total LAB concentrations in these three samples were 10.9, 10.3, and 5.1 ng/g.

The LABs were most abundant in PLWTP effluent (Figs. 2c-2e). Although the I/E ratio was not determinable for the LABs in the A-17 trap particulates collected in June, the corresponding ratios for the samples obtained in January at different depths were comparable (4.2 at 1 m and 4.4 at 5 m), indicating virtually no depth variation in the extent of biodegradation. The I/E ratio was 2.3 in the

R-61 5-m sample, slightly lower than expected. However, the concentrations of individual LAB components detected were barely above the detection limits.

DISCUSSION

Sources, Distributions, and Transport of LABs

The results described above suggest two major point sources of LABs discharged into the study areas, i.e., the PLWTP outfall and TJR. The concentrations of total LABs in the PLWTP effluent (2.63-3.40 µg/L) were significantly lower than those obtained by Eganhouse *et al.* (1983) for the County Sanitation Districts of Los Angeles County (CSDLAC) effluent in 1979 (149±69 µg/L). In the same study by Eganhouse *et al.* (1983), only qualitative analyses of PLWTP effluent were reported. Thus, temporal changes could not be assessed. The particulate LAB concentrations (34-100 µg/g) in the PLWTP effluent were slightly higher than those (18-34 µg/g) reported by Takada and Ishiwatari (1987) in the effluent of one of the largest sewage treatment plants in the Tokyo Bay area of Japan.

The concentrations of total LABs in the TJR runoff particulates were very low (3.83-8.11 µg/g dry weight or 0.057-0.714 µg/L based on aqueous volumes) compared to those in the PLWTP effluent particulates. Further, a detectable level of LABs found in the MTJR microlayer particulates (0.82 µg/g) suggested possible accumulation of sewage-derived organic matter at the nearshore sea surface water. However, the sediment collected from this location contained no detectable LAB contents. This, along with the low PAH (*Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California*) and AH (*Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California*) concentrations at the same location, indicate that tidal currents may effectively remove contaminants from this relatively shallow location into the deeper water.

Particulate materials (e.g., clay, silt, sand, shell fragments, etc.) in the water column may serve as sorptive sites for partitioning of organic contaminants. Marine sediments, on the other hand, are the major sink of suspended particulates. Therefore, suspended particulates and sediments provide the means of transport and the ultimate reservoirs, respectively, for many hydrophobic organic contaminants. The relative distributions of LABs in suspended particulates and sediments may thus be useful in assessing the possible modifications and alterations of sewage-derived contaminants during transportation to and residence in the sea floor.

The concentrations of total LABs in the A-17 trap particulates (0.37-1.90 µg/g TOC) were substantially lower than those in the PLWTP effluent (99.6-280 µg/g TOC)

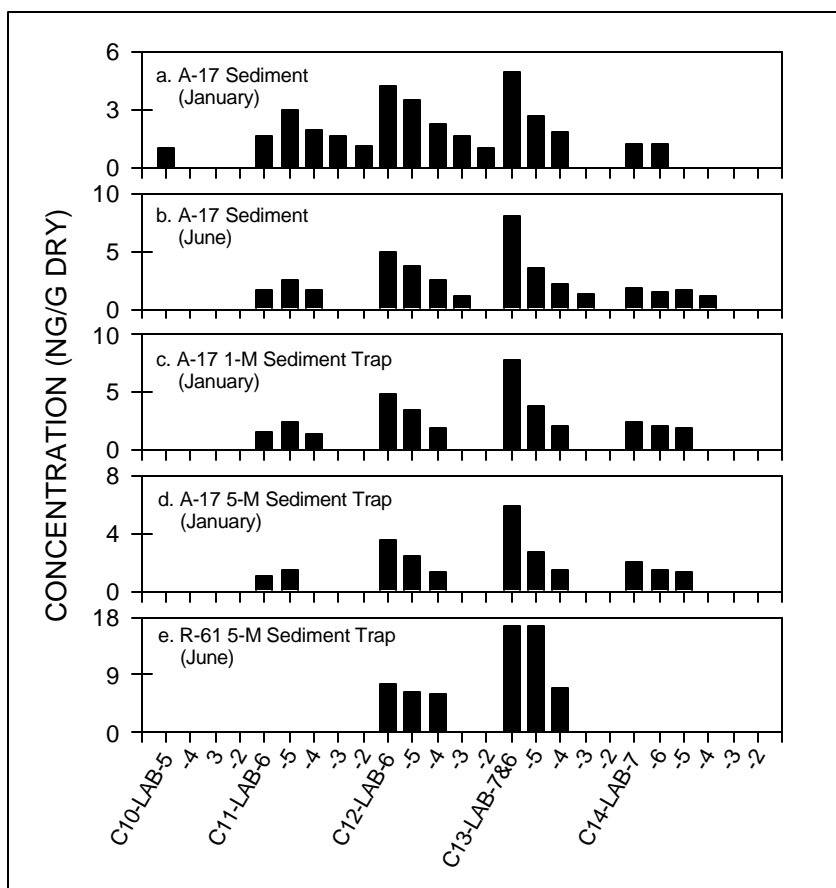


FIGURE 2. Compositions of linear alkylbenzenes (LABs) in A-17 sediments, 1-m and 5-m trap particulates, and R-61 5-m trap particulates, San Diego, California.

(Table 1). The concentrations of LABs in the A-17 sediments were also low (6.54-7.64 $\mu\text{g/g}$ TOC). Similar spatial variations have also been reported previously. Takada and Ishiwatari (1987) reported the total LAB concentrations in the sediments (0.01-15.8 $\mu\text{g/g}$ dry weight) and in the suspended particles (4.2-31.3 $\mu\text{g/g}$ dry weight) were lower than those in the wastewater effluents (8.7-36.3 $\mu\text{g/g}$ of dry weight). In another study, Eganhouse *et al.* (1983) obtained the total LAB concentrations of 21.4 $\mu\text{g/g}$ and 1,342 $\mu\text{g/g}$ in the sediments collected near the Joint Water Pollution Control Plant (JWPCP) outfall and in the JWPCP effluent of CSDLAC, respectively. It is clear that widespread redistributions of LABs in open ocean waters may account for the decrease of LAB concentrations from the PLWTP effluents to the suspended particulates and sediments. However, as discussed in the following section, other mechanisms may also be responsible for effectively removing LABs and/or altering their chemical compositions.

The TOC normalized concentration of LABs was lower in the A-17 trap particulates than in the A-17 sediments (Table 1), due to the higher TOC concentration in the trap particulates than in the sediments (*Compositional Indices of*

Polycyclic Aromatic Hydrocarbon Sources off San Diego, California). This probably resulted from inputs of carbon-enriched materials (e.g., terrestrial high plants, etc.) and/or resuspended fine particulates enriched with TOC that effectively diluted the concentrations of sewage-derived organics in sewage particulates.

Three of the four traps at R-61, as well as those at A-17, contained detectable LABs, although the R-61 sediments virtually contained no LABs (Table 1). This indicated that fine particulates enriched with LABs or other organic compounds may stay in suspension long enough to be carried into remote locations, as first proposed in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California*. A large amount of LABs in the sinking particles are probably biodegraded before reaching the sea floor. It should be noted that 5-phenylundecane and several isomeric secondary phenyl alkanes with 10 to 13 carbons in the alkyl chains were previously detected in the sediment trap particulates collected in the Santa Monica and San Pedro Basins (Crisp *et al.* 1979), further verifying long-range transport of sewage-derived contaminants.

The SDB sediment sample contained extremely low LAB contents, possibly derived from the storm runoff draining through the San Diego International Airport.

Fate of LABs in the Coastal Marine Environment

Upon entering the ocean waters, LABs may be redistributed into various phases, which may account partially for the large discrepancy between the TOC-normalized concentrations of LABs in the PLWTP effluent particulates and A-17 sediments (and trap particulates). Air, water, sediment particles, and biota are the likely compartments for redistribution of sewage-derived LABs (Glenhill *et al.* 1991). The TOC normalized concentrations of LABs in the A-17 trap particulates and sediments were about 0.13-1.9% and 2.7-6.6%, respectively, of those in the PLWTP effluent particulates (Table 1). Apparently, most LABs in effluent particulates are dispersed into water-column and sediment compartments at this location.

Another important way of removing LABs from the aquatic environment is biodegradation. As demonstrated experimentally (Takada and Ishiwatari 1990, Bayona *et al.* 1986), aerobic degradation by microbes preferably eliminates external LAB isomers, resulting high I/E ratios.

Therefore, by examining I/E ratios, one may be able to estimate the degree of biodegradation of LAB compounds.

The I/E ratios in the PLWTP effluent are all less than 1.0, suggesting little biodegradation during the treatment process (Table 1). By contrast, the I/E ratios (1.6 to 4.4) in A-17 trap particulates and sediments are significantly greater than 1. Based on the relationship between the degradation of LABs and I/E (Takada and Ishiwatari 1990), 30 to 55% of the LABs are degraded before they incorporate into the suspended particles and bottom sediments. It is clear that, in addition to biodegradation, other processes, such as dilution with nonsewage-derived particles, dissolution into water, evaporation to the atmosphere, and accumulation by marine organisms, etc., may effectively dissipate sewage-related organic materials from the discharge zone. However, relatively less attention has been given to these possible mechanisms.

Relatively high I/E ratios in the particulates of the Tijuana River runoff also indicated substantial biodegradation of LABs occurring during riverine transport.

Overview of Organic Pollutant Inputs into the Coastal Marine Environment off San Diego

The information presented thus far may allow a general assessment of the pollutant inputs into the coastal marine environment off San Diego. Based on the measured concentrations of PAHs (1,780 and 1,550 ng/L in the PLWTP effluent and 24.7 and 80.1 ng/L in the TJR runoff; *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* in this annual report), AHs (19.6 and 13.0 ng/L in the PLWTP effluent and 3,880 and 831 ng/L in the TJR runoff; *Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California*), and LABs (Table 1) in the PLWTP effluent and TJR runoff, mass emission rates of these compounds are estimated (Table 2). The vertical fluxes of PAHs, AHs, and LABs in the water column at A-17 and R-61 (Table 3) were calculated using the procedure described in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* (in this annual report).

The PLWTP outfall is a major point source for organic pollutants found in the area, as evidenced by the substantially higher sediment concentrations of LABs and PAHs in A-17 than in R-61. The sediment concentrations of AHs in these two locations, however, were not significantly different. Since AHs can be produced by *in-situ* biological processes, their background level in the marine environment may be fairly high, compared to inputs from PLWTP. This was further verified by considerably high AH concentrations in MTJR sediments, although sediment PAH and LAB concentrations were extremely low in this location.

Nonpoint sources contribute significantly to the PAH inputs, as discussed previously. This is corroborated by the higher concentrations of PAHs (126-266 ng/g dry) than those of LABs (35.3-39.2 ng/g dry) in A-17 sediments. The mass emission of LABs was almost twice as much as that of PAHs from the PLWTP outfall (Table 2) and the degree of biodegradation of LABs was about 30-55% in A-17 sediments as inferred from the I/E ratios (Table 1). This large difference between the PAH and LAB concentrations in A-17 sediments can only be accounted for by other nonpoint inputs of PAHs. Additional evidence is the higher vertical fluxes of PAHs than those of LABs at A-17 and R-61 (Table 3). If no biodegradation was assumed during the transport of PAHs from the PLWTP outfall to the sediments, approximately half of the PAHs found in the sediments would be introduced from sources other than the PLWTP outfall. Actual inputs from nonpoint sources should be more significant, since PAH biodegradation is inevitable.

Bottom currents may transport fine suspended particles enriched with sewage-derived organic materials from the discharge zone to remote areas. This transport mechanism likely has resulted in fairly high PAH and LAB concentrations in R-61 trap particulates, despite the long distance (~32 km) between these two locations.

The Tijuana River discharges relatively insignificant amounts of organics into the ocean waters (Table 2). However, a great deal of

TABLE 2. Mass emission rates of total polycyclic aromatic hydrocarbons (PAHs), aliphatic hydrocarbons (AHs), and linear alkylbenzenes (LABs) from the Point Loma Wastewater Treatment Plant (PLWTP) outfall and Tijuana River in 1994.

Compounds	Annual Mass Emission (kg/yr)	
	PLWTP Outfall	Tijuana River
PAHs ^a	395	2.7
AHs ^b	3860	101
LABs	710	17

^aEstimated in *Compositional Indices of Polycyclic Aromatic Hydrocarbon Sources off San Diego, California* in this annual report.
^bEstimated in *Petrogenic and Biogenic Sources of N-Alkanes off San Diego, California* in this annual report.

TABLE 3. Comparison of fluxes of total polycyclic aromatic hydrocarbons (PAHs), aliphatic hydrocarbons (AHs), and linear alkylbenzenes (LABs) at A-17 and R-61 off San Diego, California.

Site	Collection Date	Distance above Bottom (m)	Flux ($\mu\text{g}/\text{m}^2/\text{d}$)		
			PAHs	AHs	LABs
A-17	12/21/93-1/20/94	1 ^a	83	770	9.2
		5 ^b	24	320	2.2
	5/30/94-6/29/94	1 ^c	—	—	—
		5 ^a	4.9	160	0.24
R-61	12/21/93-1/20/94	1 ^a	13	300	NA
		5 ^b	9.1	190	0.28
	5/30/94-6/29/94	1 ^a	4.2	120	0.36
		5 ^d	1.9	120	0.88

^aThree traps.
^bNine traps.
^cTraps lost.
^dEight traps.
 NA=not applicable since the corresponding LABs were not detectable.

sewage-related organic matter may be accumulated in the sea surface microlayer near the mouth of the river. Sewage-related organic materials can be transported toward the nearby beaches and pose potential health hazard to swimmers. By contrast, extremely low concentrations of PAHs and LABs were determined in the sediments at the same location, suggesting effective removal of contaminants from the runoff into deeper waters. Therefore, the impact of the TJR runoff on the quality of the nearshore sediments should be minimal.

The microlayer particulates at SDB contained the highest PAH and n-alkane concentrations as compared to other microlayer samples. Combustion-generated hydrocarbons were the predominant components in the SDB samples, as implied by the molecular indices associated with the compositions of PAH and AH assemblages. The storm runoff draining from the San Diego International Airport and boat engine exhausts are probably the major sources of hydrocarbon inputs.

CONCLUSIONS

LABs were detected in the PLWTP wastewater effluent, Tijuana River runoff, microlayer, water column particulates, and sediments collected off the coast of San Diego in 1994. The distributions of LABs in various media and sampling locations suggested that these compounds were essentially derived from domestic waste discharges. The PLWTP outfall is a major source for LAB inputs, while the Tijuana River runoff discharges much less significant amounts of LABs. However, the contents of sewage-derived organics are sometimes enhanced in the sea surface microlayer near the mouth of Tijuana River. In addition, the I/E ratios

indicated that 30-55% of the LABs were degraded in the water-column particulates and sediments. Other processes (e.g., dilution, evaporation, bioaccumulation, etc.) may also be important in removing LABs from the discharge zone. Sewage-derived organic materials can be carried into remote areas via suspension of fine particulates.

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