Toxicity of Stormwater Runoff in Los Angeles County

Previous studies of stormwater runoff by the Southern California Coastal Water Research Project produced estimated mass emission rates of solids and contaminants into the Southern California Bight (SCCWRP 1973, Young et al. 1980, SCCWRP 1988), but toxicity levels were never tested. Valerie Raco conducted this study to obtain estimates of stormwater runoff toxicity on marine life, to compare the water toxicity of different rivers (storm channels) during a single rainstorm, and to monitor a single river during a series of rainstorms during a one-year period.

The Microtox Toxicity Analyzer System was used to measure the toxicity of stormwater runoff samples by exposing luminescent marine bacteria to each aqueous sample and measuring changes in light output. The amount of light produced by the luminescent bacteria is an indicator of the general health of the bacteria, therefore the light is reduced when the bacteria are exposed to toxic solutions.

Samples of runoff water were collected from three storm channels in Los Angeles County: the Los Angeles River, San Gabriel River, and Ballona Creek (Figure 1), during four rainstorms in 1987 and analyzed for contaminant and toxicity levels. The Los Angeles River, which accounts for the largest flow in southern California (mean annual flow volume for 1983-1987 was 1.8 x 10^8 m^3 [1 m^3 = 35.31 ft^3]), drains west Los Angeles County from the San Fernando Valley, through downtown Los Angeles, to Long Beach. The San Gabriel River, which has the third largest flow in southern California (1.3 x $10^8 m^3$), drains southeastern Los Angeles County from the San Gabriel Mountains through the San Gabriel Valley to Long Beach. Ballona Creek, with the fourth largest flow (0.36 x 10^8 m^3), drains the western part of the City of Los Angeles. The drainage basins of the Los Angeles River, the San Gabriel River, and Ballona Creek encompass 2,110 km^2, 598 km^2, and 229 km^2 respectively. Both the Los Angeles and San Gabriel Rivers receive secon-

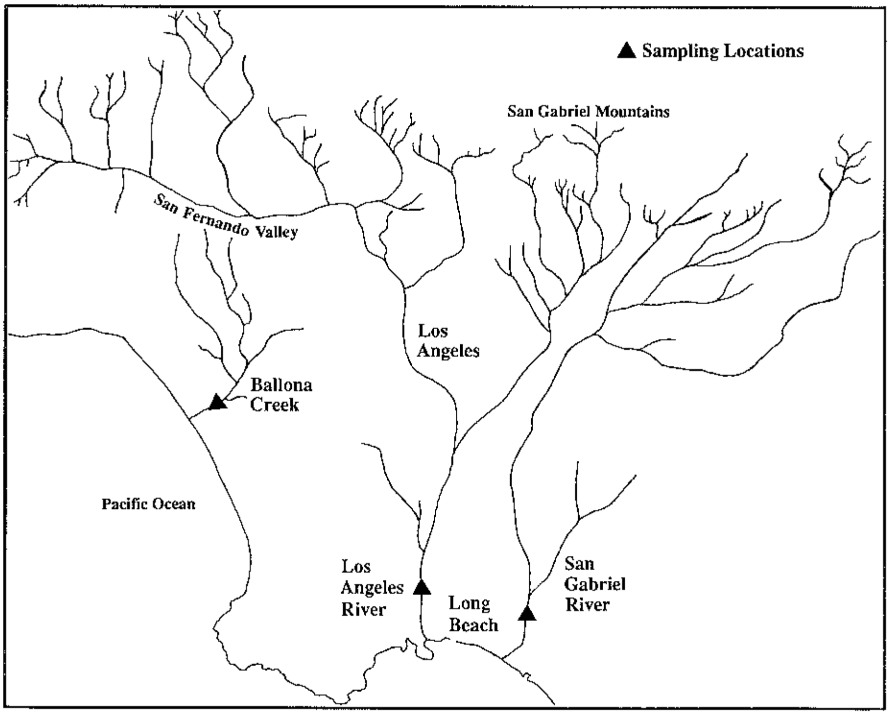


Figure 1. Location of sampling stations in the drainage basins of the Los Angeles River, San Gabriel River, and Ballona Creek.

dary and tertiary effluent from upstream municipal wastewater treatment plants throughout the year, but these discharges represent a minor flow component during storm runoff events.

Methods

Runoff samples were collected from the Los Angeles River, San Gabriel River, and Ballona Creek during rainstorms on January 4-5, March 21, October 22-23, and December 4-5, 1987. In this paper, the January runoff data is presented for all three storm channels, but only the Los Angeles River data are presented for the March, October, and December storms. Low-flow (non-storm) samples were also collected on October 31, 1986 from the Los Angeles River and Ballona Creek. The Los Angeles River collecting station was located at Willow Street in Long Beach, the San Gabriel River station was located at College Park Drive in Long Beach, and the Ballona Creek station was at Inglewood Boulevard in Los Angeles. Collecting stations were located as close to the mouth of each river as possible without encountering the tidal prism.

Runoff samples were collected during and sometimes immediately after each rainstorm. Toxicity testing was conducted within 2 days of sampling; samples were stored at 4°C until tested. Suspended solids in each sample were allowed to settle before a portion was removed for testing; if the sample remained turbid, it was centrifuged.

The Microtox Toxicity Analyzer System was used to

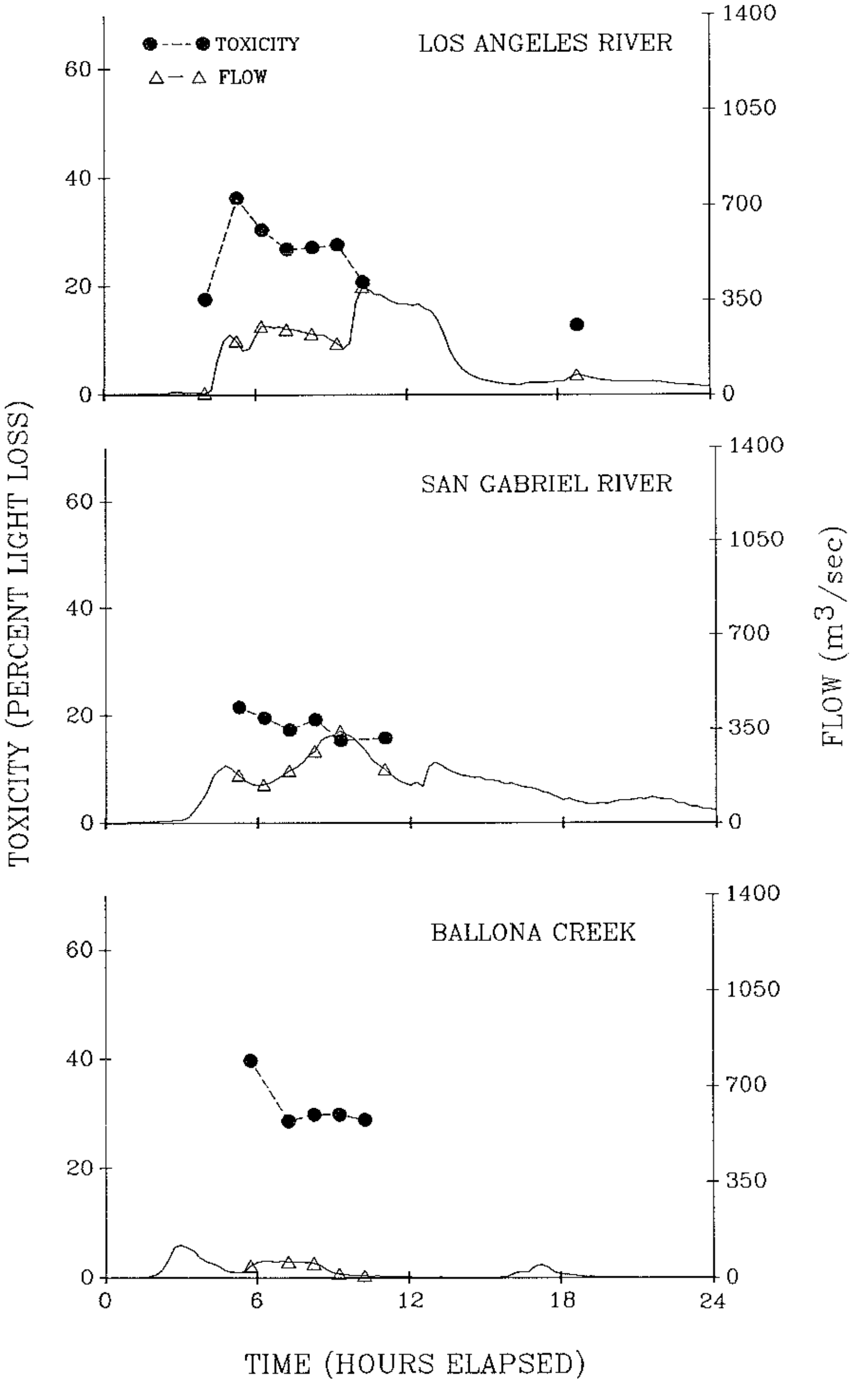


Figure 2. Runoff toxicity and flow rate for each of the rivers sampled during the January 4, 1987 rainstorm. The time axis represents the number of hours that elapsed after a time reference point before each storm.

test runoff water toxicity as described by Bulich (1982). The Microtox procedure utilized freeze-dried marine bacteria *(Photobacterium phosphoreum)* which were reconstituted, diluted, and allowed to stabilize. All analyses were conducted at a salinity level of 20 ppt; all samples were adjusted to a salinity of 20 ppt by adding a concentrated sodium chloride solution to promote osmotic protection of the bacteria. Initial light produced by the bacteria was measured with the system's photometer and recorded. The samples and a control consisting of 20 ppt sodium chloride solution were then introduced to the Microtox bacteria, which diluted the samples to 45% of the original concentrations. After 30 min of exposure, light output was measured and recorded again. Toxicity levels were calculated by measuring the decrease in light output and normalized to the control.

Results

Toxicity results for the individual samples from each storm were plotted on graphs in relation to river flow rates in Figures 2 and 3; toxicity expressed as percent light loss (relative to the control) is graphed for the Microtox values. The toxicity of runoff collected during the January 4 rainstorm ranged from 13% to 36% light loss for Los Angeles River samples, 15% to 22% light loss for San Gabriel River samples, and 29% to 40% for Ballona Creek samples (Figure 2). Los Angeles River toxicity levels for all four storms ranged from 6% to 67% (Figure 3). It appeared that there was an elevated

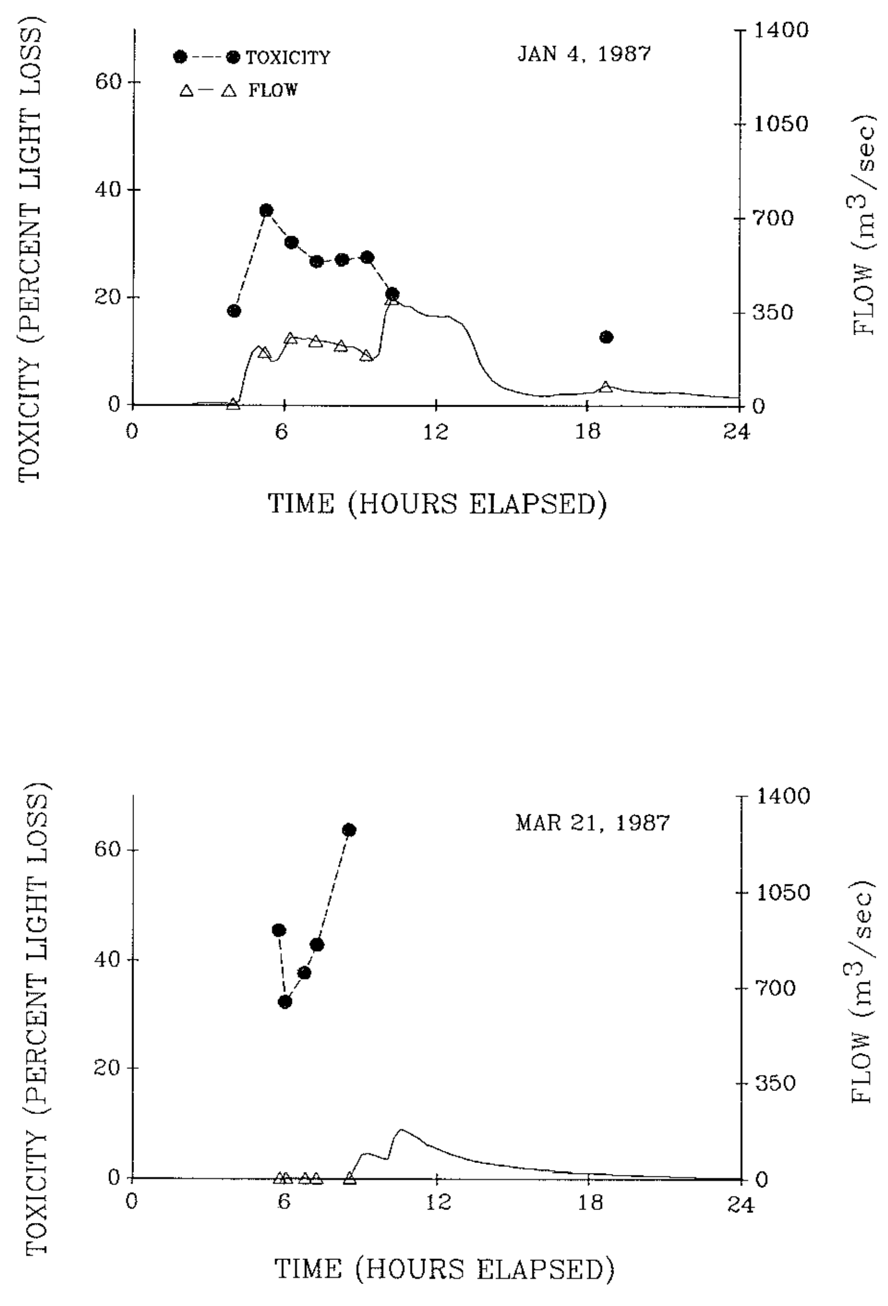
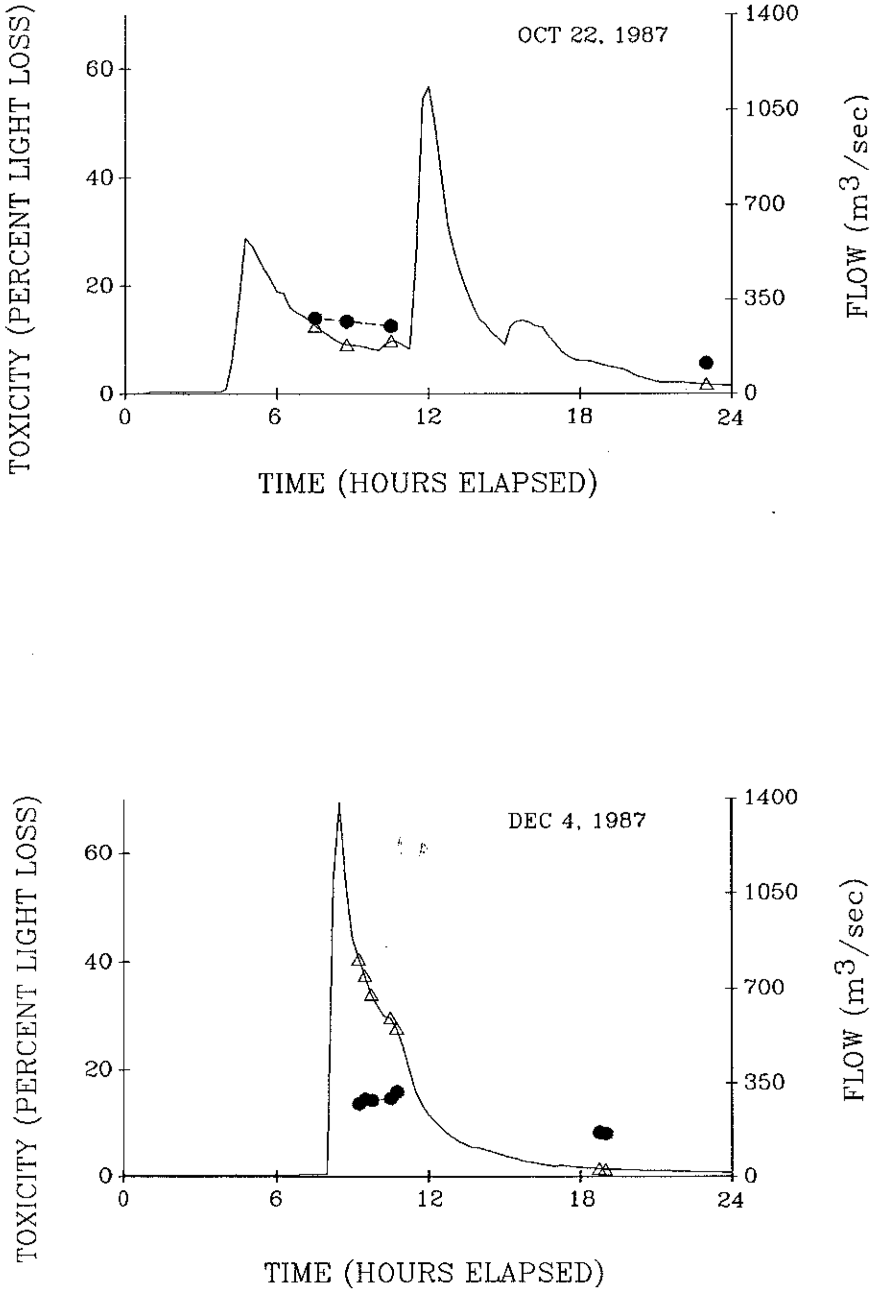


Figure 3. Runoff toxicity and flow rate of the Los Angeles River during four rain-
a time reference point before each storm.



storms in 1987. The time axis represents the number of hours that elapsed after

level of toxicity in runoff waters at the beginning of the storms that roughly corresponded to the first peak of the flow rate; runoff toxicity generally decreased as the storms continued.

Because real-time measurements of flow rate were not available at the time of sampling, the important first peak in flow was missed at Ballona Creek during the January rainstorm and at the Los Angeles River during the March and October 1987 storms. However, March storm samples collected before the initial flow peak indicated that the toxicity changed rapidly and reached relatively high levels, which illustrates the importance of sampling during the initial phase of a rainstorm.

The Los Angeles River data presented in Figure 3 suggests that the maximum flow rate for the four storms had an inverse relationship with the maximum toxicity present; runoff from storms with larger flow rates generally had less toxicity than storms with lower flow rates. However, storm runoff sampled January 17, 1988 (data not presented in this paper) had a relatively low flow rate and low toxicity values.

The wide range of toxicity present at different sampling stations and during different storms is evident when comparing the toxicity data for each storm summarized in Figure 4. Mean toxicity levels for the storms was 18% for the San Gabriel River, 31% for Ballona Creek, and 13% to 45% for the Los Angeles River. The toxicity levels of the Los Angeles River and Ballona Creek for

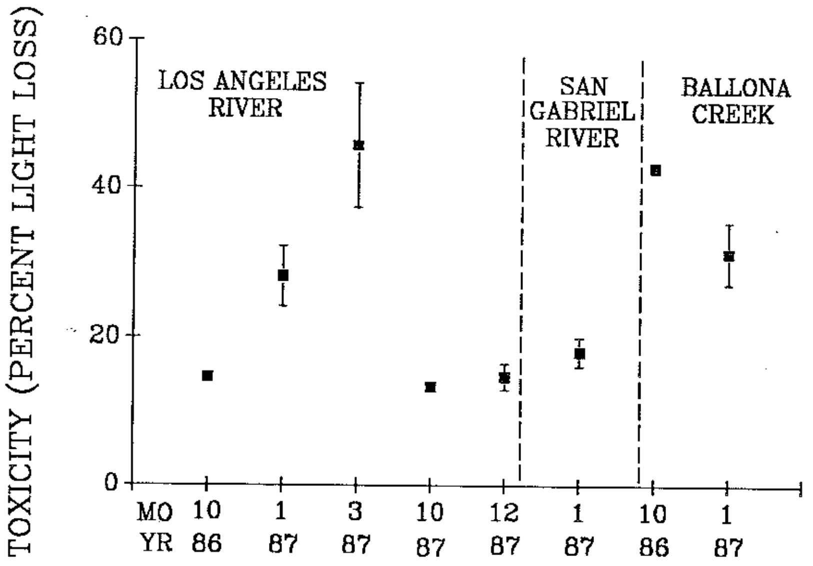


Figure 4. Stormwater toxicity levels (mean percent of light loss ±95% confidence intervals) for each storm sampled in 1987. Two low flow samples are included (October 31, 1986). Data collected after 90% of the total storm flow volume passed were not included in calculating the means.

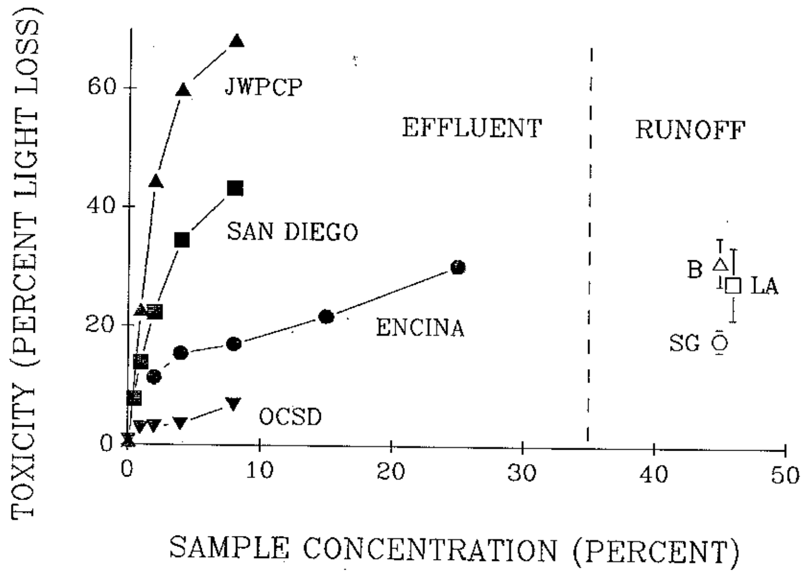


Figure 5. Comparison of wastewater effluent and runoff toxicity. Runoff data are means ±95% confidence intervals of all storms combined for each sampling station. Runoff data does not include low-flow sampling or samples taken after 90% of the total storm flow passed. Wastewater effluent toxicity was measured on 24 hr composite samples collected in 1987 or 1988.

January runoff samples were similar, while the San Gabriel River toxicity was much lower. This is probably a result of more commercial and industrial activity in the drainage basins of the Los Angeles River and Ballona Creek. However, the toxicity of the Los Angeles River low-flow sample (October 1986) was three times less than the Ballona Creek low-flow sample, possibly owing to the dilution of the Los Angeles River from the relatively clean tertiary effluent it receives. Due to insufficient sampling of the Los Angeles River during the March and October storms, trends that appear with respect to time (i.e. toxicity increases from October 1986 to March 1987, then decreases for October 1987) may be spurious.

Most southern California wastewater effluents seem to be more toxic than river runoff (Figure 5). When runoff and sewage effluent toxicities were compared, most effluent samples tested at much lower concentrations (≤25%) produced similar or greater Microtox effects than storm runoff samples tested at 45% concentrations.

Multivariate statistics were used to determine if runoff toxicity was related to the concentration of specific contaminants in the samples. A principal components analysis statistical procedure was used to reduce the number of variables by grouping those contaminants with highly correlated abundance patterns. Concentrations of suspended solids (SS), suspended volatile solids (SVS), trace metals, chlorinated hydrocarbons (CHCs), and chloroform extractables were included in this analysis. Polynuclear aromatic hydrocarbons (PAHs) were not included because they have not yet been measured.

Principal component analysis grouped the data into three factors: factor 1 was most highly correlated with concentrations of SS, SVS, Cr, Ni, and Cu; factor 2 had high correlations with the CHCs (total DDT, PCBs [Aroclors 1254 and 1242], and lindane), chloroform extractables, Pb, Zn, and Cu (almost equal to the correlation of Cu in factor 1); factor 3 was only highly correlated with Cd.

A multiple regression was performed on the principal component analysis scores versus the Microtox analysis results, which indicated that 59% of the runoff toxicity could be accounted for by changes in measured runoff characteristics. Factor 1 was the only contaminant group that had a significant correlation with toxicity (a subsequent principal component analysis on PAHs may yield different results). Within factor 1, toxicity increased with increases in SVS and decreases in SS, Cr, Cu, and Ni. Because the regression results indicated that toxicity decreased when Cr, Cu, and Ni concentrations increased, it is unlikely that the total concentrations of these trace metals were responsible for the observed toxicity. The results of principal component analysis indicate the SS or SVS content of storm runoff may substantially affect its toxicity, or that the runoff toxicity is strongly influenced by a type (e.g. PAH) of contaminant not yet measured.

Valerie Raco conducting Microtox analyses.

Discussion

This study provides information to help us understand the contribution of toxicity from stormwater into southern California marine waters. The data presented herein indicates that stormwater was generally less toxic than sewage effluent, and that runoff toxicity can vary substantially during a storm period, among a series of storms, and among runoff sampling stations.

Poor correlation between toxicity and conventional contaminant measurements calculated by principal components analysis indicate that toxicity should be measured directly by Microtox analysis or other bioassays to assess the biological impacts of stormwater runoff, instead of inferring toxicity from chemical measurements.

Continued research may provide information about which contaminants control the toxicity of stormwater and how these inputs affect nearshore organisms.

Acknowledgements

We thank Steven Bay, Dario Diehl, Richard Gossett, Darrin Greenstein, G. Patrick Hershelman, Jimmy Laughlin, Henry Schafer, Harold Stubbs, David Tsukada, Charles Ward, Skip Westcott, and Peter Szalay for helping to collect runoff water samples. Karen Englehart, Richard Gossett, G. Patrick Hershelman, Chuck Ward, Skip Westcott, and Peter Szalay are acknowledged for their assistance in extracting and analyzing trace contaminants.

Literature Cited

Bulich, A.A. 1982. A practical and reliable method for monitoring the toxicity of aquatic samples. *Process. Biochem.*(March/April):45-47.

SCCWRP. 1973. The ecology of the Southern California Bight: Implications for water quality management. Southern California Coastal Water Research, Long Beach, CA.

SCCWRP. 1988. Storm runoff in Los Angeles and Ventura Counties. Pages 13-18 *in* Southern California Coastal Water Research Project 1987 Annual Report. Southern California Coastal Water Research Project, Long Beach, CA.

Young, D.R., T.-K. Jan, R.W. Gossett, and G.P. Hershelman. 1980. Trace pollutants in surface runoff. Pages 163-169 *in* Coastal Water Research Project 1979-1980 Biennial Report. Southern California Coastal Water Research Project, Long Beach, CA.