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EFFECTS OF OCEAN SLUDGE DISPOSAL

During the past year, the Project has conducted an intensive study in the Santa Monica Submarine Canyon region of Santa Monica Bay to determine the magnitude and extent of the alterations in sediment quality caused by the discharge of sludge to that area. A major sampling effort was made to intercept and collect settling particulate matter just above the bottom using sediment traps. This report is a summary of a portion of the results we have obtained. A complete report of the study is being prepared for release as a Project technical memorandum.

Since 1960, the Hyperion Sewage Treatment Plant has been discharging between 4 and 5 million gallons/day of a mixture of plant sludges and secondary effluent through a 7-mile-long outfall pipeline that terminates at the head of Santa Monica Canyon at a depth of 100 meters. Figure 1 shows the locations of our sampling stations. These were selected with the intention of characterizing the sediments of the entire canyon area and modified by the progressive results of the sediment trap sampling program.

SAMPLING AND SAMPLE ANALYSIS

The sampling program extended over a period of 7 months beginning in June 1974. During this period, four sediment traps were used to collect 32 samples of settling particulate matter at a total of 25 sampling stations, including two control stations in Catalina Submarine Canyon just off the eastern side of Santa Catalina Island. Two or more samples were taken at Stations 1, 2, 3, 4, 7, and 10. The particulate matter collected by the sediment traps was analyzed for total solids, volatile solids (550°C for 1 hour), chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5,) , hexane extractable material (HEM), and trace metals content (chromium, copper, cadmium, nickel, lead, zinc, and mercury).

At each of the sediment trap stations, two types of bottom samples were taken—surface grab samples with a Shipek grab and vertical core samples using a gravity corer (at most stations, both samplers were successful). The core samples were sectioned at 2- to 3-cm intervals from the top, and all sections were analyzed for wet density, moisture content, and volatile solids. All bottom grab samples were analyzed for moisture content, volatile solids, and BOD_5. Selected bottom samples, both core and grab, were analyzed for COD, HEM, and trace metals content.

The results of all chemical analyses are expressed on a dry-weight basis, with appropriate corrections for the sea-salt content of the dried solids.

The flow, solids content, and chemical characteristics of the effluent discharged through the 7-mile pipe are routinely monitored by Hyperion laboratory personnel, who cooperated with us in this study by running additional analyses of the effluent properties on 10 weekly composite samples taken during the course of this research.

RESULTS AND DISCUSSION

The characteristics of the 7-mile pipe effluent are listed in Table 1. Of particular importance are the high pro-portions of the effluent constituents that are associated with the particulate matter. Whereas the impact of the dissolved components of any discharge may be mitigated by high dilutions with the receiving water, particulate matter will tend to settle and be reconcentrated at the water/sediment interface. A laboratory study determined that very little change in the discharged particulate composition occurs even after 11 days of mixing with aerated seawater. This was an important finding because it indicates that the particulate matter of effluent origin that settles to the bottom should have essentially the same properties as the discharged particulates.

The volatile solids content of both trap and bottom particulate matter was assumed to be a direct and reliable measure of the organic content of the samples. As a check on the relationship between volatile solids and organic matter, 20 samples were analyzed for organic carbon. The results, presented graphically in Figure 2, confirmed the validity of this assumption for both types of samples.

The rate of fallout of particulate matter into the sediment traps—and presumably onto the ocean bottom--is calculated from the weight of particulates collected, the sampling period, and the collecting surface area of the traps. Results of the sediment trap samplings in terms of particulate flux and particulate volatile solids are presented with respect to distance from the 7-mile effluent discharge point in Figures 3 and 4. The lines represent distinct trends in the data; for comparison, the results from the control stations in Catalina Submarine Canyon are superimposed to the extreme right of each figure. The control data fit reasonably well with respect to both total fallout rates and natural fallout volatile solids. Particulate fallout of noneffluent origin has been estimated to be 8 percent volatile. The values of other chemical characteristics (COD, HEM, and the trace metals) are highly correlated with one another and with the volatile solids content of the samples; plots of these parameters versus distance would be very similar to Figure 4. The unit of measured constituent per unit of volatile solids, indicated by the slope of the best-fit regression line for each of these constituents, was very close to the values for the effluent particulates. A typical example of the relationships found between volatile solids and metals content for both sediment trap and bottom samples is shown in Figure 5. These findings show clearly that the rapid decline in the organic con-tent and other measured properties of the settling particulates with increasing distance from the outfall is due to dilution of the effluent solids by natural marine particulates rather than to any actual changes in effluent particulate characteristics in the water column through dissolution or decay.

By assigning areas of influence to each of the sediment trap stations, it is possible to compute the total amount of particulate matter settling to the bottom within the study area. Excluding Station 22, the area we have considered is approximately 69 sq km, and the total solids flux to the bottom comes out to be 1,035 dry metric tons per day. This is considerably more than the 130 dry metric tons of particulates discharged each day. To separate effluent particulate fallout from natural fallout, we assumed the effluent solids to be unchanged during transport with respect to heavy metals, volatile solids, and COD content (based upon laboratory studies) and the natural solids to be 8 percent volatile and to have the same heavy metals and COD content as the control samples (based upon field data). Sediment trap sample sludge content has been taken as the average of six separate estimates, using volatile solids, COD, and four heavy metals. Using these numbers, the natural fall-out is about 780 tons per day, and effluent particulate fallout is 255 dry metric tons per day. This amount is in much better agreement with the quantity discharged and indicates that approximately 125 metric tons per day of the effluent particulate fallout might be called resuspended solids that have settled at more than one location.

Alterations in surface sediment quality also decrease with increasing distance from the outfall. Contaminant levels are very high close to the outfall and decrease rap-idly for the first 3 km; thereafter they decline more gradually with distance. Several stations (Stations 2, 3, 4, 20, 21, and 23) near the outfall but shoreward of it have high fallout rates and high fallout organic content, but sediment organic content and other properties are not high. This seems to show that the currents at these stations are strong enough to prevent the highly organic solids that are discharged from moving shoreward. Solids falling in the areas represented by these six stations apparently account for approximately 70 of the 125 dry metric tons of resuspended effluent particulates mentioned in the previous paragraph.

Current measurements made during this study indicate that the net current is 5.5 cm/sec downcanyon. The maximum current speed recorded was 32 cm/sec, and all currents greater than 25 cm/sec were downcanyon.

Very high correlations were found between volatile solids and other measured physical and chemical properties of the sediments. A typical example is shown in Figure 5. One striking pattern in the volatile solids/trace metal relationships found was that, in every case, the unit weight of metal per unit weight of volatile solids was higher for the sediments. This indicates that the rate of loss of organic material from the sediments (presumably due to bio-logical decomposition) is greater than the rate of metals loss from the sediments (chemical mobilization or biological uptake and transport up the food chain into water-column or mobile benthic organisms). The average increase of this metals-to-volatile-solids ratio in the sediments for five of the metals analyzed (chromium, cadmium, copper, zinc, and mercury) is 1.9. On the other hand, the highest metals concentrations found in the sediments were approximately the same as the highest values in the sediment traps, indicating that some degree of metals mobilization and loss from the sediments does take place.

The depth of sediment quality alteration is of interest, and depth profiles of concentrations and wet densities are necessary for computing the total weight of the various constituents in the sediments. The depth profiles of volatile solids for five cores are shown in Figure 6. Stations 5, 1, and 7 are each successively further downcanyon from the discharge. The influence of the sludge discharge obviously decreases with increasing distance, both in terms of sediment concentrations and depth of sediment affected. The depth of highly organic deposits in the close proximity of the discharge (Stations 1 and 5) is less than 30 cm (1 foot). By analyzing the depth profile at each station separately for background volatile solids and then subtracting out this background and computing the accumulated effluent volatile solids, one can estimate the total accumulated volatile solids of effluent origin resident in the sediments of the study area to be 157,000 dry metric tons. This accumulation is 37 percent of the 420,000 dry metric tons of volatile particulate solids that have been discharged over the entire operational history of the outfall. Using the average metals per unit of volatile solids increase in the sediments of 1.9, an average of 70 percent of the total metals discharge may be accounted for in these sediments.

To determine the changes that have taken place in sediment quality as a result of continuing discharge, we compared surface sediment heavy metals concentrations found in this study with 1971 values. When corrected for salt con-tent of the dried solids, the 1971 values are directly com-parable with our 1974 values. A typical result of this comparison is presented in Figure 7; other heavy metals show this same pattern. The highest values are nearest the outfall, with a rapid dropoff within the first 2 to 3 km and a much more gradual decrease with distance thereafter. There is no obvious change between the 1971 and 1974 surface sediment quality even though 20 percent of the total solids discharge has taken place in the 3 years between samplings.

CONCLUSIONS

- More than 90 percent of the possible pollutants discharged through the Hyperion 7-mile pipeline are associated with particulate matter, and the association of these pollutants with the particulates is essentially unchanged by mixing with seawater.
- The transport of the discharged particulate matter is predominantly downcanyon.
- The current rate of discharge of particulate matter represents 20 percent of the total (effluent plus natural) particulate matter settling to the bottom in the Santa Monica Submarine Canyon study area (69 sq km); the effluent contribution of organic matter to the bottom is twice the noneffluent organic input.

- Major sediment quality alterations resulting from 15 years of treatment plant sludge discharge are confined within the canyon, are greatest nearest the discharge point, and decrease very rapidly with distance.
- The rate of decomposition of organic matter in the sediments is substantially greater than the rate of trace metals mobilization.
- A layer of (primarily) sludge particulates exists on the canyon floor in the immediate vicinity of the outfall. This layer is approximately 25 cm deep and covers an area of about 2 sq km. Comparison with 1971 data indicates that this layer of sludge is not moving and that surface sediment quality has not changed noticeably between 1971 and 1974.

Table 1. Characteristics of effluent discharged through the 7-mile outfall, 1974[1].

Constituent	Concentration (mg/L[2])	Mass Emission Rate (metric tons/yr)	%Associated With Particulate Phase[3]
Total solids	8,400	55,000	87
Volatile solids	5,100	33,400	92
COD[4]	7,700	50,400	97
BOD_5[4]	1,900	12,400	95
Oil and grease	900	5,900	63
Ammonia-nitrogen[4]	300	1,960	—
Organic-nitrogen[4]	250	1,640	—
Total phosphate-phosphorus[4]	221	1,450	67
Trace metals			
Cd	1.27	8.3	99
Cr	15.1	99.0	94
Cu	13.9	91.0	94
Pb	1.13	7.4	61
Ni	3.1	20.3	96
Zn	23.9	156.0	89
Hg	0.154	1.01	—
Chlorinated hydrocarbons			
Total DDT	0.0026	0.017	—
Total PCB	0.0033	0.022	—

[1] Annual averages unless otherwise noted.

[2] Analysis by Hyperion Laboratory.

[3] Estimates for all constituents except COD, BOD_5, and total phosphate-phosphorus based upon analysis of a few grab samples.

[4] Estimates based upon analysis of ten weekly composite samples.

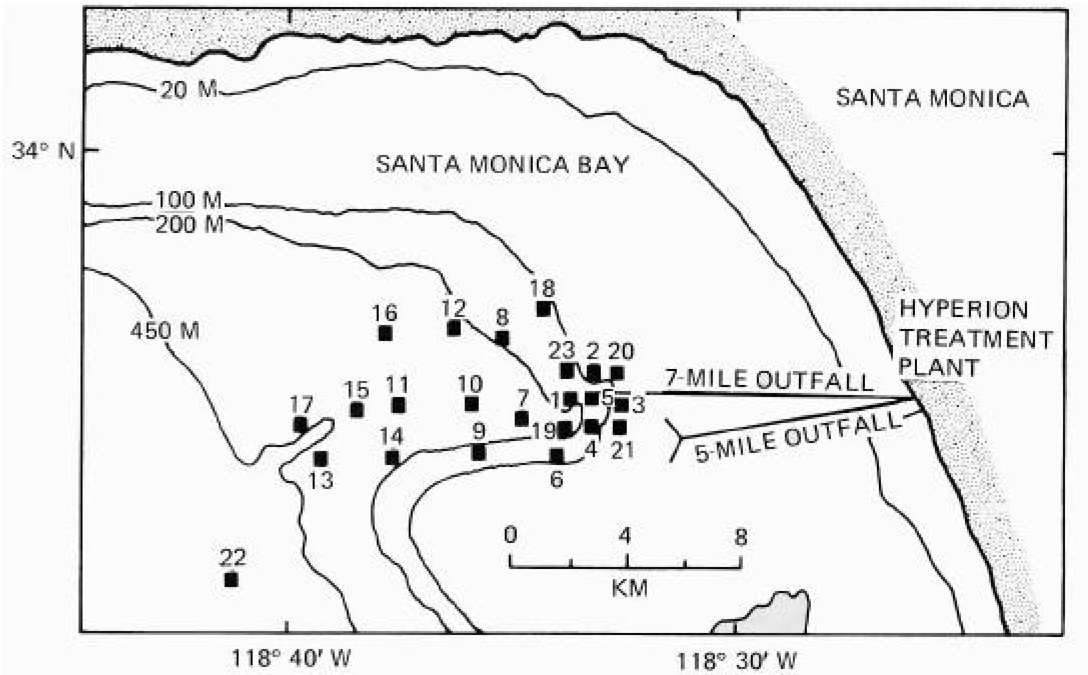


Figure 1. Hyperion outfall system and study sampling stations.

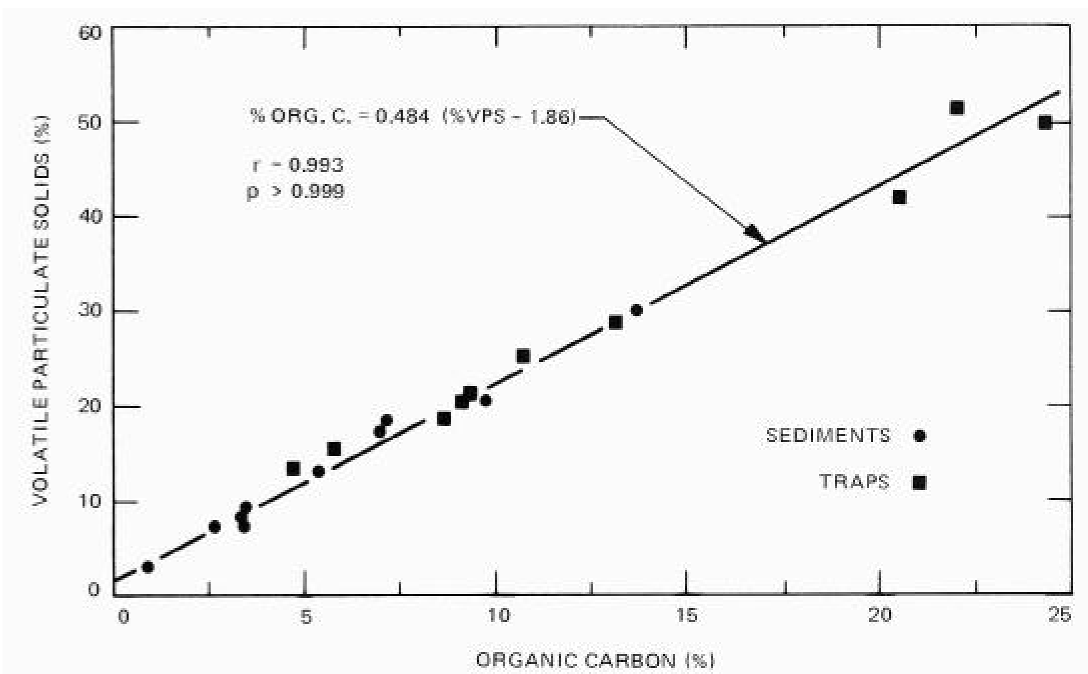


Figure 2. Volatile solids as a measure of organic carbon.

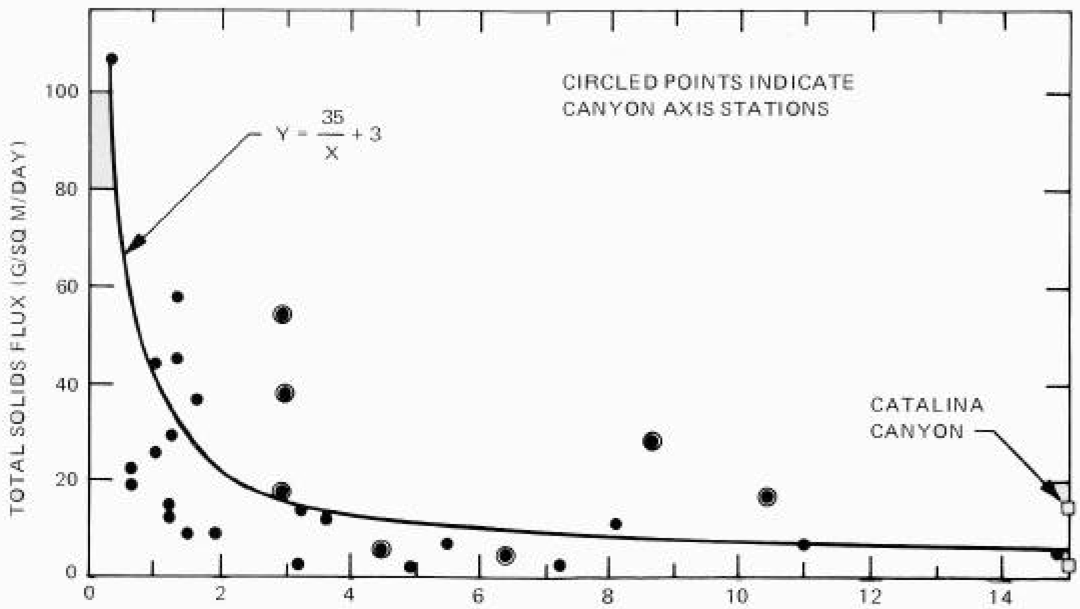


Figure 3. Observed Sedimentation Rates vs. Location

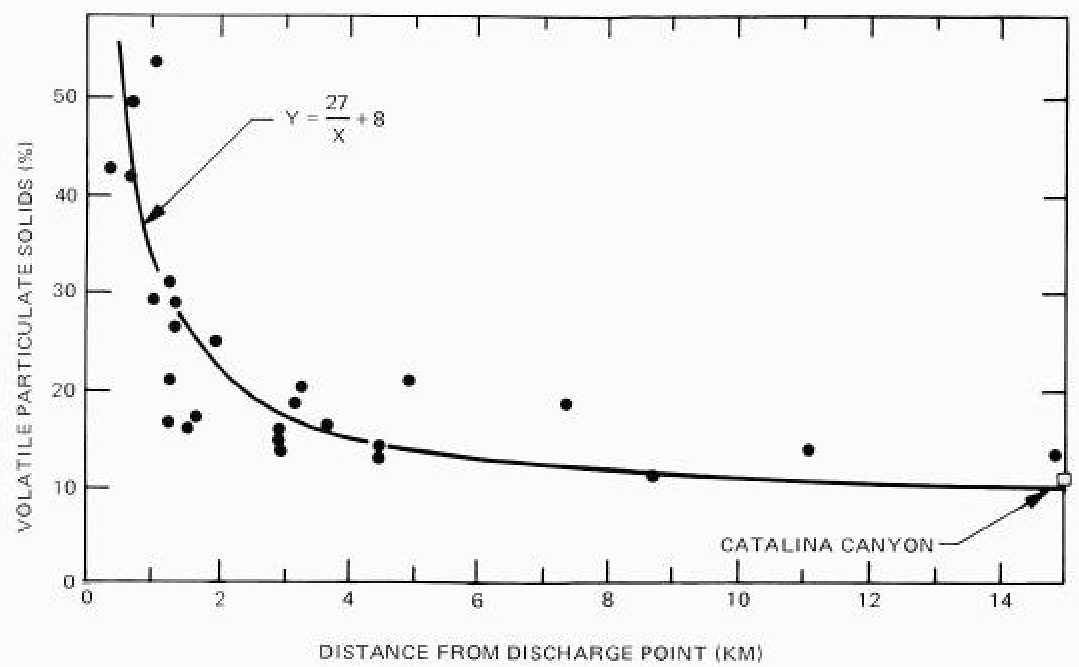


Figure 4. Organic content of settling particulates vs. location.

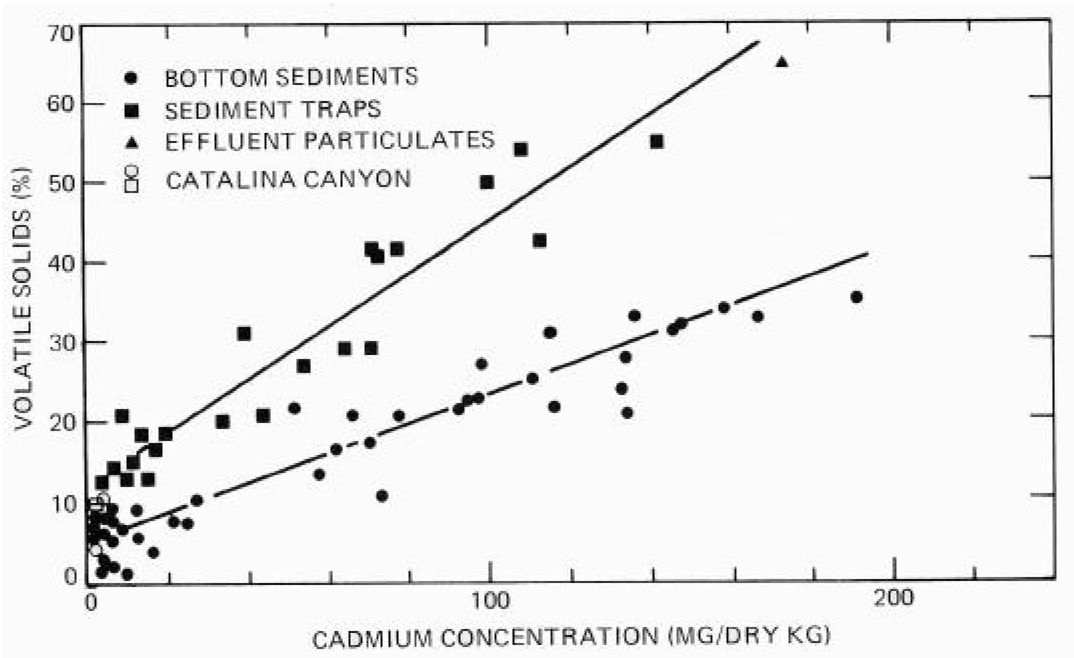


Figure 5. Cadmium vs. volatile particulate solids.

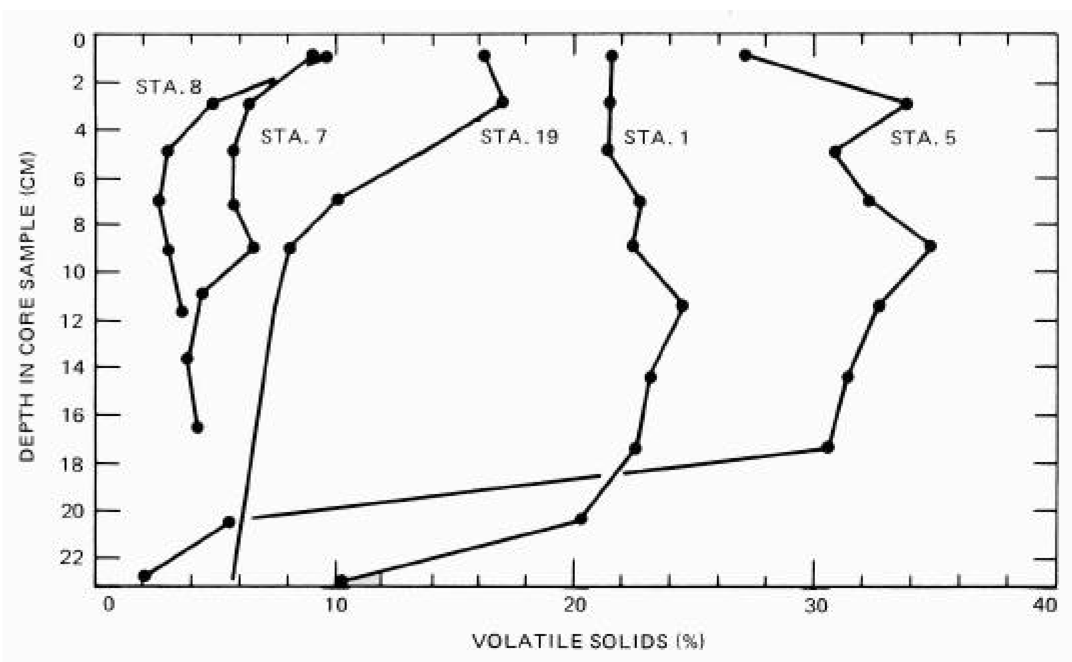


Figure 6. Core sample vertical profiles of organic content.

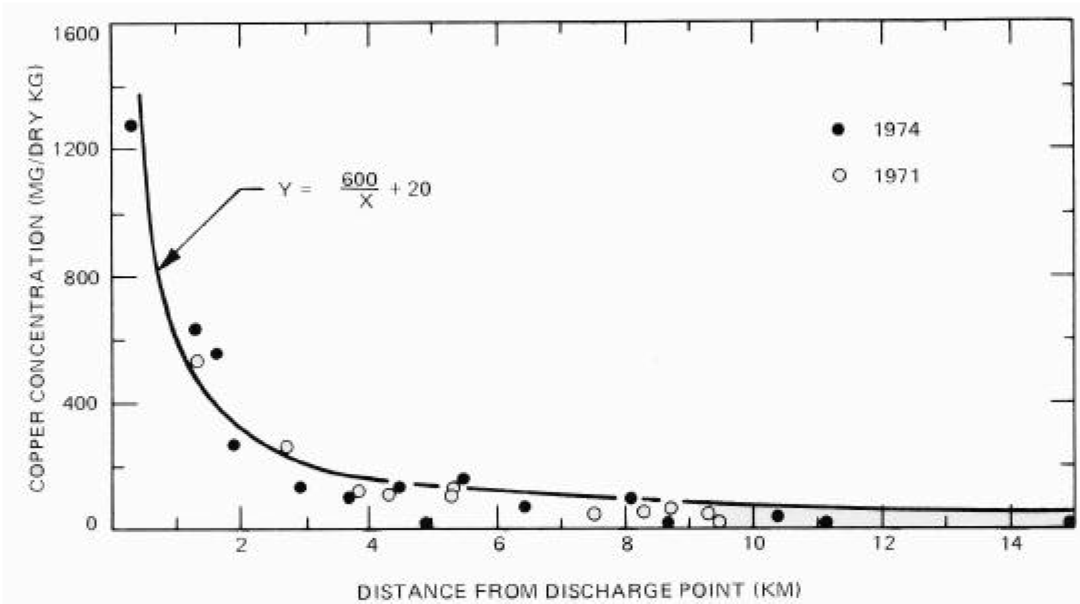
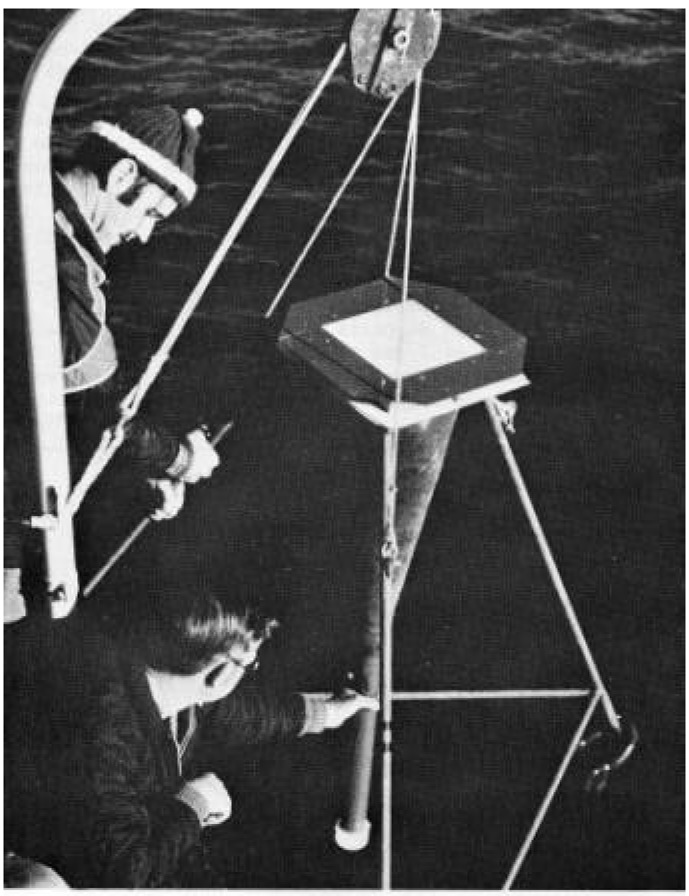


Figure 7. Copper in surface sediments (0-2 cm) in Santa Monica Canyon, 1971 and 1974.



**Harold Stubbs and Jack Mardesich lower a sediment trap to the ocean bottom.
The device collects particulate matter settling to the sea floor.**