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OTEC-1
ENVIRONMENTAL MONITORING PROGRAM

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July 1981

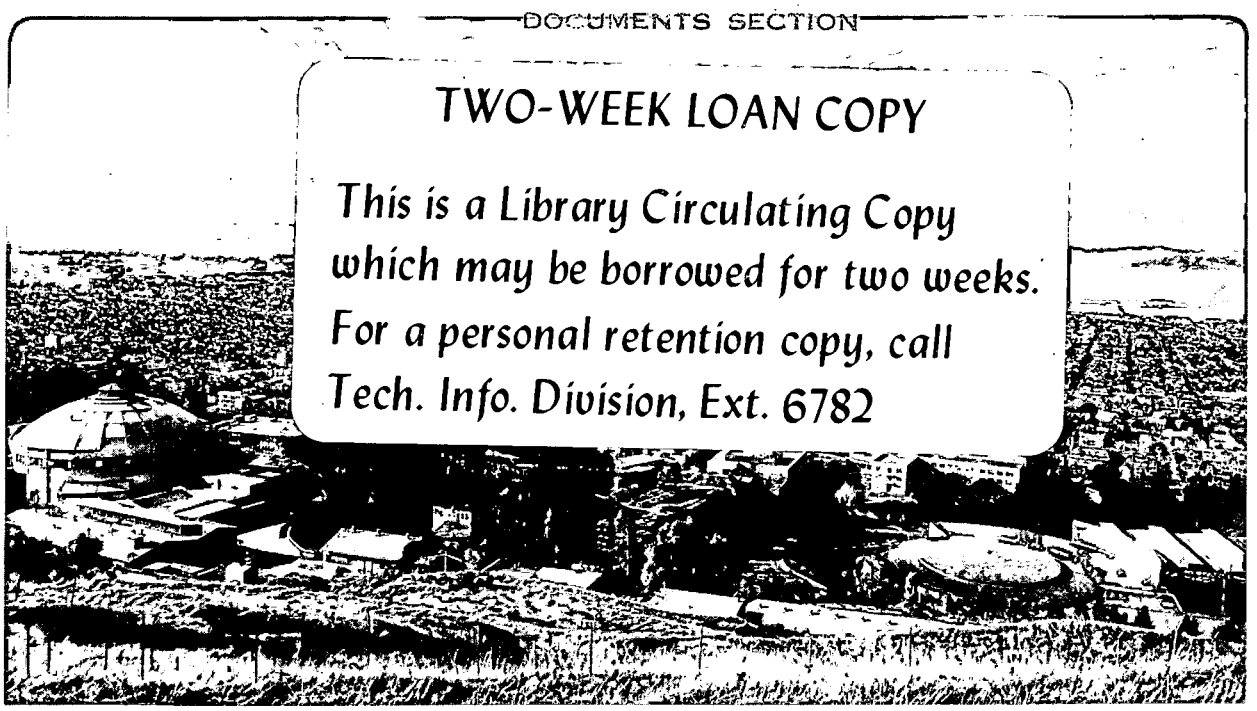
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OTEC-1
Environmental Monitoring Program

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ABSTRACT

Environmental monitoring for OTEC-1 operations consists of an on-board program conducted by Aecos, Inc., and an oceanographic sampling program, conducted from research vessels, by EG&G and the University of Hawaii. Both programs are directed by the Marine Sciences Group of the Lawrence Berkeley Laboratory. The goal of these programs is to develop environmental data for use in the various OTEC-1 experiments, to maintain the operating permit issued by EPA, and to provide the basis for estimating potential effects of larger scale plants.

Work to date includes the six initial oceanographic cruises to the OTEC-1 site (HOTEC-01-06) prior to deployment at approximately two month intervals, followed by three oceanographic cruises in the summer of 1980, January 1981 and April 1981. Current meter arrays have been operated near the site since June 1980. On-board monitoring has been continuous since the deployment of OTEC-1 from late October 1980 to April 1981.

On-board measurements in excess of the environmental permit requirements have been developed in conjunction with the ANL-operated joint test group. Additional current profile measurements from the OTEC-1 platform useful for design requirements and ship handling characteristics were planned and augmented through discussions of the needs of the Ocean Engineering group and the ship's operators.

INTRODUCTION

The OTEC-1 environmental monitoring program began in October 1978 with the first in a series of six oceanographic cruises to the proposed site prior to deployment of the OTEC-1 platform. The information collected on these cruises (HOTEC 01-06) was primarily cruise oceanographic work including hydrocast and net tow information. Serial current measurements did not begin until June 1980 and continued through the OTEC-1 platform deployment until April 1981. Oceanographic cruises continued after the initial HOTEC bimonthly occupations during deployment. In addition, in April 1981 a plume study was conducted in conjunction with the oceanographic cruise. During deployment on-board platform measurements were made using the environmental van.

This paper will briefly summarize the significant findings of the environmental program based on analyses completed to June 1981. More completed specific studies are found in these proceedings in papers by Hartwig (Biology), Hunt and others (Chemistry) and Harms (Physical and Ocean Engineering). Final reports and other specific papers based on OTEC-1 work will be published beginning in the summer of 1981. All qualified environmental data will be deposited with the National Oceanographic Data Center (NODC) in Washington.

PHYSICAL OCEANOGRAPHIC DATA

Water currents speed and direction measurements from current meter moorings in the vicinity of the OTEC-1 site off Hawaii between June 1980 and April 1981 are summarized below:

26 June - 20 July 1980 Deployment

Depth M	MAX	MEAN	SD	DIR	% OBS
177	58.60	18.88	11.64	30°-120°	58.4
281	47.12	14.06	8.23	315°-090°	62.1
924	18.35	6.06	3.28	180°-225°	29.1
24 July - 19 September 1980 Deployment					
56	151.95	44.12	36.25	0°-90°	72.3
73	133.85	42.12	30.13	345°-90°	82.2
90	117.98	34.84	25.44	345°-90°	83.3
113	89.05	29 02	21.06	345°-75°	69.7
166	81.02	22.98	18.71	345°-60°	55.3
811	26.89	7.77	3.98	255°-330°	27.7
23 September - 20 December Deployment					
45	75 61	27.26	14.28	15°-090°	53.7
70	73.00	25.10	12.20	15°-090°	51.2
155	50.97	13 96	8.02	0°-075°	31.9
811	37.90	7.96	4.76	180°-240°	26.5
26 December 1980 - 14 April 1981					
54	94.46	29.27	17.03	300°90°	64.4
101	84.38	22.87	13.24	285°-90°	74.3
151	71.50	18.87	10.23	330°-105°	61.9
350	32.86	10 81	4.73	315°-90°	49.8
771	31.93	8.53	4.44	165°-270°	39.1*

*At 771 meters, 41.43% of directions range from 285°-60°, a spread of 135° azimuth; but 39.1% of

directions range from 165°-270° a spread of 105° azimuth.

Currents in the upper 300m had a mean northerly or or northeasterly component. Current speeds were highest near the surface both in the average and during extreme events, and decreased gradually with depth to at least 289 meters. Typically speeds decreased about 50% between the 50m level and the 150m level. Between 177 and 281m, mean and extreme speeds decreased about 25%. Below 300m, current measurements were available only at about 800 or 900m depths where the mean currents are low (8 cm/sec), with a net southwesterly drift. Most of the energy in the current record from these depths was due to the mixed semidiurnal and diurnal tides.

Maximum current episodes were observed in early September throughout the upper part of the water column (to at least 166m depth). During this interval, which lasted about 2 weeks, maximum currents of 152 cm/sec (56m depth), 118 cm/sec (90m depth), 89 cm/sec (113m depth), and 81 cm/sec (166m depth) were observed. At the 56m level, speeds in excess of 100 cm/sec were observed on thirteen consecutive days. The maximum speed observed at the 800m (or 900m) depth was observed in late November when magnitudes of 38 cm/sec were recorded. The duration of these relatively high speed events at 800m was shorter than 12 hours.

Tidal currents are observed in the records from all depths at both the diurnal and semidiurnal frequencies. At both frequencies, the tidal flows were rotary and directed in a clockwise direction with typical speeds between 5 and 15 cm/sec. Currents associated with the tides were largest at above 100m and had a maximum speed associated with them of the order of 25 cm/sec. A portion of this energy was the result of internal tides, probably generated by the barotropic tide moving across the steeply shelving bottom east of the OTEC-1 site. The amplitude (1/2 of the height) of these internal tides, as deduced from temperature variations at the semidiurnal frequency, may be as large as 50m or more, with the largest amplitudes observed at the deepest measurement depth (811m).

The most important feature of the currents observed at the OTEC-1 site was the variability of the mean flow in the upper several hundred meters of the water column. The observed currents in this layer ranged from northerly flows at 150 cm/sec to southerly flows at 60 cm/sec. This variability was present over time scales of a few days to a month or more. Associated with high current speed and northeasterly flow was temperature lowering, cyclic at tidal frequencies, observed in the near surface meters. Such temperature depressions seen for example, in the late November 1980 event at 45 and 70 meters are in excess of that produced by bending the array to deeper (colder) depths in the current.

CTD casts made from the R/V Holokai at 12 stations (14 casts to 350 meters, 2 casts to 800 meters and 1 cast to 560 meters) taken in the vicinity of the OTEC-1 site from 3-5 August 1980 show:

Surface temperature	25.977-27.215°C
Salinity Maximum Depth	13-190 meters
Value	34.96-35.00%
Salinity Minimum Depth	460 meters
Value	34.1%
800 Meter Temperature	5°C

Such data is consistent with historical observations of surface North Pacific subtropical water overlying North Pacific intermediate water.

Expendable bathythermographs taken in the Alenuihaha Channel from the R/V Holokai in two parallel transects (8 XBT's 19 December 1980 and 13 XBT's 28-29 December 1980) from the OTEC-1 site to south of Kahoolawe show:

Surface Temperature	25-26°C
Mixed Layer Depth	60-90 meters
800 Meter Temperature	5°C

CHEMICAL OCEANOGRAPHIC DATA

(See Hunt and others, this volume for details)

Dissolved Oxygen

Dissolved oxygen averages about 5.3 mL/L at the surface ranging from approximately 5.0 to 5.8 mL/L.

A subsurface maximum is observed near 50-100m, the depth of the maximum depending on the time of year. On the November and December cruises (HOTEC's 06 and 01), the maximum appears at greater depths than in the April, June, July and October cruise (HOTEC's 02-05). From about 100m to the oxygen minimum, at approximately 500-600m, the concentration declines steadily to about 1 mL/L. On the December cruise (HOTEC-06), an extremely low minimum was observed - 0.2 mL/L. It was observed two separate casts at two depths, so the observation cannot be easily rejected as an analytical anomaly. There is a fair degree of variability in the data ± 0.5mL/L to the depth of the oxygen minimum, then relatively low variability ± 0.2 mL/L.

The HOTEC profiles are in fair agreement with the profile from GEOSECS station 235 (16°45'N, 161°23'W) which shows a minimum of 0.6 mL/L at 500m. The subsurface maximum at 130m at GEOSECS station 235 was deeper than that observed on HOTEC-06 at 100m.

Phosphate

At the surface, the phosphate concentration averaged about 0.3 *ug-at/L which immediately decreased to about 0.15 *ug-at/L. Below 100m the

concentration increased to about 3.0 *ug-at/L at 400-450m. The concentration then remained constant. The variability of the data remained about ± 0.02 *Ug-at/L throughout the profile. No variation could be linked directly with seasonality or time of data. The profile of the phosphate data at the surface agrees with the GEOSECS data from station 235.

Nitrates

At the HOTEC site, nitrate remains virtually undetected until 100m; at greater depths the concentration increased to about 43 *ug-at/L. Variability was about ± 2.5 *ug-at/L near 100m increasing to ± 5 *ug-at/L in the nutricline. No fluctuations could be attributed to seasonality. The data is in good agreement with the GEOSECS, station 235 results and with Gundersen and Palmer's data from Keahole Point.

Silicate

Silicate concentrations averaged 2-3 *ug-at/L at the surface to a depth of about 100m.

The concentration gradually increased to an average of about 90 *ug-at/L. Although the variability in deep water was quite high, nearly |*+ 10 *ug-at/L at 900m, no correlation could be made with the seasons. Agreement was good with the GEOSECS data.

BIOLOGICAL OCEANOGRAPHIC DATA

(See Hartwig, this volume for details)

Phytoplankton

At the HOTEC site large temporal and vertical variations in phytoplankton biomass and primary productivity were observed. Over a year, phytoplankton biomass (chlorophyll a) varied threefold, and primary productivity, although always nutrient-limited varied more than 25-fold (Table 1). Vertically, the profiles of phytoplankton biomass were similar over time showing low and uniform levels in the upper 40-60m, with a chlorophyll a maxima centered at 85m. Photosynthetic rates were highly variable over time and productivity: biomass ratios were consistently low and indicative of strong nutrient limitation. The large variation in photosynthetic activity was far in excess of the accompanying changes in the physical properties of the system, and could not be explained by variations in phytoplankton biomass or the prevailing nutrient gradients. We found significant correlations ($P<0.01$) between depth-integrated phaeopigment stocks and primary production, and between phaeopigments and ammonium levels. Phaeopigments are produced by the digestion of chlorophyll. Variations in the supply of regenerated nutrients by grazers is believed to account for most of the observed temporal variability in photosynthesis.

Macrozooplankton

The HOTEC site shows a diel vertical migration pattern, with zooplankton migration into the surface waters during the night and back into the deeper waters during the day.

One can not make the sweeping generalization that copepod abundance increases at night and decreases in the day. Day/night copepods abundance distributions are site dependent, time dependent and depth dependent.

The diel variation with depth of zooplankton biomass in two size categories (0.2-0.5mm and greater than 0.5 mm) was examined. HOTEC-05 showed evidence of diel vertical migration of biomass while HOTEC-06 did not. This is in contrast to the abundance data where both cruises showed diel vertical migration. This points out the problem of parameter selection for examining events or impacts. An investigator must choose that (those) parameter(s) which most succinctly or simply explains the event or impact under study.

On HOTEC-05, diel vertical migration occurred in smaller and larger zooplankton. The depth distribution of biomass at the HOTEC site, was similar for both size classes.

Nekton

The macronekton although capable of avoiding entrainment are attracted to structures (e.g., OTEC) in the ocean thereby increasing the number subjected to the probability of entrainment and impingement. The effect on macronekton will be highly species dependent. Experience at OTEC-1 showed that although sharks (white tips) and large adult fish (yellow fin tuna, dolphin fish) were attracted to the structure, none appeared to be impinged. However, as impingement was not studied directly, smaller species may have been impacted.

Micronekton would be much more susceptible to entrainment and impingement. Visual sightings in the OTEC-1 moon pool revealed entrainment of micronekton.

FISHERIES

(see Ryan and Jones, this volume for details)

Hawaii principal fisheries are carried on by a variety of techniques including: pole-and-line, midwater longline, trolling, handline, seines, gillnets and traps. Use of the live-bait, pole-and-line method generally results in a catch composed of at least 90% (by weight) skipjack tuna (aku) the remainder of the catch may include such offshore pelagic species as mahimahi (dolphin fish), small yellowfin tuna (ahi), and little tuna (kawakawa). Large yellowfin tuna (about 250 pounds) and large bigeye tuna (about 300 pounds), are the principal catch of the longline or flagline fishery. Flaglines also catch lesser quantities of large albacore tuna (up to 90 pounds), bill fishes, ono (wahoo), mahimahi, sharks, and other pelagic species. Trollers catch ahi, (pri-

marily yellowfin tuna), billfishes, ono (wahoo), mahimahi and smaller species of tuna. Handlines are used to catch bottomfishes such as snapper and goatfish. They are also used at night with lights to catch coastal pelagic schooling species such as, akule (bigeyed scad), and opelu (mackerel scad). Seines and gillnets are used in shallow waters for skule, opelu, mullet, reef-fishes and inshore bottom fishes. Traps are used in shallow water to catch reef fishes.

Source of the Data

Since the late 1940's, the State of Hawaii, Division of Fish and Game has required all licensed commercial fishermen to submit monthly catch reports. From these reports the Division tabulates data in three basic areas: 1) catch weight and numbers, 2) time and place of capture, and 3) fishing effort. This section of the report uses fisheries data made available by the Hawaii Division of Fish and Game.

For ease in reporting the place of capture the Hawaii Division of Fish and Game has divided the waters around Hawaii into Fishing Areas. A proposed OTEC site off the Island of Hawaii (HOTEC) is located in Area 122. The composition of the landings varied during the period examined, but generally skipjack tuna, yellowfin tuna, blue marline, and snappers were the most important groups in terms of pounds landed. On the average, skipjack tuna comprised 62% of the landings, yellowfin tuna 10%, blue marlin 9%, and snappers 5%.

During the 20 years from 1959 to 1978, the weight of the total landings varied considerably. The fluctuations are primarily due to fluctuations in tuna landings, especially the amount of skipjack. The landings of skipjack tuna range from a low of 123 pounds in 1966 to a high of 407,453 pounds in 1974. The only catch per unit of effort (CPUE) data made available from Area 122 are for blue marlin catches from 1966 to 1978. The catch of blue marlin per unit of effort varied during this period, indicating that the density of blue marlin in Area 122 varied from year to year.

In 1978, the annual landing from the fishing area (Area 122) off Keahole Point was valued at 272,15.The10-yearaveragewas141,000 (1969-1978).

ON-BOARD MONITORING

Monitoring of the effluent of the OTEC-1 platform during deployment was done by Aecos, Inc., using the environmental van as a base of operations. The purpose of the measurements was to maintain the NPDES Operational permit and to provide basic data for the environmental program and for the various heat exchanger tests. The permit requirements were maintained, with the expected operational problems, to the satisfaction of EPA. The experiment essentially was that of a surface discharge as the mixed discharge pipe was never successfully deployed to the design depth of 70 meters.

Standard analyses were taken either daily, weekly or monthly. The results reported here are summaries of the preliminary data.

Daily Measurements

Routine daily measurements for ammonia and residual oxidants were made during operations at the evaporator, the condenser and in the mixed discharge. Chlorine demand was measured daily for about one month from late December into January 1981, then weekly until the end of February. This time-consuming analysis was stopped as the values were low and uniform during the measurement interval. Summary of the ammonia, residual oxidants and chlorine demand data are given in Table 1.

Weekly Measurements

Standard oceanographic parameters such as dissolved oxygen, salinity, as well as nutrients, pH, suspended solids, and total organic carbon were scheduled on a weekly basis. Table 2 gives a summary of such observations.

Monthly Measurements

Trace metals, aluminum, copper, iron and titanium were measured as both particulate and soluble fractions monthly from the evaporator mixed discharge, and condensor flows. Such data showed high variability within replicate samples to make either the validity or the meaning of the data questionable at this time. Accordingly no summary data are given here awaiting further interpretation. Other monthly measurements for permit requirements such as discharge/sump oil and grease and standard discharge monitoring showed values within EPA guidelines and will not be given here as such measurements are of compliance value and do not pertain to OTEC specific concerns.

Other Measurements

A two day study of volatile organic compounds potentially due to chlorination of sea water was made in early April 1981. Bromoform, dichloromethane, benzene, chlorobenzene, xylene, and dibromochloromethane were detected. Analyses of that data is incomplete at this time but will be the subject of a separate report.

A comprehensive plume study was conducted in April in co-operation with the ship-board program and the cruise program using dye tracers. Data from this operation appears in part in Harms and others (this volume) and in reports in press by Noda and others.

Profiling current meter surveys were made at intervals from the platform in support of ship's operations in maintaining station. Summary of this data is reported by Harms and others (this volume).

TABLE 1

Daily Measurements - OTEC-1 Platform

SYSTEM	Ammonia (µg-at/L)	Residual Oxidants (mg/L)	Chlorine Demand (mg/L) 2 min	Chlorine Demand (mg/L) 5 min
Evaporator-Intake				
Range	ND[a*] - 0.71	ND - 0.52	0.08-0.13	0.10-0.15
Mean	0.24	0.25	0.12	0.13
Standard Deviation	0.14	0.14	0.01	0.01
Number	66	108	14	11
Evaporator-Discharge				
Range	ND-1.19	ND-0.54	-	-
Mean	0.30	0.27	-	-
S.D.	0.19	0.10	-	-
Number	112	102	-	-
Mixed Discharge [b**]				
Range	ND - 1.30	ND - 0.46	0.06-0.11	0.05-0.13
Mean	0.24	0.14	0.09	0.09
S.D.	0.14	0.06	0.02	0.02
Number	130	217	14	11
Condenser-Intake [b]				
Range	ND - 1.98	ND - 0.91	0.03-0.10	0.03-0.10
Mean	0.26	0.37	0.06	0.08
S.D.	0.24	0.13	0.02	0.02
Number	74	110	29	26
Condensor-Discharge				
Range	ND - 1.12	ND - 0.70	-	-
Mean	0.32	0.30	-	-
S.D.	0.21	0.11	-	-
Number	98	103	-	-

* ND = None Detected

** On 3/28 the ammonia concentration in the condensor discharge was 21.1 µg-at/L and in the mixed discharge was 9.4 g-at/L. These are anomalously high,and although real were not considered in the neons.

TABLE 2
Weekly Measurements - OTEC-1 Platform

System	SAL 10^{-1}	DO mL/L	pH	TOC mg/L	Suspended Solids mg/l
Evaporator					
Range	34.391-34.986	3.74-6.67	8.10-8.38	0.869-1.876	0.2-1.86
Mean	34.74	4.63	8.27	1.22	0.83
Standard Deviation	0.22	0.97	0.05	0.35	0.4
Number	16	17	16	5	14
Mixed Discharge					
Range	34.38-34.667	3.88-1.36	7.622-8.228	.765-1.075	0.13-0.8
Mean	34.51(mix 34.49)	2.55(mix 3.03)	8.06	0.91	0.44
S.D.	0.13	0.76	0.13	0.13	0.2
Number	14	16	15	5	12
Condensor					
Range	34.192-34.283	0.8-2.92	7.51-7.97	0.491-0.989	0.5-0.4
Mean	34.25	1.43	7.64	0 82	0.24
S.D.	0.02	0.55	0.15	0.18	0.13
Number	16	17	15	5	13

TABLE 2
Weekly Measurements - OTEC-1 Platform (cont.)

Evaporator	NO_3 µg-at/L	TN µg-at/L	PO_4 µg-at/L	TP µg-a/L	Si µg-at/L
Range	0.1-.29	5.75-42.4	0.09-0.25	0.05-1.77	0.62-7.35
Mean	0.13	14.3	0.16	0.50	3.43
Standard Deviation	0.09	10.9	0.05	0.38	1.94
Number	13	13	7	14	16
Mixed Discharge					
Range	0.32-36.3	6.07-58.8	0.93-2.90	.48-3.18	2.13-79.3
Mean	16.6	20.9	1.29	1.71	34.3
S.D.	8.0	9.2	0.55	0.69	17.0
Number	11	10	10	11	11
Condensor					
Range	29.8-42.2	44.2-80.7	2.25-2.86	2.49-3.78	44.2-80.7
Mean	35.16	56.2	2.59	3.03	61.3
S.D.	3.27	7.3	0.17	0.76	12.4
Number	16	14	16	15	16

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