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A COLIFORM BACTERIA SURVEY OF MONTEREY
BAY OFF DEL MONTE BEACH

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A COLIFORM BACTERIA SURVEY OF
MONTEREY BAY OFF DEL MONTE BEACH

by

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ABSTRACT

Determination of the distribution of coliform bacteria in the vicinity of the outfall effluent of the Monterey Water Pollution Control Plant was made using the membrane filter technique for enumeration. The coliforms were seen to follow the onshore mass transport of water in the surface layer in response to predominately westerly winds. The extent of penetration of coliforms into the bay north of the outfall is restricted to several hundred yards, while more extensive spreading was observed towards the surf zone. No consistent pattern of variation of the coliform distribution could be related to the tidal cycle. Higher concentrations of coliform bacteria on several occasions seemed to be related to reduced periods of solar radiation.

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1. Introduction.

The purpose of this study was to determine the concentration and distribution of coliform bacteria in the southernmost portion of Monterey Bay and to investigate qualitatively the influence of various meteorological and oceanographic parameters on this distribution.

Coliform bacteria are defined as aerobic and facultatively anaerobic non-spore-forming bacilli that ferment lactose to produce gas in 48 hours at a temperature of 35° - 37° Centigrade. Coliforms refer to a group of bacteria which are normal inhabitants of the colon or large intestine of man and most vertebrate animals; as such, they serve as an indication of fecal pollution in estimating the sanitary quality of the various waters. This group of bacteria is composed of two genera, which have nearly identical microscopic and macroscopic morphological properties, and are distinguishable only by the type of fermentative action used in cleavage of glucose. Each of these genera are in turn broken down further into species primarily on the basis of biochemical reactions. The recognized species of coliforms are as follows[1]:

Escherichia coli

Escherichia aurescens

Escherichia freundii

Escherichia intermedia

Aerobacter aerogenes

Aerobacter cloacae

Although all of these are found frequently in the intestine of vertebrates, only E. coli is strictly an intestinal organism and the other species have been found associated with soils and grains as well as in intestinal habitats. Other organisms have been suggested as alternative indices of pollution but have been found less satisfactory for widespread use than the coliform index [2].

The source of coliforms in the area surveyed is the effluent of the City of Monterey's Water Pollution Control Plant which is a primary incomplete sewage treatment plant. The outfall pipe extends northward into Monterey Bay for 800 feet from the shoreline, turns towards the surface, and terminates approximately 18 feet below the surface. The point where the effluent reaches the surface may be determined visually by the turbulence and discoloration at the surface. The volume being discharged varies from a maximum between the hours of 0900 and 1500 to a minimum between 0100 and 0600.

No other sources of coliforms were considered in this study, although increases in coliform concentration were observed at positions remote from the outfall boil.

Once discharged in the sea the concentration of coliforms decreases rapidly. Tibby, in an investigation in Santa Monica Bay, established a value for T_{90} (the time required for 90% disappearance of coliforms) of four to seven hours [3]. The reasons for this rapid decline in concentration are:

(1) The sea is a toxic environment for coliforms. In the surface layer bacteria are quite sensitive to ultra violet radiation. Bacteriophages (bacterial viruses) and antibiotic substances found dissolved in sea water are also toxic to bacteria. In addition, there is a toxicity of sea water itself which seems to be associated with the dissolved solids. This has been demonstrated with artificial sea water of several formulations [4]. The mechanism of this toxicity for coliforms is largely unknown.

(2) Coliforms are subject to predation by planktonic organisms.

(3) The bacterial cells are subject to sedimentation with particulate matter.

(4) Concentration of coliforms decreases as the effluent is diluted with sea water.

From the above considerations it is obvious that the concentration of coliform bacteria are a non-conservative property in the sea and as such are not meaningful in quantitative relationships in the sea. However, they may be used to illustrate qualitative features of the circulation.

The region being surveyed is located in the extreme southern portion of Monterey Bay extending along the beach from Monterey Municipal Wharf Number 2 to the oil tanks to the east and extending out into the bay approximately 500 yards from the shoreline (figure 1). The beach is sandy and of gentle profile. Bottom contours closely parallel the shoreline. The configuration of the coastline and the bottom contours is such that the area surveyed is largely protected from wind waves and swell approaches the beach with wave crests nearly parallel to the shoreline. The sector along the beach is also one of diverging wave orthogonals which tends to disperse wave energy for most swell directions.

Several investigations have been made into the circulation of water in this region. Brennan and Meaux [5] observed a dominant onshore flow outside the surf zone with onshore winds and a flow to the north along the beach with frequent rip currents. Stevenson [6] in investigating the mass transports around the outfall effluent found that water of all levels down to 15 feet closely follows the wind. No consistent circulation pattern could be related to any section of the tidal curve.

The locations of the stations used in the individual surveys are shown in figure 2. The stations were placed at 200 yard intervals along the beach and at 100 yard intervals extending from the beach. Stations 2, 14, 26, 38, 60 and 62 are in line with the outfall pipe. Station 38 is at the boil. Kelp beds are fairly dense to the west of the outfall boil, sparse to the north of the outfall boil, and absent to the east and shoreward of the boil.

Observations made during this survey include coliform concentration, wind speed and direction, cloud cover, tide level and state, and sea surface temperature. The means of coliform enumeration is discussed in the next section. Wind speeds and directions were measured with a portable anemometer

Figure 2. Location of stations used in coliform bacteria survey.

near station 5 at a height of ten meters above sea level. Sea surface temperatures were measured at several stations on each survey and averaged. Cloud cover was estimated visually. Tidal information was obtained by examination of the tide gauge records maintained by the Meteorology and Oceanography Department of the U. S. Naval Postgraduate School.

2. Means of Enumeration of Coliform Bacteria.

Two procedures for the enumeration of coliform bacteria were considered; the fermentation tube or most probable number (MPN) method, and the membrane filter (MF) method.

The MPN method was adopted as the official method of determining coliform densities in the 1936 edition of Standard Methods. It consists of planting several known volumes of a water sample into three or more replicates of fermentation tubes partially filled with either lactose or lauryl tryptose broth. The tubes are observed for the production of gas after 24 and/or 48 hours. By tabulating all results for each sample, the MPN or the density of bacteria most likely responsible for that combination of results can be determined by referring to MPN tables as presented in Standard Methods [7]. There are several practical disadvantages to this method.

(1) A large amount of time is required for glassware and media preparation. A minimum series for three dilutions and three replicates requires nine tubes of media in addition to dilution blanks for each sample.

(2) Planting of media, reading, and recording results is a slow process with numerous opportunities for labeling-type errors.

(3) Presumptive results take 24 to 48 hours and completed results take at least 96 hours after planting.

(4) Large laboratory facilities are required for a large number of samples.

(5) Any bacteriocidal agents in the sample are carried over into the fermentation tube.

The membrane filter procedure for the examination of water for coliform bacteria was accepted by the American Water Works Association as an alternate to the MPN procedure in November 1957 [8], and it is described as a standard test for the coliform group in the 12th edition of Standard Methods [7]. In the membrane filter method, a known volume of a water sample is drawn through a membrane filter prepared from cellulose esters with pores just smaller than the bacterial cells being sought. After filtration of the sample the filter is placed on an absorbant pad saturated with a nutrient preparation which is selective for the organisms being sought, in this case coliforms. Each living cell trapped on the filter multiplies upon incubation at an appropriate temperature and produces a macroscopic colony of bacteria which may be counted. All such colonies are counted and the coliform concentration is

simply the number of colonies divided by the volume filtered.

The advantages of this system may be listed as follows:

(1) A minimum of glassware is required. The filters can be incubated in disposable petri dishes.

(2) By use of a vacuum pump a 50 ml sample can be filtered in about 30 seconds.

(3) Initial results are available in 24 hours and completed results may be obtained in an additional 48 hours.

(4) Little space is required for a large number of samples. The petri dishes are 47 mm in diameter and may be stacked in columns to conserve space.

(5) Toxic environment in the sample is removed by filtration.

There are also disadvantages to the MF method.

(1) A fairly good estimate of the coliform concentration is needed beforehand in choosing an increment of volume to be filtered. Too many colonies on a single filter give indeterminate results.

(2) The MF method gives densities which are generally lower than those determined by the MPN method.

Jannasch and Jones[9], in evaluation of several methods of enumeration including the MPN and MF methods, observed MPN densities on the average to be an order of magnitude or more higher than MF densities. They (Jannasch and Jones[9]) attribute the larger concentrations obtained with the MPN method to dispersion of bacterial aggregates and clumps on foreign matter produced by surface tension depression of the liquid media. Also, theoretical considerations and large scale replicate determinations indicate that MPN tends to be greater than the actual number[7]. Thus, it appears that the MF method tends to produce results which are biased on the low side while the MPN method is biased on the high side, and the results are not directly interchangeable.

3. Collection of Coliform Data.

Observations were made on 20 surveys taken during the period 22 June 1966 through 3 September 1966. The first 13 of the surveys were confined to the surf zone along station 1 westward. The last seven surveys were made in the offshore region. Samples were collected in sterile 150-200 milliliter glass bottles with metal screw caps. All samples were hand shaken 30 times before increments were withdrawn for planting. All completed cultures were submitted to the differential tests known as the IMViC tests for the production of indole from tryptophane broth, the methyl red test for production of acid, the Voges-Proskauer test for the production acetyl methyl carbonol, and the use of citrate salts as a sole carbon source. Standard Methods [7], was used as a guide in the preparation of the IMViC reagents, media, and in the execution of the tests. All media, glassware and equipment except the membrane filters, Endo media, and disposable petri dishes were sterilized by autoclaving for 15 minutes at 15 pounds pressure. The excepted items were sterilized in accordance with instructions from the manufacturer.

With the MPN procedures three replicates of four dilutions (1 ml, 0.1 ml, 0.01 ml, and 0.001 ml) of the sea water samples were planted into Difco dehydrated lactose broth¹ with fermentation tubes and incubated at 37°C for 24 and 48 hours. For increments of sample less than 1 ml, dilutions were made with sterile phosphate buffered distilled water. The appearance of gas after 24 or 48 hours was recorded as positive and the absence of gas after 48 hours was recorded as negative. Representatives of the highest dilution giving positive results were confirmed on eosin methylene blue (EMB) agar. Colonies exhibiting the typical coliform morphology were inoculated into lactose broth with fermentation tubes. Nutrient agar slant cultures were made from positive lactose broth tubes and Gram stains were made. This procedure constituted the completed test for the presence of coliform bacteria[7]. The MPN procedure was suspended after 14 July in favor of the MF procedure.

In the MF procedure the Millipore bacteriological analysis kit² was used. A vacuum-pressure pump is used

¹ Difco Laboratories Incorporated, Detroit, Michigan

² Millipore Filter Corporation, Bedford, Massachusetts

to facilitate the filtration. Millipore MF type HA filters with pore size of 0.45 ± 0.02 microns were used. Various volumes ranging from 100 to 0.01 ml were filtered. The 100 ml volumes were found unsatisfactory because of overgrowth of non-coliform types. Volumes of 50 ml were used for most stations remote from the outfall boil. Volumes of 50 and 1 ml were used in the vicinity of the boil and 0.1 and 0.01 ml were found satisfactory for the samples from the outfall boil (station 38) and the station shoreward from the boil (station 26). When volumes of less than 25 ml were used, 30 to 50 ml of sterile buffered dilution water was poured into the filtering funnel prior to adding the sample to provide an even distribution. After filtration, the sides of the funnel were rinsed with 30-50 ml of sterile buffered dilution water, the filter removed and placed grid side up on an absorbant pad saturated with 1.8 to 2.0 ml of freshly prepared M Endo Broth MF³ in a petri dish, covered, and incubated at 37°C for 24 hours. Between samples, the funnel was immersed in boiling water for 10-15 seconds. (As evidenced by control filtrations of sterile water which were run periodically, it was difficult to remove bacteria from the sides of the funnel even with repeated rinsings. The immersion in boiling water between

³ Baltimore Biological Laboratories, Baltimore, Maryland

samples eliminated this cross contamination.) Coliform bacteria on Endo media form circular, convex colonies with a greenish metallic sheen in reflected light. The growth of non-coliform organisms is inhibited; those that do grow lack the characteristic sheen. After incubation, the sheen colonies were counted with the aid of ten power magnification. Non-coliform colonies were counted separately to indicate in the results the degree of overcrowding on the filters. Representative sheen colonies were selected and inoculated into lactose broth fermentation tubes. Nutrient agar slant cultures were made from the positive lactose tubes and Gram stains were made from the slant cultures. This procedure constituted the completed test for the membrane filter cultures.

4. Results.

The weather and tide observations for each survey are presented in Table 1. The actual times for sampling and inoculation are listed in Table 2. The coliform concentrations, per 100 ml, are listed in Table 3 for surveys 1 through 13 which were conducted along the beach. Tables 4 through 10 give the coliform concentrations determined from samples collected seaward of the surf zone.

Discussion of Surveys 1 through 13

The general pattern of the coliform distribution along the beach appears to be a region of maximum coliform concentration at or to the east of station 1 with the level remaining high to the outfall and a rapid decrease to the west of the outfall. The occasional higher coliform densities that were observed remote from the outfall may possibly be due to sources other than the sewage effluent. Surveys 5, 6, 9, 11, 12 and 13 all showed increasing coliform densities toward Monterey Municipal Wharf No. 2.

Surveys 1, 2, 4, 6 and 12 exhibited local maximums between stations 4 and 7. Since offshore samples were not taken on these surveys it is not known if these maximums

TABLE 1

SUMMARY OF WEATHER AND TIDE DATA
FOR EACH COLIFORM SURVEY

Survey	Date	Time* (PDT)	Wind DIR/KTS	Clouds (tenths)	Temp. (°C.)	Tide level (feet/state)
1	22 JUN	1530	290°/10	0	16.1	4.1/LHW
2	25 JUN	1400	290°/12	0	16.5	2.1/Rising
3	6 JUL	1500	275°/12	9	15.4	3.6/Falling
4	12 JUL	1230	355°/10	1	19.6	2.2/HLW
5	14 JUL	1400	285°/14	0	18.7	2.7/HLW
6	14 JUL	2000	285°/14	0	16.8	5.7/HHW
7	2 AUG	1400	295°/15	10	16.4	4.1/Falling
8	3 AUG	1500	285°/12	0	15.0	3.9/Falling
9	8 AUG	1700	270°/10	3	14.3	5.1/Falling
10	10 AUG	1230	015°/7	7	14.6	3.5/Rising
11	12 AUG	2130	245°/6	6	14.2	5.5/HHW
12	15 AUG	2230	0	10	16.3	6.9/HHW
13	16 AUG	0430	0	8	15.5	-0.7/LLW
14	18 AUG	1400	275°/13	0	16.0	5.1/LHW
15	23 AUG	1130	325°/10	0	15.8	3.0/HLW
16	25 AUG	1400	255°/10	0	16.0	3.4/Rising
17	27 AUG	1130	325°/12	0	16.5	3.3/Falling
18	30 AUG	1400	300°/14	7	15.3	3.6/LHW
19	1 SEP	1030	315°/12	0	15.3	2.8/Rising
20	3 SEP	1000	315°/12	10	15.4	2.5/Rising

*Times represent the approximate time that sampling was half completed.

TABLE 2
SAMPLING AND INOCULATION TIMES

Survey	Sampling Commenced (PDT)	Sampling Completed (PDT)	Samples Incubated (PDT)
1	1515	1600	1800
2	1340	1415	1600 MPN 1730 MF
3	1450	1550	1755 MPN 1920 MF
4	1220	1320	1545 MPN 1615 MF
5	1330	1430	1600 MPN 1630 MF
6	1940	2015	2130
7	1350	1440	1645
8	1440	1505	1620
9	1630	1730	1900
10	1210	1315	1450
11	2100	2145	2250
12	2215	2245	2400
13	0420	0515	0615
14	1340	1500	1730
15	1100	1200	1400
16	1345	1500	1700
17	1100	1200	1400
18	1340	1440	1700
19	1000	1100	1330
20	0930	1030	1330

are from an extraneous source or if they are tongues of higher coliform water extending through the surf zone from deeper water.

The wind during these observations showed little variation in direction. On all but two of the surveys along the beach, the winds were westerly with a small northerly component. On the two excepted surveys (4 and 10), the winds were predominately northerly and the same general patterns of coliform concentrations were observed along the beach.

Nearly all tidal situations occurred during these surveys. Surveys 12 and 13 correspond to extreme levels of tide of 6.9 and -0.7 feet respectively. Both surveys were made at night with zero wind velocities. The concentration observed in the low tide survey were slightly larger than those of the high tide survey. A similar pair of surveys (surveys 5 and 6) were conducted on 14 July with similar weather conditions and contrasting tidal levels. On this occasion the high tide survey appeared to have the higher concentration. No consistent pattern of coliform concentration variation with conditions of the tide could be determined. This agrees with Stevenson's [6] observations on the absence of a tidal circulation in this region.

TABLE 3

COLIFORM CONCENTRATIONS OBSERVED ALONG DEL MONTE BEACH

(MPN or MF colonies per 100 ml)

Survey	Date	Method	Station	1	2	3	4	5	6	7	8	9	10
1	22 JUN	MPN	150	11000 ^a	11000 ⁺	950	11000						
2	25 JUN	MPN	930	230	150	0	91						
2	25 JUN	MF	11	7 ^b	7	14	c						
3	6 JUL	MPN	4600	930	91	0	0						
3	6 JUL	MF	154	6	2	22	2						
4	12 JUL	MPN											
4	12 JUL	MF	190	44	30	3	1						
5	14 JUL	MPN	36	36	0	0							
5	14 JUL	MF	8	0	0	7	0						
6	14 JUL	MF	18	2	6	c	38						
7	2 AUG	MF	50	40	42	10	12						
8	3 AUG	MF	214	80	0	4	2						
9	8 AUG	MF	558 ^b	228	8	18	12						
10	10 AUG	MF	554 ^b	588 ^b	42	12	6						
11	12 AUG	MF	560 ^b	c	54	52	26						
12	15 AUG	MF	c	c	416	48	46						
13	16 AUG	MF	c	c	c	196	222						

^a indicates that gas was produced in all tubes, and the upper limit was not determined^b designates filters on which overcrowding of non-sheen colonies may influence coliform counts^c designates indeterminate results because of overcrowding or massive growth on filters

No consistent pattern could be attributed to variation of sea surface temperature. Sea surface temperature in the surf zone was found to be quite variable. The anomalously high temperatures that were recorded on surveys 4 and 5 are believed to be due to conduction of heat from the warm beach to the water in the surf zone. The higher concentrations of coliforms observed during surveys 11, 12 and 13 may possibly be explained by the absence of the bacteriocidal ultraviolet radiation from the sun, as these surveys were taken at night.

To evaluate the effect of storage of samples at room temperature while awaiting inoculation, increments of 25 ml of a sample from station 1 were filtered at one hour intervals for three hours. No significant differences were observed in the concentrations of coliforms, but non-coliform colonies did decrease with storage. Since this is within the range of times that samples were stored during most of the surveys, changes in concentration during storage were not considered important.

Large differences were observed between the MPN and MF methods during the initial surveys with the MPN method giving concentrations usually an order of magnitude or more higher

than those with the MF method (Table 3). Perhaps the use of five replicates with additional sample volumes would bring the results in closer agreement, but the additional time and space required would have further limited the number of samples that could be analyzed on each survey. The MPN procedures were suspended after survey 5 in favor of the more rapid membrane filter method.

Discussion of Surveys 14 through 20

The coliform concentrations determined for the off-shore surveys were tabulated in Tables 4 through 10. Since these concentrations were determined by the filtration of various volumes (50 ml-0.01 ml), the number of significant figures in the tables represent the number of significant figures counted. For instance 89×10^4 per 100 ml is interpreted as 89 colonies were counted from filtration of 0.01 ml.

The data of Tables 4 through 10 were plotted geographically and iso-concentration lines drawn using a contour interval of 10 coliforms per 100 ml. Where indeterminate results were recorded, the order of magnitude of the concentration was estimated on the basis of volumes filtered. These illustrations are presented as figures 3 through 7.

Survey 14 was undertaken primarily to determine the general extent and concentration of coliforms for use in planning later offshore surveys. In figure 3, a fairly tight gradient of concentration lines is found on the seaward side of the outfall boil with a lesser gradient towards shore which indicates a general onshore movement of coliforms and their accompanying surface waters. The wind for this survey was westerly and the tide is falling. The seaward extent of water with coliform bacteria is less than 200 yards from the outfall boil.

Figure 4 represents the data from three surveys. Survey 15 was conducted along the outside of the surf zone on 23 August (stations 11 through 22). Survey 16 covered the next seaward line of stations (stations 23 through 34) and survey 17 covered stations 35 through 55. The winds of these surveys were similar in magnitude but the direction of survey 16's wind was 255° while the winds of survey 15 and 17 were 325° . Although the value of such a composite distribution may be questioned, several of the general features of this distribution may be pointed out. The pattern of the elongated tongues to the east of the outfall region were not observed in later more instantaneous surveys,

TABLE 4

COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 14 ON 18 AUGUST 1966

Station	Coliform Concentration (coliforms per 100 ml)
14	128 x 10 ¹
26	294 x 10 ¹
35	4
36	0
37	10
38	c
39	c
40	26
43	8
46	6
50	10
60	0
62	0

^c designates indeterminate result because of overcrowding or massive growth on filters

Figure 3. Distribution of coliforms on 18 August 1966 (survey 14).

but they do indicate the large changes in the field which occur on a daily or shorter basis. The pattern of iso-concentration lines to the west are more continuous and were found to be more representative. Several isolated pockets of non zero coliform densities were observed at the western section of the survey region.

Since it was not practical to survey the entire region on any one survey to obtain a more instantaneous distribution, it was decided to concentrate on the region around the outfall and survey this reduced region more completely and in as short a time span as possible. Figures 5, 6, and 7 are three such surveys which represent the field based on samples collected within one hour.

The pattern of iso-concentration lines in figure 5 is elongated along a line which is nearly perpendicular to the wind. Tight gradients are present to the north and east of the outfall boil.

Figure 6 shows the distribution on 1 September. Here the wind is more northerly and the coliform distribution is more symmetrical with a greater amount of spreading to the west. A tongue of higher coliform water extends from the boil to the southwest toward the surf zone.

TABLE 5

COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 15 ON 23 AUGUST 1966

Station	Coliform Concentration (coliforms per 100 ml)
11	28
12	140
13	20
14	226×10^2
15	36×10^2
16	2
17	2
18	0
19	116
20	26
21	0
22	8
38	260×10^4

TABLE 6
COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 16 ON 25 AUGUST 1966

Station	Coliform Concentration (coliforms per 100 ml)
23	0
24	0
25	238 ^b
26	209 x 10 ³
27	0
28	4
29	2
30	0
31	0
32	0
33	0
34	0
38	214 x 10 ⁴

^b designates filters on which overcrowding of non-sheen colonies may influence coliform counts

TABLE 7

COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 17 ON 27 AUGUST 1966

Station	Coliform Concentrations (coliforms per 100 ml)	Station	Coliform Concentration (coliforms per 100 ml)
35	10	46	1
36	16	47	4
37	10×10^2	48	8
38	123×10^4	49	4
39	100	50	134
40	0	51	2
41	2	52	0
42	0	53	0
43	0	54	0
44	32	55	0
45	0

NOTE: NUMBERS REPRESENT COLIFORMS PER 100 ML

Figure 4. Composite distribution of coliform bacteria for period 23 - 27 August 1966 (surveys 15, 16, 17).

TABLE 8
COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 18 ON 30 AUGUST 1966

Station	Coliform Concentration (coliforms per 100 ml)	Station	Coliform Concentration (coliforms per 100 ml)
11	0	29	0
12	0	35	2
13	0	36	6
14	2×10^3	37	17×10^2
15	76	38	128×10^4
16	183	39	386^b
17	30	40	4
23	0	41	0
24	0	47	2
25	0	48	0
26	40×10^4	49	32
27	13×10^2	50	52
28	10		

^b designates filters on which overcrowding of non-sheen colonies may influence coliform counts

NOTE: NUMBERS REPRESENT COLIFORMS PER 100 ML

Figure 5. Distribution of coliform bacteria on 30 August 1966 (survey 18).

TABLE 9

COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 19 ON 1 SEPTEMBER 1966

Station	Coliform Concentration (coliforms per 100 ml)	Station	Coliform Concentration (coliforms per 100 ml)
11	30	41	14
12	50	43	0
13	50×10^2	47	4
14	360×10^2	48	10
15	130	49	0
16	136	50	c
17	34	51	100
19	0	52	14
35	10	53	62
36	16	55	0
37	8	59	0
38	89×10^4	60	0
39	24×10^2	61	0
40	10		

^b designates filters on which overcrowding of non-sheen colonies may influence coliform counts

Figure 6. Distribution of coliform bacteria on 1 September 1966 (survey 19).

Figure 7 shows the distribution on 3 September. The pattern presented differs from figure 6 although the observed wind conditions were nearly identical. Higher coliform density water has penetrated in all directions. The only explanation that can be offered for this phenomenon is the presence of the dense fog on 3 September which may have reduced the bacteriocidal effects of solar radiation.

Differentiation of Coliform Bacteria

Completed test for the presence of coliform bacteria were run on representative coliform cultures obtained during the sampling process. 106 of these tests were run resulting in 91 positive tests. Each of these 91 coliform cultures were submitted to the IMViC biochemical differentiation tests. 22 or 24.2% of these gave the typical reactions of Escherichia coli (indole positive, methyl red positive, Voges-Proskauer negative and citrate negative), while 38 or 41.7% gave the typical reactions of Aerobacter aerogenes (indole negative, methyl red negative, Voges-Proskauer positive and citrate positive), and 31 or 34.1% gave either intermediate or atypical results. It is likely that the atypical results were caused by cultures which

TABLE 10

COLIFORM CONCENTRATIONS DETERMINED ON
SURVEY 20 ON 3 SEPTEMBER 1966

Station	Coliform Concentration (coliforms per 100 ml)	Station	Coliform Concentration (coliforms per 100 ml)
11	522 ^b	40	2×10^2
12	c	41	410 ^b
13	346×10^2	43	14
14	107×10^2	47	4
15	17×10^2	48	910 ^b
16	196	49	c
17	c	50	242×10^2
19	c	52	42
35	c	53	70
36	374	55	56
37	c	59	134
38	84×10^4	60	0 ^b
39	64×10^3	61	4

^b designates filters on which overcrowding of non-sheen colonies may influence coliform counts

^c designates indeterminate result because of overcrowding or massive growth on filters

Figure 7. Distribution of coliform bacteria on 3 September 1966 (survey 20).

were pure "coliform cultures" but not pure cultures in the usual sense, since no particular steps were taken to determine the purity of cultures.

The significance of any particular coliform species over another has had no observable effect on this study as there is little doubt of the origin or source of coliforms depicted around the outfall boil.

5. Conclusions

The distribution and concentration of coliform bacteria have been determined, plotted and qualitatively analyzed for the surface waters surrounding the outfall of the Monterey Water Pollution Control Plant. The following general features of the surface coliform field are concluded:

(1) The general trend of coliform concentrations in the surf zone along the beach is a region of maximum coliform concentration to the east of the outfall with the level remaining high to the outfall, a rapid decrease of concentration to the west of the outfall with occasional isolated centers of higher coliform concentrations, and a slight increase in concentration towards Monterey Municipal Wharf No. 2.

(2) In the offshore region a general onshore mass transport of surface waters is indicated by the rapid decrease in coliform concentration seaward of the boil and a more gradual decrease in concentration shoreward of the boil. This phenomenon was observed in response to westerly and northwesterly winds.

(3) The seaward extend of coliforms was limited to several hundred yards north of the outfall boil.

(4) The east-west variation of coliform concentration between the outfall boil and the surf zone was seen to be quite variable.

Meteorological and oceanographic parameters observed had the following influences on this general pattern of coliform distribution:

(1) The tide and water temperatures within the ranges observed have little or no consistent effect on the distribution and concentration of coliform bacteria.

(2) The more extensive distribution on four surveys (surveys 11, 12, 13, and 20) may in part be attributable to a decrease in bacteriocidal solar radiation.

(3) The winds observed during this study showed little variation. No changes in the distribution were observed in the surf zone in response to small changes in wind direction or speed. In the offshore region the pattern of iso-concentration lines tended to be elongated along a line perpendicular to the wind direction on surveys 18, 19, and 20.

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14.

KEY WORDS

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MONTEREY BAY

MEMBRANE FILTER

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