Chapter 3

WATER QUALITY AT AQUATIC PARK: BIOLOGICAL PARAMETERS

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Introduction

Aquatic Park, which is situated along the Berkeley shoreline (Figure 1, p. 126), can be a pleasant place to spend an afternoon. Among its many features is a park along the east shoreline which has several "creeks" winding their way to the lake. There were not always "creeks" along the shore, however. With the building of the park, some storm drains were opened to create these "creeks". The drains, which run directly into the lake, have the potential to carry contaminants. Water quality is an important aspect of the lake and should be monitored very carefully. Drains which bring unfiltered, contaminated water into the lake should be of special concern to those people who use the lake for water contact sports such as water skiing and sailing. There is an added concern this year with the large amount of rainfall Berkeley has received, because effluents that might not reach the lake in a more normal year may be doing so now. These could include effluents from outside the area normally drained by this system carried in clogged lines, leaching from old tanks and pipes broken by earth movement and settling.

This report is a study of the water quality along the east shore of Aquatic Park during two different periods, one relatively wet and one relatively dry. The focus is on bacteriological contamination and includes an evaluation of the current health of the lake, as well as suggestions as to how improvements may be made. A further study of the lake focusing on heavy metals and other chemical parameters may be found in a paper by Claudette Altamirano in this same section.

Past Studies of Aquatic Park

All water quality studies done by the City of Berkeley are from the Marina. It is assumed that the water in Aquatic Park is similar to the water at the Marina. The last time the lake was tested for contamination was in 1969 (Spencer, 1983). Testing was discontinued after this time because of a sewer intercept, which was constructed to divert the storm water away from the park to Potter Creek in the south and Strawberry Creek in the north (Figure 1).

An analysis of studies done by the City at the Marina, as well as at other sites, is contained in a report on water quality written by Bessie Lee for last year's report entitled "The East Bay Shoreline" (Lee, 1982). These studies show that coliform numbers increase dramatically after a rainstorm. Studies

done during periods of dry weather show that the quality of the water is generally within the objectives set by the Regional Water Quality Control Board (RWQCB, 1975).

Water Quality Problems

As water runs off the streets and into the storm drains, it picks up whatever is on the streets, including heavy metals and fecal materials. As the water flows towards the lake, these materials become more concentrated. The San Francisco Bay Area Environmental Management Plan (ABAG, 1978) specifically identifies bacteriological contamination as one of the problems associated with surface runoff. Because bacteria originating from human and animal feces are associated with health problems, they are an important concern of health officials.

Coliforms, specifically Escherichia coli, are one of the most common organisms in the gut of humans as well as other warm blooded animals. The coliform group is defined as those bacteria which are gram negative rods, are facultative anaerobes, non-spore formers which ferment lactose with the production of acid and gas (APHA, 1980). E. coli has become very important in water quality studies because its presence is direct evidence of fecal contamination.

Since the disease organism itself is usually difficult to isolate from water, indicator organisms must be used. These organisms are ones whose numbers can be estimated and whose presence is indicative of the presence of human or animal waste. The indicator organism, in this case E. coli, plays an important part in the determination of water quality (Cooper, 1983).

The other organism tested for is fecal streptococcus, which is defined as any streptococcus commonly found in significant numbers in human or animal waste. The ratio between fecal coliforms and fecal streptococci indicates the source of contamination. A ratio of one or less is typically found with wastes originating with animals whereas a ratio greater than four is commonly found with wastes originating from a human source. Any ratio falling between one and four indicates waste which may come from either human or animal sources.

Methodology

The methods used for the determination of coliform numbers are outlined in publications by the American Public Health Association (APHA, 1980). The method employed is called the Most Probable Number (MPN) method, which uses the following equation:

$$MPN = \frac{100\ (p)}{(NT)^{\frac{1}{2}}}$$

where p = Number of positive tubes

N = Volume of inoculum in negative tubes

T = Total volume of inoculum

There are three basic steps to the MPN method, the Presumptive, Confirmed and Completed tests. To select for coliforms, special media which will enrich and encourage their growth are used. Since there are a number of gram positive organisms which can ferment lactose (a principal component of the MPN test), positive presumptive tests cannot be considered evidence of coliform contamination; therefore, a confirmed test must also be performed.

The confirmed test for coliforms consists of inoculating loopfuls of the positive presumptive tests into a medium which contains Oxgall and Brilliant Green, the first inhibiting gram positive organisms and the second selecting for coliforms. This medium cannot be used for the presumptive test because it can be toxic to low numbers of bacteria.

The presumptive and confirmed tests are usually the extent of the MPN procedure. However, if there is a doubt that the organisms isolated are coliforms, then the completed test may be performed. In this report the completed test was not performed.

All calculations were made using the MPN equation shown at the beginning of this section. Standard 100 ml samples were diluted so that concentrations of 10^{-1} to 10^{-5} were obtained.

The MPN procedure has several advantages and disadavantages. Among its advantages, the MPN procedure has a high degree of sensitivity and it requires only 100 ml of water to run the test. The other major method of coliform determination, the membrane filter method, can take up to several gallons of water and will not always get consistent results. One of the disadvantages of the MPN method is the amount of time required for each test, up to five days. If time is not an important factor, then this method is very good for the determination of coliforms.

Sampling at Aquatic Park

Tests for this study were conducted in two phases. The first phase was between February 21 and March 5, during which time there was a large amount of rainfall. The second phase was between April 4 and April 8, during which time there was little rainfall and high temperatures. Each test period consisted of five sample days; on each sample day 100 ml samples were obtained according to procedures outlined in Standard Methods (APHA, 1980).

All sample sites were located along the east shore of the lake. Only sites A, C and D (Figure 1) were used in the study of bacteriological parameters. The other sites listed were used in the study on heavy metals by Altamirano, this report.

Since during periods of heavier rainfall it was not always possible to obtain samples from the drains themselves, an alternative site, roughly five feet in a line directly downwind from the drain, was chosen. Alternative sites were chosen by examining flow patterns in the lake (Figure 1) to determine the most likely sites where any water coming from a drain would end up.

Results

The Regional Water Quality Control Board has set water quality objectives for REC-1 water uses

(water contact sports) which are as follows: the median shall be less than 50 per 100 ml for fecal coliforms with no sample greater than 400 per 100 ml and the total coliform count shall not exceed 240 per 100 ml, with no sample greater than 10,000 per 100 ml (Table 1; RWQCB, 1975).

Overall total coliform patterns show that during periods of heavy rain (2/28 - 3/2), numbers of bacteria in the lake increase significantly. Sites C and D show parallel levels of contamination except for 3/1, at which time site C showed a 10x increase in bacteria numbers over site D (Table 2).

Beneficial Use	Receiving Water	Fecal Coliform MPN	Total Coliform MPN
REC-1	tidal	median 50/100ml no sample to exceed 400/100ml	median 240/100ml no sample to exceed 10,000/100ml
REC-1	non-tidal	log mean 200/100ml 90 percentile 400/100ml	--
REC-2	non-tidal	mean 2000/100ml 90 percentile 4000/100ml	--

REC-1: Water designated as suitable for water contact recreation.
REC-2: Water suitable for uses other than water contact recreation.
MPN: Most Probable Number. An estimate of how many organisms are in the water.

Table 1. Water Quality Objectives for Coliform Bacteria (RWQCB, 1975)

Sample/Day		2-22	2-28	3-1	3-2	3-5	4-4	4-5	4-6	4-7	4-8
	W	C	R	RW	RW	R	S	S	S	S	S
TC	A	140	26,000	180,000	170,000	11,000	500	400	300	300	300
	C	1,100	1,100	180,000	14,000	1,700	400	300	300	300	200
	D	1,100	1,100	17,000	14,000	1,800	400	300	300	300	300
FC	A	20	4,000	110,000	80,000	---	17	14	14	---	---
	C	---	400	110,000	2,000	---	14	14	11	11	---
	D	---	500	110,000	3,000	---	11	9	9	---	---
FS	A	N/A	2,000	20,000	60,000	---	17	14	14	---	---
	C	N/A	4,000	20,000	---	---	17	14	9	---	---
	D	N/A	400	200,000	---	---	12	9	7	---	---
$\frac{FC}{FS}$	A	---	2.00	5.50	1.33	---	1.10	1.00	1.00	---	---
	C	---	0.10	5.50	4+	---	1.10	1.00	1.22	---	---
	D	---	1.25	0.55	4+	---	1.10	1.00	1.22	---	---

TC: Total Coliforms
FC: Fecal Coliforms
FS: Fecal Streptococci
$\frac{FC}{FS}$: Ratio between Fecal Coliforms and Fecal Streptococci
W: Weather: R-rain, W-high wind, S-sunny, C-clearing

Table 2. Results of Sampling at Aquatic Park in 1983

Studies of fecal streptococci showed more similarities between sites A and C. Site D tended to have a wide fluctuation in the numbers of bacteria. Fecal coliforms at sites C and D followed the same pattern of increase and decrease over this period.

After the storm was over and the land had a chance to dry out (4/4 - 4/8), total coliform numbers reamained constant at all three sites. Similarly, the numbers of both fecal coliforms (FC) and fecal streptococci (FS) also remained constant. MPN numbers which are $\pm$ 100 of each other can be considered to be in the same grouping because the MPN calculation has a 95% confidence limit. For example, an MPN of 14 has a 95% confidence limit of between 4 and 34 MPN per 100 ml (APHA, 1980).

Ratios of FC to FS during the period of 2/28 to 3/2 varied from site to site. On 2/28 all three sites had slightly different ratios. However, on 3/1 sites A and C were well above the 4.0 mark, which is indicative of human contamination. On 3/2 sites C and D were well above this mark.

The ratio of fecal coliforms to fecal streptococci can give an indication of the origin of the fecal material. A ration greater than 4 is indicative of human pollution (Cooper et al., 1976), which is clearly the case for water tested on 3/1 and 3/2. At other times the ratios were either 1, indicating animal contamination, or between 1 and 4, which is indicative oe either human or animal contamination. The lower ratios can be misleading because they are in part dependent upon how long the material has been in the water (Figure 2). Coliforms have a limited life in the water, and coliforms from humans will tend to die out faster than coliforms from animals (Cooper, 1983).

Trends during the rainy period show a definite peak with the numbers rising sharply, then declining sharply to a level which shows little evidence of fecal contamination.

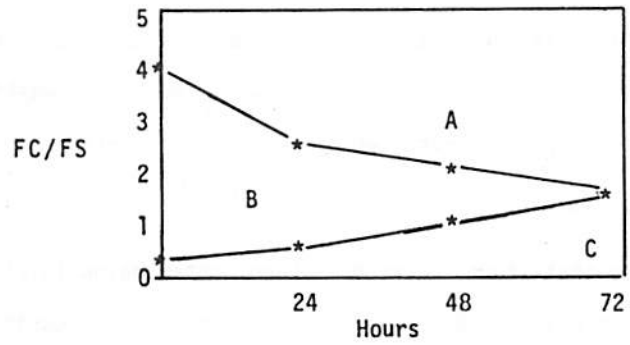

Figure 2. Fecal Coliform/Fecal Streptococci ratios for human and animal contamination over time.

A: Human contamination
B: Human and/or animal contamination
C: Animal contamination

Source: Cooper, unpublished data

Results from this year's testing indicate that during periods of heavy rainfall a large influx of bacteria may be expected. There is a constant rise in the levels of bacteria until March 1, when numbers seem to level off and even decline a bit. This change could be due to several things: as the streets are washed off, the numbers of bacteria may be decreasing, the numbers of bacteria in the lake from the first influx may be dying off or the diverter is capable of taking more of the contaminated water from the lake. A coliform bacterium has a half life of approximately 14 days (Table 3), which means that bacteria entering the lake 15 to 30 days prior to testing probably will not show up

Organism	Half life (hours)	T99.99 (days)*
Polio I	31-48	13-20
Echo 7	17-39	7-16
Echo 12	12-29	5-12
E. coli	12-17	5-7
S. fecalis	19-43	8-18

*Time in days for 99.99% reduction

Table 3. Survival of Various Microorganisms in River Water at 20°C.
Source: Cooper, Unpublished Data

in a test for coliforms. Therefore, testing for evidence of fecal contamination should be done during periods of high flow when there is a greater probability that fecal coliforms will be entering the lake.

During dry periods the lake seems to have a constant level of coliforms (Table 2). Because the coliforms have a half life of 14 days, it can be assumed that there is some constant source of contamination feeding the lake. This source could be a broken sewer line, feces washing off the lawns or a constant flow from the storm sewers or "creeks" which run into the lake.

Discussion

Results of this study indicate that storm sewers have been contaminated in at least one instance with fecal coliforms of human origin. Because contamination occurred during periods of heavy rainfall, there may be a broken sewer line which, during heavy rain, leaches contaminants into the lake. Strawberry Creek (Site D) showed contamination on March 2, the day after contamination appeared at the other sites. This high level of contamination could have been due to one of two things. Past studies indicate that Strawberry Creek consistently carries high levels of coliforms (Lee, 1982). Therefore, if Strawberry Creek was overflowing, it could be bringing additional

contamination into the lake. The second possibility is that a high wind, coupled with natural currents in the lake (Figure 1) may have combined to bring contaminants from the other sites into this area.

Results of testing when there was little rain (4/4 to 4/8) suggests that a small trickle of coliforms is entering the lake from some source. The most likely source is the "creeks", from which the highest number of coliforms were recorded in dry days. The results shown in Table 2 are not extremely consistent. There are some days when unexpected results are obtained. Unless some fault can be found with the testing procedure, such as dirty glassware or poor lab procedures, then there is no logical reason why the results should be as varied as they are. For example, on 3/1, the total coliform number for site C was 180,000 as opposed to 17,000 for site D. All other days the numbers of total coliforms at these two sites remained constant with respect to each other. A careful examination of procedures used revealed that the experiments were carried out correctly.

Even though test results show low numbers of coliforms on 4/1 to 4/8, the danger of contamination may not have passed. There are several organisms which have a longer life expectancy in water than the indicator organisms (Table 3). Polio I, for example, can survive in water for up to 20 days, whereas the coliforms and enterococci last only about 7 days (Cooper, 1983). In general, the coliform and enterococci seem to be more resistant than the bacterial pathogens.

Predictions for Summer Use

A rough prediction can be made about the use of the lake during the summer. Since the summer and spring months tend to have relatively small amounts of rainfall, if any, then the problems encountered in this study should be minimal, if not non-existent. However, should there be a significant rainstorm during the summer, there could be a major problem with fecal contamination.

Use of the lake during the winter months could continue with caution taken to maintain a monitoring program after a major storm event. Should conditions warrant it, the park should be closed until the danger has passed. Water skiers who use the lake do so with the understanding that it does not meet the REC-1 objectives for ocean water quality (Spencer, 1983).

Converting the status of the lake to REC-2 during the winter (water designated as use for non-contact recreation only) will not be acceptable under most situations since the objectives for REC-2 are a mean fecal coliform count of 2000/100 ml. The average fecal coliform count for this period was approximately 11,300/100 ml, quite a bit higher than the objectives stated (Table 1).

Pollution Prevention Recommendations

It is unrealistic for the City of Berkeley to assume that the water quality at Aquatic Park is the same as at the Marina. These two areas differ greatly both in the kinds of water they receive and in the kind of tidal action to which they are subjected.

The sewer diverter, that was installed to carry away the bulk of water which used to run into the lake, may have taken care of a large part of the pollution which ran into the lake but it has not

eliminated all of it (Berkeley, 1983). During periods of high flow, when the interceptor is too full, storm drains will still deposit a large amount of water into the lake.

When there has not been rain for some time and the diverter is capable of handling the water, pollution may still be entering the lake via the "creeks" which run through the park. Additional sources may be from watering the lawns at the park or from leaking sanitary sewers.

If the "creeks" were to be cut off and diverted from the park, city officials should consider what the park might lose. The "creeks" add a certain charm which, if eliminated, could make the park a less attractive place to go. The amount of contamination entering the lake via the "creeks" does not warrant their being diverted.

Water quality at the park meets the objectives for most of the year. It is only during those periods of high flows that contamination will enter the lake in numbers significant enough to be considered a health hazard. It is during these times that the City of Berkeley should monitor the lake for bacterial contamination.

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