

A. BACTERIOLOGICAL ANALYSIS OF PORTABLE TOILET EFFLUENT  
AT SELECTED BEACHES ALONG THE COLORADO RIVER,  
GRAND CANYON NATIONAL PARK, ARIZONA

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ABSTRACT.--Portable toilet effluent buried at nine beaches along the Colorado River, Grand Canyon National Park, Arizona, was examined for bacteria. Viable total and fecal coliforms were isolated 84 percent of the time. Organisms migrated up to 8 inches away from the burial sites at 22 percent of the beaches. Coliforms were present throughout the strata to a depth of 2 feet. No direct relation was apparent when comparing percent of soil moisture, percent of coarse sand, and numbers of organisms. As ground temperature dropped during the colder months, a comparable decline occurred in numbers of organisms. As ground temperature increased in the spring, a similar increase in numbers of organisms occurred. A definite public health hazard is seen in the numbers of coliforms and associated pathogens that are capable of surviving from one season to the next. Therefore, the health of the 15,000 individuals who annually make Colorado river trips and camp at such beaches is potentially endangered.

A significant sanitation problem was recognized by Park management and other concerned conservationists during 1970 (Bennette 1973, Carothers 1974) (table 1). In 1972, between late May and July, 132 of 256 individuals involved in 13 river trips experienced gastrointestinal illnesses. Stool specimens revealed that the probable causative organism was *Shigella sonnei* (Morbidity and Mortality Weekly report 1972).

Because no common food or water source carriers were identified, the outbreak apparently originated in part from infected boatmen who may have transmitted the illness

to passengers through food and water handling and inadequate sanitation. The disease could have spread between river parties using common eating places along the river. Contact spread among the passengers probably accounted for the high attack rate (52 percent).

With the inception of Park regulation in 1972, along with excellent cooperation from the commercial river operators, the beaches improved dramatically. The regulations required commercial river parties, representing 92 percent of the total river users, to either carry portable toilets or use other means for the concentration

Table 1.--Number<sup>1</sup> of people running the Colorado River Grand Canyon, Arizona

Year	Users	Year	Users
1955	70	1966	1,067
1956	55	1967	2,099
1957	135	1968	3,609
1958	80	1969	6,019
1959	120	1970	9,935
1960	205	1971	10,885
1961	255	1972	16,432
1962	372	1973	15,219
1963	<sup>2</sup> 6	1974	14,253
1964	<sup>2</sup> 38	1975	14,305
1965	547	Total:	95,706

<sup>1</sup>Based on revised figures, March 1976, U.S. Department of Interior, National Park Service, Grand Canyon.

<sup>2</sup>Glen Canyon Dam being filled.

(containerization) of human waste for burial. The recommendations further stipulated that burial should occur in a hole at least 2 feet deep, 6 feet above the normal high river fluctuation line, at least 50 feet from the river bank, and at least 200 feet from normal camping areas.

Despite the fact that campsites became cleaner and more appealing, beneath the beaches an ever-increasing potential health hazard existed in the form of improperly buried and accumulating human feces.

#### OBJECTIVES

Based on these and other observations, a 6-month bacteriological study was conducted at selected beaches along the Colorado River to determine: (1) the presence and levels of fecal and total coliforms and *Clostridium perfringens* (a spore former) in human fecal waste burial sites; (2) the survivorship of coliform organisms during a winter period when low temperatures prevailed; (3) whether sand substrate influenced bacterial decomposition; (4) whether bacteria migrated laterally from the burial sites toward the river; and (5) whether a significant public health problem existed at some beaches based on the above findings.

#### METHODS AND MATERIALS

Arrangements were made to accompany two 8-day commercial river parties. The commercial trips were chosen to duplicate actual sanitation practices used by large river parties for disposal of human waste. The boatmen conducted the trips as usual, selecting beaches at their convenience and burying the portable toilet effluent according to normal procedures.

A total of 10 beaches were selected between Lee's Ferry and Diamond Creek, a distance of 227 miles (table 2). The beaches were accessible principally by river boat.

Procedures used in establishing the study were as follows: the boatmen selected the site at which the effluent would be buried. A round, plywood board, 2 feet in diameter, was placed over the site and the outer perimeter of the board marked on the sand. A hole was dug 2-feet wide by 2-feet deep. A wooden stake approximately 2-feet long was centered and driven into the bottom of the hole. The contents of the portable toilet, to which a commercial chemical had been added, was emptied into the hole and covered.

Relocation of the burial sites was facilitated by using the reference markers. A substrate core was taken at each burial site by means of a core sampler. The device, 24 inches long, constructed of galvanized pipe, 2 inches in diameter, was fitted with a stainless steel tip to withstand being hammered into the ground and hitting hard obstacles. A clear plastic core tube was inserted inside and a threaded cap screwed onto the upper end to provide a means for the tube to be hammered.

The device was driven into the substrate at selected places within each effluent site. The round plywood board with holes numbered in a circle around a center hole was used to select the exact spot used each month for taking the core. The center of the board was aligned over the stake and then positioned to a permanent reference point at each beach to avoid taking repetitive samples. Each month a new hole on the board was used.

Additional core samples were taken 8 inches away from the edge of the hole to determine whether the bacteria were mi-

grating toward the river. A control sample was taken at random from each beach. Once the tube was withdrawn, the cover was removed and the inner plastic core tube, containing the actual substrate sample, was extracted. Surface and bottom core temperatures were taken at the time of the coring. Often a chemical dye was seen through the clear plastic tube indicating the presence of buried organic waste.

Ends of the core tube were covered with color-coded caps to ensure that the samples could be tested according to their position in the hole.

Distance between survey beaches ranged from 10.5 to 43.5 miles (table 2), therefore, it was only possible to collect

samples from one or two beaches per day, depending upon water conditions of the river.

#### COLIFORM COUNTS WITHIN BEACH EFFLUENT BURIAL SITES

A total of 61 beach dump site analyses were made. Results of the bacterial examinations (combined total and fecal coliform counts) at all beaches were as follows: 15.8 percent of the samples were negative; 22.3 percent had coliform readings of 1 to 25 colonies per plate; and 61.9 percent had readings of 25+ coliform colonies per plate (table 3). Three beaches, Lava Canyon, Papago, and Deer Creek had viable coliform counts every month.

Table 2.--Beaches where bacteriological analysis conducted

Beach	Side of River	River mileage <sup>1</sup>	Distance apart
Boulder Narrows	left	18.5	18.5
Silver Grotto	left	29.0	10.5
Upper Nankoweap	right	52.0	23.0
Lava Canyon	right	65.5	13.5
Papago	left	76.0	10.5
Granite	left	93.0	17.0
Deer Creek	left	136.5	43.5
Shelves	right	151.5	15.0
Mile 173.5 Beach	left	173.5	22.0
Mile 185.5 Beach <sup>2</sup>	right	185.5	12.0

<sup>1</sup>Distance from Lee's Ferry, Arizona, principal launching site for majority of river parties.

<sup>2</sup>Surveyed only once, effluent removed for laboratory experiments.

Table 3.--Monthly bacteriological results<sup>1</sup> at selected beaches, Colorado River, Grand Canyon National Park, Arizona

Beach	October	November	January	February	March	April	May	Percentage			Total	
	1-25:25+	1-25:25+	1-25:25+	1-25:25+	1-25:25+	1-25:25+	1-25:25+	Neg.	1-25:25+	1-25+		
Boulder Narrows	+	+	+				+	43	14	43	57	
Silver Grotto		+	+	+	+	vandalized		20	20	60	80	
Upper Nankoweap	+	+	+			+	+	29	42	29	71	
Lava Canyon	+	+	+	+	+	+	+	0	14	86	100	
Papago	+	+	+	+	+	+	+	0	29	71	100	
Granite	+	+		+	+	+	+	20	0	80	80	
Deer Creek	+	+	+	+	+	+	+	0	29	71	100	
Shelves		+	+	+	+	+	+	29	42	29	71	
173.5	No data	+	+	+	+		+	17	33	50	83	
185.5	+	Removed for laboratory analysis							0	0	100	100
No. positive:	7/9	4/9 5/9	3/9 5/9	1/9 6/9	2/9 5/9	2/8 4/8	2/8 6/8	15.8	22.3	61.9	84.2	
Percentage 1-25+:	78	100	89	78	78	75	100					

<sup>1</sup>Total and fecal coliform plate counts/100 ml sample.

Table 4 analyzes the bacteriological findings from all beaches, by month, by number of coliform colonies per plate, and by the type of coliform present. Fecal coliform plates were positive 74 percent of the time, while total coliforms, *E. coli* colonies, were positive 66 percent of the time. The ratio of total to fecal coliforms in normal water samples, is approximately five to one.<sup>1</sup> However, because we incubated the total coliforms at a higher temperature than the fecal coliforms, a lower total coliform count resulted. Bacteriological standards for quality of potable water requires that 95 percent of all samples be free of total coliforms. In this study a significantly higher percent of positive sample occurred, however, such standards are not applicable under these conditions.

Control core samples were negative for fecal and total coliforms.

#### COMPARISON OF BEACH TEMPERATURES VS. PRESENCE OF COLIFORMS

Surface soil temperatures ranged from 98°F in October 1975 to 31°F in January 1976, while those at the bottom of the hole ranged from 80°F in October to 38°F in January. The mean surface and bottom temperatures were 60.5°F and 61.4°F, respectively. Bottom temperatures were

<sup>1</sup>Personal communication with Mr. Don Finical, State Health Laboratory, Flagstaff, Arizona.

Table 4.--Bacterial analysis by month at selected beaches, Colorado River, Grand Canyon National Park, Arizona

	October	November	January <sup>1</sup>	February	March	April <sup>2</sup>	May	Total
Number positive beaches <sup>3</sup>	7/9	9/9	8/9	7/9	7/9	6/8	8/8	52/61
Percent positive beaches	78	100	89	78	78	75	100	85
Percent negative beaches	22	0	11	22	22	25	0	15
Percent positive (1-25 colonies)	0	33	33	0	22	25	25	20
Percent positive (25+ colonies)	78	67	56	78	56	50	75	65
Percent positive (total coliforms)	78	67	67	56	78	13	100	66
Percent positive (fecal coliforms)	78	89	67	78	67	63	75	74

<sup>1</sup>No. survey in December.

<sup>2</sup>One beach site vandalized.

<sup>3</sup>Fecal and/or total coliform.

1°F warmer than surface temperatures during the period from September 1975 to May 1976 (fig. 1). Although temperatures were at or near freezing at some beaches, vegetative cells were able to survive.

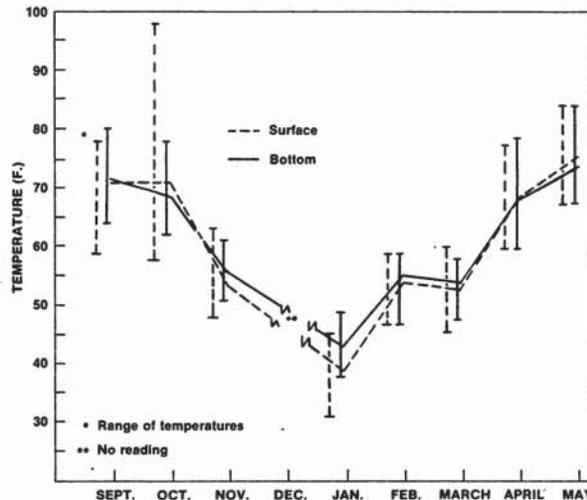


Figure 1.--Mean soil temperatures at selected Colorado River beaches, Grand Canyon National Park, Arizona, 1975-1976.

#### MIGRATION AWAY FROM BURIAL SITES

Substrate samples taken at the edge, and at 8 inches from the edge of the effluent burial sites indicate that some coliform organisms migrated. In October 1975, 61 percent of the beaches showed coliforms in numbers ranging from 1 to 25+

at the outer edge of the burial sites. Samples in November 1975, taken 8 inches from the edge of the effluent site, indicated migration was occurring at 22 percent of the beaches. In January, 56 percent of the samples taken at the outer edge of the hole were positive for coliform ranging in number from 1 to 25+. It appears that due to low rainfall, little leaching of the bacteria occurs by water movement.

#### PRESENCE OF COLIFORM IN RELATION TO DEPTH IN BURIAL SITE

In February and March 1976, a single core was taken at each beach to determine whether difference existed in numbers of organisms present in relation to their location within the substrata. From each core, samples were analyzed in the upper, middle, and lower thirds of the hole (table 5). Fifty-six percent of the beaches had coliforms in the upper one-third, 44 percent in the middle, and 72 percent in the lower. This indicates that feces float to the top at the time of burial and that viable coliforms and associated potentially pathogenic bacteria are distributed throughout the site.

#### CLOSTRIDIUM PERFRINGENS ISOLATIONS

Difficulty was encountered in attempting to isolate *C. perfringens* using the "gas-Pak" incubation system under canyon conditions. *C. limosum*, a normal soil

resident often implicated in a variety of animal infections, was identified from cultures taken in December. *C. perfringens*, an organism commonly associated with food-borne illnesses as well as being associated with wound complications causing gas gangrene, was isolated in April from several beaches.

Although this study only examined the presence of total and fecal coliforms and *C. perfringens*, other pathogens are surely present. The implication of this is seen in a case of infectious hepatitis, (Morbidity and Mortality Weekly report 1975) that occurred during a commercial Colorado River trip. The individual, who suffered onset and accompanying symptoms of the disease while on the river, probably was excreting virus during the trip and exposed approximately 35 other individuals. Such virus particles can remain viable for months.

#### ANALYSIS OF BEACH SUBSTRATE

During the February trip, substrate samples taken adjacent to each effluent site were analyzed for soil moisture and sand grain size. In general, soil moisture content and percentage of coarse sand showed little correlation to numbers of coliforms present in the samples. It is recommended that a more complete soil analysis be made to include percentages of clays and other soil types.

Table 5.--An analysis of where coliform bacteria<sup>1</sup> found in relation to depth of effluent at burial sites

Beach	February			March		
	Upper	Middle	Bottom	Upper	Middle	Bottom
Boulder Narrows						
Silver Grotto	+		+	+		+
Upper Nankoweap						
Lava Canyon		+	+			+
Papago	+	+	+	+		+
Granite	+		+	+	+	+
Deer Creek	+	+	+	+	+	+
Shelves	+	+	+	+	+	+
Mile 173.5	+					+
No. positive:	6/9	4/9	6/9	4/9	4/9	7/9
Percentage:	67	44	67	44	44	78
Totals:	Upper-56%		Middle-44%	Bottom-72%		

<sup>1</sup>Number ranged from 0-25+ colonies per plate/100 ml sample.

## CONCLUSIONS AND RECOMMENDATIONS

Coliform bacteria (total and fecal) were found in significant numbers during an 8-month study period. A public health hazard exists at and near such burial sites as seen by the numbers of coliforms isolated at surface and near-surface levels. Numbers of organisms ranged from one to too numerous to count per 100 mls of diluted sample. These data reflect only a minute portion of the actual numbers of coliforms within the substrate. Such organisms are able to survive the rigors of low winter temperatures. Coliforms migrated up to 8 inches from the burial site. It appears that chemicals added to the effluent prior to burial are ineffectual in reducing a significant number of fecal indicating bacteria.

The significance of these findings is seen in number of river parties (572) running the Colorado River in 1975 alone, with an accompanying 15,000 persons, camping an average of 8.8 nights per trip. From such trips, more than 5,000 Park regulation burials occurred, accompanied by countless number of nonregulation burials, made at times when portable toilets were not set up. If river parties used the estimated 200 readily recognized beach sites along the river, a resultant 25 regulation burials would occur per beach per season. However, some beaches received much greater use due to their locations near popular Canyon attractions. These areas could possibly have 100 or more burials per season. It is at such sites that boatmen complain of unearthing previous parties effluent. At other beaches, only limited areas for burial exist. However, when the course of "least resistance" prevails, burials occur in whatever spot is handy or free of boulders. At such sites, passengers unknowingly sleep and place their personal gear, risking bacterial contamination.

A significant aspect of this study is related to the impact of the continuing practice of burying human toilet waste at

beaches along the Colorado River, Grand Canyon National Park, Arizona.

The following recommendations are presented to assist administrators in establishing river use guidelines to safeguard the health of future river enthusiasts.

- (1) Discontinue the policy directed at commercial river parties specifying that effluent be buried. Instead, require commercial boating parties to provide watertight holding tanks for the disposal of effluent, with the accompanying responsibility of disposing of the waste outside the Park. Permit private parties to continue the practice as per current regulations.
- (2) Eliminate small, confined beaches as campsites for all river parties.
- (3) Establish rustic, pit privies at the larger beaches.
- (4) Establish Park Service effluent dump stations at a number of locations along the river.
- (5) Increase river patrols to ensure the presence of Park Service staff at all times during the river running season to assist in the enforcement of regulations.

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