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BACTERIOLOGICAL WATER QUALITY OF RECREATIONAL AREAS: J. PERCY PRIEST PARK, TENNESSEE

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Abstract

The use of water for recreational purposes, such as swimming, boating, and fishing is increasing, and those who use it take for granted that it is "safe." Seven stations, all recreational areas, on J. Percy Priest Reservoir were examined from 6 May to 5 August, 1986, for the presence of fecal coliform bacteria and fecal streptococcus bacteria by the membrane filter technique. Fecal coliforms were detected in 90.8% of the samples, and fecal streptococci were detected in 99.4% of the samples. At each of the seven areas, 28 samples for fecal coliforms and 26 samples for fecal streptococci were collected during the study period and overall a total of 378 samples were collected at the reservoir. The average fecal coliform to fecal streptococcus ratio obtained in this study (0.08), for all areas combined, indicates that the fecal contamination was of nonhuman origin because the ratio was below 0.7. The temperature, pH, and specific conductance of the water were also determined. The study also indicates that the reservoir, during the study period, was "safe" for body contact according to the pollution indicator organism standard used by the State of Tennessee Department of Health and Environment and EPA; but it also indicates that fecal streptococci should be included as a pollution indicator organism in the guidelines for recreational waters.

Introduction

J. Percy Priest Reservoir, a man made impoundment of the Stones River, was completed in 1968. It is located in Davidson, Rutherford, and Wilson counties of Middle Tennessee (Figure 1). The drainage area of the reservoir covers 2240^2 km. During normal summer pool (NSP) the elevation of the reservoir is 149.3 m above mean sea level which leaves a shoreline of 343 km and a total project area of 5746 ha (U.S. Army Corps of Engineers 1977). The average surface temperature of the lake from May through August is 26.25°C with the average temperature being highest in July and August and the lowest in May. Annual precipitation is 128.3 cm per year with an average monthly rainfall of 10.70 cm (Moore 1986). From January through August the average precipitation is 91.16 cm. Rainfall for 1986 during the same period was 63.67 cm; a deficiency of 27.49 cm. The reservoir was 9.17 cm below the average for 1986. The Corps of Engineers, along with two other agen-

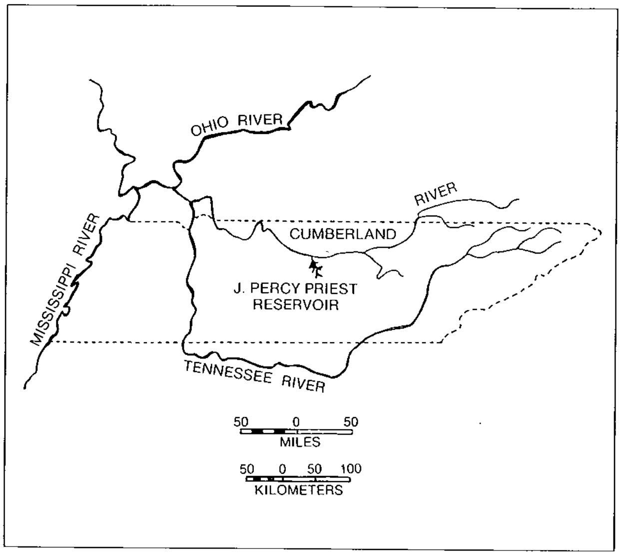

Figure 1. Location of J. Percy Priest Reservoir in the Cumberland River Basin, Tennessee.

cies, operate a total of 24 recreational areas around the reservoir.

Water quality is a major concern in this country as well as worldwide. The use of water for recreational purposes, such as swimming, boating, and fishing is increasing, and those who use it take for granted that it is "safe." One area of particular concern is contamination by fecal material from human and nonhuman sources, because sometimes fecal material contains pathogens which can be transmitted by water; thus, the more fecal material there is in the water, the greater the risk of contracting disease to those who come in contact with the water. Examples of these diseases include: diarrheal disease caused by enteropathogenic *Escherichia coli,* viral hepatitis caused by Hepatitis A, typhoid fever caused by *Salmonella typhi,* paratyphoid fever caused by *Salmonella paratyphy* A, and shigellosis caused by *Shigella dysenteriae.* Since the mid-1950s there has been a noticeable increase in the overall number of waterborne disease outbreaks as reported to the Center for Disease Control. Swimmers have an increased incidence of infections and irritations of the skin, ear, nose, and upper respiratory tract. Evidence of a swimmer's risk was manifested in Tennessee in 1976 when seven cases of leptospirosis occurred due to swimming in a creek contaminated with urinary wastes of cattle.

Mechalas et al. (1972) stated the condition of bathing water varies from day to day, and season to season. It may be altered by fixed sources of pollution, incidence of disease among the local population, the bathing load, physical factors, such as wind, water, and weather, and composition of the water.

Most bacteria in the water are derived from contact with air, soil, living and decaying plants or animals, and fecal excrement from warm and cold-blooded animals. According to Pipes (1982), bacterial populations are higher along river banks and lake shores due to the higher concentration of nutrients from land runoff, sewage, industrial discharges, and vertical mixing.

Olivieri (1982) stated that in order for an indicator to be of value it should satisfy the following criteria: the indicator should always be present when the source of pathogenic microorganisms is present and absent in clean uncontaminated water, the indicator should be present in numbers much greater than the pathogen or pathogens it is intended to indicate, the indicator should respond to natural environmental conditions and water treatment processes in a manner similar to the pathogens of interest, and the indicator should be easy to isolate, identify, and enumerate. Therefore, fecal coliforms and fecal streptococci are excellent indicators of fecal contamination since they are consistently found in human and nonhuman feces and meet the above criteria.

The coliforms may be defined as comprising all aerobic and facultative anaerobic, gram-negative, non-spore-forming, rod shaped bacteria that produce a dark colony with a metallic sheen within 24 hours at 35°C on an Endo-type medium containing lactose (American Public Health Association 1985).

The fecal coliforms are a subgroup of the coliform group and are defined by Mechalas et al. (1972) as organisms that ferment lactose and produce gas within 24 hours at 44.5°C. All coliforms from the feces of warm-blooded animals are considered to be fecal coliforms. Their presence in untreated waters should be considered as an indicator of recent fecal pollution (Geldreich 1965). According to Geldreich (1967) the fecal coliforms are more accurate indicators of pathogens in water than the total coliforms. Dufour (1977) is even more restrictive than Geldreich in suggesting that *E. coli* be used as the indicator of fecal contamination. Fecal coliform determinations do not distinguish between human and nonhuman fecal contamination.

The streptococci can be defined as gram-positive cocci that are arranged in chains of three or more individual cells spherical in shape (Brock et al. 1984). The fecal streptococci are a subgroup of the streptococci and can be defined as belonging to Lancefield group D and group Q. The fecal streptococci are normally found in the intestines of man and animals and do not multiply in polluted waters. They are thus good indicators of fecal pollution (Cooper and Ramadan 1955). Olivieri (1982) suggested that the fecal streptococci make useful indicators in relatively clean streams or in lakes that are used for recreational purposes.

The ratio of fecal coliforms to fecal streptococci (FC/FS) is often used to help indicate the probable source of the pollution. Therefore, it is very important that recreational waters be tested for the presence of fecal microorganisms, especially during the peak use months, May through August. If indicator organisms, such as those already mentioned. are found in sufficient quantity, then action should be taken to halt recreational usage until the indicator counts fall below the level accepted as being dangerous.

The purpose of this investigation was to determine the fecal coliform and fecal streptococcus level of J. Percy Priest Reservoir during the months of May through August, 1986.

MATERIALS AND METHODS

Seven stations, all of which are recreational areas, were checked on a weekly basis. At each area, 28 samples for fecal coliforms and 26 samples for fecal streptococci were collected. One hundred ninety-six fecal coliform samples and 182 fecal streptococcus samples were collected during the study period for a total of 378 samples. All samples were collected and stored in accordance with "Standard Methods" (APHA 1985). All media were from Difco. The samples were analyzed by the fecal coliform membrane filter technique or fecal streptococcus membrane filter technique. Each fecal coliform and each fecal streptococcus sample

Table 1. Percent occurrence of pollution indicator by group and percent occurrence of FC/FS ratio, all stations combined, at J. Percy Priest Reservoir during the study period of 6 May to 5 August 1986.

Individual and Combined Groups	Percent of Total
FC found	90.8
FS found	99.4
FC verified (+)	70.4
FS verified (+)	95.4
FC and no FS	0.5
FS and no FC	7.7
FC and FS together	91.8
FC/FS ratio of 0.7 or below	85.7
FC/FS ratio of 4.0 or above	1.1
FC/FS ratio between 0.7 and 4.0	13.2

FC=fecal coliform
FS=fecal streptococci

were filtered in volumes of 50 ml, 10 ml, and 1.0 ml in accordance with "Standard Methods" (APHA 1985).

A sterile filter 47 mm in diameter, 0.45 mm pore size, and grid marked was used to filter the samples.

The membrane filter technique was employed instead of the multiple-tube fermentation technique for the following reasons: 1) a higher degree of reproducibility of results, 2) a greater sensitivity with a larger volume of water filtered, and 3) a shorter time to obtain the results. Colonies were confirmed each week according to "Standard Methods" (APHA 1985).

The fecal coliforms were incubated on M-FC broth enriched pads. Verification procedures were done using lauryl tryptose broth followed by EC broth. The fecal streptococci were incubated on pads enriched with KF-streptococcus broth that had 1.0 ml of a 1% solution of 2,3,5-triphenyltetrazolium chloride (TTC). Brain Heart Infusion broth and agar slants were used for verification procedures. Catalase negative colonies were checked by showing growth at 45°C and in 40% bile in accordance with "Standard Methods" (APHA 1985).

The pH of each sample was recorded in the laboratory with a Beckman pHasar I digital pH meter. Water temperature, the depth of the water at approximately 3.5 meters from the shoreline, and the specific conductance of the sample were determined weekly at each station. Temperature (°C) was measured with a mercurial thermometer. Depth (cm) of the water at 3.5 meters from the shore was determined with a meter stick. Spcific conductance (umhos cm^{-1}) was measured with a Horiba Water Quality checker, model U-F.

Results and Discussion

Either fecal coliforms or fecal streptococci were found in samples at least 90.8% of the time (Table 1). The mere presence of fecal coliforms in recreational water does not indicate that the water contains pathogens which are hazardous to body contact. The fecal coliforms must be found in sufficient quantity before recreational water is deemed hazardous to body contact.

Fecal coliforms were found in 178 out of 196 samples, or 90.8% of the time, and fecal streptococci were found in 181 out of 182 samples, or 99.4% of the time (Table 1). The difference in the total sampling numbers is due to the accidental omission of 2,3,5-triphenyltetrazolium chloride (TTC) from the KF-streptococcus broth during week two of the study period. Colonies grew on the membranes, but all colonies were green instead of the normal pink to dark red color. Also, all 30 of the randomly selected colonies verified were catalase positive. Fecal streptococci are catalase negative (APHA 1985). These results indicate that the reservoir was recently contaminated by sewage or fecal materials and could be hazardous to body contact if found in sufficient quantity. According to Mitchell and Starzky (1975), bacteria die in natural waters rapidly, and their presence indicate recent fecal pollution. If fecal indicators of pollution are present in water samples, it is reasonable to assume that pathogens may also be present.

Table 1 also gives the verification results of the fecal coliforms (70.4%) and the fecal streptococci (95.4%). Fecal coliforms alone were isolated 0.5% of the time while fecal streptococci alone were isolated 7.7% of the time. The fecal coliforms and the fecal streptococci were isolated together 91.8% of the time.

Fecal streptococci were included in this study so that the origin of any pollution might be better determined. Geldreich et al. (1964) urged the usage of a FC/FS ratio to determine the origin of fecal materials. Geldreich and Kenner (1969) reported a FC/FS ratio of 4.0 or higher indicates pollution of a human origin while a FC/FS ratio of 0.7 or below indicates pollution from an animal source. Results from Hussong et al. (1979) differed from Geldreich and Kenner in that they found it was not possible to separate avian fecal contamination from human contamination on the basis of a shift in the FC/FS ratio. Data obtained in this study (Table 1) indicate a FC/FS ratio of 0.7 or below 85.7% of the time, a FC/FS ratio of 4.0 or greater 1.1% of the time, and a FC/FS ratio of greater than 0.7 and less than 4.0 only 13.2% of the time. Thus, the majority of the time (85.7%) the water was contaminated by fecal materials originating from a nonhuman source. The minority of the time (1.1%) the water was contaminated by fecal material from humans. The origin of the final 13.2% was uncertain due to the ratio falling between 0.7 and 4.0. Data falling in the middle range indicate a mixture of human and nonhuman pollution.

Table 2. Average colony forming units/100 ml for fecal coliforms, fecal streptococci, and average FC/FS ratios from each sampling station at J. Percy Priest Reservoir from 6 May to 5 August 1986.

Station	Area Name	Average Fecal Coliform (CFU/100 ml)	Average Fecal Streptococci (CFU/100 ml)	Average FC/FS
1	Poole Knobs	9.48	123.53	0.07
2	Four Corners	13.77	274.77	0.05
3	Anderson Road	17.37	303.50	0.06
4	Metro Hamilton Creek	41.13	313.88	0.13
5	Hermitage Landing	14.38	217.50	0.06
6	Seven Points	35.67	324.21	0.11
7	Long Hunter	20.06	257.34	0.08
	GRAND AVERAGE	21.69	259.34	0.08

Studies by Kenner et al. (1960) and Rogers and Sarles (1964) indicate that fecal streptococci are present in greater numbers than coliform bacteria in the feces of animals. In human feces fecal coliforms are found in greater numbers than fecal streptococci. Because fecal material is a waste product, the density of fecal coliform organisms in receiving waters has become the most widely accepted measure of fecal pollution (Pipes 1982). These facts, along with the known ratios of the FC/FS, help to better interpret the results of this study. A contributor to the fecal streptococcus counts was the goose and duck populations at the reservoir. The goose population at the reservoir is composed mostly of Canada geese, *Branta canadensis* ssp. *maxima*, and has a summer population estimated at greater than 250 (Tennessee Wildlife Resource Agency 1986). The geese were observed at all stations on the lake at least once during the summer study period. The highest goose population was observed at the Anderson Road station, and the lowest goose population was observed at Bryants Grove station. There does not appear to be a direct correlation between the number of geese observed and the FC/FS ratio. Station two, Four Corners, only had 35 geese observed but had an overall FC/FS ratio of 0.05 station three, Anderson Road, had 197 geese observed and a FC/FS ratio of 0.06.

The Environmental Protection Agency and the State of Tennessee Water Quality Control Board, which is an agency in the Department of Health and Environment, recognize the fecal coliform counts as the criterion for recreational waters. Neither of these agencies recognize fecal streptococci counts as criteria nor do they have any guidelines as to limits of counts. The Tennessee Water Quality Control Board (1983) has set the following standards: the concentration of a fecal coliform group shall not exceed 200 per 100 ml sample as geometric mean based on a minimum of 10 samples collected from a given sampling area over a period of not more than 30 consecutive days with samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 1,000 per 100 ml. The Environmental Protection Agency (1978) has recommended a standard for body contact in recreational water as that of a fecal coliform geometric mean density of less than 200 per 100 ml. A count that exceeds this standard indicates that the water is polluted and is not suitable for swimming or any other type of body contact.

At no time during the study period did the fecal coliform counts exceed the limits set by the EPA or the State of Tennessee Department of Health and Environment. Because fecal streptococci are not recognized as an official indicator, there are no established limits for their colony counts. The fecal streptococcus counts did exceed 1000 CFU/100 ml on eight occasions. This would be unacceptable under the fecal coliform guidelines.

Poole Knobs had the lowest fecal coliform average (9.48 CFU/100 ml) and the lowest fecal streptococcal average (123.53 CFU/100 ml) (Table 2). The highest fecal coliform average was recorded at Metro Hamilton Creek (41.13 CFU/100 ml), and the highest fecal streptococcal average was recorded at Seven Points (324.21 CFU/100 ml) (Table 2).

The data were analyzed using a one-way analysis of variance (Table 3 and Table 4). There was no significant difference in the fecal coliform counts at any of the stations.

There was no significant difference in the fecal streptococcus averages between any of the stations. There was a significant difference ($p<0.01$) when all fecal coliform samples were compared to all fecal streptococcus samples.

Data were collected on several environmental parameters: water temperature, pH, depth at time of sample, and specific conductance (Table 5). Station six, Seven Points, had the highest mean temperature (28.38°C), the highest maximum temperature (33.5°C), the highest mean pH (7.99), the highest mean specific conductance (180

Table 3. Analysis of variance table for fecal coliform counts.*

Source of Variance	df	SS	MS	F
Between Stations	6	14.244	2.3741	1.6869**
Within Stations	189	265.986	1.4073	
Total	195	280.230		

*The data were transformed using the natural log of (y+1).
**Table value of F at p = .10 (6,189 df) = 2.14.
df=degrees of freedom
SS=sum of squares
MS=mean square
F=between MS/within MS

Table 4. Analysis of variance table for fecal streptococcus counts.*

Source of Variance	df	SS	MS	F
Between Stations	6	21.67	3.6117	1.3609**
Within Stations	175	464.4	2.6537	
Total	181	486.07		

*The data were transformed using the natural log of (y+1).
**Table value of F at p = .10 (6,175df) = 2.15.
df=degrees of freedom
SS=sum of squares
MS=mean square
F=between MS/within MS

umhos cm-1), and the highest average CFU/100 ml (324.21) for fecal streptococci. Station seven also had a mean specific conductance of 180 umhos cm-1. However, station six did not have the highest fecal coliform average. Instead station four, Metro Hamilton Creek, had the highest average CFU/100 (41.13) for fecal coliforms. Station one, Poole Knobs, had the highest maximum specific conductance (290 umhos cm-1). Stations four and five had the lowest minimum specific conductance (80 umhos cm-1).

The data in this study indicate no significant hazard to body contact with the water at the seven stations and that the majority of the time (85.7%) the fecal contamination present was of a nonhuman origin; rarely (1.1%) did it appear to be of human origin. This study also indicates that the reservoir, during the study period, was "safe" for body

Table 5. Physical parameters for seven stations on J. Percy Priest Reservoir from 6 May to 5 August 1986.

	Water Temperature °C	Water Temperature °F	pH	Specific Conductance mhos cm^{-1} at 25°C	Water Depth cm
Station 1					
minimum	19.50	67.10	7.58	120	30.00
mean	26.55	79.80	7.92	170	34.60
maximum	31.10	87.98	8.25	290	44.50
Station 2					
minimum	19.10	66.38	7.72	110	19.00
mean	26.54	79.77	7.95	160	27.40
maximum	30.70	87.26	8.20	200	41/00
Station 3					
minimum	20.10	68.18	7.62	80	27.00
mean	27.03	80.65	7.96	160	34.41
maximum	31.10	87.98	8.24	250	39.30
Station 4					
minimum	20.70	69.26	7.64	140	19.00
mean	27.25	81.05	7.96	170	29.82
maximum	31.50	88.70	8.27	210	41.50
Station 5					
minimum	20.50	68.90	7.69	80	35.50
mean	27.42	81.36	7.98	150	40.17
maximum	32.20	89.96	8.24	230	46.00
Station 6					
minimum	21.00	69.80	7.71	120	21.00
mean	28.38	83.08	7.99	180	28.38
maximum	33.50	92.30	8.23	240	33.50
Station 7					
minimum	20.30	68.54	7.62	150	23.00
mean	28.30	82.94	7.98	180	29.85
maximum	32.50	90.14	8.18	200	32.30
Overall					
minimum	19.10	66.38	7.58	80	19.00
mean	27.22	80.99	7.96	170	32.09
maximum	33.50	92.30	8.27	290	46.00

contact according to the pollution indicator organism standards; but from the results obtained it can be seen that fecal streptococci should also be recognized as a pollution indicator organism in the guidelines for recreational waters.

LITERATURE CITED

American Public Health Association, American Water Works Association and Water Pollution Control Federation. 1985. Standard methods for the examination of water and waste water. 16th ed. Washington.

Brock, T.D., Smith, D.W., and M.T. Madigan. 1984. Biology of microorganisms. 4th ed. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Cooper, K.E., and F.M. Ramadan. 1955. Studies in the differentiation between human and animal pollution by means of fecal streptococci. Gen. Microbiol. 12:180-189.

Dufour, A.P. 1977. *Escherichia coli:* the fecal coliform. In: Bacterial indicators of pollution. Pipes, W.O., editor. Philadelphia. 33-36.

Environmental Protection Agency. 1978. Microbiological methods for monitoring the environment. Environmental Monitoring and Support Laboratory Office of Research and Development. EPA 600/8-78-017. U.S. Environmental Protection Agency. Cincinnati.

Geldreich, E.E., Clark, H.F., and C.B. Huff. 1964. A study of pollution indicators in a waste stabilization pond. Water Pollution Control Federation. 36:1372-1379.

Geldreich, E.E. 1965. Detection and significance of fecal coliform bacteria in stream pollution studies. Water Pollution Control Federation. 37(12):1722-1726.

Geldreich, E.E. 1967. Fecal coliform concepts in stream pollution. Water and Sewage Works. 114:R-98, 107-110.

Geldreich, E.E., and B.A. Kenner. 1969. Concepts of fecal strreptococci in stream pollution. Water Pollution Control Federation. 41(8)2:R336-352.

Graham, R.D. 1979. A survey of the benthic macroinvertebrates of J. Percy Priest Reservoir. M.S. Thesis, Middle Tennessee State University. 5,7. (Figure 1).

Hussong, D., J.M. Damars, R.J. Limpert, W.J.L. Sladen, R.M. Weiner, and R.R. Colwell. 1979. Microbial impact of canada geese *Branta canadensis* and whistling swans *Cygnus columbianus columbianus* on aquatic exosystems. Appl. and Environ. Microbiol. 37:14-20.

Kenner, B.A., H.F. Clark, and P.W. Kabler. 1960. Fecal streptococci II. Quantification of streptococci in feces. Amer. Pub. Health. 50:1553-1559.

Mechalas, B.J., K.K. Kekiman, L.A. Schinazi, and R.H. Dudley. 1972. An investigation into recreational water quality. Water Quality Criteria Data Book. Washington, D.C., U.S. Government Printing Office. 95-108.

Mitchell, D.O. and M.J. Starzyk. 1975. Survival of salmonella and other indicator microorganisms. Can. Microbiol. 21(9):1420-1421.

Moore, E.C., Chief, Engineering Division. December 1986. (Correspondence from U.S. Army Corps of Engineers, Hydrology Branch).

Olivieri, V.P. 1982. Bacterial indicators of pollution. Pipes, W.O., editor. Bacterial indicators of Pollution. Boca Raton, FL: CRC Press, Inc. 21-39.

Pipes, W.O. editor. 1982. Bacterial indicators of pollution. Boca Raton, FL: CRC Press, Inc.

Rogers, C., and W.B. Sarles. 1964. Isolation and identification of enterocci from the intestinal tract of the rat. *J. Bacteriol.* 88:965.

Tennessee Water Quality Control Board, Department of Health and Environment. 1983. Tennessee water quality criteria and stream use classification for interstate and intrastate streams. Nashville, TN.

Tennessee Wildlife Resources Agency. December 1986. Personal conversation with the game management office. Nashville, TN.

United States Army Corps of Engineers. 1977. J. Percy Priest dam and reservoir. U.S. Army Corps of Engineers Nashville District. Brochure.