# THE IMPORTANCE OF INTENSE TREND BACTERIOLOGICAL MONITORING FOR EVALUATING A RECREATIONAL WATER QUALITY ENHANCEMENT PROGRAM

**William R. Cox*, Michael D. Wright and Gary D. Woodruff**

Water Quality Control Section and Office of Planning and Research, Tulsa City-County Health Department, Tulsa, Oklahoma 74112

**Trend monitoring of fecal coliform and fecal streptococcus bacteria was conducted at nine stations in the Arkansas River through Tulsa from 1975 through 1980. Fecal coliform values violated Oklahoma Water Quality Standards only in the urbanized segment of the river. These values were significantly greater ($0.025<p<0.010$) near storm drain and lift station outfalls as compared to other stations. Fecal coliform to fecal streptococci ratios indicated violations were caused by raw sewage. Fecal coliform geometric means decreased from 11,384 colonies/100 m*l* in 1975 to 506 colonies/100 m*l* in 1980. This reduction is believed due to abatement of illegal discharges and repair of broken sewer lines in storm drains.**

## INTRODUCTION

Historically the Arkansas River near Tulsa, Oklahoma, has received wastewater from industrial and municipal sources. This has resulted in water quality degradation and has limited recreational use. Oklahoma Water Quality Standards (1, p. 19) list secondary recreation such as boating and fishing as a beneficial use along with five other beneficial uses. Recreational activity on the river has increased steadily despite warnings from health officials that the river is polluted. Boating is an annual event on Labor Day during the Great Raft Race and fishing is seasonally heavy. A low-water dam is proposed to complete the River Parks development in Tulsa.

Trend monitoring of fecal coliform and fecal streptococcus bacteria was conducted from 1975-1980 on the Arkansas River. The purpose of this study was to determine if bacterial concentrations meet water quality standards for secondary contact recreation, the locations of greatest bacterial concentrations, the cause of those high concentrations, and the effects of pollution control programs in reducing bacterial concentrations.

Fecal coliform bacteria are good indicators of polluted water since their presence usually warns of potential health hazards. Although harmless to man, fecal coliforms are associated with pathogenic organisms that may cause such diseases as hepatitis A, typhoid, paratyphoid, and gastric enteritis. Oklahoma standards for water for secondary contact recreation provide a maximum monthly geometric mean of 1,000 fecal coliform colonies/100 m*l* (1, pg. 5). The fecal coliform to fecal streptococcus (FC/FS) ratio is a good test for determining the origin of the bacteria (2). A FC/FS ratio of less than or equal to 7:10 indicates the origin of waste to be from animals other than human. A ratio greater than or equal to 4:1 indicates the origin to be human waste. Intermediate ratios show a mixture of animal and human waste.

## STUDY AREA AND METHODS

A 48-mile segment of the Arkansas River was sampled at nine stations from Keystone Dam to State Highway 72 south of Coweta, Oklahoma (Figure 1). In-stream stations were divided into three cross-sectional substations designated A, B, and C. These substation designations indicate horizontal sample collection points located one quarter, one half and three quarters, respectively, of the total channel width from the right descending bank.

Samples for bacteriological examination were taken just below the water surface with properly sterilized 500-m*l* glass containers. Samples were immediately placed on crushed ice to chill to 4 C. All samples

*Present address: Williams Brothers Engineering Co., Resource Sciences Center, 6600 S. Yale Ave., Tulsa, OK 74177

Proc. Okla. Acad. Sci. 61:58-61 (1981)

were delivered to the Tulsa City-County Health Department Laboratory for analysis where tests were performed within six hours from the time each sample was collected. Fecal coliform and streptococcus concentrations were determined by membrane filter procedures outlined in *Standard Methods for the Examination of Water and Wastewater* (3).

A monthly geometric mean of fecal coliform concentrations was determined for each substation on five samples collected within a 30-day period as required by Oklahoma Water Quality Standards (1, p. 5). Statistical comparisons of geometric means for determining differences between substations were conducted using the Newman-Keuls multiple range test. Fecal coliform to fecal streptococcus ratios were determined by dividing fecal streptococcus densities into fecal coliform densities for each sample. Power function regressions of the form $y = ax^b$ were performed on data from stations three, four and five. Geometric means for each substation were used as dependent variables (y) with time in months as independent variables (x). Time was ordered in consecutively numbered months from August, 1975 through August, 1980, resulting in a range of numbers for the months in the study period from eight through 68.

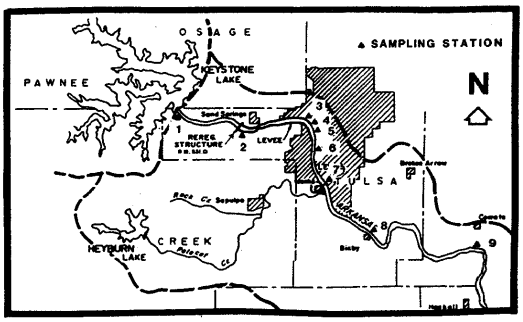


FIGURE 1. Fecal coliform and fecal streptococci sampling stations on the Arkansas river from 1975 through 1980.

## RESULTS

Concentrations of the fecal coliform group were low above and below Tulsa. Geometric means expressed in colonies/100 m*l* ranged from 2 to 96 in stream stretches above and below Tulsa and 40 to 11,384 in the Tulsa reach of the stream. Fecal coliform concentrations in the urbanized Tulsa segment of the stream exceeded Oklahoma Water Quality Standards from 1975-1979 by factors ranging from 11.4 to 1.4. The highest concentrations were found in cross-section C along the river bank with the greatest number of storm drain and lift station outfalls (Table 1 and Figure 2). Ratios of fecal coliform to fecal streptococcus for the Tulsa section of the river exceeded ratios of 4:1. These high ratios suggest the origin of bacteria to be from human and not other warm-blooded animal sources. Samples taken at storm drain outfalls on the same dates as in-stream samples had geometric means of fecal coliform bacteria in the range of 200,000 to 400,000 colonies/100 m*l*. These data also indicate raw sewage to be the source of bacterial pollution. Ratios of coliform to fecal streptococcus from stream segments above and below Tulsa indicate a mixture of human and other animal wastes.

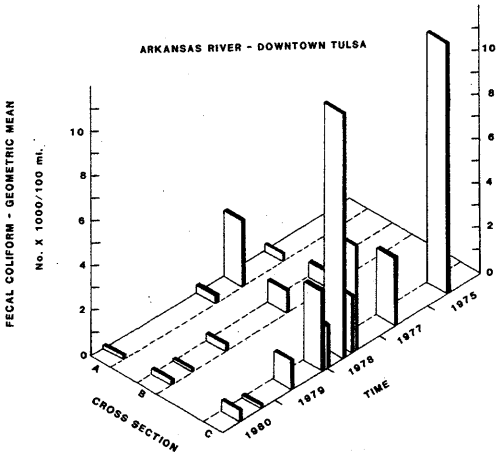


FIGURE 2. Fecal coliform bacteria geometric means for station three on the Arkansas river in urbanized Tulsa from 1975 through 1980, exclusive of 1976.

Fecal coliform geometric means were highest in the Tulsa segment in 1975 and declined in following years (Table 1, Figure 3). In-stream standards for secondary contact sports were met for the first time in the spring and summer of 1980 at substation C. Low fecal coliform geometric means of 40 colonies/100 m*l* and 506 colonies/100 m*l* were observed in April and August, 1980, respectively. These values

were significantly lower than past geometric means (Table 1).

## DISCUSSION

It was determined early in this study the high in-stream concentrations of fecal coliform in the urbanized Tulsa segment were primarily due to raw sewage. Personnel of the City of Tulsa Water and Sewer Department located open "T" joints in sanitary sewer lines where these lines cross major storm drains in the downtown area. The perpendicular leg of the "T" allowed direct overflow of sanitary sewage into storm sewers when sewer lines below the joints became plugged or were filled beyond their capacity owing to inflow and infiltration. Broken sewer lines within the storm drainage system caused similar problems. Malfunctioning and overflowing lift stations were noticed on many occasions during the study period. Corrections were made to all the above when discovered and contributed to reducing high fecal coliform levels. Another factor that helped keep bacterial concentrations low in August, 1980 was the unusually dry summer. This reduced raw sewage overflows from open "T's", broken sewer lines and faulty lift stations. Time of travel downstream from Tulsa accounted for the low concentration of the fecal coliform group due to bacterial die-off.

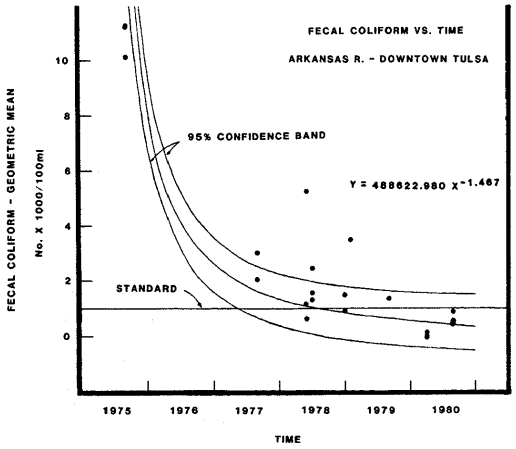


FIGURE 3. Power function regression for fecal coliform bacteria vs. time for stations three, four and five on the Arkansas river along urbanized Tulsa from 1975 through 1980.

TABLE 1. *Fecal coliform geometric means for the urbanized Tulsa reach of the Arkansas river from August, 1975 through August, 1980*

| Station | Date (month/year) | Fecal coliform geometric means (number of colonies/100 ml) Substations A | B | C |
|---|---|---|---|---|
| 3 | Aug/75 | * | * | 11,384 |
| | Aug/77 | 405 | 774 | 3,060 |
| | May/78 | * | * | 4,670 |
| | Jun/78 | 2,893 | 949 | 2,521 |
| | Aug/78 | * | * | 11,023 |
| | Dec/78 | 372 | * | 1,490 |
| | Jan/79 | * | * | 3,521 |
| | Aug/79 | * | 311 | 1,373 |
| | Mar/80 | * | 63 | 63 |
| | Aug/80 | 172 | 224 | 578 |
| 4 | Aug/75 | * | * | 10,078 |
| | May/78 | * | * | 674 |
| | Jun/78 | 611 | * | 1,347 |
| | Dec/78 | 627 | * | 922 |
| | Aug/79 | * | 575 | 964 |
| | Mar/80 | * | 98 | 70 |
| | Aug/80 | 150 | 172 | 506 |
| 5 | Aug/75 | * | * | 11,297 |
| | Aug/77 | * | 550 | 2,065 |
| | May/78 | * | * | 1,173 |
| | Jun/78 | 458 | 693 | 1,578 |
| | Dec/78 | 181 | * | 863 |
| | Aug/79 | * | 316 | 639 |
| | Mar/80 | * | 61 | 40 |
| | Aug/80 | * | 122 | 923 |

*Fewer than five observations per thirty-day period.

Unfortunately, channel catfish and carp are attracted to the outfalls in front of the major storm drains in Tulsa. Fecal coliform concentrations exceeding 20,000 colonies/100 m*l* directly in front of the storm drains pose a health hazard to fishermen. Despite warnings to the public of possible health hazards associated with the water adjacent to the storm drains, fishing and wading are prevalent during the summer. However, monitoring, maintenance and abatement efforts by the Tulsa City-County Health Department and the Tulsa Water and Sewer Department have reduced health risks for secondary contact sports significantly. It is doubtful the Tulsa segment of the river will ever be suitable for swimming.

Trend monitoring is important for identifying impacted stream segments and for measuring the effectiveness of pollution correction actions. Future trend monitoring of bacteriological quality of the Arkansas River through the urban Tulsa area will be especially important because of increasing emphasis on the recreational potential of this stream segment associated with the development of River Parks and the annual Great Raft Race.

## ACKNOWLEDGMENT

We thank Mr. Rick Hunter for reading and criticizing the manuscript.

## REFERENCES

1. ANONYMOUS, *Oklahoma Water Quality Standards 1979,* Oklahoma Water Resources Board, Oklahoma City, Oklahoma, 1979.
2. E. E. GELDREICH, FWPCA Publ. WP-20-3, 1966.
3. AMERICAN PUBLIC HEALTH ASSOCIATION, *Standard Methods for the Examination of Water and Waste Water,* 14th ed., APHA, New York, New York, 1976.