Proceedings of the Iowa Academy of Science

Volume 80 | Number Article 12

1973

The Fecal Coliform/Fecal Streptococcus Ratio as a Measure of Bacterial Contamination and Indicator of Its Source in the Des Moines River

Karen E. Messley

Phyllis J. Kingsbury
Drake University

The Fecal Coliform/Fecal Streptococcus Ratio as a Measure of Bacterial Contamination and Indicator of Its Source in the Des Moines River[1]

KAREN E. MESSLEY[2] and PHYLLIS J. KINGSBURY[3]

MESSLEY, KAREN E. and PHYLLIS J. KINGSBURY. The Fecal Coliform/Fecal Streptococcus Ratio as a Measure of Bacterial Contamination and Indicator of its Source in the Des Moines River. *Proc. Iowa Acad. Sci.* 80(2): 74-77, 1973.
SYNOPSIS: The fecal coliform/fecal streptococcus (FC/FS) ratio and total coliform test were used in attempts to determine the degree and source of bacterial contamination present in the Des Moines River between April 18 and November 14, 1970. There were no predictable changes in the FC/FS ratio as the river passed from a rural area, through a metropolitan district, and on to another rural area; however, the total coliform counts did show variation with distance. The failure of the FC/FS ratio to indicate source of contamination was probably due to the highly varying external conditions acting upon the river.
INDEX DESCRIPTORS: FC/FS Ratio, Total Coliforms, Fecal Coliforms, Fecal Streptococcus, Des Moines River.

One of the greatest problems of polluted water for man has been the spread of pathogenic bacteria. Total coliforms (TC) have been used as an indicator of possible fecal contamination of water. To separate those coliforms of fecal origin from the free-living forms, Eijkman developed the elevated temperature test for the enumeration of fecal coliforms (FC). Litsky et al. (1953, 1955) showed a positive correlation between the numbers of *E. coli* and enterococci when using an ethyl violet azide broth for enumeration of enterococci. Previously it was not possible to detect enterococci in significant numbers. Geldreich (1966) proposed that fecal streptococcus (FS) counts be used in addition to the TC and FC counts and that the FC/FS ratio be used to identify the source of bacterial contamination in water. He found a ratio less than 1.0 for feces of warm-blooded animals other than man and a ratio of approximately 4.0 for man. To determine the effectiveness of this ratio in a river, an area was chosen where the Des Moines River flows from a rural area, through a metropolitan district, and again into a rural area. The results should show the changes which occur in TC, FC, FS, and the FC/FS ratio as the river flows through different environmental areas. Seasonal variance might also be observed. Van Donsel et al. (1967) and Kittrell and Furfari (1963) have demonstrated varying survival rates for coliforms in both stormwater runoff and streams with varying temperatures.

MATERIALS AND METHODS

Five stations were selected on the Des Moines River to show the changes in bacterial populations. Station 1, located six miles north of the Des Moines city limits, would presumably show rural conditions. Station 2 was located in downtown Des Moines, just above the confluence with the Raccoon River. Major changes at this location should be due to urban runoff. The third station was located 0.8 miles downstream from the entrance of the Raccoon River and should also indicate changes produced by an urban area. Station 4 was chosen to show the influence of recent addition of domestic wastes and was located 0.6 miles downstream from the entrance of the Des Moines sewage treatment plant. The fifth station was approximately 17 miles downstream from station 4 and should show changes downstream following the river's recovery from the addition of human sewage and its exposure to rural runoff. (Figure 1)

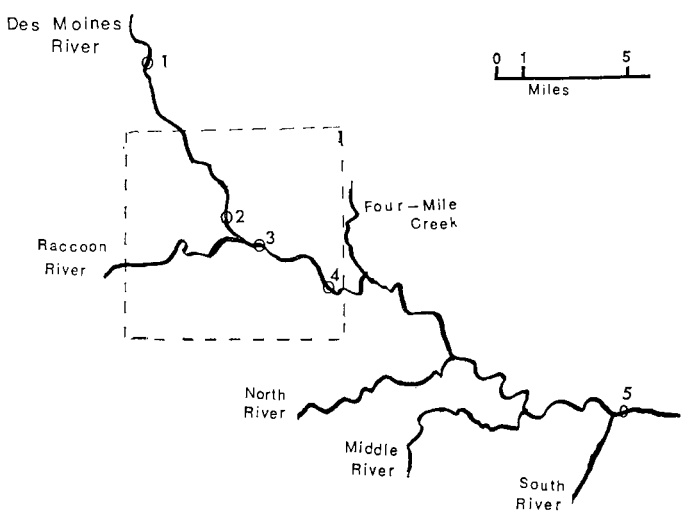

Figure 1. Sampling sites along the Des Moines River.

Samples were collected fortnightly from April 18 to November 14, 1970. Mid-stream samples were taken by lowering a 1200 ml Kemmerer sampler just under the water sur-

[1] Contribution No. 38, Department of Biology, Drake University, Des Moines, Iowa.
[2] 155 Carousel, San Antonio, Texas 78227.
[3] Department of Biology, Drake University, Des Moines, Iowa 50311.

face. Samples were normally collected between 10 AM and 2 PM, beginning at station 1. The water was transferred into sterile containers and transported to the laboratory. Serial dilutions were made as described in Standard Methods (A. P. H. A., 1965). TC counts were determined using 10^{-2} and 10^{-3} dilutions. The water samples were processed by the Millipore filter technique and plated in disposable 47 mm petri plates containing 2 ml M-Endo (Difco) broth on absorbent pads. The plates were put in Whirl Pak waterproof bags and inverted in a 37°C water bath for 24 hours. FC counts were determined with 10^{0} and 10^{-1} dilutions by plating on a 2 ml M-FC (Difco) broth in the same manner as above. Incubation was at 45°C for 24 hours. The FS dilutions of 10^{0} and 10^{-1} were plated on KF-Streptococcus (Difco) agar and incubated at 37°C for 48 hours.

Three diurnal studies were conducted at station 4 on June 26-27, October 2-3 and October 30-31 to determine changes in bacterial counts occurring over a 24-hour period. Samples were collected at 2 hour intervals from 10 PM to 8 PM and processed in the same manner as all other samples.

Results

The total coliform counts for the five stations ranged from less than 1 X 10^4/100 ml to greater than 9 X 10^7/100 ml (all bacterial counts are reported as number per 100 ml). Fecal coliforms ranged from less than 1 X 10^2 to 6.7 X 10^4 and fecal streptococcus from less than 1 X 10^2 to 8 X 10^4 (Messley, 1971). The mean counts for the five stations showed higher TC values at station 4, but those for FC and FS were highest at station 5 (Table 1).

TABLE 1. Mean Bacterial Counts (Number/100 ml) for Each Station for the Period April 18 - November 14, 1970; TC = Total Coliform; FC = Fecal Coliform; and FS = Fecal Streptococcus

Site	*TC*	*FC*	*FS*
1	4.5 X 10^6	6.2 X 10^3	2.4 X 10^3
2	2.4 X 10^6	7.9 X 10^3	2.6 X 10^3
3	2.2 X 10^6	6.6 X 10^3	4.3 X 10^3
4	14.0 X 10^6	8.3 X 10^3	4.3 X 10^3
5	2.7 X 10^6	18.0 X 10^3	8.1 X 10^3

Seasonal variation was observed at all but station 4. Higher TC, FC and FS counts appeared between June 13 and September 5. Numbers decreased in October and November except on October 17, when TC and FC counts increased at all except station 4. Station 4 showed little seasonal fluctuation with all three counts (Figure 2).

The fecal coliform/fecal streptococcus (FC/FS) ratio was determined for each sample. This ratio was often lower at station 4 than at the other stations, with the exception of the summer months. This can be seen in the mean ratios (Table 2).

TABLE 2. Fecal Coliform/Fecal Streptococcus Ratios for Five Stations on the Des Moines River, 1970

	1	2	3	4	5
4/18	——	23.30	6.90	1.90	3.33
5/2	61.00	9.00	4.00	2.97	20.50
5/17	0.31	0.50	0.69	0.52	0.67
5/30	——	>65.00	<0.18	23.30	50.00
6/13	4.25	3.25	1.71	1.09	5.68
6/27	——	——	<0.17	6.57	38.40
7/11	>1.00	<0.15	1.27	9.23	1.00
7/25	34.10	4.50	62.00	31.00	>7.00
8/8	1.68	6.67	2.97	3.33	1.19
9/5	<1.00	<1.00	2.50	7.00	——
9/19	0.40	0.14	0.33	12.20	5.71
10/3	1.00	>19.00	6.00	52.50	>30.00
10/17	>250.00	75.00	150.00	4.80	90.00
10/31	<1.00	——	7.00	0.54	3.17
11/14	15.00	1.50	5.00	4.17	7.00
MEAN	35.06	16.08	16.71	10.74	18.83

The three diurnal studies at station 4 showed periods of peak counts between 12 and 2 AM and 6 and 8 PM (Messley, 1971). Only during these high count periods were FC numbers greater than FS. Figure 2 shows a representative example of the diurnal variations.

Discussion

The total coliform (TC) results showed variation with distance. Mean counts for the five stations showed a gradual decrease from station 1 to 3, a sharp rise at 4, and a decrease again at 5. This would indicate a death rate greater than the rate of introduction and/or multiplication between stations 1 and 3. The sharp rise at station 4 might be indicative of the introduction of large numbers of organisms or the multiplication from stations 3 to 4. Once again in the samples below station 4, the mortality rate surpasses that of introduction and multiplication. Seasonal variation could also be seen with highest TC counts at station 5 during the spring months, where the highest values had been at station 4 during the other months. This might be due to the longer survival rates but decreased multiplication rate of coliforms in cold water; or it might be due to variation in the ability of the river to carry its load of sediment. In low water with slower velocity, many bacteria will precipitate out with the sediment (Streeter, 1934).

FC and FS appeared to follow identical seasonal trends. During spring and summer, the highest mean counts were at station 5, while the greatest mean value during the fall was at station 4. The lower counts at station 5 in the fall could be due to either decreased introduction of these organisms by direct runoff and tributaries between stations 4 and 5, or decreased survival rates based on water temperature or increased sedimentation rates.

The FC/FS ratio was calculated for all samples in an attempt to determine the source of bacterial contamination. Ideally, one would be able to see an increase in the ratio as the river passed through Des Moines with a subsequent drop following passage into another rural area and a 24-hour recovery period. This pattern was observed on July 11, Sep-

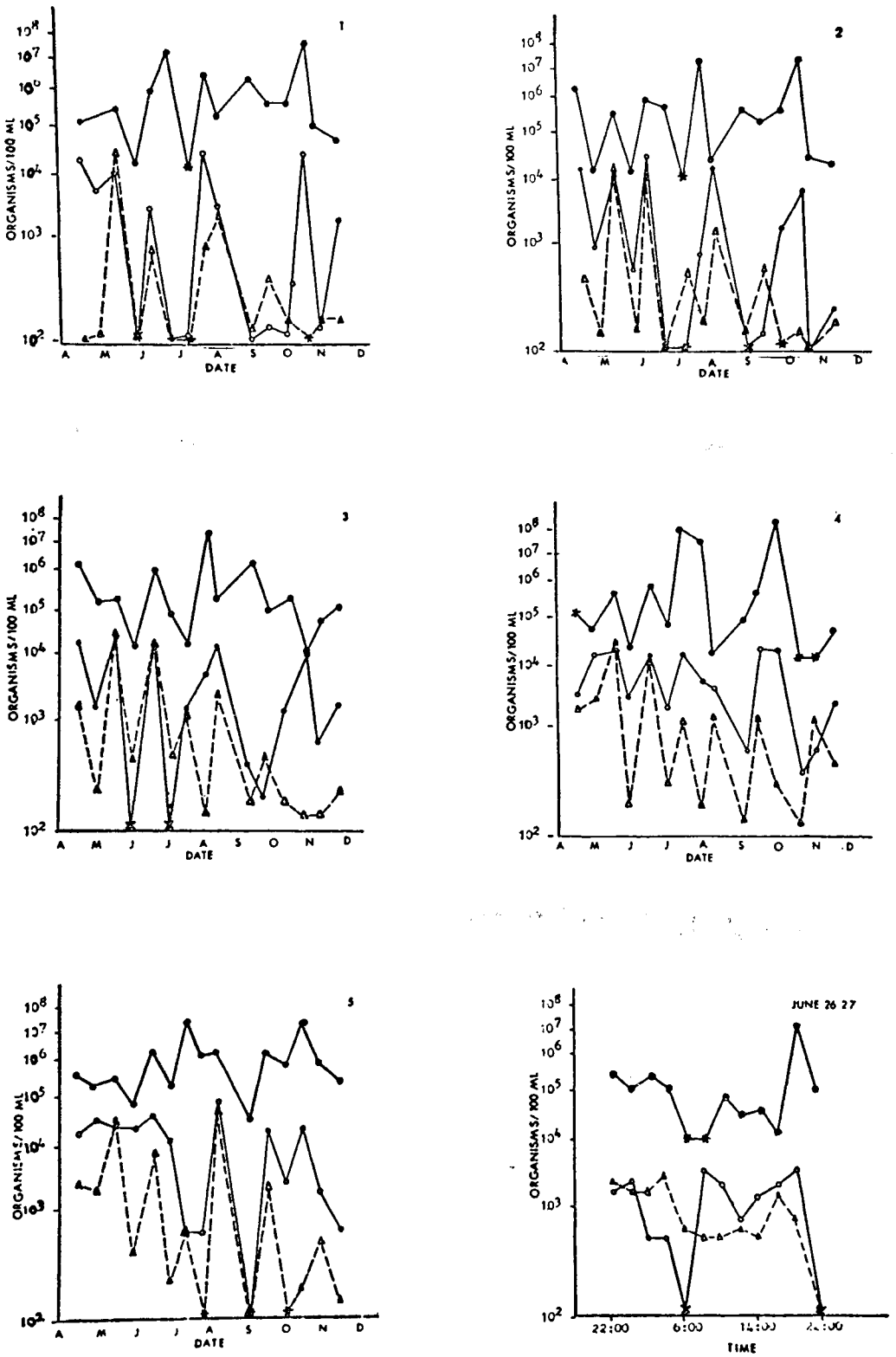

Figure 2. Results for the five sampling sites from April 18 to November 14, 1970, and for diurnal study at station 4 on June 26-27, 1970. • = total coliforms; o = fecal coliforms; Δ = fecal streptococci; and * = no definite value obtainable.

tember 5, September 11, and October 3, 1970; however, on other dates the ratios followed highly unpredictable patterns. It appears that these ratios are not applicable in all field situations because of the widely varying conditions. It is possible that station 1 was not indicative of a truly rural area. It appears that the ratio increased mainly in response to a more rapid die-off or settling out rate for FS than for FC.

Changes in TC's occurred diurnally at station 4. The FC and FS did not appear to vary in the same manner as the TC. This can be partially accounted for by changes in the volume and content of the sewage effluent at different times of day.

The FC/FS ratio was not found in this study to be an adequate measure of bacterial contamination or an indicator of its source due to the widely varying conditions which affect a water system. The TC determinations would appear to continue to be the most valid indicator of bacterial contamination of a body of water, however, FC and FS determinations contribute to the overall picture of the condition of a body of water.

Literature Cited

American Public Health Association. 1965. *Standard methods for the examination of water and sewage*, 12th ed. American Public Health Assoc., New York, N.Y. 769 pp.

Geldreich, E. E. 1966. Sanitary significance of fecal coliforms in the environment. U.S. Dept. of the Int., Fed. Water Pollut. Control Admin., Water Pollut. Control Res. Ser. Publ. WP-20-3, 122 pp.

Kittrell, F. W., and S. A. Furfari. 1963. Observations of coliform bacteria in streams. *J. Water Pollut. Control Fed.* 35:1361-1385.

Litsky, W., M. J. Rosenbaum, and R. L. France. 1953. A comparison of the most probable numbers of coliform bacteria and enterococci in raw sewage. *Appl. Microbiol.* 1:247-250.

Litsky, W., W. L. Mallmann and C. W. Fifield. 1955. Comparison of the most probable numbers of *Escherichia coli* and enterococci in river waters. *Am. J. Public Health,* 45:1049-1053.

Messley, K. E. 1971. The fecal coliform/fecal streptococci ratio as a measure of bacterial contamination and indicator of its source in the Des Moines River. Unpublished M.A. Thesis. Drake University, Des Moines, Iowa. 45 pp.

Streeter, H. W. 1934. A formulation of bacterial changes occurring in polluted water. *Sewage Wks. J.* 6:208. Cited by: Kittrell, F. W. and Furfari, S. A. 1963. Observations of coliform bacteria in streams. *J. Water Poll. Control Fed.* 35:1361-1385.

Van Donsel, D. J., E. E. Geldreich, and N. A. Clarke. 1967. Seasonal variations in survival of indicator bacteria in soil and their contribution to storm-water pollution. *Appl. Microbiol.* 15:1362-1370.