VARIATION IN THE DENSITY OF POLLUTION INDICATOR BACTERIA IN THE COTTONWOOD RIVER AS RELATED TO FEEDLOT RUNOFF

A Thesis

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Until recently the disposal of livestock wastes has been of little concern to the Kansas rancher since the wastes were dispersed as the animal grazed on open pastures. However, recent trends in feeding procedures have resulted in the concentration of large numbers of animals in relatively small spaces of commercial feedlots. Over the past decade the number of livestock confined in feedlots in Kansas has increased from 30,000 in 1956 to 468,000 in 1967. Naturally, there are certain inherent problems in mass livestock feeding operations, the primary one being adequate disposal of vast amounts of fecal wastes. For example, a feedlot with a capacity of 10,000 head of cattle yields fecal wastes equal to the wastes produced by a city of 100,000 people (Loehr and Agnew, 1967). Such large quantities of wastes, if untreated, can be expected to produce adverse effects on the surrounding environment.

Over the past ten years runoff from feedlots has become recognized as a major source of organic pollution for several Kansas rivers. In 1966 Kansas ranked second only to Pennsylvania in total number of fish killed by pollution in the United States (Lyon, 1967). However, authorities had little documentation to substantiate suspicions that the feedlots were responsible for some of the major fish kills in Kansas until the study of Smith and Miner (1963). They found that feedlot runoff was characterized by a

high biochemical oxygen demand, high ammonia content, and increased bacterial populations. They suggested that the runoff had a severe slugging effect on the receiving stream which resulted in depletion of dissolved oxygen in the stream, especially if the waste load were large.

Miner et al. (1966) utilized simulated rain showers on small experimental feedlots to predict quantitatively the degree of pollution produced by given sets of conditions and concluded that the quantity of organic waste flushed from a feedlot during rainfall was directly related to temperature, rainfall intensity, and the moisture content of the waste before rainfall. The runoff was characterized by dense populations of pollution indicator bacteria.

The primary objectives of this research were to determine the relationship between feedlot runoff and population density of indicator bacteria in the Cottonwood River in the vicinity of Emporia, Kansas, and to establish seasonal "norms" for bacterial density in the river.

DESCRIPTION OF STUDY AREA

The Cottonwood River originates in the grasslands of Marion County, Kansas, and flows eastward 137 river miles to its confluence with the Neosho River near Emporia. The Cottonwood River has a drainage area of 1.2 million acres which includes most of Marion, Chase, and Lyon counties (Schoewe, 1951). At its headwaters the gradient is approximately 10 feet per mile with a gradual decrease to an average of 2.5 feet per mile near its mouth in Lyon County (Kansas State Board of Agriculture, 1947). The confluence of the two rivers is approximately 7 miles east of Emporia.

There were several possible sources of fecal pollution along the study reach of the Cottonwood River. The Emporia cattle-feeding facilities have a combined capacity of 20,000 head of cattle. Runoff from these feedlots flows directly to the river in two small drainage ditches. In addition, the Fanestil Packing Plant occasionally discharges raw organic waste into the river and the Emporia city sewage disposal plant, consisting of both primary and secondary treatment, also discharges effluent to the river.

Sampling stations were established along a 13-mile reach of the Cottonwood River such that conditions in the river above and below the points at which drainage from the Emporia

feedlots entered the river could be monitored. The relative locations of the five river stations as well as the two drainage courses which transported feedlot runoff to the river are shown in Figure 1 and Table I.

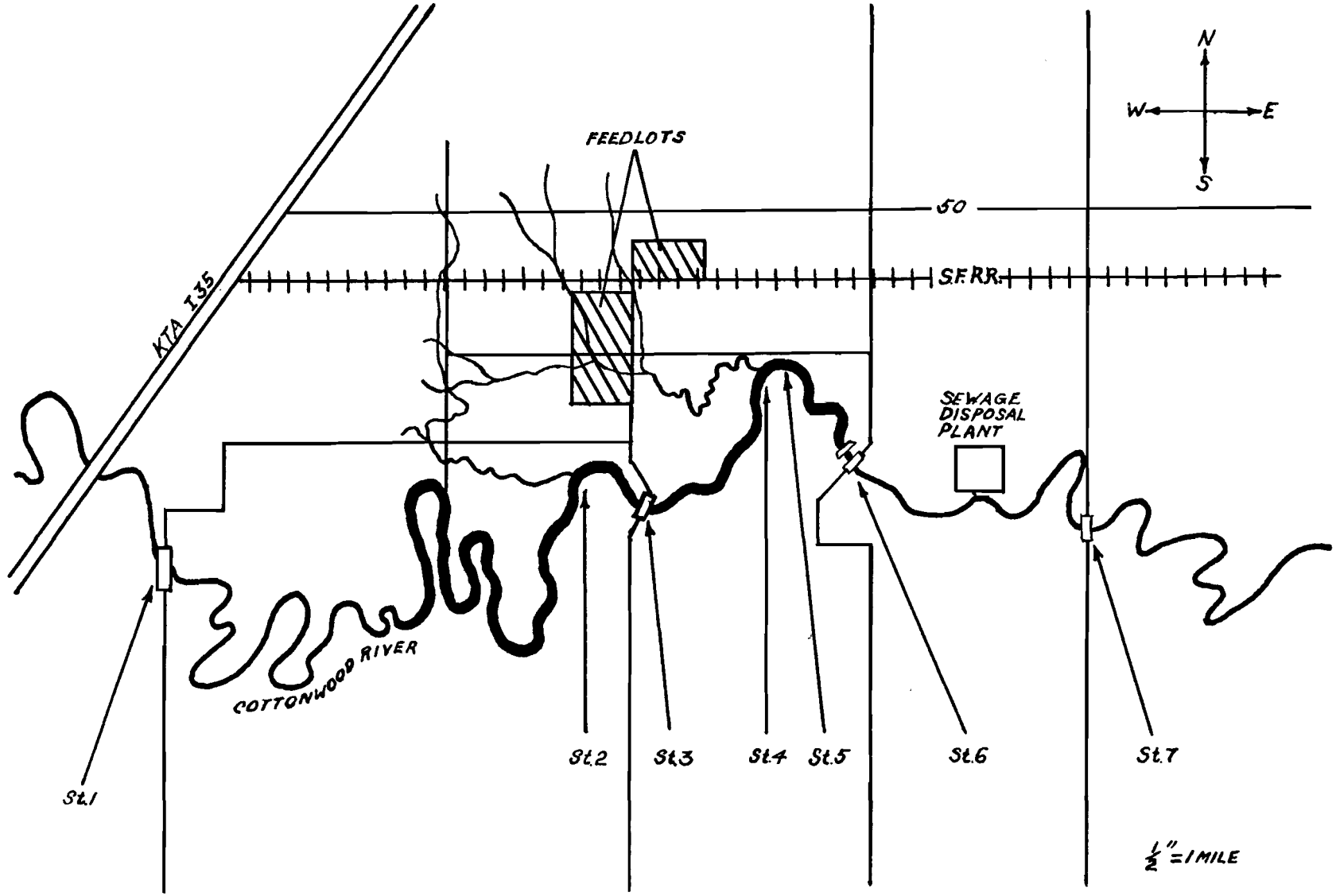


Figure 1 - Map of Cottonwood River in Emporia Area, Identifying Sample Station Location

TABLE I

LOCATION AND GENERAL DESCRIPTION OF SAMPLING STATIONS

Station	Station Objective	Station Location
I	Cottonwood River Station, Control, 25 miles below any other major source of fecal contamination	Lyon Co. (S24, T19S, R10E); 3 miles west and 1.2 miles south of Emporia at the County Road Bridge
II	Monitored Drainage Ditch from Feedlots	Lyon Co. (S18, 20; T19S; R11E); 1 mile west and 1 mile south of Emporia; 7.7 miles below Station I
III	Cottonwood River Station, Monitored effect of feedlot drainage ditch (Station II)	Lyon Co. (S21, T19S, R11E); 1.5 miles south of Emporia at the Poor Farm Bridge; 0.7 mile below Station II
IV	Monitored Major Feedlot Drainage Ditch	Lyon Co. (S16, T19S, R11E); 100 yards east of intersection of South Street and Prairie Avenue; 1.5 miles below Station III
V	Cottonwood River Station, Monitored effect of feedlot drainage on the river	Lyon Co. (S15, T19S, R11E); Directly behind Peter Pan Park; 0.2 mile below confluence of major feedlot drainage ditch
VI	Cottonwood River Station, Monitored effect of feedlot drainage as influenced by Soden's Dam	Lyon Co. Dam; intersection of Kansas Highway 99 and the Cottonwood River; 0.7 mile below Station V
VII	Cottonwood River Station, Monitored influence of city waste effluent	Lyon Co. (S23, T19S, R11E); Bridge 1 mile east of Emporia; 1.1 mile below Station VI; 0.5 mile below sewage plant effluent

METHODS AND MATERIALS

Rationale for Coliforms as Indicator Organisms

The presence of certain bacteria have been used for years to determine the sanitary quality of water courses. In 1885 Escherich (Clark and Kabler, 1964) described a bacillus he considered to be universally present in human feces. He postulated that the presence of these bacilli in water sources indicated the presence of human feces and should be considered dangerous because of the possible presence of other pathogenic bacteria found in the excretions of ill persons. This view was also shared by Smith (Clark and Kabler, 1964), who in 1895 stated that the presence of the coliform group must be considered as dangerous to health regardless of the environment in which they are detected. Nine years later Eijkman (Clark and Kabler, 1964) offered a new theory: all coliform bacteria are not of fecal origin. He recommended an elevated-temperature incubation test that gave a positive reaction with fecal coliform organisms and a negative reaction with those of non-fecal origin (Clark and Kabler, 1964). However, the Eijkman Test has been rejected by most investigators as the only criteria indicating fecal contamination because of its lack of sensitivity and poor reproducibility.

Despite their disadvantages both the Escherich and Eijkman tests are used today and are described in Standard Methods (APHA, 1965), which defines the coliform group as

"all of the aerobic and facultative anaerobic, Gram-negative, non-spore-forming rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C." The fecal coliform group is considered as a subgroup of the coliform group and is defined as, "those organisms that ferment lactose with gas production within 24 hours at 44.5°C (±0.5) and are thus more inclusive than (++—) IMVIC Stain Escherichia Coli type 1 (26)." The non-fecal coliform group has been designated as the intermediate-aerogenese cloacae (IAC) subgroup. This group is frequently found associated with various types of vegetation and soil. Its classification is based on IMVIC test other than (++--).

A common procedure in stream pollution studies is to determine the numbers of a third bacterial indicator strain, the fecal streptococci (Standard Methods, APHA, 1965). These organisms are members of the enterococcus group which includes those streptococcal species that grow in brainheart infusion broth at 45°C and 10°C or at 45°C only. Excluded are those that grow at 10°C but fail to grow at 45°C. The fecal streptococci, like the coliform group, are normal inhabitants of animal feces. The fecal streptococci have an added advantage as a pollution indicator in that they exhibit a rapid die-out rate in soil and do not increase their numbers in water. The most important aspect of the sanitary significance of the fecal streptococci is the possibility of permitting a qualitative interpretation from the possible pollution source if identified from a sample of water (Slanetz and Bortley, 1964).

Tests for the presence of any of the fecal groups possess certain advantages which warrant their use as an indicator of fecal contamination, but none of them alone is sufficient to meet the criteria of an ideal pollution indicator. The Training Course Manual Recent Developments in Water Bacteriology (PHS, 1963) and Standard Methods (APHA, 1965) recommend tests be made for each of the three groups in water quality surveys.

Sampling Techniques

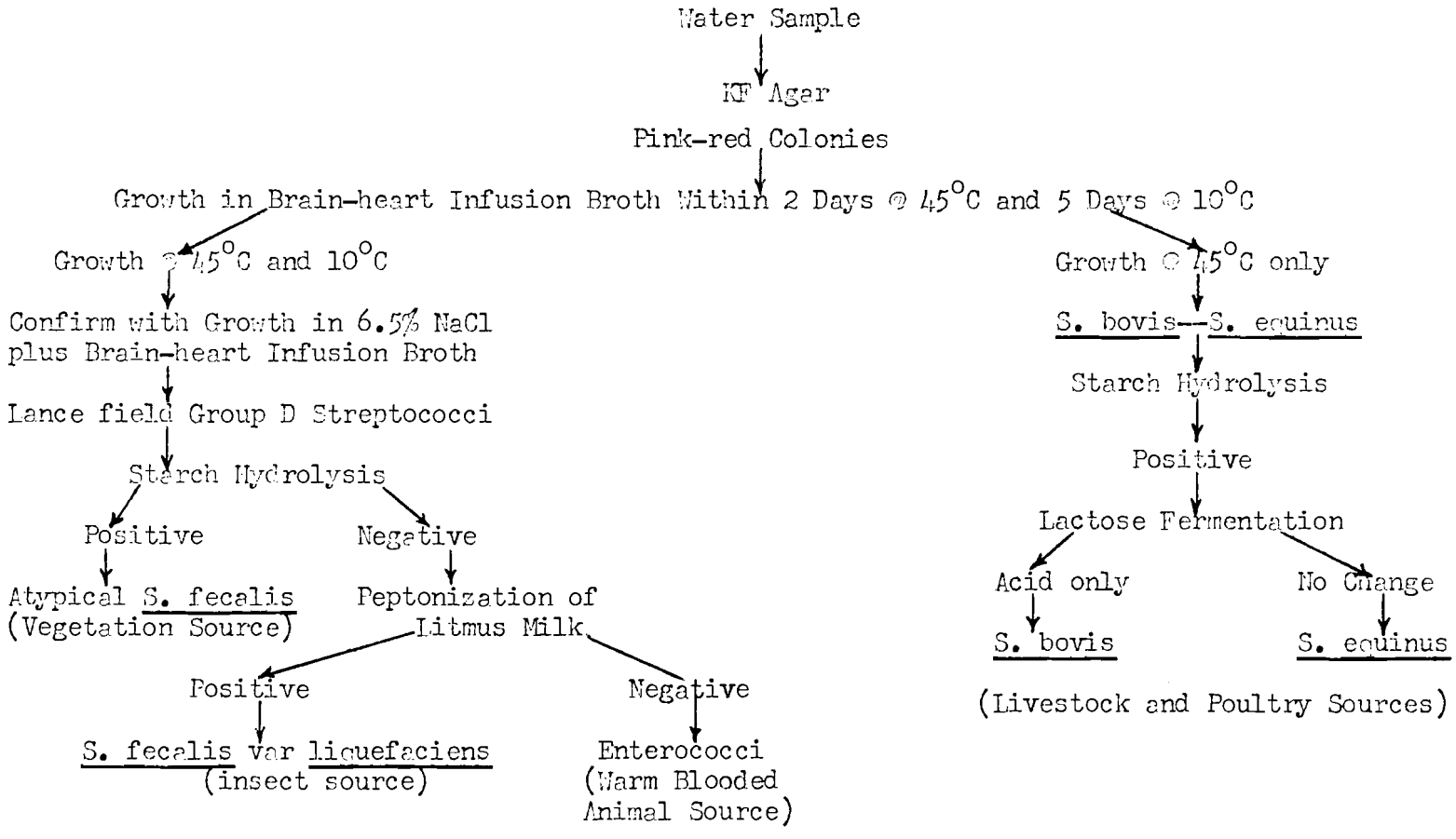
Observations of existing river conditions were conducted in two ways: (1) a periodic sampling procedure was used to survey the river for seasonal variation, and (2) a pre- and post-rainfall sampling method was utilized during periods of precipitation to monitor coliform densities prior to and immediately following surface runoff.

Sampling was initiated in May, 1967, and terminated in July, 1968. Samples were collected on 43 different occasions during this period. All water samples were taken from surface water by means of sterilized Whirl-Pak (Nasco) baggies and were returned to the laboratory and refrigerated at $4^{\circ}C$ until they were analyzed. Less than 18 hours elapsed from the time of collection until analysis was begun for any sample. Bacteriological species recorded at each station included total coliform bacteria, fecal coliform bacteria, and fecal streptococci bacteria.

Analytical Techniques

Bacterial populations were initially estimated by the most probable number (MPN) procedure as described in Standard Methods (APHA, 1965), but this procedure was time consuming and lacked reproducibility. The MPN procedure was replaced by the membrane filter procedure as discussed in Training Course Manual Recent Developments in Water Bacteriology (PHS, 1963). The membrane filter method has the advantage of being faster, more precise, and produces reproducible results.

Coliform counts were made using membrane filters, M-Endo medium, and incubation at 37°C for 24 hours. Differentiation of typical coliform type was made by counting the dark red colonies showing a gold metallic sheen. Fecal coliform counts were determined with the membrane filter procedure, M-F. C. medium, and incubation in a water bath at 44°C for 24 hours. On M-F. C. medium typical fecal coliform colonies are dark blue. A membrane filter procedure was also used to detect fecal streptococcus. M-Enterococcus agar was used for medium and the plates were incubated at 37°C for 48 hours. Enterococcus colonies are flat and light pink or smooth, raised, dark red colonies with a pink periphery (0.5-2 mm in diameter) on M-E agar. Identification of species of fecal streptococcus was initially done by the schema described in Figure 2. However, it was impractical for extensive use in a survey of this nature and was eliminated.



Adapted from Sanitary Significance of Fecal Coliforms in the Environment, U. S. Pub. WP-20-3 pp. 97.

Figure 2 - Schema for the Identification of the Species of Fecal Streptococcus

RESULTS AND DISCUSSION

By observation it was determined that a 0.5 inch rain shower was necessary to produce sufficient feedlot runoff to influence the river. This criterion was used to categorize sampling data into two groups. Non-runoff data indicated bacterial population densities in the watercourse during normal river flow conditions, and runoff data represented bacterial population densities during periods of runoff. A comparison of the two groups reveals the significance of feedlot runoff and its deleterious affects on the receiving watercourse.

Population Densities During Periods of No Runoff

The establishment of normal bacterial population densities for any river is theoretical and highly illusive. It is, however, advantageous to develop a baseline when attempting to monitor stream pollution from an isolated source. For this study the baseline was established from the average density of pollution indicator bacteria occurring during periods of no runoff, since at this time bacterial population fluxuation was least. Data falling into this category were derived from samples taken on nine different dates from January, 1968 to August, 1968. The results are presented in Table II and Figure 3, with individual sampling dates and data listed in the appendix.

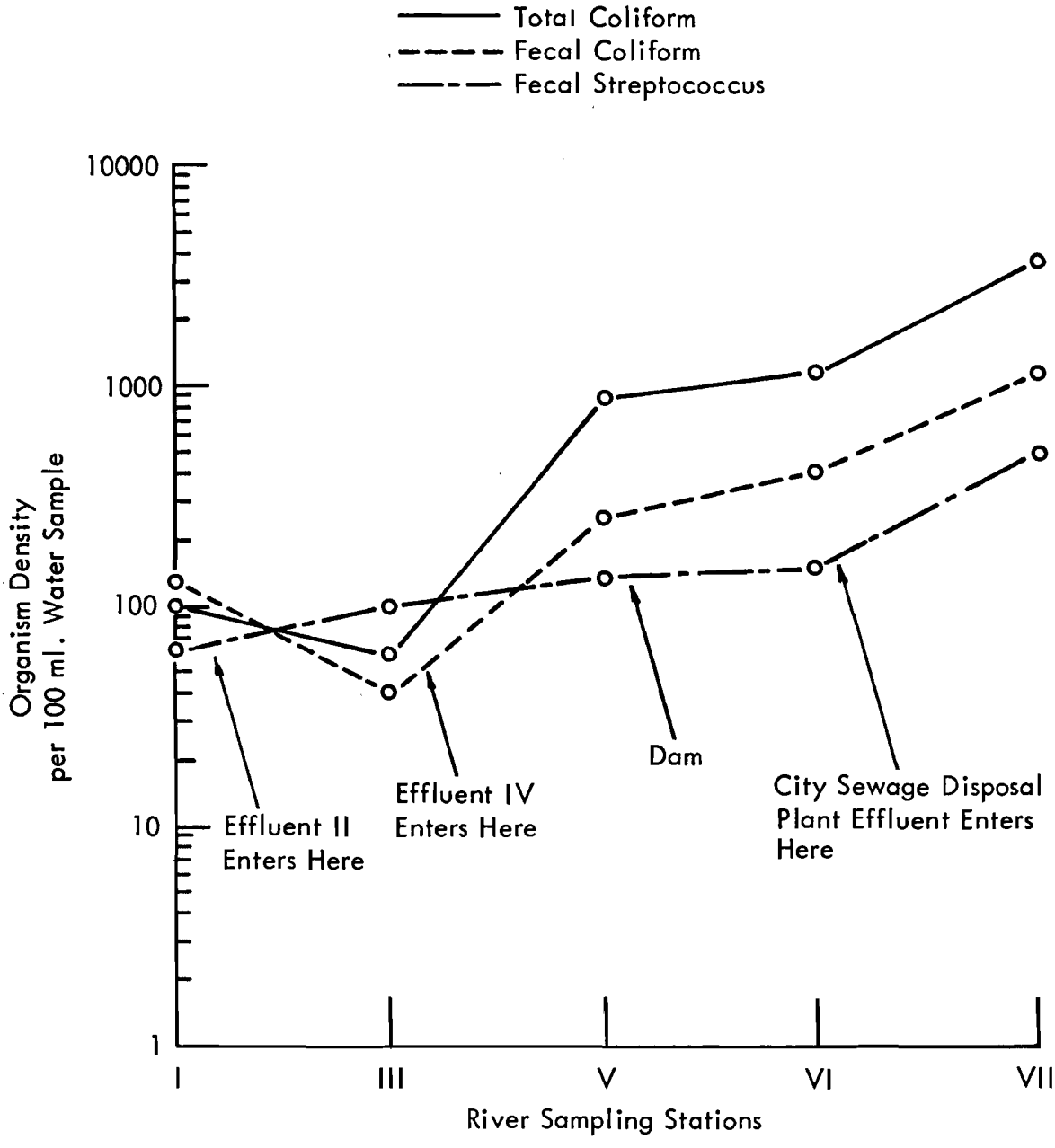


Figure 3 - Average Bacterial Populations During Periods of No Runoff

TABLE II

AVERAGE BACTERIAL POPULATIONS BY STATION
DURING PERIODS OF NO RUNOFF*

Sampling Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I—River	99	137	62
II—Drainage Ditch Effluent	1,856	2,848	296
III—River	60	40	104
IV—Drainage Ditch Effluent	2,827,746	1,892,733	460,798
V—River	906	263	142
VI—River	1,214	392	159
VII—River	3,734	1,198	491

*Individual data for specific sampling dates are contained in table form in the appendix.

Figure 3 shows all three bacterial indicators exhibiting similar density patterns throughout the study area. The average total coliform was generally highest followed by the fecal coliform and fecal streptococcus, respectively. Since the fecal coliform was considered to be the most significant indicator of recent fecal contamination of water (Geldrich, 1965), it is used in this discussion to demonstrate pollution conditions existing during sampling periods. As indicated by the data in Table II, there was a station-to-station increase in bacterial populations as the water moved through the study area. The upstream stations (Station I and Station III) exhibited nearly equal numbers of fecal bacteria, approximately 100 per 100 ml water sample. Bacterial densities at Station III were lower than those of Station I; however, the difference was small and predictable. In the absence of runoff there was little or no flow in the upper drainage ditch; therefore, population densities decreased due to dilution and bacterial die-off which probably occurred as a result of the depletion of essential nutrients. As the water mass moved downstream to Station V, the quality of the water was altered. The average number of fecal coliforms at Station V was approximately 6 times greater than that at Station III; that is, 263 org/100 ml and 40 org/100 ml respectively. This increase was attributed to the discharge from the lower drainage ditch (Station IV). Population increases at Stations VI and VII were probably due to continued growth as well as the continuous discharge from the city sewage treatment plant below Station VI.

It should be noted that the population densities reported above represented average densities for sampling dates when less than 0.5 inch of precipitation was received. Actually, there was considerable variation in densities from one date to the next. For example, fecal coliform density at the control station did not exceed 100 org/100 ml in 60 per cent of the samples and ranged from zero to 660 org/100 ml. With few exceptions, population densities were within acceptable limits for potable water prior to chlorination.

It would appear that during normal flow patterns contamination from the feedlots is minimal and that perhaps the greatest source of fecal bacteria in this area of the river was from the city sewage plant.

Conditions During Periods of Runoff

There were nine collecting dates from November, 1967 to August, 1968 which qualified as runoff periods, ie. rainfall was in excess of 0.5 inch. Data from the samples obtained during these periods are summarized in Table III and Figure 4.

The numbers of bacteria in runoff samples were high, with peak densities occurring at stations below major effluent sources. The normal runoff of the drainage area, represented by the control station, resulted in a 56 fold increase in bacterial indicator densities. Station I is approximately 25 miles below any known major source of contamination. Such increases can be expected in some streams during periods of high

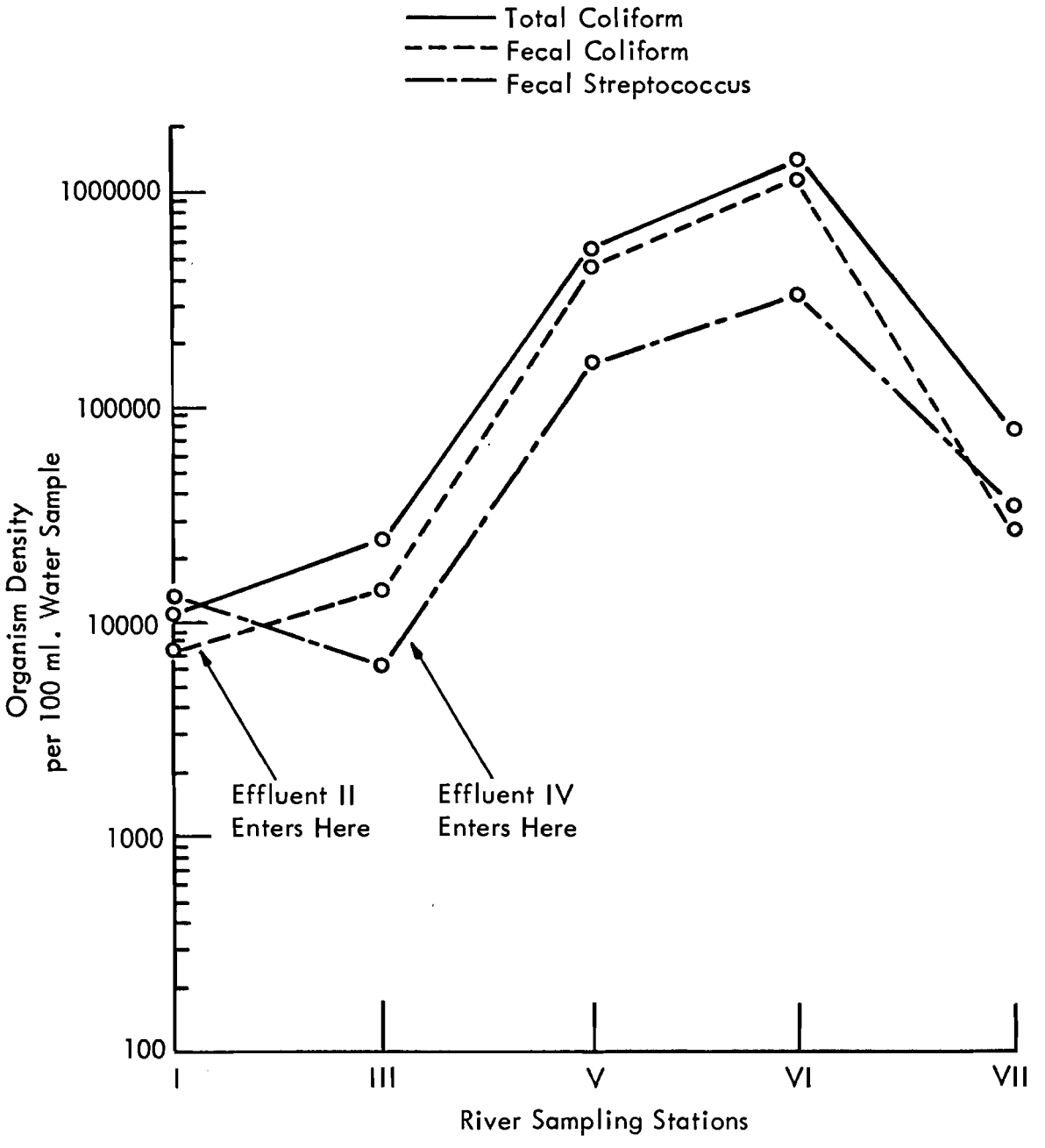


Figure 4 - Average Bacterial Populations During Periods of Runoff

TABLE III

AVERAGE BACTERIAL POPULATIONS BY STATION
DURING PERIODS OF RUNOFF*

Sampling Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I—River	10,629	7,652	12,572
II—Drainage Ditch Effluent	2,634,288	2,182,280	1,518,646
III—River	25,163	14,196	6,611
IV—Drainage Ditch Effluent	13,554,855	3,074,570	6,888,733
V—River	531,312	479,788	176,676
VI—River	1,386,341	1,161,933	319,996
VII—River	82,856	28,018	35,333

*Individual data for specific sampling dates is contained in table form in the appendix.

turbidity and high stream flow and are derived from natural and agricultural sources other than feedlots and municipal wastes (Stoltenberg, 1970). Although other sources may contribute to bacterial densities along the study reach, the marked elevation of densities below the two ditches which drain the Emporia feedlots indicated the feedlots were a significant source of contamination.

The effect of the first drainage ditch upon the water quality of the river could be readily seen at Station III where the average fecal coliform population was 14,195 org/100 ml sample or twice that of Station I. That feedlot drainage was polluting the river became more evident when the number of fecal coliform bacteria was determined at Station V. Station V was located immediately below the major system which drained the feedlots. The discharge from this drainage ditch, although continuous the year around, was of considerable volume only during periods of heavy runoff. The average density of coliform organisms occurring within the ditch during these periods was approximately 14,000,000 org/100 ml sample, which is similar to raw sewage values (Geldrich et al., 1962). As can be seen in Table III, there was a significant increase in fecal coliform bacteria after the effluent from Station IV entered the river (14,196 org/100 ml Station III to 479,788 org/100 ml Station V).

The peak bacterial densities occurred at Station VI. The fecal coliform population averaged 1,161,933 org/100 ml sample, which was three times that of Station V. The presence of an old

mill dam immediately upstream from Station VI may have contributed to the increase observed at this station. The dam restricted the flow of the river resulting in a concentration of "nutrients," nutrients which are conducive to rapid fermentation by sewage bacteria.

As the water continued downstream there was a decrease in the average density of fecal coliform bacteria at Station VII to 28,018 org/100 ml sample. In addition to surface runoff, the storm water sewer of the city of Emporia as well as the waste treatment plant discharge into the river between Station VI and VII. Therefore, this reduction in density appeared to be the result of dilution. Other factors which may have influenced the decline in density are die-off, predation, and flocuation.

It is interesting to note that the reported values were derived from many samples taken during similar periods of runoff and that practically all samples were taken while the effluents were draining fairly constantly and usually many hours after peak water levels. In other words, these data were not obtained by measuring slug conditions but were recorded during more constant runoff periods.

Although elevated coliform densities are to be expected in a stream during runoff, there can be little doubt that the feedlots constituted the primary source of coliform contamination along the study reach. This conclusion is supported by the significant increase in bacterial densities in the river below

the confluence of the ditch, which provided the main drainage course for the feedlots, and the dense populations that were observed therein. A comparison of runoff and normal conditions is presented in Figure 5.

Fecal Coliform--Fecal Streptococcus Ratio

The density relationships of the fecal coliform group and the fecal streptococcus group have been reported to be discriminatory of human versus non-human warm blooded animal waste. Geldrich (1964) states that a fecal coliform/fecal streptococcus ratio of 4.0 is indicative of human fecal material while a ratio of less than 0.7 is more representative of livestock wastes.

Unfortunately, this information was difficult to apply to the Cottonwood River study. The fecal coliform/fecal streptococcus ratios as calculated from non-runoff and runoff conditions (Table IV) showed few discriminatory patterns.

Normal river fecal coliform/fecal streptococcus ratios were higher than expected livestock fecal waste ratio values and lower than human fecal waste ratio values. The effluent (Station IV) which flows only from the feedlot, did not agree with Geldrich's theory; it exhibited a 3.85 ratio value. This effluent drains slowly during non-runoff conditions and derives its drainage from overflow of artificial lagoons within the stream. The drainage, therefore, was aged before entering the river. Fecal streptococcus are reported to exhibit no growth and rapid

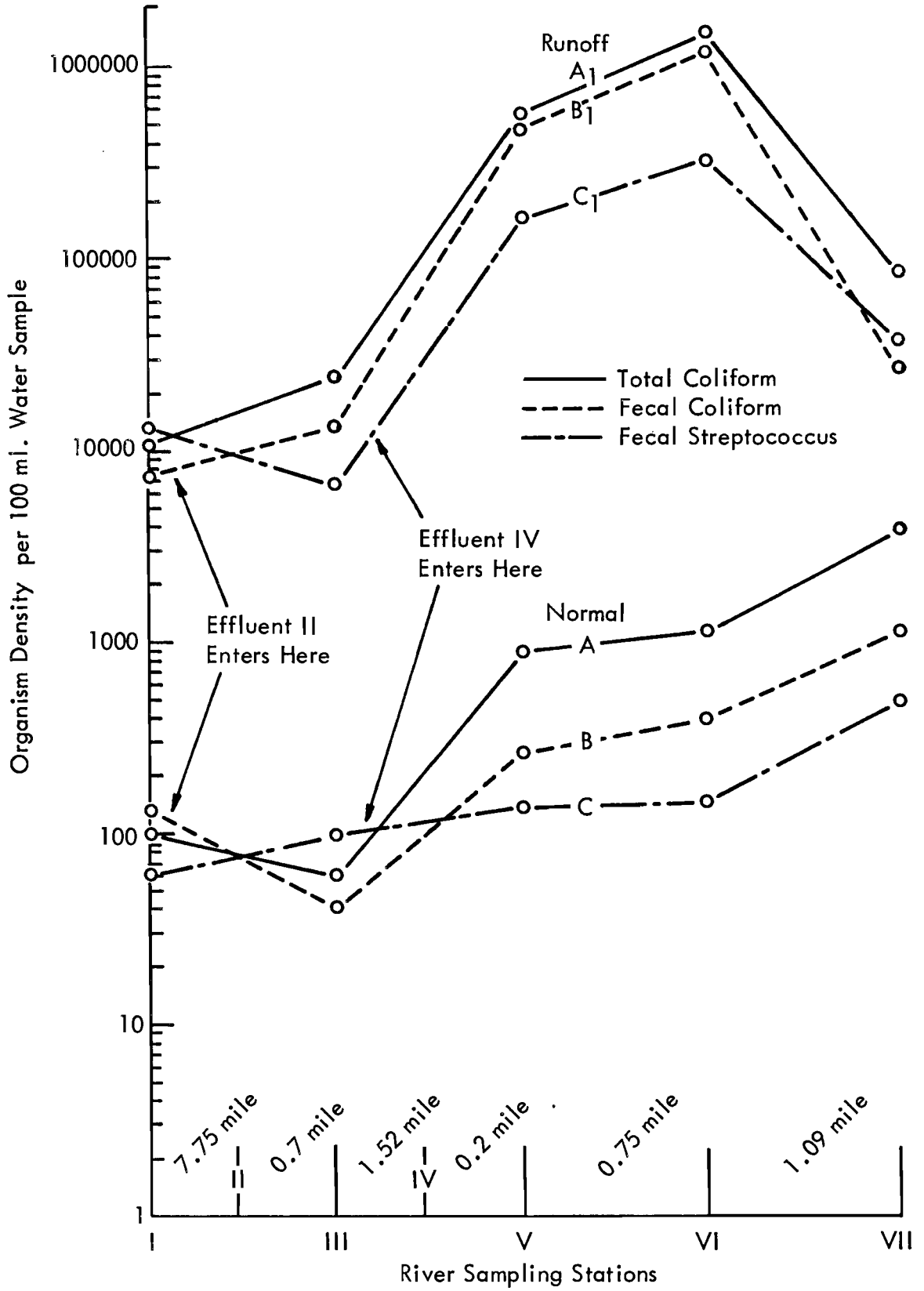


Figure 5 - Runoff (vs) Non Runoff River Bacterial Populations

TABLE IV

FECAL COLIFORM/FECAL STREPTOCOCCUS RATIOS FOR NON-RUNOFF AND RUNOFF CONDITIONS

Station	Runoff Conditions	Possible Sources	Normal Conditions	Possible Sources
I—River	0.60	Animal	2.6	Mixed
II—Drainage Ditch Effluent	1.43	Mixed	9.6	Human
III—River	2.15	Mixed	0.38	Animal
IV—Drainage Ditch Effluent	0.39	Animal	4.1	Human-Mixed
V—River	2.7	Mixed	1.8	Mixed
VI—River	3.63	Mixed	2.4	Mixed
VII—River	0.76	Animal	2.4	Mixed

die-off after entering a watery environment (Slantz and Bartley, 1964). This probably accounted for the low fecal streptococcus populations recorded in the effluent and within the river.

Fecal coliform/fecal streptococcus ratios during runoff conditions for the river stations were considerably lower than those of non-runoff conditions but could hardly be called discriminatory. However, Station IV, the major feedlot drainage ditch, did show a characteristic bovine ratio of 0.39. It has been reported that MF agar does not support good growth of Streptococcus bovis on membrane filters. During this study both MF agar and M-Enterococcus media were used with the membrane filter technique. This may have accounted for some variability within the fecal streptococcus data. Taking all variables into consideration, it would be difficult to identify the source of fecal pollution on the basis of coliform/streptococci ratios alone.

Because fecal coliform/fecal streptococcus ratios indicated little about the animal source of the pollutants, an attempt was made to determine whether identification of the streptococci species from the various samples would offer a clue. According to Bergey's Manual of Determinative Bacteriology (Breed et al., 1957) both Streptococcus bovis and Streptococcus fecalis are common inhabitants of the human intestinal tract as well as that of cattle; however, there is a predominance of Streptococcus bovis in cattle and of Streptococcus fecalis in humans. Therefore, identification of fecal streptococcus species can be helpful in determining fecal origin.

Utilizing the procedures described in Methods and Materials for the species identification of fecal streptococcus, samples were taken from the feedlot effluent during runoff conditions and were used as a source of streptococci isolates. The incidence of Streptococcus bovis or Viridans group was approximately 70 per cent of the colonies identified. The remaining 30 per cent were of the Enterococcus group. This would indicate a predominance of Streptococcus bovis as expected. However, such identification is very tedious and time consuming and was found to be impractical for frequent use in this type of survey.

Effect of Heavy Rainfall on River Pollution

On July 24, 1968, the Emporia area received a five-inch rain over a period of approximately four hours. Sampling was initiated five hours after the rain first began. The data from this set of samples was interesting because of conditions that existed at sampling time (Table V, Figure 6). At Station I, the total coliform level was 42,000 org/100 ml sample, approximately 30,000 organisms or 3 times above the average for periods of runoff. But at Station III, the total coliform level was 700,000 org/100 ml, 40 times that of the average runoff level. The sample from the effluent of Station II indicated that the total coliform density was 11,800,000 org/100 ml, 6 times greater than average runoff values. At station V the total coliform level dropped to 238,000 but climbed to 710,000 org/100 ml sample for Station VI and 1,330,000 org/100 ml at Station VII.

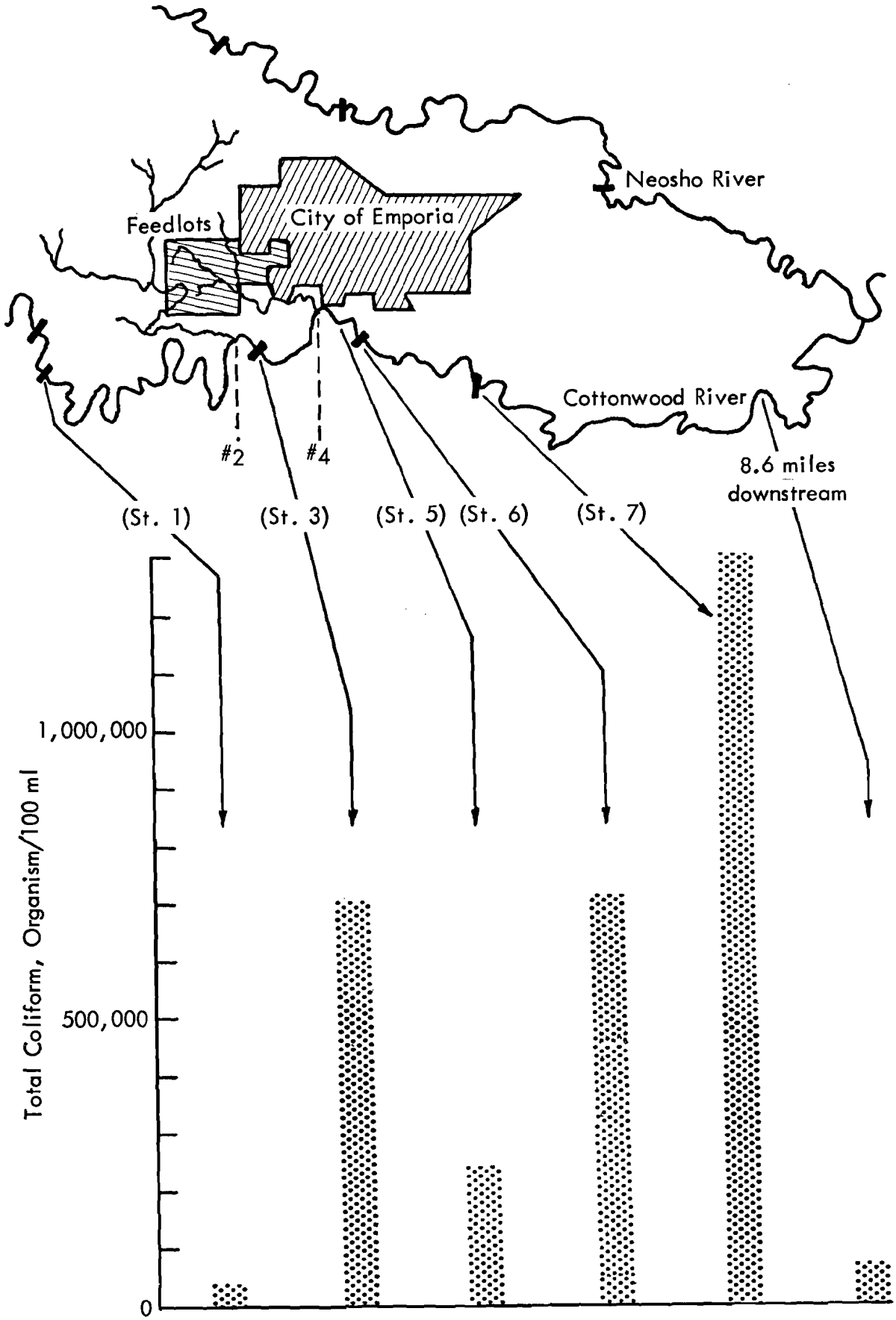


Figure 6 - Storm July 24, 1968 (Total Coliform)

TABLE V

BACTERIAL DENSITIES OF THE STUDY AREA DURING STORM OF JULY 24, 1968

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I River	42,000	31,000	27,000
II Effluent	11,800,000	19,100,000	4,600,000
Hy-50 Effluent	170,000	20,000	30,000
III River	700,000	1,050,000	338,000
IV Effluent	1,500,000	1,240,000	620,000
IV_1 Effluent	140,000	127,000	140,000
IV_a Effluent	8,000,000	10,300,000	2,200,000
IV_{a1} Effluent	700,000	700,000	470,000
$Hy\text{-}50_2$ Effluent	800,000	400,000	77,000
V River	238,000	382,000	193,000
VI River	710,000	800,000	270,000
VII River	1,300,000	1,230,000	360,000
Country Road 5.8 Miles East Emporia-River	56,000	41,000	39,000

The rainfall was hard and the runoff heavy. It appeared as if the runoff from the feedlot developed a double slug effect; one initiating from each drainage ditch. At the time of sample collection (5 hours after rainfall began), the slug from the small drainage ditch (Station II) appeared to be located between Stations III and V; and the slug from the larger drainage ditch (Station IV) appeared to be in the vicinity of Station VII. Conditions within the slugs were similar to that of untreated fecal wastes.

The effects of such slugs can become devastating with the development of slug fermentation. Kittrewell and Furfari (1963) reported that peak bacterial densities from stream fermentation occur 10 to 15 hours after the slug enters the watercourse. Fermentation densities may reach as high as 4 to 8 times discharged numbers. The fermentation itself causes almost total depletion of dissolved oxygen combined with the production of toxic amounts of ammonia.

In the case of the Cottonwood River, recovery of the stream from this type of situation would be severely retarded by the second smaller slug from Effluent Station II which followed, by several hours, the first. It is easy to theorize that conditions similar to these precipitated the disastrous fish kills of 1966.

SUMMARY

Feedlot runoff pollution of the Cottonwood River was monitored from May, 1967 to July, 1968. The degree of pollution was based on density variation of feces associated bacteria. Sampling was periodically conducted at five river stations and two effluent stations in the Emporia, Kansas area. One-half inch of rainfall was determined to be the minimum which would result in excessive feedlot runoff reaching the river. Minimal densities of fecal bacteria existed during periods of no runoff. However, even during periods when densities were minimal an overall station-to-station increase in the microbial population occurred as the water moved through the study area. During the non-runoff periods the feedlot discharge was slight and did not appear to elevate significantly bacterial densities within the receiving stream. Fecal coliform counts averaged less than 300 org/100 ml sample for all river stations except Station VII, which showed a significant increase in fecal coliform bacteria (1,198 org/100 ml sample). Station VII is located below the Emporia sewage disposal plant effluent; thus, it would appear that this source was contributing to the increased fecal contamination observed at Station VII. The increase adversely affected the sanitary quality of the water to the extent that body contact with the river (swimming, etc.) would have been considered hazardous.

Bacterial counts in runoff samples indicated the presence of extremely high populations of pollution indicator organisms throughout the watercourse. The highest numbers of fecal bacteria were recorded at stations below the point where feedlot effluents entered the river. The water samples from the upstream stations had bacterial populations 50 times (fecal coliform average density 11,000 org/100 ml sample) greater than that of samples taken during periods of normal flow. This type of increase could be due to natural agricultural runoff other than direct fecal contamination. Samples from downstream stations, those below the feedlot (Stations V and VI), had dangerously high populations of indicator organisms; populations which reached densities approximating 1.2 million fecal coliform per 100 ml sample.

The drastically elevated numbers of indicator organisms rapidly declined by the time the water reached the last monitoring station which was located approximately two miles below the feedlots. The sharp decrease from 1.2 million fecal coliforms at Station VI to 28,000 fecal coliforms at Station VII indicated that a rapid dispersal of fecal bacteria occurred as the stream flowed away from the source of its contamination.

Runoff data strongly implicated the Emporia area feedlots as a principle source of fecal contamination for the Cottonwood River. This implication was reinforced by data obtained from samples collected during an intense rain shower on July 24, 1968. These data demonstrated the presence of two distinct runoff slugs entering the watercourse from the feedlot effluents. Conditions that existed within the slugs were similar to those expected of raw sewage.

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APPENDIX

COLLECTIONS USED TO FIGURE RUNOFF VALUES
FOR POLLUTION INDICATOR ORGANISMS

November 2, 1967

December 5, 1967

December 12, 1967

December 19, 1967

March 29, 1968

March 31, 1968

April 3, 1968

April 22, 1968

June 24, 1968

*Samples were collected after a recorded rainfall in excess of one-half inch.

November 2, 1967

River about normal flow speed = 1 mph

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I	900	800	2,100
II	700	800	1,200
II_a	3,580,000	1,880,000	810,000
III	4,600	2,100	4,200
IV	1,100	1,300	1,100
VI	1,500	1,200	5,000

December 5, 1967

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	1,390	50	110	8.5	0.5	5.0
II	2,670,000	170,000	760,000	2.5	8.9	5.0
III	390	110	400	9.0	0.4	5.0
IV	8,580,000	680,000	2,880,000	2.3	0.0	5.3
V	4,450	550	670	9.0	0.4	5.1
VI	5,090	300	600	9.2	0.2	5.1
VII	3,800	100	630	9.5	0.8	5.2

December 12, 1967

Stations	Total Coliform org/1pp ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	30	10	80	10.5	0.6	4.0
II	220,000	1,000	5,400	3.0	7.9	5.0
III	0	0	10	9.5	0.7	4.0
IV	12,600	360,000	720,000	2.2	25.2	5.1
V	236,000	190	100	9.5	0.8	4.9
VI	370	0	10	9.5	0.6	4.9
VII	120	20	200	9.5	0.8	4.5

December 19, 1967

After 1 inch precipitation

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	13,300	6,400	39,000	8.5	0.3	3.0
II	630,000	140,000	780,000	8.5	1.5	3.0
III	280	70	2,500	9.0	1.0	3.5
IV	5,300,000	3,600,000	7,100,000	2.0	25.2	4.0
V	1,900	260	700	9.0	0.9	3.0
VI	1,310	220	600	9.5	0.6	3.2
VII	70	10	25	9.5	0.9	3.1

March 29, 1968

Cattle lot had just been cleaned off
11 p.m. before rain
7 p.m. 2.1 inch rainfall (local)

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	40	17.5	5	7.5		16.5
II	10,200	600	300	6.0		14.0
III	95	110	110	6.0		15.0
IV	4,600,000	4,200,000	7,600	2.5		14.0
IV_a	50,000,000	46,300,000	4,700,000	1.5		14.0
VI	8,000,000	6,310,000	264,250	1.5		15.0

March 31, 1968

Two days after 2-inch rainfall

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	2,600	2,800	80	9.0		15
II	182,000	185,000	600	2.5		14
III	3,000	700	60	9.5		15
IV	5,000,000	1,900,000	2,700,000	2.0		14
IV_a	310,000	200,000	10,000	1.5		14
V	26,000	32,000	5,000	7.5		17
VI	57,000	39,000	2,000	9.0		17
VII	280,000	23,000	3,000	10.0		17
Hartfort	152,000	41,000	3,600	5.5		18
Lebo	90	280	50	8.0		17

April 3, 1968

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	1,500	1,200	2,500	7.2	0.1	14.5
II	1,290,000	1,540,000	820,000	4.3	3.1	15.5
III	17,000	9,100	20,000	6.3	1.3	14.3
IV_a	22,000,000	17,000,000	6,000,000			
IV	1,100,000	330,000	440,000	5.5	3.9	19.5
V	50,000	25,000	30,000	6.9	0.9	18.4
VI	11,000	6,100	7,300	7.0	0.5	19.0
VII	43,000	26,000	15,000	7.5	0.8	15.0

April 22, 1968

Samples taken at 6 p.m. after a 3-inch rain shower

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	75,000	57,000	69,000	7.0	0.8	14
II	18,700,000	17,600,000	11,300,000	1.5	3.8	15
III	199,000	115,000	32,000	7.0	3.2	14
IV_a	110,000,000	68,000,000	76,000,000	5.0	0.0	12
IV	91,000,000	15,000,000	48,000,000	0.5	4.3	12
V	3,400,000	3,300,000	1,200,000	1.2	3.9	12
VI	4,400,000	4,100,000	2,600,000	1.1	4.3	13.5
VII	42,000	20,000	180,000	6.2	1.6	13

June 24, 1968

Air Temperature 30°C
Rain 11 a.m.

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. °C
I	900	590	270	9.0	0.30	26
II	5,700	3,120	320	5.5	0.25	25
III	2,100	580	220	6.0	0.30	26
IV	6,400,000	1,600,000	150,000	1.0	7.02	25
V	840	520	900	6.0	0.15	26
VI	800	580	200	5.5	0.35	26.5
VII	211,000	127,000	46,000	5.0	1.11	26.5

SAMPLING DATES IN 1968 DURING WHICH

NO RUNOFF OCCURRED

February 5, 1968

March 3, 1968

March 5, 1968

April 16, 1968

April 17, 1968

May 13, 1968

July 6, 1968

July 18, 1968

July 19, 1968

February 5, 1968

River flow low—2 feet over dam
Oil covering drainage ditch at Station IV
Oil extending into river at Station V continuous film near bank .

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	0	0	0	11.2	0.00	5.5
II	3,000	0	100	10.5	2.40	5.0
III	0	0	0	12.4	0.00	5.2
IV	45,000	0	89,000	4.0	6.95	5.7
V	100	0	320	12.5	0.40	5.5
VI	10	0	0	12.0	0.00	5.5
VII	2,080	120	430	10.0	0.40	5.5

March 3, 1968

Normal Flow

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I_a	80	10	24			
I	0	1	0	10.2	0.8	11.0
II	10	20	6	8.5	1.5	11.0
III	0	1	0	10.0	0.4	11.0
IV	700	440	180	3.5	47.2	10.5
V	30	20	0	10.0	0.5	11.0
VI	970	160	0	9.0	0.4	11.0
VII	1,500	400	3	10.0	1.4	12.0

March 5, 1968

Normal river flow at low temperatures

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. ^oC
I	0	0	0	12.5	0.5	8.2
II	0	0	1	10.5	2.0	9.0
III	0	0	0	12.0	0.4	8.2
IV	20	160	2	2.0	50.4	6.5
V	1	0	1	12.5	0.6	5.2
VI	10	10	0	12.3	0.4	5.2
VII	0	2	3	11.9	1.1	7.0

April 16, 1968

Air Temperature 22°C at 12 a.m.
Wind Velocity 20-30 mph (S. W.)
Cloud Cover 80%
River level low

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. °C
I_a	130	70	140			16.5
I	200	190	40	7.5		16.5
II	0	600	200	7.5		17.5
III	0	0	60	7.2		17.0
IV_a	140,000	90,000	110,000	0.5		17.5
IV	40,000	29,000	23,000	0.2		17.5
V	600	320	100	8.5		17.0
VI	570	220	100	8.0		17.0
VII	2,500	2,050	600	7.5		17.5

April 17, 1968

Taken after a light rain shower (less than $\frac{1}{2}$ inch)
Air Temperature 20° C at 12 a.m.
Wind Velocity 5-10 mph (N.)
Cloud Cover 80%

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. C
I	70	180	80	7.0	7.0	18.0
II	400	10	600	4.0	1.8	21.0
III	0	0	30	7.5	0.6	19.0
IV_a	3,400,000	2,200,000	1,500,000	1.0		25.0
IV	22,300,000	14,600,000	3,700,000	1.5	10.1	25.0
V	5,600	480	150	7.5	0.6	18.0
VI	2,000	1,000	900	7.0	0.5	18.0
VII	6,800	5,700	890	7.0	1.0	18.0

May 13, 1968

Taken at 2 p.m.
Rain Shower 3 p.m.
Samples Taken 4:30 p.m.

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml	Dissolved Oxygen ppm	NH_3 mg/liter	H_2O Temp. C
I	400	300	310	6.5	0.48	16.5
II	7,200	9,200	100	6.0	0.21	16.5
III	520	300	800	6.5	0.45	16.5
IV	90,000	20,000	40,000	0.5	6.05	18.0
V	1,200	840	410	6.5	1.11	16.0
VI	310	200	180	6.5	0.0	16.5
VII	5,900	400	1,200	6.5	0.75	16.5

July 6, 1968

Rain .15 to .5 inch

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I	120	420	20
II	4,300	14,000	560
III	10	0	0
IV	30,000	70,000	10,000
V	10	200	0
VI	50	0	10
VII	20	100	0

July 18, 1968

Light Rain

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I	60	90	60
II	1,300	1,000	200
III	0	0	10
IV	2,900,000	2,290,000	200,000
V	600	500	280
VI	510	450	143
VII	310	500	1,000

July 19, 1968

Stations	Total Coliform org/100 ml	Fecal Coliform org/100 ml	Fecal Streptococcus org/100 ml
I	40	60	50
II	500	800	900
III	10	60	40
IV	35,000	25,000	85,000
V	10	30	20
VI	6,500	1,220	100
VII	14,500	1,510	290