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Faecal Coliforms (FC) and Faecal Streptococci (FS) Ratio as a Tool for Assessment of Water Contamination: A Case Study of River Sokoto, Northwestern Nigeria

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Abstract

Agricultural runoff as nonpoint pollution has been responsible for rivers and streams frequently exceeding the United States Environmental Protection Agency (USEPA) standards for bacterial contamination of primary contact water (200 faecal coliforms/100 ml). The effects of cattle rearers/farmers and cattle rearing on faecal contamination of water from River Sokoto were evaluated. Water samples from six designated points P1, P2, P3, P4, P5 and P6 on River Sokoto were assessed on monthly basis for faecal coliform and faecal streptococci from January to December, 2014 using faecal coliform/faecal streptococci ratio (FC/FS). The six points were; a point 5 metres away from farmland (P1), a point close to farmland (P2), a point close to residents along the riverside (P3), a point on stream drainage immediately from Sokoto Cement factory (P4), a point on the stream close to the river (P5) and a point 5 metres away on the river (P6). Mean concentrations of FC and FS were extremely high at all sampling points and exceeded contact water standards of 200 faecal coliform/100ml. Mean FC count was highest (18,525 MPN/100ml) at P3 (29.1%) and lowest (7,592 MPN/100ml) at P2 (11.9%). Mean FS was recorded highest (2,350 MPN/100ml) at P5 (21.8%) and lowest (625 MPN/100ml) at P4 (5.8%). Mean FC/FS ratios of sampled water P1, P5 and P6 were < 4 (3.78, 3.95 and 3.95 respectively) indicating domestic animal contamination. However, P4 had the highest mean FC/FS ratio > 4 (11.53) indicating human contamination; P2 and P3 also had values > 4 (5.66 and 7.34 respectively) also pointing to human contamination. Although the FC/FS ratio identified domestic animal contamination sources, it did not distinguish between domestic animal and human sources of contamination.
The FC/FS ratio can therefore be used as a regulatory rather than a diagnostic tool to identify contamination sources.

Keywords: Animal contamination, Human contamination, Faecal coliform (FC), Faecal streptococci (FS)

1. Introduction

Faecal coliform (FC), Faecal streptococci (FS), and Escherichia coli (E. coli) are bacteria always present in the intestinal tracts of warm-blooded animals. They are eliminated in faecal waste and do not generally multiply outside the intestines. Contamination of excessive nutrients in surface streams and groundwater may result in chronic effects, but contamination of human pathogens can have acute effects making people ill within hours of exposure in some cases. Numerous diseases are transmitted by faecal contact. Water contaminated with faecal wastes are unsafe for contact recreation and drinking (McBroom *et al*., 2003).

The purpose of the routine bacteriological examination of water samples is usually to estimate the hazard due to faecal pollution and the probability of the presence of pathogenic organisms. The isolation of pathogens from water and sewage is expensive and laborious. It is not a routine practice. Normally occurring bacteria in the intestines of warm-blooded animals have been used as indicators of faecal pollution. Total coliforms, faecal coliforms, and faecal streptococci have all been used as pollution indicators at various times (Kabler, 1968; APHA, AWWA and WPCF, 1971). Other bacterial indicators have been proposed including *Closteridium*, *Pseudomonas*, and *Aerobacter*, but their value has been considered questionable or irrelevant (WGWQ, 1972). The TC group has been adopted as an indicator of faecal pollution suggestive of a hazard to health because these bacteria are associated with the gut of warm-blooded animals. Thus, the absence of TC is generally evidence of bacteriologically safe water (Lin, 1974).

Watershed characteristics, land use management, and the proximity of domestic animals to streams play an important role in the severity of faecal contamination (Tiedemann *et al.*, 1988). Cattle grazing increases faecal coliform in agricultural runoff compared with background faecal coliform levels (Dixon *et al.*, 1977; Doran and Linn, 1979; Gary *et al.*, 1983; Stephenson and Street, 1978; Tiedemann *et al.*, 1988). When cattle are allowed to graze directly adjacent to streams, stream banks and bottoms became significant bacterial reservoirs (Kunkle, 1970). To properly assess fecal contamination of a site, it is necessary to identify the contamination source.

Enumerating methods for FC by the elevated temperature tests have been developed by Geldreich *et al.* for the MPN procedure (Geldreich *et al*., 1958) and for the MF technique (Geldreich *et al*., 1965).

Geldreich *et al.*, 1964 first suggested the use of an FC to FS ratio as a more valuable informational tool for assessing pollution sources than the use solely of FC densities. Geldreich (1976) suggested that the fecal coliform/fecal streptococci ratio (FC/FS) could be used to differentiate between contamination from human (FC/FS > 4), domestic animal (FC/FS between 0.1 and 0.6), and wild animal (FC/FS < 0.1) sources. Mean FC/FS ratio has been used to characterize some sites (Doran and Linn, 1979; Jawson *et al*., 1982). The frequency of FC/FS ratios representative of each contamination source has also been used (Tiedemann *et al*., 1988). Doran and Linn (1979) indicated that the FC/FS ratio is useful in distinguishing between domestic animal and wild animal sources of contamination, but its usefulness in differentiating between human and nonhuman sources of contamination is questionable. With these considerations in mind, together with other suggested interpretations for intermediate values (MC, 1972), FS determinations can be an important tool for a stream study.

In this vein, the effects of cattle rearing and cattle rearers/farmer on faecal contamination of water from River Sokoto were evaluated to determine the quality of the water for the safety of the users.

1.1. Study Area

The segment of River Sokoto used in the study is adjacent to Kalambaina industrial area of the metropolis where factories such as cement, aluminium, foam, fertilizer and tanning industries are found. Residents along the bank of the river farm crops such as vegetables and use water from the river to irrigate them. Animal rearing is also a common practice in this area.

2. Material and Methods

Water samples from six designated points P1, P2, P3, P4, P5 and P6 on River Sokoto were assessed on monthly basis for faecal coliform and faecal streptococci from January to December, 2014. Water samples were collected in sterile amber bottles that were washed and rinsed thoroughly with nitric acid and distilled water. The samples were transported immediately to the laboratory for analyses in an ice-box to protect the samples from sunlight and excessive heat. All samples were analyzed for concentrations of faecal coliform and faecal streptococcus by the multiple- tube dilution technique using Most Probable Number (MPN) method.

For faecal coliform count, ten-fold serial dilutions of water samples were prepared in sterile distilled water. Decimal volumes (1ml, 0.1ml and 0.01ml) of each dilution was aseptically transferred to quintuplicate of 10ml sterile Lauryl tryptose broth fermentation tubes containing inverted Durham tubes and incubated at 35^0C. The tubes were examined for accumulation of gas in the Durham tubes after 24 to 48 hours to presume coliform organisms. All primary fermentation tubes showing gas accumulation after 24 to 48 hours were subjected to confirmation test. The tubes were gently shaken and one loopful of culture was transferred to a fermentation tube containing 10ml of Brilliant Green lactose broth (Lab M, U.K.) with inverted Durham tubes. The tubes were incubated at 35^0C for 48 hours. Formation of gas in the inverted tubes confirmed coliform group. One loopful of culture from the confirmed test was taken and placed in the EC medium (Lab M, U.K.) containing inverted Durham tubes and incubated in a water bath at 44.5^0C for 24 hours. Accumulation of gas in the inverted tubes confirmed the presence of faecal coliforms.

For faecal streptococci count, serial dilutions of water samples were made from 10^{-1} to 10^{-3}. Decimal volumes of 1ml and 0.1ml of each dilution were aseptically transferred to quintuplicates of 10ml aliquots of sterile Azide dextrose broth (Oxoid, England) and incubated at 35^0C. They were examined for turbidity between 24 to 48 hours. Tubes showing turbid growth were confirmed by streaking on Aesculin-azide agar (Oxoid, England) and incubated at 35^0C for 24 hours. Plates showing brownish-black colonies with brown halo indicated the presence of faecal streptococci. This was further confirmed by a negative catalase test.

The estimation of faecal coliform and faecal streptococci counts was determined by making reference to standard tables for computation of Most Probable Number and reported as MPN/100ml. The value obtained was multiplied by the dilution factor to get the actual level of the bacteria in the water.

3. Results and Discussion

Industrial effluents, domestic wastes and agricultural runoff always end up in streams and rivers, and thus become potential sources for pathogens. However, sewage is treated prior to discharge into streams or rivers. To determine the expected concentrations and ratios of FC and FS in River Sokoto, the industrial area adjacent to the river was selected as the study site where farming and animal rearing also take place.

The results show that the mean Faecal coliform (FC) and Faecal Streptococci (FS) counts were extremely high at all sampling sites and above primary contact water standards of 200 faecal coliforms/100 ml (Table 1; Fig. 1). Various activities such as bathing (Kulshrestha and Sharma, 2006), human defaecation and animal defaecation observed around the sampled area might be responsible for this. Although faecal bacteria persist in manure deposits, a source of faecal bacteria along with a driving force like rainfall must be present to move faecal bacteria through soil into streams and river (Singh *et al*., 2013).

Mean FC count was highest (18,525 MPN/100ml) at P3 (29.1%) and lowest (7,592 MPN/100ml) at P2 (11.9%) as shown in Table 1 and Fig 1. Also, mean FS was recorded highest (2,350 MPN/100ml) at P5 (21.8%) and lowest (625 MPN/100ml) at P4 (5.8%) as shown in Table 1 and Fig 1. High values of FC and FS recorded in this work was in accordance with the work done by Kulshrestha and Sharma, 2013 and may be as a result of various activities like defaecation (human and animal) at the sampling area. Mean FC/FS ratios of sampled water P1, P5 and P6 were less than four (3.78, 3.95 and 3.95 respectively) indicating domestic animal contamination (Table 2; Fig 2). However, P4 had the highest mean FC/FS ratio greater than four (11.53) indicating human contamination. Pollution rate was highest in the stream (P4) leading to the river from Sokoto Cement Factory probably because farmers using waste water from the Cement Factory to irrigate their crops defaecate on their farmland. P2 and P3 also had values less than four (5.66 and 7.34 respectively) also pointing to human contamination (Table 2; Fig 2). Although the FC/FS ratio identified domestic animal contamination sources, it did not distinguish between domestic animal and human sources of contamination.

Table-1. Mean Concentration and Percentage of FC and FS from various sampling points in River Sokoto

Sampling Points	FC (MPN/100ml)	FS (MPN/100ml)	% FC	% FS
P1	8042	2140	12.6	19.9
P2	7592	1512	11.9	14.0
P3	18525	1997	29.1	18.5
P4	8175	623	12.9	5.8
P5	10650	2350	16.7	21.8
P6	10658	2150	16.8	20.0
Total	63642	10772	100	100

Key
FC = Faecal coliform and FS = Faecal streptococci

Table-2. Monthly Ratio of Faecal Coliform and Faecal Streptococci at various sampling points in River Sokoto

	FC/FS Ratio at Sampling Sites					
Month	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
January	6.45	4.35	10.83	13.00	5.00	9.68
February	6.21	4.50	11.89	15.00	5.47	10.00
March	6.67	4.74	12.25	18.33	5.44	9.26
April	3.75	8.10	2.83	9.38	3.40	3.62
May	6.03	6.25	8.28	12.50	1.39	1.31
June	1.03	3.78	10.00	7.69	6.15	2.28
July	1.11	3.00	10.00	8.00	6.00	2.10
August	2.50	6.25	8.00	11.25	2.00	1.50
September	2.14	7.33	6.67	10.67	2.50	1.64
October	2.50	6.90	7.14	12.50	3.00	1.80
November	2.75	5.71	5.60	11.00	3.00	2.00
December	4.20	7.00	4.58	9.00	4.00	2.17
Mean	3.78	5.66	7.34	11.53	3.95	3.95

Key
FC = Faecal coliform and FS = Faecal streptococci

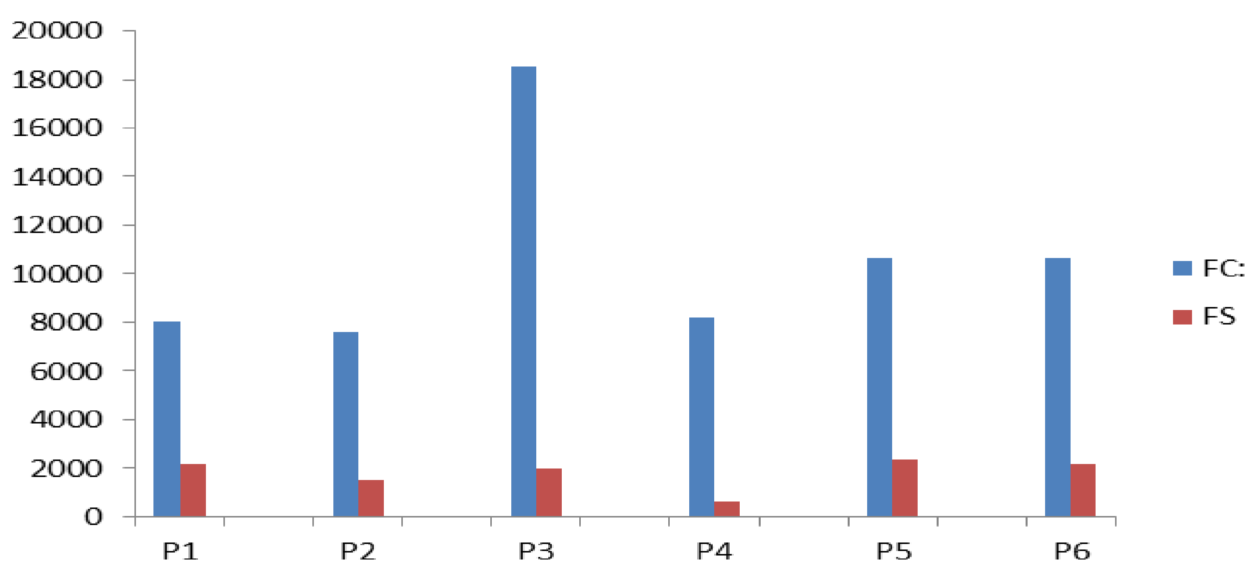

Fig-1. FC and FS (MPN/100ml) at different sampling points on River Sokoto

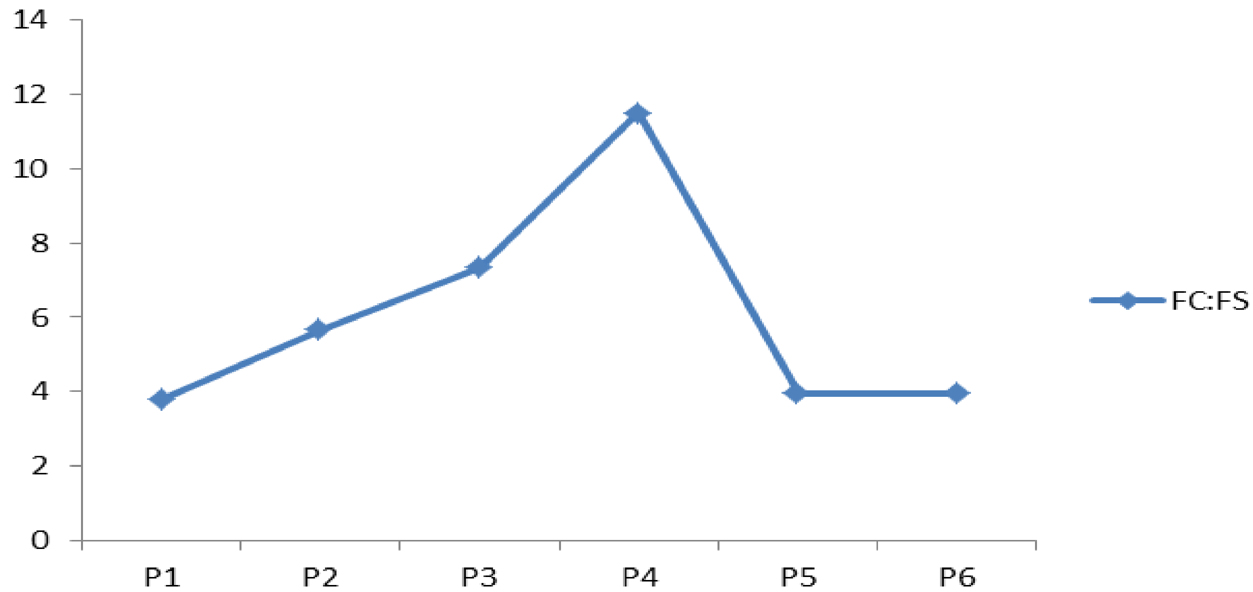

Fig-2. FC: FS Ratio at different sampling points on River Sokoto

4. Conclusion

Significantly, high concentrations of FC (18,525 MPN/100 ml), FS (2,350 MPN/100 ml) and a high ratio of FC: FS (11.53) were determined in the sampled waters of River Sokoto. Thus, inadequate treatment of sewage/effluent will always result in the discharge of FC and FS far in excess of the allowable limits with the FC: FS ratio above 4.0. The FC/FS ratio can be used as a regulatory rather than a diagnostic tool to identify contamination sources.

5. Recommendation

Further research on this topic should be done in future to further ascertain the sources of FC and FS in the natural environment to better evaluate the water quality of streams and rivers in Sokoto State, Nigeria.

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