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Modeling the transport of fecal coliform in ntanwaogba creek, influenced by variations in micronutrient deposition, velocity and dispersion coefficient

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Abstract

The study of Micronutrients in Ntanwaogba Creek were thoroughly carried out to monitor its rates of deposition at different numerous discharge location sites in the study environment, this was imperative because the rates of biological waste discharge at regular interval, based on this factor, it was necessary to conduct a comprehensive investigation of their rate of concentration at different station point of discharge. This implies that the rate of dispersions from the contaminant influenced constant discharge of waste in the creek, and based on these factors, it was determined that such comprehensive research was required. Micronutrients act as a substrate for microbial growth, but the speed at which they are injected into the rill affects how quickly they move through the system. In order to determine the effects of these two parameters on the migration rate of faecal coliform at different point sources of discharge, the study observed different growth rate at different station point in the study location. This observed condition indicates that the pollutants had a range of development speeds, including both slow and fast, which was enabled by these considerations. The system discovered that lower velocities have an effect on velocity rates with higher concentrations, and that accumulation with micronutrients increased their concentration. However, the concentration rates varied depending on the dominant characteristics of the transport under pressure at various points of discharge. In the simulation, these two parameters were used to determine the various pressure rates at different station points. Unquestionably, the study has depicted the effects of these two parameters' pressures on the movement of faecal coliform in a range of figures that correspond to the several point sources of discharge looked at. The speeds recorded at various station locations represented the pressure rates at various rates of concentration in the research environment. It has established the scope of the influence of rill flow velocity and the variance in micronutrient deposition at various point sources. On the basis of model simulation prediction results, also, the dispersions at various point sources were evaluated. Both parameters showed correlations for the best fits when the predicted and experimental values were compared for model validation.

Keywords: modeling, transport, fecal coliform, micronutrients and dispersion coefficient

Introduction

Many studies have shown that water-borne infections are extremely dangerous to human health. These facts make it clear that, if pollution rates are not controlled, there will always be significant hazards to the overall health of the ecosystem. Total Maximum Daily Load (TMDL) implementation costs were assessed by experts, and they range from $0.9 to $4.3 billion annually.[1,2] The main factor causing stream impairments is pathogen influxes from land-based agricultural activities.[2,3] Controlling pathogen contamination caused by cattle, meantime, is a difficult task. Riparian buffers can be fenced off to prevent pathogen contamination; however it is not apparent how broad the buffers need to be to be effective in preventing pathogen contamination of stream water.[4] The research that has thoroughly evaluated studies in this field has elaborated on the pathogen contamination of stream water [4–8] (Jamieson. More research has concentrated on understanding pathogen transmission in stream water using mathematical models.[5,6,9,10] Also, the principal source of drinking water is typically a surface reservoir, indicating that these bodies of surface water are frequently subjected to pathogen pollution.[9,11–13] There has been a considerable improvement in knowledge of water quality and water treatment for pathogen pollution in industrialized nations because specialists tracked the occurrences of 26 water-borne illnesses through public water sources, which were done by experts.[12–21] Also, the inflow of contaminated stream water into lakes and reservoirs during the rainy seasons might result in a significant rise in pathogen rates.[4,22–24] For purposes of measuring the quantity of pathogen uptake from torrents running into lakes and reservoirs during wet seasons it also involved monitoring pathogen movement including its dispersion.[2,3,25]

Theoretical foundation and controlling equation

$$\frac{dc}{dx} + \beta(x)K = A(x) \tag{1}$$

Nomenclatures

C = Concentration

B = Micronutrients

K = Dispersions. Velocity of flow

A= Fluid Density

X = Distance

Multiplying the equation through by $C[x]$, we have:

$$C(x)\frac{dC}{dx}+C(x)\beta(x)K=C(x)A(x) \quad (2)$$

Let $P(x)=C(x)\beta(x)$ (3)

Then Equation (2), we have:

$$C(x)\frac{dC}{dx}+C(x)\beta(x)K=C(x)A(x) \quad (4)$$

$$C(x)\frac{dC}{dx}+P(x)K=C(x)A(x) \quad (5)$$

$$C(x)P^{1}+P(x)K=C(x)A(x) \quad (6)$$

$$C(x)P^{1}=C(x)A-P(x)K \quad (7)$$

Differentiate 2[nd] term on the left hand side of (6) with respect to x, we have

$$K\frac{dC}{dx}=C(x)A(x)-C(x)P^{1} \quad (8)$$

$$\frac{dC}{dx}=\frac{1}{K}\left[C(x)A(x)-C(x)P^{1}\right] \quad (9)$$

$$\frac{dC}{dx}=\frac{C(x)}{K}\left[A(x)-P^{1}\right] \quad (10)$$

Applying separation of variables, by dividing through by C(x) and cross multiply by dx, gives:

$$\frac{dC}{C}=\frac{1}{K}\left[A(x)-P^{1}\right]dx \quad (11)$$

$$\frac{1}{C(x)}dC=\frac{1}{K}\left[A(x)-P^{1}\right]dx \quad (12)$$

$$\frac{1}{C(x)}dC=\left(\frac{A(x)}{K}-\frac{P^{1}}{K}\right)dx \quad (13)$$

$$\int\frac{1}{C(x)}dC=\int\left(\frac{A(x)}{K}-\frac{P^{1}}{K}\right)dx+\eta \quad (14)$$

$$\ln C(x)=\int A(x)dx-\int\frac{P^{1}}{K}dx+\eta \quad (15)$$

$$\ln C(x)=\frac{1}{K}\left[Ax-P^{1}\right]x+\eta \quad (16)$$

$$\ln C(x)=\left(\frac{A(x)}{K}-\frac{P^{1}}{K}\right)x+\eta \quad (17)$$

Taking exponent of the both side of the equation

$$C(x)=\ell^{\left(\frac{A(x)}{K}-\frac{P^{1}}{K}+\eta\right)} \quad (18)$$

$$C(x)=D\ell^{\frac{1}{K}\left(Ax-P^{1}x\right)} \quad (19)$$

Materials and method

The water samples were taken sequentially according to the requirements set forth at various places. These samples were obtained at various locations, which resulted in fluctuations at various distances, resulting in variable faecal coliform concentrations, and the experimental results were compared. Using the conventional procedure for the experiment at several samples at various stations, a typical laboratory experiment was carried out to track faecal coliform.

Results and discussion

Figure 1-6 shows how the major influencing factors in the research environment affect the migration rate of faecal coliform. The variance of the contaminant's exponential growth rate in terms of quick and slow growth in relation to increase in distance was depicted in the figures. However, during the transport system's exponential phase. The observed fluctuations are primarily related to the pace of micronutrient depositions, including dispersion from the pollutant at several station locations, where the starting concentrations are recorded. The growth rate's behaviour did exhibit some degree of variability. Such a condition shows that the concentration change rate at different study locations was determined by the micronutrient's function as a substrate for any bacterium. The study looked at these pressures from transport and the impact that condition had on the flow dynamics that pushed the microorganisms at different station points of discharge. The many types of micronutrient depositions that have been seen in the rill and the fluctuations in those depositions as a whole have affected the growth rate of faecal coliform in the study region, as shown in graphical representation in all of the figures. The behaviour of faecal coliforms was monitored through the use of modeling and simulation by examining the variable effect of contaminant movement at distinct station points of discharge. The experimental and prediction values of each created figure expressed best fit correlations Tables 1-6.

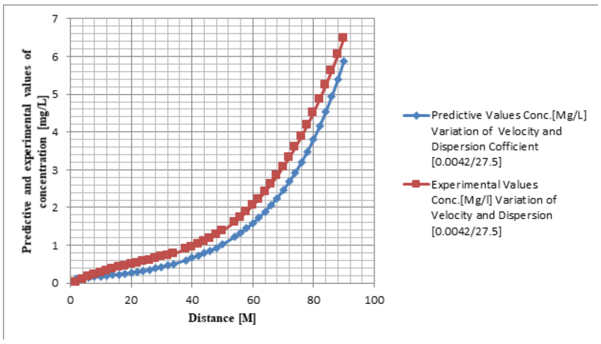

Figure 1 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances.

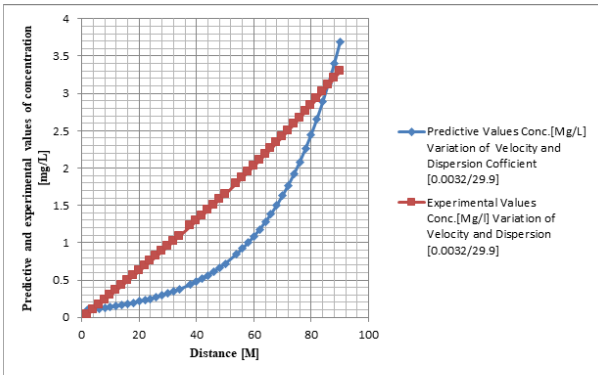

Figure 2 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances.

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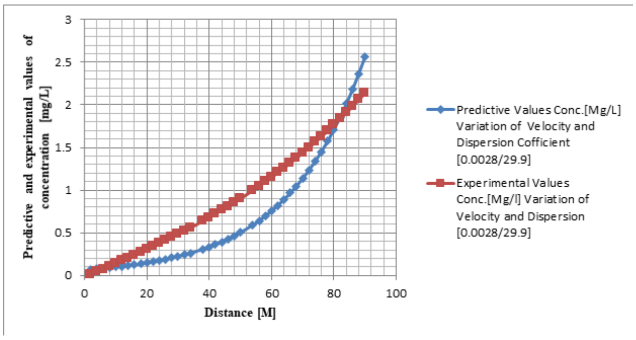

Figure 3 Shows the model's Prediction and Experimental Values for Faecal Coliform Concentrations at Various Distances.

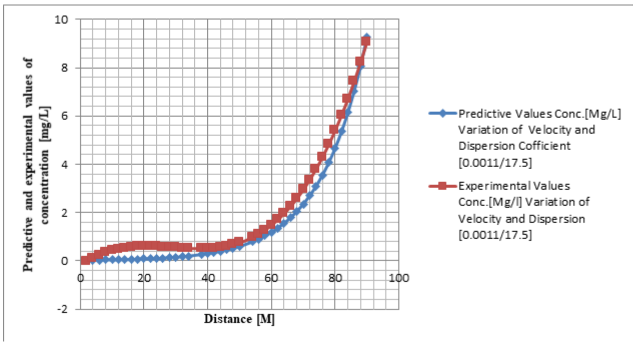

Figure 4 Shows the model's Prediction and Experimental Values for Faecal Coliform Concentrations at Various Distances.

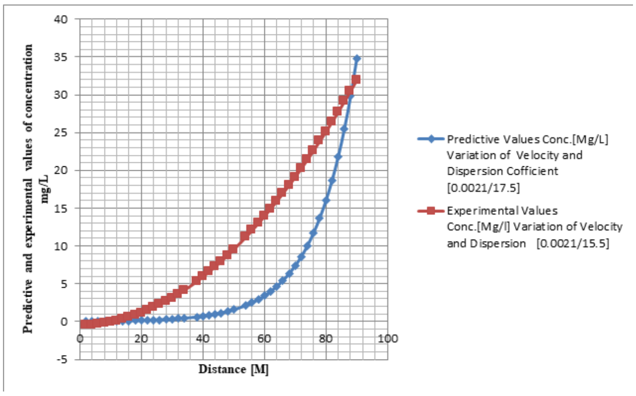

Figure 5 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances.

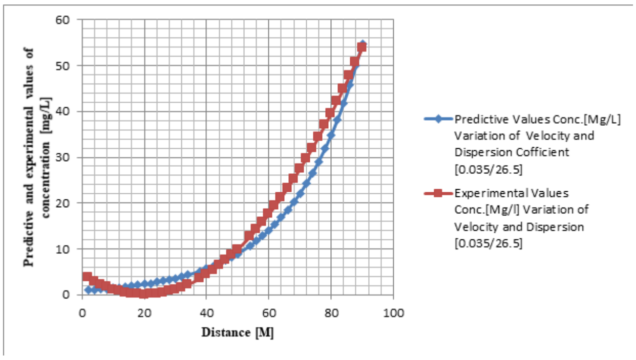

Figure 6 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances.

Table 1 Shows the model's Prediction and Experimental Values for Faecal Coliform Concentrations at Various Distances

Distance [x]	Predictive values conc.[Mg/L] variation of velocity and dispersion coefficient [0.0042/27.5]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.0042/27.5]
2	0.126042926	0.03112
4	0.137548218	0.10196
6	0.150103721	0.16624
8	0.1638053	0.22468
10	0.17875757	0.278
12	0.195074694	0.32692
14	0.212881257	0.37216
16	0.232313216	0.41444
18	0.253518939	0.45448
20	0.276660336	0.493
22	0.301914097	0.53072
24	0.32947304	0.56836
26	0.359547584	0.60664
28	0.392367355	0.64628
30	0.428182938	0.688
32	0.467267795	0.73252
34	0.509920346	0.78056
38	0.607260908	0.89008
40	0.662692134	0.953
42	0.723183165	1.02232
44	0.789195861	1.09876
46	0.861234246	1.18304
48	0.939848348	1.27588
50	1.025638403	1.378
54	1.221426272	1.61296
56	1.332918969	1.74724
58	1.454588803	1.89368
60	1.587364749	2.053
62	1.732260583	2.22592
64	1.890382616	2.41316
66	2.062938146	2.61544
68	2.251244672	2.83348
70	2.456739959	3.068
72	2.680993007	3.31972
74	2.925716041	3.58936
76	3.192777575	3.87764
78	3.484216684	4.18528
80	3.802258571	4.513
82	4.149331558	4.86152
84	4.528085626	5.23156
86	4.941412646	5.62384
88	5.392468463	6.03908
90	5.884696991	6.478

Table 2 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances

Distance [x]	Predictive values conc. [Mg/L] variation of velocity and dispersion coefficient [0.0032/29.9]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.0032/29.9]
2	0.102408622	0.0387048
4	0.111096671	0.1027384
6	0.12052179	0.1668296
8	0.130746508	0.2310072
10	0.141838662	0.2953
12	0.153871841	0.3597368
14	0.166925881	0.4243464
16	0.181087387	0.4891576
18	0.196450315	0.5541992
20	0.213116588	0.6195
22	0.23119678	0.6850888
24	0.250810842	0.7509944
26	0.272088905	0.8172456
28	0.295172137	0.8838712
30	0.320213683	0.9509
32	0.34737968	1.0183608
34	0.376850362	1.0862824
38	0.443504458	1.2236232
40	0.481130086	1.2931
42	0.521947764	1.3631528
44	0.566228295	1.4338104
46	0.614265457	1.5051016
48	0.666377952	1.5770552
50	0.72291152	1.6497
54	0.850773977	1.7971784
56	0.922951168	1.8720696
58	1.001251662	1.9477672
60	1.086194941	2.0243
62	1.178344562	2.1016968
64	1.278311889	2.1799864
66	1.386760152	2.2591976
68	1.504408852	2.3393592
70	1.632038525	2.4205
72	1.770495928	2.5026488
74	1.920699654	2.5858344
76	2.083646229	2.6700856
78	2.260416716	2.7554312
80	2.452183898	2.8419
82	2.66022005	2.9295208
84	2.885905385	3.0183224
86	3.130737206	3.1083336
88	3.396339848	3.1995832
90	3.684475446	3.2921

Table 3 Shows the model's Prediction and Experimental Values for Faecal Coliform Concentrations at Various Distances

Distance [x]	Predictive values conc. [Mg/L] variation of velocity and dispersion coefficient [0.0028/29.9]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.0028/29.9]
2	0.071382281	0.00900792
4	0.077438146	0.04106336
6	0.084007773	0.07321384
8	0.091134748	0.10550688
10	0.098866355	0.13799
12	0.107253889	0.17071072
14	0.116352997	0.20371656
16	0.126224047	0.23705504
18	0.136932529	0.27077368
20	0.148549486	0.30492
22	0.161151993	0.33954152
24	0.174823659	0.37468576
26	0.18965519	0.41040024
28	0.205744985	0.44673248
30	0.223199791	0.48373
32	0.242135413	0.52144032
34	0.262677477	0.55991096
38	0.309137641	0.63932328
40	0.33536398	0.68036
42	0.363815285	0.72234712
44	0.394680316	0.76533216
46	0.428163846	0.80936264
48	0.464488022	0.85448608
50	0.503893835	0.90075
54	0.593018302	0.99688936
56	0.643328251	1.04685984
58	0.697906349	1.09816088
60	0.757114694	1.15084
62	0.821346104	1.20494472
64	0.891026719	1.26052256
66	0.966618835	1.31762104
68	1.048623967	1.37628768
70	1.137586175	1.43657
72	1.234095678	1.49851552
74	1.338792768	1.56217176
76	1.452372053	1.62758624
78	1.575587076	1.69480648
80	1.709255302	1.76388
82	1.854263552	1.83485432
84	2.01157388	1.90777696
86	2.18222996	1.98269544
88	2.367364004	2.05965728
90	2.568204283	2.13871

Table 4 Shows the model's Prediction and Experimental Values for Faecal Coliform Concentrations at Various Distances

Distance [x]	Predictive values conc. [Mg/L] variation of velocity and dispersion coefficient [0.0011/17.5]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.0011/17.5]
2	0.022082347	-0.03668
4	0.02533143	0.11156
6	0.029058567	0.23564
8	0.033334096	0.33748
10	0.038238704	0.419
12	0.043864952	0.48212
14	0.050319016	0.52876
16	0.057722699	0.56084
18	0.066215721	0.58028
20	0.075958364	0.589
22	0.087134489	0.58892
24	0.099955012	0.58196
26	0.114661881	0.57004
28	0.131532644	0.55508
30	0.150885684	0.539
32	0.173086231	0.52372
34	0.198553254	0.51116
38	0.261279889	0.50188
40	0.299723275	0.509
42	0.343823024	0.52652
44	0.394411385	0.55636
46	0.452443059	0.60044
48	0.519013216	0.66068
50	0.595378165	0.739
54	0.783469107	0.95756
56	0.898744744	1.10164
58	1.030981448	1.27148
60	1.182674783	1.469
62	1.356687501	1.69612
64	1.556303559	1.95476
66	1.785290103	2.24684
68	2.047968555	2.57428
70	2.349296171	2.939
72	2.694959591	3.34292
74	3.091482159	3.78796
76	3.546347028	4.27604
78	4.068138387	4.80908
80	4.666703457	5.389
82	5.35333833	6.01772
84	6.141001145	6.69716
86	7.044556637	7.42924
88	8.081056661	8.21588
90	9.270061997	9.059

Table 5 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances

Distance [x]	Predictive values conc. [Mg/L] variation of velocity and dispersion coefficient [0.0021/17.5]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.0021/15.5]
2	0.038006482	-0.469408
4	0.044377655	-0.421408
6	0.051816852	-0.341408
8	0.060503111	-0.229408
10	0.070645481	-0.085408
12	0.082488055	0.090592
14	0.096315846	0.298592
16	0.112461642	0.538592
18	0.131314021	0.810592
20	0.153326697	1.114592
22	0.179029442	1.450592
24	0.209040837	1.818592
26	0.244083159	2.218592
28	0.284999759	2.650592
30	0.332775368	3.114592
32	0.388559786	3.610592
34	0.45369556	4.138592
38	0.61855438	5.290592
40	0.722245035	5.914592
42	0.843317755	6.570592
44	0.984686361	7.258592
46	1.149753131	7.978592
48	1.342490681	8.730592
50	1.567537569	9.514592
54	2.137131844	11.178592
56	2.495387493	12.058592
58	2.913698918	12.970592
60	3.4021335	13.914592
62	3.972446253	14.890592
64	4.638362732	15.898592
66	5.415909357	16.938592
68	6.32379912	18.010592
70	7.383881944	19.114592
72	8.621670538	20.250592
74	10.06695441	21.418592
76	11.75451678	22.618592
78	13.72497174	23.850592
80	16.02574166	25.114592
82	18.71219851	26.410592
84	21.84899648	27.738592
86	25.51162799	29.098592
88	29.78824053	30.490592
90	34.78175812	31.914592

Table 6 Model Prediction and Experimental Values on Fecal Coliform Concentration at Various Distances

Distance [x]	Predictive values conc. [Mg/L] variation of velocity and dispersion coefficient [0.035/26.5]	Experimental values conc.[Mg/l] variation of velocity and dispersion [0.035/26.5]
2	1.015504788	3.651
4	1.111859812	2.899
6	1.217357372	2.235
8	1.33286495	1.659
10	1.459332333	1.171
12	1.597799431	0.771
14	1.749404823	0.459
16	1.915395121	0.235
18	2.09713522	0.099
20	2.296119523	0.051
22	2.513984227	0.091
24	2.752520777	0.219
26	3.013690598	0.435
28	3.299641222	0.739
30	3.612723947	1.131
32	3.955513173	1.611
34	4.330827566	2.179
38	5.191669134	3.579
40	5.684274788	4.411
42	6.223620772	5.331
44	6.81414199	6.339
46	7.460694146	7.435
48	8.168593671	8.619
50	8.943661443	9.891
54	10.72139917	12.699
56	11.738687	14.235
58	12.85249904	15.859
60	14.07199387	17.571
62	15.4071991	19.371
64	16.86909376	21.259
66	18.46969864	23.235
68	20.2221751	25.299
70	22.14093331	27.451
72	24.24175073	29.691
74	26.54190183	32.019
76	29.06030016	34.435
78	31.81765388	36.939
80	34.83663598	39.531
82	38.14207078	42.211
84	41.76113802	44.979
86	45.72359637	47.835
88	50.0620281	50.779
90	54.81210701	53.811

Conclusion

The system keeps track of the contaminant's behaviour at several station points of discharge that are seen in the research environment. An experimental approach was used to monitor the station points, and it led to concentration variations at various stations spaced uniformly apart. The microorganisms' growth-related behaviour was evaluated, thus, it was found that the concentration of faecal coliform in Ntanwaogba Creek increased gradually and quickly. To identify the variables influencing the faecal coliform's transport behaviour, the reaction of the organism in the rill was evaluated. The pollutant was observed to rise at various station sites in response to micronutrients identified in various stations that support the behaviour, demonstrating the contrast between their effects on the concentration's slow and fast stages of growth.

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Conflicts of interest

The authors declare that they have no competing interests.

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