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Effect of some physicochemical parameters on the decay rate of enteric bacteria isolated from River Owena, Nigeria

Adewale Oluwasogo Olalemi¹ and Abiola Stephen Okunade^{1*}

Abstract

The significance of water in public health cannot be overemphasized. In Nigeria, many people living along the courses of water bodies still source and drink from the rivers and streams. There is, therefore, the need to determine the load of contamination and effect of pH and salinity on the decay rate of enteric bacteria in water samples from River Owena, Owena, Nigeria, in order to develop adequate water quality management. Water samples from River Owena were collected from three sampling points (inflow, middle course and the outflow) along the River Owena, Nigeria. The load of enteric bacteria in the water samples was enumerated using membrane filtration technique. The physicochemical parameters of the water samples were determined using standard methods. The incidence and prevalence of gastroenteritis in the community around River Owena was determined using a structured questionnaire. Microcosm studies were used to determine the decay rate of enteric bacteria at varying salinity and pH. Canonical correlation analysis was used to describe the relationship between the load of enteric bacteria and the incidence and prevalence of gastroenteritis in the community around River Owena. The incidence and prevalence of gastroenteritis in the community around River Owena were estimated to be 0.75 and 0.51, respectively. *Escherichia coli* had positive relationships with incidence ($r=0.76$) and prevalence ($r=0.65$). Similarly, faecal coliforms had positive relationships with incidence ($r=0.82$) and prevalence of gastroenteritis ($r=0.67$), while enterococci showed positive relationship with incidence ($r=0.59$) and prevalence of gastroenteritis ($r=0.87$). Increase in pH and salinity increased the decay rate of enteric bacteria thereby reducing the growth of enteric bacteria, the optimum pH for the growth and survival of enteric bacteria ranged between pH 5.0 and pH 7.0. The optimum salinity for the growth of enteric bacteria isolated in water samples from River Owena ranged between 10 and 50% salinity. Findings revealed high levels of faecal contamination at the different representative monitoring points on River Owena, pH and salinity influenced the load and decay rate of enteric bacteria in water from River Owena.

Keywords Enteric bacteria, Physicochemical parameters, Gastroenteritis, Microcosm, Decay rate

Background

In Nigeria, a large majority of people living along the course of water bodies still source and drink from rivers, streams and other water bodies not minding the present

chemical and microbiological state of these water bodies without any form of treatment [22]. The microflora present varies considerably between different water types, and it is generally accepted that sewage-polluted surface waters contain greater number of microorganisms than unpolluted waters. Polluted surface waters can contain a large variety of pathogenic microorganisms including viruses, bacteria and protozoa. These pathogens, often of faecal source, might be from point sources such as municipal wastewater treatment plants and drainage

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from areas where livestock are handled or from non-point sources such as domestic and wild animal defecation, malfunctioning sewage and septic systems, storm water drainage and urban runoff [7].

Several studies published on the survival of culturable indicator bacteria in environmental waters depends on laboratory microcosm experiments. While a great deal of information was obtained from such studies, including the relationship between salinity and *E. coli* survival, the persistence of faecal indicator bacteria in environmental waters is affected by a complex array of physical, chemical, and biological factors that are difficult to simulate in the laboratory [16].

Waterborne disease outbreaks may occur when surface waters contaminated with enteric pathogens are used for agricultural (irrigation), recreational (swimming) and/or domestic (drinking, bathing) purposes [15] This is because the probability of ingesting infective dose of disease causing microorganism is very high when microbially contaminated water are used for agricultural, recreational or domestic activities. Studies have demonstrated that physicochemical parameters such as pH and salinity oftentimes have effect on the decay rate constant of waterborne pathogens [19]. High cases of diarrhoea and other water-related diseases have been reported in Owena community. Hence, the need to determine the effect of pH and salinity on the decay rate constant of enteric bacteria in water from River Owena, Owena, Nigeria. This is to gain a better understanding of how these parameters contribute to the die-off rates of the bacteria especially those implicated in gastroenteritis in the water from the river in Owena community.

The objectives of the study are to determine the load of enteric bacteria in water samples from River Owena, Nigeria; examine physicochemical characteristics of the water samples from River Owena; determine the incidence and prevalence of gastroenteritis in the community around River Owena; investigate the relationship between incidence and prevalence of gastroenteritis and the load of enteric bacteria in water samples from River Owena; and assess the effect of varying pH and salinity on the decay rate constant of the enteric bacterial isolates from River Owena.

Description of study area

Owena town lies on the Benin–Ilesha highway, the community is straddled between Ondo and Osun States [12]. The location of the town puts it at a vantage point with free access to traders from different parts of the country. The Owena River runs through the community and serves a boundary between Ondo and Osun States on the axis. River Owena supplies water to many towns in the present day Ondo States, this made the Ondo State

government to take over the management of the Owena water works. River Owena is located about 4 km from Joseph Ayo Babalola University Ikeji Arakeji along Ilesha–Akure express way in Oriade local government area of Osun State, Nigeria on latitude N7.403135 and longitude E5.014589. It is a fresh water and free-flowing water body during raining season but slow-moving at the onset of dry season. The study area experiences a frequent rainfall between April and July with a short break in August and continues between September and November, with the heaviest rainfall in July [4]. The river was selected due to its close proximity to sources of faecal contamination, its use for recreational activities as well as the use of the water for domestic uses. The three sampling points covers the point of entry of the river, the middle portion of the river as well as the point of exit of the river (see Fig. 1).

Sample collection

Water samples were collected during wet and dry season from the three sampling points. Sample collection was done at the three different sampling points weekly for 16 weeks, 48 samples were collected in total for the study. Sterile bottles of 500 ml were used for sample collection. Samples for microbial analysis were collected aseptically, labelled and stored in ice packed plastic coolers and transported to the laboratory in the Department of Microbiology at the Federal University of Technology, Akure, Nigeria where analysis was done within one hour of collection.

Enumeration of faecal indicator bacteria in the River water samples

The concentrations of *Escherichia coli*, faecal coliforms, *Salmonella*, *Shigella* and intestinal enterococci in the water samples were determined using standard microbiological methods as described by Maheux et al. [9]. Using membrane filters (0.45 μm) (Merck HAWP04700) (Darmstadt, Germany), the concentrations of the bacteria were determined by placing the filters on freshly prepared selective media: M-lauryl sulphate agar (MLSA), eosin methylene blue (EMB), membrane faecal coliform agar (m-FC agar), membrane intestinal enterococci agar (m-EA) and *Salmonella–Shigella* agar (SSA). Agar plates were incubated at 37 °C for 24 h (MLSA, EMB, SSA), 44 °C for 24 h (m-FC) and 37 °C for 48 h (m-EA). Colonies were counted recorded and expressed as colony forming unit (CFU) per 100 ml of water utilizing a colony counter (J-2 PEC MEDICAL, New Jersey, USA). Inoculated *m-Clostridium perfringens* agar plates were incubated in the anaerobic jar with desiccants for 24 h. *Clostridium perfringens* colonies exhibit greenish yellow colouration. Colonies were counted and expressed as log₁₀ (CFU) 100 ml⁻¹ of water. Inoculated *Bifidobacterium* agar

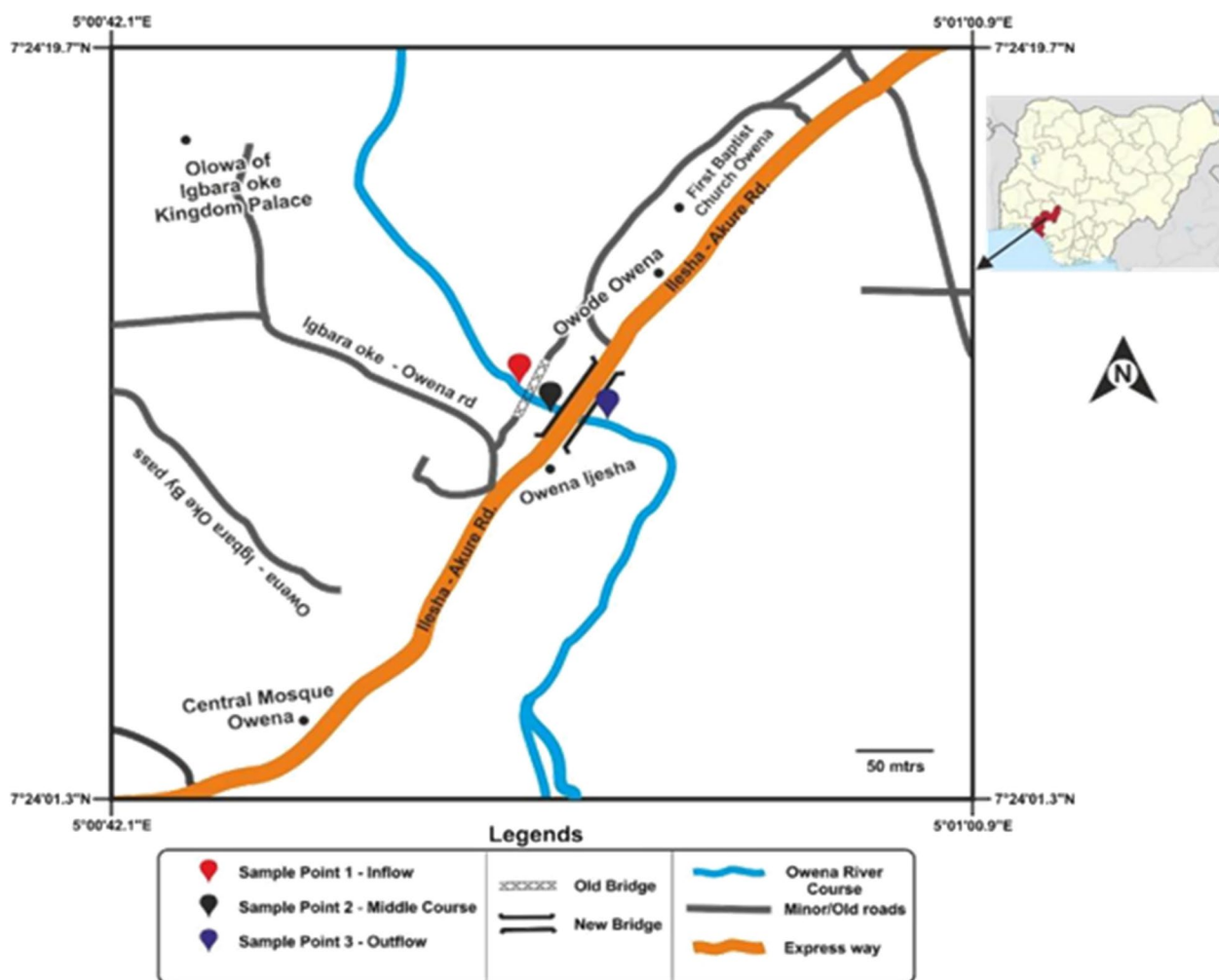


Fig. 1 Locality map showing the sampling points along River Owena

plates were incubated at 37 °C for 48 h. Colonies of enterococci exhibit brown colouration on this agar. Colonies were counted and expressed as log₁₀ (CFU) 100 ml⁻¹ of water.

Determination of physicochemical properties of water samples from River Owena

Physicochemical parameters (temperature and pH) of water samples were measured in situ using standardized handheld pH meter (HANNA) and thermometer (Mercury in glass), while electrical conductivity, total dissolved solids, salinity, turbidity and dissolved oxygen were measured at the Department of Marine Science Technology Laboratory, Federal University of Technology, Akure. The analysis was carried out in triplicates and the mean results were adequately recorded and tabulated.

Determination of the incidence and prevalence of gastroenteritis in Owena

A structured questionnaire was used to access the record of occurrence of gastroenteritis in the population living around River Owena was accessed and was used to determine the incidence and prevalence of gastroenteritis in the locality using the formula below:

$$\text{Prevalence} = \frac{\text{Number of current cases}}{\text{Total number of population at risk}} \times 100,$$

$$\text{Incidence} = \frac{\text{Total number of cases}}{\text{Total number of population at risk}} \times 100.$$

Effects of varying pH on the decay rate of enteric bacterial isolates from River Owena

About 10 ml of the water samples from River Owena was adjusted to pH 2, 5, 7, 11 and 14. The inoculum was adjusted to McFarland standard of 0.5 according to the method modified by Bayode et al. [5] using spectrophotometry (Buck Scientific Model 210 VGP Flame Atomic Absorption Spectrometer, UK). Thereafter, the water samples at varying pH were inoculated with 24-h-old culture of each isolate, then incubated at appropriate temperature for 24 h. The bacterial count in the water samples were determined after incubation. The decay rate for each isolate was determined using the formula below:

$$r = \frac{\ln(Nt) - \ln(N_0)}{t}$$

r, decay rate; Nt, log₁₀ (CFU/100 ml) at time t; N₀, log₁₀ (CFU/100 ml) at time zero; t, time in days; formula according to Ref. [16].

Effects of varying salinity on the decay rate of enteric bacterial isolates from River Owena

About 10 ml of the water samples from River Owena were adjusted to 20%, 40%, 60%, 80% and 100% salinity levels. The inoculum was adjusted to McFarland standard of 0.5 according to the method modified by Bayode et al. [5] using spectrophotometry (Buck Scientific Model 210 VGP Flame Atomic Absorption Spectrometer, UK). Thereafter, the water samples at varying salinities were inoculated with 24-h-old culture of each isolate, then incubated at appropriate temperature for 24 h. The bacterial count in the water samples was determined after incubation. The decay rate for each isolate was determined using the formula below:

$$r = \frac{\ln(Nt) - \ln(N_0)}{t}$$

r, decay rate; Nt, log₁₀ (CFU/100 ml) at time t; N₀, log₁₀ (CFU/100 ml) at time zero; t, time in days; formula according to Ref [16].

Statistical analysis

Statistical analysis was undertaken for all data using SPSS v20.0 and means were separated using Duncan's new multiple range test. Canonical correlation analysis was used to evaluate the relationship between levels of enteric bacteria in the water samples and the incidence and

prevalence of gastroenteritis in the community around River Owena.

Results

Load of bacteria in water samples from River Owena

The mean load of *Salmonella* in water samples from River Owena over a sampling period of 16 weeks was highest (5.39 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.23 log₁₀ CFU/100 ml⁻¹) in the inflow sampling point, while the mean load of *Shigella* in water samples from River Owena over a sampling period of 16 weeks was highest (5.31 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.10 log₁₀ CFU/100 ml⁻¹) was recorded in the inflow sampling point, as shown in Fig. 2. Similarly, the mean load of *Bifidobacterium* in water samples from River Owena over a sampling period of 16 weeks was highest (5.39 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.15 log₁₀ CFU/100 ml⁻¹) in the inflow sampling point, and similar data were obtained for *E. coli* which shows the highest mean load of (5.54 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.38 log₁₀ CFU/100 ml⁻¹) in the inflow sampling point, as shown in Fig. 3. The mean load of faecal coliforms in water samples from River Owena over a sampling period of 16 weeks was highest (5.73 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.63 log₁₀ CFU/100 ml⁻¹) in the inflow sampling point, as the mean load of *Clostridium* in water samples from River Owena over a sampling period of 16 weeks was highest (5.41 log₁₀ CFU/100 ml⁻¹) in the outflow sampling point and lowest (5.11 log₁₀ CFU/100 ml⁻¹) in the inflow sampling point, as shown in Fig. 4.

Physicochemical characteristics of water samples from River Owena

The physicochemical characteristics of water samples from River Owena measured in this study were temperature, pH, salinity, dissolved oxygen, total dissolved solids and electrical conductivity. The mean temperature of water samples from River Owena was lowest (25.37 °C) in the middle course sampling point and highest (26.00 °C) in the outflow sampling point. The mean pH value of water samples from River Owena was lowest (7.06) in the middle course and highest (7.16) in the outflow sampling point. The mean values of electrical conductivity of water samples from River Owena was lowest (217.68 μS/cm) in the middle course sampling point and highest (244.18 μS/cm) in the outflow sampling point. The mean values of total

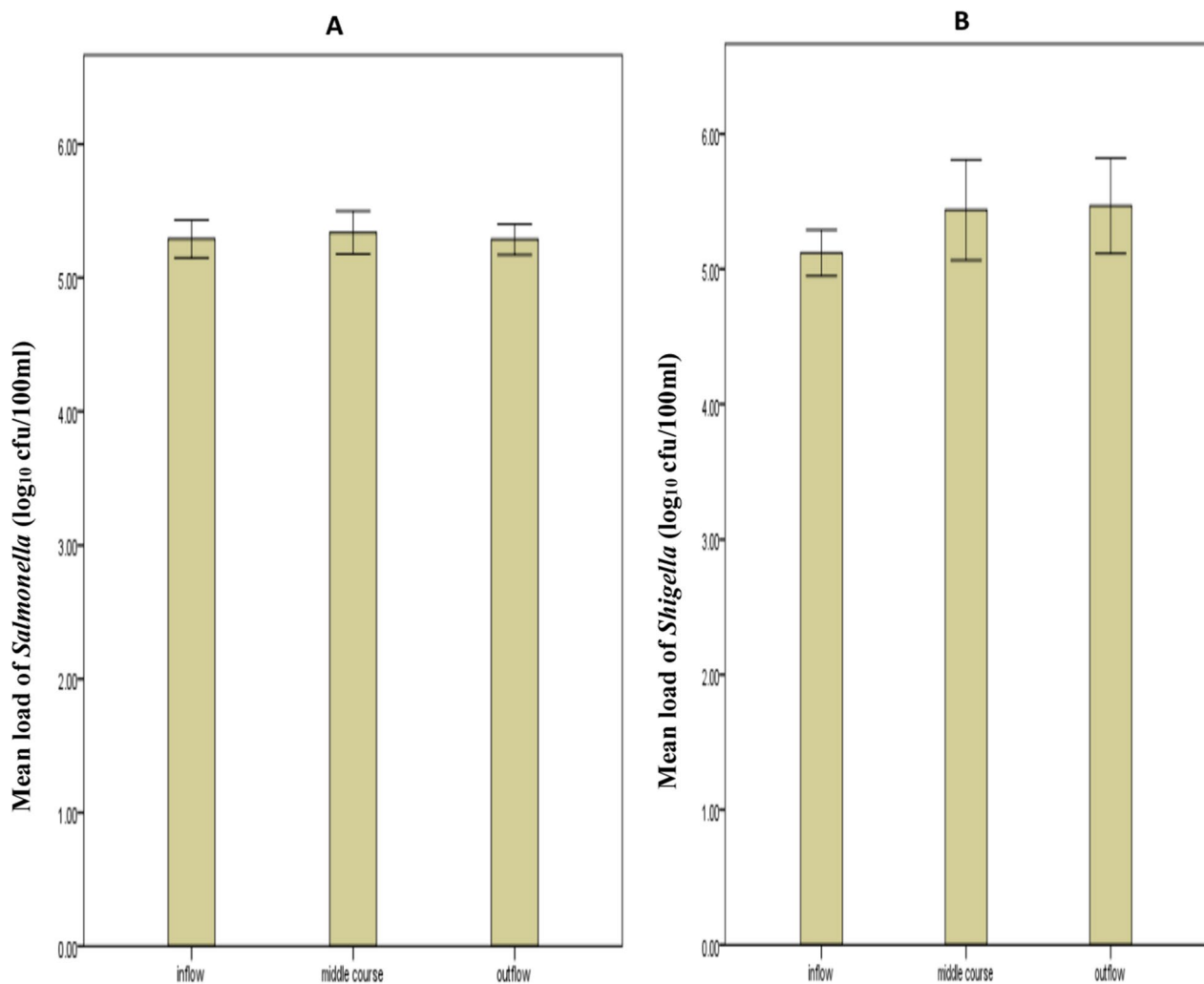


Fig. 2 Mean load of *Salmonella* in water samples (A); mean load of *Shigella* in water samples (B) from River Owena ($n = 48$)

dissolved solids in water samples from River Owena was lowest (87.68 mg/L) at the inflow sampling point and highest (92.87 mg/L) at the outflow sampling point. The mean values of salinity in water samples from River Owena were lowest (0.06 ppt) at the middle course sampling point and highest (0.11 ppt) at the outflow sampling point. The mean values of dissolved oxygen in water samples from River Owena was lowest (4.21 mg/L) in the middle course sampling point and highest (4.38 mg/L) in the outflow sampling point. The mean values of turbidity in water samples from River Owena was lowest (32.4 NTU) in the middle course sampling point and highest (33.60 NTU) in the outflow sampling point (Table 1).

Incidence and prevalence of gastroenteritis in the community around River Owena

Eighty-five residents of Owena community were interviewed on their knowledge of gastroenteritis in order to

estimate the incidence and prevalence of gastroenteritis between February 2020 and February 2021. The demographic characteristics of frequency of occurrence of gastroenteritis in Owena community are shown in Table 2. Out of the 85 respondents, 34 of the respondents were males representing 40% of the total respondents while 51 were females representing 60% of the total respondents.

Twenty-three (23) of the respondents representing 27% were between the age range 0–10, seventeen (17) of the respondents representing 20% were between 11 and 20 years, 26 of the respondents representing 30% were between the age range 21–30 years, 19 of the respondents representing 22% were between the age range 31–40 years. Forty-six of the respondents representing 54% had gastroenteritis with symptoms of vomiting and diarrhoea at the time of administering the questionnaire and 68 of the respondents representing 80% had a history of gastroenteritis as at the period of data collection.

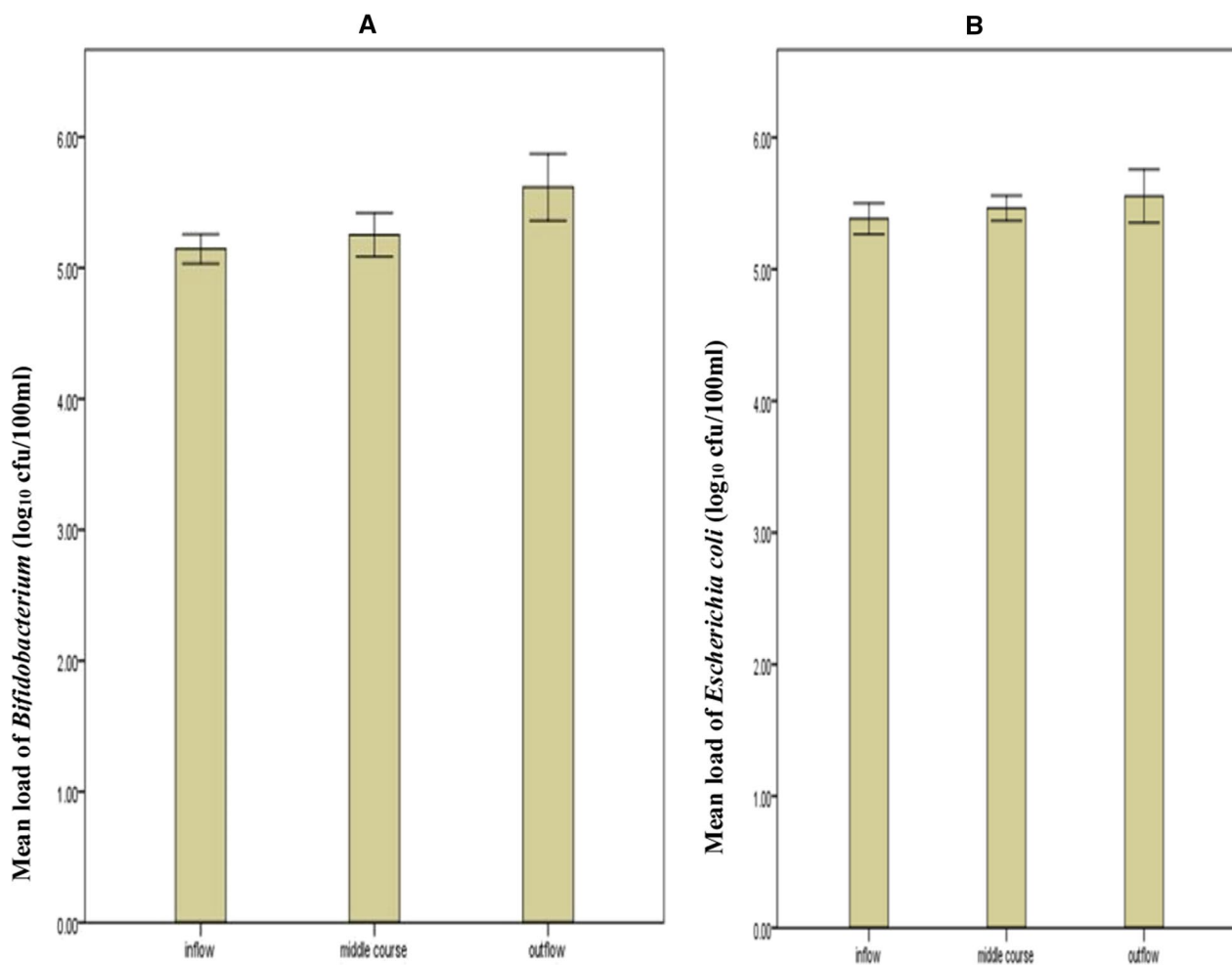


Fig. 3 Mean load of *Bifidobacterium* in water samples (A); mean load of *Escherichia coli* in water samples (B) from River Owena ($n = 48$)

Fifty-one of the respondents representing 60% used the water from River Owena as a source of drinking water while 69 of the respondents representing 81% make use of the water from the River for recreational activities (bathing or swimming) and agricultural activities. The incidence and prevalence of gastroenteritis in Owena community were estimated to be 75 per 1000 and 51%, respectively, among residents of Owena community.

Relationship between levels of enteric bacteria in water samples from River Owena and the incidence and prevalence of gastroenteritis in Owena community

The relationship between the levels of enteric bacteria in water samples from River Owena and the incidence and prevalence of gastroenteritis in Owena community was determined using a multivariate statistical technique called canonical correlation analysis. Strength of

correlation is classified as “high”, “moderate”, or “low”, corresponding to their canonical correlation coefficients values of >0.75 , $0.75-0.50$, and $0.50-0.30$, respectively. The canonical correlation analysis yielded two canonical functions; the first was statistically significant having a squared canonical correlation of 0.74 and the second function was not statistically significant having a squared canonical correlation of 0.23 (Fig. 5). The first canonical function accounted for 73.92% of the total variance in the dependent variables and 10.5% of the total variance in the independent variables. The second function accounted for 23.21% of the variance in the dependent variables and 14.13% in the independent variable set. The first function exhibited high positive correlation with *Shigella* ($r = 0.87$), *E. coli* ($r = 0.70$) and enterococci ($r = 0.92$) and moderate positive correlation with *Salmonella* ($r = 0.61$). The second function showed high positive correlation

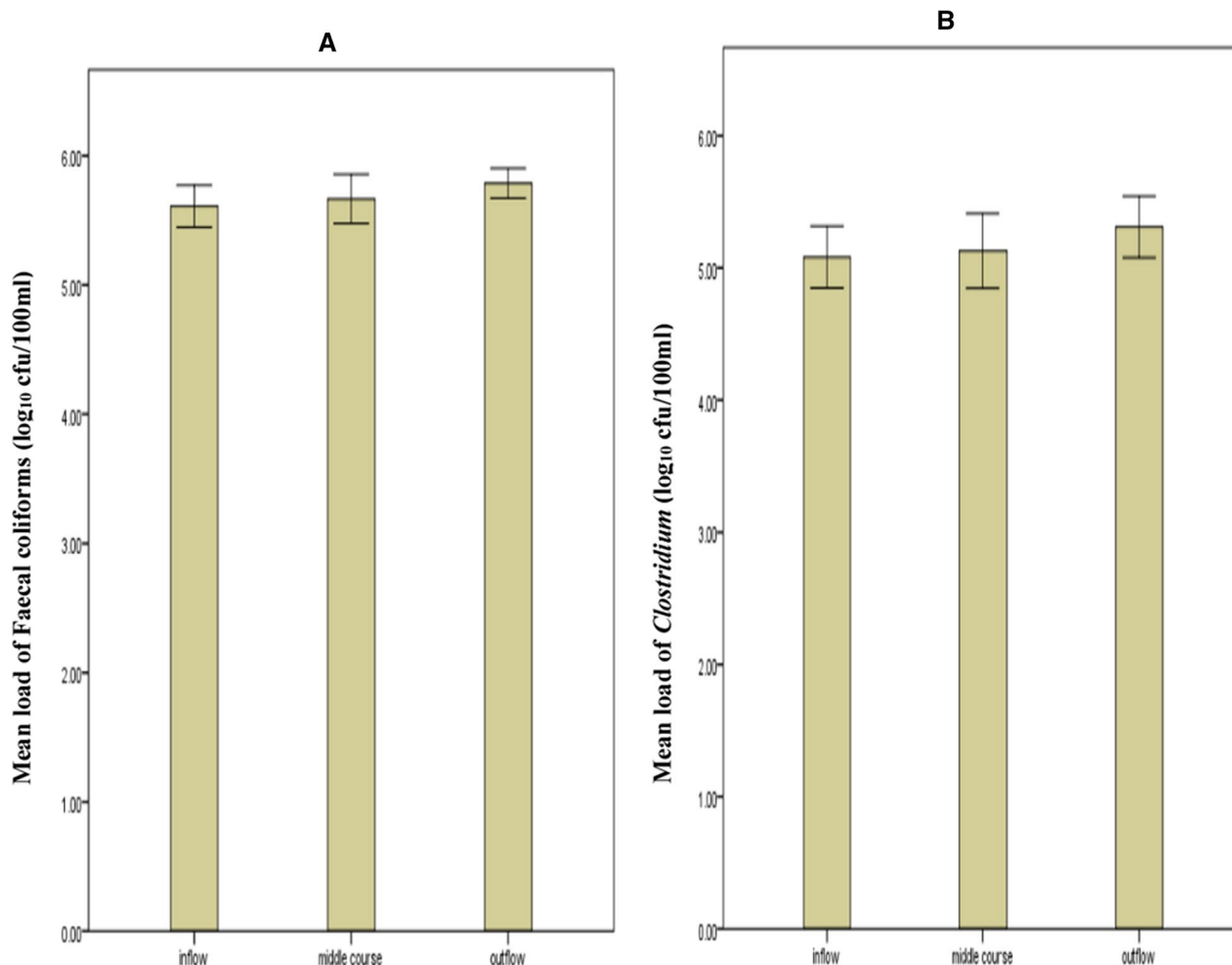


Fig. 4 Mean load of faecal coliforms in water samples (A); mean load of *Clostridium* in water samples (B) from River Owena (n=48)

Table 1 Physicochemical characteristics of water samples from River Owena

Parameters	Inflow	Middle course	Outflow
Temperature (°C)	25.75 ^a ± 2.72	25.37 ^a ± 2.13	26.00 ^a ± 2.42
pH	7.08 ^b ± 0.25	7.05 ^{bc} ± 0.28	7.16 ^{ab} ± 0.26
Electrical conductivity (µs/cm)	229.50 ^c ± 6.10	217.69 ^c ± 5.72	244.19 ^{bc} ± 9.93
Total dissolved solids (mg/l)	87.68 ^d ± 2.65	93.56 ^{cd} ± 2.79	92.87 ^c ± 2.87
Salinity (ppt)	0.09 ^b ± 0.03	0.10 ^{bc} ± 0.03	0.11 ^c ± 0.03
Dissolved oxygen (mg/l)	4.23 ^b ± 2.21	4.23 ^b ± 1.79	4.38 ^b ± 2.11
Turbidity (NTU)	33.60 ^c ± 2.01	32.46 ^{bc} ± 0.12	35.53 ^{cd} ± 4.39

Values with the same superscript are not statistically different from each other at (p = 0.05)

with *Salmonella* (r = 0.76), and moderate positive correlation with *Shigella* (r = 0.50), *E. coli* (r = 0.52), enterococci (r = 0.61), and coliforms (Table 3).

Effects of varying pH on the decay rate of enteric bacteria
 The pH values as determined by the physicochemical characteristics of the water samples was varied using

Table 2 Demographic characteristics of respondents to questionnaire in the community around River Owena

Age range	Gender			Respondents who used water for recreational activities	Respondents who drink water from River Owena	Respondents who had gastroenteritis	Respondents with history of gastroenteritis
	Male	Female	Total				
0–10	8	15	23 (27.1%)	19 (22.4%)	6 (7.0%)	12 (14.1%)	21 (24.7%)
11–20	7	10	17 (20.0%)	21 (24.7%)	14 (16.5%)	15 (17.6%)	18 (21.2%)
21–30	10	16	26 (30.6%)	18 (21.2%)	16 (18.8%)	10 (11.8%)	19 (22.4%)
31–40	9	10	19 (22.3%)	10 (11.8%)	15 (17.6%)	9 (10.6%)	10 (11.8%)
Total	34	51	85 (100%)	68 (80.0%)	51 (60.0%)	46 (54.1%)	68 (80%)

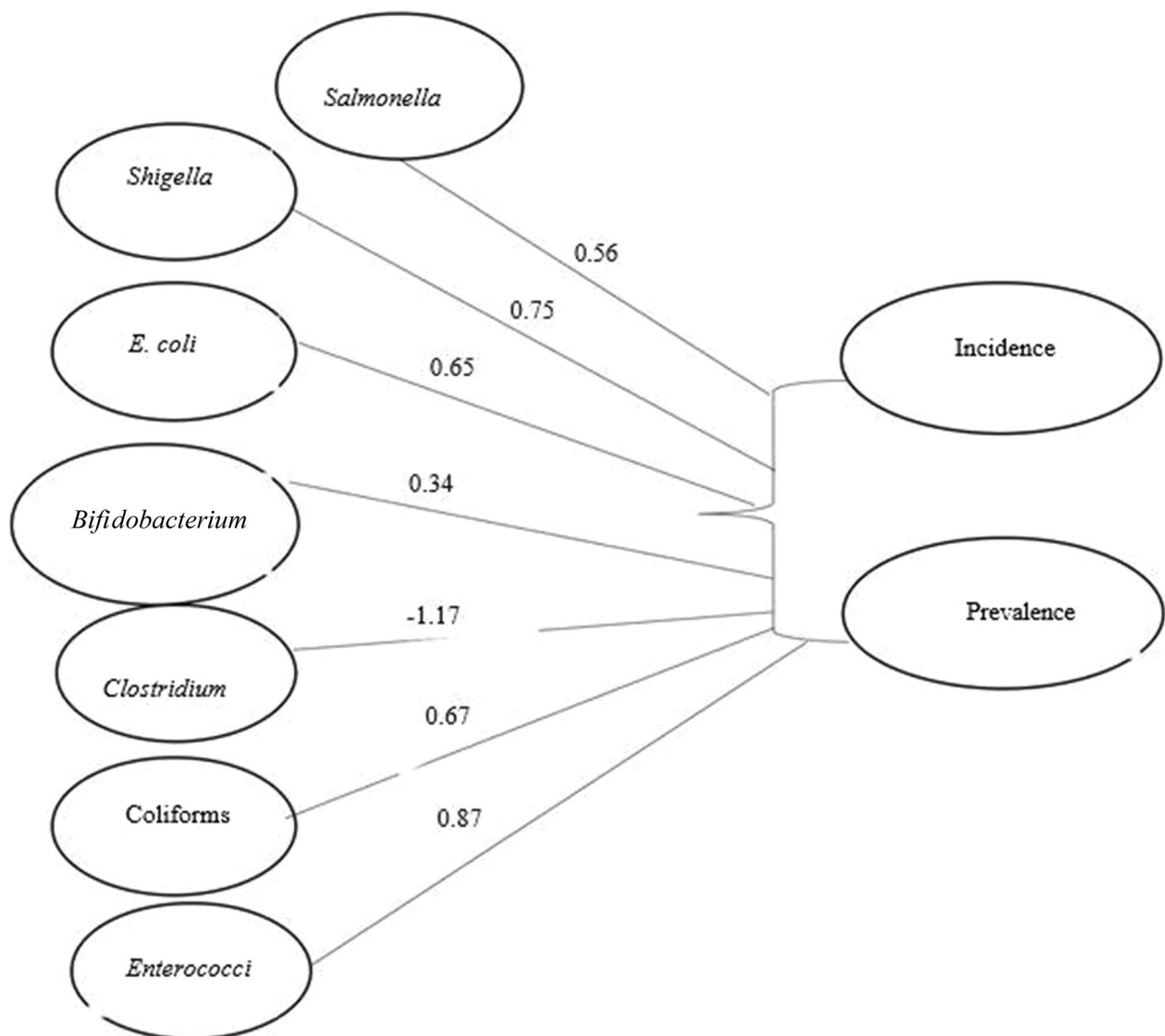


Fig. 5 Canonical correlation coefficients between the independent variables (*Salmonella*, *Shigella*, *E.coli*, *Bifidobacterium*, *Clostridium*, coliforms and *Enterococci*) and dependent variables (incidence and prevalence of gastroenteritis in Owena community)

Table 3 Standardized canonical coefficients for independent variables and canonical variates

Function	1	2
<i>Salmonella</i>	0.56^a	0.47 ^c
<i>Shigella</i>	0.75^{ab}	0.50^{ab}
<i>Bifidobacterium</i>	0.34 ^c	0.46 ^a
<i>E. coli</i>	0.65^{ab}	0.52^a
<i>Clostridium</i>	-1.17 ^d	0.38 ^{bc}
Coliforms	0.58^{bc}	0.67^{ab}
<i>Enterococci</i>	0.87^b	0.58^{bc}

Bold values indicate strong correlation between the microorganisms and the incidence and prevalence of gastroenteritis in Owena community, Nigeria

Values with the same superscript are not statistically different from each other at ($p=0.05$)

microcosm set up, this makes it possible to determine the effect of pH on the decay rate of enteric bacteria isolated in water samples from River Owena. The decay rate of enteric bacteria showed clearly differences in survival at varying pH levels. The decay rate results largely followed first order kinetics, thus results with more negative decay rates indicates a rapid decline in the number of organisms enumerated. At pH 5 the enteric bacteria (*E. coli*, *Salmonella*, *Shigella*, *Bifidobacterium* and *Clostridium*) showed a decay rate of 0.58, 0.74, 0.74, 0.33 and 0.44, respectively (Figs. 6 and 7). While at pH 7 the decay rates of enteric bacteria (*E. coli*, *Salmonella*, *Shigella*, *Bifidobacterium* and *Clostridium*) were estimated to be -0.04, 0.32, 0.04, -0.27 and -0.55 (Figs. 6 and 7). The sharp and abrupt decrease in the number of cells enumerated and subsequently the decay rate of enteric bacteria is an indication that an increase in pH have a negative effect on the decay rate of enteric bacteria, this may be due to the fact that the organisms lack the ability to fully adjust to the change in pH values. It is important to note that no growth was observed at pH 2, 11, 12 and 14.

Effects of varying salinity on the decay rate constant of enteric bacteria

Generally, under all experimental conditions lesser decay rates were observed between 10 and 50% salinity levels, this indicates that the optimum salinity level for the growth of enteric bacteria is between 10 to 50%, at this range there is tendency of extensive growth of the enteric bacteria in surface waters, meanwhile, the concentration of enteric bacteria reduced significantly at salinity level higher than 50%.

At 10% salinity, all the enteric bacteria (*E. coli*, *Salmonella*, *Shigella*, *Bifidobacterium* and *Clostridium*) exhibited a positive decay rate of (-2.87, -1.48, -1.75, -1.04 and -1.12), respectively (Fig. 8). This is an indication

that at 10% salinity levels the growth and survival of enteric bacteria was not disrupted. Similar decay rate values were obtained at 30% salinity level, all the enteric bacteria (*E. coli*, *Salmonella*, *Shigella*, *Bifidobacterium* and *Clostridium*) involved in this study showed a positive decay rate of (-0.87, -0.33, -1.04, -0.37 and -0.51), respectively, at 30% salinity (Fig. 8). The enormous decrease observed in the number of viable cells of enteric bacteria indicate that the growth and survival of enteric bacteria was adversely affected due to the increase in the salinity level of the medium, therefore forcing the organisms to lose some of their replicating ability.

Interestingly, at 50% salinity level, the decay rate of enteric bacteria further decreased, this indicate that the growth and survival of enteric bacteria were affected by the increase in the salinity content of the medium. The enteric bacteria (*E. coli*, *Salmonella*, *Shigella*, *Bifidobacterium* and *Clostridium*) involved in this study showed decay rate of (-0.37, -0.08, -0.41, -0.20 and -0.12), respectively, at 50% salinity level (Fig. 8).

Discussion

The high level of *E. coli* which ranged between 5.54 log₁₀ and 5.38 log₁₀ CFU/100 ml⁻¹ in Owena River suggests the presence of potentially harmful pathogenic bacteria in the river. The overall load of *E. coli* observed in this study appeared to be higher than those obtained by Cho et al., [8] where the authors observed a mean load of 4.2 log₁₀ CFU/100 ml⁻¹ from the Upper Oconee Watershed in Northeast Georgia. The population of *E. coli* in the water samples obtained from Owena River was influenced by the extent of faecal pollution, lack of hygienic practices and indiscriminate channeling of waste water into the river. The levels of faecal coliforms observed in Owena River during the period of this study exceeds limit set by WHO guidelines on the concentration of faecal coliforms (Zero CFU/100 ml) in a surface water that can be used for domestic, agriculture, bathing or other recreational activities [21]. The mean load of faecal coliforms in water samples from River Owena ranged between 5.63 log₁₀ CFU/100 ml⁻¹ and 5.73 log₁₀ CFU/100 ml⁻¹. Bifidobacteria have been recommended as potential indicators of human faecal pollution in surface waters even though very little is known about their presence in non-human faecal sources. Members of the *Bifidobacterium* genus have been described as some of the most common and beneficial bacteria in the intestinal tract of humans [18]. The high load of faecal coliforms (5.73 log₁₀ CFU/100 ml⁻¹) observed in this study could be attributed to the high rate of human activities, farm animal graze in and around the river and from various anthropogenic activities (such as swimming, bathing, irrigation, etc.) taking place within and around the river, similar result

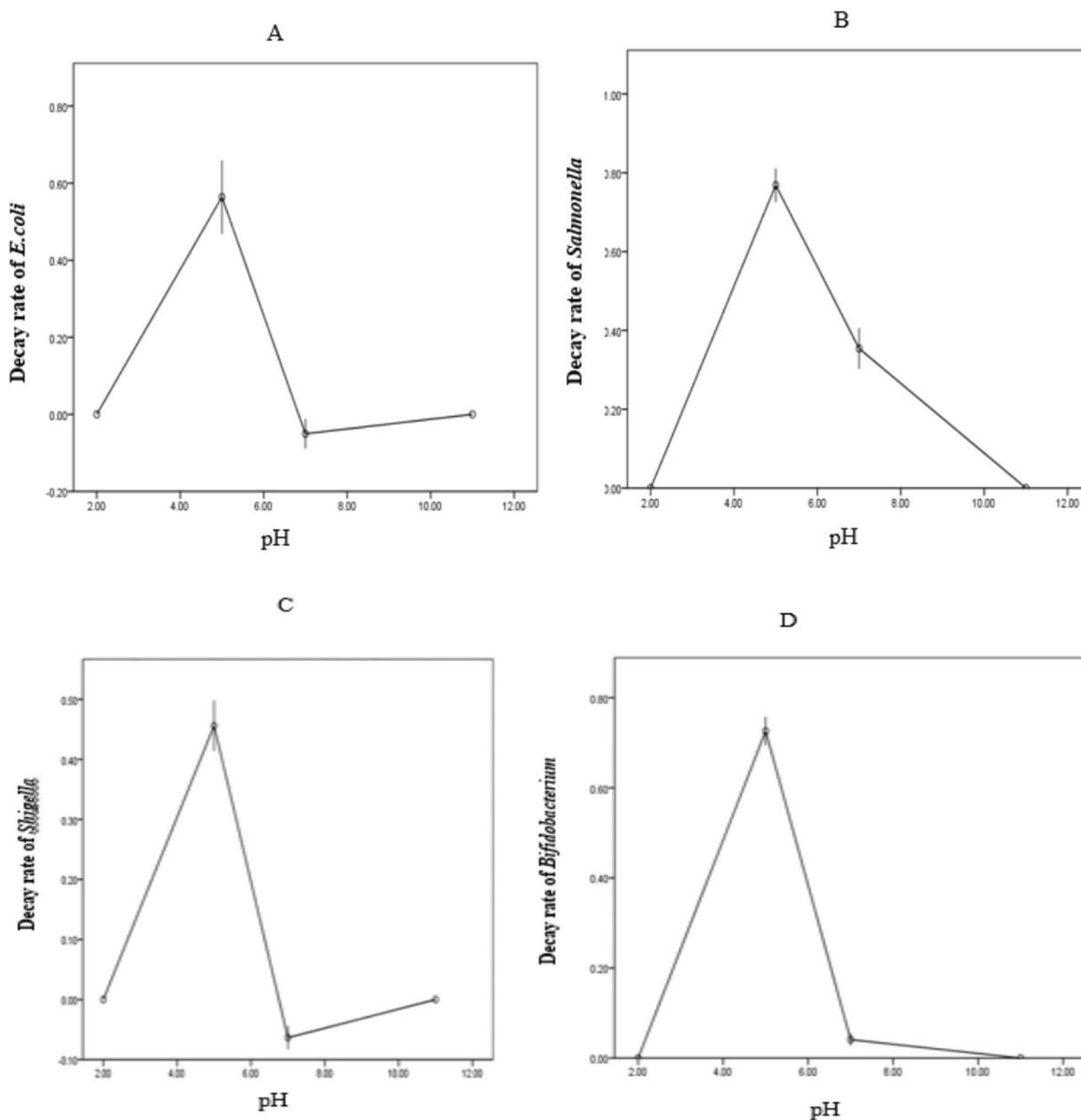


Fig. 6 Decay rate of *E.coli* (A), *Salmonella* (B), *Shigella* (C) and *Bifidobacterium* (D) obtained at varying pH

was obtained in other study carried out by Olalemi [20] where the author evaluated the environmental hazard of faecal indicator bacteria and hepatitis A virus in River Owena. The observation in this study is in line with the report of Farag et al. [11] where the authors stated that discharge of sewage, rainfall, animal husbandry, and wildlife contributed to the presence of *Salmonella* in the

monitoring point thereby rendering the water unfit for domestic activities except treated properly.

Temperature range of 25.37 °C to 26.00 °C was recorded during sampling period. Similarly, this finding conforms to the observation of Ekhaise et al. [10] where the authors reported a temperature range of 26.5 to 27.08 °C while assessing the bacteriological and physicochemical

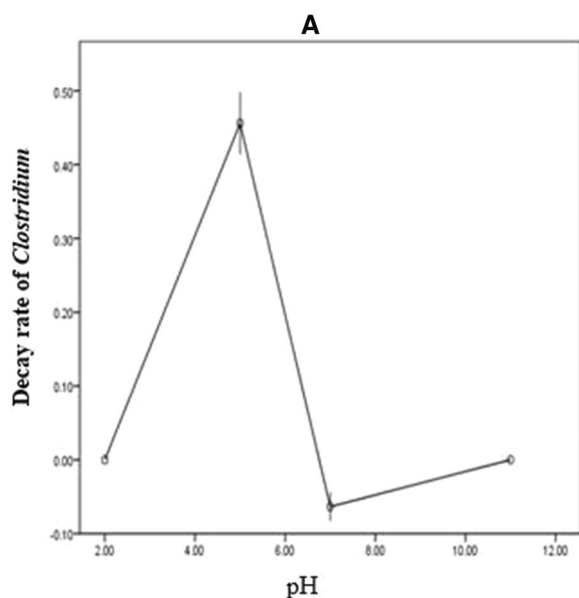


Fig. 7 Decay rate of *Clostridium* (A) obtained at varying pH

qualities of Ebutte River in Ebutte community, Uhunmwonde Local Government Area, Edo State, Nigeria. The mean pH value of water samples from River Owena was lowest (7.06) in the middle course and highest (7.16) in the outflow sampling point. These values were observed to conform to the WHO pH standard of (6.5–9.5) for drinking water; the values also conform to the acceptable limits prescribed by the Bureau of Indian standard of (6.5–8.5). The results observed in this study was similar to the reports observed by Aremu et al., [3] who worked on water samples from surface waters in Eggon, Nassarawa State, Nigeria. Electrical conductivity (EC) of water is the measure of the ability of water to conduct electricity. It measures the ionic process of a solution that enables it transmits electric current. According to the WHO standards EC values should not exceed 400 $\mu\text{S}/\text{cm}$. The mean values of electrical conductivity of water samples from River Owena ranged from 217.68 $\mu\text{S}/\text{cm}$ to 244.18 $\mu\text{S}/\text{cm}$. This result indicates that water from River Owena has a low level of ionic concentration activity. Water with high TDS value indicates that the water is highly mineralized by chemicals introduced into the water body. In this study, the mean values of total dissolved solids in water samples from River Owena ranged from 87.68 mg/L to 92.87 mg/L, this result falls within the permissible limits of 500 mg/L as prescribed by the WHO for drinking water.

In this study, the mean values of salinity in water samples from River Owena ranged from 0.06 ppt to 0.11 ppt. The occurrence of dissolved oxygen in drinking water may be mainly attributed to factors such as direct diffusion from the air and photosynthetic activities by aquatic autotrophs. Dissolved oxygen is an important factor that determines the quality of water in lakes and rivers. This observation is in line with the work of Aiyesanmi et al. [2] in the water quality assessment of the Owena multi-purpose dam, Ondo State, Southwestern Nigeria. The mean values of turbidity in water samples from River Owena ranged from 32.4 NTU to 33.60 NTU.

The turbidity values of River Owena compares favourably with a report of Ayo and Arotupin [4] where the authors recorded similar turbidity values in River Owena water samples.

In this study, the incidence and prevalence of gastroenteritis in the community around River Owena was estimated to be 75 per 1000 and 51%, respectively. This may be as result of the high load of enteric bacteria in the water samples and the usage of water from River Owena for domestic activities. This report is supported by the reports of Abdullahi et al., [1] where the authors recorded positive correlation between *Escherichia coli*, *Salmonella* and *Shigella* with the incidence of acute gastroenteritis in children attending some hospitals in Kano metropolis, Kano State, Nigeria. Information about the concentration, growth and decay rates of enteric bacteria in water bodies is essential and crucial for quantitative microbial risk assessment.

Reports from the decay rate estimation of the enteric bacteria revealed that enteric bacteria showed clearly differences in survival at varying pH levels this is in accordance to the report of [6, 23] where the authors concluded that seawater pH, normally around 8, contributes to the deleterious effects on *E. coli* survival. It was observed that the optimum pH for the growth and survival of enteric bacteria is ranged between pH 5.0 and pH 7.0. This report is similar with the report by [14] where the author observed that the optimum pH of enteric bacteria ranged between pH 4.8 and pH 9.3. In this study, it was observed that the increasing salinity has a negative effect on the growth of enteric bacteria isolated in water samples from River Owena, as the salinity content of the medium increases, the growth of enteric bacteria diminishes and the optimum salinity for the growth of enteric bacteria isolated in water samples from River Owena ranged between 10 and 50% salinity. This report compares favourably with

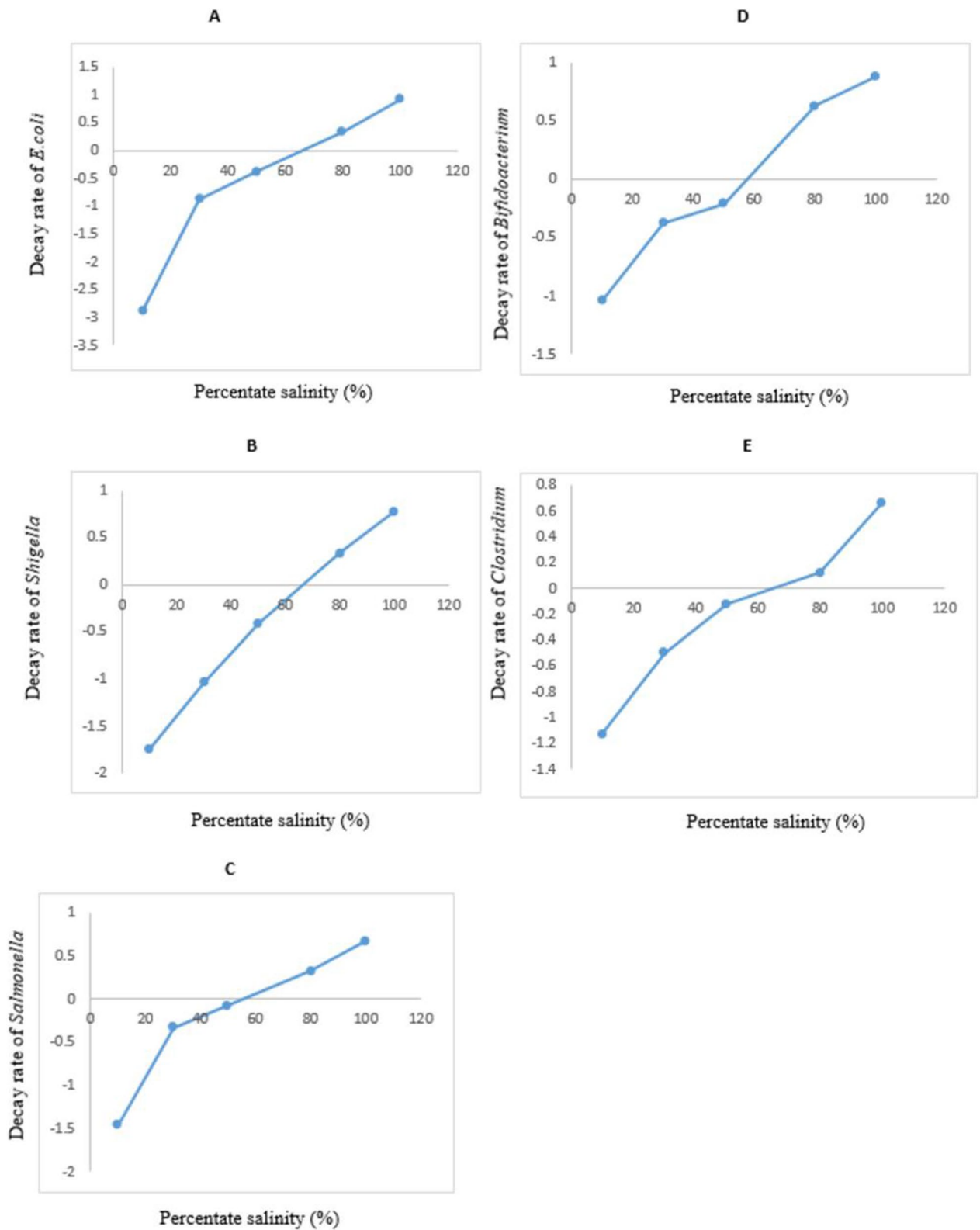


Fig. 8 Decay rate of *E. coli* (A), *Shigella* (B), *Salmonella* (C), *Bifidobacterium* (D) and *Clostridium* (E) obtained at varying salinity

the research done by Korajic et al., [17] where the authors reported that changes in salinity may cause immediate loss of culturability due to sub lethal injury sustained by the enteric bacteria thereby increasing their decay in the marine environment. This report is also supported by the work of Green et al., [13] where the authors recorded significant decay of faecal bacteroides in marine water.

Conclusion

The findings of this study revealed high levels of faecal contamination in water samples from River Owena. The outflow sampling point is the most polluted of the three sampling points. It is demonstrated that physicochemical parameters of the water samples had significant effects on the load of enteric bacteria in water samples from River Owena. The incidence and prevalence of gastroenteritis in the community around River Owena is moderately high. The canonical analysis revealed positive correlation between the incidence and prevalence of gastroenteritis in the community around River Owena and load of enteric bacteria, increase in pH and salinity affect the growth and survival of enteric bacteria negatively.

Abbreviations

WHO	World Health Organization
pH	Potential of hydrogen
EMB	Eosin methylene blue
MLSA	Membrane lauryl sulphate agar
m-EA	Membrane intestinal enterococci agar
m-FC	Membrane faecal coliform agar
m-CP	Membrane coliform agar
SSA	Salmonella Shigella agar
CFU	Colony forming units
Ppt	Parts per trillion
mg/L	Milligram per litre
NTU	Nephelometric turbidity unit
EC	Electrical conductivity

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Author contributions

AOO: designed the study; ASO: managed the literature searches, conducted the experiment, performed the statistical analysis, and wrote the first draft of the manuscript. ASO: managed the analyses of the study. Both authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

Authors have declared that no competing interests exist.

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