PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (10) 3039-3046 October, 2024

Pilot Risk Assessment of Water Sources of Selected Communities from Four Local Government Areas of Bida, Gbako, Katcha, and Lavun that Experienced 2018 Cholera Outbreak in Niger State, Nigeria

[1,4,5*]MAJIYA, H; [2,4]YAKUBU, IB; [1,4]BABA, J; [3,4]DADI-MAMUD, NJ

[1]Department of Microbiology, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[2]Department of Geography, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[3]Department of Biological Sciences, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[4]Center for Applied Sciences and Technology Research, Ibrahim Badamasi Babangida University, Lapai, Nigeria
[5]Trans-Saharan Disease Research Center, Ibrahim Badamasi Babangida University, Lapai, Nigeria

**Corresponding Author Email: husssainimajiya@ibbul.edu.ng*
**ORCID: https://orcid.org/0000-0002-0254-4402*
**Tel: +2348062703832*

Co-Authors Email: ishakubashiryakubu@gmail.com; babajohn322@gmail.com; njdadimamud@gmail.com

ABSTRACT: Recurrent cholera outbreak in Nigeria signifies a problem of water and sanitation. However, there is so much implication of open defecation and surface water pollution with little emphasis on the ground water which are predominantly sources of drinking water. The aim of this study was to carry out a pilot risk assessment of water sources in selected communities from four local government areas of Bida, Gbako, Katcha, and Lavun that experienced 2018 cholera outbreak in Niger State, Nigeria. The risk assessment was based on the guidelines for Assessing the Risk to Groundwater from On-Site Sanitation (ARGOSS). Our result showed that about 63% of the ground water sources in the study areas are of significant risk. The results also showed that the type of ground water sources did not determine the outcome of the risk assessment (Pearson's Chi-squared test, $p > 0.05$). However, the subsoil type of the sources affects or is associated with the outcome of the risk assessment (Pearson's Chi-squared test, $p < 0.05$). Generally, the Vibrio species counts of the water sources are in order of rivers/streams>> open wells>boreholes. The Vibrio species counts did not show any seasonal variation (t. test, $p > 0.05$). Also, there was no combined effect of the type of water sources and risk determination outcome on the Vibrio species counts (ANOVA, $p > 0.05$). This study can serve as basis for enforcement of well/borehole-pit latrine/septic tank distance limit in Nigeria.

DOI: https://dx.doi.org/10.4314/jasem.v28i10.12

Cite this Article as: MAJIYA, H; YAKUBU, I. B; BABA, J; DADI-MAMUD, N. J. (2024). Pilot Risk Assessment of Water Sources of Selected Communities from Four Local Government Areas of Bida, Gbako, Katcha, and Lavun that Experienced 2018 Cholera Outbreak in Niger state, Nigeria. *J. Appl. Sci. Environ. Manage.* 28 (10) 3039-3046

Dates: Received: 30 July 2024; Revised: 29 August 2024; Accepted: 21 September 2024 Published: 05 October 2024

Keywords: Risk Assessment; Cholera; Waterborne Diseases; Epidemic

Cholera is one of the waterborne diseases and its outbreak signifies a water and sanitation problem (UNICEF, 2014; WHO, 2015). Cholera is an acute diarrheal disease that kills within hours if left untreated (Elimian *et a*l., 2019; UNICEF 2016). About 1.3 to 4.0 million cases and 21,000 to 143,000 deaths due to cholera are reported annually worldwide (WHO, 2023). Nigeria including Niger State had been contributing to these annual global cases and deaths caused by cholera because of the recurrent outbreaks of the disease especially in the last five years (NCDC, 2023). In 2018, about 584 suspected cases and 29 deaths caused by cholera were reported for Niger State while 42,466 suspected cholera cases and 830 deaths

**Corresponding Author Email: husssainimajiya@ibbul.edu.ng*
**ORCID: https://orcid.org/0000-0002-0254-4402*
**Tel: +2348062703832*

were documented for the whole of Nigeria (NCDC, 2023). The first set of most of the cholera cases and deaths were reported in four (4) Local government Areas (LGAs) of Niger State which are Bida, Gbako, Katcha and Lavun (Dipo, 2018; Ajobe, 2018; Godwin, 2018). Most of the rural areas in developing countries including Nigeria and Niger State lack energy infrastructures that can power conventional water treatment system and therefore water is used directly without treatment from the available water supply sources such as river, stream, pond, wells, borehole, spring, rain etc (Majiya *et al*., 2019). These water supply sources may not be safe for direct consumption without prior treatment. The danger and risk posed by each of these water sources may vary from season to season and place to place. However, in developing countries including Nigeria, there is lack of data for risk assessment and quantification of the magnitude of the risks associated with the usage of water from sources commonly available in these regions. So, environmental health protection agencies and public health departments do not have any framework to use in classifying water supply sources either as dangerous or suitable for domestic and agricultural uses. And therefore, no policy, regulation and enforcement of laws that can prohibit the use of dangerous water sources. Risk assessment of water supply sources determines the suitability of water sources for drinking and other purposes. This information can be used to inform decisions about appropriate management of the water supply system. Generally, cholera outbreaks are usually linked to open defecation and surface water bodies pollution due to the seasonality of the disease with the cases usually peaked in the months (July, August, and September) with the highest rainfall (Elimian *et al.*, 2019). The attribution of the cholera outbreaks in most cases to only open defecation and surface water bodies pollution due to heavy rainfall maybe overstretching. This is because about 80% or more of the drinking water supply sources in developing countries including Nigeria is ground water such as open wells, closed wells and boreholes which are mostly protected from the surface and open defecation pollution but not protected from the sub-surface pollution from the pit latrines, septic tanks, sewage etc depending on the volume of rainfall and hydrogeological characteristics (Kazama and Takizawa, 2021; Graham and Polizzotto 2013; Islam *et al*., 2016). Ground water rate and extent of microbial contamination depend on many factors including the pathogens characteristics, horizontal distance between the water points and the sources of pollution (e.g., latrine), nature of saturated and unsaturated zones, distance between the base of latrines and water table, amount of liquid in the pits, and direction and velocity of ground water flow (Kazama and Takizawa, 2021; Adejuwon and Adeniyi, 2001). Although most of these factors are dependent on the hydrogeological characteristics of a place, the amount of rainfall, socioeconomic status and type of settlement are strongly correlated to rate and extent of ground water microbial pollution (Elimian *et al*., 2019). Hence, the aim of this study was to carry out a pilot risk assessment of water sources in selected communities from four local government areas of Bida, Gbako, Katcha, and Lavun that experienced 2018 cholera outbreak in Niger State, Nigeria.

MATERIALS AND METHODS

Study Design and Areas: Mix-methods (quantitative and qualitative) including experts' physical/visual observations, assessments and calculations, and water sampling for Vibrio species counts and physico-chemical analyses were employed in this study. The study areas were some villages in four (4) LGAs (Bida, Gbako, Katcha, and Lavun) in Niger state, Nigeria, which are the first set of LGAs in the State that experienced cholera outbreaks in June 2018 (Figure 1).

In each selected LGA, 5 hand dung wells, 5 rivers/streams and 5 boreholes served as study sites (figure 1). Water samples were collected three (3) times from the study sites both in wet (June- August 2020) and dry seasons (January- March 2021). Also, at each study site, distance between the study sites and available pit latrines/septic tanks were recorded as well as determination of subsurface soil/aquifer characteristics of the sites.

The risk assessment of the selected water sources/study sites (hand dung wells and boreholes) was based on the guidelines for Assessing the Risk to Groundwater from On-Site Sanitation (ARGOSS) which was produced by the British Geological Survey (BGS). The water samples were each labelled with two (2) letters and a number; the first letter represent the first letter of the LGAs (Bida, Gbako, Katcha, and Lavun) while the second letter represent the first letter of the types (Borehole, Well and River) of water sources. The numbers are sequential indicating number of samples taken at each LGA for each type of water sources. BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River;

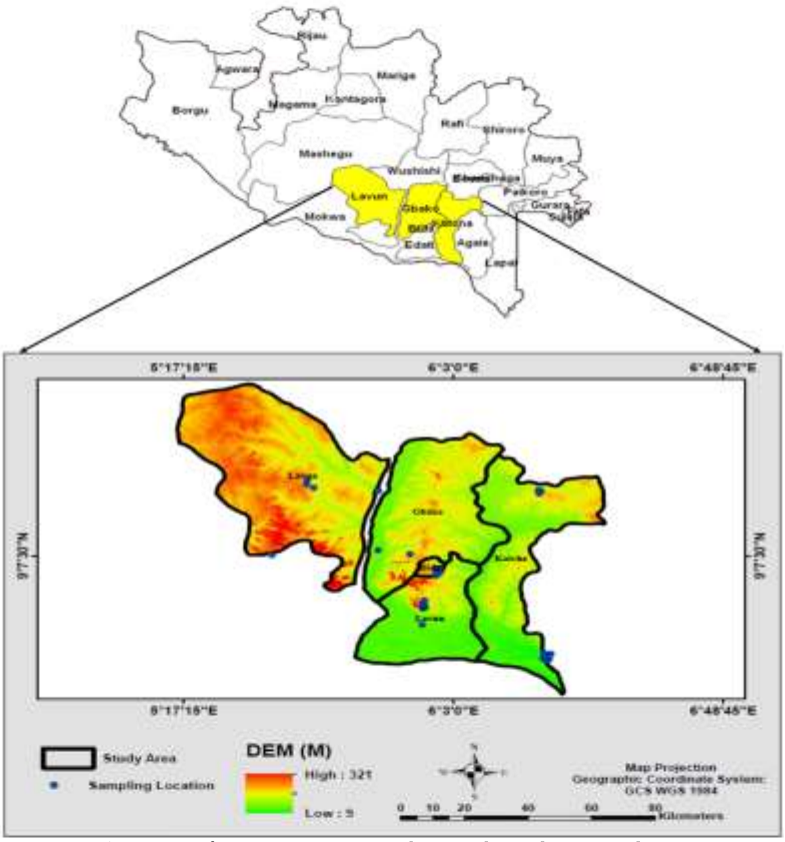

Fig 1: Map of Niger State, Nigeria, showing the study areas and sites

Risk Assessment of the Study Sites: Risk assessment of the study sites (hand dug wells and boreholes) contamination from pit latrines/septic tanks was based on the amount of time it would take the water, and the pathogens it contains, to travel from the pit latrines/septic tanks to the ground water sources under study (Equation 1). The longer time it takes for the pathogens to travel, the greater the reduction in the number of pathogens through natural die-off. The time taken to travel is a proxy indicator for risk of contamination.

$$Number\ of\ travel\ days = \frac{Porosity\ \times Horizontal\ distance}{Permeability\ \times Hydraulic\ gradient} \quad (1)$$

Vibrio species Counts and Physicochemical Analyses of Water Samples: Samples of water for bacteriological and physicochemical analyses were collected in sterile and clean sample bottles (1000 ml capacity) from the selected water sources/study sites accordingly. The samples were taken with care to prevent contamination during collection and were transported to the laboratory in cold boxes to maintain the conditions and characteristics of the water samples. The water samples were tested for the presence of Vibrio species and the number of colonies enumerated by membrane filtration technique according to standard procedure using 0.45 µM MCE sterile membrane filters (Johnson test papers) with Thiosulphate Citrate Bile Salt (TCBS) broth which is a selective differential media for vibrio species. After incubation at 37^{o}C, the number of suspected Vibrio species colonies were counted which gave the presumptive number of Vibrio species in the 100 ml water sample. The suspected Vibrio species isolates were further characterised for species identifications. For each water sample, Vibrio species colonies were randomly selected and were first Gram stained to ascertain the typical curved rod-shaped cell of Vibrio species. The isolates were then purified by three successive streaking and re-isolations on TCBS agar. Thereafter, the purified isolates were cultured on nutrient agar slants and stored at 4^{o}C. From the stock culture, each isolate was assayed for oxidase, urease and indole production, motility, and fermentation of various sugars, using the standard methods. All isolates preliminarily identified to be *Vibrio cholerae* were then serologically tested for agglutination with polyvalent O1 antiserum (BIO-RAD). The confirmed *Vibrio cholerae* Isolates were further tested with anti-Ogawa and or anti-Inaba sera to differentiate them into subtypes. Physicochemical analyses (10 parameters) of the water samples were carried out. Also, the heavy metal analyses (Atomic Absorption Spectroscopy) of the water samples were carried out.

RESULTS AND DISCUSSION

Risk Assessment of the Ground Water Sources: The risk assessment of the selected water sources/study sites (hand dung wells and boreholes) was computed according to the guidelines for ARGOSS by the BGS and the results are shown in Table 1. About 63% of the ground water sources in the study areas are of significant risk, while 20% and 17% of the sources are of low risk and very low risk respectively (Table 1).

Table 1: Risk assessment of water sources in study areas

S/N	Water Sample Source	Estimated Pathogens Travel Time (Day) to Water Sample Source	Risk Assessment Remark
1	KB1	28	Low risk
2	KB2	21	Significant risk
3	KB3	15	Significant risk
4	KB4	39	Low risk
5	KB5	16	Significant risk
6	KW1	19	Significant risk
7	KW2	2018	Very low risk
8	KW3	2	Significant risk
9	KW4	26	Low risk
10	KW5	16	Significant risk
11	BW1	31	Low risk
12	BW2	21	Significant risk
13	BW3	25	Low risk
14	BW4	12	Significant risk
15	BW5	18	Significant risk
16	BB1	23	Significant risk
17	BB2	26	Low risk
18	BB3	2536	Very low risk
19	BB4	1963	Very low risk
20	BB5	15	Significant risk
21	KB6	19	Significant risk
22	KB7	21	Significant risk
23	GB1	23	Significant risk
24	GB2	2209	Very low risk
25	GB3	19	Significant risk
26	GB4	12	Significant risk
27	LB1	16	Significant risk
28	LW1	1527	Very low risk
29	LW3	21	Significant risk
30	LW4	25	Low risk
31	LW5	16	Significant risk
32	LW6	1200	Very low risk
33	LW7	20	Significant risk
34	LW8	15	Significant risk
35	LW9	14	Significant risk

NB: Pathogen Travel Time (PTT) less than 25 days = Significant risk; PTT more than 25 days = Low risk; PTT more than 50 days = very low risk. BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River;

Statistical analysis showed that the type of ground water sources (hand dung wells and boreholes) did not determine the outcome of the risk assessment (Pearson's Chi-squared test, $p > 0.05$). However, the subsoil type affects or is associated with the outcome of the risk assessment (Pearson's Chi-squared test, $p < 0.05$). Risk assessment of the water sources from pit latrines/septic tanks is based on the understanding of the time (in days) it would take the water, and the pathogens it contains, to travel from the pits to the water sources. The time taken can be used as a proxy indicator for risk of contamination. The longer it takes, the greater the reduction in the number of pathogens through natural die-off. Therefore, siting of a latrine or water source ought to ensure that the pathogen die-off will be sufficient to reduce the risk to a level where it is not a public health concern. It is important to note that the 'low risk' classification provides confidence, but it is not a guarantee that the travel time would result in levels of microorganisms which are unlikely to represent a major risk to health. The 'very low risk' classification provides a further margin of safety, and it is therefore of greater confidence that the water will meet WHO guidelines and that the more persistent pathogens would have been removed. The pit latrines and septic tanks are reservoir of waterborne pathogens including *Vibrio cholerae* and other pathogenic Vibrio species. Many studies have reported about microbial contamination of ground water sources with the nearby poorly sited pit latrines/septic tanks (Muruka *et al*., 2012; Gokçekuş *et al*., 2020). Although one of the conditions by WHO for siting a well/borehole is that allowable minimum distance to any pit latrine/septic tank is 30 meters, it is mostly not followed and enforced. The Code of Practice for Water Well Construction by the Nigerian Industrial Standard recommends 20 meters and 50 meters for well and borehole respectively. Overwhelming majority of people in the study areas and Nigeria are ignorant of these well/borehole- pit latrine/septic tank distance limit condition.

Vibrio species counts and physicochemical characteristics of water samples: The mean Vibrio species counts of water samples from the study areas in wet and dry seasons are shown in Table 2. Generally, the counts are in order of rivers/streams (R) samples >> open wells (W) samples > boreholes (B) samples (Table 2). Statistical analysis showed no significant difference between the wet season and dry seasons Vibrio species counts (t. test, $p > 0.05$). A fitted 3-way model (Figure 2) and ANOVA showed that there was no combined/Synergistic effect of the type of water sources and risk determination outcome on the Vibrio species counts (ANOVA, $p > 0.05$). However, at individual level and cumulatively, both the type of water sources and risk determination outcome separately affect the Vibrio species counts (ANOVA, $p < 0.05$). Considering the distribution of different Vibrio species isolated from the water samples, the isolates that were confirmed to be *Vibrio cholerae* are in the range of 7.69% to 32.35 % (Table 3). *Vibrio cholerae* serotype 01 were the predominant serotype isolated from the water samples (Table 3). Although Vibrio species including *Vibrio cholerae* were isolated from all the river/stream and open well samples, some of the borehole water samples do not have *Vibrio cholerae* and or other Vibrio species (Table 3). A fitted 3-way model (Figure 3) and ANOVA showed that only the type of water sources had effect on the number of *Vibrio cholerae* isolates (ANOVA, $p < 0.05$) while the risk determination outcome had no effect whatsoever (ANOVA, $p > 0.05$). Although pathogenic Vibrio species including *Vibrio cholerae* were isolated from the water samples (especially river/streams and open wells) in the study areas (Tables 2 and 3), it is important to note that cholera as a disease is a consequence of combination of factors including the characteristics and ingestion of required quantity (infectious dose) of the aetiologic agent as well as the status of human physiology and immunity. The infectious dose *Vibrio cholerae* is 10^{10} CFU/ml in contaminated consumed food/water. Even if the contaminated food/water with the in infectious dose of Vibrio cholerae is consumed, about 75% of the people infected with the bacterium will not develop any symptom but can shed it in their faeces for 7-14 days after infection thereby contaminating water sources and potentially infecting other people. Among people who develop symptoms, 80% will have mild or moderate symptoms, while around 20% will develop acute watery diarrhoea with severe dehydration (Adagbada *et al.*, 2012). The physicochemical characteristics of the water samples are shown in (Table 4). Considering our results (Table 4) and chemical parameters that are of public health importance specifically, only 5.56% (3) of water sources/samples had Lead (Pb) and 3.70% (2) of water sources/samples Chromium (Cr) above the permitted maximum limit (Table 4). However, about 9.26% (5) of water sources/samples had Cadmium (Cd) above the accepted maximum limit (Table 4). For water quality especially drinking water, Nigerian Standard for Drinking Water Quality (NSDWQ) grouped parameters into three (3), namely, physical, chemical (organic and inorganic) and microbiological. Physical parameters such as colour, odour, taste, temperature, and turbidity do not have health impact on humans. However, although turbidity has no direct health impact, it can entrap heavy metals and biocides, and harbour microorganisms thereby protecting them from disinfection. This can bring problem in water treatment process and can also be a potential risk of pathogen in treated water. Some chemical parameters such as pH, sodium, chloride, hardness, alkalinity, sulphate, total dissolved solid, conductivity etc. do not have direct health impacts but can as well cause problems and increase the energy and cost of water treatment. Chemical parameters such as nitrate and most heavy metals in water are of health importance. Considering our results (Table 4) and chemical parameters that are of public health importance, the sources of water supply in the study areas are mostly safe from unwanted dangerous chemicals. Specifically, only 4.17% (1) of water sources/samples had nitrate above the permitted maximum limit (Table 5). Also, only 4.17% (1) of water sources/samples had Lead (Pb) and Chromium (Cr) above the permitted maximum limit (Table 4). However, about 12.50% (3) of water sources/samples had Cadmium (Cd) above the accepted maximum limit (Table 4). Health implications of nitrate in water include Cyanosis, and asphyxia ('blue-baby syndrome") in infants under 3 months. The health consequences of Lead (Pb) include being carcinogenic, interference with Vitamin D metabolism, affecting mental development in infants and toxicity to the central and peripheral nervous systems. As for Cadmium (Cd), it is toxic to kidney while Chromium (Cr) is carcinogenic.

Table 2: Vibrio species counts ($\bar{x}$±SD) in Log_{10} CFU/100 ml of water samples during wet and dry seasons

Sampling Stations	**Wet season**	**Dry season**
	($range, \bar{x}$±SD) in Log_{10} CFU/100 ml	
KR	6.6-5.0 (5.46 ±0.43)	6.6-5.4 (5.86 ±0.51)
KB	3.5-1.0 (2.12±1.19)	3.2-1.0 (2.12±0.68)
KW	3.6-2.2 (2.90±0.59)	3.5-2.5 (3.1±0.38)
BW	3.3-2.3 (2.64±0.40)	3.4-2.0 (2.74±0.60)
BB	2.9-1.3 (1.88±0.60)	2.7-1.8 (2.19±0.38)
BR	5.7-5.2 (5.48±0.18)	6.0-5.3 (5.44±0.32)
GR	6.5-6.0 (6.26±0.23)	6.7-5.0 (6.12±0.77)
GB	2.0-1.7 (1.90±0.13)	2.0-1.8 (1.92±0.12)
LB	2.3-2.3 (2.30±0)	0.9-0.9 (0.90±0)
LW	5.5-2.5 (3.74±1.14)	4.3-2.5 (3.15±0.58

NB: Where: $\bar{x}$ =mean; STD = standard deviation. BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River

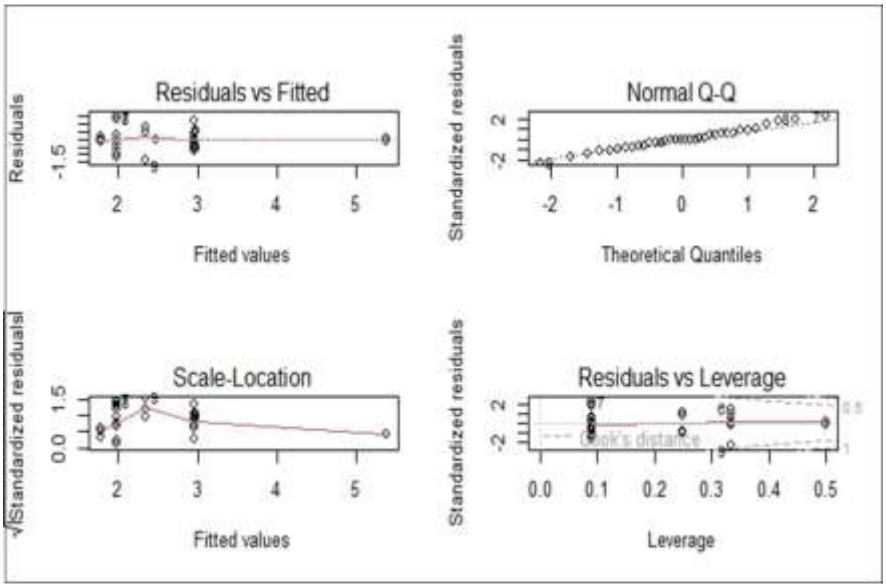

Fig 2: A fitted 3-way model: Vibrio species counts versus the combined and separate effects of the type of water sources and risk determination outcome.

Table 3: Distribution of Vibrio species and frequency of Vibrio cholerae serotypes in water samples

Water Sample	**Distribution of Vibrio species (%)**					**Frequency of *Vibrio cholerae* serotypes**	
	V. cholerae	***V. fluvialis***	***V. mimicus***	***V. parahaemolyticus***	***V. vulnificus***	**O1**	**Non-O1**
KR	7 (17.95)	5 (12.82)	8 (20.51)	16 (41.03)	3 (7.69)	6	1
KB	0 (0)	3 (21.43)	4 (28.57)	5 (35.71)	2 (14.29)	-	-
KW	5 (21.74)	3 (13.04)	4 (17.39)	9 (39.13)	2 (8.70)	5	0
BW	6 (23.08)	5 (19.23)	4 (15.38)	7 (26.92)	4 (15.38)	5	1
BB	0 (0)	3 (21.43)	4 (28.57)	5 (35.71)	2 (14.29)	-	-
BR	11 (32.35)	7 (20.59)	4 (11.76)	8 (23.53)	4 (11.76)	9	2
GR	10 (29.41)	4(11.76)	4 (11.76)	12 (35.29)	4 (11.76)	9	1
GB	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-	-
LB	1 (7.69)	2 (15.38)	3 (23.08)	6 (46.15)	1 (7.69)	1	0
LW	9 (30.00)	5 (16.67)	5 (16.67)	8 (26.67)	3 (10.00)	7	2

NB: BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River

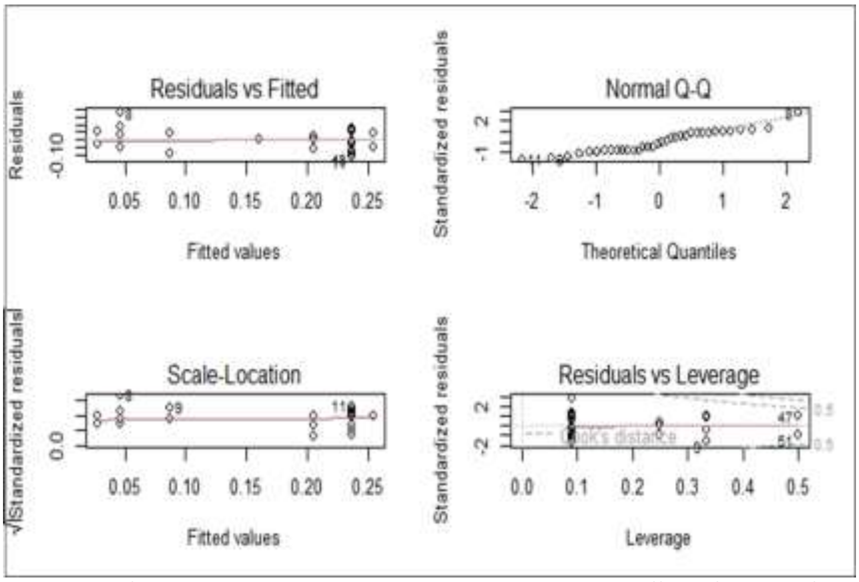

Fig 3: A fitted 3-way model: Number of Vibrio cholerae isolates versus the combined and separate effects of the type of water sources and risk determination outcome.

Table 4: Physicochemical characteristics of water samples

Water Sample Source	Physicochemical Parameters (mg/L) $\bar{x}$±SD									
	Temp.	pH	Nitrate	Sulphate	Phosphate	Sodium	TDS	T. Hardness	Alkalinity	DO
KR	26.17±0.43	5.524±0.41	25.187±5.28	24.6±7.66	0.016±0.01	50.7±9.44	127.5±42.61	114.40±12.69	33.1±6.87	2.05±0.40
KB	25.77±0.48	6.44±0.50	7.15±9.49	2.86±4.26	0	16.86±20.74	57.71±84.90	38.29±44.89	11.14±12.20	2.57±0.40
KW	26.40±0.38	5.25±0.11	28.80±4.36	29.80±3.83	0.02±0.01	55.80±2.28	96.60±8.56	111±11.60	38.60±1.82	2.36±0.30
BW	26.14±0.25	5.37±0.18	21.76±1.75	21.20±1.79	0	63.80±2.39	77.40±2.61	87.20±3.35	20.40±2.51	2.60±0.19
BB	26.22±0.44	6.43±0.49	4.01±3.16	0	0	6.20±3.27	15.60±8.14	12±0	6.60±2.80	2.8±0
BR	25.92±0.36	5.84±0.35	21.96±3.10	20.40±7.33	0.02±0.01	43.40±6.07	159.2±38.30	118.2±13.10	31.4±2.88	1.76±0.27
GR	25.83±0.34	5.27±0.12	19.21±1.62	20.25±0.50	0.01±0	63.5±2.89	62±25.13	86±3.56	19.75±0.96	2.43±0.21
GB	26.05±0.66	6.53±0.50	6.76±9.53	2.25±4.5	0	14±22	51.5±87	35±46	10.25±12.5	2.6±0.4
LB	26.1±0	6.02±0	21±0	9±0	0.01±0	47±0	182±0	104±0	29±0	2±0
LW	26.71±0.12	6.6±0.28	19.34±6.04	13.86±2.54	0.04±0.02	34.43±3.64	117.29±3.55	164.86±23.27	26.71±5.68	1.4±0.17

NB: Where: $\bar{x}$ =mean; STD = standard deviation. BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River

Table 5: Heavy Metals levels (mg/L) of water samples

Water Sample Source	Heavy Metals (mg/L) $\bar{x}$±SD					
	Cd	Zn	Pb	Cu	Fe	Cr
KR	0.01±0.01	0.61±0.13	0.01±0.01	0.04±0.03	0.15±0.02	0.03±0.02
KB	0	0.74±0.02	0.01±0	0.01±0.01	0.05±0.08	0.01±0.0114
KW	0	0.61±0.10	0.01±0.01	0.03±0.02	0.16±0.02	0.03±0.02
BW	0	0.75±0.10	0.01±0	0.13±0.02	0.13±0.02	0.03±0.02
BB	0	0.73±0	0	0	0	0
BR	0	0.63±0.18	0.01±0.01	0.03±0.01	0.14±0.02	0.03±0.01
GR	0	0.70±0.1	0.01±0	0.14±0.01	0.14±0.01	0.01±0
GB	0	0.74±0.03	0	0.01±0.01	0.04±0.1	0.01±0.01
LB	0	0.78±0	0	0.02±0	0.17±0	0.02±0
LW	0	0.22±0.04	0	0.1±0.11	0.28±0.06	0.02±0.01

NB: Where: $\bar{x}$ =mean; STD = standard deviation. BB =Bida Borehole; BW=Bida Well; BR=Bida River; GB =Gbako Borehole; GW=Gbako Well; GR=Gbako River; KB =Katcha Borehole; KW=Katcha Well; KR=Katcha River; LB =Lavun Borehole; LW=Lavun Well; LR=Lavun River

Conclusions: The risk assessment of the ground water sources showed that more than 80% of the sources can be continuously contaminated by the nearby pit latrines/septic tanks in the study areas. The outcome of risk assessment is not affected by the type of ground water source, and this mean that the practice of not adhering to well/borehole- pit latrine/septic tank distance limit condition in the study areas is indiscriminate and not related to only one type of the sources. However, the type of subsoil of the sources affects the outcome of the risk assessment. Although the Vibrio species counts of the water sources were not affected by the seasons, the counts were affected by the type of water sources. The number of *Vibrio cholerae* isolates were also affected by the type of water sources. Generally, the water supply sources in the study areas are safe from chemicals of public health concern.

Acknowledgement: This work was funded by the Tertiary Education Trust Fund (Tetfund) Institutional Based Research (IBR) grant of Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria.

Declarations of interest: The authors declare no conflict of Interest

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors.

REFERENCES

Adagbada, AO; Adesida, SA; Nwaokorie, FO; Niemogha, MT; Coker, AO (2012). Cholera epidemiology in Nigeria: an overview. *Pan Afr. Med. J.*, *12*(1).

Adejuwon, JO; Adeniyi, DO; (2001). Pollution effect of pit latrines on shallow wells at Isale–Igbehin community, Abeokuta, Nigeria. *J. Geol. Min. Res.*, *3*(8), pp.211-218.

Ajobe, A. (2018). Niger confirms 7 death, 74 cases of cholera outbreak. [online] Daily Trust. Available at: https://www.dailytrust.com.ng/niger-confirms-7-death-74-cases-of-cholera-outbreak-257086.html [Accessed 12 Jul. 2018].

Dipo, L (2018). Cholera: 97 deaths, 6,850 Cases Reported Nationwide, Says Niger Commissioner - THISDAYLIVE. [online] THISDAYLIVE. Available at:

https://www.thisdaylive.com/index.php/2018/06/20/cholera-97-deaths-6850-cases-reported-nationwide-says-niger-commissioner/ [Accessed 12 Jul. 2018].

Elimian, KO; Musah, A; Mezue, S; Oyebanji, O; Yennan, S; Jinadu, A; Williams, N; Ogunleye, A; Fall, IS; Yao, M; Eteng, WE; (2019). Descriptive epidemiology of cholera outbreak in Nigeria, January–November, 2018: implications for the global roadmap strategy. *BMC Public Health*, *19*(1), 1-11.

Godwin, A (2018). 10 dead as cholera hits Niger State - Daily Post Nigeria. [online] Daily Post Nigeria. Available at: http://dailypost.ng/2018/06/18/10-dead-cholera-hits-niger-state/ [Accessed 12 Jul. 2018].

Gokçekuş, H; Kassem, Y; Yunusa, N; Musa, MK; John, SO; Usman, S; Yahuza, MS; Ahmad, SM (2020). Study On Pit Latrine Minimum Design Requirement And Considerations In Northern Nigeria. *Int. J. Sci. Technol. Res*

Graham, JP; Polizzotto, ML (2013). Pit latrines and their impacts on groundwater quality: a systematic review. *Environ. Health Perspect.* 121(5), 521-530.

Ihejirika, P. (2018). Curbing Cholera Surge: How Prepared Is Nigeria. [online] Leadership Newspaper. Available at: https://leadership.ng/2018/06/28/curbing-cholera-surge-how-prepared-is-nigeria-2/ [Accessed 12 Jul. 2018].

Islam, MS; Mahmud, ZH; Islam, MS; Saha, GC; Zahid, A; Ali, AHM; Hassan, MQ; Islam, K; Jahan, H; Hossain, Y; Hasan, MM; (2016). Safe distances between groundwater-based water wells and pit latrines at different hydrogeological conditions in the Ganges Atrai floodplains of Bangladesh. *J. Health. Populat. Nutri. 35*(1), pp.1-10.

Kazama, S; Takizawa, S (2021). Evaluation of microbial contamination of groundwater under different topographic conditions and household water treatment systems in special region of Yogyakarta Province, Indonesia. *Wat.* 13(12), p.1673.

Majiya, H; Chowdhury, KF; Stonehouse, NJ; Millner, P (2019). TMPyP functionalised chitosan membrane for efficient sunlight driven water disinfection. *J. Water Process Engineer*. 30:100475.

Muruka, C; Fagbamigbe, FA; Muruka, A; Njuguna, J; Otieno, DO; Onyando, J; Wanjiku, ZS; Onyango, Z; Wamalwa, D (2012). The relationship between bacteriological quality of dug-wells and, pit latrines siting in an unplanned peri-urban settlement: a case study of Langas-Eldoret Municipality, Western Kenya. *Public Health Res.*, *2*(2), pp.32-36.

UNICEF 2016. One is too many: Ending Child Deaths from Pneumonia and Diarrhoea- Key Findings 2016.

UNICEF, W. A. 2014. Progress on Drinking Water and 2014 Sanitation UPDATE.

WHO 2004. Guidelines for Drinking-Water Quality: Volume 1 Recommendations, 3rd edn. World Health Organization, Geneva.

WHO 2011b. Guidelines for drinking-water quality - 4th ed.

WHO (2012). Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage.

WHO, (2015). Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment