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Determination of Physicochemical Parameters of Water Samples in Active War Zones of Borno State, Nigeria

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ABSTRACT

Assessment of physicochemical parameters of 155 water samples of some warring zones in Borno State Nigeria was conducted. Water parameters, namely, pH, Temperature, Total Dissolved Solids (TDS), Electrical Conductivity (EC), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) in the ground and surface waters were assessed. The pH and temperature of the water samples were taken at site using pH meter and Mercury-in-glass thermometer respectively. The other physicochemical parameters were determined using standard instruments. The results revealed that the water pH ranged from of 4.96 – 7.38, temperature: 27.00- 28.30 ^{0}C, EC: 11.3 - 761.80 µS/cm, TDS: 100.40 mg/L - 432.68 mg/L , DO: 3.70 – 7.60 mg/L and BOD: 1.76 – 6.82mg/L. Correlated matrix at 0.01 level (2-tailed) indicated that the water parameter influence were from same sources. The correlated matrix showed pH strongly positively correlated with EC, DO, BOD and weakly with TDS. Also EC strongly positively correlated with pH, DO, BOD and TDS and weakly with temperature. DO strongly positive correlated with pH, BOD, and weakly with EC and TDS. BOD strongly positive correlated with pH, EC, DO and weakly with temperature. While TDS strongly positively correlated with EC and weakly correlated with pH, DO, BOD, TDS and Temperature. These suggest that the ground water is of low quality since the values were below WHO and Nigeria Water Safety Standards. The result showed that water quality may have been affected by the war activities in the area. The result of this study will be useful for the management and planning of the possible remediation processes that can be employed in the warring areas in Borno State, Nigeria.

Keywords: Physicochemical, Water, Borno State, Water Pollution, Conflict Areas, Weapons.

INTRODUCTION

In war zones globally, the use of bombs, bullets, improvised explosive devices (IEDs), rockets and other ammunition release multiple toxicants into the environment. Prenatal exposures to industrial chemicals, particularly lead (Pb), are among known causes of epidemic, diarrhea, child deformity, disordered genetic systems. Cancers diseases, child deformity, skin diseases and reduced developmental neurotoxicity affect millions of children worldwide [1]. Due to the seriousness of this global health issue, accurate measurement of exposures, especially prenatal through studies of the water bodies and soils used in agricultural purposes have become a scientific priority [2].

Current knowledge on heavy and toxic metals supports the hypothesis that war-created pollution is a major factor in birth defects, diarrhea outbreak, cancers diseases and other health issues in war torn areas. Over the last century, industrialization, war and natural processes have resulted in the release of large amount of toxic compounds into the biosphere which has led to the problem of environmental pollution and ecological degradation [3].

In Nigeria, very little is known about the impact of military activities on the Nigerian environment [3]. In Borno State, Nigeria, following the insurgency, explosives and ammunitions which release organic pollutants as well as toxic heavy metals into the environment are deployed. These would cause threat to the health of the animals and humans in the area. Large numbers of bombs, rocket, cannons, and bullets have been dropped. Unconventional weapons such as IEDs have been used thus producing and releasing highly toxic environmental pollutants in the State. The hypothesis that increased war activity can alter the acceptable physiochemical parameters of water in war environment and that increased war activity coincides with increased metal levels in war environment is investigated by this research work.

Therefore, the objectives of this study are: (1) To determine physical parameters (pH, temperature, conductivity, TDS, DO and BOD in the surface and ground waters of war zone sites and compare results with control site and W.H.O standard. (2) To subject the result of the study to statistical analysis of variance (ANOVA) (3) To determine their correlation coefficient. (4) To provide update information on the 21 LGAs of Borno State water quality used for agricultural and domestic purposes in those selected warring areas of the research with a view to making recommendations. These experiments were carried out in the Chemistry laboratory of Bayero University, Kano

MATERIALS AND METHODS

Sampling Location

Fig 1: Nigerian Map Showing Location of Borno State in Nigeria

Borno State is a state in North-Eastern part of Nigeria. Its capital is Maiduguri. The coordinates are $11^{0}30$'N $13^{0}00$' E. (Figure 1). It has a landscale of about 57,799 km and rank 3^{rd} of the 36 Nigerian states in landmass. The population (2006) of the state is 4,171,104 and rank 12^{th} of 36 State with density of 721 km^2 [4]

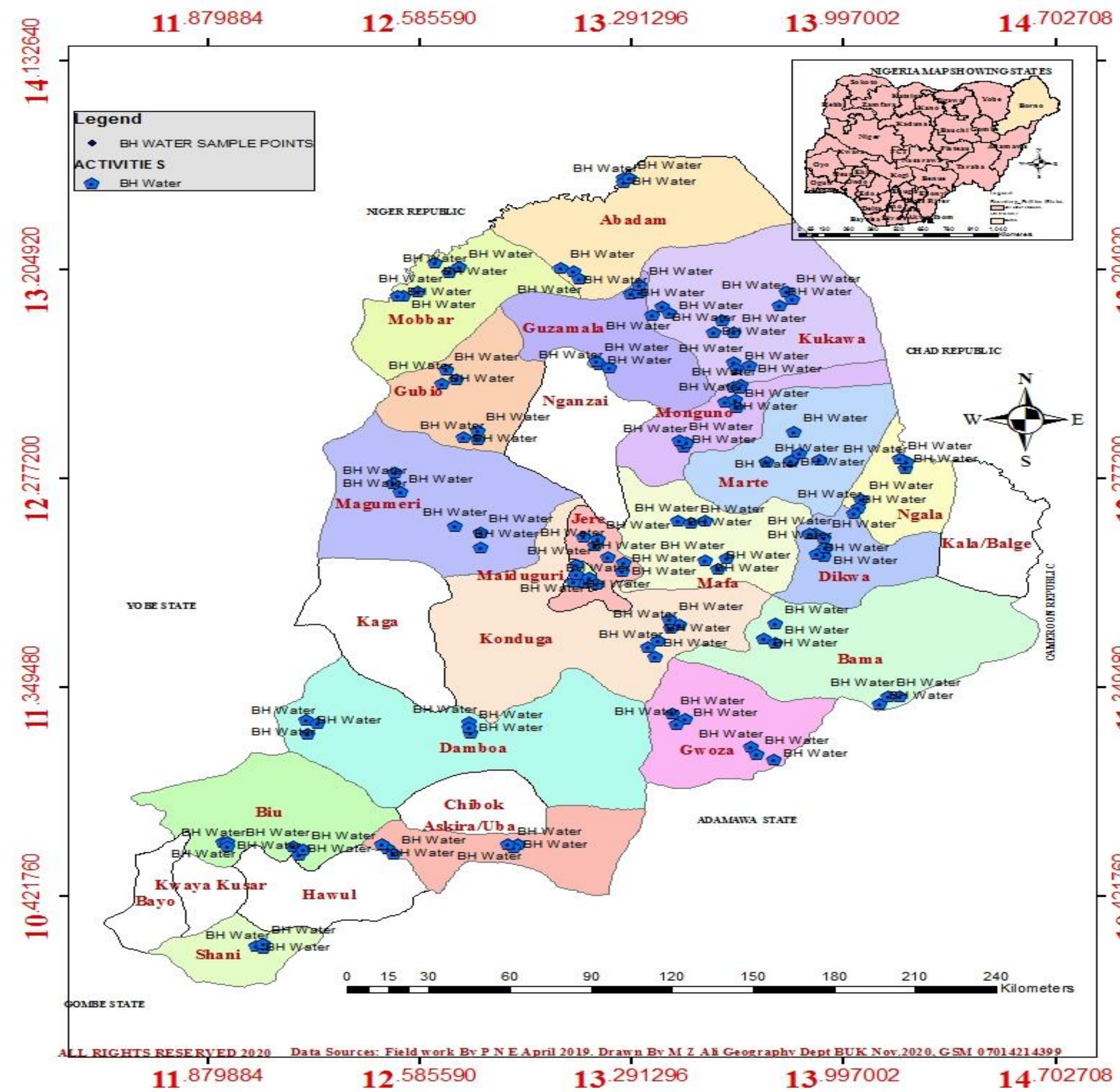

Figure 2: Map of the Study Area Showing Sampling Points for Water.

The water samples were collected from 21 LGAs for analysis. Water samples from borehole and river were collected and labeled water sample WS 1 to WS 155. In each of the LGA, five (5) water samples were collected. The samples from the river were collected by grab sampling technique. This was done by lowering the sampling bottle with a rope knotted at the neck of the bottle to ensure that the sample collected was not from the surface at locations where anthropogenic activities were carried out. Water was collected from drilled wells and hand dug wells after pumping for 5 - 10 minutes. At the point of sampling, pH and temperature were measured shortly after water withdrawal. The borehole samples these were sourced from 20

LGAs: Abadam, Bama, Biu, Damboa, Dikwa, Gubio, Guzamala, Kukawa, konduga, Mongonu, Jere, Mafa, Magumeri, Marte, Maiduguri, Mobbar , Ngala, Baga, Shanli and Gwaoza. While for the river samples these were sourced from Askira/Uba, Biu, Damboa, Dikwa, Gubio, Mafa, Magumeri, Maiduguri, Marte, Mobbar , and Baga (11 LGAs). Table 1 is the water sample areas and sample code.

Table 1: Water sampling areas and sample codes

Water Sample 1 from Marte Borehole Sampling Area					**Water Sample 2 from Mafa Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
1.	MAR HQ BH	MAR 1	WS1	BOREHOLE	2	MAF HQ	MAF 1	WS6	BOREHOLE
	MAR BH SEC A	MAR 2	WS2			MAF SEC A	MAF 2	WS7	
	MAR BH SEC B	MAR 3	WS 3			MAF SEC B	MAF 3	WS8	
	MAR BH SEC C	MAR 4	WS 4			MAF C	MAF 4	WS9	
	MAR BH SEC D	MAR 5	WS 5			MAF D	MAF 5	WS10	
Water Sample 3 from Jere Sampling Area					**Water Sample 4 from Konduga Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
3.	105 CG HQ BH	JER 1	WS11	BOREHOLE	**4.**	LOWCOST SEC 1	KON1	WS16	RIVER
	105 CG ACCM BH	JER 2	WS12			LOWCOST SEC2	KON 2	WS17	
	PRYCG BH	JER 3	WS13			LOWCOST SEC3	KON 3	WS18	
	PRYCG BH	JER 4	WS14			10 HSE UNIT SEC 1	KON 4	WS19	
	GOM	JER 5	WS15			10 HSE UNIT SEC 2	KON 5	WS20	
Water Sample 5 from Bama Sampling Area					**Water Sample 6 from Mobbar Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
5.	BAM IDP	BAM 1	WS21	BOREHOLE	6.	DSK HQ	DSK 1	WS26	BOREHOLE
	BAM NAF	BAM 2	WS22			DSK SEC 1	DSK 2	WS27	
	BAK IDP P1	BAM 3	WS23			DSK SEC 2	DSK 3	WS28	
	BAK IDP P2	BAM 4	WS24			DSK SEC 3	DSK 4	WS29	
	BAKARMY	BAM 5	WS25			DSK SEC 4	DSK 5	WS30	
Water Sample 7 from Mongonu Sampling Area					**Water Sample 8 from Dalori (MDG) Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
7.	MON HQ	MON 1	WS31	BOREHOLE	**8.**	IDPPNT 1	DAL 1	WS36	BOREHOLE
	MON SEC 3	MON 2	WS32			IDP PNT 2	DAL2	WS37	

	MON SEC 2	MON 3	WS33			IDP PNT 3	DAL 3	WS38	
	MON SEC 3	MON 4	WS34			IDP PNT 4	DAL 4	WS39	
	MON SEC 4	MON 5	WS35			IDP MED	DAL 5	WS40	

Water Sample 9 from Baga Sampling Area					**Water Sample 10 from Maiduguri Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
9.	BAG SEC 1	BAG 1	WS41	BOREHOLE	10.	MAI RGE	MDG 1	WS46	BOREHOLE
	BAG SEC 2	BAG 2	WS42			OFFR ACCM	MDG 2	WS47	
	BAG SEC 3	BAG 3	WS43			7 DIV	MDG 3	WS48	
	BAG SEC 4	BAG 4	WS44			SOGAACCM	MDG 4	WS49	
	BAG SEC 5	BAG 5	WS45			ART HQ	MDG 5	WS50	
Water Sample 11 from Gwoza Sampling Area					**Water Sample 12 from Damboa River Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
11.	PUK RI	GWO 1	WS51	BOREHOLE	**12.**	DAM R	DAM 1	WS56	RIVER
	PUK R2	GWO 2	WS52			DAM R	DAM 2	WS57	
	PUK R3	GWO 3	WS53			DAM R	DAM 3	WS58	
	PUK R4	GWO 4	WS54			DAM R	DAM 4	WS59	
	PUK R5	GWO 5	WS55			DAM R	DAM 5	WS60	
Water Sample 13 from from Biu Sampling Area					**Water Sample 14 from Dikwa Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
13.	BIU HQ	BIU 1	WS61	BOREHOLE	14.	GAJI 1	DIK 1	WS66	RIVER
	BIU SLD ACCM	BIU 2	WS62			GAJI 2	DIK 2	WS67	
	BIU OFFR ACCM	BIU 3	WS63			GAJI 3	DIK 3	WS68	
	BIU CLS	BIU 4	WS64			GAJI 4	DIK 4	WS69	
	BIU SEC	BIU 5	WS65			GAJI 5	DIK 5	WS70	
Water Sample 15 from Shanli Sampling Area									
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
15.	SHAN1	SHAN1	WS76	BOREHOLE					BOREHOLE
	SHAN 2	SHAN 2	WS77						
	SHAN 3	SHAN 3	WS78						
	SHAN 4	SHAN 4	WS79						
	SHAN 5	SHAN 5	WS80						

The control sample from Shanli was obtained at a borehole in SHANLI LGA of Brono State were no launching of ammunitions/explosives had occurred following war against insurgency.

Water Sample 16 from Abadam Borehole Sampling Area

S/N	Area	Sample Code	General Code	Source
16.	ABD HQ BH	ABD 1	WS1	BOREHOLE
	ABD BH SEC A	ABD 2	WS2	
	ABD BH SEC B	ABD 3	WS 3	
	ABD BH SEC C	ABD 4	WS 4	
	ABD BH SEC D	ABD 5	WS 5	

Water Sample 17 from Askiri /Uba Sampling Area

S/N	Area	Sample Code	General Code	Source
17.	ASK HQ	ASK 1	WS6	BOREHOLE
	ASK SEC A	ASK 2	WS7	
	ASK SEC B	ASK 3	WS8	
	ASK C	ASK 4	WS9	
	ASK D	ASK 5	WS10	

Water Sample 18 from Ngala Sampling Area

S/N	Area	Sample Code	General Code	Source
18.	NGA HQ BH	NGA 1	WS11	BOREHOLE
	NGA BH 1	NGA 2	WS12	
	NGA BH 2	NGA3	WS13	
	NGA BH 3	NGA 4	WS14	
	NGA BH 4	NGA 5	WS15	

Water Sample 19 from Biu Sampling Area

S/N	Area	Sample Code	General Code	Source
19.	Biu 1	BUU 1	WS16	RIVER
	Biu 2	BUU 2	WS17	
	Biu 3	BUU 3	WS18	
	Biu 4	BUU 4	WS19	
	Biu 5	BUU 5	WS20	

Water Sample 20 from Magumeri Sampling Area

S/N	Area	Sample Code	General Code	Source
20.	MAG 1	MAG 1	WS21	BOREHOLE
	MAG2	MAG2	WS22	
	MAG3	MAG3	WS23	
	MAG4	MAG4	WS24	
	MAG5	MAG5	WS25	

Water Sample 21 from Guzamala Sampling Area

S/N	Area	Sample Code	General Code	Source
21.	GUZML1	GUZML1	WS26	BOREHOLE
	GUZML2	GUZML2	WS27	
	GUZML3	GUZML3	WS28	
	GUZML4	GUZML4	WS29	
	GUZML5	GUZML5	WS30	

Water Sample 22 from Konduga Sampling Area

S/N	Area	Sample Code	General Code	Source
22.	KON HQ	KOND 1	WS31	BOREHOLE
	KON LOWCOST 1	KOND 2	WS32	
	KON LOWCOST 2	KOND 3	WS33	
	KON LOWCOST 3	KOND 4	WS34	
	KON LOWCOST 4	KON 5	WS35	

Water Sample 23 from Damboa Sampling Area

S/N	Area	Sample Code	General Code	Source
23.	DAM PNT 1	DAMB 1	WS36	BOREHOLE
	DAM PNT 2	DAMB 2	WS37	
	DAM PNT 3	DAMB 3	WS38	
	DAM PNT 4	DAMB 4	WS39	
	DAM PNT 5	DAMB 5	WS40	

Water Sample 24 from Dikwa Sampling Area

S/N	Area	Sample Code	General Code	Source
24.	DIKW SEC 1	DIKW 1	WS41	BOREHOLE
	DIKW SEC 2	DIKW2	WS42	
	DIKW SEC 3	DIKW3	WS43	
	DIKW SEC4	DIKW4	WS44	

Water Sample 25 from Gubio Sampling Area

S/N	Area	Sample Code	General Code	Source
25.	GUB 1	GUB 1	WS46	BOREHOLE
	GUB 2	GUB 2	WS47	
	GUB 3	GUB 3	WS48	
	GUB 4	GUB 4	WS49	

	DIKW SEC 5	DIKW5	WS45			GUB 5	GUB 5	WS50	
Water Sample 26 from Mobbar Sampling Area					**Water Sample 27 from Marte River Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
26.	MOBR RI	MOBR1	WS51	RIVER	**27.**	MARTE R 1	MARTE 1	WS56	RIVER
	MOBR R2	MOBR2	WS52			MARTE R 2	MARTE 2	WS57	
	MOBR R3	MOBR3	WS53			MARTE R 3	MARTE 3	WS58	
	MOBR R4	MOBR4	WS54			MARTE R 4	MARTE 4	WS59	
	MOBR R5	MOBR5	WS55			MARTE R 5	MARTE 5	WS60	
Water Sample 28 from from Maiduguri Samling Area					**Water Sample 29 from Mafa Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
28.	MAID PNT 1	MAID 1	WS61	RIVER	29.	MAFFF 1	MAFFF 1	WS66	RIVER
	MAID PNT 2	MAID 2	WS62			MAFFF2	MAFFF 2	WS67	
	MAID PNT 3	MAID 3	WS63			MAFFF 3	MAFFF 3	WS68	
	MAID PNT 4	MAID 4	WS64			MAFFF4	MAFFF4	WS69	
	MAID PNT 5	MAID 5	WS65			MAFFF 5	MAFFF 5	WS70	
Water Sample 30 from Magumeri Sampling Area					**Water Sample 31 from Baga Sampling Area**				
S/N	**Area**	**Sample Code**	**General Code**	**Source**	**S/N**	**Area**	**Sample Code**	**General Code**	**Source**
30.	MAGU 1	MAGU 1	WS76	BOREHOLE	**31.**	BAGA 1	BAGG 1	WS76	BOREHOLE
	MAGU 2	MAGU 2	WS77			BAGA 2	BAGG 2	WS77	
	MAGU 3	MAGU 3	WS78			BAGA3	BAGG3	WS78	
	MAGU 4	MAGU 4	WS79			BAGA4	BAGG4	WS79	
	MAGU 5	MAGU 5	WS80			BAGA5	BAGG5	WS80	

The samples were collected in the month of October 2019.

Water Sample Pretreatment and Analysis

In the preparation of reagents, chemicals of Analar grade purity and de-ionized water were used throughout the analysis. All the glass wares and the plastic containers were washed thoroughly with detergent solution, followed by several rinses with de- ionized water and finally with the analyte sample to avoid contamination.

Water samples for physiochemical parameters were collected in a cleaned 2 -litre plastic container. The pH and temperature of the water samples were taken at site using pH meter (Meter Denver Module 20) and Mercury-in-glass thermometer respectively. The TDS, EC, DO, and BOD analysis were determined using the method described by Fatima [5]

Determination of Temperature

The temperatures of the water samples were all taken at the source. Direct measurement with a Mercury-in-glass thermometer was employed. The reading was taken to the nearest 0.1 ^{o}C. The thermometer was well shaken before it was immersed directly into the water at each location.

Determination of Electrical Conductivity, Biochemical Oxygen Demand and Total Dissolved Solids of Water Samples

The electrical conductivity, Dissolved Oxygen, Biochemical Oxygen Demand and Total Dissolved Solids of the water samples were determined by collecting 50 ml of each sample into a 100 ml beaker. The instrument used was Jenway 4337 pH/Conductivity/TDS/DO meter (All in one instrument). It was inserted into the beaker and readings recorded accordingly. EC was expressed in µS/cm and TDS in mg/L following the manual instruction of the machine. The meter was standardized using deionised water by inserting the electrodes into it. The water samples were analysed for their conductivity by immersing the electrodes in the beaker containing each sample and the reading was taken [5].

RESULTS AND DISCUSSION

pH of Water Sample

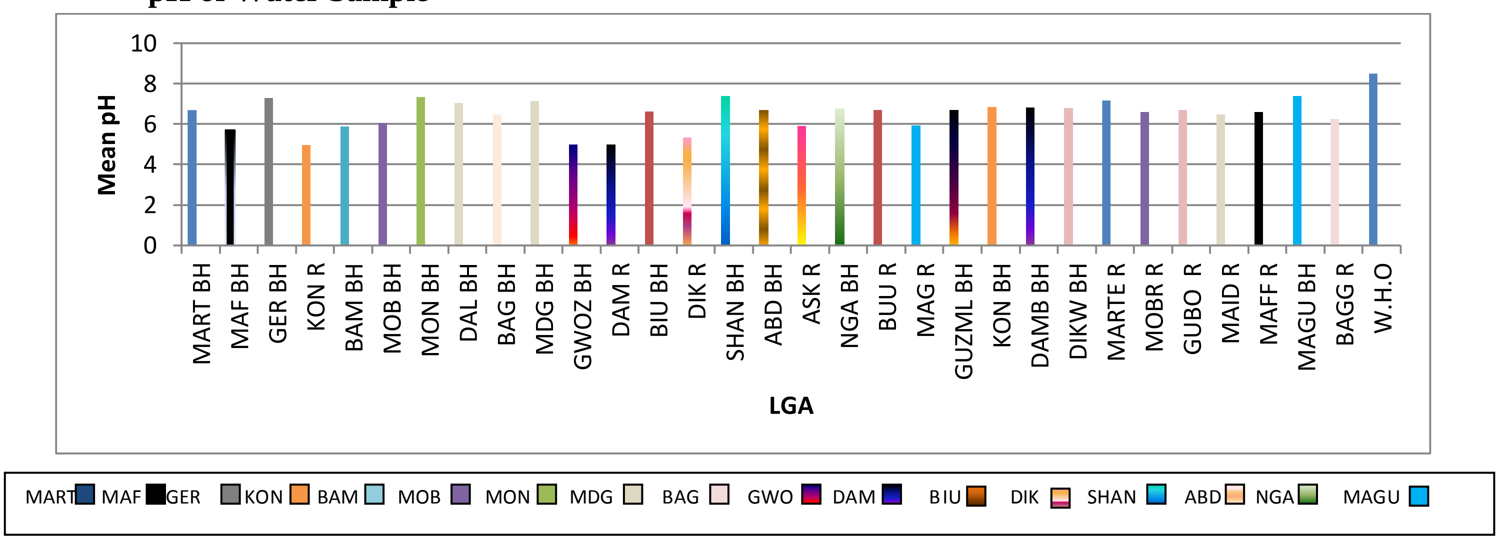

Fig. 3: Mean Variation of water pH Concentration in the Borno State war zones

Figure 3 shows the mean variation of water pH and tukey post hoc test reading which shows significant difference at $P<0.05$. The mean pH ranged from 4.96 ± 0.09 – 7.38 ± 0.11 for both borehole and river waters sampled and this indicates acidic to slightly alkaline condition. (Table 2). Water sample from WS 2, 4, 5, 6, 9, 11,12,14,17,20, 28 and 31 were all found to be below permissible limits of 6.5 – 8.5 [6, 7] thus indicating corrosiveness [8, 9]. Also most of these water samples below the permissible limits as seen in Table 3 were found to be river samples except WS 2, 5, 6 and 9 which were boreholes. Additionally, acidity could be due to high rates of organic matters decomposition from the river [10], while other samples were found from 6.6 -7.38 (Table 2) were within permissible limits of WHO.

These samples within permissible range were all found to be borehole except WS 7, 25, 26 and 27 which are river samples. The samples with highest pH of 7.38 were those from Shanli, the control zone and those from Magumeri LGA. Magumeri has had limited war activities which are similar to those of Shanli LGA where there was no war at all. The lowest pH was found in water samples of Konduga river (pH=4.96 ± 0.09) in a zone with high rate of bombardment [11] . It has been reported that absorption of metals by plants at low pH may be feasible since metals become soluble and plants can readily extract them. Also absorption of metals by plants at high pH may not be feasible since metals become insoluble and plants cannot readily extract them [12]. Thus areas with low pH are more likely to experience high absorption of metals by plants. The tukey post hoc test from Fig. 3 revealed that there are significant differences in pH values of the samples generally at $p<0.05$. The tukey post hoc test revealed that there is no significant difference at $P<0.05$ for water samples from Konguga river, Gwoza borehole and Damboa river, (WS 4, 11 and 12) which are acidic in nature. However for WS 4, 11 and 12, there were similarity in their pH which were mostly river samples but WS 14 (river samples) were significantly different from the site WS 4,11,12. Site for WS 2,5,17 are also similar, more so, similarity lies among site of WS 6 and 20.However site WS 6 and 20 were significantly different from 2,5 and 17. Site WS 31 was significantly different from WS 6 and 20 also similarity lie between site WS 9 and 28.However WS 28 and 9 were significantly different from WS 13, 19, 26, 27 and 29 even though WS 13, 19, 21, 26, 27 and 29 showed no significant difference among themselves. WS1 and 16 had no significant different but there were significantly different from WS 18, 23 and 24 which are similar but significantly different from WS 22. It was also observed that WS 22 was significantly different from WS 8 which was in turn significant different from WS10 and 25 which are similar in themselves. WS 3 and 7 were similar and are significantly different from 15 and 30 which are similar in themselves.

ANOVA of the results shows site with similarity and differences at $p<0.05$. Therefore the trend of the water pH decreasing order gives WS 30, 15 > 7 , 3 > 25 , 10 > 8 > 22 , 23 , 24 , 18 > 16 , 1 > 19 , 27 , 21 ,13,29,26> 28, 9> 31> 6, 20> 17 ,5 ,2> 17 ,5, 2> 14> 12 ,11 & 4.

The Pearson correlation for pH shows that a very strong positive correlation matrix exists between the pH versus EC, DO and BOD at a significance level of 0.01 (2 tailed). This strong correlation ship could be due to changes in land use namely deforestation and war. The result indicated that there was some original source of contamination in the sample. When results from the control were compared with the WHO standard, it was observed that the sample was within acceptable range. This further proves that the pH from the war zone were mostly acidic due to the deposition from the warring weapons.

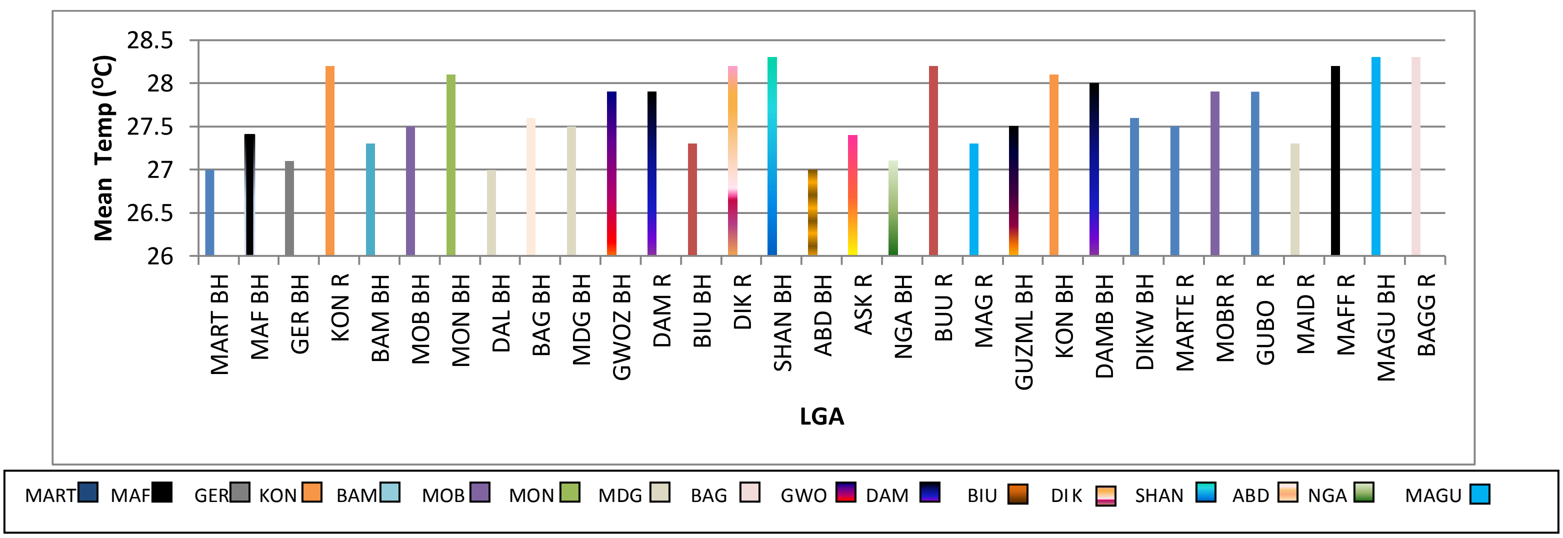

Fig. 4: Mean Variation of water temperature (^{O}C) Concentration in the Borno State War Zones.

Temperature

Figure 4 shows the mean variation of water temperature and tukey post hoc test readings. The mean and standard deviation values for the water temp of samples WS 1- 31 are represented in Table 2. The study temperature values ranged from 27.00±0.00 to 28.30±0.00 ^{0}C with an average value of 27.8±0.00 ˚C. These suggested that the water temperature is generally ambient and good for consumers who prefer cool to warm water. These specific reason explains the water quality, since high temperature negatively impact water quality by enhancing the growth of microorganism and may affect taste, color, odor and corrosiveness Besides, increase in temperature of water decrease solubility of gases such as O_2, CO_2, N_2 and CH_4 [13].

The tukey post hoc test (Fig 4) reveals that there is significant difference in water temperatures throughout the research at P < 0.05 and this is similar to the findings of Mattew, [14]. Mattew's values ranged from 25.70 – 29.00 °C. This is also consistent with results obtained by Oyem *et al*. [8]. Temperature of water samples from a similar study gave ranges between 26.5 °C to 27.5 °C [15]. These reports are in line with present study.

ANOVA of the results shows that the temperature reading follow the order WS 31, 30 ,1 5,> 2 9, 19 ,14 ,4, 22 >7, 23, >2 7,26 ,12 ,11 >24 ,9> 25, 21, 10, 6> 17 ,2, > 28 ,20,13,5>18,3,>16,1 and 8. The temperature above the permissible range could be due to change in land use namely deforestation, disruption of soil structure, climate factor as most importantly warring activities on going.

Water Conductivity

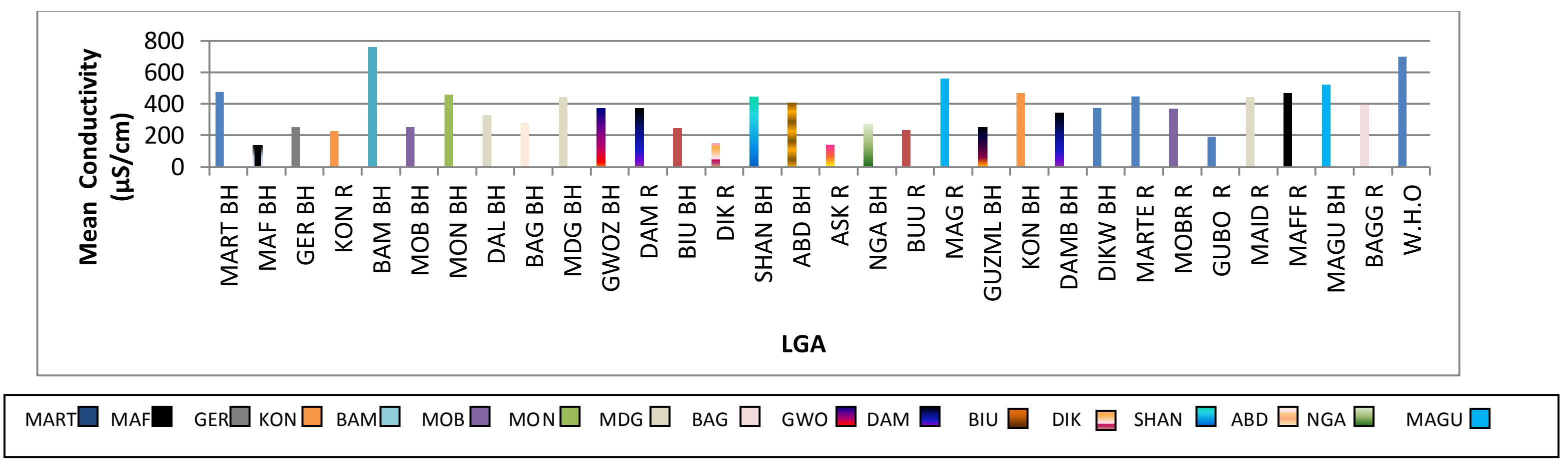

Figure 5: Mean Variation of Water Conductivity (µS/cm) in the Borno State War Zones

WS 15 had EC value of 441.2±1.09 µS/cm. This is the control zone which was within permissible limits while WS 5(761.8 ±1.64 µS/cm) had the highest value of EC and WS 2 (131.8 ±1.79 µS/cm) had lowest value of EC. A study which was conducted on borehole water samples from Akure by Akinbile and Yusoff [15] revealed that mean conductivity value of

92.3 µS/cm was obtained. This was lower than all values determined for this present study. Most of the values obtained in this study are also higher than the values determined for a study conducted on ground water samples in Bauchi, which recorded EC mean value of 196 µS/cm. Also the result of the EC on the samples from Ebenezer dam ranged from 460 – 700µS/cm [16]. This was similar to the result of this study. However, the result obtained from the Ogola's study on stream samples gave mean EC of 940µS/cm which was higher than the value obtained in the present study [16]. The tukey post hoc test shows that EC of the samples had significant difference at $P<0.05$ (Figure 5). High EC values obtained could be attributed to high deposition of ammunition in the vicinities sampled. It was reported that in Higashu – Hiroshima, Japan which is a location with a massive warring activities, that EC range of 400 – 1650µS/cm was obtained [17]. Comparing the value in this study with those of Higashu – Hiroshima in Japan, it was observed that the EC values of this study fell within the result of Higashu – Hiroshima in Japan. However, lower value of this study (131.8 ±1.79µS/cm) was below the lower limit in Higashu – Hiroshima's values (400µS/cm) while the upper value of this present study (761.8±1.643µS/cm) was lower than upper value Hiroshima's (1650µS/cm) [17]. This is similar to the study carried out by Sunil and Rajesh [18] in Bhindawas Wetland in India. Sunil's studies showed that the EC ranged from 130 – 1963µs/cm [18]. The high EC values observed in Bhindawas Wetland study by Sunil was also attributed to runoff water from surrounding farmland into water bodies same as the study of Nicolas [22].

A tukey post hoc test (Fig 5) further revealed that the EC results showed no significant difference between WS 2, 14 and 17. However these values were significantly different from WS 12 and 7 Also WS 4, 13 and 19 showed no significant difference but were slightly different from WS 3. Although there is similarity between WS 6 and 21, they differed slightly from WS 9 and 18 similarly, the values obtained from WS 8 and 23 are similar but they slightly differ from WS 11, 26 and 24. These in turn differ slightly from WS 31 and 16 which are both similar. Also there was no significant difference between site WS 7, 10, 15, 25 and 28. However their values were significantly lower compared to WS 29. Moreso, WS 1 and 22 showed no significant difference between themselves but shows significant difference from WS 30 , 20 and 5 respectively at $P<0.05$ (Table 32). High conductivity may be attributed to the rate of high bombardment due to war zone [17]. The high value of EC can also be attributed to the rate of deposition of carbonates and hydroxide ions coupled as contaminated in the harmattan dusts as reported by Haidary *et al* [17].

ANOVA shows that the EC trend in a decreasing order of 5>20>30>22, 1,29>15,28, 10, 25 and 27 > 31,16>11,26 and 24 >8,23 >9>18>6 ,21 >3>4,19,13 >27> 12>14,17,2 was obtained in this study.

The pearson correlation was performed and it was observed that EC was strongly positively correlated to pH, biochemical oxygen demand at significant level of 0.01 (2-tailed) and also correlated to TDS at significant level of 0.05 (2–tailed). This strong correlation between this parameter could be due to changes in land use namely deforestation, disruption in internal sources of hardness, alkalinity and climatic factor resulting from war activities [17]. The highest EC values obtained in this study can also be attributed to the loss of vegetation and bombardment following war activities. This study is in agreement with Sunil and Rajesh [18], were vegetation removal were said to be the cause of high value of electrical conductance in water samples. This vegetation removal also caused decrease in recharge during drier period in the study [8]. The warring activities in Borno State have also led to the destruction of vegetation during the bombardment of the environment. It is well known that conductance of water increase with salts. The strong correlations of EC with pH, BOD, TDS, indicated that there was some original relationship between studied physical parameters of the water from zones.

Water Total Dissolved Solid

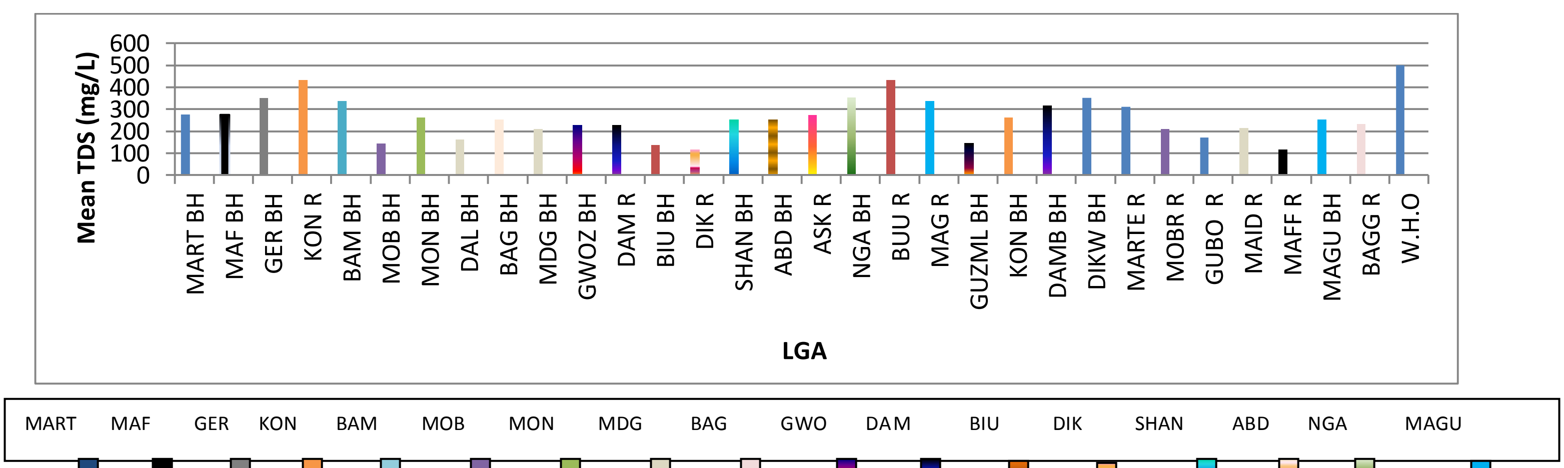

Fig. 6: Mean Variation of water TDS (mg/L) in the Borno State War Zones

Figure 6 shows the mean variation of water total dissolved solid (TDS) and tukey post hoc test reading. The water TDS values ranged from 100.40±1.82 mg/L to 432.68± 1.70 mg/L and were below WHO [6] of 500 mg/L and the SWDWQ guidelines (Table 2) [20, 21]. Standard is 500 mg/L (drinking) 2100 mg/L (irrigation). However, the values of TDS reported in this study are below acceptable limit of WHO recommended guidelines value of 500 mg/L. The values obtained in the study had TDS below acceptable limit which are characteristics of hills and uplandd areas, and represents areas of recharge according to Olubaniyi et al [22]. Olubaniyi attributed his result (TDS 7.5 – 80.6 mg/L) to the considerable topography contrasts in Agbor area. The influence of this factor though was said to have only minimal influence on his result. This describes the study area topography as seen in the area with the lowest value of this study (WS12 100.4± 1.82). The highest value was obtained in WS19 352.2± 2.00 which may be attributed to the warring activities, that is, bombardment and deposition of ammunition to the land around vicinity of the sampling. The highest value obtained in Nguri wetland study was also 119 mg/l which was attributed to the use of household refuse as manure and runoff from farmlands around the vicinity of the wetland [23]. The concentration of TDS in the present study was above that of Shuibu, [23]. However, the findings of this study are within the values of those of Sunil and Rajesh [18] who reported a range of 164-1282 mg/L for TDS in Bhindawas in India and attributed it to runoff water received by wetland from the surrounding farmlands [18]. Hence the value of TDS for control as well as WS 1, 8 and 25, which has not experienced much war activity, can be attributed to use of farm manure [23]. Additionally, values reported by Nkansah and Ephraim [24] were in the range of 779 mg/L, the upper values of Nkansah are higher than that reported in the present study.

Tukey post hoc test (Fig 6) showed that there are no significant differences between WS12, 14 and 29, but they differ significantly from WS13, at $p<0.05$; WS14 is slight different from WS13. WS 6 and 21 are similar but $p<0.05$ but differ slightly from WS18 and also WS27. However, WS 10, 11, 26 and 28which were similar differ from W31 which differ from WS 9, 15, 16 and 39(which are similar to each other). WS 2, 7, 17 and 22 are also similar but differ slightly from WS1 which differ in turn from WS 25 and 23. WS 5 and 20 are similar. WS 3, 18 and 24 are similar but significantly different WS 4 and WS19 which are both similar.

The ANOVA in decreasing order for TDS of this current work gives that WS19, 4>24, 18, 3>20, 5>23, 25, >1>17, 2, 22, 7>16, 9, 30, 15, 31>11, 28, 10, 26>27>8>21, 26>13>14, 29 and 12.

The pearson correlation was performed and it was observed that TDS was positively correlated to EC at a significance of 0.05 (2-tailed). This showed that the TDS of the water was made up of mainly inorganic compounds. Most weaponry elements are known to be inorganic compounds and could have been deposited to land surrounding vicinity of sampling due to the war activities. The result indicated that there was some original source of contamination in the sample which is deforestation and war. When results from the control were compared with the WHO standard, it was observed that the sample was below acceptable range. This is attributed to the excess use of farm manure [23].

Dissolved Oxygen and Biochemical Oxygen Demand

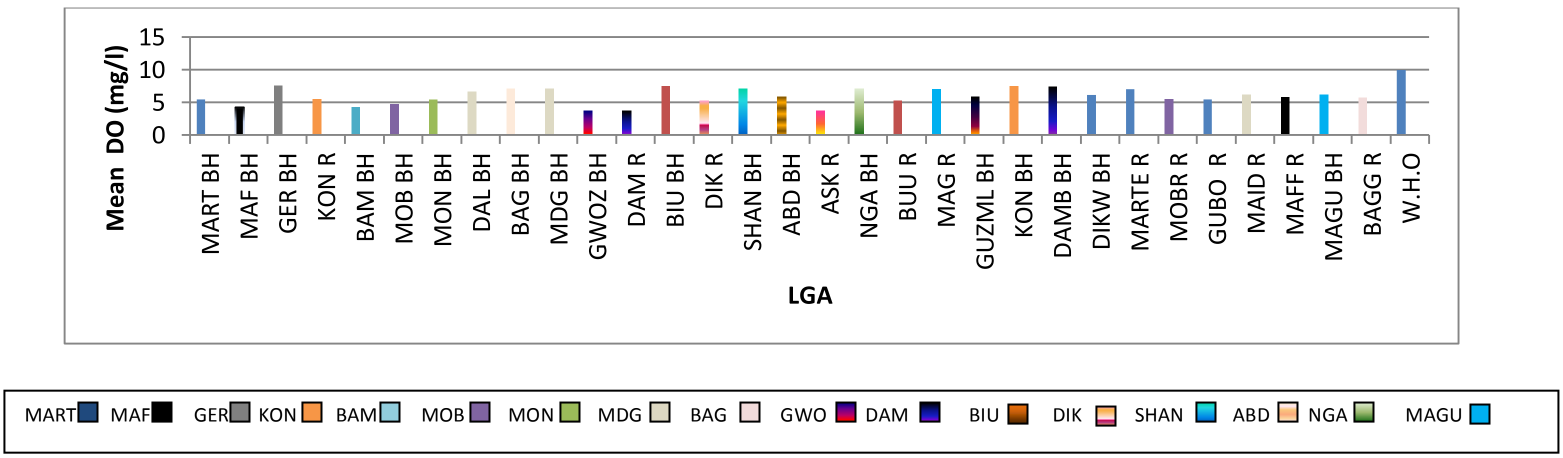

Fig. 7a: Mean Variation of water DO (mg/L) Concentration in the Borno State War Zone

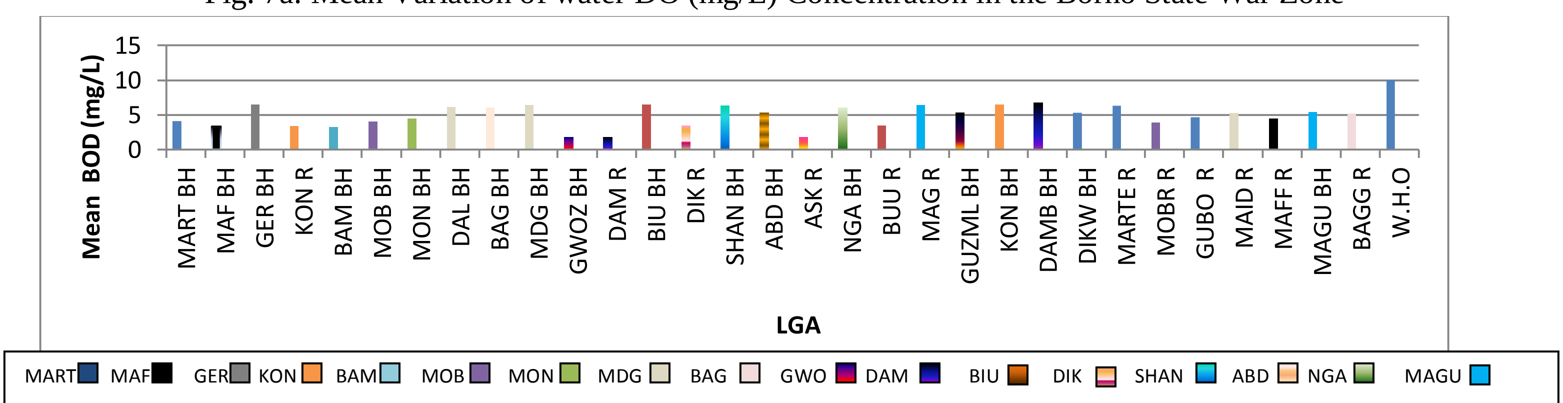

Fig. 7b: Mean Variation of water Biochemical Oxygen Demand (mg/L) Concentration in the Borno State War Zone

The dissolved oxygen mean values of the water samples WS1 – 31 are presented in Table 2. The mean variation value of dissolved oxygen reading and tukey post hoc test are presented in Figure. 7a. while the BOD is showed on Fig. 7b. BOD of the water mean reading after incubation was found to range between 3.76±0.089 and 7.66 ±0.167 mg/L.

Tukey post hoc test (Fig 7b) showed significant difference at $P<0.05$ with WS 11 with the lowest DO value while WS 3 gave the highest value recorded in the study. Studies reported that DO from wetland were within the acceptable limit of 10.0 mg/L [7]. The study conducted on borehole water samples from Akure by Akinbile and Yusoff [15] revealed that DO has valued in the range of 0.9 to 2.4 mg/L. These values were lower than the mean values for this study (3.76±0.0189 – 7.66±0.167) mg/L. Study by Odiba shows DO of 3.9 mg/L in wet season which further increase to 4.7 mg/L in dry season and this values were low in range when compared to the present study [25]. The increments in DO here compared with the high temperature recorded in this study show that the site with low values of DO had high values of temperature (28.3 ºC) which is in line with the findings of Akinbile and Yusoff [15].

The ANOVA in decreasing order for DO of this current work gives that WS3>22,13,23>18,15,9,10,2,5,20>8>28>30>24>21,16,19,31>26>4,12,17>7>19,14,6>5>2,17, 11,

The pearson correlation was performed and it was observed that DO was strongly positively correlation to pH and BOD at a significant level of 0.01 (2-tailed). In the present study the strong positive correlationship between this parameter could be due to changes in land use namely deforestations, climatic factors, and warring activities. The result of DO was further used to calculate for BOD and there was strong positive correction showing that there was original relationship between studied DO and BOD from the war zones. The strong correlationship between this parameter could be due to changes in land use namely deforestation, weapons bombardment of the environment. The result indicated that there was some original source of contamination in the sample which is deforestation and war. When results from the control were compared with the WHO standard, it was observed that the sample was within acceptable range. The temperature of this present study has the high value of 28.30±0.00 ºC. Thus DO is relative to temperature; it provides information of pollution status of the water body such that the higher the DO the lower the level of water body pollution [15].

Correlation Matrix Study of the Water Parameters

The pearson correlation as detailed in Table 3 shows the extent of the correlations between the parameters studied. Pearson correlation was carried out and it gave a positive correlation between water parameters. The Table shows how pH correlated strongly positive with EC, DO and BOD and weakly with TDS. Other strong positive correlations are between: EC with pH, DO BOD TDS weakly with Temperature. Likewise DO shows strongly positive correlation with pH BOD and also correlation with EC and TDS. BOD strong positive correlation is with pH, EC DO weakly with Temperature. TDS shows correlation with EC and weakly with temperature. pH, DO, BOD, TDS and Temperature while Temperature shows correlation weakly with pH, EC, DO, TDS. The amount by which EC rises depends on increase in temperature [26, 13]. Finally, these results indicated that there was some original relationship between the parameters and source such as warring activities

Table 2: Mean and Standard Deviation Results of Physical Parameters Analysis of Different Water Sample from War Zone Areas of Borno State

SAMPLE CODES (ppm)	Sample Code	Source	pH Value	Conductivity mS/cm	DO1 mgL-1	DO2 mgL-1	BOD mgL-1	TDS mg/L	TEMP(^{O}C)
1	**MART BH**	**B**	6.7± 0.071	477.4 ± 1.67	5.46 ± 0.23	1.34 ± 0.18	4.12 ± 0.083	275.8 ±2.05	27 ±0
2	**MAF BH**	**B**	5.68± 0.0834	131.8 ±1.79	4.26 ±0.13	0.98 ± 0.11	3.28 ±0.084	274.6 ± 0.89	27.4 ± 0
3	**GER BH**	**B**	7.28 ± 0.083	251±1	7.66 ±0.167	1.12±0.084	6.54±0.207	352±2	27.1±0
4	**KON R**	**R**	4.96 ±0.089	228.6 ±1.342	5.54 ±0.219	2.2 ±0.071	3.4 ±0.2	432.68 ±1.7	28.2 ±0
5	**BAM BH**	**B**	5.86±0.114	761.8±1.643	4.26±0.134	0.92±0.13	3.26±0.18	337.4±1.81	27.3±0
6	**MOB BH**	**B**	6.06±0.089	252±1.871	4.78±0.045	0.74±0.152	4.04±0.134	146.2±1.79	27.5±0
7	**MON BH**	R	7.34±0.1140	461.2±1.304	5.46±0.23	1.02±0.11	4.44±0.279	262.8±1.304	28.1±0
8	**DAL BH**	**B**	7.04±0.134	331±1.581	6.66±1.21	1.08±0.084	6.12±0.084	161.8±1.79	27±0
9	**BAG BH**	**B**	6.46±0.055	279.8±1.483	7.16±0.15	1.08±0.084	6.08±0.13	253.2±2.168	27.6±0
10	**MDG BH**	**B**	7.12±0.083	442±2	7.1±0.1	0.68±0.084	6.42±0.084	210.6±1.14	27.5±0
11	**GWOZ BH**	**R**	4.98±0.083	371±1.225	3.76±0.089	2±0.1	1.76±0.114	228±44.727	27.9±0
12	**DAM R**	**R**	5.06±0.09	172±1.41	5.48±0.11	1.8±0.10	3.68±0.08	100.4±1.82	27.9±0
13	**BIU BH**	**B**	6.62 ±0.130	241.8±1.303	7.5±0.2	0.98±0.13	6.52±0.13	135.6±1.5165	27.3±0
14	**DIK R**	**R**	5.34±0.134	151.2±0.837	5.3±0.12	1.82±0.109	3.48±0.083	116.86±1.38	28.2±0
15	**SHAN BH**	**B**	7.38 ±0.11	441.2±1.095	7.16±0.114	0.88±0.08	6.28±0.083	251.8±1.304	28.3±0
16	**ABD BH**	**B**	6.7±0.071	405.8±3.34	5.88±0.205	0.56±0.15	5.32±0.087	254.4±1.1401	27±0
17	**ASK R**	R	5.9 ±0.071	138.8±0.837	3.76±0.089	2±0.1	1.76±0.114	274.6±0.894	27.4±0
18	**NGA BH**	**B**	6.76±0.058	271±1	7.16±0.15	1.08±0.08	6.08±0.13	352±2	27.1±0
19	**BUU R**	**R**	6.68±0.084	231.4±1.517	5.3±0.12	1.82±0.109	3.48±0.084	432.68±1.764	28.2±0
20	**MAG R**	**R**	5.94±0.114	561.8±1.643	7±0.071	0.62±0.16	6.38±0.130	337.4±1.81	27.3±0
21	**GUZML BH**	**B**	6.68±0.0837	252±1.8708	5.88±0.205	0.56±0.15	5.32±0.083	146.2±1.789	27.5±0
22	**KON BH**	**B**	6.86±0.0547	468.8±1.64	7.5±0.2	0.98±0.13	6.52±0.13	262.8±1.3	28.1±0
23	**DAMB BH**	**B**	6.82±0.084	343±3.54	7.48±0.084	0.66±0.152	6.82±0.084	318±1.58	28±0
24	**DIKW BH**	**B**	6.78±0.084	373.8±4.38	6.14±0.055	0.82±0.086	5.34±0.089	353.2±2.167	27.6±0
25	**MARTE R**	**R**	7.16±0.055	447.2±1.30	7.04±0.152	0.74±0.114	6.3±0.071	310.6±1.1402	27.5±0
26	**MOBR R**	**R**	6.6±0.1	371±1.225	5.62±0.084	1.68±0.133	3.94±0.089	208±0.71	27.9±0
27	**MARTE R**	**R**	6.68±0.084	192.6±0.89	5.44±0.207	0.8±0.1	4.64±0.114	170.4±26.14	27.9±0
28	**MAID R**	**R**	6.48±0.1304	441.8±1.3	6.26±0.182	0.98±0.13	5.28±0.130	215.6±1.516	27.3±0
29	**MAFF R**	**R**	6.6±0.1	466.8±1.095	5.86±0.207	1.42±0.130	4.46±0.305	116.8±1.304	28.2±0
30	**MAGU BH**	**B**	7.38±0.1095	521.2±45.4	6.24±0.207	0.84±0.055	5.42±0.228	251.8±1.304	28.3±0
31	**BAGG R**	**R**	6.26±0.114	394.2±0.84	5.78±0.192	0.48±0.148	5.22±0.084	232.6±1.140	28.3±0
32	**W.H.O**		6.5 – 8.5	400 - 700	10	10	10	500	27 – 28.5

Table 3: Correlations of the Water Physicochemical Parameters

		pH	Conductivity	DO1	DO2	BOD	TDS	TEMP
pH	Person Correlation	1	.316**	.596**	.563**	.684**	-.082	-.165*
	Sig.(2-tailed)		.000	.000	.000	.000	.309	.041
Conductivity	Person Correlation	.316**	1	.152	.381**	.246**	.189*	.012
	Sig.(2-tailed)	.000		.059	.000	.002	.019	.878
DO1	Person Correlation	.596**	.152	1	.434**	.937**	.084	-.122
	Sig.(2-tailed)	.000	.059		.000	.000	.301	.131
DO2	Person Correlation	.536**	.381**	.434**	1	.937**	.070	.090
	Sig.(2-tailed)	.000	.000	.000		.000	.388	.266
BOD	Person Correlation	.684**	.246**	.937**	-.687**	1	.031	-.193*
	Sig.(2-tailed)	.000	.002	.000	.000		.699	.061
TDS	Person Correlation	.082	.189*	.084	.070	-031	1	.144
	Sig.(2-tailed)	.309	.019	.301	.388	.699		.073
TEMP	Person Correlation	.165*	.012	-.122	.090	.193*	.144	1
	Sig.(2-tailed)	.041	.878	.131	.266	.016	.073	

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

c. Listwise N=155

Recommendation

Sequel to this study, on the determination of physiochemical parameters of water samples, of ammunition/explosives bombarded war zone areas of Borno State in Nigeria**,** the authors recommend that appropriate Authorities should cooperatively take the following actions:

a. Undertake a full environmental assessment of communities that have experienced warring activities in Borno State.
b. Create a comprehensive health education plan to communicate appropriate public health messages to community members and troops in the affected war zone samples through the mass media and develop sustainable mitigation policy.
c. Undertake an occupational health hazard assessment of habitants and troops to protect their health.
d. No rehabilitation or agricultural activities are to take place on the war polluted areas until proper environmental remediation is carried out.
e. Sodium Absorption Ratio (SAR) and residual sodium carbonate (RSC) of the water samples will have to be studied.

CONCLUSION

The hypothesis that increased war activity can alter the acceptable physiochemical parameters of water in war environment is investigated by this research work. Also that the increased war activity coincides with increased metal levels in war environment is to be investigated through this study. The study determined physical parameters (pH, temp, conductivity, TDS, DO and BOD) in the surface and ground waters of war zones and compared results with control site and W.H.O standards. Additionally, the results of the study were subjected to statistical analysis of variance (ANOVA) and correlation coefficient. Finally, the result was expected to provide update information on the LGAs of Borno State water quality used for agricultural and domestic purposes in those warring areas. The results showed that water quality has been affected by the war activities in the area. This determination of physicochemical parameters of war zone water research will be useful for the management and planning of the protection of the water sources for warring zones. Additionally, some parameters' results clearly fell below WHO standards for quality water [6]. Therefore, from results of this study, the water samples from the study area can be regarded as being of averagely good quality for drinking and agricultural purposes (for bore hole and river water respectively with reference to the parameter under consideration). pH treatment is required especially in zones with more acidic values. Further studies with reference to the chemical and microbial analysis will have to be done to have a broader picture of this water quality. Strong correlationship between the water parameter could be due to change in land use namely; deforestation, warring activities (in general) apart from climatic factor.

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