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Physicochemical Analyses of Groundwater Samples of Flood Affected Areas of Hadeija, Auyo and Malam Madori Local Government Areas of Jigawa State, Northern Nigeria

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***Abstract**: Water samples from selected locations affected by flood within three selected local governments (Auyo, Hadeija and Malam Madori) of Jigawa State, Nigeria were analysed for physicochemical parameters (EC, DO, TDS, pH and Turbidity) levels. These parameters were compared with control samples and established national and international standards (WHO and NSDWQ) Control sampling sites were observed to have higher mean concentration of TDS which ranges between (362.53±4.78 mg/l and 546.55±1.39mg/l), EC (417.26±4.42µS/cm and 780.27±0.60µS/cm), DO (6.88±0.50 mg/l and 6.98±0.25 mg/l), pH (7.23±0.37 and 6.73±0.03) respectively. Pollution indices assessed showed that the samples were moderately to considerately polluted for both flooded and the control. The study revealed that not only the flood is a major pollution source in the surrounding environment. This underlines the need for appropriate government agencies of the state to initiate active remediation process such as phytoremediation in combination with physicochemical methods to recover all contamination sources and reduce the pollution level in the surrounding environment.*

Keywords: Physicochemical parameters, groundwater, Floodplains, Jigawa and Nigeria.

1.0 INTRODUCTION

Pollution as defined by the United States Environmental Protection Agency (EPA) as any substance in water, soil, or air that degrades the natural quality of the environment, offends (the senses), causes a health danger, or (impairs) the usability of natural resources. Simply said, pollution is any chemical that causes harm to the environment after entering it. There are numerous classification systems for pollution, but one popular framework divides "point source" pollution that comes from a single identifiable source from non-point source pollution, which is more difficult to identify (Gordon, 2023).

The Oxford English Dictionary defined flood as the overflowing or irruption of a large body of water over terrain that is not typically submerged. It is an extreme weather occurrence that is naturally brought on by rising global temperatures, which induce heavy rain, ocean thermal expansion, and glacier melt, all of which raise sea level and bring salt water to inundate coastal territories. Recent floods and their effects around the world are growing too frequent and pose a threat to human settlement sustainability (Magami *et al*. 2014). However, we must acknowledge that water scarcity and flooding are environmental issues that require attention if sustainability is to be ensured in Nigeria, Africa, and globally (Akolokwu, 2012). Due to exposure to extreme weather events, cities in developing nations like Nigeria are especially sensitive to the effects of climate change, especially variations in rainfall (Tawari-fufeyin *et al* 2015). Flooding being the most frequent environmental disaster, consistently results in over 20,000 fatalities annually and negatively impacts about 75 million people worldwide (Smith, 1996). A third of all natural disaster-related fatalities, injuries, and property damage are caused by floods (Ubuoh *et al*. 2016).

Floods have presented a serious threat to people's lives and property all across the world; the pattern is the same throughout the world and in Nigeria. Millions of people have been evicted from their homes due to flooding in different parts of Nigeria; businesses have been damaged; water resources have been contaminated; and the risk of disease has increased (Etuonnovbe, 2011).

Before using water for drinking, residential, agricultural, or industrial purposes, it must first be tested. Different physicochemical characteristics must be used to test the water. The sole factor in choosing the parameters for a water test is the intended use of the water and the degree to which its quality and purity are required. Water does contain a variety of pollutants, including some that are floating, dissolving, suspended, microbiological, and bacteriological. For the purpose of evaluating its physical appearance, some physical tests such as those for temperature, colour, odour, pH, turbidity, and total dissolved solids should be carried out. While chemical tests for its BOD, COD, dissolved oxygen, alkalinity, hardness, and other characteristics should be carried out. Water should be examined for its trace metal concentrations, organic substances, such as pesticide residue, in order to achieve more and more high-quality water. All of these criteria are properly controlled only in industrialized nations. For the purpose of tracking water quality, the following physical and chemical characteristics are routinely measured (Patil, 2012).

Groundwater is crucial in sustaining human life and activity, (Aouiti *et al*, 2021) and is the primary source of drinking water in the study area. Consequently, assessing water quality is essential for locating pollutants that seriously endanger human health, (Ricolfi *et al*., 2020). This study looked at 5 Physico-chemical parameters (i.e. E.C., D.O., pH, T.D.S and Turbidity) in 8 composite samples obtained from selected sites of flood and non-flood affected areas from three local government areas (Hadeija, Auyo and Malam Madori) of Jigawa State.

The specific objectives of this research work are to determine the Physicochemical parameters (EC, D.O., pH, Turbidity and TDS) of the water samples of flooded and un-flooded areas (Control), to compare the levels of contamination/pollution of the physicochemical parameters in the flooded to unflooded sample stations and with standards and to subject my findings to some pollution indices to better understand the contamination/pollution intensities of flooded and unflooded areas.

2.0 MATERIALS AND METHODS

2.1 Sampling and Sample Analysis

The study was conducted in the extensive floodplains wetlands in the dry lands of northern Nigeria of Auyo, Hadeija and Malam Madori Local Government Areas of Jigawa State. Throughout the months of August and September 2022, the state recorded a rise in the quantity and duration of rain. Due to the increased rainfall, the state's River Hadeija, which is notable for overflowing almost every rainy season and flooding communities. As a result, individuals have been drowned, farmland has been destroyed, portable water sources have been flooded, and communities have been uprooted, (Sofiullahi, 2022). A total of 40 sub site water samples were collected using the format (figure 2.1) from the 20 sampling points, which were composited to produce 8 composite samples from the three selected Local Government Areas (Auyo, Hadeija and Malam Madori) of Jigawa State affected by the 2022 flood disaster. The water physicochemical parameters determined were Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), and Turbidity were determined using EXTECH EC500Ph/Conductivity/TDS meter, SMART3 Colorimeter and MW600 DO meter.

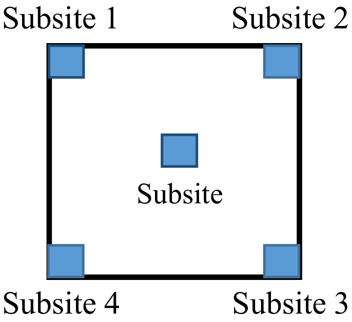

Figure 2.1: GEMAS Field manual, 2008.

2.2 Pollution Indices Assessment

After analysis, for easy understanding the different water physicochemical values obtained were subjected to Water Quality Index (weighted arithmetic index method) and Nemerow's pollution index (NPI). Which were used as a means to evaluate the contamination and pollution status of the water samples (Inengite *et al*., 2015).

2.2.1 Water Quality Index (weighted arithmetic index)

Water quality index is a mathematical tool used to condense large amounts of water data into a single number that expresses overall water quality at a specific location on a variety of water quality variables, thereby transforming complicated water quality data into knowledge that is accessible to the general public, (Rumman *et al,*. 2012). WQI was determined using the weighed arithmetic index method (Brown *et al*., 1970), and quality rating or sub index (qn) was obtained using the expression

$$q_n = 100(V_n - V_{io}) \big/ (S_n - V_{io}) \qquad \text{eqn. 2.1}$$

Where
q_n = Quality rating for the nth water quality parameters
V_n = Estimated value of the nth water quality parameters of collected sample,
S_n = Standard permissible value of the nth water quality parameters

V_{io} = Ideal value of the nth water quality parameter in pure water (i.e. 0 for all other parameters except the parameters pH and Dissolved Oxygen (7.0 and 14.6mg/1 respectively) Unit weight (W_u) was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter. $W_n = K/S_n$

Where

W_n = Unit weight for the nth parameters

S_n = Standard value for nth parameters

K = Constant for proportionality

The overall WQI was therefore calculated by aggregating the quality rating with the unit weight linearly as follows:

$$WQI = \sum q_n W_n \Big/ \sum W_n \qquad \text{eqn. 2.2}$$

Table 2.1: Water Quality Index and its classification

Class	WQI Level	Water Quality Status
1	0-25	Excellent water Quality
2	26-50	Good water Quality
3	51-75	Poor water Quality
4	76-100	Very poor water quality
5	>100	Unsuitable water quality

2.2.2 Nemerow's Pollution Index Method

In comparison to other instruments, the Nemerow's Pollution Index is thought to be a straight forward yet efficient method of determining the quality of the water. The formula for computing the NPI is presented below. It is used to identify which parameter in the sample is accountable for a decrease in water quality.

$$NPI = Cn/Sn \qquad \text{eqn.2.3}$$

Where;

Cn = Concentration of the nth parameter

Sn = Prescribed Standard limits of the nth parameter

In the formula, the grading standard for environmental quality evaluation by the Nemerow's pollution index (Table 2.3) method is shown below;

Table 2.2: Nemerow's pollution index and its classification

NPI VALUE	NPI RANGE
$NPI \leq 1$	Permissible limit and don't have the potential to contribute to pollution
$NPI > 1$	Surplus concentration and have the potential of contributing pollution

2.2.3 Statistical Analysis

Analysis of variance (ANOVA) on all the data obtained were conducted using SPSS Software, at $P<0.05$ to test the existence of significant difference in the mean concentration of the water physicochemical values obtained from the different sampling stations.

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

Table 3.1: Physicochemical Parameters of Water Samples from the Sampling sites

	Physico chemical parameters				
Locations	Electrical Conductivity (µS/cm)	Dissolved oxygen (mg/l)	pH	Total Dissolved solids (mg/l)	Turbidity (NTU)
FLOODED WATER SAMPLING LOCATIONS					
(GKK)	145.63±11.20	6.90±1.18	7.37±1.02	191.20±14.59	ND
(AZA)	246.07±1.22	7.02±0.18	7.02±0.03	358.90±1.01	ND
(AGU)	349.00±1.74	6.80±0.17	7.07±0.06	242.00±2.65	ND
(KND)	928.33±3.51	6.80±0.26	7.44±0.36	658.00±0.87	ND
CONTROL (UNFLOODED) WATER SAMPLING LOCATIONS					
(UNM)	727.03±0.25	6.43±0.38	5.98±0.02	507.00±1.73	ND
(GSK)	1159.00±1.00	6.57±0.12	7.00±0.01	812.00±1.73	ND
(TST)	1077.00±1.00	7.30±0.52	6.97±0.06	757.00±1.73	ND
(CKG)	158.03±0.15	7.60±0.10	6.96±0.02	110.20±0.35	ND
WHO (2011)	1200	8	6.5 - 8.0	500	5
NSDWQ (2007)	1000	5	6.5 - 8.5	500	5

Values are expressed as mean ± standard deviation of triplicate determination
ND: Not Detected

Table 3.2: ANOVA Comparative Physicochemical Parameters Analysis of Water Samples from Flooded Sampling Sites

LOCATIONS	**Physico-chemical parameters**			
	Electrical Conductivity (µS/cm)	**Dissolved oxygen (mg/l)**	**pH**	**Total Dissolve solids (mg/l)**
Ganuwar Kuka (GKK)	145.63 ± 11.20^{a}	6.90±1.18	7.37±1.02	191.20 ± 14.59^{a}
Azamu (AZA)	246.07 ± 1.22^{b}	7.02±0.18	7.02±0.03	358.90 ± 1.01^{c}
Aguyaka (AGU)	349.00 ± 1.74^{c}	6.80±0.17	7.07±0.06	242.00 ± 2.65^{b}
Khandahar (KND)	928.33 ± 3.51^{d}	6.80±0.26	7.44±0.36	658.00 ± 0.87^{d}

Values are expressed as mean ± standard deviation of triplicate determination

Values with different superscripts in the same column are significantly different at $p<0.05$

Table 3.3: ANOVA Comparative Physicochemical Parameters of water Samples from the Control (Unflooded areas)

LOCATIONS	**Physico chemical parameters**			
	Electrical Conductivity (µS/cm)	**Dissolved oxygen (mg/l)**	**pH**	**Total Dissolve solids (mg/l)**
Unguwar Magayaki (UNM)	727.03±0.25^{b}	6.43±0.38^{a}	5.98±0.02^{a}	507.00±1.73^{b}
Gandun Sarki (GSK)	1159.00±1.00^{c}	6.57±0.12^{a,b}	7.00±0.01^{b}	812.00±1.73^{d}
Tsohuwar Tasha (TST)	1077.00±1.00^{c}	7.30±0.52^{b}	6.97±0.06^{b}	757.00±1.73^{c}
Cikin Gari (CKG)	158.03±0.15^{a}	7.60±0.10^{c}	6.96±0.02^{b}	110.20±0.35^{a}

Values are expressed as mean ± standard deviation of triplicate determination
Values with different superscripts in the same column are significantly different at $p<0.05$

Table 3.4: WQI (Weighed Arithmetic Index) from the various sampling sites.

	SAMPLING STATIONS							
PARAMETERS	AGU (Flooded)	CKG (Control)	KND (Flooded)	TST (Control)	GKK (Flooded)	UNM (Control)	AZA (Flooded)	GSK (Control)
Conductivity	0.1898	0.0569	0.5030	0.5857	0.0792	0.3953	0.1338	0.6303
Dissolved Oxygen	55.4667	29.3647	38.2353	59.5451	36.1961	39.2549	35.6863	38.2353
Ph	15.9638	0.8956	5.6298	15.7831	1.6633	13.0510	1.0236	0.6397
TDS	0.1579	0.1579	0.4294	0.4940	0.1246	0.3308	0.2343	0.5299
OVERALL WQI	71.78	30.48	44.80	76.41	38.06	53.03	37.08	40.04

Table 3.5: Nemerow's Pollution Index (WQI) from the various sampling sites

	Nemerow's Pollution Index							
Parameters	AGU (Flooded)	CKG (Control)	KND (Flooded)	TST (Control)	GKK (Flooded)	UNM (Control)	AZA (Flooded)	GSK (Control)
E.C.	0.349	0.925	0.158	1.077	0.145	0.727	0.246	1.159
D.O.	1.133	1.133	1.267	1.217	1.150	1.050	1.167	1.083
Ph	0.832	0.875	0.819	0.822	0.839	0.704	0.833	0.818
T.D.S.	0.484	1.316	0.220	1.514	0.382	1.014	0.718	1.624

3.2 DISCUSSION

3.2.1 Electrical conductivity (EC)

The results of electrical conductivity from the different sampling sites are presented in table 3.1 with a range of 145.63±11.20µS/cm to 928.33±3.51µS/cm in the flood affected areas with a mean value of 417.26±4.42µS/cm obtained from areas of the flood affected sampling sites. Whereas EC ranged from 158.03±0.15µS/cm to 1159.00±1.00µS/cm with a mean value of 780.27±0.6µS/cm from the unflooded areas (control). Highest mean conductivity was observed at GSK with a value of 1159.00±1.00µS/cm which is within the stipulated WHO (2011) limit (1200µS/cm) but still pose a threat as the value can increase above the maximum limit, but above the NSDWQ (2007) limits of 1000µs/cm. The higher mean electrical conductivity levels recorded from the unflooded sampling sites depends on the presence of ions, their total and relative concentrations, mobility and temperature of measurement (Onoyima *et al.,* (2022). High conductivity may also be caused by organic waste and/or evaporation, which causes nutrients to concentrate. (Kpieta and Alfred, 2014). Conductivity was lower in the flooded sampling sites which might be as a result of dilution factor which increases the volume of the water. It can be concluded that the low conductivity observed in flood affected areas can be as a result of the flood water that might have flooded into the groundwater through various openings leading to the groundwater (FAO/UN, 1969).

3.2.2 Dissolved Oxygen

The dissolved Oxygen measurement can be used to determine how fresh the water is (Nurmaladewi and Yeti, 2021). Results of dissolved Oxygen at the different sampling sites are presented in table 4.1 with the highest mean range of 6.88±0.45mg/l and 6.98±0.28mg/l obtained from the flood and non-flood affected areas of the sampling sites, highest mean value of 7.6±0.10mg/l was observed at CKG an unflooded area and lowest value of 6.43±0.38mg/l was also observed in an unflooded area too. All the observed DO value ranges within the stipulated WHO (2011) limits of (8mg/l) but exceeded the NSDWQ (2007) standard for drinking water (5.0mg/l). The depth of the aquifer from which the water is drawn has a significant impact on the concentration of dissolved oxygen in the water; shallow aquifers have higher DO levels than those in deeper locations, (Yan *et al.,* 2020). The low levels of DO experienced from flood affected areas depend primarily on the amount of waste added, the size, the velocity, and the temperature as reported by USDA, (1992). Higher DO was reported during flooding, (Yard *et al.*, 2014).

3.2.3 pH

The results of pH at the different sampling sites are presented in table 4.1 with a mean range of 7.26±0.37 and 6.73±0.03 (Fig. 4.9) obtained from flood and non-flood affected areas of the sampling sites respectively. All the values obtained were within the stipulated WHO (2011) and NSDWQ (2007) limit of 6.5-8.5 except for UNM with the lowest value (5.98±0.02) less than both standards which is more acidic. Highest pH value was observed at KND (7.44±0.36) suggesting an alkaline water. The higher pH values obtained from flood affected areas conform to the findings of Nayan *et al*, (2019) but differ from that of Nurmaladewi and Yeti, (2021). Which may be due to dilution of improperly disposed industrial waste, sewage, improper waste dumping, and extensive use of agrochemicals which might have found their ways into the ground water during the flood (Nurmaladewi and Yeti, 2021).

3.2.4 Total Dissolved Solids

The results of Total dissolved solids at the different sampling sites are presented in table 4.1 with the highest mean range of 362.53±4.78 and 546.55±1.39 obtained at the flood and non-flood affected areas of the sampling sites respectively after the flood event, which the value from flood affected areas is found to be mostly within the stipulated WHO (2011) and NSDWQ (2007) limits of 500mg/l but is mostly exceeded by the non-flood affected areas. The observed values from flood affected areas as observed in table 4.1 were all within the acceptable limit of 500mg/l for drinking water quality recommended by the NSDWQ (2007) and WHO (2011) except KND with a bit higher value of 658.00±0.87mg/l and all the values obtained from non-flood affected areas exceeded the acceptable limits set by NSDWQ (2007) and WHO (2011) for drinking water quality except CKG with 110.20±0.35mg/l. The TDS values obtained agree with the EC results as stations with higher TDS values were observed to have higher EC and vice-versa (Ibrahim,G., 2017).

3.2.5 Turbidity

Turbidity was not detected/observed from all the samples collected/analysed.

3.3 ASSESSMENT OF POLLUTION INDICES

3.3.1 Water Quality Index (Weighed Arithmetic Index Method)

From table 4.4 the calculated values of water quality indices for the various stations were 71.7781, 44.7975, 38.0633, 37.0779, 30.4752, 76.4079, 53.0321 and 40.0352 for AGU, KND, GKK, AZA, CKG, TST, UNM and GSK sampling stations respectively, showed the spatial variations of the various physicochemical parameters studied in the study area. AGU and TST sampling stations were observed to have overall WQI of 71.7781 and 76.4079, which falls in the range of ‘’poor water quality’’ and ‘’very poor water quality’’ respectively with DO being the major deteriorating parameter having a value of 55.4667 and 59.5451 respectively, KND and UNM have values of 44.7975 and 53.0321, falling in the category of ‘’good water quality’’ and ‘’poor water quality’’ with DO also having higher values of 38.2353 and 39.2549 respectively. GKK, AZA, CKG and GSK with values of 38.0633, 37.0779, 30.4752 and 40.0352 respectively all fall within the ‘’good water quality’’ scale. Similar finding was also reported by Otene and Alfred, (2019), none of the water samples collected exhibited ‘’excellent water quality’’ and ‘’unsuitable for drinking’’ water quality status from the sampling sites.

3.3.2 Nemerow’s Pollution Index (NPI) Water Quality Index

From table 4.5 the values obtained when the results of the water physicochemical parameters for AGU, KND, GKK, AZA, CKG, TST, UNM and GSK were subjected to the Nemerow’s pollution index indicated the individual parameter contributing significantly to the water quality deterioration. EC was observed to be less than one in all stations except TST and GSK (1.077 and 1.159) respectively, DO was observed to be more than one in all the sampling stations, while pH was observed to be less than one in all the sampling stations. However, TDS was observed to be more than one in CKG, TST, UNM and GSK while less than one in the remaining sampling stations. It can be concluded that the water quality parameter responsible for deteriorating the water quality for AGU, to be DO which is the only parameter having a value of more than one and has the potential of contributing pollution to that sampling station and so also is observed from KND, GKK and AZA. CKG and UNM sampling stations showed that not only DO is responsible for the water deterioration from those sampling stations but TDS (with value of more than one) also contributed to water deterioration and has the potential to contribute pollution to these stations. However, TST and GSK both have EC, DO and TDS values of more than one, and is considered to be a contributing factor to these water pollution (Ammar, 2017).

4.0 CONCLUSION

The study provides information about the distribution of some physicochemical parameters in the water samples of flood affected areas of Hadeija, Malam Madori and Auyo Local Government areas, of Jigawa State Nigeria. Due to the soil's inherent ability to purify water, underground water is generally considered to be the cleanest type available. However, contamination can occur due to poor well construction and design, shallowness, and proximity to sanitary facilities, garbage dumps, and agricultural farm sites. It was noted that all of the boreholes were situated inside the study area's residential neighbourhood. As a result, it is determined that the majority of the boreholes included in this study's consideration are suitable as a supply of drinking water for the community. The majority of the physicochemical parameters measured had higher values in the control sampling sites, which may be related to the build-ups of these toxicants from industrial area emissions, high metal waste disposal, animal manure, sewage sludge, coal combustion, spilled petrochemicals, and pesticides in the soils. It was recommended that regularly conducting quality risk assessment is essential to identify and raise awareness of the potential hazard and other sources of pollutants affecting the study areas and determine effective programs to prevent and minimize health risks and also suggests that measures should be put in place by government and concerned agencies like NEMA to help reduce the probability of such heavy floods in future.

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