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Research Article
Selected Water Properties as Affected by Flooding in Abakaliki, Ebonyi State Southeast Nigeria

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Abstract

Background and Objective: Flooding is the most common of all environmental hazards that affect mankind. The objective of this study was to determine the weather variables and selected water properties affected by flooding. **Materials and Methods:** Water samples were collected from Iyiokwu and Iyiudele stream in 2018 and 2019 as follows: Azuiyiokwu before flooding (ABF), Azuiyiokwu after flooding (AAF), Iyiudele before flooding (IBF) and Iyiudele after flooding (IAF). Weather variables, selected water heavy metals, physical and chemical properties of water were determined. Data from the study were analyzed using ANOVA for CRD and the differences between means detected using F-LSD. **Results:** The result showed that onset and cessation of rainfall in 2018 was January and February, whereas onset and cessation of rainfall in 2019 was November and December, respectively with a short dry season between July and August, in both years of study. The results showed significant ($p<0.05$) changes in water parameters studied with an exception of temperature, pH and As. It is also observed from the results that the physical parameters and chemical parameters studied were within the standard and were higher in water after flooding than before flooding. The observed heavy metals were higher than the standard and were lower in water after flooding than before flooding except for Pb. **Conclusion:** The study suggests the need to use water after flooding for irrigation. However, for drinking or domestic use, there is a need to treat such water to avoid ill health associated with such water.

Key words: Environment, flood, regulation, rainfall, weather

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Flood occurs regularly among all other disasters that are not anthropogenic causing deaths and financial losses annually and resulting in the highest death rate among natural disasters worldwide[1]. Flooding also could be seen as the occurrence of a large volume of run-off water in places that are hitherto dry or usually contain much less flowing water. It is also, an abnormally large quantity of water that cannot be contained within the existing channels. Also, flooding can occur within a few hours of heavy rainfall or after a dam collapses or sudden release of water from dams or large reservoirs. Flooding is the most common of all environmental hazards and adversely affects around 75 M people world-wide[2]. Across the globe, floods have posed a tremendous danger to people's lives and properties. Floods cause about one-third of all deaths, one-third of all injuries and one-third of all damage from natural disasters[3]. The rainy season is subjected to seasonal flash in Nigeria which causes severe detrimental effects to rural areas and slums where drainages are few or not in place[4]. Heavy rainfall at the beginning of July to September, 2012 caused water reservoirs to overflow and authorities were obliged to open dams (Lamingo dam and Lagdo dam in the Northern Province of Cameroun) to relieve pressure in both Nigeria, neighbouring Cameroon and Niger, leading to destroyed river banks and infrastructure, loss of property and livestock and flash floods in many areas. Two heavy floods occurred in Nigeria in September and October at Niger-Benue and Lagdo Dam flood[5]. In tropical regions, floods of high magnitude have resulted in serious consequences caused by heavy rainstorms, hurricanes, snowmelt and dam failures[6]. In Nigeria especially Abakaliki Ebonyi State, the pattern is similar to the rest of the world. Flooding has forced several many residents of Nigeria out of their homes thus destroying their businesses, homes, foods and sources of water[7]. The main objective of this study was to determine the weather variables and selected water properties affected by flooding.

MATERIALS AND METHODS

Study area: Specifically, this study was conducted around the flood plains of the Azuiyiokwu and Iyiudele stream in Abakaliki South Eastern Nigeria. Abakaliki lies in latitude 70°45'E-80°30'N and longitude 50°35'-60°45' of South Eastern Nigeria. The study area was also known for high temperature and high rainfall where the average monthly temperature is 27°C[8]. Rainfall begins in April and stops in November, where the mean annual rainfall in the zone ranges between 1,700-1,800 mm and the relative humidity of the area is 60-80% as reviewed[9]. The soil is classified as Ultisols and is characterized by rampant flooding and waterlogging as a result of poor drainage from the impervious layers and high bulk density[10]. The flooding is experienced at the peaks of the rainy season and occurs at the floodplains around the middle and lower course of the two streams.

Field methods: Preliminary survey of the study area was conducted and the following periods and water bodies were chosen: ABF (Azuiyiokwu before flooding), AAF (Azuiyiokwu after flooding), IBF (Iyiudele before flooding) and IAF (Iyiudele after flooding).

Water sampling: Materials used for water sample collection were sterilized empty Eva water container with caps for collection of water, masking tape, a permanent marker for indicating the date, time and locations after collection, bucket for storing water samples during transportation of the samples from the collection point to the laboratory. Four replicates of water samples were collected at each sampling location before and after the flooding of 2018 and 2019. A cleaned and sterilized empty Eva water container with caps were used to collect the four replicated water samples in each of the study sites before and after the flooding of 2018 and 2019 and immediately taken to the laboratory for analysis.

Determination of physical properties of water: The total solids, total dissolved solids and total suspended solid were determined[11]. The Colour of the water sample was determined in terms of percentage transmittance of light on a photo-electronic colorimeter, model AE-IM. The instrument was initially calibrated by using distilled water and the transmittance of each sample was read and recorded in percentages[9]. The conductivity of the samples was determined using the SANXIN-SX723 conductivity meter[12].

Determination of chemical properties of water: Water pH was determined using pH meter while calcium, magnesium and total hardness were determined using estimation method[13] while Nitrate (NO_3) was determined using turbid metric method[12]. Heavy metals (As, Cd and Pb) were determined by digesting the samples in a fume cupboard and reading transmittance of light using an atomic absorption spectrophotometer[12].

Data analysis: The data from the laboratory were analyzed using Analysis of Variance (ANOVA) for CRD and the differences between means were detected using Fisher least significant difference (F-LSD) at $p = 0.05$ and compared with World Health Organization Standards[8].

RESULTS

Weather variables and consistent flooding of the study locations: The result of the weather variable and consistent flooding of the study area is presented in Table 1. In 2018 monthly temperature was highest in February, with a temperature of 30.95°C and lowest in September, with a temperature of 27.2°C. Similarly, in 2019 monthly temperature ranged between 26.75-30.6°C with the highest and lowest values in March and August, respectively. The order of increase in relative humidity in 2018 was January<December<February<March<November<April< May<June<October<August<Septemer<July, whereas relative humidity in 2019 ranged between 49-83% with the lowest and highest values in December and July, through August, respectively.

In 2018 the onset of the rainy season was in February, with 23.2 mm rainfall and cessation of rainfall was in November, with 68.7 mm rainfall. The rainfall values that could translate into flooding were recorded from June to October, with monthly rainfall that ranged between 480.70-680.90 mm. Similarly, in 2019 the onset of the rainy season was in January with a 24.4 mm rainfall value and cessation of rainfall were in November, with 118.3 mm rainfall value. The rainfall values that could translate into flooding were also observed in June, July, August, September and October, with monthly rainfall of 537.1, 399.3, 431.8, 539.4 and 480.7 mm, respectively. There was a drought condition in March, with 7.4 mm rainfall.

Effect of flood on water physical properties: The effect of flood on water physical properties is as presented in Table 2. Table 2 also shows significant ($p<0.05$) changes in water physical parameters studied with an exception on temperature which shows the non-significant change. It is also observed from the results that the physical parameters studied were within the standard. The order of increase in total suspended solids in 2018 and 2019 was ABF<IBF<AAF<IAF. In 2018 and 2019, the total suspended solids in water studied ranged between 135.44 mg L^{-1} (IBF)-210.05 mg L^{-1} (IAF) and 145.72 mg L^{-1}(AAF)-210.25 mg L^{-1} (IAF), respectively. The order of increase in total solids in 2018 and 2019 was ABF<IBF<AAF<IAF. In 2018, ABF recorded the lowest electrical conductivity values of 0.55. The observed electrical conductivity in ABF was lower than the electrical conductivity in AAF, IBF and IAF by 73, 104 and 1.27%, respectively. The order of increase in conductivity in 2019 was ABF<AAF<IBF<IBF<IAF. It was observed that physical parameters studied were higher in water after flooding than before flooding.

Effect of flood on water chemical properties: Table 3 shows the effect of flooding on water chemical properties. It is significant ($p<0.05$) changes in the chemical properties of water studied with an exception of pH which shows non-significant ($p<0.05$) changes in the locations studied. Also, it is observed that the chemical parameters studied were within the recommended standard. The order of increase in Ca in both the 2018 and 2019 studied year was ABF<IBF<AAF<IAF. The lowest Mg values of 15.14 and 15.15 mg L^{-1} were observed in ABF in 2018 and 2019 whereas the highest Mg values were observed in IAF in the corresponding years. The order of increase in total hardness in 2018 and 2019 was ABF<IBF<AAF<IAF. Similarly, the results show that chemical parameters studied were higher in water after flooding than before flooding.

Effect of flood on water-heavy metals: The effect of flooding on water-heavy metals is as shown in Table 4. Table 4 also shows significant ($p<0.05$) changes in heavy metals studied with an exemption of As which showed non-significant ($p<0.05$) changes in the 2018 and 2019 studied years. The results also showed that the observed heavy metals were higher than the recommended standard. The order of increase of Cd in 2018 was IAF<AAF<IBF = ABF, whereas in 2019, the order of Cd increase was AAF<IAF<IBF = ABF. In 2018, the lowest Pb value of 0.89 mg L^{-1} was recorded in IBF whereas AAF had the highest Pb value of 0.93 mg L^{-1}. The order of Pb increase in 2019 was IBF<IAF<ABF<AAF. The result also showed that Pb was higher in water after flooding than before flooding.

Table 1: Weather data, rainfall, temperature and relative humidity within the period of the study

	Mean temperature (°C)		Relative humidity (%)		Rainfall (mm)	
Months	2018	2019	2018	2019	2018	2019
January	28.05	28.55	40.00	49.00	0.00	24.40
February	30.95	29.25	64.00	58.00	23.20	52.20
March	30.85	30.65	67.00	74.00	31.10	7.40
April	29.50	30.05	75.00	72.00	201.00	157.70
May	28.80	28.70	77.00	76.00	239.50	265.60
June	28.45	27.40	80.00	81.00	481.30	537.10
July	27.70	27.00	83.00	83.00	592.60	399.30
August	27.15	26.75	81.00	83.00	593.00	431.80
September	27.20	27.35	81.00	81.00	680.90	539.40
October	27.60	27.60	80.00	81.00	480.70	480.70
November	29.35	28.95	73.00	75.00	68.70	118.30
December	27.65	28.15	47.00	49.00	0.00	10.00

Source: Nigeria Meteorological Agency

Table 2: The effect of flood on water physical properties

	Temperature (°C)		Total suspended solids (mg L^{-1})		Total dissolved solids (mg L^{-1})		Total solids (mg L^{-1})		Conductivity (Us)	
Locations	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
ABF	28.42	26.43	9.31	9.32	41.02	41.03	50.33	50.35	0.55	0.53
AAF	28.67	27.43	12.94	12.95	144.72	145.72	157.66	158.67	0.95	0.95
IBF	29.17	27.18	12.23	12.23	135.44	135.54	167.67	167.77	1.24	1.27
IAF	27.52	26.28	14.75	14.75	210.05	210.25	224.80	225.00	0.99	1.29
F-LSD (p = 0.05)	NS	NS	2.13	2.14	42.05	41.04	43.01	42.5	0.13	0.14
WHO STD	30-35		500		500		500		900	

ABF: Azuiyiokwu before flooding, AAF: Azuiyiokwu after flooding, IBF: Iyiudele before flooding, IAF: Iyiudele after flooding and WHO STD: World Health Organization Standard and NS: Non significant

Table 3: Effect of flood on water chemical properties

	Ca (mg L^{-1})		Mg (mg L^{-1})		Total hardness (mg L^{-1})		pH	
Locations	2018	2019	2018	2019	2018	2019	2018	2019
ABF	25.21	25.21	15.14	15.15	118.13	118.13	6.95	6.20
AAF	40.50	40.51	27.46	27.46	150.67	150.68	7.61	6.86
IBF	39.59	39.60	25.38	25.38	150.14	150.14	7.72	7.73
IAF	49.12	49.13	33.50	34.65	182.30	182.31	6.85	6.60
F-LSD (p<0.05)	5.42	5.42	4.88	4.89	20.59	20.60	NS	NS
WHO STD	75		50		500		6.5-8.5	

ABF: Azuiyiokwu before flooding, AAF: Azuiyiokwu after flooding, IBF: Iyiudele before flooding, IAF: Iyiudele after flooding, WHO STD: World Health Organization Standard and NS: Non significant

Table 4: The Effect of Flood on Heavy Metal Concentration in Water

	Cd (mg L^{-1})		As (mg L^{-1})		Pb (mg L^{-1})	
Locations	2018	2019	2018	2019	2018	2019
ABF	0.09	0.09	0.01	0.01	0.91	0.92
AAF	0.08	0.07	0.02	0.01	0.93	0.93
IBF	0.09	0.09	0.01	0.05	0.89	0.85
IAF	0.07	0.08	0.01	0.01	0.91	0.90
F-LSD (p>0.05)	0.01	0.07	NS	NS	0.02	0.07
WHO STD	0.03		0.01		0.01	

ABF: Azuiyiokwu before flooding, AAF: Azuiyiokwu after flooding, IBF: Iyiudele before flooding, IAF: Iyiudele after flooding, WHO STD: World Health Organization Standard and Ns: Non significant

DISCUSSION

The onset of the rainy season was in February in 2018 with 23.20 mm rainfall and cessation of rainfall was in November, with 68.7 mm rainfall. The highest rainfall that could lead to flooding was recorded from June to October, with rainfall amounts of 481.30 to 480.7 mm, respectively. Similarly, in 2019 the onset of the rainy season was in January, with 24.4 mm rainfall and cessation of rainfall was in December, with 10.00 mm rainfall. The highest rainfall that

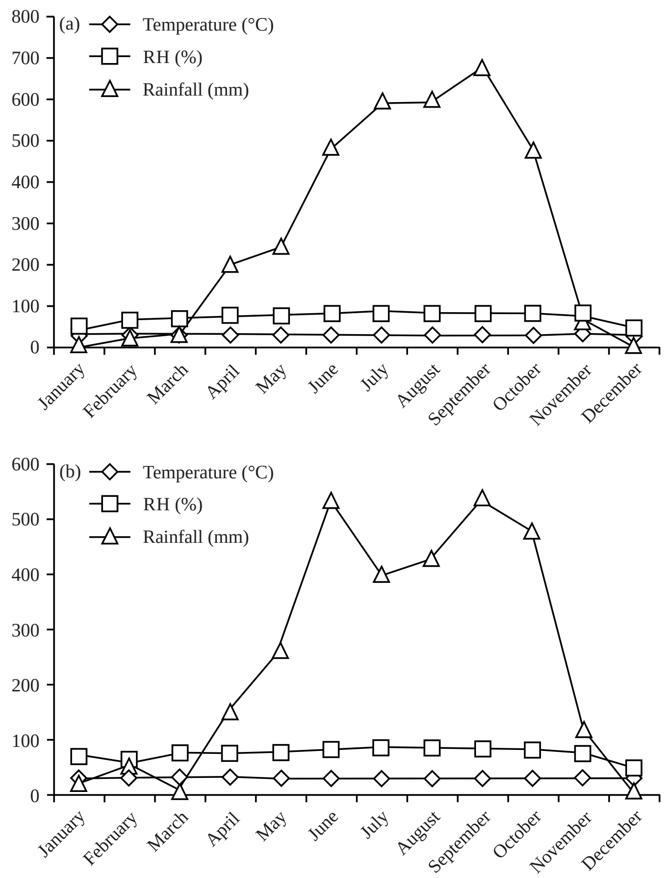

Fig. 1(a-b): (a) Rainfall, temperature and relative humidity pattern in 2018 and (b) rainfall, temperature and relative humidity pattern in 2019

could translate into flooding was also recorded in June to October, with rainfall amount of 480.7-537.1 mm, respectively. There was a drought condition in March with 7.4 mm rainfall. These were in line with an initial expectation of the rainfall pattern of the area[10]. However, the drought condition observed in March, after the heavy downpour of February, 2019 could be attributed to the effect of climate change that led to the extreme event of rainfall and excessive flooding.

The average temperature was high during the onset of the rainy session in February, with 30.95°C, then at the peak of the rainy season, the mean temperature ranged from 27.2-29.35°C in 2018, while relative humidity increased from the onset of the wet season and decreased during the cessation of the wet season (Table 1). In 2019, the average temperature was 28.35°C during the onset of the rainy season in January and then at the peak of the rainy season, the mean temperature ranged from 26.75-28.95°C, while relative humidity also increased from the onset of the wet season and decreased during the cessation of the wet season (Table 1). These implied that increased relative humidity brought about a decrease in temperature and as such relative humidity was inversely related to temperature and consequent rainfall.

From the pattern presented in Fig. 1 and 2, though there was rainfall in January, 2018, the graph showed that the onset of the wet season was from April, 2018 and ceased in November, of the same year. The peak in July and September, were the popular August break characterized by drought conditions. In 2019, the popular August break was experienced between July to August, hence the peaks at June and September, 2019. The dual peaks of rainfall pattern observed within the period of this study (2018-2019) showed the bimodal rainfall pattern of Southeast, Nigeria. The fluctuations in the popular "August break" that ought to be experienced in August every year, now comes either in June, July or August, ending could also be attributed to climate change effect. The rainfall amount was higher in 2018 than in 2019. This implied a higher incidence of flooding in 2018 than in 2019. Though the onset of the rainy season early in 2019 was characterized by drought conditions that depicted the manifestation of climate change. However, the incidence of

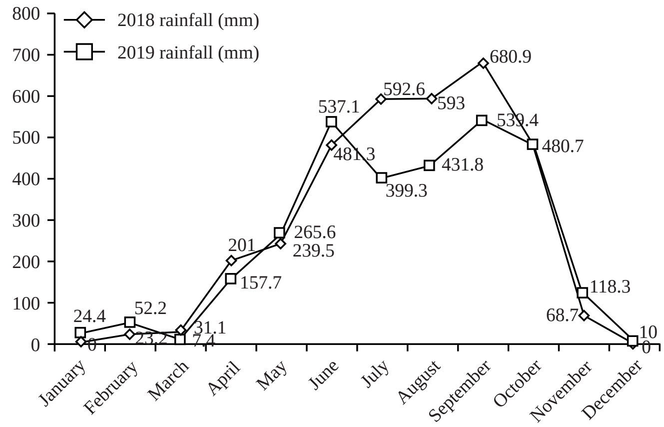

Fig. 2: Rainfall amount between 2018 and 2019 wet seasons

climate change does not affect the bimodal rainfall pattern of Southeastern, Nigeria as were shown by the two peaks of the yearly rainfall. The results of the effect of flood on water physical properties showed that total suspended solid (TSS), total dissolved solids (TDS), total solids and electrical conductivity (EC) were statistically significant at $p<0.05$ in 2018 and 2019, whereas temperature showed non-significant difference but temperature values were below the recommended standard of 30-35°C while TSS was within the recommended standard[12]. Another study[14] showed that flooding leads to a reduction in water temperatures of the area and be linked to the fact that flood water usually carries a mixture of organic materials and sediments which are poor conductors than water. The findings agreed with the review[15], who reported that surface water temperature decreased with an increase in flood intensity. Thus, it was observed that Azuiyiokwu and Iyiudele water bodies have low total suspended solids and might be aesthetically satisfactory for drinking, bath and other domestic purposes. The total suspended solids are composed of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, sodium, potassium, manganese, organic matter, silt and other particles. The effect of low total suspended solids is low turbidity which is an indication that such water body was not polluted to an extent. The low value of total suspended solids recorded in this study was in agreement with the one reported[16]. High TDS recorded in flood-affected water samples could be attributed to the high rate of evaporation and consequent reduction in water volume due to high atmospheric temperature and low humidity leading to the high concentration of dissolved salts in water. This is consistent with another study[17], who reported that total dissolved solids values could be linked to relatively same geological drainage, atmospheric precipitation, water balance (evaporation-precipitation) and moderate concentrations of the ions in the surface runoff. Similarly, in 2018 and 2019 total solids varied from 50.33-224.80 mg L^{-1} whereas in 2019 total solids ranged between 50.35-225 mg L^{-1} whereas the observed values are compared to the recommended standard of 500 mg L^{-1}. This implied that Azuiyiokwu and Iyiudele water bodies are fit for domestic uses. The study also observed that total suspended solids, total dissolved solids and total solids are higher in water bodies after flooding than before flooding. This is possible because flood carries the mixture of debris, sediments, organic matter etc. from upstream to flood areas. Electrical conductivity statistically varied significantly in 2018 and 2019 and was below the recommended standard of 900 mg L^{-1}. This may be attributed to the low rate of evaporation and consequent reduction in water volume due to low atmospheric temperature and low humidity leading to a low concentration of dissolved salts in water. The variation in electrical conductivity was supported by the findings[18], who reported increased electrical conductivity of water samples after flooding. The results of the effect of flood on water chemical properties showed that Calcium (Ca), Magnesium (Mg), total hardness were statistically significant at $p<0.05$ in 2018 and 2019, respectively while the values of pH were non-significant within the period of the study. The observed Mg and Ca in all the locations studied were below the recommended standard of 50 and 75 mg L^{-1}, respectively[19]. Also, Ca and Mg values were higher in water after flooding than before flooding and this implied that flooding increased calcium and magnesium concentration of water bodies. However, magnesium and calcium were active components of several enzyme systems in which thymine pyrophosphate, helps to activate enzymes, nerve conduction, muscle contraction, bone and tooth formation and protein metabolism. Magnesium and calcium were necessary to prevent the calcification of soft tissue. It confers a protective effect on the arterial lining and protects it from stress caused by changes in blood pressure hence Ca and Mg are important components of drinking water[18]. The study observed that results of total hardness increased after flooding and were lower than the recommended standard of water. Note that water hardness is a measure of the ability of water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap solution[20]. The findings agreed with the study[20] who reported that water bodies on the account of flood effect are moderately acidic with the hardness range of 75-150 mg L^{-1}. Also, water pH varied in 2018 and 2019, respectively compared with the recommended standard of 6.5-8.5 and this implied that flooding causes a reduction in water acidity and an increase in pH of water. These were in line with the other study[16,21] who reported that flooding led to a reduction in the acidity level of the surface water bodies and make water to become less corrosive.

The result of the study showed that Cadmium (Cd) and Lead (Pb) values observed from the studied locations were statistically different in 2018 and 2019 at ($p<0.05$), whereas Arsenic (As) showed the statistically non-significant change in the two years of the study. Cd recorded higher values after flooding more than the recommended standard of 0.03 mg L^{-1} [19]. The abnormally high values of Cd recorded by flood-affected water bodies could be attributed to the closeness of Azuiyiokwu and Iyiudele water bodies to many automobile repair workshops. These automobiles repair workshops are within the watershed that supply flood water to the two water bodies. Also, transportation of rusting metallic objects from the automobile repair workshops and deposition of the heavy metal at Azuiyiokwu and Iyiudele catchment areas might have been among the causes of this high value of Cd in the two water bodies. Arsenic showed a non-significant change in the various locations studied in the two years of the study. The observed value of As in AAF and IBF in 2018 and 2019, respectively were higher than the recommended standard (0.01 mg L^{-1}) of arsenic in water[13]. This further revealed the state of the stream water prone to flooding will harm the host environment in the area. The trace concentrations recorded in all other locations apart from AAF and IBF in 2018 and 2019, respectively were in agreement with other study[8] who reported trace concentrations of arsenic in the water bodies as a result of flooding. The observed Pb values in the various locations of the study were higher than the recommended standard and also, were higher after flooding than before flooding. The high values of Pb in the water bodies affected by flood may be attributed to the transport of debris from various automobile repair workshops located within the watershed and deposition of that debris in Azuiyiokwu and Iyiudele water bodies. This is in line with[18] who reported that water samples collected after flooding had a higher concentration of lead compared to its concentration before flooding incidence.

CONCLUSION

The results showed that onset and cessation of rainfall in 2018 was January and February, whereas onset and cessation of rainfall in 2019 was November and December, respectively with a short dry season between July and August, in both years of study. There was significant ($p<0.05$) changes in water parameters studied with an exception of temperature, pH and As which were non-significant in the two years studied in all the locations studied. The results also, showed that the physical parameters (total solids, total dissolved solids, total suspended solids, colour and electrical conductivity) and chemical parameters (calcium, magnesium, total hardness) studied were within the standard and were higher in water after flooding than before flooding. The observed heavy metals were higher than the recommended standard and were lower in water after flooding than before flooding except for Pb which was higher in water after flooding than before flooding. From the results, it is imperative to treat water from water bodies after flooding to avoid ill health effects associated with water from water bodies after flooding since these parameters studied were higher in 2019 when compared to 2018. The study also, suggests the need to use water from water bodies after flooding for irrigation because its physical and chemical parameters were higher in the water bodies after flooding than before flooding and it is also of better quality since it has lower heavy metals after flooding than before flooding.

SIGNIFICANCE STATEMENT

This study discovered the weather variables and selected water properties affected by flooding and observe that physical parameters and chemical parameters were within the standard and higher in water after flooding than before flooding. This study will help the researchers to uncover the critical areas of usage of water after flooding for irrigation.

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