Asian Journal of Water, Environment and Pollution, Vol. 12, No. 2 (2015), pp. 59–71.

Effect of Flood on Water Resources in North-Central Nigeria

Joseph Terlumun Utsev, Chidozie Charles Nnaji[1]* and Mama Cordelia Nnennaya[1]

Department of Civil Engineering, University of Agriculture, Makurdi, Nigeria
[1]Department of Civil Engineering, University of Nigeria, Nsukka, Nigeria
✉ chidozie.nnaji@unn.edu.ng

Received November 21, 2014; revised and accepted March 19, 2015

Abstract: Surface and groundwater quality of selected states within the North-Central, Nigeria were investigated to ascertain the effect of flood on water quality over a period of six months. Statistical, standardized principal component and water quality index analyses were used to interpret the results. Increase in some groundwater parameters are 198.7% for hardness, 541% for colour, 169.8% for iron, 200% for chromium and 117.6% for calcium. The increase in some surface water quality parameters after the flood is as follows: colour (316.76%), turbidity (171%), total suspended solids (156.65%), conductivity (180.5%), chromium (300%) and sulphate (121.2%). Overall groundwater quality decreased from a fair status (69.1%) before the flood to a marginal status (55.3%) after the flood. In the same vein surface water quality decreased from a fair status (72.53%) before the flood to a marginal status (55.1%). There was a 27% reduction in surface water quality and 20.4% reduction in groundwater quality.

Key words: Flood, surface water, groundwater, pollution.

Introduction

A flood is an overflow of water that submerges land which is usually dry. Flooding is one of the major environmental crises of the century. Occurrence of flood is the most frequent among all natural disasters, affecting about 178 million people in 2010 (Jha et al., 2012). Increased urbanization has caused problems with increased flash flooding after sudden rain. The immediate causes of flood are heavy rain and rise in sea level resulting from climate change, exacerbated by blocked, collapsed and poorly designed drains. Surface runoff (also known as overland flow) is the flow of water that occurs when excess water from rain, meltwater, or other sources flows over the earth's surface. This might occur because soil is saturated to full capacity, or because rain arrives more quickly than soil can absorb it. Surface runoff is a major component of the water cycle. It is the primary agent in soil erosion by water (Horton, 1933; Beven, 2004). Runoff that occurs on surfaces before reaching a channel is also called a nonpoint source. If a nonpoint source contains man-made contaminants, the runoff is called nonpoint source pollution. A land area which produces runoff that drains to a common point is called a drainage basin. When runoff flows along the ground, it can pick up soil contaminants including, but not limited to, petroleum, pesticides or fertilizers that become discharge or nonpoint source pollution (Mackenzie and Masten, 2011). In addition to causing water erosion and pollution, surface runoff in urban areas is a primary cause of urban flooding which can result in property damage, damp and mold in basements, and street flooding. Runoff carrying industrial effluents can contaminate drinking water supplies. Indusries which use large amount of water in their processes include:

*Corresponding Author

Agriculture: Run-off from crops contain pesticides, fertilizer, sediment. Run-off from animal production facilities contain bacteria, organic matter, nitrates and phosphates.

Fruit and Vegetable Processing: Waste water contains high concentration of dissolved organic matter and may be highly alkaline from the use of lye. Most of this water is now recycled.

Petroleum Refining: Oil is mixed with water in the refining process to remove salts and other impurities. It is then separated and collected. Most of this water is now recycled.

Pulp and Paper: The use of bisulfite and sulfurous acid or sulfur dioxide in the pulping process yields a waste sulfite liquor containing various wood by-products. This can be reduced or recycled into various useful products. There is presently a concern over the release of dioxins into waterways by the pulp and paper industry (U.S. EPA, 1980).

Other causes of flood as identified by Ajibola et al. (2012), Daniel et al. (2012) and Ilaboya et al. (2011) are: sea level rise, subsidence and compaction of sediments, riverbed aggradation, soil erosion due to tilling, unregulated urban development, damming of rivers, seismic/neotectonic activities, greenhouse effects, invasion of public areas, development on flood plains, ocean storms, tidal waves, lack of meteorological data for weather forecasting, burst of main pipes, dam burst/levee failures, dam spills/releases and property development along river setbacks. Although flood hazard is natural, human modification and alteration of nature's right of way can accentuate the problem, while the disastrous consequences are dependent on the degree of human activities and occupancy in vulnerable areas (Atedhor et al., 2011). Tschakert et al. (2010) observed that 69% of a total of 244 floods worldwide were attributed to heavy rains. Flooding as a natural occurrence has been also known to be beneficial (Bradshaw et al., 2007). The direct economic benefits of flood events when evaluated include, the deposition of rich topsoil in floodplain (Barley, 1995) and maintenance of wetlands that mitigate the severity of flood events (Salzman et al., 2001). The organic materials and minerals deposited by the river flood water keep the soil fertile and productive (Abowei and Sikoki, 2005).

Despite the advantageous effects of flooding, urban flooding can have devastating consequences such as pollution of water resources, loss of lives and property, destruction of agricultural farms, displacement of people, physical and mental stress as well as outbreak of epidemics. Pollution is the introduction of contaminants into the natural environment that cause adverse change (Pollution: Definition from the Merriam-Webster Online Dictionary). Pollution can take the form of chemical substances or energy, such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classed as point source or nonpoint source pollution. Water pollution is the contamination of water bodies (e.g. lakes, rivers, oceans, aquifers and groundwater). Water pollution occurs when pollutants are directly or indirectly discharged into water bodies without adequate treatment to remove harmful compounds. Water pollution affects plants and organisms living in these bodies of water. In almost all cases the effect is damaging not only to individual species and populations, but also to the natural biological communities.

Torrential rains push rivers over their banks, collapse mud houses and wash away livestock (Adelye and Rustum, 2011). According to Fabiyi (2013), 50% of water-related diseases result from flood incidences. Flooding in cities can contaminate water supplies and intensify the spread of epidemic diseases, diarrhoea, typhoid, scabies, cholera, malaria, dysentery and other water-borne diseases (Odufuwa et al., 2012). The impact of flood is felt more by people in developing countries such as Nigeria with low preparedness and slow response to flood events. Until recently (August 2008), Nigeria did not have an early warning system for flood; and up till now there is no functional flood risk map. All of the above, coupled with poor meteorological data, poor drainage system, lack of urban planning and blockage of waterways by indiscriminate dumping of municipal solid waste have made flood control very difficult. Nicholls et al. (2007) predicted that Nigeria is one of the eleven countries of the world that will have 90% of overall global exposure to flood risk.The year 2012 was a year of multiple unprecedented flood disaster across Nigeria resulting from heavy downpours, dam and bridge collapse, water release from dams and river bank overflows. The floods that occurred between July and October 2012 were adjudged the worst in about half a century, with an estimated loss amounting to 2.6tr naira (20 billion USD). It affected a total of seven million people, displacing 2.1 million people and killing over 300 persons. Summarized in Table 1 are some of the flood cases of 2012.

Most concerns about flood issues in Nigeria have always been in terms of human and economic losses, without any serious consideration of implications for water resources and consequent health effects. Surface

Table 1: Some flood cases in 2012

S/N	*Date*	*Location*	*Geopolitical zone*	*Cause*
1	14/07/2012	Cross river communities	South South	Landslide causing the blockage of River Kaala
2	30/07/2012 to 02/08/2012	Sarduana LGA of Taraba State	North East	Three-day heavy downpour
3	13/08/2012	Shendam, Langtang North and South, Quan Pan and Wase LGAs of Plateau State	North Central	Torrential downpour and subsequent collapse of Shendam Bridge
4	26/08/2012	Jimeta-Yola in Adamawa State	North East	Release of water from Ladgo Dam Cameroun
5	28/08/2012	Bagwai, Bebeji, Garun Malam, Gabasawa, Karanye, Nsssarawa and Sumaila areas of Kano State	North West	
6	01/09/2012	Niger State	North Central	Heavy downpour
7	03/09/2012	Lau, Karim-Lamido and Gasol LGAs of Taraba	North East	
8	12/09/2012	Bauchi and Kaduna States	North West	Overflow of River Katagum
9	15/09/2012	Kano	North West	Overflow of River Tiga
10	16/09/2012	Kogi State	North Central	Release of water from Kainji Dam, Jebba Hydro-Power Plant and Shiroro Dam
11	21/09/2012	Niger State	North Central	
12	23/09/2012	Etsako Central LGA of Edo State	South South	
13	23/09/2012	Delta State	South South	

water is water on the surface of the planet such as in a stream, river, lake, wetland, or ocean. Groundwater is the water located beneath the earth's surface in soilpore spaces and in the fractures of rock formations. Surface and ground water are two separate entities, so they must be regarded as such. However, there is an ever-increasing need for management of the two as they are part of an interrelated system that is paramount when the demand for water exceeds the available supply. Hence this study was conducted in order to ascertain in quantifiable terms, the effect of flooding on water quality.

Materials and Method

Surface and groundwater samples were collected from three cities of North-Central Nigeria namely, Makurdi, Lokoja and Lafia. In each city, groundwater samples were collected from three (3) hand-dug wells with an average depth of 5.08 m and an average diameter of 0.83 m. Before collection of samples, each container was rinsed three times with the sample to be collected. All water samples were taken by 5:00 GMT in the months of April, June, August, October, November and December, 2012. Physical, chemical and the bacteriological quality of the samples were assessed following the standard analytical methods of the World Health Organisation (1995) and American Public Health Association (APHA, 1995).

In order to aid interpretation, the results of laboratory water quality analyses were further subjected to statistical analyses such as mean, correlation and principal component analyses as well as water quality index analyses for water quality classification. Since the parameters had different units, the nominal principal component analysis was not used. Instead the standardized principal component analyses (SPCA) was employed, which makes use of a correlation matrix. The idea behind the standardized principal component analysis is to standardize all parameters to have a mean of 1 and a variance of zero. Varimax rotation was applied on the components and principal component selection criterion is an eigenvalue greater than 1. Extraction of principal components was performed using the Statistical Package for Social Sciences, version 16 (SPSS 16.0). Water quality classification was performed using the approach of the Canadian Council of Ministers of the Environment. The index can be used both for tracking changes at one site over time, and for comparisons among sites. Sites can be compared directly only if the same variables and objectives are used; otherwise, a comparison of the sites' ability to meet relevant objectives must be made in terms of the category obtained. This method represents water quality as a function of three parameters namely: the scope ($F1$) representing the proportion of parameters that failed water quality guidelines, frequency ($F2$) representing proportion of all water quality tests that failed water quality guidelines and amplitude ($F3$) representing the composite degree of departure of all test results from water quality guidelines. Water quality index is given as the difference of 100 and the root of the mean of the squares of $F1$, $F2$ and $F3$. Hence,

$$WQI = 100 - \sqrt{\frac{F1^2 + F2^2 + F3^2}{3}}$$

$$= 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.73}$$

While the computation of $F1$ and $F2$ are simple and straightforward, the computation of $F3$ can be cumbersome even for a moderate number of test results. Hence, a routine template was created in Microsoft Excel to facilitate computation.

Results and Discussion

A summary of average values of all parameters before and after the flood have been presented in Table 2. It is obvious that there was general increase of all parameters, except phosphate, after the flood. There was an approximately 200% increase in groundwater hardness which corresponds to an increase in calcium, magnesium and iron ions. Other groundwater parameters that experienced more than 100% increase are colour (541%), iron (169.84%), chromium (200%) and calcium (117.58%%). The increase in surface water parameters after the flood is as follows: colour (316.76%), turbidity (171%), total suspended solids (156.65%), conductivity (180.5%), chromium (300%) and sulphate (121.2%).

Results of Principal Component Analyses

As already mentioned, principal component analysis was performed on surface water parameters before and after the flood. Three components which explained 97.22% of the total variance were extracted (Table 7). PC1 explained 78.49% of the total variance and is mostly affected by physical and organic parameters. The dependence of PC1 on oxygen demand suggests that the total dissolved and suspended solids are of organic origin. This implies that before the flood, the surface waters were polluted mainly by organic pollutants possibly remains of plants and sewage. The second principal component (PC2) before the flood which explained 12.55% of the total variance is mostly dependent on chemical and biological parameters, possibly from industrial effluents and domestic effluent discharge. The third principal component (PC3) which explained 6.18% represents the polluting effect of agricultural runoff. However after the flood, there was a change in the mode of water pollution as can be seen from Table 6.

Only two principal components which explained 99.53% of the total variance were extracted. The first principal component which explained 92.66% of total parameter variance suggest a synergy between agricultural runoff and domestic effluent in causing variation in water quality. This can be explained by the fact that the flood resulted in channel overflow and resultant intermingling of river water and flood water in agricultural lands and other polluted areas. The second principal component which explained only 6.88% of total variance can be attributed to pollution caused by suspended and dissolved solids, possibly sediments. Obviously, the flood resulted in a switch of pollution mode. The flood event caused pollution from agricultural lands, industrial effluents and domestic effluent to overshadow pollution from sediments.

Only two principal components explaining 98.48% of total variance were extracted for groundwater (Table 8). The first principal component explained an overwhelming 96% of the total variance while the second principal component explained only 2.48% of total variance. The first principal component with high dependence on COD, chloride, BOD, colour and total dissolved solids represents the impact of industrial effluent. This suggests that industrial effluents are not given adequate, if any, treatment before discharge into the environment. Most times, pollutants from industrial effluent discharged into the environment are leached into groundwater by runoff.

The second principal component is dependent on coliform, sulphate, phosphate and hardness. The presence of phosphate and sulphate in water can be attributed to agricultural chemicals, fertilizers, decaying plants and animal manure. Three principal components explaining 98.48% of total variance were extracted for groundwater parameters after the flood. Just like

Table 2: Summary of mean values of parameters and particulars of analysis

Parameter	Unit	Apparatus	Programme No.	Wavelength (nm)	Average value					
					Ground water			Surface Water		
					Before flood	After flood	% Change	Before flood	After flood	% Change
Colour	TCU	AAS HACH DR/2000	120	455	1.85	11.86	541.03	2.39	9.96	316.74
Turbidity	NTU	"	750	450	2.33	2.84	21.89	1.38	3.74	171.01
pH	-	pH meter LB/2000	-	-	7.40	9.89	33.65	7.07	7.57	7.07
TSS	mg/l	AAS HACH DR/2000	650	810	22.15	29.88	34.89	29.69	76.20	156.65
TDS	mg/l	TDS meter HACH 44600	-	-	26.22	32.81	25.12	61.17	102.93	68.27
Conductivity	mg/l	Cond meter HACH 5010	-	-	65.21	69.30	6.27	79.89	224.09	180.50
Fe	mg/l	AAS HACH DR/2000	265	510	0.13	0.34	169.84	0.21	0.33	57.14
Cr	mg/l	"	90	540	0.02	0.06	200.00	0.01	0.04	300.00
Ca	mg/l	"	-	-	32.07	69.78	117.58	37.04	48.07	29.78
Mg	mg/l	"	-	-	26.24	28.55	8.79	22.00	35.33	60.59
Chloride	mg/l	"	70	455	26.02	33.54	28.89	91.17	127.83	40.21
Sulphate	mg/l	"	580	450	27.66	38.58	39.46	21.56	47.69	121.20
Phosphate	mg/l	"	490	890	32.07	28.55	-10.96	23.62	41.16	74.26
Nitrate	mg/l	"	355	500	-	-	-	45.00	54.21	20.47
Hardness	mg/l	HA-4P-MGL	-	-	34.40	102.74	198.66	48.54	67.93	39.95
Temperature	^oC	Thermometer	-	-	27.44	28.57	4.12	28.60	28.67	0.24
COD	mg/l	APHA 1998	-	-	123.79	140.52	13.51	134.12	165.69	23.54
BOD	mg/l	"	-	-	63.00	65.63	4.17	79.44	87.92	10.67
DO	mg/l	"	-	-	5.33	5.55	4.09	6.13	6.79	10.77
Coliform	Count/ 100 ml	"	-	-	427.59	717.78	67.87	511.22	789.67	54.47

TSS = Total Suspended Solid, TDS = Total Dissolved Solid

in the case of surface water, there was a switch in the mode of water contamination. The first principal component which explains 79.09% of the total variance is connected with agricultural runoff, while the second principal component which explains 11.13% of total variance represents the variation in water quality due to mineral dissolution by groundwater. The third principal component (7.10%) is dependent on total solids.

Water Quality Classification

Following the CCME method of calculating water quality indices, the quality of both groundwater and surface water before and after the flood were assessed. Water quality indices for Lokoja, Makurdi and Lafia are shown in Figure 2. Figure 2 clearly suggests that both groundwater and surface water were of poor quality, generally below 45%. However, there was a further decline in water quality after the flood. The water quality indices suggest that both groundwater and surface water are not fit for drinking, without some form of treatment. Going by Figures 2 and 3, it would seem that surface water was of better quality than groundwater. This may not be exactly the case. The seemingly poor quality of groundwater can be

Table 3: Correlation of surface water parameters before the flood

	Temp	*Turb*	*TSS*	*TDS*	*TS*	*Colour*	*Cond*	*pH*	*Fe*	*Cr*	*Hard-ness*	*Ca*	*P*	*Mg*	SO_4	*Cl*	NO_3	*COD*	*DO*	*BOD*	*Bacteria*
Temp	1.00																				
Turb	-0.79	1.00																			
TSS	-0.63	0.68	1.00																		
TDS	-0.70	0.94	0.73	1.00																	
TSS	-0.68	0.95	0.69	0.99	1.00																
Colour	-0.48	0.65	0.52	0.55	0.54	1.00															
Cond	-0.77	0.94	0.61	0.93	0.94	0.58	1.00														
pH	-0.55	0.53	0.29	0.32	0.34	0.55	0.42	1.00													
Fe	-0.32	0.39	0.22	0.24	0.29	0.45	0.31	0.52	1.00												
Cr	-0.49	0.36	0.11	0.22	0.27	-0.23	0.42	0.27	0.21	1.00											
Hardness	-0.78	0.58	0.82	0.47	0.44	0.61	0.51	0.53	0.43	0.28	1.00										
Ca	-0.40	0.54	0.08	0.36	0.43	0.38	0.60	0.58	0.72	0.59	0.30	1.00									
P	-0.73	0.48	0.71	0.40	0.36	0.29	0.30	0.26	0.11	0.22	0.78	-0.14	1.00								
Mg	-0.77	0.73	0.60	0.56	0.59	0.60	0.70	0.61	0.75	0.54	0.82	0.76	0.49	1.00							
SO_4	-0.68	0.75	0.34	0.66	0.70	0.40	0.84	0.60	0.59	0.63	0.43	0.89	0.08	0.79	1.00						
Cl^-	-0.63	0.67	0.57	0.56	0.57	0.57	0.45	0.72	0.59	0.03	0.61	0.26	0.62	0.59	0.41	1.00					
NO_3	-0.75	0.71	0.52	0.66	0.67	0.36	0.85	0.45	0.38	0.67	0.59	0.74	0.23	0.79	0.91	0.25	1.00				
COD	-0.47	0.37	0.07	0.38	0.40	-0.22	0.55	0.24	0.20	0.79	0.10	0.61	-0.07	0.41	0.78	0.01	0.78	1.00			
DO	-0.64	0.91	0.77	0.89	0.90	0.76	0.84	0.61	0.47	0.11	0.62	0.48	0.39	0.69	0.67	0.75	0.61	0.21	1.00		
BOD	-0.70	0.77	0.54	0.82	0.82	0.34	0.92	0.24	0.29	0.51	0.43	0.60	0.18	0.64	0.86	0.24	0.92	0.75	0.67	1.00	
Bacteria	-0.78	0.65	0.56	0.57	0.57	0.47	0.64	0.63	0.77	0.41	0.72	0.65	0.45	0.87	0.80	0.71	0.74	0.52	0.67	0.67	1.00

Table 4: Correlation of surface water parameters after the flood

	Temp	*Turb*	*TSS*	*TDS*	*TS*	*Colour*	*Cond*	*pH*	*Fe*	*Cr*	*Hard-ness*	*Ca*	*P*	*Mg*	*SO_4*	*Cl*	*NO_3*	*COD*	*DO*	*BOD*	*Bacteria*
Temp	1.00																				
Turb	0.30	1.00																			
TSS	0.39	0.96	1.00																		
TDS	0.21	0.95	0.86	1.00																	
TSS	0.36	0.93	0.99	0.81	1.00																
Colour	0.33	0.95	0.98	0.84	0.99	1.00															
Cond	0.21	0.81	0.89	0.67	0.94	0.95	1.00														
pH	-0.35	-0.08	0.03	-0.16	0.16	0.18	0.48	1.00													
Fe	-0.24	-0.07	0.07	-0.22	0.20	0.21	0.49	0.92	1.00												
Cr	-0.18	0.50	0.46	0.57	0.38	0.42	0.28	-0.17	-0.22	1.00											
Hardness	-0.79	0.08	-0.01	0.18	0.03	0.04	0.13	0.42	0.25	0.20	1.00										
Ca	0.21	-0.15	0.07	-0.31	0.17	0.16	0.39	0.69	0.74	-0.14	-0.30	1.00									
P	0.19	-0.14	0.07	-0.36	0.19	0.15	0.42	0.73	0.81	-0.54	-0.16	0.84	1.00								
Mg	0.01	-0.08	0.07	-0.28	0.20	0.18	0.44	0.81	0.86	-0.57	0.14	0.65	0.93	1.00							
SO_4	-0.03	-0.13	0.07	-0.31	0.21	0.17	0.46	0.84	0.89	-0.48	0.09	0.77	0.97	0.96	1.00						
Cl^-	-0.06	-0.13	0.06	-0.32	0.20	0.17	0.46	0.86	0.93	-0.45	0.11	0.78	0.96	0.96	1.00	1.00					
NO_3	0.36	0.87	0.82	0.88	0.74	0.78	0.58	-0.28	-0.33	0.74	-0.13	-0.14	-0.38	-0.44	-0.42	-0.42	1.00				
COD	-0.11	0.12	-0.11	0.30	-0.24	-0.19	-0.46	-0.76	-0.81	0.43	0.08	-0.85	-0.97	-0.88	-0.97	-0.95	0.34	1.00			
DO	0.35	0.11	0.02	0.29	-0.09	-0.05	-0.29	-0.67	-0.75	0.46	-0.46	-0.30	-0.68	-0.86	-0.79	-0.80	0.54	0.64	1.00		
BOD	0.06	0.14	-0.04	0.32	-0.18	-0.13	-0.42	-0.82	-0.87	0.55	-0.13	-0.69	-0.95	-0.97	-0.99	-0.99	0.48	0.95	0.83	1.00	
Bacteria	0.25	0.50	0.65	0.31	0.75	0.74	0.90	0.69	0.73	-0.09	0.06	0.64	0.76	0.78	0.78	0.78	0.21	-0.77	-0.55	-0.75	1.00

Table 5: Correlation of groundwater parameters before flood

	Temp	*Turb*	*TSS*	*TDS*	*TS*	*Colour*	*Cond*	*pH*	*Fe*	*Cr*	*Hard-ness*	*Ca*	*P*	*Mg*	*SO_4*	*Cl*	*COD*	*DO*	*BOD*	*Bacteria*
Temp	1.00																			
Turb	0.26	1.00																		
TSS	0.53	0.24	1.00																	
TDS	0.51	-0.27	0.34	1.00																
TSS	0.29	-0.09	0.04	0.53	1.00															
Colour	0.65	0.11	0.67	0.53	0.20	1.00														
Cond	0.11	0.28	0.18	0.03	0.29	0.06	1.00													
pH	0.01	-0.21	-0.05	0.23	0.38	-0.02	0.07	1.00												
Fe	0.33	0.60	0.42	-0.05	-0.08	0.47	0.41	-0.12	1.00											
Cr	0.26	0.09	0.08	0.31	0.00	0.21	0.21	0.22	-0.04	1.00										
Hardness	0.36	0.10	0.51	0.16	-0.25	0.29	0.24	-0.48	0.26	0.17	1.00									
Ca	0.32	0.06	0.51	0.41	0.24	0.63	0.32	0.04	0.46	0.09	0.32	1.00								
P	0.38	0.05	0.53	0.41	0.02	0.50	0.41	-0.29	0.30	0.27	0.54	0.56	1.00							
Mg	0.45	0.14	0.60	0.39	0.06	0.67	0.42	-0.01	0.49	0.26	0.47	0.47	0.52	1.00						
SO_4	0.63	0.38	0.64	0.37	0.03	0.51	0.37	0.11	0.49	0.48	0.54	0.55	0.59	0.49	1.00					
Cl^-	0.60	0.00	0.40	0.69	0.61	0.79	0.31	0.05	0.42	0.16	0.12	0.56	0.41	0.60	0.35	1.00				
COD	0.45	0.17	0.36	0.42	0.68	0.42	0.43	-0.06	0.32	-0.14	0.22	0.56	0.23	0.35	0.26	0.69	1.00			
DO	0.17	-0.01	-0.21	0.06	0.14	0.16	-0.33	-0.03	-0.08	0.06	-0.42	-0.25	-0.15	-0.25	-0.16	0.23	-0.15	1.00		
BOD	0.47	0.05	0.38	0.64	0.67	0.58	0.28	0.17	0.19	0.31	0.24	0.61	0.33	0.45	0.38	0.72	0.69	-0.08	1.00	
Bacteria	0.41	0.60	0.50	0.13	-0.03	0.46	0.34	-0.24	0.51	0.18	0.54	0.39	0.60	0.42	0.66	0.23	0.27	-0.12	0.25	1.00

Table 6: Correlation of groundwater parameters after flood

	Temp	*Turb*	*TSS*	*TDS*	*TS*	*Colour*	*Cond*	*pH*	*Fe*	*Cr*	*Hard-ness*	*Ca*	*P*	*Mg*	*SO_4*	*Cl*	*COD*	*DO*	*BOD*	*Bacteria*
Temp	1.00																			
Turb	0.33	1.00																		
TSS	0.58**	0.28	1.00																	
TDS	0.59**	0.09	0.68**	1.00																
TSS	0.40*	0.14	0.43*	0.50**	1.00															
Colour	-0.23	-0.15	-0.16	-0.23	-0.86**	1.00														
Cond	0.64**	0.16	0.54**	0.66**	0.44*	-0.14	1.00													
pH	0.13	-0.03	0.37	0.27	0.15	-0.03	0.06	1.00												
Fe	0.53**	0.24	0.64**	0.46*	0.43*	-0.14	0.50**	0.08	1.00											
Cr	0.11	0.12	0.21	0.07	-0.17	0.38	0.20	-0.15	0.59**	1.00										
Hardness	0.40*	0.17	0.44*	0.23	0.35	-0.10	0.40*	0.26	0.78**	0.43*	1.00									
Ca	0.37	0.10	0.45*	0.24	0.37	-0.12	0.43*	0.21	0.77**	0.39	0.98**	1.00								
P	-0.48*	-0.32	-0.63**	-0.30	-0.35	0.09	-0.47	-0.27	-0.83**	-0.49*	-0.78**	-0.74**	1.00							
Mg	0.27	-0.02	0.22	0.24	0.34	-0.09	0.17	0.43*	0.61**	0.22	0.79**	0.75**	-0.47*	1.00						
SO_4	-0.44*	-0.34	-0.36	-0.14	-0.23	-0.03	-0.42*	-0.26	-0.58**	-0.43*	-0.59**	-0.52**	0.85**	-0.37	1.00					
Cl^-	-0.40*	-0.28	-0.63**	-0.33	-0.42*	0.17	-0.54**	-0.31	-0.67**	-0.31	-0.52**	-0.49*	0.88**	-0.24	0.79**	1.00				
COD	-0.29	-0.20	-0.54	-0.28	-0.40	0.27	-0.41	-0.06	-0.65	-0.33	-0.61	-0.64	0.77	-0.22	0.57	0.69	1.00			
DO	-0.25	0.00	-0.10	-0.23	-0.06	-0.14	-0.12	-0.05	-0.41	-0.44	-0.40	-0.39	0.17	-0.41	0.15	-0.01	-0.03	1.00		
BOD	-0.04	-0.45	-0.15	0.27	0.11	-0.07	-0.09	0.11	-0.19	-0.37	-0.36	-0.32	0.55	0.11	0.54	0.44	0.50	-0.07	1.00	
Bacteria	0.44	0.22	0.71	0.50	0.48	-0.20	0.54	0.05	0.83	0.42	0.66	0.69	-0.66	0.42	-0.33	-0.57	-0.58	-0.22	-0.16	1.00

Table 7: Principal components of surface water quality

	Surface water before the flood			*Surface water after flood*	
	PC1	PC2	PC3	PC1	PC2
Temperature	-0.34	-0.46	***-0.51***	0.03	0.35
Turbidity	***0.85***	0.32	0.33	-0.12	***0.98***
TSS	***0.67***	0.05	0.48	0.07	***0.98***
TDS	***0.92***	0.31	0.21	-0.31	***0.92***
TS	***0.91***	0.33	0.21	0.21	***0.96***
Colour	***0.58***	-0.10	0.48	0.18	***0.98***
Conductivity	***0.80***	0.55	0.17	0.46	***0.88***
pH	0.17	0.20	***0.60***	***0.84***	0.04
Iron	0.02	0.26	***0.77***	***0.90***	0.04
Chromium	0.01	***0.72***	0.02	-0.49	***0.51***
Hardness	0.33	0.17	***0.71***	0.06	0.04
Calcium	0.14	***0.68***	0.30	***0.79***	0.02
Phosphate	0.35	-0.12	***0.56***	***0.97***	-0.02
Magnesium	0.34	0.48	***0.66***	***0.97***	0.01
Sulphate	0.39	***0.80***	0.32	***0.99***	-0.01
Chloride	0.44	-0.10	***0.81***	***0.99***	-0.02
Nitrate	0.41	***0.83***	0.24	-0.41	***0.87***
COD	0.07	***0.95***	-0.03	***-0.96***	-0.02
DO	**0.81**	0.17	0.48	***-0.78***	0.10
BOD	**0.61**	***0.77***	0.12	***-0.98***	0.04
Bacteria	0.25	***0.55***	***0.80***	***0.79***	***0.61***
Total variance explained (%)	*97.22*			*99.53*	

traced to the method of abstraction (shallow wells). Most people belonging to the lower and middle income classes cannot afford their own boreholes because of its high cost which can sometimes reach N5,000,000 ($32,467.53). These wells are usually shallow which results in insufficient filtration of percolating water. Moreover, the wells are not usually tightly covered leading to unrestricted inflow of highly polluted runoff

Table 8: Principal components of ground water quality

	Groundwater before flood		*Groundwater after flood*		
	1	2	1	2	3
Temperature	***0.52***	0.32	0.40	0.24	-0.14
Turbidity	0.04	***0.60***	0.21	0.07	-0.10
TSS	0.37	0.44	***0.69***	0.16	0.00
TDS	***0.59***	0.03	***0.52***	-0.01	-0.11
TS	***0.77***	-0.17	0.48	0.13	***-0.77***
Colour	***0.55***	0.37	-0.24	0.05	***0.97***
Conductivity	0.40	0.27	***0.51***	0.21	-0.03
pH	0.07	-0.25	-0.02	0.30	-0.06
Iron	0.30	0.46	***0.73***	***0.51***	0.02
Chromium	0.00	0.19	0.34	0.32	0.46
Hardness	0.15	***0.53***	0.45	***0.89***	-0.03
Calcium	***0.61***	0.29	0.49	***0.86***	-0.04
Phosphate	0.27	***0.57***	***-0.52***	***-0.63***	-0.01
Magnesium	0.43	0.35	0.24	***0.75***	-0.06
Sulphate	0.29	***0.62***	-0.19	***-0.58***	-0.05
Chloride	***0.85***	0.09	***-0.50***	-0.35	0.07
COD	***0.95***	0.11	-0.49	-0.47	0.18
DO	-0.03	-0.12	-0.13	-0.38	-0.16
BOD	***0.81***	0.12	-0.07	-0.38	-0.07
Bacteria	0.17	***0.98***	***0.97***	0.25	0.03
Total variance explained (%)	*98.48*		*98.48*		

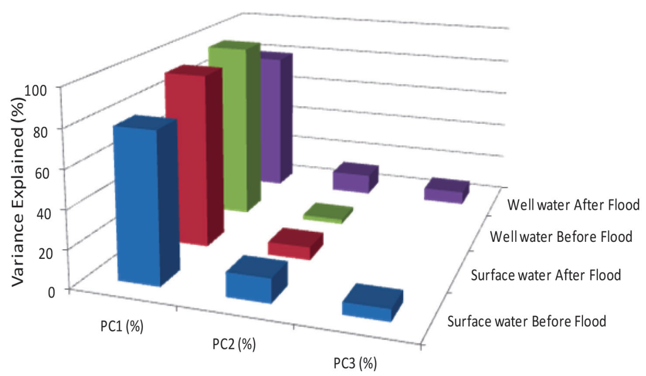

Figure 1: Percentage of variance in water quality explained by the principal components.

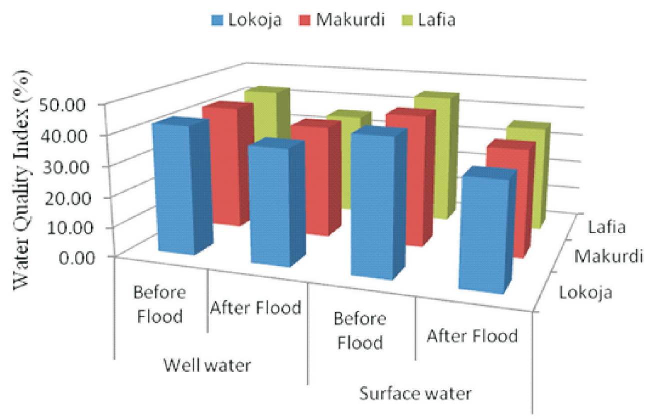

Figure 2: Water quality indices of different locations before and after the flood.

and effluents, as well as the trapping of animals which subsequently decay in the wells.

During the analyses, it was observed that the values of water quality indices were affected by the excessive departure of some parameters from water quality guidelines. In order to determine the parameters that had the most pronounced effect on water quality classification, the proportion of cumulative excursion contributed by each parameter was calculated as presented in Figure 4. Interestingly, it was discovered that magnesium contributed over 90% of departure from water quality guidelines for both groundwater and surface water, before and after the flood. This represented an undue influence of magnesium over other parameters used in the analyses. As yet, the cause of this marked departure of magnesium from stipulated standards has not been determined. Hence, the water quality index calculations were repeated with the exclusion of magnesium. The resultant water quality

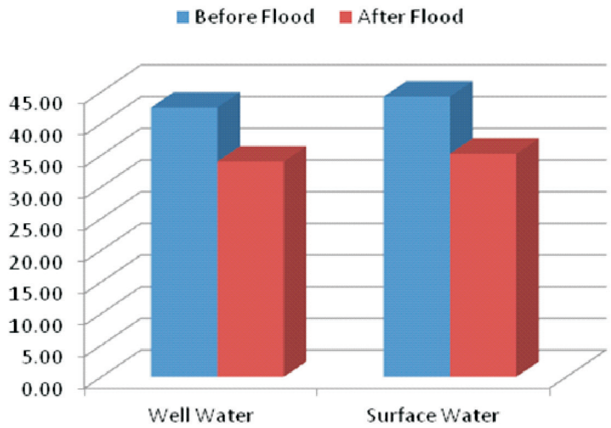

Figure 3: Overall water quality indices before and after the flood.

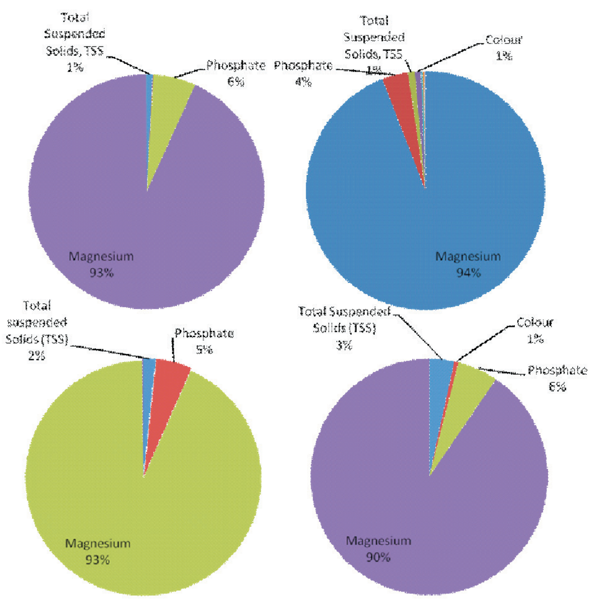

Figure 4: Parameters that exceeded guideline values (percentage exceedance)—a: groundwater before the flood, b: groundwater after the flood, c: surface water before the flood, and d: surface water after the flood.

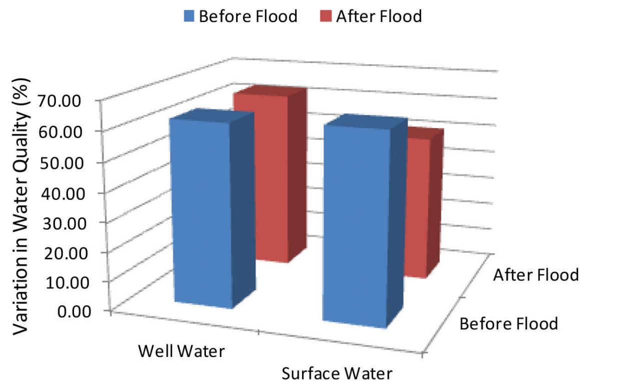

Figure 5: Percentage contribution of magnesium to decline in water quality.

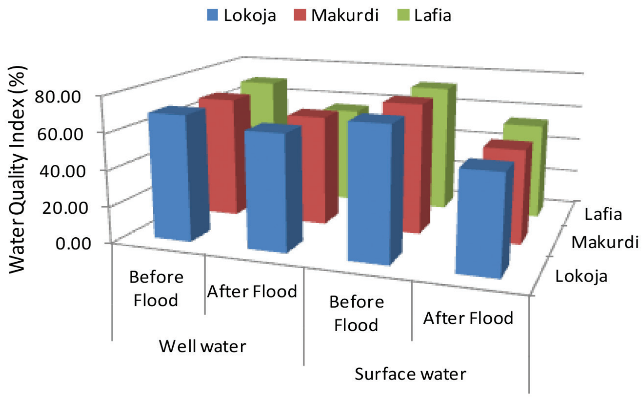

Figure 6: Water quality indices of different locations before and after the flood (magnesium excluded).

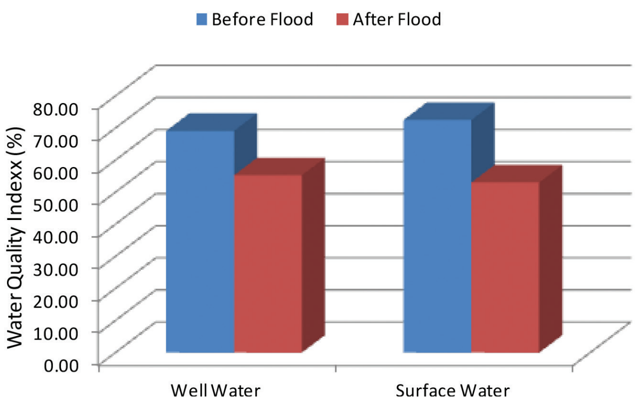

Figure 7: Overall water quality indices before and after the flood (magnesium excluded).

Table 9: Summary of interpretation of principal components

	Principal components	*PC1*	*PC2*	*PC3*
Groundwater	Before flood	Industrial effluent discharge	Surface runoff	-
	After flood	Agricultural runoff	Mineral dissolution	Sediments
Surface water	Before flood	Sediment organic pollution	Mineral dissolution Agricultural runoff Effluent discharge	Mineral dissolution Agricultural runoff Microbial contamination
	After flood	Mineral dissolution Agricultural runoff Organic pollution Microbial contamination	Sediment (primary) Agricultural runoff (secondary)	-

index showed a marked improvement. As shown in Figure 5, the improvement in surface water quality indices is 72.2% and 53.06% before and after the flood respectively; while that for groundwater were 69.14% and 55.3% before and after the flood respectively.

The impact of flood on water quality is clearly portrayed by Figures 6 and 7. As shown in Figure 6, groundwater quality indices for the different locations were generally around 69% (fair quality) before the flood, but declined to between 61% and 55% (marginal quality) after the flood. Same goes for surface water whose water quality indices for all locations was about 72% (fair quality) before the flood, but decreased to between 51 and 53% after the flood. There is clearly a significant reduction in water quality as a result of the flood. Overall, there was a 27% reduction in surface water quality as against 20.4% reduction in groundwater quality. Obviously, as expected, the flood had more severe effect on surface water than on groundwater. This is because the self purification capacity of rivers was grossly impaired by the flood, as the flood water took a long time to recede. Also, the flood had a more lasting impact on surface water. Significant improvement in surface water quality can be expected only after flood water has completely receded. However, since groundwater is a product of infiltration, some persistent pollutants will be transported to the groundwater, thereby reducing its quality.

From the analyses, the most important pollutants of surface water before the flood are dissolved solids, suspended solids, conductivity, colour and BOD; while those after the flood are chloride, sulphate, magnesium, phosphate, calcium, iron, COD, BOD and total coliform. For groundwater, the most important pollutants before the flood are COD, chloride, BOD, calcium, suspended solids and dissolved solids; while those after the flood are coliform, iron, chloride, phosphate and total suspended solids. There was a general oxygen deficit for both groundwater and surface water. There was, however, an increase in the dissolved oxygen content of surface water from an average value of 6.13 mg/l before the flood to 6.79 mg/l after the flood. This might have been as a result of increased area of exposed water surface which facilitated the mass transfer of oxygen from the atmosphere to water. However, it was impossible for diffusion to approach saturation since there was a quick depletion of dissolved oxygen as a result of abundance of organic matter. The low dissolved oxygen content of groundwater, is not unexpected since oxygen mass transfer was severely retarded. A nearly 200 fold increase in hardness of groundwater was observed after the flood. This suggests that water became more corrosive after the flood, thereby catalysing the dissolution of soil minerals of calcium, magnesium and iron which are responsible for hardness. It should be noted that before the flood, surface water was harder than groundwater; but the flood reversed the trend. The correlation table shows that a very high correlation exists between hardness on one hand and calcium (R = 0.98), magnesium (R = 0.79) and iron (R = 0.78).

Conclusion

Flood is a natural disaster which has far reaching implications for man and his environment. The 2012 flood in Nigeria led to a drastic reduction in the quality of both groundwater and surface water. The study shows that the quality of surface water can go a long way in determining the quality of groundwater; and that groundwater abstracted from shallow wells are usually of lower quality than surface water if the wells are not properly covered. The major sources of water pollution before the flood as identified in this study are industrial effluents for groundwater, and organic and inorganic suspended solids for surface water. The major sources of water pollution after the flood are agricultural runoff, organic pollution, microbial contamination and dissolved minerals for both groundwater and surface water after the flood. Generally both groundwater and surface water quality reduced from fair to marginal.

This study has shown that flood can have a severe polluting effect on water resources. Unfortunately, however, most responses to flood disaster are usually focused on lives lost and property destroyed while little or no attention is paid to water resources. If adequate measures are not taken to mitigate the effect of flood on water resources, the indirect cost in terms of health implication might be comparable to the direct impact of flood. Hence there is need for the Nigerian Government to incorporate water resources remediation measures in their flood response programme.

References

Ajibola, M.O., Izunwanne, E.M. and A.O. Ogungbemi (2012). Assessing the effects of flooding on residential property values in lekki phase I, Lagos, Nigeria. *International Journal of Asian Social* Science, **2(3):** 271-282.

Abowei, J.F.N. and F.D. Sikoki (2005). Water Pollution Management and Control. Double Trust Publications Co., Port Harcourt, Nigeria.

Adelye, A. and R. Rustum (2011). Lagos (Nigeria) flooding and influence of urban planning. *J. Urban Design and Planning*, **164(3):** 175-187.

Atedhor, G.O., Odjugo, P.A.O. and A.E. Uriri (2011). Changing rainfall and anthropogenic-induced flooding:Impacts and adaptation strategies in Benin City, Nigeria. *Journal of Geography and Regional Planning*, **4(1):** 42-52.

Barley, P.B. (1995). Uunderstanding large river floodplain ecosystems. *Bioscience*, **45:** 153-162.

Beven, Keith (2004). Robert E. Horton's perceptual model of infiltration processes, Hydrological Processes, Wiley Intersciences. DOI 10:1002 hyp 5740.

Bradshaw, C.J., Sodhi, N.S., Peh, S.H. and B.W. Brook (2007). Global evidence that deforestation amplifiers flood risk and severity in the developing world. *Global Change Biol*., **13:** 2379-2395.

Daniel, D.I., Juji, G.R., Eziukwu, N.A. and A.H. Omilola (2012). Analysis of the relationships of urbanization dynamics and incidences of urban flood disaster in Gombe metropolis, Nigeria. *Journal of Sustainable Development in Africa*, **14(2):** 1-14.

Fabiyi, I.P. (2013). Time to peak (Tp) and basin physiography in the upper Kaduna river catchment, Nigeria. *Scholarly Journal of Scientific Research and Essay* Writing, **2(1):** 1-10.

Horton, Robert E. (1933). The Horton Papers.

Ilaboya, I.R., Atikpo, E., Onaiwu, D.O., Umukoro, L. and M.O. Ezugwu (2011). Application of flood flow routing as a predictive model for flood management and control. *Journal of Environmental Technology and Environmental Sanitation*, **1(3):** 207-220.

Jha, A., Block, R. and J. Lamond (2012). Cities and Flooding. World Bank, Washington, D.C.

Mackenzie, L. Davis and Susan J. Masten (2011). Principles of Environmental Engineering and Science.

National Summary of Water Quality Conditions. Inventory Report to Congress, 1994. URL: http://www.epa.gov/305b/execsum.html

Nicholls, R.J., Hanson, S., Herweijer, C., Patmore, N., Hallegate, S., Corfee-Marlot, J., Chateau, J. and R. Muir-Wood (2007). Ranking of the World's Cities Most Exposed to Coastal Flooding Today and in the Future. OECD Environment Working Paper No. 1 (ENV/WKP(2007)/1.

Odufuwa, B.O., Adedeji, O.H., Oladesu, J.O. and A. Bongwa (2012). Floods of fury in Nigerian cities. *Journal of Sustainable Development*, **5(7):** 69-79.

Salzman, J., Thompson, B.H. and G.C. Daily (2001). Protection ecosystem services: Science, economics and law. *Stanford Environmental Law Journal*, **20:** 309-332.

Tschakert, P., Sagoe, R., Ofori-Darko, G. and N.S. Codjoe (2010). Floods in the Sahel: An analysis of anomalies, memory and anticipatory learning. *Climate Change*, doi 10.1007/s/10584-009-9776-y.

U.S. EPA (1980). Planning Workshop to Develop Recommendations for a Ground Water Protection Strategy. Appendixes. Washington DC.