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Original paper

Effects of Farming Activities and Poor Sanitary Practices on Physicochemical Characteristics of Surface and Groundwater Sources of Kaura-Namoda, Zamfara State, Nigeria

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ABSTRACT: Water naturally contains many different dissolved inorganic constituents. The two types of water under study here are groundwater and surface water. The quality of groundwater and surface water generally varies depending on the soil types and environmental activities carried out by humans. For this study, 20 samples of underground and 8 samples of surface water within Kaura Namoda Town were collected in the wet season and dry season tested and analyzed using WHO and NSDWQ quality guidelines for potable water. A total number of 19 quality parameters were tested for the wet season while 10 quality parameters were tested for the dry season. The findings reveal that in the groundwater, all the values determined show that the quality of groundwater is safe within an acceptable level and poses no health challenge to the consumers. On the other hand, the findings also establish that the quality values for the surface water in both wet and dry seasons for total hardness, total coliform, Magnesium, and Phosphate were found to exceed the permissible level but pose no health hazard to the users. Despite the negative side effects of unwholesome sanitary practices on sources of water this investigation shows that sanitary practices had not adversely affected the quality of water sources to make it unusable, however we recommends that improvement in sanitary practices is necessary for homes and the environment. Based on the increasing trend of magnesium concentration discovered in this present study it is hereby recommended that further research be conducted to find out the source of magnesium infiltration to the water sources and how to minimize the level in the study area.

Keywords: Surface water, groundwater, physicochemical characteristics, water quality, sanitation

INTRODUCTION

Next to the air is water as it may be inferred from the daily demand by human being. Water can be considered second to life's most basic requirements and despite the necessity of adequate quantity, quality and safe water supply needed by man, water has become one of the most abused. This is due to uncontrollable human activities resulting in incessant pollution of fresh surface and groundwater. Though, the pattern and containable level of life's development largely depend upon the quantity, quality, and variations in the availability and supply of water made available to the population of a particular environment. Scientific studies have revealed that the natural distribution of all the water on Earth allocates approximately 96.5% to oceans and approximately 2.5% occurs as fresh water and of the freshwater, approximately 68.7% (Water Science School, 2019) is tied up in the polar ice covers and glaciers, then of the surface fresh water 22% flows freely and slowly toward the sea as groundwater, 0.4% is found in lakes, 0.04% in streams and 0.043% in the atmosphere (Magaji, 2011) (Figure 1). It is a fact that fresh water is precious and its quality must be checked and protected against contaminants and pollution. Although the demand for fresh and quality water is fast increasing due to increased

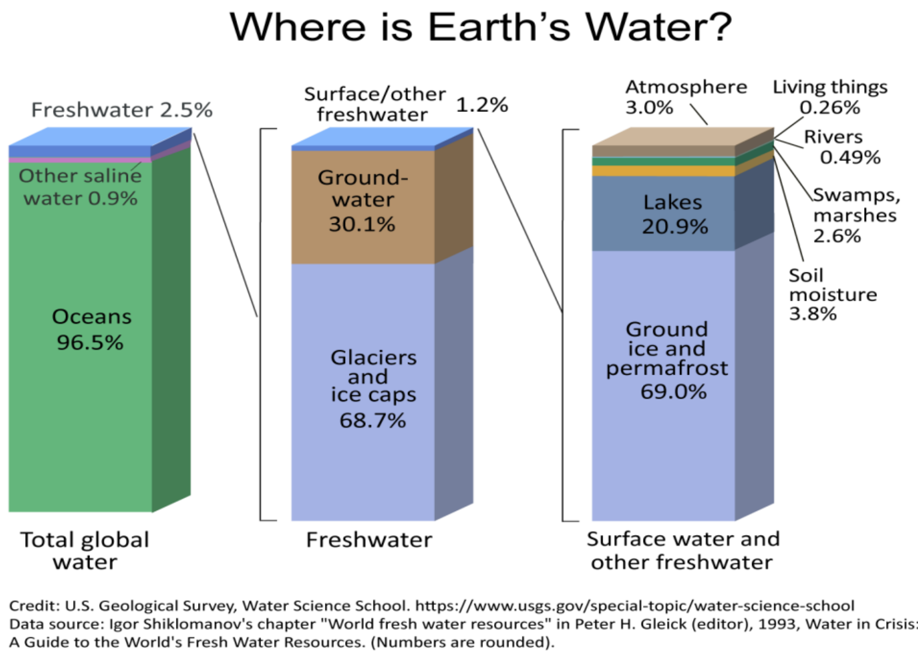

Figure 1: Where is Earth's Water?
Source: Water Science School (October 25, 2019).

knowledge and awareness of the negative consequences of unwholesome water, the persistent increasing growth in world population coupled with various daily human activities that hadcontinues to be a serious challenge to access to safe water supply, especially among rural dwellers with particular reference to the developing countries. In the course of its quest and search for a possible solution to having access to clean, safe, and quality water, the World Health Organization (WHO) in collaboration with its agency unit, UNICEF (now called the United Nations Children Fund but formally named as United Nations International Children's Emergency Fund) in their joint monitoring Programme had identified water-related diseases as the most common causes of illness and death among the poor in the developing countries (WHO, 2005; WHO/UNICEF, 2005). The essence of WHO/UNICEF launching the joint monitoring Programme is for the world population to have access to and use safe drinking water capable of making an immense contribution to human health, to avert the undesirable amenity and danger that contaminated and polluted water is posing to human health. In the study conducted by (Jibril, 2019; Ovrawah and Hymore, 2001; Moses et al, 2019; Abdulqadir et al,2020) it was revealed that the quality parameters of water available to the communities are above the maximum permissible level, hence the people in these communities are at potential risk to contracting water-borne and sanitation related diseases and illness. Galadima et al. (2011) and Enejo *et al.* (2016) also reported that cities and rural areas in Nigeria equally echoed the decline in the quality of surface and groundwater available to the people.

While several types of research have been conducted about water contamination, pollution, and its challenges globally and particularly in Nigeria, there is a dearth of scientific study regarding the effects of farming activities and poor sanitary practices on physicochemical characteristics of surface groundwater sources in Kaura Namoda, Zamfara State, Nigeria despite the formidable campaign against water pollution and its death consequential effects on world population by the World Health Organization (WHO) coupled with the collaborating efforts of governments, governmental agencies, and non-governmental agencies to always finding solutions and mitigation to water pollution problems. It is against this backdrop that the present study explores the possible effects of sanitary practices and farming activities on the water sources of Kaura Namoda Town in Zamfara State, Nigeria.

Statement of the problem

Getting safe, quality, and polluted-free water in Nigeria has been a major serious challenge to government at all levels despite the huge financial resources invested in Nigeria's annual budgetary allocations for water supply for the country's population for years coupled with the considerable investment of governments in Nigeria over the years in this essential human requirement, a large population still does not have access to water in adequate quantity and quality. According to Adeshina and Bello (2018), the Federal Government of Nigeria in a report estimated that only 48% of the inhabitants of the urban and semi–urban areas of Nigeria and 39% of rural areas have access to potable water supply. Despite these low figures, the average delivery to the urban population is only 32 liters per person per day and that for rural areas is 10 liters per person per day which is below the United Nations standard and again the quality in most cases is suspected to be poor. Various reasons were adduce to be responsible for these situations this include poor planning, inadequate funding, insufficient relevant manpower, haphazard implementation, etc., and above all, the lack of a national policy for water supply (Adeshina and Bello, 2018)*.*The case for a quest for clean, safe, and quality and quantity of water for residents of Kaura Namoda in Zamfara State is not in isolation from that of Nigeria at large as it has been a major source of concern to both the government and the inhabitants of Kaura Namoda especially as identified by research which established that in Kaura Namoda "It was found that the total required water consumption per person per day of the communities is 12,212,796 liters. An optimal value of N223, 662.39k was obtained in transporting the required quantities of water to all the communities every day (Adeshina and Bello, 2018). The water rate consumption of persons per day in Kaura Namoda going to the revelation from the study by *Adeshina and Bello (2018)* is far in shortage of the UN/WHO per person water consumption per day pegged at *"*between 50 and 100 liters of needed to ensure that most basic needs are met and few health concerns arise" *(*The Human Right to Water and Sanitation: Media Brief*)*.Adeshina and Bello (2018) in their findings from their study identified *"*Various reasons responsible for this situation to include poor planning, inadequate funding, insufficient relevant manpower, haphazard implementation, etc. and above all, the lack of a national policy for water supply. Others include corruption, mismanagement of, and embezzlement of funds.

It is therefore imperative to note, going by the challenges that are hindrances to safe and quality water that Water quality is a consequence of the natural physical and chemical state of the water as well as any alterations that may have occurred because of human activity. Water quality is determined by the solutes and gases dissolved in the water as well as the matter suspended in and floating on the water, and that is why groundwater should not be assume to meet up with potable water quality (Adebola and Sani, 2014).Most of the populace of the Kaura-Namoda area is involved in farming activities as well as extensive use of both organic and inorganic fertilizers. Poor sanitary practices are also rampant in the area which can make the available surface and groundwater contaminated or polluted.

One basic measure of water quality is the level of total dissolved solids (TDS), which is the total amount of solid in milligrams per litre that remains when a water sample is evaporated to dryness.

Water naturally contains many different dissolved inorganic constituents such as anions (calcium, magnesium, sodium, and potassium) and cations (chloride, Sulphate, carbonate, and bicarbonate). In addition, there may be minor constituents like iron, manganese, fluoride, nitrate, strontium, and boron. Trace elements such as arsenic, lead, cadmium, and chromium may be present in amounts of only a few micrograms per litre but they are important from a water quality standpoint. Therefore, contaminated groundwater and surface water pose a serious threat to health, therefore, it is on this note that the realization that surface water and groundwater quality may have become degraded due to contamination from farming activities as well as poor sanitary practices of the area demand investigation of which this research tends to unravel. Agriculture is viewed as a significant non-point source of groundwater contamination (Ahmed et al, 2016). However, the widespread use of fertilizer and pesticides to improve crop yield year by year presents a challengeable problem that demands investigation, likewise the open surface disposal of solid waste demand assessment. The outcome of the investigation will give room for monitoring water sources and upgrading methods of waste disposal.

Aim and objectives

The aim is to examine the effect of farming activities and poor sanitary practices on physicochemical parameters of surface and groundwater sources of Kaura-Namoda area while the objectives are:

i. To determine the water quality concerning Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standards
ii. To detect any heavy metals in the water that may pose a threat to health
iii. To determine the level of coliforms in the water that may pose a threat to health

Location and geography of the study area

Zamfara State covers an area of about 38,418km2 and is located between latitudes 110 8' 00'' N and 130 22' 00'' N, longitude 60 52' 00'' E and 90 20' 00'' E (source) It is bordered by the North by Niger Republic, to the South by Kaduna State, in the East by Katsina State and to the West by Sokoto and Niger States. It has a population of 3,278,873 and consists of fourteen local government areas including Kaura Namoda, the core study area (National Population Census, 2006) The population of farmers in Zamfara State is 95% of the total population of the state and is a reflection of the population of those engaged in farming activities in the communities (Chukwuji et al., 2018). Kaura Namoda Town is the Headquarter of Kaura Namoda LGA and is located in the Northeastern part of Zamfara State of North Western Nigeria between latitude 120 33' 49'' N and latitude 120 39' 00'' N, longitude 6033' 13'' E and longitude 60 37' 12'' E (source). It is located about 56.5km East of Gusau town and is accessible through a network of both tarred and untarred roads. It has an area of 868 km2 and a population of 281,367 (National Population Census, 2006)

Climate

The latitudinal position of Zamfara State and its interior location away from the sea determines its climate and therefore its 2 main seasons, the dry season from November to May and the wet season from June to October. Therefore, the climate is relatively hot with maximum day temperatures reaching 38^0C during the peak of the hot season around May (NIMET, 2018). The area is affected by two wind patterns, the harmmattan wind from the Sahara, which is responsible for the cool months of December to February (about 240C), and the Southwest Monsoon Trade Winds blowing across the Atlantic Ocean that is responsible for the rains of June to October. The average relative humidity is put at 42% (Egbuniwe, 1982; Adekoya, 1995). Average annual rainfall is from about 800mm to 1000mm (Nigerian Meteorological Agency, 2015) as shown in (Table 1 and Figure 2), but in 2018 the average annual rainfall was 756mm (NIMET, 2018).

Vegetation

The area is predominantly Sudan Savannah, which consists of scattered trees with sparse shrubs and grasses. The trees here grow long taproots and thick barks that make it possible for them to withstand the long dry season. The grass too has long durable roots that remain underground after stalks are burnt away or wilted in the dry season only to germinate with the first rains. This area has been subjected to many years of bush-burning and overgrazing. Trees such as Azadiracha Indica (Neem Tree) and Parkia Biglobosa (Locust Bean) are now being planted to check against desert encroachment and erosion.

Literature review

This section presented the reviews of the scholarly documents of previous researches and studies that are not only related to the study but are highly connected to it from which the gap of the previous studies were identified and which serves as a baseline for the present study

Surface water

Surface waters include streams, rivers, lakes, reservoirs, and wetlands. The term stream is used here to represent all flowing surface water, from brooks to large rivers. The Nation's surface-water resources, the water in the nation's rivers, streams, creeks, lakes, and reservoirs-are vitally important to our everyday life. The main uses of surface water include drinking household uses and other public uses, which include irrigation uses. Majorly, the water used for thermoelectric power, public supply, irrigation, mining, and industrial purposes came from surface-water sources (Adamu and Adekiya, 2010). An illustrative example of water exploration is that of the USA. In 2005 USA used about 410,000 Mgal/d from fresh and saline water, and about 80 percent (328,000 Mgal/d) came from surface-water sources (UNICEF, 2010). Water from groundwater sources accounted for the remaining 20 percent, while 85 percent of the water used in 2005 was fresh water, although saline water was heavily used in the thermoelectric-power industry, and, to a lesser extent, for industrial and mining purposes (UNICEF, 2010).

About 77 percent of the freshwater used is from surface water and 23 percent from groundwater. Surface water is an important natural resource used for many purposes, especially irrigation and public water supply (UNICEF 2010).

Groundwater

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground varies widely from place to place, depending on the slope of the land, the amount and intensity of rainfall, and the type of land surface. Porous, or permeable as it may be said, the land contains lots of sand or gravel which allows as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable soils, as little as 5% may seep into the ground. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater (Water Science School, 2019). As water seeps through the permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone (Amadi, 2009; Adamu and Adekiya, 2010; Dan-Hassan, et al., 2012). The top of the saturated zone is called the water table. This water table can rise or fall according to the season of the year and the amount of precipitation that occurs. The water table is typically higher in the rainy season and lowers in the dry season. The porous area between the land surface and the water table is known as the unsaturated zone (Dada, 2006; Amadi, et al., 2012). The importance of groundwater is gaining recognition, because this resource represents some 98 percent of the planet's freshwater resources (polar ice excluded), is

Table 1: Average rainfall, temperature and relative humidity from 2003 to 2012.

Year	Rainfall (mm)	T-Max (^{0}C)	T-Min (^{0}C)	Rel. Humidity (%)
2003	87.3	33	19.81	41.71
2004	139.6	34.12	19.99	42.84
2005	103.8	34.12	20.42	42.53
2006	139.28	34.27	20.14	39.6
2007	127.35	34.07	20.52	40.39
2008	79.59	33.4	19.93	40.14
2009	72.93	34.51	21.2	41.07
2010	136.53	34.01	20.92	44.48
2011	110.42	34.12	19.27	41.53
2012	121.25	33.58	20.14	45.76

T-Max = Maximum Temperature, T-Min = Minimum Temperature, Rel. Hum = Relative Humidity (Nigerian Meteorological Agency, 2015).

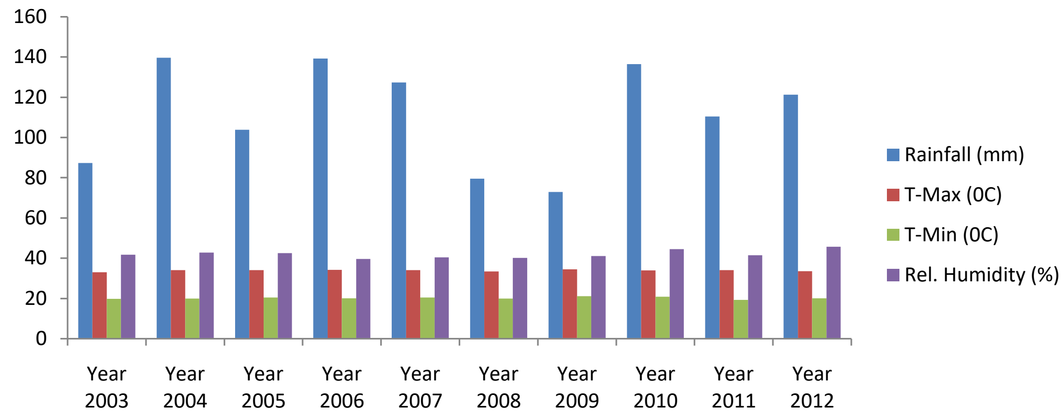

Figure 2: Chart of Average Rainfall, Temperature and Relative Humidity from 2003 to 2013 (Nigerian Meteorological Agency, 2015).

extensively used for low-cost rural water supply, is increasingly developed for both large and small-scale irrigation schemes, is generally reliable in periods of drought because of its large storage capacity, it is cheap to develop because of its widespread occurrence and the quality is generally and naturally good (Ibrahim, 1990) (Table 2).

Agricultural activities

Food demand and expansion in human activities toward meeting the growing population act as means of increasing the dispersion of substances causing surface and groundwater pollution. Several socioeconomic and environmental factors have also been identified as being responsible for high levels of diseases linked to water and sanitation (Ahmed et al, 2016). Agricultural activities involve the use of organic and non-organic fertilizers for the sole purpose of increasing soil fertility to boost increase crop yield (Serpil, 2012). Fertilizer consumption had been noted to increase exponentially throughout the world. A field survey of Kano and Kaduna States in 2008, indicated that the average of mixed fertilizer (Nitrogen N, Phosphorous P, Potassium K) used per hectare is 63kg which is about 10% of what is permissible per hectare (Ayoola,2010). The increase in agricultural activities had led to an increasing number of fertilizer-producing companies in Nigeria and an increase in fertilizer consumption. The non-organic fertilizers mainly contain Phosphate, Nitrate, Ammonium, and Potassium salts, some fertilizers also contain heavy metals like Cadmium, Chromium, and high concentration of radionuclides (Serpil, 2012). Nitrate concentration in water may increase as a result of the high level of nitrogen fertilizer. This may be through farm drainage, leaching, and flow, likewise, the amount of phosphate may increase in water and rivers due to the transport of phosphorus fertilizer with the surface water flow from farmland areas. Nitrogenous fertilizers uptake by plants had been noted to be about 50% of the quantity applied on the farmland, 2-20% lost to evaporation, 15-25% react with organic compounds in the soil and the remaining 2-10% goes into the surface and groundwater (Serpil, 2012). One of the important indices of water pollution in agricultural-

Table 2: Chemical constituents in groundwater.

Major constituents	Secondary constituents	Selected minor	Traced constituents
Calcium (Ca)	Potassium (K)	Aluminium (Al)	Molybdenum (Mo)
Magnesium (Mg)	Iron (Fe)	Arsenic (As)	Nickel (Ni)
Sodium (Na)	Manganese (Mn)	Barium (Ba)	Phosphate (PO_4)
Bicarbonate (HCO_3)	Strontium (Sr)	Cadmium (Cd)	Radium (Ra)
Chloride (Cl)	Boron (B)	Chromium (Cr)	Selenium (Se)
Sulphate (SO_4)	Fluoride (F)	Cobalt (Co)	Silver (Ag)
Silica (SiO_2)	Carbonate (CO_3)	Copper (Cu)	Uranium (U)
	Nitrate (NO_3)	Lead (Pb)	Zinc (Zn)
		Mercury (Hg)	Sulphide (H_2S_2HS)

Source: Magaji, 2011.

dominated areas is Nitrate, which is the basic component of fertilizer (Ahmed et al., 2016)

MATERIALS AND METHODS

Water samples location and collection

Borehole and surface water samples were collected from different locations within Kaura Namoda town. Twenty boreholes and 8 surface water sources were selected; the samples collection were carried out for dry season (December – January) and wet season (August-September). Marked 1.5L sterile plastic bottles (Nitric acid was used for sterilization) were used to collect the water samples directly from the mouth of the boreholes, and with the aid of sterilized water sampler, samples of water were collected from the surface water sources. The sterilized bottles were completely filled to exclude any air bubbles before they were tightly covered then transported in cold plastic container, with ice blocks that chilled the samples during transportation to the laboratories.

Data collection

On-site parameters determinations include the pH (electronic digital pH meter), Temperature (Digital thermometer), and Electrical conductivity (NORLYAB LM8 meter was used on-site and when the water samples were taken to the laboratory, data was confirmed with electrolytic method: DDS307 conductivity meter). The physicochemical parameters were carried out in the laboratory according to prescribed standard of testing according to the individual methods applied in determination of the parameters. Turbidity Nephelometric method was used to determine turbidity (turbidity meter: HACH 2100P) and for Sulphate, barium chloride was used as precipitating agent to convert Sulphate to Barium Sulphate precipitate in a colloidal form. The absorbance of the barium sulphate solution was measured by turbidimeter. The concentration of Sulphate measured was compared to a standard curve to arrive at the value obtained in each samples. Azide modification method (AMM) was employed to determine Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5). Total Hardness (T.H), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by EDTA titrimetric method. Chloride (Cl^-) was determined using the Mohr titrimetric method. Atomic Absorption Spectrometric method (AAS) was employed to determine the concentration of Iron (Fe^{3+}), Lead (Pb) and Arsenic (As) in the water samples. Nitrate (NO_3^-), Phosphate (PO_4^{3-}) and Fluoride (F^-) concentration values were obtained by UV spectrophotometric method. Alkalinity was determined using the acid titration method, while sodium (Na) and potassium (K+) were determined using the Flame Emission Photometric method. The Bacteriological analysis for water samples was carried out for Total Coliform (T.C) using the Spread Plate method and Faecal Coliform (F.C), the standard multiple tube (also referred to as the most probable number MPN) method was used. The WHO and NSDWQ standards were used as reference bench mark for the purpose of comparing the values obtained for the parameters if results are within acceptable standards.

RESULTS

The analysis of all the samples taken was analyzed in two standard-equipped laboratories. The twenty groundwater samples were taken from twenty locations during the rainy season from motorized and hand-pumped boreholes. Nineteen quality parameters were tested for in each of the 20 sampling location during the wet season, and during the dry season, 10 quality parameters were investigated for the groundwater in 20 sampling locations. The test determined for groundwater in the dry season is presented in (Table 3), while the test results for groundwater for the wet season is given in (Table 4). Surface water samples were taken from 8 water location sources and 10 quality parameters were investigated, the test results for the surface water for dry season is presented in (Table 5) and the result for wet season is presented in (Table 6). The Total Hardness for

Table 3: Ground water dry season.

Location	Turbidity	Temp	PH	EC	T.H	F-	Cl-	DO	T.C	F.C
Abu Nema	2.14	24	6.2	761	81	0.10	90	12.4	0	0
Muallimi	3.65	24	7.0	1149	112	0.20	130	9.2	0	0
Boda-1	2.04	24	6.7	847	78	0.10	110	10.8	0	0
Yardole-2	3.53	24	6.6	335	51	0.08	100	7.6	0	0
G/Gawo-3	4.11	24	7.5	582	60	0.09	60	6.6	12	0
A/Bako-5	3.46	24	6.9	586	66	0.09	60	6.4	0	0
Mahada -S4	8.66	24	6.2	621	72	0.10	70	8.2	8	0
A Audu-6	3.14	24	6.9	436	33	0.09	80	14.5	0	0
Yat Ruma-7	4.16	24	7.1	447	33	0.09	60	5.6	0	0
Kaltu-3	3.73	24	6.6	756	87	0.08	80	6.4	0	0
Boda-2	2.02	24	6.7	516	60	0.08	60	9.8	0	0
M Sanni H	2.10	25	6.8	315	48	0.10	60	6.8	0	0
GSS	2.20	24	6.9	330	45	0.08	70	6.6	0	0
Masallaci	2.15	25	7.0	310	51	0.08	60	7.2	1	0
Rimaye	1.70	25	7.1	329	57	0.10	80	8.4	0	0
Yar Ruma-8	3.20	25	7.5	398	66	0.09	70	6.9	2	0
Yar Ruma-9	2.80	24	7.2	412	60	0.10	80	7.1	0	0
Yar Ruma-10	2.60	25	7.4	388	72	0.80	65	7.6	0	0
Yardole-1	2.12	24	7.1	224	63	0.80	80	5.8	0	0
G/Gawo-4	1.90	25	7.2	294	57	0.11	90	8.6	0	0

EC- Electrical conductivity; **TDS**- Total Dissolved Solids; **TH**- Total hardness; **TA**- Total Alkalinity; **SiO_4**- Silicate; **Cl^-**- Chloride; **NO_3**- Nitrate; **Ca**- Calcium; **Mg**- Magnesium; **SO_4**- Sulphate; **Fe**- Iron; **PO_4**- Phosphate; **Pb**- Lead; **As**- Arsenic; **K**- Potassium; **F^-**-Fluoride; **DO**- Dissolved Oxygen; **BOD_5**- Biochemical Oxygen demand; **TC**- Total Coliform; **FC**- Faecal Coliform; **Na**- Sodium

Old Bridge S2 in (Table 6) is found to be 2020 mg/l because this is the river bed water and because of the rainy season flow, it is expected that storm water from several kilometers and the catchment will carry along dissolved nutrients and will find its way to the remaining water in the river bed (Tables 7 and 8).

Analysis of quality parameters by year for groundwater

In the year 2006, the Civil Engineering Department of Federal Polytechnic Kaura Namoda investigated the quality of groundwater, when it became visible that the exploitation of groundwater is gaining the attention of Zamfara State Government and individual landlords in the community. The number of boreholes that were identified in Kaura Namoda town was 8 in numbers, and all of them were hand pump type, then 3 of the wells were tested and the quality of the water found in them is presented in table 7. Also in the year 2012, the identified bore holes in Kaura Namoda town was 35 in number, with 8 numbers being motorized and with overhead storage tank while the remaining 27 were hand pump boreholes. A total number of 6 boreholes were tested and water quality is presented in table 8. The record of investigations carried out by the researchers in previous years (2006 and 2012), and the period under consideration in this work is compared to determine if there had been a considerable increase or decrease in the quality of groundwater in the Kaura Namoda environment. The common quality parameters that were determined in laboratory investigations are Total Hardness, Chloride, Magnesium, Nitrate, and Calcium as reflected in (Tables 9, 10, 11, 12 and 13). The results reflected that the quality of water in the community has not deteriorated, but a notable trend of increase concentration of Magnesium is detected, however there is no health-based guideline value proposed for it (WHO, 2011).

Total Hardness in (Table 9), one sample in 2006 (225mg/l) is above recommended level of 150mg/l (NSDWQ) but the wet season of 2018 indicated that all the values (203-1010mg/l) were greater than acceptable concentration, though one good thing is that during the dry season values obtained were all below the maximum permissible. The Chloride concentration in (Table 10), for all sample and during the periods were satisfactory and within the acceptable limit of 250mg/l (WHO and NSDWQ).

The concentration level of Magnesium as shown in (Table 11) indicated that values are above the standard recommended value of 0.2mg/l and average concentration continue to increase year by year. This trend is a cause for concern

Nitrate and Calcium concentration were not determined in the year 2012 because plan for trend analysis was not conceived earlier. The wet season nitrate concentration in (Table 12) is found to be within acceptable level only in 6 sample locations and calcium values in (Table 13) for

Table 4: Ground water wet season.

Location	Turbidity	Temperature	T.H	F-	Cl-	DO	T.C	F.C	BOD5	Ca	Mg	Fe	Alkalinity	Na	SO4	NO3	PO4	K	Pb	As
Abu Nema	2.00	28	705.0	0.10	8.2	9.3	0	0	1.30	15.00	2.90	0.003	3.20	35	3.68	110.0	18.25	2.50	0.003	0.001
Muallimi	3.50	28	1010.2	0.20	15.3	8.5	0	0	1.40	13.20	3.21	0.004	2.50	28	4.35	98.5	21.75	3.10	0.007	0.002
Boda-1	1.85	28	313.0	0.10	8.5	8.6	0	0	1.70	10.50	3.10	0.004	2.80	42	4.80	105.0	20.35	5.20	0.004	0.001
Yardole-2	4.09	28	555.5	0.07	7.49	8.4	1	0	1.60	13.50	3.60	0.002	1.90	25	2.68	112.0	25.04	4.10	0.031	0.005
G/Gawo-3	1.83	28	575.7	0.08	23	8.1	0	0	2.00	13.40	3.65	0.004	6.90	50	5.89	268.0	38.95	4.30	0.009	0.002
A/Bako-5	2.24	28	414.1	0.08	11.5	8.6	0	0	1.80	12.30	3.38	0.002	2.70	30	2.41	145.0	22.25	2.20	0.065	0.001
Mahada S4	25.00	28	1010.1	0.09	5.49	7.5	0	0	4.30	7.40	1.89	0.001	4.70	51	4.82	168.0	22.25	8.50	0.002	0.001
A Audu-6	2.18	28	585.8	0.07	56	8.6	0	0	2.60	16.50	4.50	0.004	2.50	48	9.64	145.0	22.25	2.20	0.052	0.003
Yat Ruma-7	3.20	28	203.0	0.06	17.1	8.1	0	0	1.80	11.50	2.68	0.005	2.40	45	2.65	48.0	17.95	4.50	0.008	0.002
Kaltu-3	4.05	28	406.2	0.07	14.3	7.5	0	0	1.40	8.60	2.75	0.006	2.45	46	4.02	55.0	21.55	2.50	0.006	0.001
Boda-2	3.50	28	414.1	0.09	17.5	8.6	0	0	1.30	10.30	2.80	0.007	3.50	38	3.50	71.0	22.00	5.10	0.009	0.005
M Sanni H	3.20	28	325.0	0.08	17.5	8.6	0	0	1.60	13.60	3.50	0.007	4.20	42	2.85	35.0	25.50	7.50	0.005	0.006
GSS	3.40	28	205.0	0.07	16.3	8.4	0	0	2.00	7.20	2.40	0.005	3.50	41	3.25	25.0	24.00	3.40	0.004	0.004
Masallaci	22.00	28	252.5	0.07	5.49	8.3	0	0	4.30	6.50	1.80	0.007	3.20	36	3.48	33.0	25.04	6.00	0.003	0.007
Rimaye	2.50	28	240.2	0.08	7.8	8.5	0	0	2.50	8.40	2.55	0.003	3.30	37	2.50	105.0	33.45	7.50	0.008	0.001
Yar Ruma-8	2.92	28	212.1	0.09	13	8.2	1	0	1.50	7.50	2.00	0.002	2.70	39	2.68	145.0	29.10	3.60	0.048	0.001
Yar Ruma-9	12.54	28	363.6	0.09	11	8.4	0	0	1.60	9.50	2.57	0.008	1.40	40	3.26	20.0	40.34	2.70	0.009	0.001
Yar Ruma-10	4.41	28	707.0	0.08	89	7.9	2	0	1.30	16.50	4.38	0.002	6.50	128	22.76	156.0	29.21	5.40	0.007	0.004
Yardole-1	26.00	28	444.4	0.08	16	8.2	0	0	1.40	10.50	2.84	0.002	4.90	47	2.41	112.0	26.43	3.50	0.025	0.000
G/Gawo-4	2.08	28	414.1	0.09	11.5	8.7	0	0	1.80	12.30	3.38	0.002	5.60	42	3.21	20.0	38.95	3.30	0.004	0.001

Table 5: Surface water dry season.

Location	TURBIDITY	TEMP	PH	E/Conductivity	T.H	F^-	Cl^-	DO	T.C	F.C
Old Bride S2	4.60	28	6.9	315	2020.0	0.20	7.49	8.2	0	0
G/Sambo S6	27.00	28	6.9	335	408.2	0.07	12.2	7.9	2	0
MashiganGada S9	12.54	28	7.2	822	202.0	0.10	19.49	8.1	0	0
Dangano S8	3.11	28	7.8	985	313.1	0.10	3.99	8.3	0	0
New Bridge-1	7.50	28	7.5	772	706.0	0.12	15.5	8.2	2	0
After Abbatoir-3	8.65	28	7.7	798	525.0	0,21	12.6	8.3	2	0
Shiyas Mekoji-5	7.30	28	7.2	552	315.0	0.13	11.5	8.1	2	0
GulbiGebe	2.29	28	7.1	612	262.6	0.16	6.99	8.0	2	0

all our determinations is within the acceptable standard of 250mg/l (WHO).

Statistical analysis

The Multivariate Analysis of Variance (MANOVA) was applied to determine the significant difference between the dry and the wet season of the common quality parameters that were investigated as presented in (Tables 14 and 15). The Means were considered significantly different at $P>0.05$. The groundwater determinations as presented in (Table 14) shows that means of Turbidity, pH, and Total Hardness during the wet season are higher than means of dry season hence wet season for the three is significantly higher than that of the dry season ($<0.001< P < 0.05$) whereas E.C and Cl^- during the dry season are significantly higher than that of the wet season, but with Fluoride, D.O, and T.C there is no significant difference in the quality values between the dry and wet season. For the surface water as presented in (Table 15), the Turbidity,

Table 6: Surface water wet season

Location	Turbidity	TEMP	T.H	Cl-	DO	T.C	F.C	BOD5	Ca	Mg	Fe	Alk	Na	SO4	NO3	PO4	K	Pb	As
Old Bride S2	4.60	28	2020.0	7.49	8.2	0	0	1.80	7.00	3.10	0.007	4.60	46	4.55	134.0	30.60	4.00	0.002	0.002
G/Sambo S6	27.00	28	408.2	12.2	7.9	2	0	2.10	11.40	2.55	0.002	3.30	35	3.80	132.0	31.55	6.00	0.005	0.002
MashiganGada S9	12.54	28	202.0	19.49	8.1	0	0	1.80	10.00	2.65	0.007	4.30	58	3.48	33.0	19.47	5.50	0.057	0.003
Dangano S8	3.11	28	313.1	3.99	8.3	0	0	1.80	7.50	2.03	0.002	3.60	41	2.68	33.0	25.04	6.20	0.005	0.003
New Bridge-1	7.50	28	706.0	15.5	8.2	2	0	2.40	10.50	3.30	0.003	4.80	31	3.85	103.0	25.25	5.20	0.003	0.002
After Abbatoir-3	8.65	28	525.0	12.6	8.3	2	0	2.10	11.40	3.25	0.003	4.50	28	3.70	52.0	31.05	6.10	0.004	0.002
Shiyas Mekoji-5	7.30	28	315.0	11.5	8.1	2	0	2.00	7.80	3.15	0.002	5.30	35	3.65	36.0	23.50	4.60	0.005	0.003
GulbiGebe	2.29	28	262.6	6.99	8.0	2	0	2.60	5.50	1.49	0.002	5.40	44	3.75	28.0	22.25	8.20	0.014	0.003

Table 7: Water Quality of Borehole in 2006

Location	PH	EC	TDS	TH	TA	Silicate	Cl	N03	Ca	Mg	Fe	S04
Low-cost Estate	6.6	6.95	76	225	6.5	4	10.7	3.1	18.9	14.3	3.0	17
Soho-Tasha	7.7	650	52	60	7.5	2.5	10.0	3.5	10.8	9.5	0.2	8
FPT P/Site	7.0	500	62	62	6.9	5.5	7.0	3.0	12.6	12.6	0.02	13
Location	PH	EC	TDS	TH	TA	Silicate	Cl	N03	Ca	Mg	Fe	S04
Low-cost Estate	6.6	6.95	76	225	6.5	4	10.7	3.1	18.9	14.3	3.0	17
Soho-Tasha	7.7	650	52	60	7.5	2.5	10.0	3.5	10.8	9.5	0.2	8
FPT P/Site	7.0	500	62	62	6.9	5.5	7.0	3.0	12.6	12.6	0.02	13

Table 8: Water quality of borehole in 2012.

	Turbidity (NUT)	Temperature	Taste & Odour	pH	Total Hardness	Total Dissolved Solids	Chloride (mg/l)	Chromium (mg/l)	Magnesium (mg/l)
GRA	34	25	Salty	6.6	28.67	103	15.67	0.15	0.073
KasuwaYargaje	25	31	Odour	6.7	25.33	2.33	15.67	1.1	1.06
Birnin Magaji Road	2	27	Neutral	7.4	21.67	2.3	3.3	0.033	1.01
Sabon Gari Road	157	26	Salty	7.3	31.67	10.27	15.67	0.16	0.133
NYSC Lodge	24	26	Salty	6.2	23.67	90	1.0	0.96	1.103
Behind Motor Park	21	22	Neutral	7.1	22.67	2.67	3.33	0.067	1.058

pH, T.H, Fluoride, and D.O, there is no significant difference in the parameters between the dry and wet seasons. The Temperature of surface water during the wet season is significantly higher than that of the dry season. The Chloride, T.C, and Faecal coliform (F.C) , of the dry season, is significantly higher than that of the wet season.

Solid waste disposal

The general method of solid waste disposal in the study area is the surface dumping method. This involves the disposal of solid waste like glass materials, metals, plastics, dead animals, rags, and animal dung in different locations within the town such as drainage channels, household compounds, and along the streets. Agricultural wastes are also dumped on open surfaces to

Table 9: Total hardness concentration.

Year	No. of Samples	Range	Mean	STD Deviation	Variance
2006	3	60 – 225	115.67	94.69	8966.33
2012	6	21.67 – 28.67	24.11	3.85	14.82
2018 (Dry)	20	33 – 112	62.60	18.41	338.88
2018 (Wet)	20	203 – 1010	467.83	241.63	58208.00

Table 10: Chloride concentration

Year	No. of Samples	Range	Mean	STD Deviation	Variance
2006	3	7 – 10.7	41.33	56.89	3236.33
2012	6	1 – 15.67	9.11	7.24	52.41
2018 (Dry)	20	60 – 130	77.75	18.95	359.14
2018 (Wet)	20	5 – 89	18.59	19.73	389.43

Table 11: Magnesium concentration.

Year	No. of Samples	Range	Mean	STD Deviation	Variance
2006	3	9.5 – 14.3	12.13	2.433	5.92
2012	6	0.07 – 1.10	0.745	0.500	0.250
2018 (Dry)	20	1.0 – 3.0	2.43	0.57	0.328
2018 (Wet)	20	2.0 – 5.0	2.99	0.73	0.536

Table 12: Nitrate concentration.

Year	No. of Samples	Range	Mean	STD Deviation	Variance
2006	3	3.0 – 3.50	3.20	0.264	0.070
2012	6	-	-	-	-
2018 (Dry)	20	9 – 35	19.61	8.26	68.284
2018 (Wet)	20	20 – 268	98.83	62.90	3956.876

Table 13: Calcium concentration.

Year	No. of Samples	Range	Mean	STD Deviation	Variance
2006	3	10.80 – 18.90	14.10	4.253	18.090
2012	6	-	-	-	-
2018 (Dry)	20	3 – 11	6.16	2.227	4.959
2018 (Wet)	20	7 – 17	11.21	3.065	9.396

decay to be removed later and dumped on the farmland as manure. Four major areas within Kaura Namoda town were selected for solid waste collection and analysis namely Emir Road, Yerima Quarters, Soho-Tasha, and Low-cost Estate. The weights by categories of different solid waste materials are shown in (Table 16). The organic contents (cartoon, paper, wood, bones, animal dung, and agricultural waste) of the samples indicated that it is the greatest percentage (16.89kg) of the total weight (30.50kg), and since organic materials decompose within a short period, this will not constitute any hazard to surface and groundwater quality.

DISCUSSION

Groundwater

The study investigated groundwater in 20 locations and 19 quality parameters which were determined in each of the locations in the year 2018 for both dry and wet seasons. In the wet and dry seasons, 15 quality parameters (turbidity, temperature, electrical conductivity, fluoride, chloride, calcium, iron, alkalinity, sodium, sulphate, potassium, lead, arsenic, F. coli and biological oxygen demand (BODs) were found to be acceptable within the standard recommended by World Health Organization (WHO) and the Nigerian Standards for Drinking Water Quality (NSDWQ). The raw water samples were collected according to recommended sampling techniques and the water samples were not put under any pretreatment before the analysis was carried out.

Total Hardness:

All samples for total hardness during the dry season were found to be between 33mg/l to 112mg/l and are all below the 150mg/l standard recommended, but all samples in the wet season were found to be (202 – 707mg/l) above

Table 14: Analysis of *ground water* during dry and wet seasons at Kaura Namoda.

Water quality parameters	Means of seasons			
	DRY	WET	SEM	p-values
Turbidity	3.07	6.62	1.695	0.05
Temperature	24.3	28.00	0.1051	<.001
pH	6.93	7.3	0.0827	<.001
Elect. Conduct	502.	373.	29.7	<.001
Total Hardness	63.	468	51.7	<.001
F-	0.168	0.087	0.0489	0.114
Cl	77.8	18.6	6.66	<.001
DO	8.12	8.35	0.467	0.635
T.C	1.15	0.20	0.720	0.203
F.C	0.00	0.00	0.000	

Table 15: Analysis of surface water during dry and wet seasons at Kaura Namoda.

Water quality parameters	Means of seasons			
	DRY	WET	SEM	p-values
Turbidity	13.6	9.1	4.41	0.342
Temperature	24.25	28.00	0.1637	<0.001
pH	7.30	-	0.1172	0.154
Elect. Conduct	649	-	26.2	0.005
Total Hardness	101.	594.	221.0	0.061
F-	0.1363	-	0.01176	0.028
Cl	92.5	11.2	12.38	<0.001
DO	8.15	8.14	1.971	0.995
T.C	10.5	1.2	2.51	0.008
F.C	1.75	0.00	0.31	<0.001

Table 16: Composition of solid waste.

Waste Materials	Location				
	Emir Road	Yerima Quarters	Soho -Tasha	Low-cost Estate	Material (kg)
Cartoon/Papers (kg)	0.91	0.5	0.7	0.3	2.41
Ceramics/Tiles (kg)	1.14	1.2	1.05	1.5	4.89
Metals/Glassware (kg)	1.20	0.94	0.49	1.0	3.63
Polythene/Plastics (kg)	1.07	0.92	0.7	0.8	3.49
Wood/Bones (kg)	0.30	0.46	0.21	0.2	1.17
Animal Dung (kg)	1.80	2.08	2.1	1.80	7.78
Agricultural Waste (kg)	1.18	1.60	1.75	1.0	5.53
Soil Material (kg)	0.40	0.30	0.50	0.40	1.6
Total (kg)	8.0	8.0	7.5	7.0	30.5

the standard recommended. However, no health-based guideline value had been made for Total Hardness, but only objectionable and demand more soap in washing.

Dissolved Oxygen

During the wet season, the amount of dissolved oxygen in all samples (7.5 – 9.3mg/l) is above the recommended amount of 7.5mg/l, indicating that dissolved oxygen in water samples is not in short supply, but in the dry season 11 locations (samples) had less dissolved oxygen in water (5.6 – 7.2mg/l).

Total Coliform

Total coliform also referred to as coliform organisms quality in all samples of the wet season is found to be satisfactory, while the dry season samples had only location G/Gawo (12/100); Masallachi (1/100) and Yar-Ruma (2/100) above recommended, but the other remaining samples were found to be satisfactory.

Magnesium

The amount of magnesium in water samples for both the wet and dry seasons is found to be between 1.35 – 3.25mg/l and all samples are above 0.2mg/l (NSDWQ) standard. However there are no health impact guidelines and the only consideration is consumer acceptability.

Nitrate

The nitrate concentration (25 – 268mg/l) in wet season water samples for six locations is below the WHO and NSDWQ recommendation of 50mg/l but the remaining sixteen locations' concentration is above the recommended. The noted health implication is cyanosis and asphyxia (blue-baby syndrome) in infants under the age of 3 months (WHO). The general health education and attention given to babies within the study area shows that families (nursing mothers) do not give untreated water to babies that are under four months old. Also, there is no reported case of blue-baby syndrome in the Government established General Hospitals within the Kaura Namoda Local Government Area from our investigation from the hospital.

Phosphate

The concentration of phosphate in wet season samples (18.25 – 38.95mg/l) is above the recommended standard of 5mg/l in drinking water. However, there is no health impact guideline.

Lead

5 sample locations for the wet season indicated that the quality level of lead is above the recommended concentration of 0.015mg/l. The locations are Yar-Dole 2 (0.031mg/l), A/Bako 5 (0.065mg/l); A/Audu 6 (0.052mg/l); Yar-Ruma 8 (0.048mg/l) and Yar-Dole 1 (0.025mg/l). The locations require further investigation to determine the source or why the concentration is above recommended standard. However considering the tolerance limit of 0.05mg/l by WHO (Anka et al, 2020; WHO, 1996), the sample location quality still falls within the tolerance limit.

Surface water

The surface water during the wet season for quality parameters that were determined and found to be within the recommended standards are 15 (Temperature, Electrical conductivity, Fluoride, BODs, Dissolved Oxygen, Chloride, Calcium Iron, Alkalinity, Sodium, Sulphate, Potassium, Lead, and Arsenic) though some were not investigated in the dry season but among the 10 parameters tested in the dry season, 6 of them (temperature, pH, E.C, fluoride, chloride, and Faecal coliform) were found to be within the recommended standard.

Turbidity

The turbidity for the dry and wet seasons is all above the WHO standard. This is a reflection that the water is raw and had not been subjected to any treatment, however, the range of 4.6 – 37.6 NTU for raw surface water is not unexpected.

Total hardness

All samples for Total Hardness for the wet season range between 202 – 706.6mg/l and are above the WHO standard of 150mg/l, while the dry season is within the standard and is found to be between 33 – 120mg/l. This is an indication that during raining season quantity of dissolve chemicals is more and is transported widely.

Total coliform and faecal coliform

Bacteriological quality is found and above the recommended drinking water quality in both dry and wet seasons. This outcome is unexpected since it is surface water and raw water had not been subjected to any treatment.

Magnesium and phosphate

Concentration of Magnesium and Phosphate in the wet season for surface water is found to be above the acceptable level for drinking water quality (Mg=0.2mg/l and PO_4 =5mg/l). The raw water is expected not to be consumed until the treatment of the water is done. However, the value levels show that usage of fertilizer must have constituted to the increase in the concentration of phosphate in surface water.

Lead

The concentration of lead in surface water for the wet season for Mashingan Gada-S9 (0.057mg/l) is above quality standard of 0.015mg/l, while the remaining locations are satisfactory.

Conclusion

The water quality values for physical, chemical, and bacteriological parameters investigated were generally within the permissible values recommended by WHO and NSDWQ for drinking water quality. A total of 116 quality parameters in both the wet and dry season for groundwater and surface water were found to be acceptable, however other quality parameters had varying values that are above-recommended standard, this parameters are Magnesium (1.35-3.25mg/l), Nitrate (28.0-156mg/l), Phosphate (17.95-40.34mg/l), but these ones are not among those parameters listed as having negative health impact (WHO, 2011). The surface water quality parameters are generally within the acceptable level and since the water had not been subjected to any treatment, surface drinking water should be subjected to boiling before consumption. The farming activities had not adversely contributed to healthy water and sanitary practices and also not constituted health hazards to water sources within the town from the physicochemical investigations carried out in this work. The objectives of this research work had been met because test results were compared with World Health Organization and Nigerian Standards of Drinking-Water Quality (NSDWQ). There is no heavy metal that pose health hazard and the bacteriological quality is satisfactory. The outcome of this study reflected the importance of treatment of surface and groundwater from any source before consumption and household usage; it is also in agreement with noted observations by researchers sited in this work.

Recommendations

The exploitation and sourcing of groundwater is a welcome development as the cost of provision of goods and availability of the desired quantity of water is a guarantee. To better improve the well-being of the people, it is hereby recommended that:

1. Groundwater from boreholes is subjected to testing when the hole is constructed to determine the initial quality value.
2. Direct consumption (drinking) of water should be limited to boreholes, while the surface water is subjected to avoidable minimum local treatment of boiling before consumption.
3. Agricultural chemicals usage should be monitored and controlled by the Ministry of Agriculture and the farming extension workers in various ministries and organs of the State Government.
4. Improvement in solid waste disposal should be encouraged by the Local Government Authority, through designated, controlled constructed dumping sites and regular removal of dumped waste to reduce the incidence of drainage blockages along the highways and streets.

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