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Assessment of Physicochemical Contaminants in Waters and Fishes from Selected Rivers in Nasarawa State, Nigeria

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Abstract

Levels of physicochemical parameters (pH, phosphate, chloride, nitrate, bicarbonate, turbidity, conductivity, alkalinity, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, temperature, total hardness and total solid) and microbiological properties were determined in the water samples collected from Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria using standard analytical techniques. Metals (Na, K, Ni, Cu, Mg, Fe, Ca, Zn, Pb, Cd, As, Se, Cr and Mn) were also determined from two different fish species (Tilapia zilli and Clarias lazera) caught from these three rivers using atomic absorption spectrophotometer (AAS). The results of physicochemical analyses showed that phosphate and nitrate ions were not present in the water samples during dry season but present in the wet season. Other physicochemical parameter values fall within WHO standard limits. Microbiological tests revealed that Rivers Doma and Mada were not safe for drinking. Magnesium had the highest concentrations in the bodies of two fish species irrespective of the season when the fish was caught followed by calcium while the least concentrated metal was arsenic. Lead and cadmium in the fish samples were not within the detectable range of AAS. Nickel level in the fish sample from Mada River during dry season exceeded the WHO maximum tolerable limit. Therefore, source protection is proposed for these bodies of water for the benefit of mankind because they were not safe for human consumption.

Key Words: River water, fish, physicochemical parameter, metal, AAS.

Introduction

The post independence era in Nigeria has witnessed a serious of political and socio-economical developments. Today, the nation comprises thirty six states and a Federal capital territory. Over the years, there has been a considerable growth in the awareness of environmental pollution problems and it has become a major national and international political issues. One of these major pollution problems is water pollution. Poor drinking water quality has been identified as one of the major causes of health problems in developing countries. The basic physicological requirements for drinking water as stipulated by World Health Organization (WHO) is about two litres of water per head per day, and a daily supply of one hundred and fifty to two hundred litres cannot be met by majority of developing countries like Nigeria[1]. However, access to safe drinking water and sanitation is critical in terms of health especially for children. For instances, unsafe drinking water contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhea that occur annually[2]. Consequent to the realization of the potential health hazards that may result from contaminated drinking water,

contamination of drinking water from any source is therefore of primary importance because of the danger and risk of water borne diseases[3,4].

Evidence of potential and observed human hazard due to environmentally acquired physicochemical properties and their ecological impact have been extensively studied and documented[3,5,6]. Freshwater foods serve excellent food choice for people of all ages. They vary in shape, size, colour, skin, bone and taste[7]. Foods derived on the aquatic environment fall broadly into two major categories, fish and shell fish. Nutritionally, the two groups are not significantly different. Biological magnification could lead to toxic levels of minerals in fish, even when the exposure is low. The proven toxicity of high concentrations of heavy metals in water to fishery and wild life poses the problem of an ultimate disequilibrium in the natural ecological balance[8]. Apart from the destabilizing the ecosystem, the accumulation of these toxic metals in the aquatic food organisms is a potent threat to public health[9].

Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria had been in existence before the settlement of the present dwellers. Most rural dwellers depend largely on these rivers for their daily water needs and households' requirement. The qualities of these sources are generally not guaranteed and cases abound where health problems have risen as a result of consumers drinking from such sources. Also fishes frocm the river water bodies are being sold to the public for human consumption. A number of studies have been reported on the geochemistry, pollution assessment and chemical properties of some rivers located in Nasarawa State, Nigeria[10]. but there is paucity of information on the pollution assessment of the water and freshwater foods from Rivers Doma, Farinruwa and Mada. Therefore, in realization of both the domestic and commercial advantages derived from these three rivers this work is aimed at investigating the pollution level with special interest on physicochemical contaminants in the bodies of water, and presence of some minerals in Tilapia (Tilapia zilli) and african catfish (Clarias lazera) being the most popular in the diet of the teeming population along the banks of Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria.

Material and Methods

Study Area: Nasarawa State is one of 36 States in the Federal Republic of Nigeria. It is located in north-central geopolitical zone of Nigeria otherwise known as the middle belt region. The State is made up of thirteen local government areas. Rivers Doma, Farinruwa and Mada are found in Doma, Wamba and Akwanga local government areas, respectively. Their latitudes are 08^o 66" – 08^o 72", 08^o 52 – 08^4 58" and 08^o 49 – 08^o 52" while their longitudes are 07^o 64" – 07^o 69", 07^o 53" – 07^o 57" and 07^o 51" – 07^o 56", respectively. These local government areas share boundaries with Benue, Plateau and Kaduna States in Nigeria (fig. 1). They are made up of different ethnic groups each with a distinct heritage; among the major tribes are: Mada, Eggon, Nuku, Tiv, Kulere, Kantana, Alago, while minor tribes such as Hausa, Yoruba, Igbo, Nupe, etc. are interspersed among the major ones.

The physical features of the area are largely mountainous, most of which are rocky and of undulating highlands of average height. It has a typical climate of the tropical zone because of its location. Its climate is quite pleasant with a maximum temperature of 95^oF and a minimum of 50^oF. Rainfall varies 131.73cm in some places to 145cm in others[11]. Mineral resources such as marble deposits, granite rocks, baryte and mica are found in some areas. The climate is characterized by two distinct seasons, dry and wet. The dry season spans from October to March while the raining season is from April to September. The months of December,

January and February are cold due to harmattern wind blowing across the local government areas from the north-east of Nigeria. The sediments are generally comprised of sandstones, silt stones and forest soils which are rich in humus and very good for crop production. More than 80% of the inhabitants are predominantly farmers while few engage in fishing business.

Samples Collection and Treatment: Collection of water samples was done between May to August, 2009 and November, 2009 to March, 2010 for wet and dry seasons, respectively. Representation water samples were taken just below the water surface at three different locations of each river using one litre acid leached polythene bottle. The water samples were stored in a deep freezer at –18^{o}C prior to analysis. Fish samples of two different species namely: *Tilapia zilli* and *Clarias lazera* were purchased from fishermen at the river site. The scales were removed, carefully washed, dried at 105^{o}C until constant weight, and blended using Kenwood blender. 2g of the powdered fish was digested by the following method described by Ibok[12].

All samples were collected at 6.00 hours Green – Witch Mean Time (GMT) or 7.00 local time, while temperature of the water was measured at the time of collection using a simple thermometer calibrated in degree Celsius.

Physicochemical Analyses: The water sample pH was measured using a BNC pH meter and electrical conductivity was measured using conductivity meter model NATOP PB5 (London, UK). Other physicochemical parameters determined in the water samples were; alkanity and total hardness by titrimetry method[13], chloride ion was measured by chloride ion meter (Model KRK, Cl-5Z Japan), phosphate (molybdophosphoric blue colour method in H_2SO_4 system) and nitrate were estimated using a PYE UNICAM visible spectrophotometer (London, UK), total dissolved solids by gravimetric method and chemical oxygen demand (COD) by APHA[13]. method. All the chemicals used were of analytical reagent grade and obtained from British Drug Houses (BDH, London).

Mineral Analysis: The elemental analysis (except Na and K) was done in the fish samples using Perkins Elmer and Oak Brown (UK) atomic absorption spectrophotometer. The instrument settings and operational conditions were done in accordance with the manufacturer's specifications. Na and K were determined by using a flame photometer (Model 405, Corning, UK).

Statistical Analysis: All the data generated were analyzed statistically. Parameters evaluated were mean, standard deviation and coefficient of variation.

Results and Discussion

Physicochemical parameter levels of water samples collected at dry and wet seasons from Rivers Doma, Farinruwa and Mada are displayed in table 1. Phosphate and nitrate ions were not present in all the river water samples during the dry season but present in the wet season. Phosphorus occurs in natural water and in waste water almost solely as phosphates. Phosphate and nitrate concentrations in the wet season ranged from 1.66 – 2.11 mgL^{-1} and 0.29 – 0.78 mgL^{-1}, respectively. The average concentrations of phosphate and nitrates during wet season may be due to water run-off through the applications of fertilizer and pesticides by the host communities since majority of people are predominantly farmers. The pH is a function of the dissolved materials in water and should be less than 8.50[14]. The pH values for dry and wet seasons ranged between 6.40 to 6.68 and 7.36 to 7.77, respectively. It implies that water samples from the rivers during dry season were acidic and may not be favourable to the existence of bacteria in the rivers. The temperature values (23 – 24^{o}C for dry season) and (22 – 23^{o}C for wet season) comply with WHO recommended value of 25^{o}C. Turbidity is a function of the suspended matter in water which ranged from colloidal to course dispersion while chemical oxygen demand (COD) or biochemical oxygen demand

(BOD) is used for estimating the concentration of organic matter in waste water. The values of turbidity, COD and BOD obtained in this report (table 1) showed that the water samples were not seriously polluted because high value of COD or BOD implies that such water will have objectionable odour, render the water unfit for domestic purpose and reduce oxygen available for aquatic organisms. The values of bicarbonate ions in the water samples in the dry season (9.44 – 11.90 mgL^{-1}) are greater than that of wet season (3.09 – 5.20 mgL^{-1}). Water has been classified on the basis of hardness as follows: water having 0.75mg $CaCO_3L^{-1}$ as soft, 75 – 150mg $CaCO_3L^{-1}$ as hard and > 300mg $CaCO_3L^{-1}$ as total hardness[15]. Based on this, the water samples in this study can be classified as soft water. Chloride concentrations ranged from 0.32 – $0.57L^{-1}$ and 0.22 – $0.32L^{-1}$ for dry and wet seasons, respectively (table 1). Chlorides occur in natural water at varying concentrations depending on the geochemical conditions. Chlorides are the most stable components in water with concentration that is unaffected by most natural physicochemical or biochemical processes; their amount in water is useful measure in water samples. Chloride can range from < 10 mgL^{-1} to > 2500 mgL^{-1} (in sea water)[16]. The average total dissolved solids (TDS), alkalinity and conductivity values observed in this study (Table 1) are all within the recommended limit. Table 1 also displays the wide spatial variation in the values obtained for the parameters determined in the water samples from the three rivers as revealed by the coefficient of variation percent (CV%) which ranged between 0.56 in BOD to 95.01 in bicarbonate (dry season) and 1.09 in BOD to 42.86 in nitrate (wet season).

The results of microbiological analyses for isolating microorganisms using Muellar Hinton Agar (MHA) and MacConkey Agar (MCA) media for both seasons are presented in table 2. In both seasons, only water sample from Farinruwa River had growth below 100 counts on MHA and MCA which showed that the water is within WHO acceptable limit. Rivers Doma and Mada showed massive growth of more than 100 counts on MHA in both seasons which is above WHO recommended limit and this implies that water from the two rivers are not safe for drinking.

The levels of trace metals determined in *Tilapia zilli* and *Claries lazera* caught from River Doma at two different seasons are presented in table 3 while similar results for the same types of fish caught from Rivers Farinruwa and Mada are displayed in Tables 4 and 5, respectively. It was observed that Pb and Cd were not within the detectable range of AAS for all the fish samples (tables 1 – 3). Mg had the highest concentrations in the bodies of the two fish irrespective of the season when the fish was caught followed by Ca while the least concentrated metal was As which was not even at the detectable range of AAS for some fish samples (tables 1 – 3). Ca is always abundant in the body of animal mostly present in teeth and bones. It is also, an important constituent of body fluids. Ca tends to be a kind of coordinator among inorganic elements; if excessive amounts of K, Mg or Na are present in the body, Ca is capable of assuming a corrective role. If the amount of Ca is adequate in the diet, Fe is utilized to better advantage. This is an instance of "sparing action"[17]. The different level of concentrations of Na and K observed in the fish samples caught from three different rivers (tables 1 – 3) may be due to the different in physiological activities of the fresh water fish. Animal tissues, in general, are much less rich in K but on the other hand, they usually contain more Na[18]. This observation is consistent with the report in this work. K forms loose associations with proteins and is an activator of pyruvate kinase and numerous other enzymes. Over forty enzymes are known which require a univalent cation for maximum activity; K is usually the most effective[17]. Transport ATP – uses from animal sources require Na as well as K ions for maximum activity. Na influences osmotic pressure and contributes to normal pH equilibrium[18]. All the fish samples under discussion are not going to be good sources of Na and K.

Zn had concentrations in the bodies of fish ranging from 0.09 to 0.36 ppm (tables 1 – 3). The levels of Zn reported herein are less than the values of Zn in

fish from river in Ikot Ekpene[12] and that of river Benue[7] all located in Nigeria. It has been reported that Zn contamination affects the hepatic distribution of other trace metals in fish[19]. Zn, Cu and Mn which are essential elements, compete for the same site in animals. This, no doubt, would affect tissue metal concentrations as well as certain physiological processes. The amounts of Zn determined in all the fish samples are very much below the 1000 ppm set for Zn in freshwater foods by the Australian National Health and Medical Research Council[20]. The level of concentrations of Cu, As, Se and Cr in the two fish samples caught from the rivers were relatively low with As having the lowest concentrations. The chemical toxicity of As compounds has been well studied because of their extensive medicinal use and as garden herbicide in the past[21]. The acute effect of As poisoning by oral intake are intense abdominal pairs, nausea, vomiting, diarrhea resulting from gastro-intestinal tract damage and all terminating in coma and death[22]. In China and Taiwan, 0.2 ppm As in drinking water and taken for a long time has been calculated as the threshold for skin cancer. The usual As level in drinking water is about 0.002 ppm[23,24]. However, it can be reported that the levels of As in the present study have posed threat to human health though As was below detection limit of AAS for some samples of fish caught from River Doma (table 1).

Concentration of Ni in the fish samples from three different rivers only exceeded the maximum tolerable limit of 0.6 ppm in the *Clarias lazera* fish sample caught from Mada River during dry season. Ni concentration of 2.3 ppm or greater in food sample may cause reproductive impairment and kidney recruitment[25,26].

The wide spatial variations were observed in the levels of trace metals determined with two different fish samples as revealed by coefficient of variation percent (CV%). The orders of variability were: Fe > Zn > Se = Cr > Mg > Na > Ni > Ca > Cu > Mn > K (dry season) and Mg = Fe > Cr > Se > Cu > Na > Zn > Ca > K > Mn > Ni (wet season) (table 1).

Conclusions

This work has presented levels of physicochemical and microbiological parameters in water samples collected from Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria. Metal concentrations (Na, K, Ni, Cu, Mg, Fe, Ca, Zn, Pb, Cd, As, Se, Cr and Mn) in *Tilapia zilli* and *Clarias lazera* fish samples from the three rivers were also presented. The results revealed that there was an indication of some physicochemical parameters pollution in the bodies of water although values of these parameters are within acceptable range. The study further revealed that Rivers Doma and Mada were not safe for drinking based on the microbiological tests carried out on the water samples. The fish samples from these rivers were not desirable for consumption because of the presence of some toxic trace metals above the permissible safe level. Therefore, this work will serve as baseline information for future work.

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Table-1: Levels of physicochemical parameters in the water samples

Dry Season

River Parameter	River Doma	River Farinruwa	River Mada	Mean	SD	CV%	WHO's Standard
pH	6.43 ± 1.50	6.40 ± 2.10	6.68 ± 1.20	6.5	0.13	2	6.5 – 8.5
Phosphate (mgL^{-1})	ND	ND	ND	ND	ND	ND	45
Chloride (gL^{-1})	0.32 ± 1.00	0.57 ± 1.10	0.44 ± 2.10	0.44	0.1	22.73	200
Nitrate (mgL^{-1})	ND	ND	ND	ND	ND	ND	45
Bicarbonate (mgL^{-1})	11.90 ± 1.20	10.56±1.01	9.44 ± 2.10	10.63	1.01	95.01	500
Turbidity (mgL^{-1})	0.7	0.5	0.40 ± 0.10	0.53	0.12	22.64	na
Conductivity (μscm^{-1})	0.58 ± 0.10	0.78 ± 0.20	0.64 ± 1.00	0.67	0.09	13.43	10
Alkalinity (mgL^{-1})	2.21 ± 1.10	1.56 ± 2.50	1.14	1.64	0.44	26.83	200
TDS (mgL^{-1})	749 ± 8.10	5.68 ± 1.10	899 ± 5.05	739	135	18.32	2000
COD (mgL^{-1})	3.44 ± 1.50	5.76 ± 2.30	6.22 ± 1.20	5.14	1.22	23.74	10
BOD (mgL^{-1})	2.35 ± 1.20	2.32 ± 2.20	2.33 ± 0.10	2.33	0.01	0.56	10
Temperature (^oC)	23 ± 2.00	2.4 ± 1.50	24 ± 1.00	23.67	0.47	1.72	< 40
Total hardness (mgL^{-1})	7.44 ± 2.01	6.88 ± 0.20	2.99 ± 2.10	5.77	1.98	34.32	100
Total solid (mgL^{-1})	0.09 ± 0.14	0.14 ± 0.50	0.05 ± 1.10	0.1	0.04	42.11	500

Table-1: Levels of physicochemical parameters in the water samples

Wet Season

River Parameter	River Doma	River Farinruwa	River Mada	Mean	SD	CV%	WHO's Standard
pH	7.36 ± 1.50	7.45 ± 2.50	7.77 ± 1.50	7.53	0.18	2.39	6.5 – 8.5
Phosphate (mgL^{-1})	1.66 ± 1.50	1.89 ± 1.05	2.11 ± 2.00	1.89	0.18	9.52	45
Chloride (gL^{-1})	0.32 ± 2.5	0.22 ± 1.50	0.23 ± 1.00	0.25	0.05	18	200
Nitrate (mgL^{-1})	0.29 ± 1.50	0.78 ± 1.05	0.39 ± 1.20	0.49	0.21	42.86	45
Bicarbonate (mgL^{-1})	3.09 ± 1.50	4.10 ± 2.30	5.20 ± 1.20	4.13	2.05	37.55	500
Turbidity (mgL^{-1})	9.77 ± 1.50	7.06 ± 2.01	207 ± 5.00	74.61	93.62	125.48	na
Conductivity (μscm^{-1})	0.31 ± 0.10	0.33 ± 2.01	0.34 ± 1.02	0.32	0.01	4.06	10
Alkalinity (mgL^{-1})	0.29 ± 1.00	0.57 ± 0.01	0.66 ± 1.20	0.51	0.16	32.37	200
TDS (mgL^{-1})	269 ± 8.10	241 ± 5.50	409 ± 5.10	306	73.49	24.02	200
COD (mgL^{-1})	6.38 ± 1.10	4.22 ± 2.10	7.11 ± 1.50	5.9	1.23	20.55	10
BOD (mgL^{-1})	3.71 ±1.00	3.62 ± 1.03	3.66 ± 2.0	3.66	0.04	1.09	10
Temperature (^oC)	22 ± 2.50	22 ± 1.50	23 ± 5.10	25.33	0.47	1.86	< 40
Total hardness (mgL^{-1})	2.89 ± 1.20	4.20 ± 2.50	4.33 ± 2.50	3.81	0.58	15.22	100
Total solid (mgL^{-1})	0.37 ± 1.02	0.56 ± 2.05	0.21	0.38	0.14	36.84	500

ND = not detected; **SD =** standard deviation; **CV% =** coefficient of variation percent; **na =** not available.

Table-2: Microbial analysis of sample water for Muellar Hinton agar and MacConkey agar

Dry Season

S/N	Sample	Muellar Hinton Agar	MacConKey Agar
1	Doma River	Massive growth more Than 100 counts	More than 100 counts
2	Farinruwa River	Less than 100 counts	Less than 100 counts
3	Mada River	Greater than 100 counts	More than 100 counts

Dry Season

S/N	Sample	Muellar Hinton Agar	MacConKey Agar
1	Doma River	Massive growth more Than 100 counts	More than 100 counts
2	Farinruwa River	Less than 100 counts	Less than 100 counts
3	Mada River	Massive growth more than 100 counts	More than 100 counts

Table-3: Metal concentration (ppm) in fish from Doma River

Dry Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	2.78	3.74	3.26	0.48	14.72
K	1.87	1.95	1.91	0.04	2.09
Ni	0.27	0.21	0.24	0.03	12.5
Cu	0.84	0.98	0.91	0.07	7.69
Mg	9.67	13.18	11.43	1.76	15.4
Fe	3.41	7.12	5.27	1.86	35.29
Ca	7.7	9.49	8.6	0.9	10.47
Zn	0.21	0.36	0.29	0.08	27.59
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	ND	0.01	nd	nd	nd
Se	0.15	0.2	0.18	0.03	16.67
Cr	0.35	0.48	0.42	0.07	16.67
Mn	0.88	0.98	0.93	0.05	5.38

Wet Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	1.05	2.39	1.72	0.67	38.95
K	1.12	0.87	1	0.13	13
Ni	0.07	0.07	0.07	0	0
Cu	0.29	0.69	0.49	0.2	40.82
Mg	7.67	12.87	10.27	2.6	58.05
Fe	1.38	5.2	3.29	1.91	58.05
Ca	6.93	9.02	7.98	1.05	13.16
Zn	0.19	0.11	0.15	0.04	26.67
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	ND	ND	nd	nd	nd
Se	0.05	0.12	0.09	0.04	44.44
Cr	0.12	0.38	0.25	0.13	52
Mn	0.7	0.78	0.74	0.04	5.41

ND = not detected; **SD =** standard deviation; **CV% =** coefficient of variation percent; **nd =** not determined

Table-4: Metals concentration (ppm) in fish from Farinruwa River

Dry Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	1.89	2.99	2.44	0.55	22.54
K	1.93	1.82	1.88	0.06	3.91
Ni	0.29	0.15	0.22	0.07	31.82
Cu	0.72	0.71	0.72	0.01	1.39
Mg	11.84	13.48	12.66	0.02	6.48
Fe	3.62	6.47	5.05	1.43	28.32
Ca	9.94	1.035	10.15	0.21	2.07
Zn	0.14	0.36	0.25	0.08	27.59
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	0.1	0.09	0.1	0.01	100
Se	0.2	0.22	0.21	0.01	4.76
Cr	0.01	0.5	0.26	0.25	96.15
Mn	0.74	0.55	0.81	0.07	8.64

Wet Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	0.83	1.91	1.37	0.54	39.42
K	1.2	1.09	1.15	0.06	5.22
Ni	0.09	0.08	0.09	0.01	11.11
Cu	0.5	0.59	0.55	0.05	9.09
Mg	10.1	13.11	11.16	1.5	12.92
Fe	1.87	4.29	3.08	1.21	39.29
Ca	8.45	9.2	8.83	0.38	4.3
Zn	0.09	0.15	0.12	0.03	25
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	0.08	0.02	0.05	0.03	60
Se	0.15	0.29	0.22	0.07	31.82
Cr	0.19	0.37	0.28	0.09	32.14
Mn	0.68	0.08	0.74	0.06	8.11

ND = not detected; **SD =** standard deviation; **CV% =** coefficient of variation percent; **nd =** not determined

Table-5: Metals concentration (ppm) in fish from Mada River

Dry Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	2.02	3.02	2.61	0.59	22.61
K	1.78	2.85	2.32	0.54	23.28
Ni	0.35	0.79	0.57	0.22	38.6
Cu	0.96	1.23	1.1	0.14	12.72
Mg	10.34	17.92	14.13	3.79	26.82
Fe	4.61	6.41	5.51	0.9	1.63
Ca	8.67	12.45	10.56	1.89	17.9
Zn	0.14	0.28	0.21	0.07	33.33
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	0.1	0.11	0.11	0.01	9.09
Se	0.18	0.27	0.23	0.05	21.74
Cr	0.45	0.79	0.62	0.17	27.42
Mn	0.98	0.2	0.59	0.39	55.1

Wet Season

Mineral	*Tilapia zilli*	*Clarias lazera*	Mean	SD	CV%
Na	1.38	1.79	1.59	0.21	13.21
K	0.92	1.71	1.32	0.4	30.3
Ni	0.67	0.39	0.24	0.15	62.5
Cu	0.67	1.03	0.85	0.18	21.18
Mg	8.93	16.82	12.88	3.95	30.67
Fe	4.02	4.98	4.5	0.48	10.67
Ca	8.11	11.68	9.9	1.79	18.08
Zn	0.09	0.11	0.1	0.01	10
Pb	ND	ND	nd	nd	nd
Cd	ND	ND	nd	nd	nd
As	ND	0.06	nd	nd	nd
Se	ND	0.19	0.1	0.09	90
Cr	0.11	0.59	0.35	0.24	68.57
Mn	0.79	0.11	0.45	0.34	76.56

ND = not detected; **SD =** standard deviation; **CV% =** coefficient of variation percent; **nd =** not determined

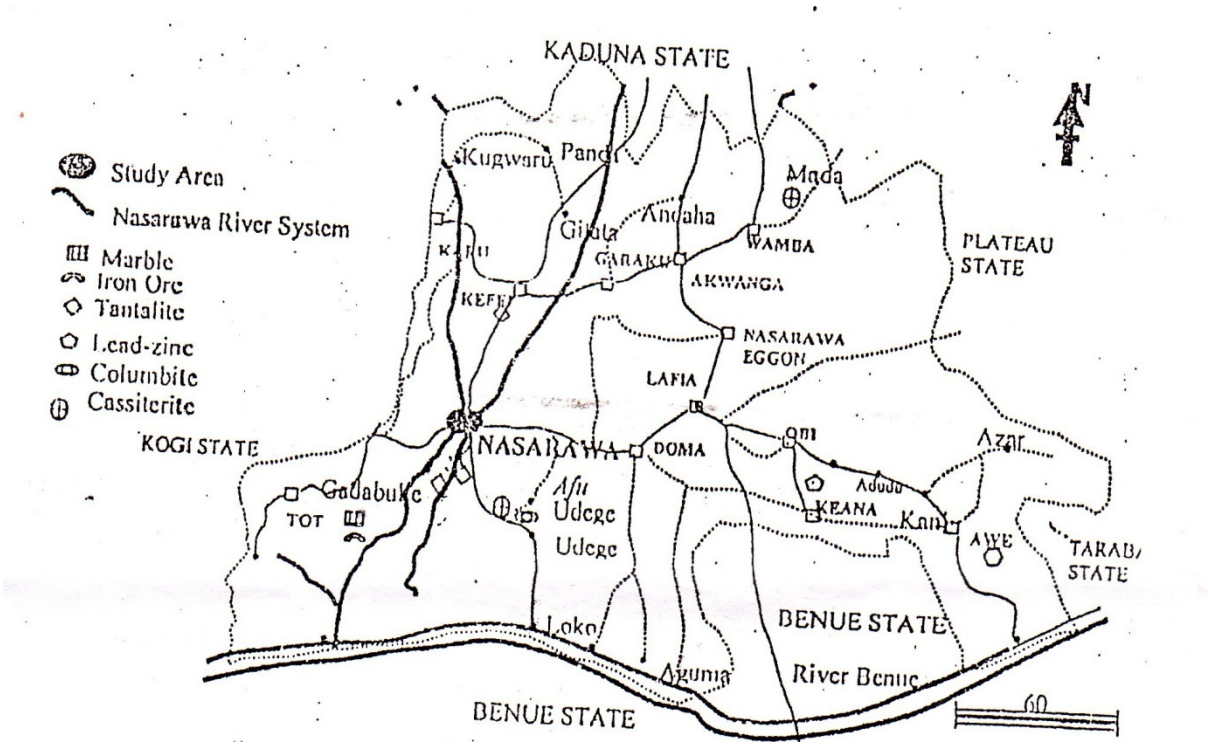

Figure-1: Map of Nasarawa State showing the study area