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Environmental Burden of Surface and Groundwater Quality: How big are the Contaminants in Girei Town, Nigeria?

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Abstract

Assessment of surface and groundwater quality was explored in Girei sub-urban town by analytical analyses on physico-chemical water quality indicators from various sources of drinking water supplies: stream, hand dug wells, boreholes and harvested rain water within the study area with the aim to quantifying the concentrations of contaminants and compare them with World Health Organization (WHO) drinking water quality standards. Water samples were collected from these sources and analyzed in the laboratory in line with methods noted in the literature. Results obtained showed that physical parameters such as turbidity and TSS for the stream and hand dug wells; 46 NTU, 42 TCN, 30-90 NTU and 25-54TCN were critically above WHO and Nigerian standards for drinking water quality. Concentrations of metal pollutants such as manganese, magnesium, chloride, calcium, iron, lead and total hardness for hand dug wells, stream and borehole water that ranged from 73mg/l to3124mg/l were also above WHO standard. The bacteriological analyses for the hand dug wells and stream values ranged from 21 to 34 MPN which shows higher values when compared to borehole, harvested rain water values and WHO standard. One-way ANOVA variance was tested on the data generated and produced F value of 14. 25 at 5% level of significance. Recommendation for effective water management strategies was made to improve water conservation and basic sanitary hygiene in the study area as a result of high level of contaminants obtained from various water supplies.

Keywords: Contamination, Environment, water quality, Surface, ANOVA

Introduction

Water is valuable because it influences the performance of many sectors of economy such as agriculture, health, industry and recreation. Over half of the population of the world depends on both surface and groundwater as its primary source of drinking water. While about 95% of all water used in rural communities in Nigeria comes from these two basic sources (Umunnakwe, et al, 2013; Ademilayi, 1998). Water is also vulnerable. Various estimates suggest that the supplies of between 1% and 5% of the U.S. population are contaminated with domestic sewage, agricultural chemicals, and industrial wastes (Edward, 1994). Recent reports suggest that 10% of community drinking water wells and 15% of rural domestic wells in Nigeria contain detectable levels of pesticide residues (Martins, 2001). The statistics are, no doubt, typical of global surface and groundwater use and contamination. The statistics are of great concern, in part, because groundwater contamination is persistent and both time-consuming and expensive to remediate. Many people in Girei Community lack access to clean and safe drinking water for their domestic and cottage commercial activities because most of their water supplies are vulnerable to contamination from sewage, agricultural and small cottage industrial wastes. Estimates of concentrations of contaminants and the assessment of pollution status and vulnerability of water supply are made in order to study the effect of management alternatives on water quality and, on community exposure to contaminants transported by groundwater. Such is the situation in Girei town because supplying safe water and sanitation to all by 2020 is the target of Nigeria's Drinking Water Supply and Sanitation Decade. It is clear that this will not be reached, and this will continue for several decades to come. Gullet (1999) articulated from experience that there has to be an orientation away from expensive, sophisticated

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techniques towards appropriate, low-cost and socially acceptable methods that are adapted to local conditions.

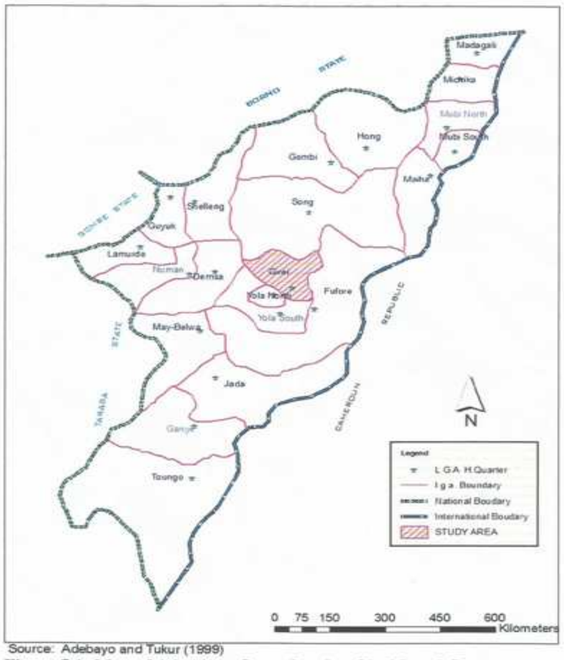
Many developing countries are located in climatic regions where rainfall is seasonal and highly erratic. Supplying water in such regions is to a large extent a matter of storing water from the rainy season to the dry season, and from years with high rainfall to dry years. Using groundwater and harvested rain water is a way of overcoming the seasonal shortages, but in some areas even the groundwater resources are depleted towards the end of dry season and in many areas there are no aquifers available, or they would require deep-drilled wells and pumps for development, a fact that makes this alternative less suitable in certain socio-economic environments notably different societies, cultures and regions (Ake Nilson, 1988). This is why; an estimated 1.2 billion people are still without safe drinking water where about 4 million people die each year of water borne diseases out of which 2 million are children under 8 years of age (UNICEF, 2000). In surface water, aquatic ecosystems perform numerous valuable environmental functions. They cycle nutrients, purify water, attenuate floods, recharge groundwater and provide habitat for wildlife and recreation for people. But increased population accompanied by intensified industrial, commercial, and residential development have led to contamination of water by fertilizers, insecticides, oil, toxic landfill leachates and feedlot waste. Water contamination can be divided into characteristic groups according to: type of contamination (organic, heavy metals, thermal, and radioactivity) and the author of contamination (sewage from people, agricultural, and industry). However, Adelana (2006) reports that the average level of nitrate in groundwater in Nigeria has increased in the last 20-30 years. This is based on the analyses of groundwater samples from over 2,200 wells (1985-2004) and 350 samples (pre-1970). The results of the survey show that 33% of wells produced water with a nitrate concentration that is above 45mg/L. It was difficult to estimate the number of people drinking water with nitrate concentrations above the permissible limit, yet a significant percentage of the population is assumed to be at risk of ingesting high doses of nitrate through drinking water. In an overview of groundwater contamination in Nigeria, Ghehe (1995) asserted that high concentration of nitrate, sulphate, and bacterial pollution has been observed in municipal as well as rural water supplies. Studies clearly demonstrate that nitrate and sulphate concentrations above 10mg/L have adverse effect on human health. In Girei town, many of their hand dug wells are uncovered and located close to sources of contaminants like toilets, waste disposal points; bore holes were drilled indiscriminately without hydrogeological surveys and presence of total dissolved solids which all affect the quality of their water supplies. Consequently, there is a need to undertake this study in order to assess the burden of surface and groundwater quality and to have the knowledge of the distribution of elevated concentrations of contaminants necessary for effective management of water resources and precautionary measures against adverse effects in Girei town, the study area. The overall objectives of the evaluation is twofold: (1) To collect water samples from River Girei, bore holes, hand dug wells and harvested rain for laboratory analyses of contaminants concentrations to aid management and conservation techniques, (2) Discuss the data with appropriate statistical tools to provide an insight into the nature of variation of natural events.

Materials and Methods

The Study Area

Girei town is the headquarters of Girei Local Government Area of Adamawa State. It is located between latitudes 9º11’ and 9º39’N and longitudes 12º21’ and 12º49’E (Adebayo and Tukur, 1999). The total land mass of the local government is 12,659 sqkm while the population is 129, 995 people according to National Population Commission (2006); this based on the annual growth rate of 2.5%. The Local Government shares common boundaries with Song Local Government Area in the North, Fufore Local Government Area in the East while River Benue is a physical boundary between the Local Government and Yola North and Demsa Local Government Areas (Fig. 1).

Girei town falls under the Sudan Savannah type of vegetation and experiences two distinct dry and wet seasons with temperature and humidity varying with the seasons. The wet season is between May and October, while dry season is between November and April. The annual amount of precipitation received in the area was 972mm and the temperature range is from $27℃ - 40℃$ (UBRBDA, 2012). The dry period is characterized by dry, dusty and hazy north – east trade winds that blow over the area from Sahara desert. The area is mainly characterized by rural settlements dominated mainly by farmers and most of their lands are intensively put into agricultural use. The whole study area was divided into four groups i.e. Zumore, Anguwan Bura, Tashan Maiturare and Anguwan Yungur for ease of sampling. The groupings also represent the traditional pattern of settlement and the catchment areas of the water supply resources.



Source: Adebayo and Tukur (1999)
Figure 1: Map of Adamawa State showing Girei Local Government

Data Collection

Rubber containers (Jeri cans) were used to collect water samples from all sources: stream, hand dug wells, bore holes and harvested rain water for laboratory analysis in Federal University of Technology, Yola. Other materials used included; measuring tape for taking the depths of water levels in hand dug wells, pH meter for determining the pH levels of all water samples collected, beakers, thermometer for temperature measurement, conductivity meter was used to determine the total amounts of dissolved salts in samples with the help of Potassium chloride (KCl), turbid meter was used to measure the turbidity of water due to the presence of dissolved suspended matter. This was achieved by allowing the displaced distilled water to stabilize, and then later recorded in nephelometric turbidity unit (NTU). Total suspended solid (TSS) was determined by filtering the water samples and weighing the residues left on filter papers while the total solids (TS) was determined by evaporating the water samples and weighing the dry residues. Since total solids include suspended solids (SS) and dissolved solids (DS), the amount of (TDS) was obtained from the difference between (TS) and (TSS).

The amount of dissolved oxygen (DO) in water especially in stream and rain water was determined using manganese sulphide solution, pipette, burette and BOD bottles mixed with water sample. Red precipitation of DO was formed, indicating the presence of DO. Total water hardness was also determined in hand dugs wells with the help of concentrated H_2SO_4, methyl orange, phenolphthalein, pH meter and ammonia buffer. Biochemical oxygen demand (BOD) was determined by adding potassium hydroxide to the water samples in the incubation bottles and stirred with magnetic stirrer. The level of mercury was set to zero and the BOD machine was connected to incubate at 20°C for 5 days after which BOD value was read directly from the scale. Chemical oxygen demand (COD) was determined through similar method but with the help of 30ml concentrated H_2SO_4, 5g Silver sulphate and diluted dichromate.

The presence of chloride in all the water samples was obtained by adding reagents according to manufacturer's instructions and after which the mixture was placed in a comparator and rotated in a standard disc until the color matches which gives free residual chlorine. To the residual chlorine, potassium iodine was added and waited for about 2 minutes which was later compared in color with the standard disc that gave the total chloride in mg/l. Water samples temperature were tested with the use of laboratory mercury thermometer. The thermometer sensory edge with a size range from 0 - 360°C was plunged directly into the water samples at in-situ from all the sources while the corresponding readings were recorded. Odour in water as caused by the presence of algae, decayed leaves and vegetables, a combination of domestic and industrial wastes and some chemical compounds. It was determined when the given samples was mixed with odour free water and tested with the instrument for detecting odour. Similarly the water colour was determined by dissolving 1mg of platinum cobalt in 1litre of water sample which was then read on a cobalt scale. The presence of heavy metals (Cu, Cd, Zn, Pb, Fe, Cr, As, etc) in all the sampled water was detected with the atomic absorption spectrophotometer (AAS). Content indicator organisms and membrane filter technique methods were applied to detect the coliform group of bacteria. A known volume of water sample was passed through the filter that had very small pore sizes and the coliform bacteria were captured by the filter then exposed to nutrients which promoted the growth of coliform while inhibiting that of other organisms. After incubation, the number of coliform colonies was counted with the aid of an optical device where they appeared whitish in colour.

Results and Discussion

Results obtained from this study showed that the pH for the water samples from stream, boreholes, harvested rain water and hand dug wells in different locations ranged from 6.5 to 7.45. This does not exceed WHO permissible limit of 6.5 to 8.5 for drinking water (Table 1). The obtained values for

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concentrations of calcium that range from (71 - 668mg/l), magnesium (0.5 -0.61mg/l for hand dug wells and 0.68 – 0.87mg/l for bore holes), chloride (780 – 2850mg/l for hand dug wells and 630 – 1930mg/l for bore holes), lead (0.04 – 0,09mg/l for hand dug wells and 0.024 – 0.073mg/l for bore holes, 0.86mg/l for stream water), total faecal coliform (34 MPN for stream, 21 – 33 MPN for hand dug wells and 13 – 23 MPN for bore holes), etc. These values are worrisome because as primary pollutants, they are above the permissible limits of WHO (2007) Standards for drinking water quality; and are capable of having harmful effects on public health especially diarrhea and the neuromatics among children and the elderly (Tables 1 & 2). The concentration of total suspended solids (TSS) for all the samples ranged from 0.98 to 2.8mg/l while the electrical conductivity ranged from 126.08 to 277.5μ/Hos/cm at 20ºC. Total hardness for all the samples were high and above WHO Standard for drinking water. This was due to the presence of sulphide chloride and nitrate of calcium and magnesium Ca $(HCO_3)_2$; Mg $(HCO_3)_2$ in the water samples collected. Total dissolved solids (TDS) concentration obtained ranged from 63.04mg/l – 138,7mg/l while the turbidity levels ranged from 30 – 90 NTU for hand dug wells, 7.4 – 23.21 NTU for bore holes and 46 NTU for the stream water. Other parametric results can be followed up in Tables 1 & 2 below.

Table 1: Results of Water Quality Analysis for Location 1 (Zumore)

Parameters	Stream sample (mg/l)	Hand dug well (mg/l)	Bore hole (mg/l)	Harvested rain (mg/l)	WHO Standard '07
pH	7.41	7.43	7.45	7.22	6.5 – 8.5
Temperature	30.00ºC	28.50°C	27.00°C	30.30°C	-
Total solids	106.8	132.00	99.30	83.40	-
TSS	2.80	2.30	2.50	2.70	-
TDS	104.00	129.7	96.80	80.70	500
Total hardness	690.00	1070.00	440	400	150
Calcium	73.00	144.90	110.00	193.20	75
Magnesium	617.00	925.30	330	266.40	0.2
EC at 20°C	208.00$\mu/Hos/cm$	259.4 0$\mu/Hos/cm$	193.64 $\mu/Hos/cm$	161.40 $\mu/Hos/cm$	1000
BOD	8.00	5.00	6.00	7.00	-
DO	10.48	6.20	4.30	5.60	-
Sodium	0.87	0.75	0.65	0.42	200
Potassium	0.85	0.57	0.77	0.57	-
Carbonate/bicarbonate	28.00	75.00	38.00	32.00	-
Manganese	0.24	0.64	0.72	0.02	0.2 – 0.5
Turbidity	46.00 NTU	30.00 NTU	8.00 NTU	0.02 NTU	5
Iron	0.74	0.24	0.142	0.001	0.3
Lead	0.86	0.07	0.052	0.01	0.01
Colour	42.00	62.00	0.00	0.00	15
Total coliform test	0.34MPN/ml	0.26MPN/ml	0.13MPN/ml	0.00MPN/ml	10
Odour	odourless	odourless	odourless	odourless	-
Chloride	3124	2932	1704	92.00	250

Table 2: Results of Water Quality Analysis for Location 2 (Tashan Maiturare)

Paramaters	Stream sample (mg/l)	Hand dug well (mg/l)	Bore hole (mg/l)	Harvested rain (mg/l)	WHO Standard '07
pH	7.41 no unit	7.30 no unit	7.00 no unit	7.45 no unit	6.5 – 8.5
Temperature	30.00ºC	28.00°C	25.00ºC	28.10°C	-
Total solid	106.80	122.00	82.00	78.00	-
TSS	2.80	2.30	1.62	1.08	-
TDS	104.00	119.70	80.38	76.92	500
Total hardness	690.00	1020.00	830.00	390.00	150
Calcium	73.00	103.00	668.00	302.00	75
Magnesium	617.00	917.00	162.00	88.00	0.2

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EC at 20°C	208.00 $\mu/Hos/cm$	239.40 $\mu/Hos/cm$	160.70 $\mu/Hos/cm$	153.40 $\mu/Hos/cm$	1000
BOD	8.00	5.30	6.70	2.00	-
DO	10.48	7.20	4.20	3.12	-
Sodium	0.87	0.84	0.93	0.34	200
Potassium	0.85	0.54	0.67	0.27	-
Carbonate	28.00	55.00	42.00	24.00	-
Manganese	0.24	0.46	0.72	0.02	0.2 – 0.5
Turbidity	46.00 NTU	41.02 NTU	9.24 NTU	0.04 NTU	5
Iron	0.74	0.42	0.18	0.001	0.3
Lead	0.86	0.082	0.067	0.00	0.01
Colour	42.00	20.00	12.00	9.00	15
Total coliform test	0.34 MPN/ml	0.27 MPN/ml	0.17MPN/l	0.00 MPN/ml	10
Odour	odourless	odourless	odourless	odourless	-
Chloride	3124.00	780.00	630.00	260.00	250

Analysis of variance (ANOVA) was applied to three treatments, (TSS), (BOD) and (DO) concentrations (mg/l) in Table 1 to determine whether their sample means could have been obtained for populations with the same true mean. This was done by estimating the amount of variation within treatments and comparing it with the variance between treatments. The "within variance" and the "between variance" were compared using F statistic, which is a measure of the variability in estimated means. The analysis of variance is a rich and widely used field of statistic; its analysis is more than a technique for statistical analysis because it provides an insight into the nature of variation of natural events. If one speaks of beauty in a statistical method, analysis of variance possesses it more than any other (Paul and Linfield, 2002). The within fromthis equation: sum of squares was calculated from the residuals of the observations within a treatment and the average for that treatment. The variance within each treatment is:

$$S^2{}_t = \sum_{i=1}^{n_i} \frac{\left(y_{ti} - \bar{y}_t\right)}{\left(n_t - 1\right)} \text{ .... (Equation 1)}$$

Where; y_{it} are the n_t observations under each treatment. Assuming all treatments have the same population variance, we can pool the k sample variances to estimate the within – treatment variance ($S^2{}_w$):

i.e, $S^2{}_w = \dfrac{\sum_{t=1}^{K}\left(n_t - 1\right)S^2{}_t}{\sum_{t=1}^{K}\left(n_t - 1\right)}$ .... (Equation 2)

The between treatment variance ($S^2{}_b$) was calculated using the treatment averages $\bar{y}_t$ and the grand average, $\bar{\bar{y}}$:

$$S^2{}_b = \frac{n_t \sum_{t=1}^{K}\left(\bar{y}_t - \bar{\bar{y}}\right)^2}{k-1} \text{ ....(Equation 3)}$$

If there is equal number of observations in each treatment, the equations for $S^2{}_w$ and $S^2{}_b$ simplify to:

$S^2{}_w = \dfrac{\left(n-1\right)\sum_{t=1}^{K} S^2{}_t}{N-k}$ .... (Equation 4), N – k is the degree of freedom. The computations for the one – way ANOVA are comparing three treatments A, B, and C of TSS, BOD, and DO which yields the data shown below.

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	A: TSS	B: BOD	C: DO
	2.80	8.0	10.48
	2.30	5.0	6.20
	2.50	6.0	4.30
	2.70	7.0	5.60
Treatment average	$\bar{y}_A = 2.6$	$\bar{y}_B = 6.5$	$\bar{y}_C = 6.7$
Treatment variance	$S^2_A = 0.05$	$S^2_B = 1.7$	$S^2_C = 7.2$
Grand average	$\bar{\bar{y}} = 5.3$		

The order of the experimental runs was randomized within and between treatments. The grand average of all 12 observed values is $\bar{\bar{y}} = 5.3$. The averages for each treatment are: $\bar{y}_A = 2.6$, $\bar{y}_B = 6.5$, and $\bar{y}_C = 6.7$. The within and between treatments were obtained by applying Equations 1, 2, and 3 above as: $S^2_A = 0.05$, $S^2_B = 1.7$, and $S^2_C = 7.2$ while the pooled within-treatment variance was obtained by the use of Equation 4 as: $S^2_w = 2.98$. However, the between variance was computed from the mean for each treatment and the grand mean, as: $S^2_b = 42.76$. These values are presented in Table 3 below.

Table 3: Analysis of Variance Table for Comparing Treatments A, B, and C (TSS, BOD, DO)

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F Ratio
Between treatments	85.52	2	42.76	14.25
Within treatments	26.82	9	2.98	
Total	112.34	11		

The question whether the between-treatment variance is larger than the within-treatment variance was judged by comparing the ratio of the between variance and the within variance. The ratios of sample variance were distributed according to the F distribution and the tabulation of F values was arranged according to the degrees of freedom in the variance used to compute the ratio.

The test was made at 5% level with degrees of freedom $v_1 = 2$ and $v_2 = 9$. The relevant value was $F_{2,9,0.05} = 4.26$. But the computed F = 14.25 is greater than 4.26. So we conclude that $\sigma^2_b > \sigma^2_w$. This provides sufficient evidence to conclude at the 95% confidence level that the means of the three treatments are not equal, or the concentrations of the contaminants are not equal, i.e. $\eta_A \neq \eta_B \neq \eta_C$. The mean square values estimate the within-treatment variance (S^2_w) and the between-treatment variance (S^2_b). Note that the mean square for variation between treatments is 42.76, which the between-treatment variance is computed above. Also, note that the within treatment mean square of 6 is the within-treatment variance also computed above. The F value is the ratio of these two mean squares being 14.25.

Conclusion

Water samples were collected from different supply sources within Girei town according to areas grouped for this study. The samples were analyzed in the laboratory for Physico-chemical parameters of contaminants in order to quantify their concentrations for the knowledge of vulnerability of water supply sources to the inhabitants. Instruments such as atomic absorption spectrophotometer (AAS), autoclave, weighing balance, reagents and other equipment were used to achieve these analyses. The obtained range of results for calcium (71-668mg/l) from hand dug wells, magnesium (0.68-0.87mg/l) for boreholes, chloride (780-2850mg/l), lead (0.04-0.09mg/l for well water, 0.86mg/l for stream water), turbidity level of 46-90NTU for stream water, total focal coliform (34MPN for stream, 21-33MPN for well water), etc are worrisome as they are above allowable limits of WHO Standards for drinking water quality. A one-way ANOVA variance of comparing three treatments (TSS, BOD, and DO) was applied to test data at 5% level of freedom which produced an F value of 14.25 for two mean squares. This provides enough evidence to conclude at 95% confidence level that the means of the three treatments are not equal; or rather the concentrations of contaminants are not equal and high.

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