

EFFECTS OF SEWAGE DISPOSAL ON THE QUALITY OF SHALLOW GROUNDWATER IN SONG TOWN, ADAMAWA STATE, NIGERIA

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ABSTRACT

Over the years, there were reports of cases of waterborne diseases such as cholera and typhoid in Song town and these are increasing at alarming rates. This research is aimed at investigating the impact of the sewage disposal methods on available water supplies in the town. Questionnaires were administered and observational study was conducted at random on 150 houses to generate information about shallow wells and toilet facilities in the study area. Water samples were taken from 19 different locations across the study area for physico-chemical and bacteriological analyses; in order to assess the groundwater quality. From the results obtained, it was observed that 55% of the resident's wells are located at a distance less than 9m from the toilets. The physico-chemical analysis results indicate the presence of certain sewage sensitive parameters such as chloride (Cl⁻), Total Dissolved Solids (TDS), Electrical Conductivity (EC) and Nitrates (NO³⁻), in mild quantities. The results of bacteriological analysis of the samples reveal very high concentrations of coliform bacteria and Escherichia coli varying between 130 and ≥ 2400 MPN/100ml of water. This is an indication of faecal contamination of the groundwater. It is recommended that, hydrogeological survey of the area be conducted to ascertain the direction of groundwater flow and depth to water table before location of toilets and wells. Environmental and health authorities should educate, regulate and control the people regarding sewage disposal.

Keywords: Groundwater, Sewage, Contamination, Water Supplies, Toilets, Physico-chemical, Coliform bacteria, Escherichia coli

1 INTRODUCTION

Song town is a fast growing settlement and the headquarters of Song Local Government Area of Adamawa State; where surface water and groundwater are the main sources of water supply. Surface water in the area is obtained from River Song and its tributaries whereas groundwater is obtained from boreholes and hand-dug wells. Both sources of water are prone to contamination and pollution. Hence, the need for water quality assessment for enhanced socio-economic growth and development. Proper evaluation of water quality for human consumption has not been given attention especially in this area. As a primary need for every living thing, the composition of water is an important factor to be considered before it is used for domestic purposes. Hence it is imperative to conduct hydrogeochemical and bacteriological analysis of water in order to know its portability. The dissolved geochemical constituents in water affect its quality. The concentrations of the dissolved constituents have to be correlated with the standards of the global organizations charged with the responsibility of providing safe drinking water to people [1]. Sewage is any liquid waste containing some solids produced by humans such as washing water, faeces, urine, laundry waste and other materials which go down drains and toilets from households and industry. It is a domestic wastewater and a major source of pollution especially in urban areas [1]. Improper

disposal of sewage can often lead to groundwater contamination which normally results to epidemic of water borne diseases such as typhoid fever and cholera. In some cases these lead death of people globally. Sewage constitutes a major contaminant of groundwater in Song town. Contamination of groundwater in the area is always increasing due to negligence of the aquifer and improper design of toilet facilities in terms of width, depth and other parameters. Hand dug wells are designed and located without proper site investigation to determine nearness to sources of pollution (pit latrines and soak-away pits). Toilet facilities are also constructed without investigation to ascertain the nature of the soil (topography, porosity and permeability), groundwater flow direction and water table depth. Population growth and urbanization in the study area lead to a situation whereby most hand-dug wells are located close soak-away pits and pit toilets. This research attempts to investigate the different sewage disposal methods used and evaluate the quality groundwater from shallow water sources in the study area with the aim of assessing the geochemical processes affecting the groundwater chemistry.

2 THE STUDY AREA

The study area Song town lies between longitudes $12^{\circ}36'E$ and $12^{\circ}40'E$ and latitudes $9^{\circ}48'N$ and $9^{\circ}52'N$. It is the headquarters of Song LGA of Adamawa State and is located about 72km north of Yola the state capital (Figure 1). It is easily accessible by the Yola-Song-Gombi-Mubi road. The study area falls within the northeastern Nigerian basement complex – the Hawal Massif [2]. It is characterized by a hilly topography with structural ridges and inselbergs surrounding the alluvial plains. The landforms resulted from various past geological and geomorphological processes. The study area has tropical climate characterized by distinct dry and wet seasons. The rainy season starts in April and ends in October, while the dry season lasts from November to March. The mean annual rainfall ranges from 800 mm to 900 mm. The wettest months are August and September while the driest months are March and April [3]. Temperature in the study area is typical of the West African Savannah climate. It is high between March and June, when the daily maximum temperatures may reach $42^{\circ}C$. Also in October and November, immediately after the rainy season, the temperature may rise till the onset of the harmattan sub-season when the temperature drops. During the months of December and January, temperatures are as low as $20^{\circ}C$ due to the harmattan dusts in the sky which obstructs sunrays. Also between July and September, temperature drops to $26^{\circ}C$ due the influence of the humid maritime air mass which cover sun rays during this time. There is a seasonal variation in relative humidity in the study area. During the rainy season, the relative humidity rises up to 90%. It reaches its peak in August and September. This is due to the influence of the tropical maritime air mass which covers sun rays during this time.

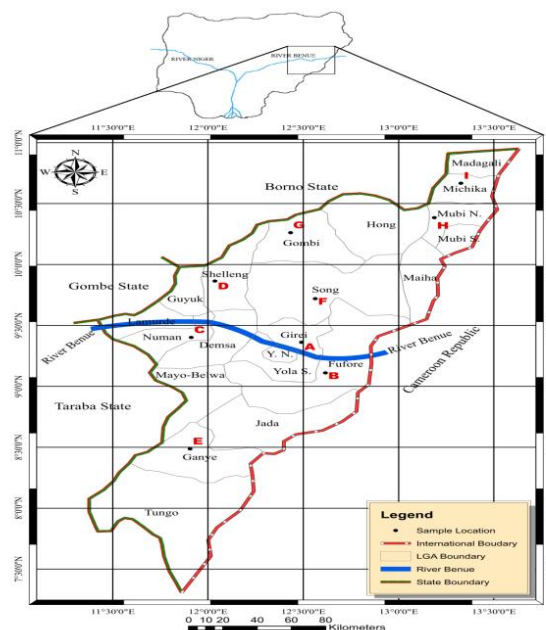


Figure 1. Map of Adamawa State, Nigeria showing the Study Area

2.1 Geology of the Study area

The study area is a basement complex terrain which have undergone both pre-pan African and pan-African orogenies and resulted into consequent metamorphism, migmatization and granitization of the pre-existing rocks. The upper parts of the underlying geology have been weathered to superficial deposits consisting of a mantle of gravels, sands, loamy sands and clayey soils. The grain sizes and thicknesses of the soil decrease with distance towards the plain areas. However, outcrops of the basement rocks are still preserved in the hilly regions [3]. Lithologically, the underlying basement rocks consist of gneisses, older granites and tertiary volcanics (Figure 2). The gneisses are coarse-grained high-grade metamorphic rocks formed at high pressures and temperatures, in which light and dark mineral constituents are segregated into visible bands [4]. They are comprised of two main types: the biotite gneiss and the banded gneiss. The biotite gneisses are fine-grained with strong foliation caused by the parallel arrangement of alternating dark and light minerals. The banded gneisses show alternating light-coloured and dark bands and exhibit intricate folding of their bands. The rock units have been subjected to tectonism giving rise to fractures, veins, fissure, faults, joints and fractured zones [5]. In some cases the veins are filled with remobilized minerals such as quartz and feldspars called the quartzo-feldspathic veins. The older granites which cover about 70% of the area is a coarse-grained igneous rocks made up of feldspar, mica, quartz, biotites, and occasionally microcline. They occur as large circular masses within the older gneiss complexes [6]. During the Pan-African orogeny (about 1500 Ma), granites were emplaced into the metamorphic Basement Complex of Nigeria [6], and they probably mark the terminal end of the event. On the geodynamic evolution of the Pan-African belt in West Africa, which includes north-eastern Basement Complex of Nigeria, [5] had opined that based on petrographic and structural studies, a model of continent-continent collision between the Congo Craton and West African Plate can be proposed. According to him, geodynamic disturbances and magmatic activity generated deep within the Earth's crust may have initiated faulting exploited by the granites. Thus, tectonism in the area seems to be so strong to have led to the emplacement of Older Granites Series [5, 6]. Volcanic rocks of Cambrian age occur as pockets in the study area both as interbedded lavas among the basement complex and as post metamorphic extrusives. It is believed that these rocks originated during the volcanic activity associated with the Pan-African Orogeny. These are composed largely of calcic plagioclases and ferromagnesian minerals. Basalts, the most prominent volcanic rocks in the study area and are characterized by small grain sizes (less than 5mm) and approximately equal proportion of calcium-rich plagioclase, feldspar and calcium rich pyroxenes [5]. The presence of vesicles in basalts indicates that they evolved gas in low pressure environments during their time of formation. Basaltic flow develop a characteristic of fracture called columnar jointing, where by the rocks split into polygonal columns oriented perpendicular to the cooling surfaces. The basalts occurred as low ridges along stream channels of rivers that drained the study area, as pumices, bombs and columnar joints.

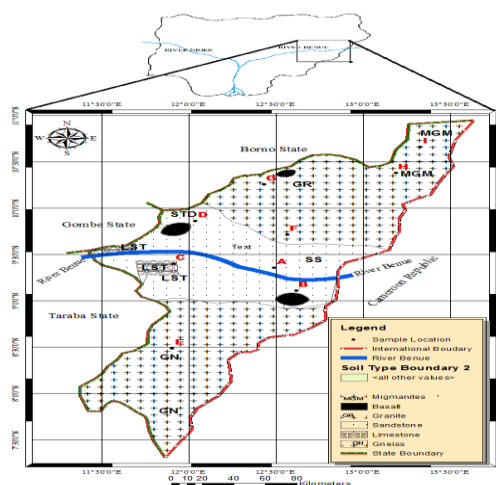


Figure 2. Geologic Map of Adamawa State Showing the Different Rock Types Found in the Study Area

The surface water sources in the study area are from rivers and streams such as Mayo Song, Mayo Chaddewa and Mayo Bongo. All these streams are seasonal; reaching their peak in August/September and drying up during the dry season. These serve as sources of recharge to hand dug wells located nearby and adjacent to them through base flow and groundwater seepage. The occurrence of groundwater in crystalline basement rocks is unpredictable due to absence of primary porosity or permeability. In the study area, groundwater occurs in the unconsolidated weathered overburden and fractured basement aquifer [7]. The unconsolidated weathered overburden aquifer unit is heterogeneous and consists of layers of fine to coarse grained sands, silts, sandy clays and clays. It provides water to most of the hand dug wells in the study area.

3 METHODOLOGY

One hundred and fifty questionnaires were distributed to one hundred and fifty houses which were randomly selected to cover the entire Song town. The areas sampled include Tiken-Shanu, Bicchel, Tsangaya, Gudure, Kolere, Gadamayo and Burawo. Others are Dabere, Mbal'yebbe, Tarawo, Fadde-Murke, Fadde-Babal and Bongo. The questionnaires were used to generate information about well depth, uses of well water, distance of toilets to wells, toilets types and presence of waste dump around wells. Water sampling was carried out from nineteen hand-dug wells. Sterilized standard one-litre white plastic bottles, which were systematically labelled, were used in collecting the water samples. They were properly rinsed with water from the wells before collecting samples for laboratory analysis. Samples were preserved in bucket of iced containers during conveyance to the laboratory, where they were carefully preserved in refrigerators. Weighed rope and tape were used in measuring the depths of water table in the various wells studied. The latitudes, longitudes and elevations of the wells were obtained with the help of the GPS 12 channel XL Garmin model, the locations of the wells and the toilets were ascertained using the compass. The acidity and alkalinity of the water samples was measured using standardized pH meter while Electrical conductivity was measured using a Wissenschaftlich Technische Werkstaetior, (wtw) LF9 conductivity meter. Total Dissolved solid was measured using TDS meter. Chloride and nitrate were determined by simple titration method using the Merck field chemical kits. Sodium (Na^+) was determined by flame photometric method using Gallenkamp Flame analyzer model FGA 330c. Escherichia coli were measured using Eosin Methylene Blue algae (EMB) while Coliform count test was performed using Mac Conkey Broth medium.

4 RESULTS AND DISCUSSION

Table 1 shows the results of statistical analyses. According to the results, 55% of the resident's wells are found to be located at a distance less than 9m from toilet facilities and 98% of the residents use the well water for domestic purposes. The depths to water table in 65% of the wells range from 1 to 10m and it is more than 10m in 35% of the wells. These showed that the depths to water tables in majority of the wells fall with the same level (1 to 10m) with depth to soak-away pits and pit toilets. Those respondents whose wells are close to toilet facilities agreed of suffering from water borne diseases more often than those whose wells are at a far distance from toilet facilities.

Table 1. Results of Statistical Interpretation

Questions	Frequency	Respondent View (%)
Depth of Well		
1-10m	97	64.7
Above 10m	53	35.3
Uses of well water		
Domestic purposes e.g. cooking, laundry etc	147	98
Distance of toilet to well		
1 - 9m	82	54.7
> 9m	68	45.3
Types of toilet used in Song town		
WC/Soak-away	52	34.7
Pit toilet	90	60
Bush latrine	8	5.3
Presence of waste dump around wells		
No	145	96.7
Yes	5	3.3

Table 2 shows the results of physico-chemical analysis of the water samples from the study area. From the results, the pH varies between 3.0 and 6.6. This is low when compared with [8] standard for drinking water. The Electrical Conductivity of the water samples ranges from 1.5 to 45 us/cm. Since conductivity increases with increase in ion concentration, it is regarded as Total Dissolved Solids (TDS) indicator. Electrical conductivity is a sensitive parameter used for the study of sewage contamination [9, 10]. The portability of water is a function of the Total Dissolved Solids. High amounts of dissolved salts from domestic sewage are often found in wastewater effluents [11]. [12], standard for drinking water gave constituents concentrations of Total Dissolved Solids in domestic wastewater as 850 mg/l (strong), 500mg/l (medium) and 250 mg/l (weak). Water samples with high values of TDS are those wells located close to toilet facilities. From Table 2, water samples from locations 1, 2, 3, 5, and 8 generally have very high concentrations of sodium. [12] Recommended 20mg/l of sodium in drinking water. Water samples from locations 4 and 6 contain 37.45 mg/l and 26.75 mg/l of sodium respectively. These are also slightly higher than the [12] recommended standard of 20mg/l. High concentrations of sodium usually have adverse effects on human health because sodium in drinking water causes increase in blood pressure. Washing products and human excreta are possible sources of Sodium contents in the study area. The values of chloride in the studied water samples range from 8.0 mg/l to 250 mg/l. [12] gave constituent concentration of chloride in domestic wastewater as 100mg/l (strong), 50mg/l (medium), and 30mg/l (weak). Water samples from locations 2, 5, 8, 10, 11, 15, 18 and 18 have high chloride concentrations. Incidentally, these locations with high chloride concentrations are observed to be very close to toilet facilities. The source of chloride in the water sample could possibly be from sodium chloride (NaCl) in sewage. [14] Opined that human excretion contains about 6g of chlorides per person per day. Water samples from locations 1 and 12 where wells are at a close distance to toilet facilities have low chloride concentrations. This is because sewage might probably flow away from the well. Generally, the concentration of nitrates in the water sample is low. It ranges from 0.2 mg/l to 2.5 mg/l (Table 2). Presence of nitrates in water is a probable indicator of sewage contamination [15, 16]. The values of chloride in the studied water samples range from 8.0 mg/l to 25 0mg/l. [12] gave constituent concentration of chloride in domestic wastewater as 100 mg/l (strong), 50 mg/l (medium), and 30mg/l (weak). Water samples from locations 2, 5, 8, 10, 11, 15, 18 and 18 have high chloride concentrations. Incidentally, these locations with high chloride concentrations are observed to be very close to toilet facilities. The source of chloride in the water sample could possibly be from sodium chloride (NaCl) in sewage. [14] opined that human excretion contains about 6g of chlorides per person per day. Water samples from locations 1 to 12 where wells are at a close distance to toilet facilities have low chloride concentrations. This is because sewage might probably flow away from the well. Generally, the concentration of nitrates in the water sample is low. It ranges from 0.2mg/l to 2.5mg/l (Table 2). Presence of nitrates in water is a probable indicator of sewage contamination [15, 16]. Table 4 shows the results of bacteriological analysis. From the results, coliform concentration ranges from 130 to 2400 mpn/100ml, which is far above W.H.O standard. The presence of coliform in water strongly indicates recent sewage contamination since faecal coliform is associated with human or animal intestinal tract. Generally, bacteria thrive well in an environment which contains compounds associated with sewage and until recently, faecal coliform have been used to identify sources of sewage pollution [17]. The existence of the coliform group as a whole and the confirmation of *Escherichia coli* are indicative of faecal contamination of the groundwater [18].

Table 2. Results of Physico-Chemical Analysis

S/ N	Location	Sources Type	Date Of Analysis	Well Depth (M)	pH	EC us/c m	Na ⁺ mg/l	TDS mg/l	NO ₃ mg/l	CL mg/l	Dist B/W Well And Toilet (M)
1	Tiken Shanu	Hand Dug Well	15-06-2017	3.8	4.8	3.0	50.83	30	0.5	9.0	3-6
2	Bicchel EYN	Hand Dug Well	15-06-2017	6.0	3.6	45	111.65	450	0.9	250	1-3
3	Bicchel Naso	Hand Dug Well	15-06-2017	6.7	4.3	14	238.7	140	0.9	58.0	3-6
4	Tsangaya A.Babuga	Hand Dug Well	15-06-2017	1.9	4.5	6.0	37.45	60	0.2	28.0	6-9
5	Tsangaya Jauro	Hand Dug Well	15-06-2017	7.0	3.0	42	215.6	420	1.0	189.9	1-3

6	Gadamayo Lambu	Hand Dug Well	15-06-2017	8.0	4.4	2.0	26.75	20	0.2	9.0	>9
7	Gudure Ahmaadu Goni	Hand Dug Well	15-06-2017	6.8	4.0	9.0	18.73	90	0.7	36.0	>9
8	Gudure Umaru Bara	Hand Dug Well	15-06-2017	5.7	3.5	25	231.0	250	0.9	155.0	3-6
9	Kolere Ya Mu'allim	Hand Dug Well	22-06-2017	10.2	5.0	15	6.52	150	1.6	68.0	3-6
10	Kolere A. Magaji	Hand Dug Well	22-06-2017	7.6	4.4	13	6.13	130	2.2	138.0	1-3
11	Kolere A. Abduwa	Hand Dug Well	22-06-2017	10.8	6.3	31	1.84	310	0.5	138.0	3-6
12	Dabere Alim Muleng	Hand Dug Well	22-06-2017	11	6.6	32	3.25	320	0.6	8.0	3-6
13	Dabere Old Market	Hand Dug Well	22-06-2017	10.1	6.5	4	4.9	40	0.2	63.0	3-6
14	Dabere Ali Mai Goro	Hand Dug Well	22-06-2017	10.5	4.0	21	3.67	210	2.4	83.0	>9
15	Mbal'yebbe Ardo Kesure	Hand Dug Well	22-06-2017	10	5.5	34	4.29	340	2.5	138.0	3-6
16	Mbal'yebbe Komishina	Hand Dug Well	22-06-2017	3.2	5.9	33	4.29	330	1.0	103.0	1-3
17	Tarawo A. Basadu	Hand Dug Well	22-06-2017	7.8	5.3	12	1.23	120	0.1	48.0	>9
18	Tarawo Kurndadi	Hand Dug Well	22-06-2017	11.0	4.9	28	4.9	280	2.3	115.0	6-9
19	Fadde Babal A. Mamudu	Hand Dug Well	22-06-2017	12.0	3.4	25	1.84	250	2.2	84.0	6-9

Water samples with high values of coliform count are those whose wells are located close to toilet facilities except in locations 1, 12, 18 and 19. In location 1 which is 3 to 6m from toilet facility, the toilet is located at eastside while the well is at the west side and since groundwater flow direction is eastward, toilet probably flows away from the well and this probably resulted to low coliform count in the location. In location 12 which is 3 to 6 m from toilet facility, the toilet is located northward while the well southward, sewage possibly flows away from the well resulting to a low coliform count observed in the location, regardless of its proximity to soak-away pit. Locations 18 and 19 which recorded a high coliform counts were also observed to be at a reasonable distance of 6 to 9 m away from the toilet facilities. Table 3 shows the directions of toilets and wells.

Table 3. Directions of Toilets and Wells

S/N	Location	Distance B/W Well And Toilet	Toilet	Well	Remarks
1	Tiken Shanu	3-6	East	West	-
2	Bicchel EYN	1-3	West	East	+
3	Bicchel Naso	3-6	West	East	+
4	Tsangaya A.Babuga	6-9	East	West	-
5	Tsangaya Jauro	1-3	West	East	+
6	Gadamayo Lambu	>9	West	East	+
7	Gudure Ahmadu Goni	>9	East	West	-
8	Gudure Umaru Bara	3-6	West	East	+
9	Kolere Ya Mu'allim	3-6	West	East	+
10	Kolere A. Magaji	1-3	North	South	X
11	Kolere A. Abduwa	3-6	West	East	+
12	Dabere Alim Muleng	3-6	North	South	X
13	Dabere Old Market	3-6	North	South	X
14	Dabere Ali Mai Goro	>9	North	South	X
15	Mbal'yebbe Ardo Kesure	3-6	West	East	+
16	Mbal'yebbe Komishina	1-3	West	East	+
17	Tarawo A. Basadu	>9	South	North	0
18	Tarawo Kurndadi	6-9	West	East	+
19	Fadde Babal A. Mamudu	6-9	n.d	n.d	X

Legend: + (Toilet flows into Well), - (Toilet Flows away from well), × (Toilet may likely flow away or into well), 0 (Not certain)

E.coli is indicative of faecal contamination. The human intestine is the primary host for *E. coli* and the bacteria are excreted in large numbers with faeces. They have been shown to be associated with some water borne disease causing organisms. Table 4 shows the results of bacteriological analysis.

Table 4. Results of Bacteriological Analysis

S/N	Location	Source Type	Date Of Analysis	Well Depth (M)	Coliform Mpn/100ml	E. Coli
1	Tiken Shanu	Hand Dug Well	15-06-2017	3.8	550	11
2	Bicchel EYN	Hand Dug Well	15-06-2017	6.0	2400	22
3	Bicchel Naso	Hand Dug Well	15-06-2017	6.7	1100	3
4	Tsangaya A.Babuga	Hand Dug Well	15-06-2017	1.9	460	3
5	Tsangaya Jauro	Hand Dug Well	15-06-2017	7.0	1800	13
6	Gadamayo Lambu	Hand Dug Well	15-06-2017	8.0	130	8
7	Gudure Ahmadu Goni	Hand Dug Well	15-06-2017	6.8	380	3
8	Gudure Umaru Bara	Hand Dug Well	15-06-2017	5.7	1600	35
9	Kolere Ya Mu'allim	Hand Dug Well	22-06-2017	10.2	2,400	3
10	Kolere A. Magaji	Hand Dug Well	22-06-2017	7.6	2,400	20
11	Kolere A. Abduwa	Hand Dug Well	22-06-2017	10.8	1,100	3
12	Dabere Alim Muleng	Hand Dug Well	22-06-2017	11	460	3
13	Dabere Old Market	Hand Dug Well	22-06-2017	10.1	210	3
14	Dabere Ali Mai Goro	Hand Dug Well	22-06-2017	10.5	140	03
15	Mbal'yebbe Ardo Kesure	Hand Dug Well	22-06-2017	10	1800	22
16	Mbal'yebbe Komishina	Hand Dug Well	22-06-2017	3.2	2400	9
17	Tarawo A. Basadu	Hand Dug Well	22-06-2017	7.8	130	8
18	Tarawo Kurndadi	Hand Dug Well	22-06-2017	11.0	1600	3
19	Fadde Babal A. Mamudu	Hand Dug Well	22-06-2017	12.0	1400	01

5 CONCLUSIONS

Many households in Song town use pit latrines, soak-away pits and occasionally open defecation methods for disposing human waste (Sewage), incidentally appropriate distance between wells and toilets are not considered during construction. This research has proved that the aquifer is contaminated through sewage from soak-away pits and pit latrines and it has been observed that the nearer the toilet facilities to the sources of water, the higher the level of contamination. From the results of the study, it is evident that the most effective solution that will safeguard the aquifer from further contamination is by introduction of central sewer system where sewage could be treated and made less harmful.

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