# RURAL GROUNDWATER ASSESSMENT USING WQ INDEX: A CASE STUDY OF BOSSO LOCAL GOVERNMENT AREA, NIGER STATE, NIGERIA

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## ABSTRACT

Due to the ever increasing need for water and food security, there is need for continuous assessment of water bodies in order to preserve the existing water resources and prevent further degradation. As such, it is of great importance to see that the water required for human need is made potable. This paper assessed the level of potability of groundwater in rural communities of Bosso LGA of Niger State, Nigeria. To achieve this aim, physicochemical analysis was carried out on thirty water samples from fifteen different locations(fifteenwater samples from boreholes and fifteen water samples from shallow wells). The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was applied on the analysed results of the parameters to obtain a single value that was used to rank the groundwater of the sampling stations. The results showed that 53%, 40% and 7% of water from the boreholes can be ranked as good, fair and marginal respectively while, 7%, 60% and 33% of water from the shallow wells can be ranked as good, fair and marginal respectively. The implication of this is that the groundwater in the area is good and fair for drinking purpose though water from the boreholes are more potable than water from the shallow well.

**Keywords:** CCME WQI, Assessment, Rural water supply, Groundwater, Groundwater Potability.

## 1. INTRODUCTION

Water is an essential resource to the life of all living organisms on earth. About 75% of the earth is filled with water (Ohimain and Angaye, 2014). As a result of rapid expansion of cities and subsequent population explosion, the development of groundwater resources for potable use has increased substantially over the last decade especially in developing countries. One means of establishing and assuring the purity and safety of water is to set a standard for the various contaminants. A standard therefore is a definite rule, principle or measurement which is established by government authority (Shelton, 1995).

Adekunle *et al*., (2007) reported that among various sources of water available, groundwater appeared to be the most reliable source due to its relative abundance and its unpolluted nature as a result of restricted movement of pollutant in the soil profile. Some compounding factors are responsible for the inadequacy of potable water: but two major factors include; rapid urbanization (Amadi*et al*., 2012), and increasing population, agricultural and industrial activities (Amangabara, and Ejenma, 2012) Inadequacy of potable water or poor water quality can result to substantial problems like, toxicity, poor agricultural productivity and health problems such as outbreak of diseases (Ohimain*et al*., 2013; Angaye*et al.,* 2015).

Potable water is defined as water that is free from microbial contaminants, low in compounds that are toxic to human health, which is clear, not saline and free from colour, odour and taste (Pritchard et al., 2008). Groundwater will possess all these attributes if the top surface through which the aquifer is recharged is protected from both natural and anthropogenic pollution. This will be achieved if the permeable soil stratum through which the water passes to water table is not polluted from lateral contaminant transferred from contaminated sites like poultry waste dumps (Lerner and Harris, 2009).Groundwater quality and availability is one of the most critical environmental and sustainability issues of the twenty-first century (UNEP,2006). It is widely used, for instance, for drinking and irrigation in food production (Zekster and Everett, 2004). However, groundwater is not only a valuable resource for water supply but also a vital component of global water cycle and the environment.

Shekwlo and Brisbe (1999) in their studies remarked that 50.8% of people living in Minna which is the State capital of Niger State rely on shallow dug wells, 23.3% on borehole, 16.3% on tap, 3.5% on river and 6% on springs.

Groundwater contamination occurs when pollutants released on the ground surface find their way down to the aquifer (Heath, 2004). The pollutants result majorly from improper disposal of waste on land; major sources which include industrial and household chemicals and garbage landfills, industrial lagoons and process waste water from mines, oil field, brine pit, leaking underground oil storage tanks and pipeline, sewage sludge and septic tank. Groundwater vulnerability is a measure of how easy or hard it is for contaminant at the land surface to reach a production aquifer or it is a measure of the degree of insulation that natural or man-made factors provide to keep pollution away from the aquifer (Morris, 2003).

Because of the ever increasing need for water and food security, there is need for continuous monitoring of the water body in order to preserve the existing water resources and prevent further degradation. Most importantly, it is of great importance to see that the water required for human need must be made potable. In this present study, the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) was used, which is well-accepted and universally applicable for evaluating the water quality index. It can combine a variety of different measurement units in a single metric and is also effective as a communication tool. The index has the ability to convey relative differences in water quality between sites even when the same objectives and variables are used.(CCME, 1999).

## 1. MATERIALS AND METHODS

### *2.1 Study Area*

The location used as a case study is Bosso local government area of Niger State, Nigeria. It has an area of 1,592km $^2$ and a population of 147,359 as at the 2006 census (NSG, 2007). It falls between longitude 6.200000$^0$E to 6.800000$^0$E and latitude 9.400000$^0$N to 9.800000$^0$N. The area has a special savannah climate with distinct rainy, dry and harmattan season respectively. The dry season usually occurs between October/November and ends around March/April while the rainy season starts around April/May through September/October and harmattan period starts around November through February. Temperature prevailing in the area is generally high with values ranging from 24$^0$C to 32$^0$Cwith an annual mean of about 27$^0$C. The average rainfall is about 250mm. Peasant farmers cultivate yam, rice, guinea corn, maize, pepper, vegetables and tomatoes, which thrive abundantly due to the availability of sandy soil from weathered rocks of the Minna batholiths (NSG, 2007).Figure 1 indicate location of the study area;

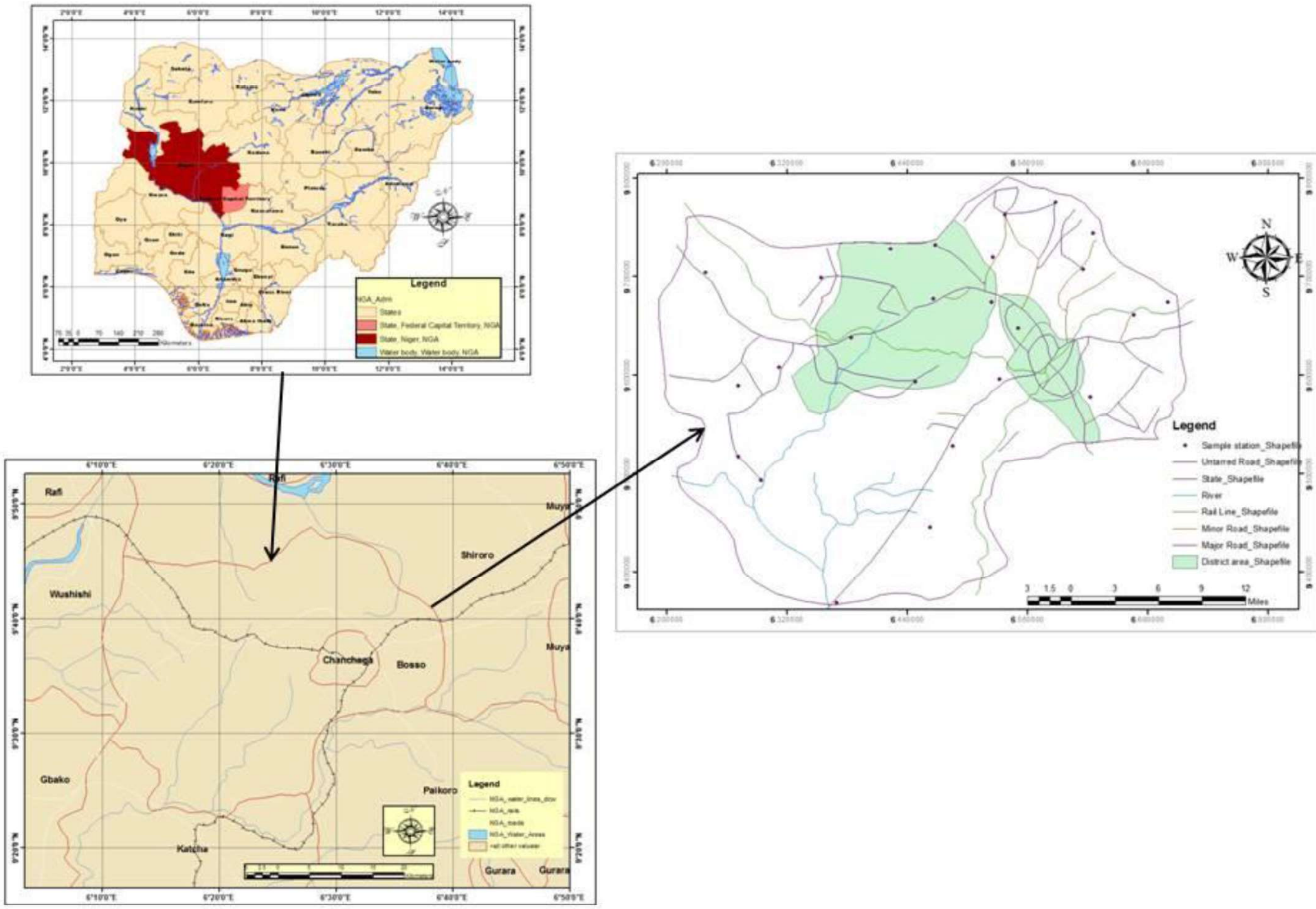


**Figure 1: Study area indicating the sampling stations**

***1.2 Sampling Procedure and Analysis***

***1.3*** Groundwater samples were collected from fifteen communities in Bosso Local Government Area of Niger State. The samples were collected at fifteen different locations. Four samples were taken from both boreholes and shallow wells at different locations. Each sampling location was recorded with global positioning system (GPS). The samples were collected using plastic bottles rinsed with trioxo-nitrate (V) acid and distilled water Lerner and Harris (2009) to avoid unpredicted change in the characteristics of the water samples. The bottles were marked and labeled in reference to the sampling points. Before the collection of water samples at the point of collection, each bottle was rinsed with the water source to be collected and firmly corked after sample collection to prevent contamination. The samples were then analyzed for ten physiochemical parameters namely: temperature, colour, turbidity, pH, electrical conductivity (EC), nitrates ($NO_3^-$), sulphate ($SO_4^{2-}$), phosphate ($PO_4^{3-}$), biochemical oxygen demand (BOD), dissolved oxygen (DO).The analysis was conducted according to the standard method for examination of water and waste water (APHA, 2005).

### *2.3 Water Quality Indices*

### *2.3.1 General Description of the CCME WQI Index*

The CCME WQI depends on measures of the scope; frequency and amplitude of excursions from guidelines. Once the CCME WQI value has been calculated, water quality can be converted into ranking by using the categorization scheme presented in Table 1.

**Table 1. CCME WQI Categorization**

| Ranking | WQI | Description |
|---|---|---|
| Excellent | 95-100 | Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. |
| Good | 80-94 | Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels. |
| Fair | 65-79 | Water quality is usually protected but occasionally threatened or impaired; this implies that conditions sometimes depart from natural or desirable levels. |
| Marginal | 45-64 | Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels |
| Poor | 0 – 44 | Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels. |

### *2.3.2 Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI)*

The detailed formulation of the WQI, as documented by CCME (2001) and Amir *et al.* (2008) comprises three factors as follows:

Factor 1: $F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ numbers\ of\ variables}\right) \times 100$ (1)

The measure for **scope** is $F_1$. This represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (failed variables)

Factor 2:$F_2 = \left(\frac{Numberoffailedtests}{Totalnumbersoftests}\right) \times 100$ (2)

The measure for **frequency** is $F_2$. This represents the percentage of individual tests which do not meet objectives (failed tests).

Factor 3: ($F_3$) is the measure for **amplitude**. This represents the amount by which failed test values do not meet their objectives. This is calculated in three steps:

**Step 1**: Calculation of Excursion. Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.
When the test value must not exceed the objective:

$$excursion = \left(\frac{Failedtestvaluei}{Objectivej}\right) - 1 \qquad (3a)$$

When the test value must not fall below the objective:

$$excursion = \left(\frac{Objectivej}{Failedtestvaluei}\right) - 1 \qquad (3b)$$

**Step 2**: Calculation of Normalized Sum of Excursions. The normalized sum of excursions, (*nse*) is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum_{i=1}^{n} excursion}{NumberofTests} \qquad (4)$$

**Step 3**: Calculation
of $F_3$. $F_3$ ($Amplitude$) is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right) \qquad (5)$$

The CWQI is finally calculated as:

$$CWQ1 = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \qquad (6)$$

The constant, 1.732, is a scaling factor to ensure the index varies between 0 and 100. It normalizes the resultant values.

## 2. RESULTS AND DICUSSIONS

Water Quality index for each of the fifteen stations (for borehole water samples and shallow well water samples) in Bosso Local Government Area was determined using the physicochemical parameters listed in Table 2a, Table 2b, Table 3a and Table 3b, respectively. The values of the various scopes (F1), Frequency (F2) and amplitude (F3) with their respective water quality index are presented in Table 4. The bolden values are higher than the standard recommended by the WHO and CCME for drinking water.

In Table 4., The results of the CCME WQI ranking values shows that water quality for drinking purposes for Borehole water in the area can be ranked as good at Jikpan, Gidan Mangoro, Dogonruwa, Shatai, Saegbe, Kanakaka Bagu, Jikobe and Jigbe, and ranked as fair at Mangoro Hassan, Jikuchi, Popopi, Garatu, Tawo and She Station while only the borehole water at B Mugada can be ranked as marginal. Also from Table 4, the results of the CCME WQI ranking values shows that water quality for drinking purposes for shallow well waterin the area can be ranked as good only at Jikpan and as fair at Gidan Mangoro, Dogon Ruwa, Shatai, B Mugada, Saegbe, Kanakaka Bagu, Jikuchi, Jikobe and Jigbe and be ranked as marginal at Mangoro Hassan, Popopi, Garatu, Tawo and She station. Table 5 shows the percentage in ranking for groundwater in the area. From Table 5 and Figure 2, it can be shown that 53%, 40% and 7% of water from the boreholes can be ranked as good, fair and marginal respectively while 7%, 60% and 33% of water from the shallow wells can be ranked as good, fair and marginal respectively. The area with fair and marginal ranking shows the pollution status in those locations which might be due to proximity to domestic waste dump, well not properly covered or lined, use of too many fetchers thus introducing contaminants into the water etc.

**Table 2a: Physicochemical parameters for borehole water samples for eight villages**

| Location | Temp (0C) | Col (Ptco) | Tur (NTU) | pH | EC (µs/cm | NO3 (mg/L) | SO4 (mg/L) | TDS (mg/L) | PO4 (mg/L) | DO (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Jikpan | **27** | 3 | 0.3 | 6.8 | 20.6 | 22 | 93.8 | 20.9 | 0.02 | **3.6** |
| | **28.1** | 2.5 | 0.1 | 8.1 | 22.3 | 34 | 100.1 | 25.1 | 0.05 | **4** |
| | 23 | 4 | 0.3 | 5.7 | 17.4 | 50 | 122 | 58.4 | 0.2 | 6.2 |
| | **25.3** | 3.6 | 0.2 | 7.4 | 19.1 | **74.7** | 154.8 | 22.9 | 0.18 | 5.1 |
| G/mangoro | **27.7** | 5.7 | 3.17 | 8.1 | 534.2 | 10.3 | 151.4 | 235.9 | 0.03 | 5.6 |
| | **29** | 6.1 | 3.3 | 7.8 | 416.1 | 10.3 | 161.3 | 100.8 | 0.01 | 5.9 |
| | **30** | 4.5 | 3.7 | 8.3 | 300.4 | 7.5 | 141.3 | 240.1 | 0.02 | **4.2** |
| | **28.9** | 5.8 | 3.4 | 8.5 | 333.1 | 7.8 | 155 | 238.8 | 0.1 | 5.2 |
| Dongoruwa | **25.7** | 3.6 | 1.4 | **9.8** | 343.4 | 24.2 | 79.9 | 39.8 | 0.08 | 6.3 |
| | **27.1** | 3.9 | 2 | 6.9 | 341.1 | 23 | 81.2 | 300.8 | 0.1 | **4.2** |
| | 23.5 | 3.2 | 1.7 | 7..0 | 343.2 | 29.1 | 85.3 | 69.3 | 0.06 | 6.1 |
| | **30** | 3.8 | 2 | 7.1 | 343.9 | 28.2 | 83.8 | 433.6 | 0.18 | **4.6** |
| Shatai | **29.8** | 5.3 | 4.9 | 6.9 | 747.6 | 22.9 | 80.1 | 113.4 | 0.13 | 8.7 |
| | **28.4** | 5 | 4.9 | 6.4 | 721.4 | 25 | 74.3 | 97.3 | 0.1 | 6 |
| | **31** | 6.2 | 5 | 7.5 | 760.1 | 30 | 91 | 114.3 | 0.12 | 5.2 |
| | **30.3** | 6.9 | 4.9 | 7 | 731.5 | 27.3 | 90.4 | 89.2 | 0.01 | 6.7 |
| Bmugada | **29.2** | 5.7 | 3.12 | 7 | 633.7 | 13.1 | 22.9 | 471.2 | 0.08 | **4.8** |
| | **31.1** | 4.5 | 3.2 | 8 | 410.6 | 10.3 | 20.8 | 420 | 0.06 | **3.9** |
| | **28.7** | 4 | 3.4 | 7.4 | 294.6 | 8.9 | 28.7 | 206.3 | 0.05 | **4.6** |
| | **31.6** | 3.8 | 3.39 | 7.6 | 234.3 | 4.9 | 27.6 | 467.2 | 0.06 | 5.2 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Saegbe | **31.9** | 2 | **5.9** | 7.2 | 449.4 | 2.1 | 36.4 | 306.8 | 0.02 | 6.3 |
| | **30.1** | 2.8 | 4.1 | 7.6 | 470.1 | 2.1 | 22.9 | 364.1 | 0.06 | 6.1 |
| | **27.9** | 3.1 | 2.9 | 7.4 | 497.3 | 2.4 | 19.1 | 240.3 | 0.04 | **4.7** |
| | **28.9** | 2.6 | 2.3 | 7 | 490.4 | 2.7 | 5 | 285.4 | 0.04 | **4.8** |
| M/ Hasssan | **29** | 8.9 | 3.4 | 6.8 | 757.3 | 6.4 | 7.1 | 158.1 | 0.03 | 6.4 |
| | **30** | 8.4 | 4 | 6.9 | 730.2 | 15.2 | 6.4 | 100.1 | 0.01 | 5 |
| | **28.9** | 8.1 | **5.2** | 8.1 | 741.3 | 20.6 | 6 | 140.5 | 0.04 | **4.7** |
| | **28.4** | 8.6 | **6.5** | **8.7** | 724.3 | 30.5 | 6.2 | 160.2 | 0.06 | 5.2 |
| K/ Bagu | **27.3** | 4.5 | **5.3** | 6.9 | 416.2 | 13.6 | 11.4 | 246.5 | 0.06 | 5.5 |
| | **26** | 4.9 | 4.1 | 6.8 | 400.9 | 15 | 11.5 | 205.5 | 0.04 | 5.9 |
| | 23.4 | 3.2 | 3 | 7 | 452.3 | 20.6 | 11.4 | 281 | 0.05 | 5.5 |
| | 22.7 | 3.8 | 2.1 | 7.2 | 437.4 | 19.4 | 11.9 | 235.9 | 0.06 | 5.8 |
| WHO(objective) | 25 | 15 | 5 | 6.5 - 8.5 | 1000 | 50 | 500 | 1000 | 0.5 | _ |
| CCME(objective) | 15 | _ | 5 | 6.5 - 8.5 | _ | 48.2 | 500 | 500 | _ | 5 |

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

**Table 2b: Physicochemical parameters for borehole water samples for seven villages**

| Location | Temp (0C) | Col (Ptco) | Tur (NTU) | pH | EC (μs/cm) | NO3 (mg/L) | SO4 (mg/L) | TDS (mg/L) | PO4 (mg/L) | DO (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Jikuchi | **25.2** | 1.7 | 1.9 | 7.3 | 9.4 | 83 | 11.1 | 476.4 | 0.29 | 6.1 |
| | **26** | 1.3 | **5.6** | 7.3 | 9.1 | 53 | 10.4 | 472.1 | 0.15 | 6.5 |
| | **28** | 1.9 | **12** | 7.4 | 9.6 | 42.5 | 8 | 500.2 | 0.17 | **4.3** |
| | **27** | 1.3 | **11.3** | 7.3 | 9.9 | 23.5 | 8.4 | 517 | 0.18 | 5 |
| Jikobe | **27** | 2.8 | 0.4 | 7.5 | 6.1 | 29.1 | 79.6 | 161.3 | 0.19 | **1.5** |
| | **26.5** | 2.4 | 0.2 | 7.3 | 6.9 | 25.4 | 80.3 | 164.3 | 0.17 | **3** |
| | **30** | 3.6 | 0.5 | 7.6 | 7.6 | 10.2 | 114.6 | 160.9 | 0.17 | **3.4** |
| | **28.9** | 3.1 | 0.1 | 7.4 | 7.2 | 13.1 | 129.3 | 171.2 | 0.18 | **3.8** |
| Jigbe | **27.7** | 3.3 | 1.45 | 7.3 | 88.3 | 16.02 | 199.5 | 328.6 | 0.1 | **1.9** |
| | **28.5** | 2.9 | 1.31 | 7.7 | 88.2 | 20.11 | 199.2 | 200.1 | 0.11 | **3.4** |
| | **30.1** | 4.2 | 2 | 6.5 | 90 | 12.17 | 199 | 180.7 | 0.08 | **4.5** |

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|---|---|---|---|---|---|---|---|---|---|---|
| | **29** | 3.7 | 1.01 | 6.9 | 89.1 | 11.09 | 199.1 | 179.4 | 0.06 | **4.1** |
| Popopi | **28.2** | 1.7 | **5.12** | 6.2 | 392.3 | 9.68 | 211.1 | 175 | 0.07 | **3.8** |
| | **28.5** | 1.9 | 4.16 | 6 | 390.4 | 10.65 | 201.8 | 180.1 | 0.1 | 5.2 |
| | **27.9** | 1.5 | **6.55** | 7 | 392.6 | 20.14 | 200.8 | 329.7 | 0.09 | 5 |
| | **28.1** | 1.6 | **9.42** | 7.4 | 391 | 17.92 | 200.4 | 324 | 0.18 | **4.5** |
| Garatu | **30.3** | 6.8 | 4.09 | 6.3 | 413.4 | 18.57 | 12.7 | 657.7 | 0.23 | 6.5 |
| | **30** | 7 | 4.31 | 6.8 | 400.2 | 19.1 | 14.1 | 400.6 | 0.21 | 7.5 |
| | **29.5** | 6.7 | **5.55** | 6.9 | 514.8 | 18.57 | 120.6 | 648.6 | 0.12 | **4** |
| | **29.1** | 6.9 | **5.32** | 6.8 | 548.3 | 18.67 | 124.3 | 646.9 | 0.13 | 5 |
| Tawo | **30.8** | 3.8 | 3.39 | **8.8** | 538 | 19.06 | 186.6 | 708 | 0.04 | 5.3 |
| | **30.8** | 3.5 | 3.37 | 8.3 | 511.1 | 20.6 | 187.6 | 706.1 | 0.07 | 6.8 |
| | **30.7** | 2 | 2.31 | **8.6** | 7 | **479.2** | 61.47 | 141.3 | 0.36 | **4.5** |
| | **30.8** | 2.6 | 2.2 | 8.5 | 495.1 | **62.37** | 167.2 | 688.7 | 0.05 | **4.8** |
| She Station | **31.7** | 5.6 | 3.04 | 8.4 | 642.8 | 22.63 | 151.2 | 56.8 | 0.26 | 6.3 |
| | **32.9** | 5.8 | 4 | 8.3 | 622.1 | 25.01 | 155.4 | 59.7 | 0.24 | **4.3** |
| | **30.6** | 4.9 | **7.6** | 8.4 | 640 | 24.11 | 87.5 | 70.4 | 0.16 | **2.9** |
| | **30.5** | 5 | **7.48** | 8.4 | 637 | 26.23 | 87.1 | 69.2 | 0.18 | 5.1 |
| WHO(objective) | 25 | 15 | 5 | 6.5 - 8.5 | 1000 | 50 | 500 | 1000 | 0.5 | _ |
| CCME(objective) | 15 | _ | 5 | 6.5 - 8.5 | _ | 48.2 | 500 | 500 | _ | 5 |

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

**Table 3a: Physicochemical parameters for shallow well water samples for eight villages**

| Location | Temp (0C) | Col (Ptco) | Tur (NTU) | pH | EC (µs/cm | NO3 (mg/L) | SO4 (mg/L) | TDS (mg/L) | PO4 (mg/L) | DO (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Jikpan | **28.1** | 7.6 | 0.61 | 6.5 | 46.9 | 0.67 | 249.6 | 53.6 | 0.06 | 16.4 |
| | **29** | 6.6 | 0.53 | 6.6 | 47.1 | 0.59 | 300.1 | 53.7 | 0.07 | 18.1 |
| | 25 | 9.9 | 0.59 | 7 | 44.4 | 14.3 | 413 | 58.6 | **0.65** | 24.5 |

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|---|---|---|---|---|---|---|---|---|---|---|
| | **26.4** | 8.9 | 0.43 | 7.1 | 43.4 | 14.21 | 411.6 | 58.9 | **0.61** | 23 |
| G/mangoro | **28.9** | 14.3 | **7.21** | 7.8 | **1214** | 31.4 | 402.6 | 606.4 | 0.12 | 25 |
| | **29.5** | 12.7 | **7.56** | 7.5 | **1213.1** | 33.4 | 214.4 | 607.4 | 0.25 | 23.1 |
| | **31.6** | 13.9 | **7.81** | 8.4 | **1209.1** | 25.4 | 421.5 | 614.9 | 0.31 | 24.5 |
| | **30.1** | 14.5 | **7.77** | 8.2 | **1211.6** | 23.9 | 412.3 | 613.9 | 0.33 | 23.6 |
| Dongoruwa | **26.8** | 8.9 | 3.2 | 9.4 | 780.4 | **73.9** | 212.6 | 102.4 | 0.29 | 28.2 |
| | **25.4** | 10.3 | 4.2 | 9 | 782.3 | **74.3** | 221.4 | 110.3 | 0.23 | 27.4 |
| | **32.5** | 10.9 | 3.8 | 7.2 | 779.2 | **88.1** | 241.3 | **1116.3** | 0.43 | 20.71 |
| | **31.2** | 9.4 | 4.6 | 6.8 | 781.6 | **86.2** | 222.9 | **1114.6** | **0.61** | 2016 |
| Shatai | **31** | 13.3 | **11.3** | 6.6 | **1699.2** | **70.1** | 213 | 291.6 | 0.44 | 39.3 |
| | **32** | 14.5 | **11** | 6.5 | **1673.2** | **75.1** | 24.6 | 275.7 | 0.47 | 41.3 |
| | **30.7** | **18.5** | **11.7** | 6.8 | **1666.4** | **84.1** | 235.3 | 230.1 | 0.05 | 33.3 |
| | **31.6** | **17.2** | **11.2** | 6.7 | **1662.4** | **83.6** | 240.4 | 229.3 | 0.02 | 30 |
| Bmugada | **30.4** | 14.3 | **7.1** | 6.7 | **1440.2** | 40.1 | 60.8 | **1211.3** | 0.27 | 21.6 |
| | **31.2** | 10.2 | **7.3** | 5.2 | **1441.3** | 41.1 | 65.9 | **1215.1** | 0.3 | 22.5 |
| | **34** | 10.5 | **7.7** | 7.7 | **1441.4** | 13.9 | 80.5 | **1213.6** | 2.25 | 24.1 |
| | **32.9** | 9.6 | **7.7** | 7.3 | **1441.6** | 14.9 | 73.4 | **1200.9** | 0.22 | 23.6 |
| Saegbe | **33.2** | 4.9 | **13.6** | 6.9 | **1021.4** | 6.4 | 96.7 | 788.6 | 0.06 | 28.2 |

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|---|---|---|---|---|---|---|---|---|---|---|
| | **30.1** | 6.4 | **18.9** | 6.7 | **1114.6** | 8.2 | 13.3 | 733.6 | 0.14 | 21.6 |
| | **31.1** | 3.4 | **16** | 6.8 | **1022.3** | 6.3 | 34.6 | 789.3 | 0.08 | 29.5 |
| | **30.5** | 7.9 | **19.1** | 6.6 | **1114.3** | 8 | 25.3 | 732.5 | 0.1 | 22.5 |
| M/Hasssan | **30.2** | **22.3** | **7.7** | 6.5 | **1721.1** | 19.7 | 18.9 | 406.4 | 0.11 | 28.9 |
| | **31.1** | **20.9** | **8.7** | 6.6 | **1722.3** | 20.1 | 18.2 | 409.2 | 0.13 | 29.1 |
| | **29** | **22.1** | **12.7** | **9** | **1600** | **95.3** | 17 | 415.7 | **0.71** | 22.5 |
| | **29.6** | **21.6** | **14.8** | 8.4 | **1646.1** | **93.4** | 16.6 | 411.9 | 0.21 | 23.6 |
| K/Bagu | **28.4** | 11.3 | **12.1** | 6.6 | 946 | 41.6 | 30.2 | 633.6 | 0.22 | 24.8 |
| | **27.8** | 11.4 | **10.6** | 6.8 | 929.4 | 42.5 | 30.5 | 640.1 | 0.23 | 21.4 |
| | 24.2 | 8.9 | **5.3** | 7.1 | 957.4 | **55.4** | 31.2 | 621.5 | **0.99** | 30.2 |
| | 23.6 | 9.6 | 4.8 | 6.9 | 994 | **59.3** | 31.6 | 606.4 | 0.21 | 26.1 |
| WHO(objective) | 25 | 15 | 5 | 6.5 - 8.5 | 1000 | 50 | 500 | 1000 | 0.5 | _ |
| CCME(objective) | 15 | _ | 5 | 6.5 - 8.5 | _ | 48.2 | 500 | 500 | _ | 5 |

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

**Table 3b: Physicochemical parameters for shallow well water samples for seven villages**

| Location | Temp | Col (Ptc | Tur (NTU | pH | EC (µs/c | NO3 (mg/L | SO4 (mg/L | TDS (mg/L | PO4 (mg/ | DO (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|

| | (0C ) | o) | ) | | m | ) | ) | ) | L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Jikuchi | **26.2** | 4.3 | 4.3 | 7 | 21.4 | **70.4** | 29.6 | **1224.6** | **0.99** | 27.6 |
| | **27.6** | 4.5 | 4.5 | 7 | 20.9 | **70.8** | 30.8 | **1214.7** | **0.93** | 25.6 |
| | **27.9** | 3.5 | 0.9 | 7.1 | 21.7 | **71.5** | 22,5 | **1330.3** | **0.65** | 22.1 |
| | **28.1** | 3.2 | 0.7 | 7 | 22.6 | **71.9** | 22.4 | **1329** | **0.61** | 22.4 |
| Jikobe | **27.6** | 4.5 | 4.5 | 7 | 20.9 | **70.8** | 30.8 | **1214.7** | **0.93** | 25.6 |
| | **27.9** | 3.5 | 0.9 | 7.1 | 21.7 | **71.5** | 22,5 | **1330.3** | **0.65** | 22.1 |
| | **28.1** | 3.2 | 0.7 | 7 | 22.6 | **71.9** | 22.4 | **1329** | **0.61** | 22.4 |
| Jigbe | **28.9** | 8.3 | 3.3 | 7 | 200.7 | 49 | **530.7** | 330.5 | 0.33 | 8.4 |
| | **29.1** | 8.5 | 3.5 | 7.2 | 201.3 | **50.3** | **540.5** | 360.7 | 0.3 | 10.4 |
| | **30.4** | 9 | 2.6 | 6.2 | 202.5 | 35.7 | **531.3** | 450.1 | 0.25 | 16.4 |
| | **30.2** | 9.2 | 2.3 | 6.6 | 202.4 | 33.9 | **529.4** | 461.2 | 0.21 | 18.4 |
| Popopi | **29.4** | 4.2 | **18.46** | 6 | 891.6 | 29.6 | **561.4** | 449.9 | 0.24 | 16.9 |
| | **29.1** | 4.3 | **22.1** | 6.5 | 889.3 | 29.4 | 452.3 | 7.1 | 0.26 | 17 |
| | **29.5** | 4.4 | **20.6** | 7.4 | 893 | **55** | **531.5** | 800.2 | **0.61** | 21.4 |
| | **29.3** | 4.1 | **21.4** | 7.1 | 888.7 | **54.8** | **533** | 833 | **0.61** | 20.1 |
| Garatu | **31.6** | **16.9** | **9.3** | 6.1 | 939.6 | **56.8** | 33.9 | **1690.8** | **0.79** | 29.3 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **31.6** | **17.3** | **10.2** | 6.3 | 940.3 | **56.9** | 33.7 | **1671.2** | **0.77** | 30.1 |
| | **30.7** | **16.5** | **11.2** | 6.9 | **1248.2** | **57.3** | 331.11 | **1666.1** | 0.45 | 25.1 |
| | **30.3** | **17.3** | **12.1** | 6.5 | **1246.1** | **57.1** | 330.6 | **1662.9** | 0.43 | 22.6 |
| Tawo | **32.1** | 9.4 | **7.7** | 8.5 | **1222.8** | **58.3** | 496.4 | **1820** | 0.14 | 23.8 |
| | **32.4** | 9.5 | **6.8** | **8.9** | **1224.3** | **59.3** | 498.4 | **1810.3** | **0.8** | 24.1 |
| | **32.1** | 7.6 | **5.7** | 8.1 | **1127.3** | **68.9** | 444.8 | **1779.3** | 0.21 | 20.7 |
| | **32.1** | 6.6 | 5 | 8.2 | **1125.2** | **68.4** | 444.6 | **1770.5** | 0.18 | 21.6 |
| She Station | **33** | 13.9 | **6.9** | 8.1 | **1461** | **69.2** | 402.1 | 145.9 | **0.89** | 28.4 |
| | **33.3** | 13.6 | **6.8** | 8.5 | **1463.2** | **70.1** | 300.2 | 150.4 | **0.85** | 28.5 |
| | **32.9** | 11.5 | **18.4** | 7.9 | **1450.9** | **75.7** | 241.2 | 176.7 | **0.63** | 24.4 |
| | **31.8** | 12.6 | **17** | 8.1 | **1447.8** | **80.2** | 231.6 | 177.9 | **0.61** | 22.8 |
| **WHO**(objective) | **25** | **15** | **5** | **6.5 - 8.5** | **1000** | **50** | **500** | **1000** | **0.5** | _ |
| **CCME**(objective) | **15** | _ | **5** | **6.5 - 8.5** | _ | **48.2** | **500** | **500** | _ | **5** |

*The bolden values do not meet the objective (i.e. values that exceeded WHO and CCME standard)

**Table 4: Quality of water according CCMEWQI**

| LOCATION | BOREHOLE | | | | | SHALLOW WELL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | WQI | RANKING | F1 | F2 | F3 | WQI | RANKING |
| Jikpan | 30 | 15 | 3 | 80 | Good | 20 | 13 | 2 | 86 | Good |
| G/mangoro | 20 | 13 | 6 | 85 | Good | 30 | 30 | 9 | 75 | Fair |
| Dangoruwa | 30 | 15 | 8 | 80 | Good | 40 | 28 | 8 | 71 | Fair |
| Shatai | 18 | 10 | 2 | 92 | Good | 40 | 35 | 14 | 68 | Fair |
| B mugada | 20 | 70 | 9 | 57 | Marginal | 40 | 40 | 11 | 67 | Fair |
| Saegbe | 30 | 17 | 3 | 80 | Good | 30 | 30 | 20 | 73 | Fair |
| Mangoro Hassan | 40 | 20 | 6 | 73 | Fair | 70 | 50 | 20 | 48 | Marginal |
| KanakakaBagu | 20 | 8 | 1 | 86 | Good | 40 | 20 | 9 | 74 | Fair |
| Jikuchi | 30 | 20 | 11 | 78 | Fair | 40 | 40 | 12 | 67 | Fair |
| Jikogbe | 20 | 20 | 10 | 83 | Good | 30 | 20 | 6 | 79 | Fair |
| Jigbe | 20 | 20 | 10 | 82 | Good | 30 | 23 | 3 | 78 | Fair |
| Popopi | 30 | 23 | 6 | 78 | Fair | 50 | 38 | 26 | 61 | Marginal |
| Garatu | 30 | 18 | 8 | 79 | Fair | 70 | 60 | 21 | 45 | Marginal |
| Tawo | 40 | 23 | 3 | 73 | Fair | 70 | 53 | 16 | 48 | Marginal |
| She station | 30 | 20 | 7 | 79 | Fair | 50 | 50 | 24 | 57 | Marginal |

**Table 5: Percentage of Water Quality in the study area**

| Ranking | Borehole | Percentage (%) | Shallow well | Percentage (%) |
|---|---|---|---|---|
| Excellent | - | - | - | - |
| Good | 8 | 53 | 1 | 7 |
| Fair | 6 | 40 | 9 | 60 |
| Marginal | 1 | 7 | 5 | 33 |
| Poor | - | - | - | - |

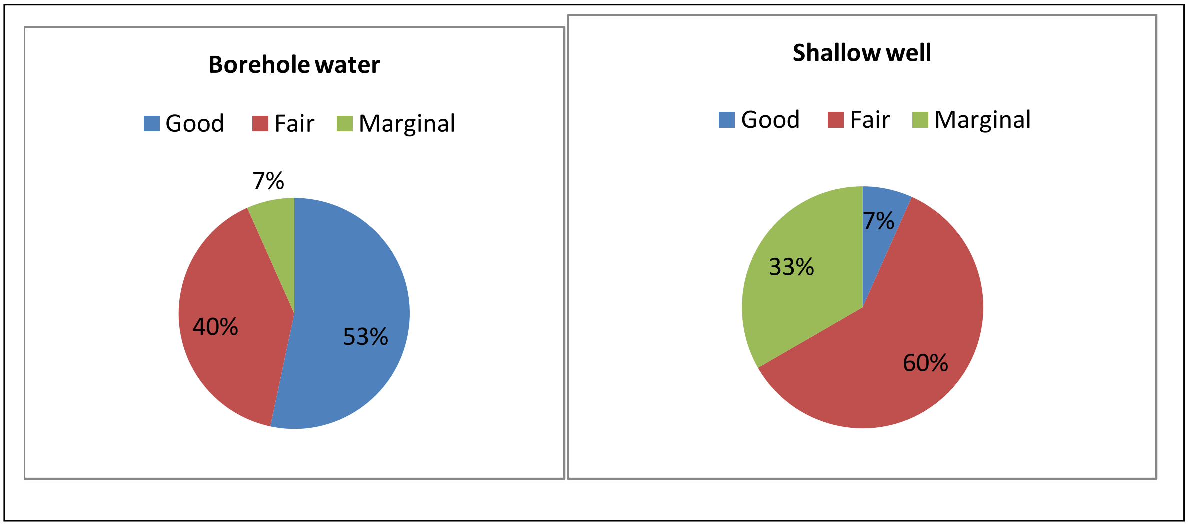


**Figure 2: Percentages in ranking for both boreholes and shallow well**

## CONCLUSIONS

The water quality status of Bosso Local Government Area was evaluated using CCME water quality index. The results of the study revealed that groundwater in the area is good and fair for drinking purposes though water from the boreholes are more potable than water from the shallow well. The water can also be used for irrigation and drinking purposes. Furthermore, the application of water quality index is a reliable tool in assessing the overall quality of groundwater.

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