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Comparative assessment of Shallow Quaternary aquifer potability in Tombia and Ahoada Communities, Niger Delta, Nigeria: A Water Quality Index approach

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Abstract*: An assessment of groundwater potability in two (2) Niger Delta communities of Tombia and Ahoada West was carried out by Water Quality Index (WQI) approach. Physico-chemical analysis was done on 25 (twenty five) water samples from shallow boreholes randomly collected around each community. Results of 11 (eleven) parameters analyzed (pH, conductivity, total dissolved solids, nitrates, chloride, sulphate, bicarbonate, total alkalinity, total hardness, magnesium and iron) were used to compute WQI for groundwater in both areas using the WHO standard for potable water as a reference. Results from computation showed water from 10 (ten) random boreholes which represented 40% of the total samples collected in Tombia town was fit for consumption (WQI < 100), while water from 15 (fifteen) boreholes which represented 60% of the total samples collected was unfit for consumption without treatment (≥ 100). On the other hand, water from 21 (twenty one) random boreholes which represented 84% of the total samples collected in Ahoada West was fit for consumption (WQI < 100), whereas, water from 4 (four) boreholes which represented 16% of the total samples collected was unfit for consumption without treatment (WQI≥ 100). Results from WQI computation showed water from shallow boreholes in Ahoada West was relatively more potable compared to that from Tombia town, it also showed poor water quality was attributed mainly to iron content in Tombia town, random occurrence of unfit boreholes in both areas also showed water quality in both areas had little general geological control.*

Keywords*: Groundwater, Comparative Studies, Water Quality Index, Niger Delta*

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I. Introduction

Water is a basic necessity for life to flourish. In Nigeria, groundwater serves as a vital source of water to both rural and urban communities (Olatunji et al, 2015). An increasing threat to the groundwater quality due to urbanization, industrialization and other human activities has prompted various water quality monitoring schemes (Tirkey, 2015). Assessment of water quality can be a very complex process involving input of a large volume of contributing variables.

Water Quality Index (WQI) is a mathematical method proposed by Horten (1965), which outputs a single number rating reflecting the composite influence of a number of parameters or variables on the overall quality of water (Bangalore and Latha, 2008; Ramakrishnaiah et al., 2009; Yisa and Jimoh, 2010). WQI simplifies the presentation of results, as such, information on water quality can easily be communicated to the end users and policy makers. This approach has successfully been employed by several water quality researchers in the Niger Delta (Amadi et al, 2010; Etim et al, 2013; Udom et al, 2016; Oki and Ombu, 2017).

Reports of flaring of gas, hydrocarbon spills, poor waste management and other environmental degrading activities in Ahoada West and Tombia communities of the Niger Delta have prompted this study, to assess and compare the potability of groundwater in both areas by WQI approach.

II. Description Of Study Area

Tombia town in Yenagoa Local Governement Area of Bayelsa State lies within latitude 4° 55’ 29” and Longitude 6° 15’ 51” while Ahoada West Local Government of Rivers State falls within latitude 5° 5’ 0’’ and longitude 6° 39’ 0’’ (Fig 1). Both Tombia town and Ahoada West are drained by tributaries and creeks linked to the River Nun and Orashi River respectively. Both areas are accessible by a good network of major and minor roads and also rivers. The average rainfall and temperature of the area are 2,899mm and 26.7°C respectively. Ahoada West community is home to several hydrocarbon flow stations owned by the Agip Oil Company, whereas Tombia community plays host to the massive Gbarian Liquified Natural Gas Plant. Flaring of gas is a constant factor in both communities all through the year.

The study area falls within the Niger Delta Basin, the fresh water bearing zone is the Eocene aged Benin Formation which is overlain in most areas by quaternary deposits. Sands and sandstones in the Benin Formation are coarse to fine grained, commonly granular in texture with can be unconsolidated. The main composition of the Benin Formation are fresh water bearing continental sands and gravels with some clay and shale intercalations characteristic of partly lagoonal and fluvio-lacustrine/deltaic depositional environment (Reyment, 1965). The clayey intercalation within the Benin Formation gave rise to a multi-aquifer system in the Niger Delta, with the shallow unconfined aquifer occurring at depths between 20m and 40m across the area (Etu-Efeotor and Ogidi, 1983; Etu-Efeotor and Akpokodge, 1990; Udom and Amah, 2006)

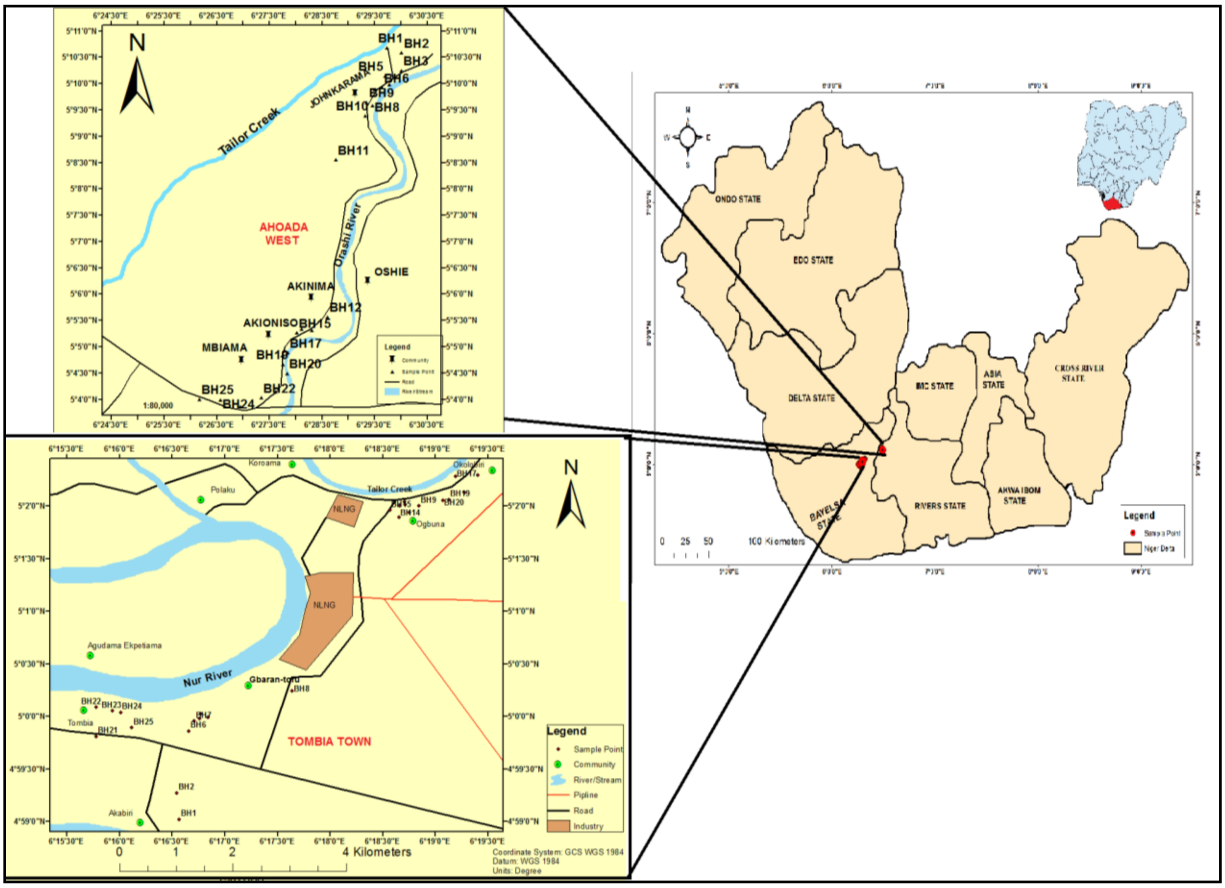

Fig 1 Sample location map of Tombia and Ahoada Towns

III. Materials And Methods

The criteria for "shallow" borehole for the purpose of this work, was considered as an average depth of 30 m. 25 water samples each were randomly collected using sterilized 50 cl polyethylene bottles across Tombia and Ahoada communities during the August break of the wet season. Sample collection, preservation and transportation was done with strict adherence to the American Public Health Association (APHA, 2002) standard and delivered to the laboratory for analysis within 12 hours. Analysis for 11 physico-chemical parameters was carried out on water (pH, conductivity, total dissolved solids, nitrates, chloride, sulphate, bicarbonate, total alkalinity, total hardness, magnesium and iron), result obtained was used to compute the WQI for both areas. Locations of collected water samples were determined using a Global Positioning System (GPS) and recorded.

Computation of WQI in this study was done using results of 11 (eleven) physico-chemical parameters from a total of 50 (fifty) borehole water samples from 2 (two) communities. Parameters were selected on the basis on their influence on potability of water for consumption and other domestic uses with reference to WHO (2006) standard. WQI by weighted arithmetic method employed here was due to its simplicity for handling data and flexibility for handling data under varying environmental conditions. Also, the relative importance of a parameter by weighted average determines its influence on the final outcome (Akoteyon et al., 2011; Etim et al., 2013; Ushurhe et al., 2014; Udom et al., 2016). For a detailed explanation of data processing see (Oki and Oboshenure, 2017). The classification of water potability based WQI are 0 – 25 as excellent, 26 – 50 as good, 51 – 75 as poor, 76 – 100 as very poor, greater than 100 as unfit for consumption (Chatterjee and Raziuddin, 2002; Asuquo and Etim, 2012a).

Quality rating or Sub-index (Qn) was determined by

$$Qn = 100 *\{\frac{Vn - Vi}{Sn - Vn}\} \quad (1)$$

Where: Qn quality rating for the nth water quality parameter
Vn estimated value of the nth parameter at a given sampling point
Sn standard permissible value of the nth parameter as given by WHO
Vi ideal value of the nth parameter in portable water (0 except when pH=7)

The unit weight is inversely proportional to the standard value Sn, given by

$$Wn = \frac{K}{Sn} \quad (2)$$

Where: Wn unit weight for the nth parameter
Sn standard value for the nth parameter
K constant of proportionality (value is 1)

Aggregating the quality rating with the unit weight linearly gives the overall water quality index

$$WQI = \frac{\Sigma QnWn}{\Sigma Wn} \quad (3)$$

IV. Results And Discussion

The results of the physico-chemical analysis of groundwater from Tombia and Ahoada communities are presented as Tables 1 & 2 respectively. The average pH values in Tombia and Ahoada was 6.17 and 6.14 respectively, pH was thus outside the WHO standard of 6.5 – 6.8 for potable water. High acidity associated with low pH causes an undesirable bitter taste in water, it also causes corrosion of metallic water distribution pipes and appliances. Average Electrical Conductivity (EC) was 353 µS/cm in Tombia and 341 µS/cm in Ahoada Town, both values were acceptable when compared to WHO standard. Average values of Total Dissolved Solids (TDS) was 175 mg/l in Tombia and 167 mg/l in Ahoada, both values were within acceptable limits. Nitrate had average values of 0.24 mg/l and 0.18 mg/l for both towns, values were with WHO acceptable limits for potable water. Cloride had average values of 20 mg/l in Tombia and 9 mg/l in Ahoada communities, these values were acceptable by WHO standard. Sulphate had mean values of 3.5 mg/l in Tombia and 3.6 mg/l in Ahoada Town, these concentrations were acceptable when compared to WHO 2006 standard.

Table 1 Results of Physico-chemical analysis on Groundwater samples from Tombia town

SAMPLE CODE	Latitude	Longitude	pH	COND	TDS	NO_3	Cl	SO_4	TA	TH	Ca	Mg	Fe
BH1	4.9837	6.2761	6.13	284	142	0.22	14	2.48	17	17	10.35	2.87	0.21
BH2	4.9879	6.2757	6.48	355	178	0.23	20	3.5	18	34	14.36	3.54	0.16
BH3	5.0004	6.2796	6.00	420	210	0.31	20	4	22	52	13.30	4.2	0.14
BH4	4.9999	6.2807	5.98	583	292	0.32	34	4.8	20	48	22.18	5.68	0.14
BH5	4.9997	6.2794	5.96	363	182	0.22	20	3.85	18	30	14.70	2.53	0.14
BH6	4.9977	6.2777	5.73	282	141	0.22	24	2.46	12	30	13.82	4.54	0.14
BH7	4.9992	6.2785	5.92	364	182	0.23	30	3.64	17	24	17.48	4.86	0.13
BH8	5.0041	6.294	6.15	310	155	0.20	12	3.00	18	26	8.76	3.38	0.23
BH9	5.0333	6.3141	6.43	260	130	0.19	15	1.78	17	22	9.47	2.84	0.22
BH10	5.0323	6.3126	6.49	379	189	0.27	13	4.30	18	43	10.20	3.00	0.21
BH11	5.0335	6.3119	6.35	304	152	0.18	14	2.34	23	27	9.78	2.56	0.19
BH12	5.034	6.3118	6.52	279	140	0.19	11	2.97	15	30	8.50	2.28	0.20
BH13	5.0334	6.3111	6.08	285	143	0.12	12	2.58	17	21	8.64	2.30	0.17
BH14	5.0315	6.3109	6.15	330	165	0.23	11	3.36	17	46	7.72	4.38	0.20
BH15	5.0327	6.3095	6.06	641	321	0.38	27	5.24	26	45	20.47	10.72	0.21
BH16	5.0382	6.3234	6.15	382	191	0.29	62	4.84	23	43	32.76	3.52	0.19
BH17	5.038	6.3199	5.99	457	274	0.33	16	4.75	28	44	13.60	2.84	0.17
BH18	5.0354	6.3214	6.60	348	174	0.28	12	3.84	24	41	9.55	1.78	0.13
BH19	5.0343	6.3188	6.83	298	199	0.22	12	3.76	21	35	9.28	2.10	0.15
BH20	5.0343	6.3179	6.62	306	153	0.23	13	4.00	22	35	10.32	3.00	0.15
BH21	4.9968	6.2629	6.24	436	218	0.29	14	3.46	18	45	9.88	4.34	0. 2
BH22	5.0014	6.263	6.08	307	154	0.21	21	3.20	12	22	13.25	5.63	0.24
BH23	5.0009	6.2655	6.10	376	188	0.25	32	4.00	16	19	18.72	5.82	0.14
BH24	5.0006	6.2668	5.67	357	178	0.24	33	3.85	13	10	19.30	1.86	0.12
BH25	4.9982	6.2686	5.57	120	60	0.08	15	1.54	10	12	8.80	1.94	0.11
Mean			6.17	353	175	0.24	20	3.50	18	32	13.41	3.77	0.20
WHO			6.5-8.5	1000	1000	50	250	400	500	150	75	50	0.3

****Concentrations of all the parameters are expressed in milligrams per liter (mg/l) except pH without a unit and EC in µS/cm**

Table 2 Results of Physico-chemical analysis on Groundwater samples from Ahoada town

SAMPLE CODE	Latitude	Longitude	pH	COND	TDS	NO_3	Cl	SO_4	TA	TH	Ca	Mg	Fe
BH1	5.177972	6.4956806	6.21	141	70	0.12	10	3.42	5	10	7.26	2.40	0.12
BH2	5.176333	6.500278	6.47	181	91	0.14	6	4.20	7	11	6.54	1.72	0.16
BH3	5.170694	6.500139	6.58	150	74	0.12	8	2.86	6	12	6.78	2.22	0.21
BH4	5.166306	6.496361	6.47	170	85	0.13	5	3.00	4	13	4.27	1.20	0.17
BH5	5.169	6.495167	6.12	345	123	0.21	10	3.54	4	22	8.76	2.30	0.05
BH6	5.16525	6.494056	6.49	306	153	0.14	8	2.84	5	10	6.57	1.63	0.07
BH7	5.164835	6.491903	6.08	381	141	0.13	10	3.81	4	17	6.72	2.60	0.13
BH8	5.159639	6.491	6.47	241	121	0.17	8	2.41	6	14	6.48	2.00	0.09
BH9	5.160667	6.489222	6.38	206	103	0.11	7	2.06	4	10	5.87	1.84	0.14
BH10	5.156417	6.488778	6.20	238	119	0.13	14	2.38	6	14	6.20	1.78	0.13
BH11	5.142493	6.479444	6.00	678	339	0.32	9	4.78	6	20	12.40	2.87	0.14
BH12	5.092694	6.476806	6.29	216	108	0.13	6	2.16	4	11	6.75	2.72	0.05
BH13	5.088444	6.471889	6.08	145	73	0.12	5	1.45	3	14	4.04	1.56	0.13
BH14	5.088722	6.468667	6.42	113	57	0.11	5	1.31	6	7	3.68	1.28	0.22
BH15	5.087596	6.467104	6.59	247	124	0.13	6	2.47	4	15	5.00	1.72	0.12
BH16	5.082028	6.463111	5.88	108	54	0.13	10	3.12	5	14	5.75	1.40	0.11
BH17	5.081361	6.464167	5.87	312	156	0.22	9	4.10	5	18	8.62	2.35	0.11
BH18	5.080444	6.462611	5.84	410	205	0.22	16	4.22	4	20	7.40	2.28	0.12
BH19	5.077583	6.462722	5.84	420	210	0.34	29	7.47	2	28	13.90	4.56	0.06
BH20	5.074722	6.463996	6.25	774	387	0.56	10	14.53	10	35	25.30	6.54	0.15
BH21	5.068917	6.460444	6.20	144	718	0.29	9	5.04	9	23	10.30	3.40	0.14
BH22	5.067087	6.455906	5.63	503	252	0.22	5	2.83	3	19	7.43	2.11	0.15
BH23	5.064222	6.449222	5.77	282	141	0.11	9	1.32	5	8	3.76	1.10	0.14
BH24	5.066278	6.442861	5.94	122	61	0.27	6	4.20	7	16	9.57	2.00	0.05
BH25	5.066611	6.436222	5.69	411	206	0.28	8	1.19	3	12	4.27	2.26	0.13
Mean			6.14	341	167	0.18	9	3.60	5	16	7.74	2.31	0.12
WHO			6.5-8.5	1000	1000	50	250	400	500	150	75	50	0.3

****Concentrations of all the parameters are expressed in milligrams per liter (mg/l) except pH without a unit and EC in µS/cm**

Total Alkalinity (TA) and Total Hardness (TH) in both towns had average values of 18 mg/l and 32 mg/l respectively in Tombia and 5 mg/l and 16 mg/l respectively in Ahoada West communities, both parameters were within the WHO accepted limits for potable water. Calcium had a mean value of 13.41 mg/l in Tombia and 7.74 mg/l in Ahoada West, these values were within the acceptable limits by WHO 2006. Magnesium and Iron in both communities of Tombia and Ahoada West had mean values of 3.77 mg/l and 0.20 mg/l and 2.31 mg/l and 0.12 mg/l respectively, both parameters were within the acceptable limit for potable water proscribed by WHO 2006.

A graphical presentation of the summary of WQI in Tombia town was shown on Table 3 and on a pie-chart (Fig 2). Six (6) sampled boreholes revealed water quality as poor, four (4) as very poor and fifteen (15) as unfit for consumption without treatment, as such, 10 samples representing 40% of sampled boreholes in Tombia was potable (WQI<100), whereas, 25 samples representing 60% of sampled boreholes was not potable (WQI≥100). WQI analysis in Ahoada West presented in Table 4 and Fig 3 show four (4) sampled boreholes fell into a class of excellent, two (2) were classed good, nine (9) sampled boreholes were classed poor, six (6) very poor and four (4) unfit for consumption without treatment. On pie chart, results of sampled boreholes from Ahoada West showed 21 boreholes representing 84% of total boreholes sampled were potable (WQI<100) and 4 sampled boreholes representing 16% of total sampled boreholes were not potable (WQI≥100).

Random nature of sampled boreholes with non potable water suggested that water quality was not directly influenced by geological processes like groundwater flow, poor quality of water was ascribed to local sources like infiltration or percolation from septic tanks, chemicals used on ground surface like fertilizers, weed killers, waste oils e. t. c.

A statistical comparison of sampled boreholes in Tombia and Ahoada West towns (Fig 4), showed water to be more potable in Ahoada West.

Table 3 Summary of WQI for Groundwater samples at Tombia town

Sample location	WQI	Remark	Sample location	WQI	Remark
1	218	unfit	14	196	unfit
2	111	unfit	15	217	unfit
3	75	poor	16	155	unfit
4	82	Very poor	17	127	unfit
5	75	poor	18	68	poor
6	81	Very poor	19	102	unfit

7	79	Very poor	20	83	Very poor
8	302	unfit	21	184	unfit
9	261	unfit	22	368	unfit
10	209	unfit	23	75	poor
11	144	unfit	24	61	poor
12	187	unfit	25	53	poor
13	125	unfit			

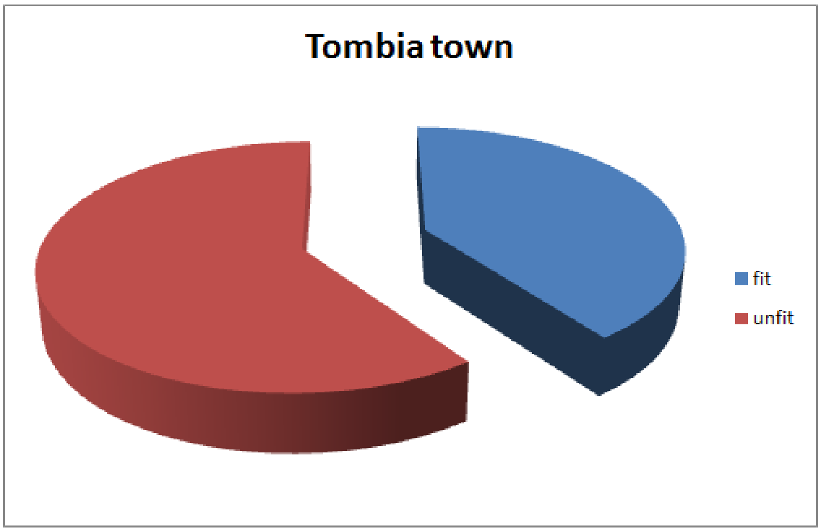

Fig 2 Percentage of water fit and unfit for consumption by WQI analysis for sampled wells in Tombia town

Table 4 Summary of WQI for Groundwater samples at Ahoada West town

Sample location	WQI	Remark	Sample location	WQI	Remark
1	57	poor	14	235	unfit
2	105	unfit	15	61	poor
3	210	unfit	16	50	good
4	124	unfit	17	52	poor
5	18	excellent	18	63	poor
6	23	excellent	19	19	excellent
7	66	poor	20	92	very poor
8	36	good	21	79	very poor
9	82	very poor	22	93	very poor
10	70	poor	23	80	very poor
11	80	very poor	24	16	excellent
12	60	poor	25	64	poor
13	66	poor			

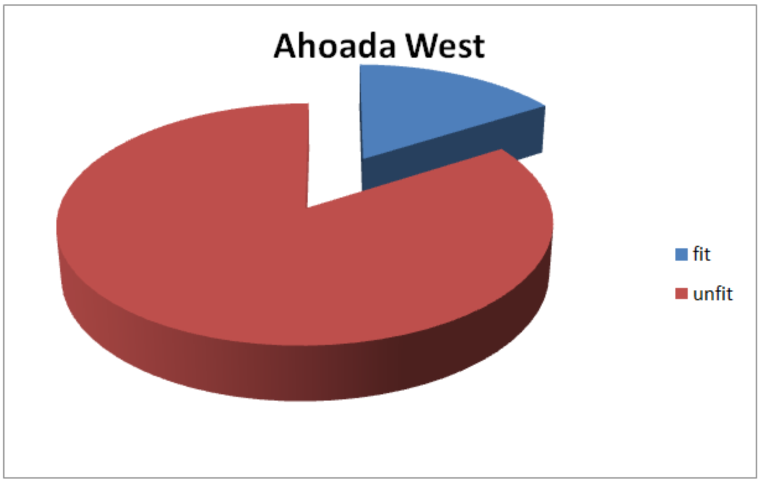

Fig 3 Percentage of water fit and unfit for consumption by WQI analysis for sampled wells in Ahoada West communities.

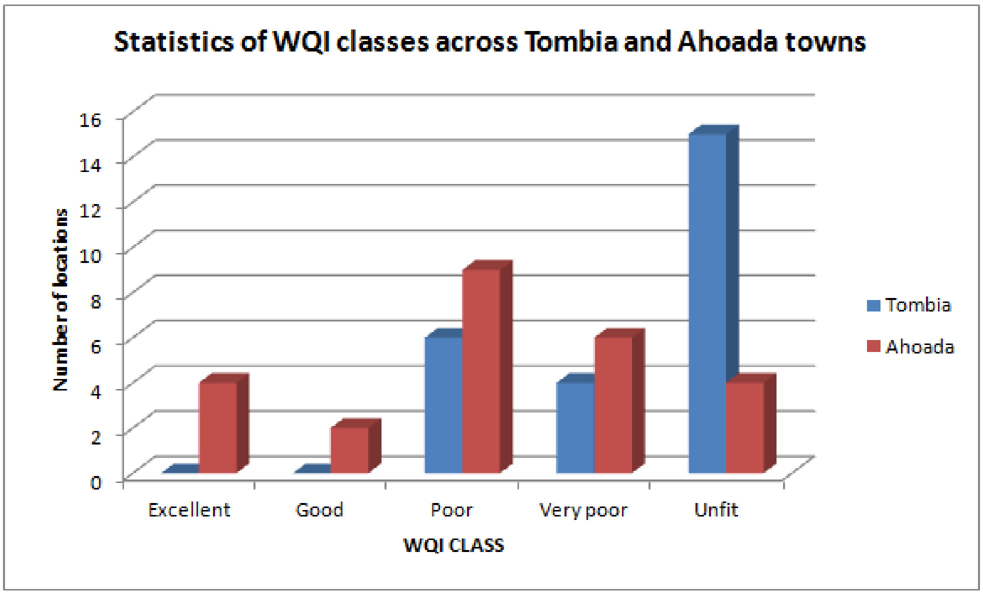

Fig 4 Statistical occurrence of classes of water by WQI across sampled locations in both towns

V. Conclusion

The study of groundwater quality status of Tombia and Ahonda West was carried out successfully using Water Quality Index method. Three (3) classes of water by WQI (Poor, very poor and unfit) was identified in Tombia town, whereas, Five (5) classes (excellent, good, poor, very poor and unfit) were identified in Ahonda West. Groundwater in Ahoada West was far better than that from Tombia based on the data collected from both areas. Groundwater from both areas were acidic, as such, alkaline materials can be added to water in these locations as a measure of treatment to make groundwater in these areas fit or suitable for consumption. Alternatively, polyvinylchloride (PVC) and other non-corrosive materials are highly recommended for borehole installation and water conveyance due to the acidic nature of groundwater in both areas.

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