ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 12, Issue, 05, pp.11748-11754, May, 2020

DOI: https://doi.org/10.24941/ijcr.38619.05.2020

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

WATER QUALITY VARIATION OF SELECTED OPEN WELLS AND BOREHOLES IN TOLON DISTRICT OF NORTHERN GHANA

***Abagale, F. K., Osei, R. A. and Antwi, P. K.**

School of Engineering, University for Development Studies, Tamale, Ghana

ARTICLE INFO

Article History:
Received 09th February, 2020
Received in revised form
14th March, 2020
Accepted 08th April, 2020
Published online 31st May, 2020

Key Words:
Water Quality,
Open Wells, Boreholes,
Salinity, Groundwater,

ABSTRACT

Previously, water was regarded as a free commodity, considered unlimited in quantity and available as required, however, with continued population growth and diversified demands, the resource is becoming increasingly scarce and often of inferior quality due to pollution. The study assessed the water quality of open wells and boreholes in Tolon District. Data was taken at 6 days intervals for a period of twenty-two (22) months. Mean salinity level of open wells and boreholes were in the range of 0.02 ppt to 0.15 ppt and 0.55 ppt to 0.82 ppt respectively. The results indicated that salinity in all open wells was below 0.50 ppt considered standard for good drinking water whilst the boreholes were above the recommended standards. Turbidity of open wells was between 32.75 to 369 NTU and above the WHO acceptable standard of 5 NTU for drinking water but with borehole turbidity ranging from 0.61 to 2.65 NTU. Aside geology, seasonality was identified as a factor affecting water quality as salinity and other parameters were higher in the dry season than the wet season. A positive correlation existed between salinity and reduced water levels in open wells with source as groundwater and a coefficient of correlation (r) ranging from 0.511 to 0.876. The study noted that water quality monitoring is very important in delivery of the desired and acceptable potable water for human use as local climatic factors with associated water withdrawals and recharge rates greatly influenced the water quality of boreholes and open-wells.

Citation: ***Abagale, F. K., Osei, R. A. and Antwi, P. K.* 2020.** "Water Quality Variation of Selected Open Wells and Boreholes in Tolon District of Northern Ghana", *International Journal of Current Research*, 12, (05), 11748-11754.

INTRODUCTION

Groundwater makes up about 20 % of the world's freshwater supply, which is about 0.61 % of the entire world's water, including oceans and permanent ice. Global groundwater storage is roughly equal to the total amount of freshwater stored in the snow and ice pack, including the north and south poles. This makes it an important resource which can act as a natural storage that can buffer against shortages of surface water, as in during times of drought (CWC, 2009). Koffie (2006) reported that the problem of water is more a case of distribution and quality than one of quantity. In the Northern Region of Ghana, the impact of inadequate potable water supply on the health status of the people is reflected in such widespread waterborne related ailment like intestinal infestation, stomach disorders, skin diseases and septic wounds. Koweh (2009) noted that these have to do with unhealthy environment, poor sanitation and personal hygiene.

All groundwater contains salts in solution and the type of salt depends on the geological environment, the source of groundwater and its movement. The weathering of primary minerals is the direct source of salts in groundwater. Salinity increases during drought as a result of increase evaporation and subsequent decline in water level. The study assessed the water quality of selected open wells and boreholes over space and time in the Tolon District of the Northern Region of Ghana.

MATERIALS AND METHODS

Study Area: The study was carried out in eight (8) open wells of which four (4) were connected directly to dams (labelled; WD01, WD02, WD03 and WD04) and the other four (4) taking their source from groundwater (labelled; WG01, WG02, WG03 and WG04) all in the Gbullung-West Inland Valley (GbW-IV). Four (4) boreholes (labelled; BH01, BH02, BH03 and BH04) were also selected in the GbW-IV except BH01 which is outside the GbW-IV but contributes to the catchment area. Table 1 presents the georeferencing of the study communities and the selected open wells and boreholes. The GbW-IV is a sub-basin of the catchment basin of the Bontanga River, a tributary of the White Volta, which flows through the Tolon and Kumbungu Districts in Northern Region of Ghana.

****Corresponding author:*** **Abagale, F. K.,**
School of Engineering, University for Development Studies, Tamale, Ghana.

Figure 1 is a plain view of the GbW-IV. The district experiences one raining season with mean annual rainfall of 1052.1 mm (Mote, 1997) and a long period of dry season (October to April). The mean monthly temperature ranges from 17˚C to 40˚C (TKDA, 2007) with mean annual evapotranspiration being about 1,800 mm (Mote, 1997). Middle Voltain Palaeozoic rocks (the Obosum and Oti beds) that comprise shale, mudstone, sandstone, limestone and conglomerate form practically the basement rocks that underlie the district (Kesse, 1985).

Materials and Data Collection

YSI 556 MPS and 5 m tape measure were the materials used to collect data on water quality parameters, and water level respectively. LaMotte 2020 Turbidimeter was also used to measure the turbidity of water from the wells and boreholes. Primary data was collected on water level, salinity and other water quality parameters of the eight (8) open wells whilst salinity and other water quality parameters were collected from the four (4) boreholes selected in the study area for a period of twenty-two (22) months. A 5 m tape measure was used to measure the reduced water level of wells from ground level. Data was collected at 6 days interval.

RESULTS AND DISCUSSION

Physicochemical Quality of Open-Well and Borehole Water: The mean salinity values for the boreholes were in the range of 0.55 ppt to 0.82 ppt and are therefore classified as brackish thus having a salty taste. Abagale *et al.* (2009) noted that deeper tube wells in the study area were brackish. Table 2 presents the mean values of the physicochemical parameters for boreholes and open wells in the study area. Salinity and total dissolved solids (TDS) levels increased in open wells with dams as sources, open wells with groundwater as source and boreholes in that order. The study presented the effects of salt intrusion from basement rocks as evidenced in Table 2. Rusydi (2018) reported that the relationship between TDS and EC is not always linear as it is highly dependent on water salinity and material contents whilst ILRI (1994) reported that, groundwater salinity increases with depth. Khan (2014) reported that hypertensive disorders were associated with salinity in drinking water. Furthermore, reducing salt consumption from the global estimated levels of 9–12 g/day (Brown, 2009) to an acceptable limit of 5 g/day (WHO, 2013) would be predicted to reduce blood pressure and stroke/cardiovascular disease by 23 and 17 %, respectively (He, 2013).

According to Shiraz *et al.* (2015), groundwater recharge and distribution depend on the underlying geological formations, surface expression, local and regional climate settings. A positive correlation between salinity, TDS, conductivity and specific conductivity was observed for borehole water from the study. Higher levels for % dissolved oxygen and oxygen concentration (Table 2) was recorded in borehole water and groundwater although it is expected of the open wells with direct connection to dams. pH of borehole water during the study was also noted to be slightly higher than the water from the open wells and moving the pH levels from high levels of acidity to neutrality for the open wells to boreholes. Due to the source of water for the open wells as dams and the non-secured nature of the open wells with groundwater as the source, pollution of open wells resulted in relatively higher turbidity levels compared to the boreholes. Lower turbidity levels were recorded in wells with direct groundwater as source than those dam-connected wells. EPA (1999) noted turbidity to be caused by the presence of clay particles, silt, finely divided inorganic and organic matter, soluble coloured organic compounds, plankton and other microscopic organisms with the WHO (1996) indicating drinking water turbidity should not exceed 5 NTU. The study results noted the mean turbidity borehole water as being below WHO (1996) limit but with the well water being higher. The exposure level of the micro-dams to the environment especially the effects of runoff, animal and human activities increases the turbidity level compared to the borehole water with source from groundwater as a result of the filtering effect of the soil layers and geologic parent material. ILRI (1994), noted that fresh groundwater occurs in topographic highs which, if composed of permeable materials, are areas of recharge. On its way to topographic lows (areas of discharge), the groundwater becomes mineralized through dissolution of minerals and ion exchange. The geological formation of the area which is mainly Paleozoic shale and as the basement rock as reported by Kesse (1985) was noted to have influenced the brackish nature of the wells. ILRI (1994) reported that groundwater salinity has been realized to vary with the texture of sediments, solubility of minerals and contact time. Salinity levels of the boreholes was noted to be above the standard for good drinking whilst the well water was noted to be below the recommended standard. Upper Voltaian sandstone and quartzite underlie a small portion of the district at extreme northwest. Shale is the basement rock that underlies all the selected wells and boreholes (Darko *et al.,* 2006).

Water Level and Water Salinity Relations: Water levels in open-wells and boreholes were largely influenced by the local climatic conditions, intensity of water withdrawals and rate of recharge. Water levels were generally low during the dry season which is associated with reduced levels of recharge but higher levels of withdrawals. Figure 3 presents the mean monthly water levels of the study open-wells during the study period. A positive linear correlation between water salinity and reduced water level in open-wells with groundwater as source was established with a degree of association ranging from weak to fairly strong and correlation coefficients (r) between 0.511 to 0.876. According to Upson (2003) water in wells become more mineralized as it moves down or falls in water level as a result of increased solid dissolution. Correlation between salinity and water level in wells directly connected to micro-dams was non-existent. Even though 3 out of 4 open-wells showed very weak negative correlation and the others showed very weak positive correlation between salinity and reduced water level, their coefficient of determination indicates that these relationships may be by chance since less than 4 % of the data is explained by the equation of line of best fit. Table 3 presents the relationship fitted for salinity and reduced water level in open wells showing the coefficient of correlation (r), coefficient of determination (r^2), coefficient of regression (b) and the intercept (a). A simple linear regression line in the form of Equation 1 defines the relationship between salinity and reduce water level.

$y = a + bx$ …………………………Equation 1

Where:

y is salinity
x is water level

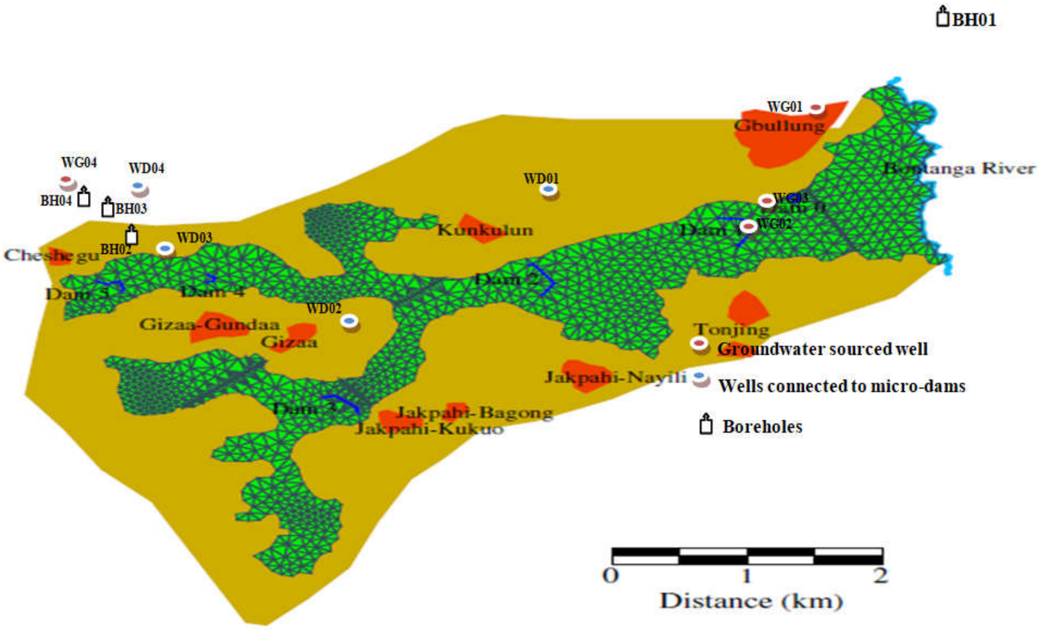

Figure 1. Plain View of the GbW-IV

Table 1. Locations of the Selected Open-Wells and Boreholes

Well/Borehole	Labels	Latitude	Longitude
Kunkulun Well	WD01	09˚ 28' 23.0" N	001˚ 01' 93.8" W
Gizaa Well	WD02	09˚ 27' 53.2" N	001˚ 02' 32.2" W
Gizaa-Gundaa Well	WD03	09˚ 28' 13.9" N	001˚ 03' 14.5" W
Cheshegu Hand Dug Well	WD04	09˚ 28' 21.3" N	001˚ 03' 22.5" W
Gbullung Well	WG01	09˚ 28' 51.7" N	001˚ 00' 40.8" W
Tongjing Old Well	WG02	09˚ 28' 25.7" N	001˚ 00' 50.9" W
Tongjing New Well	WG03	09˚ 28' 29.3" N	001˚ 00' 49.4" W
Cheshegu Community Well	WG04	09˚ 28' 24.9" N	001˚ 03' 32.9" W
Gung Well	BH01	09˚ 29' 55.7" N	000˚ 59' 18.5" W
Mid Gizaa-Gundaa Well	BH02	09˚ 28' 16.9" N	001˚ 03' 17.6" W
Cheshegu Down Well	BH03	09˚ 28' 18.7" N	001˚ 03' 25.0" W
Cheshegu Up Well	BH04	09˚ 28' 20.7" N	001˚ 03' 26.8" W

Table 2. Physicochemical Parameters of Open-Wells and Borehole Water

Parameter	Water level (m)	Temperature (ºC)	Salinity (ppt)	TDS (g/L)	Conductivity (mS/cm)	Specific Conductivity (mS/cm)	Resistivity (Kohm.cm)	DO (%)	DO Concentration (mg/L)	ORP (mV)	pH	pHmV (mV)	Turbidity (NTU)
Wells with Source as Direct Groundwater													
WG01	1.47	29.52	0.04	0.06	0.10	0.10	14.5	20.6	1.53	44.60	6.60	16.94	32.75
WG02	1.69	28.77	0.02	0.04	0.06	0.06	19.1	47.9	3.92	128.8	6.28	53.78	47.67
WG03	1.36	27.71	0.10	0.14	0.23	0.21	4.73	39.1	3.06	43.05	7.58	-43.58	37.05
WG04	2.38	28.54	0.15	0.20	0.33	0.31	3.15	48.3	3.74	68.65	6.68	10.84	33.97
Wells Directly Connected to Micro-Dams													
WD01	0.52	27.52	0.03	0.05	0.10	0.07	16.7	12.1	0.95	82.24	7.09	8.86	62.41
WD02	1.91	29.02	0.02	0.03	0.05	0.05	23.0	18.8	1.48	32.08	6.77	3.67	36.99
WD03	1.35	27.38	0.02	0.03	0.05	0.05	21.5	20.1	1.59	63.07	6.13	42.44	98.14
WD04	0.96	27.08	0.02	0.03	0.05	0.05	24.5	25.3	2.03	83.30	6.93	17.43	91.94
BH01		30.11	0.55	0.73	1.23	1.12	0.82	28.4	1.91	53.65	7.18	-18.89	0.61
BH02		30.72	0.58	0.78	1.33	1.20	0.76	40.1	2.91	24.28	7.53	-18.67	2.65
BH03		31.17	0.82	1.07	1.83	1.64	0.55	34.7	2.57	49.24	7.08	-13.28	1.08
BH04		30.14	0.69	0.90	1.54	1.38	1.17	30.3	2.31	55.31	7.53	-8.32	0.71

Table 3. Relationships Parameters for Salinity and Reduced Water Level in Open-Wells

Well	Parameter			
	a	b	r	r^2
WG01	-0.003	0.032	0.838	0.702
WG02	0.013	0.005	0.653	0.427
WG03	0.058	0.003	0.876	0.768
WG04	0.027	0.050	0.511	0.261
WD01	0.028	0.005	0.105	0.011
WD02	0.022	-0.0001	-0.032	0.001
WD03	0.O26	-0.002	-0.190	0.036
WD04	0.023	-0.001	-0.077	0.006

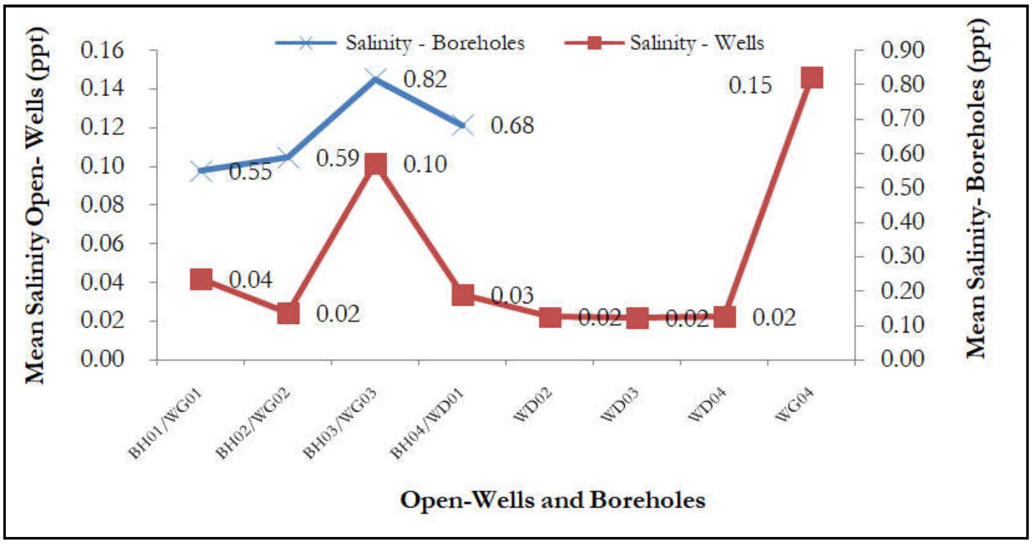

Figure 2. Variation of Salinity in Open-Wells and Boreholes

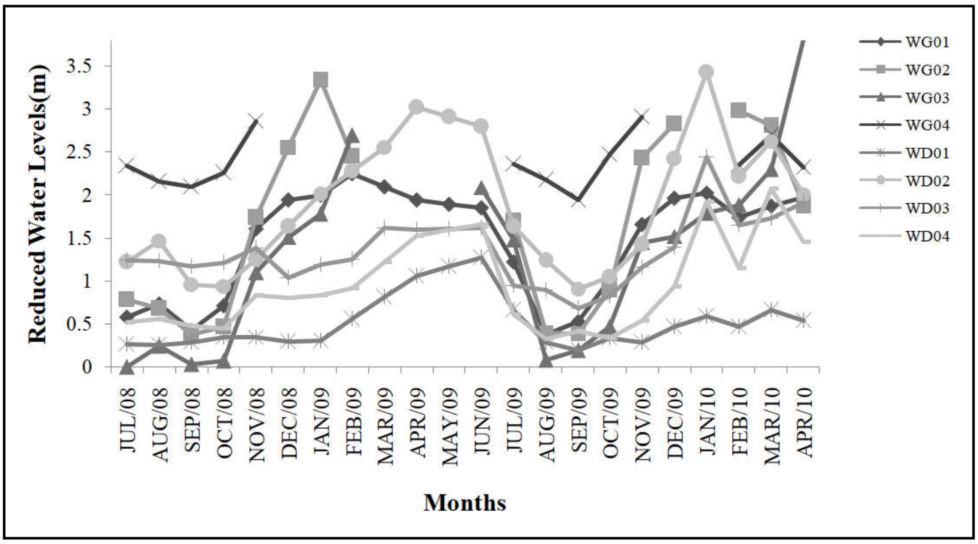

Figure 3. Mean Monthly Water Levels of Open Wells

Table 4: Salinity Variation with Borehole Distance

Boreholes		**BH01**	**BH02**	**BH03**	**BH04**
Boreholes	Salinity(ppt)	0.55	0.59	0.82	0.68
BH01	0.55	0.00	7900.99 m	8089.33 m	8118.09 m
BH02	0.59	0.04 ppt	0.00	232.44 m	304.00 m
BH03	0.82	0.27 ppt	0.23 ppt	0.00	82.42 m
BH04	0.68	0.13 ppt	0.09 ppt	0.14 ppt	0.00

Table 5: Salinity Variation with Distance among Open-Wells

Wells		WG01	WG02	WG03	WD01	WD02	WD03	WD04	WG04
Wells	Salinity (ppt)	0.04	0.02	0.10	0.03	0.02	0.02	0.02	0.15
WG01	0.04	0.00	856.32 m	736.64 m	3558.46 m	3844.80 m	4830.85 m	5020.85 m	5314.65 m
WG02	0.02	0.02 ppt	0.00	119.72 m	3140.43 m	3247.91 m	4396.02 m	4627.07 m	4942.43 m
WG03	0.10	0.06 ppt	0.08 ppt	0.00	3190.97 m	3326.72 m	4452.02 m	4677.31 m	4989.96 m
WD01	0.03	0.01 ppt	0.01 ppt	0.07 ppt	0.00	917.02 m	1272.79 m	1486.67 m	1803.98 m
WD02	0.02	0.02 ppt	0 ppt	0.08 ppt	0.01 ppt	0.00	1438.77 m	1760.83 m	2092.44 m
WD03	0.02	0.02 ppt	0 ppt	0.08 ppt	0.01 ppt	0.00 ppt	0.00	333.58 m	655.26 m
WD04	0.02	0.02 ppt	0 ppt	0.08 ppt	0.01 ppt	0.00 ppt	0.00 ppt	0.00	336.02 m
WG04	0.15	0.11 ppt	0.13 ppt	0.05 ppt	0.12 ppt	0.13 ppt	0.13 ppt	0.13 ppt	0.00

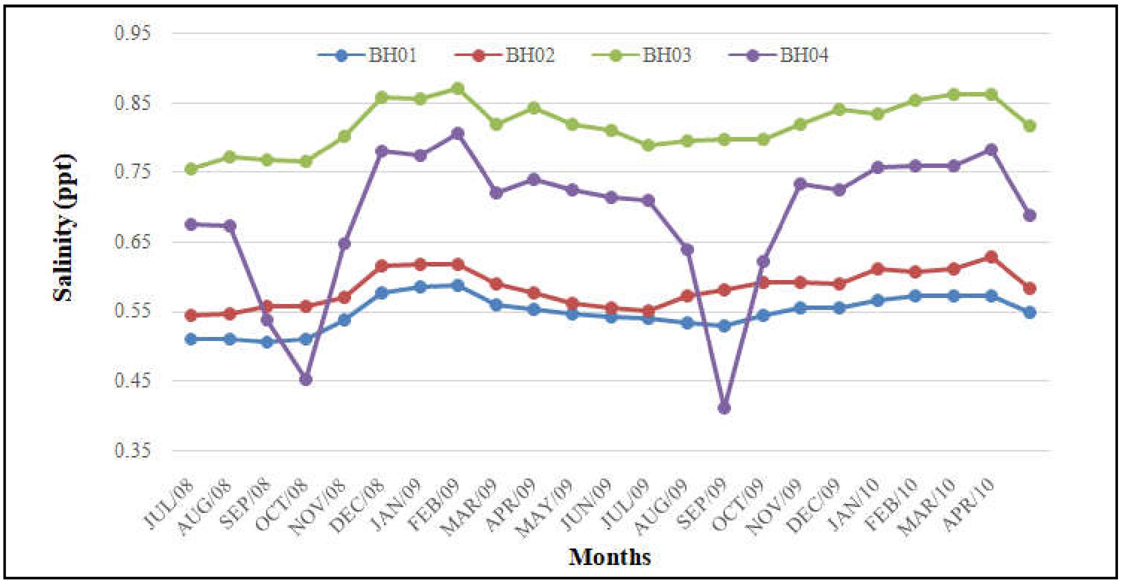

Figure 4: Salinity in Borehole Water with Time

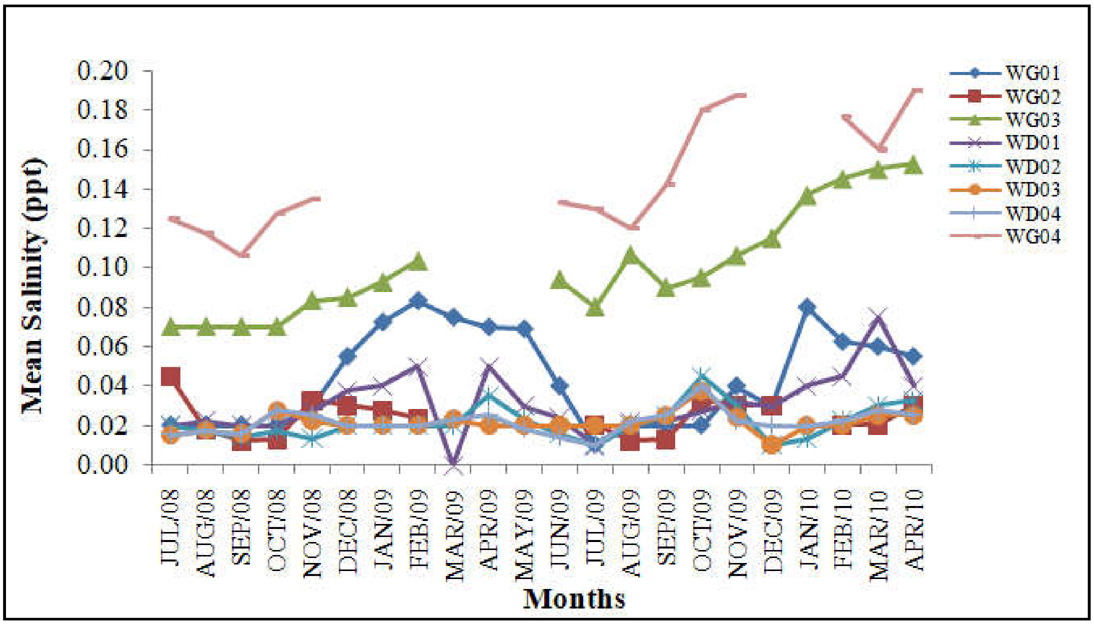

Figure 5: Salinity in Open Well Water with Time

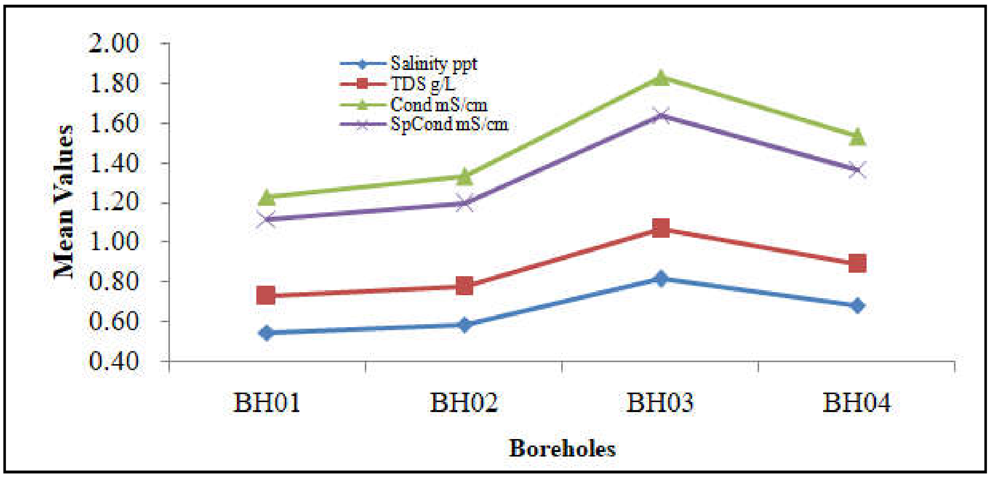

Figure 6: Relationships between Salinity, TDS, Conductivity and Specific Conductivity in Boreholes

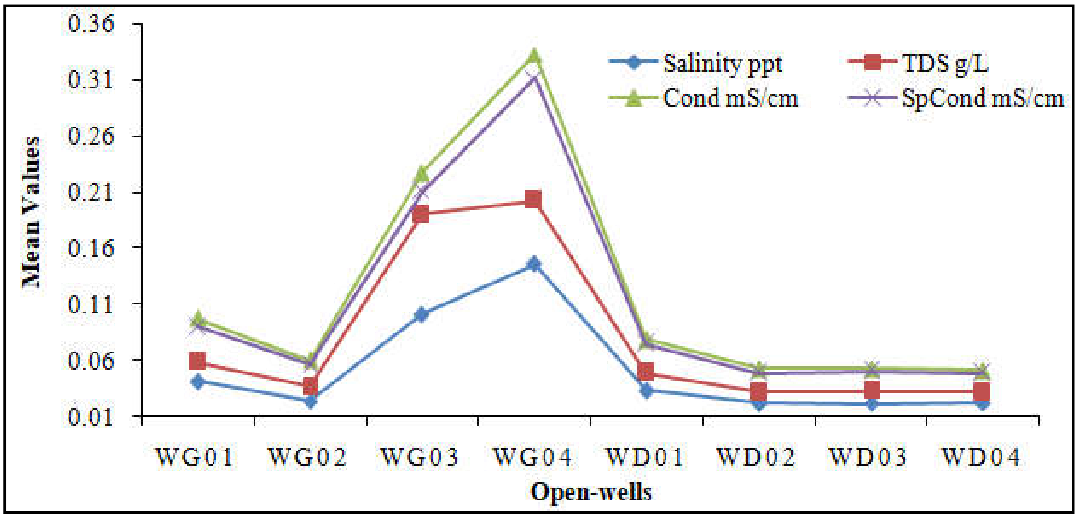

Figure 7. Relationships between Salinity, TDS, Conductivity and Specific Conductivity in Open-Wells

Tables 4 and 5 presents salinity variation with distance of the study for boreholes and open-wells respectively. The dotted cells represent the distance in meters (m) whilst the dark shaded cells represent salinity levels in parts per million (ppt). Salinity in space was noted not to be statistically significant with f-probability of 0.95 and as can be observed in Table 4, the distance between BH01 and BH02 is 7.9 km with salinity difference as 0.04 ppt and increased to 0.27 ppt for BH01 and BH03 with a distance of 8.1 km. A decrease or increase in distance between boreholes and open wells did not result in a corresponding linear salinity relationship as can be observed in Table 5. For salinity levels in relation to time, the dry season recorded higher levels than the wet season for both open-wells and boreholes. Precipitation, rate of recharge, temperature and evaporation rate which will ultimately concentrate dissolved solids in the water were noted as the influential factors. According to Upson (2003), groundwater quality is largely affected by local climatic conditions. Figure 4 and Figure 5 presents the salinity level in time for boreholes and open-wells respectively and in Figure 5, the gaps in trend for well-WG02, WG03 and WG04 resulted from dry wells and water levels below 5 m.

Salinity, TDS, Conductivity and Specific Conductivity Relations: The coefficient of determination (r^2) ranges from 0.82 to 0.99 for conductivity in wells and 0.83 to 0.99 for both TDS and specific conductivity in open-wells. In boreholes, the coefficient of determination ranged from 0.81 to 0.96 for conductivity and from 0.95 to 0.99 for both TDS and specific conductivity. It was realized that conductivity multiplied by 0.45 or specific conductivity multiplied by 0.49 closely approximated salinity both in open-wells and boreholes. This means that the more dissolved salt in the water, the stronger the current flow and the higher the electrical conductivity. Also, TDS multiplied by 0.73 closely approximated salinity in open-wells whereas TDS multiplied by 0.76 also approximated salinity in boreholes. Figure 6 and 7 presents the relationship between salinity, TDS, conductivity and specific conductivity in boreholes and open-wells of the study.

Conclusion

Salinity of borehole water from the study results indicated high levels and a positive correlation between salinity, TDS, conductivity and specific conductivity was also observed for borehole water from the study. Lower turbidity levels were recorded in wells with direct groundwater as source than those dam-connected wells. A positive linear correlation between water salinity and reduced water level in wells with groundwater as source was established with a degree of association ranging from weak to fairly strong. Local climatic factors with associated water withdrawals and recharge rates influenced the water quality of boreholes and open-wells.

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