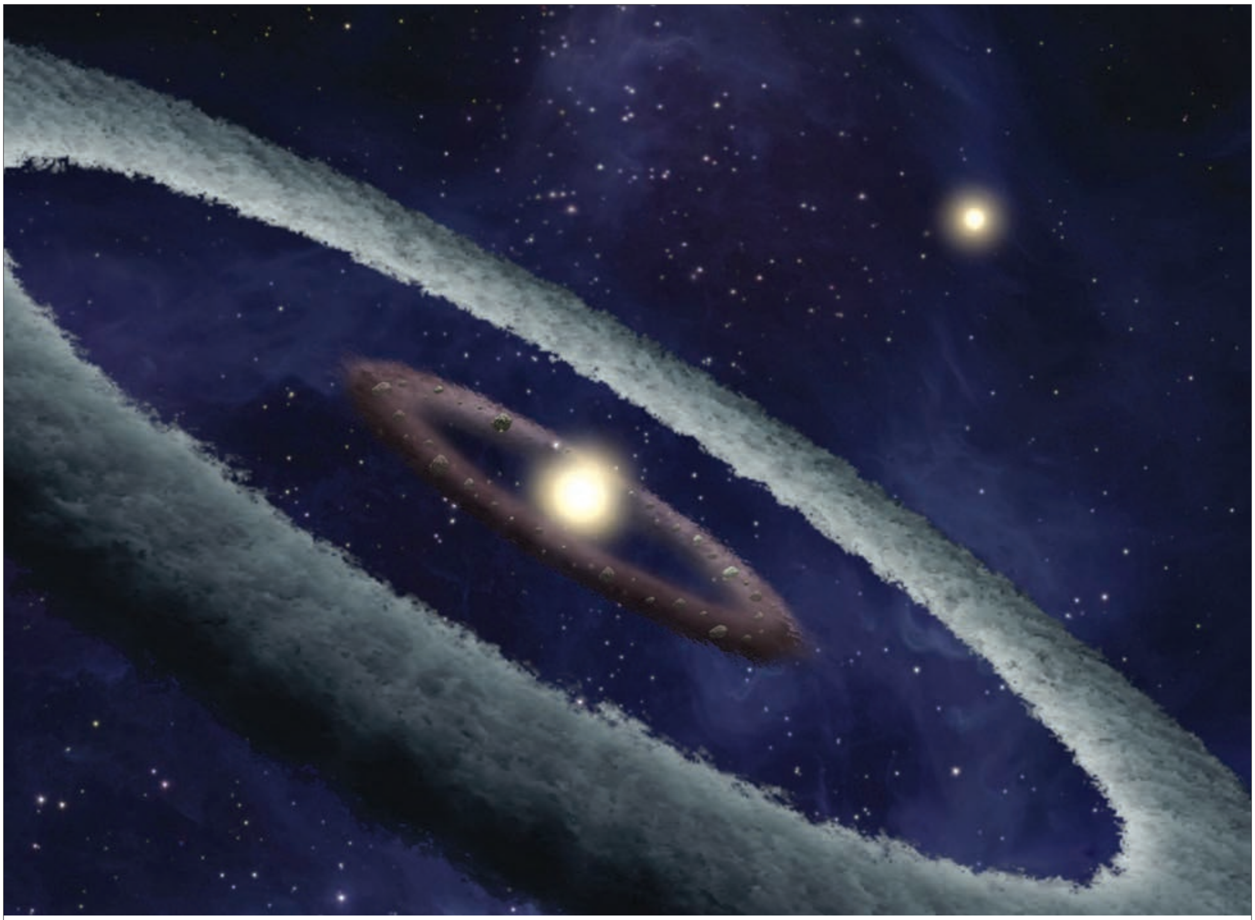

Research Journal of
Physics

ISSN 1819-3463

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Physics 9 (1): 1-10, 2015
ISSN 1819-3463 / DOI: 10.3923/rjp.2015.1.10

Seasonal Variations of Physico Chemical Properties and Quality Index of Groundwater of Hand-Dug Wells Around Ajakanga Dump Site in Southwestern Nigeria

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ABSTRACT

Ajakanga landfill located within Ibadan metropolis, southwestern Nigeria was opened in 1998 and still in operation till date. The leachate emanated from decomposed solid wastes have adverse effects on nearby groundwater sources. The aim of this study was to assess the groundwater quality using an indexing approach from existing hand-dug wells bordering this active landfill site and assess its suitability for drinking and domestic purposes during dry and wet season. Ten water samples from different locations within the landfill were identified for groundwater sampling. The samples were collected in March and August, 2013 and analyzed for different physico-chemical parameters. The analyzed physicochemical parameters such as pH, TDS, TH, HCO_3^-, CO_3^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} fall within the standard limits of WHO and NSDWQ. The values of GWQI of water samples during dry and wet seasons were found in the range of 16.8-38.4 and 11.4-48.9, respectively. About 50% of sampling waters belong to "Excellent" water status and 50% under "Good" class during dry season. During wet season, 70% of sampling points come under "Excellent" water status while 30% belongs to "Good" water status. The GWQI value of each well for both seasons revealed their fitness for drinking and human consumption purposes. Pearson's correlation coefficients among selected water quality parameters show very strong association between EC and TDS in both seasons.

Key words: Landfill, groundwater, GWQI, leachate, physico-chemical parameter, season

INTRODUCTION

Solid wastes are being produced everyday by residential, commercial and agricultural sources as a direct consequences of human activities. In an attempt to dispose of these large volume of daily wastes, man has carelessly polluted the environment especially surface, groundwater, soil and air through leachate and landfill gases. Pollution of groundwater is a major threat posed by leachate which is formed by anaerobic decomposition of waste and may infiltrate and join the aquifer (Tesfaye, 2007). According to Freeze and Cherry (1979), water table mounding and gravity causes leachate to move through the subsurface soil to the bottom and sideway until it reaches the groundwater zone thereby polluting the groundwater. With the inconsistent variation of groundwater table soil condition and contamination by leachate plume through percolation, infiltration and seepage, groundwater quality determination assumes greater significance in the field of water quality management (Mohan *et al.*, 1998). At Ibadan, the capital of Oyo State in southwestern part of Nigeria, there is scarcity of pipe borne water due to non-availability and inadequate presence of laid down pipe in most parts of the city. Consequently, groundwater from hand-dug wells serves as an alternative and major source of water supply for domestic purposes. Siting of dump site within the vicinity of residential areas can contaminate groundwater quality of wells bordering the landfill. The use of polluted groundwater for drinking and consumption purposes can cause major health problems. According to WHO, about 80% of all diseases in human beings are caused by water (Ramakrishnaiah *et al.*, 2009). Therefore, a periodic assessment of groundwater quality is necessary in order to ascertain the quality of water to be used for human consumption purpose as well as to provide an overall scenario about the sources of groundwater contamination, thereby open an avenue for better planning to achieve sustainable management of groundwater.

The Groundwater Quality Index (GWQI) indicates the overall quality of waters in terms of a single value at a certain location and time, based on several water quality parameters (Saeedi *et al.*, 2010). It is a mathematical equation used to transform large number of water quality data into a single number (Stambuk-Giljanovic, 1999).

It is also one of the most effective ways of communicating the information on water quality trends to the general public and policy makers in water quality management. It is associated with the need to provide a general means of comparing and ranking various bodies of water throughout a particular region (Armah *et al.*, 2012). Moreover, GWQI assessment is important in assessing the spread of water-borne diseases as several epidemiological studies advocated that greater percentage of human diseases in the world are due to poor quality of drinking water.

Several researchers have evaluated groundwater quality using indexing method. Sayed and Gupta (2013) investigated the quality of groundwater samples from hand-pump and bore wells in Beed City of Maharashtra India. The quality of groundwater in Tarkwa Gold Mining area in Ghana was assessed using GWQI method by Armah *et al.* (2012) while Gupta and Roy (2012) evaluated spatial and seasonal variations in groundwater quality at Kolar Gold Fields, India, Rao and Nageswararao (2013) used the method of GWQI to assess the quality of groundwater at Greater Visakhapatnam city using water quality index method.

In this study, groundwater samples from hand-dug wells within the vicinity of landfill were surveyed to analyze physico-chemical characteristics of water for the assessment of safe drinking water source and seasonal variation of GWQI for hand-dug wells around dump site to ascertain their suitability for drinking and consumption purposes.

MATERIALS AND METHODS

Study area and its local geology: Ibadan is located approximately within the squares of longitude 3^0 35^1-4^0 10^1 7 east of the Greenwich meridian and latitude 7^0 20^1-7^0 40^1 north of the equator. In this locality, wastes are dumped indiscriminately on open grounds in so many places. There are several collection points from which refuses are cleared by government trucks at regular intervals and deposited at the central landfill sites managed by the government. The city generates about 1,618,293 kg of solid waste daily. There are four designated dump sites (open landfill) in Ibadan namely: Aba-Eku, Ajakanga, Awotan and Lapite. For this study, the study area is Ajakanga landfill in southwestern part of Ibadan. Ajakanga landfill lies between longitude of 3^0 50 187-3^0 50 696 E and longitude 7^0 18 021-7^0 18 979 N. It was opened in 1998 and still in operation till date. The study area falls within the humid and sub humid tropical climate of southwestern Nigeria with a mean annual rainfall of about 1230 mm and mean maximum temperature of 32°C.

The geology of the area is a basement complex formation of southwestern Nigeria and are mainly the metamorphic rocks of precambrian age with few intrusions of granites and porphyries of Jurrasic age. The dominant rock types are quartzite of metasedimentary series, banded gneiss, augen gneisses and migmatites which constitute the gneiss-migmatite complex. Other minor rock types include pegmatite, quartz, aplites, anphibolites and xenolith (Okunlola *et al.*, 2009). Banded gneiss constitutes over 75% of the rocks in and around Ibadan while augen gneisses and quartzites share the remaining in about equal percentages (Okunlola *et al.*, 2009), as shown in Fig. 1.

Collection of samples: Ten water samples were collected from hand-dug wells bordering Ajakanga landfill in the month of March and August, 2013 inside 2 L polyethylene bottles. The bottles were washed thoroughly with dilute nitric acid and then rinsed with water. Prior to sampling, sampling bottles were rinsed thoroughly with groundwater to be analyzed before sampling process. The samples were collected in different seasons, dry season in March, 2013 and wet season in August, 2013. Preservation of water samples and analyses were carried out as per standard methods of APHA (1998). Parameters such as pH, TDS and EC were measured *in situ* with the aid of multipurpose conductivity meter. The depth of the well, depth to static water level and geographic coordinates of the sampling points were also taken on the field during both seasons (Table 1). The sampling locations and dump site are depicted in Fig. 2. Sodium and potassium were determined with flame photometric method, calcium and magnessium concentration were analyzed using absorption mode of Atomic Absorption Spectrometric (AAS) method. Sulphate and nitrate were analyzed by turbidimetric and UV spectrophotometric method, respectively, chloride, carbonate and bicarbonate by titration method while total hardness was determined by Ethylene Diamine Tetra Acetic Acid (EDTA) titration method using Eriochrome black-T as an indicator. The obtained chemical parameters were used for the computation of GWQI from the point of view of assessing suitability for drinking and human consumption purposes during both seasons.

Groundwater quality index: For GWQI analysis, 11 parameters consisting of pH, TDS, TH, HCO_3^-, Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+} and Mg^{2+} in each sample were assigned a weight (wi) according to their relative importance in the overall water quality for drinking purpose. Nitrate was assigned maximum weight of 5 due to its major importance in water quality assessment. The weight of other parameters varied from 2-5 depending on their significant importance in water quality determination. The relative weight of chemical parameters is shown in Table 2.

In the second step, the relative weight (wi) is calculated using the equation:

$$\mathrm{Wi} = \frac{\mathrm{wi}}{\sum_{j=1}^{n} \mathrm{wi}} \tag{1}$$

where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. In the third step, the quality rating scare (q_i) was calculate by using:

$$q_i = \left(\frac{C_i}{S_i}\right) \times 100 \tag{2}$$

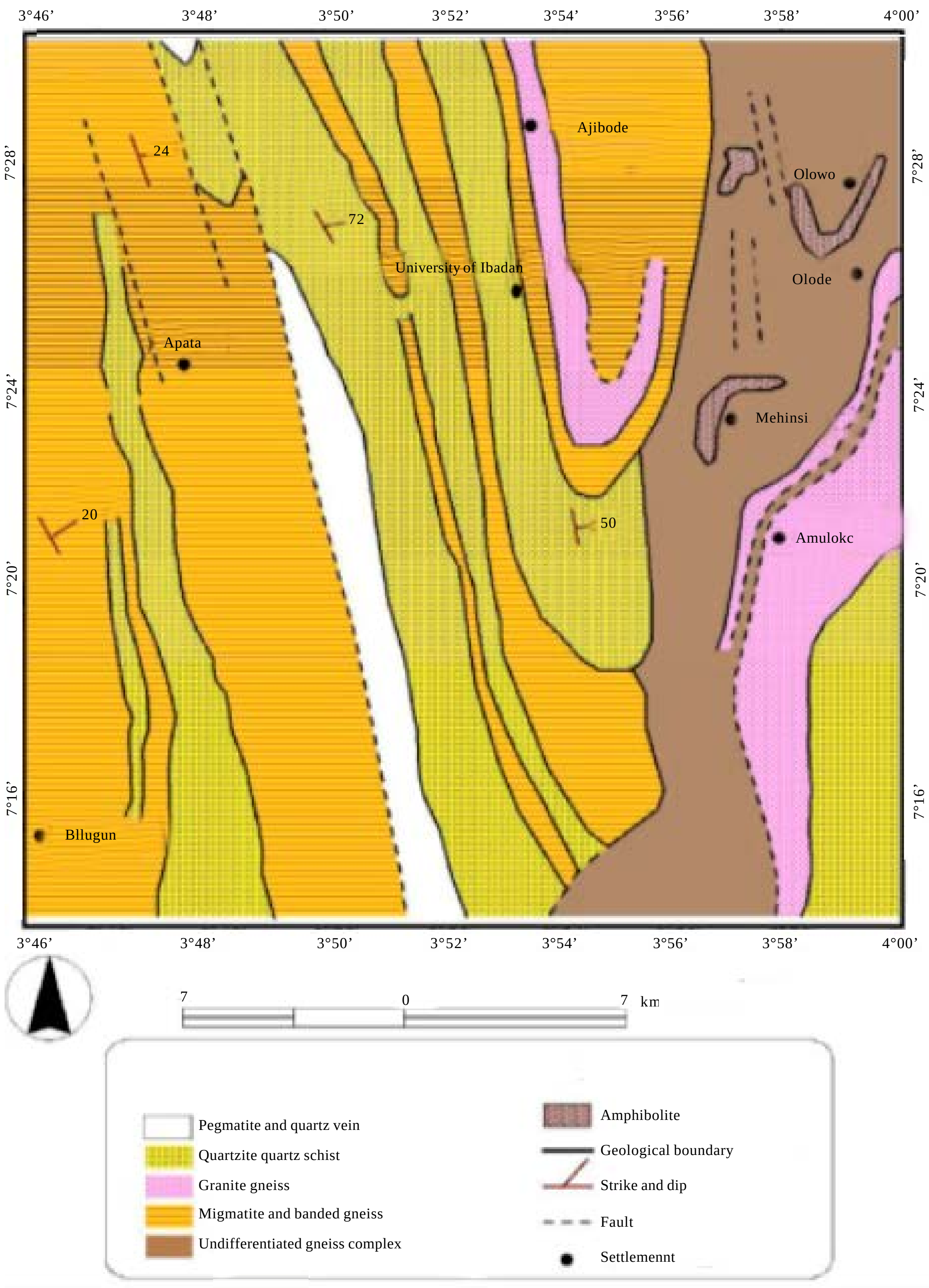

Fig. 1: Generalized geological map of Ibadan after Okunlola *et al.* (2009)

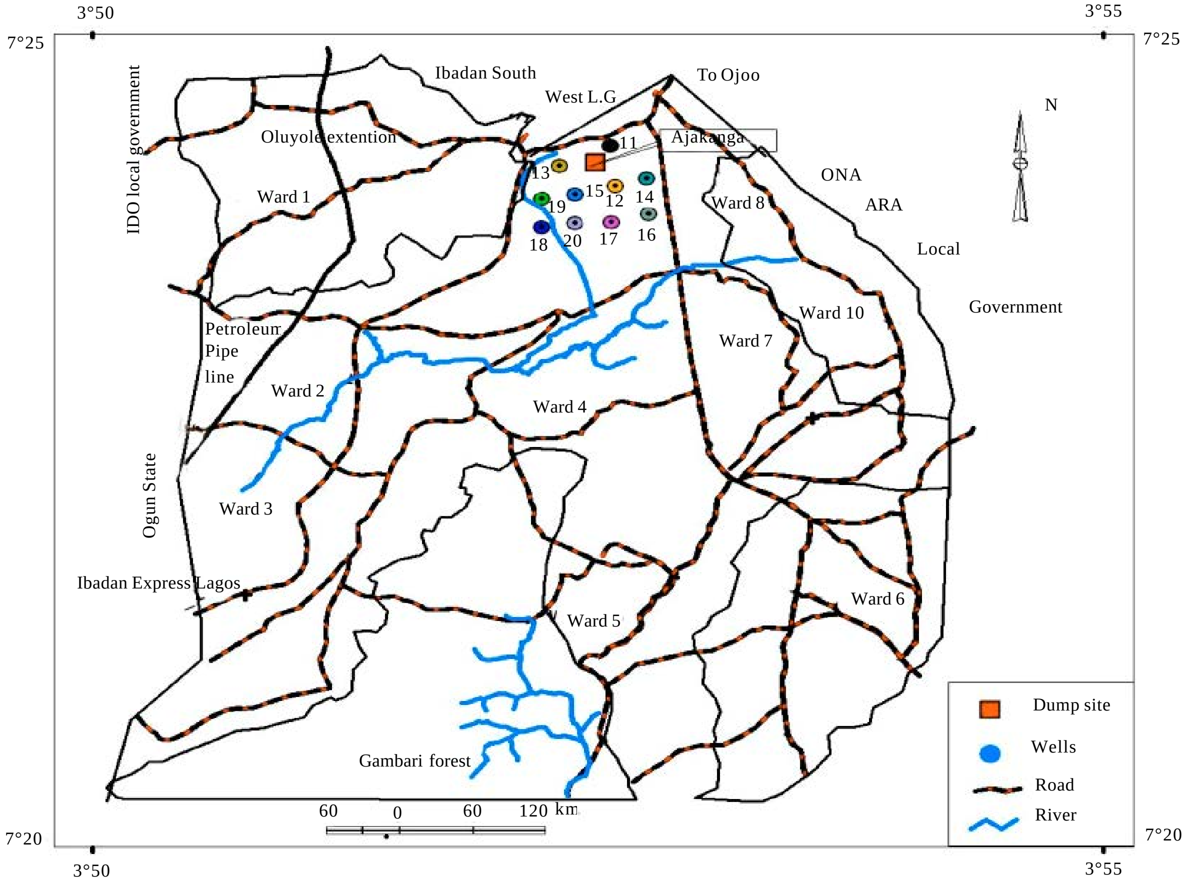

Fig. 2: Map of the study area showing water samples locations

Table 1: Well parameters for Ajakanga water samples (dry and wet season)

	Depth of water table (m)			
Well	Dry	Wet	Depth to bottom (m)	Distance to landfill (m)
11	3.70	2.70	9.10	90
12	2.00	2.10	2.70	110
13	3.50	3.20	4.50	100
14	5.80	2.70	6.40	200
15	5.20	2.70	5.50	220
16	4.60	4.30	5.50	200
17	5.50	3.20	5.80	270
18	7.20	6.50	8.20	520
19	-	-	-	120
20	1.80	1.80	3.70	120

where, q_i is the quality rating, C_i is the concentration of selected parameter in mg L^{-1} and S_i is the WHO drinking water standard (WHO, 2007). For calculating the GWQI, the sub index SI_i is first determined for each parameter which is then used to determine the GWQI using the Eq. 3:

Table 2: Relative weight of chemical parameters

Chemical parameters	S_i	Weight (wi)	Relative weight (Wi)
pH	6.5-8.5	4	0.121
TH	150	2	0.061
Ca^{2+}	75	2	0.061
Mg^{2+}	50	2	0.061
Na^+	200	2	0.061
K^+	55	2	0.061
HCO_3^-	1000	3	0.091
Cl^-	250	3	0.091
TDS	500	4	0.121
NO_3^-	50	5	0.152
SO_4^{2-}	250	4	0.121
		$\Sigma wi = 33$	$\Sigma WI = 1.002$

Table 3: Water quality index scale

Water quality status	GWQI level
Excellent	0-25
Good	26-50
Poor	51-75
Very poor	76-100
Unsuitable for drinking	> 100

$$SI_i = W_i q_i \tag{3}$$

And:

$$GWQI = \sum_{i=1}^{n} SI_i$$

Based on GWQI value, quality of water was assessment using the water quality index scale (Mishra and Patel, 2001; Sindhu and Sharma, 2007). This is shown in Table 3.

RESULTS AND DISCUSSION

The concentration of water quality parameters have been compared with the drinking standard prescribed by Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO, 2007) for both sampling periods and the percentage compliance as shown in Table 4.

Water quality parameters around Ajakanga landfill: The pH values of water samples during dry and wet season sampling periods ranged from 6.97-7.81 and 6.71-7.33, respectively. The result did not vary significantly in both seasons. All pH values for the two seasons lie within the permissible limit. The TDS concentrations for both dry and wet seasons varied from 88-299 mg L^{-1} and 95-351 mg L^{-1}, respectively. Seasonal changes showed the highest (299 mg L^{-1}) value at S_1 (90 m to the gate of Ajakanga landfill) during dry season and highest (351 mg L^{-1}) at S_{10}

Table 4: Comparison of water quality parameters with drinking water standard for dry and wet season

Parameters	Range (dry) Min	 Max	Percentage compliance (dry)	Range (wet) Min	 Max	Percentage compliance (wet)	WHO (2007) and SON (2007)
pH	6.97	7.81	100	6.71	7.33	100	6.5-.5
EC	176	598	100	191	705	100	1000
TDS	88	299	100	95	351	100	500
Cl^-	16	113	100	10	53	100	250
HCO_3^-	122	586	100	122	610	100	1000
CO_3^-	60	288	40	60	300	50	120
TH	46	406	50	116	432	10	150
Na^+	12	30	100	11	24	100	200
K^+	1	6	100	1	6	100	55
NO_3^-	1.54	15.9	100	3.90	0.00	100	50
Ca^{2+}	1.32	49.2	100	2.01	173.4	100	75
Mg^{2+}	1.12	14.23	100	3.29	49.34	100	50
SO_4^{2-}	14.36	127.74	100	7.58	52.26	100	250

(well inside Garden Farm) in wet season. Dumping activities might have caused high value of TDS in well 1 while agricultural runoff and animal husbandry practice might have caused high value in well 10. The observed values are within the permissible limit. Electrical conductivity measures the amount of dissolved ions in a solution. The EC value showed highest value of 598 mS cm^{-1} at well 1 in dry and 705 mS cm^{-1} at well 10 during wet season. All EC values in both season lie within the standard limit of WHO and NSDWQ.

The average concentration of Total Hardness (TH) varies form 46-406 and 116-432 mg L^{-1} during dry and wet sampling periods, respectively. Highest value of TH (406 mg L^{-1}) was observed in well 10 during dry and 432 mg L^{-1} during wet season in well 1 (about 90 m to the landfill). Based on Sawyer and McCarty (1967) classification for total hardness, 20% of water samples revealed “Soft” class, 40% showed “Hard” class, 30% revealed “Moderate” class while 10% falls under “Very hard” (as shown in well 10) during dry season. During wet season sampling period, none of the samples fall under “Soft” class of hardness, 10% revealed “Moderate” class, 60% indicated “Hard” class while 30% showed “Very hard” class. At all sampling locations, total hardness was higher in wet season than in dry season.

The chloride concentration of water samples during dry and wet seasons ranged from 16-113 and 10-53 mg L^{-1}, respectively. The observed values for chloride in both seasons were within the permissible limit. Nitrate concentration in groundwater and surface water is normally low, ranging from 1.54-15.9 mg L^{-1} in dry season and 0-3.9 mg L^{-1} during wet season. The low concentration of nitrate value for the study area during both sampling periods were found to be within the limit of 50 mg L^{-1} specified by WHO. Seasonal variations of bicarbonate in groundwater showed higher value of 586 mg L^{-1} at well 14 during dry season and 610 mg L^{-1} at well 20. All bicarbonate values for both seasons at all sampling locations lie within the specified standard limits. Sodium concentrations in groundwater ranged from 12-30 and 11-24 mg L^{-1} during dry and wet seasons period. High value of 30 mg L^{-1} was observed in well 1 during dry season while well 6 and 10 have highest value of 24 mg L^{-1} during wet season. There is no significant seasonal variation of potassium. The lowest and highest concentration value in both seasons are the same. The lowest (1 mg L^{-1}) concentration was found at well 3 in dry and the highest (6 mg L^{-1}) at well 4 during wet season. The low concentration of K^+ in groundwater may be due to the fact that most potassium bearing minerals are resistant to decomposition by weathering process and fixation in the formation of clay minerals (Scheytt, 1997).

The calcium concentrations during both sampling periods ranged from 1.32-49.2 mg L^{-1} and 2.01-173.4 mg L^{-1}, respectively. At most of the locations, calcium values were higher in wet than dry season. Highest values of 49.2 and 173.4 mg L^{-1} in both dry and wet seasons were observed in well 10. The magnesium concentration value ranged from 1.12-14.23 and 3.29-49.32 mg L^{-1} during dry and wet seasons, respectively with well 10 having highest value in both seasons. The average concentration of calcium in all analyzed water samples lie within the specified limit of WHO and NSDWQ.

The computed GWQI values for 10 sampling locations in dry and wet season are given in Table 5. The minimum and maximum values of GWQI indicate the range of water quality of sampling locations in both seasons. In dry season, 50% of water samples belong to "Excellent" class while the remaining 50% belong to "Good" class. In wet season, the range of GWQI showed that 70% of analyzed groundwater samples belong to "Excellent" class while 30% belong to "Good" class. The dilution properties due to rain might be the reasons for improved water quality in wet season. It was observed that even at the same sampling location, the quality of water varied for some sampling locations.

At location S_1, S_2 and S_{10}, the water quality is "Good" in both dry and wet seasons. However, at well 4 (S_4) it is "Good" in dry season but "Excellent" in wet season. Similarly at S_6, the water quality was "Good" in dry season but "Excellent" in wet season.

The GWQI values of groundwater samples valued from 16.8-38.4 and 11.4-48.9 during dry and wet seasons, respectively. The status of water samples during dry and wet season sampling periods based on Mishra and Patel (2001) are presented in Table 5.

The degree of a linear association between any two parameters as measured by Pearson correlation coefficient for both seasons are presented in Table 6 and 7 for dry and wet season, respectively. It was observed that there is very strong association between EC and TDS, carbonate

Table 5: GWQI of sampling locations in dry and wet season

	Dry Season		Wet Season	
Sampling location	GWQI	Status	GWQI	Status
S_1	28.84	Good	34.17	Good
S_2	25.34	Good	35.18	Good
S_3	22.92	Excellent	14.51	Excellent
S_4	26.57	Good	22.45	Excellent
S_5	16.79	Excellent	16.01	Excellent
S_6	34.89	Good	22.41	Excellent
S_7	21.20	Excellent	11.36	Excellent
S_8	17.82	Excellent	16.06	Excellent
S_9	19.83	Excellent	20.12	Excellent
S_{10}	38.43	Good	48.94	Good
Min	16.79		11.36	
Max	38.43		48.94	

Table 6: Correlation coefficient of Ajakanga water samples parameters during dry season

Parameters	pH	EC	TDS	Cl	Bicarbonate	Hardness	Carbonate	SO_4	NO_3	Na	K	Mg	Ca
pH	1												
EC	-0.735*	1											
TDS	-0.736*	1.000**	1										
Cl	-0.255	0.680*	0.678*	1									
Bicarbonate	-0.001	0.282	0.286	0.121	1								
Hardness	-0.687*	0.784**	0.784**	0.165	0.308	1							
Carbonate	-0.001	0.282	0.286	0.121	1.000**	0.308	1						
SO_4	-0.049	0.032	0.029	0.504	-0.256	-0.229	-0.256	1					
NO_3	-0.106	-0.264	-0.266	0.078	-0.271	-0.381	-0.271	0.837**	1				
Na	-0.481	0.640*	0.640*	0.614	0.270	0.226	0.270	-0.004	-0.162	1			
K	-0.124	0.154	0.152	0.422	-0.153	0.079	-0.153	0.569	0.409	-0.076	1		
Mg	-0.425	0.795**	0.796**	0.448	0.289	0.746*	0.289	-0.302	-0.588	0.230	0.170	1	
Ca	-0.656*	0.748*	0.749*	0.148	0.490	0.907**	0.490	-0.376	-0.460	0.421	-0.185	0.642*	1

*'**Correlation is significant at the 0.05 and 0.01 level (2-tailed), respectively

Table 7: Correlation coefficient of Ajakanga water samples parameters during wet season

Parameters	pH	EC	TDS	Cl	CO_3	HCO_3	Hardness	SO_4	NO_3	Na	K	Mg	Ca
pH	1												
EC	0.075	1											
TDS	0.077	1.000**	1										
Cl	-0.321	0.717*	0.729*	1									
CO_3	0.333	0.889**	0.882**	0.344	1								
HCO_3	0.333	0.889**	0.882**	0.344	1.000**	1							
Hardness	0.164	0.379	0.391	0.473	0.338	0.338	1						
SO_4	-0.104	0.738*	0.738*	0.595	0.541	0.541	-0.235	1					
NO_3	-0.376	-0.130	-0.135	-0.020	-0.253	-0.253	-0.704*	0.360	1				
Na	-0.361	0.375	0.387	0.775**	0.055	0.055	0.626	0.069	-0.296	1			
K	0.719*	-0.034	-0.037	-0.238	0.131	0.131	0.036	-0.104	-0.367	-0.020	1		
Mg	0.171	0.961**	0.957**	0.538	0.934**	0.934**	0.243	0.730*	-0.057	0.155	-0.022	1	
Ca	0.277	0.816**	0.809**	0.311	0.840**	0.840**	-0.129	0.836**	0.103	-0.145	0.114	0.887**	1

*'**Correlation is significant at the 0.05 and 0.01 level (2-tailed), respectively

and bicarbonate for both seasons. This buttress the fact that EC depends largely on the quality of the dissolved salts present in the sample.

CONCLUSION

The result of physicochemical parameters of groundwater from hand-dug wells at ten different sampling locations showed that most groundwater samples fall within the standard limit by WHO and NSDWQ. Effect of leachate and agricultural runoff might caused higher concentration of some parameters in wells 1 and 10, respectively. Assessment of GWQI values show their fitness for drinking and consumption purposes as GWQI values during both seasons fall below 100. Water quality Index showed more “Excellent” status in wet season than in dry season.

The highest value of GWQI during both sampling periods were observed at well 10 which might be due to agricultural runoff, leaching of fertilizers and low depth of the well. The high value of GWQI at well 10 has been found to be mainly due to higher concentration values of TH, HCO_3^-, Ca^{2+} Mg^{2+} and TDS.

Based on the results of physicochemical parameters analysis of water samples, the groundwater can be used for drinking and consumption purposes. The analysis of GWQI concludes that the groundwater of the study area fall within the “Excellent” and “Good” category, thus fit to domestic purpose.

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