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Evaluation of Seasonal Variations of Physico-chemical and Bacteriological Quality of Groundwater from a Chemical Industry in Port Harcourt Area, Port Harcourt, Rivers State, Nigeria

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ABSTRACT

Groundwater samples were collected from a chemical industry in Port Harcourt Area of Rivers State, Nigeria in two sampling seasons (Wet and Dry seasons) and were evaluated for Physico-chemical and Bacteriological Quality. Physico-chemical and Bacteriological results of the dry season groundwater samples showed slightly higher concentrations when compared to the wet season ground water samples except for acidity which had higher value of 43.67 ± 1.20 obtained for the wet season samples. Physico-chemical groundwater parameters such as electrical conductivity, acidity, pH, chloride, sodium chloride and silica showed significant seasonal variations ($p<0.05$). Results of the average physico-chemical concentrations of the seasonal groundwater samples were all in compliance with the Nigerian Standard for Drinking Water Quality (NSDWQ) except for pH which had an average seasonal concentration of 4.90 ± 0.17. Average seasonal bacteriological results of the potable groundwater samples indicated the presence of total bacterial concentration of 5.34 ± 0.17/100mg/l which was above the NSDWQ stipulated value of Nil/100mg/l. Based on these findings, it is therefore necessary to properly disinfect the groundwater before human use so as to avoid the risk of contracting water-borne diseases.

Keywords: Groundwater, Pollution, Chemical Industry, Physico-chemical, Bacteriological.

I. INTRODUCTION

The importance of water in a society cannot be overemphasized as water is a limited commodity that is of great significant importance for agricultural purposes, industrial purposes as well as human existence, etc. thus in the absence of quality and adequate water supply the development and sustenance of a country is greatly deterred. Most developing countries are often faced with issues of adequate and quality water supply due to their economy or shortage/absent of advance technology for the treatment of obtainable water which is meant to serve the growing population of these countries thus, the populace have no choice but to resort to the obtainable water whose quality is uncertain (Calamari and Naeve, 1994; Aina and Adedipe, 1996). Insufficiency of Quality water and contamination of clean water has thus brought about situations in which one-fifth of those living in the metropolis in developing countries and three-quarters of those living in rural areas lack access to potable water sources (Lloyd and Helmer, 1992). However, people around the world have used groundwater as a source of drinking water, and even today more than half the world's population depends on groundwater for survival (UNESCO, 1992). The value of groundwater lies not only in its wide spread occurrence and availability but also in its consistent good quality, which makes it an ideal supply of drinking water (UNESCO, 2000).

Intensive use of natural resources and the large production of wastes in modern society often pose a threat to groundwater quality and have already resulted in many incidents of groundwater contaminations. As said by Adeyeye, (2002); "industrial growth is identified as a major tool for economic development in Nigeria". Man in its pursuits to boost his food bank, get uncontaminated water for consumption and reduce damage and injury to his healthiness; the industrial

materials, waste and chemicals supposedly meant for his benefits had become a quiet vanquisher and danger to his life (NEST, 1991).

Contamination of ground water and surface water often repeatedly happens due to escapes, spills and constant release of contaminants from dispensational activities from industries, municipalities, etc (NORAD, 1996). This has consequently resulted to reported cases of water bone diseases which cause health damage to those affected (Ratna and Deepti, 2012). Hence, this research seeks to assess the wet and dry season's physicochemical status of ground water from a chemical industry in Port Harcourt Area, Rivers State of Nigeria, if it meets the minimum requirements set by the Nigerian Standard for Drinking Water Quality (NSDWQ) standard limits and also if the groundwater from the said chemical industry poses any risk to the health of consumers of the groundwater.

II. METHODS AND MATERIAL

2.1 Study Area

This study was conducted in a chemical industry located along East West road, Rumuodara in Port Harcourt Area, Rivers State. The chemical industry produces organic and inorganic chemicals and industrial gases. They are also into the production of chemical products such as pesticides, inks, detergents and cosmetics. The climate of the area is a humid torrential rain type of weather with prolonged and profound rainy seasons and very short dry season. December and January are the only months are eligible for dry season months in the area. Normally, December is often the least rainy month of the year, with average rainfall of 20mm. The heaviest precipitation occurs during September with an average of 367mm of rain. Temperatures all through the year are frequently stable, presenting slight deviation all through the year. On the average, the temperature range is normally between 25^{o}C and 28^{o}C.

2.2 Collection of water samples

Groundwater samples were collected from different locations within the chemical industry in two sampling seasons (July, 2015 in wet/rainy season and December, 2015 in dry season), in pre cleaned plastic bottles from bore hole well head, tank supply, and public pump supply points respectively. Another potable groundwater sample serving as control was also collected from a non-industrial area (Diobu, Port Harcourt, Rivers State).

Before collection of the samples from the public pump supply, the pump was allowed to flow out for about two minutes to avoid any water resident in the pipe being taken as a sample. The piping material can contaminate the water resident in the piping system with the result such water is not a true representative of the potable water source.

The sample from the bore hole well head was not collected from the surface but from inside of the water body so as to avoid possible particles on the surface.

The sample from the tank supply was collected directly from the pipe connected to the overhead reservoir tank after allowing the water to flow out of the pipe for about two minutes. After collection, the groundwater samples were immediately taken to the laboratory for analyses.

2.3 Analysis of water samples

Physicochemical and bacteriological water quality parameters analyzed in accordance to standard methods (APHA (1995), Bartran and balance (1996) were; Appearance, Temperature, Colour, Turbidity, Odour, Taste, Conductivity, Acidity, pH, Chlorides as Cl, Chlorides as NaCl, Total Alkalinity, Total Hardness, Calcium Hardness, Magnesium Hardness, Sulphate, Bicarbonates, Saline & Free Ammonia, Nitrate, Silica, TDS, TSS, Dissolved Free CO_2, Total Iron, Total Bacteria and E. Coli (Coliform). The quality of groundwater has been assessed by comparing the wet season parameters to the dry season parameter, using student t-test, employing the Statistical Package for Social Sciences (SPSS) and comparing each parameter with the standard desirable limit of that parameter in drinking water as prescribed by NSDWQ and WHO.

III. CONCLUSION

Comparative Physical and Bacteriological Results of the Seasonal variations of the Groundwater Samples from the Chemical Industry are summarized and presented on Table 1a. Results of the average concentrations of the Seasonal Physical and Bacteriological Parameters of the Groundwater Samples from the Chemical Industry are summarized and presented on Table 1b. Comparative

Chemical Results of the Seasonal variations of the Groundwater Samples from the Chemical Industry are summarized and presented on Table 2a. Results of the average concentrations of the Seasonal Chemical Parameters of the Groundwater Samples from the Chemical Industry summarized and presented on Table 2b.

3.1 Appearance

The groundwater samples were clear in appearance both in the wet and dry season samples. These appearance results of the groundwater samples were in conformity with the control groundwater sample as well as with the NSDWQ limit value for appearance in drinking water samples.

3.2 Temperature

The temperature values of the groundwater samples for both wet (24.00 ± 0.00 (^{0}C)) and dry (25.00 ± 0.00 (^{0}C) seasons were in agreement with the (25.00 (^{0}C)) value obtained for the control groundwater sample. These results were therefore in compliance with the 25^{0}C value set by NSDWQ. Though, temperature value obtained for the dry season groundwater samples was slightly higher than the value obtained for the wet season samples, this increase was however not significant difference ($p<0.05$).

3.3 Colour

The colour of the groundwater samples were found the same as 5.00 ± 0.00 (HU) for both the wet and dry season samples as well as in the control groundwater sample. These values were all in compliance with the 15 (HU) colour limited set by NSDWQ and are similar to those reported by Ukpong and Okon, (2013).

3.4 Turbidity

Turbidity in most waters is due to the presence of suspended matter such as silts, finely divided organic and inorganic matter, and microscopic organisms which cause light to be scattered and absorbed rather than be transmitted through the samples (APHA, 1995). Turbidity value of the groundwater sample was 0.57 ± 0.00 (NTU) for dry season samples which was slightly higher than the turbidity value of the 0.18 ± 0.00 (NTU) obtained for the wet season groundwater samples. The slight increase was however not significant ($p<0.05$). Though these values obtained for both seasons were higher than the 0.00 (NTU) value obtained for the control groundwater sample, they were however all in compliance with the 5 (NTU) turbidity value set by the NSDWQ.

3.5 Odour

Odour in groundwater samples is indicative of organic or non-organic contaminants that originate from municipal or industrial discharges or from natural sources in the ground water samples (Patherson *el al.,* 1984). Odour of the groundwater samples were nil for both seasons, which was in conformity with the control ground water sample and also in compliance with the nil value set by NSDWQ.

Table 4.1a: Comparative Physical and Bacteriological Results of the Seasonal Variations of the Groundwater Samples from the Chemical Industry.

PARAMETERS	Season		CONTROL	NSDWQ
	Wet	Dry		
Appearance	Clear[a]	Clear[b]	Clear	Clear
Temperature (^{o}C)	24.00 ± 0.00[a]	25.00 ± 0.00[b]	25.00 ± 0.00	25^{o}C
Colour in Hazen Unit	5.00 ± 0.00[a]	5.00 ± 0.00[b]	5.00 ± 0.00	15 Hazen Units
Turbidity in NTU	0.18 ± 0.04[a]	0.57 ± 0.09[b]	0.00 ± 0.00	5 NTU
Odour	Nil[a]	Nil[b]	Nil	Nil

Taste	Unobjectionable[a]	Unobjectionable[b]	unobjectionable	Unobjectionable
TDS Dried at 180°C (mg/l)	10.33 ± 0.67[a]	10.93 ± 0.01[b]	10.28 ± 0.34	500 mg/l
TSS (mg/l)	0.03 ± 0.01[a]	0.06 ± 0.02[b]	0.03 ± 0.00	25 mg/l
Total Bacteria (mg/l)	5.00 ± 0.00[a]	5.67 ± 0.33[b]	2.48 ± 0.20	Nil/100mg/l
E. Coli [Coliform] (mg/l)	0.00 ± 0.00[a]	0.00 ± 0.00[b]	0.00 ± 0.00	Nil/100mg/l

Results presented are Means ± SEM for n = 3. Values in the same row with the same superscript (a) are significantly different at $p<0.05$ level.

Legend:
NSDWQ = Nigerian Standard for Drinking Water Quality

Table 4.1b: Results of the average concentrations of the Seasonal Physical and Bacteriological Parameters of the Groundwater Samples of the Chemical Industry.

PARAMETERS	AVERAGE CONCENTRATION	CONTROL	NSDWQ
Appearance	Clear	Clear	Clear
Temperature (^{0}C)	24.50 ± 0.00	25.00 ± 0.00	25(^{0}C)
Colour in Hazen Unit	5.00 ± 0.00	5.00 ± 0.00	15 Hazen Units
Turbidity in NTU	0.75 ± 0.07	0.00 ± 0.00	5 NTU
Odour	Nil	Nil	Nil
Taste	Unobjectionable	unobjectionable	Unobjectionable
TDS Dried at 180 ^{0}C (mg/l)	10.63 ± 0.34	10.28 ± 0.34	500 mg/l
TSS (mg/l)	0.05 ± 0.02	0.03 ± 0.00	25 mg/l
Total Bacteria (mg/l)	5.34 ± 0.17	2.48 ± 0.20	Nil/100mg/l
E. Coli [Coliform] (mg/l)	0.00 ± 0.00	0.00 ± 0.00	Nil/100mg/l

Legend:

NSDWQ = Nigerian Standard for Drinking Water Quality

Table 4.2a: Comparative Chemical Results of the Seasonal Variations of the Groundwater Samples of the Chemical Industry.

PARAMETERS	Season		CONTROL	NSDWQ
	Wet	Dry		
Conductivity (µS/cm)	69.40 ± 0.34[a]	130.73 ± 0.98[a]	60.97 ± 0.22	1000 µS/cm
Acidity	43.67 ± 1.20[a]	37.67 ± 1.45[a]	35.86 ± 0.09	NS

pH	4.40 ± 0.10^{a}	5.40 ± 0.23^{a}	7.09 ± 0.14	6.5 – 8.5
Chlorides as Cl (mg/l)	3.57 ± 0.24^{a}	6.80 ± 0.00^{a}	5.00 ± 0.44	250 mg/l
Chlorides as NaCl (mg/l)	5.20 ± 0.11^{a}	8.63 ± 0.03^{a}	4.98 ± 0.35	250 mg/l
Total Alkalinity (mg/l)	9.67 ± 0.33^{a}	9.83 ± 0.17^{b}	10.05 ± 0.53	NS
Total Hardness (mg/l)	11.67 ± 0.33^{a}	12.50 ± 0.29^{b}	10.20 ± 0.05	150 mg/l
Calcium Hardness (mg/l)	8.00 ± 0.58^{a}	8.67 ± 0.33^{b}	5.95 ± 0.19	NS
Magnesium Hardness (mg/l)	3.67 ± 0.67^{a}	3.88 ± 0.60^{b}	3.00 ± 0.21	20 mg/l
Sulphates as SO_4^{2-} (mg/l)	0.07 ± 0.00^{a}	0.08 ± 0.00^{b}	0.00 ± 0.00	100 mg/l
Bicarbonates as HCO_3 (mg/l)	9.67 ± 0.33^{a}	9.83 ± 0.17^{b}	10.02 ± 0.72	NS
Saline & Free Ammonia (mg/l)	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00	0.05 mg/l
Nitrate (mg/l)	0.17 ± 0.11^{a}	0.02 ± 0.00^{b}	0.01 ± 0.00	50 mg/l
Silica as SiO_2 (mg/l)	0.02 ± 0.00^{a}	0.04 ± 0.00^{b}	0.00 ± 0.00	NS
Dissolved Free CO_2 (mg/l)	30.33 ± 0.88^{a}	31.33 ± 0.87^{b}	32.50 ± 0.038	NS
Total Iron as Fe (mg/l)	0.00 ± 0.00^{a}	0.00 ± 0.00^{b}	0.00 ± 0.00	0.3 mg/l

Results presented are Means ± SEM for n = 3. Values in the same row with the same superscript (a) are significantly different at $p<0.05$ level.

Legend:

NS = Not Stated.
NSDWQ = Nigerian Standard for Drinking Water Quality

Table 4.2b: Results of the average concentrations of the Seasonal Chemical Parameters of the Groundwater Samples of the Chemical Industry.

PARAMETERS	**AVERAGE CONCENTRATION**	**CONTROL**	**NSDWQ**
Conductivity (µS/cm)	100.07 ± 0.66	60.97±0.22	1000 µS/cm
Acidity	60.67 ± 1.33	35.86±0.09	NS
pH	4.90 ± 0.17	7.09±0.14	6.5 – 8.5
Chlorides as Cl (mg/l)	5.19 ± 0.24	5.00±0.44	250 mg/l
Chlorides as NaCl (mg/l)	6.92 ± 0.07	4.98±0.35	250 mg/l
Total Alkalinity (mg/l)	9.75 ± 0.25	10.05±0.53	NS
Total Hardness (mg/l)	12.09 ± 0.31	10.20±0.05	150 mg/l
Calcium Hardness (mg/l)	8.34 ± 0.46	5.95±0.19	NS
Magnesium Hardness (mg/l)	3.78 ± 0.64	3.00±0.21	20 mg/l
Sulphates as SO_4^{2-} (mg/l)	0.08 ± 0.00	0.00±0.00	100 mg/l

Bicarbonates as HCO_3 (mg/l)	9.75 ± 0.25	10.02±0.72	NS
Saline & Free Ammonia (mg/l)	0.00 ± 0.00	0.00±0.00	0.05 mg/l
Nitrate (mg/l)	0.10 ± 0.06	0.01±0.00	50 mg/l
Silica as SiO_2 (mg/l)	0.03 ± 0.00	0.00±0.00	NS
Dissolved Free CO_2 (mg/l)	30.83 ± 0.87	32.50±0.038	NS
Total Iron as Fe (mg/l)	0.00 ± 0.00	0.00±0.00	0.3 mg/l

Legend:

NSDWQ = Nigerian Standard for Drinking Water Quality
NS = Not Stated.

3.6 Taste

There was no seasonal variation in taste parameter of the groundwater samples. The tastes of the groundwater samples for both seasons were unobjectionable which was in agreement with the unobjectionable taste vale of the control groundwater sample as well as with the unobjectionable taste value set by NSDWQ. Yadav *et al.,* (2012) also reported similar result.

3.7 Total Dissolved Solids (TDS)

Total dissolve solid (TDS) values of the groundwater samples were all in compliance with the 500mg/l TDS limit value set by NSDWQ. The TDS value 10.93± 0.01 (mg/l) obtained for the dry season groundwater samples was slightly higher but not significantly higher than the 10.33 ± 0.67 (mg/l) TDS value obtained for the wet season groundwater samples.

3.8 Total Suspended Solids (TSS)

Total suspended solids (TSS) value of 0.06±0.02 (mg/l) obtained for the dry season groundwater samples was slightly higher, though not significantly higher than the TSS value of 0.03 ± 0.01 (mg/l) obtained for the wet season groundwater samples. These values were in conformity with the TSS value of 0.03 (mg/l) obtained for the control groundwater sample and also in compliance with the 25(mg/L) TSS value set by NSDWQ. TSS are a significant factor in observing water clearity, the more solids presence in the water the less clear the water will be (Langland and Crown, 2003).

3.9 Total Bacteria

Total bacteria value of 5.67 ± 0.33/(100mg/l) obtained for the dry season groundwater samples was slightly higher, though not significantly higher than the total bacteria value of 5.00 ± 0.00/(100mg/l) obtained for the wet season groundwater samples. These value were higher than the total bacteria value of 2.48/(100mg/L) obtained for the control groundwater sample. The NSDWQ limit value for total bacteria in drinking water is nil/100mg/L, thus, the total bacteria results of the groundwater were not in compliance with NSDWQ limit.

3.10 E.coli

E.coli (Coliform) was absent in all the groundwater samples, which therefore indicates compliance with the Nil/100mg/l *E.coli* value set by NSDWQ. The presence of *E.coli* in water samples is of great concern, as it implies faecal contamination which may pose a health problem (Pipes and Christian, 1984).

3.11 Electrical Conductivity (EC)

The electrical conductivity (EC) result of the dry season groundwater samples was 130.73± 0.98 (µS/cm), which was significantly higher than the EC value of 69.40± 0.34 (µS/cm) obtained for the wet season groundwater samples. Though these values were higher than the EC value of 60.97 (µS/cm) obtained for the control groundwater sample, they were all in agreement with the EC value of 1000 (µS/cm) set by NSDWQ. Ukpong and Okon, (2013) obtained EC range of 89.18 - 103 (µS/cm) for public bore hole water, in their studies of comparatives analysis of public and private bore hole

water supply sources in Uruan, Akwa Ibom State of Nigeria.

3.12 Acidity

Acidity value obtained for the wet season groundwater samples was 43.67 ± 1.20, which was significantly higher than the 37.67± 1.45 acidity value obtained for the dry season groundwater samples. These values were higher than the 35.86 acidity value obtained for the control groundwater sample. Acidity limit value was not stated by NSDWQ.

3.13 pH

The pH value obtained for the wet season groundwater samples was 4.40 ± 0.10 which was significantly more acidic than the 5.40 ± 0.23 pH value obtained for the dry season groundwater samples. These results did not comply with the 7.00 pH value obtained for the control groundwater sample as well as with the 6.5-8.5 pH limit range set by NSDWQ. Agbalagba *et al.,* (2011) and Nwala *et al.,* (2007) also reported similar values in the Niger Delta region of Nigeria.

3.14 Chloride (Cl^-)

The chloride value of 6.80 ± 0.00 (mg/l) obtained for the dry season groundwater was significantly higher than the 5.20 ± 0.11 (mg/l) value obtained for the set season samples. These values though higher than the control groundwater sample, were all in compliance with the 250 (mg/l) limit value set by NSDWQ for chloride in drinking water. These values were also within the range values reported by Nwala, (2007) and Agbalagba *et al.,* (2011).

Chloride usually occurs as NaCl, $CaCl_2$ and MgCl in widely varying concentration, in all natural waters. They may enter water from polluting materials like sewage and trade wastes (Shaikh and Mandre, 2009). NaCl result of the dry season groundwater samples of 8.63 ± 0.03 (mg/l) was significantly higher than the 5.20 ± 0.11 (mg/l) obtained for the wet season groundwater samples. Though, these values were higher than the 4.98 (mg/l) NaCl value obtained for the control groundwater, they were however in conformity with the 250 (mg/l) NaCl value limit set by NSDWQ.

3.15 Alkalinity

Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate and hydroxide compounds of calcium, sodium and potassium (Pandey *et al.,* 2012). Total alkalinity values of the ground water samples were 9.67± 0.33 (mg/l) for wet season samples and 9.83 ± 0.17 (mg/l) for dry season samples. There was no significant difference ($p<0.05$) between the wet and dry season total alkalinity values. Though, NSDWQ alkalinity value was not stated, these values were however in compliance with the 10.05 (mg/l) total alkalinity value obtained for the control groundwater sample.

3.16 Total Hardness

The total hardness value of 12.50 ± 0.29 (mg/l) obtained for the dry season groundwater samples was slightly higher, though not significantly higher than the 11.67 ± 0.33 (mg/l) total hardness value obtained for the wet season groundwater samples. Though, these values were slightly higher than the 6.62 (mg/l) value obtained for the control groundwater sample, they were however in compliance with the 150 (mg/l) total hardness value set by NSDWQ. Ukpong and Okon (2013) reported total hardness range of 12-26 (mg/l).

3.17 Calcium Hardness

Calcium hardness values of 8.00 ± 0.67 (mg/l) and 8.67 ± 0.33 (mg/l) obtained respectively for wet and dry season water sample were not significantly difference ($p<0.05$). Though the NSDWQ for calcium hardness was not stated, these values were higher than the 5.95 (mg/l) calcium hardness value obtained for the control groundwater samples.

3.18 Magnesium Hardness

Results of magnesium hardness of the groundwater samples were 3.67 ± 0.67 (mg/l) for wet season samples and 3.88 ± 0.60 (mg/l) for dry season samples. These results did not indicate significant difference at ($p<0.05$). These results though higher than the 3.00 (mg/l) value obtained for the control groundwater sample, were all in compliance with the 20 (mg/l) magnesium hardness value set by NSDWQ.

3.19 Sulphate (SO_4)

Sulphate value of the groundwater samples was 0.08 ± 0.00 (mg/l) for the dry season samples, which was slightly higher but not significantly higher than the 0.07 ± 0.00 (mg/l) value obtained for the wet season samples. Sulphate was not detected in the control groundwater sample. These values were in conformity with the 100 (mg/l) sulphate limit value set by NSDWQ. Ukpong and Okon, (2013) reported sulphate value range of 0.38-2.64 (mg/l).

3.20 Bicarbonate (HCO_3^-)

The presence of bicarbonate in water contributes to water total alkalinity concentration (Pandey *et al.,* 2012). Bicarbonate value of the groundwater samples were 9.83 ± 0.17 (mg/l) for the dry season samples which was slightly higher, though not significantly higher than the 9.67 ± 0.33 (mg/l) value obtained for the wet season samples. Bicarbonate value for NSDWQ was not stated, however, these values were in conformity with the 10.02 (mg/l) bicarbonate value obtained for the control groundwater sample.

3.21 Saline and Free ammonia

Saline and free ammonia occurs in water supply as a result of microbiological reduction and can also indicate sewage pollution (Dieter and Moller, 1991). Saline and free ammonia were not detected in all the ground samples. These results were therefore in compliance with the 0.05 (mg/l) Limit value set by NSDWQ for saline and free ammonia in potable water samples.

3.22 Nitrate (NO_3)

The nitrate value of 0.17 ± 0.11 (mg/l) obtained for the wet season groundwater samples was slightly higher but, not significantly higher than the 0.02 ± 0.00 (mg/l) nitrate value obtained for the dry season groundwater samples. These values, though, higher than the 0.01 (mg/l) nitrate value obtained for the control groundwater sample, were all in agreement with the 50 (mg/L) limit value set by NSDWQ for nitrate in drinking waters. Ukpong and Okon, (2013) also reported similar nitrate values.

3.23 Silica

Silica results revealed 0.04 ± 0.00 (mg/l) for the dry season groundwater samples and 0.02 ± 0.00 (mg/l) for the wet season groundwater samples. These values did not show significant difference ($p<0.05$). Silica Limit value was not stated by the NSDWQ. However, these values were slightly higher than the 0.00 (mg/l) silica value obtained for the control groundwater samples.

3.24 Dissolved Free Carbon Dioxide (CO_2)

The dissolved free CO_2 values of the groundwater samples were 30.33 ± 0.88 (mg/l) for wet season and 31.33 ± 0.87 (mg/l) for dry season. These values were not significantly different ($p<0.05$). Though the dissolved free CO_2 limit value was not stated by NSDWQ, these values were slightly higher than the 32.50 (mg/l) dissolved free CO_2 value obtained for the control ground water sample. Decomposition of organic matter by microbes leads to formation of CO_2 in water, which increases the concentration of carbonate and bicarbonate, increasing the level of alkalinity in groundwater (Vyas *et al.,* 2008).

3.25 Total Iron (Fe)

The concentration of total iron in all the groundwater samples were at a not detectable level which were in compliance with the 0.3 (mg/l) limit value set by NSDQ for total iron in drinking waters.

IV.CONCLUSION

The results from this study are supportive with the conclusion that, the physicochemical parameters had higher values during the dry season which could be attributed to increased industrial activities carried out by the chemical industry during the dry season and also by the fact that during the wet season, run off by rain water washes off most of the pollutants from the chemical industry. Average physicochemical concentrations of the seasonal ground water samples of the chemical industry were all in compliance with the standards set by NSDWQ except for pH which had an average seasonal concentration of 4.90 ± 0.17 which was not in compliance with the 6.5 - 8.5 pH limit value set by NSDWQ. pH however does not have any direct adverse effect on human health. On the other hand,

bacteriological results of the groundwater samples indicated the presence of total bacterial concentration of 5.34 ± 0.17/(100mg/l) which was above the NSDWQ stipulated value of Nil/(100mg/l). Based on this result, the groundwater poses human health risk to the consumers. It is therefore necessary to disinfect the groundwater before human use so as to avoid the risk of contracting water-borne diseases.

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