American Journal of Sciences and Engineering Research

E-ISSN -2348 – 703X, Volume 7, Issue 6, 2024

Spatial and Seasonal Effects of Landfill on Some Physico-Chemical Properties and Heavy Metals of Groundwater, Yenagoa, Nigeria

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ABSTRACT: *Seasonal effects of ground water pollution from dumpsites has recently become a global concern because of the increasing wastes generated coupled with the inadequate management strategies. This study is concerned with the evaluation of seasonal variation of ground water contamination by leachate from uncontrolled landfill in Bayelsa State, Nigeria. Seven ground water samples (PT 1 – PT 7) were collected radially from the central reference point (PT 1) from drilled boreholes across the study area. Parameters analyzed were, pH, EC, TDS, COD, BOD, TH, NH_4^+, SO_4^{2-}, NO_3^-, Phosphate, Cd, Cr, Cu^{2+}, Pb, Zn, Ca^{2+}, Mg^{2+}, Na^+, Fe^{2+}, and K^+, using standard methods. The concentration of these parameters were compared with WHO to ascertain their levels of concentration. The samples taken throughout the study for both seasons were somewhat acidic. Most parameters were lower in the December, 2019 sampling regime as compared to the March, 2019 sampling period. However, concentrations of Iron, Magnesium and Potassium were higher in the December, 2019 sampling regime. All the heavy metals sampled in this study were below equipment detectable limits for the two sampling regimes and all the sampling points. Point PT 1 had the highest concentration of parameters followed by PT 2, which is an indication of the flow pattern of pollutants towards PT 2. As a consequence of this analysis, it can be concluded that heavy metals influence in ground water across the investigated areas was negligible, possibly due to geology or the types of waste disposed. It was finally observed that there were temporal and spatial variation of parameters in the study. It is recommended that a proper scientific monitoring program be initiated and implemented for water quality monitoring in the study area to be observed across temporal and spatial scales.*

Keywords: *Groundwater, Seasonal, Spatial, Pollution, Landfill*

I. INTRODUCTION

Water serves as one of the most important resource for the maintenance of life. The need for water for many purposes includes drinking, irrigation, and industrial purposes etc, is rising locally and globally. This is due largely to our inability to do without it as well as the ongoing expansion in population, increasing urbanization with the lifestyle shift, and growing industrialization (Sharma et al., 2014). There are different sources of water, which includes air, surface and ground water. With growing populations, changing weather patterns, and increasing pollution of surface water sources, countries across the world are relying more and more on scarce groundwater supplies for homes, agricultural and industrial requirements (Adebola et al., 2021). However, due to human development pressures, this valuable source of water is prone to pollution, particularly from sources close to uncontrolled landfills (International Water Management Institute, 2006).

 Received-14-09-2024, Accepted- 25-10-2024

Groundwater is that fraction of the total available water that is trapped in the pore spaces and cracks of rocks and sediments under the earth's surface. It originates as rainfall or snow and then becomes penetrated or percolated into the ground surface, but still makes its way back to surface streams, lakes, or seas etc (Han, 2014). According to Christiana and Amobichukwu, (2014), groundwater has become a significant source of drinking water worldwide, especially in underdeveloped/developing nations. This is partially because groundwater is assumed to be free of the viruses widely present in surface waters (Amini, 2011).

The concentration of pollutants in the groundwater can also be changed by seasonality. Seasonal fluctuations in rainfall, temperature, and other environmental conditions can influence the transit and distribution of pollutants in groundwater (Allison et al., 2018; Frank et al., 2022]. However, there is minimal evidence on the seasonal fluctuations in groundwater contamination by physico-chemical parameters and heavy metals at Yenagoa, Bayelsa State. There is a need therefore, for extensive research to analyze the seasonal fluctuations in groundwater contamination and the accompanying threats to human health and the ecology.

II. MATERIALS AND METHODS

2.1 Sample collection

An array of activities within the landfill as captured by the scholar is presented as shown in Figure 1.0 below. Plate 1 shows a pictorial view of the landfill, while Plate 2 shows a progressive and active drilling of the central borehole point (PT 1). Plate 3 shows an active sample collection process within the study, while plates 4, 5 and 6 shows some of the drilled boreholes of points 1, 2 and 7 respectively, which were among a total number of seven boreholes drilled for this study.

Figure 1.0: An Array of Activities within the Dumpsite Showing Active Drilling and some Drilled Boreholes

2.2 SAMPLING DESIGN

A total of seven boreholes with average depths of 40 meters of basement formation were drilled and groundwater samples taken in and around a 550m radius of the municipal solid waste (MSW) landfill. In this study, points 1 through 7 were labeled Pt 1 - Pt 7. Figure 2.0 below shows the sample collection pattern within the study area.

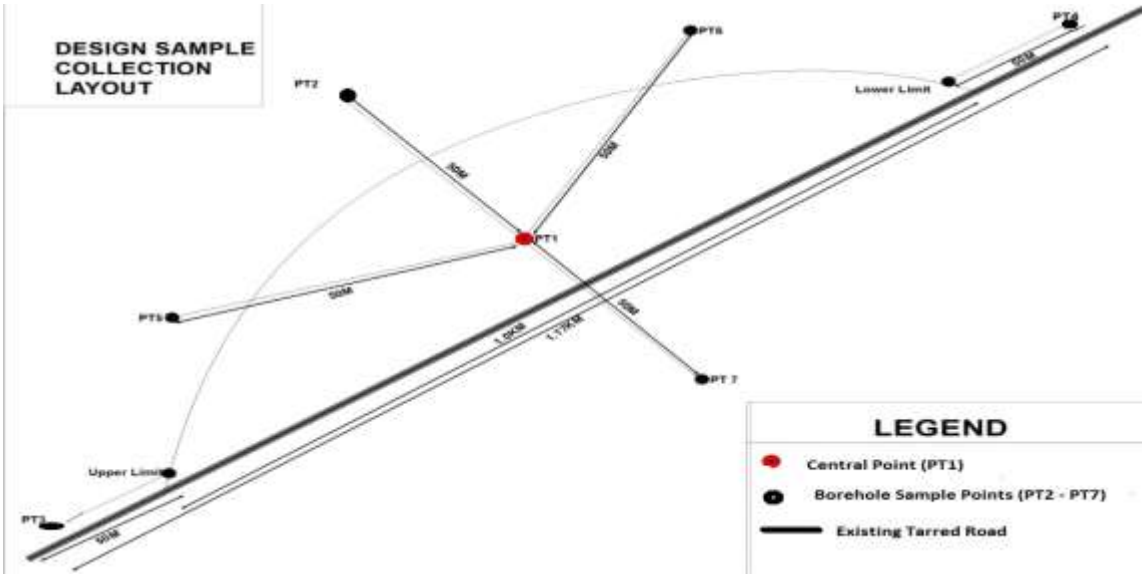


Figure 2.0: A Schematic Diagram Showing Sampling Design

A total of six black dots were used to identify the sapling points, with a red dot indicating the seventh point, which is the central point (PT1).

To analyze the direction of leachate (pollutant) transport via pollutant concentrations, the central point was utilized as a reference to points Pt 2, Pt 5, Pt 6, and Pt 7, which were between 50m - 800m radially from the center as shown in Figure 2.0 above. Points Pt 3 and Pt 4 were 50 meters from the northernmost and southernmost ends of the landfill respectively. The samples were taken with the help of clean 1.5L plastic bottles and preserved using standard methods.

Table 1.0:Details of Sampling Sites

S/N	SAMPLING LOCATIONS	COORDINATES		DESCRIPTION
		LATITUDE (N)	LONGITUDE (E)	
1.	POINT 1	$4^0$59'40.79328"	$6^0$19'56.01864"	Central Borehole
2.	POINT 2	4° 59' 40.19"	6° 19' 58.32"	60m from Center of Dump Site
3.	POINT 3	4° 59' 58.94"	6° 20' 12.01"	Northernmost Borehole (50m from edge of Dumpsite)
4.	POINT 4	4° 59' 27.68064"	6° 19' 43.92804"	Southernmost Borehole (50m from edge of Dumpsite)
5.	POINT 5	4° 59' 41.39"	6° 19' 58.40"	70m From Center of Dump Site
6.	POINT 6	4° 59' 38.41"	6° 19' 56.59"	80m from Center of Dump Site
7.	POINT 7	4° 59' 41.78"	6° 19' 54.87"	51 m from the Center of Dump, Farmland across the Road

A handheld GPS was used to collect the data of the sampling points as shown in Table 1.0 above. The water quality parameters analyzed were physico-chemical and heavy metals (Rakh, *et al.*, 2011). Samples analyzed in accordance with standard laboratory methods (NSDWD, 2015), were; pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Hardness (TH), Ammonium (NH_4^+), Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Phosphate and Heavy Metals such as Cadmium (Cd), Chromium (Cr), Copper (Cu^{2+}), Lead (Pb), Zinc (Zn), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^+), Iron (Fe^{2+}) and Potassium (K^+) ions.

III. RESULT AND DISCUSSIONS

In this study, a total of seven ground water samples were taken for laboratory analysis. The samples were analyzed for, Physico-chemical characteristics, and heavy metals. The variations of parameters from sampling points PT 1 – PT 7 as compared with World Health Organization (WHO) (WHO, 2011) are shown in Table 2.0 below.

Table 2.0: Summary of Physico-Chemical Properties and Heavy metals of Ground Water During the March 2019 Analytical Regime

Sample ID	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	MEAN	WHO GUIDELINES (2011)
pH	6.91	6.33	6.58	6.44	6.49	6.44	6.49	6.53	6.5-8.5
Temperature	21.4	21.8	22	21.9	22.2	21.1	21.9	21.76	25
Conductivity	821	217	100.9	69.7	115.7	105.4	93.2	217.56	1000
TDS	410.5	109	50.45	48.35	77.85	75.2	46.6	116.85	500
SO^{2-}_4	18	27	1	16	1	1	1	9.29	500
NO_3	0.2	16.2	0.1	0.3	0.1	0.1	0.2	2.46	50
PO^{3-}_4	1.12	0.4	0.72	0.8	0.56	1.07	1.25	0.85	0.1
NH_4	0.045	3.66	0.022	0.068	0.022	0.022	0.045	0.56	NA
Alkalinity	187.8	45.5	28.5	28.5	39.83	45.5	28.5	57.73	200
BOD	14	16	14	14	10	16	12	13.71	5
COD	23	24	23	23	21	25	21	22.86	10
Hardness	110	76	42	28	42	42	220	80	200
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Cu	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2
Zn	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	3
Fe	4.43	1.03	0.12	0.38	1.1	0.14	0.17	1.05	0.3
Ca	1.98	0.34	<0.001	<0.001	0.29	0.07	<0.001	0.67	75
Mg	5.51	3.12	0.96	0.91	1.84	1.74	1.14	2.17	20
K	9.01	0.95	1.06	0.42	1.04	0.73	0.7	1.99	20
Na	37.46	8.22	9.02	5.81	6.92	6.88	7.76	11.72	200
Cd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Cr	<0.001	<0.001	<0.001	<0.001	<0.001	0.26	<0.001	0.26	0.05

NB: All parameters are in mg/l except Temp., EC and Total plate count. ^0C, µS/cm and cfu/ml.

Table 3.0: Summary of Physico-Chemical Properties and Heavy metals of Ground Water During the December 2019 Analytical Regime

Sample ID	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	MEAN	WHO GUIDELINES (2011)
pH	5.56	6.58	6.13	6.4	5.82	6.17	6.11	6.5-8.5
Temperature	23.5	23.9	23.7	24.2	24.1	23.6	23.83	25
Conductivity	144	82.4	69.8	50.5	68.3	72.5	81.25	1000
TDS	70.9	41.1	34.9	25.2	34	36.2	40.38	500
SO^{2-}_4	14	1	2	1	1	1	3.33	500
NO_3	1.8	2	1.1	0.2	1.8	2	1.48	50
PO^{3-}_4	0.24	0.09	0.64	0.64	0.36	0.7	0.45	0.1
NH_4	0.407	0.452	0.249	0.045	0.407	0.452	0.34	NA
Alkalinity	140	100	90	30	90	90	90	200
BOD	15	16	14	12	10	12	13.17	5
COD	19	21	18	21	20	18	19.5	10
Hardness	130	70	48	164	50	330	132	200
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Cu	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2
Zn	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	3
Fe	<0.001	<0.001	0.746	1.642	1.412	1.618	1.3545	0.3
Ca	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	75
Mg	9.394	1.75	1.831	4.925	3.812	2.37	4.01	20
K	3.35	5.233	1.95	1.998	2.94	3.35	3.14	20
Na	3.609	7.594	4.252	5.112	0.112	0.401	3.51	200
Cd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Cr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.05

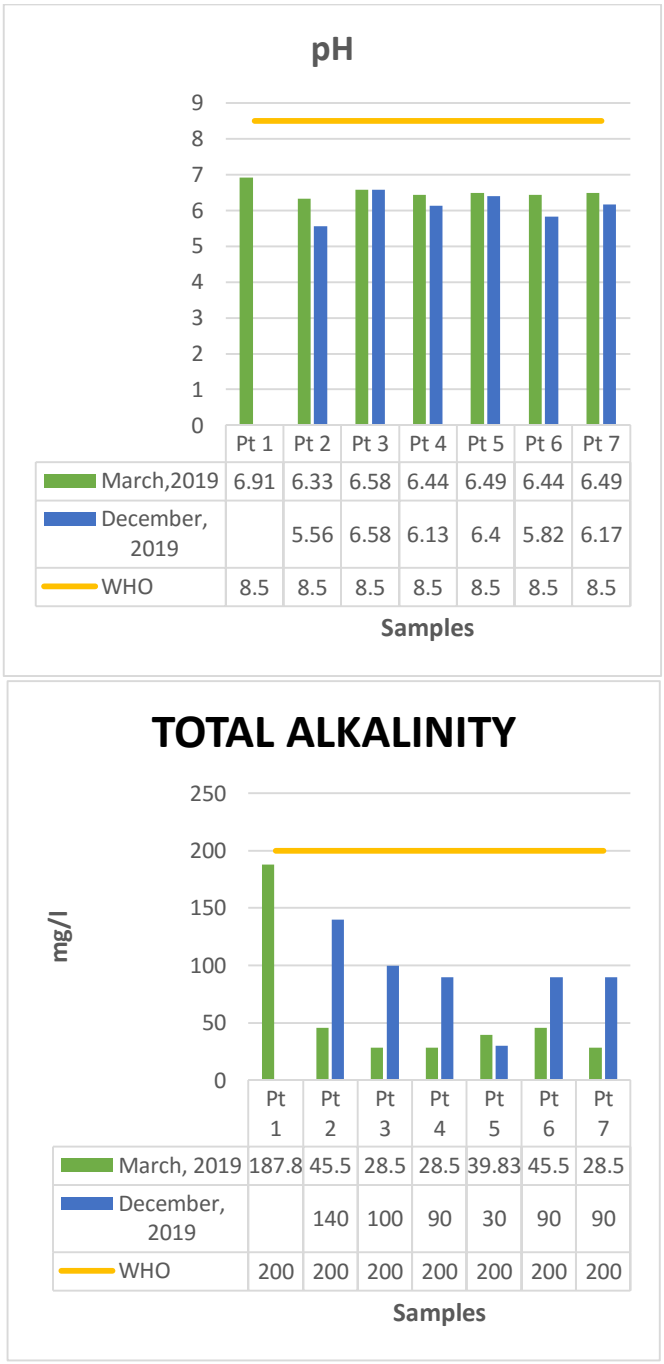


Figure 3.0: Ground Water pH & Total Alkalinity Spacio-temporal Variations

pH changes were seen across all the groundwater samples analyzed as indicated in Figure 3.0. The pH values of the samples collected in March, 2019 ranged from 6.33 at PT 2 to 6.91 at PT 1 (middle of the dump site), whereas those collected in December, 2019 showed values that ranged from 5.56 at PT 2 to 6.58 at PT 6. It was also revealed that roughly 75% of the samples collected in March 2019 had pH values that were higher than those obtained in December 2019. The average pH values of the March 2019 analysis (6.5) was likewise greater than that of the December, 2019 analysis (6.1). These pH levels were low when compared to the WHO recommended pH range for drinking water (6.5-8.5). Approximately 75% of samples taken in March 2019 and nearly 85% of samples collected in December 2019 were below the permissible limit, indicating that the bulk of the samples were moderately acidic.

All samples studied were found to have very high Total Alkalinity (TA) levels that varied widely. Samples taken in March, 2019 had values ranging from 28.5 mg/l at PT 3, PT 4 and PT 7 to 187.8 mg/l at PT 1, while those

collected in December, 2019 had values that fell between 30 mg/l at PT 5 and 140 mg/l at PT 2. There were considerable temporal discrepancies between the two sets of samples. The TA values of over 75% of the samples tested in December 2019 were greater than those collected in March 2019.

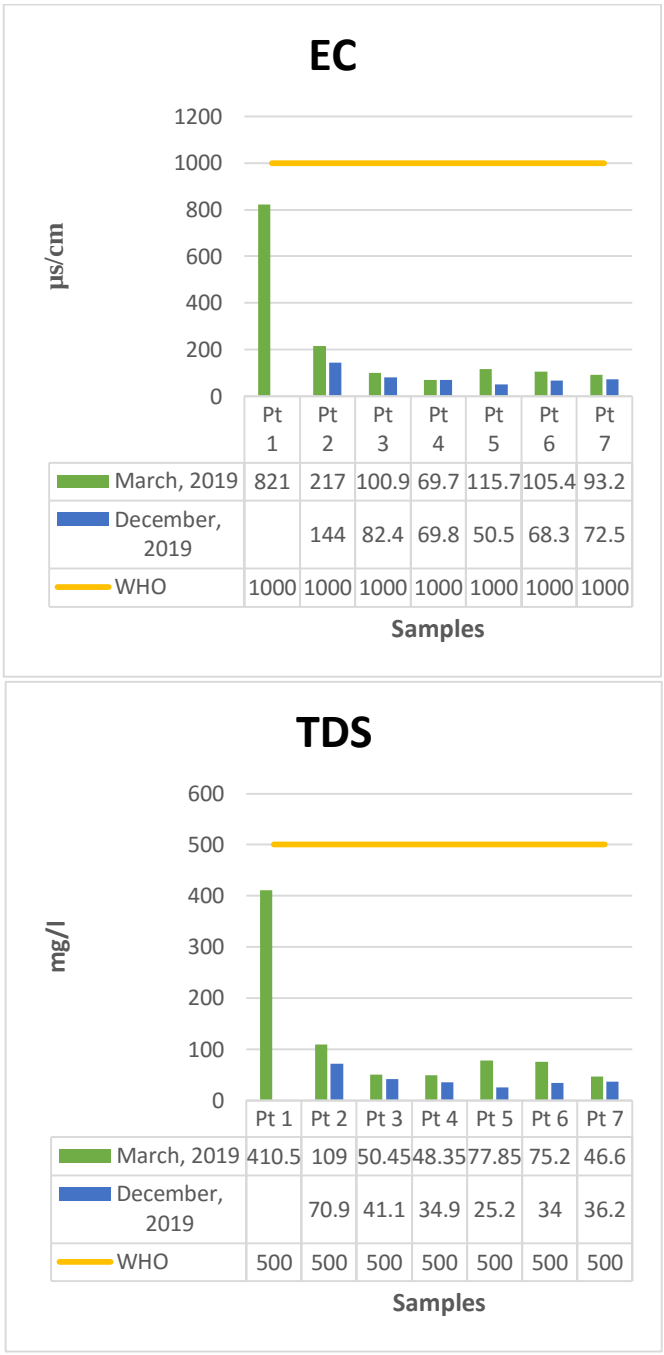


Figure 4.0: Ground Water Electrical Conductivity & TDS Spacio-temporal Variations

The March, 2019 samples showed EC values that ranged from 69.7 µS/cm at PT 4 to 821 µS/cm at PT 1, whereas those collected in December, 2019 had values that ranged from 50.5 µS/cm at PT 5, to 144 µS/cm at PT 2. Nearly 87.5% of samples collected in March, 2019 had EC values comparably higher than those collected in December, 2019. However, the levels of EC across the seasons and samples indicated comparatively lower values than the WHO criteria.

Low TDS values were observed generally as indicated in Figure 4.0. However, samples collected in March, 2019 exhibited concentrations higher than those collected in December, 2019. Samples taken in March, 2019 varied from 46.6 mg/l at PT 7 to 410.5 mg/l at PT 1, whereas those collected in December, 2019 showed values ranging

from 25.2 mg/l at PT 5 to 70.9 mg/l at PT 2. TDS readings were found to be larger in the samples acquired in March 2019 than in the samples taken in December 2019. As a result, it can be inferred that samples taken during the March 2019 sampling regime had more mineralization than those collected during the December 2019 survey regime. There was a general trend detected while examining EC and TDS, revealing the association they have. An increase in TDS, increases the Electrical Conductivity of the samples, this is clearly illustrated in Fig. 4.0.

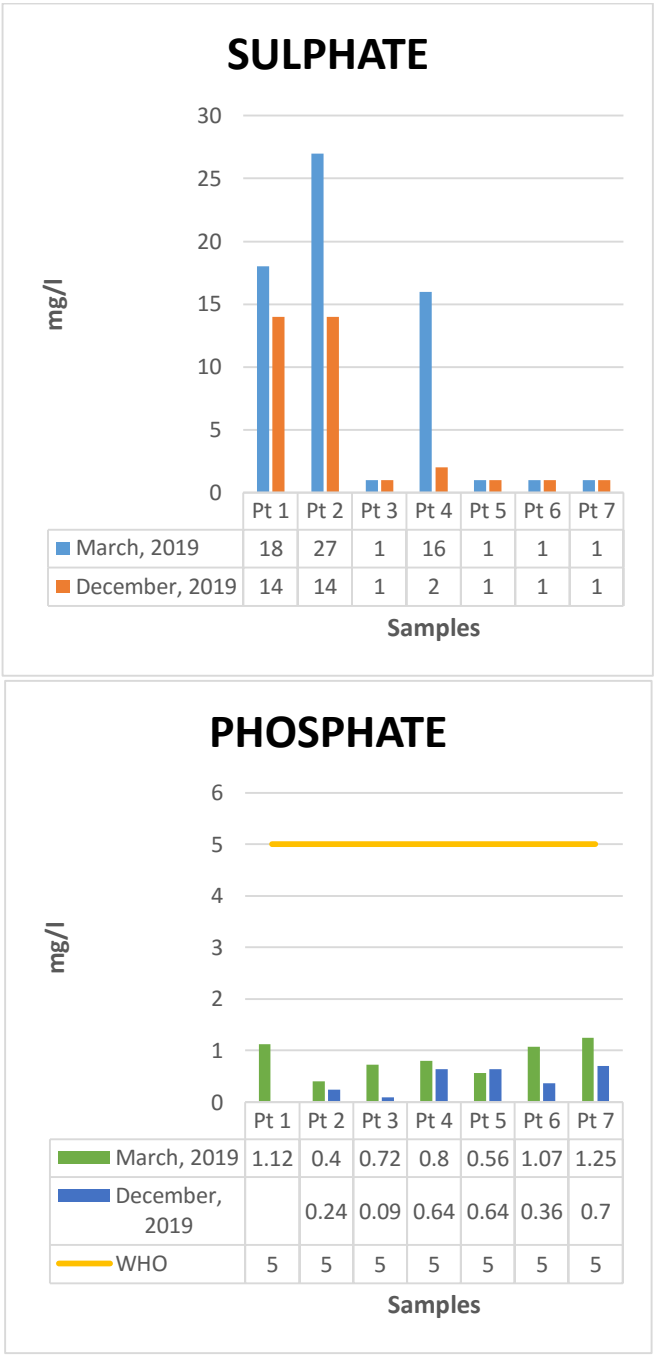


Figure 5.0: Ground Water Sulphate & Phosphate Spacio-temporal Variations

Sulphate variations are given in Figures 5.0 above. The concentrations for samples collected in March, 2019 ranged from 1 mg/l at PT 3, PT 5, PT 6 and PT 7 respectively to 27 mg/l at PT 2, while those collected in December, 2019 had concentrations that ranged from 1 mg/l again at PT 3, PT 5, PT 6 and PT 7 to 17 mg/l at PT 1 and PT 2, however, all the examined samples in both seasons were well below the threshold for WHO (100 mg/l).

Observations showed that, sulphate concentrations in samples taken in March, 2019 were considerably higher than those collected in December, 2019 in roughly 50% of the samples.

Phosphate contents were found to be very low and varied among the studied groundwater samples reported in Figures 5.0 above. The values varied from 0.4 mg/l at PT 2 to 1.25 mg/l at PT 7 for samples collected in March, 2019, and from 0.09 mg/l at PT 3 to 0.7 mg/l at PT 7 for samples collected in December, 2019. About 100% of the samples taken in March, 2019 indicated a substantial rise in phosphate concentrations compared with samples collected in December, 2019. Almost all samples (90%) obtained across seasons and locales showed phosphate concentrations in the study were considerably below the WHO criteria.

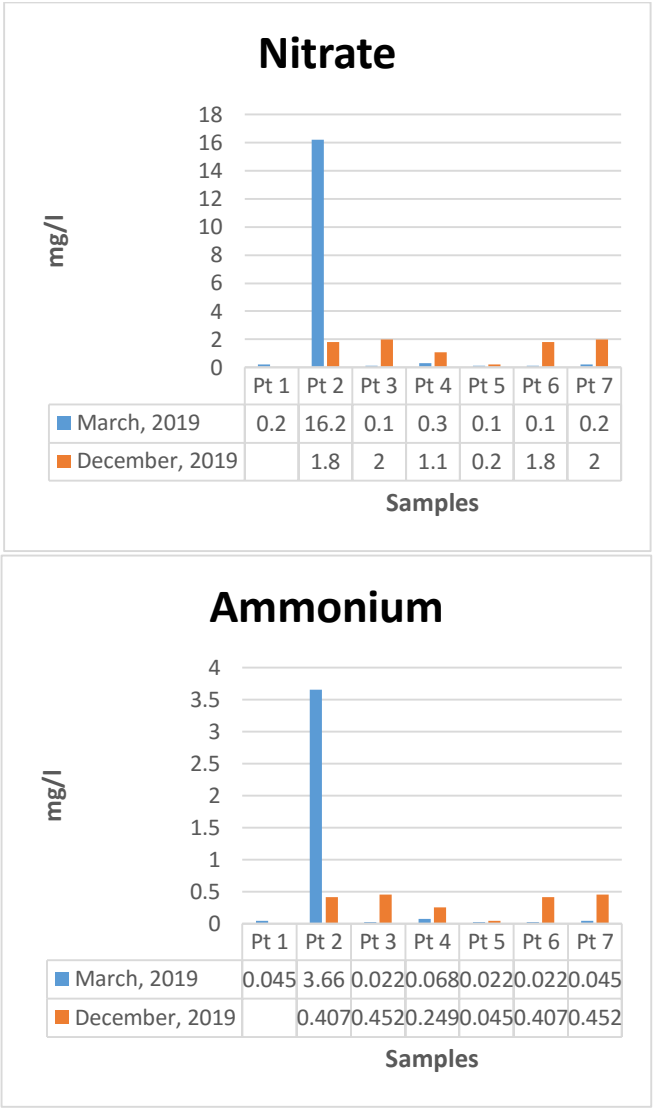


Figure 6.0: Ground Water Nitrate & Ammonium Spacio-temporal Variations

Nitrate contents were determined to be impressively low although varied across the tested groundwater samples depicted in Figures 6.0. The concentrations varied from 0.1 mg/l at PT 3, PT 5, and PT 6 to 16.2 mg/l at PT 2 for samples collected in March, 2019, and from 0.2 mg/l at PT 5 to 2 mg/l at PT 3 and PT 7 for samples collected in December, 2019. About 87.5% of the samples taken in December, 2019 revealed a substantial rise in nitrate concentrations compared with samples collected in March, 2019. Although the samples collected in March, 2019 at PT 2 revealed the highest concentration for all the stations and seasons, the nitrate concentrations generally in the research were significantly below the WHO criteria.

As shown above, ammonium contents were determined to be impressively low yet varied among the groundwater samples studied. The values varied from as low as 0.002 mg/l at PT 3, PT 5, and PT 6 to 3.66 mg/l at PT 2 for samples taken in March, 2019, just as Nitrate in Figure 6.0. While the December samples varied from

0.045 mg/l at PT 5 to 0.452 mg/l at PT 3 and PT 7. In comparison to March 2019, over 75% of the tests obtained in December 2019 exhibited a large rise in Ammonium concentrations. In the study, however, all samples taken across seasons and locales demonstrated extremely low levels of ammonium contents. Again, the occurrence of Nitrate and Ammonium revealed similar trends as depicted in Figure 6.0.

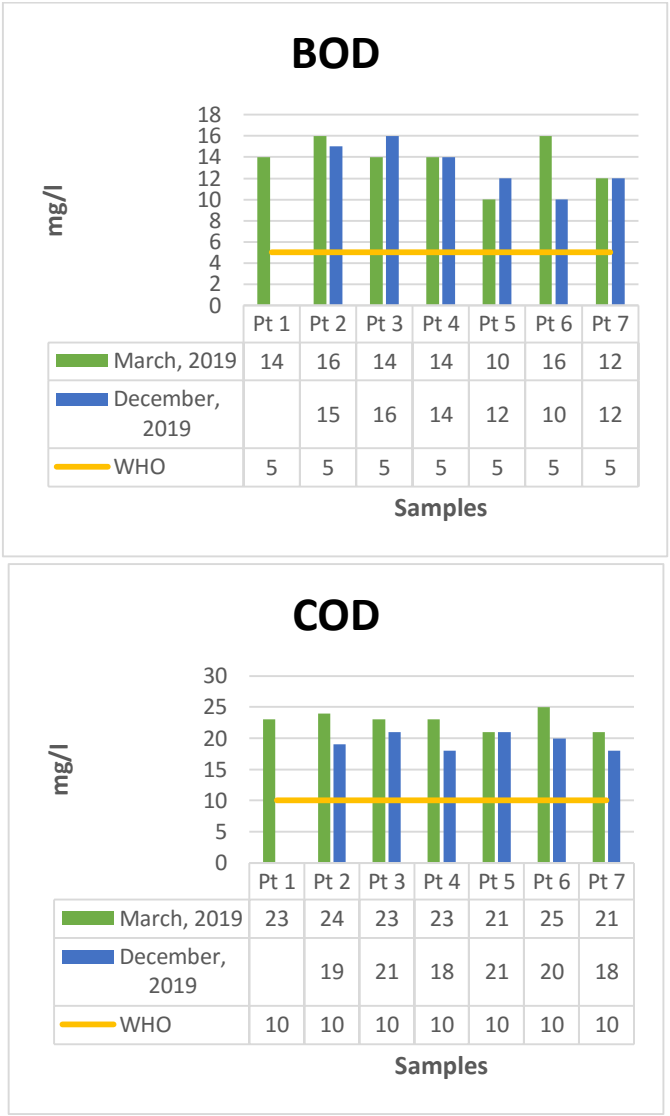
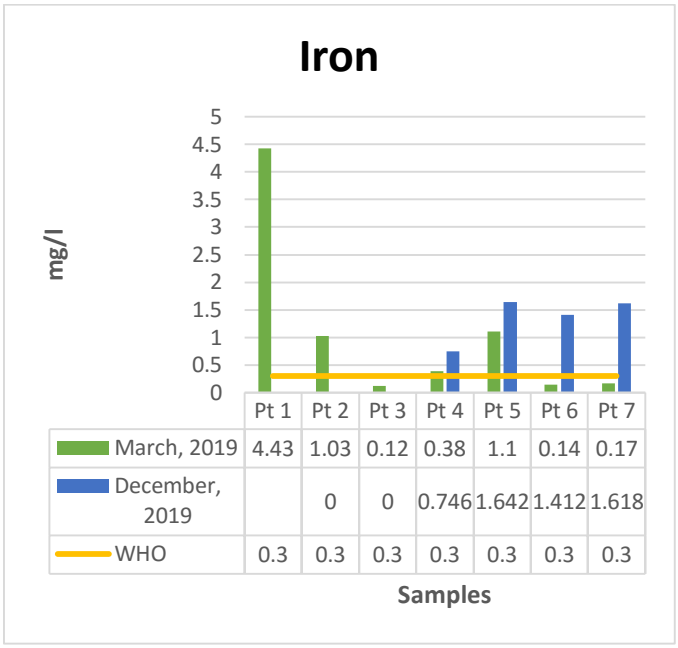


Figure 7.0: Ground Water BOD & COD Spacio-temporal Variations

High BOD levels that varied widely were observed in the study. Samples collected in March, 2019 had values ranging from10 mg/l at PT 5 to 16 mg/l at PT 2 and PT 6, while those collected in December, 2019 had values that fell between 10 mg/l at PT 6 and 16 mg/l at PT 3. Approximately half of the samples collected during the March 2019 sampling period were higher than those collected during the December 2019 survey period. The amounts of BOD found in this study were far higher than the WHO guidelines, as seen in Figure 7.0.

Similarly, high COD levels that varied widely just like the BOD concentrations were also noticed in this study. Samples collected in March, 2019 had values ranging from 21 mg/l at PT 5, PT 7 and CBH to 25 mg/l at PT 6, while those collected in December, 2019 had values that ranged between 18 mg/l at PT 4 and PT 7 to 21 mg/l at PT 3 and PT 5. About 75% of the samples collected during March, 2019 sampling were higher than the samples collected during December, 2019. All the samples collected across seasons and locations showed considerably high COD levels. The high levels of COD signifies a reduced dissolved oxygen levels which means lower water quality, an indication of anthropogenic conditions which is deleterious to higher aquatic life forms (Blog, 2017).

The levels of COD observed in this study, are well above the WHO standards prescribed and presented in Figure 7.0.



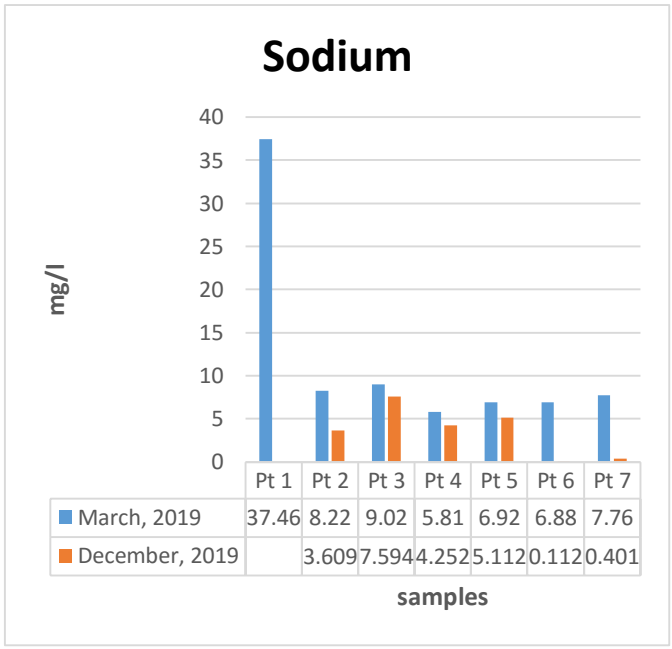


Figure 8.0: Ground Water Iron & Sodium Spacio-temporal Variations

Concentrations of iron in groundwater samples of this study varied considerably among the samples as presented in Figures 8.0 above. The concentrations varied from 0.13mg/l at PT 3 to 4.43 mg/l at PT 1 for samples collected in March, 2019 and from values that were not detected at PT 2, and PT 3 to 1.618 mg/l at PT 7 for samples collected in December, 2019. Although the March, 2019 samples at PT 1, the central borehole showed levels that were considerably high, about 50% of the samples collected in the December, 2019 had comparatively higher Iron concentrations than those collected in March, 2019. Accordingly, more than 80% of samples collected in both regimes (March 2019 and December 2019) had concentrations above the WHO threshold value. Whereas, sodium concentrations varied from 5.81 mg/l at PT 4 to 37.46 mg/l at PT 1 for the samples collected in March, 2019, and varied from 0.112 mg/l at PT 6 to 7.5 mg/l at PT 3 in samples collected in December, 2019. There was a noticeable spike at PT 1 during the March sampling. The increase in levels of sodium from March, 2019 to December, 2019 was over 90% of the samples locations.

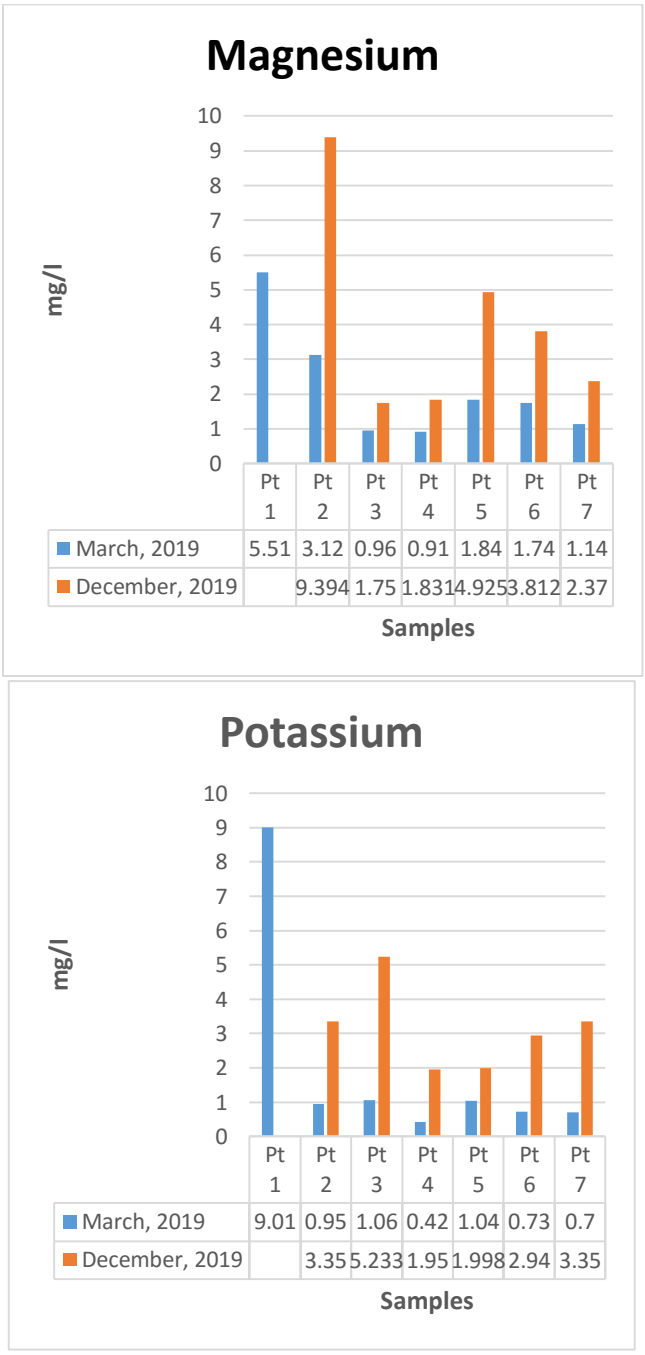


Figure 9.0: Ground Water Magnesium & Potassium Spacio-temporal Variations

The variation of magnesium concentrations among the samples of this investigation showed that samples collected in March, 2019 had concentrations that ranged from 0.91 at PT 4 mg/l to 5.51 mg/l at PT 1, while those collected in December, 2019 had values that varied between 1.75 mg/l at PT 3 to 9.39 mg/l at PT 2. More than 85% of the samples collected in December 2019 exhibited greater values than the samples collected in March 2019. Within the research locations, there was a wide range of low magnesium.

Potassium concentrations were significantly low in almost all the samples, as presented in Figures 9.0. The concentrations ranged from 0.42 mg/l at PT 4 to 9.01 mg/l at PT 1 in samples collected in March, 2019, and varied from 1.95 mg/l at PT 4 to 5.23 mg/l at PT 3 for samples collected in December, 2019. In comparison to the samples taken in March, over 85% of the samples collected in December 2019 showed an increase in potassium contents. Although the amounts of potassium at PT 1 were the highest among all samples during the

March 2019 sampling, the overall quantities were relatively low, hence potassium posed no substantial hazard to the environment.

While most of the metals were found in the samples collected during the two sampling regimes, the heavy metal were below instrument detectable levels across all locations and sample periods. Lead (Pb), Cadmium (Cd), and Chromium (Cr) were among the heavy metals studied in this research. However, Cr showed presence of 0.26 mg/l at PT 6 during the March 2019 analytical period.

IV. CONCLUSION AND RECOMMENDATIONS

The samples taken throughout the study for both seasons were moderately acidic. Acidic pH, in general, indicating the probability of pollution from natural or anthropogenic sources, or both. Most measurements were lower in the December, 2019 sampling regime as compared to the March, 2019 sampling period. Several factors, including rainfall penetration and dilution effects are likely to blame for the variations of parameters concentration. Interferences from the flooding that had barely receded at the time of the study could have caused the low parameters levels reported during the December 2019 sampling. However, concentrations of Iron, Magnesium and Potassium were greater in the December, 2019 sample regime.

All heavy metals collected in this investigation were below equipment detection limits for the two sampling regimes and all the sampling locations. This could have occurred as a result of the garbage generation pattern within the Yenagoa metropolis, or the activity of scavengers who gathered metals at the dumpsite. Point PT 1 exhibited the highest concentration of values followed by PT 2, which is an indication of the flow pattern of pollutants towards PT 2. As a consequence of this investigation, it may be determined that heavy metals influence in ground water across the tested locations was insignificant, presumably due to geology or the sorts of trash disposed of, as well as the dump site's management practices.

Therefore it was recommended that mentioning of landfills should be done after a careful research of the environment since they have been confirmed to bring toxins into the ecosystem.

Ground water sources within landfills should also be appropriately monitored to avoid intake of contaminated water. This research is however recommended for further studies.

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