# Spatio -Temporal Variation in Municipal Water Quality in Abuja, Nigeria

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**Abstract:** A total number of Eighty eight water samples were collected at different designated point areas in the area councils of FCT, Abuja. The qualities of the samples were analyzed for the physico-chemical properties of water supplied from difference sources in the council areas. However fourteen parameters were determined in the water samples supplied to these areas, using appropriate physical and chemical laboratory technics. The results of the physico-chemical analyses indicated variation in the amount elements (eg. pH, TDS, Colour, BOD. Anion and cations) that are present in the water consumed and supplied. Significant positive correlation was observed between and among the parameter at 0.05significant level (Kruskal-Wallis Statistical Technique).Furthermore Moran's I was computed to examined global spatial autocorrelation. In addition to this spatial autocorrelation analysis, local clustering of the values was also examined using Hot Spot Analysis (Getis-OrdGi*) revealed point that are statistically significant hot or cold spot across the area sample. One cold spot was found for Nitrate, one cold and one hot spot for conductivity in February. For Iron, three significant hot spots were found; three hot spots were also found for Free Chlorine while 2 hot spots were found for F- in the month of June. In October, Iron has 3 cold spots and one hot spot. From the results, we could conclude that the water quality across the sampled area meets the specified quality standards for most of the parameters. These parameters also vary significantly over time across these areas and this variation sometimes lead to exceedance of standard limits for some of the quality parameters. There are clustering of similar and also dissimilar values across space and time in relation to the water quality parameters. None of the parameter shows spatial autocorrelation across the three periods however, Iron showed a positive spatial autocorrelation for two of the period under investigation. Therefore, Iron is the most variable temporally and spatially among the parameters. This study presented a rapid assessment of water quality which incorporate spatial and temporal dimension. It offers a means of identifying potential location of weak link within the distribution system and thereby allowing for effective management of water supply systems within a metropolitan area.

**Key Words:** Water quality, Spatio-temporal analysis, Spatial autocorrelation, Hot Spot Analysis (Getis-OrdGi*), physico – chemical analysis.

## 1 Introduction:

Water is very important to human existence, not all available water on the earth is a resource until it has been process and refined by scientist and made it available for daily need of the people. Nigeria is not devoid of global perspective, because raw water is refined before being delivered to human populace. The control and provision of water in Nigeria has long be left in the domain of the three tier of governance, the Local, State and Federal government. In Nigeria today more than 95million people living in urban and semi – urban and some part of the rural area have no access to portable water. Many household end up purchasing water from private water vendor, of which the quality is below World

Health Oraganisation required standard. Many water supply system firms show extensive deterioration and poor utilization of existing capacities, due to lack of funds for operation erratic government policy and maintenance. One of the main factors facing industrial development in Nigeria today is that of inadequate water supply most communities in the country in the past few years had experienced water shortage, most especially during the dry season; water is an important pre-requisite of social agricultural and industrial development

The water problem calls for an appreciation of geological structure, morphological features and climatic conditions, when has to be considerate with the human activities of the land. It is also a call for the study of man in relationship to the environment. This is necessary since about three –quarter of the earth is covered with water, and yet the problem of portable water still exists around the world. These problems vary and manifest in different forms ranging from quantity, quality new sources of supply to distribution and allocation over space.

Considering total rainfall in Nigeria, there is no surplus of water to meet all demand for the various uses (Ayoade, 2004). Recently, water shortage problem in Nigeria has been on the increase, this demands more attention now that, the federal government is making preposition such as “water for all the year 2010”. The present projections for developing countries show that over one thousand million or nearly one-third of the world population has no portable water supply (Stephenson & Petersen, 1991). Additionally, the high cost of imported equipment especially in terms of availability of hard foreign currency, and couple with inadequate development plan and policies have contributed to large dwindle of water supply and distribution in many State Water Authorities (SWAs) in Nigeria. This has left most State Water Authorities collapsed and water is supplied below capacity level.

It is therefore clear that the supply of clean and reliable water system is one essential factor necessary not only for good health, welfare and productivity of the population but also for overall economic growth of any nation. This is because; improved water supply would stimulate and promote agricultural productivity, successful small-scale industrial development and improvement in the standard of living of the people. Although, about 70 percent of the Nigerian’s human population inhabit the basement complex area, only a very small proportion are provided, it is less efficient in the sense that the water taps are often dry for a considerable part of a given period. Water usage has actually generated a lot of interest by scholars especially source and use, together with how a continued supply can be maintained. Ogunnawo (2004) established that the provision of adequate water supply for domestic, agricultural, industrial and other uses is an increasing problem, as dynamic man-water relationship becomes more complex. They further established blushed that the primary objectives of water supply quality and reduction in water- boon diseases. In a study on urban domestic water supply in Ogun State by Oyebande (1986), he examined the disequilibrium between water supply and domestic demand. He placed emphasis on both federal and state governments plan for water development. He did this by evaluating the 1981 and 1984 development plans of the Federal Government for Ogun State and arrived at an estimate of supply the needs of a rapidly growth city.

On water availability, Biswas and Banu (2006)pointed out that in urban communities only 57 percent of the population had piped-in water while 18 percent had reasonable access to stand pipes, making a total of 75 percent on 390 million people had reasonable access to safe water. They also admitted that there is a close relationship between availability of water and economic development in Nigeria, and that this is one of the major factor controlling the distribution of population because it is observed that area where water is difficult to obtain the inevitable sparsely populated this was further stressed by Ayoade (2004) that an average man is two - third water and would weigh 13 kilograms when completely dehydrated.

He further revealed that man can stay alive only for three days with nothing to drink. Therefore, there is need for proper planning and management of water resources. He further stated that despite the fact that water supplies are at present obtained from surface and ground water sources, rain water is still an important source particularly in developing countries where rain water is stored in tanks for use during dry season. It was estimated also by white in 1972 that 70 percent of total human population draw water from sources outside their dwelling place. He recognized the effect of distance on the per capital consumption of domestic water.

The aim of the European Ell 487 project according to Simonovic (1996), was to develop a comprehensive decision support system (D.S.S) for river basin planning, capable of addressing a wide spectrum of issues such as determining the limit of sustainable water development deciding what, where, and when new sources should be developed, and assessing the environmental impactof water and ground development, formulating strategies for river and ground water pollution control programmes.

In his lead paper to the adjustment to scare water in the middle east", Professor Allan in 1996, stressed the relevance of water to everyone everywhere and noted that the inability to implement water policies in an integrated manner often leads to water policies in an integrate water supply always improves the environmental management, economic development and the social well-being of the people (Simonovic, 1996). From another perspective, Prüss-Üstün, Kay, Fewtrell, and Bartram (2004) asserted that in many humid tropical be it, the problem is not lack of water resources and transporting water to centers of demand, but associated with such water transporting problems is water resources management problems. The supply sources have to be estimated and compared with estimated demand to obtain the water balance or gaps planning to these balances can be accomplished through the tapping of other sources hither to untapped(Simonovic, 1996). Ogunnawo (2004)proposed that water supply situation in a community is necessary but the World Public Health Paper (Series 23 of 1963) holds that there are some relationship between the supply of suitable water and the rate of economic growth of an urban area. Though this relationship has not been strictly quantified and studied up to1999 have shown that most of the water available does not meet all the standards recommended by the world health organization (Prüss-Üstün et al., 2004).

Based on the aforementioned, this study looked into the problems of domestic water supply in Federal Capital Territory (FCT), Abuja. The sources of water in this territory include pipe borne water, bore hole, hand dug well, streams, and lakes among others. This has led to the spread of deadly water-borne diseases which is now becoming a characteristic feature of water supply problems (Postel, 1999).

Based on available data on rainfall and the geology of the territory, FCT has adequate surface and ground water resources to meet current demands for potable water though spatial distribution of water has led to scarcity in some area the satellite towns of the FCT, Abuja. As neighboring satellite towns become more and more dependent on alternative sources and experience the difficulties associated with treating such water, water shortages are common in the area, where quality water need to be transferred and exchanged between satellite towns where it is necessary.

Water is essential to life and is the basis of life. This being so, it was almost inevitable that the development of water resources proceeded any real understanding of their origin and formation (Egboh & Emeshili, 2007). Water makes life possible as without it; life and civilization cannot develop or survive. Water forms the largest part of most living matter. Plants on which man depends for food cannot grow without water. They need it for photosynthesis and they take their nutrients from the soil in solution. Water is a vital need to man just as air and food are. Apart from the air that we breathe, water is the most important element to man.

Currently, the emphasis on water supply and utilization in Nigerian states is becoming more urgent, considering the prevailing water-borne diseases in the country. The poor supply of water to households and other establishments has been widely reported in science literature.

## 2 Materials and Methods:

### 2.1 Study Area

The area falls within the FCT, located West of Niger State, bounded by latitude $8^0$ 10' and $9^0$ 45'N and longitude $6^0$ 30' and $7^0$ 45'E and shares boundaries with Kaduna State to the north, Niger State on the west and Nasarawa State on its eastern border (Figure. 1). The population of the study area as projected from 2006 is put at 1, 405, 201; its landmass is about 713.84 square kilometer having a population density of 1700 people per square kilometer.The area lies between 450 – 1000 m above mean sea level.

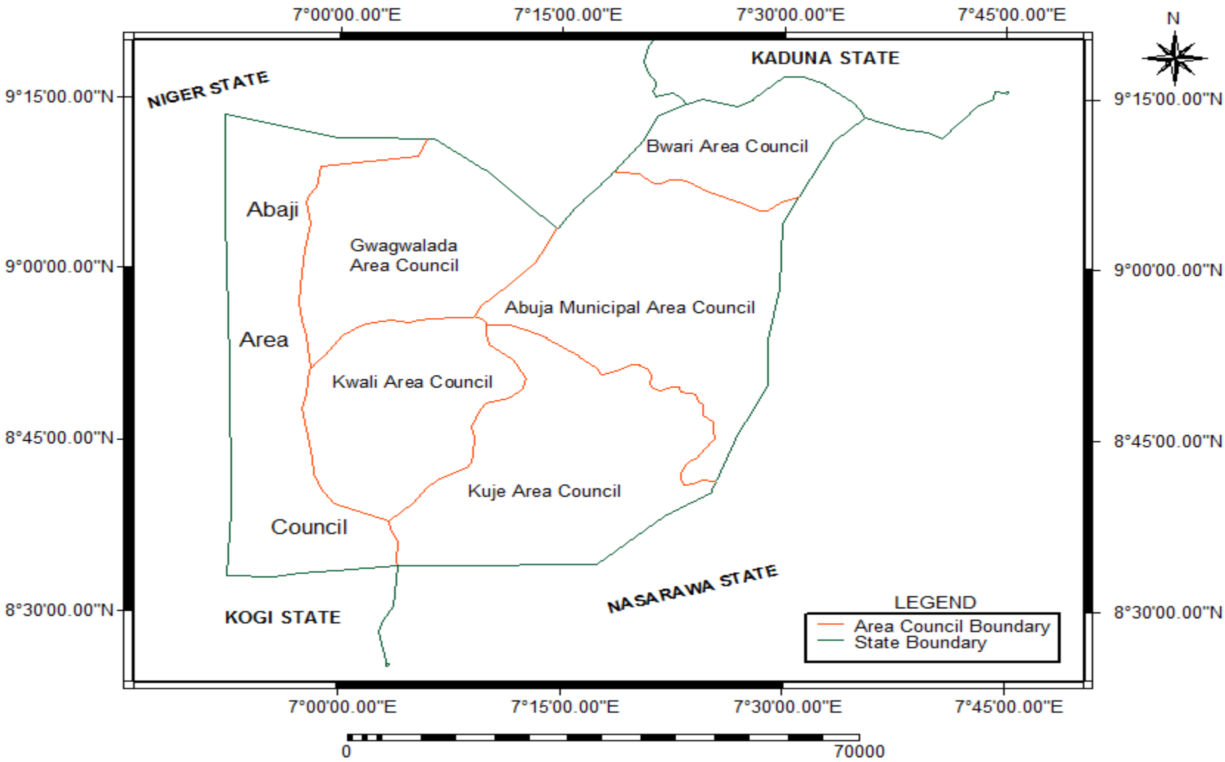


Fig: 1.Map ofthe Federal Capital Territory, Abuja Showing Area Council

The topography is gentle and undulating. There are however, steep escarpments doting the study area. The elevation is about 46m with the lowest point slightly less than 290m and the highest point slightly above 920 m above mean sea level. The surface drainage of the study area is synonymous with its relief whereby most of the streams have their sources from ridges and highlands and emptied into River Kaduna in the northern part of the study area. Tropical humid climate characterized by two distinct seasons is experienced in the area. The wet (rainy) season started in the beginning of April and ends in October. The dry season continued from November and in March. Annual rainfall figures of the area ranges from 1200mm to about 1600mm and 90% of the rain falls are experience between May and September (Ayoade, 2004). Temperatures are generally high during the day particularly between the months of March and April. The mean monthly temperature in Abuja ranges between $20^0$C and $34^0$C with the hottest months being March and April and the coldest, December and January. The climate controls the natural forces that affect all components of the ecosystem. It modifies the structural differences between them and maintains a balanced equilibrium for the macro environment. Annual rainfall is characterized by a single maximum and in the range of 1,400mm per annum. The number of rainy days ranges between 48 and 96 days with the highest values recorded in July. Average relative humidity is about 60.9%.The climate of the study area is typically tropical continental in nature. Consequent upon apparent movement of the sun across the tropics is the major factor besides the prevailing winds and the relative stability of the Inter-Tropical Convergence Zone (ITCZ) are responsible for the stability of temperature in the study area, though variations are experienced between the dry and the wet season(Ayoade, 2004). The vegetation of the study area is that of the central southern guinea savannah type. The vegetation is characterized by grass, weeds, shrubs and leguminous fauna, due to general vegetation degradation, through burning, over cultivation, and over grazing. Most dominant grasses include sorghum and other turf species like *Pennisetumpurpureum*, *Axonopus*, *compressus* to mention but a few.

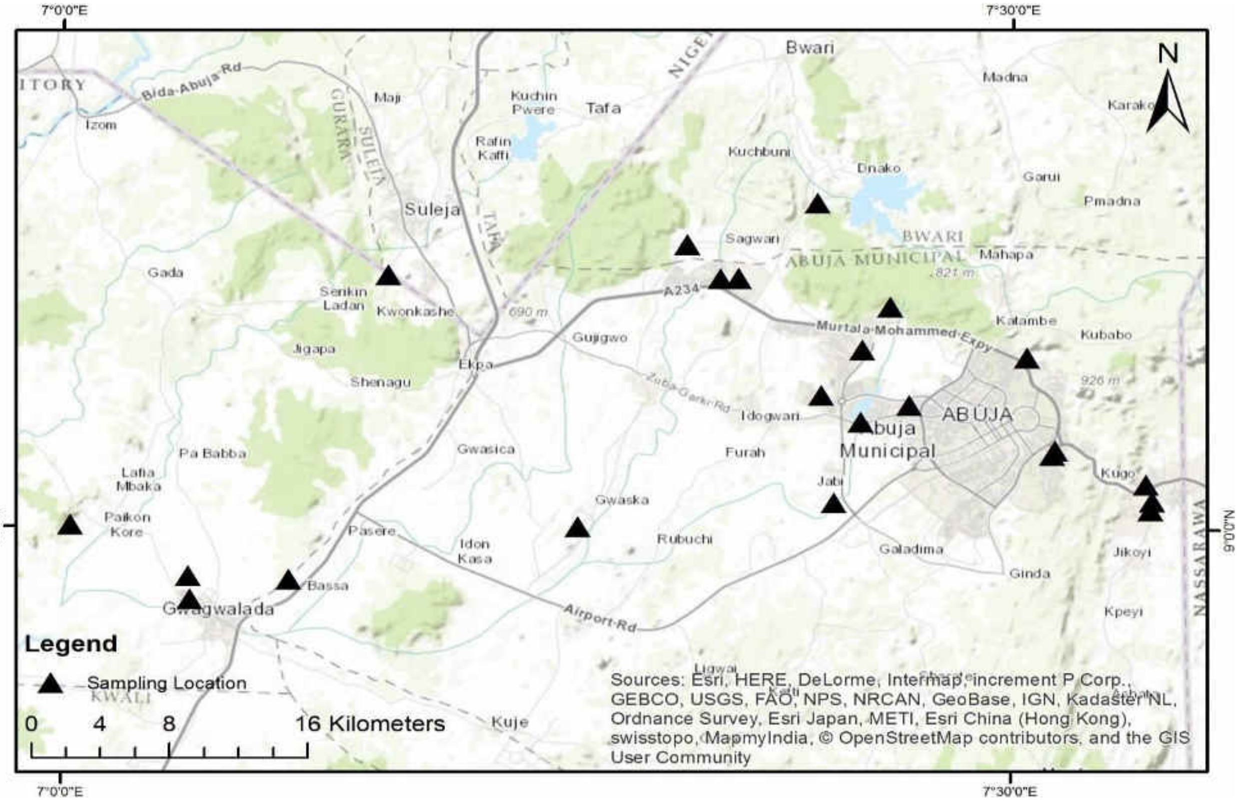


Fig: 2. Study area in FCT, Abuja, showing location of water sample collection

## 2.2 Data Collection

Water samples were collected in the month of February during the pick of dry season, June during the rainy season and in October during the sensation of the rainy season. Twenty two areas were chosen from each of the six area councils in the FCT by simple random sampling method as sample size for the study (Fig. 2). Each of the communities in the study area was coded and a table of random digits was used to draw out twenty two communities; this technique was used to ensure an unbiased selection. Samples were collected in 2 litres plastic containers which had been adequately washed and rinsed with distilled water for sampling. About 1 litre of each of the samples collected was filtered and the volumes were used for the analyses of metal with acidified nitric acid to prevent the metal from adhering to the wall of containers. For further preservation purposes, the entire samples collected were refrigerated at $10^0$C before eventual analysis. In order to determine the quality of the various water supplied and consumed in the FCT, Abuja samples were also compared with set standards by Federal Ministry of Environment(FMENV, 2001).

### 2.2.1 Mineral Analysis

All the analyses were carried out in the laboratory in accordance withAmerican Public Health Association (1989) standard methods for examination of water. The elemental analysis was done with the water samples using Perkin Elmer and Oak Brown, atomic Spectrophotometer. The instrument setting was as described byAremu, *et al.* (2007). Sodium was determined by using a Flame Photometer (Model 405, Corning, UK) as described by Aremu*et al.* (2007).

### 2.2.2 Physico-Chemical Analyses

Temperatures were measured using a mercury thermometer while pH was done using a BNC pH meter. Conductivity measurement was done using conductivity metre model NATOP PBS while total hardness were done by titremetry(APHA, 1995). Chloride was measured by chloride ion water (model KRK Cl-SzJapan).Nitrate were estimated using a PYE UNICAM visible spectrophotometer in NAFDAC, in Lagos. Total dissolved solids were determined by gravimetry method. Fourteen parameters were analyzed for in the statistical testing so it is incomplete here in the methods

### 2.3 Data Analysis

From the results of the field and laboratory tests on the samples, fourteen parameters selected are subjected to statistical analysis. In line with the aim and objective to the study, a non-parametric test of was carried out to test the differences over time among the selected parameters. Non-parametric test was used because of the small sample size (<30). For the testing the variation over time the Kruskal-Wallis Test was used, this is the non-parametric alternative to Analysis of Variance (ANOVA). Furthermore, Moran's I (Moran, 1950) was computed to examine global spatial autocorrelation among the parameters across the three sampling periods. In addition to this spatial autocorrelation analysis, local clustering of the values was also examined using Getis-OrdGi* (Getis & Ord, 1992) analysis, this would revealed points that are statistically significant hot or cold spots across the area sampled.

## 3 Results and Discussion:

### 3.1 Temporal variation in water quality

In order to summarize the data collected, a descriptive analysis was conducted and the result on Table 1 shows the property of the distribution of the data collected across the Study area. Colour was found to vary across the study area with the highest variation recorded for the samples obtained in October (Mean = 9.52, SD = 2.23). However, the highest value of 14 Pt-Co (compared to a standard of 15Pt-Co) was recorded during the February sampling.

Samples collected during June have the lowest variation (SD =1.18), however the mean is recorded for this period is the highest in comparison to other months.

For pH, the samples across the three times have values between 6.9 and 7.9, while the variation ranges between 0.13 and 0.23. The mean value for February was found to be highest followed by June. In comparison to other months October, has a lower minimum and maximum. However, none of the samples has values above or below the benchmark range by the FMENV. Conductivity was also found to be generally low compared to the benchmark – this is a positive development. Mean values ranges between 67.2 and 76.2 with the highest variation recorded for the month of February (SD = 4.06). TDS also recorded the highest variation in the month of February, followed by October.

Table 1: Summary statistics of selected water quality parameters

| Parameter | Time | N | Min. | Max. | Mean | SD | Benchmark |
|---|---|---|---|---|---|---|---|
| Color (Pt-Co) | February | 25 | 5.000 | 14.000 | 9.360 | 2.196 | 15.000 |
| | June | 22 | 7.000 | 11.000 | 9.636 | 1.177 | |
| | October | 21 | 5.000 | 13.000 | 9.524 | 2.228 | |
| pH | February | 26 | 7.400 | 7.940 | 7.761 | 0.136 | 6.5 -8.5 |
| | June | 21 | 7.000 | 7.940 | 7.320 | 0.218 | |
| | October | 21 | 6.870 | 7.660 | 7.175 | 0.232 | |
| Conductivity (µs/cm) | February | 26 | 67.000 | 91.000 | 76.196 | 4.064 | 1000.000 |
| | June | 22 | 64.200 | 70.000 | 67.150 | 1.457 | |
| | October | 21 | 68.700 | 78.800 | 72.986 | 2.746 | |
| Total Dissolved Solid (mg/L) | February | 25 | 49.000 | 60.000 | 51.480 | 2.220 | 500.000 |
| | June | 22 | 43.000 | 47.000 | 45.000 | 1.113 | |
| | October | 20 | 46.000 | 53.000 | 48.800 | 1.852 | |
| Turbidity (NTU) | February | 25 | 0.750 | 4.130 | 1.286 | 0.645 | 5.000 |
| | June | 22 | 1.600 | 2.790 | 2.074 | 0.320 | |
| | October | 20 | 0.480 | 4.640 | 2.420 | 1.194 | |
| Iron (mg/L) | February | 25 | 0.000 | 0.110 | 0.065 | 0.027 | 0.300 |
| | June | 22 | 0.045 | 0.180 | 0.100 | 0.047 | |
| | October | 22 | 0.043 | 0.180 | 0.109 | 0.037 | |
| Sodium (mg/L) | February | 25 | 6.000 | 10.000 | 7.600 | 1.041 | 200.000 |
| | June | 22 | 7.000 | 9.000 | 8.000 | 0.816 | |
| | October | 21 | 7.000 | 9.000 | 8.048 | 0.740 | |
| Magnesium (mg/L) | February | 25 | 3.900 | 22.000 | 8.374 | 3.715 | 20.000 |
| | June | 22 | 0.480 | 7.900 | 2.841 | 2.137 | |
| | October | 16 | 0.300 | 6.500 | 2.986 | 1.818 | |
| Hardness (mg/L) | February | 25 | 36.000 | 108.000 | 51.600 | 14.955 | 150.000 |
| | June | 22 | 18.000 | 54.000 | 34.227 | 8.826 | |
| | October | 22 | 26.000 | 50.000 | 39.364 | 5.473 | |
| Free Chlorine (mg/L) | February | 25 | 0.050 | 0.460 | 0.158 | 0.103 | 0.20 - 0.25 |
| | June | 22 | 0.040 | 0.960 | 0.343 | 0.305 | |
| | October | 21 | 0.110 | 0.400 | 0.234 | 0.098 | |
| Chloride (mg/L) | February | 25 | 8.000 | 16.000 | 12.320 | 2.015 | 250.000 |
| | June | 22 | 8.000 | 18.000 | 11.182 | 2.302 | |
| | October | 22 | 8.100 | 14.300 | 10.477 | 1.871 | |
| F- (mg/L) | February | 25 | 0.170 | 0.410 | 0.266 | 0.053 | 1.500 |
| | June | 22 | 0.000 | 0.670 | 0.097 | 0.159 | |
| | October | 22 | 0.040 | 0.650 | 0.162 | 0.135 | |
| Nitrate (mg/L) | February | 25 | 4.200 | 6.500 | 5.876 | 0.597 | 50.000 |
| | June | 22 | 4.900 | 7.800 | 5.700 | 0.744 | |
| | October | 22 | 4.600 | 7.800 | 5.714 | 0.691 | |
| Nitrite (mg/L) | February | 25 | 0.001 | 0.017 | 0.004 | 0.003 | 0.200 |
| | June | 22 | 0.006 | 0.040 | 0.015 | 0.007 | |
| | October | 22 | 0.009 | 0.045 | 0.017 | 0.009 | |

Source: Researcher’s data analysis result

Similarly, the mean values are also higher for these months compared to that of June. Mean turbidity (and its variability) was highest in October and, the highest value was recorded in the October (4.6) – a value very close to the benchmark value. Iron was found to be small (ranging between 0 and 0.18) compared to the benchmark value (0.3) and the highest value were found in the months of June and October. Amount of Sodium in the sampled water was very small compared to the benchmark value of 200mg/L. Mean values ranges between7.6 and 8.04 with the highest variation (SD =1.04) obtained in February. Mean amount of Magnesium in the sample ranges between 2.84 and 8.37. However, the maximum value obtained for February is 22mg/L which is above the 20mg/L benchmark. The highest value for hardness was recorded in the month of February (108mg/L), this month also has the highest minimum value, thus resulting in the highest variation recorded across the periods considered. All the samples have hardness values within the limit of 150mg/L. Free Chlorine across the three periods was between 0.04mg/L and 0.96mg/L, with mean between 0.16mg/L and 0.34mg/L. In comparison to the standard of 0.20 – 0.25mg/L, the mean for June is not desirable. In terms of Chloride, F-, Nitrate and Nitrite, all the samples across the periods examined are within the desirable limit.

Analysis was conducted to ascertain if there are statistical differences in the parameters over the months sampled. Kruskal-Wallis test results (Table 2) shows the difference over time for the selected parameters. At a significance level of 5%, no statistically significant difference was found across the months for Colour, Sodium and Nitrate. Essentially, there are statistically significant differences across most of the water quality parameters over time, thus the quality of the water is varies over time.

Table 2: Kruskal-Wallis test results for comparison of parameters over time

| Parameters | Kruskal-Wallis Test Statistics | Asymptotic Sig. (2-Sided) |
|---|---|---|
| Color (Pt-Co) | 0.452 | 0.789 |
| pH | 42.133 | 0.000 |
| Conductivity (µs/cm) | 46.355 | 0.000 |
| Total Dissolved Solid (mg/L) | 50.921 | 0.000 |
| Turbidity (NTU) | 28.156 | 0.000 |
| Iron (mg/L) | 14.475 | 0.001 |
| Sodium (mg/L) | 3.238 | 0.198 |
| Magnesium (mg/L) | 35.529 | 0.000 |
| Hardness (mg/L) | 28.242 | 0.000 |
| Free Chlorine (mg/L) | 8.395 | 0.015 |
| Chloride (mg/L) | 8.323 | 0.016 |
| F- (mg/L) | 29.611 | 0.000 |
| Nitrate (mg/L) | 4.459 | 0.108 |
| Nitrite (mg/L) | 41.923 | 0.000 |

### 3.2 Exploration of Global and Local correlation

In order to test spatial dependency, global autocorrelation tests were carried out within GeoDa software (Anselin, Syabri, & Kho, 2006) while hotspot analysis was carried out within ArcGIS (ESRI, 2015). The result presented in Table 3 shows the water quality parameters and their respective global spatial autocorrelation statistics.

Table 3: Global spatial autocorrelation analysis result across different months

| Parameters | Moran's I | | | Z scores | | | P (at 999 permutations) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Feb | Jun | Oct | Feb | Jun | Oct | Feb | Jun | Oct |
| Color (Pt-Co) | -0.032 | -0.030 | -0.093 | 0.058 | 0.107 | -0.467 | 0.440 | 0.411 | 0.349 |
| pH | 0.067 | -0.038 | -0.067 | 0.968 | 0.011 | -0.240 | 0.167 | 0.453 | 0.467 |
| Conductivity (μs/cm) | -0.248 | 0.023 | -0.057 | -2.221 | 0.516 | -0.147 | 0.012 | 0.267 | 0.497 |
| Total Dissolved Solid (mg/L) | -0.117 | 0.026 | -0.026 | -2.076 | 0.563 | 0.144 | 0.038 | 0.239 | 0.400 |
| Turbidity (NTU) | 0.049 | 0.023 | 0.094 | 1.166 | 0.547 | 1.194 | 0.124 | 0.265 | 0.108 |
| Iron (mg/L) | -0.079 | 0.183 | 0.225 | -0.330 | 1.961 | 2.251 | 0.404 | 0.034 | 0.033 |
| Sodium (mg/L) | -0.136 | 0.006 | -0.132 | -1.126 | 0.443 | -0.786 | 0.129 | 0.277 | 0.231 |
| Magnesium (mg/L) | 0.108 | -0.018 | 0.165 | 1.389 | 0.186 | 1.761 | 0.099 | 0.395 | 0.057 |
| Hardness (mg/L) | 0.0001 | -0.006 | 0.017 | 0.376 | 0.312 | 0.531 | 0.352 | 0.354 | 0.258 |
| Free Chlorine (mg/L) | -0.005 | 0.214 | 0.132 | 0.331 | 2.283 | 1.407 | 0.344 | 0.020 | 0.090 |
| Chloride (mg/L) | -0.165 | 0.106 | 0.025 | -1.288 | 1.299 | 0.617 | 0.091 | 0.102 | 0.261 |
| F- (mg/L) | -0.125 | -0.168 | 0.042 | -0.835 | -1.403 | 0.837 | 0.211 | 0.045 | 0.192 |
| Nitrate (mg/L) | -0.176 | -0.066 | -0.055 | -1.825 | -0.257 | -0.113 | 0.030 | 0.429 | 0.499 |
| Nitrite (mg/L) | -0.108 | 0.145 | 0.094 | -0.911 | 1.777 | 1.222 | 0.184 | 0.051 | 0.124 |

Colour across the across the time of sampling showed no statistically significant (P>0.05) spatial autocorrelation. The same can be of pH, Turbidity, Sodium, Magnesium, Hardness, Chloride and Nitrite. The indication therefore, is that there is no spatial dependency in the values of these parameter i.e. distance plays no role in the distribution of the values for these quality parameters.

Conductivity showed a statistically significant (P<0.05) spatial autocorrelation for samples taken in February. However, such spatial dependency was not found in June and October. A similar result was recorded for TDS and Nitrate. It is should be noted that the spatial autocorrelation recorded for these parameters is negative in nature i.e. clustering of dissimilar values. Electrical conductivity is known to be associated to TDS, thus the similarity in spatial autocorrelation results is expected. The hotspot analysis carried (Figure 3) out to identify points with significantly high or low values for Nitrate, shows that most of the sample locations are not statistically significant hot or cold spot except one sampling point (TW006FC011). This point is a statistically significant (99% confidence) cold spot, giving an indication that this point has a considerably lower Nitrate level compared to its neighbors.

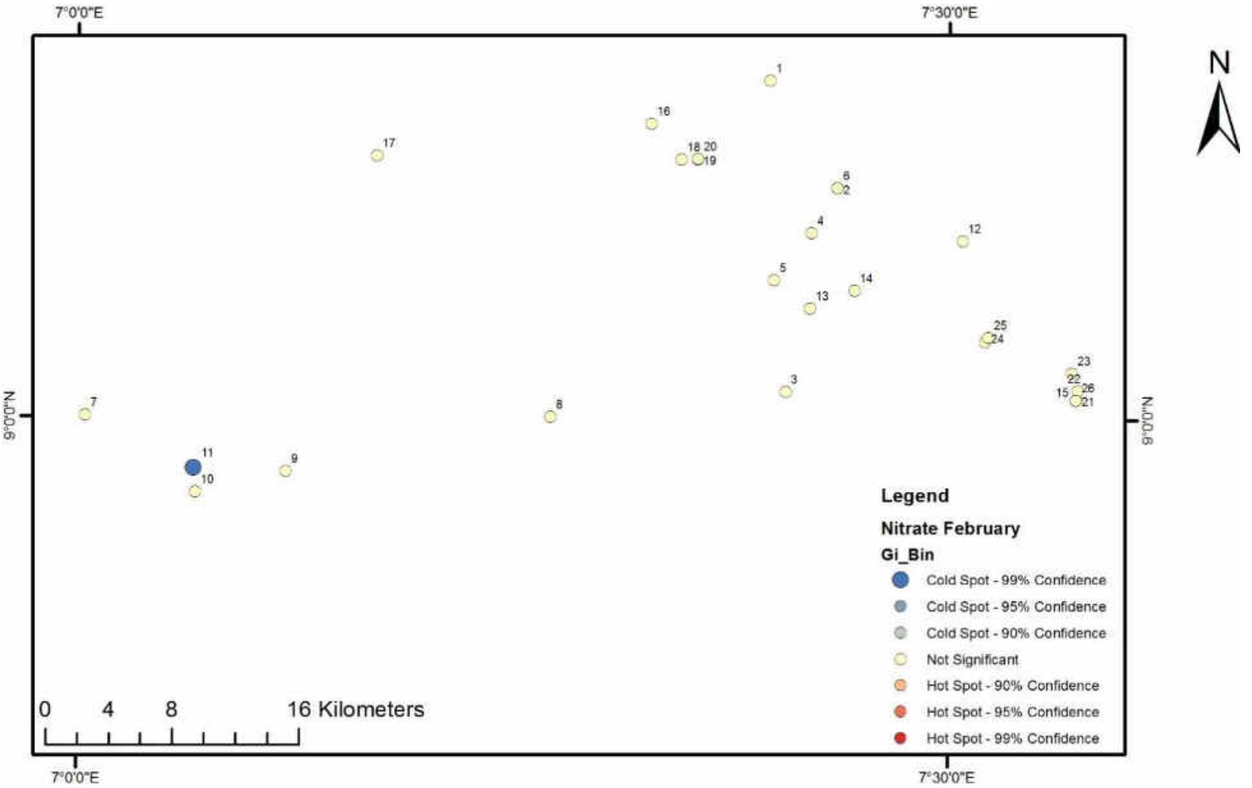


Figure 3: Hotspot analysis results for Nitrate levels (February)

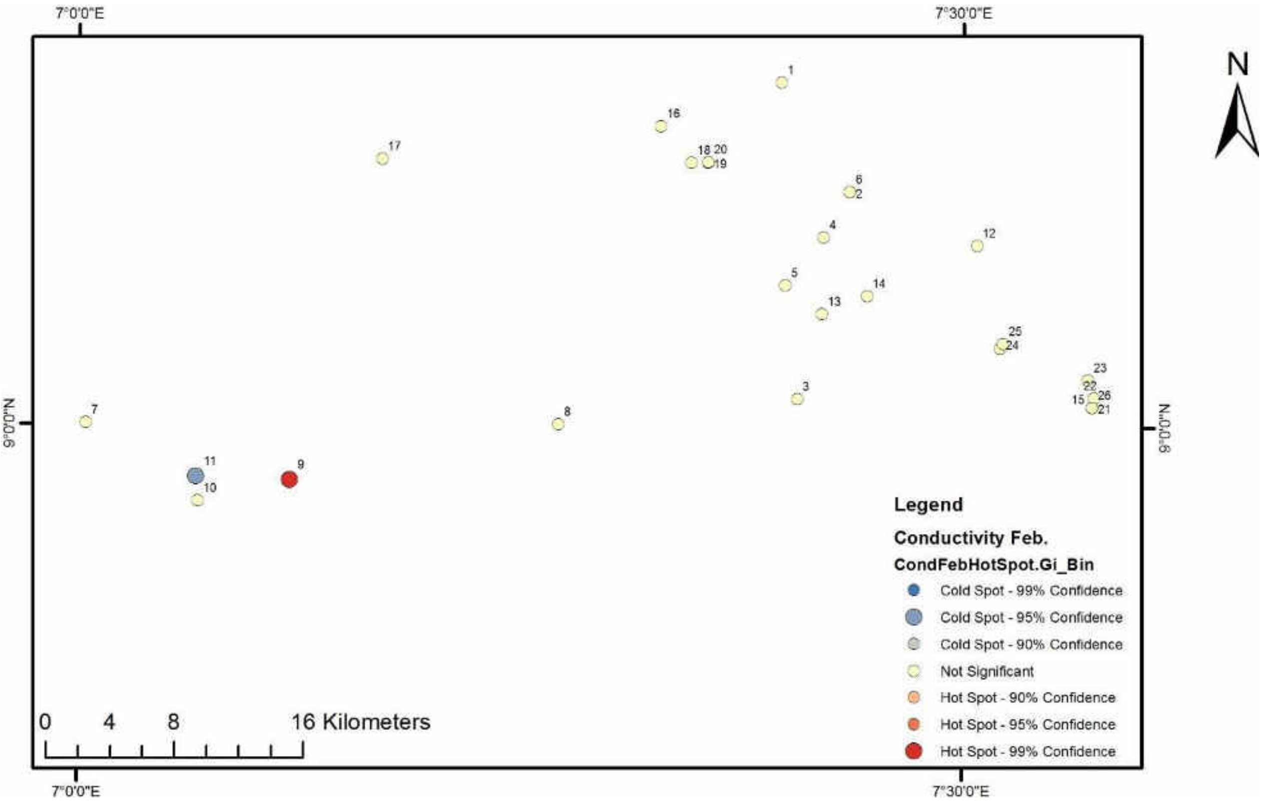


Figure 4: Hotspot analysis map for conductivity across samples in February

Hotspot analysis for the conductivity of samples for February (Figure 4) shows that two samples – TW006FC011 and TW006FC009 belongs to statistically significant cold and hotspot respectively. Sample TW006FC011 was found to be a cold spot for Conductivity (consequently TDS) and Nitrate, this might be why there is a similarity in the spatial autocorrelation for February samples.

Iron, Free Chlorine and F-, displayed significant ($P<0.05$) for only June, with an indication that there is spatial dependency on the values of these parameters. Iron and Free Chlorine show a positive spatial autocorrelation (clustering of similar values) while F- shows a clustering of dissimilar values (negative spatial autocorrelation). Further analysis, revealed that Samples 6, 7 and 8 (TW00FC006 – 008) are statistically significant (Confidence level 90%) hotspot. Thus, indicating that these three points are significantly higher than their neighbours. Similar analysis for Chlorine (Figure 5), shows that samples 1, 12 and 16 are significant hotspots (90-95% confidence).

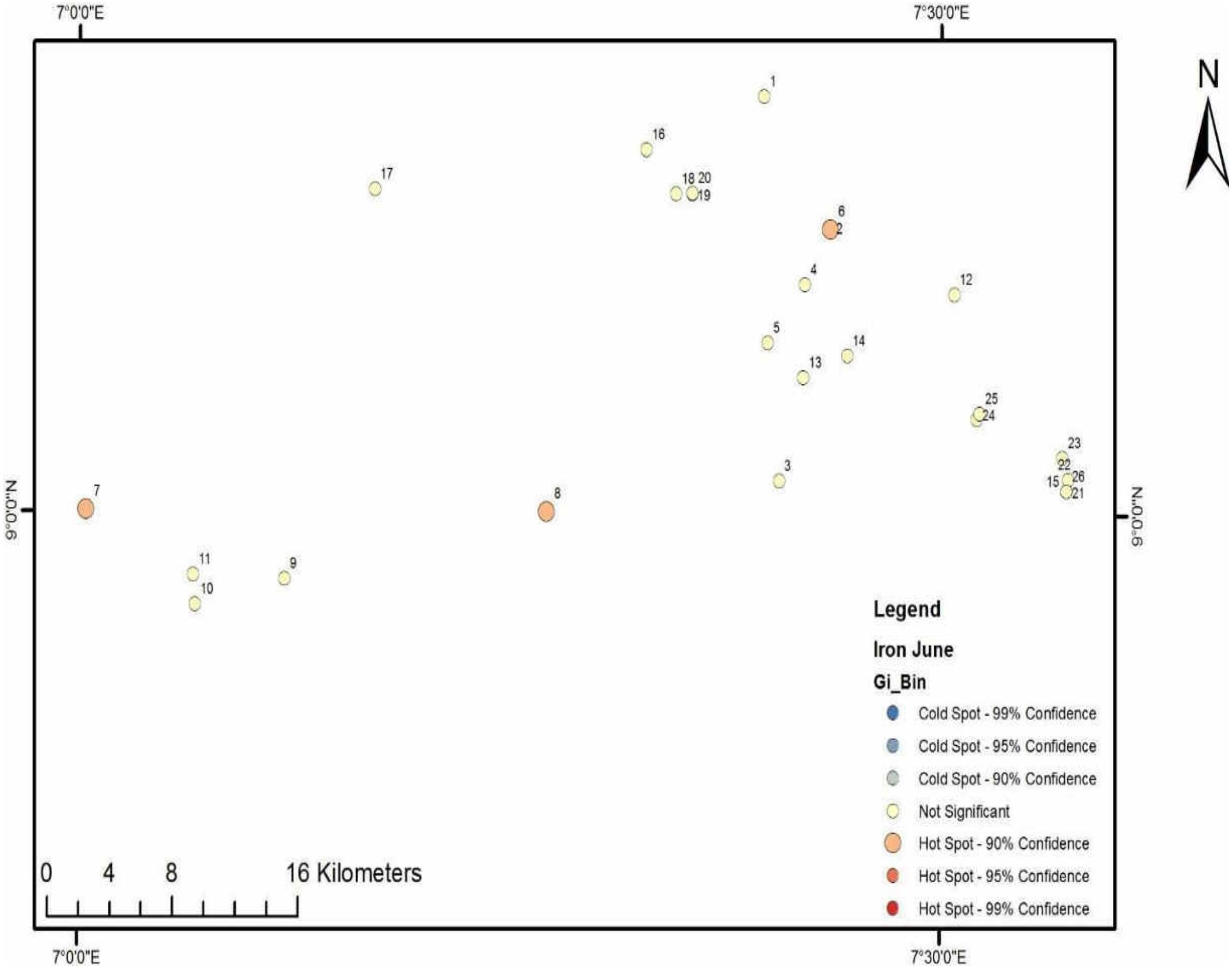


Figure 5: Hotspot analysis results for Iron in samples for the month of June

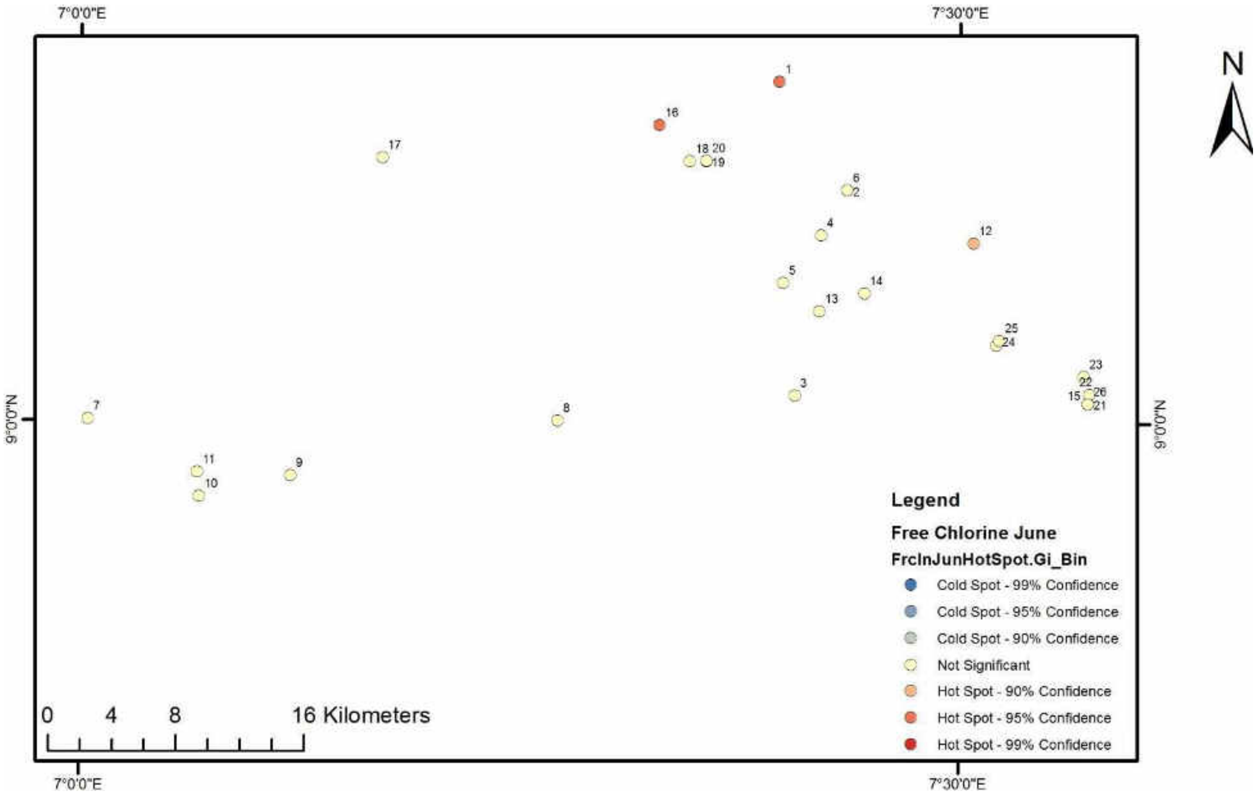


Figure 6: Hotspot analysis result for Free Chlorine in water samples (June samples)

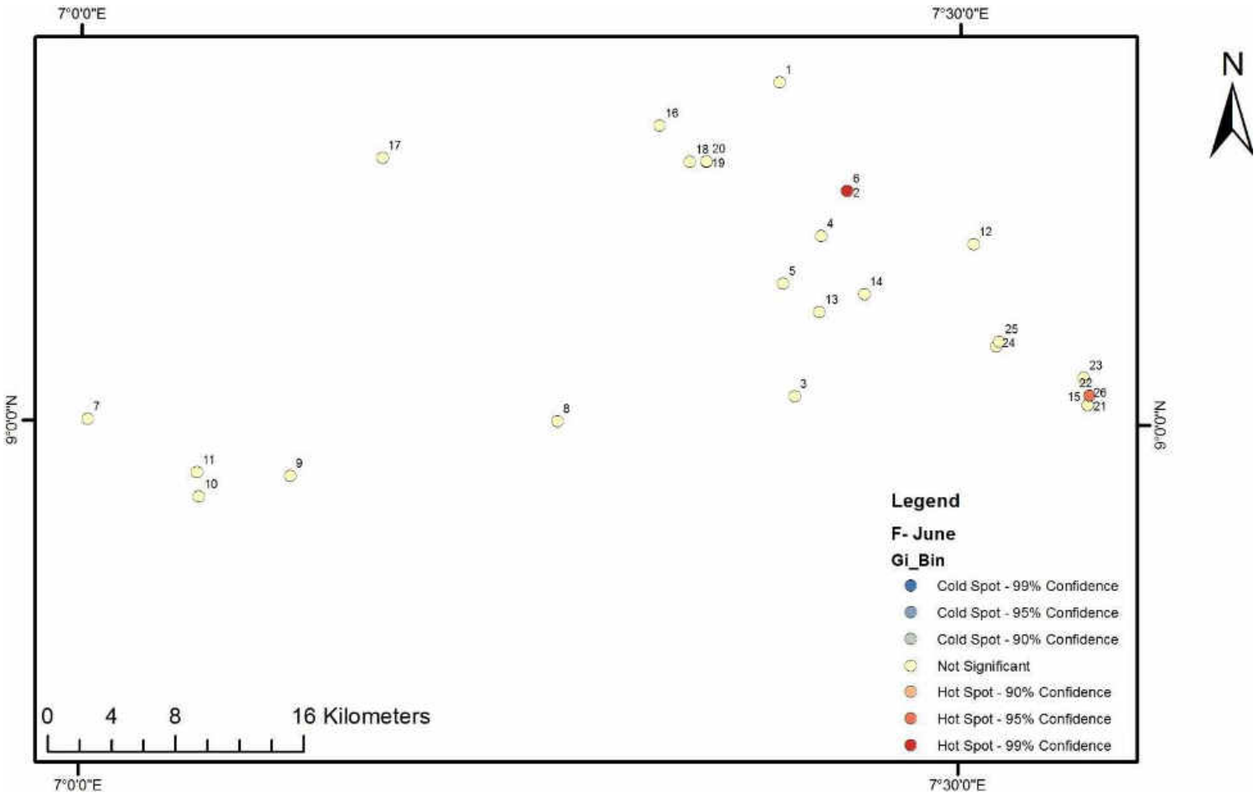


Figure 7: Hotspot analysis results for F negative for June

In the case of F- (Figure 7), hot spot analysis revealed that sample 2 and 22 are statistically significant hotspot. The indications therefore, while there are spatial dependencies most of the samples did not show statistically significant clustering.

For the month of October, Iron also showed a significant spatial autocorrelation (P<0.05), indicating that both June and October values for Iron levels in the water samples are dependent on location. Both periods shows positive spatial autocorrelation across the samples (similar values cluster together).

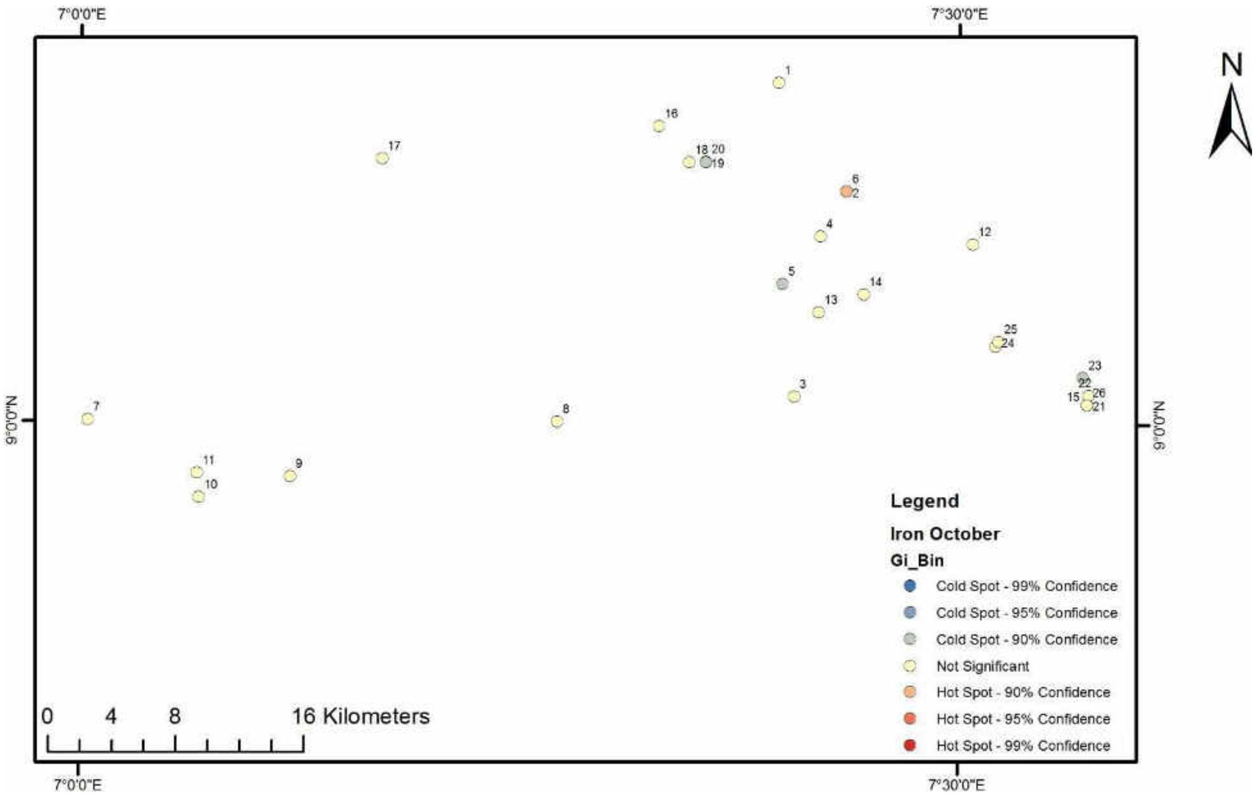


Figure 8: Hotspot analysis result for Iron level in water samples for October

Hot spot analysis (Figure 8), for the Iron level in the water samples shows that there are three statistically significant cold spots (samples 15, 19 and 23) while sample 6 is the only hotspot while all the other sample are not statistically significant.

From the foregoing, although spatial autocorrelation were found across the three months and a number of parameters, only a handful of samples displayed statistically significant clustering. This gives an indication that, clusters are very isolated which thus differences observed are more likely to be as a result of localized factors (Contamination etc.) rather than a wider scale factors. Comparison revealed that many of the parameters are within benchmark values for good quality water, the variation over time and in spatial autocorrelation shows that, there is a possibility that during distribution quality changes. These changes were also found to have been worse in a number of isolated location (Hot spots in Figure 3 - 8).

## 4 Summary and Conclusion:

There is a clear understanding that water supply is of great importance for domestic, social, economic and industrial development. Supply must be at required quantity and quality in order to meet the need of the people. However, over the year there has been problems across different part of the country, with quality and quantity of water supply being below the required standard or even not been made available at all. Therefore, showing that there is need to continue to explore possibilities of providing adequate water supply for places without such while monitoring area where such facilities have been provided. In Abuja public water supply covers some areas and it is on this basis that this study seeks to examine the quality of the water supply over time and across different locations. From, the result, the quality of the water supply across the area sampled and over the period of sample area all within the standard specified by the FMENV. However, there are some locations with parameter values close to the upper limit (Colour, Turbidity) or exceeding (Magnesium and Free Chlorine) the standard. Furthermore, analysis examining temporal differences revealed that there are significant ($P<0.05$) temporal differences across all the parameters except for Colour, Sodium and Nitrate. Essentially, water quality varies across considerably across different times of the year. While it is tempting to adduce this occurrence to seasonal variation in the sources of the water used by the utility companies or agencies, there need to examine if there is a spatial dimension to this variation. The study examined the spatial dependencies across all the 14 parameters selected over the three periods. Result shows that there are significant ($P<0.05$) spatial autocorrelation for Conductivity, TDS and Nitrate (February), Iron, Free Chlorine and F- (June) and Iron (October). In essence, there are spatial associations in the values of some of the water quality indicators across the area sample over time. It should be noted that there is a mixture of positive and negative spatial autocorrelation across these parameters. Furthermore, using Hot Spot Analysis (Getis-OrdGi*), we identified significant sampling point with significantly high or low values across for the parameters that were found to exhibit spatial autocorrelation. One cold spot was found for Nitrate, one cold and one hot spot for conductivity in February. For Iron, three significant hot spots were found; three hot spots were also found for Free Chlorine while 2 hot spots were found for F- in the month of June. In October, Iron has 3 cold spots and one hot spot.

From the results, we could conclude that the water quality across the sampled area meets the specified quality standards for most of the parameters. These parameters also vary significantly over time across this area and this variation sometimes lead to exceedance of standard limits for some of the quality parameters. There are clustering of similar and also dissimilar values across space and time in relation to the water quality parameters. None of the parameter shows spatial autocorrelation across the three periods however, Iron showed a positive spatial autocorrelation for two of the period under investigation. Therefore, Iron is the most variable temporally and spatially among the parameters. From the results, we could also conclude that the variation across the parameters over space and time localized, giving a clear indication that factors influencing the quality are closer to the source of the sampling.

This study presented a rapid assessment of water quality which incorporate spatial and temporal dimension. It offers a means of identifying potential location of weak link within the distribution system and thereby allowing for effective management of water supply systems within a metropolitan area. It is recommended that regular location inspection of the distribution network be carried out to identify the point of contamination leading to exceedance of some of the parameters examined. A formalized system of sampling along the distribution system should also be implemented to study the quality of water distributed from the source as it flows through the distribution network.

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