

Full Length Research Paper

Physico-chemical analysis of selected groundwater samples of Ilorin town in Kwara State, Nigeria

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This study was conducted to assess the impacts of industrial activities on the ground water quality in industrial and non- industrial area in Ilorin Town. The quality assessment was focused on physico-chemical parameters. Groundwater samples were collected from industrial area and from non-industrial area which were used as control. The results obtained were compared with standards prescribed by WHO. Total of 5 parameters were investigated. It was found out that all the sites had pH values between the permissible limit of 6.5 to 8.5 indicating that they are fit for domestic purpose. Sites 1 and 3 recorded highest conductivity of 285 to 320 μScm^{-1} which was above the acceptable limit, this could be as a result of industrial activities taking place in the area, that is, influence of dissolved ions from the effluent coming from soap, cement, sawmill industries located in the area. The alkalinity value recorded ranged between 3.00 to 19 mg/L. The values obtained in all the sampling sites are well below the limit. Seven out of the ten sites had total organic carbon (TOC) higher than the acceptable limit. Analysis of variance (ANOVAs), Pearson correlation and principal component analysis (PCA) were used to evaluate the data.

Key words: Groundwater, physicochemical parameters, water quality, drinking water, total organic carbon (TOC), pH.

INTRODUCTION

Water is the world's most abundant natural substance and it is in constant circulation. About 1460 petcitones (pt) (10 kg) of water covers 71% of the earth's surface, mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapour, clouds and precipitation. It comprises about 70 to 90% of the weight of living organism. It is a dispersion medium for all biochemical reactions which constitutes the living process and takes part in many of these reactions. Without water, life cannot survive. It is absolutely essential to life, not only human but all life, plant and animal.

Therefore, the quality of water is of vital concern for mankind since it is directly linked with human welfare. Over 97% of the total water supply is contained in the oceans and other saline bodies of water and is not readily usable for most purposes. Of the remaining 3%, a little over 2% is tied up in ice caps and glaciers (about 12.4%), 0.62% was found in groundwater supplies, the surface water like lakes and rivers cover about 0.019% and finally, the water vapour constitute 0.00%.

Groundwater is believed to be comparatively much clean and free from pollution than surface water. However, indiscriminate discharge of industrial effluents, domestic sewage and solid waste dump cause groundwater to become polluted and creates health problems (Patil and Patil, 2010). There are various ways in which groundwater is contaminated, amongst which are; the use of fertilizer in farming (Altman and Parizek,

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1995), seepage from effluent bearing water body (Adekunle, 2009). Most of the industries discharge their effluent mostly without proper treatment into nearby open pits or pass them through unlinked channels, resulting in the contamination of groundwater (Jinwal and Dixit, 2008).

The vast growth in urbanisation has further affected groundwater quality due to overexploitation of resources and improper waste disposal practises. Large volumes of waste are concentrated and discharged into a relatively small area (Rao and Mamatha, 2004). Hydro-geochemical conditions are also reported to be responsible for causing variations in water quality (Manhata et al., 2004).

Groundwater has usually higher total dissolved solid (TDS) concentration than the surface water because of mineral pick up from soils and rocks. Groundwater in some area is noted for high concentration of particular ions or elements such as magnesium, boron etc. Groundwater contains various types of pollutants and several other substances are dissolved in it. These substances may be useful for human body but in a specific limit (Ranjana, 2009). Groundwater is a preferred source of water because of its high quality with respect to portability and the minimum treatment requirement. For individual homes, they find surface water in remote mountains is as attractive because of their more desirable chemical characteristics and reliability.

In general, the importance of groundwater for existence of human society cannot be overemphasised. Hence, there is always a need for the protection and management of groundwater quality. With respect to the above mentioned groundwater quality, this study aims at carrying out qualitative analysis of physicochemical parameters of selected groundwater in industrial and non-industrial areas in Ilorin.

MATERIALS AND METHODS

Description of the study area

Ilorin is situated approximately between latitudes 8.5 (8° 30' 0" N) and longitude 4.55 (4° 33' 0" E). Ilorin was built as a residential, industrial and agricultural city. The ground water from the wells also serves as a source of drinking water in the study area. The terrain, in the study area is generally flat, low lying and riddled with an intricate system of ground water channels.

This area is located mainly within wooded savannah and is characterized by average temperature ranges between 30 and 36°C and generally. The area is marked by two climatic seasons: the dry and wet seasons with an intervening cold and dry harmattan from December to January and an annual rainfall range between 1,000 and 1,500 mm. This area is marked by high industrial activities. Figures 1 and 2 show the locations where samples were collected for this investigation. The sampling sources generally are shallow wells ranging about 3.35 to 5.79 m and not very far from each other about 100 m and above. There are 10 locations altogether. The depth, well water features for each location are summarised in Table 1.

The objective of sampling is to collect a portion of material, small enough to be transported conveniently and handled in the

laboratory while still accurately representing the material being sampled. This implies that the relative proportions or concentrations of all pertinent components will be the same in the samples as in the materials being sampled, and that the sample will be handled in such a way that no significant changes in composition occur before the analysis is carried out (Adeniyi, 2009). Sample labels were used to prevent sample misidentification. These labels carried such information as date and time of collection, place of collection and preservation method. A field logbook was kept in which all information pertinent to a field survey or sampling were recorded such as location of sampling point, the purpose of sampling and the method of preservation, if applicable (Adeniyi, 2009).

The type of container used is of utmost importance as containers are basically made of plastic or glass but one type of materials may be preferred over the other; for example, silica and sodium may be leached from glass but not plastic and trace levels of metals sorb onto the wall of glass containers. For these reasons, samples containing organic compounds were collected in glass bottles while samples for determination of trace amounts of heavy metals were collected in plastic containers.

The micro pH 2000 crison meter was standardized using the buffer solution of pH 4 before it was used. After the standardization, the electrode was placed in a beaker of distilled water. This process clears the electrode of the standard solutions into which it is dipped previously. Then the electrode was dipped inside 200-ml beakers that contained each of the water samples. Readings were noted on the meter and recorded; this value is the pH values of the water samples. The pH values of each water samples were determined at the site of collection.

The mercury-in-glass thermometer was immersed into each 1-L water sample in a plastic bottle. The actual reading was recorded after 30 s of immersing it in the water sample. The time at which the temperature of water samples detected was recorded. The temperature of each water samples was determined immediately at the site of the collection of the water sample. The conductivity value of water is affected by temperature, so the electrical conductivity of each water sample was determined at the site of the collection. The electrode of the conductivity meter was first dipped into distilled water, before sample conductivity measurements were made. The value of the electrical conductivity of each of the water sample was recorded.

Reagents and instrumentation

Deionised water was used for the preparation of solution throughout the study. All reagents used were of analytical grade. Bottles were prewashed with laboratory grade detergent followed by adequate rinsing with deionised water. They were then soaked in 0.1 M HNO₃ overnight followed by thorough rinsing with deionised water. The pH meter, conductivity meter, mercury in glass thermometer, flame photometer was used to analyze these parameters. The procedure for calculating the different parameters were conducted in the laboratory.

Determination of total alkalinity

This is determined by measuring 100 ml of water samples into conical flasks. Phenolphthalein was prepared by weighing 0.5 g in 50 ml of 95% ethanol and 50 ml distilled water with constant stirring. 2 to 3 drops of phenolphthalein was added to the water samples in the conical flasks. Each water sample was titrated with 0.01 M HCl until the pink colour disappeared. This end point represents phenolphthalein alkalinity. A few drops of methyl orange indicator were added to the samples in conical flasks (samples already treated with phenolphthalein indicator. The sample turned yellow immediately on addition of methyl orange. The solution was

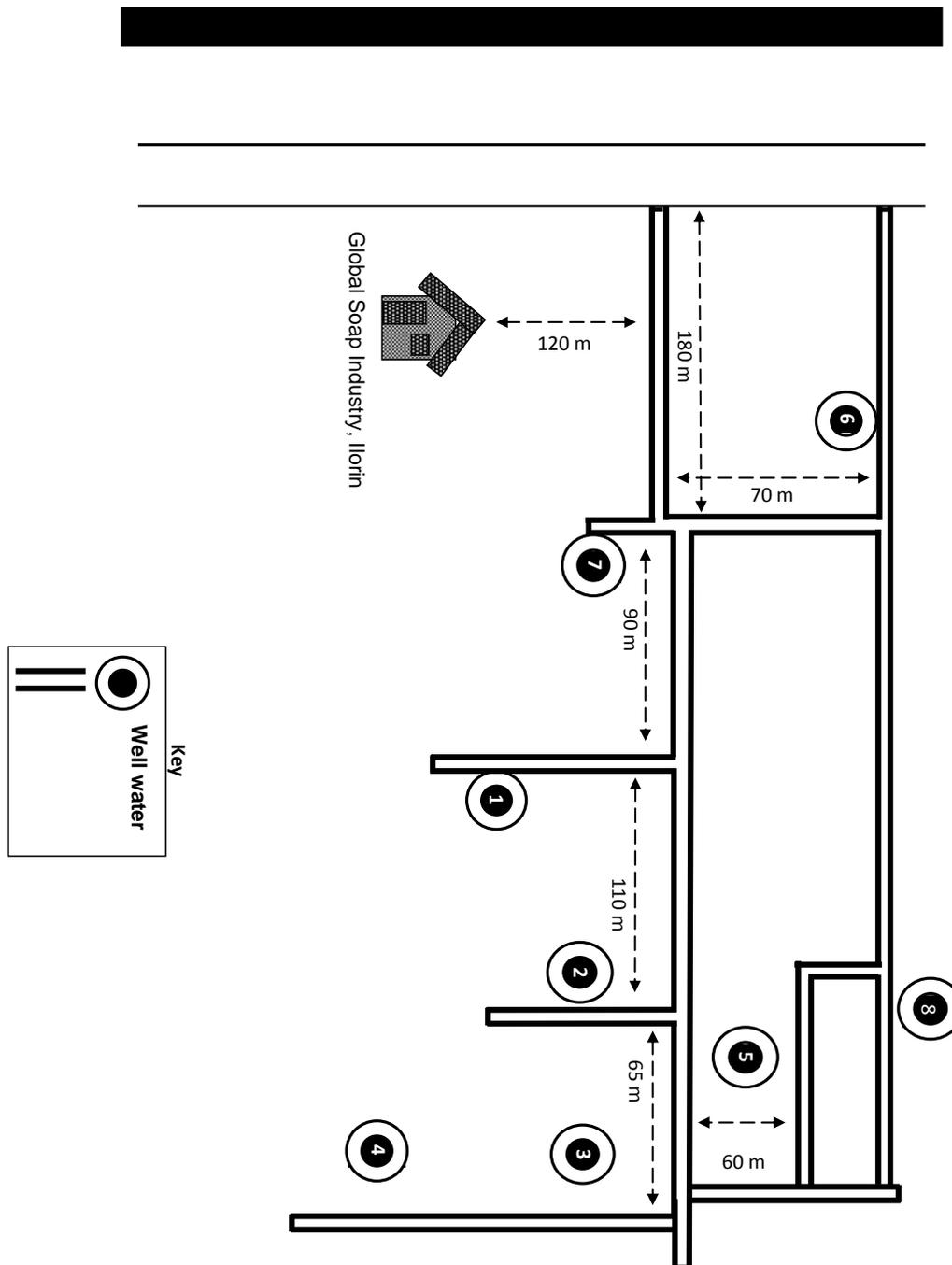


Figure 1. Map indicating the layout of sampling points (Industrial area, Ilorin).

titrated with 0.01 N HCl until the colour change was observed which represents the total alkalinity.

Determination of total organic carbon

The sample was acidified and the inorganic carbon (IC) was removed prior to analysis for organic carbon (OC) content using a TOC instrument system. The organic carbon in the water sample was oxidized to produce carbon dioxide (CO₂) by combustion which

is then measured by a detection system. The carbon dioxide formed by oxidation is determined either directly or after reduction, for example methane and a calibration curve was established by analyzing potassium hydrogen phthalate standard solutions of adequate concentration. Each sample solution and the blank solution analyzed were analyzed. A calibration curve was plotted by plotting the mass concentrations of TOC in milligrams per litre of carbon against the instrument-specific response units. The reciprocal value of the slope of the resulting calibration line is the calibration factor f in milligrams per litre of carbon.

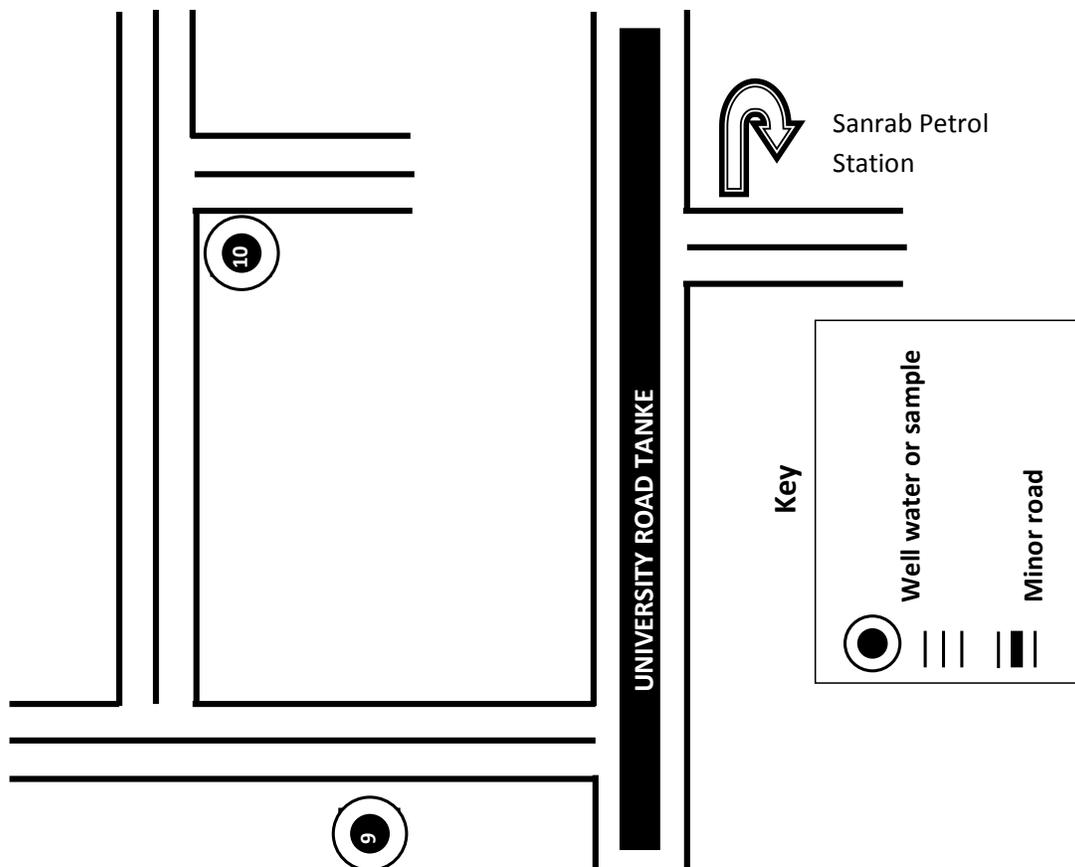


Figure 2. Map indicating the layout of control site (non-industrial area).

Table 1. Description of sampling points.

| Locations | Sampling depths (m) | Water type | Water features |
|-----------|---------------------|------------|--|
| 1 | 5.79 | Open well | Slightly muddy and unclear. |
| 2 | 4.88 | Open well | Dirty, bad odour, not muddy and not clear. |
| 3 | 4.27 | Open well | Odourless, little clean, not muddy and slightly clear. |
| 4 | 4.57 | Open well | Unclear water, very muddy. |
| 5 | 3.35 | Open well | Very shallow well, very clean and clear and odourless. |
| 6 | 3.96 | Open well | Very shallow well, very clean and clear and odourless. |
| 7 | 5.18 | Open well | Little foamy well water, slight soapy odour and not clean and clear. |
| 8 | 5.48 | Open well | Odourless, very close to tide road, not very clean and clear. |

Statistical analyses

The results were statistically analysed using SAS 9 software (Cary, NC, USA). The *posteriori* analysis of variance (ANOVA) procedure was performed to determine the variation and significance variations in the dependent variables due to sites with a $P \leq 0.05$ were considered significant. A *post-hoc* test was then conducted using *Scheffes* test for mean comparison. Pearsons correlations was applied to evaluate the relationships between the variables; a correlation with $P \leq 0.05$ was regarded as significant and principal component analysis (PCA) was used to sort sampling sites into

groups with similar responses.

RESULTS AND DISCUSSION

Physicochemical parameters in ground water for eight industrial areas in Ilorin town in Nigeria are presented in Table 2. Temperature, conductivity and total organic carbon varied significantly ($P \leq 0.05$) whereas insignificant variation was observed for data.

Table 2. Physicochemical parameters in eight industrial areas in Ilorin town in Nigeria.

| Stations | Physicochemical parameters | | | | |
|-----------|----------------------------|------|----------------------|--------------------|------------|
| | Temperature (°C) | pH | Conductivity (µS/cm) | Alkalinity (mg /L) | TOC (mg/L) |
| S1 | 32.75 | 7.29 | 320 | 7.5 | 34.87 |
| S2 | 31.25 | 7.78 | 141.5 | 12.5 | 34.55 |
| S3 | 32.00 | 7.73 | 285.5 | 19.0 | 32.53 |
| S4 | 33.25 | 7.04 | 232.0 | 12.5 | 38.04 |
| S5 | 32.00 | 7.27 | 72.00 | 3.00 | 2.83 |
| S6 | 30.25 | 7.19 | 48.0 | 6.5 | 3.54 |
| S7 | 31.75 | 7.41 | 187.5 | 5.5 | 3.54 |
| S8 | 32.75 | 7.02 | 53.5 | 7.0 | 2.83 |
| Control 1 | 31.50 | 7.46 | 169.5 | 9.0 | 21.31 |
| Control 2 | 30.50 | 7.78 | 172.0 | 9.5 | 2.20 |
| Mean | 31.8 | 7.39 | 168.15 | 9.2 | 29.38 |
| SD | 1.05 | 0.36 | 91.28 | 5.28 | 7.08 |
| MSD | 3.4 | 1.61 | 42.69 | 20.79 | 23.85 |
| P ≤ 0.05 | *** | NS | *** | NS | *** |

**** = Significance at 95% confidence level, NS = not significant at 95% confidence level, MSD= minimum significant difference.

Water temperature during the study period varied between 30.25 and 33.25°C. The higher temperature values of the water samples observed during the study period can be attributed to the climatic condition of the area which is characterized generally by the higher temperatures during the dry season. The temperature readings were found to remain approximately constant throughout the water body. Ground water temperature tends to remain constant. However, shallow ground water displays an appreciable fluctuation in temperature. Thus, the spatial variations of temperature can be attributed to several factors such as heat transfer between water and land surface due to the release of the industrial effluents. The ground water in these sampled areas is not good for domestic purposes since it exceeds the WHO temperature limit of 25°C.

The pH value of the study area ranged between 7.02 and 7.78. Site 8 has the lowest pH value of 7.02 while sample sites 2 and 10 recorded the highest pH value of 7.78. The entire ten measured samples had pH values between the permissible limit of 6.5 to 8.5 which indicate that they are fit for domestic purpose.

Electrical conductivity

The electrical conductivity values in this study area ranged from 48 to 320 µscm⁻¹. Electrical conductance of water is a measure of its ability to carry electric current as a result of dissolved salts in the water. Pure water is supposed to have a very low electrical conductance of about 1 × 10⁶ µscm⁻¹ at 25°C. This value has only theoretical significance since for water this purity is very difficult to come by. The acceptable limit of conductivity in

drinking water is 1400 µscm⁻¹. The mean range of electrical conductance in the study area is within the limit standard for drinking water. Higher conductivity values are expected because of the industrial activities taking place in that area. Another factor is the influence of dissolved ions from the effluents of the industrial activities in the study area. However, the high value recorded at sites 1 and 3 (320 and 285 µScm⁻¹), respectively are presumably high due to the proximity of the well to the industrial site. Low conductivity value recorded in the sampling stations is because of the dilution effect of the rainwater on the land as rainfall progresses.

The mean alkalinity in the study area ranged between 3.00 and 19.0 mgL⁻¹. The acceptable limit of alkalinity in drinking water is 100 mgL⁻¹. The values observed in all the sampling sites during the study period are well below the limit. Water that has high alkalinity values are considered undesirable because of excessive hardness and high concentration of sodium salts. Water with low alkalinity has little capacity to buffer acidic inputs and is susceptible to acidification (low pH). The total organic carbon values for the ground water samples sites ranged between 2.20 and 38.04 mgL⁻¹. Sample site 4 has the highest values of TOC (38.04 mg/L) while site 10 (control site) recorded the lowest values of TOC (2.20 mg / L). Seven out of the ten measured samples had TOC higher than the acceptable limit; this may be attributed to the industrial activities taking place in the area.

Correlation coefficients for physicochemical parameters in ground water are presented in Table 3. All the physicochemical parameters analysed showed weak correlation of $r < 0.7$ with the correlation between alkalinity and pH showing significant correlation at ($P \leq 0.05$). Temperature and pH showed inverse correlation

Table 3. Correlation coefficient matrix for different physicochemical parameters in ground water.

| Correlation coefficient | Temperature | pH | Conductivity | Alkalinity | TOC |
|-------------------------|-----------------|-----------------|-----------------|-----------------|------|
| Temperature | 1.00 | | | | |
| pH | -0.176 (0.458) | 1.00 | | | |
| Conductivity | 0.3755 (0.1076) | 0.2599 (0.2683) | 1.00 | | |
| Alkalinity | 0.2861 (0.2214) | 0.6142 (0.0040) | 0.1310 (0.5818) | 1.00 | |
| TOC | 0.4414 (0.0514) | 0.1650 (0.4868) | 0.4389 (0.0588) | 0.2137 (0.3657) | 1.00 |

Value outside parenthesis denotes the correlation coefficient r while value in parenthesis denotes significance level at 95% confidence limit.

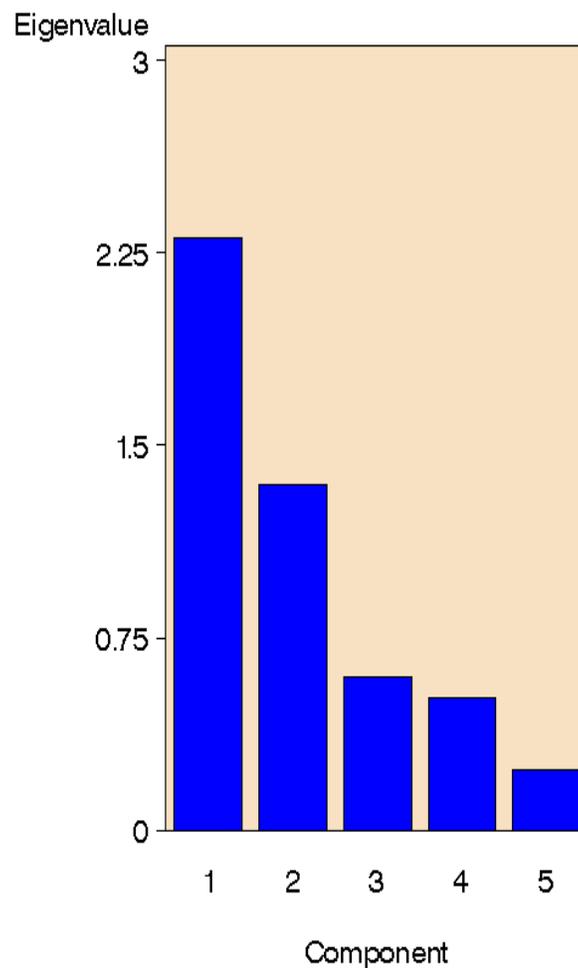


Figure 3. Scree plot showing variation in physicochemical parameters in ground water.

$r = -0.176$.

Component variations in the physicochemical parameters eigenvalues are shown in Figure 3 in the order Temperature > pH > Conductivity > Alkalinity > Total Organic Carbon.

Standard two-dimension PCA for five physicochemical parameters (temperature, pH, conductivity, alkalinity and

total organic carbon), sites 1-8 and two control sites for ground water in Asadam industrial estates of Ilorin city in Nigeria (Figure 4) are plotted on the axes. The distribution of the component concentrations are highly concentrated in station 4 (S4) in both dimensions and the least contributions are from the control sites, S1, S2, S3, S5, S6, S7 and S8 respectively.

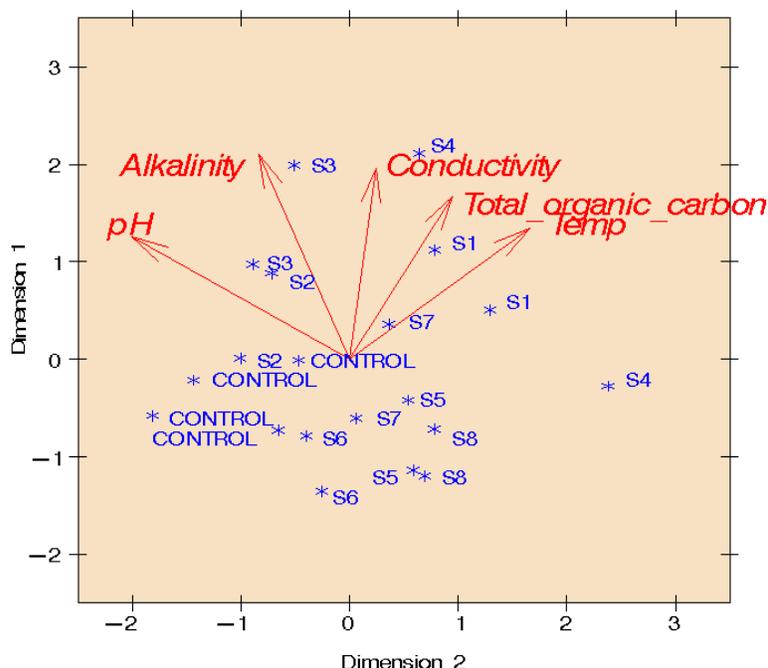


Figure 4. Principal component analysis (PCA) for physicochemical parameters in ground water.

Conclusion

In general, groundwater quality of selected groundwater samples in Ilorin town, Kwara State, Nigeria has been investigated. It was found out that all the sites had pH values between the permissible limit of 6.5 to 8.5 indicating that they are fit for domestic purpose. Sites 1 and 3 recorded highest conductivity of 285 to 320 μScm^{-1} which is above the acceptable limit, and could be as a result of industrial activities taking place in the area, that is, influence of dissolved ions from the effluent coming from soap, cement, sawmill industries located in the area. The alkalinity value recorded ranged between 3.00 and 19 mg/L. The values obtained in all the sampling sites are well below the limit. Seven out of the ten sites had total organic carbon (TOC) higher than the acceptable limit. The ANOVAs, Pearson Correlation and PCA were used to evaluate the data. Significant correlation between alkalinity and pH at ($P \leq 0.05$) was found. Scree plot showed variation in physicochemical parameters in ground water in the order Temperature > pH > Conductivity > Alkalinity > Total Organic Carbon. The ground water quality in this region is not harmful to human beings and where the physicochemical parameters were above the WHO standard was due to industrial discharges, urbanization and contribution from human activities.

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