THE EFFECTS OF PETROLEUM ACTIVITIES AND WOOD INDUSTRIES ON WATER AND SOIL IN OLOGBO AND ENVIRONS, SOUTHERN NIGERIA.

BY

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PG/PSC 0904747

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, UNIVERSITY OF BENIN, EDO STATE

DEPARTMENT OF GEOLOGY,

FACULTY OF PHYSICAL SCIENCE,

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BEING A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF GEOLOGY, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA. IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN ENVIRONMENTAL GEOSCIENCE

OCTOBER, 2019.

CERTIFICATION

This title entitled“ **THE EFFECTS OF PETROLEUM ACTIVITIES AND WOOD INDUSTRIES ON WATER AND SOIL IN OLOGBO AND ENVIRONS, SOUTHERN NIGERIA.**” by Israel Giwa DUDU meets the regulations governing the award of the degree of Environmental Geosciences of University of Benin, Edo state and is approved for its contribution to knowledge and literary presentation.

Professor. C. N. AKUJIEZE (Date)
Supervisor

Professor. C. N. AKUJIEZE (Date)
Head of Department

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Abstract

Soil, surface water and groundwater samples were collected for physico-chemical, microbial and heavy metal analysis from different locations in Ologbo and environs. Thirteen (13) soil samples including Three controls (Pristine environment) were randomly collected at subsurface depth of 0-30cm, Thirteen surface water samples were collected including three controls and Ten (10) Groundwater samples were collected using random sampling Technique. The samples were collected in order to evaluate the level of pollution/Contamination of the media as a result of petroleum activities, wood industries and other anthropogenic activities within the study area. The results for the groundwater analysis showed pH (5.61-5-78), EC (54.64-65.74), Turbidity (0.05-0.12NTU), Cu (0.38-0.49mg/l), Zn (0.3-0.39mg/l), Cr (0.09-0.16mg/l), Ni (0.64-0.85mg/l), Fe (0.38-2.49mg/l), Mn (0.1-0.15mg/l and Pb (0.01-0.16mg/l). The results for the surface water showed pH (5.71-6.05), turbidity (7.31-13.92NTU), EC (87.11-95.2uS/cm), Zn (0.41-0.45mg/l), Fe (1.24-1.3mg/l), Cu (0.51-0.54mg/l), Cr (0.35-0.38mg/l), Ni (0.09-0.21mg/l) and Pb (0.02-0.06). These results were compared with world and national standards and control samples were collected and used for comparison where needed .The result, of the analyses were further subjected to statistical treatment such as Spearman's correlation Co-efficient, ANOVA and concentration Factor Analysis, to ultimately ascertain the spatial relationship between sample. The ANOVA results for soil samples indicated a very strong significant difference at ($p<0.01$) between control and soil samples for all parameters. Correlation results revealed positive and negative correlation Co-efficient at r (0.01) and r (0.05) indicating strong relationship between them, which probably reflects their source of Contamination. Concentration maps generated for the area showed high concentrations of Lead, Copper and Iron around the central area, increasing towards the south western part of the maps. The groundwater flow map showed a 2-way flow direction towards the central part where the major river dividing the map is located. The overall results revealed moderate contamination/pollution of all varieties of samples analyzed and it's here by recommended that important steps be taken to minimize the negative effects of oil exploration and wood industries in Ologbo.

Chapter One

1.1 Introduction

Water is one of the most essential of all natural resources because it is fundamental to all vital processes of mankind. The quantitative supply of water can be a local issue, but in many regions the most serious problem hindering the utilization of water resources is the deterioration of water caused by pollution, which leads to an estimated 25,000 deaths daily because of water – related sicknesses (United Nations Population Information Network, Popin, 1994).

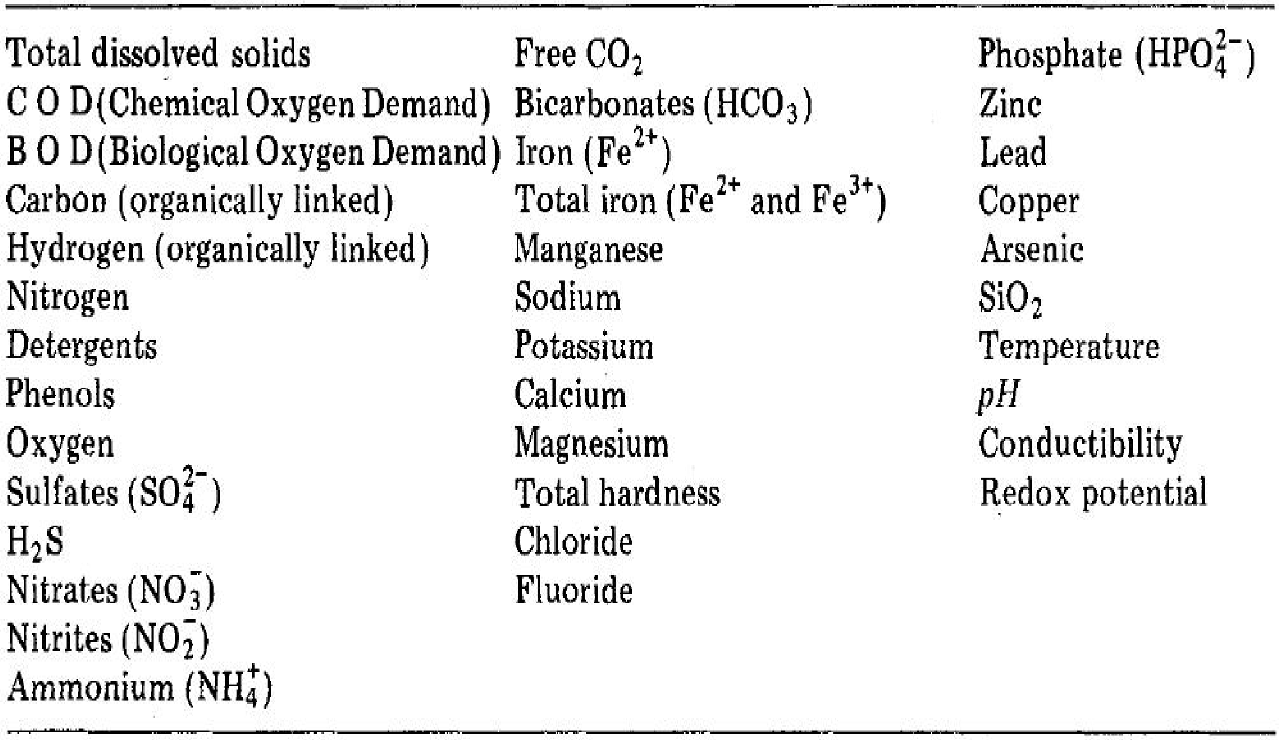
Deficient water supplies and sanitation therefore pose the most serious environmental problems that face developing countries today. Ayoade and Oyebande (1973) noted that less than 30% of Nigerian cities are served by public water schemes. This fact remains true and is evident in Warri and its environs where private wells and boreholes ownership are common.

Nigeria is blessed with large quantity of groundwater resources. For instance, Rijswljk (1981) estimated the amount of groundwater resource in Nigeria to be $6 \times 10^{18}m^3$. The resource plays an important role in the social an economic life of the people in terms of domestic industrial and agricultural use. However, little is done to assess and understand the quality of groundwater especially within the different aquifer systems.

Most literature on groundwater quality of Nigeria is localized, small scale and scattered. Besides, no known publication to date has been highlighted on quality alongside the sources and processes responsible for the water chemistry for the entire nation as an entity.

Groundwater pollution is usually traced back to four main origins: industrial, domestic, agricultural and environmental pollution. The occurrence of these elements and compounds in the water does not necessarily mean that it is polluted, and, actually, pollution criteria will depend on the type of use made of the water: e.g., drinking purposes are a possibility, but also personal hygiene or recreation (swimming pools, for instance) or irrigation; in these last cases the hazards are less well known than the hazards to drinking water and there are no norms or international regulations for their control,

Table 1.1: List of Possible Groundwater Pollutants And Pollution Indicators (Fried, 1975)



Total dissolved solids
C O D(Chemical Oxygen Demand)
B O D(Biological Oxygen Demand)
Carbon (organically linked)
Hydrogen (organically linked)
Nitrogen
Detergents
Phenols
Oxygen
Sulfates (SO_4^{2-})
H_2S
Nitrates (NO_3^-)
Nitrites (NO_2^-)
Ammonium (NH_4^+)

Free CO_2
Bicarbonates (HCO_3)
Iron (Fe^{2+})
Total iron (Fe^{2+} and Fe^{3+})
Manganese
Sodium
Potassium
Calcium
Magnesium
Total hardness
Chloride
Fluoride

Phosphate (HPO_4^{2-})
Zinc
Lead
Copper
Arsenic
SiO_2
Temperature
pH
Conductibility
Redox potential

Minimization of potential of soil and water contamination, also due to use of waste materials such as sewage sludge and other biosolids for soil amendment requires source control of contaminants' emission not only from large industries, but also from small artisan enterprises. For this purpose, simple and inexpensive methods, preferably with use of abundant waste materials, e.g. as efficient and cost-effective sorbents of pollutants may be used.

Soil pollution can be defined as entry of materials, mostly chemicals that are out of place or are present at concentrations higher than normal and have the potential to produce adverse effects on humans and/or other organisms. These adverse effects include the danger of acute toxicity, mutagenesis (genetic changes), carcinogenesis, and teratogenesis (birth defects).

Soil pollution is often caused by human activities such as pesticide application and industrial waste materials, leading to the contamination of food grown on the soils. The rapid industrialization of agriculture, expansion of the chemical industry, and the need to generate cheap forms of energy have caused the continuous release of manmade chemicals into natural ecosystems. Consequently, the atmosphere, water, and many soil environments have become polluted by a large variety of toxic compounds.

Pollutants that are of more than local interest as far as contamination of the geosphere is concerned, must possess a number of characteristics, the more important of which are toxicity, persistence and a capacity to disperse, which in turn depends on the pollutant's leachability (or water solubility), volatility and tendency to sorb on particulate matter that has the potential to be air-borne.

Remediation of soils, water/sediments and groundwater contaminated by complex mixtures of organic pollutants and heavy metals is one the greatest challenges facing environmental restoration.

There is therefore a significant demand for environmentally safe and economically feasible technologies for treatment of contaminated ecosystems. Although fundamental and applied studies have provided many novel treatment technologies, we must improve the means to bridge between research and practice, and means to combine different capabilities.

In Ologbo town and its environs, high hydrocarbon exploration activities and industrialization are ongoing, which implies an increase in the generation of domestic and industrial wastes, preponderance of individual septic tanks, indiscriminate drilling of boreholes with its attendant over–abstraction problems that enhance pollutant concentrations and saline water intrusion of the groundwater resources.

Therefore, periodic examination to ascertain the quality of the groundwater and surface water is indispensable. The fact that most of the water consumed does not undergo treatment by the state public water utilities makes it pertinent to regularly conduct and monitor physical, chemical and biological state of groundwater.

1.2 Aim and Objectives

The aim of this project is to carry out a geochemical characterization of soil, groundwater and surface water samples from locations within and around Ologbo town to ascertain the level of contamination due to lumbering and hydrocarbon exploration activities.

The objectives include:

1. Physico-chemical analysis of the samples to ascertain the concentration of the analyzed parameters.
2. Heavy metal concentration analysis on the samples to know the level of contamination of the samples.
3. Generate a heavy metal concentration map for the area as it relates with the concentrations in the soil, groundwater and surface water
4. Geostatistical characterization of the available data to understand the spatial distribution of the analyzed parameters
5. Be able to characterize the heavy metals and other parameters based on their source.

1.3 The Study Area

The study area is located within Ologbo town, Ikpoba Okha LGA area of Edo state. The major activities of the area include fishing around the riverine areas, farming and lumbering activities and hydrocarbon exploration activities.

The climate is an equatorial bimodal system with an alternating wet and dry season influenced by its proximity to the Atlantic Ocean, wind patterns and sunshine. The area is dominated by two major air masses: the warm and dry topical continental air mass from the Sahara (harmattan wind) in the dry season months (November to February), and the humid tropical maritime air mass from the Atlantic Ocean (South-Westerly Monsoon winds).

Temperature in the Project area is influenced by the sun, wind regime and nearness to the Atlantic Ocean. The annual temperature cycle is characterized by two peaks and two minima. The annual high temperature occurs in March/April while the annual low occurs in November/December. A seasonal cooling trend coincides with the peak of the rainfall. Mean monthly temperature value ranges between a minimum of 25.3°C and maximum of 28.2°C, while relative humidity is high throughout the year, with cloud cover. The high relative humidity is due to the proximity of the area to the ocean.

The geology of the study area reveals that the entire area is underlain by sedimentary rocks. These rocks are of ages between Paleocene to Recent. The sedimentary rock contains about 90 percent of sandstone and shale intercalation. It is coarse grained, locally fine grained in some areas, poorly sorted, sub- angular to well-rounded and bears lignite streaks and wood fragment (Kogbe, 1989).The sedimentary rock of the study area constitutes the Benin Formation.

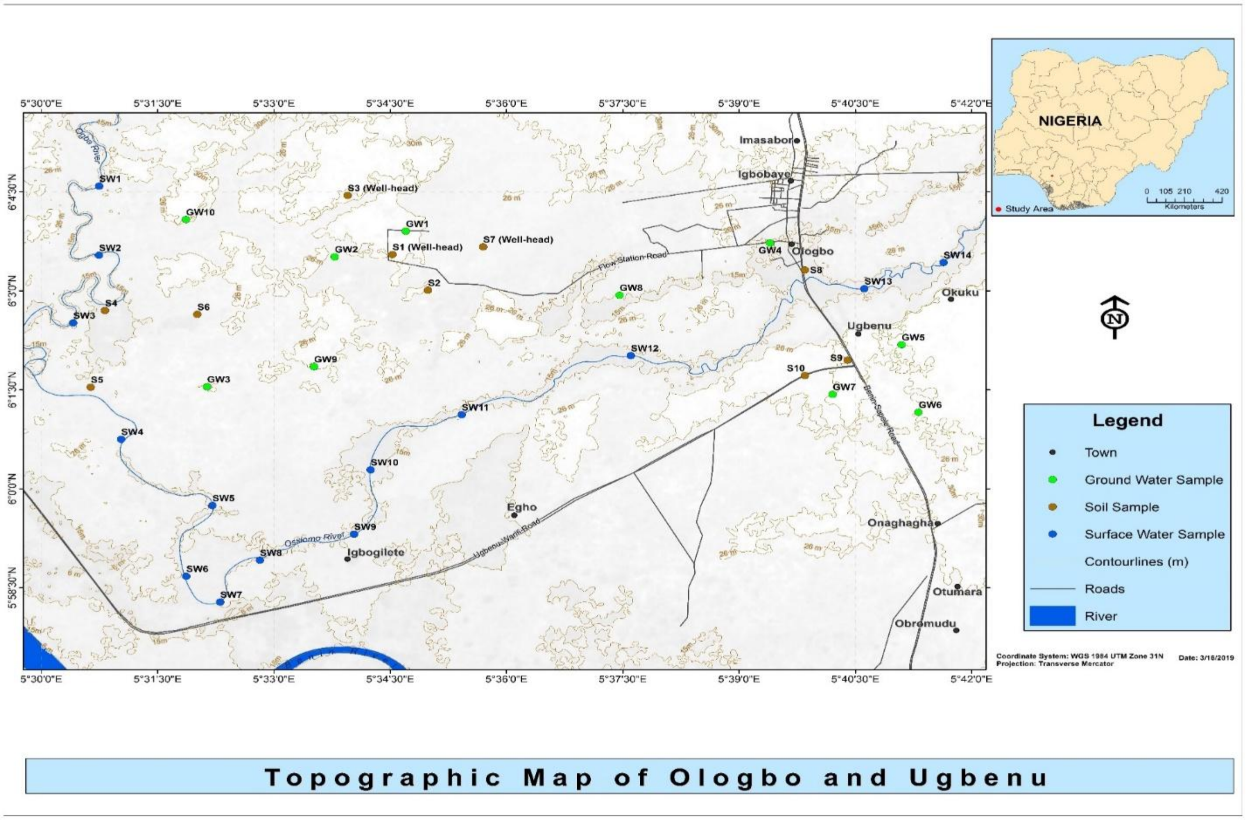


Figure 1.1: Location Map of the Study Area showing Sample points and Topography

CHAPTER TWO

Literature Review

2.1 Geology of Niger Delta

During the Cenozoic, until the Middle Miocene, the Niger Delta grew through pulses of sedimentation over an oceanward-dipping continental basement into the Gulf of Guinea; thereafter progradation took place over a landward-dipping oceanic basement.

The evolution of the Niger Delta is controlled by pre- and synsedimentary tectonics described by Evamy et al. (1978), Ejedawe (1981), Knox and Omatsola (1989) and Stacher (1995). The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic.

The fracture zone ridges subdivide the margin into individual basins, and, in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. Rifting started in the Late Jurassic and persisted into the Middle Cretaceous (Lehner and De Ruiter 1977).

The Benin Formation is the youngest lithostratigraphic unit in the Niger Delta. It is Miocene—Recent in age with a minimum thickness of more than 6000ft and made up of continental sands and sandstones (>90 %) with few shale intercalations. The shallowest part of the sequence is composed almost entirely of non-marine sand.

The sands and sandstones are coarse-grained, sub-angular to well-rounded and are very poorly sorted. It was deposited in alluvial or upper coastal plain environments following a southward shift of deltaic deposition into a new depobelt. The oldest continental sands are probably Oligocene, although they lack fauna required to date them directly. Offshore, they become thinner and disappear near the shelf edge.

The Niger Delta Basin covers most areas of Rivers, Bayelsa, Edo and Delta States of Nigeria. Its areal extent is about 75,000km2 and consists predominantly of Cretaceous to Recent clastic sediment piles of about 8000m thick that rest unconformably on the sialic basement complex.

The Delta consists of broad riverine areas through which the River Niger enters the Atlantic Ocean, dividing into numerous rivulets, which fan out into the sea. It also includes a number of tidal creeks separating small islands of less than 10m above sea level (Offodile, 2002).

The geological sedimentary sequence of the Niger Delta is made up as follows: The Ameki Formation, the Ogwash- Asaba Formation, the Benin Formation, and the Somebreiro Deltaic Plains Sands

The Ameki Formation was deposited during the regression of the sea in early Eocene. Its lower unit consists of fine to coarse sandstone with intercalations of calcareous shale and thin limestone, while the upper unit consists of coarse cross-bedded sandstones and sandy clay (Reyment, 1965).

The Ogwashi-Azaba Formation (Miocene) overlies the Ameki Formation and extends from just west of the Siluko River on the eastern flank in the Okitipupa area with a steady widening outcrop towards Onitsha. The formation consists dominantly of clays, sands, grits and seams of lignite alternating with gritty clays. Within the Ogwashi-Asaba Formation, the lignites are confined to a narrow belt of about 16 km wide 241 km long trending northwest-southeast from the Niger in the west of the Nigeria-Cameroun frontiers, east of Calabar.

The Benin Formation is Oligocene to Pleistocene in age. This formation outcrops in the north east of the coastal belt in the Niger Delta and dips at a low angle in the southwest. The sediments consist, generally, of lenticular unconsolidated, dominantly sandy formations. Lenticular clays and shales occur particularly in the eastern areas where they confine small but moderately high yielding aquifers. The 90-150m confining clay beds encountered in the Niger Delta area, (Brass, Bonny and Opobo) disappear in the regions, north of the area, and adjacent to the Benin Formation area (Bodo, Okrika and Port Harcourt) (Offodile, 2002).

The thickness of the Benin Formation is variable, but generally exceeds 2000m.The Somebreiro Deltaic Plains Sands is late Pleistocene to Holocene in age. It occupies most of the area of the present delta and stretches narrowly eastwards along the coastline. The sediments consist of medium to coarse –grained unconsolidated sands forming lenticular beds with intercalation of peaty matter and lenses of soft silty clay and shale. These beds dip at varying angles towards the sea, forming units, which represent series of old deltas (Offodile, 2002). The gravelly beds of the formation could be up to 9m thick.

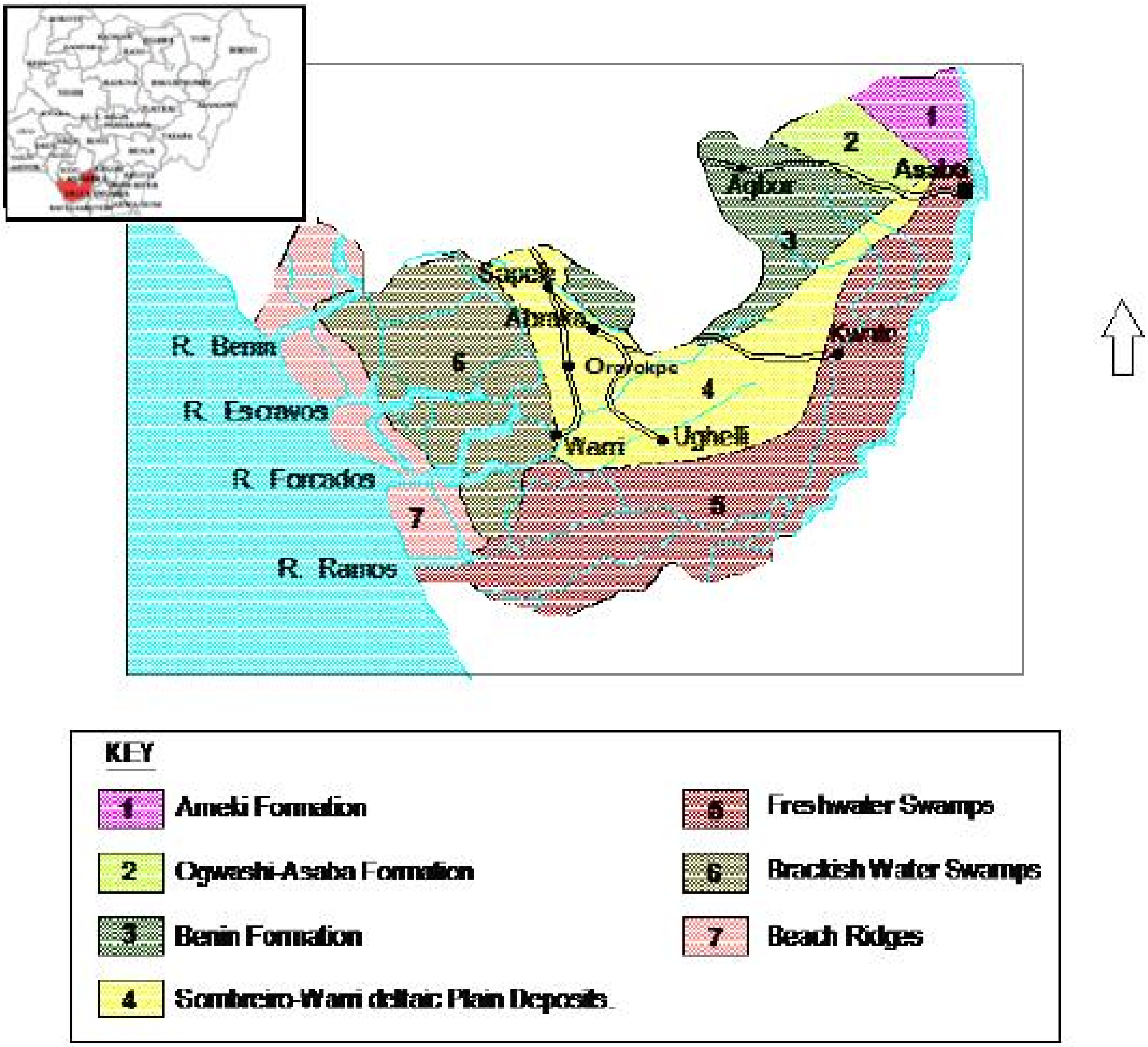


Figure 2.2 Geological Map Of Parts Of The Western Niger Delta (Modified from Akpoborie, et al., 2011).

2.2 Geology of Benin

The Benin Region is underlain by sedimentary formation of the Niger Delta Basin. The geology of the region is under continuous and intense physico-chemical transformation. It is generally marked by top Red Tropical Soils composed of low silica-sesquioxide ratio clay sand which is soft when wet and considerably hard when dry (Alayaki, et. al., 2015). Parkinson (1907) first used the term Benin sand to describe the Red Tropical Soils underlain by sands, sandy clays and ferruginous sandstone that mark the Paleo-Coastal Environment of Paleocene-Pleistocene Age.

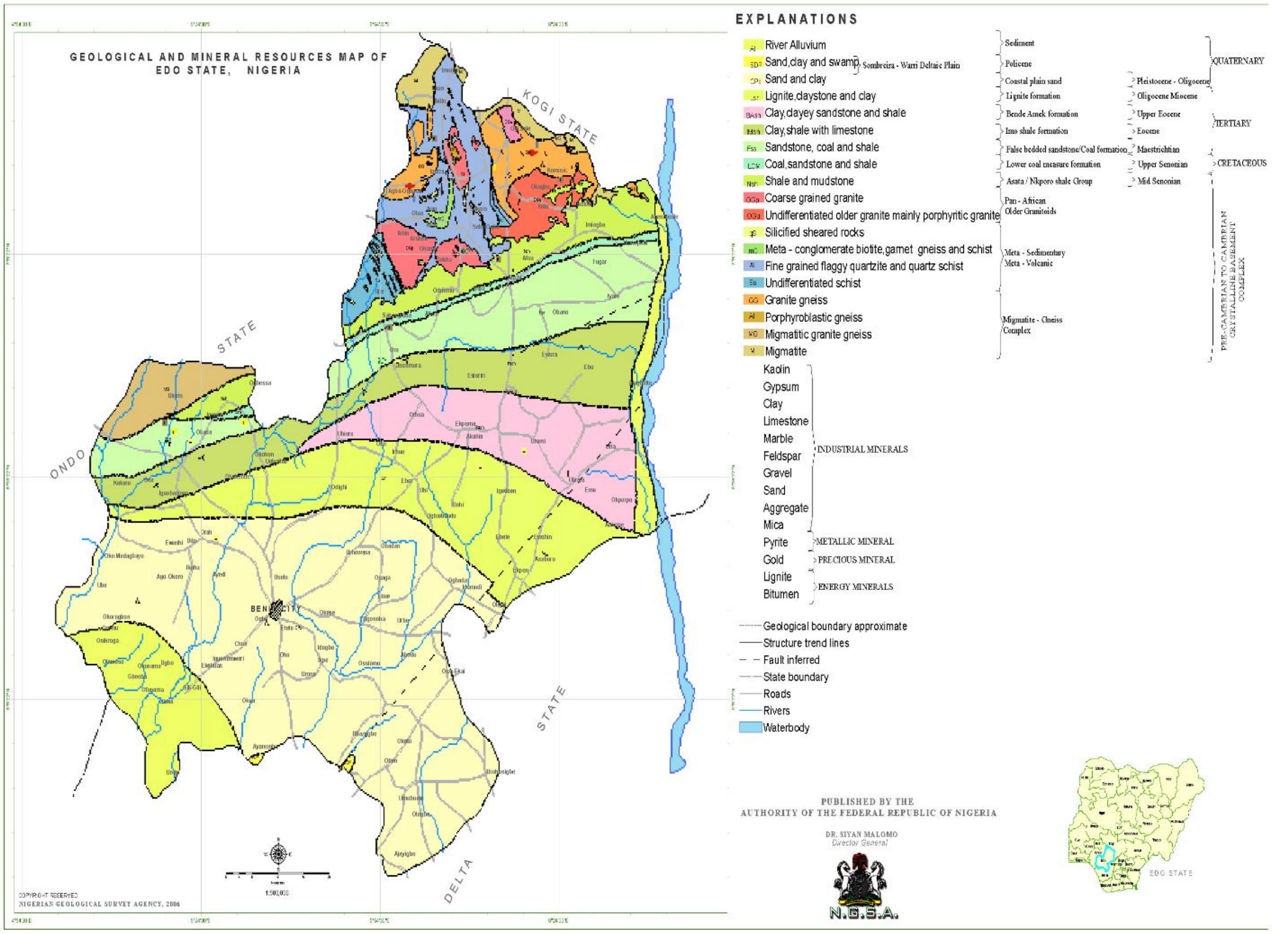


Figure 2.3: Geologic Map of Edo State (NGSA, 2006)

These sediments spread across the southern fringes of the Anambra Basin and mark the upper fancies off-flaps of the Niger Delta. Tattam (1943) used the name Coastal plain sands to describe the formation of Red Tropical Soils underlain by sands and clays that mark an ancient coastal plain environment now exposed in Calabar, Owerri, Onitsha and the Benin Region with the age Oligocene-Pleistocene.

However, Reyment (1965) reinstated the name Benin Formation to identify the reddish-brown-yellow, generally white sands often with clayey and pebbly horizons with type-locality around Benin. This is also referenced at Calabar and other parts of South Eastern Nigeria. The formation was further established by well logging of Etete 1, well drilled on-shore east of River Niger by Shell Nigeria. Petroleum Development Company (SPDC) and described by Short and Stauble (1967). The formation is about 1830 m thick at the seashore but thins landwards. The sedimentary suites of the Benin Formation dip 2˚ - 8˚ south

Geologically, the Benin Region comprises

1) Drift/Top soil
2) Alluvium
3) The Benin Formation
4) The Ogwashi - Asaba Formation.

Sedimentary Unit	**Lithological Description**
Drift	Loose Light Gray-Dirty white Sands, Silts, and Mudflows.
Alluvium(Only at River Banks)	Light Gray-Brown-Dirty White Sands, silts, clays gravel and pebble.
Benin Formation	Top reddish brown clays sands, crapping thick sequences of poorly bedded friable-loose sands gravelly-pebble sands and pinkish- white clay stingers.
Asaba-Ogwashi(Azagba-Ogwashi Formation)	Dark gray-woody clays, alternating with dark clay and lignite

Table 2.1 Typical Stratigraphic Sequence of the Benin Region after Akujieze, 2004.

Drift/Top Soil

Drifts are sediments still in the process of transportation or movement. They are made up of light brown-yellowish silt, mudflows and sands derived from the weathering of the parental Benin Formation. Drifts are washed down by fluvial agents especially the storms and floods dominating the wet season of the region. The drifts are not part of the solid geology. But they are mainly derived and reworked materials and loads dropped by moving floods. Drifts cover roadsides; fill up areas, concealing the underlying geology. Drifts vary from very thin veneers to up to 0.55 m. The drifts cover about 2% of the urban area. Where the drifts are stabilized, soil profile formation is developed (Akujieze, 2004 and Ikhile, 2016).

Alluvium

These are found along Ikpoba and Ovia flood plains. They are made up of grayish-dirty white-yellowish-white sands, silts, clayey sands, gravels and even wood-plant materials. These have been washed down the river valley and deposited at the river banks. They are recent deposits (Akujieze, 2004 and Ikhile, 2016).

It lies in the Northern part of the petroliferous Niger-Delta Sedimentary Basin. About 80% of the present day Benin City is underlain by the Benin Formation (i.e. all of southern and parts of northern Benin. The lithostratigraphy of the Benin Formation (Miocene- Recent) is characterized by 90% sand, conglomeratic gravels (pebbles and cobbles), clays, peat and lignite (infrequent;, occurring as beds or dispersed fragments) deposited in a continental coastal plain (fluvial) depositional setting (Nwajide, 2013).

The sands of the Benin Formation are dominantly coarse grained; poorly to moderately sorted, sub angular – to well rounded, generally loose (although weakly to moderately cemented in some areas) becoming progressively finer with abundant clay, some peat/ lignite and ferruginous bands towards the top, which is commonly reddish due to Fe-oxide coating. From the aforementioned, the textural properties of the Benin sands resulted in good petrophysical/ aquifer characteristics (porosity and permeability). The sands of the Benin Formation is the most productive aquifer in the Niger- Delta Basin (Ohagi and Akujieze, 1989)

The various formations in the geology of Edo State are the Benin, Bende Ameki, Ogwashi-Asaba, Imo and Nsukka. The geology of the project areas is characterized by deposits laid during the tertiary and cretaceous periods. The area is underlain by sedimentary rock constituting part of the Benin formation which is made up of over 90% massive, porous, coarse sand with clay/shale interbeds having high groundwater retention capacity. Soil particles vary from coarse-grained to fine grained in some areas, poorly sorted, sub-angular well rounded particles with lignite streaks and fragments.

The area conforms to a typical basin hydrology. The groundwater is recharged by infiltration from rainfall and neighboring surface water body (River Ossiomo). Consequently the groundwater rises during the wet season and drops in the dry season. The lithology of the monitoring borehole (BH) revealed that the surface formation (topsoil) to a depth of 1.5ft is predominantly sand. The sand fraction overlies silty clay material of about 9 ft. The silty clay material is underlain by sand which becomes coarser with increasing depth as the water bearing zone is reached. The aquifers were all unconfined and shallow.

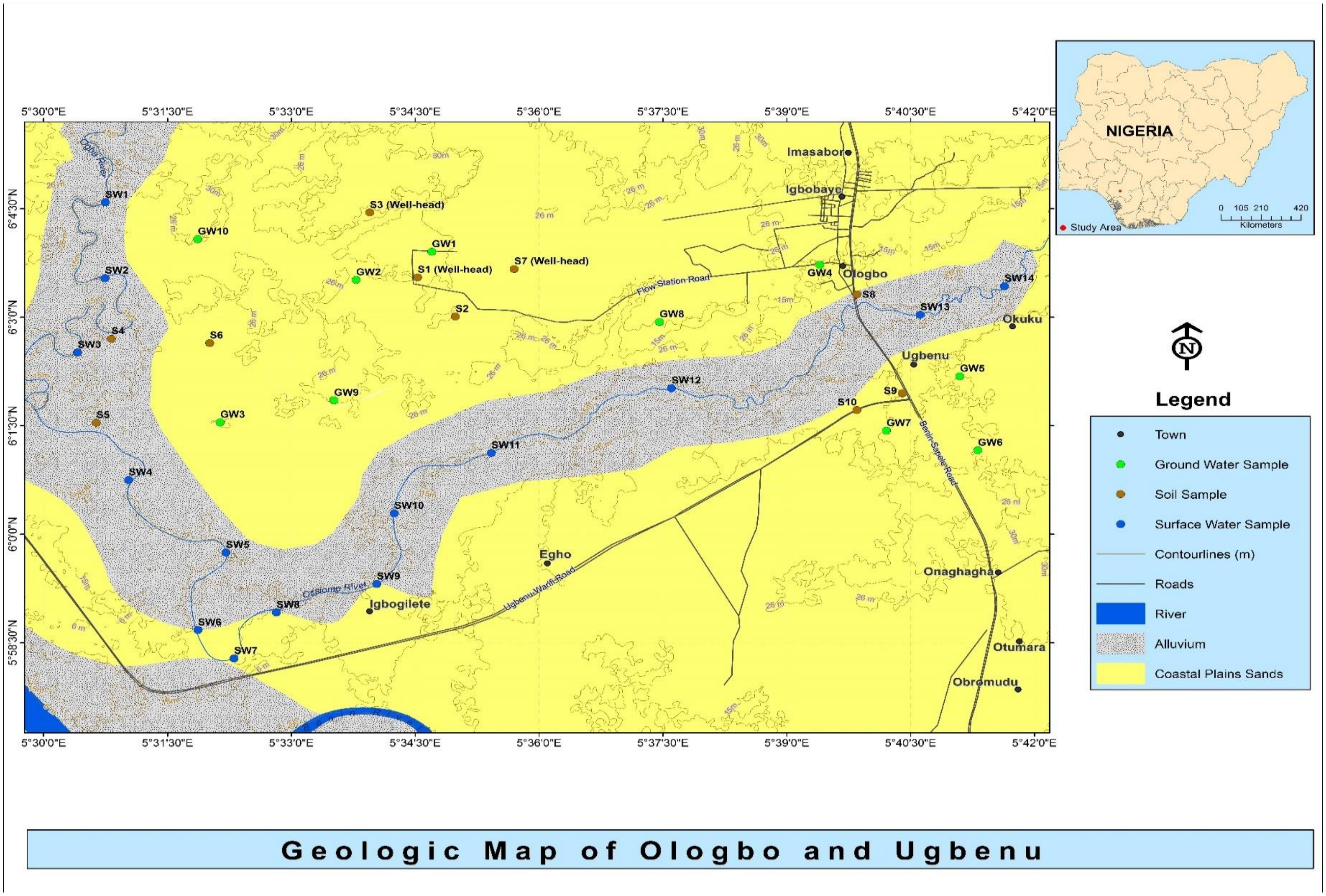


Figure 1.1: Geologic map of Study Area

2.3 Review of Past Literature

Imasuen and Onyeobi 2013 studies soil samples taken from locations within Edo state in a bid to understand the chemical and mineralogical compositions of the soils. The results showed that the soils of the rainforest zone were relatively deficient in the major oxides.

Oteri, (1983) carried out electric log to determine the various depths to fresh water in the western Niger Delta and reported that the area experiences varying degrees of saltwater intrusion.

Amajor, (1986) detailed the geochemical characteristics of groundwater in Port Harcourt and its environs and found that the groundwater in the area is enriched with Na+, Ca2+ ,Mg2+,Cl-, HC03 and S042-.

Amajor and Ofoegbu, (1988) found fluoride concentrations of 0.2mg/l in groundwater from the eastern Niger Delta. Oteri, (1988) evaluated saltwater intrusion in the eastern Niger Delta.

Amadi, et al, (1989) found total iron concentration up to 6.2mg/l in the groundwater from the Niger Delta.

Edet, (1993) carried out a detailed groundwater quality assessment in parts of the eastern Niger Delta and found an increase in Cl- and decrease in HC03- content towards the coast indicating saltwater encroachment.

Olobaniyi and Owoyemi, (2004) found a high coliform count in the bacteriological determination of groundwater from the Deltaic Plain Sands aquifer underlying Warri.

Efe et al., (2005) investigated the influence of seasons on the physico-chemical characteristics of water in the western horn of the Niger Delta and observed fast deteriorating levels of groundwater quality in the area due to human activity.

Akujieze and Irabor (2014) assessed the environmental degradation of soil and groundwater in some parts of Benin City by checking the pedo-geological and hydrogeological settings of the area to understand the impact of water disposal on the soil and groundwater system. Results indicated a contamination of soil with Al, Cd, Fe, Pb and THC at $P<0.05$. Also, the groundwater is polluted with presumptive coliform of 1.0 x 102 to 1.5 x 103 cfu/ml-1 and heavy metals; Al, Cd, and Pb at $P<0.01$ indicating high significant difference

Erah et al., (2002) studied the quality of groundwater in Benin City as part of a baseline study on inorganic chemical and microbial contaminants in boreholes and open wells. The result indicated that all the boreholes and open wells studied were contaminated with abnormal levels of Pb, Cr and Cd. High levels of Zn were also detected in the boreholes and open wells.

Edet et al., (2011) studied the groundwater chemistry and quality of Nigeria, reviewing their statuses. The study covered four major groundwater sedimentary basins, including the Niger Delta Basin. The data show that on the average, TDS for the groundwater from the different basins was < 250 mg/l compared to the saline groundwater with average TDS as high as 15700 mg/l. The high salinity was attributed to dissolution of salts and seawater intrusion

CHAPTER THREE

MATERIALS AND METHODS

3.1 Methodology

The soil samples collected for this project were collected at a depth of 0-30cm. The sample bags were clean bags properly labelled for this purpose. The site for sampling were randomly picked so as to give a true representative of the area and also to cover a large area of sampling. A total of Thirteen (13) soil samples including three (3) controls were collected from the area and proposed for analysis. This was achieved using the random number table (The Rand Corporation, 1955).

The water samples were collected in very clean containers for analysis. The mode of collection of water samples for analysis was in accordance with the purpose for which the results of the analysis are intended. It is desirable to commence analysis soon after collection because of the frequent changes that normally occurs in water samples. In cases where analysis could not commence immediately, preservatives were added to the samples and/or kept in a refrigerator at 4°C.

Based on the scope of this work, all the water samples used were collected and taken to the laboratory immediately.

3.2 Atomic Absorption Spectrometry (AAS)

AAS is used for the determination of metals. It is based on the phenomenon that the atom in the ground state absorbs the light of wavelengths that are characteristics to each element when light is passed through the atoms in the vapour state. Because this absorption of light depends on the concentration of atoms in the vapor, the concentration of the target element in the water sample is determined from the measured absorbance. The Beer Lambert law describes the relationship between concentration and absorbance.

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In flame atomic absorption spectrometry (FAAS), a sample is aspirated into a flame and atomized. A light beam from a hollow cathode lamp of the same element as the target metal is radiated through the flame, and the detector measures the amount of absorbed light.

This method is much more sensitive than other methods and free from spectral or radiation interference by coexisting elements. Pretreatment is either unnecessary or straight forward. However, it is not suitable for simultaneous analysis of many elements, because the light source is different for each target element.

Determination of Escherichia Coli and Coliform Count

Membrane filtrations were employed. The membrane filter is placed on a filter holder in a filtration unit and clamped in position below the funnel. The volume of the water to be tested is drawn through this filter disc by the aid of a vacuum pump and the bacterial are retained on the surface of the membrane.

Approximately 2ml of Endo medium and Eosin methylene blue (EMB) agar is added to the pad contained in the Petri dishes for Coliform and E. coli and special Petri dishes of a dishes of a size to accommodate the absorbent pad and filtration disk are employed for incubation.

The funnel is removed and the filter disk, handled with sterile forceps is placed upon an absorbent pad that has previously been saturated with the appropriate medium.

The plates are incubated at 37^0C and 44^0C for 24hrs for Coliform and E. coli respectively at which time the number of Coliform and E. coli colonies can be determined.

3.3 Physico-chemical Analysis for Water Samples

Hydrogen potential (pH)

The pH of each sample was measured with the Hanna pH meter instrument Hi-1922 model. The meter was calibrated with pH buffer solution of 4.0, 7.0 and 9.0, rinsed severally with distilled water and inserted into each of the samples. The readings were taken when the digital display was stable.

Conductivity determination

The conductivity meter was standardized with 0.01N potassium chloride (KCl) solution. The conductivity of this solution was found to be 1413 µS/cm at 25°C with a cell constant of 1. Each sample of 100ml volume was measured into a beaker, and its conductivity was determined using Hanna 911 conductivity meter. The test was done after refrigerated samples were allowed to attain room temperature.

Total dissolved solids (TDS) determination

A 50ml well-mixed sample was measured into a beaker. The WTW TDS/ Conductivity meter probe was immersed in the sample and its conductivity recorded.

Temperature determination

This was determined at the time of analysis. An aliquot of 50 ml of sample was measured into a 100ml beaker and a 0-60°C thermometer immersed in the solution. The reading on the thermometer was then recorded.

Sulphate determination

Five series of standard solution with concentration range of 1mg/l to 5mg/l were prepared and analyzed with the samples. To each 10ml of standard, 1ml of barium chloride gelatin was added. The mixtures were allowed to stand for 45 minutes. The respective absorbance of the solution at 420nm was determined. From this data a graph of absorbance against concentration was plotted.

Barium chloride gelatin (1ml) was added to 10ml of sample and the mixture was diluted to 50ml with double distilled water. Prepared samples were allowed to stand for 45 minutes. The concentrations were determined using UV-Visible spectrophotometer at 420nm. A blank without sample was prepared and read at the same wavelength.

Phosphate determination

Ascorbic acid Method (orthophosphate-Phosphorus) was used. Five series of phosphate standard solution with concentration range of 0.2mg/l to 1mg/l orthophosphate (PO_4^{3-}) was used to standardize the UV-Visible spectrophotometer, 50ml of standard was measure into test tube and 2ml of ascorbic acid molybdenum was added. The absorbance of the solutions after 10 minutes was taken at 655nm against a blank solution with UV-Visible spectrophotometer. A curve of absorbance verses concentration was plotted. To 50ml of the sample was added 2ml of ascorbic acid molybdenum. The mixture was allowed to stand for 10 minutes after which the absorbance of the samples was taken at 655nm with UV-Visible spectrophotometer. A blank analysis was performed with all the reagents without the samples for all the analysis.

Nitrate determination

Aliquots of 0.1, 0.2, 0.3 and 0.4ml of nitrate stock solution were measured into different 100ml volumetric flasks. Two millilitre (2ml) of 0.1M sodium hydroxide (NaOH) was added followed by the addition of 1ml of brucine to each. The mixture were diluted to 100ml mark. A straight line graph was plotted at the absorbance of 543nm with UV-Visible spectrophotometer against concentration which passed through the origin. An aliquot of 2ml of 0.1M sodium hydroxide (NaOH) solution and 1ml of brucine was added to a 50ml sample. The mixture was allowed to stand for 15 to 20 minutes and the nitrite concentration was determined at wavelength of 543nm with UV-Visible spectrophotometer. A blank analysis was run with all the reagents without the sample for all the analysis.

Alkalinity determination

A 50 ml sample was measured into a conical flask. Two drops of methyl orange indicator was added and the resulting mixture titrated against the standard 0.1M Hydrochloric acid (HCl) solution to a permanent pink colour end point at pH 4.5.

The following equation was used in the calculation

$$\text{Alkalinity mg calcium carbonate } (CaCO_{3)}/L = \frac{AXNX50,\ 000}{1\text{ml sample}} \qquad \text{Equation 3.1}$$

Where A=ml of acid used.

N= Normality of standard acid used

Chloride determination by titration

An aliquot of 50ml of sample was measured into a conical flask. The pH was then adjusted to a range of 7-10 with tetraoxosulphate (vi) acid

(H_2SO_4) for high pH samples and sodium hydroxide (NaOH) for low pH samples. Two drops of potassium heptaoxodichromate (vii) (K_2CrO_4) indicator was added.

Standard silver nitrate ($AgNO_3$) solution of 0.01M was titrated against the resulting mixture above to a pink yellow end point.

Blank titration with only the reagents and no water sample was also performed

$$\text{Chloride (mg chloride per liter)} = \frac{T \times N \times 1000 \times 35.5}{\text{1ml of sample}} \quad \text{Equation 3.2}$$

T=end point volume.

N=Normality of $AgNO_3$.

Mineral analysis

Calcium (Ca^{2+}), magnesium (Mg^{2+}) and heavy metals iron (Fe^{2+}) and zinc (Zn^{2+}) were determined with flame photometric and atomic absorption spectrometric (AAS) methods (APHA, 1992)

Determination of Dissolved Oxygen (DO) by Winkler's method

Filled a 200ml bottle to the brim, care was taken to minimize contact with air. 1ml of the Alkali-Iodide-Azide solution was added. The stopper was closed tightly and shook. When the precipitate had settled, most of the clear liquid was decanted, 2ml of conc. H_3PO_4 and some water was added to dissolve the precipitate. The released iodine was then titrated with 0.025M Thiosulphate.

1ml of 0.025M $Na_2S_2O_3$ =0.2mg of Oxygen

*if titre xml, then DO=x(0.2mg) of oxygen per Aliquot of water taken.

Determination of Biological Oxygen Demand (BOD)

The sample of water was thoroughly aerated. Make a measured dilution with water if the DO is likely to be greater than the DO level. Seed with a little diluted domestic wastewater (1-2ml per litre). Carry out a DO determination on a suitable portion. Fill a screw-topped incubation bottle to the brim with the remainder of the diluted water. Seal the bottle and incubate in the dark for 5 days at 20°C. Carry out a DO determination on a suitable portion of the incubated sample. BOD is the difference between the two determination DO levels.

1ml of 0.025M $S_2O_3^{2-}$ = 0.2mg of oxygen

If Titre, (DO_1) – $Titre_5$ (DO_5) = Yml = BOD

Determination of Chemical Oxygen Demand

Pipette 50ml of water sample into a conical flask. Add 10ml 0f the 0.00833 $K_2Cr_2O_7$ solution. Add 1g of $HgSO_4$ and 80ml 0f Ag_2SO_4 – H_2SO_4 solution and a few beads. Fit a reflux greaseless condenser and heat gently to boiling and then boil for exactly 10 minutes. Leave to cool. Rinse the condenser with 50ml of water and cool the flask under running tap. Add two drops of Ferroin indicator and titrate with 0.025M $Fe(NH_4)_2\ (SO_4)_2 6H_2O$ until the colour changes from blue-green to red-brown. Do a blank determination as above on 50ml of water and cool the flask under running tap. Add two drops of Ferroin indicator and titrate with 0.025M $Fe(NH_4)_2\ (SO_4)_2 6H_2 0$ until the colour changes from blue-green to red-brown. Do a Blank Determination as above on 50ml of water.

The difference in value between the two Titres gives the Titre of the sample. That is 1ml of difference = 0.2mgDO or 4mgDO/L if a 50ml sample is taken. Or

$$\text{COD (mg/l)} = \frac{8000 \times}{\text{Vol of sample}} \qquad \text{Equation 3.3}$$

Determination of Turbidity

Pour 25ml of water into the curette and read at zero in the spectrophotometer at 450nm. Pour 25ml of the water sample into another curette and read in the meter. Read the working standards similarly.

Turbidity (FTU) = instr. Reading × Slope Recip. Equation 3.4

Determination of Suspended Solids in Water by Gravimetry

Dry a 15cm Whatman Filter Paper No. 1 at 180°C to constant weight (X_1g). Filter through the paper, 100ml of water sample. Dry in the same oven to constant weight at 180°C. Weigh the filter paper with its contents (X_2g).

Weight of suspended solids = $(X_2 – X_1)$g Equation 3.5

Suspended solids (mg/l) = $(X_2 - X_1) \times 1000 \times 10$ Equation 3.6

Determination of Total Dissolved Solid (TDS) and Total Suspended Solids (TSS).

Oven dry a Whitman Filter paper No.1 (15cm) and a 250ml Conical Flask in an oven at 180°C for 3 hours. Cool both in a desiccator and then weigh each. Filter exactly 100ml of water sample through the filter paper into the conical flask. Evaporate the water to dryness on a hot plate (gently to avoid spouting) and the filter paper in the oven set at 180°C until a constant weight is obtained for record weights of the paper and flask separately.

i. Filter Paper

Weight of filter paper = X_1g

Weight of filter paper + residue = X_2g

Therefore, weight of residue (TSS) = (X_2-X_1)g.

Then TSS (mg/l) = $(X_2-X_1) \times 1000 \times 10$

ii. Conical Flask

Weight of empty conical flask = X g

Weight of Flask + Residue = Y g

Weight of Residue (TDS) =$(Y - X)$g

Then TDS (mg/L)= $(Y-X)\times1000\times10$

3.4 Physico-chemical Analysis for Soil Samples

Determination of pH

The pH reading was obtained with the aid of a Hanna microprocessor pH multimeter which was earlier standardized with buffer 4.0, 7.0 and 9.0. Twenty (20) grams of the fresh soil sample was weighed into a 100 ml glass beaker. Twenty (20) milliliters of sterile distilled water was added and the suspension was stirred continuously for 30 minutes. The mixture was allowed to stand for another 30minutes undisturbed. A Hanna microprocessor pH meter was dipped into the solution and steady readings noted (Karla and Maynard, 1991).

Electrical Conductivity

Twenty (20) grams of the fresh soil sample was weighed into a 100 ml glass beaker. Twenty (20) milliliters of sterile distilled water was added and the suspension was stirred continuously for 30 minutes. The mixture was allowed to stand for another 30minutes undisturbed. A Digital Conductivity Meter (Labtech) was used in determining soil conductivity by dipping the sensitive rod into the mixture and a steady reading taken.

Moisture Content

An aluminum dish was pre weighed (W_1) using a sensitive weigh balance (State Model). Ten (10) grams of the fresh soil sample was transferred to the dish and weight of both the dish and soil was noted (W_2). The dish containing the soil sample was placed in a hot air oven (State Model) at 130^0C and dried to obtain a constant weight for 24 hours. The dish was immediately transferred to a desiccator and allowed to cool for 30 minutes. The resultant weight was taken

(W_3). The moisture content was calculated and recorded as a percentage by weight of the respective soil sample (Karla and Maynard, 1991)

Oven dry soil (g) = $W_3 - W_1$

Moisture (g) = $W_2 - W_3$

$$\text{Water content (\% by weight)} = \frac{\text{moisture}}{\text{Oven dried soil (g)}} \times 100\% \qquad \text{Equation 3.7}$$

Total Organic Carbon Content

Air dried soil was passed through a 2 mm sieve in other to remove large particles, roots, organic debris and ensure for consistency. This soil samples were used for both carbon and nitrogen analyses. A weighed amount (1.0g) of prepared soil sample was dispensed into a 250 ml conical flask. Ten (10)ml of Normal Potassium dichromate was added to the flask followed by the addition of 20 ml of concentrated tetraoxosulphate (VI) acid.

The flask was shaken for 1 minute and allowed to cool. Distilled water was then added to the cold solution to make the volume up to 150 ml. This solution was shaken and allowed to cool. Ten (10) ml of phosphoric acid was added to the solution followed by the pipetting of 1ml of 1% diphenylamine solution (indicator). Titration with 0.5 ferrous ammonium sulphate solution was done until there was colour change from dark violet to green. A blank determination was done for each soil sample (Onyeonwu, 2000)

$$\frac{\text{Blank - Sample} \times \text{Normality of Ferrous Ammonium Sulphate} \times 0.03 \times 1.3 \times 100}{\text{Weight of Sample}}$$

Determination of Total Nitrogen

The total nitrogen content of the soil samples were determined using micro Kjeldahl digestion and colorimetric method (Bremmer and Mulvaney, 1982). 1g soil sample was placed into 30ml Kjeldahl digestion flask. One tablet of a catalyst (Kjeldahl) and 10 ml concentrated $H_2SO_4$was added, and the mixture was hand shaken to ensure mixing. At completion of digestion, the mixture was clear and upon removal from the digestion chamber, it was allowed to cool. Then, 10 ml distilled water was added and the solution was decanted through a Whitman filter paper No 42 into a 100ml volumetric flask.

The Kjeldahl flask were washed with 2 to 3 small aliquots of distilled water and all the washings were added into the volumetric flask via the filter paper and made up to volume. The nitrogen content of the filtrate was then determined colorimetrically. For colorimetric analysis, a standard nitrogen stock solution was prepared using dry ammonium sulphate and from the resultant 100 ppm nitrogen stock solution, 5, 10, 15, 20 and 25 ppm nitrogen standards were prepared and in each standard, 4 ml concentrated H_2SO_4 and 0.95g anhydrous sodium Sulphate was added.

A blank solution containing no nitrogen standard but having the same quantity of acid and anhydrous sodium Sulphate was also prepared. Then, 5 ml of the digested filtrate was pipetted into a 25 ml glass flask, and 2.5ml alkaline phenol, 1 ml sodium potassium tartrate and 2.5 ml of sodium hypochlorite were added. The mixture was hand shaken, and made to 25ml mark with distilled water. The solution was read colorimetrically at 630 nm, using a spectrophotometer.

Available Phosphorus Content

Five (5) grams of the soil sample was weighed and dispensed into plastic bottle. Forty (40) milliliters of the extracting solution (0.03M NH_4F in 0.025 M HCl) was added and the bottle was shaken for 1 minute. The solution was filtered with the aid of a Whitman filter paper No 42. The clear supernatant was used for determining the phosphorus content of the respective soil samples. Five (5) milliliters of the supernatant was pipetted into a 100 ml flask.

The pH of the supernatant was adjusted to 5 respectively by the addition of 3 drops of p-nitrophenol, and upon the development of yellow colour, some drops of 2 M NH_4OH were added until a deep yellow colour was developed. Also, 2 M HCl was added dropwise until the supernatant became colourless. (The resultant pH was between 3 and 5). Thirty (30) milliliters of water was added, followed by the addition of 10 ml of ascorbic acid reagent. The absorbance of the solution was read at 660 nm using a spectrophotometer (Model). (Onyeonwu, 2000)

$$P\ (\mathrm{mg/kg}) = \frac{\text{Instrument reading} \times \text{Colour volume} \times \text{Extract volume}}{\text{Weight of sample} \times \text{aliquot taken}} \qquad \text{Equation 3.8}$$

Determination of Na, K, Mg and Ca

Five (5) grams of air dried soil was weighed into a plastic bottle. One hundred (100) milliliters of neutral 1 M ammonium acetate was then added to the soil and the mixture was shaken with the aid of a mechanical shaker for 30 minutes. The mixture was filtered using a No 42 Whitman filter paper into a 100 ml volumetric flask.

The filtrate was made up to mark with the acetate. Stock working standards 0,2,4,6,8 and 10 ppm were prepared for sodium, potassium, calcium and magnesium using 2.54g of oven dried sodium chloride, 100 ml of ammonium acetate, 1.9067 g oven dried potassium chloride, 0.5004g of calcium carbonate (at 105^0C) in 5 ml of hydrochloric acid and 0.1216 g of magnesium turning in volume of 6 M hydrochloric acid.

The concentration of the exchangeable cations (Na, Ca, K and Mg) in the filtrate was determined using a flame photometer (Model). The flame photometer was adjusted according to its instruction manual and the standards were aspirated to obtain reliable curves before aspirating the samples. The blank utilized was ammonium acetate (Onyeonwu 2000).

$$\text{Ca (Meq/100g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq. wt.}} \qquad \text{Equation 3.9}$$

$$\text{K (Meq/ 100g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq. wt.}} \qquad \text{Equation 3.10}$$

$$\text{Mg (Meq/ 100 g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq. wt.}} \qquad \text{Equation 3.11}$$

$$\text{Na (Meq/ 100 g)} = \frac{\text{Instrument reading} \times 100}{\text{Weight of sample} \times \text{Eq. wt.}} \qquad \text{Equation 3.12}$$

Determination of Total Hydrocarbon Content (THC)

One (2.5) grams of the air dried soil sample was dissolved in 10ml of hexane and shaken for ten minutes using a mechanical shaker. The solution was filtered using a Whitman filter paper No. 42. The absorbance of this solution was read at 460nm with a spectrophotometer using n-hexane as blank. The THC (mg/kg) of the sample was calculated with reading obtained from the spectrophotometer (Akpoveta *et al*., 2011), using the formulae below:

$$\text{THC (mg/Kg)} = \frac{\text{OD reading} \times \text{Volume of Solvent Used}}{\text{Weight of soil sample (Kg)}} \qquad \text{Equation 3.13}$$

Minerals (Metals) Analyses

The soil sample was spread on a clean plastic sheet placed on a flat surface and air dried under room condition for 72hrs. The soil was sieved and 5g sample was taken from the sieved soil and put in a beaker. Ten (10) ml of nitric perchloric acid, ratio 2:1 was added to the sample. The sample was digested at 105°C. 5ml of HCl was added to the digester again and digested for 30mins. The digest was then removed from the digester and allowed to cool to room temperature.

The cooled digest was washed into a 100ml standard volumetric flask and was made up to 100ml mark with distilled water. Determination of Iron (Fe), Chromium (Cr), Manganese (Mn), Zinc (Zn), Vanadium (V), Arsenic (As), Mercury (Hg), Lead (Pb), Copper (Cu), Cadmium (Cd) and Nickel (Ni) were done by aspirating the solution for (analyzed) each metal analysis into the Atomic Absorption Spectrometer (ASS) PG 550 model (Adelekan and Abegunde, 2011).

Extraction of Nitrate, Sulphate and Ammonium Nitrogen from Soil

Ten (10) grams of air dried soil was weighed into a plastic bottle. Fifty (50) extraction solution (100g of sodium acetate, and 30ml of acetic acid in one litre of distilled water) was added and the mixture was shaken with the aid of a mechanical shaker for 30 minutes. The mixture was filtered using a No 42 Whitman filter paper into a 100 ml volumetric flask. The filtrate was made up to mark with the distilled water and preserved for nitrate, sulphate, and ammonium nitrogen determination.

Nitrate Determination

Ten milliliter of digest was transfer into fifty milliliter flask, two milliliter of brucine and ten milliliter of concentrated sulphuric acid were added. The mixture was mixed and allow to stan for ten minutes. Stock working standards of 0,2,4,6,8 and 10 ppm were prepared and treated in similar way. The optical density (OD) of the samples and standard were taken at 470nm (Onyeonwu 2000).

$$NO_3\,(mg/kg) = \frac{OD \times SR \times Colour\ Vol \times Ext.\ vol}{Weight\ of\ sample \times Vol.\ taken} \qquad Equation\ 3.14$$

Sulphate Determination

Ten milliliter of digest was transfer into fifty milliliter flask, five milliliter of water, one milliliter of barium chloride gelatin reagent were added and the solution was allowed to stand for thirty minutes, and ten milliliter of concentrated sulphuric acid were added the mixture was mixed and allow to stand for ten minutes. Stock working standards 0,2,4,6,8 and 10 ppm were prepared and treated in similar way. The optical density (OD) of the samples and standard were taken spectrophotometrically at 420nm

$$SO_4^{2-}\text{-}S\,(mg/kg) = \frac{OD \times SR \times Colour\ Vol \times Ext.\ vol}{Weight\ of\ sample \times Vol.\ taken} \qquad Equation\ 3.15$$

Ammonium Nitrogen Determination

Five milliliter of digest was transfer into fifty milliliter flask, two and half (2.5ml) milliliter of alkaline phenate, one milliliter of sodium potassium tatrate reagent, and two and half (2.5ml) milliliter of sodium hypochlorite (parazone) were added. The mixture was shaken. Stock working standards of 0, 2,4,6,8 and 10 ppm were prepared and treated in similar way. The optical density (OD) of the samples and standard were taken spectrophotometrically at 636nm.

$$NH_4^+\text{-N (mg/kg)} = \frac{\text{OD x SR x Colour Vol x Ext. vol}}{\text{Weight of sample x Vol. taken}} \qquad \text{Equation 3.16}$$

Determination of Total Hydrocarbon Content (THC)

Fifty milliliter (1000ml) of the sample was extracted with 50ml of dichloromethane and shaken for ten minutes using a mechanical shaker. The solution was filtered using a separating funnel. The absorbance of this solution was read at 460nm with a spectrophotometer using dichloromethane as blank. The THC (mg/l) of the sample was calculated with reading obtained from the spectrophotometer (Akpoveta *et al*., 2011), using the formulae below:

$$\text{THC (mg/l)} = \frac{\text{OD reading} \times \text{Volume of Sample Used}}{\text{Volume of dichloromethane(ml)}} \qquad \text{Equation 3.17}$$

CHAPTER FOUR

PRESENTATION OF RESULTS AND INTERPRETATION

The results of the analysis carried out on the soil and water samples are presented below in (Table 4.1 – Table 4.6). The parameters analyzed include the general physico-chemical parameters – pH, electrical conductivity, alkalinity, turbidity, nitrates, phosphates, sulphates, dissolved oxygen (biological and chemical), total dissolved solids and total suspended solids, potassium, calcium, magnesium, sodium amongst others. Other parameters analyzed are the heavy metal concentration for iron, nickel, zinc, copper, manganese, chromium and lead. The total coliform count and E. coli count were also analyzed. Basic statistical treatment was performed on the samples to understand the statistical relationship of the different parameters.

Concentration maps for some heavy metals and the groundwater flow direction were also modeled.

Table 4.1: Physicochemical Parameters of Groundwater Samples in the Study Area.

	Units	GW1	GW2	GW3	GW4	GW5	GW6	GW7	GW8
pH $_{gw}$		5.64	5.7	5.61	5.61	5.67	5.72	5.78	5.69
EC $_{gw}$	uS/cm	62.64	62.77	62.57	65.64	65.74	58.64	58.81	58.55
$Cl^{-}{}_{gw}$	mg/l	8.14	8.19	8.11	9.31	9.35	6.58	6.65	6.55
Alk $_{gw}$	mg/l	4.51	4.56	4.48	4.62	4.34	4.44	4.49	4.42
TSS $_{gw}$	mg/l	20.05	15.06	22.04	26.09	18.1	16.9	21.01	19.07
TDS $_{gw}$	mg/l	31.95	32.02	31.92	33.48	33.53	29.91	30	29.48
Turb $_{gw}$	mg/l	0.08	0.12	0.07	0.09	0.05	0.11	0.07	0.06
COD $_{gw}$	mg/l	3.15	3.29	2.9	3.78	3.8	3.09	3.02	3.12
DO $_{gw}$	mg/l	2.25	2.4	2.04	2.05	2.04	1.85	2.28	2.19
BOD $_{gw}$	mg/l	1.14	1.02	1.03	1.01	0.93	1.26	1.1	1.23
$SO_4^{2-}{}_{gw}$	mg/l	1.19	1.22	1.13	1.34	1.19	0.98	0.99	0.98
$NO_3^{-}{}_{gw}$	mg/l	1.88	1.9	1.84	1.97	2.03	1.76	1.77	1.75
$PO_4^{3-}{}_{gw}$	mg/l	0.63	0.64	0.62	0.66	0.66	0.59	0.57	0.58
NH_4N_{gw}	mg/l	0.06	0.14	0.05	0.08	0.1	0.03	0.01	0.03
$Ca^{2+}{}_{gw}$	mg/l	2.82	2.84	2.6	3.08	2.83	2.48	2.5	2.48
$Mg^{2+}{}_{gw}$	mg/l	0.69	0.77	0.66	0.75	0.82	0.6	0.5	0.6
$Na^{+}{}_{gw}$	mg/l	4.52	4.55	4.51	5.18	5.2	3.64	3.68	3.62
$K^{+}{}_{gw}$	mg/l	1.59	1.69	1.48	2.01	1.59	1.02	1.05	1.01
$Zn^{2+}{}_{gw}$	mg/l	0.36	0.34	0.35	0.37	0.39	0.33	0.3	0.33
$Cu^{2+}{}_{gw}$	mg/l	0.44	0.46	0.41	0.46	0.49	0.41	0.38	0.41
$Cr^{6+}{}_{gw}$	mg/l	0.13	0.16	0.12	0.16	0.15	0.12	0.11	0.1
$Pb^{2+}{}_{gw}$	mg/l	0.09	0.11	0.01	0.13	0.14	0.16	0.16	0.15
$Mn^{2+}{}_{gw}$	mg/l	0.13	0.14	0.12	0.14	0.12	0.12	0.15	0.1
$Fe^{2+}{}_{gw}$	mg/l	1.9	1.92	1.89	2.47	2.49	1.14	1.17	1.12
$Ni^{2+}{}_{gw}$	mg/l	0.75	0.79	0.81	0.82	0.84	0.64	0.65	0.64
Coliform $_{gw}$	cfu/ml	11	11	12	13	11	14	12	8
E. coli $_{gw}$	cfu/ml	0	0	0	1	0	0	0	0

Table 4.2: Physicochemical parameters of surface water and control samples in the study area.

	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	SW9	SW
pH_{sw}	6.01	5.46	5.59	5.52	6.01	5.95	6.07	6.31	6.39	6.3
EC_{sw}	92.82	90.11	87.11	90.25	92.11	94.11	92.23	95.11	93.11	95.
$\text{Cl}^{-}_{\text{sw}}$	9.73	9.22	9.51	9.26	9.82	9.52	9.85	10.72	10.12	10.
Alk_{sw}	7.59	9.28	8.66	9.23	7.55	7.71	7.51	7.55	6.57	7.5
TSS_{sw}	25.78	28.49	31.49	28.35	26.49	24.49	26.37	23.49	25.49	23.
TDS_{sw}	8.16	6.81	5.31	6.88	7.81	8.81	7.87	9.31	8.31	9.3
Turb_{sw}	9.8	13.92	12.42	13.79	9.7	10.09	9.61	9.7	7.31	9.6
COD_{sw}	5.71	4.6	3.37	4.66	5.42	6.24	5.47	6.65	5.83	6.6
DO_{sw}	4.39	2.27	1.77	2.4	4.49	4.1	4.58	4.49	6.88	4.5
BOD_{sw}	2.05	1.36	1.98	1.41	2.09	1.93	2.13	2.09	3.07	2.1
$\text{SO}_4^{2-}{}_{\text{sw}}$	1.82	1.72	1.54	1.73	1.84	1.77	1.85	2.03	1.9	2.0
$\text{NO}_3^{-}{}_{\text{sw}}$	2.24	2.13	2	2.13	2.21	2.29	2.22	2.34	2.25	2.3
$\text{PO}_4^{3-}{}_{\text{sw}}$	0.75	0.67	0.73	0.67	0.73	0.79	0.73	0.82	0.76	0.8
$\text{NH}_4\text{N}_{\text{sw}}$	7.08	7.38	8.4	8.5	8.71	8.46	8.6	8.39	8.42	8.
$\text{Ca}^{2+}{}_{\text{sw}}$	3.37	3.38	3.36	3.38	3.36	3.38	3.37	3.39	3.37	3.3
$\text{Mg}^{2+}{}_{\text{sw}}$	0.83	0.77	0.8	0.77	0.81	0.86	0.82	0.88	0.84	0.8
$\text{Na}^{+}{}_{\text{sw}}$	5.66	5.27	4.91	5.29	5.51	5.95	5.52	5.87	5.63	5.8
$\text{K}^{+}{}_{\text{sw}}$	2.98	2.92	2.71	2.93	3.06	2.8	3.07	3.27	3.13	3.2
$\text{Zn}^{2+}{}_{\text{sw}}$	0.43	0.42	0.41	0.42	0.44	0.43	0.45	0.44	0.43	0.4
$\text{Cu}^{2+}{}_{\text{sw}}$	0.52	0.54	0.53	0.54	0.51	0.53	0.52	0.54	0.52	0.5
$\text{Cr}^{6+}{}_{\text{sw}}$	0.35	0.36	0.38	0.37	0.36	0.38	0.37	0.36	0.36	0.3
$\text{Pb}^{2+}{}_{\text{sw}}$	0.02	0.05	0.04	0.03	0.03	0.06	0.05	0.04	0.03	0.0
$\text{Mn}^{2+}{}_{\text{sw}}$	0.16	0.15	0.17	0.15	0.16	0.16	0.16	0.16	0.16	0.1
$\text{Fe}^{2+}{}_{\text{sw}}$	1.27	1.24	1.28	1.24	1.26	1.28	1.26	1.3	1.27	1.
$\text{Ni}^{2+}{}_{\text{sw}}$	0.19	0.2	0.09	0.2	0.2	0.17	0.2	0.21	0.2	0.2
T. Coliform SW	19	18	19	16	15	21	20	22	23	18
E. Coli. $_{\text{sw}}$	8	11	8	7	6	10	9	7	6	4

Table 4.3: Physicochemical parameters of soil and control samples in the study area.

	SS 1	SS 2	SS 3	SS 4	SS 5	SS 6	SS 7	SS 8	SS 9	SS 10	SSC1
pH $_{ss}$	5.91	6.05	5.71	5.76	6.03	5.85	5.85	5.85	5.84	5.83	5.11
EC $_{ss}$	166	208	188	159	219	176	191.4	192.94	194.49	196.03	69.6
$Cl^{-}{}_{ss}$	48.58	57.82	53.42	47.04	60.24	50.78	54.17	54.51	54.85	55.19	19.4
$SO_4^{2-}{}_{ss}$	72.37	82.87	77.87	70.62	85.62	74.87	78.72	79.11	79.49	79.88	12.2
$NO_3^{-}{}_{ss}$	59.98	68.38	64.38	58.58	70.58	61.98	65.06	65.37	65.68	65.99	9.2
$PO_4^{3-}{}_{ss}$	37.66	43.54	40.74	36.68	45.08	39.06	41.22	41.43	41.65	41.86	12.3
NH_4N $_{ss}$	3.07	3.91	3.51	2.93	4.13	3.27	3.58	3.61	3.64	3.67	1.9
$Ca^{2+}{}_{ss}$	14.97	17.91	16.51	14.48	18.68	15.67	16.75	16.86	16.96	17.07	2.4
$Mg^{2+}{}_{ss}$	29.73	36.45	33.25	28.61	38.21	31.33	33.79	34.04	34.29	34.53	4.2
$Na^{+}{}_{ss}$	49.92	60.47	55.45	48.17	63.23	52.43	56.3	56.69	57.07	57.46	25.2
$K^{+}{}_{ss}$	68.48	84.02	76.62	65.89	88.09	72.18	77.88	78.45	79.02	79.59	31.4
$Zn^{2+}{}_{ss}$	6.38	7.06	6.74	6.27	7.23	6.54	6.79	6.81	6.84	6.86	1.2
$Cu^{2+}{}_{ss}$	14.46	16.14	15.34	14.18	16.58	14.86	15.48	15.54	15.6	15.66	6.8
$Cr^{6+}{}_{ss}$	31.19	35.05	33.21	30.54	36.06	32.11	33.52	33.66	33.81	33.95	2.9
$Pb^{2+}{}_{ss}$	8.02	9.28	8.68	7.81	9.61	8.32	8.78	8.83	8.87	8.92	0.1
$Mn^{2+}{}_{ss}$	12.14	13.66	12.94	11.89	14.05	12.5	13.06	13.11	13.17	13.22	2.42
$Fe^{2+}{}_{ss}$	148.56	167.46	158.46	145.41	172.41	153.06	159.99	160.68	161.38	162.07	1.9
$Ni^{2+}{}_{ss}$	20.79	23.31	22.11	20.37	23.97	21.39	22.31	22.41	22.5	22.59	0.9
Org. C. $_{ss}$	4.48	4.95	4.73	4.41	5.07	4.59	4.76	4.78	4.8	4.81	1.65
Total N. $_{ss}$	0.35	0.4	0.37	0.34	0.41	0.36	0.38	0.38	0.38	0.38	0.18

Table 4.4: Summary of physicochemical parameters for groundwater samples from the study area

	Mean	St. Err.	Std. Dev.	Minimum
pH $_{gw}$	5.69	0.02	0.06	5.61
EC $_{gw}$	60.5	1.3	4.0	54.64
$Cl^{-}{}_{gw}$	7.30	0.494	1.561	5.02
Alk $_{gw}$	4.48	0.02	0.08	4.34
TSS $_{gw}$	19.64	1.05	3.32	15.06
TDS $_{gw}$	30.81	0.65	2.07	27.87
Turb $_{gw}$	0.08	0.007	0.022	0.05
COD $_{gw}$	3.113	0.141	0.445	2.47
DO $_{gw}$	2.185	0.058	0.184	1.85
BOD $_{gw}$	1.112	0.038	0.119	0.93
$SO_4^{2-}{}_{gw}$	1.059	0.059	0.186	0.78
$NO_3^{-}{}_{gw}$	1.819	0.041	0.129	1.64
$PO_4^{3-}{}_{gw}$	0.607	0.013	0.040	0.55
NH_4N_{gw}	0.056	0.013	0.041	0.01
$Ca^{2+}{}_{gw}$	2.593	0.096	0.304	2.14
$Mg^{2+}{}_{gw}$	0.652	0.033	0.106	0.5
$Na^{+}{}_{gw}$	4.047	0.278	0.880	2.76
$K^{+}{}_{gw}$	1.239	0.164	0.517	0.46
$Zn^{2+}{}_{gw}$	0.341	0.009	0.027	0.3
$Cu^{2+}{}_{gw}$	0.427	0.011	0.036	0.38
$Cr^{6+}{}_{gw}$	0.126	0.008	0.024	0.09
$Pb^{2+}{}_{gw}$	0.114	0.015	0.046	0.01
$Mn^{2+}{}_{gw}$	0.125	0.005	0.015	0.1
$Fe^{2+}{}_{gw}$	1.49	0.241	0.761	0.38
$Ni^{2+}{}_{gw}$	0.764	0.028	0.088	0.64
T. Coliform $_{gw}$	10.7	0.76	2.41	6
E. coli $_{gw}$	0.2	0.13	0.42	0

Table 4.5: Summary of physicochemical parameters for Surface water and control from the study area

	Surface water					Surface Wat		
	Mean	St. Err.	Std. Dev.	Minimum	Maximum	Mean	St. Err.	Std. De
pH $_{sw}$	5.97	0.109	0.345	5.46	6.39	6.573	0.003	0.006
EC $_{sw}$	92.22	0.792	2.504	87.11	95.2	11.957	0.979	1.696
Cl^{-} $_{sw}$	9.85	0.171	0.54	9.22	10.75	8.703	0.385	0.667
Alk $_{sw}$	7.916	0.273	0.863	6.57	9.28	8.753	0.436	0.756
TSS $_{sw}$	26.38	0.792	2.504	23.4	31.49	3.05	1.016	1.759
TDS $_{sw}$	7.86	0.396	1.251	5.31	9.35	5.978	0.490	0.848
Turb $_{sw}$	10.60	0.665	2.103	7.31	13.92	4.167	0.067	0.115
COD $_{sw}$	5.464	0.325	1.027	3.37	6.69	2.373	0.200	0.347
DO $_{sw}$	3.995	0.473	1.496	1.77	6.88	2.137	0.258	0.446
BOD $_{sw}$	2.024	0.147	0.466	1.36	3.07	2.487	0.104	0.18
SO$_4^{2-}$ $_{sw}$	1.823	0.047	0.147	1.54	2.03	0.763	0.026	0.046
NO$_3^{-}$ $_{sw}$	2.215	0.033	0.105	2	2.34	0.763	0.012	0.021
PO$_4^{3-}$ $_{sw}$	0.747	0.017	0.053	0.67	0.82	0.415	0.019	0.032
NH$_4$N $_{sw}$	8.214	0.171	0.54	7.08	8.71	5.120	0.053	0.092
Ca^{2+} $_{sw}$	3.375	0.003	0.011	3.36	3.39	0.074	0.006	0.011
Mg^{2+} $_{sw}$	0.826	0.013	0.040	0.77	0.88	0.295	0.01	0.018
Na^{+} $_{sw}$	5.549	0.103	0.325	4.91	5.95	0.837	0.069	0.119
K^{+} $_{sw}$	3.015	0.059	0.186	2.71	3.28	1.435	0.117	0.203
Zn^{2+} $_{sw}$	0.431	0.004	0.012	0.41	0.45	0.051	0.004	0.007
Cu^{2+} $_{sw}$	0.529	0.003	0.011	0.51	0.54	0.060	0.005	0.008
Cr^{6+} $_{sw}$	0.366	0.003	0.010	0.35	0.38	0.007	0.002	0.003
Pb^{2+} $_{sw}$	0.039	0.004	0.012	0.02	0.06	0.003	0	0.001
Mn^{2+} $_{sw}$	0.16	0.002	0.007	0.15	0.17	0.043	0.010	0.017
Fe^{2+} $_{sw}$	1.27	0.007	0.021	1.24	1.3	1.290	0.108	0.187
Ni^{2+} $_{sw}$	0.187	0.011	0.036	0.09	0.21	0.053	0.018	0.031
T. Coli. $_{SW}$	19.1	0.795	2.514	15	23	4	0.577	1
E. Coli. $_{sw}$	7.6	0.653	2.07	4	11	1.33	0.33	0.577

Table 4.6: Summary of physicochemical parameters for Soil and control from the study area

	Soil					So		
	Mean	St. Err.	Std. Dev.	Minimum	Maximum	Mean	St. Err.	S
pH $_{ss}$	5.87	0.03	0.11	5.71	6.05	5.15	0.038	
EC $_{ss}$	189.09	5.74	18.14	159	219	76.73	5.745	
Cl^{-} $_{ss}$	53.66	1.26	3.99	47.04	60.24	17.5	1.23	
SO_4^{2-} $_{ss}$	78.14	1.43	4.53	70.62	85.62	11.23	0.61	
NO_3^{-} $_{ss}$	64.60	1.15	3.63	58.58	70.58	8.5	0.38	
PO_4^{3-} $_{ss}$	40.89	0.80	2.54	36.68	45.08	13.67	0.88	
NH_4N $_{ss}$	3.53	0.11	0.36	2.93	4.13	1.93	0.09	
Ca^{2+} $_{ss}$	16.59	0.40	1.27	14.48	18.68	2.43	0.20	
Mg^{2+} $_{ss}$	33.42	0.92	2.90	28.61	38.21	4.4	0.25	
Na^{+} $_{ss}$	55.72	1.44	4.55	48.17	63.23	24.97	0.73	
K^{+} $_{ss}$	77.02	2.12	6.71	65.89	88.09	31.33	1.04	
Zn^{2+} $_{ss}$	6.75	0.09	0.29	6.27	7.23	1.23	0.09	
Cu^{2+} $_{ss}$	15.38	0.23	0.73	14.18	16.58	6.7	0.058	
Cr^{6+} $_{ss}$	33.31	0.53	1.67	30.54	36.06	2.93	0.088	
Pb^{2+} $_{ss}$	8.71	0.17	0.54	7.81	9.61	0.09	0.006	
Mn^{2+} $_{ss}$	12.97	0.21	0.65	11.89	14.05	2.28	0.068	
Fe^{2+} $_{ss}$	158.95	2.58	8.16	145.41	172.41	1.82	0.044	
Ni^{2+} $_{ss}$	22.18	0.34	1.09	20.37	23.97	0.97	0.12	
Org. C. $_{ss}$	4.74	0.06	0.20	4.41	5.07	1.78	0.08	
Total N. $_{ss}$	0.38	0.01	0.02	0.34	0.41	0.16	0.01	

The distribution of pH Concentration values in groundwater across the study area is presented in figure 4.1

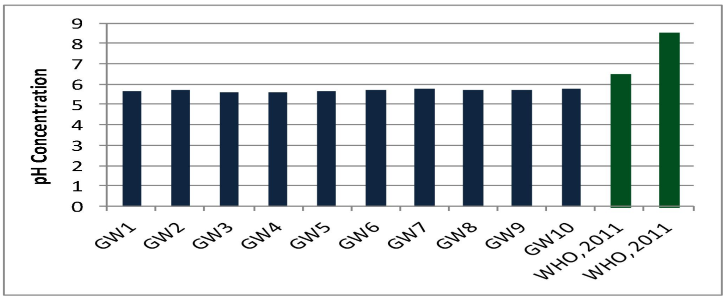

Figure 4.1 **Graphical Representation of pH Concentration in Groundwater**

The distribution of Electrical conductivity values in groundwater across the study area is presented in figure 4.2

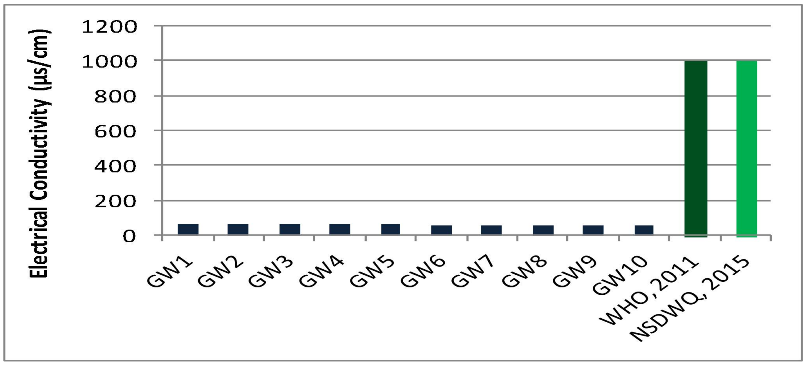

Figure 4.2 **Graphical Representation of Electrical Conductivity in Groundwater**

The distribution of Chloride Concentration values in groundwater across the study area is presented in figure 4.3

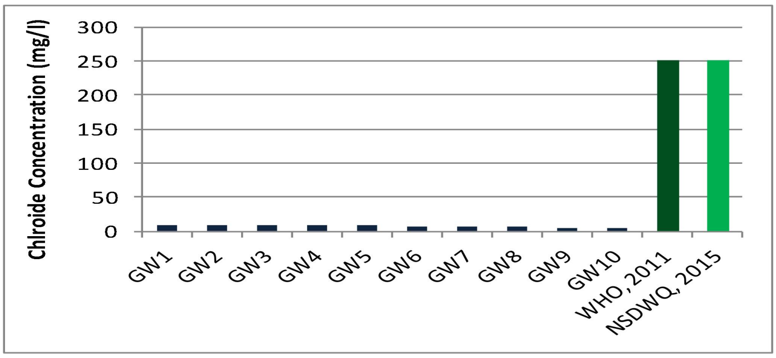

Figure 4.3 **Graphical Representation of Chloride Concentration in Groundwater**

The distribution of Alkalinity Concentration values in groundwater across the study area is presented in figure 4.4

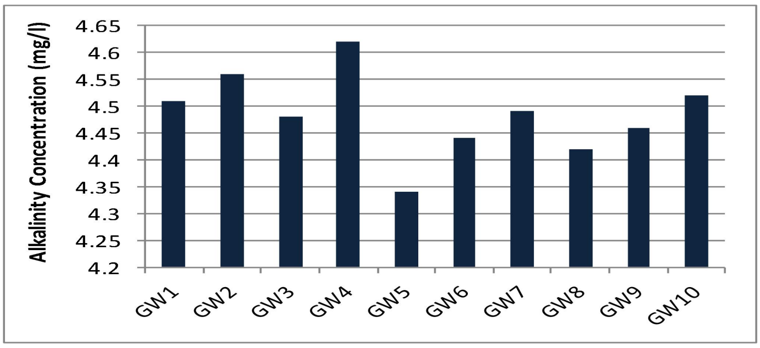

Figure 4.4 **Graphical Representation of Alkalinity Concentration in Groundwater**

The distribution of Total Suspended Solids values in groundwater across the study area is presented in figure 4.5

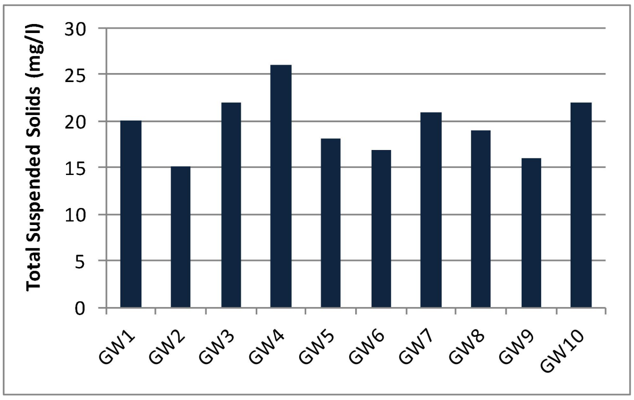

Figure 4.5 Graphical Representation of Total Suspended Solids in Groundwater

The distribution of **Total Dissolved** Solids values in groundwater across the study area is presented in figure 4.6

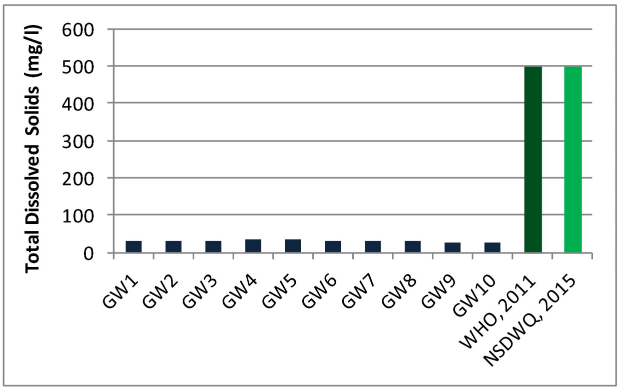

Figure 4.6 Graphical Representation of Total Dissolved Solids in Groundwater

The distribution of Turbidity values in groundwater across the study area is presented in figure 4.7

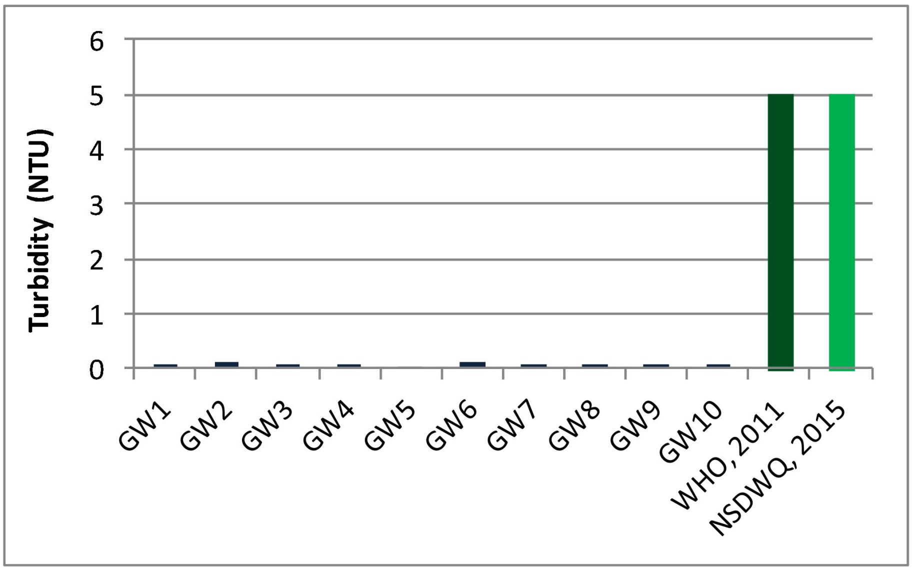

Figure 4.7 Graphical Representation of Turbidity in Groundwater

The distribution of Chemical Oxygen Demand values in groundwater across the study area is presented in figure 4.8

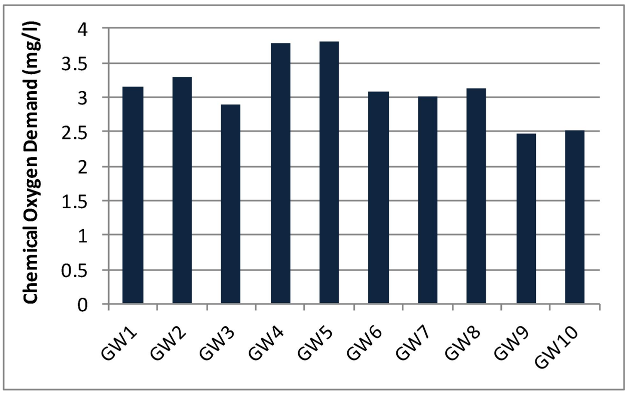

Figure 4.8 Graphical Representation of Chemical Oxygen Demand in Groundwater

The distribution of Dissolved Oxygen values in groundwater across the study area is presented in figure 4.9

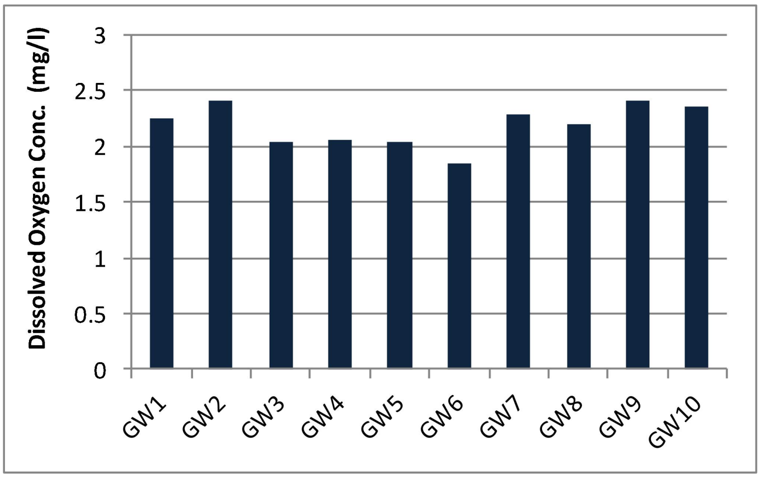

Figure 4.9 Graphical Representation of Dissolved Oxygen in Groundwater

The distribution of Biological Oxygen Demand in groundwater across the study area is presented in figure 4.10

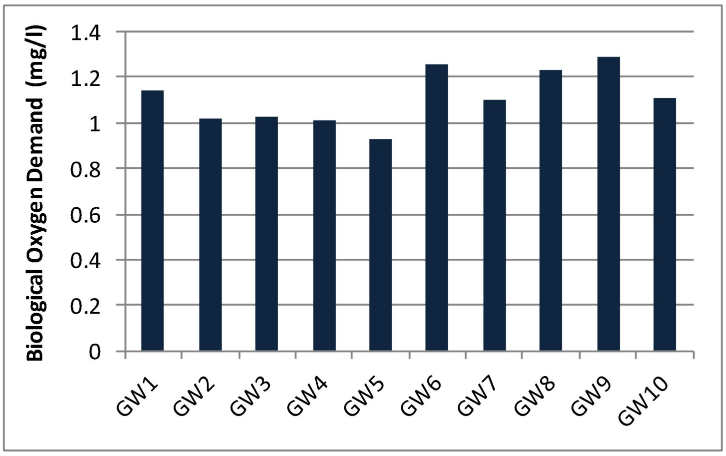

Figure 4.10 Graphical Representation of Biological Oxygen Demand in Groundwater

The distribution of Sulphate Concentration values in groundwater across the study area is presented in figure 4.11

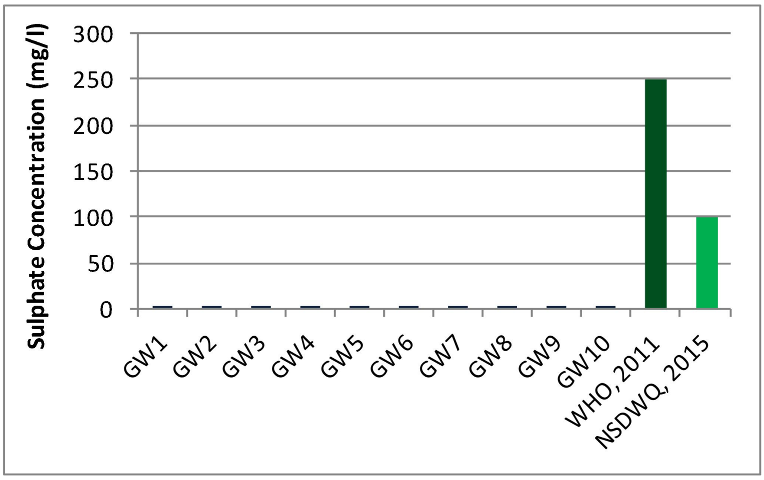

Figure 4.11 Graphical Representation of Sulphate Concentration in Groundwater

The distribution of Nitrate Concentration values in groundwater across the study area is presented in figure 4.12

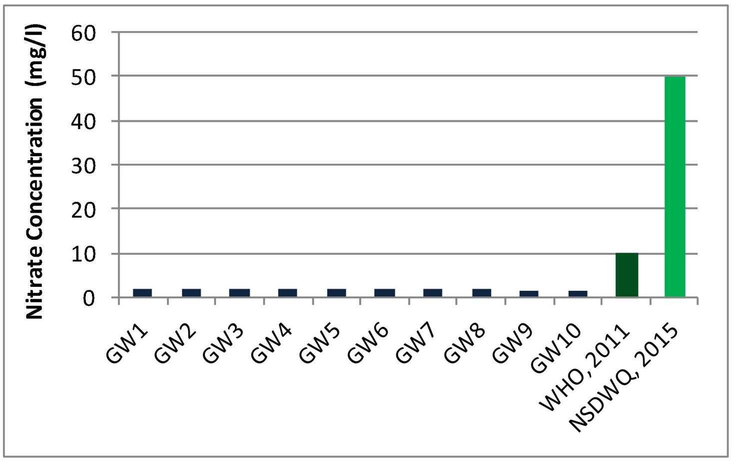

Figure 4.12 Graphical Representation of Nitrate Concentration in Groundwater

The distribution of Phosphate Concentration values in groundwater across the study area is presented in figure 4.13

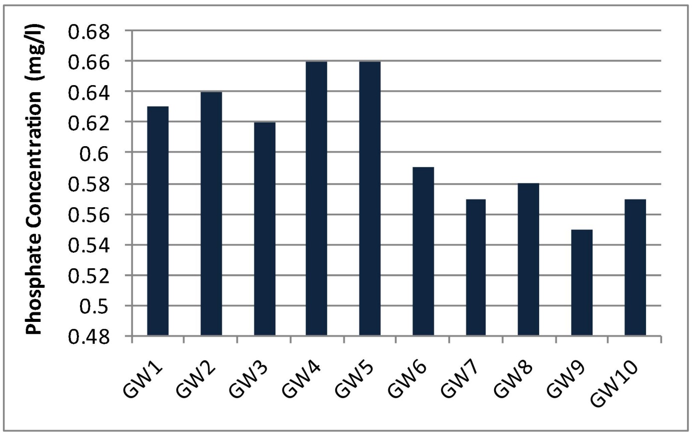

Figure 4.13 Graphical Representation of Phosphate Concentration in Groundwater

The distribution of Ammonium Nitrogen values in groundwater across the study area is presented in figure 4.14

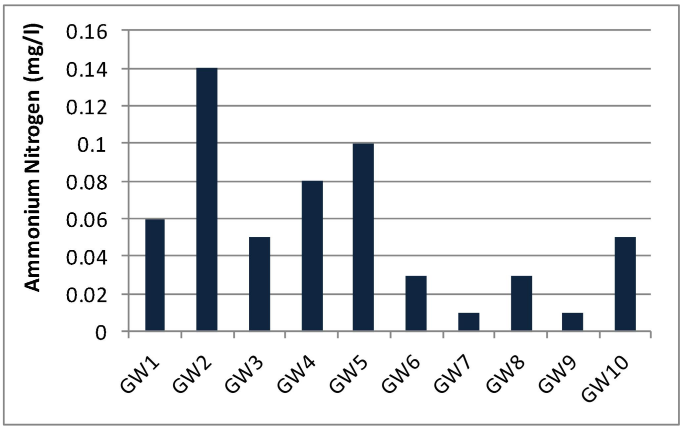

Figure 4.14 Graphical Representation of Ammonium Nitrogen in Groundwater

The distribution of Calcium Concentration values in groundwater across the study area is presented in figure 4.15

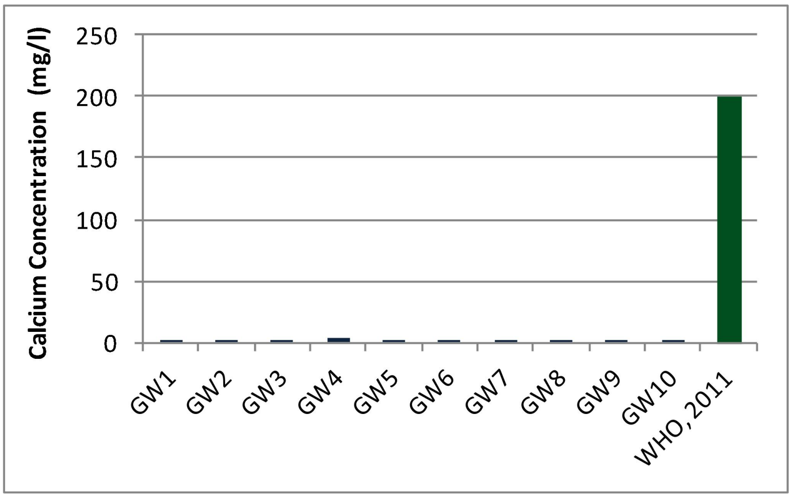

Figure 4.15 Graphical Representation of Calcium Concentration in Groundwater

The distribution of Magnesium Concentration values in groundwater across the study area is presented in figure 4.16

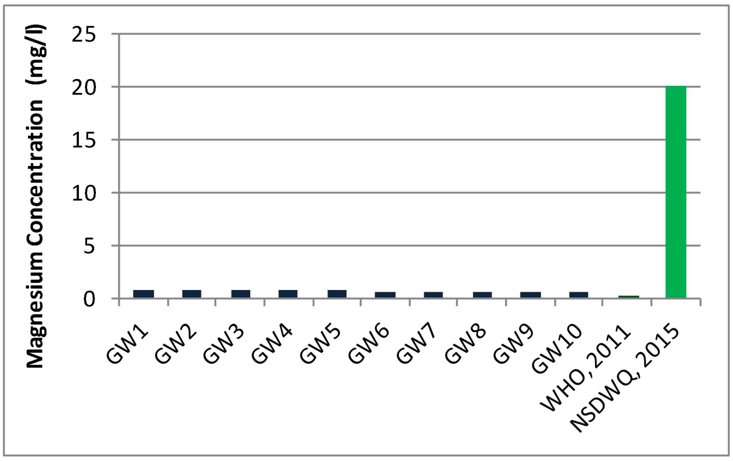

Figure 4.16 Graphical Representation of Magnesium Concentration in Groundwater

The distribution of Sodium Concentration values in groundwater across the study area is presented in figure 4.17

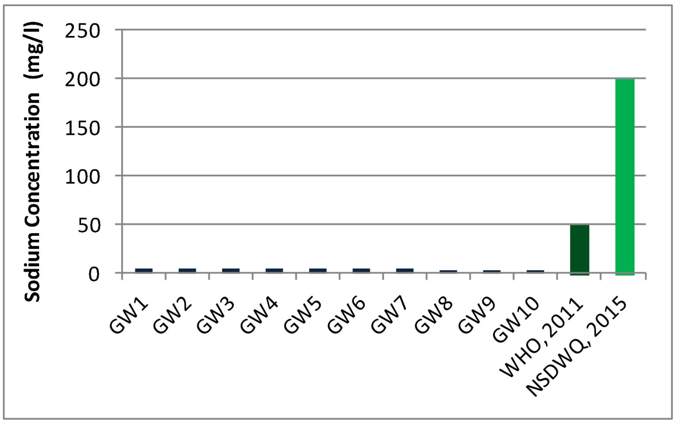

Figure 4.17 **Graphical Representation of Sodium Concentration in Groundwater**

The distribution of Potassium Concentration values in groundwater across the study area is presented in figure 4.18

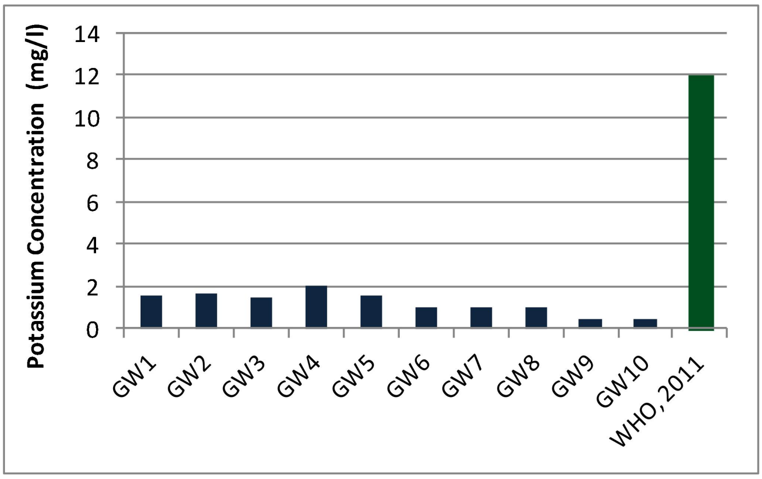

Figure 4.18 **Graphical Representation of Potassium Concentration in Groundwater**

The distribution of Copper Concentration values in groundwater across the study area is presented in figure 4.19

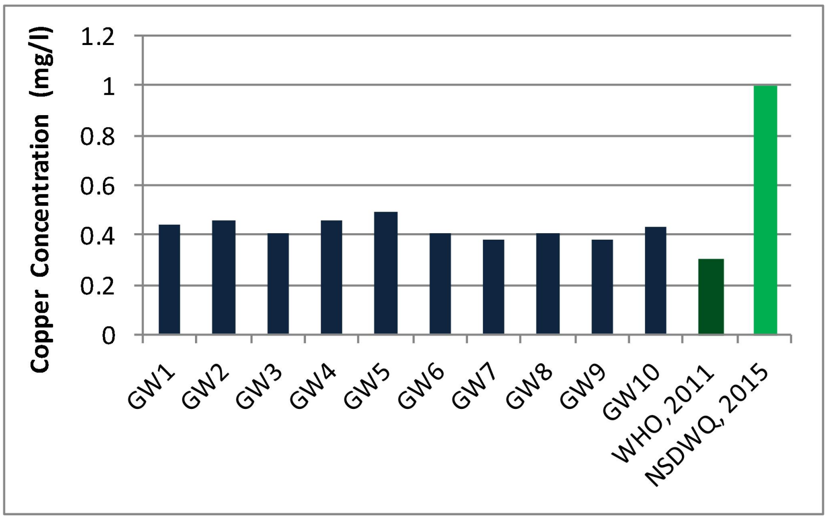

Figure 4.19 Graphical Representation of Copper Concentration in Groundwater

The distribution of Chromium Concentration values in groundwater across the study area is presented in figure 4.20

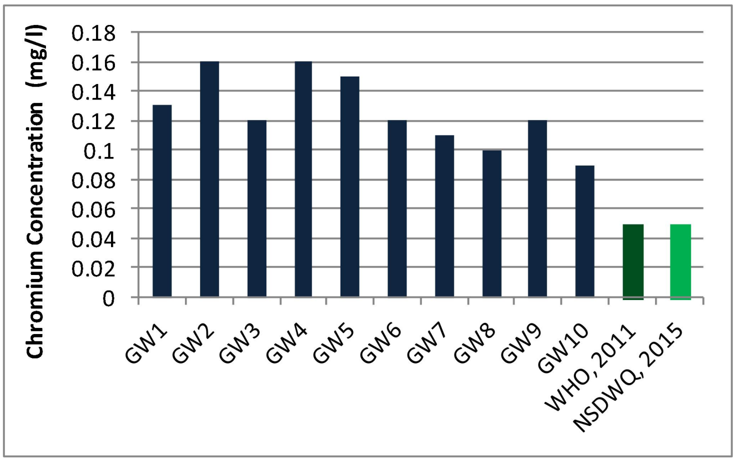

Figure 4.20 Graphical Representation of Chromium Concentration in Groundwater

The distribution of Lead Concentration values in groundwater across the study area is presented in figure 4.21

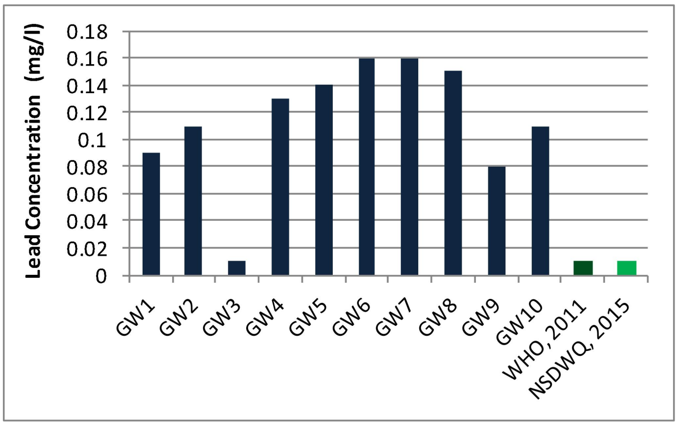

Figure 4.21 Graphical Representation of Lead Concentration in Groundwater

The distribution of Manganese Concentration values in groundwater across the study area is presented in figure 4.22

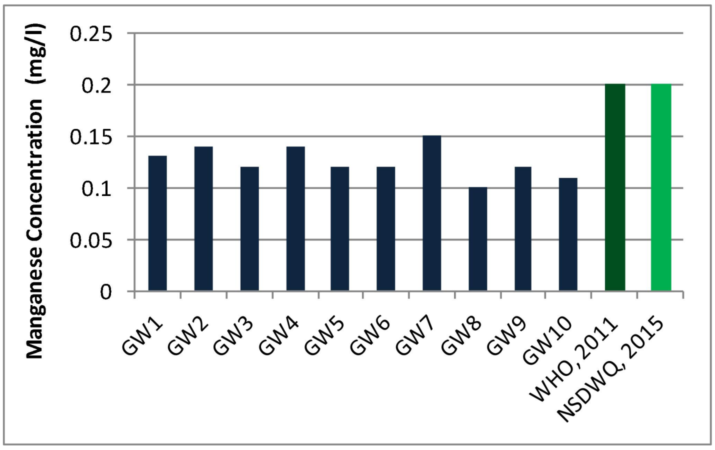

Figure 4.22 Graphical Representation of Manganese Concentration in Groundwater

The distribution of Iron Concentration values in groundwater across the study area is presented in figure 4.23

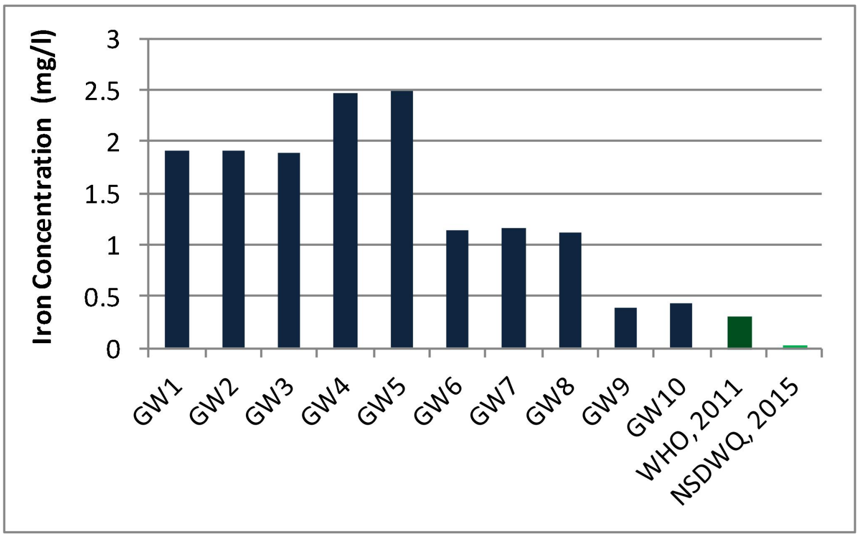

Figure 4.23 Graphical Representation of Iron Concentration in Groundwater

The distribution of Nickel Concentration values in groundwater across the study area is presented in figure 4.24

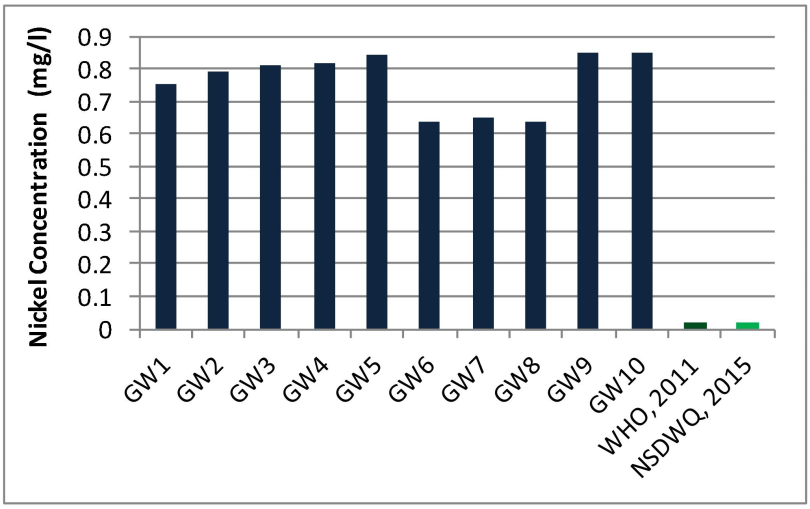

Figure 4.24 Graphical Representation of Nickel Concentration in Groundwater

The distribution of Coliform Concentration values in groundwater across the study area is presented in figure 4.25

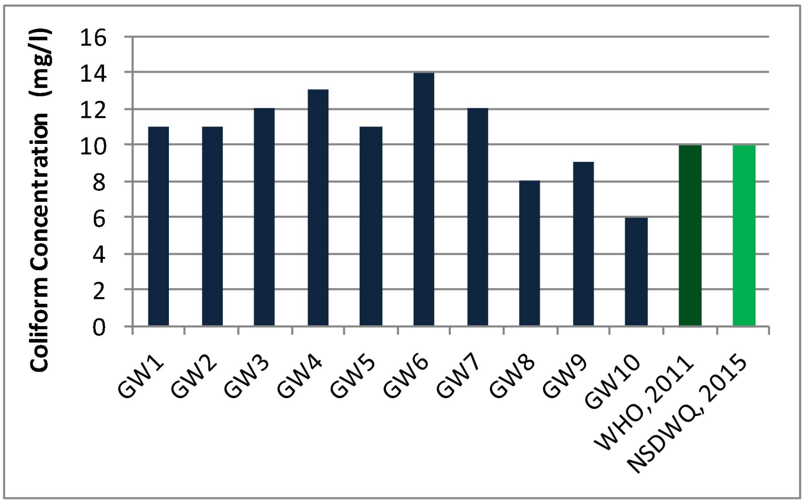

Figure 4.25 Graphical Representation of Coliform Concentration in Groundwater

The distribution of E-Coli Concentration values in groundwater across the study area is presented in figure 4.26

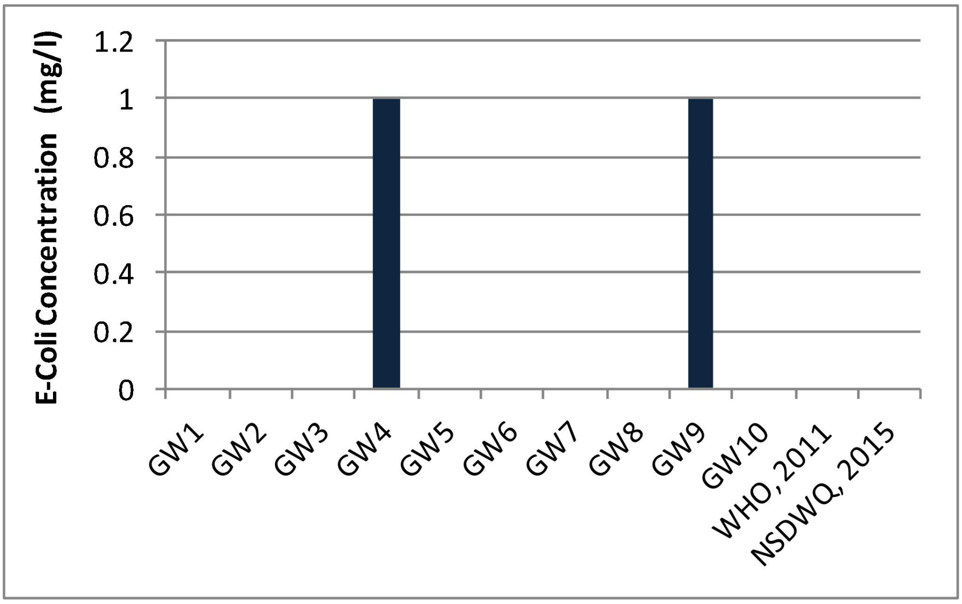

Figure 4.26 Graphical Representation of e Coli Concentration in Groundwater

The distribution of pH Concentration values in surface water across the study area is presented in figure 4.27

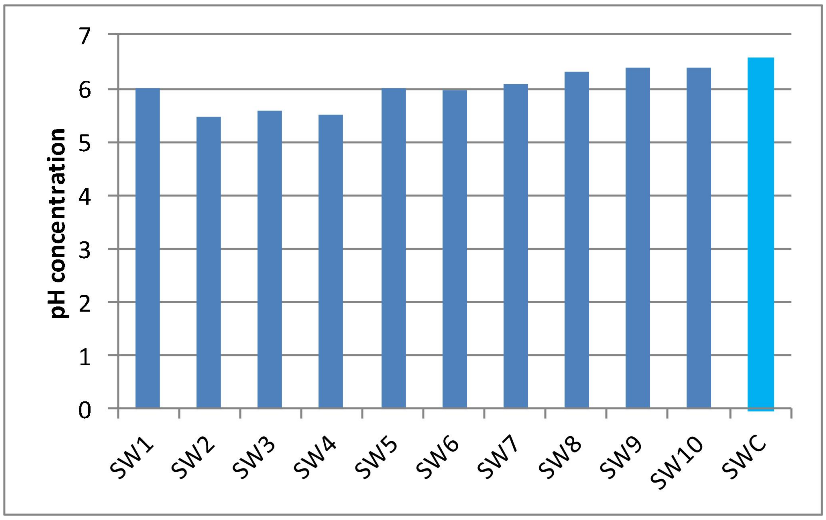

Figure 4.27 Graphical Representation of pH Concentration in Surface Water

The distribution of Electrical Conductivity values in surface water across the study area is presented in figure 4.28

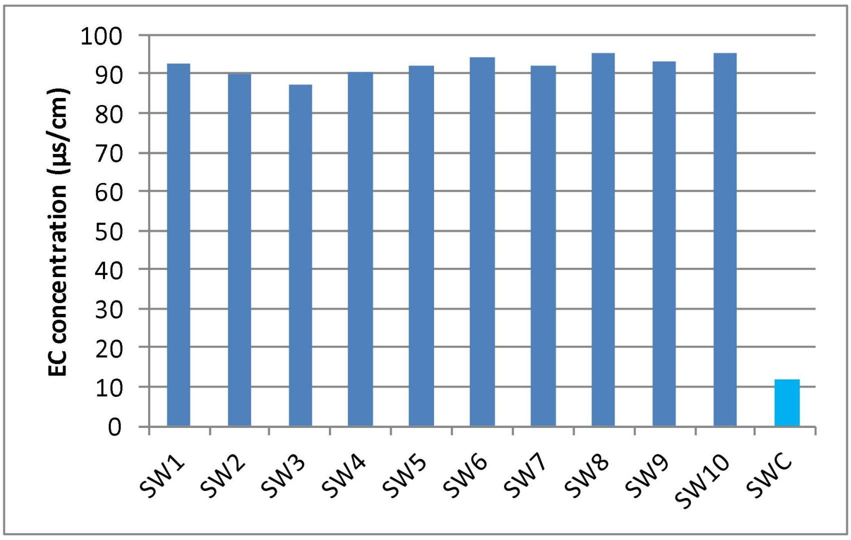

Figure 4.28 Graphical Representation of Electrical Conductivity in Surface Water

The distribution of Chloride Concentration values in surface water across the study area is presented in figure 4.29

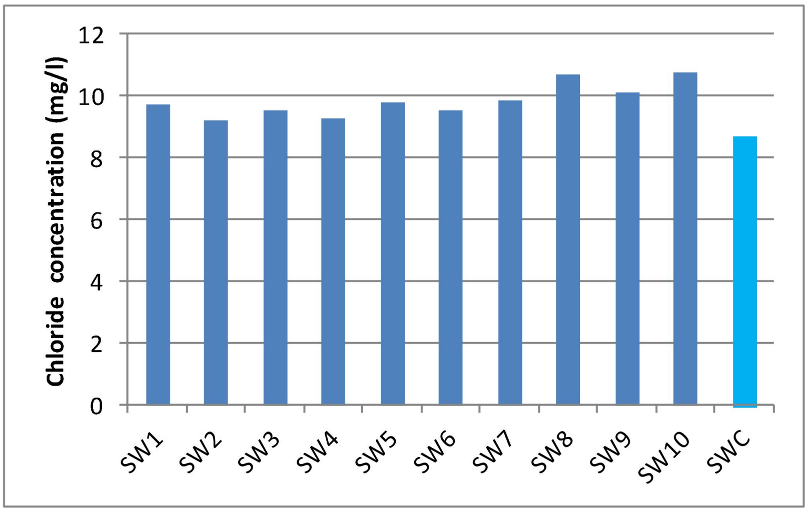

Figure 4.29 Graphical Representation of Chloride Concentration in Surface Water

The distribution of Alkalinity values in surface water across the study area is presented in figure 4.30

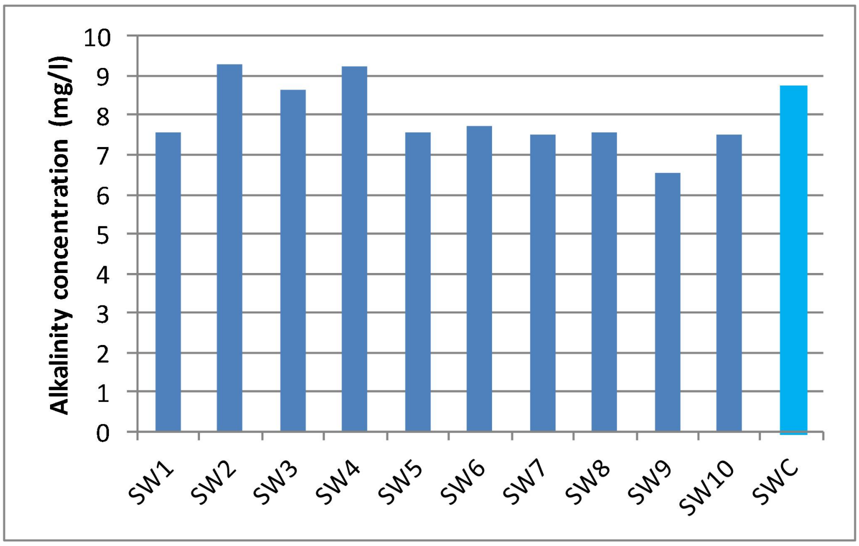

Figure 4.30 Graphical Representation of Alkalinity in Surface Water

The distribution of Total Suspended Solids values in surface water across the study area is presented in figure 4.31

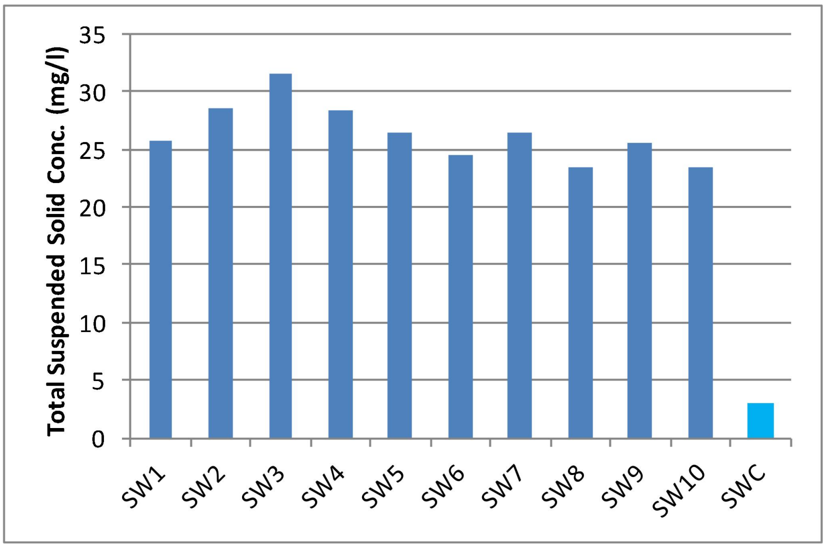

Figure 4.31 Graphical Representation of Total Suspended Solids in Surface Water

The distribution of Total Dissolved Solids values in surface water across the study area is presented in figure 4.32

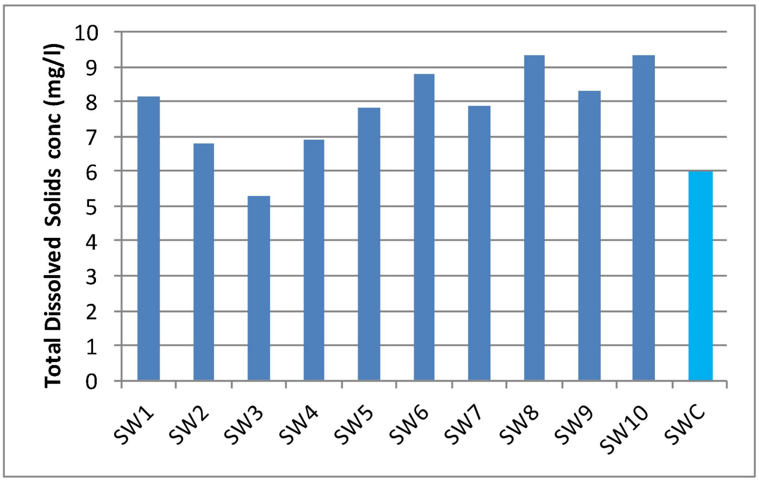

Figure 4.32 Graphical Representation of Total Dissolved Solids in Surface Water

The distribution of Turbidity values in surface water across the study area is presented in figure 4.33

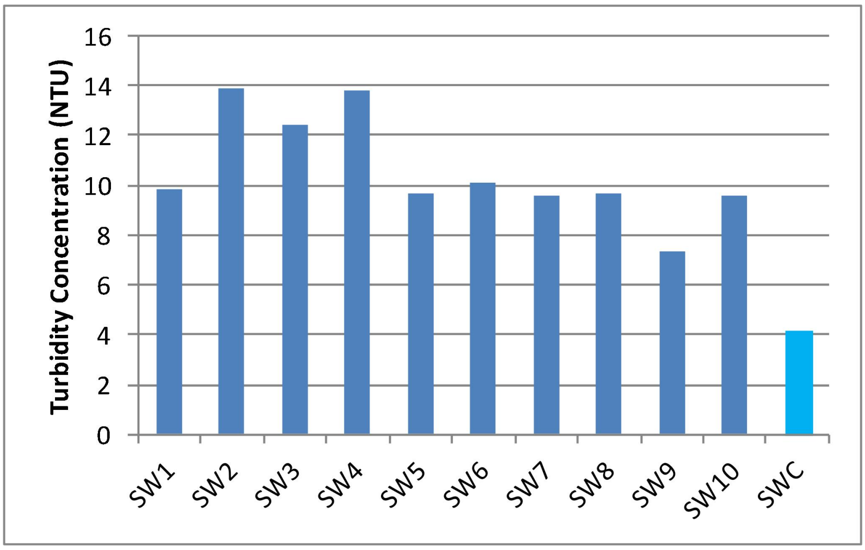

Figure 4.33 Graphical Representation of Turbidity in Surface Water

The distribution of Chemical Oxygen Demand values in surface water across the study area is presented in figure 4.34

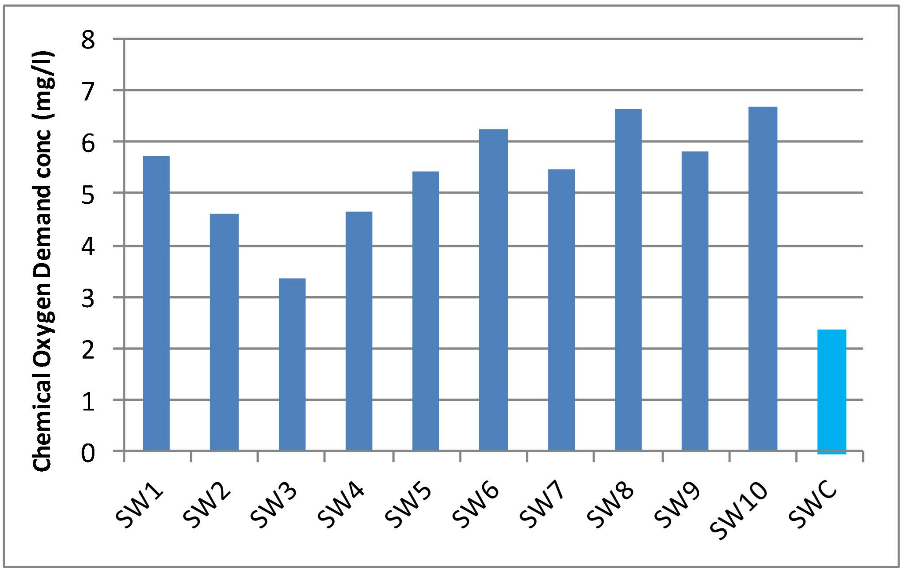

Figure 4.34 Graphical Representation of Chemical Oxygen Demand in Surface Water

The distribution of Dissolved Oxygen values in surface water across the study area is presented in figure 4.35

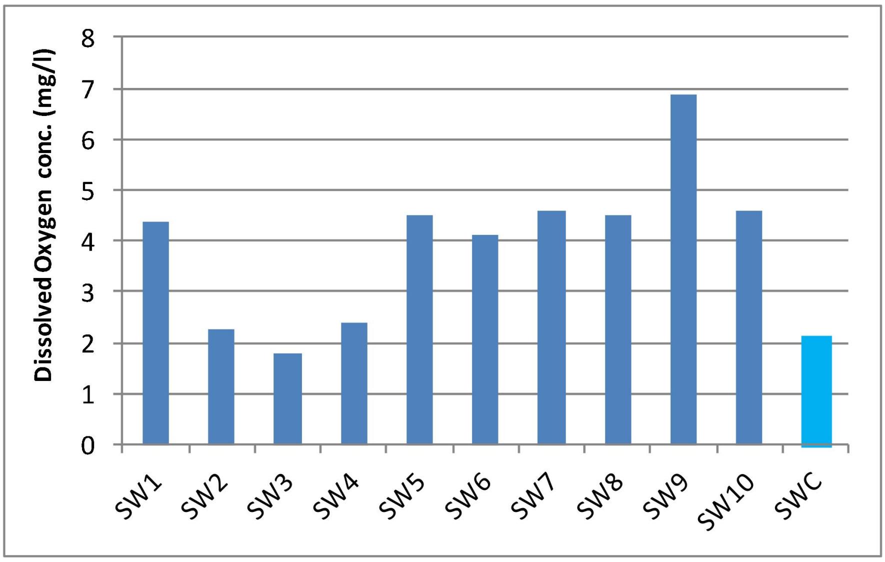

Figure 4.35 Graphical Representation of Dissolved Oxygen in Surface Water

The distribution of Biological Oxygen Demand values in surface water across the study area is presented in figure 4.36

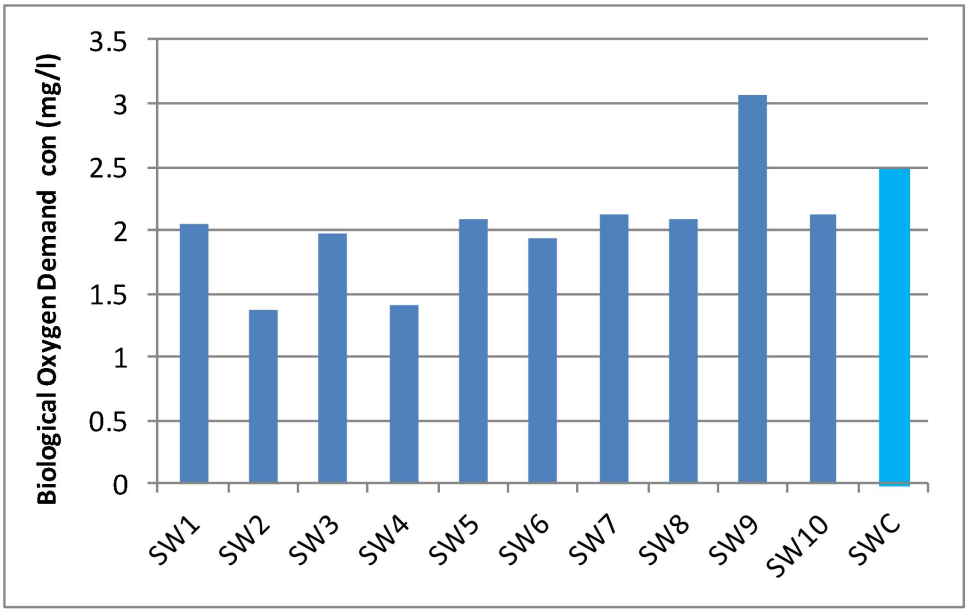

Figure 4.36 Graphical Representation of Biological Oxygen Demand in Surface Water

The distribution of Sulphate Concentration values in surface water across the study area is presented in figure 4.37

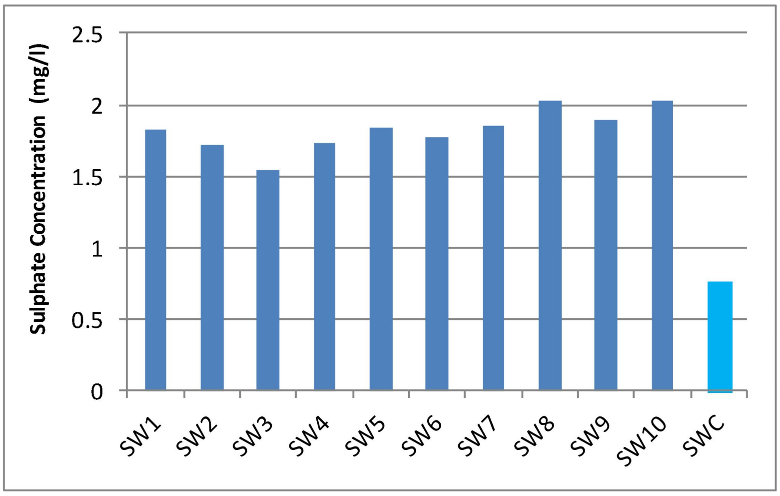

Figure 4.37 Graphical Representation of Sulphate Concentration in Surface Water

The distribution of Nitrate Concentration values in surface water across the study area is presented in figure 4.38

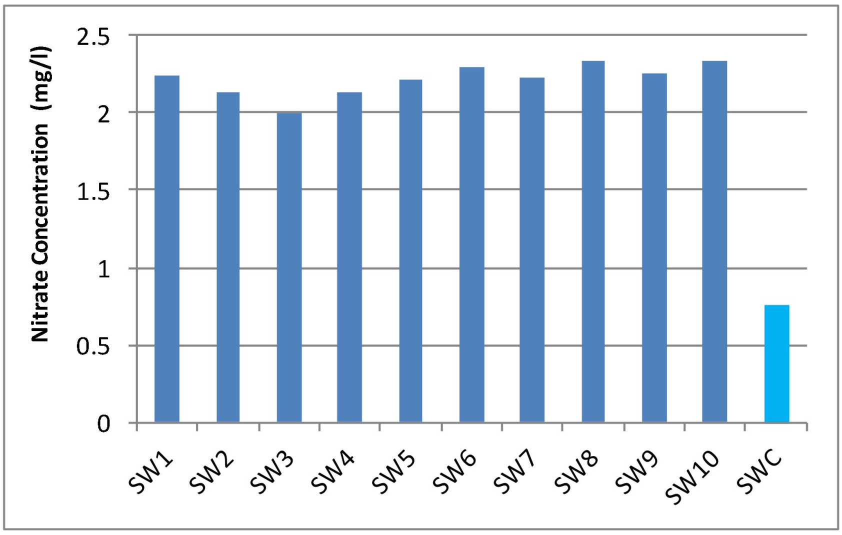

Figure 4.38 Graphical Representation of Nitrate Concentration in Surface Water

The distribution of Phosphate Concentration values in surface water across the study area is presented in figure 4.39

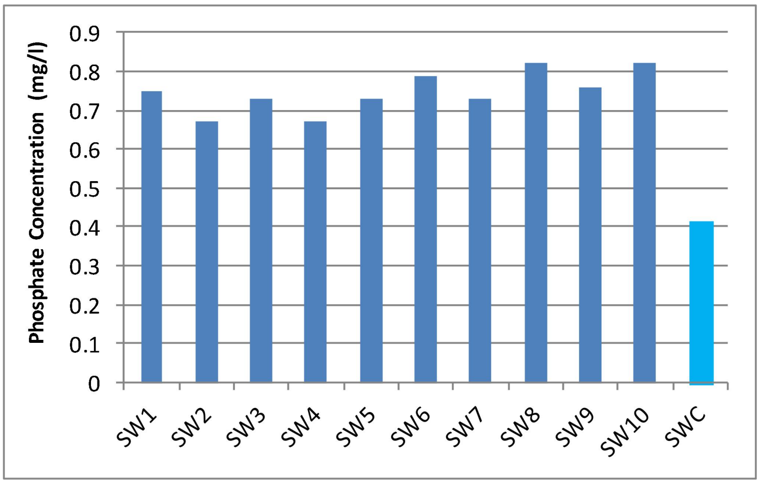

Figure 4.39 Graphical Representation of Phosphate Concentration in Surface Water

The distribution of Ammonium Nitrogen Concentration values in surface water across the study area is presented in figure 4.40

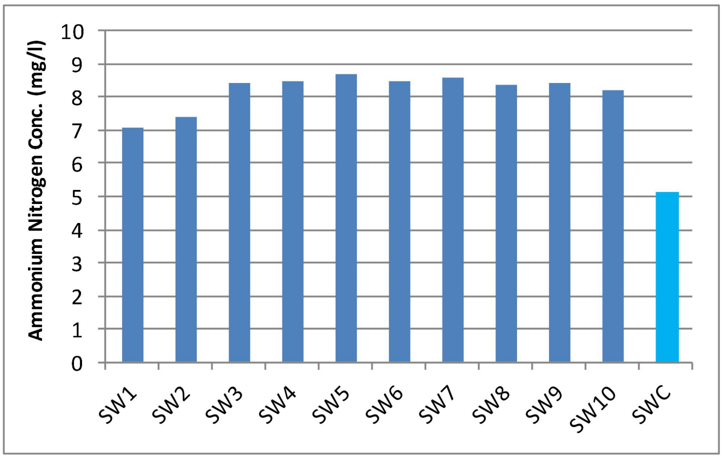

Figure 4.40 Graphical Representation of Ammonium Nitrogen in Surface Water

The distribution of Calcium Concentration values in surface water across the study area is presented in figure 4.41

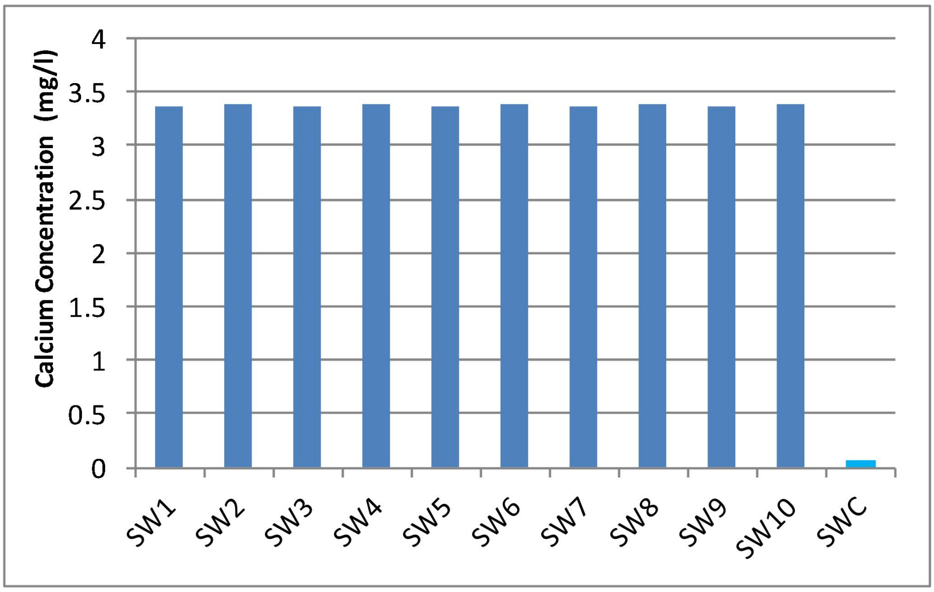

Figure 4.41 Graphical Representation of Calcium Concentration in Surface Water

The distribution of Magnesium Concentration values in surface water across the study area is presented in figure 4.42

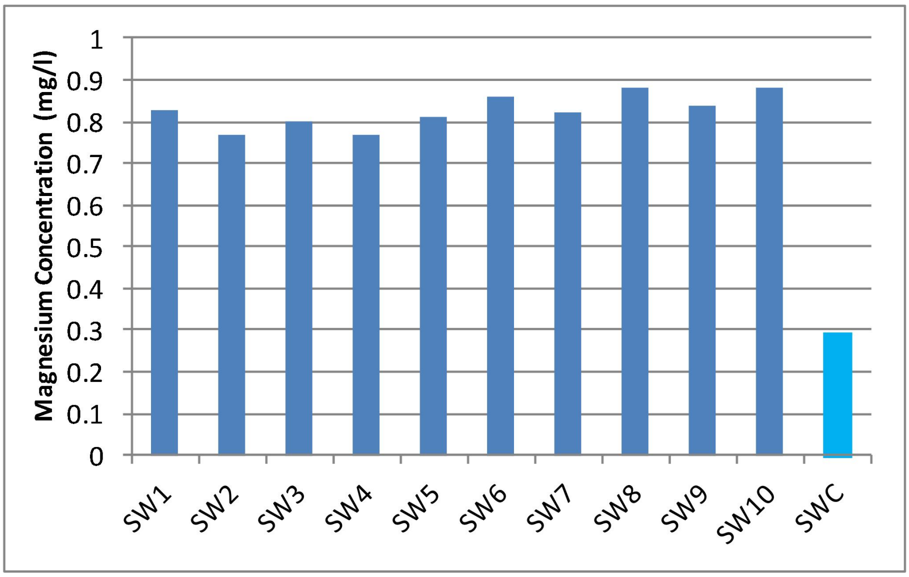

Figure 4.42 Graphical Representation of Magnesium Concentration in Surface Water

The distribution of Sodium Concentration values in surface water across the study area is presented in figure 4.43

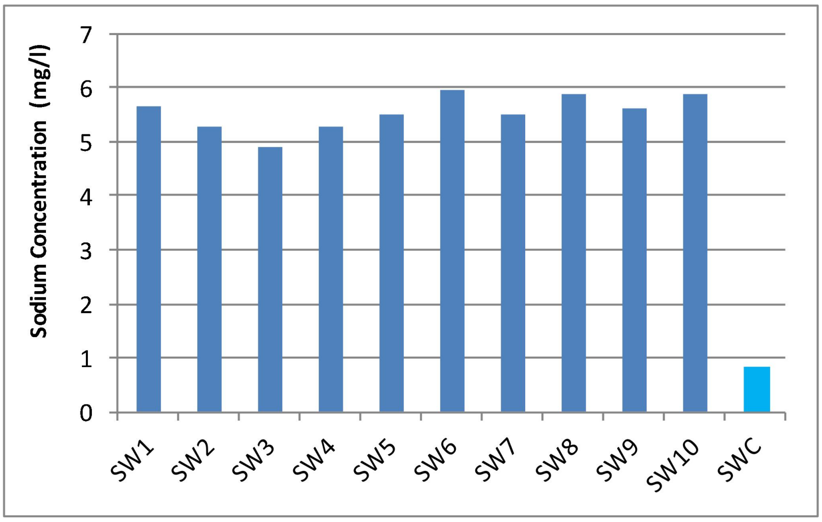

Figure 4.43 Graphical Representation of Sodium Concentration in Surface Water

The distribution of potassium Concentration values in surface water across the study area is presented in figure 4.44

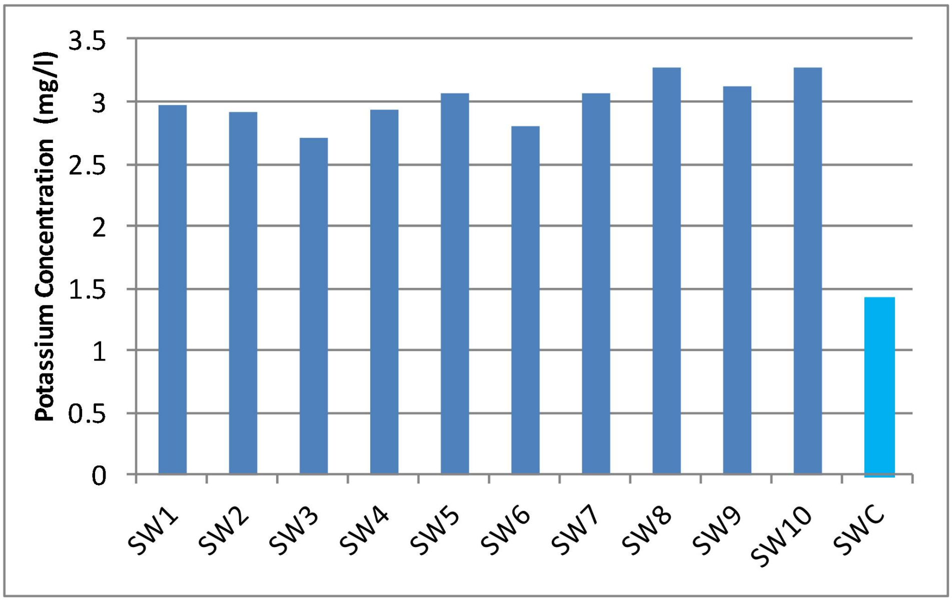

Figure 4.44 Graphical Representation of potassium Concentration in Surface Water

The distribution of Zinc Concentration values in surface water across the study area is presented in figure 4.45

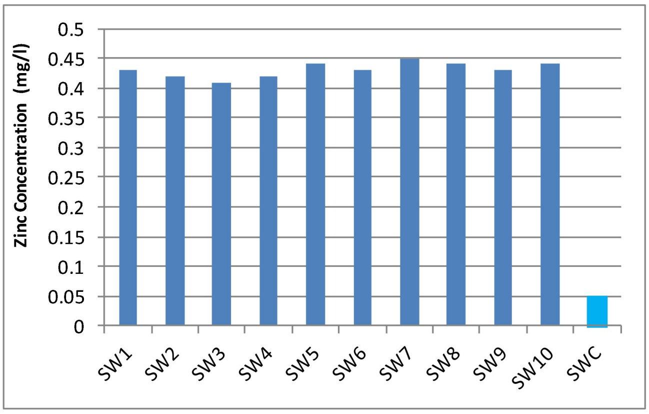

Figure 4.45 Graphical Representation of Zinc Concentration in Surface Water

The distribution of copper Concentration values in surface water across the study area is presented in figure 4.46

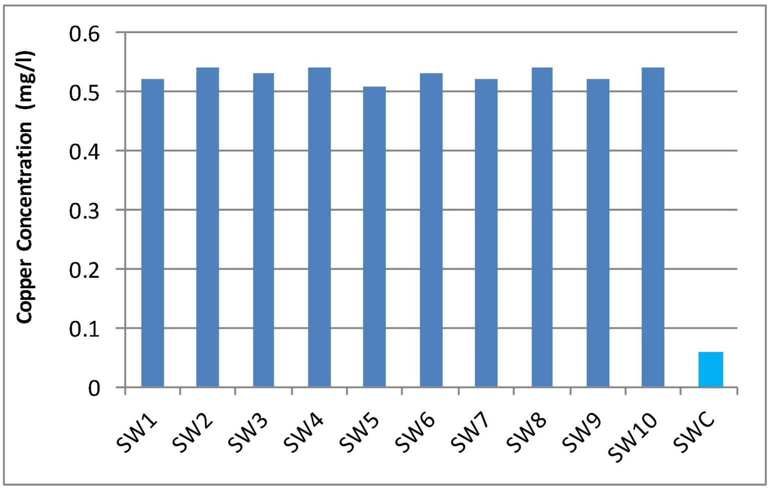

Figure 4.46 Graphical Representation of copper Concentration in Surface Water

The distribution of Chromium Concentration values in surface water across the study area is presented in figure 4.47

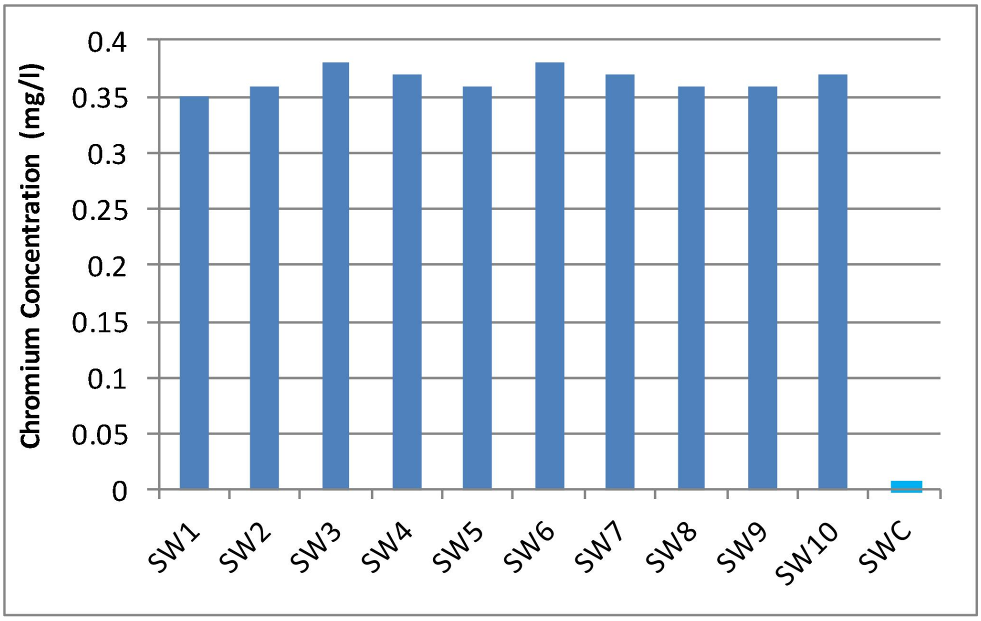

Figure 4.47 **Graphical Representation of Chromium Concentration in Surface Water**

The distribution of Lead Concentration values in surface water across the study area is presented in figure 4.48

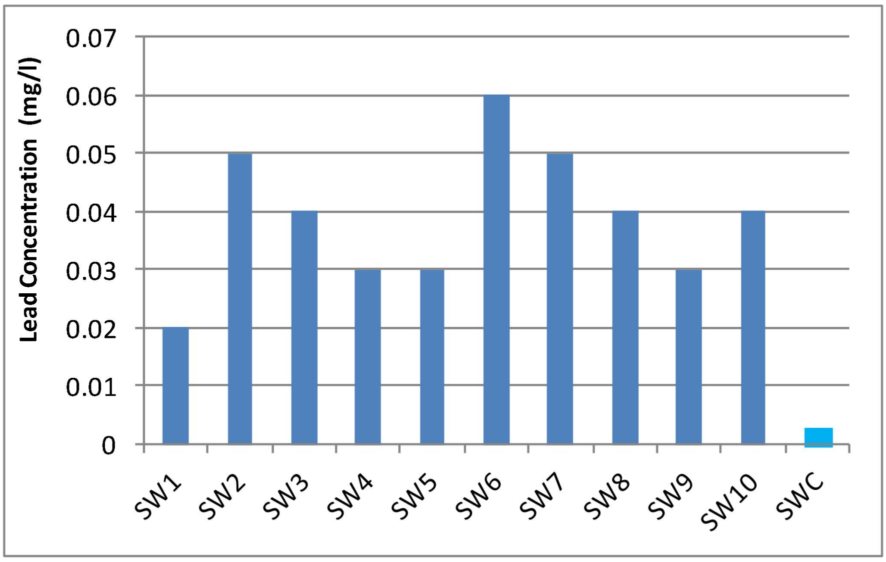

Figure 4.48 **Graphical Representation of Lead Concentration in Surface Water**

The distribution of Manganese Concentration values in surface water across the study area is presented in figure 4.49

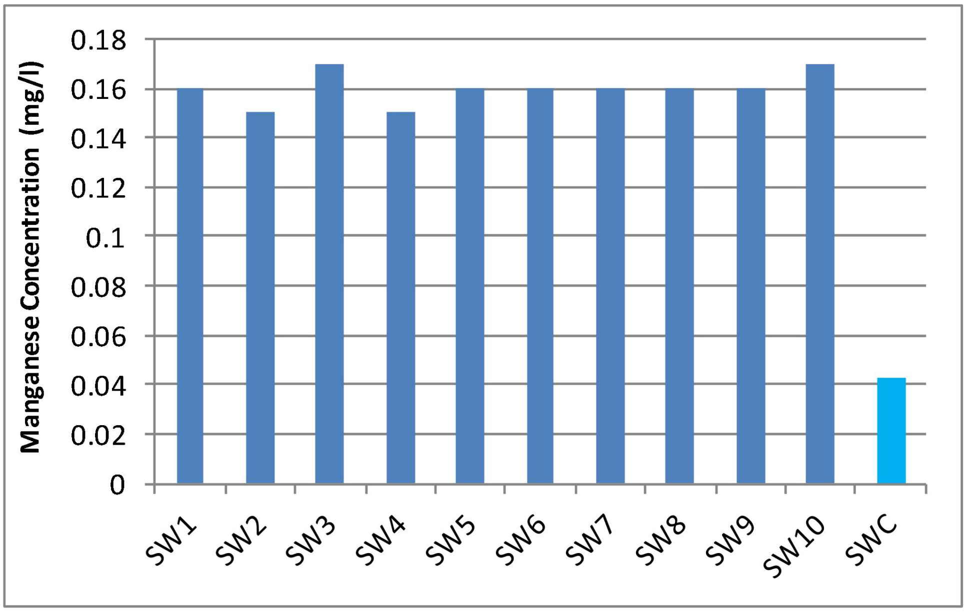

Figure 4.49 Graphical Representation of Manganese Concentration in Surface Water

The distribution of Iron Concentration values in surface water across the study area is presented in figure 4.50

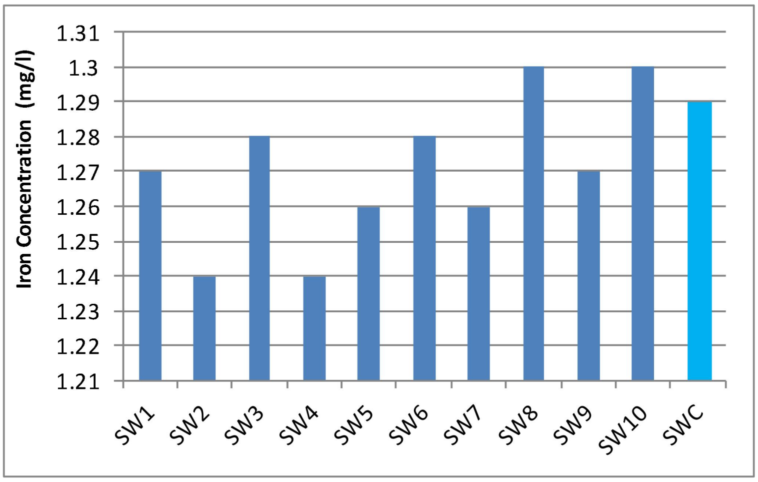

Figure 4.50 Graphical Representation of Iron Concentration in Surface Water

The distribution of Nickel Concentration values in surface water across the study area is presented in figure 4.51

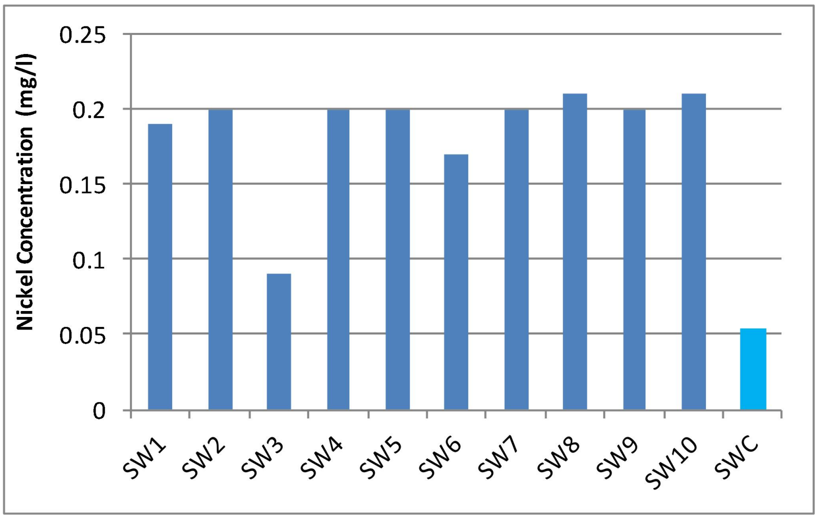

Figure 4.51 Graphical Representation of Nickel Concentration in Surface Water

The distribution of Coliform Count values in surface water across the study area is presented in figure 4.52

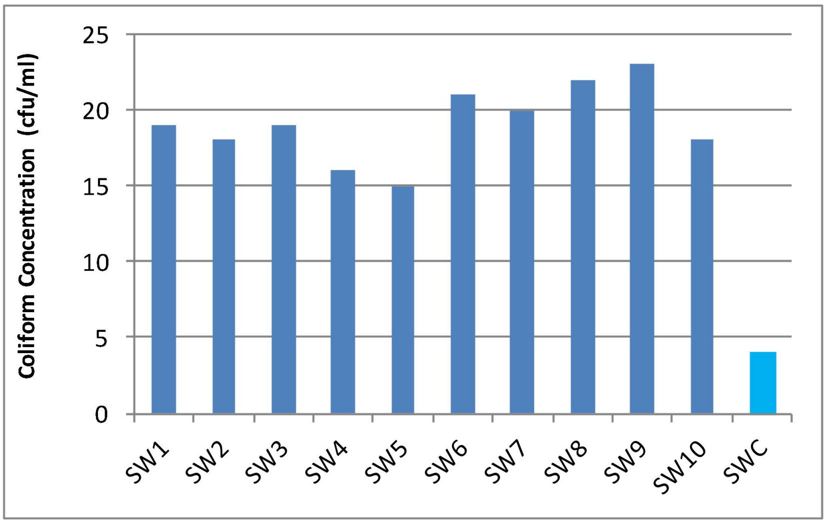

Figure 4.52 Graphical Representation of Coliform Count in Surface Water

The distribution of E-Coli Concentration values in surface water across the study area is presented in figure 4.53

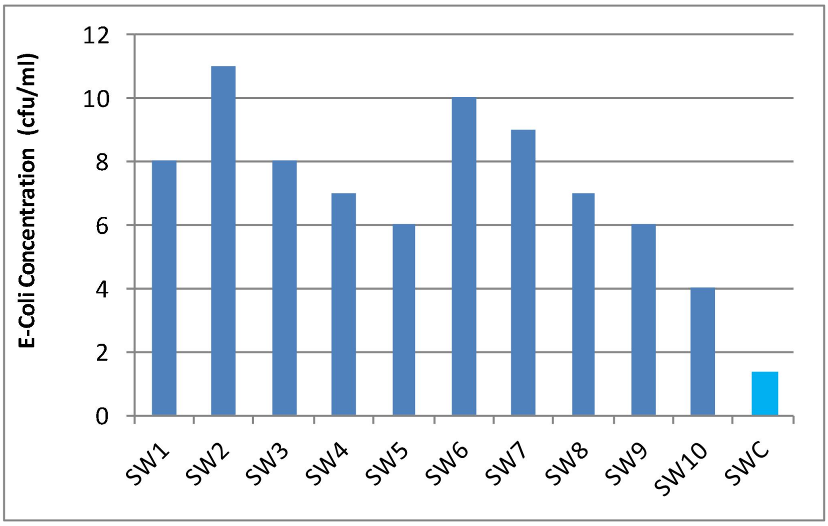

Figure 4.53 Graphical Representation of E-Coli Concentration in Surface Water

The distribution of pH Concentration values in soil across the study area is presented in figure 4.54

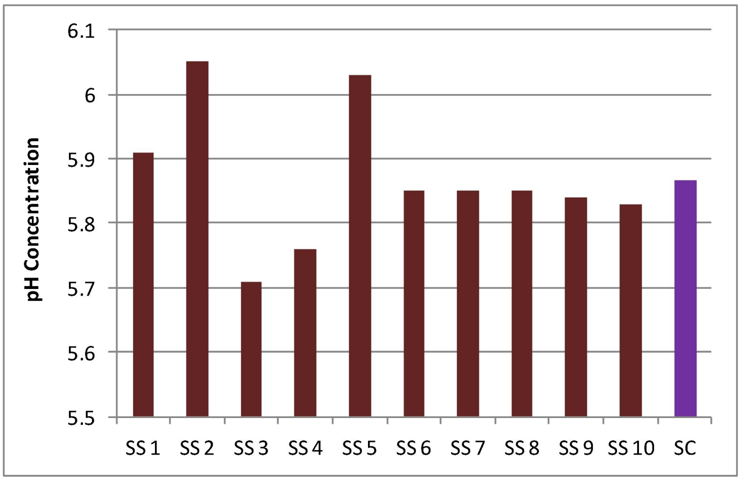

Figure 4.54 Graphical Representation of pH Concentration in Soil

The distribution of Electrical Conductivity values in soil across the study area is presented in figure 4.55

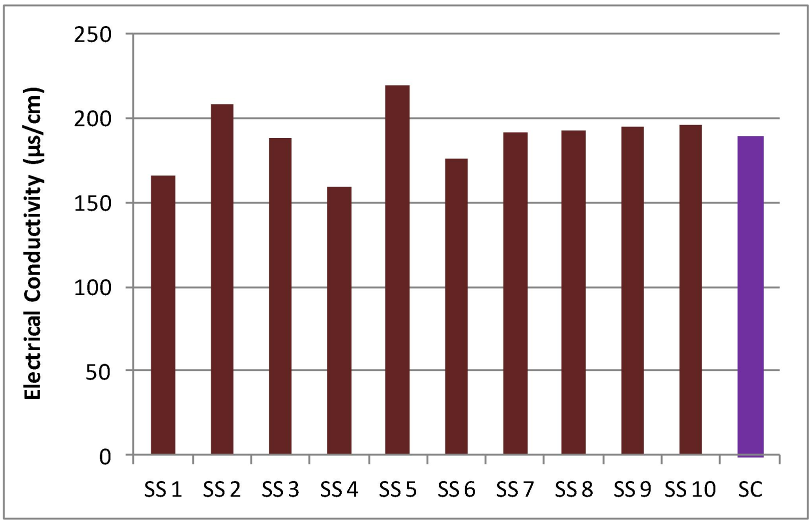

Figure 4.55 Graphical Representation of Electrical Conductivity in Soil

The distribution of Chloride Concentration values in soil across the study area is presented in figure 4.56

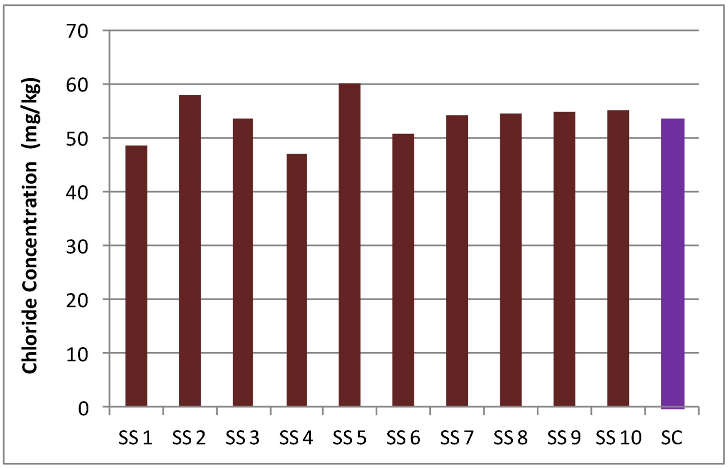

Figure 4.56 Graphical Representation of Chloride Concentration in Soil

The distribution of Sulphate Concentration values in soil across the study area is presented in figure 4.57

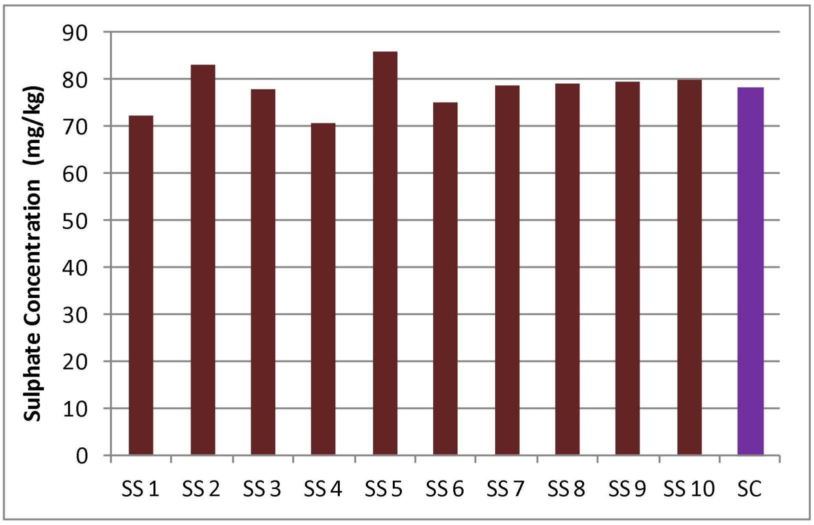

Figure 4.57 **Graphical Representation of Sulphate Concentration in Soil**

The distribution of Nitrate Concentration values in soil across the study area is presented in figure 4.58

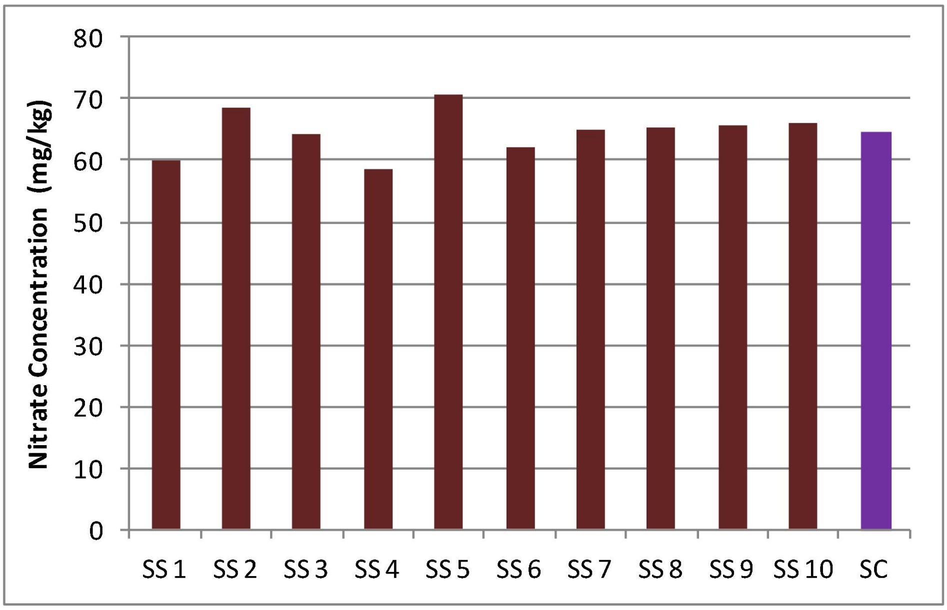

Figure 4.58 **Graphical Representation of Nitrate Concentration in Soil**

The distribution of Phosphate Concentration values in soil across the study area is presented in figure 4.59

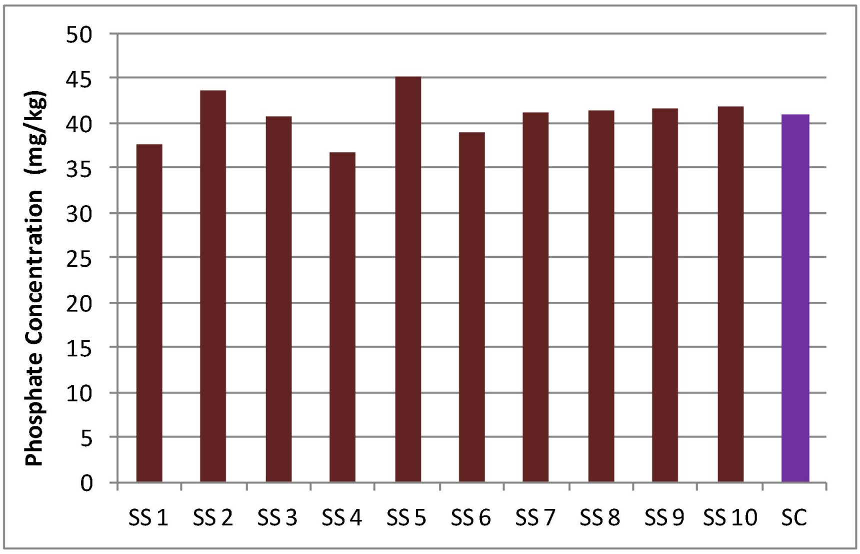

Figure 4.59 Graphical Representation of Phosphate Concentration in Soil

The distribution of Ammonium Nitrogen Concentration values in soil across the study area is presented in figure 4.60

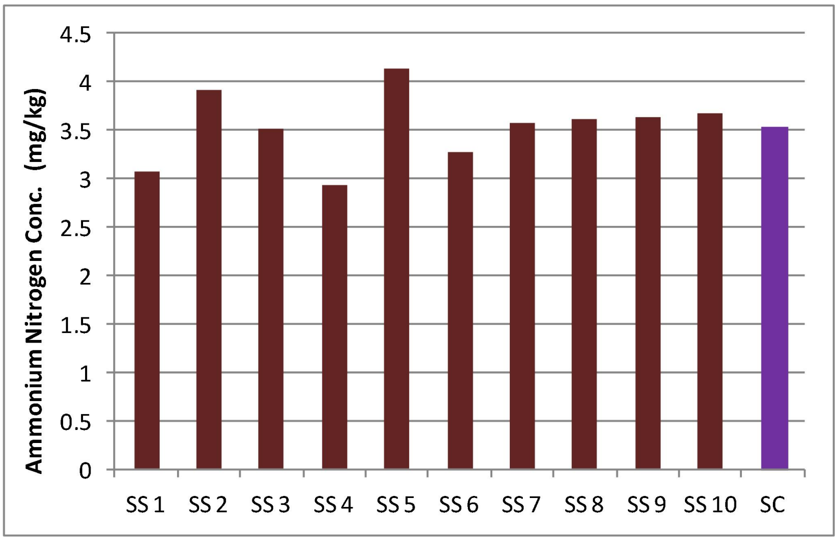

Figure 4.60 Graphical Representation of Ammonium Nitrogen Concentration in Soil

The distribution of Calcium Concentration values in soil across the study area is presented in figure 4.61

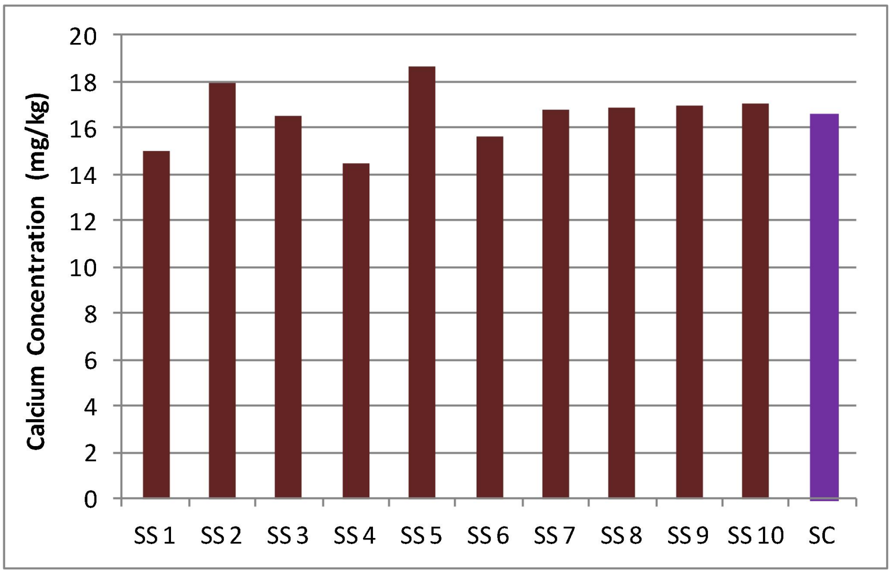

Figure 4.61 Graphical Representation of Calcium Concentration in Soil

The distribution of Magnesium Concentration values in soil across the study area is presented in figure 4.62

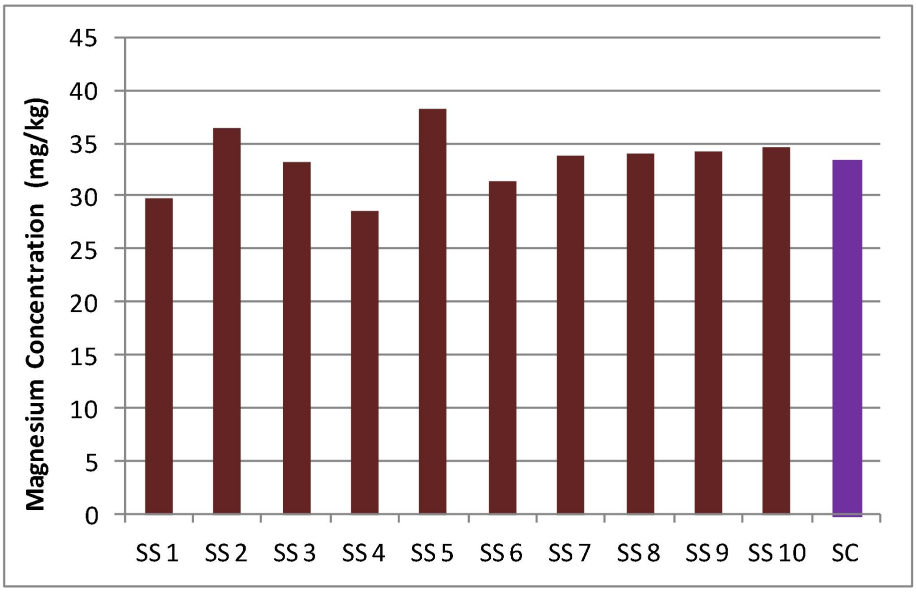

Figure 4.62 Graphical Representation of Magnesium Concentration in Soil

The distribution of Potassium Concentration values in soil across the study area is presented in figure 4.63

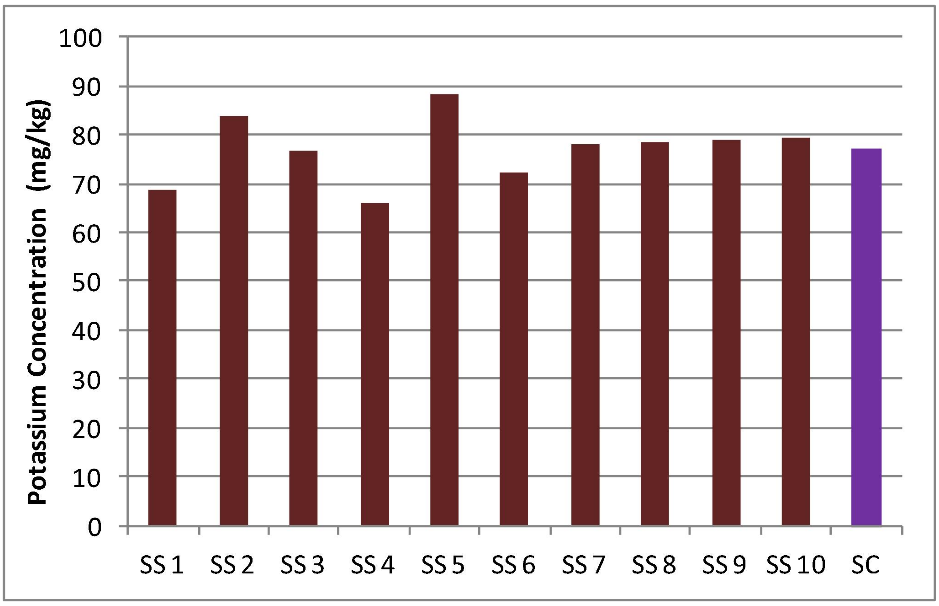

Figure 4.63 **Graphical Representation of Potassium Concentration in Soil**

The distribution of Zinc Concentration values in soil across the study area is presented in figure 4.64

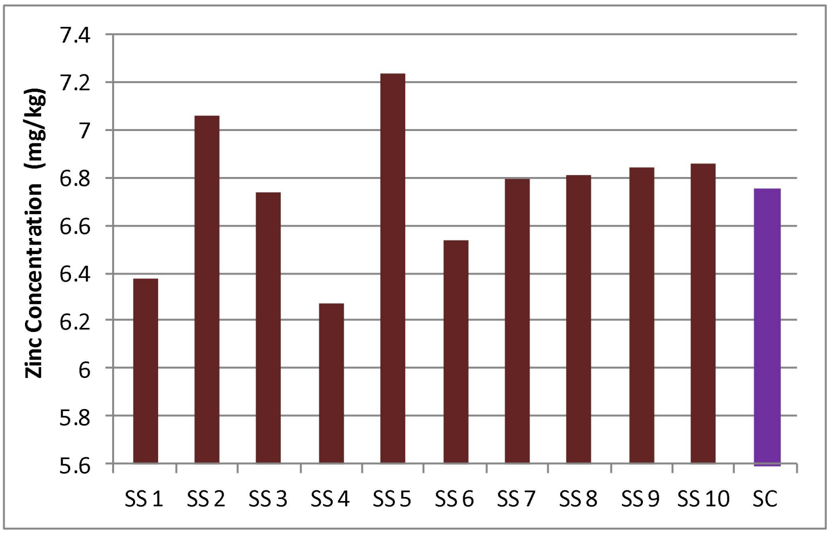

Figure 4.64 **Graphical Representation of Zinc Concentration in Soil**

The distribution of Copper Concentration values in soil across the study area is presented in figure 4.65

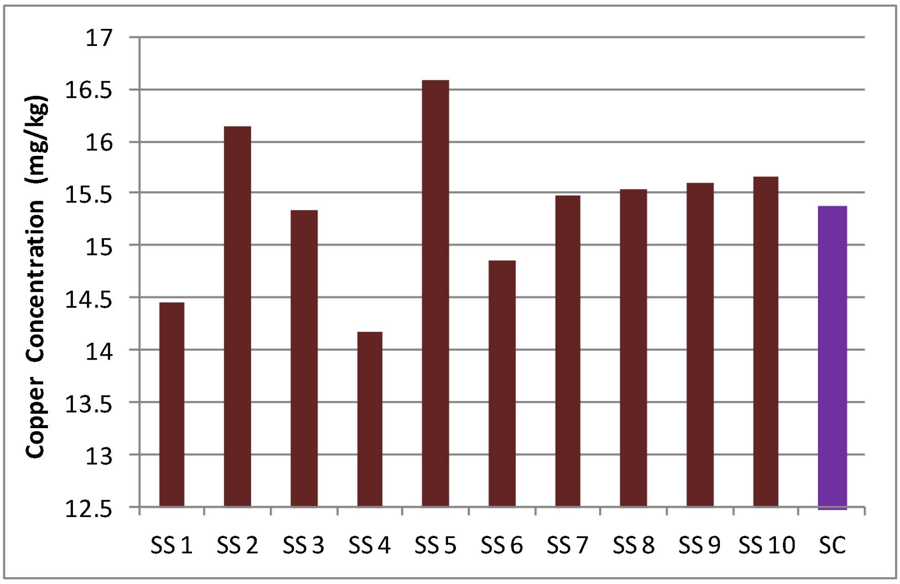

Figure 4.65 Graphical Representation of Copper Concentration in Soil

The distribution of Chromium Concentration values in soil across the study area is presented in figure 4.66

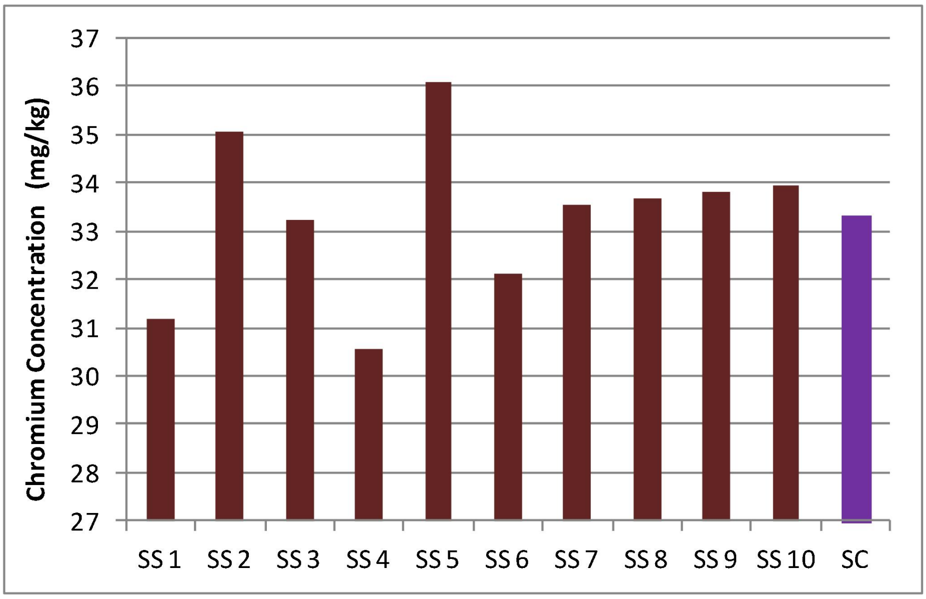

Figure 4.66 Graphical Representation of Chromium Concentration in Soil

The distribution of Lead Concentration values in soil across the study area is presented in figure 4.67

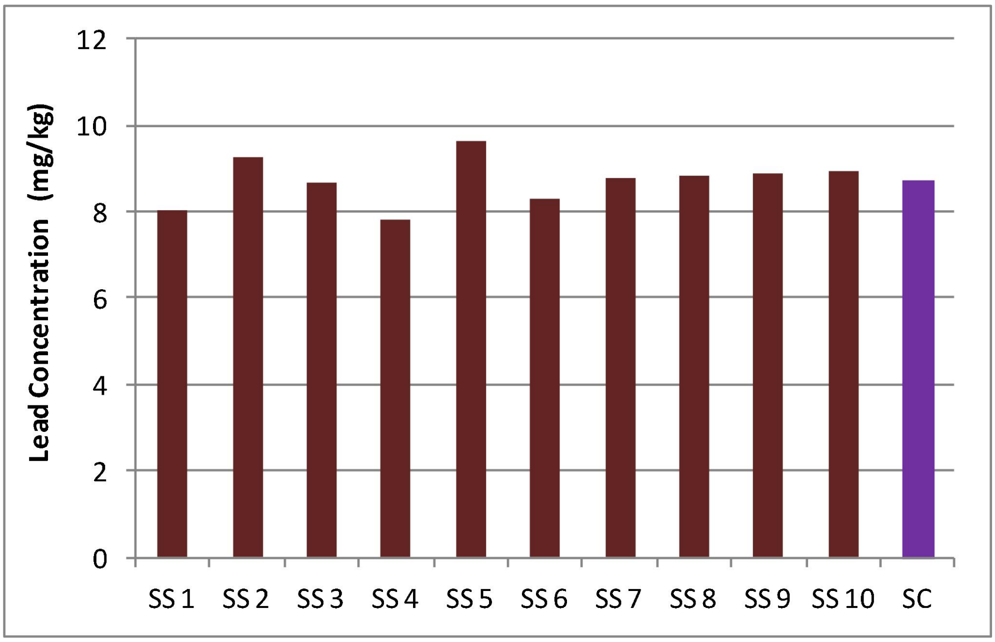

Figure 4.67 Graphical Representation of Lead Concentration in Soil

The distribution of Manganese Concentration values in soil across the study area is presented in figure 4.68

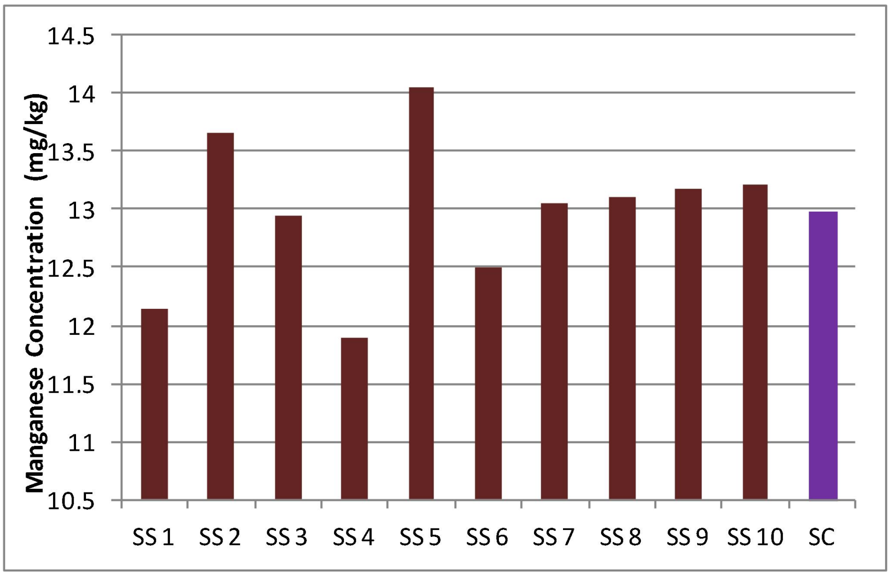

Figure 4.68 Graphical Representation of Manganese Concentration in Soil

The distribution of Iron Concentration values in soil across the study area is presented in figure 4.69

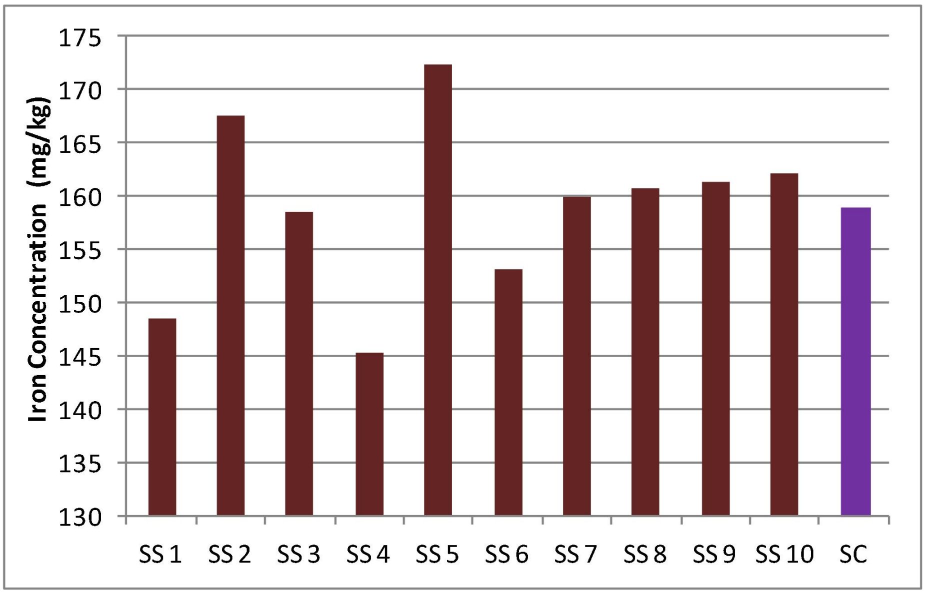

Figure 4.69 Graphical Representation of Iron Concentration in Soil

The distribution of Nickel Concentration values in soil across the study area is presented in figure 4.70

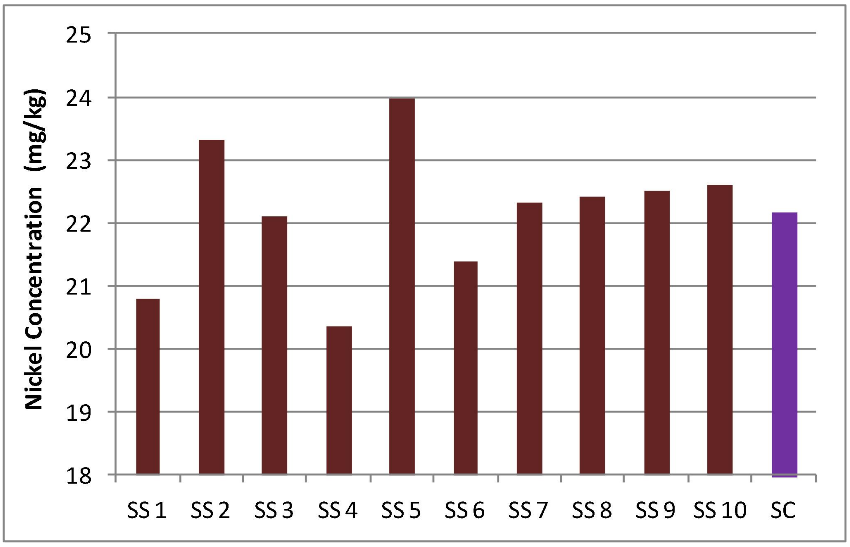

Figure 4.70 Graphical Representation of Nickel Concentration in Soil

The distribution of **Organic Carbon Concentration** values in soil across the study area is presented in figure 4.71

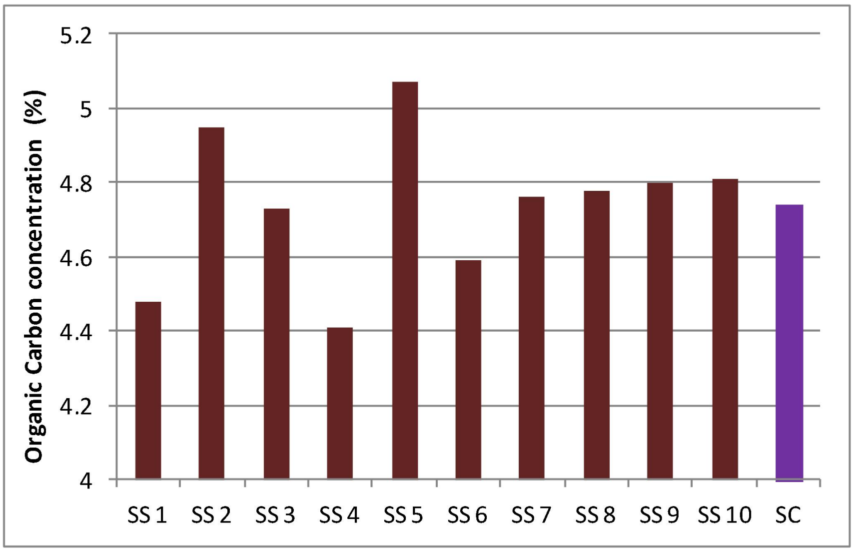

Figure 4.71 Graphical Representation of Organic Carbon Concentration in Soil

The distribution of **Total Nitrogen Concentration** values in soil across the study area is presented in figure 4.72

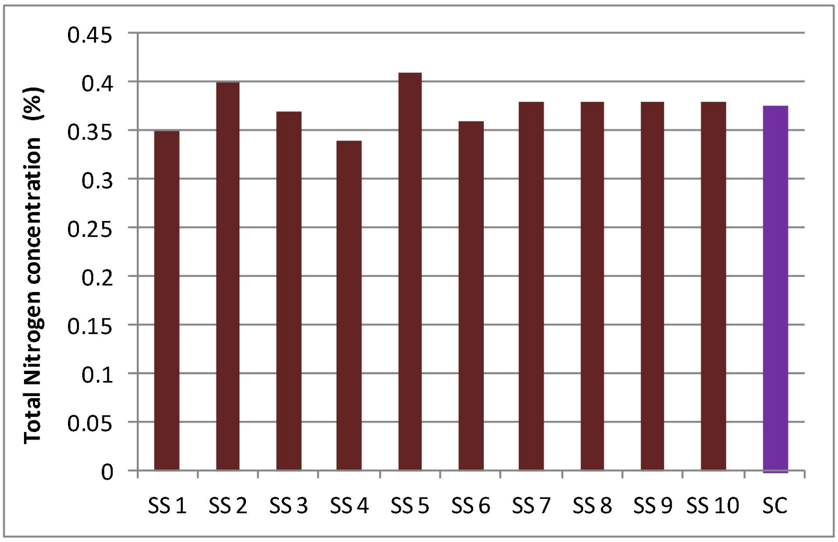

Figure 4.72 Graphical Representation of Total Nitrogen Concentration in Soil

Table 4.7: Test of Difference Between Control And Soil Samples

	Control Mean ± SD	Soil Mean ± SD	P-Value
pH	5.15±0.07	5.87±0.11	$^{**}P<0.01$
EC uS/cm	76.73±9.95	189.09±18.1	$^{**}P<0.01$
Cl^- mg/kg	17.5±2.13	53.66±3.99	$^{**}P<0.01$
SO_4^{2-} mg/kg	11.23±1.06	78.14±4.53	$^{**}P<0.01$
NO_3^- mg/kg	8.5±0.7	64.6±3.63	$^{**}P<0.01$
PO_4^{3-} mg/kg	13.7±1.52	40.89±2.54	$^{**}P<0.01$
NH_4N mg/kg	1.93±0.15	3.53±0.36	$^{**}P<0.01$
Ca^{2+} mg/kg	2.43±0.35	16.59±1.27	$^{**}P<0.01$
Mg^{2+} mg/kg	4.4±0.44	33.42±2.9	$^{**}P<0.01$
Na^+ mg/kg	24.97±1.27	55.72±4.55	$^{**}P<0.01$
K^+ mg/kg	31.33±1.8	77.02±6.71	$^{**}P<0.01$
Zn^{2+} mg/kg	1.23±0.15	6.75±0.29	$^{**}P<0.01$
Cu^{2+} mg/kg	6.7±0.1	15.38±0.73	$^{**}P<0.01$
Cr^{6+} mg/kg	2.93±0.15	33.31±1.67	$^{**}P<0.01$
Pb^{2+} mg/kg	0.09±0.01	8.71±0.54	$^{**}P<0.01$
Mn^{2+} mg/kg	2.28±0.12	12.97±0.65	$^{**}P<0.01$
Fe^{2+} mg/kg	1.82±0.08	158.95±8.16	$^{**}P<0.01$
Ni^{2+} mg/kg	0.97±0.21	22.18±1.09	$^{**}P<0.01$
Org. Carb %	1.78±0.14	4.74±0.2	$^{**}P<0.01$
Total N. %	0.16±0.02	0.38±0.02	$^{**}P<0.01$

*Bold values indicate significant difference and **Bold indicate highly significant difference

There is very strong significant difference (at $p<0.01$) between Control and soil in all the parameters. This means there is mineralization occurring in soil samples when compared to control due to geo settings, anthropogenic or climate, etc.

Table 4.8: Test of Difference Between Control And Surface Water Samples

	Control Mean ± SD	Surface Water Mean ± SD	P-Value
pH	6.57±0.01	5.97±0.35	*$P<0.05$
EC uS/cm	11.96±1.7	92.22±2.5	**$P<0.01$
Cl^- mg/l	8.7±0.67	9.85±0.54	*$P<0.05$
Alkalinity	8.75±0.76	7.92±0.86	$P>0.05$
TSS mg/l	3.05±1.76	26.38±2.5	**$P<0.01$
TDS mg/l	5.98±0.85	7.86±1.25	*$P<0.05$
Turbidity NTU	4.17±0.12	10.6±2.1	**$P<0.01$
COD mg/l	2.37±0.35	5.46±1.03	**$P<0.01$
DO mg/l	2.14±0.45	4.0±1.5	$P>0.05$
BOD mg/l	2.49±0.18	2.02±0.47	$P>0.05$
SO_4^{2-} mg/l	0.76±0.05	1.82±0.15	**$P<0.01$
NO_3^- mg/l	0.76±0.02	2.22±0.11	**$P<0.01$
PO_4^{3-} mg/l	0.42±0.03	0.75±0.05	**$P<0.01$
NH_4N mg/l	5.12±0.09	8.21±0.54	**$P<0.01$
Ca^{2+} mg/l	0.07±0.01	3.39±0.01	**$P<0.01$
Mg^{2+} mg/l	0.3±0.02	0.83±0.04	**$P<0.01$
Na^+ mg/l	0.84±0.12	5.55±0.32	**$P<0.01$
K^+ mg/l	1.44±0.2	3.02±0.19	**$P<0.01$
Zn^{2+} mg/l	0.05±0.007	0.43±0.01	**$P<0.01$
Cu^{2+} mg/l	0.06±0.009	0.53±0.01	**$P<0.01$
Cr^{6+} mg/l	0.007±0.004	0.37±0.01	**$P<0.01$
Pb^{2+} mg/l	0.003±0.001	0.04±0.01	**$P<0.01$
Mn^{2+} mg/l	0.04±0.02	0.16±0.007	**$P<0.01$
Fe^{2+} mg/l	1.29±0.19	1.27±0.02	$P>0.05$
Ni^{2+} mg/l	0.05±0.03	0.19±0.04	**$P<0.01$
Coliform cfu/ml	4±1	19.1±2.5	**$P<0.01$
E-Coli cfu/ml	1.33±0.58	7.6±2.07	**$P<0.01$

*Bold values indicate significant difference and **Bold indicate highly significant difference

There is no significant difference (at $p>0.05$) between Control and surface water in Alkalinity, DO, BOD and Fe. There is significant difference (at $p<0.05$) between control and Surface water in pH, Cl and TDS. The rest of the parameters show very strong significant difference between surface water and control. It just point to the fact that bioaccumulation of these parameters is ongoing in the study area. This may be due to geo settings, anthropogenic or climate, etc.

Table 4.9: Correlation Coefficient Matrix of Groundwater Quality Parameters

	pH gw	EC gw	Cl^- gw	Alk gw	TSS gw	TDS gw	Turb gw	COD gw	DO gw	BOD gw	SO_4^{2-} gw	NO_3^- gw	PO_4^{3-} gw	NH_4N gw	Ca^{2+} gw	Mg^{2+} gw	Na^+ gw	K^+ gw	Zn^{2+} gw	Cu^{2+} gw	Cr^{6+} gw	Pb^{2+} gw	Mn^{2+} gw	Fe^{2+} gw	Ni^{2+} gw	T.Coli gw	E. coli gw
pH gw	1																										
EC gw	-.689*	1																									
Cl^- gw	-.689*	0.99**	1																								
Alk gw	-.168	.107	.107	1																							
TSS gw	-.332	.267	.267	.472	1																						
TDS gw	-.682*	.998**	.998**	.123	.267	1																					
Turb gw	.081	.030	.029	.593	-.225	.049	1																				
COD gw	-.468	.900**	.901**	.003	.205	.889**	.021	1																			
DO gw	.382	-.432	-.432	.288	-.233	-.427	-.006	-.484	1																		
BOD gw	.342	-.774**	-.773**	-.146	-.359	-.785**	.087	-.642*	.111	1																	
SO_4^{2-} gw	-.684*	.969**	.969**	.308	.291	.966**	.202	.866**	-.353	-.697*	1																
NO_3^- gw	-.600	.985**	.985**	.031	.188	.984**	.004	.931**	-.395	-.792**	.934**	1															
PO_4^{3-} gw	-.684*	.965**	.965**	.177	.231	.967**	.141	.863**	-.369	-.791**	.940**	.963**	1														
NH_4N gw	-.351	.689*	.688*	.240	-.111	.694*	.375	.609	.043	-.730*	.694*	.727*	.815**	1													
Ca^{2+} gw	-.634*	.957**	.958**	.301	.285	.954**	.201	.904**	-.344	-.671*	.991**	.938**	.932**	.686*	1												
Mg^{2+} gw	-.585	.843**	.842**	.074	.065	.843**	.141	.770**	-.248	-.763*	.794**	.873**	.943**	.912**	.791**	1											
Na^+ gw	-.689*	0.99**	0.99**	.108	.268	.998**	.030	.899**	-.432	-.774**	.969**	.985**	.965**	.689*	.957**	.842**	1										
K^+ gw	-	.969*	.969*	.311	.295	.966*	.204	.855	-	-	.999	.930	.937	.692	.987	.790	.969	1									

	.691*	*	*			*		**	.358	.702*	**	**	**	*	**	**	**										
Zn^{2+}_{gw}	-.714*	.832**	.832**	-.076	.259	.831**	-.132	.753*	-.444	-.683*	.738*	.848**	.899**	.668*	.736*	.911**	.832**	.733*	1								
Cu^{2+}_{gw}	-.423	.749*	.749*	.045	.090	.750*	.100	.753*	-.196	-.740*	.691*	.811**	.874**	.878**	.714*	.966**	.749*	.681*	.888**	1							
Cr^{6+}_{gw}	-.543	.807**	.806**	.272	-.058	.819**	.341	.762*	-.162	-.586	.823**	.828**	.838**	.765**	.831**	.777**	.806**	.818**	.632	.690*	1						
Pb^{2+}_{gw}	.528	-.042	-.041	-.171	-.108	-.058	.089	.371	-.159	.128	-.031	.061	-.071	-.055	.082	-.066	-.043	-.053	-.119	.102	-.004	1					
Mn^{2+}_{gw}	.026	.396	.396	.534	.155	.426	.375	.337	.134	-.390	.489	.392	.322	.250	.502	.111	.396	.489	-.041	.072	.549	.112	1				
Fe^{2+}_{gw}	-.690*	0.99**	0.99**	.106	.268	.998**	.028	.900**	-.433	-.774**	.968**	.985**	.965**	.688*	.957**	.842**	0.99**	.968**	.833**	.749*	.806**	-.043	.395	1			
Ni^{2+}_{gw}	-.346	.152	.151	.193	.144	.180	-.122	-.030	.288	-.450	.079	.178	.305	.420	.047	.432	.153	.081	.427	.431	.336	-.556	-.025	.153	1		
T.Coli $_{gw}$	-.350	.587	.587	.121	.074	.603	.363	.544	-.651*	-.215	.612	.540	.474	.132	.601	.229	.587	.619	.242	.104	.570	.092	.597	.587	-.291	1	
E. coli $_{gw}$	-.302	-.045	-.046	.382	.227	-.035	0.000	.014	.114	.168	.003	-.057	-.026	-.141	.029	-.085	-.046	-.004	-.019	-.103	.306	-.103	.175	-.045	.423	.066	1

r (0.05)(∞2) df (8)=0.576

r (0.01)(∞2) df (8)=0.708

Values with single asterisk = Significant (P<0.05)

Values with double asterisk = Highly Significant (P<0.01)

Table 4.10: Correlation Coefficient Matrix of Surface Water Quality Parameters

	pH_{sw}	EC_{sw}	Cl^-_{sw}	Alk_{sw}	TSS_{sw}	TDS_{sw}	$Turb_{sw}$	COD_{sw}	DO_{sw}	BOD_{sw}	$SO_4^{2-}{}_{sw}$	$NO_3^-{}_{sw}$	$PO_4^{3-}{}_{sw}$	NH_4N_{sw}	Ca^{2+}_{sw}	Mg^{2+}_{sw}	Na^+_{sw}	K^+_{sw}	Zn^{2+}_{sw}	Cu^{2+}_{sw}	Cr^{6+}_{sw}	Pb^{2+}_{sw}	Mn^{2+}_{sw}	Fe^{2+}_{sw}	Ni^{2+}_{sw}	T. Coli. sw	E. Coli. sw
pH_{sw}	1																										
EC_{sw}	.827**	1																									
Cl^-_{sw}	.886**	.737*	1																								
Alk_{sw}	-.927**	-.683*	-.672*	1																							
TSS_{sw}	-.827**	-0.99**	-.737*	.683*	1																						
TDS_{sw}	.827**	0.99**	.737*	-.683*	-0.99**	1																					
$Turb_{sw}$	-.927**	-.684*	-.671*	0.99**	.684*	-.684*	1																				
COD_{sw}	.827**	0.99**	.738*	-.683*	-0.99**	0.99**	-.684*	1																			
DO_{sw}	.893**	.720*	.608	-.945**	-.720*	.721*	-.946**	.720*	1																		
BOD_{sw}	.796**	.391	.555	-.906**	-.391	.391	-.905**	.391	.866**	1																	
$SO_4^{2-}{}_{sw}$	.857**	.913**	.868**	-.650*	-.913**	.913**	-.650*	.913**	.716*	.426	1																
$NO_3^-{}_{sw}$	.828**	0.99**	.744*	-.680*	-0.99**	0.99**	-.681*	0.99**	.717*	.386	.919**	1															
$PO_4^{3-}{}_{sw}$	.828**	.773**	.846**	-.702*	-.773**	.773**	-.701*	.773**	.555	.531	.684*	.771**	1														
NH_4N_{sw}	.223	.052	.202	-.233	-.052	.053	-.233	.052	.178	.272	.091	.046	.177	1													
Ca^{2+}_{sw}	.253	.608	.450	.066	-.608	.608	.065	.608	.046	-.232	.591	.612	.416	-.126	1												
Mg^{2+}_{sw}	.866**	.841**	.849**	-.739*	-.841**	.841**	-.739*	.841**	.624	.547	.745*	.839**	.991**	.159	.462	1											
Na^+_{sw}	.763*	.982**	.634*	-.655*	-.982*	.982**	-.656*	.982**	.676*	.347	.819**	.978**	.771**	.032	.585	.837**	1										

*

K^+_{sw}	.787**	.747*	.863**	-.560	-.747*	.747*	-.560	.747*	.644*	.413	.953**	.757*	.534	.103	.501	.586	.606	1								
Zn^{2+}_{sw}	.726*	.744*	.626	-.658*	-.744*	.745*	-.658*	.745*	.652*	.362	.787**	.755*	.494	.276	.215	.565	.678*	.732*	1							
Cu^{2+}_{sw}	-.252	.020	.086	.552	-.020	.020	.552	.021	-.479	-.523	.057	.024	.051	-.156	.795**	.040	.009	.063	-.329	1						
Cr^{6+}_{sw}	-.259	-.275	-.194	.254	.275	-.275	.255	-.275	-.389	-.174	-.413	-.284	.061	.565	.000	.011	-.193	-.477	-.250	.272	1					
Pb^{2+}_{sw}	-.146	.062	-.120	.172	-.062	.062	.172	.062	-.217	-.258	-.112	.066	.117	.227	.301	.130	.140	-.237	.085	.329	.634*	1				
Mn^{2+}_{sw}	.473	.130	.549	-.452	-.130	.129	-.450	.130	.187	.479	.136	.127	.659*	.222	-.154	.583	.118	.126	.139	-.151	.345	.000	1			
Fe^{2+}_{sw}	.696*	.563	.813**	-.552	-.563	.562	-.551	.563	.352	.457	.519	.562	.952**	.164	.342	.908**	.552	.420	.308	.144	.164	.088	.791**	1		
Ni^{2+}_{sw}	.440	.689*	.379	-.287	-.689*	.689*	-.289	.689*	.514	.061	.776**	.696*	.117	-.085	.530	.222	.607	.759*	.654*	.048	-.583	-.137	-.464	-.117	1	
T. Coli. $_{sw}$	.520	.380	.381	-.550	-.380	.380	-.550	.379	.525	.610	.287	.380	.535	.019	.225	.567	.400	.180	.144	.044	.018	.262	.199	.482	-.033	1	
E. Coli. $_{sw}$	-.606	-.364	-.688*	.460	.364	-.364	.460	-.365	-.445	-.482	-.555	-.358	-.447	-.342	-.100	-.424	-.254	-.640*	-.297	.078	.134	.566	-.484	-.459	-.243	.137	1

r (0.05)(∞2) df (8)=0.576

r (0.01)(∞2) df (8)=0.708

Values with single asterisk = Significant (P<0.05)

Values with double asterisk = Highly Significant (P<0.01)

Table 4.11: Correlation Coefficient Matrix of Soil Quality Parameters

	pH $_{ss}$	EC $_{ss}$	$Cl^{-}{}_{ss}$	$SO_4^{2-}{}_{ss}$	$NO_3^{-}{}_{ss}$	$PO_4^{3-}{}_{ss}$	NH_4N $_{ss}$	$Ca^{2+}{}_{ss}$	$Mg^{2+}{}_{ss}$	$Na^{+}{}_{ss}$	$K^{+}{}_{ss}$	$Zn^{2+}{}_{ss}$	$Cu^{2+}{}_{ss}$	$Cr^{6+}{}_{ss}$	$Pb^{2+}{}_{ss}$	$Mn^{2+}{}_{ss}$	$Fe^{2+}{}_{ss}$	$Ni^{2+}{}_{ss}$	Org. C. $_{ss}$	Total N. $_{ss}$
pH $_{ss}$	1																			
EC $_{ss}$	.604	1																		
$Cl^{-}{}_{ss}$	.604	0.999**	1																	
$SO_4^{2-}{}_{ss}$	.604	0.999**	0.999**	1																
$NO_3^{-}{}_{ss}$	.604	0.999**	0.999**	0.999**	1															
$PO_4^{3-}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	1														
NH_4N $_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	1													
$Ca^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1												
$Mg^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1											
$Na^{+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1										
$K^{+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1									
$Zn^{2+}{}_{ss}$	.603	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1								
$Cu^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1							
$Cr^{6+}{}_{ss}$	.605	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1						
$Pb^{2+}{}_{ss}$	.605	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1					
$Mn^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1				
$Fe^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1			
$Ni^{2+}{}_{ss}$	.604	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1		
Org. C. $_{ss}$	.602	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	0.999**	1	
Total N. $_{ss}$	.668*	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.995**	.994**	1

r (0.05)(∞2) df (8)=0.576
r (0.01)(∞2) df (8)=0.708
Values with single asterisk = Significant (P<0.05)
Values with double asterisk = Highly Significant (P<0.01)

Table 4.12: Correlation Coefficient Matrix of Groundwater to Surface Water Quality Parameters

	pH $_{sw}$	EC $_{sw}$	Cl^-_{sw}	Alk $_{sw}$	TSS $_{sw}$	TDS $_{sw}$	Turb $_{sw}$	COD $_{sw}$	DO $_{sw}$	BOD $_{sw}$	SO_4^{2-} $_{sw}$	NO_3^- $_{sw}$	PO_4^{3-} $_{sw}$	NH_4N $_{sw}$	Ca^{2+} $_{sw}$	Mg^{2+} $_{sw}$	Na^+ $_{sw}$	K^+_{sw}	Zn^{2+} $_{sw}$	Cu^{2+} $_{sw}$	Cr^{6+} $_{sw}$	Pb^{2+} $_{sw}$	Mn^{2+} $_{sw}$	Fe^{2+} $_{sw}$	Ni^{2+} $_{sw}$	T. Coli. $_{sw}$	E. Coli. $_{sw}$
pH $_{gw}$	.554	.612	.467	-.475	-.612	.612	-.474	.612	.496	.282	.590	.621	.434	.157	.376	.507	.582	.513	.746*	-.021	.084	.562	.174	.275	.476	.332	-.007
EC $_{gw}$	-.762*	-.621	-.685*	.667*	.621	-.621	.667*	-.621	-.661*	-.668*	-.601	-.621	-.716*	-.126	-.434	-.755*	-.592	-.521	-.400	-.133	-.110	-.277	-.457	-.637*	-.210	-.747*	.295
Cl^-_{gw}	-.761*	-.620	-.685*	.667*	.620	-.620	.666*	-.620	-.661*	-.668*	-.600	-.620	-.716*	-.125	-.434	-.755*	-.591	-.520	-.399	-.133	-.110	-.277	-.458	-.637*	-.209	-.747*	.296
Alk $_{gw}$	-.497	-.321	-.375	.620	.321	-.322	.619	-.320	-.463	-.505	-.264	-.320	-.490	-.403	.346	-.458	-.327	-.191	-.438	.607	.083	-.031	-.389	-.430	.049	-.180	.185
TSS $_{gw}$	-.201	-.237	-.009	.330	.237	-.238	.331	-.236	-.381	-.305	-.125	-.240	-.133	.239	.060	-.162	-.272	-.034	-.102	.261	.316	-.303	.147	-.005	-.156	-.415	-.374
TDS $_{gw}$	-.774**	-.638*	-.711*	.669*	.638*	-.638*	.668*	-.638*	-.661*	-.663*	-.624	-.639*	-.736*	-.131	-.458	-.774**	-.606	-.543	-.412	-.152	-.095	-.275	-.452	-.659*	-.221	-.762*	.298
Turb $_{gw}$	-.520	-.123	-.541	.536	.123	-.123	.536	-.123	-.409	-.551	-.332	-.127	-.319	-.469	.381	-.282	-.017	-.449	-.430	.514	.213	.516	-.463	-.366	.000	.000	.647*
COD $_{gw}$	-.578	-.304	-.537	.534	.304	-.303	.533	-.304	-.468	-.651*	-.310	-.303	-.584	.064	-.195	-.586	-.281	-.284	-.107	-.097	-.139	-.156	-.622	-.610	.124	-.697*	.247
DO $_{gw}$	.310	.162	.348	-.201	-.162	.162	-.201	.162	.347	.288	.413	.177	-.021	-.439	.209	.032	.032	.563	.214	.090	-.562	-.214	-.054	-.046	.454	.217	-.175
BOD $_{gw}$	.617	.606	.430	-.618	-.606	.607	-.619	.606	.628	.591	.435	.600	.648*	-.001	.389	.697*	.651*	.256	.209	.078	-.012	.189	.154	.528	.142	.921**	.004
SO_4^{2-} $_{gw}$	-.834**	-.625	-.742*	.767**	.625	-.625	.767**	-.625	-.725*	-.764*	-.618	-.623	-.768**	-.263	-.296	-.792**	-.589	-.546	-.468	.027	-.126	-.230	-.573	-.691*	-.170	-.674*	.412
NO_3^- $_{gw}$	-.691*	-.529	-.642*	.594	.529	-.529	.594	-.530	-.567	-.632	-.505	-.529	-.699*	-.104	-.427	-.727*	-.509	-.430	-.288	-.205	-.182	-.282	-.492	-.659*	-.085	-.789**	.253
PO_4^{3-} $_{gw}$	-.755*	-.559	-.655*	.700*	.559	-.559	.700*	-.559	-.665*	-.707*	-.546	-.561	-.689*	-.227	-.321	-.729*	-.531	-.473	-.457	-.033	-.149	-.308	-.458	-.619	-.138	-.825**	.212
NH_4N $_{gw}$	-.658*	-.410	-.494	.695*	.410	-.410	.695*	-.410	-.587	-.696*	-.339	-.406	-.621	-.426	-.050	-.644*	-.418	-.244	-.397	.186	-.268	-.099	-.486	-.576	.081	-.737*	.241
Ca^{2+} $_{gw}$	-.781**	-.531	-.712*	.724*	.531	-.531	.723*	-.531	-.658*	-.759*	-.531	-.530	-.749*	-.254	-.242	-.759*	-.498	-.474	-.379	.011	-.181	-.243	-.636*	-.709*	-.052	-.682*	.391
Mg^{2+} $_{gw}$	-.617	-.407	-.478	.618	.407	-.407	.617	-.407	-.565	-.639*	-.369	-.409	-.548	-.264	-.194	-.592	-.399	-.297	-.405	.031	-.241	-.305	-.393	-.493	-.019	-.827**	.075
Na^+ $_{gw}$	-.763*	-.622	-.685*	.668*	.622	-.622	.668*	-.622	-.663*	-.668*	-.602	-.622	-.716*	-.126	-.434	-.755*	-.593	-.522	-.401	-.132	-.109	-.277	-.456	-.636*	-.211	-.747*	.296
K^+ $_{gw}$	-.846**	-.647*	-.750*	.778**	.647*	-.647*	.777**	-.647*	-.742*	-.765**	-.639*	-.645*	-.772**	-.259	-.307	-.799**	-.610	-.565	-.486	.031	-.105	-.219	-.558	-.687*	-.199	-.671*	.420
Zn^{2+} $_{gw}$	-.452	-.339	-.358	.418	.339	-.340	.417	-.339	-.434	-.450	-.328	-.347	-.374	-.099	-.321	-.433	-.323	-.280	-.344	-.144	-.194	-.507	-.183	-.309	-.121	-.796**	-.150
Cu^{2+} $_{gw}$	-.456	-.200	-.327	.499	.200	-.200	.499	-.199	-.428	-.599	-.158	-.202	-.430	-.228	-.072	-.457	-.206	-.104	-.199	.020	-.295	-.318	-.371	-.426	.182	-.870**	-.063
Cr^{6+} $_{gw}$	-.753*	-.566	-.813**	.622	.566	-.565	.620	-.566	-.453	-.538	-.563	-.569	-.877**	-.216	-.341	-.869**	-.534	-.491	-.485	-.100	-.219	-.208	-.760*	-.896**	.023	-.597	.388
Pb^{2+} $_{gw}$	.241	.618	.152	-.161	-.618	.619	-.162	.618	.267	-.179	.520	.623	.155	.255	.447	.245	.628	.385	.698*	.009	-.085	.351	-.435	-.080	.714*	-.033	.124
Mn^{2+} $_{gw}$	-.565	-.478	-.709*	.422	.478	-.478	.422	-.478	-.299	-.387	-.468	-.473	-.797**	-.192	-.307	-.735*	-.459	-.399	-.092	-.167	.000	.092	-.552	-.838**	.051	-.307	.535
Fe^{2+} $_{gw}$	-.762*	-.621	-.685*	.666*	.621	-.621	.666*	-.622	-.661*	-.667*	-.602	-.621	-.715*	-.125	-.435	-.755*	-.592	-.522	-.401	-.134	-.109	-.278	-.456	-.636*	-.211	-.747*	.294
Ni^{2+} $_{gw}$	-.124	-.340	-.074	.126	.340	-.341	.126	-.340	-.040	.112	-.148	-.349	-.319	-.054	-.279	-.359	-.412	.028	-.382	-.075	-.148	-.552	.094	-.238	-.055	-.487	-.537
T.Coli $_{gw}$	-.683*	-.530	-.869**	.437	.530	-.529	.437	-.530	-.454	-.423	-.757*	-.538	-.581	.087	-.449	-.579	-.393	-.842**	-.374	-.222	.373	.258	-.416	-.591	-.410	-.197	.689*
E. coli $_{gw}$	-.020	-.113	-.156	-.010	.113	-.112	-.011	-.112	.227	.244	-.029	-.125	-.317	.240	0.000	-.276	-.145	.043	-.264	.048	-.055	-.396	-.395	-.375	.191	.084	-.281

r (0.05)(∞2) df (8)=0.576
r (0.01)(∞2) df (8)=0.708
Values with single asterisk = Significant ($P<0.05$)
Values with double asterisk = Highly Significant ($P<0.01$)

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 DISCUSSION

pH

The mean pH concentration for the groundwater was 5.69, with the minimum and maximum values being 5.61 and 5.78 respectively. This was below the WHO standard range between 6.5 and 8.5 respectively. This was also noticed for the surface water with a mean concentration of 5.97, comparing with the control sample of 6.57 pH concentration. The pH for the soil samples collected ranged between 5.71 and 6.05, with a mean concentration of 5.87.

Nelson (2002) defined a pH less than 7 as acidic and a pH greater than 7 as alkaline. Exposure to extreme pH values (less than 4 and greater than 11) may result in irritation of the eyes, skin and mucus membranes (Hoko, 2008) There were no health implications associated with low or high pH which were found in the study, however, indicted that indicated that a low pH tends to make the water corrosive while a high pH results in taste complaint.

Ezomo et al., (2013) sampled groundwater in Uromi and environs and noticed low levels of pH (5.25) and high levels of nitrite (4.44mg/L), with the results showing evidences of both physical and chemical sources and this was noticed more in wells close to farms where there was use of inorganic fertilizers. The samples (groundwater, surface water and soil) collected from the area all fall below the acceptable standards.

From the result, it shows that the pH levels for the groundwater and surface water are quite low which makes the waters slightly acidic. This is also the same for the soils sampled in the area.

Electrical Conductivity

Conductivity indicates the presence of dissolved solids and contaminants especially electrolytes but does not give information about specific chemical. Most drinking waters have conductivity measurement below 2000μS/cm but the recommended value is ≈ 250μS/cm (WHO 1998)

The electrical conductivity of the groundwater sample range between 54.64 and 65.74, with a mean value of 60.5μS/cm. This way far below the WHO standard of 1000μS/cm. The EC values for the surface water were between 87.11μS/cm and 95.2μS/cm. The control sample had a much more lower mean value of 11.96μS/cm. The values for the soil ranged between 159μS/cm and 219μS/cm, with mean value of 189.09μS/cm. The control sample had a mean value of 76.73μS/cm.

Groundwater points which reported high conductivity had also high total dissolved solids and this was consistent with what Chilton and Smith-Carington (1984). The electrical conductivity for both the groundwater and surface water samples were far below the WHO (2011) standards, however, the values are higher than the control samples. Conductivity of water is dependent on its ionic concentration and temperature

Total Dissolved Solid

The total dissolved solids in the groundwater had concentrations that ranged between 27.87 and 33.53 with a mean value of 30.81. The WHO standard for TDS in water is 600. The TDS concentration in the surface water ranged between 5.31 and 9.35, with 7.86. The control samples had a mean concentration 5.97.

According to Freeze and Cherry (1979) reference values, the groundwater is fresh (TDS < 1000 mg/l) and soft (Hardness < 75 mg/l).

The TDS was derived from the interaction of water with the sediments originating from different parent materials in the saturated zone, unsaturated zone and on the surface during run off. Generally, high TDS which is greater than WHO recommendations of 1000 mg/l is commonly objectionable or offensive to taste and the TDS levels over 2000 mg/l are generally considered undrinkable due to strongly offensive taste (WHO, 1996; ODNR, 1997).

A higher concentration of TDS usually poses no health threat to humans until the values exceed 10,000 mg/l where it causes a gastrointestinal irritation in the consumers (Subba Rao, 2006).

Turbidity

Turbidity values in the groundwater samples ranged between 0.05NTU and 0.12NTU, with a mean value of 0.08NTU. This was below the WHO (2011) standard for portable drinking water and also, the values for the surface water range between 7.31NTU and 13.92NTU and a mean concentration value of 10.60NTU. This was way above the WHO (2011) permissible standards and also the control samples which had a mean of 4.16NTU.

Suspended solids are rarely harmful, yet elimination of turbidity increases the aesthetic quality and acceptability of the water. Pritchard et al., (2007) suggest that the impact of turbidity is that the colloidal particles which cause turbidity can harbor pathogens thereby making disinfection ineffective. Turbid waters demand relatively higher dosage of disinfectants if disinfection, which is the only treatment method for groundwater in rural areas, is deemed necessary (Hoko, 2008).

Secondly, toxic contaminants can adsorb to suspended particles, which in turn may be ingested by humans and cause health problems (ODNR, 1997). Turbidity also makes the water aesthetically unacceptable. Water with less 5 NTU is more appealing to drink (WHO, 1996). It is important to look for causes of the turbidity when trying to treat the water. For instance in a borehole look for improperly installed casing, cracked casing, missing well cap or cracked sanitary pack. One of the simplest methods of treating water from turbidity is a filtration.

Alkalinity

Alkalinity for the groundwater samples had a mean value of 4.48. The values range between 4.34 and 4.62. The surface water samples also had values between 6.57 and 9.28, mean value of 7.91. This was below the alkalinity values for the control samples that was between 8.23 and 9.26. The mean alkalinity value for the con troll sample is 8.75.

Alkalinity relates to concentration of calcium and carbonate and high alkalinity has a bearing on the hardness of the water.

Hardness is defined as water that is rich in calcium (Ca2+) and/or magnesium (Mg2+) (ODNR, 1997). Sawyer et al., (1994) suggests that the upper limit for soft water is 150 mg/l. Although hard water may be satisfactory for drinking, there adverse effects on soap consumption may be unsatisfactory (Sawyer et al., 1994). Hard water leads to incidence of urolithiosis, anencephaly, some types of cancer and cardiovascular disorders (Subba Rao, 2006).

High water volume, greater water retention and good buffering capacity of total alkalinity may have been the reason why pH was slightly acidic (Mustapha, 2008). Moreso, rivers flowing through forest have been reported to contain humic acid, which is as a result of the decomposition and oxidation of organic matter in them, hence, a slightly acidic pH (Deekae *et el.,* 2010)

Calcium

Calcium concentration for the groundwater was quite low when compared with the WHO (2011) standard. The calcium concentration in the groundwater ranged between 2.14mg/l and 3.08mg/l, the mean concentration was 2.59mg/l. A similar trend was recorded for the surface water from the area with concentration ranging between 3.36mg/l and 3.39mg/l.

Calcium concentration for the soils were quite higher with concentrations between 14.48mg/l and 18.65mg/l. Mean calcium concentration for the soil was 16.59mg/l. These values were quite higher than the control samples taken. Mean concentration for surface water control was 0.074mg/l, while mean calcium concentration for the soils was 2.43mg/l.

Calcium is the principal parameter in hardness of the water (WHO, 1996). Calcium is a dietary mineral that is present in the human body in amounts of about 1.2kg and no other element is more abundant in the body (ODNR, 1997). It comes from a variety of different dietary sources such that a concentration above 180 mg/l from drinking water alone is considered very high (EPA, 2008).

When one takes up large amounts of calcium this may negatively influence human health. Metallic calcium corrodes the skin when it comes in contact with skin, eyes and mucous membranes (NIHCC, 2009).

Excessively high intakes of calcium in drinking water have adverse effects such as hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals such as iron, zinc, magnesium, and phosphorus (NIHCC, 2009).

Magnesium

Magnesium concentrations in the ground water ranged between 0.5mg/l and 0.52mg/l. This is far below the WHO permissible limit of 20mg/l. The surface water concentration of magnesium was between 0.77mg/l and 0.88mg/l. This was above the control sample with 0.29mg/l mean concentration. The magnesium concentrations in the soils of the study area range between 26.61mg/l and 38.1mg/l, with mean concentration of 33.42mg/l. The control sample for the soils had mean magnesium concentration of 4.4mg/l

Magnesium is one of the principal components responsible for the hardness of the water. Magnesium deficiency may increase the risk for cardiac arrhythmia and the contractility of blood vessels, as shown in animal experiments. A lack of magnesium leads to a decrease in the concentration of intracellular potassium and an increase in calcium levels in human body (NIHCC, 2009). Magnesium is an activator for several enzyme systems and is essential for cell membrane permeability and neuromuscular excitability (NIHCC, 2009).

The results from the study area indicates that while the concentration of magnesium in the groundwater and surface water were below the WHO permissible limits, they were above the control samples. This was also true for the soils.

Sodium

Sodium concentration was also analyzed for the groundwater, surface water and soil samples. The concentration ranged between 2.76mg/l and 5.2mg/l with a mean concentration of 4.04mg/l in the groundwater, between 4.91mg/l and 5.92mg/l with a mean concentration value of 5.54mg/l in the surface water. The WHO permissible limit for sodium in drinking water is 250mg/l. also, the control water samples analyzed had a mean concentration of 0.83mg/l

The sodium concentration in the soils analyzed, ranged between 48.17 and 63.23, with a mean concentration value of 55.72. The control samples for the soils ranged between 23.6 and 26.1, with mean value of 24.97

Sodium is an evaporite and is common where the water table is high and the climatic conditions are hot (BGS, 2004). It is the common cause of well abandonment due to salty taste of the water especially when the concentration is above 500 mg/l.

From the study, the sodium content in the groundwater and surface water samples, although below the WHO permissible threshold, (WHO 2011), it was higher than the control samples for water quality. The sodium concentration in the soils were also higher than the soil control samples.

Potassium

The potassium concentration in the groundwater samples analyzed from the study area range between 0.46mg/l and 2.01mg/l. The potassium concentration in the surface water range between 2.71mg/l and 3,28mg/l, with a mean concentration of 3.01mg/l. The control water sample had a mean potassium concentration of 1.43mg/l, while the WHO permissible threshold for potassium in water stands at 12mg/l

The potassium concentration in the soils range between 65.89 and 88.09 with mean concentration being at 77.02. The control soil sample had a mean potassium concentration of 31.33.

Potassium mostly is derived from surface agricultural land which uses K-containing fertilizers and manure (including human waste from pit latrines) through infiltration of water to the groundwater Griffioen (2001). Additionally, weathering of biotite, muscovite and feldspar from the subsurface may be the internal sources of potassium. Potassium does not have limits in drinking water however high concentration would give the water a salty taste as it relates to sodium.

Chloride

Chloride concentrations in the groundwater samples ranged between 5.02mg/l and 9.35mg/l, with a mean con centration of 7.30mg/l. the chloride concentration in the surface water ranged between 9.22mg/l and 10.75mg/l. The control sample had a mean chloride concentration of 8.73mg/l, this is seen to be below the WHO permissible limit for Chloride in water, which is set at 250mg/l.

Chloride in the study area may have derived from the sediments originating from igneous rocks, evaporates, pit latrines and animal waste. Excess concentration of Cl- in drinking water gives a salty taste and has a laxative effect in people not accustomed to it (Subba Rao, 2006).

Sulphate

Sulphate was found to be in minor proportions in the groundwater samples and the concentrations range between 0.78mg/l and 1.34mg/l. The Sulphate concentration in the surface water range between 1.54mg/l and 2.03mg/l, with a mean concentration of 1.82m g/l. the control sample had a mean concentration of 0.76mg/l, while the WHO permissible limit for Sulphate in water is 260mg/l.

Sulphate concentration in the soils analyzed ranged between 70.62 and 85.62 and a mean concentration of 78.14. The soil control sample had a mean Sulphate concentration of 11.23

Sources of sulphate are from the weathering of pyrite and the dissolving of ammonium sulphate fertilizers. EPA (2006) noted that health concerns regarding sulphate in drinking water were raised because of reports that diarrhea may be associated with the ingestion of water containing high levels of sulphate especially in the population that react to abrupt change from drinking water with low sulphate concentrations to drinking water with high sulphate concentrations.

Subba Rao (2006) noted that higher concentration of sulphate in drinking water is associated with respiratory problems and in combination with Na^+ and Mg^{2+}, SO_4^2 also exerts a cathartic effect on digestive tracts however such health problems were not reported.

Nitrate

Nitrate concentration in the groundwater range between 1.64mg/l and 2.03mg/l with a mean concentration of 1.81mg/l. the WHO standard for nitrate in drinking water is set at 10mg/l. The nitrate concentrations that was recorded in the surface waters ranged between 2mg/l and 2.34mg/l. The control samples had low mean concentration of 0.76mg/l

The Nitrate concentration in the soils range between 58.58 and 70.58, with mean concentration at 64.60. The mean nitrate concentration in the control samples for the soils was 8.5. The Total nitrogen in the samples range between 0.34 and 0.41.

The nitrogen compounds that were found in the groundwater of the study area might have derived from the atmosphere through specific plants fixation of nitrogen from the atmosphere onto their roots (BGS, 2004). The other major source in the study area might be the agricultural fields which uses fertilizers. Nitrogen not used by the plant was released into the soil where free reactions with water, minerals, and bacteria took place.

The secondary sources of nitrogen compounds which were detected may include, manure and urine from animal kraals, pit latrines, and landfills. ODNR (1997) noted that nitrates are especially toxic to children less than six months of age. Excessive NO3 in drinking water can cause a number of health disorders, such as methaemoglobinemia, gastric cancer, goitre, birth malformations and hypertension (Majumdar and Gupta, 2000; BGS, 2004; Subba Rao, 2006).

Iron

Iron concentrations in the groundwater samples range between 0.38mg/l and 2.49mg/l. this was recorded to be beyond the WHO permissible limit of iron in water, which is set at 0.3mg/l. Iron concentration in the surface water ranged between 1.24mg/l and 1.3mg/l with the control sample having a mean iron concentration of 1.29mg/l

Iron concentration range between 145.41 and 172.41 in the soils with mean concentration of 158.95. This was far higher than the iron concentration in the soil control samples that had a mean concentration of 1.82.

The WHO (1996) guidelines recommends that domestic water should not exceed 0.3 mg/l. Iron concentrations exceeding this level may cause the characteristic reddish staining ODNR (1997). Iron (Fe^{+2}) in groundwater provides the typical well water "rust" taste. Not only is the taste unpleasant, iron can also stain plumbing fixtures, clothes, and dishes.

Manganese

Manganese concentrations in the groundwater samples range between 0.1mg/l and 0.15mg/l, the mean concentration is 0.125mg/l. The surface water sample analyzed had manganese concentrations between 0.15mg/l and 0.17mg/l. The mean manganese concentration in the control water sample is 0.043mg/l, while the WHO permissible limit for manganese in drinking water is 0.2mg/l

Manganese concentration in the soils from the study area range between 11.89 and 14.05, with a mean concentration of 12.97. The control samples recorded a mean concentration of 2.28

The principle controls on manganese concentration in groundwater are acidic and redox conditions and the concentration can be higher in acidic groundwater (BGS, 2003).

Under aerobic conditions typical of many shallow aquifers and surface waters, manganese is stable in its oxidised form, $Mn(IV)O_2$ which is highly insoluble. Hence, concentrations of manganese in aerobic water are usually low and commonly below analytical detection limits (BGS, 2003). Manganese in concentrations more than the acceptable limits of the WHO guidelines of 0.5 mg/l can cause black staining of food, laundry and sanitary ware and can impact on the metallic taste of water (BGS, 2003). Studies in Japan have shown a link between consumption of manganese and the motor neuron disease (Iwami et al., 1994).

Zinc

Zinc concentration in the ground had a mean concentration of 0.34mg/l, with concentrations as high as 0.39mg/l. The zinc concentration in the surface water is between 0.41mg/l and 0.45mg/l. The control water sample had a mean zinc concentration of 0.05mg/l. This is far above the WHO permissible threshold for zinc in drinking water, the WHO (2011) permissible limit for zinc n water is 0.01mg/l

Zinc concentration for the soils in the study area ranged between 6.27 and 7.23. The control soil sample had a mean zinc concentration of 1.23.

Chromium

Chromium concentration in the groundwater samples range between 0.09mg/l and 0.16mg/l. the mean concentration for chromium in the groundwater sampled is 0.126mg/l. Chromium concentration in the surface water samples was also high, ranging between 0.35mg/l and 0.38mg/. This exceeded the WHO permissible standard of 0.05mg/l for chromium in water. The control water sample had a mean chromium concentration of 0.007

Chromium concentration was relatively high in the soils from the area. The concentrations range between 30.54 and 36.06 with mean concentration of 33.31. The mean chromium concentration for the control samples is 2.93.

Copper

Copper concentration in the groundwater samples range between 0.38mg/l and 0.49mg/l. Even the point with the lowest concentration value is higher than the permissible limit for copper in drinking water as set by the WHO (2011). The mean concentration of copper in the area is 0.42mg/l, while the WHO threshold limit is 0.3mg/l. The surface water had copper concentrations ranging between 0.51mg/l and 0.54mg/l, while the mean copper concentration in the control water samples is 0.06mg/l.

Copper concentration was also quite high in the soils. The concentration range between 14.18 and 16.58. The control sample had low concentration value of between 6.6 and 6.8. Copper enters water system through mineral dissolution and industrial effluents.

Lead

Lead, which is a known poisonous substance was also found in high amounts in the waters sampled. The concentration ranged between 0.01mg/l and 0.16mg/l, the mean concentration of Lead in the water is 0.11mg/l. Lead was also analyzed for in the surface water samples and it had concentrations of between 0.02 and 0.06mg/l. The mean Lead concentration in the control water sample is 0.003, while the threshold set by the WHO for Lead in drinking water is 0.01mg/l.

Lead concentrations in the soils ranged between 7.81 and 9.61 with mean concentration value of 8.71. The lead concentration in the control samples had a mean value of 0.09.

Nickel

Nickel was analyzed also for their concentrations in the ground water and high concentrations were found to be present in the waters. The concentrations range between 0.64mg/l and 0.85mg/l, with a mean concentration of 0.76mg/l. The nickel concentration in the surface water range between 0.09mg/l and 0.21mg/l, while the control samples had mean nickel concentration of 0.05mg/l. The WHO (2011) permissible threshold for nickel in drinking water is 0.02mg/l

Nickel concentration was also high in the soils sampled from the study area, with concentrations ranging between 20.37 and 232.97. The mean concentration was 22.18. The mean nickel concentration in the control soil sample is 0.97.

Phosphate

Phosphate was also found to be present in small amounts in the groundwater samples. The concentrations range between 0.55mg/l and 0.66mg/l. Phosphate concentrations in the surface waters studied ranged between 0.67mg/l and 0.82mg/l. The control sample had a mean concentration of 0.41mg/l

Phosphate concentration was also high in the soils and ranged between 36.68 and 45.08, with mean phosphate concentration of 40.89 in the soils. The soil control samples analyzed had con centration between 12.3 and 15.3, with mean concentration of 13.67.

Total Coliform Count

The total coliform count that was found in the groundwater sample range between 6 and 10 and the WHO permissible threshold is 10. The total coliform count in the surface water range between 15 and 23, while the control sample had mean total coliform count of 4

E. coli

The E. coli count was found to be as much as 1 in the groundwater samples when the WHO limit is set at 0. The E. coli count in the surface water was much higher than the groundwater. The surface water had counts between 4 and 11. The control sample analyzed had counts as high as 2.

5.12 Concentration Map Models

Concentration maps of some heavy metals were modelled in order to see their spatial distribution across the study area. The heavy metals modelled for copper, iron and lead concentrations are presented below in (Figure 5.1 – Figure 5.3).

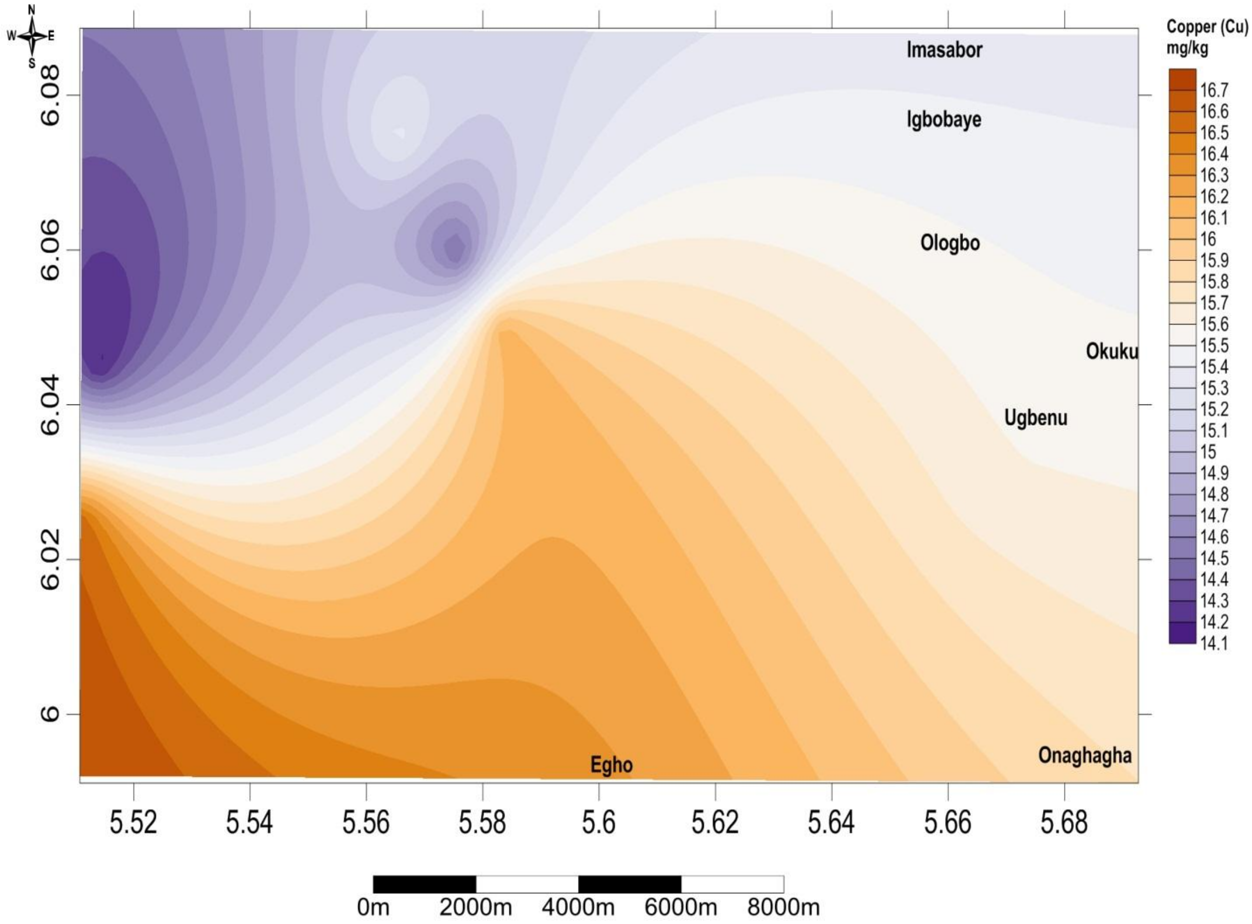

Figure 5.1 Concentration Map for Copper in the Study Area

From Figure 5.1 above, the distribution of copper concentration around the study area seems to be highest around the southwestern part of the area and lowest in the northwestern parts area. The eastern half of the study area have average concentrations around Ologbo area

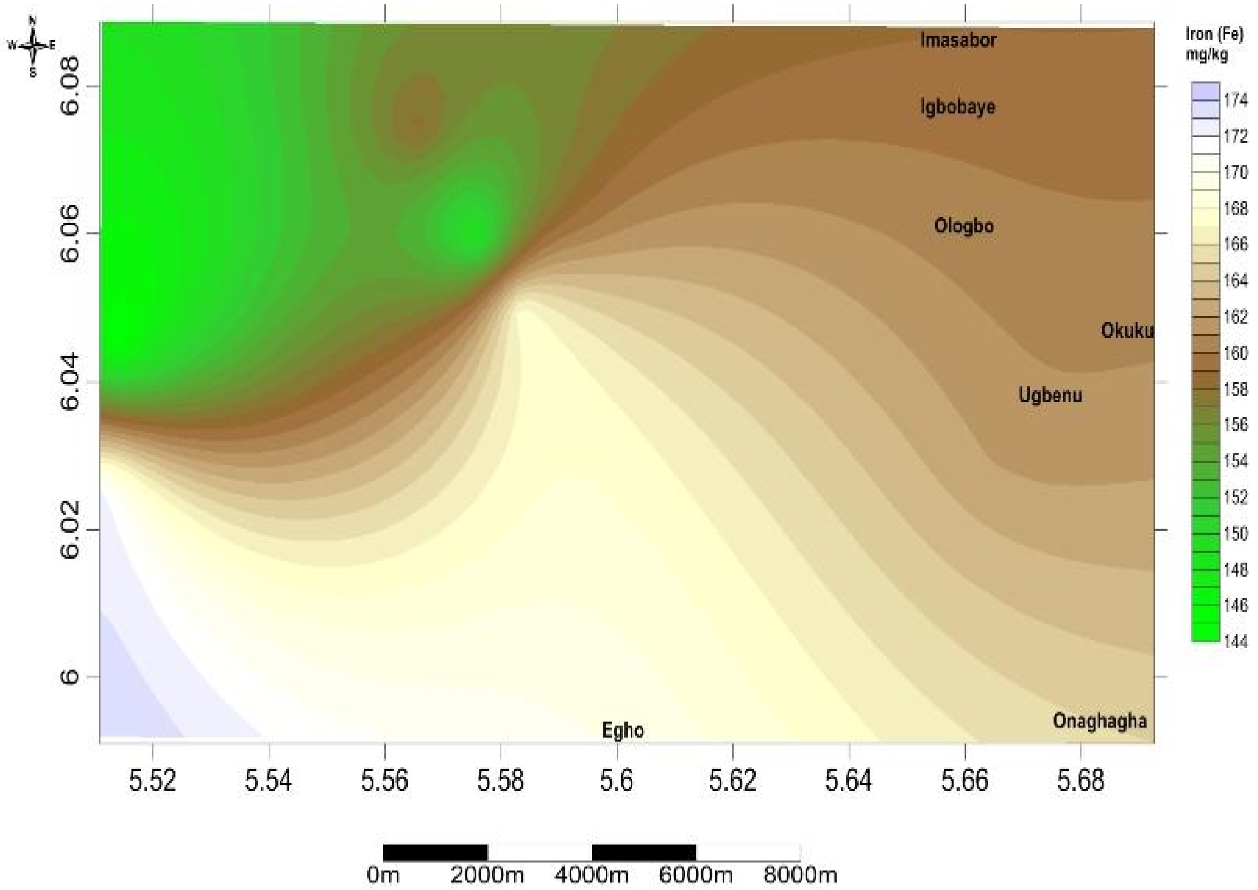

Figure 5.2 **Concentration Map for Iron in the Study Area**

The distribution of iron concentration around the study area seem to be highest around the southwestern part of the area and lowest in the northwestern parts of the area. The eastern half of the study area have average concentrations around Ologbo area.

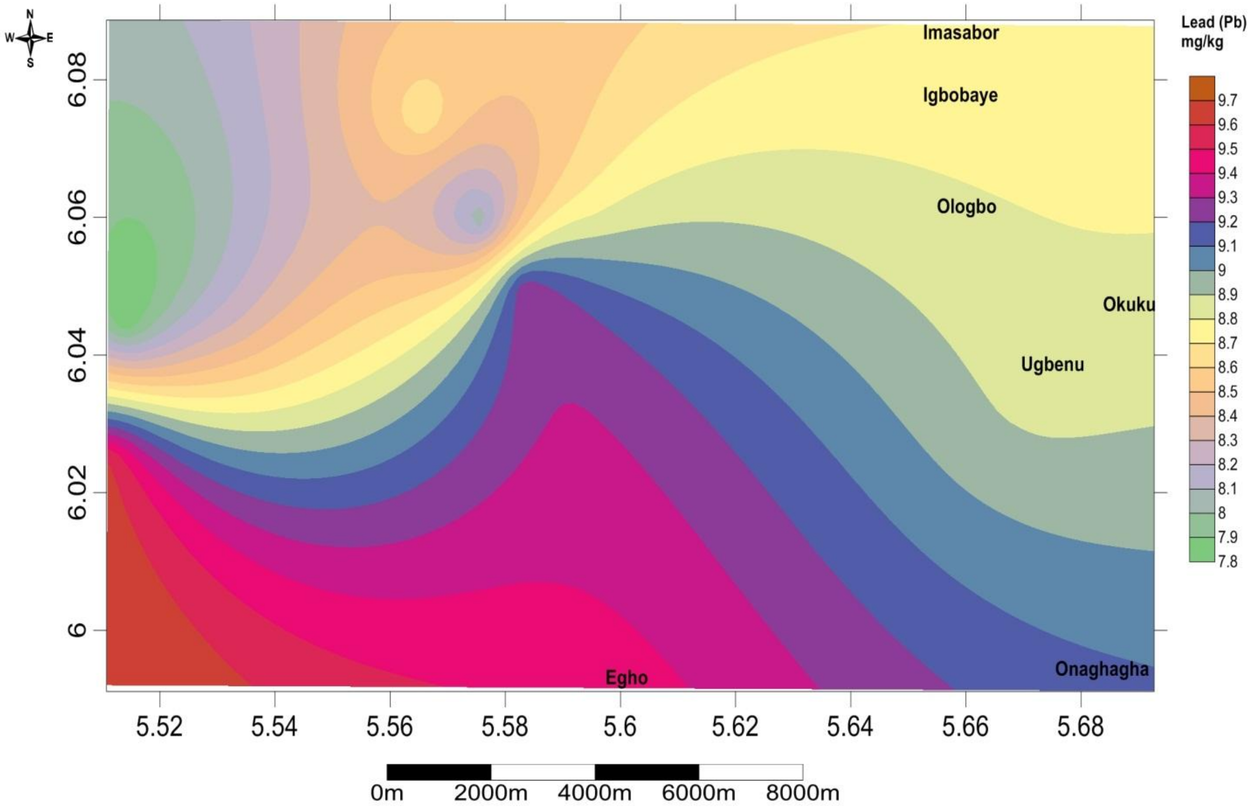

Figure 5.3 Concentration Map of Lead in the Study Area

Lead concentrations were seen to be higher around the southern half of the area, with highest concentrations noticed in the southwestern parts. Average lead concentrations were noticed around Imasabor, Ologbo and Okuku areas,

It can be seen from the map that the areas that recorded low heavy metal concentrations are the areas with relatively thick vegetation where anthropogenic factors have not taken hold. The areas that have higher concentrations are areas close to major roads where human activities are high and there is considerable environmental impact.

5.13 Groundwater Flow Direction

The groundwater flow direction as seen from the map (Figure 5.4), shows a two directional flow pattern with one flowing from the north-northwest direction towards the central part of the study area, while the other flows from the south-southeastern part towards the central area.

The major river in the area is the Ossiomo River, which runs through the central part of the study area. The river runs from the northeast towards the southwestern part of the area. The Ossiomo River serves as a major source of water and its tributaries and networks run within the different parts of the study area.

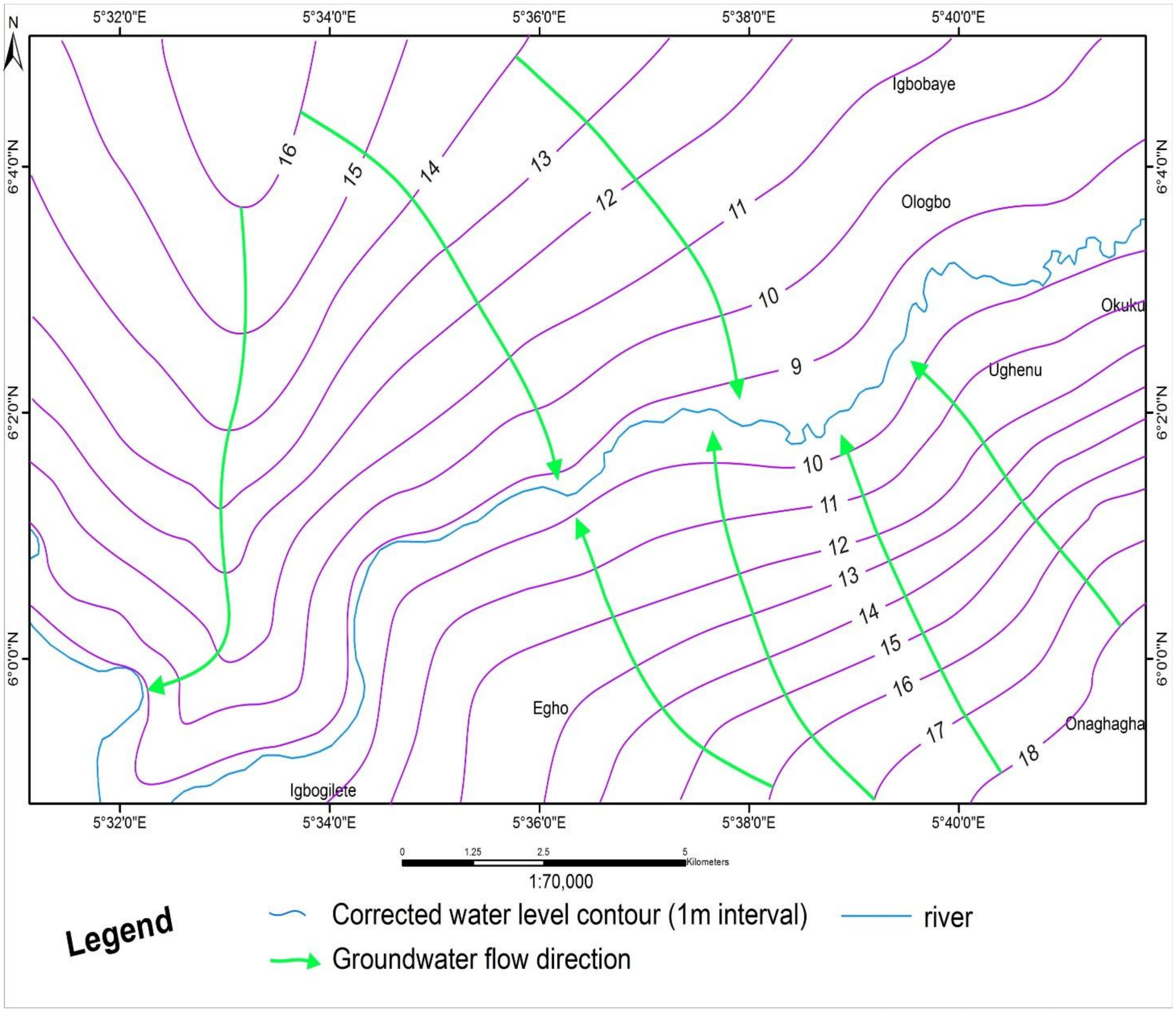

Figure 5.4 Groundwater Flow Direction in the Study Area.

5.2 CONCLUSION

The result of the parameters analyzed in the study revealed that the soil samples obtained at specific point and depth within the oil exploration sites in Ologbo and environs had pH values ranging from 5.71-6.05. Most of the heavy metals analyzed apart from Zinc (Zn) and Lead (Pb) recorded very high concentrations beyond the standard for soil. These heavy metals include Iron (158.95mg/kg), Cr (33.31mg/kg), Ni (22.18mg/kg)

The physico-chemical parameters for surface water samples agree with the approved standard while the heavy metal results for the surface water fell short of standard, with exception for manganese (Mn). Also, the groundwater samples with a mean pH of 5.96 (slightly acidic) fell short of the heavy metal concentration standard, with exception of manganese.

The soil samples collected far away from an environment devoid of oil exploration activities had a lower concentration compared with those around the vicinity of the oil exploration. This shows that the heavy metal content from the by-products of the oil exploration is interacting with the soil.

The correlation results between analyzed parameters in surface and groundwater revealed Positive and Negative correlation Co-efficient at r (0.01) and r (0.05) indicating a strong association between them, which probably reflects a common source of Contamination. By extrapolating results, it can be concluded that the natural top soil quality around areas dominated by petroleum exploration activities is a reflection of anthropogenic contribution from the exploration activities. Therefore there is need for strict petroleum exploration management practice to ameliorate the impending health risk from heavy metals

5.3 Recommendations

1. Groundwater exploitation systems such as boreholes and hand dug wells should only be sited after proper sanitary inspection and approved recommendation.
2. It is therefore recommended that areas of safe limits of chemical quality of groundwater should be opted for development notwithstanding their convenience and reliability.
3. It is further recommended that thorough groundwater quality investigations should be carried out before drilling of boreholes to avoid investing in construction of boreholes which will not be used. The maps showing spatial variation produced in this study should be used as a guide in future groundwater development in locating areas on safe limits of groundwater chemistry.
4. A longitudinal study should be carried out on the seasonal variations of chemical compounds and the health impacts associated with consumption of groundwater with high concentration of inorganic compounds especially at Ologbo community, since it is a fast growing community

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