PHYSICAL AND BIO-CHEMICAL CHARACTERISTICS OF OTAMIRI RIVER AND ITS SEDIMENTS IN PARTS OF OWERRI AREA, SOUTHEASTERN NIGERIA

BY

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CERTIFICATION

This is to certify that this work "Physical and Bio-Chemical Characteristics of Otamiri River and its Sediments in Parts of Owerri Area, Southeastern Nigeria" was carried out by I Fagorite, Victor Inumidun (20164997058) in partial fulfilment for the requirements for the award of the degree of Master of Science in Environmental Geology in the Department of Geology, Federal University of Technology, Owerri.

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DEDICATION

Dedicated to my lovely and wonderful parents; Pastor Francis Oloruntobi Fagorite JP and Deaconess Faith Kehinde Fagorite.

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ABSTRACT

Physical and Bio-chemical characteristics of Otamiri river were investigated using digital meters, Atomic Absorption Spectrometer (AAS) and Standard plate count technique. The results indicates that the mean pH concentrations of the Otamiri river obtained at four strategic gauge stations designated $SSWS_1$ (Egbu), $SSWS_2$ (Timber Market), $SSWS_3$ (FUTO) and Downstream (Mbirichi) were 6.45, 6.58, 6.45 and 6.50 respectively while mean Total coli form count were 3.0×10^2, 3.0×10^3, 4.1×10^3 and 1.0×10^3 cfu/100ml respectively. The mean Total bacterial counts were 3.0×10^4, 2.0×10^3, 1.1×10^3 and 0.8×10^3cfu/100ml respectively while the mean values for Total *E. Coli.* were 1.1×10^2, 3.0×10^2, 4×10^3 and 2.0×10^3 cfu/100ml with biochemical identification of some organisms such as; *Escherichia Coli.*, *Vibro spp.*, *Klebsiella spp.*, and *Entrobacteria spp*. The mean values for Pb^{2+} were 0.02, 0.02, 1.67and 0.02 mg/l respectively while that of Cd^{2+} were 0.004, 0.0036, 0.004 and 0.002 mg/l respectively. The mean concentrations for Fe^+ were 0.01, 0.016, 0.23 and 0.10 mg/l while for Ni were 0.046, 0.06, 0.03and 0.01 mg/l respectively. The mean pH, total bacterial count, total coli form count, total *E. Coli.*, Pb^{2+}, Cd^{2+}, Fe^+ and Ni concentrations were below the World Health Organisation (WHO) 2011 Standard for safe drinking water and thus constitute a threat to the River. The Sodium Adsorption Ratio (SAR) of the river indicates that it is excellent for irrigation purposes even though correction of the pH needed to be done. The pollution index (PI) of the river shows that it is tending towards its critical value of 1. The results also show that concentrations of the major constituent cations (Na^+, Ca^{2+}, K^+ and Mg^{2+}) and anions (HCO_3^-, NO_3, Cl^- and SO_4^{2-}) conformed to WHO (2011) standard for safe drinking water. The result of stream sediment samples indicates that the concentrations of pH were 5.8, 5.90, 6.30 and 6.45 respectively while the Total Bacterial Count were 3.5×10^4, 5.0×10^4 , 6.5×10^4 and 2.0×10^4 cfu/g respectively and that of Total Coliform Count was 6.5×10^3, 2.0×10^3 , 2.5×10^3 and 0.8×10^3cfu/g respectively. For the Total *E. Coli* Count, the values were 2.5×10^3, 1.0×10^3, 2.5×10^3 and 0.5×10^5cfu/g respectively with biochemical identification of some organisms such as; *Escherichia Coli.*, *Vibro spp.*, *Klebsiella spp.*, *Entrobacteria spp.* and *Bacillus spp.* The mean concentrations values for Pb^{2+} were 0.08, 0.07, 0.06 and 0.05 mg/kg respectively while the values for Cd^{2+} were 0.32, 0.28, 0.30 and 0.25 mg/kg respectively. The values for Hg were 0.10, 0.13, 0.15and 0.18 mg/kg. The mean pH, total bacterial count, total coli form count, total *E. Coli.*, Pb^{2+}, Cd^{2+}, and Hg concentrations were below Federal Ministry of Environment (FME) 2006 standard for soil and thus constitute a threat to the River; these are attributed to waste dumps and anthropogenic activities around the four stations. The results also show that concentrations of the major constituent cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and anions (trend Cl^-, CO_3^-, PO_4^{-3}, SO_4^{2-}, HCO_3^- and NO_3) conformed to FME (2006) standard for soil. The pH of the water can be treated using sodium bicarbonate while the sediment by liming method. The excessive concentrations of heavy metals especially iron can be treated using ascobic acid or ion exchange methods while the microbial constituents can be reduced by chlorination.

Keywords: pH, Heavy metals, Ascobic acid, Landfill, Water and Sediment

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Surface water has been and is still being used for many purposes, which include drinking, irrigation, livestock farming, recreation and serves as habitat to numerous organisms. The aesthetic properties of most rivers and streams have made them sites for tourist attraction and recreation. It has also served as sources of employment, particularly for the fishing industry. However, Surface water bodies in developing countries are predisposed to pollution. Water is generally said to be polluted when its acceptable quality has been altered by man's activities through anthropogenic inputs such that its intended usage for commercial or domestic purpose is hampered (lbeh & Mbah, 2007). Industrial activities and urbanization in developing countries like Nigeria, have gradually led to surface water deterioration in recent years and consumption of such water could threaten health since it consists of grouped organic and inorganic pollutants (Akaninwor &Egwim, 2006). The presence of objectionable tastes, odour, colour as well as harmful substances in such water no matter how abundant it is, renders it unsuitable for domestic, industrial and agricultural uses (Okeke & Igboanua, 2003).

The impact of human activities in the urban, municipal and populated area makes surface water bodies like streams, rivers, lagoons, etc, and ground water bodies to be susceptible to contamination from pollutants. Pollution of sediments and water by heavy metal occurs due to industrial wastes, application of fertilizer, corrosion of sheeting, wires, pipes, and burning of coal and wood (Nwankwoala & Ekpewerechi, 2007).

Sediment is the loose sand, clay, silt and other soil particles that settle at the bottom of a body of water. Sediments can come from soil erosion or from the decomposition of plants and animals. Wind, water and ice carry these particles to rivers, lakes and streams. In general, the chemical composition of stream sediments depends on several factors, such as the lithology, morphology and structural setting of the catchment, and on the effect of climate, which controls weathering rates and hydrological features as well as the density and type of vegetation cover (Salomons & Förstner, 1984). In addition, human activity can sometimes strongly influence fluvial dynamics and the environmental quality of the fluvial systems (Mantei & Foster, 1991).

Sediments, being an integral component of aquatic ecosystem, provide habitat, feeding, spawning and rearing areas for many aquatic organisms (SIDA, 2013), and Otamiri River, Imo State Nigeria, serves the surrounding populace for several usages such as drinking, cooking, fishing, washing, sand dredging and irrigation. It equally serves as a major recipient of several arrays of anthropogenic pollutants arising from industrial, agricultural and domestic inputs, thus the need to investigate the likely effect of these pollutants in the river. Although, the Otamiri River is small when compared with other freshwater resources in Nigeria like rivers Niger and Benue, it is however, a very well-known river in Owerri because of its economic and social potentials. The Otamiri River is of strategic importance to both the Imo State Government of Nigeria and the local community living near its shore.

1.2 PROBLEM STATEMENT

The physical and bio-chemical characteristics of surface water resources are constantly changing, from activities within and around it. Such activities may include: farming, fishing, indiscriminate dumping of waste, exploration and exploitation of solid minerals etc. These activities are capable of introducing toxic substances such as heavy metals into the surface water thereby altering the resource status and usefulness.

Studies have been carried out on this area which shows high concentration of some heavy metals according to Onyekuru *et al.* (2017) as indicated in their study that the concentration of iron (Fe) was above 0.20mg/l in the study area which was above the recommended limit. In a study by Temitope *et al.* (2016) the river shows heavy metal contamination levels and physico-chemical characteristics between August and October 2015, with the sediments of the four stations also revealed the presence of heavy metals. Likewise, Ahirakwem (2013) concluded that except for Cu^{2+} and Zn^{2+}, the concentrations of other measured heavy metals (Cd^{2+}, Cr^{6+}, Pb^{2+} Ni and $Mn^{2+)}$ were below WHO (2006) standard for safe drinking water and thus constitute a threat to the Otamiri River. Hence, the Otamiri river has been proven to be polluted both in heavy metals and microbial constituents with respect to water and sediments in the last five years.

1.6 OBJECTIVES OF STUDY

Main Objective

The main object of the study is to provide useful information for the sustainable management and development in terms of control of solid waste input to Otamiri River, constituent budget monitoring and utilization of the water for agricultural, domestic, commercial and recreational purposes.

Specific Objectives

The objectives of the study are as follows:

i. The quality status of the water and sediments of Otamiri River through physico-chemical and biochemical determination.

ii. The microbial Assay of the water and sediments of Otamiri River through some microbiological parameters determination.
iii. The Pollution Index (PI) and Sodium Adsorption Ratio (SAR) determination of the River.

1.7 JUSTIFICATION OF STUDY

Contamination of water bodies such as surface water and groundwater, can also be caused by natural phenomenon such as volcanoes, earthquake algae blooms and anthropogenic activities such as runoff from agricultural field, sewage disposal, industrial effluent and so on which can be harmful to organism that are dependent on it. The Otamiri River is of great economic significance to the people of the communities where it passes, it serves as a source of domestic water for those that do not have boreholes. For example, tanker drivers go and collect water from the river around the Egbu axis of the river. Sand and gravel mining is going on along the river channel from the Nekede axis down to as far as Umuagwo. Fishing activities has been noticed around the river confluence with Nworie River. Therefore, constant monitoring of the quality of surface water cannot be overstressed especially now that increase in population has resulted in generation of more waste thus exposing the water to more pollutants.

Secondly, there is lack of information from previous work as regards to the microbial assay of both the water and the sediments. Thus, serve as a resource to other scholars and researchers interested in carrying out further research in this area and also provide new explanation to the topic.

1.8 SCOPE OF STUDY

This study is delimited to samples (water and sediment) which were obtained at the source of the river at Egbu down to Mbirichi the downstream and were later analysed for their physical and biochemical contents. Due to lack of accessibility to some parts of the river, samples were taken along the stream channel.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREVIOUS WORKS

It is a proven fact that environmental issues have become major concerns to governments and citizens of various nations, including Nigeria. The environment, which is at the heart of economic, social, cultural and human activities, has been disturbed by man's disregard and abuse (Ibeh, 2017). If water is properly harnessed and utilized, it can prove useful, and of immense value to mankind. In case it is not properly controlled, it may become a curse and cause of misery and destruction to humanity.Investigations of the chemical composition of stream and river sediments have been used as a prospecting tool for mineral deposits (Levinson, 1974; Rose *et al*., 1979; Plant & Hale, 1994) but the same principles and techniques can be extended to more environmentally-related studies (Howarth & Thornton, 1983; Förstner, 1983; Förstner *et al*., 1991).

Onyekuru *et al*. (2017), of Otamiri River in Imo State, South-Eastern Nigeria stated that the sources of the river's iron (Fe) pollution were majorly point sources like refuse dumps, runoff from metal scrape collection sites, runoff from Nekede mechanic village, iron smelting company at garage and runoff from roadside welding workshops. It was recommended that regular monitoring of the Otamiri River be carried out to monitor pollution levels. According to Temitope et al. (2016) the Otamiri River shows heavy metal contamination levels and physico-chemical characteristics with the sediments of four stations indicating heavy metal concentrations. The mean pH concentrations of the Otamiri River in 2008, 2009 and 2010 were 6.20, 6.32 and 6.25 respectively while the mean total iron concentrations were 4.50, 6.70 and 7.20 mg/l respectively was investigated by Ahiarakwem (2013) using standard plate count techniques for microbial constituents ans atomic adsorption spectrometry for the elements in terms of laboratory analyses. Indiscriminate disposal of municipal wastes remains a major threat to surface water pollution in Nigeria (Taiwo, 2010). The Investigation of the pollution index of Oramiriukwa, Nworie and Otamiri rivers, Imo State, Nigeria was studied by Egereonu *et al.* (2012). Physicochemical analysis conducted on samples collected from the three sample stations revealed that 1.039, 1.051, and 1.051 critical pollution index values for temperature were obtained for Otamiri, Nworie, and Oramiriukwa rivers respectively, while the total dissolved solids critical pollution index values were 0.039, 0.087, and 0.020 for Otamiri, Nworie and Oramiriukwa sample stations respectively. However, critical pollution index values of 1.311, 2.584, and 2.588 for chromium in the three sample sites indicated relative chromium pollution of the three river bodies.

Duru *et al.* (2012) concluded that analyzed water samples collected from the river showed that apart from total iron at upstream I, all other identified heavy metals in the river water were lower than those of maximum permissible limits. Metals such as cadmium, chromium, arsenic, mercury and cobalt used as indices of heavy metal pollution of water body were absent in Otamiri River. *Pseudomonas aeruginosa, Proteus spp, Staphylococcus epidermuchsi, Escherichia coli, Klebsiella species, Proteus species, Vibro species, Shigella species and Salmonella* species were among the microbes identified and isolated from Otamiri River.

Undoubtedly, water represents the most significant transport pathway for metals and metalloids, derived from the chemical weathering of mineralized rocks (Efstratios *et al.*, 2012). The ionic speciation (dissolved metals) is one of their most mobile and bioavailable forms. Together with major ion content, they are routinely accomplished to the status of surface water quality. Stream sediments play a crucial role in controlling heavy metal concentration in aquatic environment as a sink for trace elements (Efstratios *et al.*, 2012).

In terms of stream sediments, Alther (1981) established that both water and stream sediment chemistry were analyzed because the water chemistry only assesses the effluent impact at time of sampling, while the stream sediment geochemistry gives a cumulative assessment of the pollution. If samples can be collected only once, and speed is important, this seems to be a good method to study stream pollution.

The effects of untreated sewage effluent on Otamiri River water were examined by Adieze *et al.*(2016) in which the changes in microbial population and other water quality parameters such as Biochemical Oxygen Demand (BOD), pH, Temperature, Total Dissolved Solids (TDS), Turbidity, Chloride, Nitrate and Total Hardness of the water samples were assessed at four different stations. Though these mean values increased with the river water's contamination by sewage effluent, samples taken at 200 meters downstream showed a reduction in the values probably by dilution. This study showed that the discharge of sewage effluent into Otamiri River altered adversely its quality microbiologically and physicochemically.

In another study for sediments in the study area, Ofulume & Amadi (2011) investigated the suitability of the Otamiri River (Ihiagwa, Imo State, Nigeria) sands as a possible raw material source for the glass industry. But their results indicate that the sands of the river in their natural state of deposition fail to meet the specification for glass making. However, when subjected to some sand processing technique such as washing, attrition scrubbing and acid leaching the sand from the river terrace showed improved percentage silica content of 98.04 which is still inadequate.

It can be observed from the previous studies that a detail and concise microbiological parameters of sediments has not been undertaken. Therefore this research has further made provisions and information for other research works in the aspect with regards to the study area.

2.2 GEOCHEMICAL MODELS

A variety of graphical and multivariate statistical techniques have been devised since the early 1920's in order to facilitate the classification of waters with the ultimate goal of dividing a group of samples into similar homogeneous groups (each representing a hydrogeochemical facies). Several commonly used graphical methods and multivariate statistical techniques are available including: Collins bar diagram, pie diagram, Stiff pattern diagram, Schoeller semi-logarithmic diagram, Piper diagram, Q-mode hierarchical cluster analysis (HCA), K-means clustering (KMC), Principal components analysis (PCA), and Fuzzy k-means clustering (FKM). This work utilizes a relatively large data set to review these techniques and compare their ease of use and ability to sort water chemistry samples into groups. But for the purpose of this study only the following techniques were used vis: Stiff Diagram, Piper Diagram, Schoeller Diagram and Durov Diagram.

All the graphical methods use a limited number of parameters, usually a subset of the available data, unlike the statistical methods that can utilize all the available parameters. The fundamental aim of the techniques compared here is to identify the chemical relationships between water samples. Samples with similar chemical characteristics often have similar hydrologic histories, similar recharge areas, infiltration pathways, and flow paths in terms of climate, mineralogy, and residence time.

2.2.1 Stiff Diagram

The Stiff pattern is a polygon that is created from three (or four) parallel horizontal axes extending on either side of a vertical zero axes (Stiff, 1951). In this diagram, cations are plotted on the left of the axes and anions are plotted on the right in units of milliequivalents per liter (meq L-1). The Stiff diagram is usually plotted without the labeled axis and is useful making visual comparison of waters with different characteristics. The patterns tend to maintain its shape upon concentration or dilution, thus visually allowing us to trace the flow paths on maps (Stiff, 1951).

2.2.2 Piper Diagram

This is a graphical representation of the chemistry of a water sample or samples. The cations and anions are shown by separate ternery plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassium cations. The apexes of the anion plot are sulphate, chloride and carbonate plus bicarbonate anions. The two ternery plot are then projected up to into a diamond. The diamond is a matrix transformation of a graph of the anions and cations. Unlike the Stiff diagram, the Piper diagram concentration is expressed in %meq/l. Many analyses can be plotted on the same diagram and useful in classifying waters by hydrochemical facies. Piper diagram is convienent to identify mixing of waters and can track changes through space and time. Its own disadvantages are concentrations are renormalized and it cannot easily accommodate other cations or anions may be significant.

2.2.3 Schoeller Diagram

Schoeller diagram is a semi-logarithmic diagram of the concentration of the main ionic constituents in water (SO_4, HCO_3, Mg, Ca, and Na/K) in equivalent per million per kg of solution (meq/kg). An equivalent is the amount of an anion or cation species needed to add or remove one mole of electrons from a system. The concentration of each ion in each sample are represented by points are connected by a line. The diagram gives absolute concentration but the line also gives the ratio between two ions in the same sample. The Schoeller semi-logarithmic diagram (Schoeller, 1955 &1962) allows the major ions of many samples to be represented on a single graph, in which samples with similar patterns can easily discriminated. The Schoeller diagram shows the total concentration of major ions in log-scale.

2.2.4 Durov Diagram

The Durov diagram in AquaChem is an alternative to the Piper diagram. The Durov diagram plots the major ions as percentages of mill-equivalents in two base triangles. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto a square grid that lies perpendicular to the third axis in each triangle. The plot reveals useful properties for large sample groups. The main purpose of the Durov diagram is to show clustering of data points to indicate samples that have similar compositions. The Durov diagram can be used to plot all samples in the open database or selected sample groups.

2.2.5 Sodium Adsorption Ratio (SAR)

SAR is an expression that is used for characterizing the sodium hazard of irrigation water. SAR value is used to calculate the degree to which irrigation water tends to enter into cation exchange section in the soil. The main problem with high sodium concentration is its effect on soil permeability. Sodium also contributes directly to the total salinity of the water and may be toxic to sensitive crops such as fruits trees.

Table 2.1: Classification of Water Based on Sodium Absorption Ratio (SAR) (After The U.S Department of Agric, 1965)

SAR	WATER CLASS
0-10	Excellent
10-18	Good
18-26	Fair
>26	Poor

2.3 LOCATION OF THE STUDY AREA

Otamiri River is one of the main rivers in Imo state, Nigeria. The river takes its name from “Otamiri”, a deity that owns all the water that are called by its name, and who is often the dominating god of Mban houses (Ihenyen & Aghimien, 2002). The watershed is located on latitude 5˚17'N and 5˚30'N, and Longitude 6˚58'E and 7˚04'E (Figure 2.1). The river runs south from Egbu, Owerri and through Nekede, Ihiagwa, Eziobodo, Obowuumuisu, Mgbirichi and Umuagwo to Ozuzu in Etche Local Government Area of Rivers state from where it flows to the Atlantic Ocean. The length of the river from its source to its confluence at Emeabiam with Uramiriukwa River is 30 km (Ihenyen & Aghimien, 2002). The Otamiri watershed covers about 10,000 km2 with annual rainfall of 2250 – 2500 mm. The watershed is mostly covered by depleted rain forest vegetation, with mean temperature of 27˚C throughout the year (Ihenyen & Aghimien, 2002).

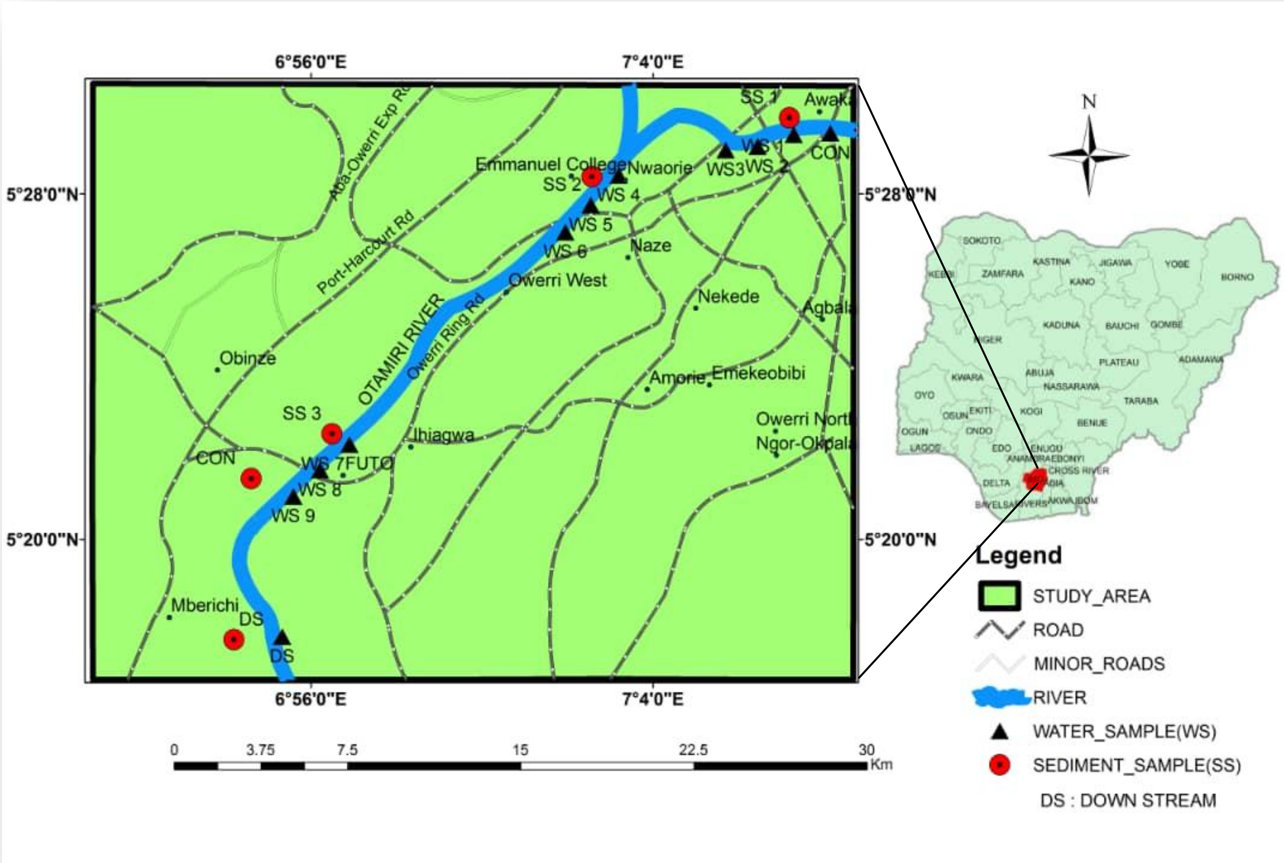

Figure 2.1: Location and Accessibility Map of the Study Area

2.3.1 Vegetation and Drainage Pattern

This study area is located within the tropical rainforest belt of Nigeria. Over the years the original tropical rainforest has been cultivated and deforested and has to a large extent been replaced by secondary forest. Economic trees like the iroko, mahogany obeche, gmelina bamboo, rubber and oil palm predominate. But due to high population density, most of the state has been so farmed and degraded that the original vegetation has disappeared. Deforestation has triggered off acute soil erosion in some parts of the state. The region experiences a mean annual temperature of 270^0 C and an annual rainfall of 200 – 300cm with most of the rainfall in the rainy season – from April to early November (Iloeje, 1976).

2.3.2 Climatic Setting

The study area is located within the equatorial rain forest belt of Nigeria. The mean monthly temperature of the area varies from 25 to 28.5 ^{o} C while the mean annual rainfall is about 2500 mm most of which fall between the months of May and October (National Root Crop Research Institute, 2010). The rainfall distribution consists of two minima and two maxima. The first minima are in November and December while the second minimum is in August which is usually associated with August break. From February, total rainfall increases sharply to primary maxima in June and July. The second maximum is in September which increases sharply and subsequently decreases in November and December. The geomorphologic setting of the area is sub horizontal with a gentle slope. The wind direction in Owerri area and environs (of which the study area is a part) is mainly South-West to North-West. However, the South-West wind direction is the strongest (Iloeje, 1981).

2.4 THE GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The geology of the area shows that it is underlain by the Benin Formation (Figure 2.2) which is an extensive statigraphic unit in Southern Nigeria (Ananaba *et al*., 1993). The Benin Formation consists of friable high percentage of sands (70-100 percent), with few intercalations of clay, sandstone, conglomerates and isolated units of gravel (Obaje, 2009). The sand are mostly coarse-grained pebbly, poorly sorted and contains lenses of fine- grained sands (Avbovbo, 1978). The presence of Benin Formation is a contributory factor to soil erosion especially where they are exposed unprotected by vegetation (Ahiarakwem & Onunkwo, 2011).

In general it ranges from Miocene to Recent. Stratigraphically, the Benin Formation is overlain by Quaternary alluvinum and recent sediments, and underlain by the Agbada Formation.

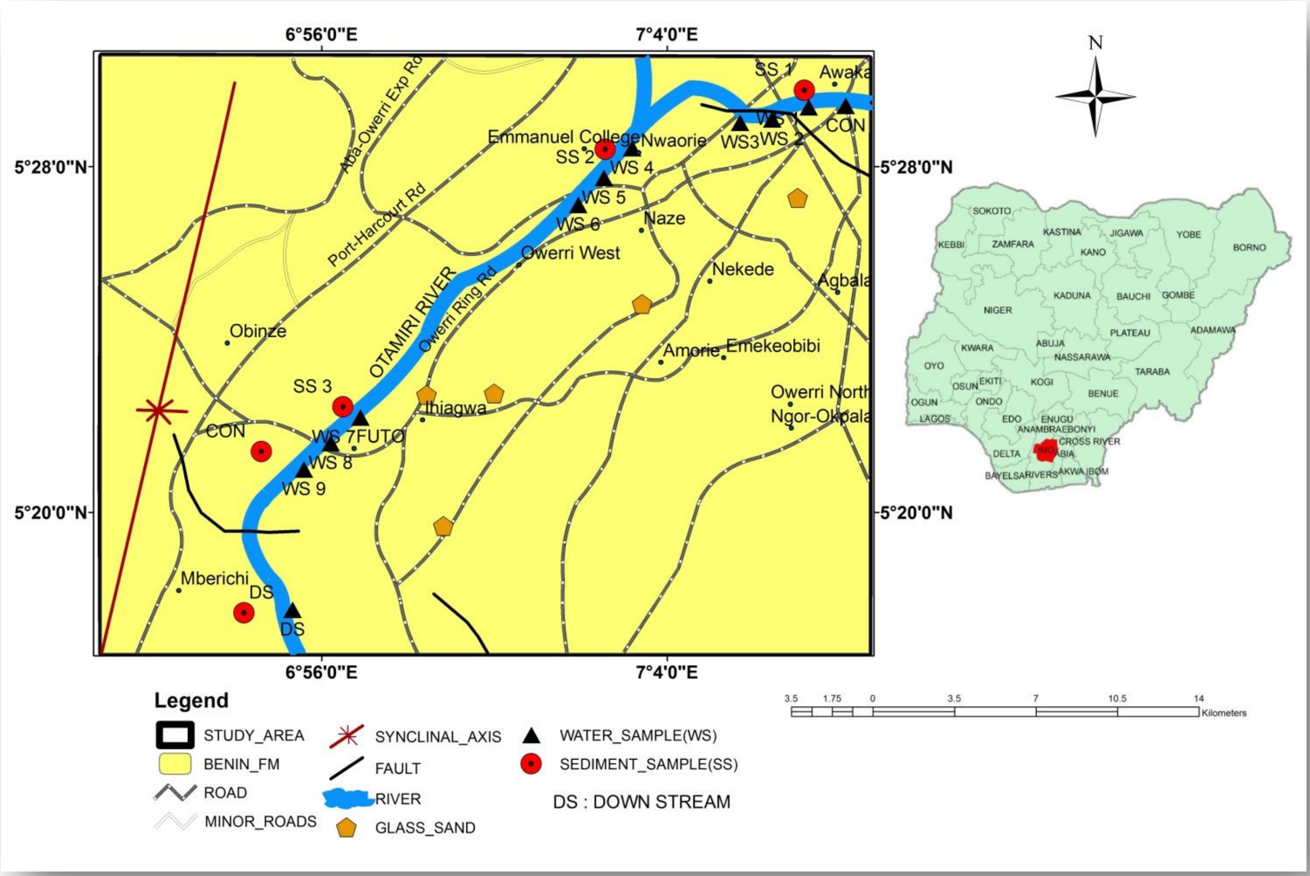

Figure 2.2: Geologic Map of the Study Area

The Benin sands and sandstones are mainly deposits of continental upper deltaic plain environment. It is predominantly sandy with few shale intercalations becoming more abundant towards the base. The sands and sandstone are coarse grained pebbles, sub angular to well rounded and whitish or yellowish in colour probably because of limonite coating and bears lignite streaks and wood fragments (Ananaba *et al*., 1993).

The Benin Formation provides the aquifer for groundwater storage. The incidence of high porosity and permeability as well as shallow water conditions make the groundwater system in some parts of the area very vulnerable to pollution (Ibe *et al.*, 2003).

CHAPTER THREE

MATERIALS AND METHOD

3.1 MATERIALS

Table 3.1: Showing all materials ranging from the field tools, laboratory tools, reagents and software used

S/N	FIELD TOOLS	LABORATORY TOOLS	REAGENTS	SOFTWARES USED
1	Topographic map	pH meter	Sabourand Dextrose Agar	Microsoft word and excel
2	Global positioning system (e trex GPS)	Glass ware	Nutrient agar	Grapher 4
3	Sample bottles and sample bags	Hanna Hi 83200 photometer	Distilled Water	SLUMBERGER aqua V.1
4		Hox box oven	Mineral Salts Agar (medium)	
5		Burrette	Nitric acid	
6		Cornical flask	Perchloric acid	
7		Pipettes	Sulphuric acid	
8		Atomic Absorption Spectrophotometer	Air oxidant gas	
9.		Crucibles	Acetylene gas	
10.		Incubator	E.D.TA	
11.		Autoclave	Sodium hydroxide	
12.		Burnsen burner	Solochrome	
13		Petric dishes	Moedant Black	
14.		Test tubes	FAS	
15.			Ferroin indicator	
16.			Phosphoric acid	
17.			Potassium dichromate	
18.			Nessler reagent	
19.			Barium chloride	
20.			Hydrochloric acid	
21.			Sodium acetate	
22.			Buffer 7.0, 4.0, and 9.0	
23.			Potassium Chloride Solution	
24.			1000ppm Hg standard solution	
25.			1000ppm Fe standard solution	

3.2 METHODOLOGY

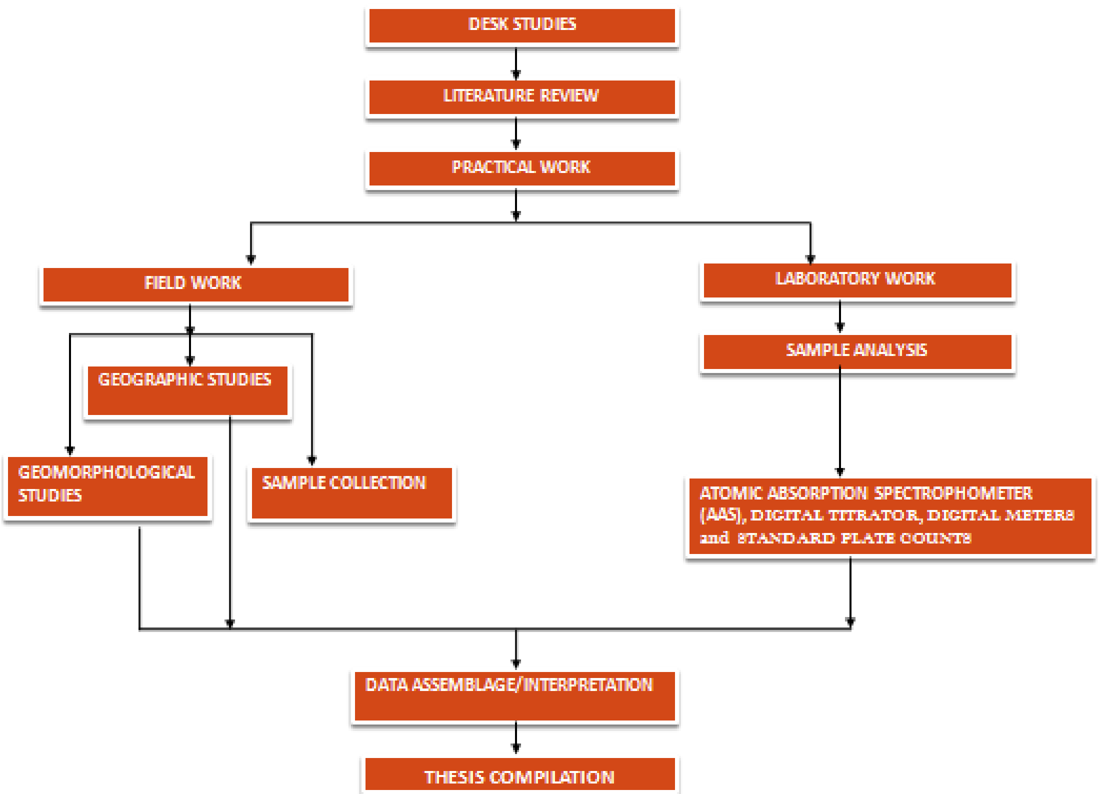

Figure 3.1: Workflow of the study

3.2.1 Fieldwork

Topographic and geologic maps were obtained from Nigeria geological survey department, Owerri. Geological, hydrogeological and geomorphological observations were made. They include the channel of the river, the accessibility, topography, slope and source of the river.

3.2.2 Sampling and Sampling Plan

Water samples and sediments were obtained at five (5) strategic gauge stations designated $SSWS_1$-Egbu, $SSWS_2$ –Timber Market, $SSWS_2$ – FUTO, DOWNSTREAM-Mbirichi and Control Point along the stretch of the river. Land use elements especially waste dump sites were visited and examined.

Samples were taken at a distance of 300 meters. A total of eleven (11) water samples were obtained along the stretch of the Otamiri River using a point method; the water samples were geo-referenced. The numbers of samples were collected at points with heavy activities by finding their mean. The stream sediments were obtained at 5 strategic locations using manual dredging method.

Table 3.2: Showing coordinates for sites and stations of sample collection

Stations	Samples	Coordinates	Elevation
$SSWS_1$	WS1	05°28'59" N, 07°04'01" E	163ft
	WS2	05°28'30" N, 07°03'10" E	160ft
	WS3	05°28'19" N, 07°03'14" E	161ft
$SSWS_2$	WS4	05°28'31" N, 07°02'50" E	165ft
	WS5	05°28'26" N, 07°11'31" E	150ft
	WS6	05°28'16" N, 07°02'21" E	146ft
$SSWS_3$	WS7	05°23'49" N, 06°59'46" E	170ft
	WS8	05°23'06" N, 06°59'14" E	145ft
	WS9	05°22'47" N, 06°59'04" E	139ft
CONTROL		05°22'55" N, 06°59'20" E	185ft
$SSWS_1$	SS1	05°28'59" N, 07°04'01" E	163ft
$SSWS_2$	SS2	05°28'31" N, 07°02'50" E	165ft
$SSWS_3$	SS3	05°23'49" N, 06°59'46" E	170ft
DOWNSTREAM		05°18'48" N, 06°58'17" E	168ft
CONTROL		05°23'35" N, 06°59'25" E	148ft

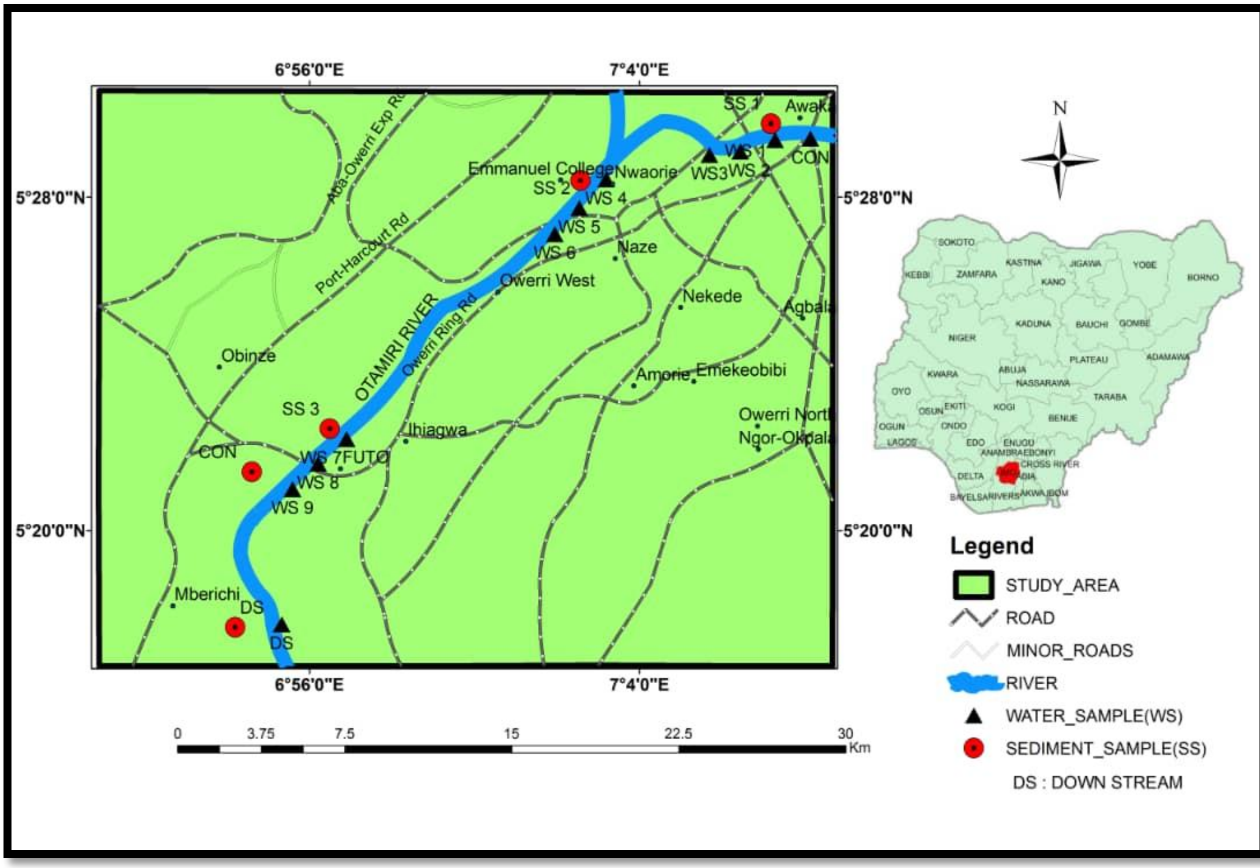

Figure 3.2: Sampling Map of water and sediments

3.2.3 Sample Treatment

Samples were collected with the aid of sterilized 1.5litres plastic containers. The samples were corked under water immediately after collection so as to avoid the oxidation of the constituents and later sent to the laboratory within 24 hours for analysis. The sediment samples were collected into black polyethene bags and sent to the laboratory for analysis within 24 hours.

3.2.4 Analyses of Samples

The water samples were analysed using the Atomic Absorption Spectrophotometer (AAS). The sediment samples were first digested using x-ray fluorescence (XRF) method and aspirated into the Atomic Absorption Spectrophotometer (AAS). The sampling points were geo-referenced using a global positioning system (GPS).

Land use elements especially waste dump sites were visited and examined. Samples were taken at a distance of 300 meters.

The concentrations of Ca^{2+}, Mg^{2+} and Na^{+} in milli equivalent/litre were used to obtain Sodium Absorption Ration (SAR). Turbimetric method was used to assess turbidity. Physical parameters like pH and dissolved oxygen were measured institu in the field with appropriate standard meters. Anions like HCO_3 were estimated by titrimetric method. Clean plastic bottles were used to contain the water samples and sampling bags for the sediments. The bottles were rinsed several times, with the same water samples to be analyzed, then covered with air tight cork and carefully labeled and sent to the laboratory for analysis within 24 hours of collection. The parameters analyzed are turbidity, oduor, appearance, conductivity, total dissolved solid, Iron (Fe^{2+}), Calcium (Ca^{2+}), Chloride (Cl^{-}), Bicarbonates (HCO_3^{-}), total hardness and Sodium (Na^{+}) etc.

Total Coli form count was analyzed to estimate possible bacteria presence using standard plate count technique.

<u>Calculations</u>

The concentrations of the major constituent cations and anions in milligram/liter (mg/l) were converted to milliequivalent/liter (meq/l) using the equation (3.1) developed by Todd (1980)

$$\textbf{Concentrations (meq/l)} = \frac{\textbf{Concentrations (mg/l)}}{\textbf{Equivalent mass}} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \textbf{(3.1)}$$

The concentrations in meq/l were used to prepare Piper trilinear, Schooler, Durov and Stiff diagrams as well as calculation of Sodium Adsorption Ratio (SAR).

The SAR was determined using the equation (3.22) (Wilcox, 1955).

$$\mathbf{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3.2)}$$

The total hardness as ($CaCO_3$) of the Otamiri River water was determined using the equation (3.3) developed by Todd (1980). Total hardness as

$$\mathbf{CaCO_3\ mg/l = 2.5\ [Ca^{2+}] + 4.1\ [Mg^{2+}]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \mathbf{(3.3)}$$

Concentration of pH, total alkalinity, Total dissolved solids (TDS), Total Hardness, sulphate and chloride in mg/l were used to determine the pollution index (PI) of the water samples. This was done using the method below:

The parameters considered for the determination of the pollution index (PI) of the Otamiri River water samples were pH, Total Alkalinity, Total Hardness, Total dissolved solids (TDS), sulphate and chloride. The PI was calculated using the equation (3.4) developed by Horton (1965).

$$\mathbf{PI} = \sqrt{\frac{\left(\frac{maxCij}{Lij}\right)^{2} + \left(\frac{meanCij}{Lij}\right)^{2}}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3.4)}$$

Where:

Ci = concentration of chemical parameters

Lj = World Health Organization (2011) permissible limit.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

The results of the physical and biochemical characteristics of Otamiri River and its sediments are shown in Tables 4.1 and 4.2 respectively while the Pollution Index (PI) and Sodium Adsorption Ratio (SAR) is shown in Table 4.4 and 4.5 respectively. The results of the microbial assay of the river and its sediments are shown in Table 4.6, 4.7, 4.8 and 4.9 respectively.

Table 4.1: Physical and Bio-Chemical Characteristics of waters from Otamiri River

Parameters	WHO 4th edition (2011) Guideline Value	SSWS$_1$			Mean	SSWS$_2$			Mean	SSWS$_3$			Mean	DOWNSTREAM (Mbirichi)	CONTROL POINT
pH @ 25^0C	8.2– 8.8	6.45	6.40	6.49	6.45	6.50	6.46	6.90	6.58	6.45	6.40	6.48	6.45	6.50	6.60
Odour	Unobjectionable	Objectionable			Objectionable	Objectionable			Objectionable	Objectionable			Objectionable	Objectionable	Objectionable
Appearance	Clear	Slightly turbid	Slightly turbid	Slightly turbid	Slightly turbid	Turbid	Turbid	Clear	Turbid	turbid	turbid	turbid	Turbid	Turbid	Clear
Total Dissolved Solid, mg/l TDS	1500	9.00	9.50	8.18	8.89	9.00	10.80	9.50	9.32	10.00	11	12	11	10.05	9.50
Conductivity, µS/cm	1400	15.00	15.87	13.64	14.83	15.00	18.00	15.83	15.53	10.50	14.00	10.60	11.70	10.30	9.30
Turbidity, NTU	1.00	10.80	9.80	11.50	10.37	11.00	11.40	4.50	11.00	10.00	11.86	11	12.95	8.50	4.50
Total Chloride, mg/l Cl^-	400	6.20	4.37	5.04	5.20	6.20	4.60	3.50	5.27	5.20	3.80	5.22	4.74	3.30	2.10
Total hardness, mg/l $CaCO_3$	100	13.40	14.90	11.30	13.20	13.35	14.89	9.53	13.13	11.10	11.17	11.30	11.19	10.50	9.53
Calcium hardness, mg/l $CaCO_3$	150	8.00	9.50	7.20	8.23	8.15	9.49	6.25	7.43	6.05	7.10	7.30	6.82	5.80	4.45
Magnesium hardness, mg/l $MgCO_3$	150	5.40	5.40	4.10	4.97	5.20	5.40	3.28	5.20	4.05	4.07	5.00	4.38	5.00	3.28
Calcium, mg/l Ca	200	4.06	3.84	3.08	3.66	4.04	3.82	2.5	3.66	3.26	2.94	3.25	3.15	2.80	2.5
Magnesium, mg/l Mg	100	1.32	1.44	1.12	1.28	1.30	1.40	0.8	1.25	0.90	1.30	1.00	1.04	1.10	0.8
Mercury, mg/l Hg	0.006	0.003	0.002	0.003	0.0026	0.004	0.002	0.001	0.003	0.004	0.003	0.002	0.003	0.002	0.001
Bi-carbonate, mg/l HCO_3^-	500	18.02	15.70	17.80	17.00	18.00	15.50	11.00	17.17	14.34	16.40	14.35	15.03	13.45	11.00
Nitrate, mg/l NO_3^-	50	6.16	5.12	7.00	6.09	6.15	5.10	2.40	6.05	5.20	4.07	5.22	4.83	4.90	2.40
Phosphate, mg/l PO^{-3}	0.05	0.10	0.07	0.06	0.07	0.05	0.05	0.01	0.053	0.04	0.03	0.04	0.036	0.54	0.01
Sulphate, mg/l SO_4^-	400	4.55	4.90	5.05	4.83	4.60	4.80	3.00	4.80	4.70	4.60	4.68	4.66	4.00	3.00

Iron, mg/l Fe	<0.1	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.016	0.02	0.20	0.30	0.23	0.10	0.008
Sodium, mg/l Na	200	6.02	5.58	6.40	6.00	6.00	5.60	6.50	6.03	6.40	5.80	6.40	6.20	5.30	4.30
Potassium, mg/l K	50- *70*	1.84	1.42	1.48	1.58	1.80	1.40	1.50	1.57	1.20	1.90	1.21	1.45	1.32	0.80
Lead, mg/l Pb	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.02	0.02	0.02	0.01	1.67	0.02	Trace
Copper, mg/l Cu	2.00	0.95	1.00	1.20	1.05	0.85	0.72	0.94	0.84	0.96	1.30	1.10	1.12	0.70	ND
Cadmium, mg/l Cd	0.003	0.004	0.005	0.004	0.004	0.003	0.004	0.004	0.0036	0.004	0.005	0.003	0.004	0.002	ND
Aluminum, mg/l Al	0.10max	0.006	0.005	0.007	0.006	0.004	0.003	0.005	0.003	0.004	0.006	0.005	0.005	0.003	0.002
Zinc, mg/l Zn	5.00	1.40	1.46	1.33	1.39	1.54	1.48	1.50	1.49	1.29	1.35	1.40	1.35	1.20	Trace
Nickel, mg/l Ni	0.07	0.05	0.04	0.05	0.046	0.03	0.05	0.06	0.06	0.04	0.05	0.06	0.03	0.01	ND
Chromium, mg/l Cr	0.05	0.02	0.03	0.04	0.03	0.03	0.04	0.03	0.033	0.02	0.04	0.03	0.03	0.01	ND
Total bacteria count, cfu/ml	Absent	4.5×10^{4}	$3.5.0\times10^{4}$	4.0×10^{4}	$3.0x\ 10^{4}$	2.0×10^{3}	3.0×10^{3}	1.3×10^{3}	$2.1x\ 10^{3}$	1.0×10^{3}	1.0×10^{3}	1.3×10^{3}	$1.1x\ 10^{3}$	$0.8x\ 10^{3}$	$0.2\ x\ 10^{3}$
Total Coliform Count, cfu/ml	Absent	2.3×10^{2}	3.0×10^{2}	5.0×10^{2}	$3.1x\ 10^{2}$	2.0×10^{3}	3.0×10^{3}	4.0×10^{3}	$3.0\ x10^{3}$	3.3×10^{3}	3.0×10^{3}	$3.x10^{3}$	$4.1x\ 10^{3}$	$1.0x\ 10^{3}$	$0.5\ x\ 10^{3}$
Total E. Coli Count, cfu/ml	Absent	1.0×10^{2}	1.3×10^{2}	1.0×10^{2}	$1.1x\ 10^{2}$	2.0×10^{2}	3.0×10^{2}	4.0×10^{2}	$3.0x\ 10^{2}$	4.0×10^{3}	4.0×10^{3}	4.3×10^{3}	$4x\ 10^{3}$	$2.0x\ 10^{3}$	$0.2\ x\ 10^{3}$

$SSWS_1$ - Egbu

$SSWS_2$ – Timber Market

$SSWS_3$ – FUTO

DOWNSTREAM - Mbirichi

WHO – World Health Organization (2011)

Table 4.2: Physical and Bio-chemical Characteristics of Sediment Samples

Parameters	FME Standard	$SSWS_1$	$SSWS_2$	$SSWS_3$	DOWNSTREAM	CONTROL POINT
Ph	6.5	5.8	5.90	6.30	6.45	6.48
Conductivity, µS/cm	100	11	12	15	13	10
Total chloride, mg/kg Cl^-	250	125.80	140.69	162.45	130.25	100
Calcium, mg/kg Ca	200	5.00	3.68	4.40	3.80	2
Magnesium, mg/kg Mg	100	0.50	3.00	4.00	3.50	2
Carbonate, mg/kg CO^-_3	150	90	114	100	97	52
Mercury, mg/kg Hg	0.001	0.10	0.13	0.15	0.18	ND
Bi-carbonate, mg/kg HCO^-_3	30	7.70	9.07	8.00	12.20	10
Nitrate, mg/kg NO^-_3	205,80	6.90	5.40	5.50	7.00	4.00
Phosphate, mg/kg PO^{-3}_4	>100	60	54	46	50	35
Sulphate, mg/kg SO^-_4	100	65.00	60	76	58	45
Iron, Mg/kg Fe	1	0.4	0.3	0.4	0.30	0.1
Sodium, mg/kg Na	NS	20.96	21.40	22.00	100.20	45.20
Potassium, mg/kg K	>100	6.77	6.98	6.70	6.89	5
Lead, mg/kg Pb	0.05	0.08	0.07	0.06	0.05	ND
Copper, mg/kg Cu	2	0.55	0.88	0.95	0.80	ND
Cadmium, mg/kg Cd	0.1	0.32	0.28	0.30	0.25	ND
Aluminum, mg/kg Al	<0.01	0.006	0.005	0.004	0.003	0.002
Zinc, mg/kg Zn	5	3.3	4	2.5	2.00	1.50
Total Bacteria Count, cfu/g	NS	3.5×10^4	5.0×10^4	6.5×10^4	2.0×10^4	1.5×10^2
Total Coliform Count, cfu/g	NS	6.4×10^3	2.0×10^3	2.5×10^3	0.8×10^3	0.5×10^2
Total E. Coli Count, cfu/g	NS	2.0×10^3	1.0×10^3	1.1×10^3	0.5×10^3	0.5×10^2

NS- No Standard
ND- Not Detected

4.1.1 Physical and Bio-Chemical Characteristics of Water Samples

Physical and Chemical Parameters

pH

The hydrogen index (pH) is a parameter that indicates the acidity or alkalinity of a water sample. pH is a simple parameter but is extremely important, since most of the chemical reactions in aquatic environment are controlled by any change in its value. Anything either highly acidic or alkaline would kill marine life (Pravin *et al.*, 2011). The pH of the Otamiri river at $SSWS_1$, $SSWS_{2,}$ $SSWS_3$ and Downstream were 6.45, 6.58, 6.45 and 6.50 respectively (Table 4.1) with a control point value of 6.60. These values do not conform to WHO (2011) standard for safe water. The lowest mean pH value (6.45) representing highest mean acidity was obtained at $SSWS_1$ and $SSWS_3$ respectively while the highest (6.58) representing lowest acidity was obtained at $SSWS_2$ (Figure 4.1). The pH values indicate that the Otamiri River is acidic. As acidity of surface water increases, submerged aquatic plants decreases and deprives water fowls of their basic food source (Ahiarakwem, 2013). At pH of 6.0, freshwater shrimp cannot survive; at pH of about 5.50, bottom-dwelling bacteria decomposer begins to die leaving un-decomposed leaf litter and other organic debris to collect on the bottom (Ahiarkwem, 2013). This deprives planktons their food resulting in their death. As un-decomposed organic leave litter increases due to the loss of bottom- dwelling bacteria, toxic metals such as aluminums, mercury and lead within the litter are released. These toxic metals are inimical to the human health (Bourodemos, 1974). It is therefore imperative to monitor the pH of the river on a regular basis so as to guard against the introduction of aluminium and the other toxic metals from the above-mentioned process into it. Below pH value of about 4.50, all fish will die (Bourodemos, 1974). On the basis of the pH values of the river, pre-use treatment with sodium bicarbonate is recommended.

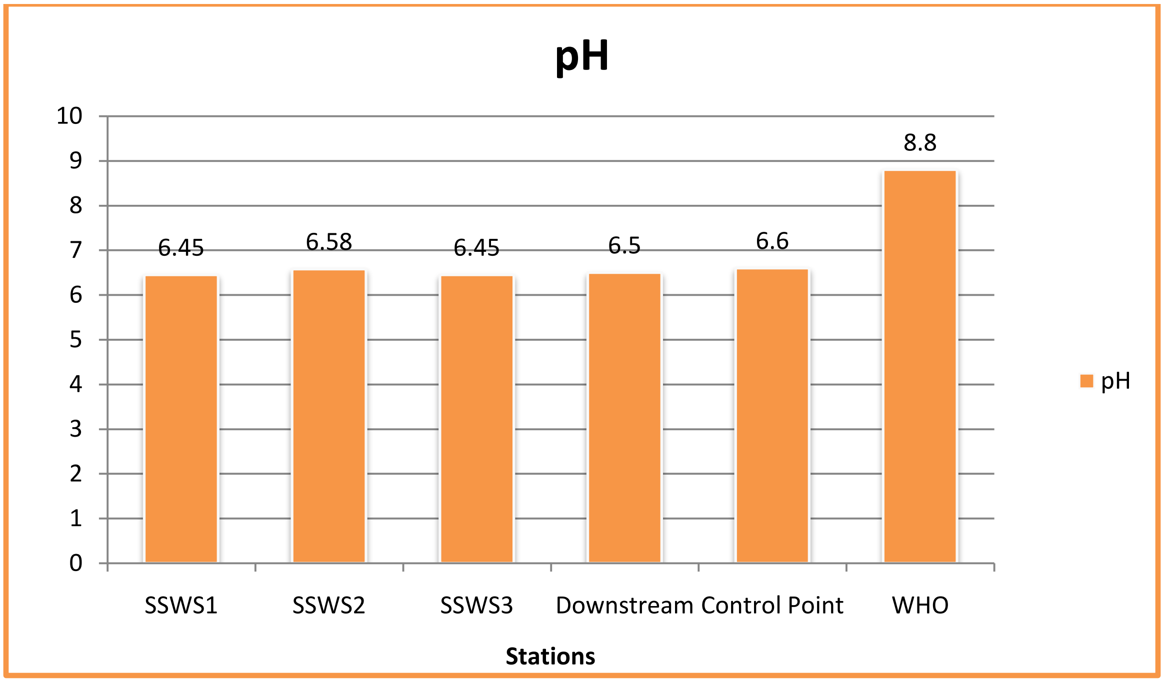

Figure 4.1: Bar Chart Showing the Mean pH Variations for water

Electrical Conductivity and TDS

The mean concentrations of electrical conductivity of the waters of Otamiri River at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream were 14.83, 15.53, 11.70 and 10.30 µS/cm respectively (Table 4.1 and Figure 4.2) with control point value of 9.30 µS/cm while the mean concentrations of total dissolved solids (TDS) were 8.89, 9.32, 11and 10.05 mg/l respectively (Table 4.1 Figure 4.3) with control point value of 9.50 mg/l. The concentrations of TDS and electrical conductivity conformed to WHO (2011) standard for safe drinking water. The TDS values indicates that the river is fresh (Carol, 1962) while the electrical conductivity values shows no salinity hazards (Todd, 1980).The lowest mean electrical conductivity values were obtained at $SSWS_3$ and the lowest values for TDS were obtained at $SSWS_1$ while the highest values for electrical conductivity were at $SSWS_2$ and the highest values for TDS was at $SSWS_3$.

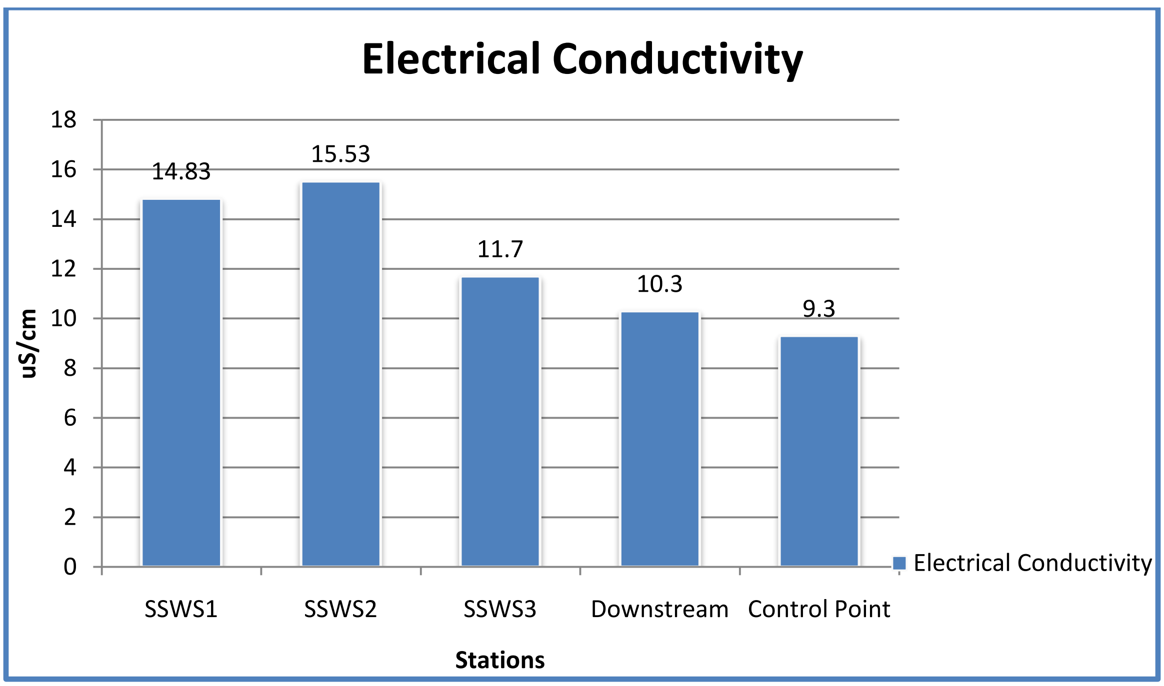

Figure 4.2: Bar Chart Showing the Mean Variations of Electrical Conductivity for water

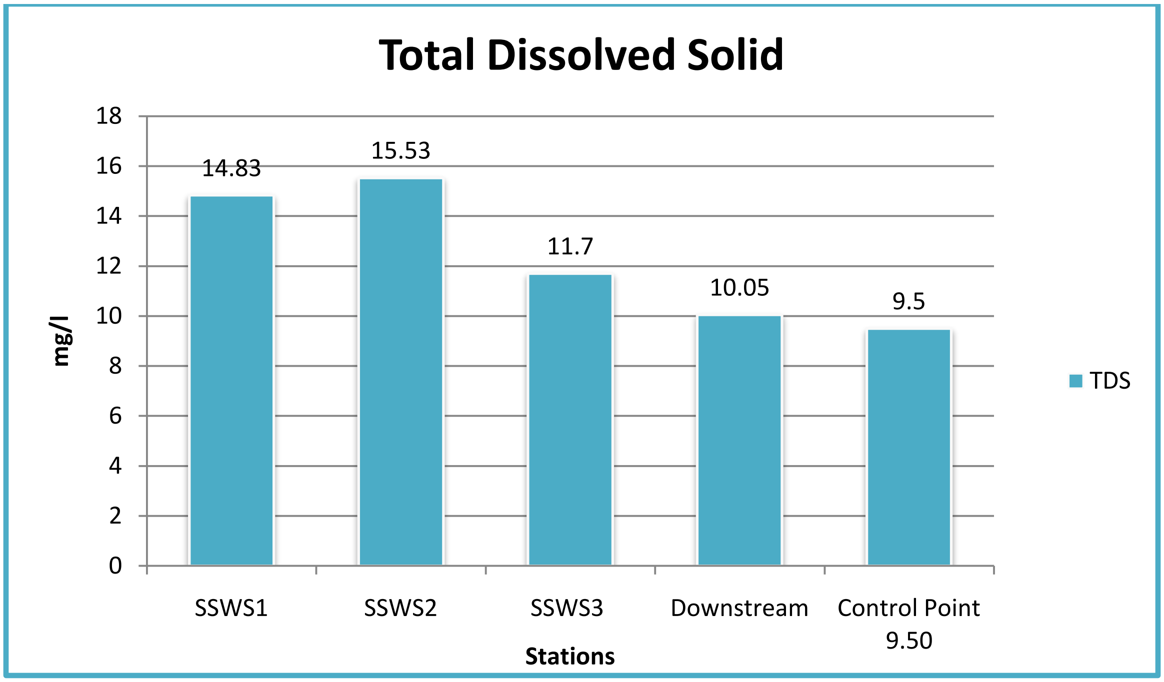

Figure 4.3: Bar Chart Showing the Mean Variations of Total Dissolved Solids for water

Total Hardness, Calcium Hardness and Magnesium Hardness

The total hardness values were 13.20, 13.13, 11.19 and 10.50 mg/l respectively at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream (Table 4.1 and Figure 4.4) with control point value of 9.53 mg/l. These values were less than 50mg/l and thus indicate that the water is soft (Wilcork, 1993). The calcium hardness values were 8.23, 7.43, 6.82 and 5.80 mg/l respectively with control point values of 4.45 mg/l. These values conformed to the (WHO, 2011) guideline of 150mg/l $CaCO_3$. For magnesium hardness the mean values were 4.97, 5.20, 4.38 and 5.00 mg/l respectively for at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream with control point value of 3.28 mg/l. The values conform to WHO (2011) guideline of 150mg/l $MgCO_3$.

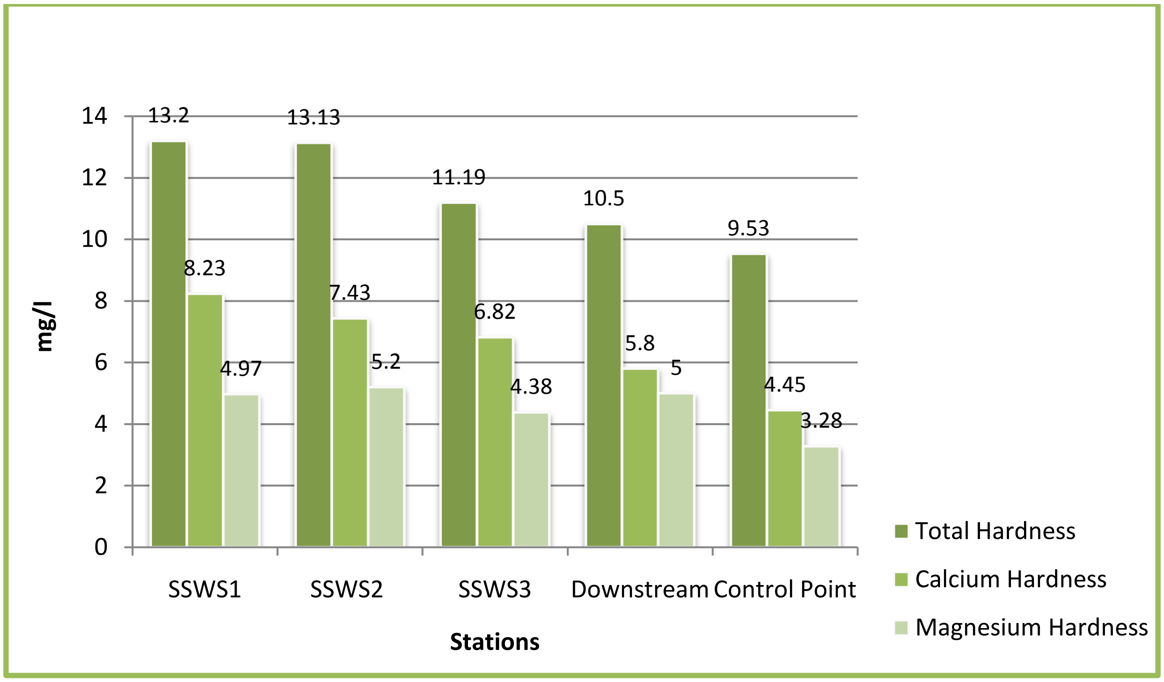

Figure 4.4: Bar Chart Showing the Mean Variations of Total Hardness, Calcium hardness and magnesium hardness for water

Turbidity, Appearance and Odour

The mean concentrations values for turbidity were 10.37, 11.00, 12.95 and 8.50 NTU respectively at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream (Table 4.1 and Figure 4.5) with control point value of 4.50 NTU which exceed the permissible limit with highest value at $SSWS_3$ and the lowest value at $SSWS_1$. The river waters are slightly turbid at $SSWS_1$, turbid at $SSWS_2$ and turbid at $SSWS_3$ in terms of appearance while the control point indicates clear. Turbidity in water arises from the presence of very finely divided solids (which are not filterable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. As turbidity can be caused by sewage matter in water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant.

The odour of the water is objectionable and the control point also is objectionable which was below the WHO (2011) guideline for drinking water. Odour indicates some toxic pollution of the river. Water may smell due to the presence of decaying organic matter. The decaying organic matter may accumulate in bottom where conditions are suitable for the anaerobic bacteria. Sources of the organics include plant debris washed into streams, dead animals, microorganisms, and wastewater.

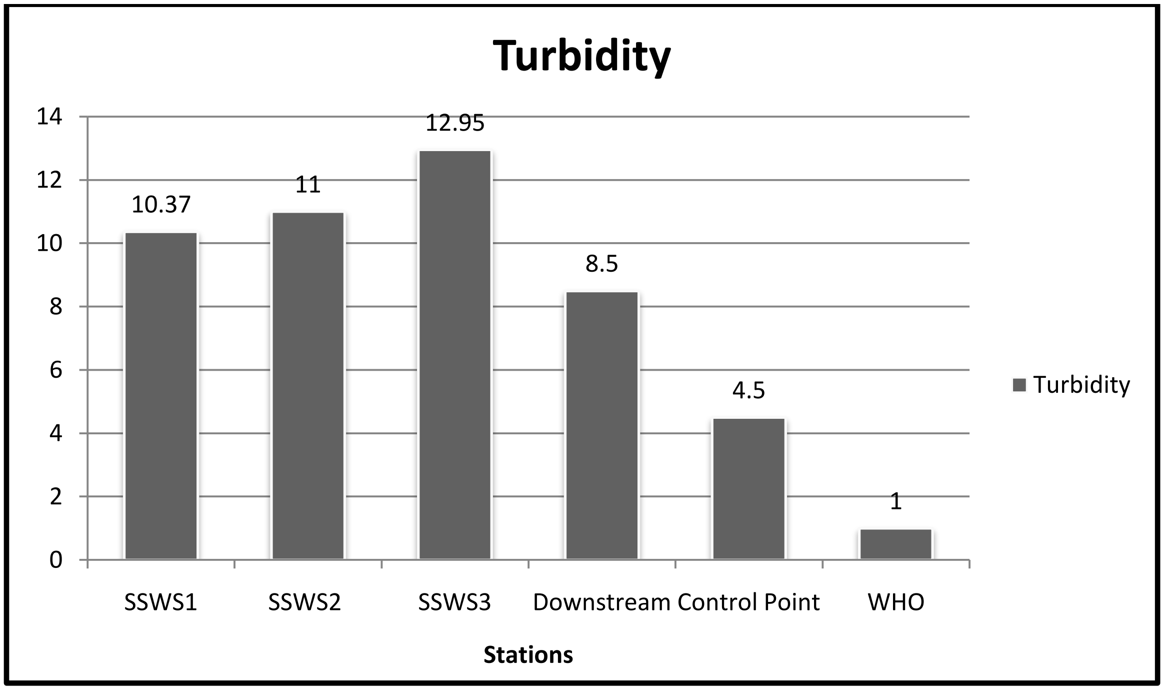

Figure 4.5: Bar Chart Showing the Mean Variations of Turbidity for water

Total Chloride

The mean concentration values for total chloride were 5.20, 5.27, 4.74 and 3.30 mg/l respectively at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream (Table 4.1 and Figure 4.6) with control point value of 2.10 mg/l. These values conform to the WHO (2011) guideline values which is 400mg/l Cl^-.

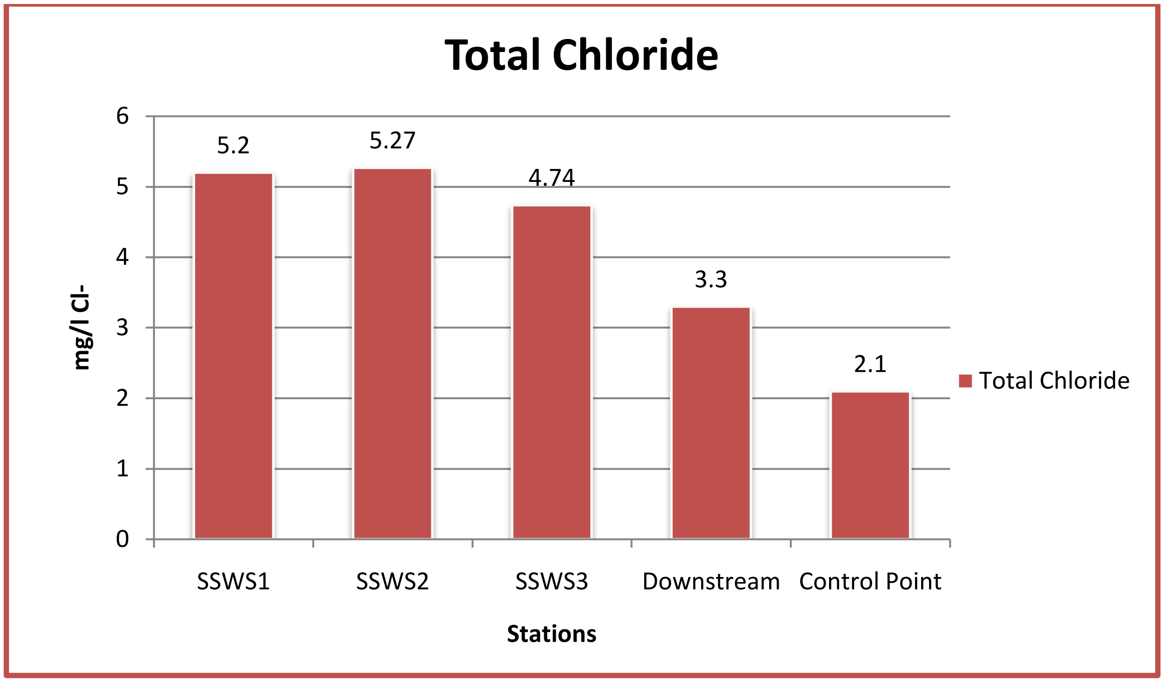

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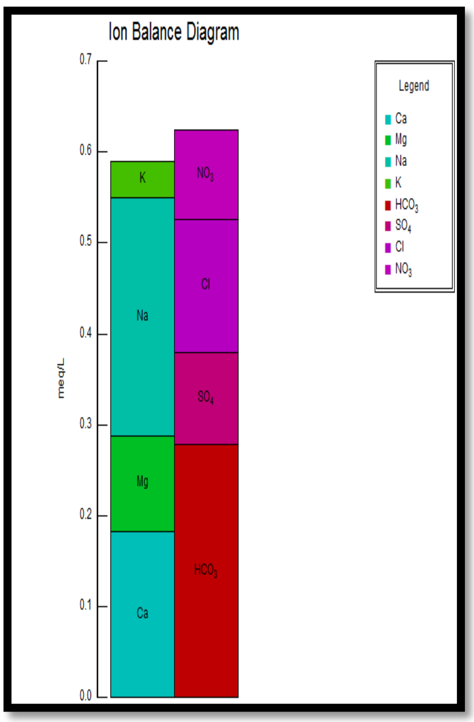
Figure 4.6: Bar Chart Showing the Mean Variations of Total Chloride for water

Chemical Parameters

Major Cations and Anions

The mean concentrations of Ca^{2+} at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream were 3.66, 3.66, 3.15 and 2.80 mg/l respectively (Table 4.1) with control point value of 6.25 mg/l while the mean concentrations of Mg^{2+} were 1.28, 1.25, 1.05 and 1.10 mg/l respectively with control point value of 0.8 mg/l. The mean concentrations of Na^+ were 6.00, 6.03, 6.20 and 5.30 mg/l respectively with control point value of 4.30 mg/l while the mean values of K^+ were 1.58, 1.57, 1.45 and 1.32 mg/l respectively with control point value of 0.80 mg/l. Sources of sodium (Na^+) are halite (NaCl), sea spray, hot springs, brines and some silicates or rare minerals such as nahcolite ($NaHCO_3$).

The concentrations of the major constituent cations are generally low and conformed to WHO (2011) standard for safe drinking water. The relative abundance of the major constituent cations follows the trend $Na^+ > Ca^{2+} > K^+ > Mg^{2+}$. The mean concentrations of HCO_3^- at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream are 17, 17.17, 15.03 and 13.45 mg/l respectively with control point value of 11.00 mg/l while the mean concentrations of SO_4^{2-} are 4.83, 4.80, 4.66 and 4.00 mg/l respectively with control point value of 3.00 mg/l. Most bicarbonate ions in surface water are derived from carbon dioxide in the atmosphere, carbon dioxide in the soil and dissolution of carbonate rocks. Water containing more than 1000 mg/l sulfate are harmful for plants (Sagnak, 2010). The mean values for NO_3^- were 6.09, 6.05, 4.83 and4.90 respectively with control point value of 2.40 mg/l. Nitrogen fertilizers are widely used in agricultural practice, organic nitrogen is present in number of waste products, notably sewage effluents, animal excrement and manure and municipal wastes. The mean values of Cl^- were 5.20, 5.27, 4.74 and 5.30 mg/l respectively with control value of 3.50 mg/l. The major anions were within the WHO (2011) standard for safe drinking water. High concentrations of chloride can occur near sewage and other waste outlets. Chloride ion cause severe problem in the crops at concentration >350 mg/l (Hopkins *et al*., 2007). The relative abundance of major anions follow the trend HCO_3^- > NO_3> Cl^- > SO_4^{2-}. The water type is Sodium Bicarbonate ($NaHCO_3^-$) and this is typical of most surface water resources in Southeastern Nigeria (Ahiarakwem, 2013). The ionic balance and pie chart concentration in meq/l at the three stations and control point are shown in Figure 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14 and 4.15 respectively.



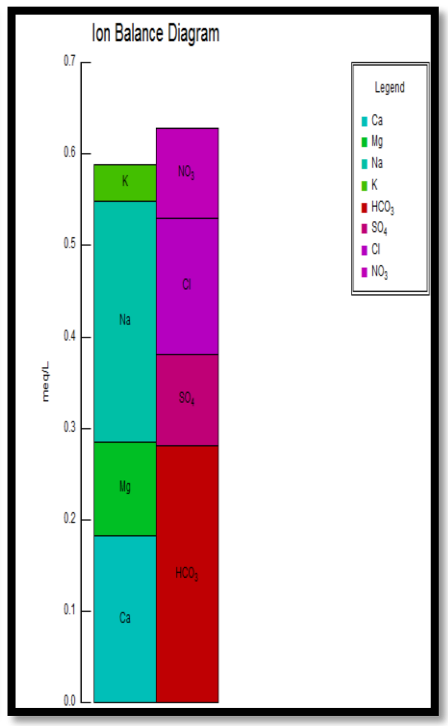
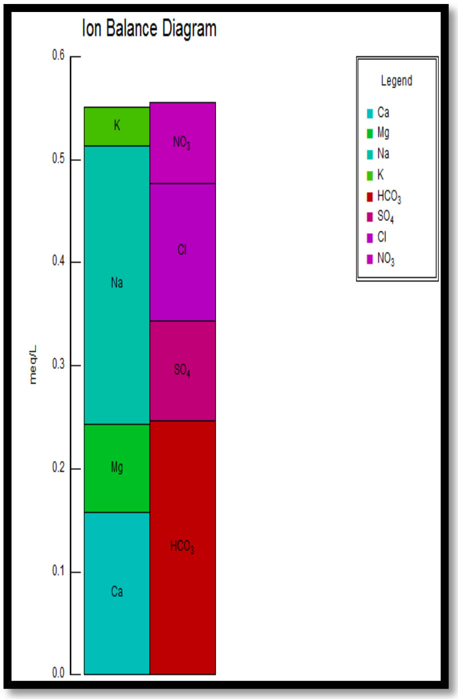


Figure 4.7: Ionic Balance for $SSWS_1$ Figure 4.8: Ionic Balance for $SSWS_2$



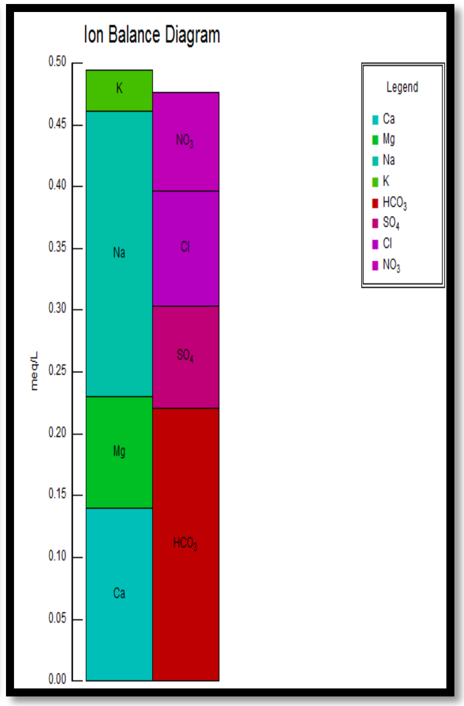


Figure 4.9: Ionic Balance for SSWS$_3$ **Figure 4.10: Ionic Balance for Downstream**

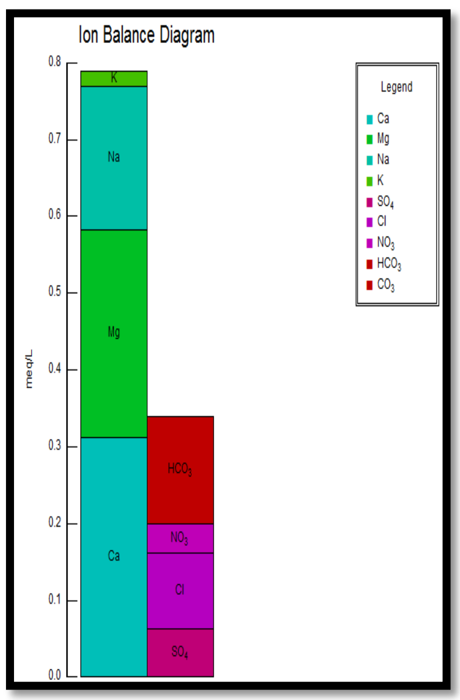
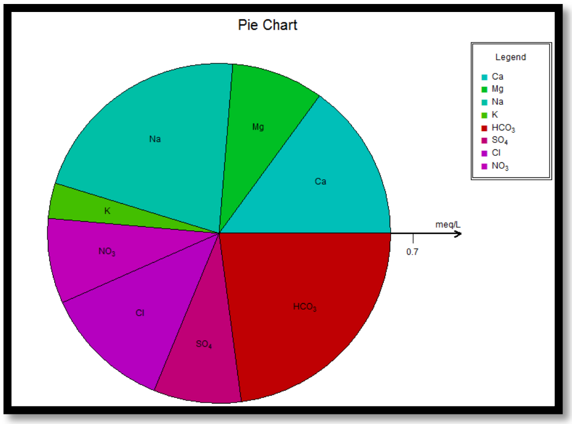


Figure 4.11: Ionic Balance for Control Point



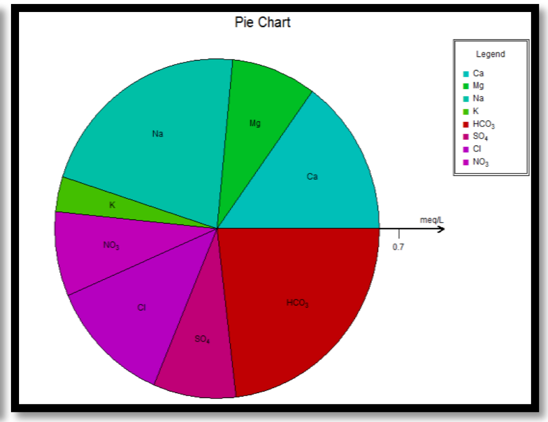
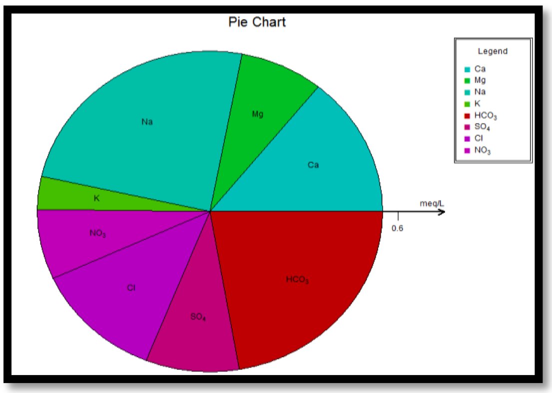


Figure 4.12: Pie Chart Sat $SSWS_1$

Figure 4.13: Pie Chart at $SSWS_2$



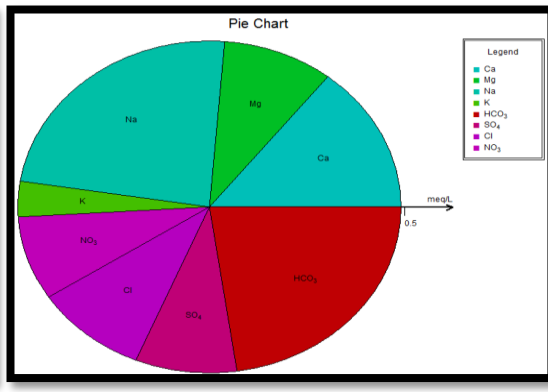


Figure 4.14: Pie Chart at $SSWS_3$

Figure 4.15: Pie Chart at Downstream

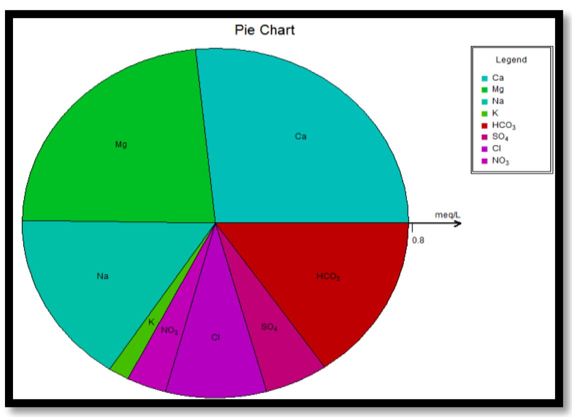


Figure 4.16: Pie Chart at Control Point

Table 4.3: The Mean Concentrations of Constituents of Otamiri River waters in Milliequivalent/Liter (meq/l)

Parameters	Equivalent mass	$SSWS_1$		$SSWS_2$		$SSWS_3$		DOWNS		CON		SSW_1	$SSWS_2$	$SSWS_3$	DOWN	CON
		Mean (mg/l)	Mean (meq/l)	Mean (mg/l)	Mean (meq/l)	Mean (mg/l)	Mean (meq/l)	Mean (mg/l)	Mean (meq/l)	Mean (mg/l)	Mean (meq/l)	%	%	%	%	%
Ca	20	3.66	0.183	3.66	0.183	3.15	0.158	2.80	o.14	2.50	0.125	31.01	31.17	28.67	28.39	31.56
Mg	12.2	1.28	0.105	1.25	0.102	1.05	0.086	1.10	0.09	0.80	0.065	17.79	17.37	15.60	18.25	16.41
Na	23	6.00	0.261	6.03	0.262	6.20	0.270	5.30	0.23	4.30	0.186	44.23	45.48	49.00	46.65	46.96
K	39.1	1.58	0.041	1.57	0.040	1.45	0.086	1.32	0.033	0.80	0.020	6.94	6.81	6.71	6.69	5.06
TOTAL CATIONS (meq/l)			**0.590**		**0.587**		0.270		**0.493**		**0.396**	**100**	**100**	**100**	**100**	**100**
HCO_3^-	61	17	0.279	17.17	0.281	15.03	0.246	13.45	0.220	11.00	0.180	44.35	44.74	44.32	46.41	53.09
SO_4^{2-}	48	4.83	0.101	4.80	0.100	4.66	0.097	4.00	0.083	3.00	0.062	16.05	15.92	17.47	17.51	18.28
NO_3	62	6.09	0.098	6.05	0.098	4.83	0.078	4.90	0.079	2.40	0.038	15.58	15.60	14.05	16.67	11.20
Cl^-	35.5	5.20	0.146	5.27	0.149	4.74	0.134	3.30	0.092	2.10	0.059	23.21	23.72	24.14	19.41	17.40
TOTAL ANIONS (meq/l)			**0.629**		**0.628**		**0.555**		**0.474**		**0.339**	**100**	**100**	**100**	**100**	**100**
SAR			**0.97**		**0.98**		**1.09**		**0.68**		**0.60**					

4.2 GEOCHEMICAL MODELS

For the purpose of interpretation using geochemical models, the following parameters were used; Na^{+}, Ca^{2+}, K^{+} and Mg^{2+} for cations while the anions were HCO_3^{-}, NO_3, Cl^{-} and SO_4^{2-}. Their values in milligram per liter were converted to milli-equivalent per liter and were further used to generate Piper's trilinear, Durov, Stiff and Scholler diagrams.

Piper Diagram

Piper Diagrams (Piper, 1944), are a combination anion and cation triangles that lie on a common baseline diamond shape between them can be used to make a tentative conclusion as to the origin of the water represented by the analysis and to characterize different water types. Piper divided waters into four basic types according to their placement near the four corners of the diamond. Water that plots at the top of the diamond is high in Ca^{2+} + Mg^{2+} and Cl^{-} + SO_4^{2-}, which results in an area of permanent hardness. The water that plots near the left corner is rich in Ca^{2+} + Mg^{2+} and HCO_3^{-} and is the region of water of temporary hardness. Water plotted at the lower corner of the diamond is primarily composed of alkali carbonates (Na^{+} K and HCO_3^{-} + CO_3^{2-}). Water lying near the right-hand side of the diamond may be considered saline (Na^{+} K and Cl^{-} + SO_4^{2-}).

From the plot (Figure 4.17), it is seen that all the three stations fall within the central part of the diamond indicating that they are Ca – HCO_3 water (typical of shallow, fresh surface waters) to Na-Cl waters (typical of marine waters).

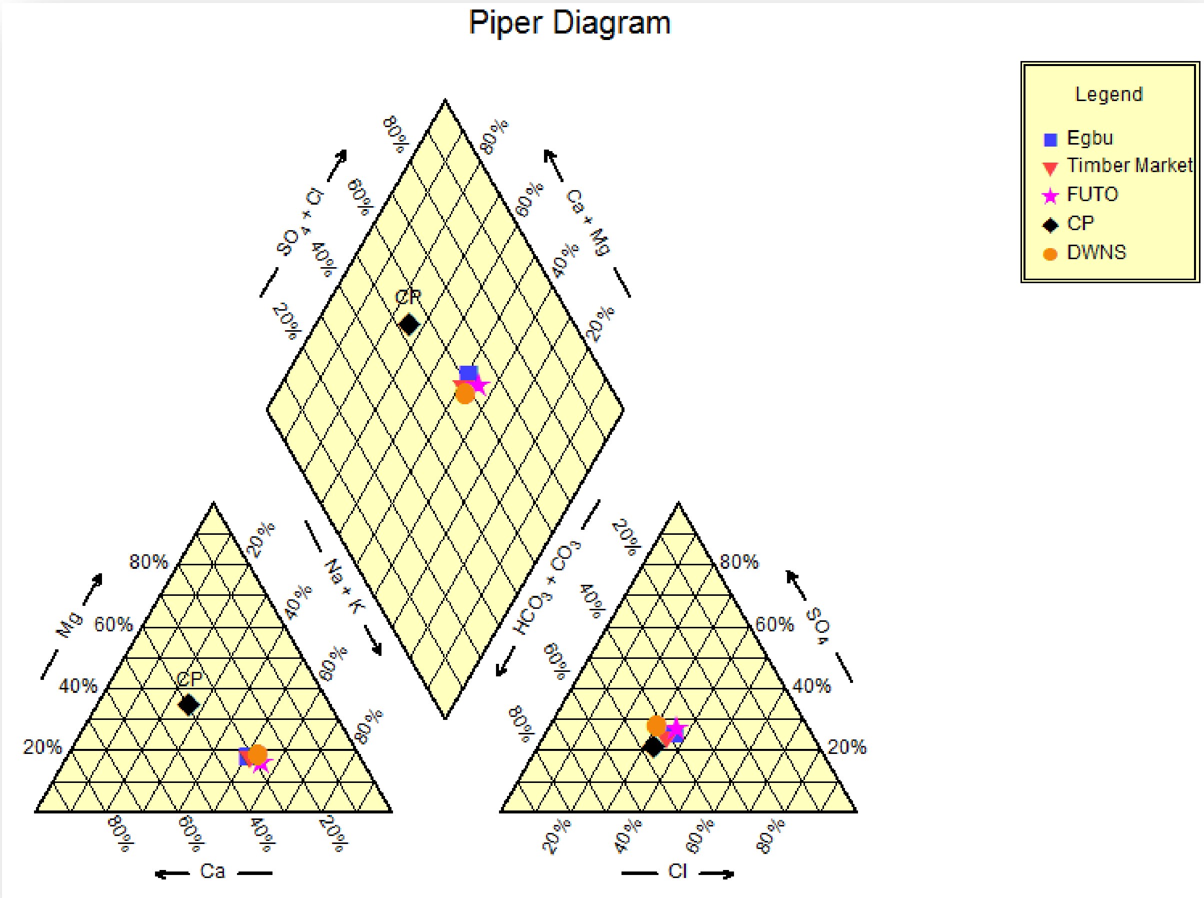


Figure 4.17: Piper Diagram Showing the major Cations and Anions

Durov Diagram

Durov, (1948) introduced this diagram which provides more information on the hydrochemicalfacies by helping to identify the water types and it can display some possible geochemical processes that could help in understanding quality of groundwater and its evaluation. The diagram is a composite plot consisting of 2 ternary diagrams where the cations of interest are plotted against the anions of interest; sides form a binary plot of total cation vs. total anion concentrations; expanded version includes electrical conductivity (µS/cm) and pH data added to the sides of the binary plot to allow further comparisons. The pH part of the plot reveals that water in the river is acidic which is not good for drinking. The electrical conductivity of river lies in the range of WHO (2011) standard for drinking water (Figure 4.18).

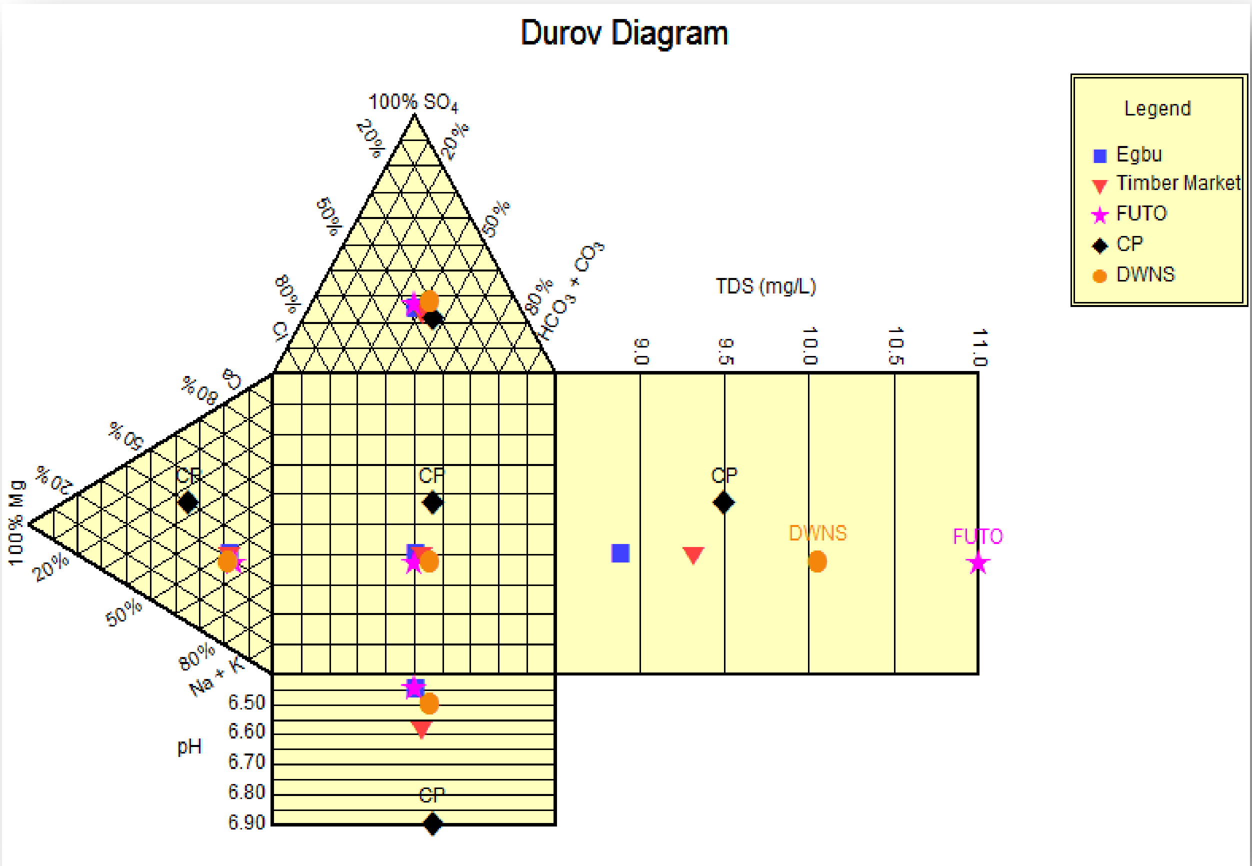


Figure 4.18: Durov Diagram Showing the major Cations and Anions

Scholler Diagram

Schoeller (1977) diagram is also used to present average chemical composition of waters from Otamiri River at the three stations. The relative tendency of ions in mg/l shows Na^{+} > Ca^{2+} > K^{+} > Mg^{2+} and HCO_3^{-} > NO_3> Cl^{-} > SO_4^{2}. The hydrogeochemical facies identified in the study area is mainly the water type Na^{+}+K - SO_4 as shown in the plotted Scholler diagram below (Figure 4.19).

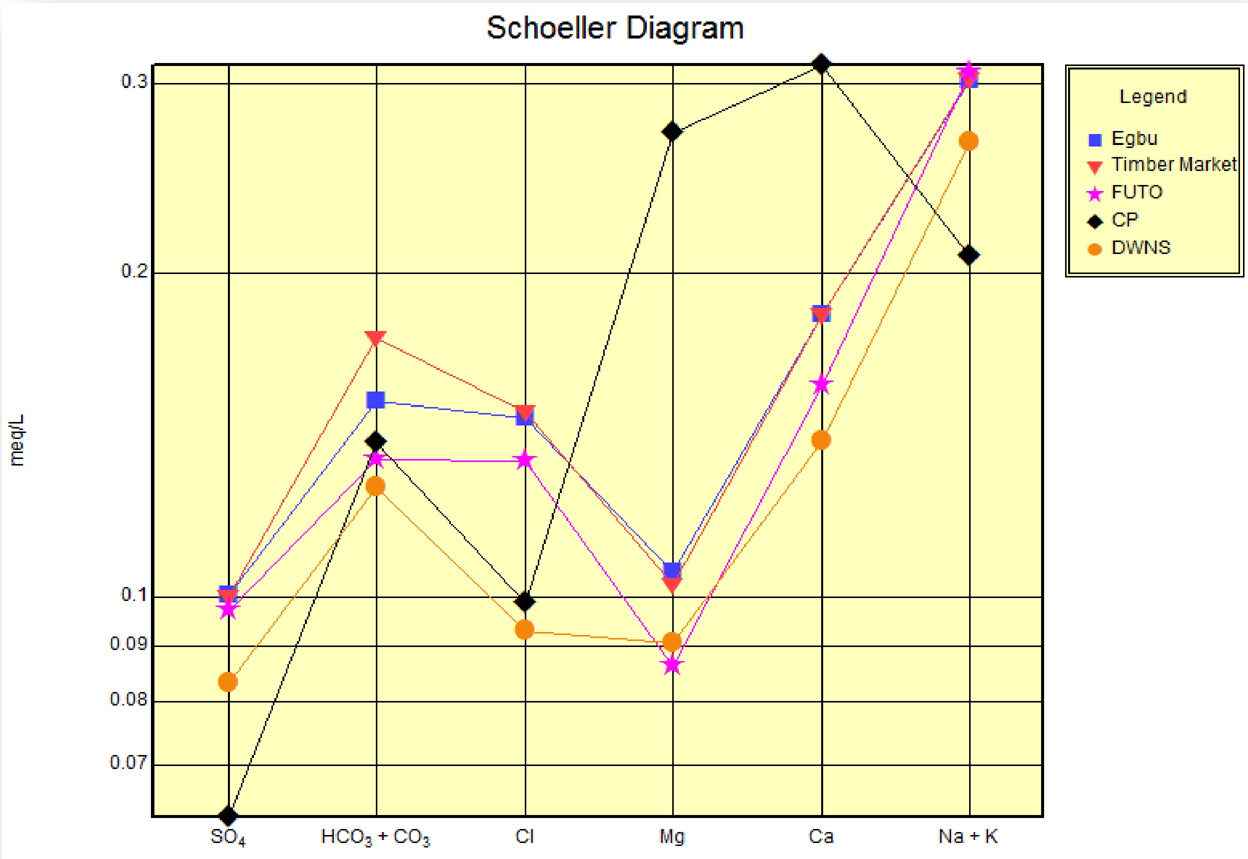


Figure 4.19: Schoeller Diagram Showing the major Cations and Anions

Stiff Diagrams

Stiff (1951) diagram is a graphical representation of the different water ions. The average ionic composition analysis by stiff diagram shown in Figure 4.20, 4.21, 4.22, 4.23 and 4.24 respectively signifies dominance of Na+ K – HCO_3 +CO_3 are nearly equal in proportion. The hydrogeochemical water types interpreted is based on the respective shapes of the different Stiff plots.

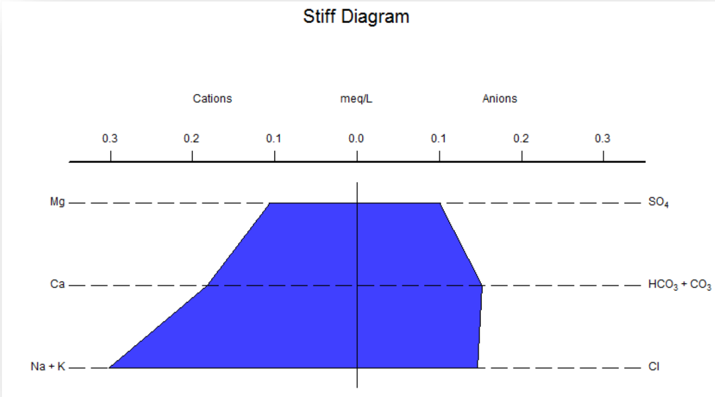


Figure 4.20: Stiff Diagram for $SSWS_1$

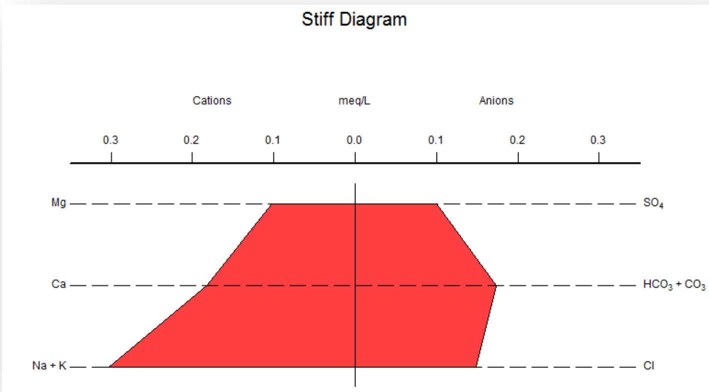


Figure 4.21: Stiff Diagram for $SSWS_2$

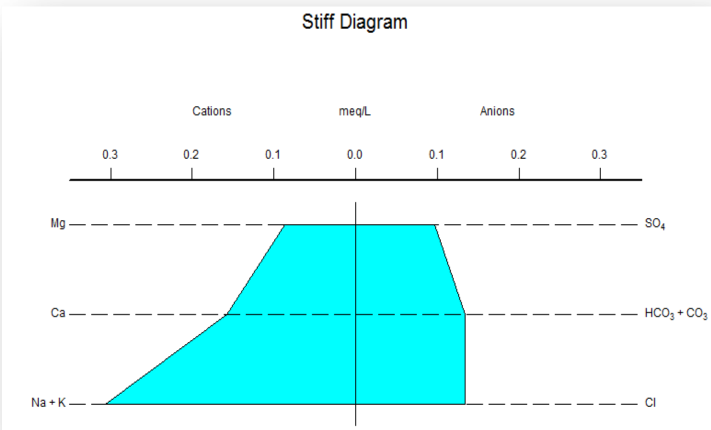


Figure 4.22: Stiff Diagram for $SSWS_3$

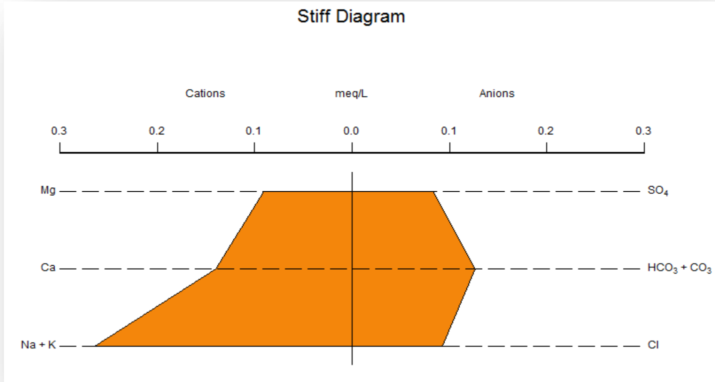


Figure 23: Stiff Diagram for Downstream

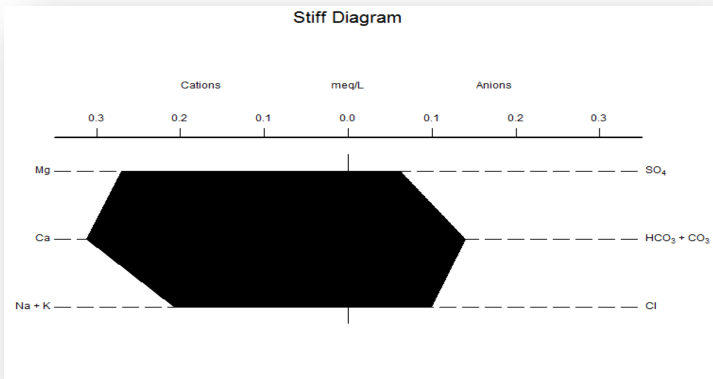


Figure 4.24: Stiff Diagram for Control Point

Heavy Metals and Other Metals in water

Iron Fe^{+}

The mean concentrations of Fe^{+} of at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream were 0.01, 0.016, 0.23 and 0.10 mg/l respectively with control point value of 0.008 mg/l (Table 4.1 and Figure 4.25). The values of $SSWS_1$ and $SSWS_2$ was within the WHO (2011) standard for drinking water while that of $SSWS_3$ and the Downstream which is 0.23 and 0.20 mg/l respectively exceeds the limit of WHO (2011) standard for drinking water. Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discoloured on cooking. Taste problems may also occur. It can also interfere with fish food and with spawning.

Copper Cu^{2+}

The mean values for Cu^{2+} were 1.05, 0.84, 1.12 and 0.70 mg/l respectively which were not detected at the control point.

Zinc Zn^{2+}

The mean concentrations of Zn^{2+} were 1.39, 1.49, 1.35 and 1.20 mg/l respectively with control point indicating just a trace of it. Zinc is essential to man but if ingested in gross amounts it has an emetic effect on human (Cancerous) and aquatic life (EPA, 2001).

Cadmium Cd^{2+}

The mean concentrations of Cd^{2+} during the study period were 0.004, 0.0036, 0.004 and 0.002 mg/l respectively in which the whole station exceeded the permissible limit for WHO (2011) standard for drinking water and was not detected at the control point. High level of Cd^{2+} in water is toxic to the kidney (Ahiarakwem, 2013), causes bone damage, cancer and highly toxic to aquatic life.

Chromium Cr^{6+}

The mean concentration of Cr^{6+} was 0.03, 0.033, 0.03 and 0.01 mg/l respectively and shows no detection at the control point. High concentrations of Cr^{6+} can cause cancer in high concentrations, aggravates diabetes (Ahiarakwem, 2013) and it can also act as a skin irritant.

Lead Pb^{2+}

The mean values of Pb^{2+} were 0.02, 0.02, 1.67 and 0.02 mg/l respectively with only a trace at the control point, where $SSWS_3$ station did not conform to the WHO

(2011) standard for safe drinking water. A high concentration of Pb^{2+} causes cancer and interference with vitamin D metabolism; it also affects mental development in infants and is toxic to the central and peripheral nervous systems (Ahiarakwem, 2013).

Nickel Ni

The mean values of Ni were 0.046, 0.06, 0.03 and 0.01 mg/l respectively with no detection at the control point. It can lead to carcinogenicity as far as humans are concerned; it also has variable harmful effects on aquatic life. It is toxic to plant life, too, and is a hazard to fish

Mercury Hg^+

While the mean concentrations of values for Hg^+ at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.0026, 0.003, 0.003 and 0.002 mg/l respectively with control point value of 0.001 mg/l.

Aluminium Al^+

The mean values for Al^+ were 0.006, 0.003, 0.005 and 0.003 mg/l respectively with control point value of 0.002 mg/l. Not originally considered to be a significant health hazard in drinking waters, aluminium has more recently been shown to pose a danger to persons suffering from kidney disorders (EPA, 2001). It causes neurological problems and has been cited as a contributory factor to Alzheimer disease (EPA, 2001).

Except for Ni, Cr^{6+}, Cu^{2+} and Zn^{2+}, the concentrations of other measured heavy metals (Cd^{2+}, Fe^+ and Pb^{2+}) were below the WHO (2011) standard for safe drinking water and thus constitute a threat to the Otamiri River. However, the concentrations of Zn^{2+}, Cr^{6+} and Cu^{2+} were quite significant and may exceed the permissible limit in the near future. The heavy metals owe their sources mainly from discarded electronic wastes (e-wastes) components of the waste dumps. Although many heavy metals are problematic environmental pollutants , nevertheless, because of their useful physical and chemical properties, some heavy metals, including , Pb^{2+}, Cd^{2+}, Zn^{2+} and Ni (to mention but a few) are intentionally are added to certain consumer and industrial products such as switches, batteries, circuit boards, cell phones, and some pigments (Ahiarakwem, 2013). These products, when discarded, are disposed in waste dumps like landfills. The disposal of discarded products that are capable of releasing heavy metals in waste dumps and landfills is more worrisome in developing Nations such as Nigeria where the importation of used electronic wares is still in vogue. This has resulted in an increase in e-wastes at landfills in developing Nations such as Nigeria and consequently a significant increase in the heavy metal contents of the recipient environment (Ahiarakwem, 2013). Excessive concentrations of heavy metals in water constitute a variety of health hazards to both humans and animals. It should be noted that ingestion of these heavy metals by aquatic life such as fish can result in serious food poisoning (Ahiarakwem, 2013). The relative abundance of the measured heavy metals at Otamiri river follow the trend $Pb^{2+} > Cd^{2+} > Fe^{+} > Zn^{2+} > Cr^{6+} > Cu^{2+} > Ni^{+}$.

This is because the waste dumps are closer to the river drainage in which the wastes are washed from land into the river and also some are disposed directly into the river especially at stations $SSWS_1$. However pre-use treatment of the water from the river is recommended. The iron can be treated using aeration or ozonation methods while other heavy metals can be treated using ascobic acid, ion exchange methods, chemical precipitation or any other standard methods.

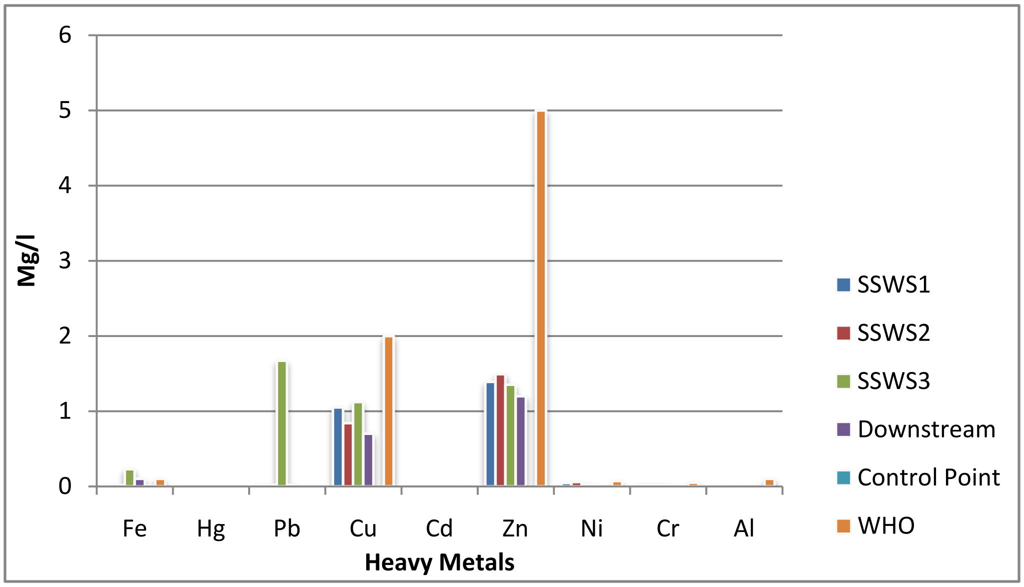


Figure 4.25: Bar Chart Showing the Relative Abundance of Heavy Metals for water

Microbiological Parameters

Total Bacteria, Coliform and E. Coli Count

The mean total coli form count of the Otamiri River at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 3.0 x 10^2, 3.0 x 10^3, 4.1 x 10^3 and 1.0 x 10^3 cfu/100 ml respectively with control point value of 0.5 x 10^3 cfu/100 ml while the mean total bacterial counts were 3.0 x 10^4, 2.0 x 10^3, 1.1 x 10^3 and 0.8 x 10^3 cfu/100 ml respectively with control point value of 0.5 x 10^3 cfu/100 ml. For the total *E. Coli.*, the mean values were 1.1 x 10^2, 3.0 x 10^2, 4 x 10^3 and 2.0 x 10^3 cfu/100 ml (Table 4) with control point value of 0.2 x 10^3 cfu/100 ml. Although the WHO guideline indicates absent, their presence in water indicates faecal contamination of the water. *Escherichia coli*, an indicator of these enterobacteria in water is harmless but the others have been implicated as the causative agent of one waterborne disease or the other (Duru *et al*., 2012). The indiscriminate disposal of diapers at dumpsites in addition to defecations within and around the watershed of the river is responsible for its poor microbial assay. The presence of bacteria in water can cause cholera, hepatitis, dysentery and typhoid. Pre-use treatment with chlorine is recommended.

4.3 SODIUM ADSORPTION RATIO (SAR)

The sodium adsorption ratio (SAR) values of the river at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.97, 0.98, 1.09 and 0.68 respectively with a control point value of 0.60 (Table 4.4). According to Wilcox (1955), water resources with SAR value of between 0 and 10 (as is the case with the Otamiri River) are classified as excellent for irrigation purpose while those with SAR value of more than 26 are classified as poor for irrigation purposes.

Table 4.4: Classification of Water Based on Sodium Absorption Ratio (SAR) (After The U.S Department of Agric, 1965)

SAR	WATER CLASS
0-10	Excellent
10-18	Good
18-26	Fair
>26	Poor

4.4 POLLUTION INDEX (PI)

The mean pollution index (PI) of the Otamiri River at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.56, 0.57, 0.56 and 0.57 respectively with Control Point value of 0.58 (Table 4.5). It has been noted that the critical value of pollution index is 1; hence pollution index of more than 1 indicates very high degree of pollution (Horton, 1965). Although, the PI is yet to reach the critical value of 1, there is need to monitor the PI value since it is already tending to 1.

Table 4.5: Pollution Index of Otamiri River

		Mean Concentration (C_{ij})					(C_{ij}/L_{ij})				
Parameters	**L_{ij}**	**$SSWS_1$**	**$SSWS_2$**	**$SSWS_3$**	**DOWN .S**	**CON**	**$SSWS_1$**	**$SSWS_2$**	**$SSWS_3$**	**DOWN. S**	**CON**
pH	8.2	6.45	6.58	6.45	6.50	6.60	0.786	0.802	0.786	0.79	0.80
TDS mg/l	1500	8.89	9.32	11	10.05	9.50	0.005	0.006	0.007	0.006	0.006
HCO_3^- mg/l	500	17	17.17	15.03	13.45	11.00	0.034	0.034	0.030	0.027	0.022
SO_4^- mg/l	400	4.83	4.80	4.66	4.00	3.00	0.012	0.012	0.011	0.01	0.007
Cl^- mg/l	400	5.2	5.27	4.74	3.30	2.10	0.013	0.013	0.011	0.008	0.005
Total							0.350	0.867	0.845	0.841	0.840
PI							0.56	0.57	0.56	0.57	0.58

4.5 MICROBIAL ASSAY FOR WATER SAMPLES

Table 4.6: Biochemical identification of some bacteria isolated from water samples from Otamiri River.

Key: A = Acidic condition, B = Basic condition, + = positive, - = negative

Stations	Most probable organism	Colony Morphology	Microscopic character	Gram Stain	Triple sugar ion agar (TSIA)						INDOLE	MOTILITY	OXIDASE	CITRATE	UREASE	CATALASE	V.P	METYL RED
					SLANT	BUTT	Glucose	Lactose	Gas	H_2S								
SSWS$_{1a}$	*Vibrio spp*	Creamy colony on nutrient agar	Rod	-	B	A	-	+	+	+	+	+	+	+	-	+	+	-
SSWS$_{1b}$	*Escherichia coli*	Creamy colony on nutrient agar	Rod	-	A	A	-	-	+	+	+	+	-	-	-	+	-	+
SSWS$_{1C}$	*Enterobacteria spp*	Mucoidal Creamy colony on nutrient agar	Rod	-	A	A	+	+	+	+	-	-	-	+	-	+	+	-
SSWS$_{2a}$	*Klebsiella spp*	Creamy colony on nutrient agar	Rod	-	A	A	-	-	+	+	-	-	-	+	-	+	-	+
SSWS$_{2b}$	*Vibrio spp*	Creamy colony on nutrient agar	Rod	-	B	A	-	+	-	-	+	+	_	+	-	+	+	-
SSWS$_{2C}$	*Klebsiella spp*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+
SSWS$_{3a}$	*Klebsiella spp*	Creamy colony on	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+

		nutrient agar																
$SSWS_{3b}$	*Escherichia coli*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	+	+	-	_	-	+	+	-
$SSWS_{3c}$	*Vibrio spp*	Creamy colony on nutrient agar	Rod	-	B	A	+	-	-	-	+	+	-	+	-	+	-	+
CONTROL POINT	*Escherichia coli*	Creamy colony on nutrient agar	Rod	-	A	A	-	-	+	+	+	+	-	-	-	+	-	+
DOWNSTREAM	*Klebsiella spp*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+

Table 4.7: Showing Most Probable Organisms in Water Samples per Stations

Stations	Most Probable Organisms			
	Vibro spp.	*Escherichia Coli*	*Enterobacteria spp.*	*Klebsiella spp.*
WS_1	✓			
WS_2		✓		
WS_3			✓	
WS_4				✓
WS_5	✓			
WS_6				✓
WS_7				✓
WS_8		✓		
WS_9	✓			
CON		✓		
DS				✓

4.6 PHYSIICAL AND BIOCHEMICAL CHARACTERISTICS OF STREAM SEDIMENTS

Physical Parameters

pH

pH is the negative logarithm of the hydrogen ion concentration of a solution and it is thus a measure of whether the liquid is acid or alkaline. The concentrations values for sediments at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 5.8, 5.90, 6.30 and 6.45 respectively with control point value of 6.48 (Table 4.2 and Figure 4.26). These values show that the sediments are slightly acidic which was below the Federal Ministry of Environment Standard (2006).

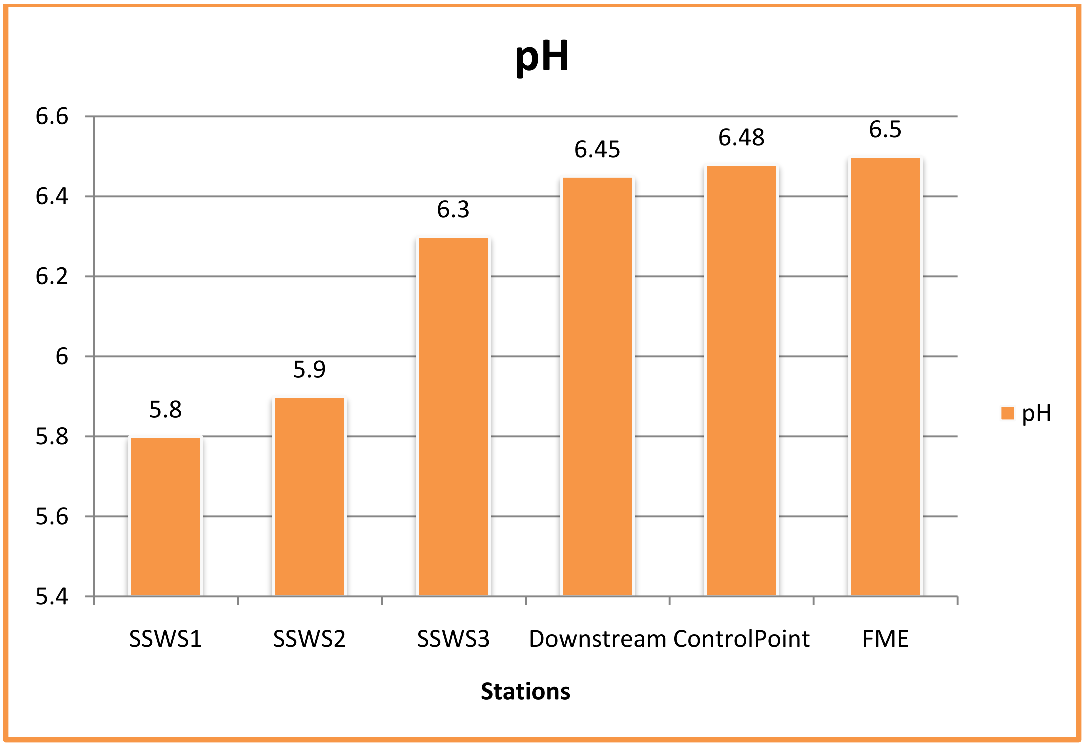


Figure 4.26: Bar Chart Showing the Mean pH Variations for Sediment

Electrical Conductivity

The values for the conductivity were 11, 12, 15 and 13 us/cm at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations respectively with control point value of 10 us/cm (Table 4.2 and Figure 4.27). These values were within the FME (2006) Standard.

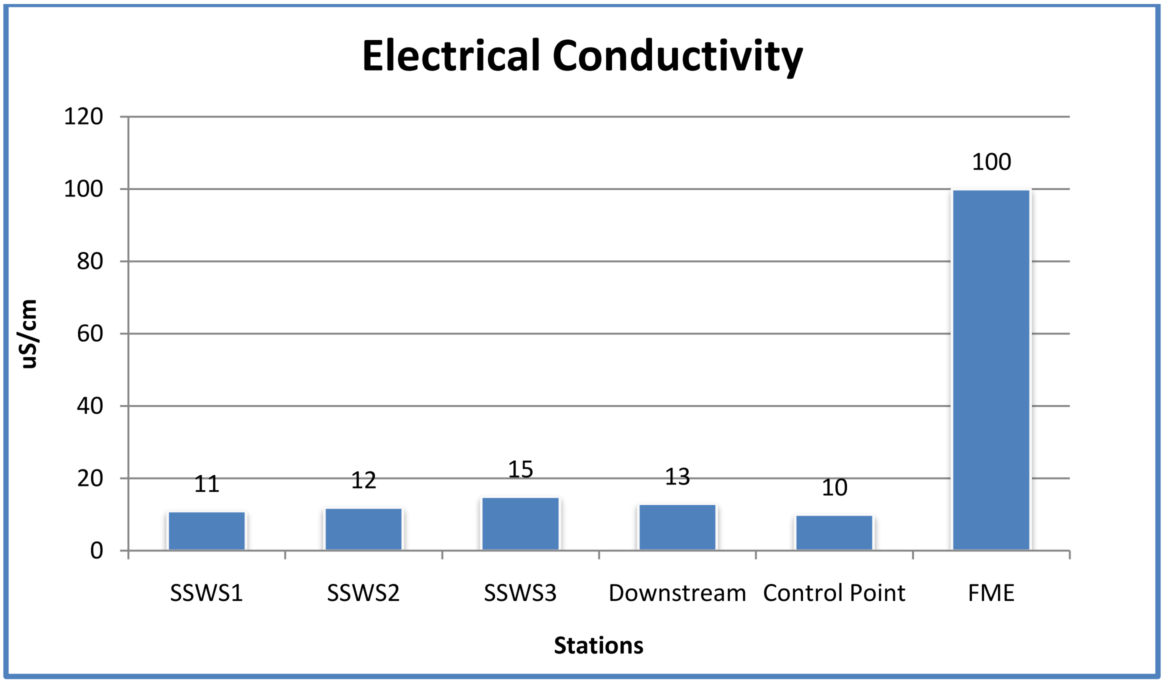


Figure 4.27: Bar Chart Showing the Mean Electrical Conductivity Variations for the Sediments

Chemical Parameters

Total Chloride

The mean concentration values for Total Chloride at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream were 125.80, 125.80, 162.45 and 130.25 mg/kg respectively with control point value of 100 mg/kg (Table 4.2 and Figure 4.28). These values were within the FME (2006) Standard. Also the control point value was in accordance to the standard.

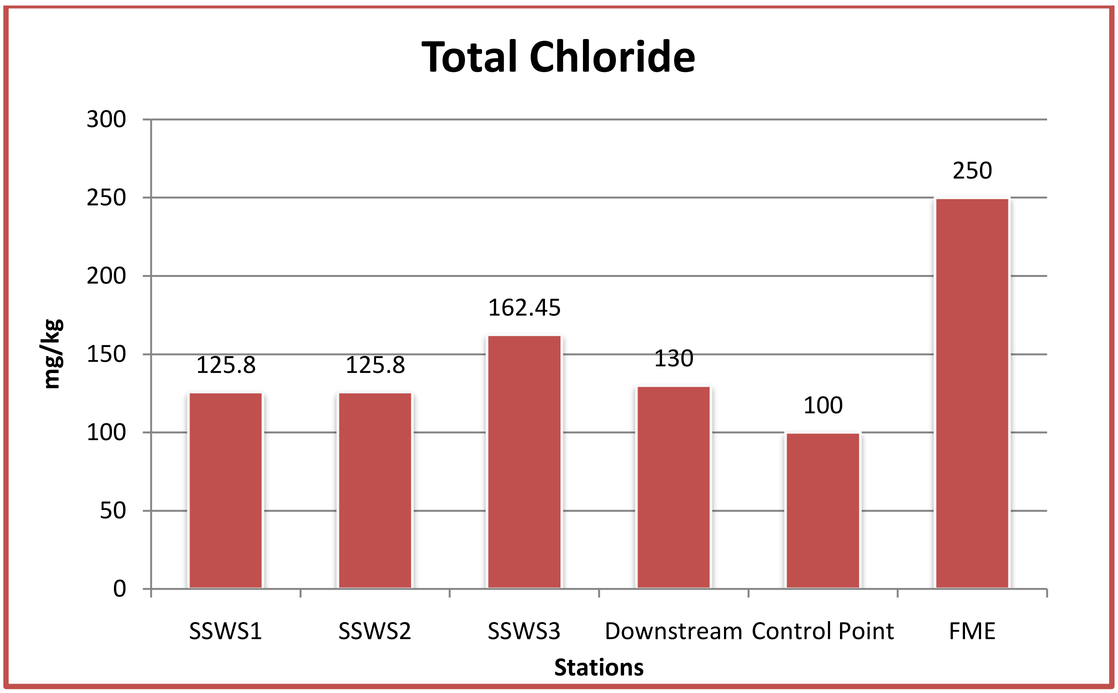


Figure 4.28: Bar Chart Showing the Mean Total Chloride Variations for sediments

Major Cations and Anions

The concentrations of Ca^{2+} at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream were 5.00, 3.68, 4.40 and 3.80 mg/kg Ca^{2+} respectively with the control point of 2 mg/kg. These values were within the FME Standard, even though the values exceeded the control point value. While the concentrations of Mg^{2+} were 0.50, 3.00, 4.00 and 3.50 mg/kg Mg^{2+} respectively with the control point of 2 mg/kg. These values were within to the FME Standard, even though the values for $SSWS_2$, $SSWS_{3,}$ and Downstream exceeded the control point value. The concentrations of Na^+ were 20.96, 21.40, 22.00 and 45.20 mg/kg Na^+ respectively with a control point of 198.00 mg/kg. While the values of K^+ were 6.77, 6.98, 6.70 and 6.89 mg/kg K^+ respectively with a control point of 5 mg/kg. These values were within to the FME Standard with all the three stations above the control point. The relative abundance of the major constituent cations follows the trend $Na^+ > K^+ > Ca^{2+} > Mg^{2+}$ (Table 4.2 and Figure 4.29). The concentration values of HCO_3^- at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations are 7.70, 9.07, 8.00 and 12.20 mg/kg HCO_3^- respectively with control point of 10 mg/kg. The values were within the FME Standard but slightly lower than the control point value. While the concentrations of SO_4^{2-} are 65.00, 60, 76 and 58 mg/kg SO_4^{2-} respectively with a control point of 45 mg/kg. These values were within the FME Standard but exceed the control point value. The concentration values of CO_3^- at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 90, 114, 100 and 97 mg/kg CO_3^- respectively with a control point of 52 mg/kg. These values fell within the FME Standard but the values exceed the control point value. While the values for PO_4^{-3} were 60, 54, 46 and 50 mg/kg respectively with a control point of 35 mg/kg PO_4^{-3} and the values fell within the FME Standard but exceeded the control point value. The values for NO_3^- were 6.90, 5.40, 5.50 and 7.00 mg/kg NO_3^- respectively with a control point of 4.00 mg/kg. These values were also within the FME Standard but were above the control point value. The values for Cl^- were 125.80, 140.69, 162.45 and 130.25 mg/kg Cl^- respectively at $SSWS_1$, $SSWS_2$ and $SSWS_3$ stations of Otamiri River with a control point value of 100 mg/kg. These values likewise fell within the FME (2006) Standard but exceed the control point value. The relative abundance of major anions follow the trend $Cl^- > CO_3^- > PO_4^{-3} > SO_4^{2-} > HCO_3^- > NO_3$ (Table 4.2 and Figure 4.30).

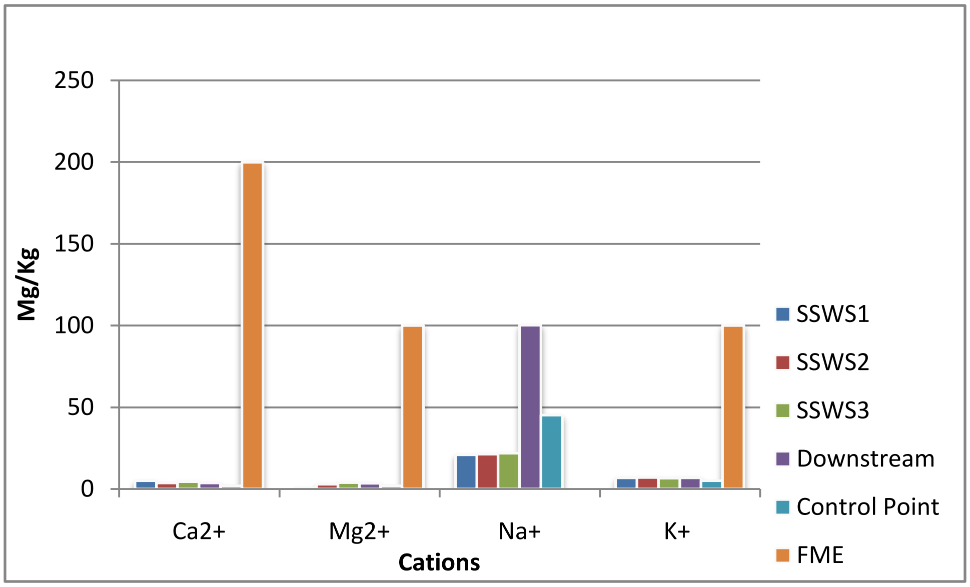


Figure 4.29: Bar Chart Showing the Mean Variations of Cations for sediments

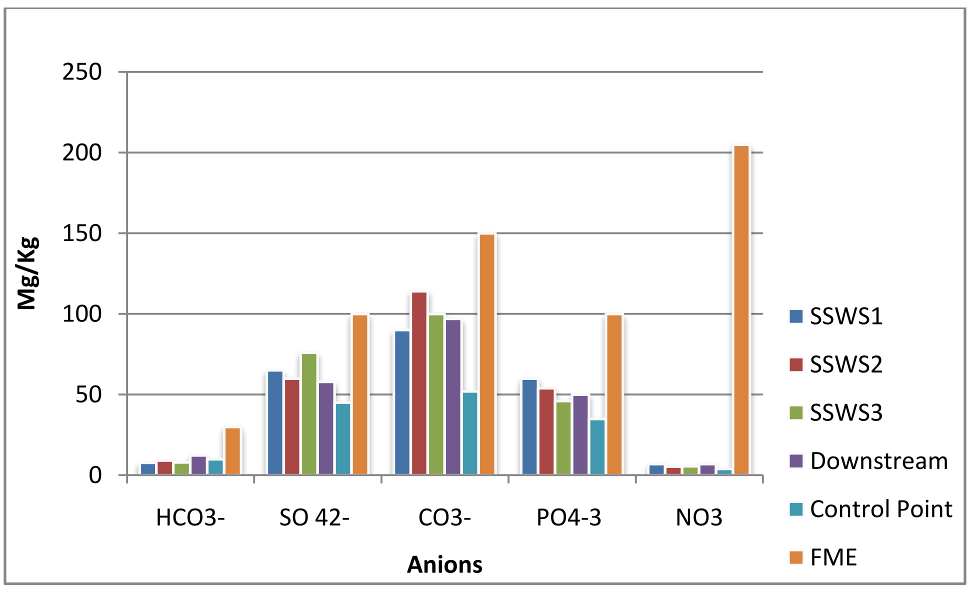


Figure 4.30: Bar Chart Showing the Mean Variations of Anions for sediments

Heavy Metals and Other Metals for sediments

Iron Fe

Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. The mean concentration values of Fe at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.4, 0.3, 0.4 and 0.30 mg/kg Fe respectively with a control point value of 0.1 mg/kg (Table 4.2 and Figure 4.31). These values were within the FME (2006) Standard but exceeded the control point value slightly.

Lead Pb

The mean values for Pb were 0.08, 0.07, 0.06 and 0.05 mg/kg respectively with no detection of the metal at the control point and the values fell below the FME Standard for so which is slightly higher which indicates the presences of anthropogenic activities such as disposal of batteries in to the river. Lead is one of the most commonly determined heavy metals because it accumulates in body tissue.

Copper Cu

The mean values for Cu were 0.55, 0.88, 0.95 and 0.80 mg/kg Cu respectively with no detection at the control point and they conform to the FME (2006) standard for soil.

Mercury Hg

The mean values for Hg was 0.10, 0.13, 0.15 and 0.18 mg/kg with no detection at control point and the values do not conform to the FME (2006) standard for soil (Table 5 and Figure 35). This is a very toxic element, the hazards of which are magnified by the accumulation of organo-mercury compounds in fish. When the fish is consumed it can carcinogenic to humans.

Cadium Cd

The mean concentration values for Cd at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream stations were 0.32, 0.28, 0.30 and 0.25 mg/kg Cd respectively with no detection at control point. These values fell below the FME Standard and it indicates heavy disposal of e-wastes in the sediments of Otamiri River. In high concentration in sediments it can hamper plant reproductive system when used for farming activities.

Zinc Zn

The mean values for Zn were 3.3, 4, 2.5 and 2.00 mg/kg with a control value of 1.5 mg/kg. These values were within the FME Standard. But the value of Zn at $SSWS_2$ was close to the standard value which may be due to high influx of wastes. Therefore, there is need for close monitoring of the station in the near future.

Aluminium Al

The values for Al at the three stations were 0.006, 0.005, 0.004 and 0.003 mg/kg respectively with a control point value of 0.002 mg/kg. These values were within the FME Standard.

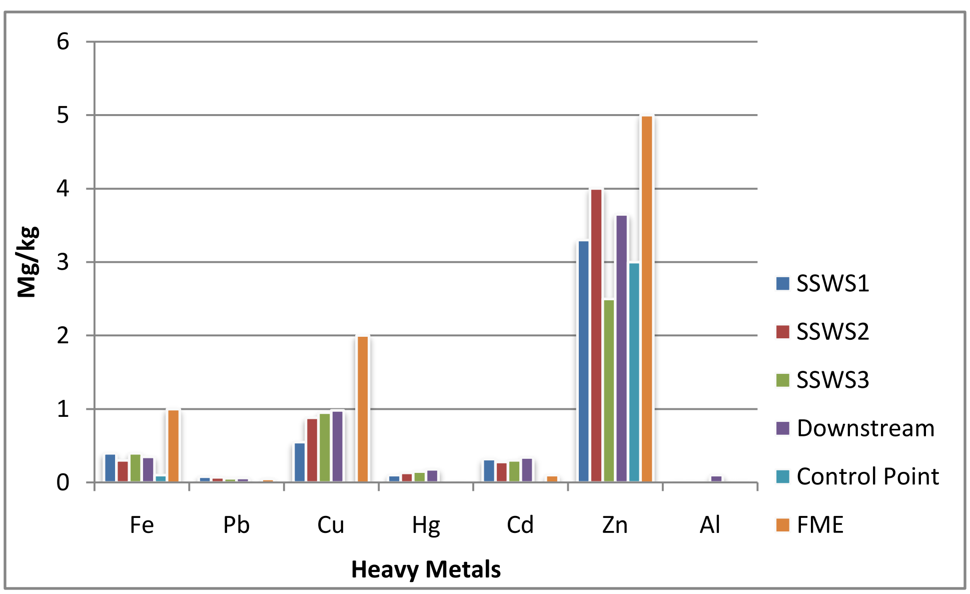


Figure 4.31: Bar Chart Showing the Mean Relative Abundance of Heavy Metals

Microbiological Parameters

Total Bacteria, Coliform and E. Coli Count

The values for the Total Bacterial Count at $SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream station were 3.5 $x10^4$, 5.0 $x10^4$, 6.5 $x10^4$ and 2.0 $x10^4$ cfu/g respectively with control point value of 1.5 $x10^2$ cfu/g. There is no standard but the values all exceed the control point value. While the Total Coliform Count was $6.5x10^3$, $2.0x10^3$, $2.5x10^3$ and 0.8 $x10^3$ cfu/g with a control point value of 0.5 $x10^2$ cfu/g. There is no standard but the values all exceed the control point value. For the Total *E. Coli* Count, the values were $2.5x10^3$, $1.0x10^3$, 2.5 $x10^3$ and 0.5 $x10^3$ cfu/g respectively with control point value of $0.5x10^2$ cfu/g. There is no standard but the values all exceed the control point value.

4.7 MICROBIAL ASSAY FOR SEDIMENT SAMPLES

Table 4.8: Biochemical identification of some bacteria isolated from sediment samples from Otamiri River.

Location	Most probable organism	Colony Morphology	Microscopic character	Gram Stain	Triple sugar ion agar (TSIA)						INDOLE	MOTILITY	OXIDASE	CITRATE	UREASE	CATALASE	V.P	METYL RED
					SLANT	BUTT	Glucose	Lactose	Gas	H_2S								
$SSWS_1$	*Baccillus spp*	Creamy colony on nutrient agar	Rod	+	B	A	+	-	-	-	-	+	-	+	-	+	-	+
	Escherichia coli	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	+	+	-	-	-	+	-	+
	Enterobacteria spp	Mucoidal Creamy colony on nutrient agar	Rod	-	A	A	-	-	-	-	-	-	-	+	-	+	+	-
$SSWS_2$	*Klebsiella spp*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+
	Vibrio spp	Creamy colony on nutrient agar	Rod	-	B	A	+	-	-	-	+	+	_	+	-	+	+	-

	Klebsiella spp	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+
$SSWS_3$	*Klebsiella spp*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	-	-	-	+	-	+	-	+
	Escherichia coli	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	+	+	-	_	-	+	+	-
	Vibrio spp	Creamy colony on nutrient agar	Rod	-	B	A	+	-	-	-	+	+	-	+	-	+	-	+
C. Point	*Escherichia coli*	Creamy colony on nutrient agar	Rod	-	A	A	+	+	-	-	+	+	-	-	-	+	-	+
DOWNSTREAM	*Vibrio spp*	Creamy colony on nutrient agar	Rod	-	B	A	+	-	-	-	+	+	_	+	-	+	+	-

Key: A = Acidic condition, B = Basic condition, + = positive, - = negative

Table 4.9: Showing Most Probable Organisms in Sediment Samples per Stations

Stations	Most Probable Organisms				
	Vibro spp.	*Escherichia Coli*	*Enterobacteria spp.*	*Klebsiella spp*	*Baccillus spp.*
					✓
$SSWS_1$		✓			
				✓	
				✓	
$SSWS_2$	✓				
				✓	
				✓	
$SSWS_3$		✓			
	✓				
CONTROL POINT		✓			
DOWNSTREAM	✓				

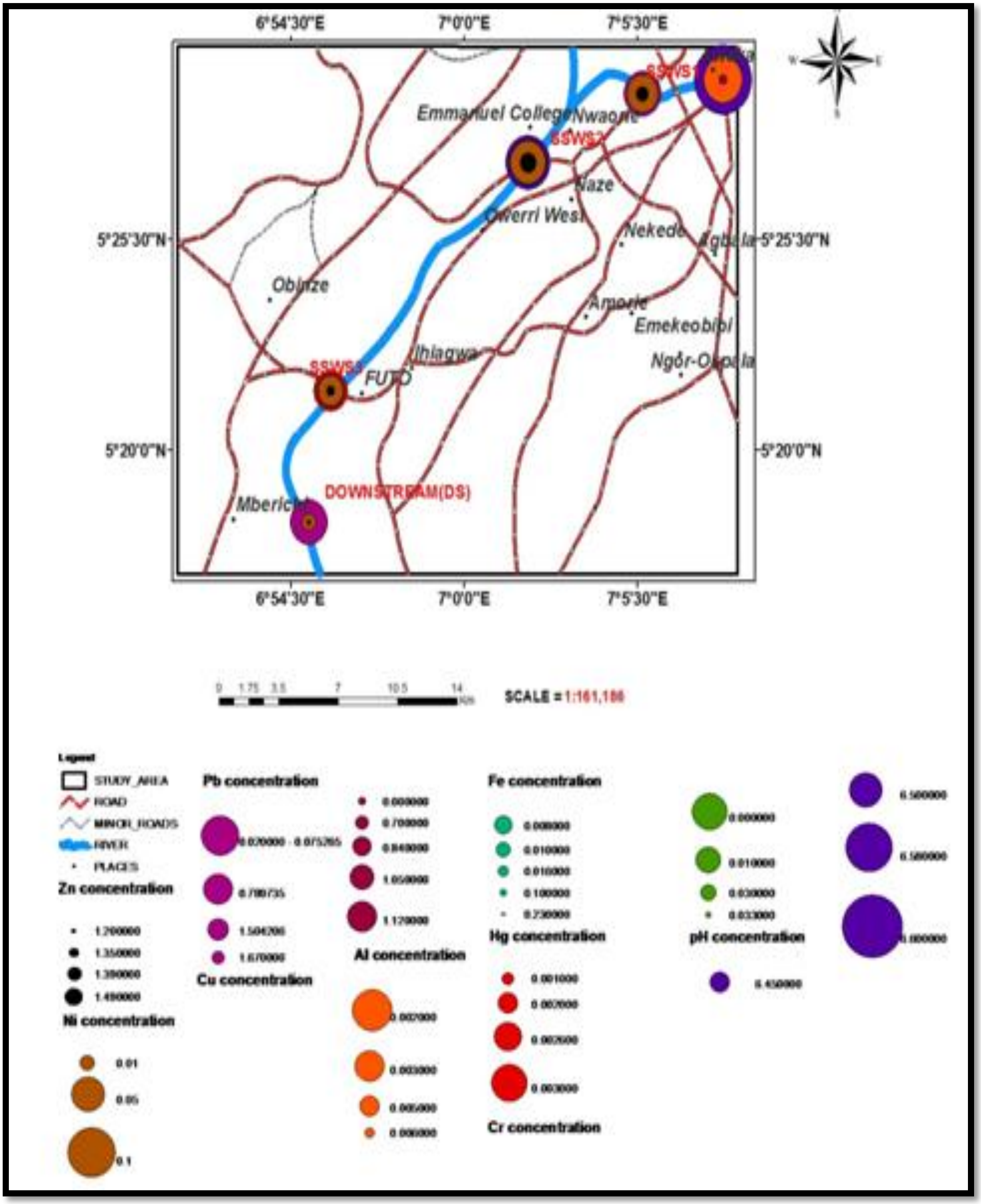


Figure 4.32: Concentration Map of pH and Heavy Metals

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The Otamiri River at the Four stations (**$SSWS_1$, $SSWS_2$, $SSWS_3$ and Downstream**) with **Control Point** is polluted with respect to pH, microbial constituents (bacteria such as; *Escherichia Coli., Vibro spp., Klebsiella spp.*, and *Entrobacteria spp.*) as well as heavy metal (Pb^{2+}, Cd^{2+}, Fe^{+} and Ni) contents. These pollutants are attributed to the waste and effluents disposed from land of the three stations. This calls for proper waste management practices and pre-use treatment of the river water with chlorine and sodium bicarbonate so in order to reduce the microbial constituents and raise the pH of the water respectively. The heavy metals would be treated using ascobic acid or ion exchange methods while iron can be treated using aeration method. The SAR values of the river indicate that it is excellent for irrigation purposes. However, the pollution index (PI) of the river is already tending to the critical value of 1.

For the sediment, it shows pollution with respect to pH, microbial constituents (bacteria such as; *Escherichia Coli., Vibro spp., Klebsiella spp., Entrobacteria spp.* and *Bacillus spp.*) as well as heavy metal (Pb^{2+}, Cd^{2+}, and Hg) contents. They are also attributed to waste and effluents disposed from land at the four stations. The pH can be treated by liming method.

Generally, the Otamiri River can be described as slightly acidic, soft, fresh but with excessive concentrations of certain heavy metals. There is need for constant monitoring of the bio-chemical characteristics of the river with special attention to heavy metal contents.

5.2 RECOMMENDATIONS

In order to ensure the sustainable development of the surface water resource in Owerri area, it is recommended that:

1. River pollution abatement programmes including the prohibition of discharge of untreated effluents and solid wastes into the Otamiri River.
2. Conventional water treatment methods should be used to treat Otamiri River water before being used for domestic purposes.
3. Periodic measurement and monitoring of the concentration of the aspects of Otamiri River is required to forestall pollution impacts.
4. Irrigation projects are recommended in the Otamiri River watershed based on the values of Sodium Absorption Ratio (SAR)
5. The replacement of waste dumps and land fill with a sanitary one which must be located outside the Otamiri watershed is strongly recommended.

5.3 CONTRIBUTION TO KNOWLEDGE

Owing to the fact that there is paucity of knowledge with respect to the microbial assay for the sediments in Otamiri River, a detailed bio-chemical identification of microorganisms of the river has being analysed and presented which includes; ***Escherichia Coli., Vibro spp., Klebsiella spp., Entrobacteria spp.*** and ***Bacillus spp***. In the same vein, a comprehensive physical and biochemical analysis showing the trends of some parameters of the River was carried out respectively.

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APPENDIX

Appendix 1: Field note and bottles for water sample collection

Appendix 2: Collection of Water samples using Grab Method

Appendix 3: Waste being dumped in the River at Egbu

Appendix 4: Landfill along the river channel at FUTO

Appendix 5: Landfill along the Otamiri River channel at Timbe

LABORATORY ANALYSIS FOR WATER AND SEDIMENTS

Water Constituents

Determination of pH (ISO: 3025 Electrometric Method)

The pH meter was switched on for at least 30 minutes before the test. Preparation of buffer solution to 4.0, 7.0 and 9.0. The pH meter calibrate to 9.2 using the buffer and by adjusting the calibration knob. Then calibrated the pH meter to 7.0 using the buffer and by adjusting the calibration knob. The pH meter was calibrated to 4.0 using the buffer and by adjusting the calibration knob**.** Read the pH meter by inserting the sample.

Determination of Turbidity

Turbidity was determined by photometric method using HACH DR/2010 spectrometer at a wavelength of 860 nm and program number 750. 250 ml of the filtered de-ionized water is poured into a 25 ml sample cell bottle as blank. The blank is to zero the spectrophotometer, then the sample is vigorously shaken and 25mL of the sample is poured into another 25 ml sample cell bottle. The sample is put into the light shield and closed after the blank is removed and the read button is press. The value is digitally displayed in mg/l.

Determination of Conductivity/ Total Dissolved Solid

Conductivity was determined using hand held conductivity meter model HI98302 (HANNA). The meter was first rinsed in distilled water. The conductivity was then calibrated using conductivity solution at 25^{o}C it was then switched on and inserted into the 50ml water sample conductivity was recorded in µs/cm when the reading became stable.

Determination of Nitrate

Nitrate was determined by Cadmium reduction method using Hanna HI 83200 multi parameter bench photometer at a wavelength of 525 nm. 10 ml of the sample was poured into two separate sample cell bottles. One(1) was used as blank to zero the photometer and one (1) satchet of Nitrate reagent powder pillow was added to the second sample cell bottle and was inserted into the cell compartment and time for 4 minutes and 30 seconds. At the end of the countdown, the READ button was pressed to display the result in mg/L of Nitrate and Nitrate – Nitrogen.

Determination of Phosphate

Phosphate was determined by Amino Acid methods using HI 83200 multi parameter bench photometer at a wavelength of 525 nm. 10 ml of the sample was poured into two (2) separate sample cell. One was used for blank to zero the photometer and 10 drops of HI 93717 A-0 molybdate Reagent, then the content of one packet of HI 93717 B-0 phosphate HR reagent B added to the curette. It was shaken gently to dissolve and was inserted into cell comportment and time foe 5 minutes. At the end of the countdown, the READ button was pressed to display the result in mg/l of phosphate phosphorus and phosphate (P_2O_s)

Determination of Chlorides (Cl^-): (Argentometric Titration Method, APHA 1998)

In 100ml of sample, 1ml of K_2CrO_4 indicator was added and titrated against 0.02N $AgNO_3$ till brick red precipitates were formed.

Formula:

$$\text{Mg } Cl^-/l = \frac{B.R \times N \times 35.45 \times 1000}{\text{Vol of sample (ml)}}$$

Where; B.R= Burette reading (amount of titrant used)

N= normality of $AgNO_3$

35.45= Equivalent weight of Chloride.

Determination of Bi-Carbonate (Titration Method)

This is determined by titration method. Add 50 ml or 100 ml of the water sample in a clean flask and add slight excess of Barium Chloride solution to precipitate the carbonate which does not affect the bicarbonate. Add two (2) drops of phenolphthalein indicator to the solution. Shake and titrate to the end point with 0.02 M standard HCl (hydrochloric Acid). Record the volume of acid use and calculate as:

$$\frac{V \times M \times 100{,}000}{\text{ml of sample used}}$$

Determination of Sulphate

100 to 400ml of the sample was taken, filtered when necessary. Added 1:1 HCL in drops until acid to litmus, added three drops in excess and evaporate to 50ml. Boiled the solution and added boiling Barium chloride solution until all the sulphate was precipitated. Digested on a water bath until the precipitate settled. Dried a sintered-glass crucible to constant weight. Connected the filtering equipment to the vacuum pump and filtered the precipitate through sintered-glass crucible. Washed a number of times with hot water until the filtrate was chloride-free ($AgNO_3$ test). Then dried the crucible precipitate in an oven at 103- 105^0C to constant weight. The weight of the precipitate alone was known by difference.

Calculation:

$$SO_4\ (\text{mg/kg}) = \frac{\text{mg } BaSO_4 \times 411.5}{\text{ml. Sample}}$$

Determination of Heavy Metals Using Atomic Absorption Spectrometer

Water Digestion for Heavy Metal Analysis

50ml of sample was digested in 250mL conical flask by adding 10mL of aqua regia and heated on a hot plate until volume remains about 7-12mL. The digest was filtered using what-man filter paper and the volume made up to the mark in a 50mL volumetric flask, and was then stored in a plastic container for AAS analysis.

Preparation of Working Solution

Fe working solution

100ppm of Fe working solution was first prepared in 100mL distilled water

Calculation

C1V1 = C2V2

C1 = concentration of the working solution = 100ppm

V1 = volume of distilled water used to prepare the working solution =100mL

C2 = concentration of zinc stock solution = 1000ppm

V2 = volume of stock that will be used.

$$\frac{1000ppm \times 100mL}{1000ppm} = V2$$

V2 = 10mL of stock solution + 90mL of distilled water

Hg working solution

100ppm of Al working solution was first prepared in 100mL distilled water

Calculation

C1V1 = C2V2

C1 = concentration of the working solution = 100ppm

V1 = volume of distilled water used to prepare the working solution =100mL

C2 = concentration of zinc stock solution = 1000ppm

V2 = volume of stock that will be used.

$$\frac{1000ppm \times 100mL}{1000ppm} = V2$$

V2 = 10mL of stock solution + 90mL of distilled water

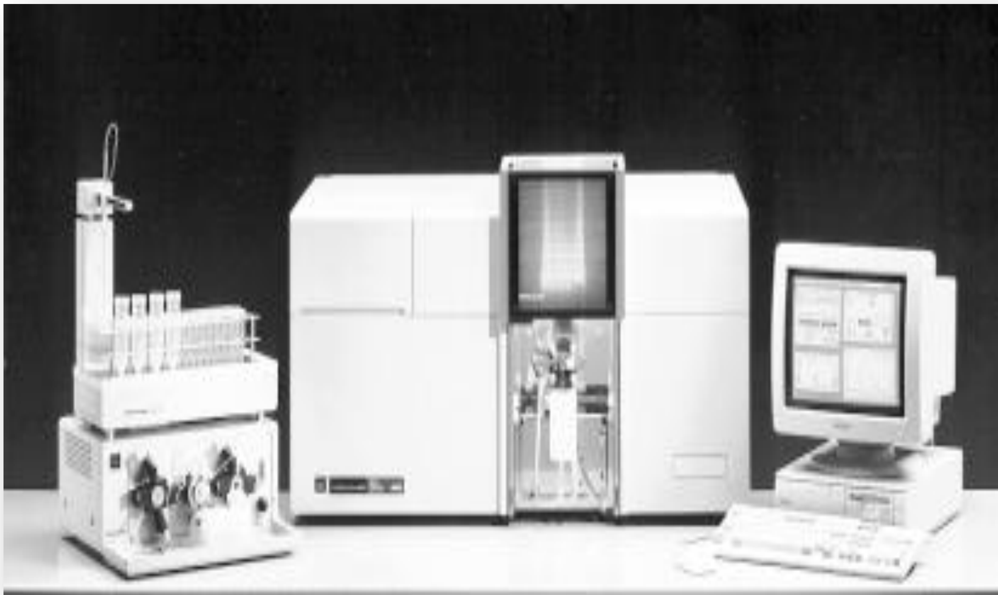
Principles of Atomic Absorption Spectrophotometer

Working principles: Atomic absorption spectrometer's working principles is based on the sample being aspirated into flame and atomized when the AAS's light beam is directed through the flame into monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wave length a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Procedure

The sample is thoroughly mixed by shaking and 100mL of it is transferred into a glass beaker of 250mL volume. The sample is aspirated into the oxidizing air-acetylene flame or nitrous oxide acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1% absorption is observed.

A typical example of an Atomic Absorption Spectrometry (AAS) is shown below (Figure 3)



A typical example of an Atomic Absorption Spectrometry (AAS) (Source: *The Royal Society of Chemistry Fine Chemicals and Medicinals Group*)

Microbiology for Water Samples Serial Dilution (Spread Plate/Pour Plate Method)

Inoculation

1ml of each water samples was pipette into a test tube containing 9mls of sterile distilled water.

- 10 fold serial dilution of the water sample were prepared using sterile distilled water as the diluents.
- Aliquots (0.1ml) of each (10^{-2}, 10^{-3}, 10^{-4} or 10^{-5}) of the test tube were inoculated in a Nutrient agar plate, Sabouraud dextrose agar and Mineral Salt Agar by spread plate technique and incubated at 37°C for 24hrs for bacteria and 25°C for 78hrs-96hrs for fungi on the incubator.

- After incubation, colonies were observed on different plate and was counted and recorded.

$$\text{NO OF MICROORGANISMS} = \frac{\text{NO OF COLONY}}{0.1} \times \frac{1}{DF}$$

DF= Dilution factor (10^{-1}, 10^{-2} , 10^{-3} e.t.c)

Media Preparation

A) Nutrient agar

This is a basic media mostly used for culturing, subculturing and for total viable bacterial count.

Procedure

Dissolve 28.0gm in 1000ml distilled water, gently heat to dissolve the medium completely sterile by autoclaving at 15psi (121^0c) for 15 minutes. Dispense the medium as desired in the plate. incubate at 35^0C for 24hrs.

B) Sabourand Dextrose Agar

For cultivation of yeast mould and acidic microorganisms.

Procedure

- Prepare by dissolving 65gms of media in 1000ml distilled water/purified water.
- Heat to boiling to dissolve the medium completely. Sterilize by autoclaving at 121^0c and 15ibs pressure for 15minutes.

C) **Mac-conkey Agar**

This is a differential medium best for total coliform counts.

Procedure

Dissolve 52.5g powder of the mac-conkey agar to 1000mL of distilled water. Mix and heat until dissolved. Sterilize by autoclaving 15minutes at 121^0c and petri dishes.

STREAM SEDIMENT ANALYS

Stream Sediment Parameters

Determination of pH and Conductivity Determination

The pH of the sample were determined using a Jewniary digital pH meter in a sample to water ratio of 1:10 that is twenty (20) grms of each sample will be weighed in a beaker. Then two hundred milliliters (200) ml of distilled water will be added to it. The pH electrode will be dipped into the solution and also conductivity electrode was dipped.

Determination of Nitrate

The sample was extracted using 1M of Sodium Acetate solution by adding 250ml of Sodium Acetate to ten (10) grams of the sample. It was shaken for one (1) hour and filtered, and then the filtrate was used for the determination of nitrate. Nitrate was determined by Cadmium reduction method using HI83200 multi parameter bench photometer at a wavelength of 525nm. 10ml of the sample was poured into two separate sample cell bottles. One (1) was used as blank to zero the photometer and one (1) sachet of Nitrate reagent powder pillow was added to the second sample cell bottle and was inserted into the cell compartment and time for 4 minutes 30 seconds. At the end of the countdown, the READ button was pressed to display the result in mg/L of Nitrate and Nitrate – Nitrogen.

Determination of Phosphate

Phosphate was extracted using 0.5M of Sodium bicarbonate at soil to water ratio of 1:25**.** Phosphate was determined by Amino Acid methods using HI83200 multiparameter bench photometer at a wavelength of 525mm. 10ml of the sample was poured into two (2) separate sample cell. One was used for blank to zero the photometer and 10 drops of HI93717A-0 molyb date Reagent, then the content of one packet of HI 93717B-0 phosphate HR reagent B added to the cuvette. It was shaken gently to dissolve and was inserted into cell compartment and time for 5 minutes. At the end of the countdown, the READ button was pressed to display the result in mg/l of phosphate phosphorus and phosphate (P_2O_5)

Determination of Sulphate: (Gravimetric Method)

Took 100 to 400ml of the sample, filtered where necessary. Added 1:1 HCL in drops until acid to litmus, added three drops in excess and evaporate to 50ml. Boiled the solution and added boiling Barium chloride solution until all the sulphate was precipitated. It was digested on a water bath until the precipitate settled. Dried a sintered-glass crucible to constant weight. Connect the filtering equipment to the vacuum pump and filter the precipitate through sintered-glass crucible. Wash a number of times with hot water until the filtrate is chloride-free ($AgNO_3$ test). Dry the crucible precipitate in an oven at 103- 105^{0}C to constant weight.

Know the weight of the precipitate alone by difference.

Calculation:

$$SO_4\,(mg/kg) = \frac{mg\ BaSO_4 \times 411.5}{ml.\ Sample}$$

Determination of Heavy Metals Using Atomic Absorption Spectrophotometer

Sediments Digestion for Heavy Metal Analysis

1gram of sample was digested in 250ml conical flask by adding 30ml of aqua regia and heated on a hot plate until volume remains about 7-12ml. The digest was filtered using what-man filter paper and the volume made up to the mark in a 50ml volumetric flask, and was then stored in a plastic container for AAS analysis.

Preparation of Working Solution

Fe working solution

100ppm of Fe working solution was first prepared in 100ml distilled water

Calculation

$C_1V_1 = C_2V_2$

C_1 = concentration of the working solution = 100ppm

V_1 = volume of distilled water used to prepare the working solution =100ml

C_2 = Concentration of zinc stock solution = 1000ppm

V_2 = Volume of stock that will be used.

$$\frac{1000ppm \times 100ml}{1000ppm} = V_2$$

V2 = 10ml of stock solution + 90ml of distilled water

Al working solution

100ppm of Al working solution was first prepared in 100ml distilled water

Calculation

$C_1V_1 = C_2V_2$

C_1 = concentration of the working solution = 100ppm

V_1 = volume of distilled water used to prepare the working solution =100ml

C_2 = concentration of zinc stock solution = 1000ppm

V_2 = volume of stock that will be used.

$$\frac{1000\text{ppm} \times 100\text{ml}}{1000\text{ppm}} = V_2$$

V_2 = 10ml of stock solution + 90ml of distilled water

Sample of Digestion

(i) Weight out 2g of the dried sample in to a digestion flask and add 20ml of the acid mixture (650ml conc HNO_3), 30ml per chloric acid , 20ml conc. $H2SO_4$

(ii) Heat the flask until a clear digest is obtained.

(iii) Dilute the digest with distilled water to the 25ml mark

(iv) Appropriate dilutions are then made for each element.

Principles of Atomic Absorption Spectrophotometer

Working principles: Atomic absorption spectrometer's working principles is based on the sample being aspirated into flame and atomized when the AAS's light beam is directed through the flame into monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wave length a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Procedure

The sample was thoroughly mixed by shaking and 100ml of it is transferred into a glass beaker of 250ml volume. The sample is aspirated into the oxidizing air-acetylene flame or nitrous oxide acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1% absorption is observed.

Microbiology of Stream Sediments Sampling Serial Dilution (Spread Plate/Pour Plate Method)

Inoculation

1ml of each water samples was pipette into a test tube containing 9mls of sterile distilled water.

- 10 fold serial dilution of the water sample were prepared using sterile distilled water as the diluents.
- Aliquots (0.1ml) of each (10^{-2}, 10^{-3}, 10^{-4} or 10^{-5}) of the test tube were inoculated in a Nutrient agar plate, , Sabouraud dextrose agar and Mineral Salt Agar by spread plate technique and incubated at 37°C for 24hrs for bacteria and 25°C for 78hrs-96hrs for fungi on the incubator.
- After incubation, colonies were observed on different plate and was counted and recorded.

$$\text{NO OF MICROORGANISMS} = \frac{\text{NO OF COLONY}}{0.1} \times \frac{1}{\text{DF}}$$

DF= Dilution factor (10^{-1},10^{-2} , 10^{-3} e.t.c)

Media Preparation

D) Nutrient agar

This is a basic media mostly used for culturing, subculturing and for total viable bacterial count.

Procedure

Dissolve 28.0gm in 1000ml distilled water, gently heat to dissolve the medium completely sterile by autoclaving at 15psi (121^0c) for 15 minutes. Dispense the medium as desired in the plate. incubate at 35^0C for 24hrs.

E) Sabourand Dextrose Agar

For cultivation of yeast, mould and acidic microorganisms.

Procedure

- Prepare by dissolving 65gms of media in 1000ml distilled water/purified water.
- Heat to boiling to dissolve the medium completely. Sterilize by autoclaving at 121^0c and 15ibs pressure for 15minutes.

BIOCHEMICAL TESTS FOR THE IDENTIFICATION OF BACTERIA IN WATER AND SEDIMENT SAMPLES

Oxidase Test

This is used to determine organisms that produce the enzyme oxidaze. Isolated organisms are smeared on filter paper impregnated with a solution of freshly prepared oxidase test reagent – N-tera-methyl-p-phenylene diaminedihydrochloride. A dark purple colour within 10 seconds indicates a positive test. It is important in distinguishing Neisseria and Moraxella spp. (positive) from Acinobacter (negative) and enteric (all negative from pseudomonas positive).

Catalase Test

This determines the ability of the isolates to produce the enzyme catalase which converts hydrogen peroxide to water and oxygen. Isolates are collected by using a flamed wireloop and emulsified in a drop of hydrogen peroxide (H_2O_2) on a clean slide. The appearance of gas bubbles after few seconds indicates a positive test. It is used to differentiate Streptococcus (negative) from Staphylococcus (positive) and Bacillus (positive) from Clostridium (negative).

Citrate Test

This test is used to determine organisms that could utilize citrate as sole carbon source for metabolism. Simon's citrate agar prepared as slants in tubes according to the manufacturers instructions are inoculated with the isolates using a sterile wireloop and incubated at 37^0C for 24-48 hours. A colour change from green to blue of the media indicates a positive result. It is used in the identification of enteric bacteria, Klebsiella (positive), Enterobacter (positive), Salmonella (often positive), Escherichia Coli (negative) and Edwardsiella (negative).

Indole Test

The indole test detects the production of indole from the amino acid tryptophan. Peptone water are prepared and dispensed into test tubes, these will be sterilized and inoculated with the test organism and incubated for 24 hours at 37^0C. Five drops of Kovac's reagent will be added to each of the tubes. The formation of a deep red colour in the inoculated tubes indicates a positive result. It is used to separate Escherichia Coli (positive) from Enterobacter (negative) and Klebsiella pneumonia (negative).

Hydrogen Sulphide Test

It detects the formation of hydrogen sulphide from the amino acid cysteine due to cysteine desulphrase. It is important in the identification of Edwardsiella, proteins and Salmonella.

Methyl Red Test

Methyl Red is a pH indicator to determine whether the bacterium carries out mixed acid fermentation. A positive reaction is indicated by a distinct red colour showing the presence of acid.

Voges- Proskauer (VP)Test

This detects the production of acetoin. A positive reaction is indicated by a red colourization. Methyl red and Voges- Proskauer tests are used to separate Escherichia Coli M-R (positive), VP (negative) from Enterobacter MR (negative) VP (positive) and Klebsiella pneumonia (MR- negative, VP- positive), also used to character members of the genus Bacillus.

Urease Test

This detects the enzyme that splits urea to NH_3 and CO_2 positive urease production of red-violet colour while a yellow colourization showed inability of the isolate to produce urease enzyme. It is used to distinguish proteus, providencia retigeri and klebsiella pneumonia (positive) from Salmonella, Shigella and Escherichia Coli (negative).

Biochemical Identification of Some Bacteria Isolated from Water Samples

SSWS1

WS1

Vibro spp

The Colony morphology is creamy colony on nutrient agar and its microscopic character is Rod shaped. It was negative in terms of Gram stain. Upon the test of Triple sugar ion agar (TSIA), Slant was Basic and butt was acidic, Glucose was Negative, Lactose, Gas and H_2S were positive. The test for Indole, Motility, Oxidase and Citrate were all positive. That of Urease and Metyl Red was negative respectively. While for Catalase and V.P was Positive.

WS2

Eschreichia Coli

The Colony morphology is creamy colony on nutrient agar and its microscopic character is Rod shaped. On Gram stain it was negative. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic, glucose and lactose was negative and Gas and H_2S was positive respectively. For the test of Indole and Motility, they were positive. That of Oxidase, Citrate, V.P and Urease was negative respectively. While it was positive for Catalase and Metyl Red.

WS3

Enterobacteria spp

The Colony morphology is creamy colony on nutrient agar and its microscopic character is Rod shaped. On Gram Stain it was negative. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic, Glucose, Lactose, Gas and H_2S were positive respectively. The test of Indole was positive while Motility, oxidase , Urease and Metyl Red were negative. Citrate, Catalase and V.P test were positive.

SSWS2

WS4

Klebsiella spp

The Colony Morphology is creamy colony on nutrient agar the microscopic character is Rod Shaped. It was negative on Gram Stain. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic. Glucose and Lactose was negative. The Gas and H_2S was positive. For the test of Indole, Motility, Urease, V.P and Oxidase, it indicate negative. While Citrate, Catalase and Metyl Red were positive.

WS5

Vibro spp

The Colony Morphology is creamy colony on nutrient agar and the microscopic character was Rod shaped. The Gram Stain was negative. The Triple sugar ion agar (TSIA) test for Slant was basic and Butt was acidic. Glucose, Gas and H_2S were negative while Lactose was positive. The test of Indole, Motility, Citrate, Catalase and V.P were positive respectively while that of Oxidase, Urease and Metyl Red was negative respectively.

WS6

Klebsiella spp

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain is negative. For the Triple sugar ion agar (TSIA), Slant and Butt was acidic. The Glucose and Lactose was positive while the Gas and H_2S was negative. The test of Indole, Motility, Oxidase, Urease and V.P were negative respectively. While for Citrate, Catalase and Metyl Red it was positive.

SSWS3

WS7

Klebsiella spp

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. It was negative on Gram Stain. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic. Glucose and Lactose was positive while Gas and H_2S was negative. The test of Indole, Motility, Oxidase, Urease and V.P were negative respectively. While Citrate, Catalase And Metyl Red were positive respectively.

WS8

Eschrichia spp

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic, Glucose and Lactose was positive while Gas and H_2S was negative. The test of Indole, Motility, Catalase and V.P was positive respectively. While that of Oxidase, Citrate, Urease and Metyl Red was negative respectively.

WS9

Vibro spp

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. On Gram Stain it was negative. For the Triple sugar ion agar (TSIA) test; Slant was basic and Butt acidic, the Glucose was positive while Lactose, Gas and H_2S was negative. The test of Indole, Motility, Citrate, Catalase and Metyl Red were positive respectively. While Oxidase, Urease and V.P were negative.

CONTROL POINT

Eschreichia Coli

The Colony morphology is creamy colony on nutrient agar and its microscopic character is Rod shaped. On Gram stain it was negative. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic, glucose and lactose was negative and Gas and H_2S was positive respectively. For the test of Indole and Motility, they were positive. That of Oxidase, Citrate, V.P and Urease was negative respectively. While it was positive for Catalase and Metyl Red.

DOWNSTREAM

Klebsiella spp

The Colony Morphology is creamy colony on nutrient agar the microscopic character is Rod Shaped. It was negative on Gram Stain. For the Triple sugar ion agar (TSIA) test, Slant and Butt was acidic. Glucose and Lactose was negative.

The Gas and H_2S was positive. For the test of Indole, Motility, Urease, V.P and Oxidase, it indicate negative. While Citrate, Catalase and Metyl Red were positive.

Biochemical Identification of Some Bacteria Isolated from sediment Samples

$SSWS_1$

Bacillus spp.

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. It is positive on Gram Stain. For the Triple sugar ion agar (TSIA) test; Slant was basic and Butt was acidic. The Glucose was positive while Lactose, Gas and H_2S were negative. The test for Indole, Oxidase, Urease and V.P were negative respectively. While that of Motility, Citrate, Catalase and Metyl Red were positive.

Escherichia Coli

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. On the Triple sugar ion agar (TSIA) test; Slant and Butt was acidic, Glucose and Lactose was positive while Gas and H_2S were both negative. For the test of Indole, Motility, Catalase and Metyl Red were positive. While that of Oxidase, Citrate, Urease and V.P were negative.

Entrobacteria spp.

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test; Slant and Butt was acidic. The Glucose, Lactose, Gas and H_2S were negative respectively. For the test of Indole, Motility, Oxidase, Urease and

Metyl Red were negative. While Citrate, Catalase and V.P were positive respectively.

$SSWS_2$

Klebsiella spp.

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test Slant and Butt was acidic. The Glucose and Lactose were positive while the Gas and H_2S was negative. The test on Indole, Motility, Oxidase, Urease and V.P were all negative. While Citrate, Catalase and Metyl Red were positive.

Vibro spp.

The Colony Morphology is Creamy colony on nutrient agar and Microscopic character Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test; Slant was basic and Butt was acidic. Glucose was positive while Lactose, Gas and H_2S were negative. The test On Indole, Motility, Citrate, V.P and Catalase were positive. While Oxidase, Urease and Metyl Red were negative.

Kiebsiella spp.

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA); Slant and Butt was acidic. The Glucose and Lactose were both positive while Gas and H_2S was negative respectively. The test on Indole, Motility, Oxidase, Urease and V.P were negative. While Citrate, Catalase and Metyl Red were positive.

$SSWS_3$

Klebseilla spp.

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA); Slant and Butt was acidic, Glucose and Lactose was positive while Gas and H_2S were both negative. The test on Indole, Motility, Oxidase, Urease and V.P were negative respectively. While Citrate, Catalase and Metyl Red were positive.

Escherichia Coli

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test; Slant and Butt were acidic, Glucose and Lactose were positive while Gas and H_2S was negative. The test for Indole, Motility, Catalase and V.P was positive respectively. While Oxidase, Citrate, Urease and Metyl Red were negative.

Vibro spp

The Colony Morphology is Creamy colony on nutrient agar and the Microscopic character is Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test; Slant was Basic and Butt acidic, Glucose was positive while Lactose, Gas and H_2S were negative. The test for Indole, Motility, Citrate, Catalase And Metyl Red were positive respectively. While Oxidase, Urease and V.P were negative.

DOWNSTREAM

Vibro spp.

The Colony Morphology is Creamy colony on nutrient agar and Microscopic character Rod shaped. The Gram Stain was negative. For the Triple sugar ion agar (TSIA) test; Slant was basic and Butt was acidic. Glucose was positive while Lactose, Gas and H_2S were negative. The test On Indole, Motility, Citrate, V.P and Catalase were positive. While Oxidase, Urease and Metyl Red were negative.

CONTROL POINT

Escherichia Coli

The colony morphology is creamy colony on nutrient agar and on microscopic character it is rod shaped. The gram stain test for this specie is negative. While on the Triple sugar ion agar (TSIA) test, it is acidic in terms of slant and butt, positive in glucose, negative in lactose and negative both in gas and H_2S^- . It was positive test of indole and motility, negative for oxidase, citrate, V.P and urease. For the test of catalase and metyl red the organism was positive.