EARTHWORM DIVERSITY AND ABUNDANCE IN SELECTED DUMPSITES IN IBADAN, AND TOXICITY OF CONTAMINATED WATER ON ASSOCIATED FAUNA

BY

OLUTOMI ADEOLA **ADEWOYIN**
MATRIC NO: 123811

B.Sc.Ed. (Biology) (Ife), M.Sc. Zoology (Ibadan)

A Thesis in the Department of Zoology,
Submitted to the Faculty of Science
In partial fulfilment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY

of the

UNIVERSITY OF IBADAN

AUGUST, 2016

ABSTRACT

Huge quantities of wastes which are indiscriminately disposed into uncontrolled dumpsites and flowing waters around residential areas are generated from Ibadan, metropolis. These may adversely affect soil, surface- and ground-water qualities and the fauna. Limited information exists on toxic effects that wastes from these non-designated sites have on associated fauna. Earthworms are one of the dominant fauna in soils and are pollution bioindicators. Therefore this study was designed to investigate physico-chemical parameters, earthworm diversity and abundance, and acute toxicity of contaminated-water on some fauna in selected dumpsites in Ibadan.

One-hundred and twenty water samples from streams (Irefin, Gege, Gbagi, Odinjo, and Omi-Adio) receiving domestic wastes; 60-composite soil samples each from dumpsites (Ojokondo, Olodo, Moniya, Idi-Ope and Oremeji) and stream banks; 12-composite soil samples from a control site at University of Ibadan (UI); 72 groundwater samples from wells around the dumpsites and UI were purposively collected once every two months from March 2008 to February 2010. Earthworms from top-soil were sampled using 0.25x0.25 m^2 quadrat, handpicked, identified and density determined following standard procedures. Earthworm species' diversity and evenness were determined using Shannon-Wiener diversity index and Shannon's evenness, respectively. Water samples were analysed for physico-chemical parameters [including Dissolved-Oxygen (DO), Biochemical-Oxygen-Demand (BOD), and Chemical-Oxygen-Demand (COD)] and soil samples including lead and zinc using standard methods and results were compared with NESREA standards. The 48-hour-LC_{50} of stream-samples were determined for *Cloeon perkinsi* (mayfly) larvae (CP); while 96-hour-LC_{50} for *Rana temporaria* tadpoles, *Clarias gariepinus* frys (CG1) and fingerlings (CG2) were determined using Probit method. Data were analysed using descriptive statistics and ANOVA at p=0.05.

Three earthworm species (*Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus*) were identified at UI, streams and dumpsites. Highest density of *Eudrilus euginiae* (30.0±13.7/m^2) was recorded at UI and this was significantly different from other sites, while lowest (6.4±2.2/m^2) was recorded at Ojokondo. Highest densities of *Hyperiodrilus africanus* (32.7±14.6/m^2) and *Dichogaster modigliani* (40.0±0.0/m^2) were recorded at UI and Gbagi, respectively; while lowest value of 4.0±0.0/m^2 was recorded at Irefin and Gege. *Eudrilus euginiae*

and *Dichogaster modigliani* were not found at Gege and Idi-Ope, respectively, while *Hyperiodrilus africanus* was not found at Odinjo, Moniya and Olodo. Earthworm diversity (0.5) was highest in UI and lowest (0.3) at Gege. Earthworms were most evenly distributed at Odinjo (2.4) and least at Ojokondo (0.8). The DO (mg/L) for streams ranged from (0.4±0.4) to (2.6±0.6) and were lower than permissible limit for aquatic life. Lead (260.6±77.7mg/kg, 269.6±46.4mg/kg) and zinc (456.9±69.9mg/kg, 1685.1±420.3mg/kg) values in Gege and Ojokondo soils, respectively were significantly higher than NESREA limits. In all groundwater samples, BOD (46.7±21.0mg/L) and COD (154.0±7.0mg/L) exceeded NESREA limits. The 48-hour-LC_{50} of stream-water to CP (Irefin, 12.7%; Gege, 8.6%), and 96-hour-LC_{50} to CGI (Gege, 0.8%; Gbagi, 2.8%) and CG2 (Gege, 3.3%; Irefin, 0.6%) indicated high toxicity of the sites.

The low earthworm abundance, poor physico-chemical qualities and high toxicity of the study sites revealed that the soil, streams and groundwater were polluted in Ibadan. Consequently, there is need for adequate management and disposal of solid-wastes to prevent further environmental contamination.

Keywords: Uncontrolled dumpsites in Ibadan, Earthworm abundance, Physico-chemical qualities, Acute toxicity.

Word count: 500

ACKNOWLEDGEMENTS

My appreciation goes to the Lord Almighty for seeing me through the period of this research work, for his faithfulness, provision and journey mercies He granted me throughout the period.

I am greatly indebted to my supervisor, Professor A. T. Hassan for his constructive criticism, unflinching support and reposing great confidence in my ability to carry out this wok. I deeply appreciate the support and assistance of Dr Adeola Oni of the Department of Zoology, University of Ibadan, all academic staff of the Department, the Postgraduate committee of the Department and Faculty and the Heads of Department during my period of study.

The assistance on the field and laboratory works, encouragement, financial, moral, and emotional support given to me by my loving husband Muyiwa Adeyemi-Ale is highly appreciated. I am also indebted to Dr A. A Aladesida of the Department of Biological Sciences, Federal University of Agriculture, Abeokuta for his assistance on the field, identification of the earthworms and statistical analysis.

I acknowledge Prof Sylvester Ogbogu of the Department of Zoology, Obafemi Awolowo University, Ile –Ife on his assistance on the collection of *Cloeon perkinsi* (mayfly) larvae and also his words of encouragement. I am also grateful to Dr Efere Obuotor of Biochemistry Department, Obafemi Awolowo University, Ile –Ife on his assistance and the use of his laboratory for the toxicity tests.

I appreciate Dr O. D. Owolabi for creating time out for me on the assistance of reading through my abstract, his prayers and words of encouragement.

I wish to thank my parents Late Venerable R. O Adewoyin and Mrs T. E. Adewoyin for their prayers, support, encouragement and especially to my mum who helped me out to use her laboratory at the Department of Pharmaceutical Chemistry, Obafemi Awolowo University, Ile –Ife for the analysis of the physico-chemical parameters of soil, streams and groundwater samples. I also appreciate the entire laboratory staff of the Department and the Heads of Department during those periods.

I thank my children Iyanuoluwa and Iyinnifoluwa for cooperating and understanding with me during the course of the study. I appreciate my siblings and Mrs Bunmi Babatunde for taking care of my children during those times I was not available.

Lastly, I thank the Administration of University of Ilorin for granting me staff development study leave and also the past Heads of Department of Zoology, University of Ilorin for releasing me to enjoy the programme.

CERTIFICATION

I certify that this work was carried out by **Olutomi Adeola ADEWOYIN** in the Department of Zoology, University of Ibadan

---

Supervisor
A. T. Hassan,
B.Sc., Ph.D. (Ibadan)
Professor, Department of Zoology
University of Ibadan, Nigeria

DEDICATION

This research work is dedicated to my late dad, Venerable Rufus Olubukola Adewoyin and to my late uncle, Elijah Obafemi Adewoyin. The two of them believed in me but unfortunately death took them away, not to see the heights I will attain.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

47. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to Gege stream during the study period
48. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to Odinjo stream during the study period
49. The bimonthly variation of the physico-chemical analysis of groundwater samples close to the dumpsites from April 2008 to February 2010.
50. The range and mean values of the anions and cations of groundwater (well) samples around the dumpsites from April 2008 to February 2010
51. The range and mean values of the trace and heavy metals of groundwater (well) samples around the dumpsites from April 2008 to February 2010
52. ANOVA table of physico-chemical characteristics, anions, cations, trace and heavy metals of groundwater (well) samples close to the dumpsites
53. Duncan tests of physico - chemical values, anions, cations, trace and heavy metals groundwater (well) samples close to the dumpsites
54. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) before the Ojokondo dumpsite during the study period
55. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) after the Ojokondo dumpsite during the study period
56. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to the Olodo dumpsite during the study period
57. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to the Moniya dumpsite during the study period
58. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to the Idi Ope dumpsite during the study period
59. Monthly values of physico-chemical characteristics, anions, cations, trace and heavy metals of the groundwater (well) close to the Oremeji dumpsite during the study period

CHAPTER ONE

INTRODUCTION

1.1 Waste

Wastes are substances or objects which are disposed off or are intended to be disposed off or are required to be disposed off by the provisions of national laws (Basel Convention, 1989). They are unwanted residues that are usually perceived to be of negative value (Hamer, 2003). According to Taylor and Allen (2006), waste can be loosely defined as any material that is considered to be of no further use to the owner, hence discarded. It is generated universally and is a direct consequence of all human activities. It can also be defined as any unavoidable material resulting from an activity, which has no immediate economic demand and which must be disposed off (NISP, 2003). The major classification of wastes include solid, liquid and gaseous.

Solid waste as defined by Olexa *et al.* (2003) includes garbage, refuse, yard trash, clean debris, white goods, special waste, ashes, residuals (sludge), solid, or semi-solid material, or contained gaseous material. The definition specifically includes agricultural, commercial, domestic, governmental, and mining wastes. The definition specifically excludes pollution. Liquid wastes are wastes dissolved in water emanating from industrial processes known as effluent, domestic liquid, acid waste and waste oil from workshop (NISP, 2003). While gaseous wastes are waste substances in the air (neither solid nor liquid) and they move freely to fill any available space. These include wastes resulting from gas flaring, particulate dust, waste gases from stack, cement factories, stone crushing, excavation activities, lime dust, asbestos dust, acid fumes from automobiles and cigarette fumes (NISP, 2003).

1.2 Solid waste

Solid wastes as defined by Omofonmwan and Eseigbe (2009) are residual from homes, businesses and institutions and are referred to as trash, garbage, rubbish, refuse, discards and throwaways that are no longer of any relevance to the disposer.

Solid waste also means unwanted materials or substances that are left or discarded after use, also included are by-products of process lines or materials that may be required by law to be disposed off (Okecha, 2000).

According to Omofonmwan and Eseigbe (2009), solid waste can be classified in a number of ways, on the basis of source, environmental risks, utility and physical property. On the basis of source which is commonly used, solid wastes are classified as: municipal solid wastes, industrial solid wastes, agricultural solid wastes, mining and mineral wastes, construction and demolition wastes, healthcare wastes, radioactive (nuclear) wastes, human and animal wastes.

Improved standard of living contributes to increased quantities of solid wastes (Pandard *et al.*, 2006). In the core, rural or local areas, there are high quantities of organic wastes like leaves used for wrapping food, faeces, and so on, while in the high class areas there are huge quantites of metallic wastes like tins for packaged or processed food. The generation of solid waste from household, industries, markets, abattoir and shops result in improving the standard of living of the inhabitants (Omofonmwan and Eseigbe, 2009).

Solid-waste generation and composition in Ibadan is at the rate of 153/Kg/pers./year with paper 15%, food 43%, plastics 4%, glass 6%, metals 21%, textiles 1% and other wastes 10% (Onibokun and Kumuyi, 1999). Oni (2010) also observed solid waste composition in Aba-eku landfill in Ibadan to constitute polyethylene plastics 11.5 %, rigid plastics 3.76 %, papers 17.59 %, glass or ceramics 6.62 %, metals 24.79% , food wastes 6.49 %, biodegradable humus 5.86 %, textiles 3.39 %, leather 2.29 %, wood, bones and straw 2.24 %, health care wastes 2.07 %, rubber 2.07 %, construction materials 1.58 %, car parts 0.30 %, polystyrene packaging plastics 0.21 % and miscellaneous fraction 9.25 %. Amber *et al.* (2012) observed solid wastes composition in Ibadan to include food/organics 58.5 %, paper/polythene 37.6 %, textile 1.4 %, glass and metal 0.6 %, others (dust, ash, rubber, soil, bones, ceramics 8.9 % and moisture content 23.52 %.

Literatures from different research studies indicated that urban areas produce more waste than the rural areas and this might be as a result of the high income that is being generated by the urban dwellers and also a lot of industries being located in urban areas (Ogu, 2000; Babanyara *et al.*, 2010; Aliyu, 2011).

1.3 Categories of solid wastes

Solid wastes have been categorized by various authors. According to Hamer (2003), some of the main categories of solid waste include: municipal solid waste (domestic, market and trade wastes); construction industry and demolition waste; fuel production and energy-generation waste; food, beverage and agro-industry waste; catering industry waste; forestry and forest product industry waste; amenity area and garden waste; slurries from intensive animal husbandry (animal manures); slaughterhouse solid waste (including specified materials) and diseased carcasses; waste sewage sludge (treated or untreated) and night soil; and septic hospital waste. These could further be categorized as : non-biodegradable inorganic matter; recalcitrant synthetic organic matter; biodegradable natural organic matter; off-specification and fire- and water-damaged chemicals of unknown composition and characteristics; toxic organic compounds; metals, metalloids and their derivatives; and partially biodegradable natural organic matter.

Taylor and Allen (2006) made a simple classification of waste into broad categories according to its origin and risk to human and environmental health, these are: household waste; municipal waste (MSW); commercial and non-hazardous industrial wastes; hazardous (toxic) industrial wastes; construction and demolition waste; health care wastes – waste generated in health care facilities (e.g. hospitals, medical research facilities); human and animal wastes; and incinerator wastes.

1.4 Solid waste disposal patterns

Disposal as defined in Florida Statutes 403.703 (2010) means the discharge, deposit, injection, dumping, spilling, leaking, or placing any solid waste or hazardous waste or any constituent thereof may enter other lands or be emitted into the air or discharged into any waters, including groundwaters or otherwise enter the environment.

There are different methods of solid waste disposal; Hamer (2003) described simple methods of waste disposal which solid waste management industry finds its origin in as local terrestrial dumping (landfill), dumping into both fresh and marine waters and uncontrolled burning.

According to Nelson (2007) solid waste disposal methods are:

Source Reduction – This involves the reduction of the amount of solid waste that is initially produced. This is meant to be the ideal solution, but so far, has been unsuccessful. According to USEPA (1999), source reduction is often called waste prevention and it is any change in the design, manufacturing, purchase or use of materials or products (including packaging) to reduce their amount of toxicity before they become municipal solid waste.

Reducing waste volume.

Pigs – Initially pigs were domesticated to consume peoples' left overs and convert them into pork and bacon (Commons abundance network, 2015). In the United States, this method was a major source of reducing food wastes until in the 1960's when the practice was stopped because diseases were spread in this manner (Nelson, 2007). However, it was banned in European Union when there was an outbreak of Foot and Mouth disease in pigs in 2001 and it was thought that the outbreak of the disease was due to feeding of pigs with catering waste (Commons abundance network, 2015).

In-sink garbage disposal - A garbage diposal unit is an electrically powered device that is installed under a kitchen sink between a sink's drain and the trap (https://www.geapplianceparts.com/store/parts/category/disposers). It shreds food wastes into small pieces (generally less than 2 mm or 0.079 inches) to pass through a plumbing system (Shpiner, 1997). However, the method doesn't really reduce the volume of waste; rather, it transfers the waste into the sewer system (or into the septic tanks) (Nelson, 2007).

Composting – The nature's way of recycling is composting. It biodegrades organic wastes and turns them into valuable organic fertilizers (Ecochem, 2014). This method of recycling works very well to reduce the volume of organic wastes and the wastes can then be used in gardens, fields etc (Nelson, 2007).

Recycling – This is a process of converting waste materials into new products to prevent wastes of potentially useful materials, reduction of consumption of fresh raw materials, reduction of energy usage, air pollution reduction (from incineration), reduction of water pollution (from landfilling) by reducing the need for conventional waste disposal and lower greenhouse gas emissions as compared to plastic production (Letsrecycle.com, 2006; The league of women voters, 1993).

Open dumps and sanitary landfills – Open dump is the improper disposal of any waste including household trash, garbage, tyres, barrels, demolition/construction waste, appliances, shingles, pipes, metal or any metal material which will rust, rot or burn (St. Clair County Health Department, 2014). Open dumps are often sited in wetlands, they are unlined and this makes them very unsafe, in terms of water contamination (Nelson, 2007).

The uncontrolled disposal of municipal solid wastes (refuse) on land is sanitary landfilling. Sanitary landfills are covered up daily, to reduce vermin and smell (Nelson, 2007). Sanitary landfills are engineered disposal systems that are operated in accordance with environmental protection standards (USEPA, 1994).

Incineration – The treatment for a wide range of wastes is incineration. In most waste treatments, the objective of waste incineration is to treat waste so as to reduce its volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances (European Commisssion, 2006). The means to enable recovery of energy, mineral and/or chemical content from waste is also provided by incineration (European Commisssion, 2006). Incineration is beginning to play a much larger part in solid waste disposal and incinerated waste has a much smaller volume as ash, which is a lot easier (and safer) to dispose off (Nelson, 2007).

Ocean dumping – This is the act of depositing all the waste materials from plastics, factories and industries, tankers and ships, and sewareage waste materials into the oceans and seas (Marine Insight News Network, 2016). This practice is no longer allowed; although at one time it was fairly popular (Nelson, 2007).

Illegal Dumping – This is the deliberate act or unauthorized dumping, tipping or burying of waste on unlicensed or unfit land (EPA Victoria, 2012). It is a prolific disposal method, whether individually (tossing trash out of a window while driving down the highway) or on a large scale by industries (Nelson, 2007).

Globally, there are different forms of disposal and management of solid wastes depending on the development of each country. For instance, according to Commonwealth of Australia (1996) urban areas of Australia and New Zealand have adequate sewerage systems and waste disposal services but in recent years they have come under strain especially in the largest cities. In the case of Sao Paulo in Brazil, 47

% of the garbage collected was disposed off in sanitary landfills, 32 % in controlled landfills and 30 % in open dumps (Gouveia and Ruscitto do Prado, 2010).

In Western Europe, 66 % of municipal wastes went to landfills, 18 % was incinerated, 9 % was recycled, 6 % was composted and 1 % was treated in other ways (OECD, 1997). In some countries of West Asia, up to 50 % of waste generated is left uncollected; in their urban areas, disposal of waste is by open dumping and burning. In some Gulf Co-operation Council (GCC) countries, however, waste collection and sanitary landfills are highly efficient (Kanbour, 1997).

In Latin America, 35 % of their wastes went to sanitary landfills while 25 % went to semi-uncontrolled landfills (PAHO, 1995). In North Africa, at least 20 % and as much as 80 % of urban solid wastes are disposed off by dumping in open spaces.

Nigerian cities and towns are still facing waste handling disposal problems which are due to improper waste management. In Nigeria, dumping in open spaces is the most common form of waste disposal, uncontrolled burning and disposal in surface water bodies. There are some states that have pieces of land designated as legal or controlled dumpsites or sanitary landfills. Waste disposal in Ibadan involves direct dumping into water bodies, uncontrolled burning and disposal unto designated dumpsites or sanitary landfills.

1.5 Solid waste contamination of soil, surface water and groundwater

1.5.1 Soil

Soil is a complex mixture of eroded rock, mineral nutrients, decaying organic matter, water, air, and billions of organic living organisms, most of them microscopic decomposers (Miller,1999). It is the major receiving medium of solid wastes. According to Marshal *et al.* (1996), the soil has traditionally been an important medium for organic waste disposal. The excessive input of unsorted municipal household wastes may likely lead to changes in soil physical and chemical characteristics and this can distort interrelationships among biophysical and chemical soil functions which may also lead to loading nitrates and heavy metals in soil and groundwater (Anikwe and Nwobodo, 2002).

Soil pollution also arises when wastes are being leached from landfills and the most common pollutants are metals such as mercury, cadmium, copper, lead, etc (Raman and Narayanan, 2008).

The potential effects of soil pollution are as follows:

1) Release of contaminants to the land surface, groundwater or surface water.
2) Uptake of contaminants by plants.
3) Direct contact by humans with contaminated soil.
4) Inhalation of dust particles or volatile substances.
5) Fire or explosion of landfill gases.
6) Corrosion of underground pipelines and other building components.
7) Generation of hazardous and secondary waste streams.
8) Conflict with proposed land use.

1.5.2 Surface water

Water pollution is the undesirable change in physical, chemical and biological characteristics in the water bodies which may cause harmful effects on human and aquatic life (Tian *et al.*, 2012).

The function of the source quality, the nature of the physical, chemical and biological properties of contaminants and the re-aeration capacity of a system is the capacity of the surface water environment to assimilate contaminants and pollution (Olaniyan *et al.*, 2009).

Surface water is usually rain water that collects in surface water bodies, like oceans, lakes or streams, and also groundwater that discharges to the surface from springs (Surface Water Contamination Superfund USEPA. mht). It may also be referred to as water on the surface of the planet such as in a stream, river, lake, wetland, or ocean (http://imnh.isu.edu/digitalatlas/hydr/concepts/surfhyd/srfwtr.htm). Sources of water pollution are generally grouped into two categories based on their origin. These are point sources and non-point sources.

According to section 502 (14) of the Clean Water Act (USEPA, 2012), the term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture. The point sources of pollution include municipal landfills, industrial waste disposal sites, leaking gasoline storage tanks, leaking septic tanks, accidental spills, leaks of petroleum products and of dense industrial organics. The non-point source is any source of water that does not meet the legal definition of point source (USEPA, 2012), this include atmospheric deposition, contaminated sediments, horticulture, agriculture (pesticides and fertilizers), logging, and onsite sewage disposal, bacteria and nutrients from livestock, pet wastes and faulty septic systems, atmospheric deposition and hydromodification.

When water passes through waste in a landfill cell, there is formation of leachate (landfill leachate.htm). It is as a result of fluids derived from rainfall; snowmelt and groundwater, together with liquids generated by the waste itself through processes of hydrolysis and solubilisation, brought about by a whole series of complex biochemical reactions during degradation of organic wastes, percolate through the deposit and mobilize other components within the waste (Taylor and Allen, 2006). According to Ozanne (1990), leachate corresponds to atmospheric water that has percolated through waste, interacting with bacteriological activity and especially organic substances. It has the ability to pollute either groundwater or surface water since it might percolate through the soil or direct infiltration on site (Leachate. www.foe.org/site1/ptp/chapter 3.html).

1.5.3 Groundwater

Surface water seeps through the soil and becomes groundwater; so also groundwater can also feed surface water sources. Groundwater is water that occupies the pores or crevices of soil or rock (Water or Rivers Commission, 1998). These include wells and boreholes.

One of the potential causes of groundwater contamination is land disposal of municipal solid waste. Soluble components of solid waste in contact with water will

change the groundwater quality either directly or indirectly by infiltration of contaminated surface water (Golwer and Matthess, 1968). According to Noring (1951) and Legrand (1965), the extent and intensity of contamination of groundwater depends on the factors listed below:

a) The waste materials' chemical and physical qualities
b) The variable pattern of waste disposal by man and the accidental release of contaminants in the ground.
c) Duration and surface size of contact between waste material and water in the saturated and unsaturated zones of the ground varying in time.
d) The contaminants' behavior in the surface water and in the saturated and unsaturated zone of the ground.
e) The physical and chemical properties of soil and rock environment varying within space.
f) Microorganisms' influence in saturated and unsaturated zone varying in time.
g) The qualities of water percolating from surface water or from other aquifers into an aquifer of specific character varying in time.
h) Climatic conditions varying in time.
i) Hydrologic conditions varying in time and space.
j) Man's pattern of water development from wells.

The soil is linked to groundwater pollution in various ways:

1) When a chemical comes into contact with soil moisture, the chemical has the characteristics of solubility, adsorption, volatility, and degradation.
2) The texture, permeability and organic matter content of the soil are the important characteristics of the soil which help determine groundwater contamination.
3) The depth to groundwater at a specific location is also important because the soil between the surface and groundwater acts as a filter. Less soil means more leaching, less adsorption, less degradation.
4) Cold soils due to the climatic condition slow the rate of degradation and increase the time a chemical is available for leaching.

The linkage of soil to groundwater pollution was supported by Critto *et al.* (2003). They observed a migration of hydrophilic organic compounds, which was identified cumulatively by dissolved organic carbon (DOC) from the soil to the surface and semi–confined aquifers. The evidence of the migration was supported by behavior of anions sulphate and chloride, which also underwent transfer from surface soils to underlying aquifer. Also highest concentration of chloride leachated from the urban solid waste discharged into the landfill was found within the semi–confined aquifer while highest concentration of sulphate and dissolved organic carbon were in the surface aquifer.

1.6 Impacts of solid waste and leachate on organisms

Leachate has an origin other than domestic or commercial waste. For example, leachate from a chemical waste site can have an effect that is totally different, there may not be any changes in the physical appearance of the water but it may cause sterility in the water (Henton, 1982). Studies by Henton (1982) revealed that in Scotland, leachate polluted surface water bodies with biochemical oxygen demand (BOD) and ammonia as the chief pollutants. The BOD deoxygenated the water and resulted in "thick growths of sewage fungus" on the bed of the water course. Ammonia was highly toxic to fish life and caused instantaneous fish-kills when it first entered the water. High chlorides and heavy metals were also present. This thus affected activities such as fishing, stockwatering and land drainage but overwhelmingly the destruction of the amenity value of the water course was the most serious effect. Further studies by Alkassasbeh *et al.* (2009) on the toxicity of leachate from three landfills in Malaysia, revealed that at the different leachate concentrations, the Common Carp (*Cyprinus carpio*) showed behavioural changes, decline in general activity, loss of balance, breathing difficulties, excessive mucosal secretion and gathering at the surface for breathing.

Further investigation on leachate toxicity showed that rats exposed to raw and simulated leachates of different concentrations showed chromosome aberrations in a concentration dependent manner (Alimba *et al.*, 2006).

Indiscriminate dumping of refuse also permits the breeding of different organisms, like flies and rodents that can transmit various diseases to man.

1.7 Ibadan city

Ibadan city in Nigeria is one of the largest in sub-Saharan Africa. There are huge quantities of waste production and improper methods of disposal of wastes in Ibadan, which is causing environmental pollution. Aesthetic values of some areas have also been negatively affected. This city is seriously experiencing problem of municipal waste management, principally as a result of unplanned development, rural-urban migration and natural increase within the city (Akinbiyi, 1992).

Inhabitants of the core areas of Ibadan majorly deposit their wastes and defaecate directly into streams flowing around them. Along the highways of Ibadan, heaps of wastes are found there; if not recently that the present government has now intensified effort by clearing the refuse. There are some streets (Ojokondo) within the city where there are heaps of wastes that even reach the height of a-storey building. However, in some areas where the high-class people inhabit, there are refuse drums placed in front of various houses for wastes and the workers of the state's waste management board move the wastes to the legal dumpsites within the city.

1.8 Justification

Ibadan city is still facing waste handling disposal problems which are due to improper waste management. Most of the core areas within the city experience indiscriminate dumping of refuse into water bodies and land. This affects qualities of soil, streams and groundwater around such waste sites. This also affects the existence or abundance of certain fauna inhabiting such areas.

Earthworms are the dominant fauna in most soils, therefore, there is need to check their abundance in soil from stream banks and dumpsites.

There is also a need to assess the ecotoxicological effects of the waste by using some animals as test models. Therefore, the use of:

- Earthworms - *Eudrilus euginiae* (Kinberg, 1867),
- Aquatic insects - larvae of mayflies, *Cloeon perkinsi* (Barnard, 1932),
- Amphibians tadpoles - *Rana temporaria* (Linnaeus, 1758) and
- Frys and fingerlings of *Clarias gariepinus* (Burchel, 1822).

The soil is a sink for contaminant, so there is need to check the top soil (0 -15 cm) qualities.

The streams receive most of the wastes; they serve as sources for larger bodies such as dams or reservoirs. There is need to investigate the effects of the refuse dump on their physico-chemical qualities.

The groundwater qualities also need to be investigated since most of the population depends on them for drinking.

1.9 Aim of the study

The aim of this study was to investigate the physico-chemical qualities of soil, streams and groundwater (wells), abundance and diversity of earthworms; and acute toxicity of solid waste-contaminated water on some fauna associated with dumpsites in ten local government areas of Ibadan.

1.10 Objectives

The study had the following objectives:

- Determination of the impact of solid waste on top soil qualities.
- Determination of the impact of solid waste on soil from banks of streams receiving the wastes.
- Assessment of the physico-chemical analysis of the streams that receive wastes.
- Assessment of the physico-chemical analysis of the groundwater close to the different waste sites.
- Ascertain the negative impacts of the waste disposal patterns on the local community.
    - Identification of the different species of earthworms found in the soil of the dumpsites.
    - Determination of the acute toxicity of the solid waste in five taxonomic groups:

        Annelids (*Eudrilus euginiae*)

        Arthropods (Insecta – *Cloeon perkinsi*)

        Amphibian (*Rana temporaria*)

        Fish (*Clarias gariepinus*)

CHAPTER TWO

LITERATURE REVIEW

2.1 Solid waste: Definition and generation

Solid waste as defined by Olexa *et al.* (2003) includes garbage, refuse, yard trash, clean debris, white goods, special waste, ashes, residuals (sludge), solid, or semi-solid material, or contained gaseous material. The definition specifically includes agricultural, commercial, domestic, governmental, and mining wastes. The definition specifically excludes pollution.

Solid wastes are generated by almost every activity and the amount varies by source, season, geography and time (Robert, 1999). The by-product of urbanization is solid waste (Tahir *et al.*, 2015). According to Hoornweg and Bhada-Tata (2012), municipal solid waste which is one of the most important by-products of an urban lifestyle is growing faster than the rates of urbanization. Their report estimated that in 1992, 2.9 billion urban residents generated about 0.64 kg of municipal solid waste per day (0.68 billion tonnes per year) which has increased to about 3 billion residents generating 1.2 kg per person per day (1.3 billion tones per year) in 2013 and by 2025, about 1.42 kg/capital/day (2.2 billion tones per year) of municipal solid waste will be generated by 4.3 billion urban residents. By 2025, globally solid waste management costs will increase from today's annual $ 205.4 billion to about $ 375.5 billion and cost increases will be most severe in low income countries (more than five-fold increases) and lower-middle income countries (more than four-fold) (Hoornweg and Bhada - Tata, 2012).

In the United States, 158 million tonnes of municipal solid wastes are produced annually (Olafusi, 2004), it increased to 254 million tonnes in 2013 (USEPA, 2013), while it was estimated in 2014 that 1.99 kg of municipal solid waste was generated per person per day (USEPA, 2014).

In Nigeria, 25 million tonnes of municipal solid wastes are generated annually and the waste generation rates ranged from 0.66 kg per capital per day in urban areas to 0.44 kg per capital per day in rural areas (Ogwueleka, 2009). Olafusi (2004) reported that estimate of 44 pounds (20 kg) of municipal solid waste was generated per capita per year while Babayemi and Dauda (2009) reported 0.58 kg per person per day. In Lagos, 9 000 to 10 000 metric tonnes of wastes were produced per day (Olubori, 2011) while the rate of solid waste generation per person was 0.3 kg per capita per day (Habitat, 1997). Ibadan has 1.1 kg per capita solid waste generation per person per day (Habitat, 1997).

Solid waste generation rate of some cities in Nigeria was reviewed by the Federal Ministry of Housing and Environment (FHME, 1982), Lagos generated 55,991 tonnes per year; Ibadan, 55, 224; Port Harcourt, 51, 390; Aba, 54, 458; Kano, 39, 885 while Jos, 18, 792. Another review by the Enugu State Environmental Sanitation (1994), reported that there was tremendous increase with Ibadan having 733, 542 tonnes, Port Harcourt had 285, 466, Aba had 113, 300, Enugu 78 603, Abeokuta 73, 386, Kano 72, 066, Jos 33, 977 and Benin had 32, 327 (Ezeji, 2010). A review carried out in 2007 also showed a significant monthly increase with Lagos generating 255, 556 tonnes with 0.63 kg per capital per day; Kano, 156, 676 tonnes with 0.56 kg per capital per day; Ibadan; 135, 391 tonnes with 0.51 kg per capital per day; Port Harcourt, 117 825 tonnes with 0.60 kg per capital per day; Makurdi, 24, 242 tonnes with 0.48 kg per capital per day; Onitsha, 84, 137 tonnes with 0.53 kg per capital per day; Nsukka, 12, 000 with 0.44 kg per capital per day; and Abuja, 14, 785 tonnes with 0.66 kg per capital per day (Ogwueleka, 2009). According to Iruruaga (2012), the rate of waste generation in Lagos state was 9, 000 tonnes per day while in Kano it was 3, 849 tonnes per day and generally, the average rate was 0.5 kg/capital/day.

2.2 Refuse storage

There are different ways of storing household refuse. These include the following:

A container of capacity 100-200 litres, preferably plastic or metal and with a tight-fitting lid should be provided for 10-20 families not more than 15 m from the shelter (United Nations High Commissioner for Refugees, 1999).

One container of 50-100 litres may be provided for every 25-50 people (Pan American Health Organization, 1996).

Large street-corner storage containers, with tight-fitting lids.

All the above allow two days worth of refuse to be stored.

Large containers or collection bays to be used in markets and commercial areas.

2.3 Treatment and movement of household refuse and market wastes

1) Burial

a) Small refuse pits in low-density settlements, where relatively small quantities of refuse are produced.

b) Communal trench 1.5 metres wide and 2 metres can be excavated by hand for refuse.

2) Sanitary landfill

The landfill site should be

a) Located away from the settlement;

b) Accessible;

c) On vacant or uncultivated land;

d) Located in natural depressions with slight slopes;

e) Downwind from the settlement;

f) Sited and organized to avoid surface water and groundwater pollution;

g) In an area that is not exposed to landslides or earthquakes.

It has been estimated by World Health Organization, United Nations Environmental Programme (1991) that an area of 0.4 – 0.5 hectares (4000m – 5000 m^2) can serve 10, 000 inhabitants.

3) Incineration

4) Waste recycling

2.4 Earthworms, environmental factors and contamination

Earthworms are one of the dominant fauna in soil. They are often grouped according to their physical appearance (body color, shape and size) and ecological functions such as burrowing abilities and food preferences (Bouché, 1977). This makes

researchers to ecologically group them as epigeic, anecic and endogeic earthworms. Epigeic earthworms are small earthworms that live in the upper litter layer of the soil, typically ingest litter and humus without extensively mixing organic and inorganic materials (Lavelle, 1988). Anecics are large deep burrowers that come to surface when it is time to feed whereas endogeics live near the surface of soils in the organic horizons while producing horizontal galleries (Paoletti, 1999). Endogeics are found in the first 10 to 20 cm and anecics in the deeper recesses of the soil (Mainoo, 2007). The combinations of these ecological categories, together or individually are responsible for maintaining the fertility of soils in the majority of habitats (Bhadauria *et al.*, 1997).

Environmental conditions critically affect cocoon production, rates of development, and growth of earthworms (Dominguez and Edwards, 2011). So also, earthworm communities are influenced by a suite of hierarchial factors with temperature dominating, followed by edaphic (nutrient status) and environmental (seasonality) factors (Fragoso and Lavelle, 1992). According to Chauhan (2014), soil factors that regulate earthworm population include organic matter, total nitrogen, available phosphorus, texture and pH. Earthworms have fairly complex responses to changes in temperature (Dominguez and Edwards, 2011). The unfavorable effect of high temperatures (above 30°C (86°F)) on most species of earthworms is not entirely a direct effect because these warm temperatures also promote chemical and microbial activities in the substrate, and the increased microbial activity tends to consume the available oxygen, with negative effects on the survival of earthworms (Dominguez and Edwards, 2011). The moisture content of organic wastes and the growth rate of earthworms have strong relationships (Dominguez and Edwards, 2011). The pH range that is suitable for earthworms' growth is about 4.2 to 8.0 (Sherman, 2003). Most epigeic earthworms can tolerate pH levels of 5–9, but when given a choice in the pH gradient, they move toward the more acidic material, with a pH preference of 5.0; They are very sensitive to anaerobic conditions since they lack specialized respiratory organs, and oxygen and carbon dioxide diffuse through their body wall; They are very sensitive to ammonia and cannot survive in organic wastes containing high levels of this cation, they also die in wastes with large quantities of inorganic salts (Dominguez and Edwards, 2011).

Earthworms enrich and improve the soil or plants, animals and also humans. They aerate the soil layers and feed on organic matter. The mixing of the soil and organic matter made Charles Darwin (1881) to refer to them as nature's plough (Earthworm Society of Britain, 2014). They are the best known and often the most important animals influencing the functioning of soil ecosystems (Hendrix and Bohlen, 2002). They significantly influence soil structure, nutrient cycling and crop productivity (Gonzalez *et al.*, 2006). They often dominate the fauna of soil food webs in terms of biomass (Lee, 1985; Lavelle *et al.*, 1999) and their casting and burrowing activities increase soil porosity, stimulate microbial activities, and accelerate litter decay and the release of nutrients into the soil (Lee, 1985; Lavelle *et al.*, 1999; Gonzalez and Seastedt, 2001; Gonzalez, 2002; Liu and Zou, 2002). The abundance and species composition of earthworms fauna at a particular site and also the preference, avoidance or activity of individual earthworms (that is, the behavior) in contact with a soil substrate, can indicate the quality of the soil (Heinz-Christian *et al.*, 2011). Anthropogenic activities generally spread populations of exotic earthworms therefore leading to a dominance of exotic species in agricultural soils (Lee, 1985).

2.5 Impacts of solid waste on soil

The soil is the major receiving medium of solid wastes. According to Marshal *et al.* (1996), the soil has traditionally been an important medium for organic waste disposal. The excessive input of unsorted municipal household wastes may likely lead to changes in soil physical and chemical characteristics and this can distort interrelationships among biophysical and chemical soil functions which may also lead to loading nitrates and heavy metals in soil and groundwater (Anikwe and Nwobodo, 2002).

Soils differ in their response to organic waste amendments and it is important to investigate more closely the influence of these organic and inorganic wastes on a range of soil physico-chemical properties (Mbagwu, 1989). There could be changes in soil physical properties when humic acid, which is an exogeneous substance in municipal wastes react with soil components (the hydrophilic groups in the humic acid can interact with the polyvalent cations present on the surface of soil particles) to cause changes in soil physical properties (Piccolo and Mbagwu, 1997).

Soil organic matter is a reservoir of essential and non-essential mineral elements for plant growth and development; hence increased organic matter may lead to increased soil productivity (Anikwe and Nwobodo, 2002). It can reduce bulk density and increase total porosity and hydraulic conductivity in heavy clay soils (Anikwe, 2000) and influences the degree of aggregation and aggregate stability (Mbagwu and Piccolo, 1990). High levels of organic matter were observed in municipal solid waste dumpsites in Uyo municipality, Nigeria (John *et al.*, 2006; Anikwe and Nwobodo, 2002). Okeke (2014) also observed high organic matter contents of topsoil and subsoil of ferrealsol soil receiving solid waste in Owerri, Nigeria. Soil samples collected from a dump-field in Yenagoa, Bayelse state, Nigeria also had high levels of organic matter (Amos-Tautua *et al.*, 2014). In addition, waste-amended soils have also been reported to have high organic matter content (Anikwe, 2000). An increase in soil pH of waste dumpsites in urban Abakaliki, Southeastern Nigeria was observed by Anikwe and Nwobodo (2002). Ideriah *et al.* (2006) also observed increase in pH of a dumpsite in Port Harcourt, Nigeria. In the analysis of soils from waste dumpsites in Benin, Nigeria, Oviasogie and Oviasogie (2014) also obtained an increase in the soil pH. This may be due to high organic matter content which tends to buffer the soil by preventing excessive pH changes due to exchangeable cations during mineralization of organic matter (Woomer *et al.*, 1994). Increased pH in dumpsite soils is a positive productivity indicator in an acidic tropical soil where low pH limits uptake of nutrient elements.

John *et al.* (2006) observed high nitrogen content in municipal dumpsites in Uyo. High nitrogen content was also observed by Oviasogie and Oviasogie (2014) in waste dumpsites in Benin. This was also observed in soils from a municipal dumpsite in Abakaliki by Anikwe and Nwobodo (2002) which they reported that this may be due to the high amount of vegetation observed at their dumpsites.

High cation exchange capacity (CEC) which increased down the profile by 7 – 25%, and also higher percent base saturation which was as a result of increased sodium, potassium, calcium, and magnesium were observed by Anikwe and Nwobodo (2002) in soils from a municipal dumpsite in Abakaliki.

Critto *et al.* (2003) observed high concentrations of sulphate and chloride in soils of an illegal landfill in Venice, Italy. The high concentrations were likely to be derived from the rainfall leaching processes that dissolve the large quantities of the chalks and

transport the liquors percolated from urban solid waste discharged into the landfill. Waters percolated from urban solid waste landfill normally contain high chloride levels, commonly in 2 000 – 3 000 mg/L average range (Cecchi *et al.*, 1993).

Continuous disposal of municipal wastes in soil may increase heavy metal concentration and this may consequently have harmful effects on soil, plants and human health. Environmental contamination and exposure to heavy metals, is a serious growing problem throughout the world because metals are non-biodegradable and persistent in the ecosystem; physical, chemical and biological processes may combine under certain conditions to concentrate metals rather than dilute them: and the societal impact of a contaminated system is substantial.

In uncontaminated soil, the typical metal recommended are Zinc 80 mg/kg, copper 20 mg/kg, nickel 25 mg/kg and cadmium 0.5 mg/kg (DOE/NWC, 1981). Lead is the most widespread source of contamination of soils and plants (Wild, 1973). It stays a long time in both soil and water (Tuberose.com, 2005). Because lead is immobilized by the organic components of soil, most of it deposited from air is generally retained in the upper 2 – 5 cm of undisturbed soil (EPA, 1986; NSF, 1977). According to Kabata-Pendias and Pendias (1984), the normal range of lead in soils is from 2 to 300 mg Kg^{-1}. Oketola and Akpotu (2014) observed high contents of heavy metals (Zn, Pb, Cr, Cu and Cd) in topsoils of some dumpsites in Lagos and Ibadan. Anikwe and Nwobodo (2002) observed increased levels of heavy metals (Pb, Cu, Fe and Zn) in soils of the municipal waste sites in Uyo. They observed lead content of Waterleaf (*Talinum triangulare*) leaves to be 83.92 mg Kg^{-1} which is within critical concentration of 30 to 300 mg Kg^{-1} reported by Kabata-Pendias and Pendias (1984). This is contradictory to what Amusan *et al.* (1999) found out in Waterleaf (*Talinum triangulare*) and Okra (*Abelmuscus esculentus*) grown in a dumpsite at Obafemi Awolowo University garbage dump. They observed that lead uptake of Waterleaf increased by 2003 % and 733 % in leaves and roots respectively and 126 % in roots of Okra relative to those grown in non-dumpsite. However, Miller and Miller (2000) postulated that lead is not taken up by plants to any degree, and thus plants are not a major risk pathway for ingesting lead.

Trace elements accumulation in soil in dumpsite may lead to increased uptake of trace elements in plants although their transfer ratios differ from crop to crop (Anikwe and Nwobodo, 2002). This may mean that as the level of these metals in the soil is

significantly increased, some test crops have the potential of showing increased uptake of metals (Amusan *et al.*, 1999). Voutsa *et al.* (1996) maintain that there is generally not a strong relationship between the concentrations of heavy metals in soil and plants, because it depends on many factors such as soil metal bioavailability, plant growth, and metal distribution to plants.

Anikwe and Nwobodo (2002) observed normal range of copper in soil (2 – 250 mg Kg^{-1} as reported by Kabata-Pendias and Pendias (1984)). However, Amusan *et al.* (1999) found that leaves of Waterleaf plants grown in dump soil contained 29.20 mg Kg^{-1} Cu which was well within the critical range found in plant tissues (20 – 100 mg Kg^{-1}). They also obtained zinc values which were within the normal range obtained in soil (10 – 300 mg Kg^{-1}, Logan, 2000). Miller and Miller (2000) noted that zinc and copper are toxic to plants before they accumulate in sufficient tissue concentrations to affect animals or humans. As a result, over application tends to kill or stunt plants, minimizing opportunities for poisoning animals and humans consuming them (Anikwe and Nwobodo, 2002).

2.6 Impacts of municipal solid wastes and leachate on terrestrial organisms

Since the soil is the major receiving medium of solid wastes, therefore the organisms (minute microorganisms to human beings) found on land are exposed to various effects of solid wastes and leachates.

Simonsen and Scott-Fordsmand (2004) found significant correlation of copper and zinc in earthworms with the total concentration and $CaCl_2$ extractable fraction of the metal in the soil. Canbek *et al.* (2005) found the mean lead concentrations of earthworms to be lower than those of the mean soil samples. This conformed to the work of Bamgbose *et al.* (2000); they reported lower levels of lead in earthworms from dumpsites in Abeokuta, Nigeria. Nahmani *et al.* (2004) observed that metal pollution reduced species richness of earthworms (from 6 to 1 species). Morgan and Morgan (1988) in their research on two ecophysiologically dissimilar earthworm species, found tissue lead concentration of earthworms to be substantially lower than the total soil lead concentrations but at a particular site, the tissue lead concentration were approximately 5 to 10 times higher than that of the soil. High heavy metals (Pb, Cd, Ni, Cr, As, Mn, Hg) concentrations were also observed by Uzoije *et al.* (2013) in their analysis of heavy metals present in earthworms collected from waste-polluted

soils of Nnewi, Nigeria. Udousoro *et al.* (2015) observed high accumulation of lead (Pb), cadmium (Cd) and iron (Fe) in *Eudrilus euginiae* earthworms collected from toxic metals impacted soils in Akwa Ibom, Nigeria.

Rats exposed to raw and simulated leachates of different concentrations were observed and they showed chromosome aberrations in a concentration-dependent manner (Alimba *et al.*, 2006). *Leachate*-induced genotoxicity were found in mouse (Tewari *et al.*, 2005; Sang and Li, 2005; Bakare *et al.*, 2005), *Drosophila melanogaster* (Siddique *et al.*, 2005) and *Allium cepa* (Cabrera and Rodriguez, 1999; Bakare and Wale-Adeyemo, 2004; Sang and Li, 2004). Alimba *et al.* (2012) observed histopathological lesions in the liver and kidney of wistar albino rats exposed to leachates from Olusosun and Aba Eku landills in Ibadan, Nigeria. Alimba and Bakare (2016) also observed significant increase in micronucleated normochromatic erythrocytes formation in the bone marrow of rats exposed to landfill leachates from Aba Eku, Ibadan.

Microorganisms enter the human body through hand-to-mouth contact during eating, drinking, and smoking, or by wiping the face with contaminated hands or by licking splashes from the skin (SEPA, 2007). Improper disposal of human faeces transmit a number of major diseases, which include diarrhoea, schistosomiasis, hepatitis A and E, dysentery, cholera, typhoid fever, and also infection with helminthes and trachoma. Improper disposal of solid wastes are also associated with vector-borne diseases such as malaria and dengue fever (http://www.emro.who.int/CEHA/pdf/Pakistan.pdf).

Nitrate causes metheglobinemia, or blue baby syndrome, a condition that prevents the normal uptake of oxygen in the blood of young babies (National Small Flows, Clearinghouse, 2007).

Fecal coliforms do not pose a health threat but serve as an indicator for bacteria that can cause illness in humans and aquatic life (Caldwell, 2007). However, if they are in high concentrations, they are a problem to human drinking water.

When wastes that are not properly disposed contaminate drinking water, diseases may result which may finally lead to death. The disease may be diarrhea especially in children, with major enteric pathogens which include rotavirus, *Camplobacter jujeni*, enterotoxigenic *Escherichia coli*, *Shigella spp.* and *Vibrio cholerae* 01, and possibly enteropathogenic *E. coli*, *Aeromonas spp. V. cholera* 0139, enterotoxigenic

Bacteroides fragilis, *Clostridium difficile*, and *Crytosporidium parvum*. In adults, in addition to traditional pathogens (helminthes, *Entamoeba histolytica*, *Giardia lamblia* hepatitis A and E), enterovirus, *C. jujen* and *Helicobacter pylori* are emerging issues (Ashbolt, 2004).

Alkaline Comet assay was used to observe human peripheral blood lymphocytes exposed to leachates and solid wastes from a polyfiber factory, an aeronautical plant, and a municipal sludge leachate. The result showed that there were DNA damages in the lymphocytes (Bakare *et al.*, 2006).

Onyidoh (2006) reported that most developing cities due to poor waste disposal are infested with arthropods, rodents, mollusks or alternative hosts of human disease, sleek, fat and rats which expose people to rat bite fever, murine typhus, bubonic plague and other diseases. Furthermore, some outbreaks of bubonic plague, secondary cases of plague pneumonia are seen.

A famous episode of Minamata disease occurred in Japan in the fifties due to consumption of fish contaminated by methyl mercury (Central Pollution Control Board, 2006). Sharma (2002) reported that in Shimla, India, waste indiscriminately thrown into nullahs and on the roadside contaminated the water supply and stomach ailment increased in the town. Cancer risk analysis conducted in United States indicated that 60 % of municipal solid wastes landfills posed a cancer risk of less than one in 10 billion, another 6 % posed a risk of less than one in a million (Chilton and Chilton, 1992).

2.7 Mayflies and contamination

Mayflies are aquatic insects belonging to the order Ephemeroptera. Ephemeropterans are sensitive indicators of water qualities (Pontasch and Cairns, 1988; Short *et al.*, 1991; Williams and Williams, 1998) particularly to contaminants such as metals and ammonia (Peckarsky and Cook, 1981) and they have been regarded as the most sensitive order of aquatic invertebrates (Echols *et al.*, 2010).

Mayflies' nymphs are important components of freshwater ecosystems (www.science.jrank.org/pages/4188/Mayflies-Ecological-economic-importance-mayflies.html). They live for a very long time in the bottom of water in U-shaped burrows that they construct. There have been significant effects on mayflies diversity

throughout the world due to impact of human activities (Landa and Soldan, 1995). The presence of mayflies in an aquatic ecosystem is a strong indication that the water quality conditions are good and a healthy water body (Krieger, 1997; Voshell and Reese, 2002). They are specific in their choice of habitat requirements and tolerance of environmental conditions such as water temperature and chemistry (Krieger, 1997). They also play an important role in the food web because they acquire energy from decomposed plant material, move it to higher consumers like macroinvertebrates, fish, birds, etc. More mayflies result in more fish (Krieger, 1997).

Mayflies' nymphs are very sensitive to pollutants in the water and the sediments because of their constant contact with the sediments where the pollutants accumulate. If there is high concentration of pollutants, the mayflies could die or their development could be altered. If the sediments and the water qualities are good, they complete their life cycle. There was mass death of nymphs of mayflies *Hexaginia rigida* and *Hexaginia limbata* in Lake Erie during the 1950s and early 1960s, due to its pollution by organic debris associated with sewage and algal growth which used up oxygen in the bottom of the lake (Krieger, 1997).

Exposure to sublethal concentration of metals reduces growth, fecundity and survival of aquatic organisms. Mayflies are sensitive indicators of metal pollution. Their abundance and species richness were biological indices to detecting impacts of metal pollution in Rocky Mountain stream in Colorado (Kiffney and Clements, 1994; Kiffney and Clements, 1996; Clements *et al.*, 2000). Lower abundance of mayflies, especially heptageniid mayflies was observed by Clements *et al.* (2000) in their survey of 95 sites in the southern Rocky Mountain ecoregion in Colorado.

Mayflies are sensitive to acidification, show reduced densities and/or richness at low-pH sites, which is as a result of acidic deposition through precipitation (that is, acid rain) (Thorp and Rogers, 2014).

One of the most common and diversified genera is the genus *Cloeon* Leach, 1815 Ephemoreptera (Salles *et al.*, 2014). *Cloeon perkinsi* is the most abundant of the African *Cloeon* with nymphs occurring in many types of still or slowly moving water from temporary ponds to the margin of large lakes (Gillies, 1980). However, *Cloeon dipterum* larvae (a species found in the temperate zones) support water of low quality, that is α-β mesosaprobic (Zelinka and Marvan, 1961) and temporary anoxia (Nagell, 1977). Four saprobic zones according to biochemical oxygen demand (BOD) were

divided. They are oligosaprobic – 1 - 2.5 mg/L and β mesosaprobic (2.5 – 5 mg/L), α-mesosaprobic (5 – 10) and polysaprobic (10 - 50 mg/L) (Curds, 1992).

2.8 Tadpoles and contamination

Amphibians are bioindicators of environmental stress (Hall and Mulhern, 1984; Freda, 1991; Dunson *et al.*, 1992), especially due to decline of some population (Barinaga, 1990). Amphibians are very important components of different ecosystems worldwide. The deposition of their unshelled eggs in aquatic environment, development into a gill-respiring, swimming herbivorous/detritivorous larval stage and an adult stage which is semi-aquatic climbing/hopping insectivorous make them highly vulnerable to numerous stressors in both aquatic and terrestrial environment (Wassersaug, 1997). They are highly sensitive to many pollutants such as aluminium, cadmium, iron, lead and zinc and pesticides such as atrazine and DDT (Gupta, 2009). They can take up toxicants by both dietary ingestion and dermal absorption, this makes them to potentially accumulate significant body burdens (Gupta, 2009). Their highly permeable skin that is involved in dermal respiration also facilitates potential uptake of contaminants.

Tadpoles growth and survival can be affected by alterations in environmental factors such as limitation of resources, predation, crowding and dessication of habitat (Shi, 2000). If these factors are present, they either stimulate growth during prometamorphosis or inhibit it during premetamorphosis (Shi, 2000).

Anuran amphibians are susceptible to the uptake of heavy metals due to their highly permeable skin that allows the rapid absorption of metal ions (Ficken and Byrne, 2003). Tadpoles frequently ingest sediments that have accumulated heavy metals; this is due to the microphagous feeding habit of most species (Hopkins and Rowe, 2010). Ecological relevant concentrations of metals are lethal to amphibian embryos, larvae and adults (Linder and Grillitsch, 2000; Hopkins and Rowe, 2010). Sublethal concentrations can have harmful effects on tadpoles, which include reduced growth rates, delayed metamorphosis and impaired behavioural responses (Hopkins *et al.*, 2000; Hopkins and Rowe, 2010).

Ficken and Byrne (2003) observed that the concentrations of copper, nickel, lead, zinc, cadmium and mercury in water of Merri Creek Corridor in Victoria, south-

eastern Australia significantly affected anuran species richness. It was also negatively affected by orthophosphate and conductivity of the water.

Juveniles of anurans accumulated greater concentrations of polychlorinated biphenyls (PCBs) compared to adults collected from the same contaminated stream locations flowing from Paducah gaseous diffusion plank, Paducah, Kentucky (De Garaday and Halbrook, 2006).

2.9 Fish and contamination

Fish is very high in protein, which makes it very important in the human diet to help for body growth and maintenance of muscle tissues. About 25 % of animal protein is from fish and shellfish, about 35 % of all fish is eaten fresh, frozen or chilled, 16 % each is cured or canned, while 32 % is made into oil and fish meal (Ayoola, 2010). In Nigeria, the local production of fish is 0.51 million tonnes, while the national demand for fish is about 1.85 million tonnes based on population figure of 140 million people, therefore, to meet the growing demand, tilapia and catfish are being produced by domestic fish farmers (Ayoola, 2010).

Clarias gariepinus is a major fish species for aquaculture in Africa (Sotolu, 2010). It has omnivorous feeding habit, high growth rate, and resistance to handling and stress (Fagbenro and Davies, 2001). Naturally, it is found in fresh water bodies such as streams, rivers, floodplains, swamps and lakes. A mature female lays about 60, 000 eggs.

Clarias gariepinus is of commercial importance in aquaculture due to its positive attributes like resistance to diseases, high fecundity and ease of larval production (Hogendoorn, 1980; Haylor, 1991; Kestemont *et al.*, 2007). However, in the larval stages of catfish, there is high mortality attributed to infectious diseases caused by parasites. Reproduction in the African catfish is in response to environmental stimuli such as a rise in water level and inundation of low-lying areas (FAO, 2015).

Fishes are a key unit in many natural aquatic food webs and they can also serve as environmental indicators of polluted water (APHA, AWWA, WEF, 1998).

Temperature, dissolved oxygen, pH, salinity and water movement are often the dominant factors that affect fish distribution in the aquatic environment (Boyd, 1982). Nevertheless, temperature has effect on the rate of metabolism and consequently on

the rates of feeding, growth and reproductive activities (Crillet and Quetin, 2006). In Lake Victoria, the young of two groups of Cichlids sorted themselves out in shallow water on hot days according to their ability to tolerate high temperature; tilapiine Cichlids were found in the hottest shallowest water, while haplochromine Cichlids were found in slightly cooler and deeper water (Lowe-McConnel, 1987). A sudden change of temperature of 5 °C will stress or even kill fish, this formed the basis of acclimatization of fish especially when transporting them (Wootton, 1996). Generally, temperature has a pronounced effect on the rate of chemical and biological processes in water. For some processes such as the rate of oxygen consumption, an increase in temperature causes an increase in these rates until the lethal temperature is reached. Therefore, there is an optimum temperature at which the rate of oxygen consumption is maximal. At temperatures lower or higher than the optimum, the rate of oxygen consumption declines (Shreeder, 1975).

Rapid breathing of fish and increase in the amplitude of respiratory movement are caused by a decline of oxygen supply (Mason, 1991). A marked increase in opercula movement of three-spined stickleback (*Geasterosteus aculeatus*) when placed in deoxygenated water for 28 minutes was reported by Mason (1991). A rapid decline in the movement was followed. The rate of opercular movement gradually returned to normal when the water was re-aerated. Organic pollution causes depletion of oxygen, which causes increase in the ventilation volumes of fishes and cardiac output is reduced at low levels of oxygen. This reduces the rate of passage of blood through the gills, therefore prolonging the period of time for oxygen and also conserving oxygen by reducing muscular work.

Heavy metals may enter fin-and shell-fishes through direct absorption from the water through their gills and other exposed membranes (Matagi, 1996). However, most pollutants in aquatic organisms pass through the food chain (Olaniyan, 1975). Firstly, phytoplankton, bacteria, fungi and other small organisms absorb these substances and are in turn eaten by fishes (Fagade and Olaniyan, 1974; King and Jonathan, 2003).

Heavy metal contamination of fish has adverse effect on humans and wildlife, because the consumption of fish is the primary route of heavy metal exposure in the aquatic evironment (Albaret and Lae, 2003). Fufeyin and Egborge (1998) reported the presence of unacceptable levels of mercury and lead in the tissues of the African catfish, *Clarias gariepinus* from Ikpoba River. *Oreochromis niloticus* and *C.*

gariepinus cultured in some disused mining lakes have been shown to bioaccumulate higher concentration of Copper, Iron, Magnesium, and Zinc in their muscle, liver and gill tissues. They also reported that heavy metal concentrations in aquatic fauna are often proportional to the levels in the aquatic environment in which the fauna resides. Variation in the feeding habits of fish species can be a function of the levels of heavy metal found in their tissues (Wootton, 1996). Reash (1986) showed that mercury concentrations in edible muscles of pelagic fish species are lower than those of benthic fish species. Continuous pollution of our streams, rivers, lagoons, estuaries, creeks and other surface water bodies constitute significant threat to aquatic flora and fauna, posing considerable setback to fishing either for recreation or commercial purposes, and ultimately constitute adverse health hazards to humans (Chapman and Kimstach, 1992).

2.9 Impacts of solid waste on physico–chemical qualities of water

When large amount of organic matter and soil materials are washed into water bodies, it can raise the biochemical oxygen demand of the water and this can deplete the water of dissolved oxygen, therefore creating anoxic condition. Therefore, fish kills might result due to asphyxiation (Pidgeon, 2001).

Biochemical oxygen demand refers to the ability of organic material to reduce dissolved oxygen in water. Bacteria remove oxygen from water as they metabolize organic materials high in biochemical oxygen demand. The oxygen depletion eventually results in the death of not only the bacteria, but of oxygen–dependent aquatic species. The subsequent decomposition of the bacteria will further reduce dissolved oxygen concentration in water.

Ikem *et al.* (2002) observed poor qualities of groundwater near two waste sites in Ibadan and Lagos. The results of pH, conductivity, TDS, chloride, nitrate, ammonia, chemical oxygen demand, aluminium, cadmium, chromium, iron, lead, nickel and total coliforms all exceeded the World Health Organization (WHO) standards for drinking water irrespective of source of pollution. Some samples were polluted with aluminium, cadmium, chromium, iron, lead, nickel and total coliforms greater than zero. Some Ibadan wells were polluted with ammonia due to seepage from sewage tanks into drinking wells. Aderemi *et al.* (2011) observed high electrical conductivity

and total dissolved solids in eight groundwater samples near a municipal waste dumpsite in Lagos, Nigeria.

Chofqi *et al.* (2004), on their analysis of wells located from landfill sites, observed high salinity related to sea water intrusion (Younsi *et al.*, 2001; El Achheb, 2002), nitrate concentration of more than 50 % of the wells exceeding 50mg/L (OMS, 1993), high contents of organic and inorganic chemicals, more than 4.5 mS/cm in electrical conductivity, 1600 mg/L in chloride, 1000 mg/L in sulphate, 15 – 25 µg/L in cadmium and 60 – 100 µg/L in chromium and high concentrations of heavy metals, and high chemical oxygen demand.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the study area

Ibadan is the capital of Oyo state in Nigeria, West Africa. It has a land size covering an area of 3 123.30 km^2 (Tomori, 2008) and with human population of 2,550,593 by 2006 census (National Population Commission, 2007). The city lies approximately on the longitude $3^0$5` East of Greenwich Meridian and latitude $7^0$23` North of the Equator at a distance of some 145 km northeast of Lagos (Tomori, 2008).

Ibadan is directly connected to many cities and towns in Nigeria, as its rural hinterland by a system of roads, railways and air routes. The physical setting of the city consists of ridges of hills that run approximately in northwest – southeast direction (Tomori, 2008).

Ibadan is made up of eleven local government areas with five urban local government areas in the city and six semi-urban local government areas in the less city. The five urban local government areas in the city are Ibadan North, Ibadan Northeast, Ibadan Northwest, Ibadan Southeast, and Ibadan Southwest while the six semi-urban local government areas in the less city are Ido, Egbeda, Oluyole, Akinyele, Ona Ara and Lagelu.

According to Tomori (2008), there are three residential patterns in Ibadan. These are:

- Core area, inhabited largely by the indigenous Ibadan population. This is a high density area of compound disintegration.
- Low to medium quality residential areas where population densities are the order of 400 people per hectare.
- High class government reservation areas that have low population and housing densities of 4 to 8 houses per hectare.

Within the core area, there is lack of comprehensive water and sewage systems, inadequate garbage collection and disposition and unstable urban environment.

Vegetation pattern in Ibadan is a patchwork of broken forest, savannah woodland, dense thickets and large tracts of forbs vegetation dominated by *Chromolaena odorata* (Siam weed) (Eupatorium) (Fagbami, 1976).

Ibadan is naturally drained by four rivers with many tributaries: Ona River in the north and west; Ogbere River towards the east; Ogunpa River flowing through the city and Kudeti River in the central part of the metropolis. Ogunpa River is a third-order stream with a channel length of 12.76 km and a catchment area of 54.92 km^2 (https://en.wikipedia.org/wiki/Ibadan). Kudeti and Ogbere rivers are tributaries of Ogunpa river.

3.1.1 Sampling sites

A dumpsite each from ten local government areas was sampled; five streams receiving domestic wastes from five local government areas and five dumpsites from the other five local government areas. Oluyole local government area was excluded from the sampling because it is located on the outskirt of Ibadan and the major rivers in Ibadan metropolis empty into the major river (Odo Ona) located within the local government area.

Figure 3.1 shows the map of the study area with the sampling locations. Earthworms, soil, streams and ground water (wells close to the dumpsites) were sampled. For the streams, upstream and downstream of the flow of water were sampled. The sampling points were located with the aid of a Geographical Positioning System GPS 76 Garmin model The sampling locations are as follows:

Irefin

This is located at Ibadan Northeast local government area. Irefin stream was chosen for sampling (Plate 3.1). There are residential buildings around the stream with drainages channelled into it; a piggery is also very close to the site and wastes from the piggery are washed into the stream. There are refuse heaps along the stream, residents defaecate directly into it and around its bank.

Figure 3.1: The map of Ibadan showing the sampling stations

The soil around the banks of Irefin stream and the upstream and downstream of the stream were sampled. The upstream is located on longitudes $3^0$54'50.3" E and $7^0$23'20.3" N while the downstream of is located on longitudes $3^0$54'50.8" E and $7^0$23'21.7" N. This was about 400 m from the upstream.

Gege

This is located at Ibadan Southwest local government area. Gege stream (Plate 3.2) and a well very close to the stream were sampled. The stream receives domestic wastes. Residential buildings surround the site and the residents defecate directly into the stream. There are refuse heaps along the stream. A petrol station is very close to it and oil from the station might probably spill into the stream; drainages from residential buildings enter the stream, and a bakery is very close to it. The sampled well is the source of water for the production of bread. People around the area also depend on it for drinking and domestic purposes.

The soil around the banks of Gege stream, the upstream and downstream of the stream and a well close to the stream were sampled. The upstream is located on longitudes $3^0$53'26.9" E and latitudes $7^0$22'27.2" N while the downstream is located on longitudes $3^0$53'25.2" E and latitudes $7^0$22'29.1" N. The downstream was about 400 m from the upstream. The sampled well is located on longitudes $3^0$53'24.8" E and latitudes $7^0$21'28.9" N and it is about 100 m away from the stream.

Gbagi

This is located at Egbeda local government area. Around this station, there is a market and an abattoir. The activities around this site include slaughtering of animals, burning of animal hides, refuse dump, market wastes dump, animal wastes dump and human defaecation. Gbagi (odo eran) stream in the location was sampled (Plate 3.3).

The soil around the banks of Gbagi stream, the upstream and downstream of Gbagi stream were sampled. The upstream is located on longitudes $2^0$57'20.1" E and latitudes $7^0$22'26.3" N while the downstream is on longitudes $3^0$57'20.6" E and latitudes $7^0$23'25.3" N. This downstream was about 500 m from the upstream.

Plate 3.1: Irefin stream

RB – Residential building, **VG –** Vegetation, **SW –** Solid wastes, **ST** – The stream, **FN –** Faeces in nylon.

Plate 3.2: Gege stream

RB – Residential building, **VG –** Vegetation, **SW –** Solid wastes, **ST** – The stream, **FN –** Faeces in nylon, **HB** – Human being defaecating directly into the stream, **GA** – Grazing animal.

Plate 3.3: Gbagi stream

MB – Market building, **MW –** Market waste, **SW –** Solid wastes, **VG –** Vegetation, **ST** – The stream, **MA** – Meat from abattoir.

Odinjo

This is located at Ibadan Southeast local government. Odinjo stream and a well close to its downstream were sampled (Plate 3.4). Around the upstream, there is a car wash and a food canteen. Around the downstream, there is a vehicle panel beating shop.

The soil around the banks of Odinjo stream, its upstream and downstream were sampled. The upstream is located on longitudes $3^0$55'05.4" E and latitudes $7^0$21'25.6" N while the downstream is located on longitudes $3^0$55'05.0" E and latitudes $7^0$21'24.9" N and this was about 500 m from the upstream.

The well located at the downstream of Odinjo is located on longitudes $3^0$55'04.5" E and latitudes $7^0$21'24.9" N. It was about 50 m from the stream.

Omi Adio

Omi Adio is located in Ido Local government area. Omi Adio stream where wastes are dumped was sampled (Plate 3.5). The stream flows along the Apata - Abeokuta road. An auto-mechanic workshop, saw mill, block industry, car wash, welding shop and food canteens were very close to the stream. Canals run along the dumpsite. Rail line runs along the canals to some point.

The soil around the banks of the Omi Adio stream, the upstream and downstream of the stream were sampled. The upstream is located on longitudes $3^0$45'00.9" E and latitudes $7^0$23'33.2" N while the downstream is located on longitudes $3^0$45.014' E and latitudes $7^0$23.53.7' E. This was about 500 m from the upstream.

Ojokondo

This is located at Ibadan north local government area. A dumpsite located on longitudes $3^0$54'32" E and latitudes $7^0$31'39.2" N within the residential area (Plate 3.6) was sampled. An auto-mechanic workshop and a food canteen are located at the upper part of the dumpsite. There are two wells around the dumpsite; one is found at the upper part before getting to the dumpsite and the other one is located after the dumpsite (downslope). These two wells were also sampled.

The well at the upper part; just before the Ojokondo dumpsite is located on longitudes $3^0$54'31.1" E and latitudes $7^0$26'39.2" N. This was about 200 m before the dumpsite.

Plate 3.4: Odinjo stream

SW – Solid wastes, **VG –** Vegetation, **ST** – The stream, **RB – Residential building**, **CW –** Car wash, **RD** – Road.

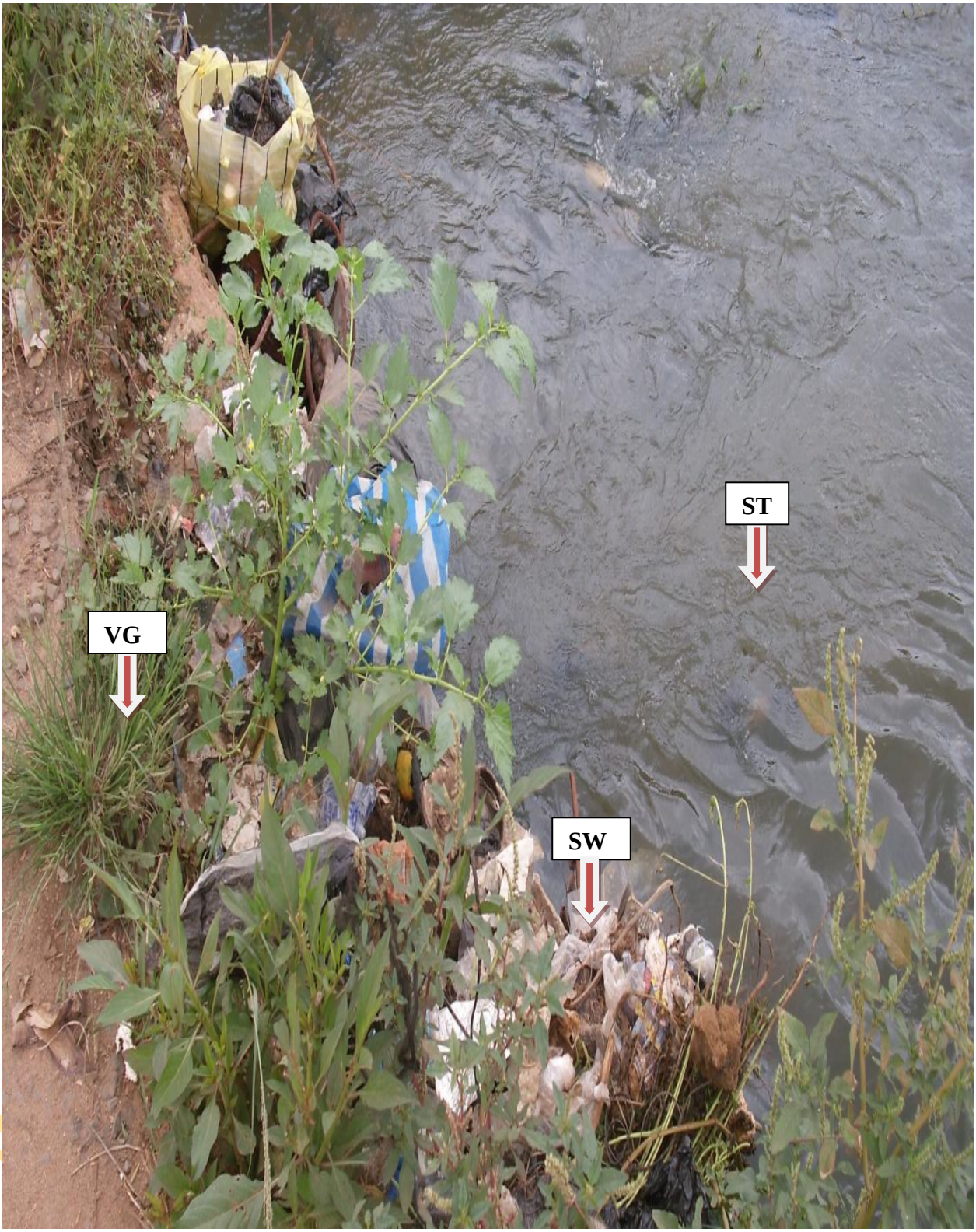


Plate 3.5: Omi Adio stream

ST – The stream, **VG –** Vegetation, **SW –** Solid wastes

The well located at the down slope, after the Ojokondo dumpsite is located on longitudes $3^0$54’32.5” E and latitudes $7^0$26’39.8” N. This was about 200 m after the dumpsite.

Olodo

This is located at Lagelu local government area. A dumpsite was chosen for sampling (Plate 3.7). This is located on longitudes $4^0$00’13.3” E and latitudes $7^0$26’0.1” N. The dumpsite is surrounded by developing buildings. Block molding factory and metal fabricating shop are nearby the dumpsite. A well close to the dumpsite was also sampled. It is located on longitudes $4^0$00’12.7” E and latitudes $7^0$26’03.5” N. This was about 100 m from the dumpsite.

Moniya

This is located at Akinyele local government area. There is a dumpsite stretching about 250 meters (Plate 3.8) located on longitudes $3^0$54’38.8” E and latitudes $7^0$31’28.3” N. A high tension cable runs along and across the dumpsite. Mechanic workshops and motor parks are situated near the site. A well in a residential compound down the dumpsite was also sampled. The well is very close to the dumpsite and it was located on longitudes $3^0$54’36.5” E and latitudes $7^0$31’30.1” N. This was located downslope after the dumpsite and about 200 m distance from where the dumpsite starts.

Idi Ope

This is located at Ibadan northeast local government. A dumpsite located on longitudes $3^0$51’51.6” E and latitudes $7^0$24’50.3” N was sampled (Plate 3.9). The dumpsite is behind an abandoned National Horticulture Research Institute (NIHORT) garden which is now being used as garri and fufu processing industry. Residential buildings and a car wash border the site. A well in a residential compound very close to the dumpsite was also sampled. The well is located on longitudes $3^0$51’51.0” E and latitudes $7^0$24’50.4” N. This was about 200 m away from the dumpsite.

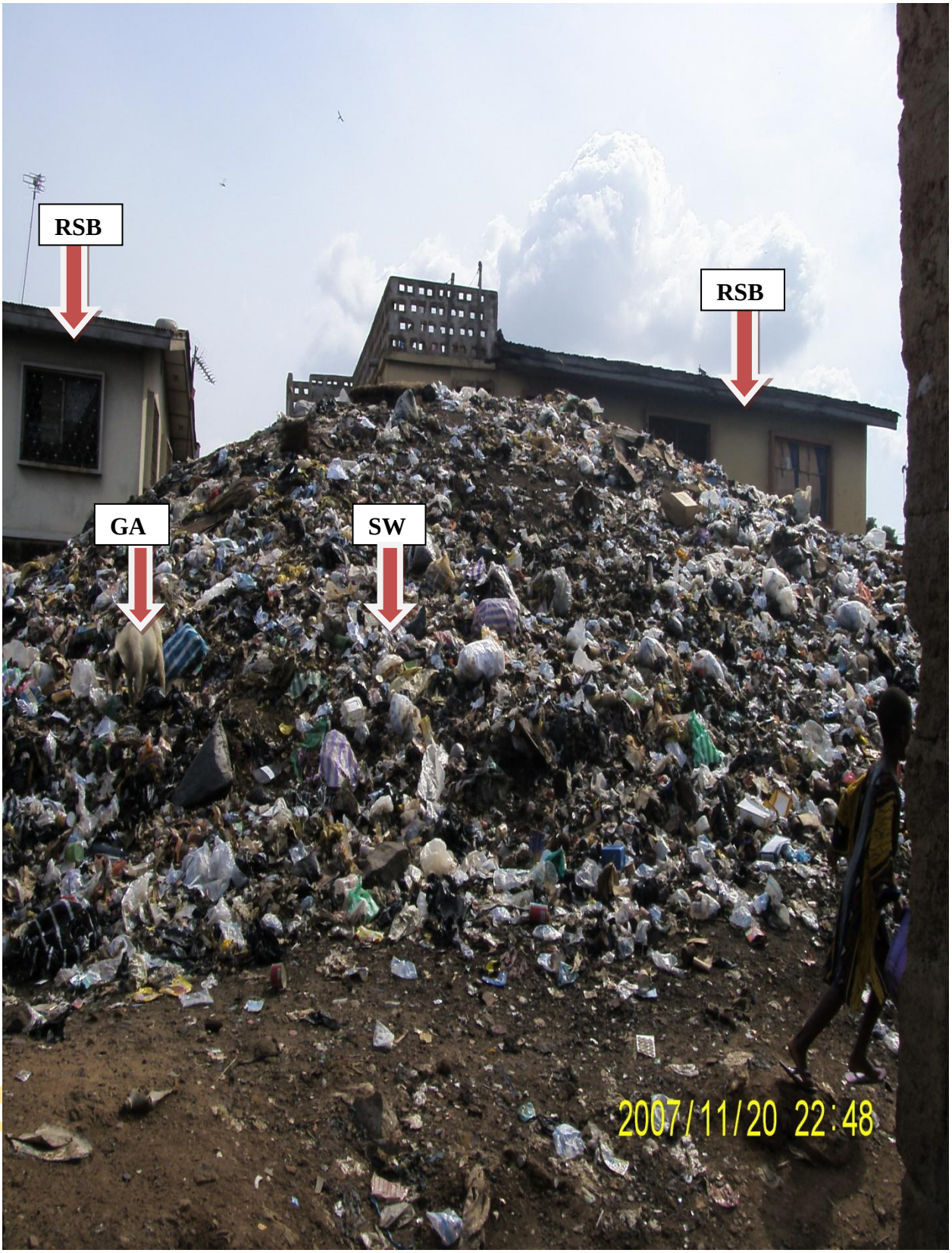


Plate 3.6: Ojokondo dumpsite

SW – Solid wastes, **RSB** – Residential storey-building, **GA** – Grazing animal.

Plate 3.7: Olodo dumpsite

RB – Residential building, VG – Vegetation, **SW –** Solid wastes, **MCH** – Methodist church.

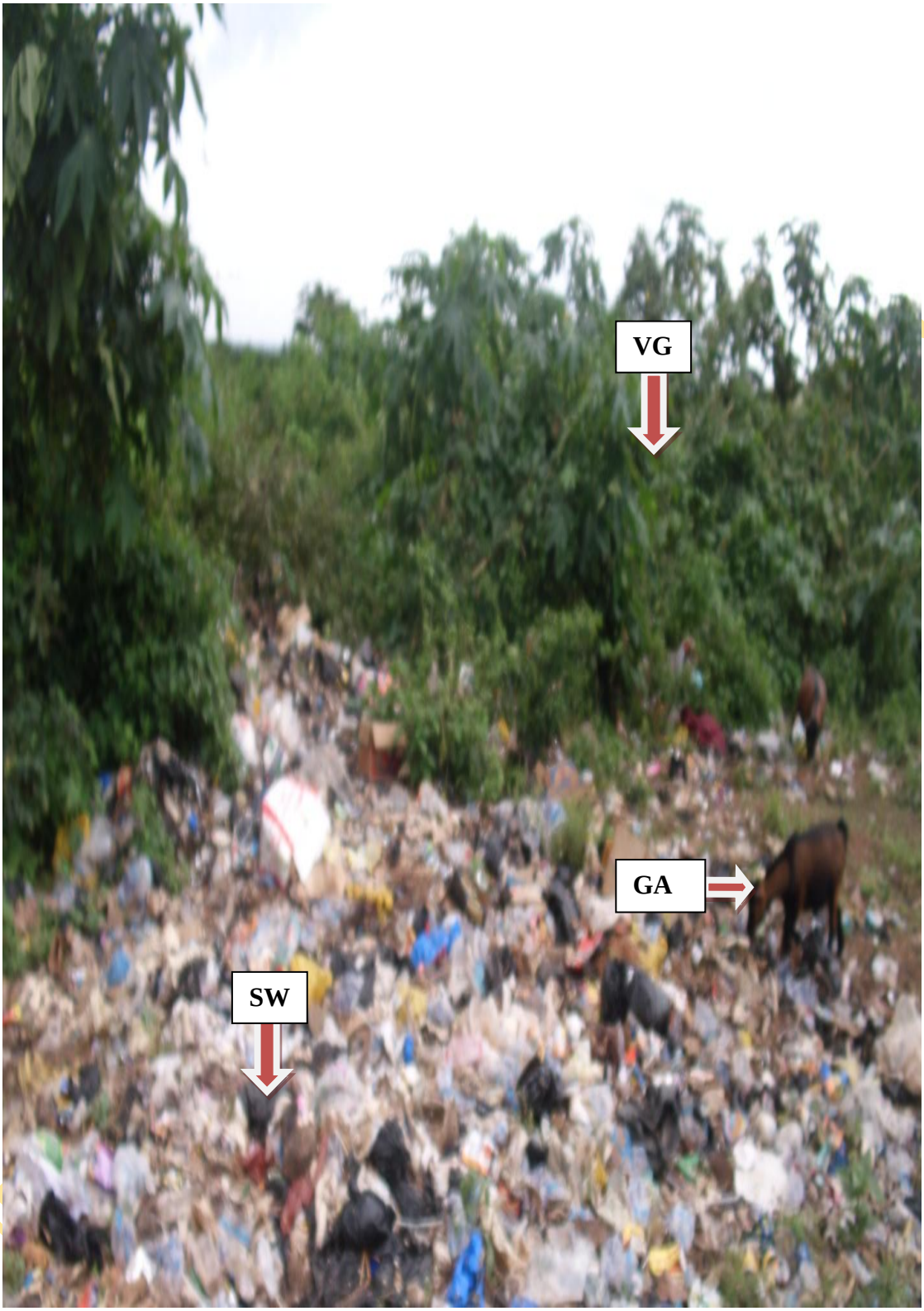


Plate 3.8: Moniya dumpsite

VG – Vegetation, **SW –** Solid wastes, **GA** – Grazing animal.

Plate 3.9: Idi Ope dumpsite

RB – Residential building, **VG –** Vegetation, **SW –** Solid wastes.

Oremeji expressway

This is located at Ona Ara local government area. A dumpsite located on longitudes $3^0$55'58.0" E and latitudes $7^0$22'47.7" N along the Lagos - Ibadan Expressway was sampled (Plate 3.10). Beside the dumpsite, there is a car wash, an auto-mechanic workshop and a block making industry. A well is located very close to the dumpsite, which the car wash and block making industry use for their activities. The well is about 50 m away from the dumpsite.

Control sites

Two control sites were chosen for this work:

Awba stream

This is found within the University of Ibadan. This was chosen as control site for the stream samples. The part of the stream chosen for the research work is the one that flows through the Independent and Nnamdi Azikiwe halls of residence (Plate 3.11). It is located on longitudes $3^0$53'58.6" E and latitudes $7^0$26'26.6" N. The soil around the banks of the stream and the stream water were sampled.

Tafawa Balewa Hall – This is a postgraduate hall of residence at the University of Ibadan. The soil and a well within the hall were chosen as control for the dumpsites (Plate 3.12). The sampled area is located on longitudes $3^0$53'52.6" E and latitudes $7^0$26'32.0" N. The well is located on longitudes $3^0$53'53.3" E and latitudes $7^0$26'31.3" N within the hall and within the same area where the soil was sampled.

3.2 Sampling

A preliminary sampling of some of the dumpsites was done in February 2008 prior to sampling proper while the proper sampling was done from March, 2008 to February, 2010.

3.2.1 Sampling, preservation and identification of collected earthworm samples

Quadrat (size 0.25 x 0.25 m^2) was used to randomly sample earthworms around the waste sites. Digging and hand sorting methods (Reynolds, 1977) were used for the collection of earthworm samples on each quadrat plot. A shovel was used to dig in

Plate 3.10: Oremeji dumpsite

VG – Vegetation, **SW –** Solid wastes, **CH** – Church.

Plate 3.11: Control stream (Awba stream, UI)

ST – The stream

Plate 3.12: Control site for dumpsite (Tafawa Balewa Hall, UI)

BH – Balewa Hall, **VG –** Vegetation.

blocks up to 30 cm straight into the mud in four different places (square), the soil was lifted on to a flat board, it was sorted and earthworms were picked with a pair of forceps. The earthworm samples were then preserved in formoacetic alcohol (i.e. 10 % formalin, 2 % acetic acid, 38 % ethanol and 50 % distilled water). The preserved earthworms were identified in the laboratory using the keys of Owa (1992).

3.2.2 Sampling, preservation and analytical methods for collected stream water

One hundred and twenty (120) stream water samples were obtained once every two months from March 2008 to February 2010 from the upstreams and downstreams of Irefin, Gege, Gbagi, Odinjo and Omi Adio streams. Ten (10) water samples were also obtained from the control stream (Awba stream) within the University of Ibadan. In all, a total of one hundred and thirty (130) stream water samples were collected.

3.2.2.1 Physico-chemical analysis

3.2.2.1.1 pH

The pH of the water samples was determined on the field by electro-metric method using a Kent EIL 7045/46 pH meter. The pH metre was calibrated prior to use with buffers 4 and 7 solutions.

3.2.2.1.2 Electrical conductivity

Electrical conductivity of the water samples was determined on the field by the use of Extech conductivity/TDS meter model ExStik EC 400. The meter was calibrated prior to use with 3.3 mol solution of potassium chloride. The result was expressed as µS/cm.

3.2.2.1.3 Total dissolved solids

The total dissolved solids of the water samples were determined with the use of Extech conductivity/TDS meter model ExStik EC 400. The meter was calibrated prior to use with 3.3 mol solution of potassium chloride. The result was expressed as mg/L.

3.2.2.1.4 Dissolved oxygen

Samples for dissolved oxygen (DO) were collected by submerging 250 ml amber–coloured sample bottles in water and stoppering them when filled without any air

bubbles (APHA, 1998). The samples were immediately treated with Winkler's A and B. For each 250 ml bottle, 2 ml of Winkler's A (Manganese sulphate) was introduced below the surface of the water and 2 ml of Winkler's B (alkaline iodide-azide solution) was introduced at the sample surface, using wide mouth pipettes and capped immediately. This was followed by vigorous agitation to preserve oxygen (APHA, 1998).

In the laboratory, the dissolved oxygen concentration was determined using the azide modification of the iodometric method as reported by (APHA, 1998) and the result expressed as mg/L.

3.2.2.1.5 Biochemical oxygen demand (BOD)

Samples for biochemical oxygen demand (BOD) were collected by submerging 250 ml amber–coloured sample bottles in water and stoppering them when filled without any air bubbles (APHA, 1998). The azide modification of the iodometric method was used (APHA, 1998) and the dissolved oxygen contents of the samples before and after incubation for five days at 20^{o}C was determined. The difference from the initial and final DO was the BOD, expressed in mg/L.

3.2.2.1.6 Chemical oxygen demand (COD)

Samples for chemical oxygen demand and anions analysis were collected in pre-washed 4 L polyethylene bottles and were taken to the laboratory. These were stored at 4^{0}C before analysis.

The chemical oxygen demand (COD) of the water samples was determined by the Heptaoxochromate (vi) test which involved titration (Ademoroti, 1996 and APHA, 1998). The result was expressed in mg/L.

3.2.2.1.7 Total alkalinity

The total alkalinity due to hydroxides (strong bases), carbonate and hydrogen carbonate (salts of weak acids but of strong bases) of Ca, Mg, Na, and K were determined by titration of the sample to a color change at pH 4.6 (APHA, 1998). The result was expressed in mg/L.

Calculation

Total Alkalinity as mg/L $CaCO_3$ = $\frac{V_T \text{ X M X } 100{,}000}{\text{ml sample}}$

V_T = Volume of the titrant

M = Molarity of the acid used

3.2.2.2 Anions

3.2.2.2.1 Chloride

The method used for chloride determination was Argentometric method which involved titration (APHA, 1998). The result was expressed in mg/L.

Calculation

mg Cl^-/L = $\frac{(A - B) \text{ x N x } 35450}{\text{ml sample}}$

A – ml titration of sample

B - ml titration for blank

N – Normality of $AgNO_3$

3.2.2.2.2 Phosphate - phosphorus

The ultraviolet spectrophotometric screening method (APHA, 1998) was used for the determination of phosphate in the water samples. The absorbance was measured at a wavelength of 470 nm using Cecil ultraviolet/visible spectrophotometer. The result was expressed in mg/L.

Calculation

mg P/L = $\frac{\text{mg P (in 50 ml final volume) X } 1000}{\text{ml sample}}$

3.2.2.2.3 Nitrate - nitrogen

Nitrate in water was determined by ultraviolet spectrophotometric screening method (APHA, 1998). The absorbance was read with Cecil ultraviolet/visible spectrophotometer at wavelengths of 220 nm and 270 nm. 220 nm was to determine nitrate reading and 270 nm was to determine interference due to organic matter.

Calculation

For samples and standards, the absorbance reading at 220 nm was subtracted from the absorbance at 270 nm to obtain absorbance due to nitrate. A standard curve was constructed by plotting absorbance due to nitrate against nitrate-nitrogen concentration of standard. The result was expressed in mg/L.

3.2.2.2.4 Sulphate - sulphur

The ultraviolet screening method (APHA, 1998) was used for the determination of sulphate in the water samples. The absorption was measured at a wavelength of 425 nm using Cecil ultraviolet/visible spectrophotometer. The result was expressed in mg/L.

Calculation

$$\text{mg } SO_4^{2-}/L = \frac{\text{mg } SO_4^{2-} \text{ X } 1000}{\text{ml sample}}$$

3.2.2.3 Cations (Calcium and Magnesium)

Samples for cations (calcium and magnesium) analysis were collected in 500 ml containers and were immediately preserved with 0.75 ml of concentrated nitric acid (HNO_3) prior to digestion and further analysis (APHA, 1998). The results were expressed in mg/L.

3.2.2.4 Trace and heavy metals

Samples for trace and heavy metals analysis were collected in 500 ml containers and were immediately preserved with 0.75 ml of concentrated nitric acid (HNO_3) prior to digestion and further analysis (APHA, 1998).

Metals determined include:

Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), nickel (Ni) and chromium (Cr).

The above metals were analysed using the nitric acid digestion (APHA, 1998) and the concentrations were determined by the Alpha Atomic Absorption Spectrophotometer (AAS) at the Obafemi Awolowo University Central Science Laboratory. The results were expressed in mg/L.

3.2.3 Sampling, processing and analytical methods for collected soil

Samples for soil analysis were collected from top soils (0 to 15 cm). This was done by using a soil auger. Soils from the banks of the streams were collected randomly and bulked down to one representative sample and put in well labeled polyethylene bags.

Sixty (60) composite soil samples were collected from Irefin, Gege, Gbagi, Odinjo and Omi Adio stream banks. Ten (10) composite soil samples were collected from the control stream (Awba stream) within the University of Ibadan.

At the dumpsites, starting at the centres of the sites, soil samples were taken in five directions at the North, South, East and West of the sites. Each composite sample was bulked down to one representative sample and put in well labeled polyethylene bags.Sixty (60) composite soil samples were collected from the Ojokondo, Olodo, Moniya, Idi Ope and Oremeji dumpsites. Ten (10) composite soil samples were collected from the control site (Tafawa Balewa Hall, University of Ibadan) for dumpsites. In all, a total of one hundred and forty (140) soil samples were collected from the stream banks and dumpsites once every two months from March 2008 to Februrary 2010.

The soil samples were transferred on to sheets of papers and spread out to air dry in a dust-free environment at room temperature 27^0C for a period of seven days in the laboratory of Zoology Department, University of Ibadan. After drying, the samples were pulverised separately with a porcelain mortar and pestle and care was taken to avoid contamination. Sieving of each soil sample was done through different mesh-sized sieves depending on the mesh-size that was required for the analysis. This was done in order to obtain fine powder representations of each sample.

3.2.3.1 Particle size distribution

The soil samples for particle size distribution analysis were not sieved. This was determined by the soil Bouycous hydrometer method (Pramer and Schmidt, 1964; Olaitan and Lombin, 1984; and Awolumate, 1977) as described in the International Institute of Tropical Agricultural (IITA) laboratory manual (1979).

50 g of air-dried soil was weighed out into a 250 ml beaker. 50 ml of NaOH dispersing agent (80 g NaOH dissolved in 2 L of distilled water) and 100 ml distilled water was added to the soil. The suspension was left to stand for 30 minutes with

occasional stirring. It was then transferred from the beaker to a 1 L measuring cylinder. The suspension was rinsed out of the beaker with distilled water until none was left in the beaker. This was made up to the mark with distilled water. The top of the measuring cylinder was covered with the palm of the hand firmly to seal it completely and it was shaken vigorously by turning end-cover several times until all the soil was in suspension.

The cylinder was placed on the laboratory bench and the time of placement was noted. It was allowed to stand for 30 seconds and the soil hydrometer was gently inserted into the soil suspension. The hydrometer was read after 10 seconds of insertion. This gave the first hydrometer reading (H_1). A thermometer was inserted into the suspension and the temperature of the suspension was taken. This gave the first temperature reading (T_1). After the readings were taken, the suspension was left to stand for 2 hours. Then, the second hydrometer reading (H_2) and the second temperature reading (T_2) were taken.

Calculation

% Sand = $100.0 – (H_1 + 0.2 (T_1 – 68) – 2.0) 2$

% Clay = $(H_2 + 0.2 (T_2 – 68 – 2.0) 2$

% Silt = 100.0 – (%Sand + % Clay)

T_1 and T_2 were converted to degrees Fahrenheit before applying the formulae above. This conversion from degrees Celsius to degrees Fahrenheit was done by multiplying by 9; product was divided by 5 and 32 added.

i. e. $^0F = \frac{^0C \times 9}{1} + \frac{32}{5}$

3.2.3.2 pH

The pH of the soil samples were determined at a ratio of 1:1 soil to water ratio (Clark, 1923; Bates, 1954; and Black, 1965) as described in the International Institute of Tropical Agricultural (IITA) laboratory manual (1979).

20 g of air-dried soil which had passed through 2-mm sieve was measured into a 50 ml beaker. 20 ml distilled water was added (ratio 1:1) and allowed to stand for 30 minutes with occasional stirring with a glass rod. The electrode of the pH meter (Kent EIL 7045/46) was dipped into the partly settled suspension and the pH was measured.

Prior to measurement, the pH meter was calibrated with pH buffers 7.00 and 4.00 solutions.

3.2.3.3 Electrical conductivity

The suspension of the soil pH sample was allowed to settle for thirty minutes, and then the electrical conductivity of the supernatant liquid was determined by Extech conductivity meter model ExStik EC 400 (Anderson and Ingram, 1993). The meter was calibrated prior to use with 3.3 mol solution of potassium chloride. The result was expressed in µS/cm.

3.2.3.4 Total organic carbon and matter

The soil total organic carbon was determined using colorimetric determination (Anderson and Ingram, 1993). The soil total organic matter was calculated from the result of the soil total organic carbon also suggested by Anderson and Ingram (1993).

Calculation

The solution concentrations for each unknown and the blanks were determined and a graph of absorbance against standard concentration was plotted. The mean blank value was subtracted from the unknowns; this gave a value for corrected concentration, K.

Where W = Weight of soil

% Organic Carbon = (K X 0.1) / (W X 0.74)

To calculate organic matter:

% Organic matter = % Organic carbon X 1.729

3.2.3.5 Anions

3.2.3.5.1 Nitrate

Nitrate was determined by the turbidimetric method (Greweling and Peech, 1965) as described in the International Institute of Tropical Agricultural (IITA) laboratory manual (1979).

The transmittance was measured at a wavelength of 470 nm using Jenway 6051 colorimeter and the result was multiplied by 22 putting into consideration the volume

of extracting solution and some other reagents. The result was therefore expressed in mg/kg.

3.2.3.5.2 Sulphate

Sulphate was determined by the turbidimetric method (Ensminger, 1954; Fox *et al.*, 1964; and Tabatabai, 1974) as described in the International Institute of Tropical Agricultural (IITA) laboratory manual (1979).

The transmission was measured at a wavelength of 420 nm and the result was multiplied by 12.5 putting into consideration the volume of extracting solution and some other reagents. The result was therefore expressed in mg/kg.

3.2.3.6 Cations

The cations determined include:

Phosphorus

Calcium

Magnesium

Sodium

Potassium

Extractable phosphorus was determined by colorimetric (Bray No. 1) method according to Bray and Kurtz (1945) and Jackson (1962) as described in the International Institute of Tropical Agricultural (IITA) laboratory manual (1979).

The transmittance was measured at a wavelength of 600 nm using Jenway 6051 colorimeter and the result was multiplied by 28 putting into consideration the volume of extracting solution and some other reagents. The result was therefore expressed in mg/kg.

All other cations were determined using the Alpha Atomic Absorption Spectrophotometer after nitric – hydrochloric acid digestion according to the method described by Chen and Ma (2001).

The results of all cations were expressed in mg/kg.

3.2.3.7 Cation exchange capacity (CEC)

The cation exchange capacity of the soil samples were analysed using one of the calculation methods described by Madeira *et al.* (2003) with some modifications. It was done by the addition of values of calcium, magnesium, potassium and sodium. The modification was the non-addition of aluminium since aluminium was not analysed. Before the addition, the mg/kg units of the cations were first converted to millimoles/kg by dividing the result in mg/kg by the equivalent weight of each cation and then converting back to centimole/kg by dividing it by 10 (NRES497-3, 2012).

3.2.3.8 Trace and heavy metals

The trace and heavy metals determined include:

Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), nickel (Ni) and chromium (Cr).

All the above were determined using the Alpha Atomic Absorption Spectrophotometer after nitric – hydrochloric acid digestion according to the method described by Chen and Ma (2001). Their results were expressed in mg/kg.

3.2.4 Sampling, preservation and analytical methods for collected groundwater

Groundwater samples were collected from groundwater wells via a pulley system. Twenty two (22) samples were obtained once every two months from March 2008 to February 2010 from the wells close to the Gege and Odinjo streams; seventy-two (72) samples from the wells close to Idi Ope, Moniya, Olodo, Oremeji, before Ojokondo and after the Ojokondo dumpsites; and ten (10) samples from the control well located at the Tafawa Balewa Hall of Residence in the University of Ibadan. In all a total of one hundred and four (104) well water samples were collected.

The samples were collected in pre-washed 4 L polyethylene bottles and taken to the laboratory for storage at approximately 4^0C until analysis was carried out. All the parameters determined for stream water samples were determined for the groundwater samples using the same analytical methods except dissolved oxygen content of groundwater samples that was not determined.

3.2.5 Toxicity assays

The downstream water samples collected in the month of January, 2009 were the test solutions used for the toxicity assays in the laboratory.

The toxicity assays for organisms exposed to the downstream water samples were carried out according to the method described by Obuotor and Onajobi (2000).

3.2.5.1 Mayflies toxicity assay

Cloeon perkinsi (Barnard, 1832) larvae were collected from the Opa dam of the Obafemi Awolowo University, Ile-Ife. The 9th instar larvae were selected and acclimated to laboratory conditions for twelve hours in holding tanks at a stocking density of 3 g/L at a laboratory temperature of 25 ^{0}C.

After acclimation, 10 larvae each were randomly assigned to the test chambers (cylindrical glass containers with volume capacity of 175 ml) in quadruplicates. Each test chamber contained 150 ml of appropriately diluted test solutions (downstream water samples) to give a final concentration of 50 %, 25 %, 12.5 %, 6.25 % and 3.125 %. The larvae were then exposed for 48 hrs during which the mortality was monitored every 2 hrs for the first 24 hrs. Death was ascertained by the loss of reflex activity (failure to react to external prodding).

Estimation of median lethal concentration

In order to estimate the median lethal concentration and the 95 % confidence intervals, the mortality data were analysed using EPA Probit Analysis Program, Version 1.5 (USEPA, 1997) obtained from the United States Environmental Protection Agency website (http://www.epa.gov/nerleerd/stat2.htm).

3.2.5.2 Tadpoles bioassay

Laboratory hatched tadpoles were used for this test. The test was carried out as follows: To each of five test glass jars (175 ml) containing 150 ml of the appropriately diluted downstream water samples (50 %, 25 %, 12.5 %, 6.25 % and 3.125 %), 10 laboratory hatched 5-day old tadpoles were introduced into each of the five test jars and the control. Each test concentration and the control were carried out in quadruplicates.

The tadpoles were exposed for 96 hours and the set up was monitored for mortality every 2 hours for the first 24 hrs.

Estimation of median lethal concentration

The mortality data were analysed by using an EPA Probit Analysis Program, Version 1.5 (USEPA, 1997) to estimate the median lethal concentration (LC_{50}).

3.2.5.3 Fish toxicity assay

Frys and fingerlings of *Clarias gariepinus* (Burchel, 1822) were used for this experiment.

3.2.5.3.1 *Clarias gariepinus* frys toxicity assay

One and a half week's old frys of *Clarias gariepinus* (Burchel, 1822) were obtained from a commercial fish farm in Osogbo, Osun state. They were acclimated to laboratory conditions for seven days in holding tanks at a stocking density of 3 g/L. After acclimation, 10 frys each were randomly assigned to the test chambers (cylindrical glass containers with volume capacity of 175 ml) in quadruplicates. Each test chamber contained 150 ml of appropriately diluted test solutions (downstream water samples) to give a final concentration of 50 %, 25 %, 12.5 %, 6.25 % and 3.125 %. The frys were then exposed for 96 hrs during which the mortality was monitored every 2 hrs for the first 24 hrs. Dead fish were promptly removed from the chambers. Death was ascertained by the loss of reflex activity (failure to react to external prodding).

Estimation of median lethal concentration

In order to estimate the median lethal concentration and the 95 % confidence intervals, the mortality data were analysed using EPA Probit Analysis Program, Version 1.5 (USEPA, 1997) obtained from the United States Environmental Protection Agency website (http://www.epa.gov/nerleerd/stat2.htm).

3.2.5.3.2 *Clarias gariepinus* fingerlings bioassay

Four weeks old fingerlings of *Clarias gariepinus* (Burchel, 1822) were obtained from a commercial fish farm in Osogbo, Osun state. They were acclimated to laboratory

conditions for seven days in holding tanks at a stocking density of 5 g/L. After acclimation, 10 fingerlings each were randomly assigned to the test chambers (cylindrical glass containers with volume capacity of 1 L) in triplicates. Each test chamber contained 150 ml of appropriately diluted test solutions (downstream water samples) to give a final concentration of 50 %, 25 %, 12.5 %, 6.25 % and 3.125 %. The fingerlings were then exposed for 96 hrs during which the mortality was monitored every 2 hrs for the first 24 hrs. Dead fish were promptly removed from the chambers. Death was ascertained by the loss of reflex activity (failure to react to external prodding).

Estimation of median lethal concentration

In order to estimate the median lethal concentration and the 95 % confidence intervals the mortality data were analysed using EPA Probit Analysis Program, Version 1.5 (USEPA, 1997) obtained from the United States Environmental Protection Agency website (http://www.epa.gov/nerleerd/stat2.htm).

3.2.5.4 Earthworms' toxicity assay

The earthworms' toxicity assay was carried out with modifications of the sediment test procedure using freshwater oligochaetes as proposed by APHA (1998). The modification was that instead of using sediment for the analysis, soil samples were used.

Eudrilus eugeniae (Kinberg, 1867) earthworms were collected from the Tafawa Balewa Hall of residence. They were fed ad libitum for a period of seven days to acclimatize them to laboratory conditions.

Soil samples were collected from the various dumpsites, streams and the two control sites. 10 kg of each soil sample were put in test chambers in quadruplicates in the laboratory and 10 earthworm samples were put per chamber to determine the toxicity of the soil samples on earthworms. The earthworms were then exposed for 96 hours during which mortality was monitored.

3.3 Analytical procedures for stream water, soil and groundwater

Digestion of stream water samples and all analytical procedures for stream water and groundwater samples were carried out at the Pharmaceutical Chemistry Department

laboratory, Faculty of Pharmacy, Obafemi Awolowo University, Ile – Ife. All cations, trace and heavy metals analysis were carried out at the Obafemi Awolowo University Central Science laboratory, Ile – Ife.

All analytical procedures for soil, except for particle size distribution were also carried out at the Pharmaceutical Chemistry Department laboratory, Faculty of Pharmacy, Obafemi Awolowo University, Ile – Ife. Particle size distribution was carried out at the Department of Zoology, University of Ilorin, Ilorin.

3.3.1 Cations, trace and heavy metals determination in stream water: sample digestion

100 ml of well-mixed, acid-preserved stream water samples were transferred into a 250 ml beaker and 5 ml concentrated nitric acid (HNO_3) was added. The beakers were covered with watch glasses and evaporated on a hot plate to about 10 ml. For some highly coloured samples, concentrated nitric acid (HNO_3) was continuously added until digestion was shown by a light-coloured, clear solution.

The beakers and watch glasses were then washed down with distilled water. On cooling, filtrate was transferred to 100 ml volumetric flask and made up to mark with distilled water. Blank solution was also digested.

Cations (Ca, Mg), trace metals (Fe and Mn) as well as heavy metals (Cu, Zn, Pb, Cd, Ni, and Cr) were determined in the digested samples using Alpha Atomic Absorption Spectrophotometer (AAS). Their results were expressed in mg/L.

3.3.2 Cations, trace and heavy metals determination in soil samples: sample digestion

The cations (Ca, Mg, Na and K), trace (Fe and Mn) and heavy metals (Cu, Zn, Pb, Cd, Ni, and Cr) in the soil samples were determined by the Atomic Absorption Spectrophotometry as described by Chen and Ma (2001).

A well-mixed sample of 1 g of air–dried soil sample which had passed through a 2 mm mesh–sized sieve was digested in 12 ml aqua regia ($^1/_3$ HNO_3 – HCl, vv, i. e. 3 ml HNO_3 and 9 ml HCl) in a water bath at 100 ^{0}C for 2 hours. After evaporating to near dryness on a hot plate, the sample was diluted with 20 ml of 2 % (v/v with water) nitric acid. This was cooled and filtered through Whatman No. 42 filter paper into a

100 ml volumetric flask. It was made up to volume with distilled water. The samples were then taken to the Central Science Laboratory at the Obafemi Awolowo University, Ile–Ife to check for the metals concentration by using Alpha Atomic Absorption Spectrophotometer. Their results were expressed in mg/kg.

3.4 Statistical analysis

3.4.1 Biological parameters

Biological parameters were used in analyzing earthworms' data. These include:

3.4.1.1 Shannon Wiener's diversity index for the measure of species' diversity:

$$H^1 = \frac{(N\log N - \sum n_i \log n_i)}{N}$$

Where H^1 = Shannon Wiener's index

N = total number of individuals

n_i = observed proportion of individuals belonging to the i^{th} species.

3.4.1.2 Shannon's Evenness measures or measures of "**relative density**" equitability given by Pielou's (1975) equation as $E = \frac{HS}{\log s}$

Where HS = Shannon Wiener's index

s = number of species or taxa

3.4.1.3 Menhinick's index for the measures of species richness:

$$D_{\alpha} = \frac{s}{\sqrt{N}}$$

Where s = the number of species

N = the total number of individuals in all the species.

3.4.1.4 Sorensen's coefficient (quotient of similarity) given by Horn's (1966) equation as $CCS = \frac{2C}{S_1 + S_2}$

Where CCS = Sorensen coefficient

C = number of species common to both stations

S_1 = number of species in site 1

S_2 = number of species in site 2

3.4.2 Graphical illustrations and descriptive statistics

Microsoft excel 2007 (Microsoft Corporation 1985-2007) was used for all graphical illustrations. SPSS version 17 was used to compute the mean and standard error of means of all physico – chemical parameters, anions, cations, trace and heavy metals of all soil, stream water and groundwater samples.

3.4.3 Physico-chemical parameters

3.4.3.1 ANOVA (Analysis of variance) was used to test for the statistical differences between the physico-chemical qualities of soil, stream water samples and groundwater samples of the sample stations.

3.4.3.2 Duncan's multiple range tests was used to measure the similarities of the sample stations.

3.4.3.3 Pearson's correlation coefficient was used to compare the relationship between the parameters.

3.4.4 Toxicity Assay

Probit's analysis using a statistical package USEPA version 1.5 (1997) was used to calculate the LC_{50} of the ecotoxicological test organisms.

CHAPTER FOUR

RESULTS

4.1 Earthworms composition and abundance during the study period

4.1.1 Streams

The earthworm species identified at the banks of the streams were *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus*. An additional species, *Alma millsoni* was found at the control site (Awba stream). The total population of all earthworm species was 778 individuals.

The earthworms found at the bank of Gege stream accounted for the least abundance of the earthworms found at all the stream banks with *Dichogaster modigliani* and *Hyperiodrilus africanus* having the population of 5 and 3 respectively with percentage abundances of 0.64 % and 0.39 % respectively. *Eudrilus euginiae* was not found at the bank of the Gege stream. The population of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* found at the bank of the Gbagi stream were 60, 40, 22 with percentage abundances of 7.73 %, 5.15 % and 2.84 % respectively. At the bank of Irefin stream, the population of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* were 8, 2 and 6 respectively with percentage abundances of 1.03 %, 0.26 % and 0.77 % respectively. *Hyperiodrilus africanus* was not found throughout the study period at the Odinjo site while population of *Eudrilus euginiae* and Dichogaster *modigliani* were 72 and 28 respectively with percentage abundances of 9.28 % and 3.61 % respectively for the two. At the Omi Adio site, the *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* population were 39, 24 and 21 respectively with the percentage abundances of 5.03 %, 3.09 % and 2.71 % respectively. The earthworms found at the bank of the control site (Awba stream) were the most abundant. The population of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* were 87, 188, 152 and 22 respectively with percentage abundances of 11.21 %, 24.22 %, 19.56 % and 2.71 % respectively. It was only the control site that recorded more than two species of earthworms at any particular time during the sampling period (Figure 4.1a; Appendix 1).

Eudrilus euginiae

Hyperiodrilus africanus

Dichogaster modigliani

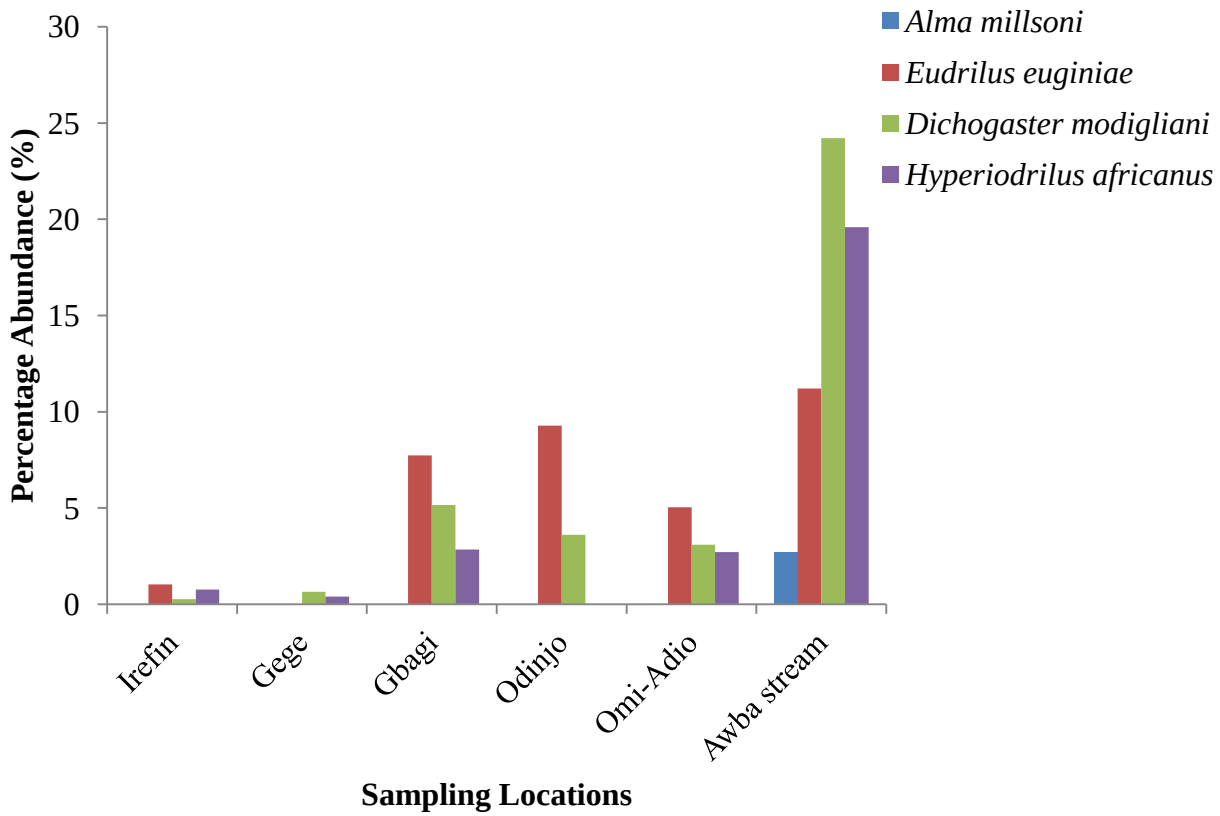
Plate 4.1: Earthworms encountered at the streams and dumpsites during the study period

During the wet season of the sampling period, all earthworm species were found at the streams' banks except *Alma millsoni*. At the Irefin stream bank, all the earthworms present were found during the wet season (*Eudrilus euginiae* – 8 individuals, *Dichogaster modigliani* – 2 individuals and *Hyperiodrilus africanus* – 6 individuals) while no earthworm was found during the dry season. Earthworms observed at the Gege stream bank were present during the wet season (*Dichogaster modigliani* - 5 individuals and *Hyperiodrilus africanus* – 3 individuals), none was found during the dry season. At the Gbagi stream bank, 48, 40 and 22 individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* respectively were obtained during the wet season. It was only 12 individuals of *Eudrilus euginiae* that were observed during the dry season. At the Odinjo stream bank, 69 and 28 individuals of *Eudrilus euginiae* and *Dichogaster modigliani* respectively were observed during the wet season. *Eudrilus euginiae* (3) were also observed during the dry season. Omi Adio stream banks had 24, 24 and 14 individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* respectively during the wet season. The earthworms observed during the dry season were 15 individuals of *Eudrilus euginiae* and 7 individuals of *Hyperiodrilus africanus*. The control site (Awba stream) recorded the highest number of individual earthworms during the two seasons. Individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* found during the wet season were 132, 162 and 87 respectively. During the dry season, there were 20 and 26 individuals of *Eudrilus euginiae* and *Dichogaster modigliani* respectively. No *Hyperiodrilus africanus* was found during the dry season. An additional earthworm species, *Alma millsoni* (21 individuals) was found during the dry season and was only present at the control site (Awba stream) (Figures 4.1b; Appendix 2).

4.1.2 Dumpsites

Throughout the study period, *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* were the three species of earthworms identified at the dumpsites and the control site (Balewa) (Appendix 3). A total population of 1,140 individuals of earthworms was found throughout the sampling period.

The least population of earthworms found at the soil from dumpsites and control were observed at the Ojokondo dumpsite with the population of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* being 33, 28 and 3 respectively



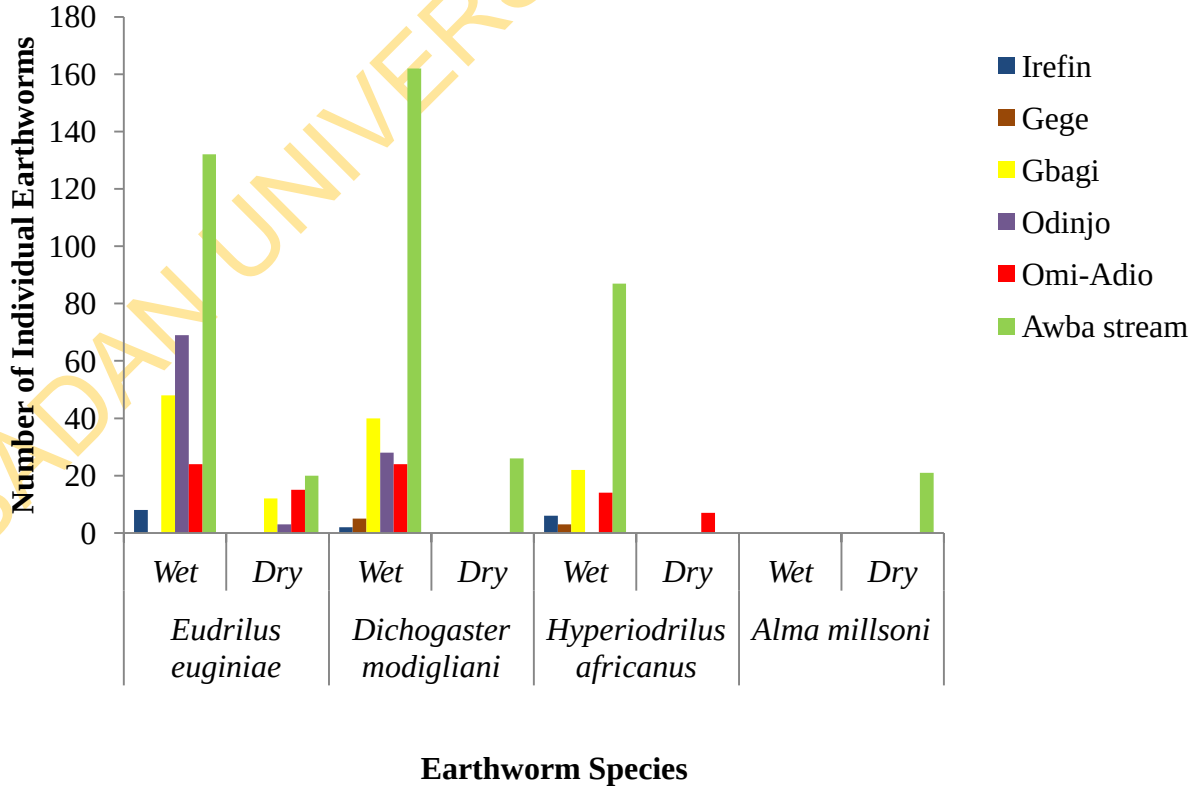


Figure 4.1: a) Percentage abundance of earthworms at the streams' banks
b) Seasonal variation of earthworm species at the streams' banks

with percentage abundances of 2.89 %, 2.46 % and 0.26 % respectively. At the Olodo dumpsite, the population of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* were 38, 46 and 8 respectively while their abundance patterns were 3.33 %, 4.04 % and 0.70 % respectively. The population of *Eudrilus euginiae* and *Dichogaster modigliani* observed at the Moniya dumpsite were 64 and 52, while their percentage abundances were 2.98 % and 4.56 % respectively. *Hyperiodrilus africanus* was not found at the Moniya dumpsite throughout the study period. At the Idi Ope dumpsite, *Dichogaster modigliani* was not found throughout the study period. However, the population of *Eudrilus euginiae* and *Hyperiodrilus africanus* were 56 and 12 respectively while their abundances were 4.91 % and 1.05 % respectively. The populations of the earthworms obtained at the Oremeji dumpsite were 39, 27 and 22 for *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* respectively while their abundance patterns were 3.42 %, 2.37 % and 1.93 % respectively. The highest populations of earthworms were observed at the control site (Balewa) with *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* being 241, 262 and 209 respectively while their abundances were 21.14 %, 22.98 % and 18.33 % respectively (Figure 4.2a; Appendix 3).

All species of earthworms were found during the wet season at the dumpsites. At the Ojokondo dumpsite, 33, 28 and 3 individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* respectively were found during the wet season. The individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* found at the Olodo dumpsite during the wet season were 8, 46 and 8 respectively. At the Moniya dumpsite, 64 and 52 individuals of *Eudrilus euginiae* and *Dichogaster modigliani* respectively were observed during the wet season. Individuals of *Eudrilus euginiae* and *Hyperiodrilus africanus* observed at the Idi Ope dumpsite during the wet season were 56 and 12 respectively. At the Oremeji dumpsite, individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* were 39, 27 and 22 respectively. During the wet season, individuals of *Eudrilus euginiae*, *Dichogaster modigliani* and *Hyperiodrilus africanus* observed at the control site (Balewa) were 228, 241 and 196 respectively. It was the only site that had the three earthworm species present during the dry season.

Individuals of *Eudrilus euginiae* and *Hyperiodrilus africanus* observed were 13 each. *Dichogaster modigliani* were 21 individuals (Figures 4.2b; Appendix 4).

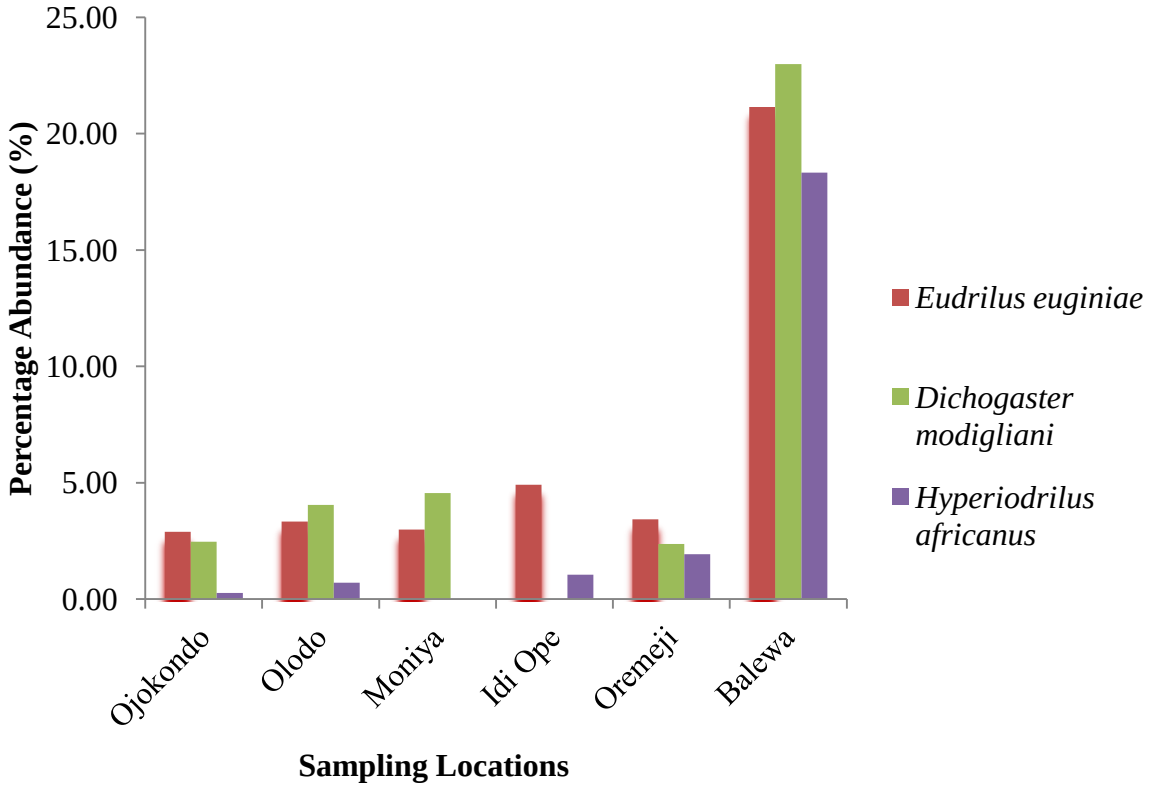
4.2 Earthworms' density and biomass

4.2.1 Streams

The densities of *Eudrilus euginiae* earthworms found at the banks of the streams ranged from 0 to 8 individuals/m^2 (8.00±0.00 individuals/m^2) at the Irefin stream, 3 to 25 individuals/m^2 (14.00±9.52 individuals/m^2) at the Gbagi stream, 4 to 16 individuals/m^2 (12.67±5.32 individuals/m^2) at the Odinjo stream and 3 to 13 individuals/m^2 (8.00±4.62 individuals/m^2) at the Omi Adio dumpsites, 9 to 27 individuals/m^2 (22.40±8.29 individuals/m^2) at the control site (Awba stream). Their biomasses were 0 to 5.76 g/m^2 (5.76±0.00 g/m^2), 3.2 to 5.4 g/m^2 (10.06±6.10 g/m^2), 4.4 to 15.24 g/m^2 (11.54±3.98 g/m^2), 2.28 to 13.68 g/m^2 (7.24±5.37 g/m^2) and 8 to 28 g/m^2 (25.47±10.55 g/m^2) at the Irefin, Gbagi, Odinjo and Omi Adio and the control streams respectively (Appendix 1).

The densities of *Dichogaster modigliani* earthworms found at the banks of the streams ranged from 0 to 4 individuals/m^2 (4.00±0.00 individuals/m^2) each at the Irefin and Gege streams, 0 to 40 individuals/m^2 (40.00±0.00 individuals/m^2) at the Gbagi stream, 6 to 22 individuals/m^2 (14.00±8.42 individuals/m^2) at the Odinjo stream, 3 to 17 individuals/m^2 (10.67±6.11 individuals/m^2) at the Omi Adio dumpsites and 18 to 31 individuals/m^2 (25.33±3.27 individuals/m^2) at the control site (Awba stream). Their biomasses were 0 to 0.96 g/m^2 (0.96±0.00 g/m^2), 0 to 1.84 g/m^2 (1.84±0.00 g/m^2), 0 to 32.84 g/m^2 (32.84±0.00 g/m^2), 5.12 to 15.08 g/m^2 (10.10±7.04 g/m^2), 1.56 to 10.20 g/m^2 (6.84±4.62 g/m^2) and 17.36 to 42.16 g/m^2 (29.94±31.44 g/m^2) at the Irefin, Gege, Gbagi, Odinjo, Omi Adio and the control streams respectively (Appendix 1).

Hyperiodrilus africanus densities found at the banks of the streams ranged from 0 to 4 individuals/m^2 (4.00±0.00 individuals/m^2) at the Irefin stream, 0 to 20 individuals/m^2 (20.00±0.00 individuals/m^2) at the Gbagi stream, 7 to 13 individuals/m^2 (10.00±2.83 individuals/m^2) at the Omi Adio dumpsites and 23 to 29 individuals/m^2 (26.00±2.31 individuals/m^2) at the control site (Awba stream). Their range and mean biomasses were 0 to 1.72 g/m^2 (1.72±0.00 g/m^2), 0 to 15 g/m^2 (15.00±0.00 g/m^2), 4.40 to 7.16 g/m^2 (5.78±1.95 g/m^2) and 27.76 to 31.44 g/m^2 (30.04±3.06 g/m^2) at the Irefin, Gbagi,



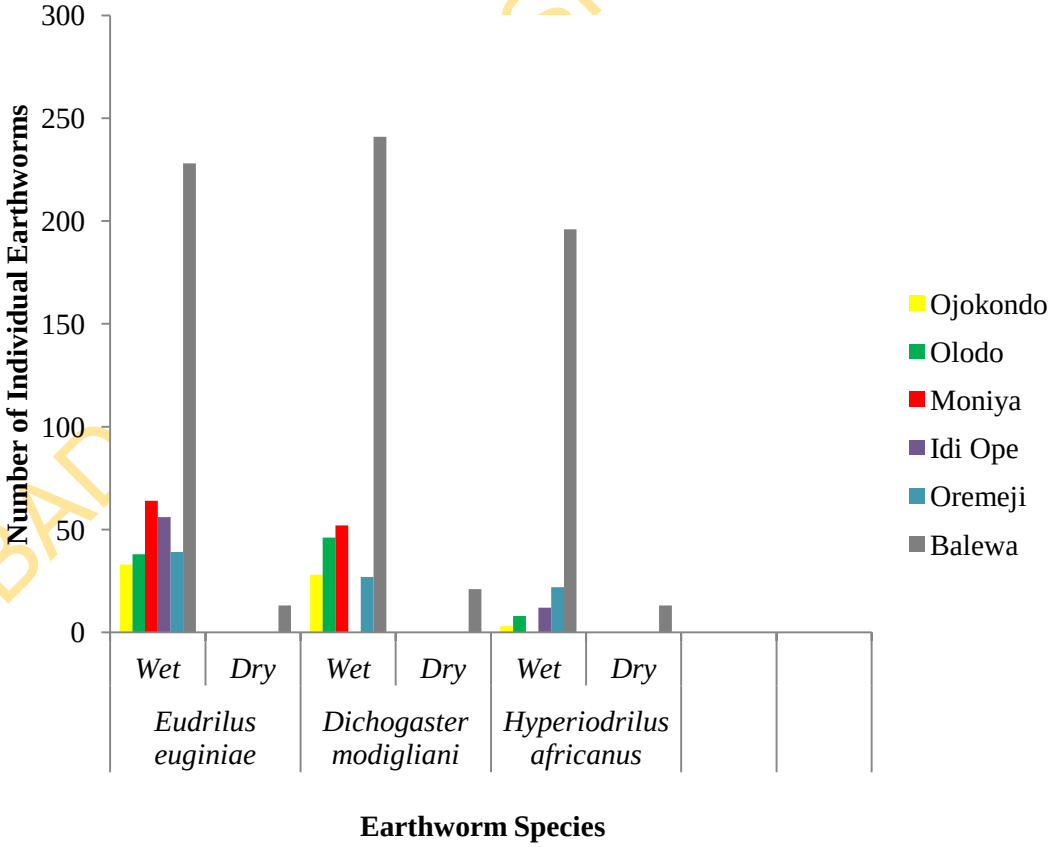


Figure 4.2: a) Percentage abundance of earthworms at the dumpsites
b) Seasonal variation of earthworm species at the dumpsites

Omi Adio and the control streams respectively (Appendix 1).

The analysis of the streams showed that the density of *Alma millsoni* found at the control site (Awba stream) ranged from 2.37 to 20.95 individuals/m^2 (17.32±2.31 individuals/m^2) and biomass ranged from 3.80 to 15.95 g/m^2 (12.04±1.98 g/m^2) (Appendix 1).

4.2.2 Dumpsites

The densities of *Eudrilus euginiae* earthworms found in the soils from the dumpsites ranged from 3 to 8 individuals/m^2 (6.40±2.19 individuals/m^2) at the Ojokondo dumpsite, 4 to 10 individuals/m^2 (9.00±3.83 individuals/m^2) at the Olodo dumpsite, 4 to 10 individuals/m^2 (8.50±5.83 individuals/m^2) at the Moniya dumpsite, 3 to 9 individuals/m^2 (8.00±4.00 individuals/m^2) at the Idi Ope dumpsites, 7 to 11 individuals/m^2 (9.00±2.00 individuals/m^2) at the Oremeji dumpsite and 15 to 36 individuals/m^2 (30.00±13.69 individuals/m^2) at the control site (Balewa). Their biomasses were 1.80 to 7.52 g/m^2 (4.22±2.62 g/m^2), 4.04 to 9.44 g/m^2 (7.12±2.25 g/m^2), 1.76 to 13.76 g/m^2 (6.12±2.46 g/m^2), 1.84 to 10.04 g/m^2 (6.80±5.38 g/m^2), 3.56 to 10.04 g/m^2 (7.64±4.23 g/m^2) and 5.80 to 49.84 g/m^2 (36.04±24.29 g/m^2) at the Ojokondo, Olodo, Moniya and Idi Ope, Oremeji and the control site (Balewa) respectively (Appendix 3).

The densities of *Dichogaster modigliani* earthworms found in the soils of the dumpsites ranged from 7 to 9 individuals/m^2 (6.00±2.31 individuals/m^2) at the Ojokondo dumpsite, 5 to 17 individuals/m^2 (9.60±6.07 individuals/m^2) at the Olodo dumpsite, 9 to 16 individuals/m^2 (12.00±4.00 individuals/m^2) at the Moniya dumpsite, 4 to 13 individuals/m^2 (9.33±4.62 individuals/m^2) at the Oremeji dumpsite and 13 to 56 individuals/m^2 (32.00±12.65 individuals/m^2) at the control site (Balewa). Their biomasses were 1.80 to 5.28 g/m^2 (4.15±1.60 g/m^2), 1.16 to 10.12 g/m^2 (5.04±4.03 g/m^2), 7.36 to 13.84 g/m^2 (11.20±3.40 g/m^2), 0.84 to 10.40 g/m^2 (6.55±5.04 g/m^2) and 9.24 to 80.56 g/m^2 (36.23±18.68 g/m^2) at the Ojokondo, Olodo, Moniya, Oremeji dumpsites and the control site respectively (Appendix 3).

Hyperiodrilus africanus densities found in the soils of the dumpsites ranged from 0 to 4 individuals/m^2 (4.00±0.00 individuals/m^2) at the Ojokondo dumpsite, 0 to 8 individuals/m^2 (8.00±0.00 individuals/m^2) at the Olodo dumpsite, 4 to 8 individuals/m^2 (6.00±2.83 individuals/m^2) at the Idi Ope dumpsite, 7 to 17

individuals/m^2 (12.00±5.66 individuals/m^2) at the Oremeji dumpsite and 13 to 52 individuals/m^2 (32.67±14.62 individuals/m^2) at the control site (Balewa). Their range and mean biomasses were 0 to 2.00 g/m^2 (2.00±0.00 g/m^2), 0 to 2.80 g/m^2 (2.80±0.00 g/m^2), 1.84 to 8.96 g/m^2 (5.78±1.95 g/m^2), 3.56 to 18.88 g/m^2 (11.20±10.75 g/m^2), and 6.56 to 73.27 g/m^2 (41.03±25.35 g/m^2) at the Ojokondo, Olodo, Idi Ope, Oremeji dumpsites and the control site (Balewa) respectively (Appendix 3).

4.3 Earthworms' diversity

4.3.1 Streams

Shannon Wiener's diversity index showed that earthworms were mostly diverse in the soil at the Odinjo site (0.73), followed by the control site (0.57), Omi Adio (0.47), Irefin (0.45), Gbagi (0.44), while the least was at Gege (0.30) (Table 4.1).

The Shannon's evenness index showed that earthworms were most evenly distributed in the soil at the Odinjo site (2.43), followed by Gege (1.00), Omi Adio (0.98), control site (Awba stream) (0.95) and Irefin (0.95) were equally evenly distributed and the least was Gbagi (0.92) (Table 4.1).

Maximum species richness in terms of Menhinick's index was recorded at Gege (2.03), followed by Irefin (1.42), Omi Adio (0.66), Odinjo (0.6), Gbagi (0.5) and the control site (Awba stream) (0.38) was the minimum (Table 4.1).

The Sorensen's coefficient of community similarity showed that the most similar sites in earthworms' composition were Gbagi and Irefin (1.00), Omi Adio and Irefin (1.00), Omi Adio and Gege (1.00), and Omi Adio and Gbagi (1.00). The least similar sites were the control site (Awba stream) and Gege (0.67), and also the control site (Awba stream) and Odinjo (0.67) (Table 4.2).

4.3.2 Dumpsites

Shannon Wiener's diversity index showed that earthworms were mostly diverse at the control site (Balewa) (0.52), Oremeji site (0.50), followed by Olodo (0.49), Ojokondo (0.38), Idi Ope (0.37) while the least was at Moniya (0.27) (Table 4.3). Shannon's evenness index showed that earthworms were most evenly distributed at the control

Table 4.1: Diversity indices of earthworms observed at the streams

Sites	Shannon Weiner Diversity Index	Shannon's Evenness Index	Menheinick's Species Richness
Awba stream	0.57	0.95	0.38
Irefin	0.45	0.95	1.42
Gege	0.30	1.00	2.03
Gbagi	0.44	0.92	0.50
Odinjo	0.73	2.43	0.60
Omi Adio	0.47	0.98	0.66

Table 4.2: Sorensen's coefficient of similarity for streams' earthworms

Sites	Awba stream	Irefin	Gege	Gbagi	Odinjo	Omi Adio
Awba stream		0.86	0.67	0.86	0.67	0.86
Irefin			0.8	1	0.8	1
Gege				0.8	0.8	1
Gbagi					0.8	1
Odinjo						0.8
Omi Adio						

site (Balewa) (1.00), followed by the Oremeji dumpsite (0.99), Idi Ope (0.96), Olodo (0.93), Moniya (0.84), and the least was observed at the Ojokondo dumpsite (0.80) (Table 4.3).

Maximum species richness in terms of Menhinick's index was recorded at Ojokondo (0.75), followed by Oremeji (0.64), Olodo (0.63) and Idi Ope (0.49). The control site (Balewa) and Moniya were equally the same and they had the minimum values (0.37) (Table 4.3).

The Sorensen's coefficient of community similarity showed that the sites were closely similar in terms of earthworms' composition (Table 4.4).

4.4 Result of analysis of stream water samples

4.4.1 Bimonthly variation of physico-chemical characteristics of stream water samples

The range and mean values of the physico-chemical characteristics of stream water samples are shown in Appendix 5. Details are shown in Appendices 9 to 19.

4.4.1.1 Hydrogen ion concentration (pH)

The bimonthly values of pH of the stream water samples ranged from 6.24 to 8.38 (7.06±0.21) at Irefin upstream, 6.52 to 7.23 (6.75±0.07) at Gege upstream, 6.27 to 7.86 (6.94±0.14) at Gbagi upstream, 6.28 to 8.26 (6.98±0.14) at Odinjo upstream, 6.23 to 8.12 (7.06±0.16) at Omi Adio upstream, and 6.60 to 9.00 (7.34±0.22) at the control site (Awba stream) (Figure 4.3a; Appendix 5). It ranged from 6.38 to 7.99 (6.84±0.12) at Irefin downstream, 6.32 to 8.18 (7.15±0.18) at Gege downstream, 6.27 to 8.20 (7.00±0.17) at Gbagi downstream, 6.48 to 8.33 (7.07±0.14) at Odinjo downstream, 5.48 to 7.60 (6.87±0.17) at Omi Adio downstream (Figure 4.3b; Appendix 5).

One way analysis of variance showed that the pH of the samples were not significantly different from one another at $P<0.05$ (Appendix 7). However, Duncan's multiple range test showed that the pH of Gege upstream was significantly different from that of the control site (Awba stream) but the two were not significantly different from those of the other stream samples at $P<0.05$ (Appendix 8).

Table 4.3: Diversity indices of earthworms observed at the dumpsites

Sites	Shannon Weiner	Shannon's Evenness	Menheinick's Species Richness
Balewa	0.52	1.00	0.37
Ojokondo	0.38	0.80	0.75
Olodo	0.49	0.93	0.63
Moniya	0.27	0.84	0.37
Idi Ope	0.37	0.96	0.49
Oremeji	0.50	0.99	0.64

Table 4.4: Sorensen's coefficient of similarity for dumpsites' earthworms

Sites	Balewa	Ojokondo	Olodo	Moniya	Idi Ope	Oremeji
Balewa		1	1	0.8	0.8	1
Ojokondo			1	0.8	0.8	1
Olodo				0.8	0.8	0.8
Moniya					0.8	0.8
Idi Ope						0.8
Oremeji						

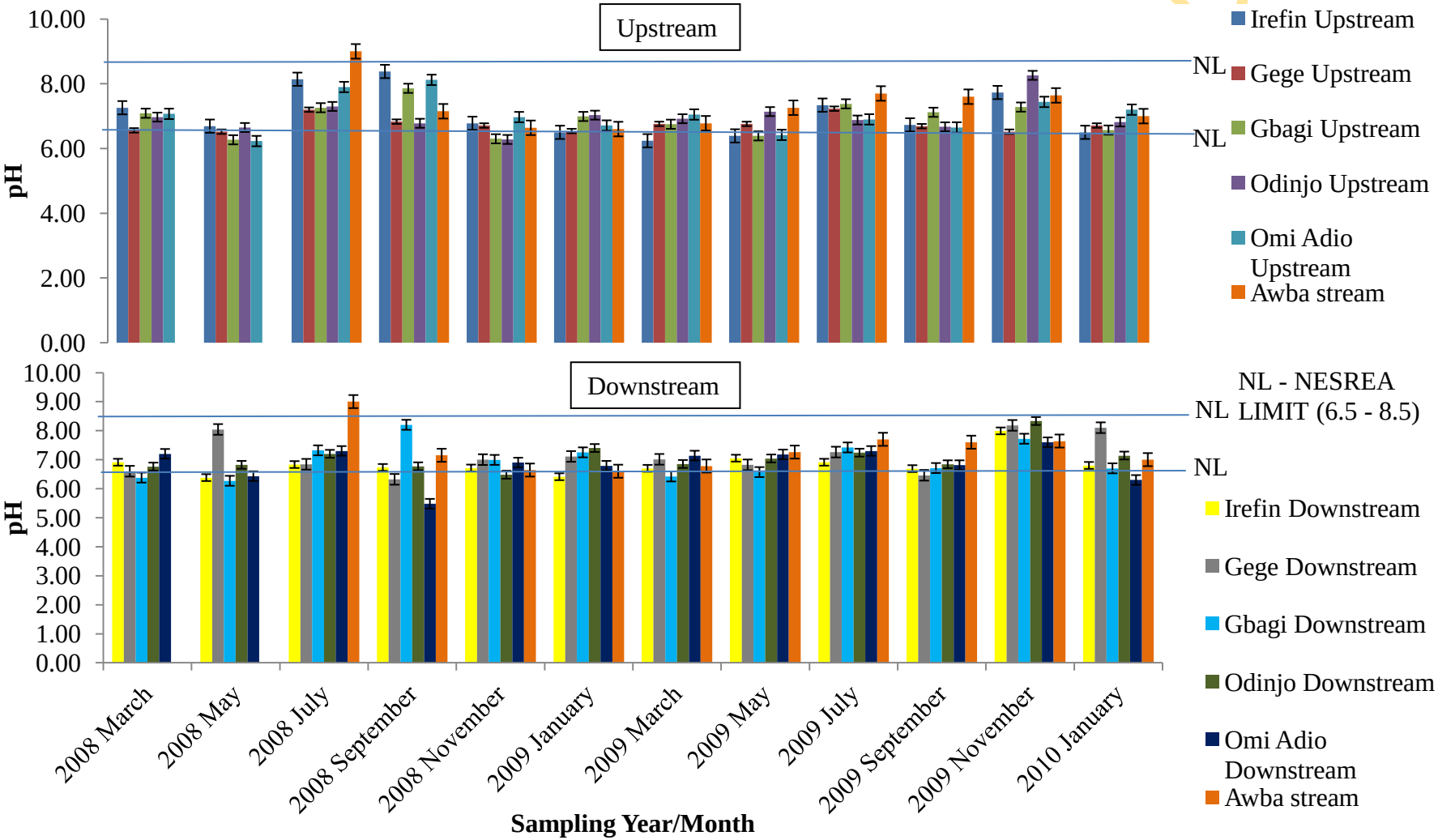


Figure 4.3: Bimonthly variation of pH values of streams

(a) Upstream (b) Downstream

4.4.1.2 Dissolved oxygen (DO)

During the sampling period, dissolved oxygen was not detected (0 mg/L) in the samples from the Irefin upstream in the months of March and July 2008, March to November 2009 and January 2010. Samples obtained from the Irefin downstream had no dissolved oxygen content in March, May, July and November 2008; January, May, July, September and November 2009; and January 2010. Samples obtained from the Gege upstream had no dissolved oxygen content in May and November 2008; January, May to November 2009; and January 2010.Gege downstream had no dissolved oxygen content in the sampled months except in March 2008 with a value of 2.24 mg/L. Gbagi upstream had no dissolved oxygen content in the samples obtained from July and September 2008; May, July, September and November 2009; and January 2010. At Gbagi downstream, it was not detected in July 2008; May, July September and November 2009; and January 2010. At the Odinjo upstream, dissolved oxygen was not detected in May 2008, January to September 2009 and January 2010. At Odinjo downstream, it was not detected in May and November 2008; March to November 2009; and January 2010. Samples collected from the Omi Adio upstream had no dissolved oxygen in May, July and September 2009. At the Omi Adio downstream, it was not detected in March, May, July and September 2009. The control site (Awba stream) had no dissolved oxygen content in July 2008 and May to November 2009 (Figure 4.4; Appendices 9 to 19).

However, the dissolved oxygen contents observed during the sampling period ranged from 1.22 to 2.13 mg/L (1.69±0.13 mg/L) at the Irefin upstream, 0.81 to 3.30 mg/L (2.05±0.48 mg/L) at the Gege upstream, 0.46 to 3.55 mg/L (1.89±0.43 mg/L) at the Gbagi upstream, 0.61 to 4.01 mg/L (2.05±0.57 mg/L) at Odinjo upstream, 0.20 to 5.89 mg/L (2.09±0.50 mg/L) at Omi Adio upstream, and 3.96 to 5.98 mg/L (5.31±0.17 mg/L) at the control site (Awba stream) (Figure 4.4a; Appendix 5). It ranged from 1.52 to 1.98 mg/L (1.75±0.23 mg/L) at the Irefin downstream, 1.50 to 2.24 mg/L (1.87±0.37 mg/L) at the Gege downstream, 1.68 to 4.67 mg/L (2.53±0.42 mg/L) at the Gbagi downstream, 1.07 to 3.86 mg/L (2.29±0.51 mg/L) at Odinjo downstream and 0.25 to 4.78 mg/L (1.74±0.47 mg/L) at the Omi Adio downstream (Figure 4.4b; Appendix 5).

One way analysis of variance showed significant differences of the dissolved oxygen of the streams at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the

dissolved oxygen of the control site (Awba stream) was significantly different from those of all the other stream samples at P<0.05 (Appendix 8).

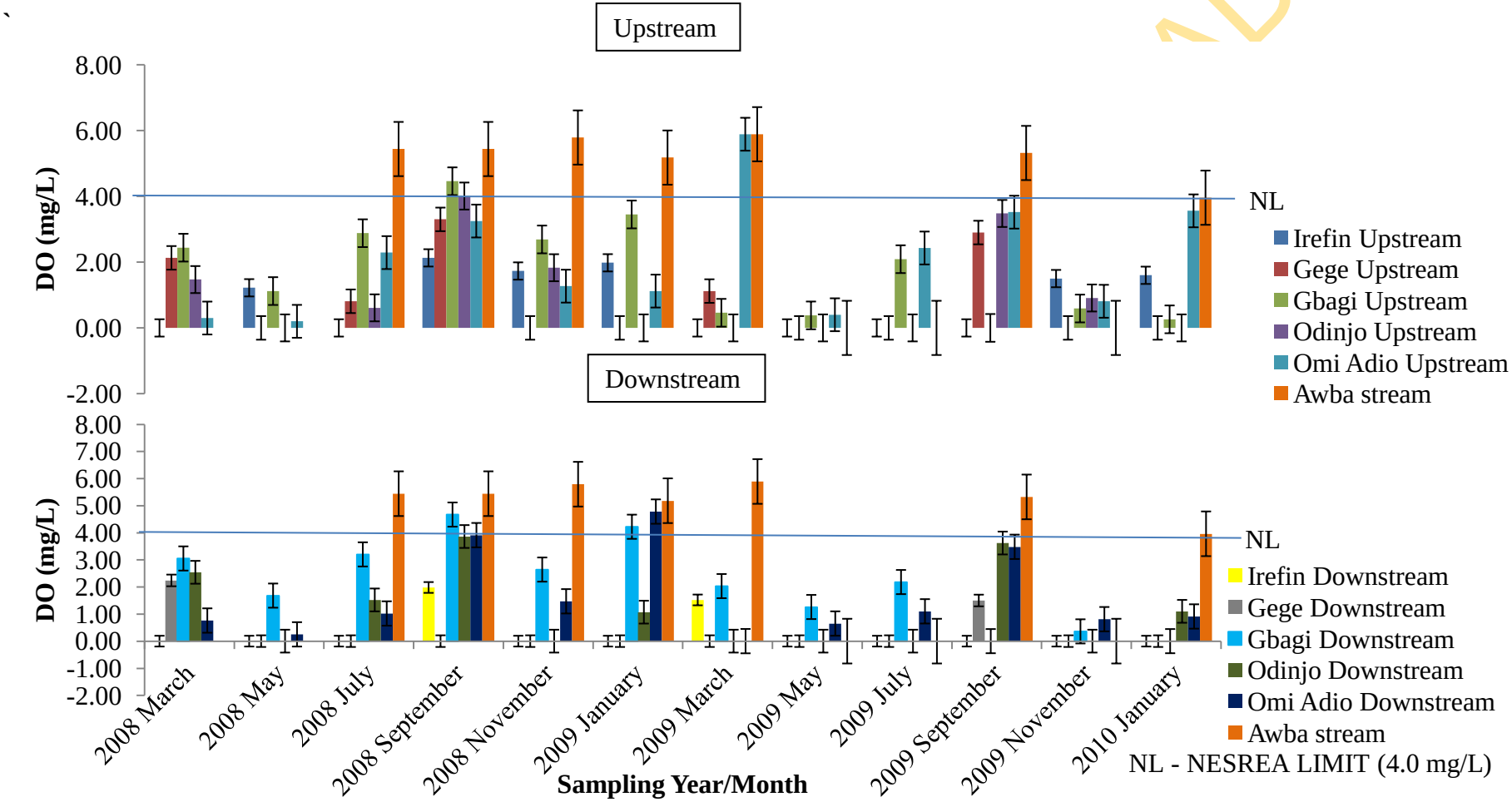
4.4.1.3 Biochemical oxygen demand (BOD)

The bimonthly values of biochemical oxygen demand (BOD) of the stream water samples ranged from 26.39 to 138.12 mg/L (84.27±8.97 mg/L) at Irefin upstream, 18.43 to 147.03 mg/L (96.72±13.03 mg/L) at Gege upstream, 30.72 to 126.88 mg/L (89.84±9.48 mg/L) at Gbagi upstream, and 39.20 to 103.79 mg/L (66.57±7.07 mg/L) at Odinjo upstream and 21.45 to 105.34 mg/L (55.46±8.82 mg/L) at Omi Adio upstream (Figure 4.5a; Appendix 5). It ranged from 28.31 to 146.03 mg/L (93.37±11.83 mg/L) at Irefin downstream, 21.0 to 160.66 mg/L (104.51±14.01 mg/L) at Gege downstream, 23.25 to 141.21 mg/L (90.46±10.96 mg/L) at Gbagi downstream, 41.66 to 112.39 mg/L (72.21±7.16 mg/L) at Odinjo downstream, 13.36 to 92.60 mg/L (46.70±7.88 mg/L) at Omi Adio downstream and 9.48 to 85.71 mg/L (44.98±7.18 mg/L) at the control site (Awba stream) (Figure 4.5b; Appendix 5).

One way analysis of variance showed significant differences of the biochemical oxygen demand (BOD) of the stream samples at P<0.05 (Appendix 7). Duncan's multiple range test showed that the biochemical oxygen demand (BOD) content of the control site (Awba stream) was not significantly different from those of the upstream and downstream of Omi Adio and Odinjo but they were significantly different from the other samples at P<0.05 (Appendix 8).

4.4.1.4 Chemical oxygen demand (COD)

The bimonthly values of the chemical oxygen demand (COD) of stream water samples ranged from 146.53 to 480.00 mg/L (315.47±28.51 mg/L) at Irefin upstream, 188.69 to 600 mg/L (396.81±37.96 mg/L) at Gege upstream, 130.68 to 500.00 mg/L (338.42±29.68 mg/L) at Gbagi upstream, 118.64 to 520.00 mg/L (260.06±34.62 mg/L) at Odinjo upstream, 50.00 to 328.02 mg/L (191.51±28.73 mg/L) at Omi Adio upstream and 28.86 to 272.13 mg/L (143.43±22.42 mg/L) at the control site (Awba stream) (Figure 4.6a; Appendix 5). It ranged from 142.87 to 487.10 mg/L (361.97±34.13 mg/L) at Gege downstream, 166.52 to 540.00 mg/L (343.74±34.21 mg/L) at Irefin downstream, 132.81 to 540.00 mg/L (382.09±31.59 mg/L) at Gbagi



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that dissolved oxygen was not detected in the samples.

Figure 4.4: Bimonthly variation of dissolved oxygen (DO) values of streams
(a) Upstream (b) Downstream

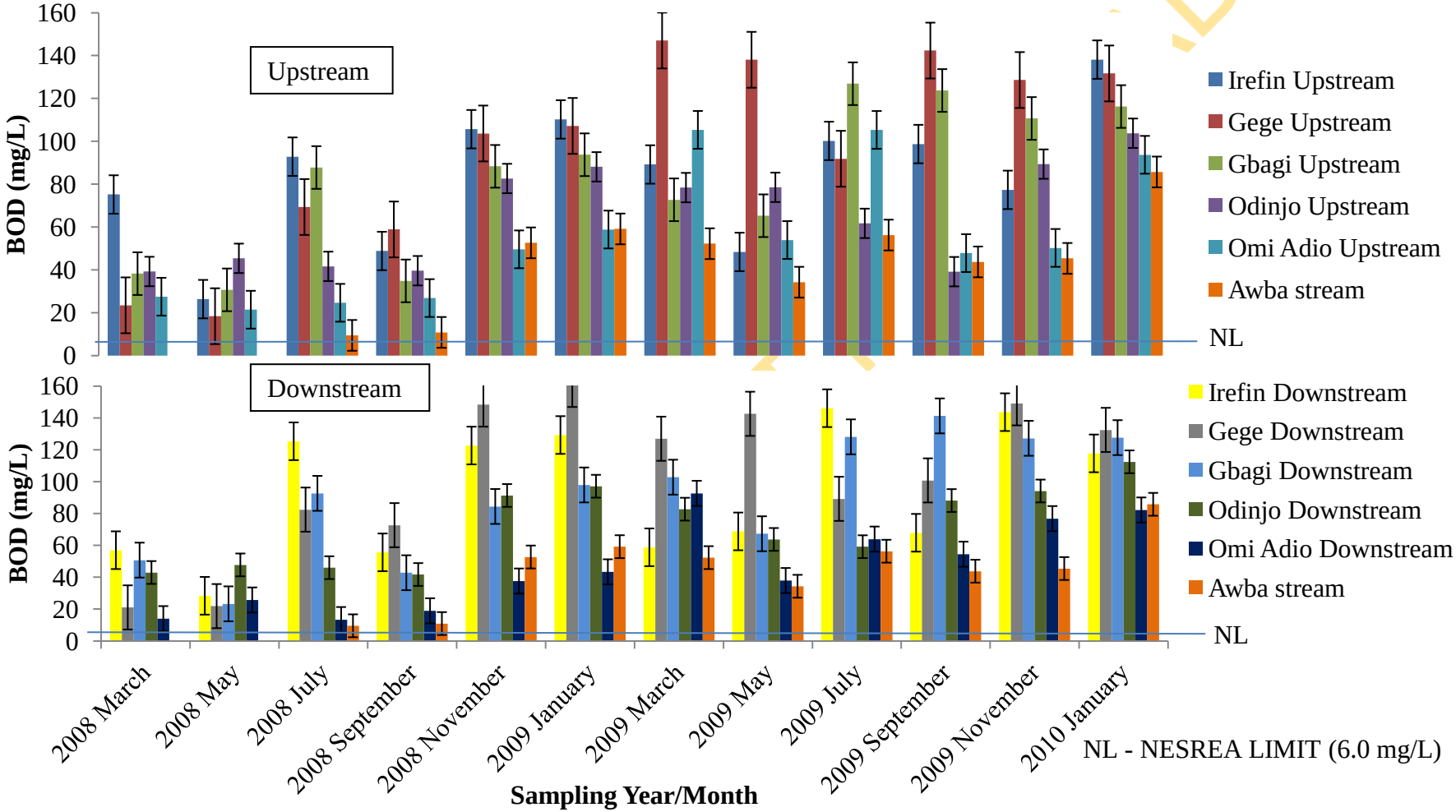


Figure 4.5: Bimonthly variation of biochemical oxygen demand (BOD) values of streams
(a) Upstream (b) Downstream

downstream, 121.88 to 480.00 mg/L (274.57±29.43 mg/L) at Odinjo downstream and 43.08 to 315.67 mg/L (154.69±25.96 mg/L) at Omi Adio downstream (Figure 4.6b; Appendix 5).

One way analysis of variance showed significant differences of the chemical oxygen demand (COD) of the streams at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the chemical oxygen demand (COD) of the control site (Awba stream) was not significantly different from those of the upstream and downstream of Omi Adio but they were significantly different from the other samples at $P<0.05$ (Appendix 8).

4.4.1.5 Total dissolved solids (TDS)

The bimonthly values of total dissolved solids (TDS) of the stream water samples ranged from 363.00 to 1630.00 mg/L (810.17±114.96 mg/L) at Irefin upstream, 552.00 to 2640.00 mg/L (1161.08±161.97 mg/L) at Gege upstream, 52.5 to 492.00 mg/L (281.98±35.32 mg/L) at Gbagi upstream, 159.00 to 1350.00 mg/L (865.00±112.88 mg/L) at Odinjo upstream, 29.20 to 262.00 mg/L (171.93±20.82 mg/L) at Omi Adio upstream and 42.10 to 255.00 mg/L (154.01±18.93 mg/L) at the control site (Awba stream) (Figure 4.7a; Appendix 5). It ranged from 555.00 to 1792.00 mg/L (904.75±101.30 mg/L) at Irefin downstream, 847.00 to 2847.00 mg/L (1344.00±158.99 mg/L) at Gege downstream, 60.60 to 513.00 mg/L (297.88±30.15 mg/L) at Gbagi downstream, 264.00 to 1600.00 mg/L (862.17±121.95 mg/L) at Odinjo downstream and 77.10 to 621.00 mg/L (254.15±47.75 mg/L) at Omi Adio downstream, (Figure 4.7b; Appendix 5).

One way analysis of variance showed that some of the streams' total dissolved solids (TDS) were significantly different at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the upstream and downstream of Gege were not significantly different from each other but they were significantly different from all other stream samples at $P<0.05$ (Appendix 8).

4.4.1.6 Electrical conductivity (EC)

The bimonthly values of electrical conductivity (EC) of the stream water samples ranged from 606.00 to 3056.00 µS/cm (1532.17±219.85 µS/cm) at Irefin upstream, 920.00 to 4690.00 µS/cm (2119.50±286.61 µS/cm) at Gege upstream, 105.00 to

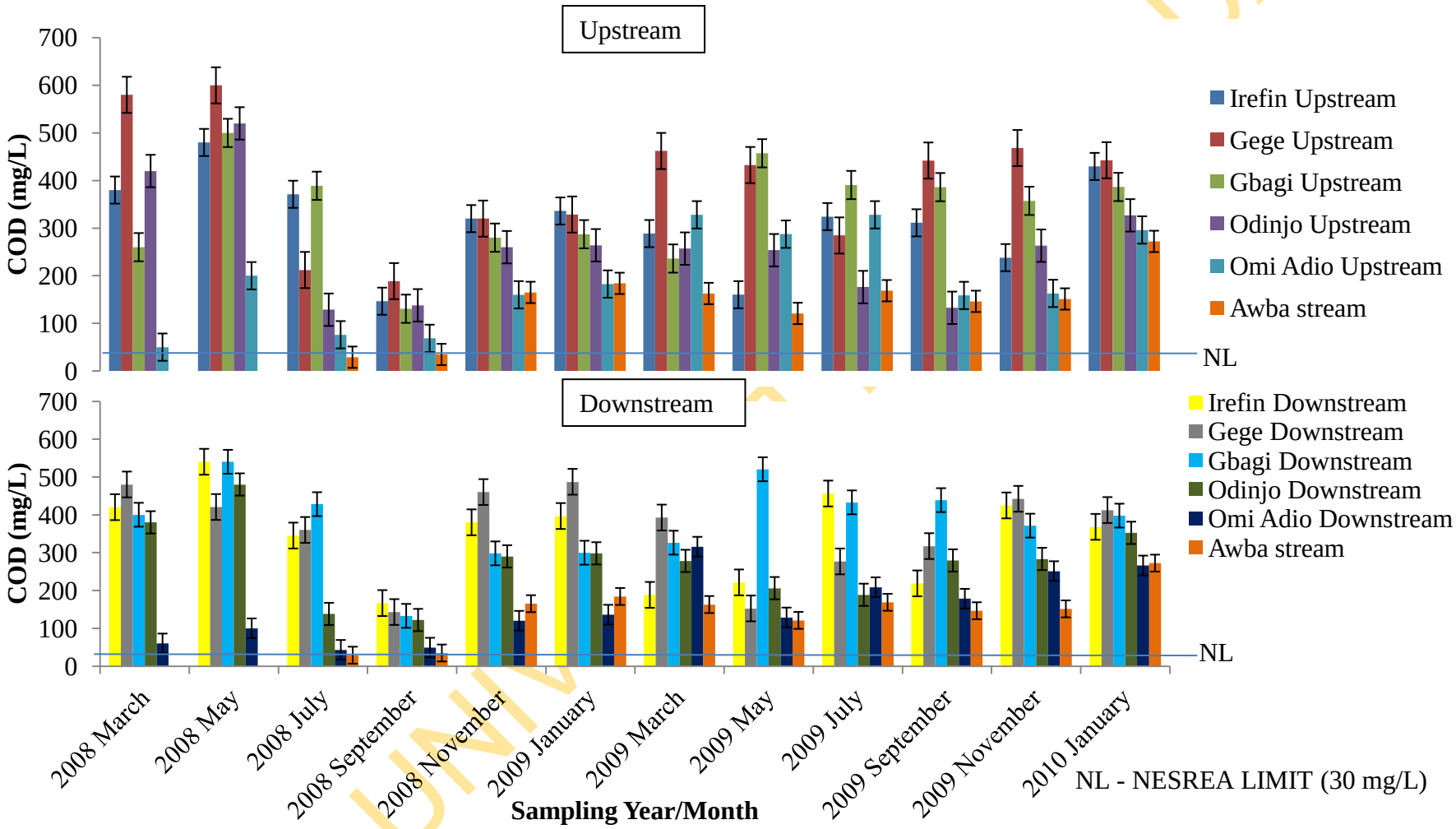


Figure 4.6: Bimonthly variation of chemical oxygen demand (COD) values of streams
(a) Upstream (b) Downstream

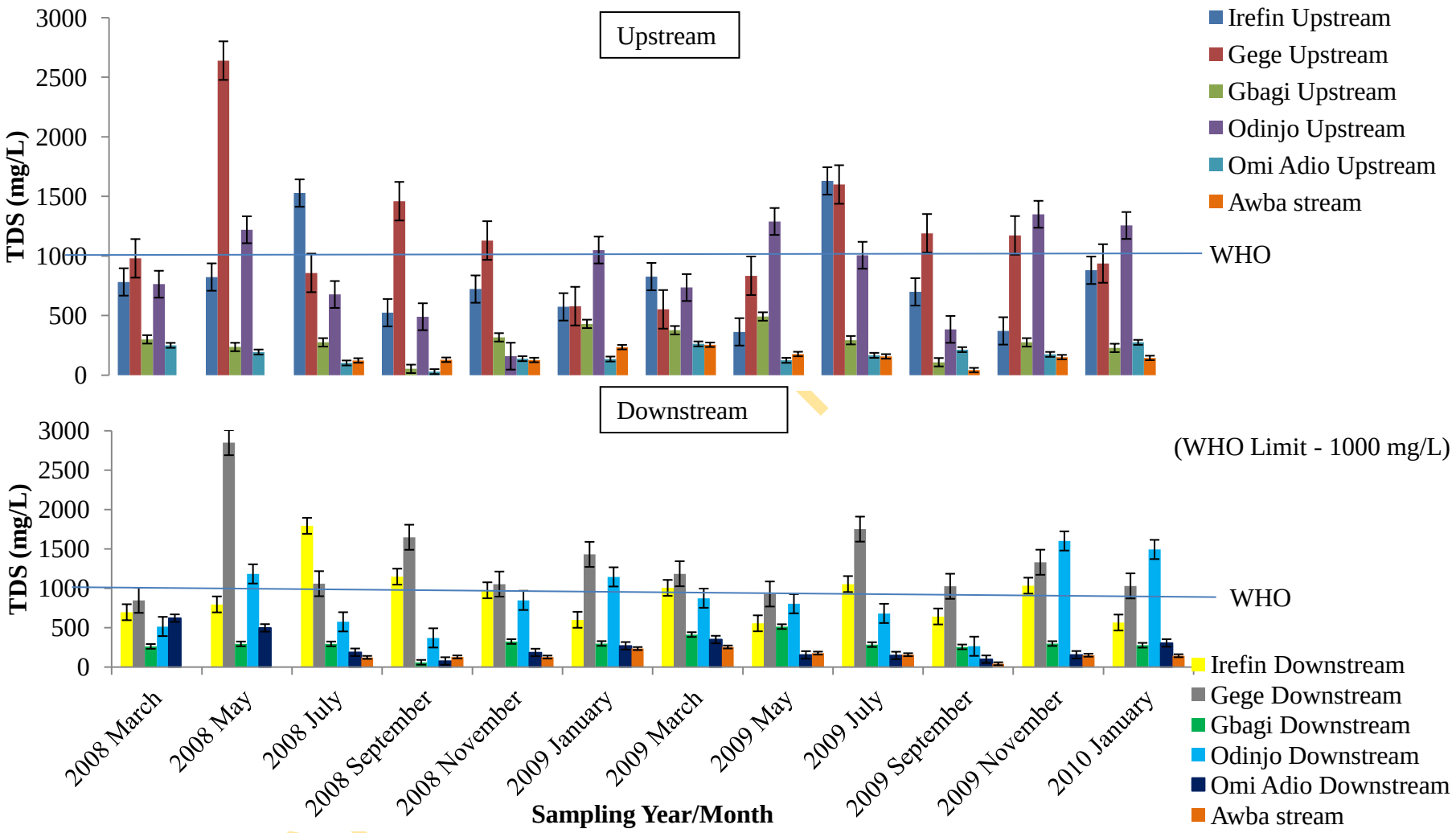


Figure 4.7: Bimonthly variation of total dissolved solids (TDS) values of streams
(a) Upstream (b) Downstream

984.00 µS/cm (532.79±65.31 µS/cm) at Gbagi upstream, 265.00 to 2530.00 µS/cm (1585.50±210.73 µS/cm) at Odinjo upstream, 48.80 to 688.00 µS/cm (328.73±47.93 µS/cm) at Omi Adio upstream and 70.30 to 426.00 µS/cm (275.03±32.39 µS/cm) at the control site (Awba stream) (Figure 4.8a; Appendix 5). It ranged from 935.00 to 3584.00 µS/cm (1647.58±198.87 µS/cm) at Irefin downstream, 1684.00 to 5694.00 µS/cm (2518.50±323.32 mg/L) at Gege downstream, 100.90 to 1026.00 µS/cm (561.99±61.88µS/cm) at Gbagi downstream, 440.00 to 4728.00 µS/cm (1737.17±347.66 µS/cm) at Odinjo downstream and 128.60 to 1240.00 µS/cm (497.41±104.25 µS/cm) at Omi Adio downstream (Figure 4.8b; Appendix 5).

One way analysis of variance showed significant differences of the electrical conductivity of the streams at $P<0.05$ (Appendix 7). Duncan's multiple range test showed the same trend with those of total dissolved solids contents of the samples $P<0.05$ (Appendix 8).

4.4.1.7 Total alkalinity

The bimonthly values of total alkalinity of the stream water samples ranged from 205.20 to 836.55 mg/L (546.02±56.67 mg/L) at Irefin upstream, 266.40 to 1487.50 mg/L (741.19±99.12 mg/L) at Gege upstream, 3.56 to 524.02 mg/L (277.04±42.94 mg/L) at Gbagi upstream, 230.40 to 902.70 mg/L (518.72±66.96 mg/L) at Odinjo upstream, 101.32 to 336.30 mg/L (201.41±20.31 mg/L) at Omi Adio upstream and 98.00 to 430.70 mg/L (188.93±31.19 mg/L) at the control site (Awba stream) (Figure 4.9a; Appendix 5). It ranged from 327.60 to 926.36 mg/L (594.57±55.32 mg/L) at Irefin downstream, 374.92 to 1497.39 mg/L (795.98±91.21 mg/L) at Gege downstream, 99.98 to 452.60 mg/L (284.89±31.52 mg/L) at Gbagi downstream, 151.90 to 1052.87 mg/L (416.75±76.50 mg/L) at Odinjo downstream and 89.64 to 424.15 mg/L (249.72±32.80 mg/L) at Omi Adio downstream (Figure 4.9b; Appendix 5).

One way analysis of variance showed that some of the total alkalinity contents of the streams were significantly different at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the upstream and downstream of Gege were not significantly different from each other but they were significantly different from all other stream samples at $P<0.05$ (Appendix 8).

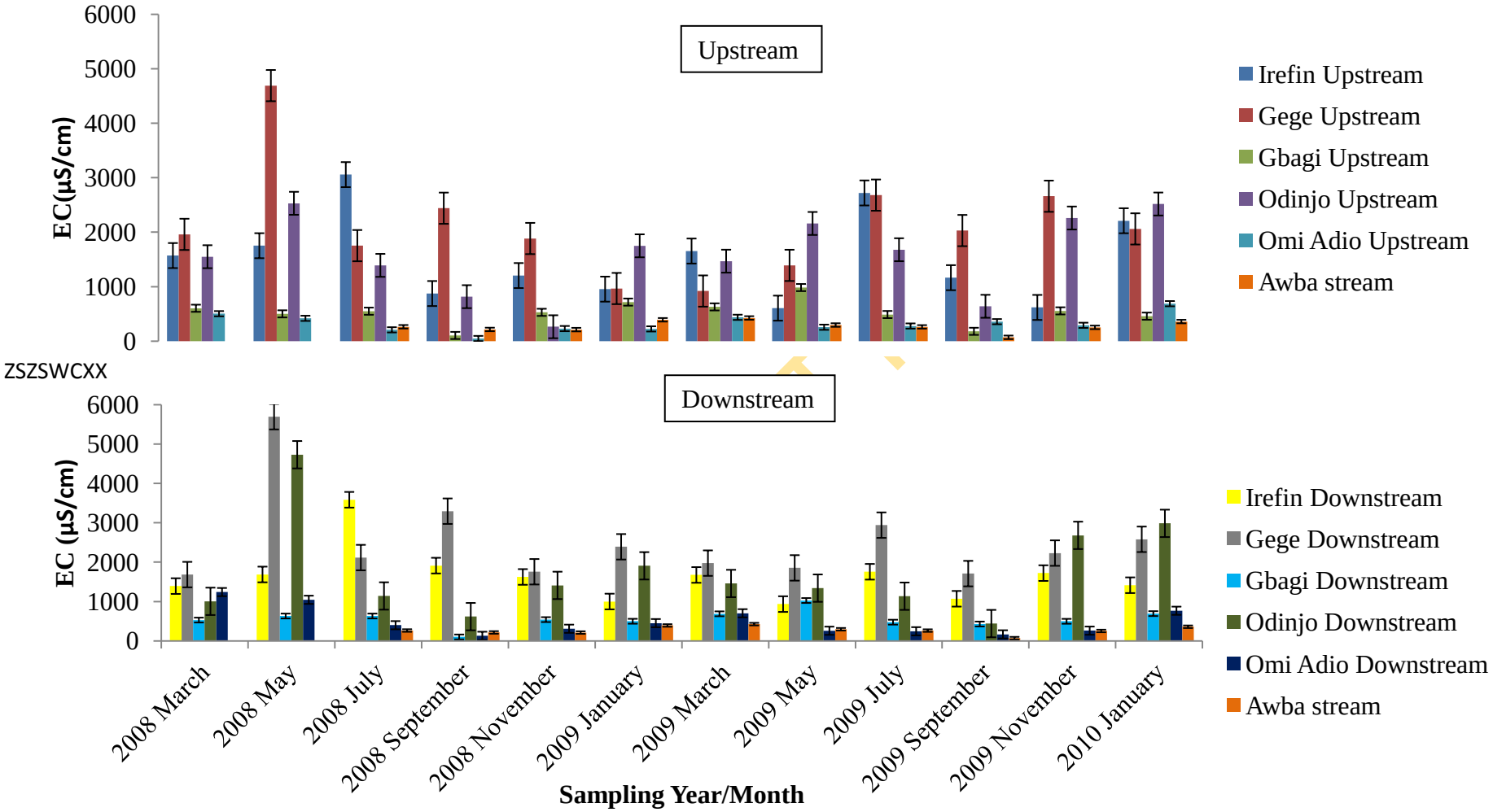


Figure 4.8: Bimonthly variation of electrical conductivity (EC) values of streams
(a) Upstream (b) Downstream

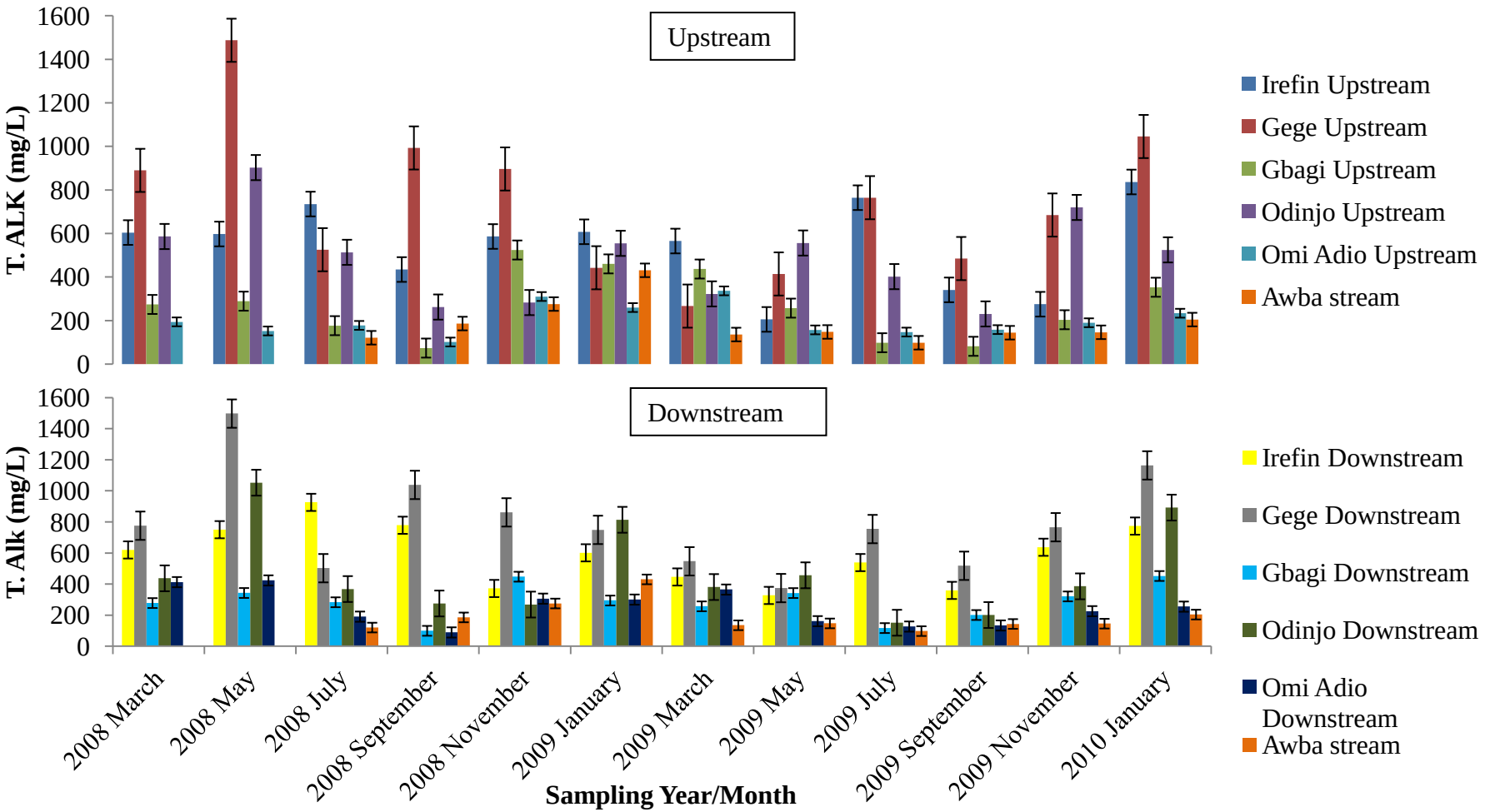


Figure 4.9: Bimonthly variation of total alkalinity values of streams
(a) Upstream (b) Downstream

4.4.2 Bimonthly variation of anions of stream water samples

The range and mean values of the anions of the stream water samples are shown in Appendix 5. Details are shown in Appendices 9 to 19.

4.4.2.1 Chloride

The bimonthly values of chloride contents of the stream water samples ranged from 76.50 to 391.33 mg/L (200.58±29.77 mg/L) at Irefin upstream, 68.81 to 658.94 mg/L (280.57±45.27 mg/L) at Gege upstream, 24.53 to 89.76 mg/L (47.95±4.40 mg/L) at Gbagi upstream, 24.99 to 374.79 mg/L (228.34±31.74 mg/L) at Odinjo upstream, 21.34 to 97.10 mg/L (45.70±6.83 mg/L) at Omi Adio downstream and 13.63 to 47.08 mg/L (29.18±2.89 mg/L) at the control site (Awba stream) (Figure 4.10a; Appendix 5). It ranged from 62.21 to 385.45 mg/L (199.48±25.24 mg/L) at Irefin downstream, 110.09 to 527.40 mg/L (280.59±42.24 mg/L) at Gege downstream, 36.58 to 94.16 mg/L (52.45±4.30 mg/L) at Gbagi downstream, 42.93 to 270.54 mg/L (155.49±17.03 mg/L) at Odinjo downstream and 8.69 to 94.16 mg/L (35.67±7.08 mg/L) at Omi Adio upstream (Figure 4.10b; Appendix 5).

One way analysis of variance showed significant differences of some of the chloride contents of the streams at $P<0.05$ (Appendix 7). Duncan's multiple range test also showed further significant differences (Appendix 8).

4.4.2.2 Phosphate – phosphorus

During the sampling period, phosphate – phosphorus was not detected at Gbagi upstream and downstream in the months of July and September 2008, 2009 March, July and November. In the month of July 2008, it was not detected at the Omi Adio downstream while in May 2009, it was not detected at its upstream. In 2009 March, July and November and so also January 2010, it was not detected at both upstream and downstream of Omi Adio. At the upstream of Odinjo, phosphate - phosphorus was not detected in March 2009, May 2009 and January 2010, while at its downstream, it was not detected in July 2009. It was not detected at the control site (Awba stream) in the months of July 2008, May, July and November 2009 and also January 2010 (Figure 4.11; Appendices 9 to 19).

However, the ranges observed in the months detected were from 180.95 to 1265.31 (542.03±103.67 mg/L) at the Irefin upstream, 146.94 to 2751.02 mg/L

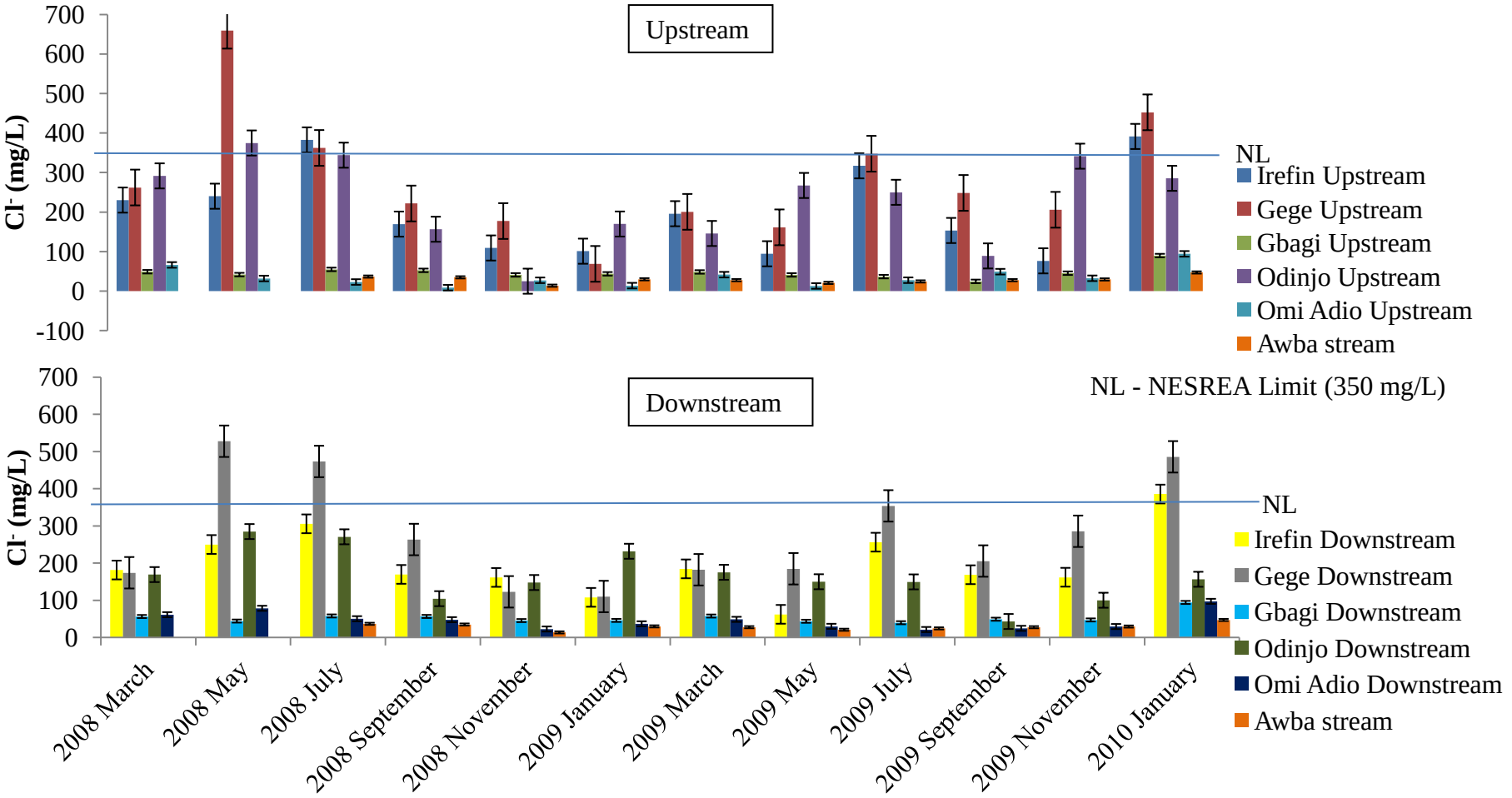


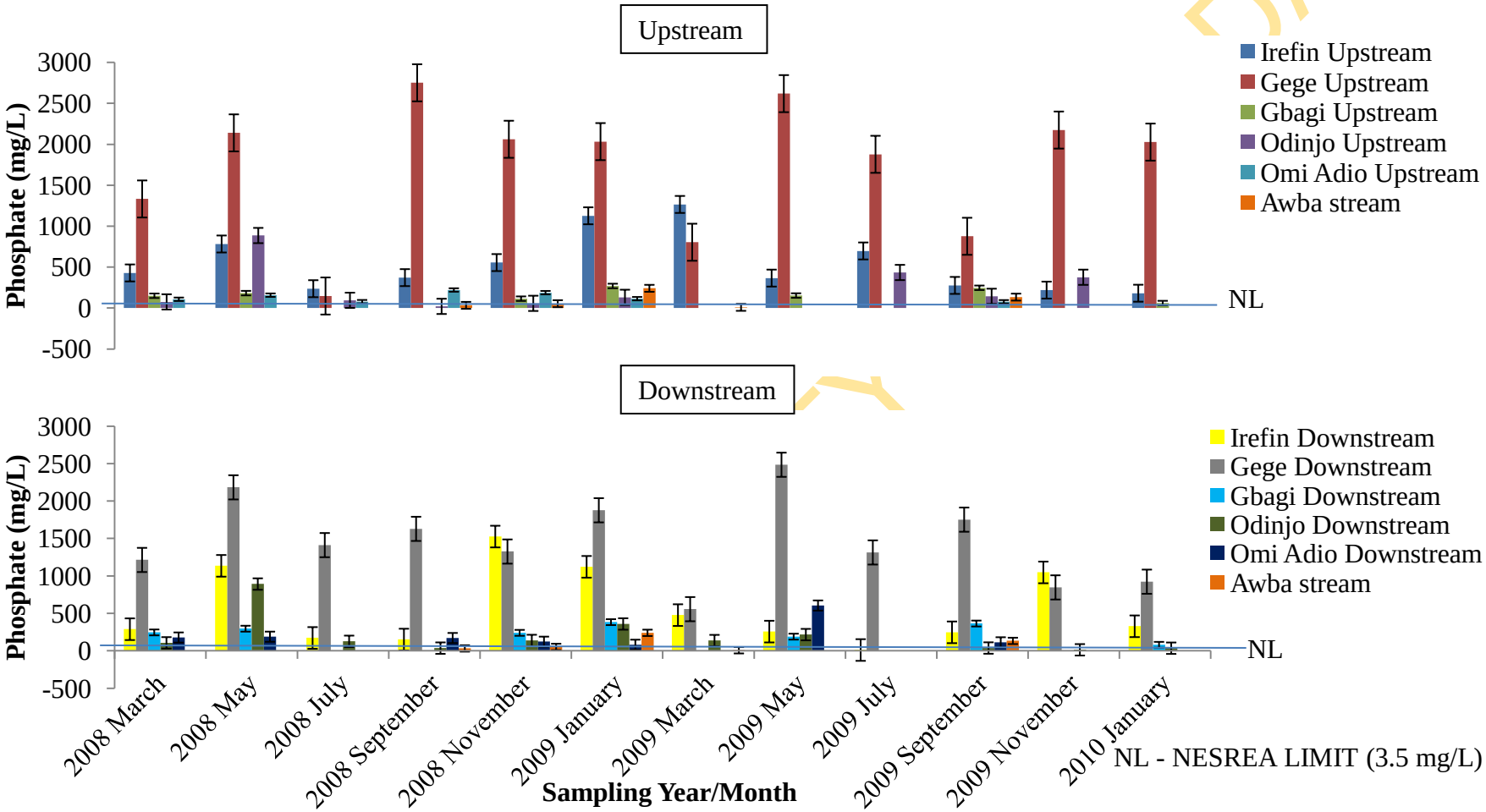
Figure 4.10: Bimonthly variation of chloride values of streams
(a) Upstream (b) Downstream

(1736.66±226.29 mg/L) at the Gege upstream, 60.57 to 269.39 mg/L (181.82±29.37 mg/L) at the Gbagi upstream, 20.41 to 885.71 mg/L (246.30±93.12 mg/L) at the Odinjo upstream, 76.19 to 220.41 mg/L (134.35±21.00 mg/L) at the Omi Adio upstream and 8.16 to 240.82 mg/L (93.60±42.37 mg/L) at the control site (Awba stream) (Figure 4.11a; Appendix 5). It ranged from 11.43 to 1526.53 mg/L (563.99±144.61 mg/L) at the Irefin downstream, 557.14 to 2485.32 mg/L (1460.38±161.51 mg/L) at the Gege downstream, 80.95 to 383.67 mg/L (243.86±42.35 mg/L) at the Gbagi downstream, 14.29 to 892.35 mg/L (191.30±76.28 mg/L) at the Odinjo downstream and 81.63 to 605.71 mg/L (209.05±67.75 mg/L) at the Omi Adio downstream (Figure 4.11b; Appendix 5).

One way analysis of variance showed that some of the phosphate – phosphorus contents of the streams were significantly different at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the upstream and downstream of Gege were not significantly different from each other but they were significantly different from all other stream samples at $P<0.05$ (Appendix 8).

4.4.2.3 Nitrate – nitrogen

Nitrate – nitrogen was not detected at the control site (Awba stream) in March 2009, September 2009, November 2009 and January 2010. It was not also detected at Gege upstream in May 2008, March 2009, May 2009 and September 2009. At the downstream of Gege, nitrate-nitrogen was not detected in March and July, September and November 2009 and also January 2010. At both upstream and downstream of Irefin, nitrate-nitrogen was not detected September 2008, throughout sampling months of 2009 and January 2010. However, it was detected at the upstream in March 2009 with the value of 4.04 mg/L. At Gbagi upstream, nitrate-nitrogen was not detected in July 2009 and September 2009, at its downstream, nitrate-nitrogen was not detected in September 2008, July 2009, September 2009, November 2009 and January 2010. At Omi Adio upstream and downstream, it was not detected throughout the sampling months of 2009 and January 2010, except at the downstream in March 2009 with a value of 2.86 mg/L, and also at the upstream in May 2009, with a value of 3.65 mg/L. At the upstream of Odinjo, it was not detected in May 2008, July, September and November 2009. At the downstream of Odinjo, it was not detected in March, September and November 2009 (Figure 4.12; Appendices 9 to 19).



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that phosphate-phosphorus was not detected in the samples.

Figure 4.11: Bimonthly variation of phosphate values of streams
(a) Upstream (b) Downstream

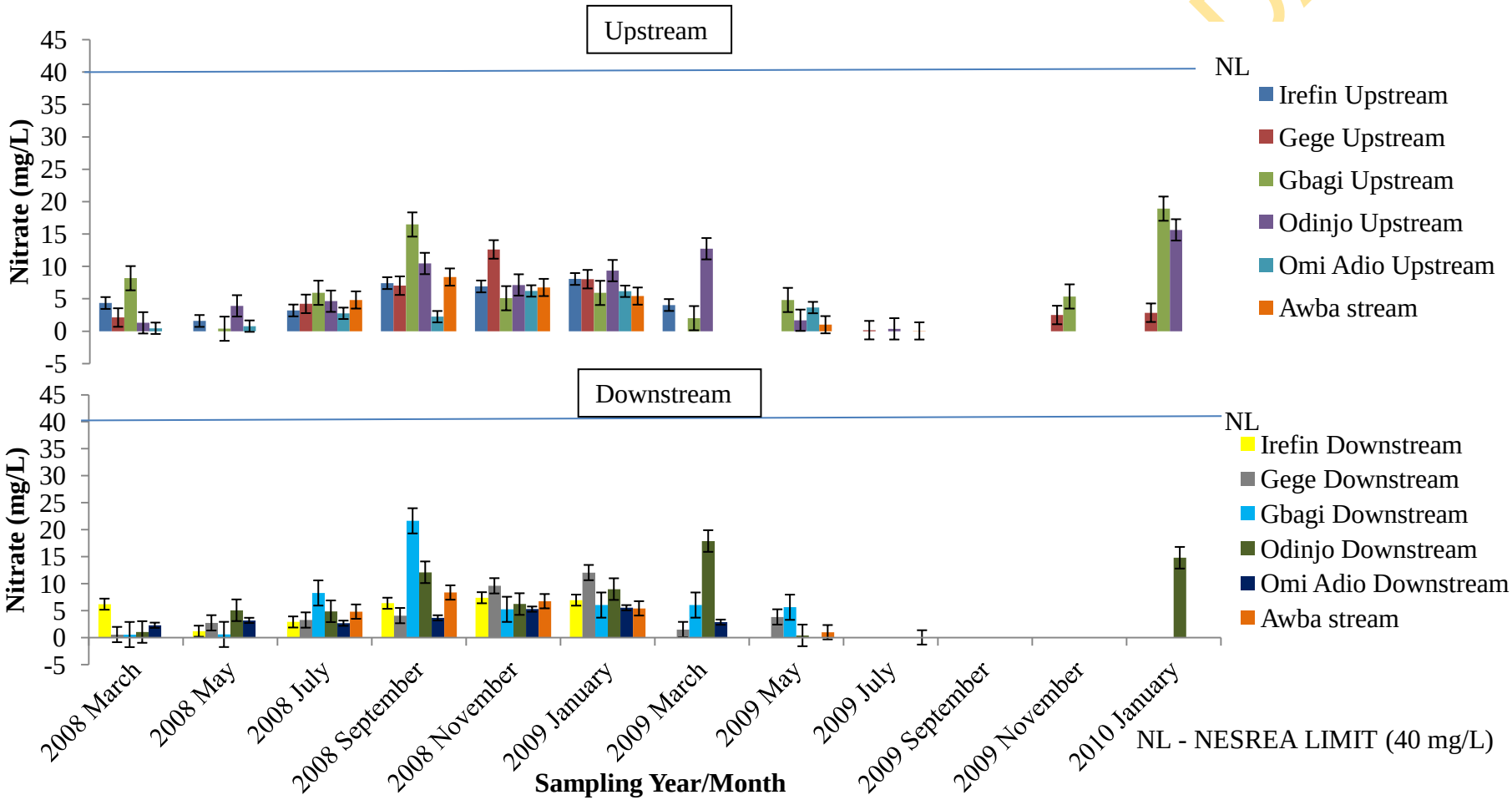
However, the bimonthly values of nitrate-nitrogen detected in the stream water samples ranged from 1.58 to 8.06 mg/L (5.08±0.91 mg/L) at Irefin upstream, 0.16 to 12.62 mg/L (4.94±1.43 mg/L) at the Gege upstream, 0.38 to 18.92 mg/L (7.31±1.87 mg/L) at Gbagi upstream, 0.36 to 17.90 mg/L (7.24±1.92 mg/L) at Odinjo upstream and 0.45 to 6.21 mg/L (3.18±0.88 mg/L) at Omi Adio upstream and 0.04 to 8.36 mg/L (4.40±1.33 mg/L) at the control site, (Awba stream) (Figure 4.12a; Appendix 5). It ranged from 1.19 to 7.39 mg/L (5.17±1.03 mg/L) at Irefin downstream, 0.57 to 12.05 mg/L (4.70±1.42 mg/L) at the Gege downstream, 0.57 to 21.64 mg/L (6.75±2.33 mg/L) at Gbagi downstream, 0.04 to 14.80 mg/L (5.95±1.74 mg/L) at Odinjo downstream and 2.29 to 5.54 mg/L (3.64±0.48 mg/L) at Omi Adio downstream (Figure 4.12a; Appendix 5).

One way analysis of variance showed that the nitrate-nitrogen content of the stream samples were not significantly different from one another at $P<0.05$ (Appendices 6 and 7).

4.4.2.4 Sulphate - sulphur

The bimonthly values of sulphate-sulphur contents of the stream water samples ranged from 570.45 to 4850.00 mg/L (1913.93±433.37 mg/L) at Irefin upstream, 1066.67 to 6481.25 mg/L (3469.28±633.38 mg/L) at Gege upstream, 254.55 to 2731.25 mg/L (804.20±392.53 mg/L) at Gbagi upstream, 475.00 to 1795.45 mg/L (1207.88±139.40 mg/L) at Odinjo upstream, 233.33 to 3050.00 mg/L (816.73±271.27 mg/L) at Omi Adio upstream and 133.33 to 5550.00 mg/L (1582.58±496.21 mg/L) at the control site (Awba stream) (Figure 4.13a; Appendix 7). It ranged from 418.18 to 4487.50 mg/L (2307.28±390.26) at Irefin downstream, 612.50 to 14068.75 mg/L (4460.84±1492.60 mg/L) at Gege downstream, 100.00 to 1931.25 mg/L (774.56±207.09 mg/L) at Gbagi downstream, 200.00 to 2968.75 mg/L (1044.63±265.40 mg/L) at Odinjo downstream and 21.34 to 3050.00 mg/L (986.73±355.72 mg/L) at Omi Adio downstream; In November 2009, sulphate-sulphur was not detected at the downstream of Omi Adio (Figure 4.13b; Appendix 5).

One way analysis of variance showed that some of the streams' sulphate - sulphur were significantly different at $P<0.05$ (Appendix 7). Duncan's multiple range test showed that the sulphate - sulphur of the upstream and downstream of Gege were not significantly different from each other but they were significantly different from all



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that nitrate-nitrogen was not detected in the samples.

Figure 4.12: Bimonthly variation of nitrate values of streams
(a) Upstream (b) Downstream

other stream samples except that the Gege upstream was not significantly different from Irefin upstream and downstream at P<0.05 (Appendix 8).

4.4.3 Bimonthly variation of cations of stream water samples

The range and mean values of the cations of stream water samples are shown in Appendix 6. Details are shown in Appendices 9 to 19.

4.4.3.1 Calcium

The bimonthly values of calcium contents of the stream water samples ranged from 10.89 to 129.99 mg/L (73.83±15.31 mg/L) at Irefin upstream, 38.89 to 82.67 mg/L (60.81±5.48 mg/L) at Gege upstream, 58.99 mg/L (42.85±6.28 mg/L) at Gbagi upstream, 8.57 to 72.09 mg/L (35.09±11.37 mg/L) at Odinjo upstream, 8.69 to 29.57 mg/L (18.98±3.74 mg/L) at Omi Adio upstream and 24.72 to 55.50 mg/L (32.60±5.82 mg/L) at the control site (Awba stream) (Figure 4.14a; Appendix 6). It ranged from 11.83 to 82.91 mg/L (56.25±9.54) at Irefin downstream, 61.15 to 126.34 mg/L (78.84±10.28 mg/L) at Gege downstream, 31.10 to 36.73 to 62.93 mg/L (47.47±4.36 mg/L) at Gbagi downstream, 0.92 to 101.31 mg/L (50.75±11.02 mg/L) at Odinjo downstream and 14.01 to 44.73 mg/L (30.62±4.18 mg/L) at Omi Adio downstream (Figure 4.14b; Appendix 6).

Calcium was not detected at Gbagi upstream in the months of March, May, July and September 2008; January, May and November 2009; and January 2010. Throughout the sampling months of 2008, January 2009 and May 2009, calcium was not detected at Gbagi downstream. In March, July, September and November 2008; May 2009 and January 2010, calcium was not detected at Omi Adio upstream. In July, September and November 2008 and March 2009, it was not detected at Omi Adio downstream. At the Odinjo upstream, calcium was not detected in July, September and November 2008; March and July 2009; and January 2009. At the Odinjo downstream, it was not detected in July, September and November 2008 and May 2009; and January 2010. Throughout the sampling months of 2008 and in January 2009, calcium was not detected at the control site (Awba stream) (Figure 4.14; Appendices 9 to 19).

One way analysis of variance showed significant differences of the calcium contents of the streams at P<0.05 (Appendix 7). Duncan's multiple range test also showed further significant differences (Appendix 8).

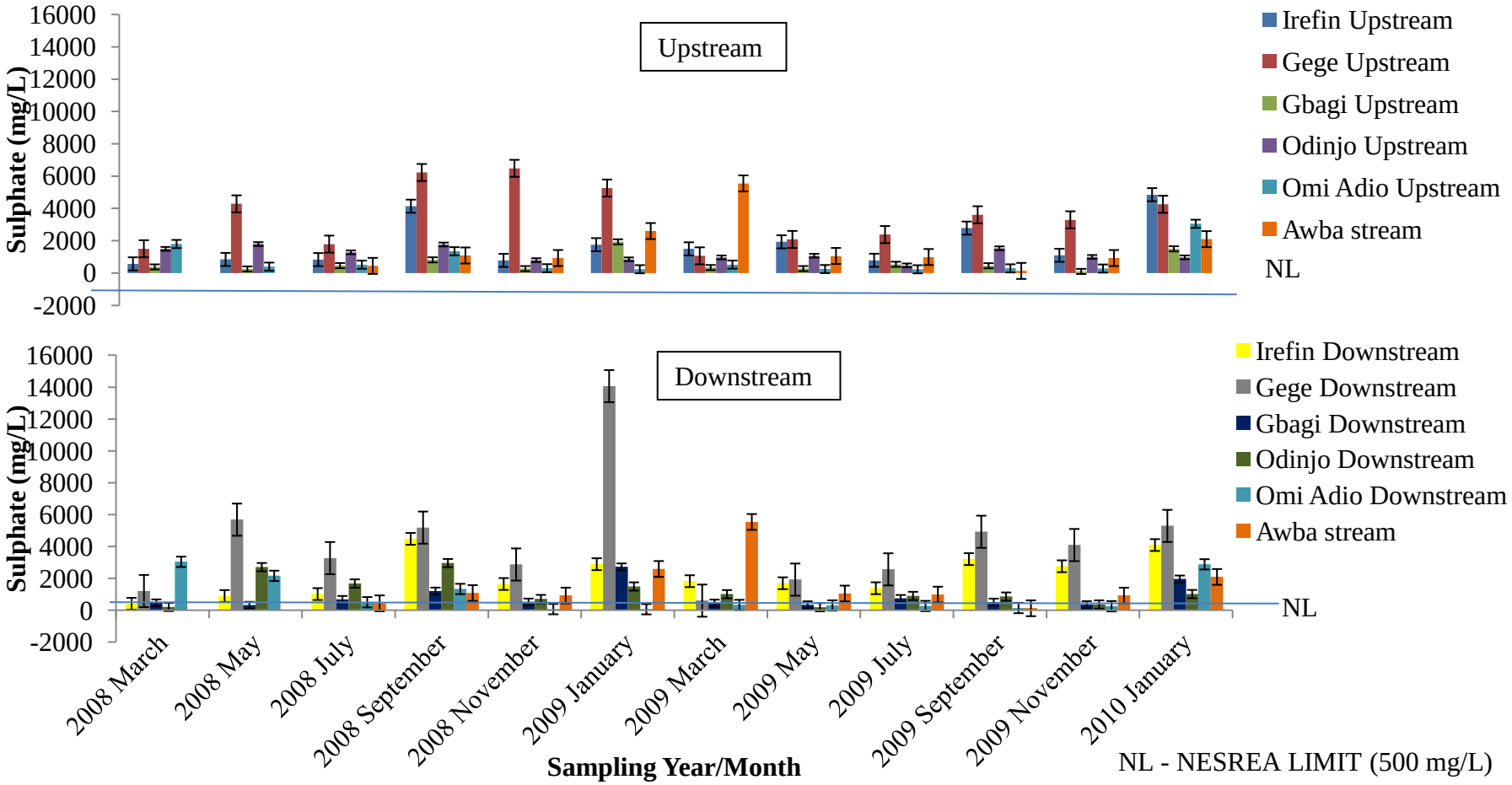
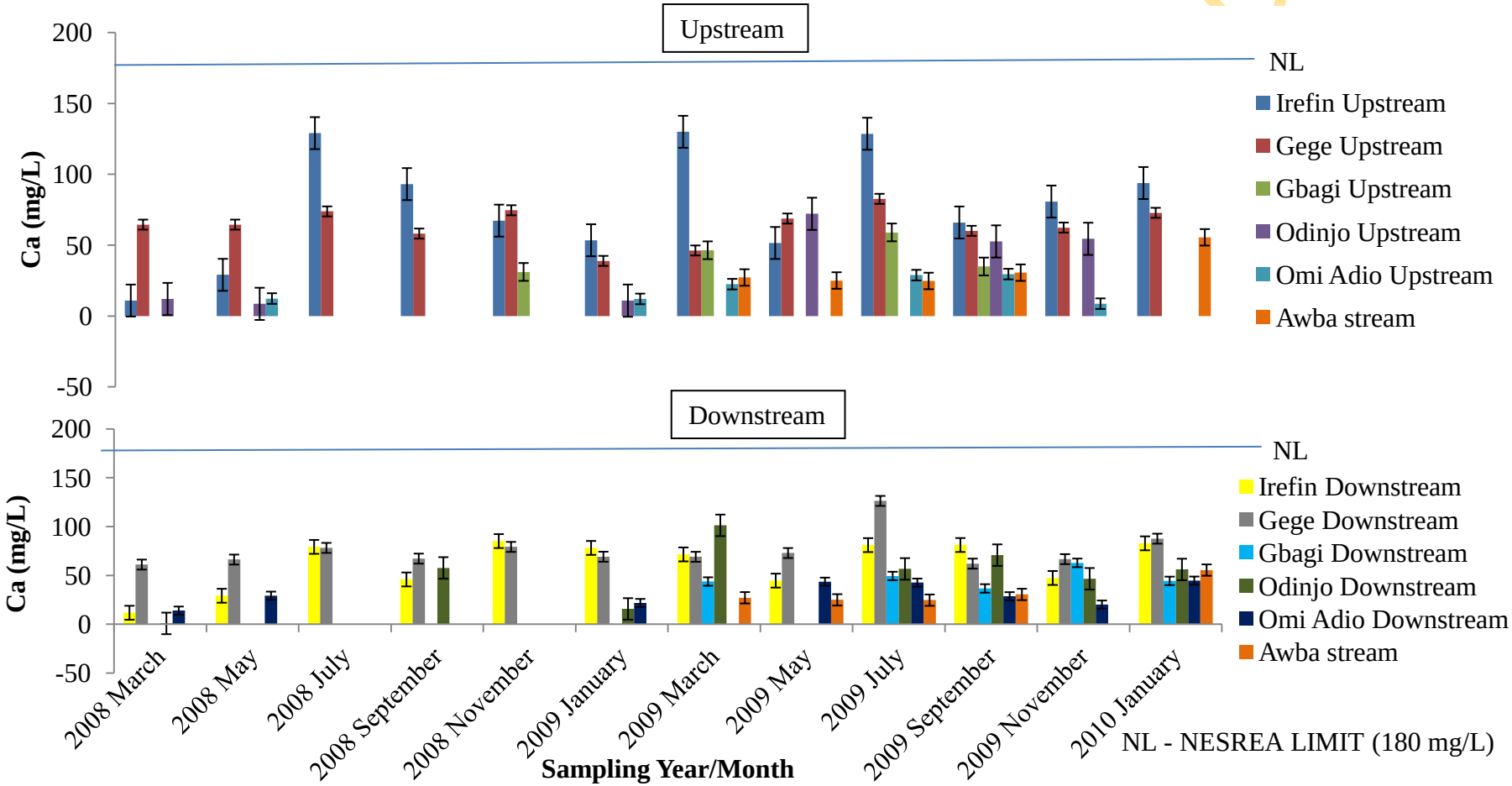


Figure 4.13: Bimonthly variation of sulphate values of streams
(a) Upstream (b) Downstream



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that calcium was not detected in the samples.

Figure 4.14: Bimonthly variation of calcium values of streams
(a) Upstream (b) Downstream

4.4.3.2 Magnesium

The bimonthly values of magnesium contents of the stream water samples ranged from 5.53 to 40.72 mg/L (27.57±3.72 mg/L) at Irefin upstream, 4.87 to 38.42 mg/L (23.88±3.61 mg/L) at Gege upstream, 8.25 to 38.27 mg/L (19.39±4.96 mg/L) at Gbagi upstream, 5.96 to 38.33 mg/L (19.18±3.95 mg/L) at Odinjo upstream, 7.49 to 49.96 mg/L (21.50±4.46 mg/L) at Omi Adio upstream and 8.14 to 35.30 mg/L (18.25±4.22 mg/L) at the control site (Awba stream) (Figure 4.15a; Appendix 6). It ranged from 9.53 to 36.93 mg/L (26.55±2.88) at Irefin downstream, 20.45 to 58.29 mg/L (31.52±4.47 mg/L) at Gege downstream, 6.48 to 36.84 mg/L (18.01±3.81 mg/L) at Gbagi downstream, 4.44 to 38.53 mg/L (20.85±3.86 mg/L) at Odinjo downstream and 9.21 to 36.09 mg/L (19.85±3.33 mg/L) at Omi Adio downstream (Figure 4.15b; Appendix 6).

One way analysis of variance showed that the magnesium of the stream samples were not significantly different at $P<0.05$ (Appendix 7). However, Duncan's multiple range test showed that Gege downstream was significantly different from the Gbagi downstream and control site, but it was not different from the others at $P<0.05$ (Appendix 8).

4.4.4 Bimonthly variation of trace and heavy metals of stream water samples

The range and mean values of the trace and heavy metals of stream water samples are shown in Appendix 6. Details are shown in Appendices 9 to 19.

4.4.4.1 Iron

In May 2008, iron was not detected in the samples from the Irefin downstream, Gege downstream, Gbagi upstream and downstream, Odinjo downstream and Omi Adio downstream. In July 2008, iron was not detected in all sampling sites except the upstream and downstream of Odinjo. In September 2008, it was not detected at the Gege downstream, Gbagi upstream and Omi Adio upstream. In November 2008, iron was not detected at the Omi Adio upstream. In March 2009, it was not detected at the Omi Adio downstream and Odinjo upstream. In May 2009, iron was not detected at the Gege downstream, Gbagi upstream and downstream, Odinjo downstream and Omi Adio upstream. In July 2009, it was not detected at the Odinjo upstream. In November 2009, iron was not detected at the Gege upstream, Gbagi upstream and the

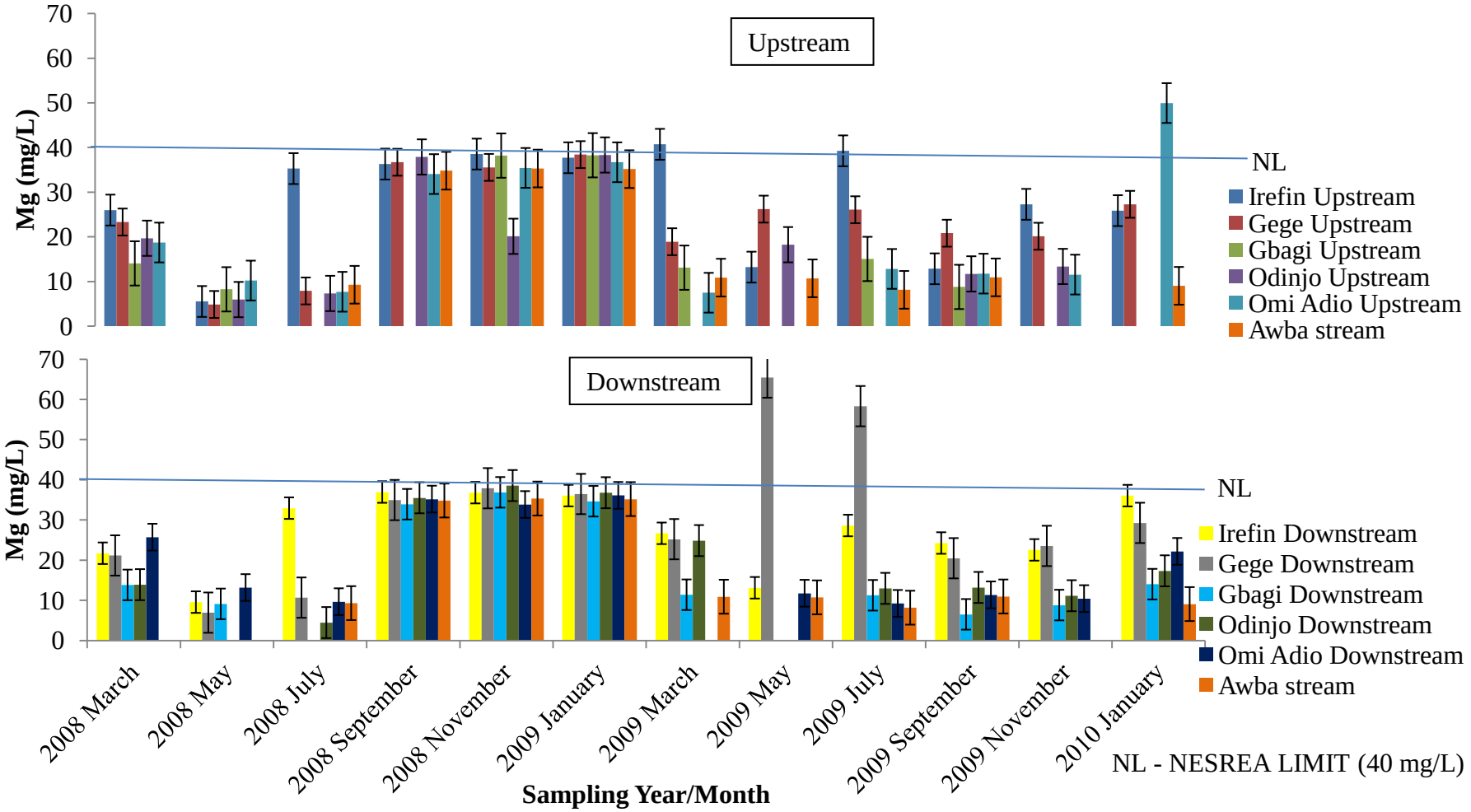


Figure 4.15: Bimonthly variation of magnesium values of streams
(a) Upstream (b) Downstream

control site, while in January 2010, it was not detected at the upstream of Gege, Gbagi and Odinjo (Figure 4.16; Appendix 9 to 19).

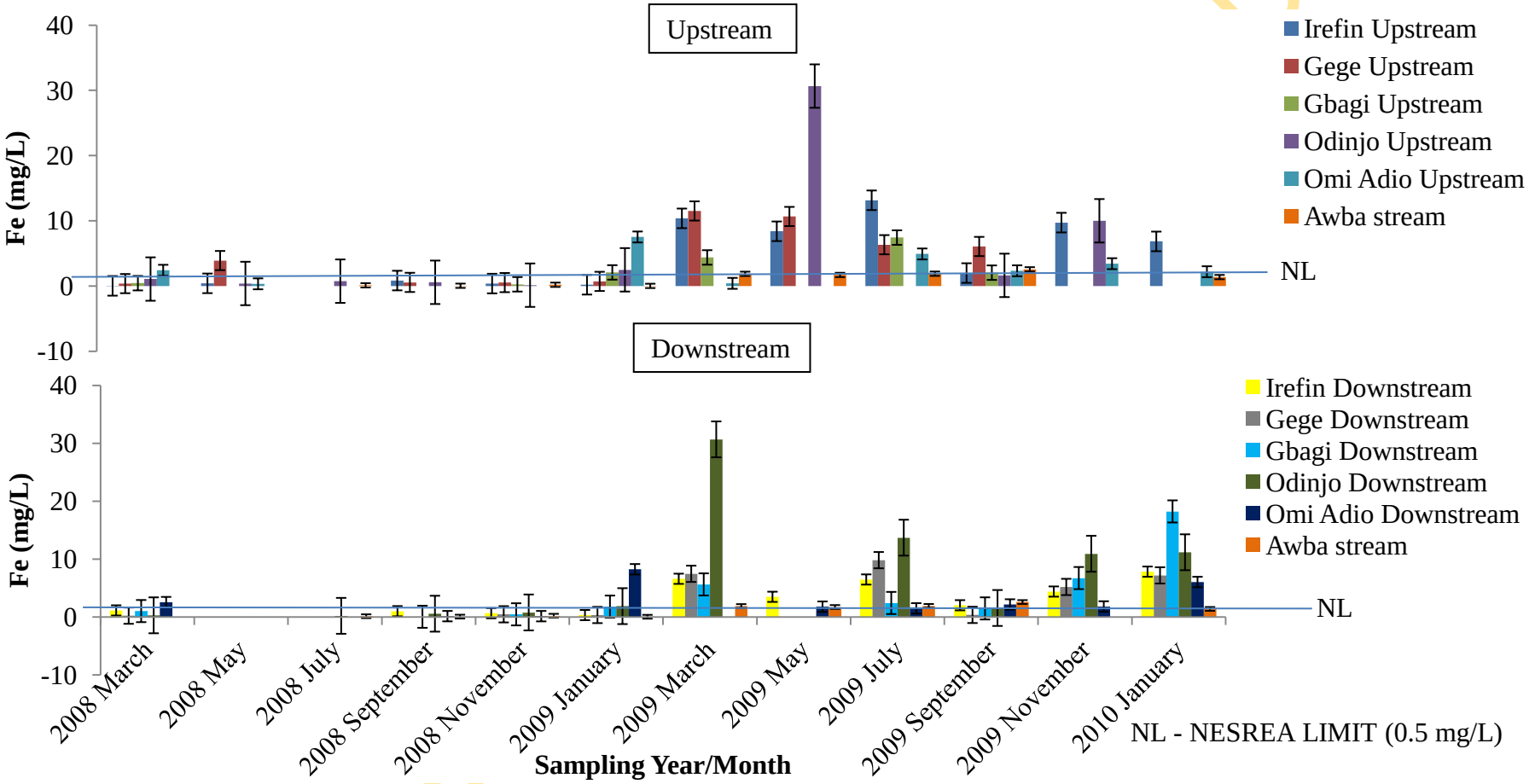
The bimonthly values of iron ranged from 0.03 to 13.15 mg/L (4.76±1.50 mg/L) at the Irefin upstream, 0.37 to 11.51 mg/L (4.52±1.47 mg/L) at the Gege upstream, 0.27 to 7.43 mg/L (2.78±1.11 mg/L) at the Gbagi upstream, 0.13 to 11.75 mg/L (3.20±1.48 mg/L) at the Odinjo upstream, 0.34 to 7.52 mg/L (2.95±0.84 mg/L) at the Omi Adio upstream and 0.02 to 2.56 mg/L (1.09±0.33 mg/L) at the control site (Awba stream) (Figure 4.16a; Appendix 6). It ranged from 0.31 to 7.81 mg/L (3.37±0.88 mg/L) at the Irefin downstream, 0.21 to 9.80 mg/L (3.86±1.40 mg/L) at the Gege downstream, 0.02 to 18.21 mg/L (4.18±1.91 mg/L) at the Gbagi downstream, 0.18 to 30.66 mg/L (7.15±3.10 mg/L) at the Odinjo downstream and 0.12 to 8.22 mg/L (2.69±0.90 mg/L) at the Omi Adio downstream (Figure 4.16b; Appendix 6).

One way analysis of variance showed that the iron contents of the stream samples were not significantly different at $P<0.05$ (Appendix 7). However, Duncan's multiple range test showed that the iron contents of the Odinjo downstream was significantly different from those of the control site (Awba stream) (Appendix 8).

4.4.4.2 Manganese

Manganese was not analysed in all the stream samples in the months of March, May and July 2008. It was not detected at the Gege upstream in the months of November 2009 and January 2010, while at the Gege downstream it was not also detected in the months of Sept 2008 and May 2009. At Gbagi upstream, manganese was not detected in September 2008, January 2009, May 2009, November 2009 and January 2010. At Gbagi downstream, manganese was not detected in the months of November 2008 and May 2009. In the months of March 2009, July 2009 and January 2010, manganese was not detected at the Odinjo upstream, while at the downstream, it was not detected in May 2009. In the months of March and May 2009, manganese was not detected at the downstream and upstream of Omi Adio respectively. At both November 2008 and 2009, it was not detected at the control site (Awba stream) (Figure 4.17; Appendices 9 to 19).

The bimonthly values of manganese ranged from 0.07 to 2.50 mg/L (1.06±0.30 mg/L) at the Irefin upstream, 0.02 to 11.55 mg/L (2.22±1.57 mg/L) at the Gege upstream, 0.21 to 3.17 mg/L (1.29±0.67 mg/L) at the Gbagi upstream, 0.0007 to 3.20 (1.25±0.47



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that iron was not detected in the samples.

Figure 4.16: Bimonthly variation of iron values of streams
(a) Upstream (b) Downstream

mg/L) at the Odinjo upstream, 0.16 to 3.31 mg/L (1.15±0.39 mg/L) at the Omi Adio upstream and 0.02 to 1.36 mg/L (0.48±0.20 mg/L) at the control site (Awba stream) (Figure 4.17a; Appendix 6). It ranged from 0.06 to 1.67 mg/L (0.81±0.19 mg/L) at the Irefin downstream, 0.15 to 2.09 mg/L (0.99±0.25 mg/L) at the Gege downstream, 0.07 to 1.88 mg/L (0.88±0.29 mg/L) at the Gbagi downstream, 0.13 to 3.04 mg/L (1.23±0.35 mg/L) at the Odinjo downstream and 0.11 to 10.13 mg/L (2.06±1.20 mg/L) at the Omi Adio downstream (Figure 4.17b; Appendix 6).

One way analysis of variance showed that manganese contents of the samples were not significantly different from one another (Appendices 6 and 7).

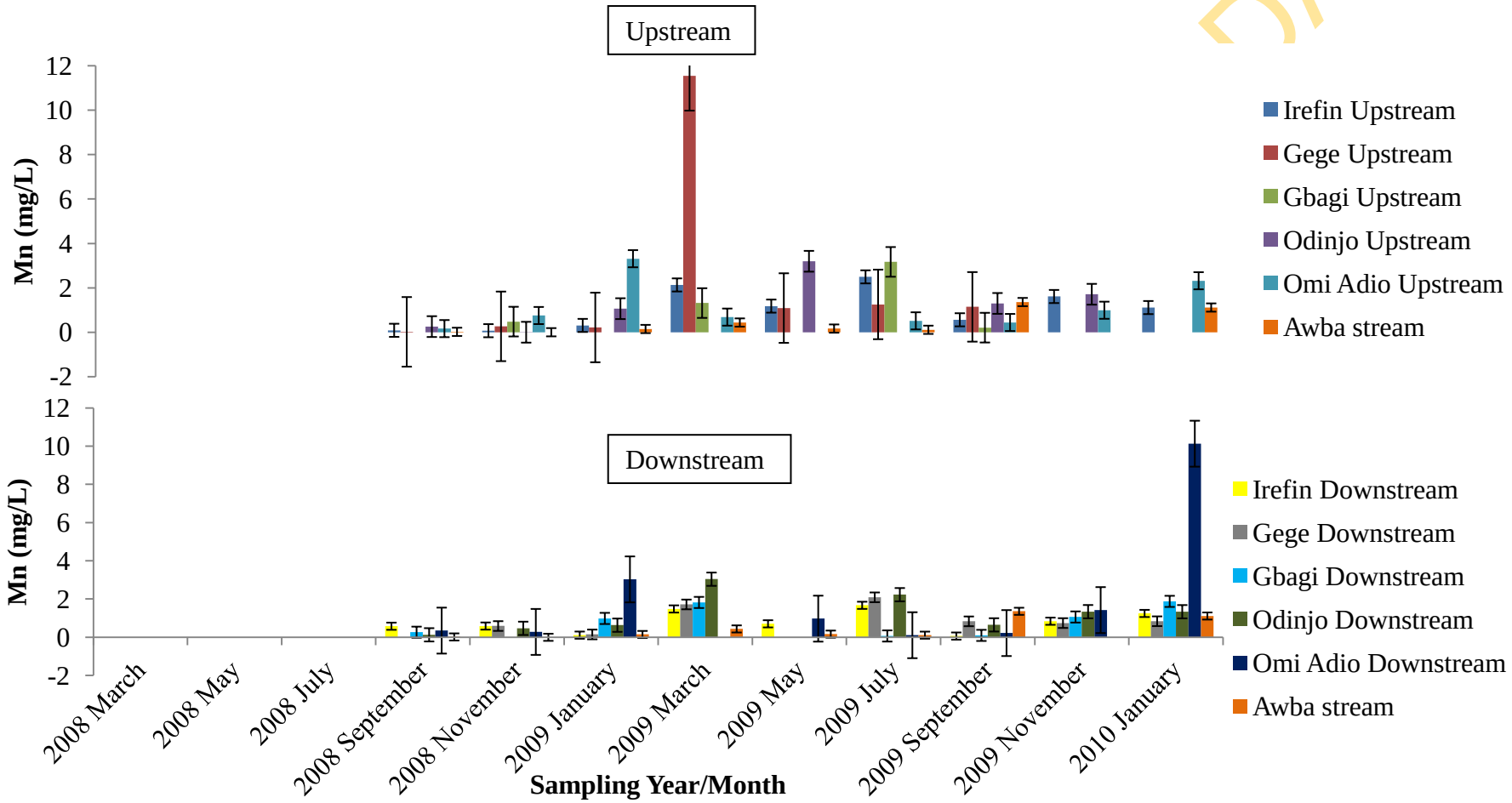
4.4.4.3 Copper

In the month of May 2008, copper was not detected at the Irefin downstream, Gege upstream and downstream, Gbagi upstream and downstream, Odinjo upstream and downstream, and Omi Adio downstream. In July 2008, it was not detected at the Irefin upstream and downstream, Gege downstream, Gbagi upstream and downstream, and Omi Adio upstream. In September 2008, it was not detected at the Gege downstream, Gbagi upstream and Odinjo upstream. In November 2008, it was not detected at the Omi Adio upstream and the control site (Awba stream). In March 2009, copper was not detected at the Irefin downstream, Gbagi upstream and downstream, Odinjo upstream, Omi Adio upstream and downstream, and the control site (Awba stream). Copper was not detected in all samples in the months of May 009, July 2009, September 2009, November 2009 and January 2010 except at the Gege upstream, Gbagi downstream, Omi Adio downstream, Odinjo upstream and Irefin upstream respectively with values of 0.019 mg/L, 0.114 mg/L, 0.08 mg/L, 0.007 mg/L and 0.002 mg/L respectively (Figure 4.18; Appendices 9 to 19).

One way analysis of variance showed that the copper contents of the streams were not significantly different from one another at $P<0.05$ (Appendices 6 and 7).

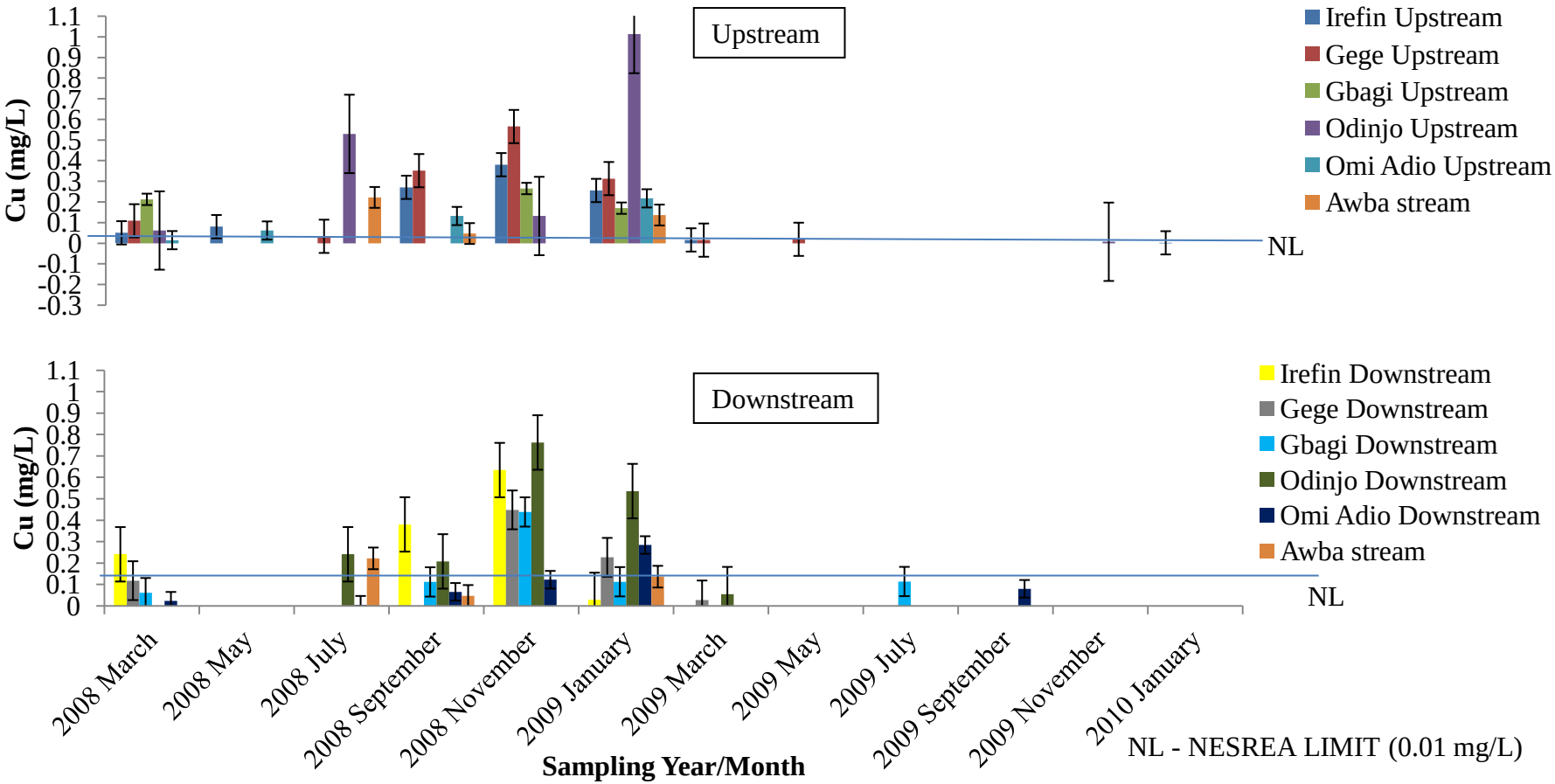
4.4.4.4 Zinc

During the sampling period, zinc was not detected at the downstream of Odinjo in March 2008. In the month of May 2008, it was not detected in all stream samples except at the upstream of Odinjo with a value of 0.0122 mg/L. In July 2008, it was not detected in all stream samples except at the Omi Adio upstream, Odinjo downstream



NOTE: Manganese was not analysed in all the samples in March, May and July, 2008. All other blank spaces indicated that it was not detected.

Figure 4.17: Bimonthly variation of manganese values of streams
(a) Upstream (b) Downstream



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that copper was not detected in the samples.

Figure 4.18: Bimonthly variation of copper values of streams
(a) Upstream (b) Downstream

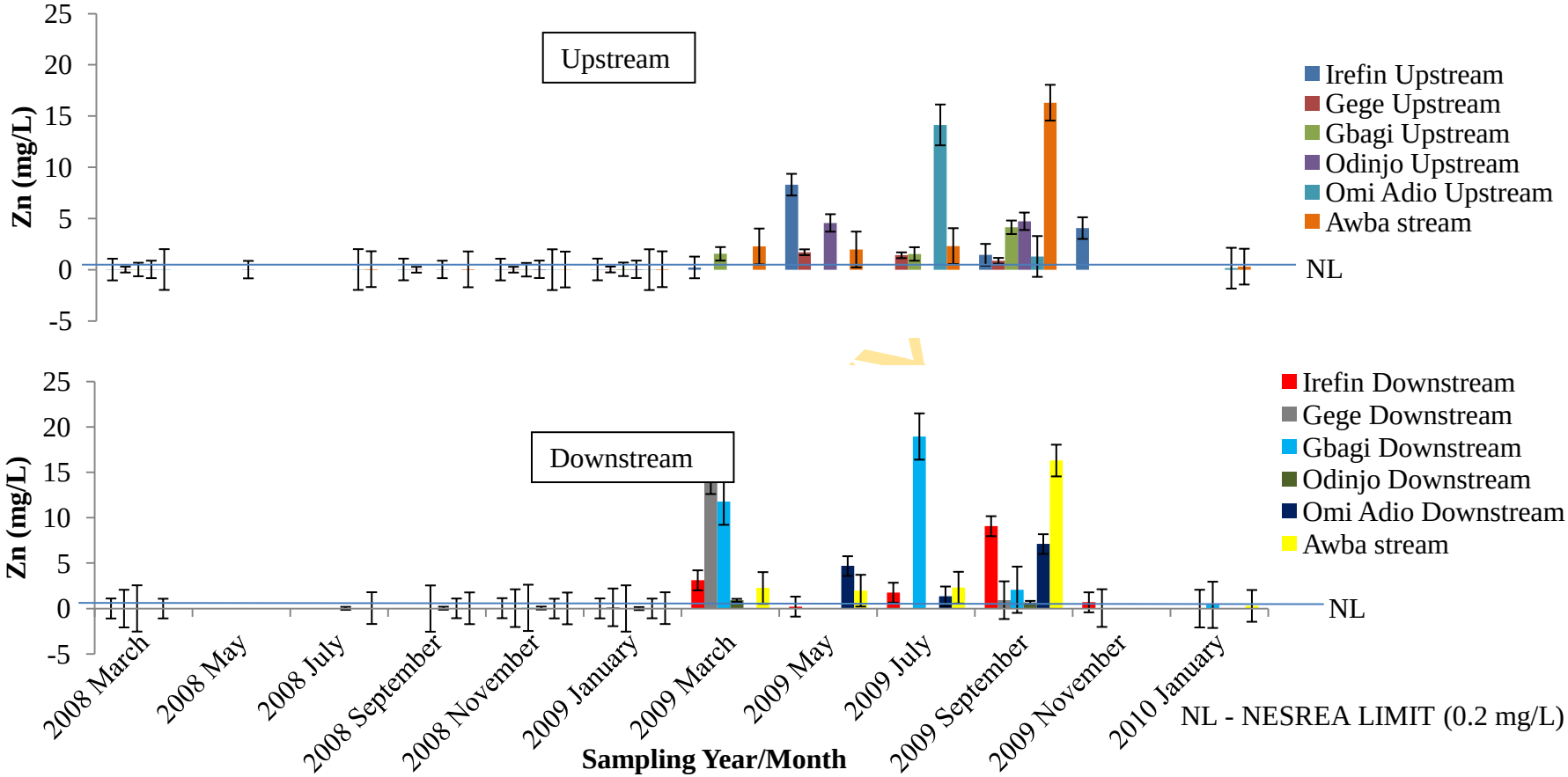
and the control site (Awba stream). In September 2008, zinc was not detected at the Irefin downstream, Gege downstream, Gbagi upstream and Omi Adio upstream. In March 2009, it was not detected at the Gege downstream, Gbagi upstream and downstream, Odinjo downstream and Omi Adio upstream. In July 2009, zinc was not detected at the Irefin upstream, Gege downstream, and Odinjo upstream and downstream. In November 2009, it was not detected in all samples except at the Irefin upstream and downstream. In January 2010, it was not detected in all stream samples except at Gege downstream, Gbagi downstream, Omi Adio upstream and the control site (Awba stream) (Figure 4.19; Appendices 9 to 19).

The bimonthly values of zinc ranged from 0.02 to 8.20 mg/L (1.77±1.06 mg/L) at the Irefin upstream, 0.002 to 1.71 mg/L (0.58±0.28 mg/L) at the Gege upstream, 0.002 to 4.15 mg/L (1.22±0.66 mg/L) at the Gbagi upstream, 0.012 to 4.73 (1.35±0.85 mg/L) at the Odinjo upstream, 0.01 to 14.14 mg/L (2.23±1.99 mg/L) at the Omi Adio upstream and 0.02 to 16.31 mg/L (2.59±1.75 mg/L) at the control site (Awba stream) (Figure 4.19a; Appendix 6). It ranged from 0.02 to 9.08 mg/L (1.87±1.10 mg/L) at the Irefin downstream, 0.004 to 14.70 mg/L (2.27±2.07 mg/L) at the Gege downstream, 0.01 to 18.95 mg/L (4.17±2.55 mg/L) at the Gbagi downstream, 0.01 to 0.91 (0.29±0.16 mg/L) at the Odinjo downstream and 0.01 to 7.11 mg/L (1.88±1.08 mg/L) at the Omi Adio downstream (Figure 4.19b; Appendix 6).

One way analysis of variance showed that the zinc contents of the stream samples were not significantly different from one another at $P<0.05$ (Appendices 6 and 7).

4.4.4.5 Lead

In March 2008, lead was not detected in all stream water samples except the upstreams of Irefin and Gege with values of 0.2625 mg/L and 0.0914 mg/L respectively. In May 2008, it was not detected in all stream samples except Gege upstream, Gbagi downstream and Odinjo upstream with values of 0.0336 mg/L, 0.52333 mg/L and 0.0541 mg/L respectively. In July 2008 lead was not detected in all stream samples except Gbagi upstream and downstream, and Omi Adio upstream with values of 0.2347 mg/L, 0.47628 mg/L and 0.0077 mg/L respectively. In September 2009, it was not detected at the Gege downstream. In March 2009, lead was not detected in all stream samples except its occurrence at the Odinjo downstream with a value of 0.499 mg/L. In May 2009, it was not detected in all stream samples. In July



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that zinc was not detected in the samples.

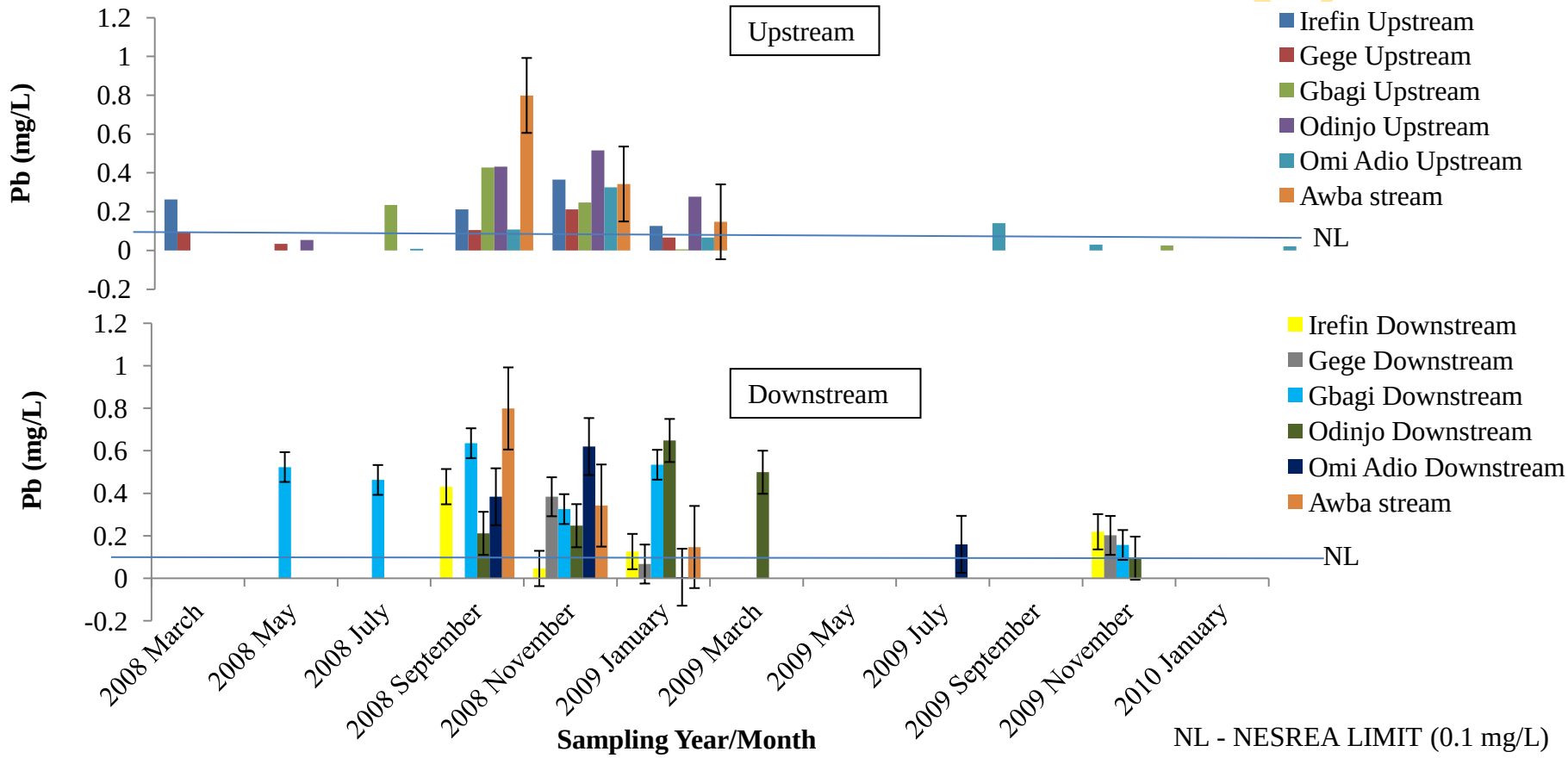
Figure 4.19: Bimonthly variation of zinc values of streams
(a) Upstream (b) Downstream

2009, it was only observed at the upstream and downstream of Omi Adio with values of 0.1410 mg/L and 0.1600 mg/L respectively. In September 2008, it was only observed at Omi Adio upstream with a value of 0.0330 mg/L, so also in January 2010 with a value of 0.0210 mg/L. In November 2009, lead was not detected at the upstream of Irefin, Gege and Odinjo, and also at the upstream and downstream of Omi Adio (Figure 4.20; Appendices 9 to 19).

One way analysis of variance showed that the lead contents of the stream samples were not significantly different from one another at $P<0.05$ (Appendix 7). However, Duncan's multiple range tests showed that Gege upstream, Omi Adio upstream and the control site (Awba stream) were significantly different from the other sites but Gege upstream and Omi Adio upstream were not significantly different from each other but each of them was different from the control site (Awba stream) (Appendix 8).

4.4.4.6 Cadmium

Cadmium was not detected in March 2008 in all stream samples except at the Odinjo downstream with a value of 0.0112 mg/L. In May 2008, cadmium was not detected at the downstream of Irefin, Gege, Gbagi and Odinjo. In July 2008, it was not detected at the upstream and downstream of Irefin, Gege and Gbagi. In the months of September 2008, November 2008 and January 2009, it was not detected in all the stream water samples. In March 2009, cadmium was not detected at Gege downstream, Omi upstream and downstream, Odinjo upstream and the control site (Awba stream). In May 2009, it was not detected in downstream of Irefin and Gege, upstream and downstream of Gbagi, Odinjo downstream, and the control site (Awba stream). In July 2009, it was not detected in the Gege downstream, Gbagi upstream and downstream, and Odinjo upstream. In September 2009, it was not detected at the upstream and downstream of Irefin, Omi Adio downstream and the control site (Awba stream). In November 2009, it was not detected at the Gege upstream, Gbagi upstream, Odinjo upstream, Omi Adio upstream and the control site (Awba stream). In January 2010, cadmium was not detected at the Irefin upstream, Gege upstream, Gbagi upstream and downstream, Odinjo upstream, Omi Adio upstream and the control site (Awba stream) (Figure 4.21; Appendices 9 to 19).



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that lead was not detected in the samples.

Figure 4.20: Bimonthly variation of lead values of streams
(a) Upstream (b) Downstream

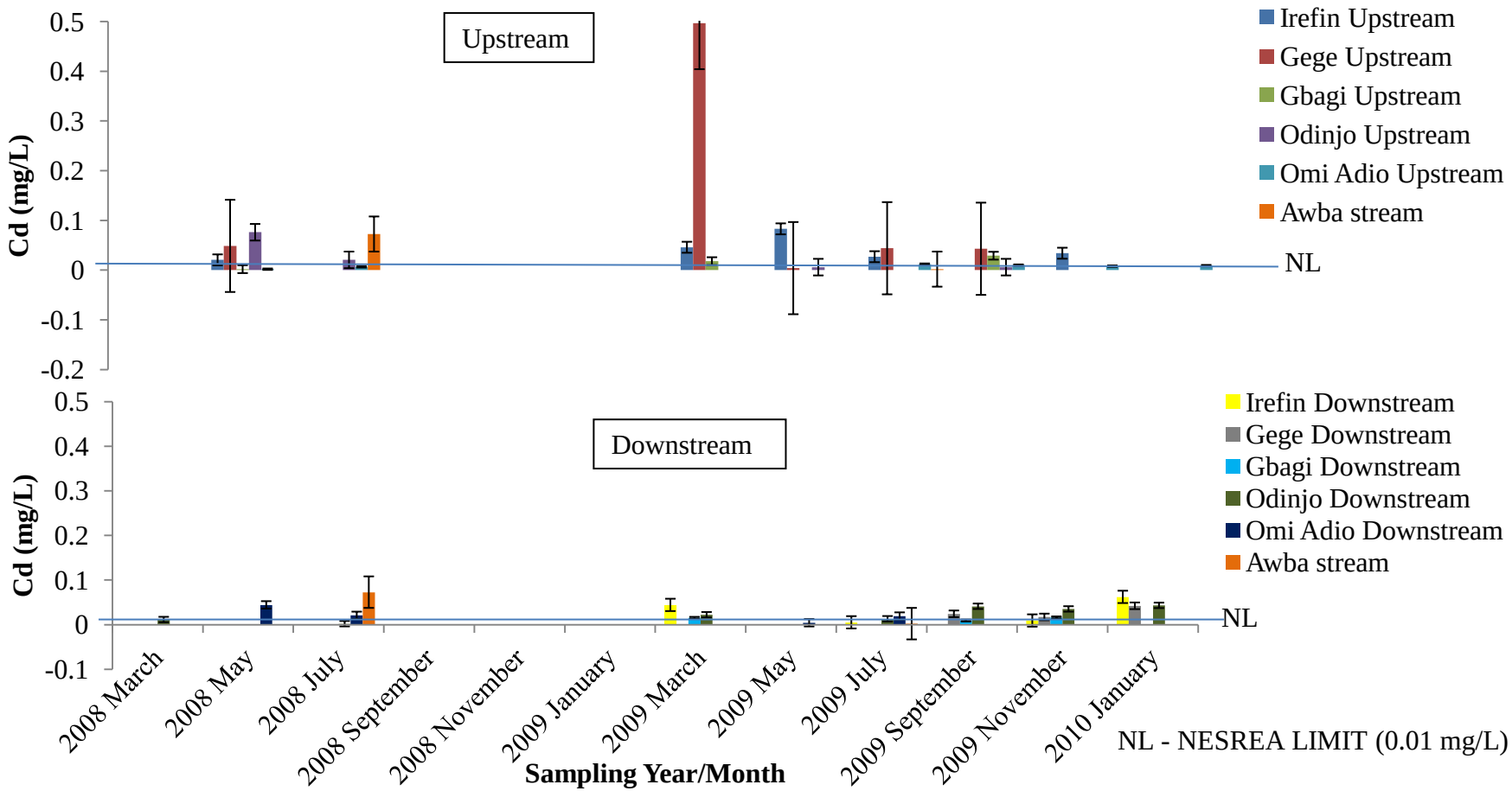
The bimonthly values of cadmium ranged from 0.02 to 0.08 mg/L (0.04±0.01 mg/L) at the Irefin upstream, 0.004 to 0.50 mg/L (0.13±0.09 mg/L) at the Gege upstream, 0.002 to 0.03 mg/L (0.02±0.01 mg/L) at the Gbagi upstream, 0.01 to 0.08 (0.03±0.02 mg/L) at the Odinjo upstream, 0.002 to 0.01 mg/L (0.01±0.001 mg/L) at the Omi Adio upstream and 0.002 to 0.07 mg/L (0.04±0.04 mg/L) at the control site (Awba stream) (Figure 4.21a; Appendix 6). It ranged from 0.01 to 0.06 mg/L (0.03±0.01 mg/L) at the Irefin downstream, 0.02 to 0.04 mg/L (0.03±0.01 mg/L) at the Gege downstream, 0.01 to 0.02 mg/L (0.01±0.002 mg/L) at the Gbagi downstream, 0.002 to 0.04 (0.02±0.01 mg/L) at the Odinjo downstream and 0.004 to 0.04 mg/L (0.02±0.01 mg/L) at the Omi Adio downstream (Figure 4.21b; Appendix 6).

One way analysis of variance showed that the cadmium contents of the stream samples were not significantly different at $P<0.05$ (Appendices 6 and 7).

4.4.4.7 Nickel

In March 2008, nickel was not detected in all stream water samples except at the Odinjo downstream with a value of 0.1488 mg/L. In May 2008, it was not detected at the downstream of Gege and Odinjo. It was not also detected in all samples in July 2008 except at Omi Adio upstream and the control site (Awba stream) and with values of 0.0470 mg/L and 0.2260 mg/L respectively. In September 2008, nickel was detected in all stream water samples except Gege downstream, Gbagi upstream and Omi Adio downstream. In November 2008, it was not detected at the downstream of Irefin and Omi Adio. In January 2009, nickel was not detected at the Gege upstream and the upstream and downstream of Gbagi (Figure 4.22; Appendices 9 to 19).

In the month of March 2009, nickel was not detected in all stream water samples except Irefin upstream and Odinjo downstream with values of 0.0090 mg/L and 0.0540 mg/L respectively. In May 2009, it was only detected at the Gege upstream with a value of 0.0400 mg/L. Also in July 2009, it was detected at the Irefin upstream and downstream and Omi Adio downstream with the values of 0.0670 mg/L and 0.0800 mg/L and 0.007 respectively. In September 2009, it was detected at the Irefin upstream, Irefin downstream, Gege upstream, Gbagi upstream and Odinjo downstream with the values of 0.0060 mg/L, 0.0560 mg/L, 0.0030 mg/L, 0.0030 mg/L and 0.0610 mg/L respectively. Samples collected in November 2009 from the Gege upstream, Gbagi upstream, Odinjo downstream, Omi Adio downstream and the



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that cadmium was not detected in the samples.

Figure 4.21: Bimonthly variation of cadmium values of streams
(a) Upstream (b) Downstream

control site (Awba stream) had no nickel content. Nickel was not detected in January 2010 in all stream water samples except the samples from Irefin upstream, Irefin downstream and Odinjo downstream with the values of 0.0890 mg/L, 0.0980 mg/L and 0.0050 mg/L respectively (Figure 4.22; Appendices 9 to 19).

One way analysis of variance showed that the nickel contents of the stream water samples were not significantly different from one another at P<0.05 (Appendix 7). However, Duncan's multiple range tests revealed that Gbagi upstream and the control site (Awba stream) were significantly different from the other stream samples and they were also significantly different from each other at P<0.05 (Appendix 8).

4.4.4.8 Chromium

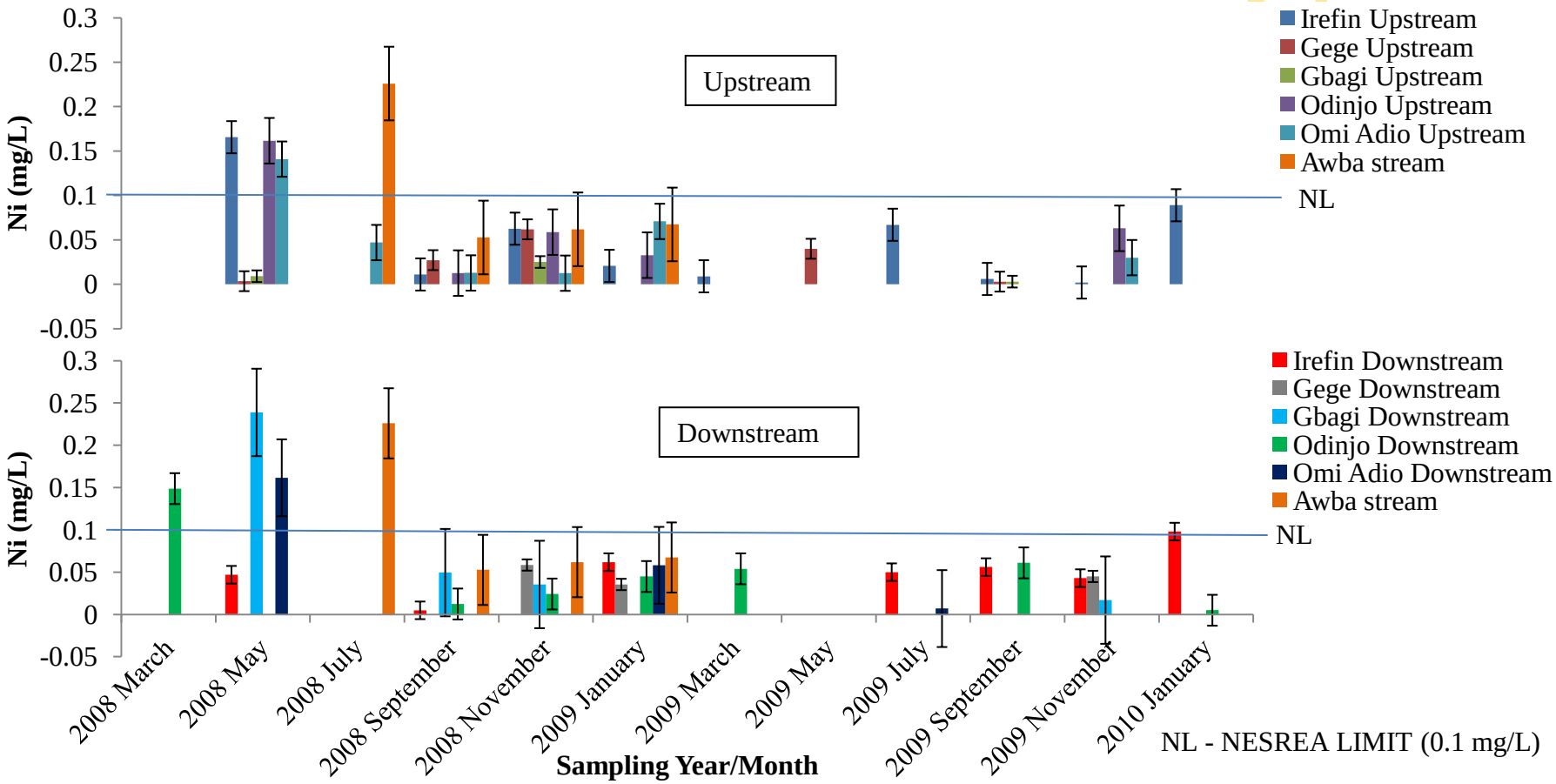
Chromium was not analysed in March and May 2009. It was not detected in all stream samples in the months of November 2008, May 2009, September 2009 and January 2010. In July 2008, it was not detected in Gege downstream, Irefin upstream and downstream, and Gbagi upstream and downstream. In September 2008, it was only detected at the Irefin upstream and downstream, and Gege upstream with the values of 0.1180 mg/L, 0.1804 mg/L, and 0.1097 mg/L respectively. In January 2009, it was only detected at the Gbagi upstream with a value of 0.0255 mg/L. In March 2009, it was detected at the downstream of Gbagi and Odinjo with the values of 0.0910 mg/L and 0.0340 mg/L respectively. In July 2009, it was only detected at the Omi Adio downstream with a value of 0.0190 mg/L. In November 2009, it was only detected at the Gege downstream with a value of 0.0660 mg/L (Figure 4.23 to 20; Appendices 9 to 19).

One way analysis of variance showed that the chromium contents of the stream samples were not significantly different from one another at P<0.05 (Appendix 7).

4.5 Result of analysis of soil samples from the banks of the streams

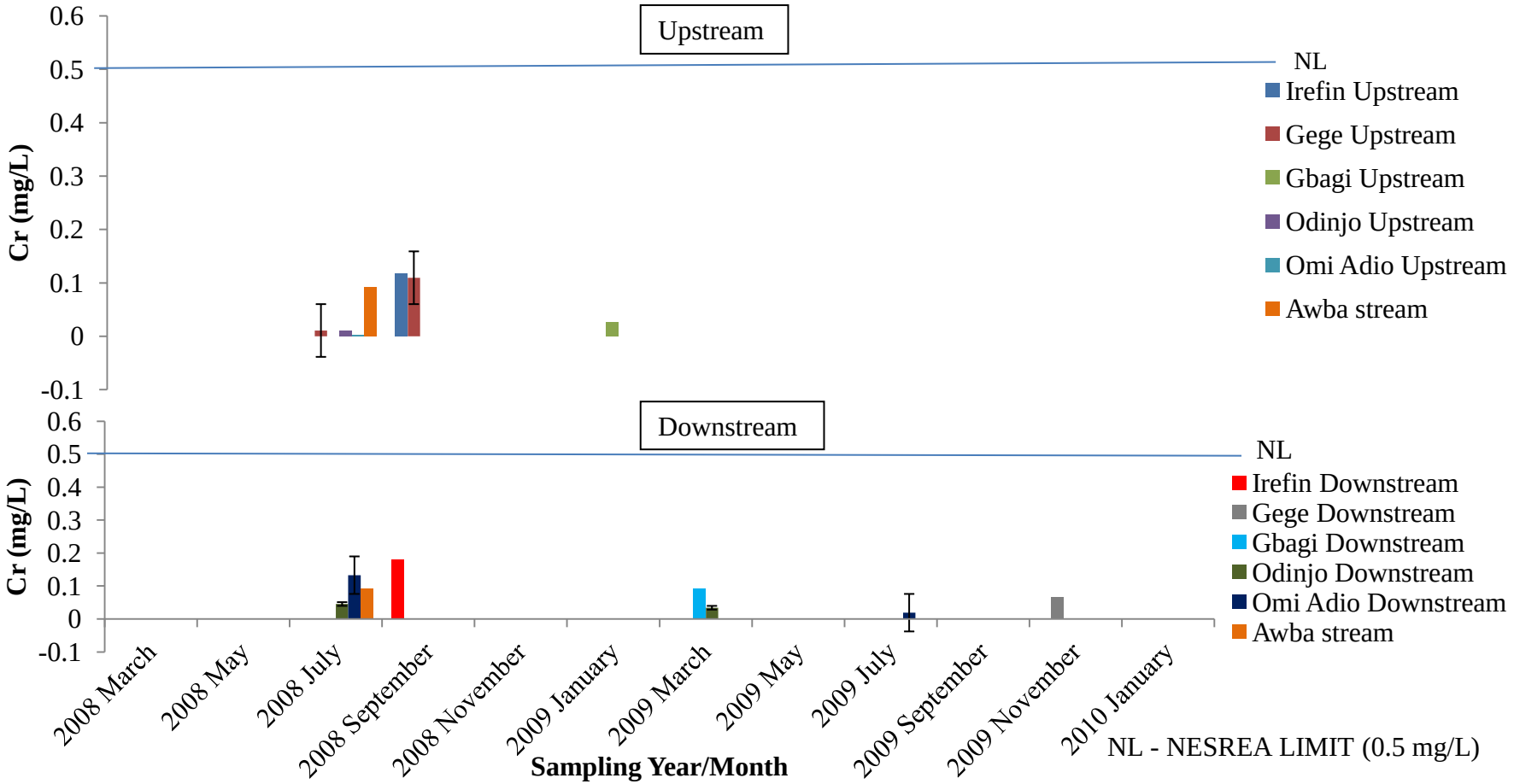
4.5.1 Bimonthly variation of physico-chemical characteristics of soil samples from the banks of the streams

The bimonthly range and mean values of the physico-chemical characteristics of soil samples from the streams are shown in Appendix 20. Details are shown in Appendices 26 to 31.



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that nickel was not detected in the samples.

Figure 4.22: Bimonthly variation of nickel values of streams
(a) Upstream (b) Downstream



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that chromium was not detected in the samples.

Figure 4.23: Bimonthly variation of chromium values of streams
(a) Upstream (b) Downstream

4.5.1.1 Soil particle size distribution

The percentage sand contents of the soil samples from the stream banks ranged from 90 to 100 % (94.75±0.87 %) at the Irefin stream, 94 to 97 % (95.83±0.34 %) at the Gege stream, 83 to 97 % (87.91±1.27 %) at the Gbagi stream, 80 to 97 % (91.83±1.56 %) at the Odinjo stream, 68 to 94 % (82.50±2.58 %) at the Omi Adio stream and 90 to 99 % (92.90±0.95 %) at the control site (Awba stream) (Figure 4.24a; Appendix 20).

The percentage silt content of the soil samples ranged from 0 to 5 % (2.25±0.46 %) at the Irefin stream, 1 to 4 % (2.17±0.30 %) at the Gege stream, 1 to 5 % (2.75±0.39 %) at the Gbagi stream, 0 to 5 % (2.00±0.43 %) at the Odinjo stream, 1 to 16 % (5.25±1.27 %) at the Omi Adio stream and 0 to 4 % (2.11±0.35 %) at the control site (Awba stream) (Figure 4.24b; Appendix 20).

The percentage clay content of the soil samples ranged from 1 to 6 % (3.17±0.60 %) at the Irefin stream, 1 to 5 % (1.83±0.44 %) at the Gege stream, 2 to 15 % (9.33±1.33 %) at the Gbagi stream, 1 to 18 % (6.17±1.59 %) at the Odinjo stream, 4 to 16 % (10.83±1.19 %) at the Omi Adio stream and 1 to 8 % (5.20±0.81 %) at the control site (Awba stream) (Figure 4.24c; Appendix 20).

Using their mean values for textural classification, the soil samples of the Irefin stream, Gege stream and control site (Awba stream) were sandy while those from Gbagi stream, Odinjo stream and Omi Adio stream were loamy sand (Appendix 21).

4.5.1.2 Hydrogen ion concentration (pH)

The range of pH values of the soil samples were 6.40 to 8.30 (7.27±0.15) at the Irefin stream, 6.40 to 8.40 (7.32±0.16) at the Gege stream, 6.70 to 8.90 (7.49±0.21) at the Gbagi stream, 6.40 to 9.20 (7.61±0.20) at the Odinjo stream, 6.60 to 8.10 (7.34±0.11) at the Omi Adio stream and 6.00 to 7.50 (6.90±0.15) at the control site (Awba stream), (Figure 4.25a; Appendix 20).

One way analysis of variance showed that the pH of the soil samples were not significantly different at $P<0.05$ (Appendix 24). However, Duncan's multiple range tests showed some significant differences of some of the samples at $P<0.05$. It showed that the pH of the soil from the control site was significantly different from those of the soil from Gbagi and Odinjo streams (Appendix 25).

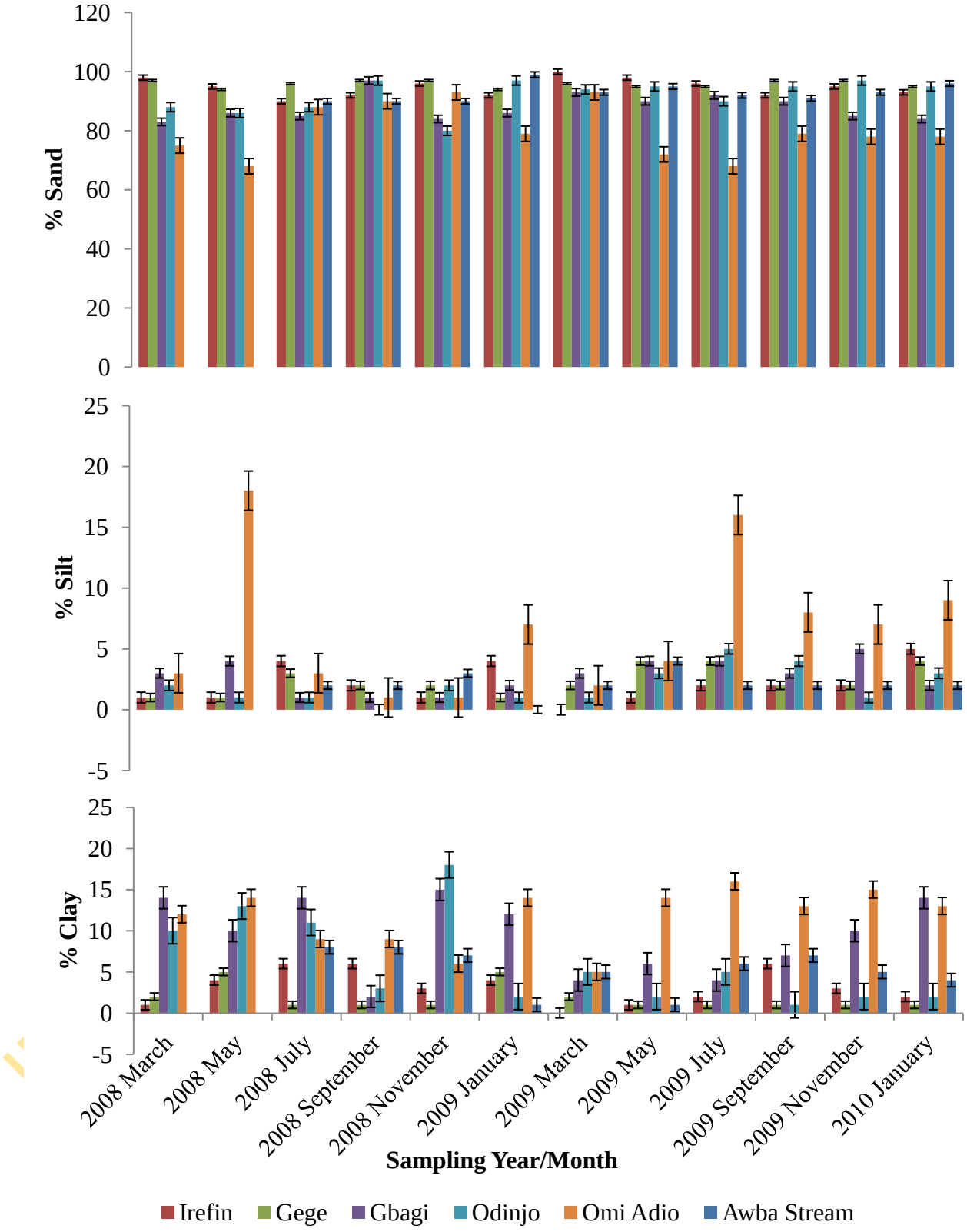


Figure 4.24: Bimonthly variation of particle size distribution values of soil from streams' banks (a) Sand (b) Silt (c) Clay

4.5.1.3 Electrical conductivity

The range of the electrical conductivity values of the soil samples were 455.00 to 1465.00 µS/cm (770.58±82.81 µS/cm) at the Irefin stream, 889.00 to 1809.00 µS/cm (1346.92±99.48 µS/cm) at the Gege stream, 226.00 to 11570.00 µS/cm (2723.42±933.87 µS/cm) at the Gbagi stream, 352.00 to 1285.00 µS/cm (617.92±80.08 µS/cm) at the Odinjo stream, 128.70 to 1386.00 µS/cm (610.38±103.37 µS/cm) at the Omi Adio stream, 46.60 to 498.00 µS/cm (199.25±55.29 µS/cm) at the control site (Awba stream) (Figure 4.25b; Appendix 21).

One way analysis of variance showed that the electrical conductivity values of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the electrical conductivity value of the soil from Gbagi stream was significantly different from all soil samples (Appendix 25).

4.5.1.4 Total organic carbon

The bimonthly total organic carbon observed in the soil samples from the Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) were 0.17 to 1.89 % (0.83±0.16), 0.08 to 1.24 % (0.60±0.13 %), 0.37 to 6.2 % (2.42±0.59 %), 0.78 to 2.10 % (1.47±0.22 %), 0.75 to 5.29 % (2.03±0.40) and 0.08 to 1.53 % (0.72±0.19 %) respectively (Figure 4.25c; Appendix 20).

The soil sample from Odinjo stream had no total organic carbon in September 2008 and throughout the sampling months of 2009. In September 2008, Gbagi soil had no total organic carbon. So also the soil sample from Gege stream had no total organic carbon in September 2009. In the month of November 2009, the soil samples from the Omi Adio stream and the control site (Awba stream) had no total organic carbon (Figure 4.25c).

One way analysis of variance showed that the total organic carbon contents of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the total organic carbon contents of the soil from Gbagi and Omi Adio streams were significantly different from all soil samples except that of Odinjo stream (Appendix 25).

4.5.1.5 Total organic matter

The bimonthly total organic matter observed ranged from 0.30 to 3.27 % (1.44±0.27 %), 0.14 to 2.14 % (1.03±0.22 %), 0.63 to 10.72 % (4.18±1.02 %), 1.35 to 3.63 % (2.54±0.38 %), 1.30 to 9.15 % (3.51±0.68 %) and 0.14 to 2.65 % (1.25±0.32 %) in the soil samples from the Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) respectively. The same trend of none detection of total organic carbon was also seen in total organic matter of the samples (Figure 4.25d).

One way analysis of variance showed that the total organic matter contents of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed the trend seen in the total organic carbon (Appendix 25).

4.5.2 Bimonthly variation of anions of soil samples from the banks of streams

The range and mean values of the anions of soil samples from the streams are shown in Appendix 22. Details are shown in Appendices 26 to 31.

4.5.2.1 Nitrate – nitrogen

Nitrate – nitrogen was not detected in the soil samples from the bank of Irefin stream in July 2008, January 2009, May – September 2009, and January 2010. In the months of March 2008, November 2008 and 2009, September 2009, and January 2010, it was not detected in the soil samples from the bank of Gege stream. It was not detected in the soil samples from the banks of Gbagi stream in the months of May to September 2008, January 2009, May, July, November 2009, and January 2010. Nitrate – nitrogen was not detected in the soil samples from the banks of Odinjo stream in the months of May and September 2008, throughout the sampling months of 2009 and also in January 2010. In May 2008, November 2008, May 2009, September and November 2009, and also January 2010, nitrate – nitrogen was not detected in the soil samples from the bank of Omi Adio streams. Throughout the sampling period, nitrate – nitrogen was not detected in the soil samples from the banks of the control site (Awba stream) (Figure 4.26a; Appendices 26 to 31).

The bimonthly variation of nitrate – nitrogen from the banks of the streams ranged from 255.20 to 1132.78 mg/kg (658.71±143.79 mg/kg) at the Irefin stream, 21.12 to 840.18 mg/kg (507.86±143.79 mg/kg) at the Gege stream, 196.68 to 1425.38 mg/kg

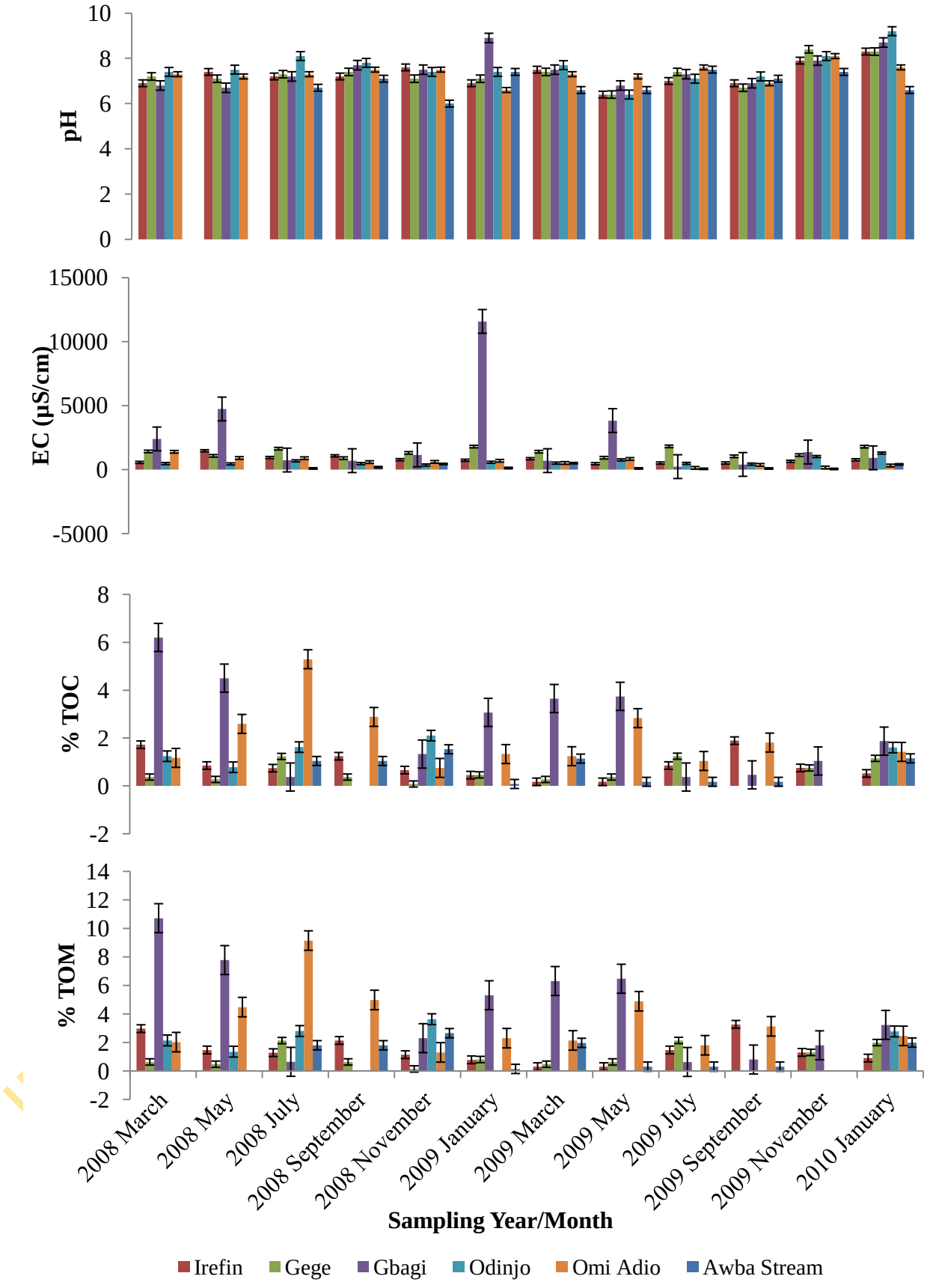


Figure 4.25: Bimonthly variation of physico-chemical values of soil from streams' banks (a) pH (b) EC (c) TOC (d) TOM

(635.47±277.02 mg/kg) at the Gbagi stream, 196.68 to 1249.82 mg/kg (606.17±325.78 mg/kg) at the Odinjo stream and 21.12 to 840.18 mg/kg (333.30±137.25 mg/kg) at the Omi Adio stream (Figure 4.26a; Appendix 22).

One way analysis of variance showed that the nitrate - nitrogen contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24).

4.5.2.2 Sulphate - sulphur

In the months of March 2008 and September 2008, sulphate – sulphur was not detected in all soil samples except in the soil from the bank of Gege stream with values of 39.63 mg/kg and 17.88 mg/kg respectively. In May 2008, it was detected only in the soil from the Irefin stream with a value of 9.75 mg/kg. In July 2008, it was only detected in the soil samples from the banks of Odinjo stream and control site (Awba stream) with values of 9.75 mg/kg and 34.25 mg/kg respectively. In September 2008, it was only detected in the soil sample from Gege stream with a value of 17.88 mg/kg. In November 2008, it was not detected in the soil from the control site (Awba stream). In January 2009, it was not detected in the soil sample from the bank of Irefin stream. In the month of March 2009, it was not detected in the soil samples from Gege and Omi Adio streams. In July 2009, it was detected in the soil samples from Odinjo and Omi Adio soils with values of 1.63 mg/kg and 23.38 mg/kg respectively. In September 2009, sulphate – sulphur was detected only at the control site (Awba stream) with a value of 1.63 mg/kg. In November 2009, it was not detected in the soil samples from the banks of Irefin stream, Omi Adio stream and control site (Awba stream). In January 2010, it was not detected in the soil samples from the banks of Odinjo and Omi Adio streams (Figure 4.26b).

One way analysis of variance showed that the sulphate – sulphur contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24).

4.5.3 Bimonthly variation of cations of soil samples from the banks of streams

The range and mean values of the cations of soil samples from the banks of the streams are shown in Appendix 22. Details are shown in Appendices 26 to 31.

4.5.3.1 Phosphorus

The bimonthly range of 61.04 to 150.08 mg/kg (110.72±8.47 mg/kg) of phosphorus was observed in the soil sample from the bank of Irefin stream, Gege soil had a range of 2.93 to 108.08 mg/kg (79.59±9.18 mg/kg), Gbagi soil had a range of 58.24 to 123.76 mg/kg (85.94±6.29 mg/kg), Odinjo soil had a range of 45.36 to 115.92 (73.59±7.14 mg/kg) mg/kg, Omi Adio soil had a range of 19.04 to 115.92 mg/kg (74.30±8.06 mg/kg) while the control site (Awba stream) had a range of 11.20 to 58.24 mg/kg (36.65±4.69 mg/kg) (Figure 4.26c; Appendix 22).

One way analysis of variance showed that the phosphorus contents of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the phosphorus content of the soil from the banks of Irefin stream and control site (Awba stream) were significantly different from phosphorus contents of all the other soil samples and also different from each other (Appendix 25).

4.5.3.2 Calcium

Calcium was not detected in the soil samples from the banks of the Omi Adio dumpsite and control site (Awba stream) in the months of September and May 2009 respectively (Appendices 26 – 31).

The bimonthly calcium content of soil samples observed at the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) ranged from 5064.80 to 28486.70 mg/kg, 7004.00 to 30466.30 mg/kg, 13286.20 to 58110.00 mg/kg, 261.70 to 23406.40 mg/kg, 762.20 to 37041.40 mg/kg and 14447.70 to 46010.20 mg/kg respectively (Figure 4.26d).

The mean values observed in the soil samples from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) were (20644.70±2294.42 mg/kg), (18978.10±3040.18 mg/kg), (27404.10±4148.02 mg/kg), (16181.00±2652.98 mg/kg), (15963.00±4143.68 mg/kg) and (23229±343.81 mg/kg) respectively (Appendix 22).

One way analysis of variance showed that the calcium contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24). However, Duncan's multiple range tests showed some significant differences of some of the samples at $P<0.05$. It showed that the calcium content of the soil from Gbagi stream was

significantly different from the calcium contents of Odinjo and Omi Adio streams but not different from calcium contents of Irefin, Gege and the control site (Awba stream) (Appendix 25).

4.5.3.3 Magnesium

The bimonthly values of magnesium content of soil samples from the steams' banks ranged from 668.70 to 2175.64 mg/kg (1067.88±144.13 mg/kg) at the Irefin stream, 746.40 to 1676.54 mg/kg (1181.59±101.17 mg/kg) at the Gege stream, 733.80 to 5928.90 mg/kg (1682.56±451.75 mg/kg) at the Gbagi stream, 162.60 to 2073.08 mg/kg (1082.18±180.56 mg/kg) at the Odinjo stream, 229.80 to 1898.72 mg/kg (851.95±175.35 mg/kg) at the Omi Adio stream and 206.70 to 1145.40 mg/kg (693.69±91.67 mg/kg) at the control site (Awba stream) (Figure 4.27a; Appendix 22).

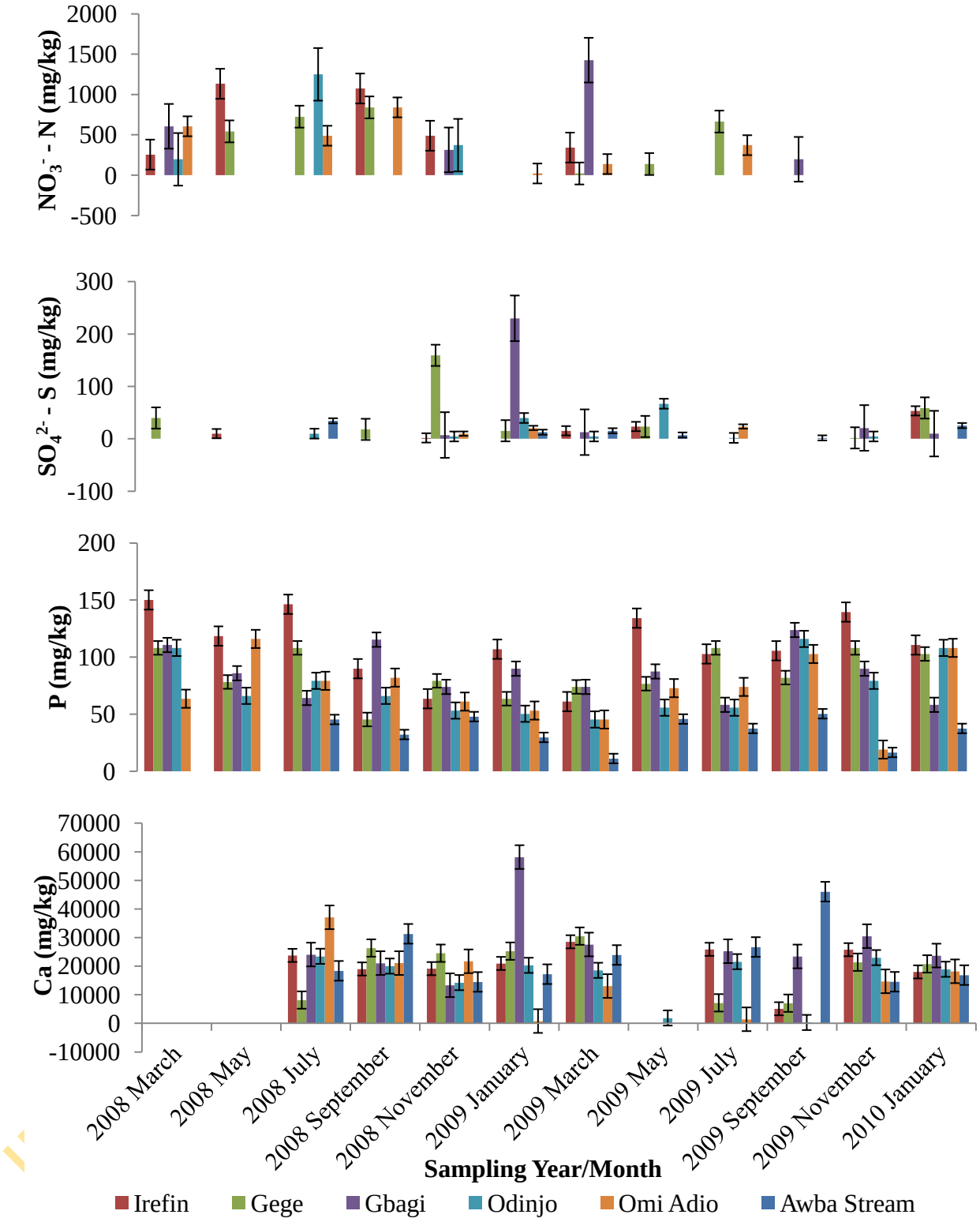
One way analysis of variance showed that the magnesium contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24). However, Duncan's multiple range tests showed some significant differences of some of the samples at $P<0.05$. It showed that the magnesium content of the soil from Gbagi stream was significantly different from the magnesium content of the Omi stream and control site (Awba stream) but it was not different from the other soil samples (Appendix 25).

4.5.3.4 Sodium

In September 2008 and May 2009, sodium was not detected in the soil samples from the Odinjo stream and the control site (Awba stream) respectively (Figure 2.27b).

The bimonthly sodium values observed ranged from 100 to 900 mg/kg (550.45±67.37 mg/kg) in the soil sample from the Irefin stream, 100 to 900 mg/kg (570.09±77.85 mg/kg) in the sample from Gege stream), 400 to 3700 mg/kg (1138.73±337.08 mg/kg) in the sample from Gbagi stream, 200 to 1500 mg/kg (680.55±104.04 mg/kg) in the sample from Odinjo stream, 100 to 900 mg/kg (464.00±67.50 mg/kg) in the sample from Omi Adio stream and 200 to 1200 mg/kg (600±104.08 mg/kg) in the soil sample from the control site (Awba stream) (Figure 4.27b; Appendix 22).

One way analysis of variance showed that the sodium contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24). However, Duncan's multiple range tests showed that the sodium content of the soil from the bank of



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that NO_3 – N, SO_4^{2-} S and Ca were not detected in the samples.

Figure 4.26: Bimonthly variation of some anions and some cations values of soil from stream banks (a) NO_3 - N (b) SO_4^{2-} S (c) P (d) Ca

Gbagi stream was significantly different from sodium contents of all the other soil samples except those from Odinjo stream's bank (Appendix 25).

4.5.3.5 Potassium

The bimonthly values of potassium observed in the soil samples ranged from 630 to 1230 mg/kg (905.27±61.47 mg/kg), 648 to 1630 mg/kg (973.45±88.72 mg/kg), 530 to 19330 mg/kg (2665.00±1672.21 mg/kg), 330 to 2230 mg/kg (944.00±190.51 mg/kg), 130 to 1030 mg/kg (596.91±87.52 mg/kg) and 130 to 3230 mg/kg (596.91±87.52 mg/kg) in the soil samples from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream),respectively (Figure 4.27c; Appendix 22).

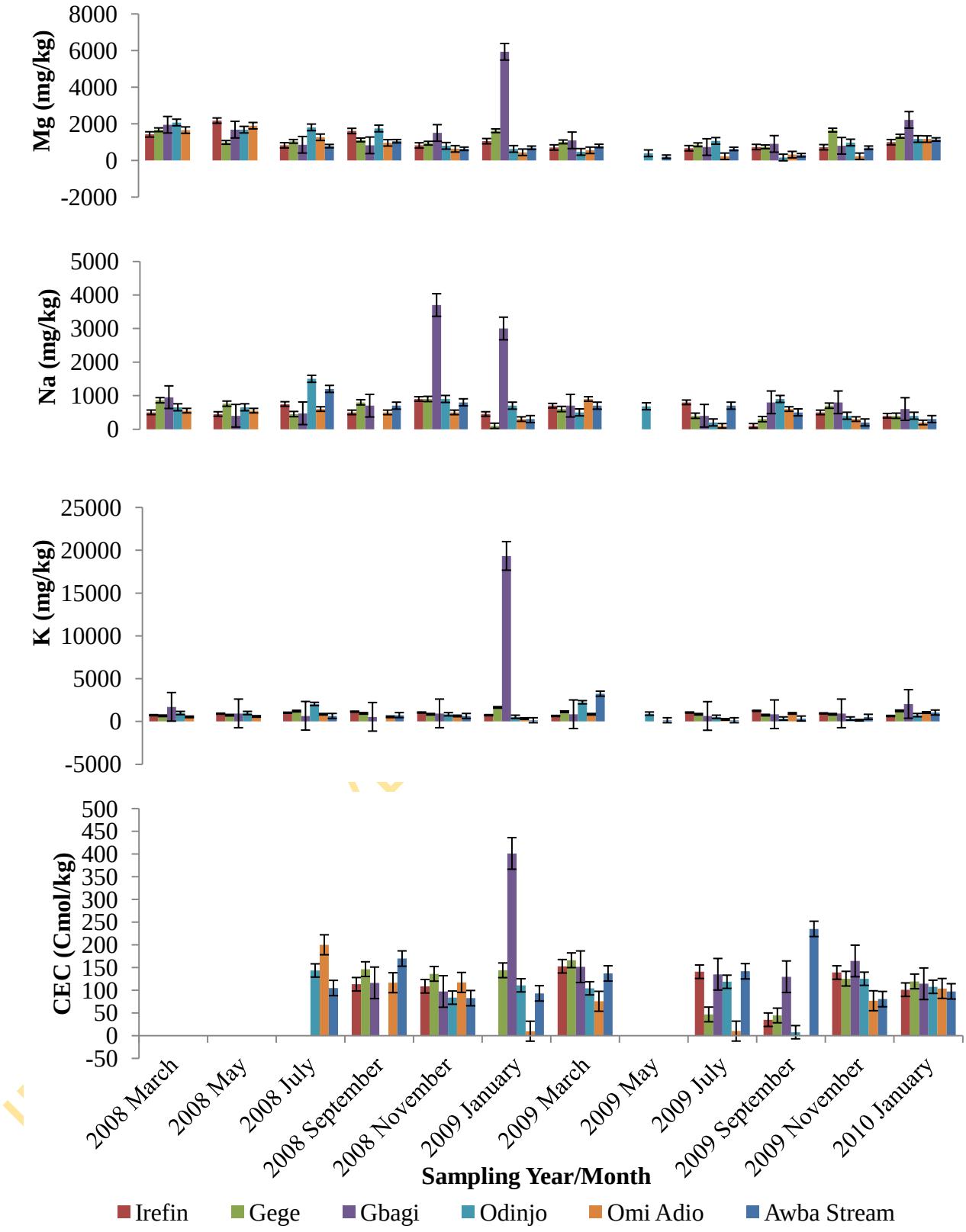
One way analysis of variance showed that the potassium contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24).

4.5.3.6 Cation exchange capacity (CEC)

The bimonthly range of cation exchange capacity observed at the soil from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) were 34.91 to 152.65 Cmol/kg, 44.27 to 165.88 Cmol/kg, 97.13 to 401.23 Cmol/kg, 7.40 to 143.38 Cmol/kg, 7.62 to 200.00 Cmol/kg and 2.03 to 235.00 Cmol/kg respectively (Figure 4.27d; Appendix 22).

The mean values observed at the control site (Awba stream), Irefin stream, Gege stream, Gbagi stream, Odinjo stream and Omi Adio stream were (112.83±14.85 Cmol/kg), (115.92±16.17 Cmol/kg), (167.41±34.21 Cmol/kg), (101.58±12.94 Cmol/kg) and (79.61±21.35 Cmol/kg), (114.30±19.58 Cmol/kg) respectively (Appendix 22).

One way analysis of variance indicated that the cation exchange capacities of the soil samples from all the streams' banks were not significantly different from one another at $P<0.05$ (Appendix 24). However, the cation exchange capacities of the soil samples from the banks of Gbagi and Omi Adio streams were significantly different from each other at $P<0.05$ (Appendix 25).



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that Mg, Na, K and CEC were not detected in the samples.

Figure 4.27: Bimonthly variation of some cations values and cation exchange capacities of soil from streams' banks (a) Mg (b) Na (c) K (d) CEC

4.5.4 Bimonthly variation of trace and heavy metals of soil samples from the banks of streams

The range and mean values of the trace and heavy metals of soil samples from the banks of the streams are shown in Appendix 23. Details are shown in Appendices 26 to 31.

4.5.4.1 Iron

The bimonthly iron content of soil samples from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and the control site (Awba stream) were 21374.80 to 47141.30 mg/kg, 24623.80 to 37684.90 mg/kg, 25462.90 to 58402.80 mg/kg, 15693.70 to 81733.80 mg/kg, 20268.40 to 38424.40 mg/kg and 6852.40 to 19590.10 mg/kg respectively (Figure 4.28a; Appendix 23).

The mean values observed at the Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) were (31605.76±2606.91 mg/kg), (28676.30±1402.12 mg/kg), (33428.22±33193.60 mg/kg), (31322.16±5861.84 mg/kg), (2903.43±1944.15 mg/kg) and (13146.50±1428.28 mg/kg) respectively (Appendix 23).

One way analysis of variance showed that the iron contents of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the iron content of the soil from the bank of the control site (Awba stream) was significantly different from iron contents of all other soil samples (Appendix 25).

4.5.4.2 Manganese

The bimonthly values of manganese content of soil samples from the banks of streams ranged from 13.47 to 1692.90 mg/kg at the Irefin stream, 12.60 to 505.90 mg/kg at the Gege stream, 42.78 to 642.90 mg/kg at the Gbagi stream, 40.98 to 559.40 mg/kg at the Odinjo stream, 35.60 to 506.00 mg/kg at the Omi Adio stream and 128.80 to 506.00 mg/kg at the control site (Awba stream) (Figure 4.28b; Appendix 23).

The mean values observed were (465.73±165.80 mg/kg), (385.79.72±48.82 mg/kg), (420.49±65.99 mg/kg), (317.69±44.23 mg/kg), (320.98±58.16 mg/kg) and (255.15±36.89 mg/kg), at the control site (Awba stream), Irefin, Gege, Gbagi, Odinjo and Omi Adio streams respectively (Appendix 23).

One way analysis of variance showed that the manganese contents of the soil samples were not significantly different at P<0.05 (Appendix 24). However, Duncan's multiple range tests showed that manganese contents of soil samples from the banks of Irefin stream was significantly different from that of control (Awba stream) (Appendix 25).

4.5.4.3 Copper

Copper was not detected in the soil samples from the Irefin stream and the control site (Awba stream) in the months of May 2008 and May 2009 respectively (Figure 4.28c).

The bimonthly values of copper content of soil samples from streams' banks ranged from 56.60 to 590.10 mg/kg at the Irefin stream, 33.90 to 594.30 mg/kg at the Gege stream, 17.40 to 210.00 mg/kg at the Gbagi stream, 11.90 to 130.00 mg/kg at the Odinjo stream, 15.90 to 70.40 mg/kg at the Omi Adio stream and 2.50 to 37.00 mg/kg at the control site (Awba stream) (Figure 4.28c; Appendix 23).

The mean values observed at the banks of Irefin stream, Gege stream, Gbagi stream, Odinjo stream, Omi Adio stream and the control site (Awba stream) were (154.86±63.27 mg/kg), (118.04±60.06 mg/kg), (86.63±21.99 mg/kg), (39.34±9.62 mg/kg), (40.51±5.27 mg/kg) and (15.42±3.38 mg/kg) respectively (Appendix 23).

One way analysis of variance showed that the copper contents of the soil samples from the streams' banks were significantly different at P<0.05 (Appendix 24). Duncan's multiple range tests also showed some significant differences at P<0.05. It showed that the copper content of the soil from bank of Irefin stream was significantly different from the copper content of all the soil from other streams' banks except those of the Gege and Gbagi streams (Appendix 25).

4.5.4.4 Zinc

Zinc was not detected in the soil from the bank of Odinjo stream in March 2009. In May and July 2009, it was also not detected at the control site (Awba stream) (Figure 4.28d; Appendices 26 to 31).

The bimonthly values of zinc observed in the soil samples ranged from 207.70 to 760.40 mg/kg (484.77±68.16 mg/kg), 342.10 to 684.40 mg/kg (514.05±45.64 mg/kg), 88.30 to 961.60 mg/kg (321.68±112.29 mg/kg), 2.26 to 669.10 mg/kg (261.07±65.90

mg/kg), 2.65 to 369.40 mg/kg (188.38±38.23 mg/kg) and 11.80 to 67.80 mg/kg (45.34±7.13 mg/kg) in the soil samples from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) respectively (Figure 4.28d; Appendix 23).

One way analysis of variance showed that the zinc contents of the soil samples were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the zinc content of the soil from Gege stream was significantly different from zinc content of the control site (Awba stream) (Appendix 25).

4.5.4.5 Lead

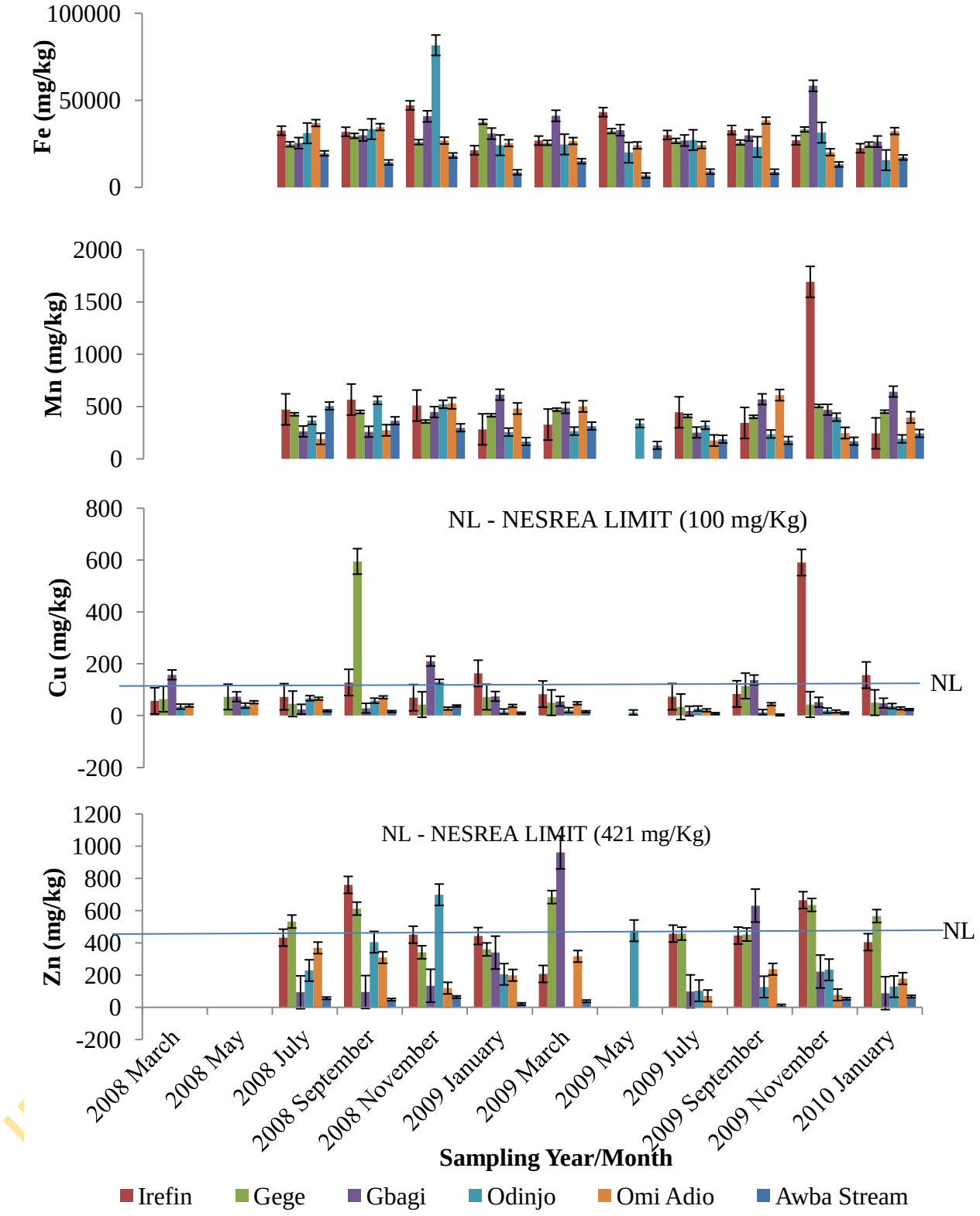
Lead was detected in all soil samples in May 2008 except in the soil sample from Omi Adio stream. It was not detected in the soil sample from the control site (Awba stream) in September 2008 and May 2009 (Figure 4.29a).

The bimonthly values of lead observed in the soil samples ranged from 0.77 to 787.70 mg/kg (293.18±80.04 mg/kg), 64.00 to 178.70 mg/kg (102.19±12.41 mg/kg), 76.60 to 394.70 mg/kg (161.73±34.83 mg/kg), 27.00 to 1213.00 mg/kg (227.27±100.59 mg/kg), 44.10 to 458.20 mg/kg (177.21±42.00 mg/kg) and 11.70 to 87.70 mg/kg (51.61±9.79 mg/kg) in the soil samples from the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream),respectively (Figure 4.29a; Appendix 23).

One way analysis of variance showed that the lead contents of the soil samples from the streams' banks were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the lead content of the soil from the bank of Irefin stream was significantly different from those of other soil samples except that of the Odinjo stream (Appendix 25).

4.5.4.6 Cadmium

The bimonthly cadmium values observed ranged from 1.3000 to 3.0000 mg/kg (1.96±0.22 mg/kg), 1.0000 to 3.30000 mg/kg (1.71±0.30 mg/kg), 0.7000 to 2.7000 mg/kg (1.80±0.20 mg/kg), 1.3000 to 2.6000 mg/kg (1.85±0.14 mg/kg), 0.5000 to



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that Fe, Mn, Cu and Zn were not detected in the samples.

Figure 4.28: Bimonthly variation of trace and heavy metal values of soil from streams' banks (a) Fe (b) Mn (c) Cu (d) Zn

2.1000 mg/kg (1.20±0.17 mg/kg) and 0.4000 to 1.6000 mg/kg (0.99±0.13 mg/kg) at the banks of Irefin, Gege, Gbagi, Odinjo, Omi Adio streams and control site (Awba stream) respectively (Figure 4.29b; Appendix 23).

One way analysis of variance showed that the cadmium contents of the soil samples from the streams' banks were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests also showed that the cadmium content of the soil from the banks of Omi Adio stream and control stream (Awba) were significantly different from those of other soil samples but not different from each other (Appendix 25).

4.5.4.7 Nickel

The bimonthly values of nickel content of soil samples ranged from 11.20 to 19.20 mg/kg (16.04±1.07 mg/kg) at the Irefin stream, 12.10 to 28.80 mg/kg (17.65±1.84 mg/kg) at the Gege stream, 14.80 to 23.60 mg/kg (19.29±1.02 mg/kg) at the Gbagi stream, 2.20 to 40.20 mg/kg (14.69±3.56 mg/kg) at the Odinjo stream, 2.65 to 24.9 mg/kg (14.71±2.1 mg/kg) at the Omi Adio stream and 1.10 to 17.60 mg/kg (8.47±1.55 mg/kg) at the control site (Awba stream) (Figure 4.29c; Appendix 23).

One way analysis of variance showed that the nickel contents of the soil samples were not significantly different at $P<0.05$ (Appendix 24). However, Duncan's multiple range tests showed some significant differences of some of the samples at $P<0.05$. It showed that the nickel content of the soil from the bank of control site was significantly different from the nickel content of the soil from the other soil samples (Appendix 25).

4.5.4.8 Chromium

Chromium was not detected in all soil samples in March 2008 except the soil sample from the bank of Gbagi stream with a value of 38.61 mg/kg. In all soil samples analysed in the month of May 2008, chromium was not detected except in the sample from the bank of Omi Adio stream with a value of 3.81 mg/kg (Figure 4.28d).

The bimonthly values of chromium content of soil samples ranged from 5.10 to 32.90 mg/kg (19.59±3.57 mg/kg) at the Irefin stream, 15.60 to 37.50 mg/kg (24.48±2.35 mg/kg) at the Gege stream, 23.20 to 56.80 mg/kg (42.99±3.77 mg/kg) at the Gbagi stream, 5.90 to 42.70 mg/kg (21.01±3.14 mg/kg) at the Odinjo stream, 3.81 to 37.90

mg/kg (24.62±3.44 mg/kg) at the Omi Adio stream and 4.20 to 27.70 mg/kg (14.51±2.50 mg/kg) at the control site (Awba stream) (Figure 4.29d; Appendix 23).

One way analysis of variance showed that the chromium contents of the soil samples from the banks of the streams were significantly different at $P<0.05$ (Appendix 24). Duncan's multiple range tests showed that the chromium content of the soil from Gbagi stream was significantly different from the chromium contents of all other soil samples at $P<0.05$ (Appendix 25).

4.6 Result of analysis of soil samples from the dumpsites

4.6.1 Bimonthly variation of physico-chemical characteristics of soil samples from the dumpsites

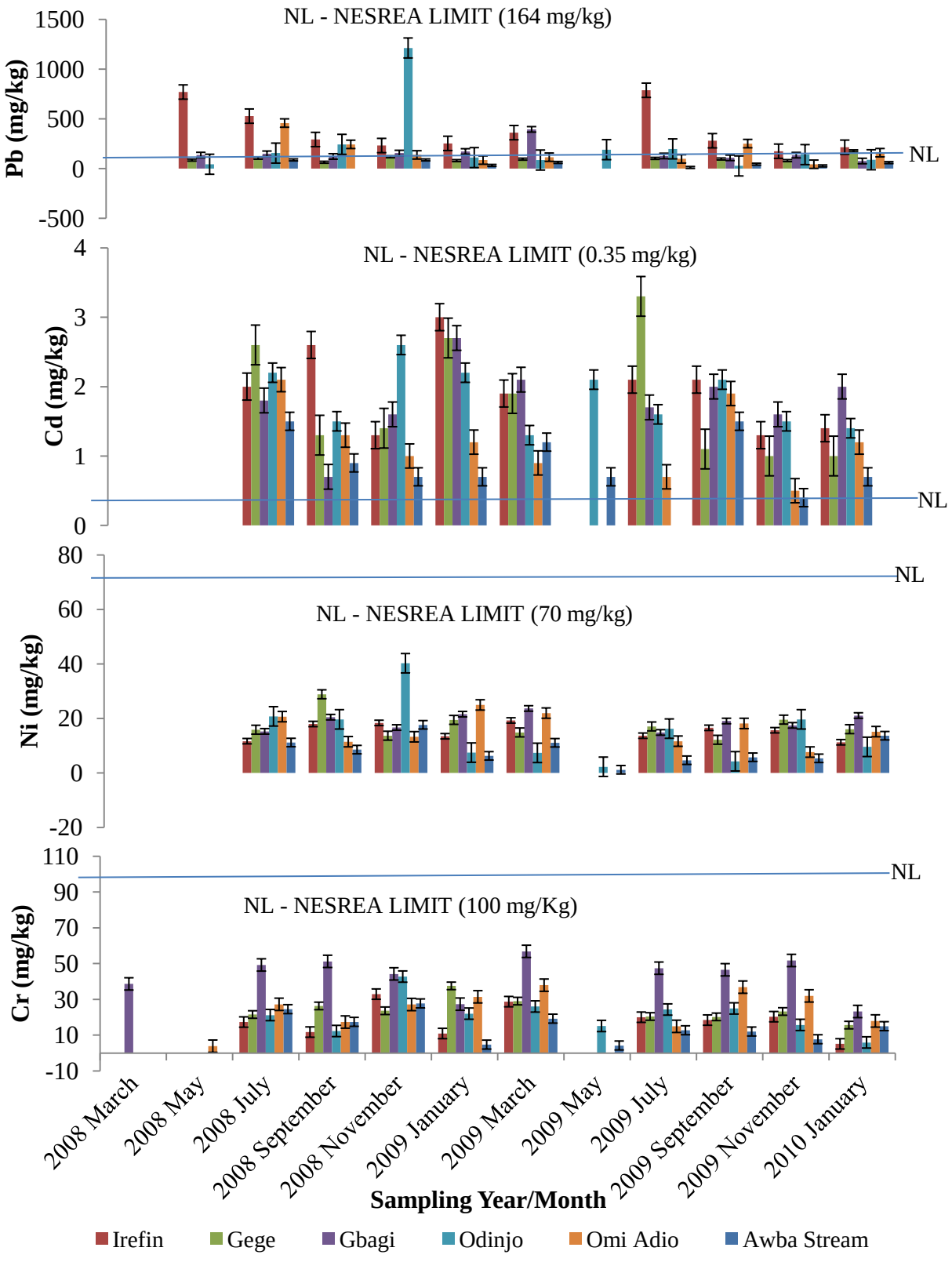
The range and mean values of the physico-chemical characteristics of soil samples from the dumpsites are shown in Appendix 32. Details are shown in Appendices 37 to 42.

4.6.1.1 Soil particle size distribution

The percentage sand contents of the soil samples ranged from 68 to 92% (84.00±1.93 %) at the Ojokondo dumpsite, 70 to 85 % (78.03±1.66 %) at the Olodo dumpsite, 79 to 87 % (83.75±0.79 %) at the Moniya dumpsite, 74 to 94 % (86.75±1.64 %) at the Idi Ope dumpsite, 6 to 83 % (69.08±2.82 %) at the Oremeji dumpsite and 84 to 92 % (87.30±0.82 %) at the control site (Balewa) (Figure 4.30a; Appendix 32).

The percentage silt content of the soil samples ranged from 1 to 30 % (5.00±2.33 %) at the Ojokondo dumpsite, 2 to 7 % (4.50±0.54 %) at the Olodo dumpsite, 1 to 8 % (3.33±0.48 %) at the Moniya dumpsite, 1 to 11 % (2.83±0.80 %) at the Idi Ope dumpsite, 2 to 12 % (7.42±1.02 %) at the Oremeji dumpsite and 2 to 5 % (3.20±0.39 %) at the control site (Balewa) (Figure 4.30b; Appendix 32).

The percentage clay content of the soil samples ranged from 2 to 19 % (10.83±1.43 %) at the Ojokondo dumpsite, 10 to 23 % (16.42±1.12 %) at the Olodo dumpsite, 10 to 18 % (12.92±0.68 %) at the Moniya dumpsite, 4 to 15 % (10.25±1.07 %) at the Idi Ope dumpsite, 13 to 36 % (23.50±2.17 %) at the Oremeji dumpsite and 6 to 12 % (9.75±0.77 %) at the control site (Balewa) (Figure 4.30c; Appendix 32).



NOTE: Blank spaces indicated that the control site (Awba stream) was not sampled in the months of March and May, 2008. Other blank spaces indicated that Pb, Cd, Ni and Cr were not detected in the samples.

Figure 4.29: Bimonthly variation of trace and heavy metals values of soil from streams' banks (a) Pb (b) Cd (c) Ni (d) Cr

Using their mean values for textural classification, the soil from the control site (Balewa), Ojokondo, Olodo, Moniya and Idi Ope dumpsites were all loamy sand while the soil from Oremeji dumpsite were sandy clay loam (Appendix 21).

4.6.1.2 Hydrogen ion concentration (pH)

The bimonthly values of the pH of soil samples ranged from 6.30 to 8.40 (7.48±0.15) at the Ojokondo dumpsite, 6.60 to 9.00 (7.65±0.16) at the Olodo dumpsite, 6.20 to 8.00 (7.33±0.14) at the Moniya dumpsite, 6.80 to 8.10 (7.57±0.12) at the Idi Ope dumpsite, 7.20 to 8.00 (7.62±0.07) at the Oremeji dumpsite and 6.60 to 8.30 (7.23±0.20) at the control site (Balewa) (Figure 4.31a; Appendix 32).

One way analysis of variance showed that the pH values in the soil samples were not significantly different at $P<0.05$ (Appendix 35).

4.6.1.3 Electrical conductivity

The bimonthly electrical conductivity values of the soil samples ranged from 662.00 to 3960.00 µS/cm (1978.50±291.17 µS/cm) at the Ojokondo dumpsite, 119.70 to 11780.00 µS/cm (3444.08±1205.16 µS/cm) at the Olodo dumpsite, 274.00 to 6390.00 µS/cm (1628.25±467.00µS/cm) at the Moniya dumpsite, 164.50 to 3790.00 µS/cm (1073.38±325.05 µS/cm) at the Idi Ope dumpsite, 293.00 to 1360.00 µS/cm (802.00±105.35 µS/cm) at the Oremeji dumpsite and 126.40 to 343.00 µS/cm (212.15±19.72 µS/cm) at the control site (Balewa) (Figure 4.31b; Appendix 32).

One way analysis of variance showed that the electrical conductivity values in the soil samples were significantly different at $P<0.05$ (Appendix 35). Duncan's multiple range tests also showed that the electrical conductivity of the soil from the Olodo dumpsite was significantly different from electrical conductivity contents of all the other dumpsites except that of the Ojokondo dumpsite (Appendix 36).

4.6.1.4 Total organic carbon

The bimonthly values of total organic carbon of soil samples ranged from 2.28 to 8.07 % (4.76±0.49 %) at the Ojokondo dumpsite, 0.95 to 5.56 % (2.89±0.41 %) at the Olodo dumpsite, 1.81 to 15.21 % (4.98±1.03 %) at the Moniya dumpsite, 1.14 to 5.39 % (3.19±0.39 %) at the Idi Ope dumpsite, 0.27 to 6.14 % (2.27±0.43 %) at the Oremeji dumpsite and 0.85 to 3.36 % (2.01±0.26 %) at the control site (Balewa)

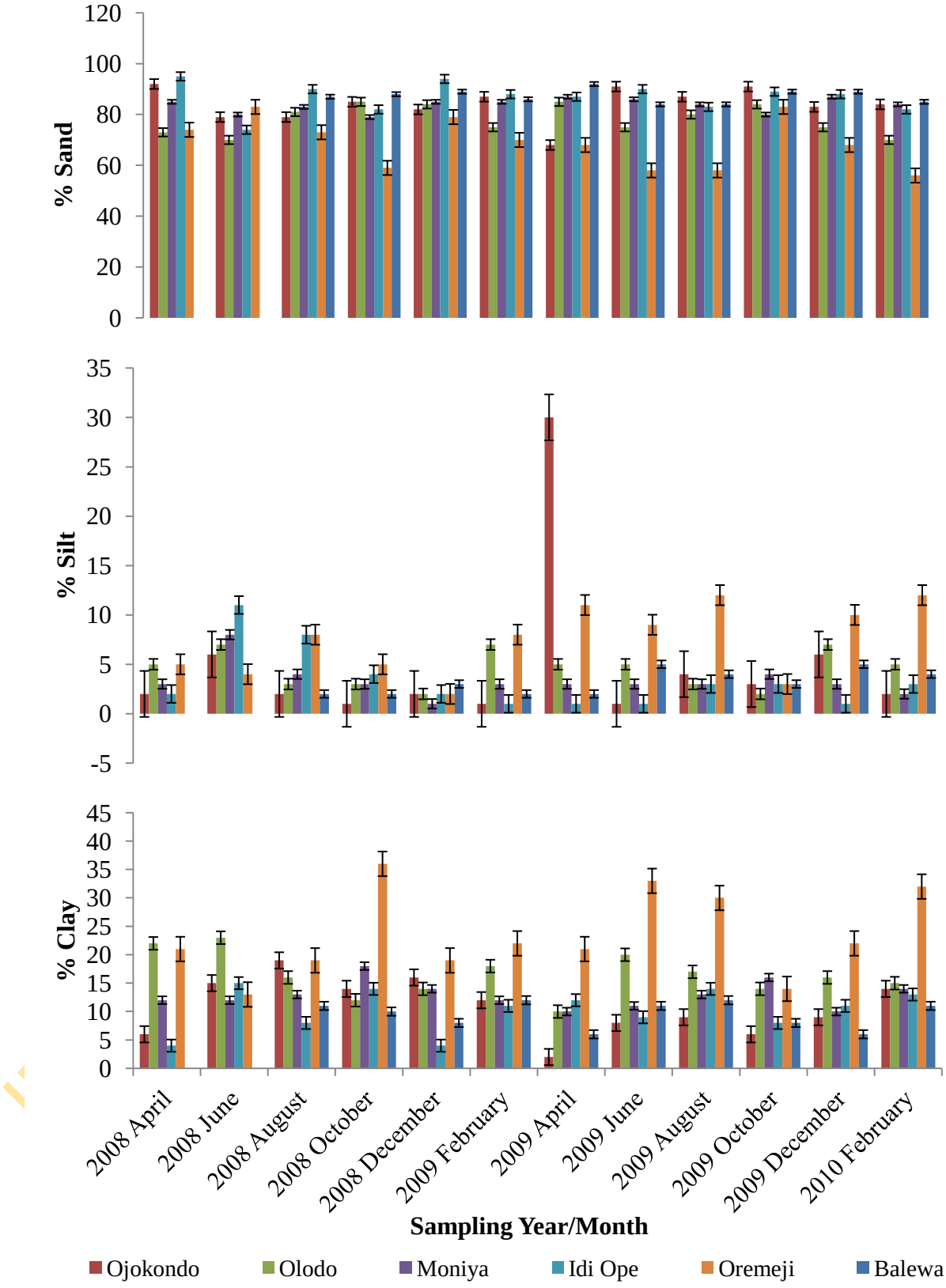


Figure 4.30: Bimonthly variation of particle size distribution values of soil from dumpsites (a) Sand (b) Silt (c) Clay

(Figure 4.31c; Appendix 32).

One way analysis of variance showed that the total organic carbon in the soil samples were significantly different at $P<0.05$ (Appendix 35). Duncan's multiple range tests also showed that the total organic carbon of the soil from the Moniya dumpsite was significantly different from total organic carbon contents of all the other dumpsites except that of the Ojokondo dumpsite at $P<0.05$ (Appendix 36).

4.6.1.5 Total organic matter

The bimonthly values of total organic matter ranged from 3.94 to 13.95 % (8.23±0.86 %) at the Ojokondo dumpsite, 1.64 to 9.61 % (4.99±0.71 %) at the Olodo dumpsite, 3.13 to 26.30 % (8.62±1.78 %) at the Moniya dumpsite, 1.97 to 9.32 % (5.51±0.68 %) at the Idi Ope dumpsite, 0.47 to 10.62 % (3.92±0.75 %) at the Oremeji dumpsite and 1.47 to 5.81 % (3.47±0.44 %) at the control site (Balewa) (Figure 4.31d; Appendix 32).

One way analysis of variance and Duncan's multiple tests showed the same trend as those of the total organic carbon contents of the soil samples (Appendices 35 and 36).

4.6.2 Bimonthly variation of anions of soil samples from dumpsites

The range and mean values of the anions of soil samples from the dumpsites are shown in Appendix 33. Details are shown in Appendices 37 to 42.

4.6.2.1 Nitrate – nitrogen

Nitrate – nitrogen was not detected in the soil sample from the Idi Ope dumpsite in June 2008, but it was detected in all other soil samples. It was not detected in the soil samples from the control site (Balewa) and the Olodo dumpsite in October 2008 and October 2009. In April 2009, it was not detected in the soil from the Olodo and Idi Ope dumpsites. In June 2009, it was not detected in the control soil (Balewa) and the soil samples from Ojokondo and Oremeji dumpsites but it was detected in the soil samples from Olodo, Moniya and Idi Ope dumpsites with values of 152.02 mg/kg, 1659.46 mg/kg and 547.58 mg/kg respectively. In February and August 2009, nitrate – nitrogen was not detected in the soil samples from the Idi Ope dumpsite and the control site (Balewa) respectively. In December 2009, it was not detected in the soil samples from the control site (Balewa), Olodo and Idi Ope dumpsites but it was

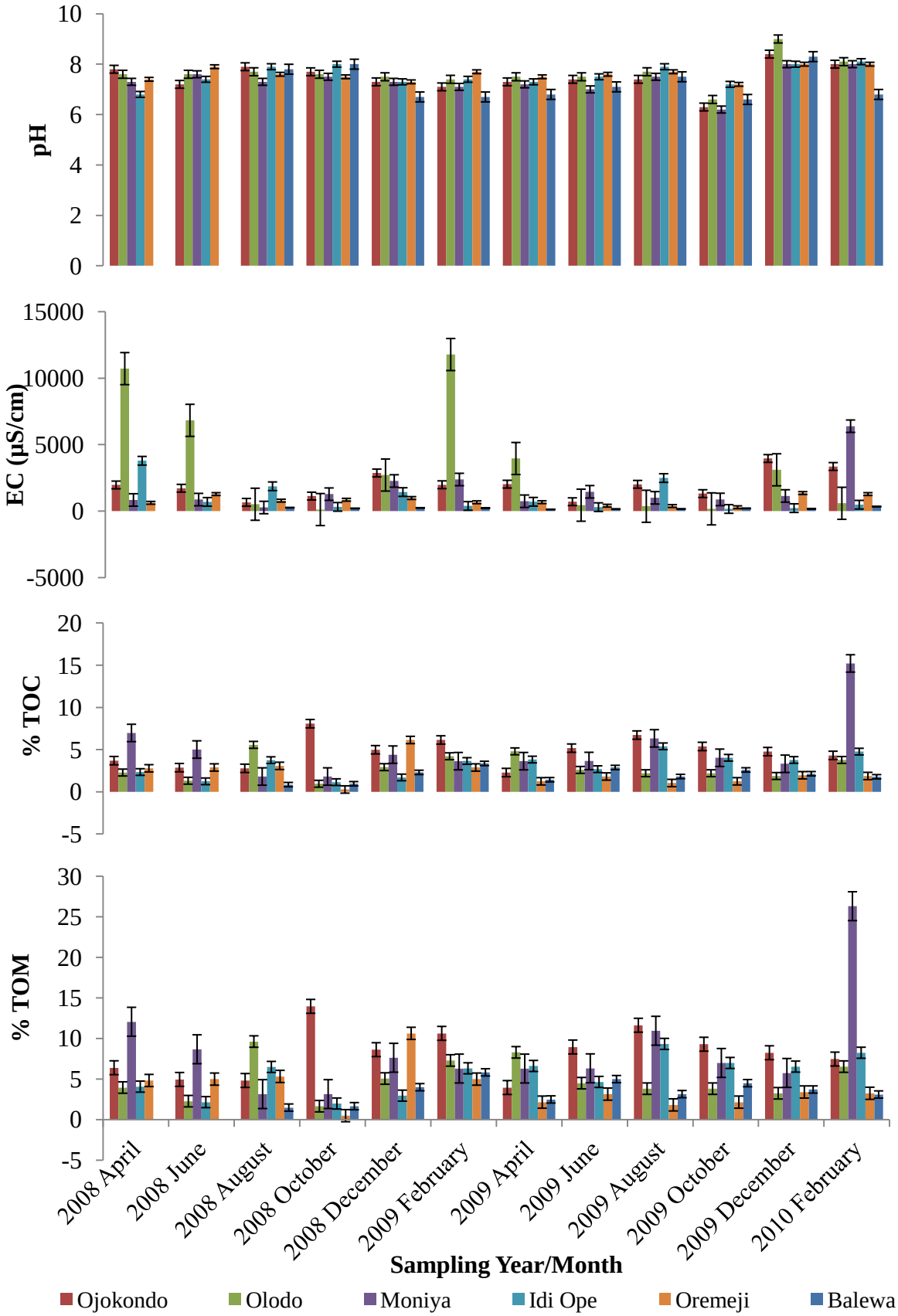


Figure 4.31: Bimonthly variation of physico-chemical values of soil from dumpsites (a) pH (b) EC (c) TOC (d) TOM

detected in the soil samples from Ojokondo, Moniya and Oremeji dumpsites with the values of 898.70 mg/kg, 592.02 mg/kg and 547.58 mg/kg respectively. In February 2010, it was not detected in the soil samples from the control site (Balewa) and Idi Ope dumpsite (Figure 4.32a; Appendix 33).

One way analysis of variance showed that the nitrate – nitrogen contents in the soil samples were not significantly different at $P<0.05$ (Appendix 35).

4.6.2.2 Sulphate - sulphur

In April 2008, the control site was not sampled. Sulphate - sulphur was present in all other sites except its non-occurrence in the soil sample from Moniya dumpsite. However, in June 2008, sulphate – sulphur was not detected in soil samples except in the soil sample from the Oremeji dumpsite with a value of 1.63 mg/kg. In August 2008, it was present in all soil samples except the sample from the Olodo dumpsite. In October 2008, it was not detected in the samples from the control site (Balewa) and the Oremeji dumpsite. In December 2008, it was not present in the soil samples from the control site, Olodo and Oremeji dumpsites but it was detected in the soil samples from Ojokondo, Moniya and Idi Ope dumpsites with values of 1.63 mg/kg, 12.5 mg/kg and 2.88 mg/kg respectively (Figure 4.32b; Appendices 37 to 42).

In February 2009, sulphate – sulphur was present in all soil samples except the samples from the control site (Balewa) and the Idi Ope dumpsite. In April 2009, it was also present in all soil samples except the samples from the Idi Ope and Oremeji dumpsites. In June 2009, it was not detected in the soil samples from the control site, Olodo and Idi Ope dumpsites but it was detected in the soil samples from Ojokondo, Moniya and Oremeji dumpsites with the values of 1.63 mg/kg, 1.63 mg/kg and 4.38 mg/kg respectively. In August 2009, sulphate – sulphur was detected in all soil samples except the soil sample from the control site. In October 2009, it was also present in all soil samples except the samples from the Idi Ope and the Oremeji dumpsites. In December 2009, it was not detected in the soil samples from Olodo, Moniya and Idi Ope dumpsites but it was detected in the soil samples from the control site, Ojokondo and Oremeji dumpsites with values of 7.13 mg/kg, 9.75 mg/kg and 7.13 mg/kg respectively. In February 2010, it was not detected in the soil samples from Olodo and idi Ope dumpsites (Figure 4.32b; Appendices 37 to 42).

One way analysis of variance showed that the sulphate - sulphur contents in the soil samples were not significantly different at P<0.05 (Appendix 35).

4.6.3 Bimonthly variation of cations of soil samples from dumpsites

The range and mean values of the cations of soil samples from the dumpsites are shown in Appendix 33. Details are shown in Appendices 37 to 42.

4.6.3.1 Phosphorus

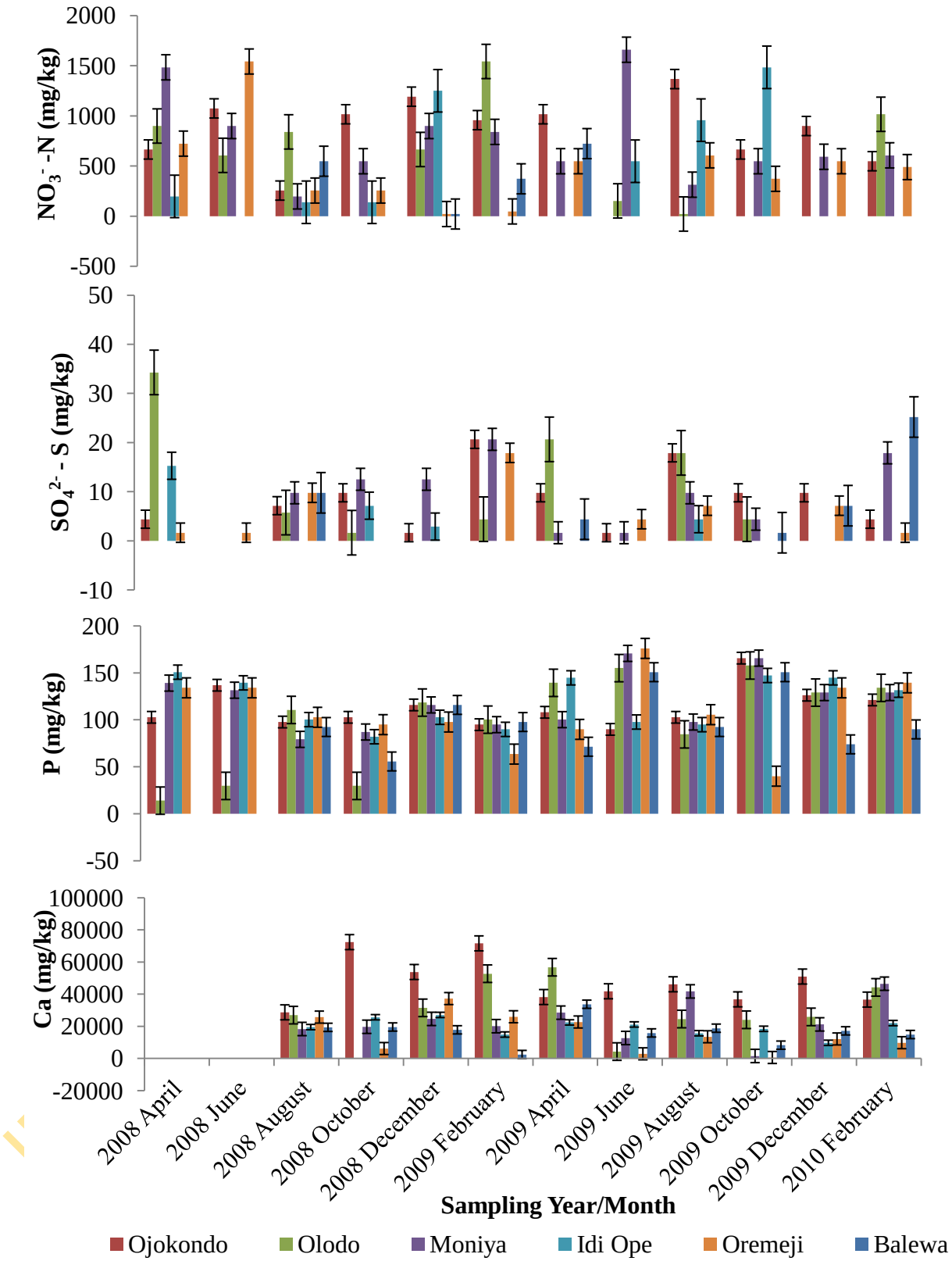
The bimonthly contents of phosphorus in the soil samples ranged from 89.88 to 165.76 mg/kg (113.75±6.18 mg/kg) at the Ojokondo dumpsite, 14.00 to 157.92 mg/kg (100.24±14.55 mg/kg) at the Olodo dumpsite, 79.24 to 170.80 mg/kg (120.05±8.54 mg/kg) at the Moniya dumpsite, 82.04 to 150.08 mg/kg (118.79±7.55 mg/kg) at the Idi Ope dumpsite, 40.04 to 176.12 mg/kg (109.36±10.62 mg/kg) at the Oremeji dumpsite and 55.72 to 150.80 mg/kg (99.10±10.05 mg/kg) at the control site (Balewa) (Figure 4.32c).

One way analysis of variance showed that the phosphorus contents in the soil samples were not significantly different at P<0.05 (Appendix 35).

4.6.3.2 Calcium

The bimonthly calcium contents in the soil samples ranged from 28637.20 to 72330.80 mg/kg (47644.85±4666.11 mg/kg) at the Ojokondo dumpsite, 4216.40 to 56716.20 mg/kg (32268.59±5456.36 mg/kg) at the Olodo dumpsite, 1478.10 to 46474.80 mg/kg (23441.63±4143.81 mg/kg) at the Moniya dumpsite, 9663.90 to 27032.30 mg/kg (19609.60±1650.37 mg/kg) at the Idi Ope dumpsite, 549.70 to 37203.00 mg/kg (15615.00±3733.82 mg/kg) at the Oremeji dumpsite and 2398.40 to 33688.20 mg/kg (16740.00±2560.00 mg/kg) at the control site (Balewa) (Figure 4.32d).

One way analysis of variance showed that the calcium contents in the soil samples were significantly different at P<0.05 (Appendix 35). Duncan's multiple range tests also showed that the calcium contents of the soil from the Ojokondo dumpsite was significantly different from the calcium contents of all samples (Appendix 36).



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that NO_3 – N, SO_4^{2-} - S and Ca were not detected in the samples.

Figure 4.32: Bimonthly variation of some anions and cations values of soil from dumpsites (a) NO_3^- - N (b) SO_4^{2-} - S (c) P (d) Ca

4.6.3.3 Magnesium

The bimonthly magnesium contents in the soil samples ranged from 418.33 to 9312.90 mg/kg (3589.57±822.83mg/kg) at the Ojokondo dumpsite, 508.97 to 4919.40 mg/kg (2216.05±371.58mg/kg) at the Olodo dumpsite, 460.80 to 8343.30 mg/kg (2045.60±613.03mg/kg) at the Moniya dumpsite, 652.56 to 2432.70 mg/kg (1503.54±166.68mg/kg) at the Idi Ope dumpsite, 92.69 to 6919.20 mg/kg (2452.88±532.25mg/kg) at the Oremeji dumpsite and 584.70 to 3312.60 mg/kg (1438.35±239.72mg/kg) at the control site (Figure 4.33a).

One way analysis of variance showed that the magnesium contents in the soil samples were not significantly different at $P<0.05$ (Appendix 35). However, Duncan's multiple range tests showed that the magnesium contents of the soil samples from Ojokondo dumpsite was significantly different from the soil samples from Idi Ope dumpsite and control (Balewa) (Appendix 36).

4.6.3.4 Sodium

The bimonthly values of sodium in the soil samples ranged from 300.00 to 2700.00 mg/kg (1277.55±219.82 mg/kg) at the Ojokondo dumpsite, 400.00 to 11400.00 mg/kg (2790.30±1266.13 mg/kg) at the Olodo dumpsite, 100.00 to 1800.00 mg/kg (708.83±151.51 mg/kg) at the Moniya dumpsite, 200.00 to 2400.00 mg/kg (686.08±65.62 mg/kg) at the Idi Ope dumpsite, 600.00 to 1700.00 mg/kg (1046.25±98.66 mg/kg) at the Oremeji dumpsite and 300.00 to 5500.00 mg/kg (1170.00±490.59 mg/kg) at the control site (Figure 4.33b; Appendix 33).

One way analysis of variance showed that the sodium contents in the soil samples were not significantly different at $P<0.05$ (Appendix 35). However, Duncan's multiple range tests showed that the sodium contents of the soil from the Olodo dumpsite was significantly different from the sodium contents of the other soil samples (Appendix 36).

4.6.3.5 Potassium

The bimonthly potassium contents in the soil samples at the Ojokondo, Olodo, Moniya, Idi Ope dumpsites, Oremeji and control site (Balewa) ranged from 1330 to 6830 mg/kg (3239.17±476.18 mg/kg), 1130 to 6930 mg/kg (2962.27±614.76 mg/kg), 530 to 18630 mg/kg (3157.42±1428.50 mg/kg), 1130 to 3822 mg/kg (2132.08±202.53

mg/kg), 1030 to 9730 mg/kg (3630.33±737.37 mg/kg) and 1030 to 8330 mg/kg (2030.00±708.05 mg/kg) respectively (Figure 4.33c; Appendix 33).

One way analysis of variance showed that the potassium contents in the soil samples were not significantly different at P<0.05 (Appendix 35).

4.6.3.6 Cation exchange capacity (CEC)

The bimonthly values of cation exchange capacity of the soil samples ranged from 173.93 to 449.70 Cmol/kg (274.34±27.87 Cmol/kg) at the Ojokondo dumpsite, 40.48 to 358.00 Cmol/kg (201.53±35.19 Cmol/kg) at the Olodo dumpsite, 13.39 to 348.63 Cmol/kg (146.63±29.04 Cmol/kg) at the Moniya dumpsite, 64.78 to 159.71 Cmol/kg (119.64±10.17 mg/kg) at the Idi Ope dumpsite 20.34 to 256.56 Cmol/kg (113.19±22.12 Cmol/kg) at the Oremeji dumpsite and 23.67 to 188.14 Cmol/kg (113.89±17.53 Cmol/kg) at the control site (Figure 4.33d).

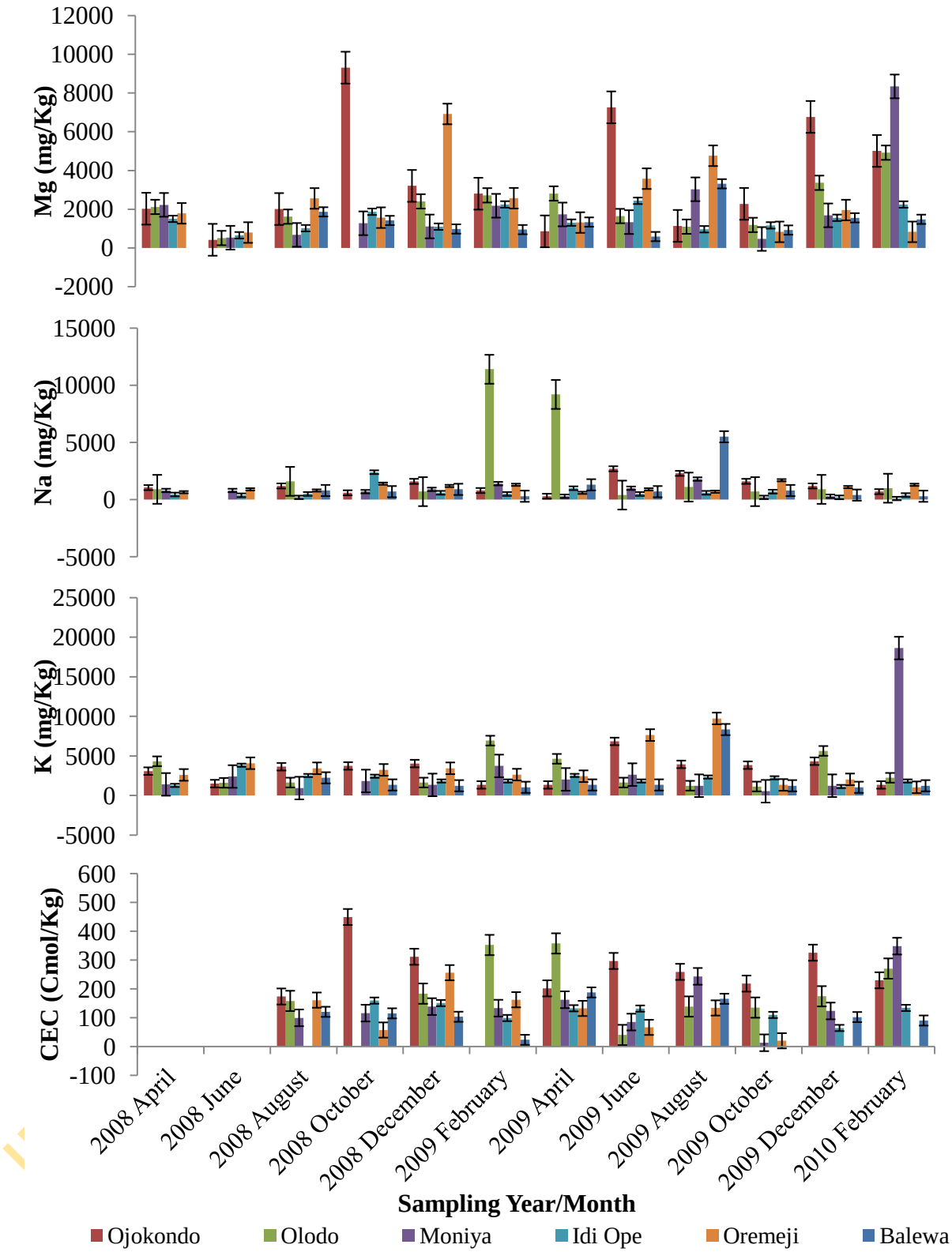
One way analysis of variance showed that the cation exchange capacities of the soil samples were significantly different at P<0.05 (Appendix 35). The cation exchange capacity of the soil samples from Ojokondo dumpsite was significantly different from those of the other soil samples except Olodo dumpsite at P<0.05 (Appendix 36).

4.6.4 Bimonthly variation of trace and heavy metals of soil samples from dumpsites

The range and mean values of the trace and heavy metals of soil samples from the dumpsites are shown in Appendix 34. Details are shown in Appendices 37 to 42.

4.6.4.1 Iron

The bimonthly values of iron in the soil samples ranged from 17407.30 to 59319.10 mg/kg (38586.58±3677.56 mg/kg) at the Ojokondo dumpsite, 17555.20 to 28703.80 mg/kg (20882.10±1187.06 mg/kg) at the Olodo dumpsite, 9284.20 to 47007.70 mg/kg (26343.13±3115.56 mg/kg) at the Moniya dumpsite, 11741.20 to 54270.10 mg/kg (27167.73±3893.89 mg/kg) at the Idi Ope dumpsite, 14434.00 to 80639.50 mg/kg (45208.21±5938.85 mg/kg) at the Oremeji dumpsite and 16698.40 to 41540.50 mg/kg (26401.13±2695.83 mg/kg) at the control site (Balewa) (Figure 4.34a).



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that Mg, Na, K and CEC were not detected in the samples.

Figure 4.33: Bimonthly variation of cations values and cation exchange capacities of soil from dumpsites (a) Mg (b) Na (c) K (d) CEC

One way analysis of variance showed that the iron contents in the soil samples were significantly different at P<0.05 (Appendix 35). Duncan's multiple range tests also showed that the iron contents of the soil from the Ojokondo and Oremeji dumpsites were significantly different from the iron contents of all other soil samples but not different from each other at P<0.05 (Appendix 36).

4.6.4.2 Manganese

The bimonthly values of manganese in the soil samples ranged 206.53 to 2799.60 mg/kg (1408.03±232.14 mg/kg), 492.80 to 847.00 mg/kg (681.98±38.23 mg/kg), 205.51 to 798.60 mg/kg (535.04±54.33 mg/kg), 265.00 to 903.30 mg/kg (548.68±51.70 mg/kg), 195.50 to 1380.40 mg/kg (622.46±103.61 mg/kg) and 549.50 to 6178.00 mg/kg (1338.24±606.74 mg/kg), at the Ojokondo, Olodo, Moniya, Idi Ope, Oremeji dumpsites and the control site respectively (Figure 4.34b).

One way analysis of variance showed that the manganese contents in the soil samples were significantly different at P<0.05 (Appendix 35). Duncan's multiple range tests also showed that the manganese contents of the soil from the Ojokondo dumpsite and control site (Balewa) were significantly different from the manganese contents of all soil samples but not different from each other at P<0.05 (Appendix 36).

4.6.4.3 Copper

The bimonthly values of copper in the soil samples ranged from 37.80 to 239.88 mg/kg (147.79±19.64 mg/kg) at the Ojokondo dumpsite, 47.70 to 273.00 mg/kg (92.02±19.42 mg/kg) at the Olodo dumpsite, 9.00 to 227.78 mg/kg (69.92±16.10 mg/kg) at the Moniya dumpsite, 47.40 to 231.90 mg/kg (85.74±15.36 mg/kg) at the Idi Ope, 16.51 to 479.60 mg/kg (133.52±36.40 mg/kg) at the Oremeji dumpsite and 12.20 to 36.20 mg/kg (23.84±2.54 mg/kg) at the control site (Figure 4.34c).

One way analysis of variance showed that the copper contents in the soil samples were significantly different at P<0.05 (Appendix 35). Duncan's multiple range tests also showed that the copper contents of the soil from the control site was significantly different from the copper contents of all samples except those of Moniya and Idi Ope dumpsites (Appendix 36).

4.6.4.4 Zinc

The bimonthly values of zinc in the soil samples ranged from 304.30 to 5458.90 mg/kg (2022.04±428.24 mg/kg) at the Ojokondo dumpsite, 48.50 to 1636.00 mg/kg (352.11±167.50 mg/kg) at the Olodo dumpsite, 66.00 to 871.30 mg/kg (438.60±95.06 mg/kg) at the Moniya dumpsite, 92.70 to 944.10 mg/kg (466.89±86.94 mg/kg) at the Idi Ope dumpsite, 66.60 to 2683.60 mg/kg (688.50±238.20 mg/kg) at the Oremeji dumpsite and 43.10 to 113.60 mg/kg (76.90±5.80 mg/kg) at the control site (Figure 4.34d).

One way analysis of variance showed that the zinc contents in the soil samples were significantly different at $P<0.05$ (Appendix 35). Duncan's multiple range tests also showed that the zinc contents of the soil from the Ojokondo dumpsite was significantly different from the zinc contents of all samples (Appendix 36).

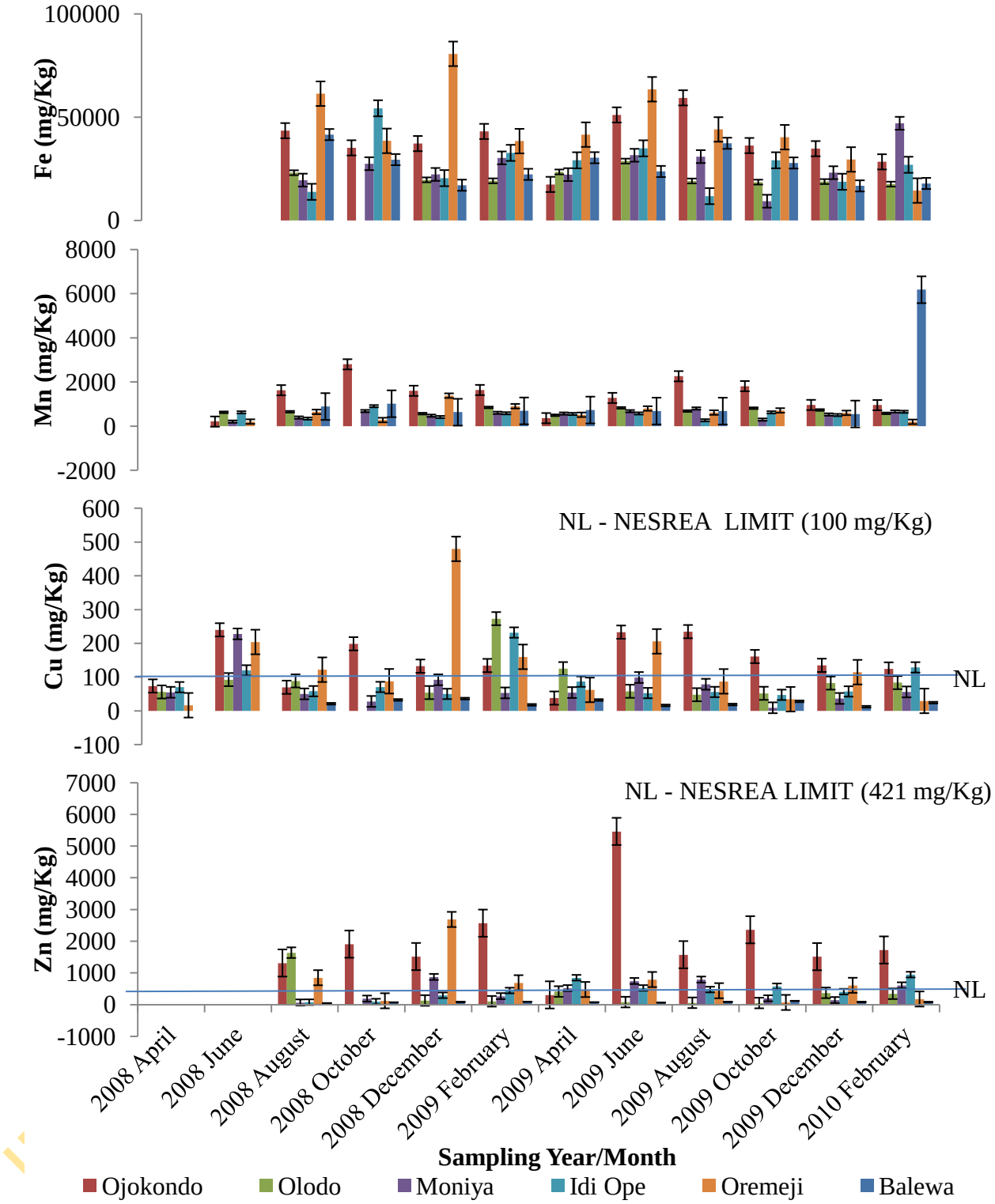
4.6.4.5 Lead

The bimonthly values of lead in the soil samples ranged from 150.30 to 552.60 mg/kg (319.97±38.14 mg/kg) at the Ojokondo dumpsite, 23.60 to 143.80 mg/kg (87.91±11.96 mg/kg) at the Olodo dumpsite, 10.60 to 310.10 mg/kg (116.06±26.41 mg/kg) at the Moniya dumpsite, 83.40 to 410.00 mg/kg (232.51±40.13 mg/kg) at the Idi Ope dumpsite, 51.38 to 1081.00 mg/kg (265.37±94.46 mg/kg) at the Oremeji dumpsite and 0.40 to 84.90 mg/kg (51.71±8.88 mg/kg) at the control site (Figure 4.35a).

One way analysis of variance showed that the lead contents in the soil samples were significantly different at $P<0.05$ (Appendix 35). Duncan's multiple range tests also showed that the lead contents of the soil from the Ojokondo dumpsite was significantly different from lead contents of other soil samples except those of the Idi Ope and Oremeji dumpsites at $P<0.05$ (Appendix 36).

4.6.4.6 Cadmium

In April 2008, the control site was not sampled. Cadmium was not present in all soil samples except the soil from the Oremeji dumpsite with a value of 3.00 mg/kg. However, in June 2008, cadmium was present in all soil samples except the soil from the Idi Ope dumpsite (Figure 4.35b).



NOTE: Blank spaces indicated that in the months of April and June, 2008, the control site (Tafawa Balewa Hall) was not sampled.

Figure 4.34: Bimonthly variation of some trace and heavy metals of soil from dumpsites (a) Fe (b) Mn (c) Cu (d) Zn

The bimonthly values of cadmium in the soil samples ranged from 0.19 to 26.50 mg/kg (8.78±2.14 mg/kg) at the Ojokondo dumpsite, 0.90 to 5.83 mg/kg (2.10±0.44 mg/kg) at the Olodo dumpsite, 0.70 to 36.00 mg/kg (5.77±3.09 mg/kg) at the Moniya dumpsite, 1.60 to 6.50 mg/kg (3.27±0.46 mg/kg) at the Idi Ope dumpsite, 0.40 to 7.90 mg/kg (4.15±0.64 mg/kg) at the Oremeji dumpsite and 0.60 to 2.40 mg/kg (1.26±0.15 mg/kg) at the control site (Figure 4.35a).

One way analysis of variance showed that the cadmium contents in the soil samples were significantly different at $P<0.05$ (Appendix 35). Duncan's multiple range tests also showed that the cadmium contents of the soil samples from the Ojokondo dumpsite were significantly different from others except those of Moniya and Oremeji dumpsites (Appendix 36).

4.6.4.7 Nickel

In June 2008, nickel was present in all soil samples except the soil from the Olodo dumpsite (Figure 4.35c). The bimonthly values of nickel in the soil samples ranged from 11.90 to 1217.70 mg/kg (144.78±107.35 mg/kg) at the Ojokondo dumpsite, 8.70 to 169.00 mg/kg (33.49±17.01 mg/kg) at the Olodo dumpsite, 13.30 to 30.38 mg/kg (18.47±1.60 mg/kg) at the Moniya dumpsite, 9.77 to 34.70 mg/kg (18.91±2.39 mg/kg) at the Idi Ope dumpsite, 8.00 to 53.90 mg/kg (28.99±4.03 mg/kg) at the Oremeji dumpsite and 10.00 to 22.20 mg/kg (18.91±2.39 mg/kg) at the control site (Figure 4.35c).

One way analysis of variance showed that the nickel contents in the soil samples were not significantly different at $P<0.05$ (Appendix 35).

4.6.4.8 Chromium

In April 2008, the control site was not sampled; chromium was not present in all other soil samples. So also in June 2008, the control site was not sampled, chromium was present in all soil samples except the soil from the Ojokondo dumpsite. In October 2009, chromium was also present in all soil samples except the soil from the Moniya dumpsite (Figure 4.35d). The bimonthly values of chromium in the soil samples ranged from 16.00 to 1137.40 mg/kg (137.60±111.11 mg/kg) at the Ojokondo dumpsite, 2.80 to 21.80 mg/kg (12.15±1.86 mg/kg) at the Olodo dumpsite, 8.50 to 24.20 mg/kg (16.35±1.74 mg/kg) at the Moniya dumpsite, 7.13 to 100.40 mg/kg

(23.51±8.10 mg/kg) at the Idi Ope dumpsite, 5.70 to 42.20 mg/kg (28.98±4.25 mg/kg) at the Oremeji dumpsite and 3.10 to 30.70 mg/kg (17.65±2.75 mg/kg) at the control site (Figure 4.35d).

One way analysis of variance showed that the chromium contents in the soil samples were not significantly different from one another at P<0.05 (Appendix 35).

4.7 Result of analysis of groundwater samples close to the streams

4.7.1 Bimonthly variation of physico-chemical characteristics of groundwater samples close to the streams

The well close to the Odinjo stream was not sampled in the months of March and May 2008. However, the range and mean values of the physico-chemical characteristics of the well close to the Gege stream (sampled from March, 2008 to January, 2010) and also the Odinjo stream (sampled from July, 2008 to January, 2010) are shown in Appendix 43. Details are shown in Appendices 47 and 48.

4.7.1.1 Hydrogen ion concentration (pH)

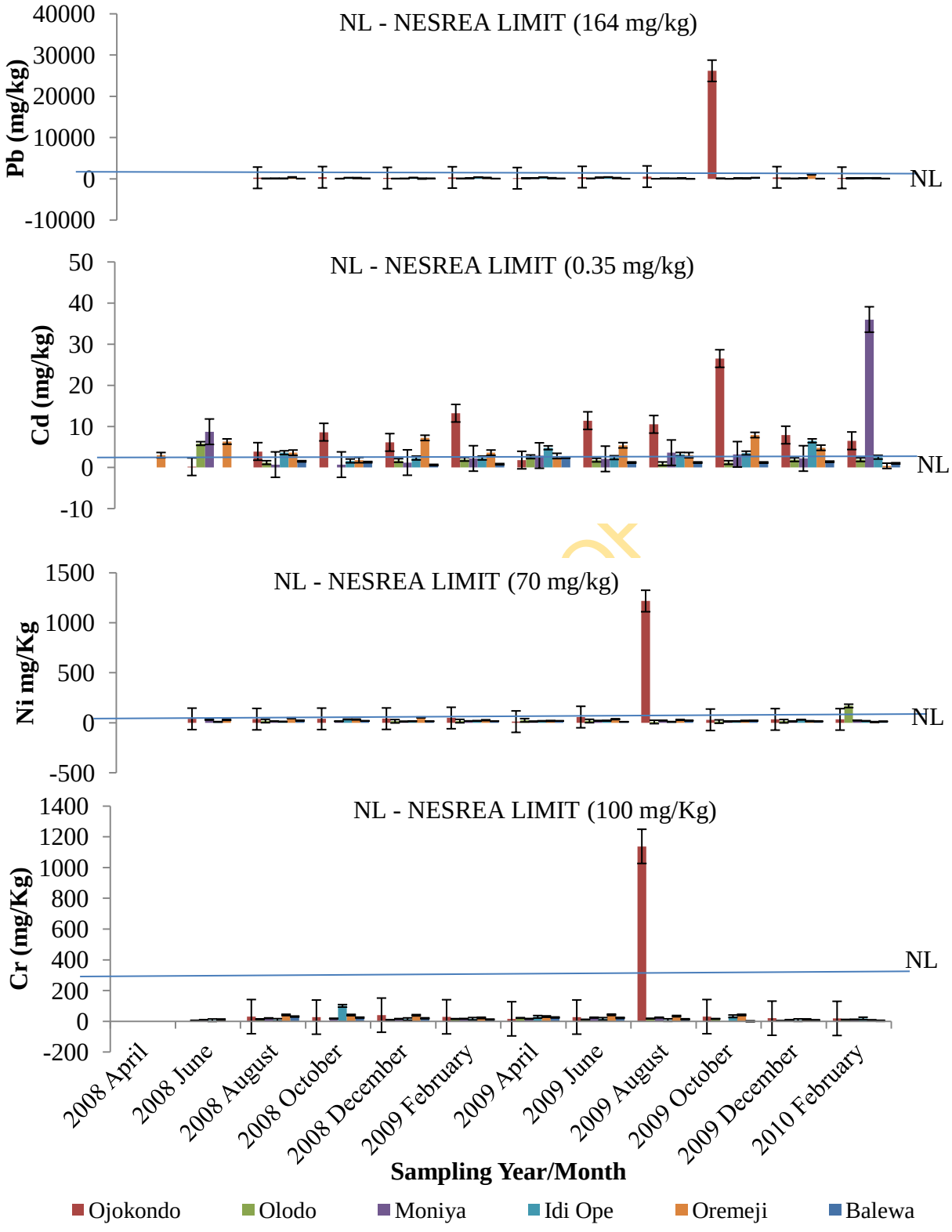
The bimonthly values of the pH of groundwater samples ranged from 6.39 to 8.15 (7.29±0.16) at the well close to the Gege stream and 6.11 to 7.92 (7.08±0.17) at the well close to the Odinjo stream (Figure 4.36a; Appendix 43).

T-test showed that the pH values of the two wells were not significantly different from each other at P<0.05 (Appendix 46).

4.7.1.2 Biochemical oxygen demand (BOD)

The bimonthly biochemical oxygen demand (BOD) values of the wells close to the Gege and Odinjo streams ranged from 34.84 to 102.62 mg/l (62.76±7.79 mg/L) and 27.23 to 115.39 mg/L (73.02±8.91 mg/L) respectively (Figure 4.36b; Appendix 43).

T-test showed that the biochemical oxygen demand (BOD) values of the two wells were not significantly different from each other at P<0.05 (Appendix 46).



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that Cd, Ni and Cr were not detected in the samples.

Figure 4.35: Bimonthly variation of some trace and heavy metals of soil from dumpsites (a) Pb (b) Cd (c) Ni (d) Cr

4.7.1.3 Chemical oxygen demand (COD)

The range of bimonthly values of chemical oxygen demand (COD) detected at the well close to the Gege stream was from 104.65 to 340.00 mg/L (220.91±24.59 mg/L) and that of the well close to the Odinjo stream was from 84.61 to 361.18 mg/L (230.22±28.22 mg/L) (Figure 4.36c; Appendix 43).

T-test showed that the chemical oxygen demand (COD) values of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).

4.7.1.4 Total dissolved solids (TDS)

The bimonthly range of 528.00 to 1350.00 mg/L (1080.83±77.34 mg/L) of the total dissolved solids was observed at the well close to the Gege stream while the range of 346.00 to 688.00 mg/L (553.7±29.63 mg/L) was observed at the well close to the Odinjo stream (Figure 4.36d; Appendix 43).

T-test showed that the total dissolved solids of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.1.5 Electrical conductivity (EC)

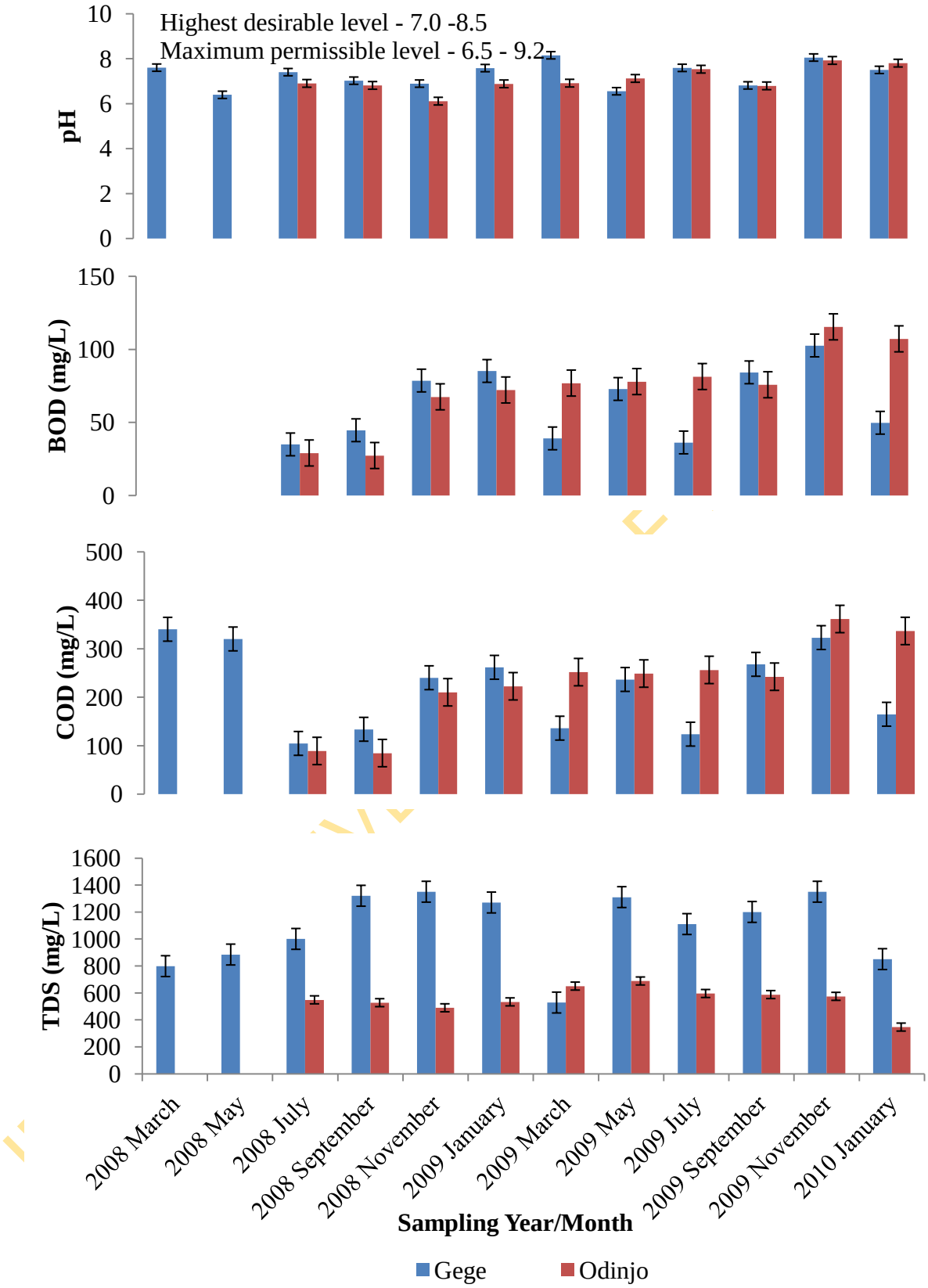
The bimonthly ranges of 880 to 2250 µS/cm (1952.75±111.31 µS/cm) and 814.00 to 1148.00 µS/cm (970.40±35.12 µS/cm) of electrical conductivity (EC) were observed at the wells close to the Gege and Odinjo streams respectively (Figure 4.37a; Appendix 43).

T-test showed that the electrical conductivity (EC) values of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.1.6 Total alkalinity

The bimonthly ranges of total alkalinity detected at the wells close to the Gege and Odinjo streams were from 176.40 to 660.80 mg/L (403.70±46.36 mg/L) and 161.70 to 468.86 mg/L (318.65±29.59 mg/L) respectively (Figure 4.37b; Appendix 43).

T-test showed that the total alkalinity values of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).



NOTE: Blank spaces indicated that the well close to the Odinjo stream was not sampled in the months of March and May, 2008.

Figure 4.36: Bimonthly variation of physico-chemical characteristics of groundwater samples close to streams (a) pH (b) BOD (c) COD (d) TDS

4.7.2 Bimonthly variation of anions of groundwater samples close to the streams

The range and mean values of the anions of groundwater samples close to the streams are shown in Appendix 44. Details are shown in Appendices 47 and 48.

4.7.2.1 Chloride

The bimonthly ranges of chloride content were from 178.19 to 541.08 mg/L (279.55±26.65 mg/L) and 79.52 to 210.93 mg/L (123.38±11.76 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.37c; Appendix 44).

T-test showed that the chloride contents of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.2.2 Phosphate - phosphorus

In July 2008, November 2009 and January 2010, phosphate - phosphorus was not detected at the well close to the Odinjo stream while in March 2009, November 2009 and January 2010, it was not also detected at the well close to the Gege stream (Appendices 47 and 48).

The bimonthly ranges observed were from 40.82 to 2822.86 mg/L (571.44±331.21 mg/L) and 12.24 to 308.57 mg/L (129.37±41.14 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.37d; Appendix 44).

T-test showed that the phosphate - phosphorus contents of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.2.3 Nitrate - nitrogen

The bimonthly values of nitrate - nitrogen detected at the wells close to the Gege and Odinjo streams ranged from 25.36 to 43.84 mg/L (36.41±1.94 mg/L) and 4.67 to 39.37 mg/L (24.47±4.00 mg/L) respectively (Figure 4.38a; Appendix 44).

T-test showed that the nitrate - nitrogen contents of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.2.4 Sulphate - sulphur

The bimonthly values of sulphate – sulphur ranged from 1762.50 to 4129.17 mg/L (2733.64±179.68 mg/L) and 1580.00 to 2512.50 mg/L (2018.63±108.03 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.38b; Appendix 44).

T-test showed that the sulphate - sulphur contents of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.3 Bimonthly variation of cations of groundwater samples close to the streams

The range and mean values of the cations of groundwater samples close to the streams are shown in Appendix 44. Details are shown in Appendices 47 and 48.

4.7.3.1 Calcium

The bimonthly values of calcium detected at the wells close to the Gege and Odinjo streams were 8.4118 to 104.0770 mg/l (49.23±10.76 mg/L) and 2.7289 to 82.2160 mg/L (27.45±12.71 mg/L) respectively (Figure 4.38c; Appendix 44).

T-test showed that the calcium contents of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).

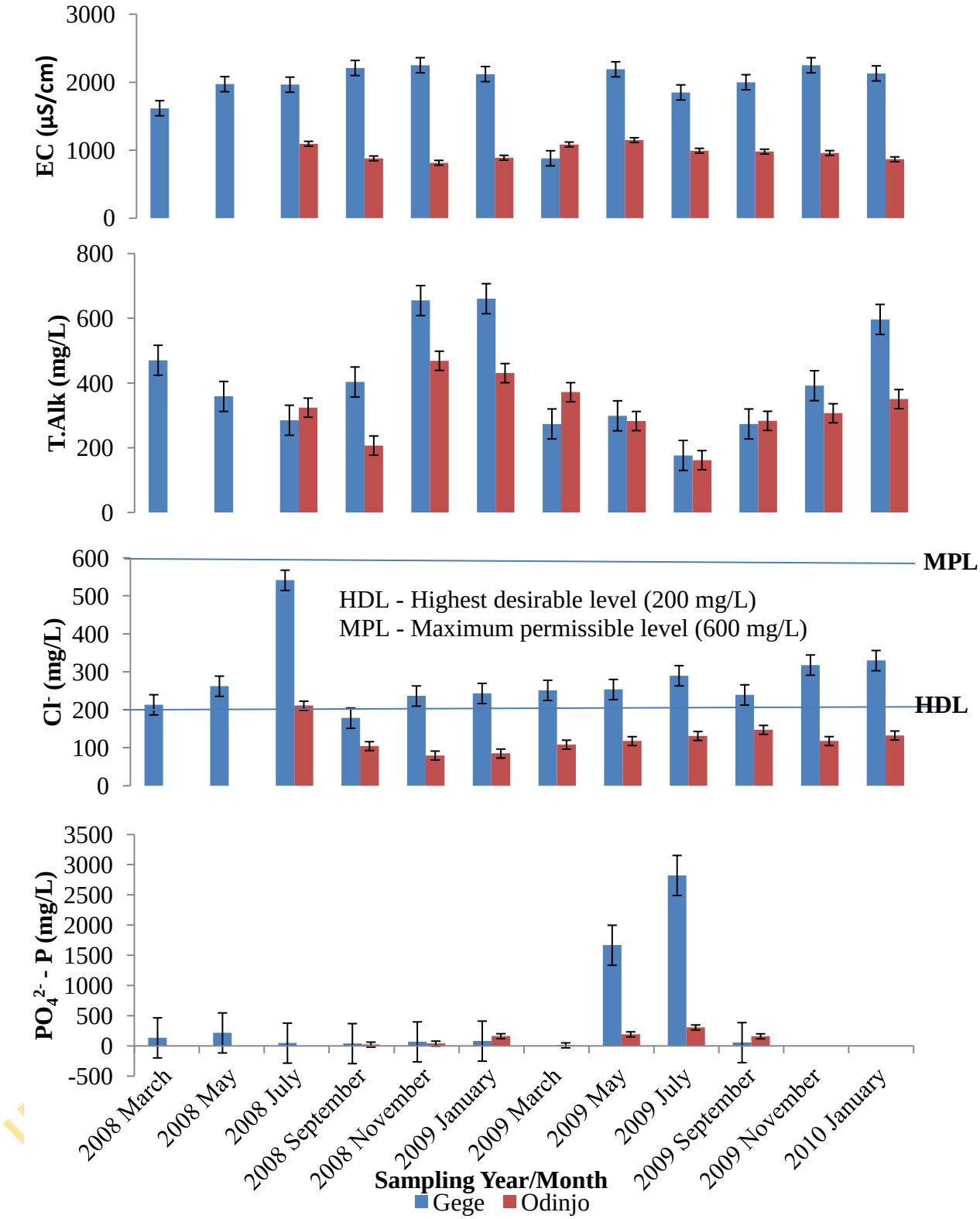
4.7.3.2 Magnesium

The bimonthly magnesium values ranged from 25.5179 to 123.2960 mg/L (42.31±9.08 mg/L) and 10.5590 to 36.4667 mg/L (23.32±4.91 mg/L) at the wells close to Gege and Odinjo streams respectively (Figure 4.38d; Appendix 44).

T-test showed that the magnesium contents of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).

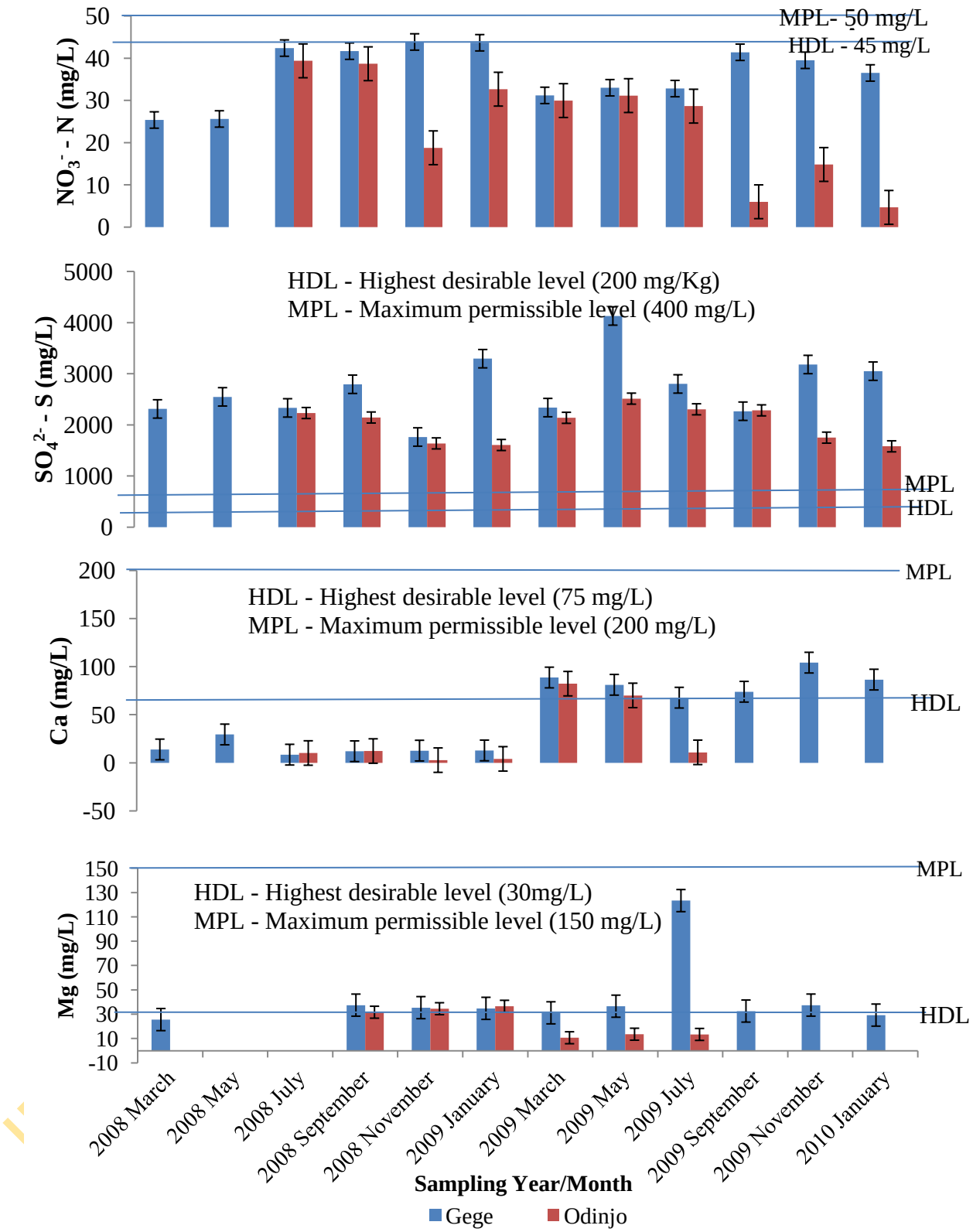
4.7.4 Bimonthly variation of trace and heavy metals of groundwater samples close to the streams

The range and mean values of trace and heavy metals of groundwater samples close to the streams are shown in Appendix 45. Details are shown in Appendices 47 and 48.



NOTE: Blank spaces indicated that the well close to the Odinjo stream was not sampled in the months of March and May, 2008 and PO_4^{2-}-P was not detected in samples from the two wells in November, 2009 and January, 2010.

Figure 4.37: Bimonthly variation of some physico-chemical characteristics and some anions of groundwater samples close to streams (a) EC (b) Total alkalinity (c) Chloride (d) Phosphate – phosphorus



NOTE: Blank spaces indicated that the well close to the Odinjo stream was not sampled in the months of March and May, 2008 and Ca and Mg were not detected in samples from the two wells in September and November, 2009 and January, 2010.

Figure 4.38: Bimonthly variation of some anions and some cations of groundwater samples close to streams (a) NO_3^- - N (b) SO_4^{2-} - S (c) Ca (d) Mg

4.7.4.1 Iron

Iron was not detected in the well water sample close to Gege stream in the month of May 2008. It was also not detected in the well water sample close to Odinjo stream in the months of July to November 2008 and January 2009 (Appendices 47 and 48).

The bimonthly ranges observed were from 0.33 to 4.37 mg/L (0.92±0.39 mg/L) and 0.30 to 6.30 mg/L (2.57±2.11 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.39a; Appendix 45).

T-test showed that the iron contents of the two wells were significantly different from each other at $P<0.05$ (Appendix 46).

4.7.4.2 Manganese

Manganese was not detected in the well water sample close to the Gege stream in the months of September 2009, November 2009 and January 2010 (Appendices 47 and 48).

The bimonthly ranges observed were from 0.04 to 0.36 mg/L (0.19±0.06 mg/L) and 0.01 to 0.21 mg/L (0.10±0.04 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.39b; Appendix 45).

T-test showed that the manganese contents of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).

4.7.4.3 Copper

Throughout the sampling period, copper was not detected in the well water sample close to the Odinjo stream. However, it was detected in the well water close to the Gege stream in the months of March, May and September 2008; and January 2009 with values of 0.2438 mg/L, 0.0710 mg/L, 0.0469 mg/L and 0.1580 mg/L respectively (Figure 4.39c; Appendices 47 and 48).

4.7.4.4 Zinc

Zinc was not detected in the groundwater sample close to Gege stream in the months of May 2008 and January 2010 (Appendices 47 and 48).

The bimonthly values observed at the groundwater sample close to the Gege stream ranged from 0.004 to 9.61 mg/L (1.38±1.05 mg/L) while that of the well close to the

Odinjo stream was from 0.004 to 4.654 mg/L (1.05±0.67 mg/L) (Figure 4.39d; Appendix 45).

T-test showed that the zinc contents of the two wells were not significantly different from each other at P<0.05 (Appendix 46).

4.7.4.5 Lead

Lead was not detected in the groundwater sample close to Gege stream in the months of March 2008; July 2008 and 2009; May 2009; September 2009; November 2009 and January 2010. It was not also detected in the groundwater sample close to Odinjo stream in the months of July 2008 and 2009; November 2008 and May 2009 (Appendices 47 and 48).

However, the bimonthly ranges observed were from 0.05 to 0.25 mg/L (0.17±0.04 mg/L) and 0.16 to 0.19 mg/L (0.17±0.01 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.40a; Appendix 45).

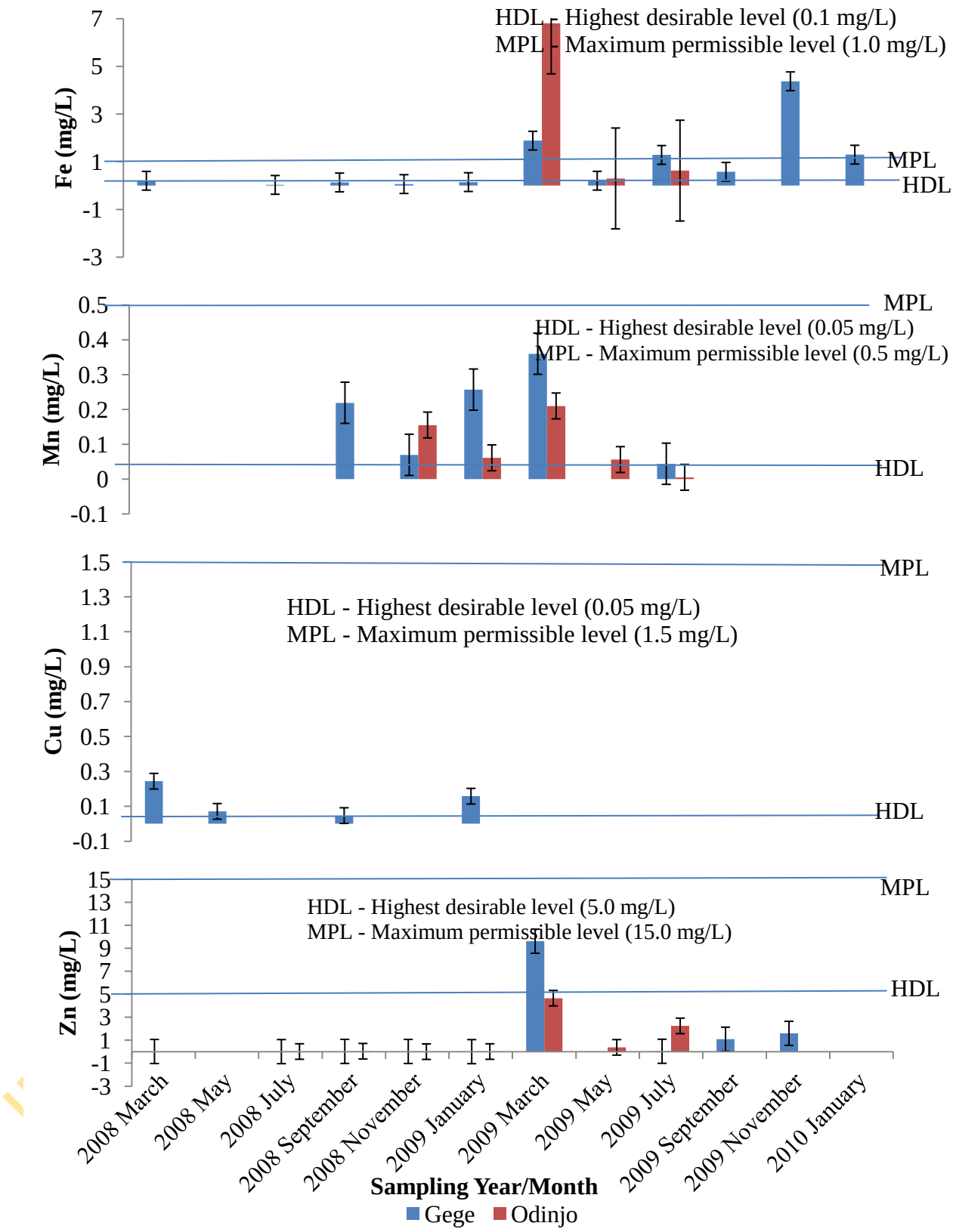
T-test showed that the lead contents of the two wells were significantly different from each other at P<0.05 (Appendix 46).

4.7.4.6 Cadmium

Cadmium was not detected in the groundwater sample close to Gege stream in the months of May 2008; July 2008 and 2009; September 2008; November 2008 and January 2009. It was not also detected in the groundwater sample close to Odinjo stream in the months of September 2008, November 2008 and January 2009. However, the bimonthly ranges observed were from 0.02 to 0.06 mg/L (0.04±0.01 mg/L) and 0.08 to 0.09 mg/L (0.08±0.004 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.40b; Appendix 45).

4.7.4.7 Nickel

Nickel was not detected in the groundwater sample close to Gege stream in the months of March 2008, July 2008, May 2009, September 2008 and 2009; November 2008 and January 2010. It was not also detected in the groundwater sample close to



NOTE: Blank spaces indicated that the well close to the Odinjo stream was not sampled in the months of March and May, 2008 and Fe, Mn, Cu and Zn were not detected in samples from the two wells.

Figure 4.39: Bimonthly variation of some trace and heavy metals of groundwater samples close to streams (a) Fe (b) Mn (c) Cu (d) Zn

Odinjo stream in the months of July 2008 and 2009; and May 2009 (Appendices 47 and 48).

However, the bimonthly nickel ranges observed were from 0.02 to 0.07 mg/L (0.04±0.02 mg/L) and 0.002 to 0.08 mg/L (0.04±0.04 mg/L) at the wells close to the Gege and Odinjo streams respectively (Figure 4.40c; Appendix 45).

T-test showed that the nickel contents of the two wells were not significantly different from each other at $P<0.05$ (Appendix 46).

4.7.4.8 Chromium

During the sampling period, chromium was detected once in each of the groundwater samples. 0.0849 mg/L was detected at the well from the Gege stream in September, 2008 while 0.0020 mg/L was detected at the well from the Odinjo stream in March, 2009 (Figure 4.40d; Appendices 47 and 48).

4.8 Result of analysis of groundwater samples around the dumpsites

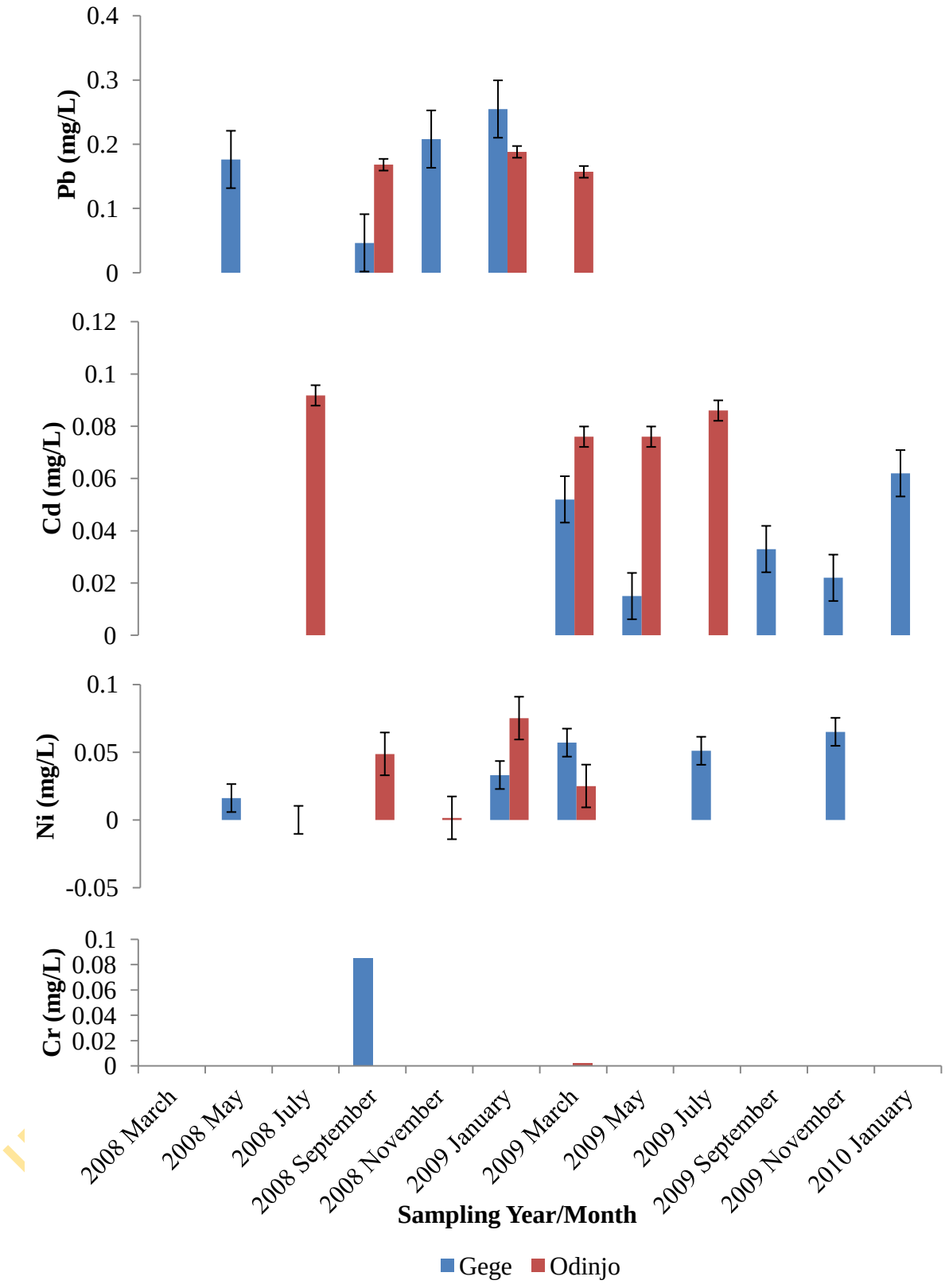
4.8.1 Bimonthly variation of physico-chemical characteristics of groundwater samples around the dumpsites

The range and mean values of the physico-chemical characteristics of groundwater samples around the dumpsites are shown in Appendix 49. Details are shown in Appendices 54 to 60.

4.8.1.1 Hydrogen ion concentration (pH)

The bimonthly values of the pH of groundwater samples around the dumpsites ranged from 6.48 to 7.35 (6.8±0.08) at the well before the Ojokondo dumpsite, 6.70 to 8.00 (7.16±0.13) at the well after the Ojokondo dumpsite, 6.30 to 7.64 (6.94±0.12) at the well close to the Olodo dumpsite, 5.19 to 6.76 (6.08±0.11) at the well close to the Moniya dumpsite, 6.14 to 7.80 (7.05±0.15) at the well close to the Idi-Ope dumpsite, 6.11 to 7.20 (6.71±0.10) at the well close to the Oremeji dumpsite and 6.63 to 7.90 (7.05±0.14) at the well at the control site (Balewa) (Figure 4.41a; Appendix 49).

One way analysis of variance showed that the pH values of the groundwater samples close to the dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that the pH of the



NOTE: Blank spaces indicated that the well close to the Odinjo stream was not sampled in the months of March and May, 2008 and Pb, Cd, Ni and Cr were not detected in samples from the two wells.

Figure 4.40: Bimonthly variation of some trace and heavy metals of groundwater samples close to streams (a) Pb (b) Cd (c) Ni (d) Cr

well close to the Moniya dump dumpsite was significantly different from the pH of all the other samples (Appendix 53).

4.8.1.2 Biochemical oxygen demand (BOD)

The bimonthly values of the biochemical oxygen demand (BOD) of groundwater samples around the dumpsites ranged from 25.03 to 67.39 mg/L (47.06±4.51 mg/L) at the well before the Ojokondo dumpsite, 32.02 to 138.89 (54.25±9.63 mg/L) at the well after the Ojokondo dumpsite, 27.14 to 60.05 mg/L (42.05±2.53 mg/L) at the well close to the Olodo dumpsite, 30.88 to 60.28 mg/L (39.38±2.67 mg/L) at the well close to the Moniya dumpsite, 18.16 to 140.62 (47.39±9.94 mg/L) at the well close to the Idi-Ope dumpsite, 31.02 to 93.36 (51.60±5.65 mg/L) at the well close to the Oremeji dumpsite and 22.21 to 74.10 (44.65±5.85) at the well at the control site (Balewa) (Figure 4.41b; Appendix 49).

One way analysis of variance showed that the biochemical oxygen demand values of the groundwater samples close to the dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.1.3 Chemical oxygen demand (COD)

The bimonthly values of the chemical oxygen demand (COD) of groundwater samples around the dumpsites ranged from 78.22 to 208.61 mg/L (147.92±12.09 mg/L) at the well before the Ojokondo dumpsite, 102.62 to 246.26 mg/L (161.21±15.18 mg/L) at the well after the Ojokondo dumpsite, 88.26 to 186.16 mg/L (137.94±7.57 mg/L) at the well close to the Olodo dumpsite, 98.62 to 217.86 mg/L (141.83±10.59 mg/L) at the well close to the Moniya dumpsite, 60.46 to 420.00 mg/L (173.44±33.40 mg/L) at the well close to the Idi-Ope dumpsite, 96.16 to 320.00 mg/L (178.13±20.55 mg/L) at the well close to the Oremeji dumpsite and 72.86 to 226.12 mg/L (134.27±15.49) at the well at the control site (Balewa) (Figure 4.41c; Appendix 49).

One way analysis of variance showed that the chemical oxygen demand of the groundwater samples close to the dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.1.4 Total dissolved solids (TDS)

The bimonthly values of the total dissolved solids (TDS) of groundwater samples around the dumpsites ranged from 260.00 to 523.00 mg/L (357.67±25.19 mg/L) at the well before the Ojokondo dumpsite, 846.00 to 1370.00 mg/L (1104.17±62.78 mg/L) at the well after the Ojokondo dumpsite, 102.00 to 1015.00 mg/L (334.50±67.60 mg/L) at the well close to the Olodo dumpsite, 96.00 to 1177.00 mg/L (264.17±84.53 mg/L) at the well close to the Moniya dumpsite, 167.00 to 1004.00 mg/L (284.50±66.34 mg/L) at the well close to the Idi-Ope dumpsite, 153.00 to 1123.00 mg/L (688.50±75.16 mg/L) at the well close to the Oremeji dumpsite and 53.80 to 280.00 mg/L (191.08±21.01 mg/L) at the well at the control site (Balewa) (Figure 4.41d; Appendix 49).

One way analysis of variance showed that the groundwater samples around the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that the total dissolved solids of the well after the Ojokondo dumpsite and the well close to the Oremeji dumpsite were significantly different from the total dissolved solids of all the other samples. They were also different from each other at $P<0.05$ (Appendix 53).

4.8.1.5 Electrical conductivity (EC)

The bimonthly values of the electrical conductivity (EC) of groundwater samples around the dumpsites ranged from 516.00 to 873.00 µS/cm (650.25±29.06 µS/cm) at the well before the Ojokondo dumpsite, 1510.00 to 2380.00 (2030.00±90.33 µS/cm) at the well after the Ojokondo dumpsite, 255.00 to 1693.00 µS/cm (597.08±107.94 µS/cm) at the well close to the Olodo dumpsite, 197.50 to 1963.00 µS/cm (467.88±137.80 µS/cm) at the well close to the Moniya dumpsite, 325.00 to 1674.00 µS/cm (510.42±106.50 µS/cm) at the well close to the Idi-Ope dumpsite, 255.00 to 1870.00 µS/cm (1271.50±130.16 µS/cm) at the well close to the Oremeji dumpsite and 89.70 to 468.00 (348.77±38.32 µS/cm) at the well at the control site (Balewa), (Figure 4.42a; Appendix 49).

One way analysis of variance of electrical conductivity showed that the samples from the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests showed the same trend with total dissolved solids of the samples (Appendix 53).

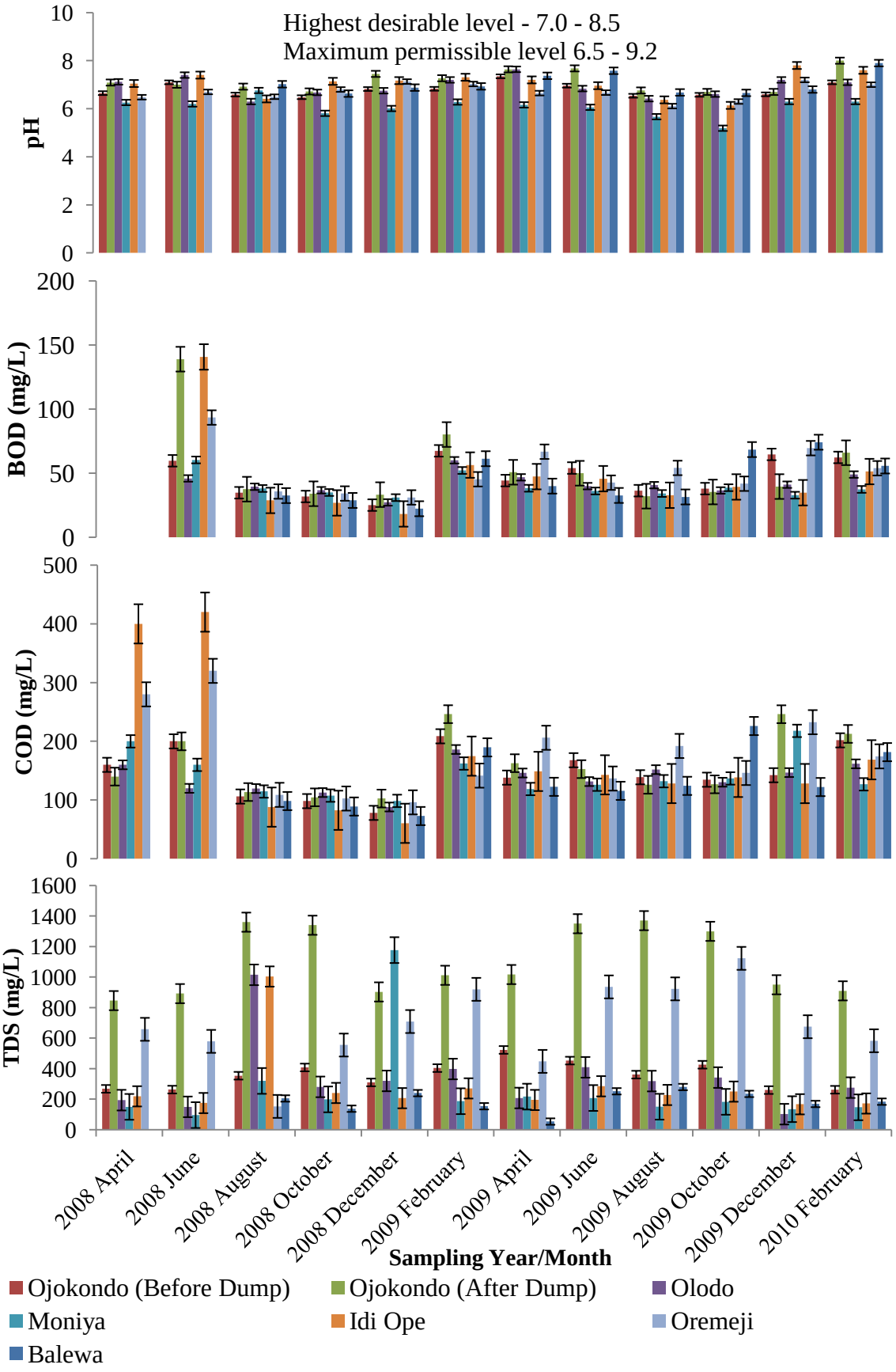


Figure 4.41: Bimonthly variation of physico-chemical characteristics of groundwater samples close to dumpsites (a) pH (b) BOD (c) COD (d) TDS

4.8.1.6 Total alkalinity

The bimonthly values of the total alkalinity of groundwater samples from dumpsites ranged from 85.05 to 344.75 mg/L (203.30±19.64 mg/L) at the well before the Ojokondo dumpsite, 233.28 to 558.50 mg/L (400.92±26.98 mg/L) at the well after the Ojokondo dumpsite, 113.80 to 317.17 mg/L (190.67±19.85 mg/L) at the well close to the Olodo dumpsite, 25.92 to 218.30 mg/L (84.16±14.44 mg/L) at the well close to the Moniya dumpsite 81.00 to 265.50 mg/L (163.88±18.10 mg/L) at the well close to the Idi-Ope dumpsite, 193.60 to 589.50 mg/L (353.64±39.06 mg/L) at the well close to the Oremeji dumpsite and 91.80 to 258.56 mg/L (171.42±15.79 mg/L) at the well at the control site (Balewa) (Figure 4.42b; Appendix 49).

One way analysis of variance showed that the total alkalinity values of the groundwater samples from the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests showed that the total alkalinity values observed at the well close to the Moniya dumpsite was significantly different from all other samples (Appendix 53).

4.8.2 Bimonthly variation of anions of groundwater samples from the dumpsites

The range and mean values of the anions of groundwater samples around the dumpsites are shown in Appendix 50. Details are shown in Appendices 54 to 60.

4.8.2.1 Chloride

The bimonthly values of the chloride contents of groundwater samples from dumpsites ranged from 34.40 to 101.26 mg/L (66.86±5.92 mg/L) at the well before the Ojokondo dumpsite, 105.51 to 471.83 mg/L (287.77±29.75 mg/L) at the well after the Ojokondo dumpsite, 30.56 to 84.02 mg/L (55.48±4.39 mg/L) at the well close to the Olodo dumpsite, 18.35 to 60.85 mg/L (37.74±4.36 mg/L) at the well close to the Moniya dumpsite, 29.54 to 56.02 mg/L (38.78±2.15 mg/L) at the well close to the Idi-Ope dumpsite, 90.88 to 261.87 mg/L (156.57±16.59 mg/L) at the well close to the Oremeji dumpsite and 16.13 to 47.81 mg/L (32.80±3.32 mg/L) at the well at the control site (Balewa) (Figure 4.42c; Appendix 49).

One way analysis of variance showed that the samples from the various dumpsites were significantly different from one another at P<0.05 (Appendix 52). Duncan's multiple range tests showed that the chloride content observed at the well after the Ojokondo dumpsite and the well close to the Oremeji dumpsite were significantly different from the chloride contents of all the other samples. They were also significantly different from each other at P<0.05 (Appendix 53).

4.8.2.2 Phosphate-phosphorus

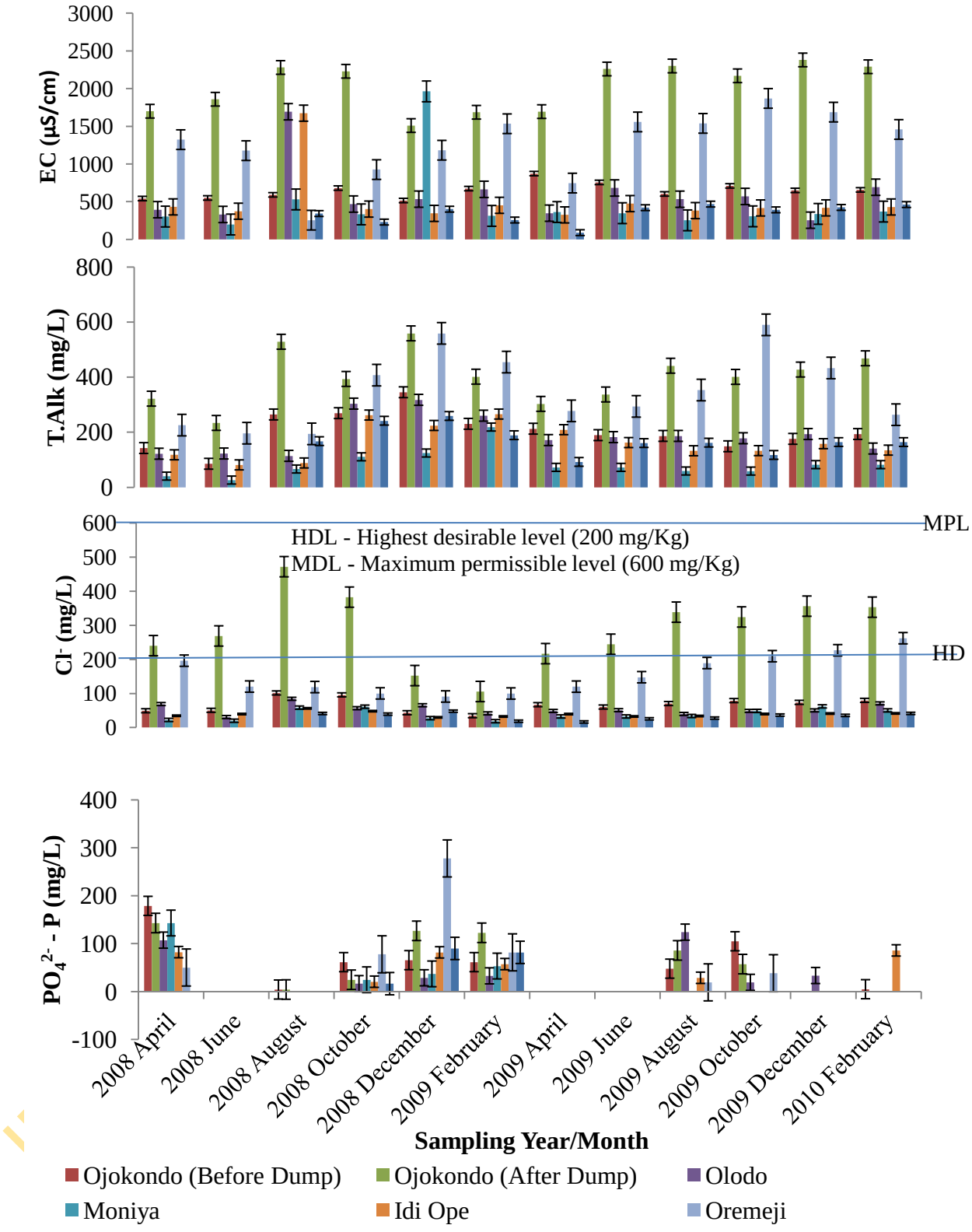
During the sampling months of June 2008, April 2009 and June 2009, phosphate-phosphorus was not detected in all groundwater samples. In August 2008, it was detected at the wells before and after the Ojokondo dumpsite with same value of 4.08 mg/L. In August 2009, phosphate-phosphorus was not detected at the well at the control site and the well at the Moniya dumpsite; the same occurrence was observed in October 2009 with the non-detection at the Idi Ope well inclusive. In December 2009, it was not observed in all groundwater samples except that of Olodo well with a value of 33.33 mg/L. In February 2010, it was observed at the Idi Ope well and the well before the Ojokondo dumpsite with the values of 85.71 mg/L and 4.76 mg/L respectively (Figure 4.42d; Appendix 49).

One way analysis of variance showed that the samples from the various dumpsites were not significantly different from one another at P<0.05 (Appendix 52).

4.8.2.3 Nitrate-nitrogen

During the sampling period in October 2009, nitrate-nitrogen was not detected at the wells at the Idi Ope, Oremeji and control site. In December 2009, it was not also detected at the wells before the Ojokondo dumpsite, Idi Ope dumpsite and the control site (Figure 4.41a; Appendices 54 to 60).

The bimonthly values observed ranged from 3.2 to 38.38 mg/L (27.99±3.19 mg/L), 21.17 to 42.09 mg/L (33.64±1.88 mg/L), 13.42 to 42.03 mg/L (25.10±2.32 mg/L), 20.50 to 42.42 mg/L (31.25±2.12 mg/L), 8.46 to 25.6 mg/L (16.12±1.82 mg/L), 11.84 to 38.07 mg/L (23.70±2.30 mg/L) and 4.14 to 25.11 mg/L (19.22±2.89 mg/L) at the wells before the Ojokondo dumpsite, after the Ojokondo dumpsite, close to the Olodo dumpsite, close to the Moniya dumpsite, close to the Idi Ope dumpsite, close to the Oremeji dumpsite and at the control site (Figure 4.43a).



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that phosphate-phosphorus was not detected in the samples.

Figure 4.42: Bimonthly variation of some physico-chemical characteristics and some anions of groundwater samples close to streams (a) EC (b) Total alkalinity (c) Chloride (d) Phosphate - phosphorus

One way analysis of variance showed that the nitrate-nitrogen contents of the samples from the various dumpsites were significantly different from one another at P<0.05 (Appendix 52). Duncan's multiple range tests showed that the nitrate - nitrogen content observed at the well close to the Idi-Ope dumpsite and the well at the control site were significantly different from those of all the other samples but they were not different from each other at P<0.05 (Appendix 53).

4.8.2.4 Sulphate-sulphur

In October 2008 and December 2009, sulphate-sulphur was not detected at the well close to the Moniya dumpsite (Appendix 57). The bimonthly values ranged from 1425.00 to 3195.83 mg/L (2240.21±179.07 mg/L) at the well before the Ojokondo dumpsite, 1216.67 to 4016.67 mg/L (2540.44±276.97 mg/L) at the well after the Ojokondo dumpsite, 656.30 to 1756.25 mg/L (1130.20±113.86 mg/L) at the well close to the Olodo dumpsite, 25.00 to 608.33 mg/L (212.71±57.28 mg/L) at the well close to the Moniya dumpsite, 987.50 to 2690.00 mg/L (1772.16±138.74 mg/L) at the well close to the Idi-Ope dumpsite, 706.25 to 5431.82 mg/L (2989.84±395.59 mg/L) at the well close to the Oremeji dumpsite and 704.17 to 4110.00 mg/L (1929.63±319.88 mg/L) at the well at the control site (Balewa) (Figure 4.43b; Appendix 50).

One way analysis of variance showed that the groundwater samples close to the various dumpsites were significantly different from one another at P<0.05 (Appendix 52). Duncan's multiple range tests also showed that the sulphate – sulphur of the well close to the Moniya dumpsite was significantly different from the sulphate – sulphur of all the other samples (Appendix 53).

4.8.3 Bimonthly variation of cations of groundwater samples close to the dumpsites

The range and mean values of the cations of groundwater samples from the dumpsites are shown in Appendix 50. Details are shown in Appendices 54 to 60.

4.8.3.1 Calcium

In June, August and December 2008, calcium was not detected at the well close to the Moniya dumpsite. So also in December 2008 and February 2009, it was not detected

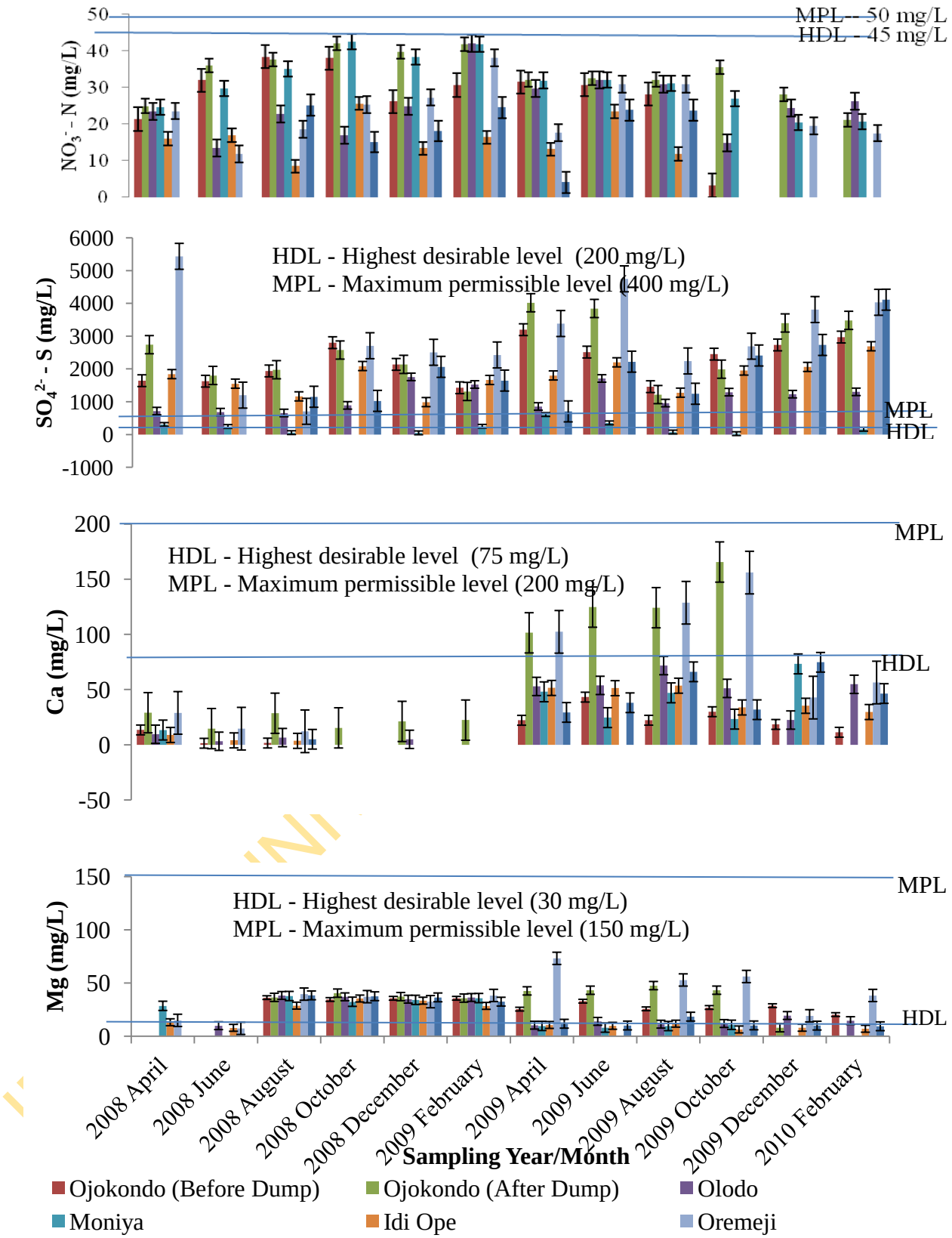
at the wells before the Ojokondo dumpsite and at the control site (Balewa) (Figure 4.43c; Appendices 54, 57 and 60). The bimonthly values ranged from 1.38 to 43.16 mg/L (18.18±4.41 mg/L) at the well before the Ojokondo dumpsite, 14.64 to 165.56 mg/L (64.70±18.22 mg/L) at the well after the Ojokondo dumpsite, 3.18 to 71.4 mg/L (33.08±8.28 mg/L) at the well close to the Olodo dumpsite, 13.36 to 73.27 mg/L (38.25±9.00 mg/L) at the well close to the Moniya dumpsite, 3.57 to 53.53 mg/L (30.17±6.80 mg/L) at the well close to the Idi-Ope dumpsite, 12.22 to 155.99 mg/L (67.73±19.30 mg/L) at the well close to the Oremeji dumpsite and 5.01 to 74.74 mg/L (41.64±8.89 mg/L) at the well at the control site (Balewa) (Figure 4.43c; Appendix 50).

One way analysis of variance showed that the calcium contents of the samples close to the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that the calcium content of the well before the Ojokondo dumpsite and the well at the Oremeji dumpsite were significantly different from each other but not different from the other samples (Appendix 53).

4.8.3.2 Magnesium

The bimonthly values of magnesium contents of groundwater samples close to the dumpsites ranged from 20.30 to 36.24 mg/L (30.19±1.75 mg/L) at the well before the Ojokondo dumpsite, 35.78 to 47.51 mg/L (40.79±1.44 mg/L) at the well after the Ojokondo dumpsite, 7.97 to 38.26 mg/L (20.58±3.87 mg/L) at the well close to the Olodo dumpsite, 8.08 to 37.74 mg/L (22.60±3.90 mg/L) at the well close to the Moniya dumpsite, 6.32 to 35.37 mg/L (16.69±3.24 mg/L) at the well close to the Idi-Ope dumpsite, 7.36 to 73.10 mg/L (37.18±5.75 mg/L) at the well close to the Oremeji dumpsite and 9.34 to 38.35 mg/L (21.43±4.12 mg/L) at the well at the control site (Balewa) (Figure 4.43d; Appendix 50).

One way analysis of variance showed that the magnesium contents of the samples from the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that the magnesium contents of the wells before the Ojokondo dumpsite, after the Ojokondo dumpsite and close to the Oremeji dumpsite were significantly different from other samples but not significantly different from one another at $P<0.05$ (Appendix 53).



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that Ca and Mg were not detected in the samples.

Figure 4.43: Bimonthly variation of some anions and some cations of groundwater samples close to dumpsites (a) NO_3^- - N (b) SO_4^{2-} - S (c) Ca (d) Mg

4.8.4 Bimonthly variations of trace and heavy of groundwater samples close to the dumpsites

The range and mean values of the trace and heavy metals of groundwater samples from the dumpsites are shown in Appendix 51. Details are shown in Appendices 54 to 60.

4.8.4.1 Iron

In April 2008, iron was not detected in all groundwater samples. In June 2008, it was not also detected in all groundwater samples except the one close to the Oremeji dumpsite with a value of 0.3727 mg/L. In August and October 2008, iron was not detected at the wells close to the Moniya dumpsite and the one close to the Olodo dumpsite. In December 2008, it was not detected in the groundwater close to the Idi Ope dumpsite (Figure 4.44a; Appendices 54 to 60).

One way analysis of variance showed that the iron content in the groundwater samples from the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.4.2 Manganese

Manganese was not detected in the groundwater sample after the Ojokondo dumpsite in October 2008. It was not also detected in the groundwater sample at the control site in April and June 2009 (Figure 4.44b; Appendices 55 and 60). The bimonthly values of manganese contents of groundwater samples close to the dumpsites ranged from 0.02 to 1.32 mg/L (0.38±0.14 mg/L) at the well before the Ojokondo dumpsite, 0.15 to 2.00 mg/L (0.52±0.25 mg/L) at the well after the Ojokondo dumpsite, 0.07 to 0.33 mg/L (0.20±0.03 mg/L) at the well close to the Olodo dumpsite, 0.02 to 1.27 mg/L (0.23±0.15 mg/L) at the well close to the Moniya dumpsite, 0.08 to 0.43 mg/L (0.28±0.05 mg/L) at the well close to the Idi-Ope dumpsite, 0.13 to 11.98 mg/L (2.48±1.24 mg/L) at the well close to the Oremeji dumpsite and 0.06 to 0.25 mg/L (0.18±0.04 mg/L) at the well at the control site (Balewa) (Figure 4.44b; Appendices 54 to 60).

One way analysis of variance showed that the manganese contents of the groundwater samples close to the various dumpsites were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that the

manganese contents of the well close to the Oremeji dumpsite was significantly different from those of all the other samples (Appendix 53).

4.8.4.3 Copper

In April 2008, copper was not detected in all groundwater samples except the one before the Ojokondo dumpsite and the one close to the Idi Ope dumpsite with values of 0.099 mg/L and 0.062 mg/L respectively. In June 2008 it was not detected in the groundwater samples before and after the Ojokondo dumpsite and also the well close to the Olodo dumpsite. In August 2008, it was not detected in the samples from the well close to the Idi Ope dumpsite and the well close to the Oremeji dumpsite. In October 2008, it was not detected in the sample from the control well (Balewa) and the well close to the Oremeji dumpsite. In December 2008, it was not detected in the samples from the well after the Ojokondo dumpsite, the well close to the Moniya dumpsite and the well close to the Idi Ope dumpsite (Figure 4.44c; Appendices 54 to 60).

In February 2009, copper was detected in all groundwater samples except from the control site (Balewa). However, in April 2009, it was not detected in all groundwater samples. In June 2009, it was detected only in the samples from the well before the Ojokondo dumpsite and the one close to the Oremeji dumpsite with values of 0.026 mg/L and 0.097 mg/L respectively. In August 2009, it was detected only in the samples from the Moniya well and the Oremeji well with values of 0.002 mg/L and 0.007 mg/L respectively. In October 2009, it was only detected in the sample from the well before the Ojokondo dumpsite with a value of 0.019 mg/L. In December, it was detected at the Moniya well with a value of 0.075 mg/L and lastly, in February 2010, it was detected at the Olodo well with a value of 0.009 mg/L (Figure 4.44c; Appendices 54 to 60).

One way analysis of variance showed that the copper content in the samples from the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.4.4 Zinc

Zinc was not detected in all groundwater samples in the month of April 2008. In June 2008 it was not also detected in all samples except at the well after the Ojokondo

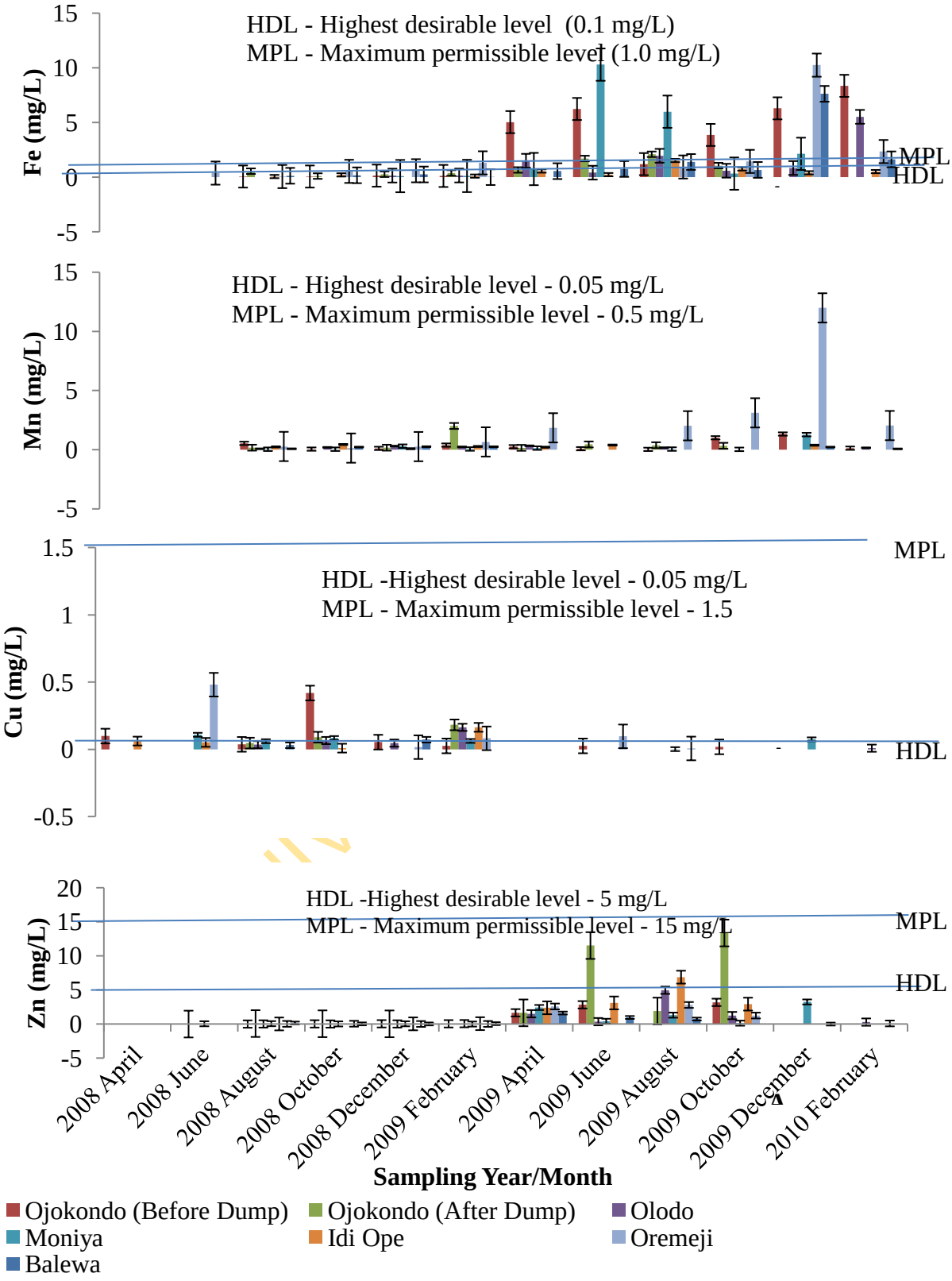
dumpsite and the well close to the Moniya dumpsite with the values of 0.0002 mg/L and 0.0475 mg/L respectively. In October 2008, February 2009, August 2009 and October 2009, zinc was not detected at the Idi Ope well, the well after the Ojokondo dumpsite, the well before the Ojokondo dumpsite and the well at the control site (Balewa) respectively. In December 2009, it was not detected in all samples except that from the control site (Balewa) and the well close to the Moniya dumpsite with values of 0.0020 mg/L and 3.246 mg/L respectively. In addition, in February 2010, zinc was not detected in all samples except from the wells close to the Oremeji and Olodo dumpsites with the values of 0.0960 mg/L and 0.2920 mg/L respectively (Figure 4.44d; Appendices 54 to 60).

One way analysis of variance showed that the zinc contents of the samples from the various wells were significantly different from one another at $P<0.05$ (Appendix 52). Duncan's multiple range tests also showed that zinc contents of the well after the Ojokondo dumpsite and the well at the Idi Ope dumpsite were significantly different from the zinc contents of all the other samples but not significantly different from each other (Appendix 53).

4.8.4.5 Lead

Lead was not detected in all groundwater samples in April and June 2008 except at the ones close to the Olodo and Moniya dumpsites respectively with values of 0.1960 mg/L and 0.2625 mg/L respectively. In October 2008, it was only in the sample from the well close to the Idi Ope dumpsites that lead was not detected (Appendices 56 to 58).

In April 2009, lead was not detected in all groundwater samples except those close to the Oremeji and Moniya dumpsites with values of 0.2100 mg/L and 0.2010 mg/L respectively. Furthermore, in June 2009, lead was detected in the well after the Ojokondo dumpsite, and the wells close to Idi Ope and Oremeji dumpsites with values of 0.0590 mg/L, 0.0200 mg/L and 0.2480 mg/L respectively. In addition, in August 2009, lead was discovered in the well after the Ojokondo dumpsite – 0.0340 mg/L; the well close to the Moniya dumpsite – 0.1990 mg/L; and the well close to the Oremeji dumpsite – 0.0950 mg/L. In October 2009, it was detected in the well before the Ojokondo dumpsite – 0.0030 mg/L, the well after the Ojokondo dumpsite – 0.0010 mg/L and the well close to the Oremeji dumpsite – 0.0930 mg/L. In December



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that Fe, Mn, Cu and Zn were not detected in the samples.

Figure 4.44: Bimonthly variation of some trace and heavy metals of groundwater samples close to dumpsites (a) Fe (b) Mn (c) Cu (d) Zn

2008 and February 2010, lead was detected in the groundwater samples from the control site (Balewa) and Olodo dumpsite respectively with values of 0.1490 mg/L and 0.1990 mg/L respectively (Figure 4.45a; Appendices 54 to 60).

One way analysis of variance showed that the lead contents in the wells close to the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.4.6 Cadmium

Cadmium was not detected in the sample from the well close to the Idi Ope dumpsite in April 2008. In June 2008, it was not detected in the groundwater samples close to the Olodo, Moniya and Oremeji dumpsites. In August 2008, it was detected in the groundwater sample from the Oremeji dumpsite with a value of 0.0147 mg/L. In October 2008, December 2008 and February 2009, cadmium was not detected in all groundwater samples (Figure 4.45b; Appendices 54 to 60).

In April 2009, cadmium was not detected in the sample from the well before the Ojokondo dumpsite and the well close to the Olodo dumpsite. In December 2009 and February 2010, it was not detected in the well close to the Idi Ope dumpsite and the well after the Ojokondo dumpsite respectively (Figure 4.45b; Appendices 54 to 60).

The bimonthly values of cadmium contents of groundwater samples close to the dumpsites ranged from 0.002 to 0.04 mg/L (0.02±0.01 mg/L) at the well before the Ojokondo dumpsite, 0.006 to 0.07 mg/L (0.04±0.01 mg/L) at the well after the Ojokondo dumpsite, 0.002 to 0.07 mg/L (0.04±0.01 mg/L) at the well close to the Olodo dumpsite, 0.004 to 0.04 mg/L (0.02±0.01 mg/L) at the well close to the Moniya dumpsite, 0.001 to 0.07 mg/L (0.03±0.01 mg/L) at the well close to the Idi-Ope dumpsite, 0.002 to 0.06 mg/L (0.02±0.01 mg/L) at the well close to the Oremeji dumpsite and 0.004 to 0.07 mg/L (0.03±0.01 mg/L) at the well at the control site (Balewa) (Figure 4.45b; Appendices 54 to 60).

One way analysis of variance showed that the cadmium contents in the samples from the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.4.7 Nickel

Nickel was not detected in all groundwater samples in June 2008. In August 2008, it was not detected in the sample from the control site (Balewa). In October 2008, it was not detected in the samples from the well after the Ojokondo dumpsite and the well close to the Oremeji dumpsite. Furthermore, in April 2009, it was not detected in the samples from the wells close to the Olodo and at the control site. In June 2009, it was not detected in the samples from the Moniya and control site wells. In addition, in August 2009, it was not detected in samples from the well before the Ojokondo dumpsite, Idi Ope well and the control site (Figure 4.45c; Appendices 54 to 60).

In October 2009, nickel was detected in the sample from the well after the Ojokondo dumpsite and the Oremeji well with values of 0.0590 mg/L and 0.0420 mg/L respectively. In December 2009, it was not detected in samples from the well before the Ojokondo dumpsite, the well at the Olodo dumpsite and the Idi Ope well. However, nickel was detected in February 2010 in the samples from the Idi Ope well and the control site with values of 0.0550 mg/L and 0.0590 mg/L respectively (Figure 4.45c; Appendices 54 to 60).

One way analysis of variance showed that the nickel contents in the wells close to the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.8.4.8 Chromium

Chromium was not detected in all samples in the months of October 2008, October 2009, December 2009 and February 2010 (Figure 4.45d; Appendices 54 to 60).

In June 2008, chromium was not detected in the samples from the Olodo, Moniya and Oremeji wells. In December 2008, it was detected in the sample from the control site with a value of 0.1292 mg/L. Furthermore, in February 2009, it was still detected in the sample from the well before the Ojokondo dumpsite and also the control site with values of 0.1369 mg/L and 0.1445 mg/L respectively. In addition, in April 2009, June 2009 and August 2009, chromium was detected in the samples from Moniya well – 0.0320 mg/L, Oremeji well – 0.0190 mg/L and Moniya well – 0.1100 mg/L respectively (Figure 4.45d; Appendices 54 to 60).

One way analysis of variance showed that the chromium contents in the samples from wells close to the various dumpsites were not significantly different from one another at $P<0.05$ (Appendix 52).

4.9 Toxicity assays

4.9.1 Earthworms' toxicity assay

4.9.1.1 Streams

The result of the *Eudrilus euginiae* earthworms exposed to the soil from the streams' banks is presented in Figure 4.46a and Appendix 61.

The result of the earthworms' toxicity test of the soil from the streams indicated that throughout the 96 hours, there was no mortality observed in the soils from Omi Adio stream and the control site (Awba stream) (that is, 0 % mortality).

Mortality of earthworms increased with duration of exposure. During the first 24 hours, no mortality (0 %) was observed in the soil from the Irefin stream, at 48 hours 6.67 % mortality was recorded, at 72 hours 20 % mortality was recorded, and at 96 hours, 30 % mortality was recorded.

The earthworms exposed to the Gege soil had 10 % mortality during the first 24 hours, 13.33 % at 48 hours, 13.33 % mortality still maintained at 72 hours, while there was 30 % mortality at 96 hours.

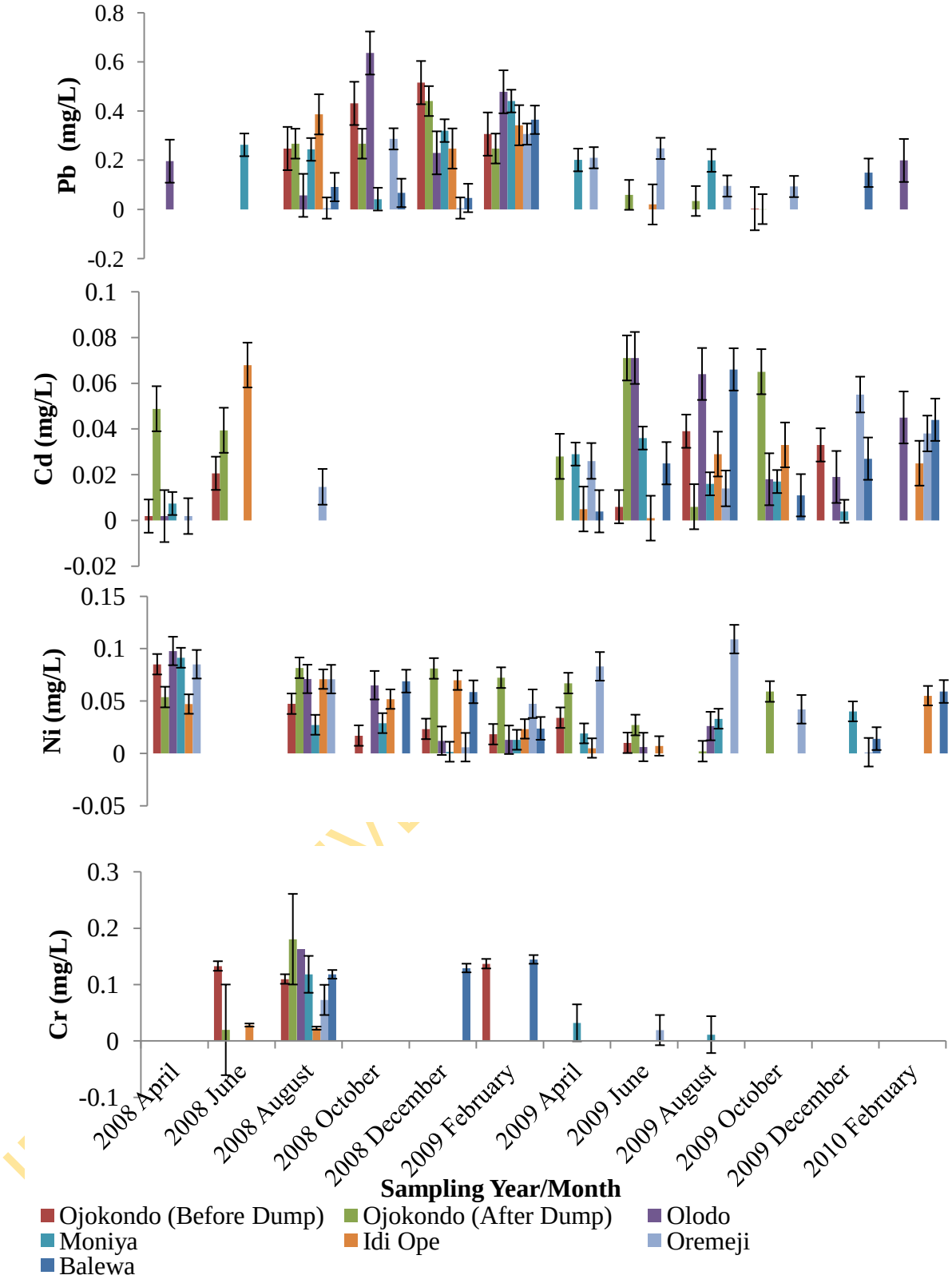
The result of the toxicity assay of earthworms exposed to the Gbagi soil indicated that 13.33 % mortality was recorded at 24 hours, 33.33 % at 48 hours, and 43.33 % at both 72 and 96 hours.

Mortality of earthworms exposed to Odinjo soil indicated that 13.33 % mortality was observed at both 24 and 48 hours, it increased to 20 % at 72 hours and 33.33 % at 96 hours.

4.9.1.2 Dumpsites

The result of the *Eudrilus euginiae* earthworms exposed to the soil from the dumpsites is presented in Figure 4.46b and Appendix 62.

The result of the earthworms' toxicity test of the soil from the dumpsites indicated that throughout the 96 hours, there was no mortality observed in the soils from the Moniya dumpsite and the control site (Balewa). In all the other soil samples, mortality



NOTE: Blank spaces indicated that the control site (Tafawa Balewa Hall) was not sampled in the months of April and June, 2008. Other blank spaces indicated that Pb, Cd, Ni and Cr were not detected in the samples.

Figure 4.45: Bimonthly variation of some trace and heavy metals of groundwater samples close to dumpsites (a) Pb (b) Cd (c) Ni (d) Cr

increased with duration of exposure. Highest mortality was observed in the earthworms exposed to the Ojokondo dumpsite. At 24 hours, 50 % mortality was recorded. It increased to 66.67 % at 48 hours, 73.33 % at 72 hours and 76.67 % at 96 hours.

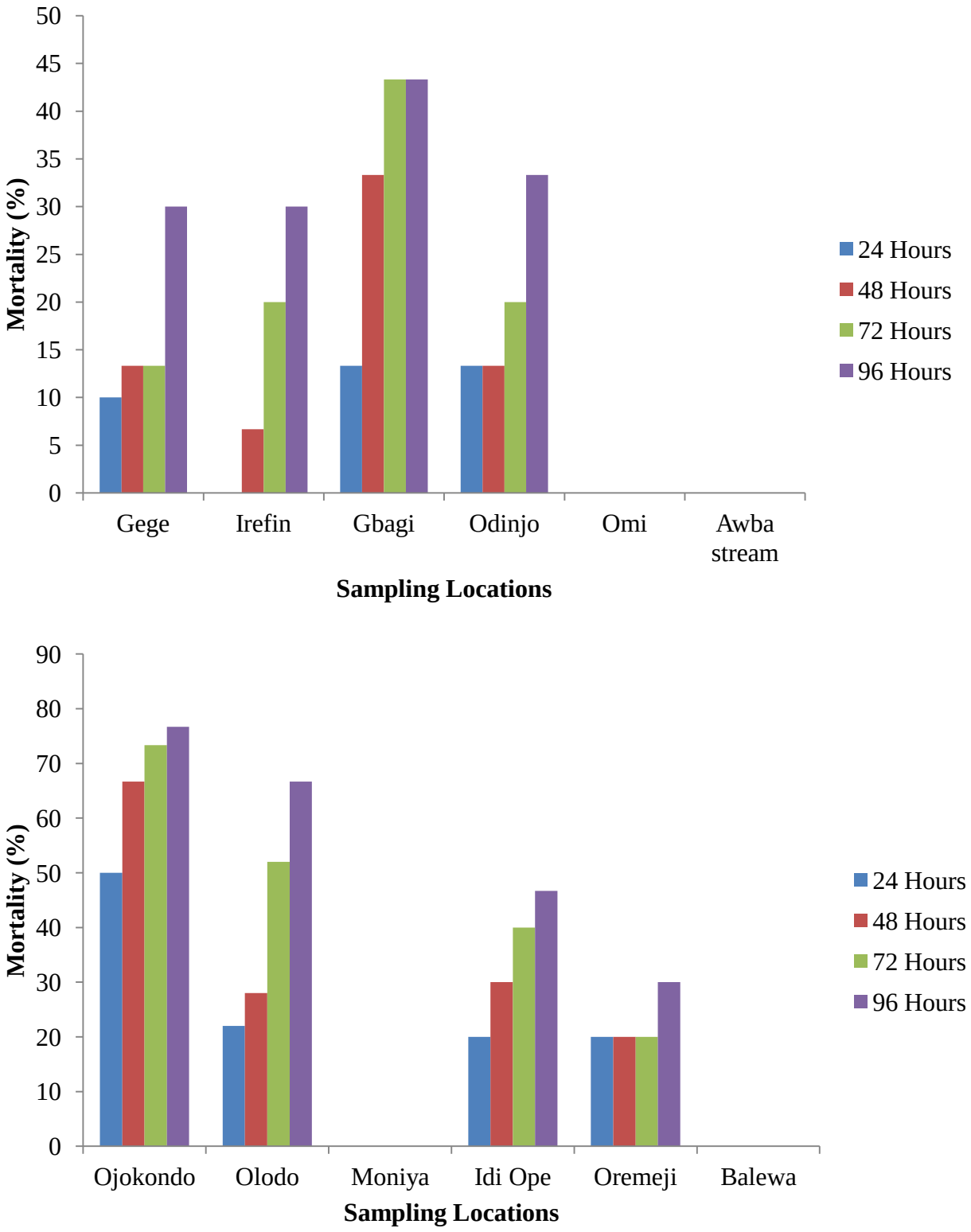
Earthworms exposed to the soil from the Olodo dumpsite showed 22 % mortality at 24 hours, 28 % at 48 hours, 52 % at 72 hours, and 66.67 % at 96 hours.

The result of mortality observed in the earthworms exposed to the Idi Ope dumpsite indicated 20 %, 30 %, 40 % and 46.67 % mortalities at 24, 48, 72 and 96 hours respectively.

Earthworms exposed to the soil from the Oremeji dumpsite maintained 20 % mortality form 24 hours to 72 hours, 30 % mortality was observed at 72 hours.

4.9.2 Mayflies toxicity assay

Mayflies' mortality occurred in all test chambers except the control. The mortality was concentration-dependent. At 24 hours, the number of mortalities of mayflies exposed to 1.56 %, 3.125 %, 6.25 %, 12.5 %, 25 % and 50 % concentrations of Irefin stream were 0, 4, 8, 10, 14 and 30 respectively, while at 48 hours, the number of mortalities were 2, 6, 12, 18, 22 and 40 respectively. For 1.56 %, 3.125 %, 6.25 %, 12.5 %, 25 % and 50 % concentrations of Gege stream, the number of mortalities at 24 hours were 0, 2, 6, 16, 30 and 34 respectively, while at 48 hours the number of mortalities were 4, 6, 12, 24, 34 and 40 respectively. For 1.56 %, 3.125 %, 6.25 %, 12.5 %, 25 % and 50 % concentrations of Gbagi stream, the number of mortalities at 24 hours were 0, 0, 2, 4, 8 and 8 respectively, while at 48 hours, the number of mortalities were 2, 4, 4, 10, 12 and 18 respectively. At 24 hours, 4 mortalities each were recorded for 1.56 %, 3.125 %, 6.25 % and 12.5 % concentrations of Odinjo stream while 10 and 12 mortalities were recorded for 25 % and 50 % concentrations respectively; For 48 hours, 6, 4, 8, 10, 12 and 30 mortalities were recorded for 1.56 %, 3.125 %, 6.25 %, 12.5 %, 25 % and 50 % concentrations respectively. At 24 hours, the number of mortalities of mayflies exposed to 1.56 %, 3.125 %, 6.25 %, 12.5 %, 25 % and 50 % concentrations of Omi Adio stream were 6, 8, 8, 12, 14 and 16 respectively, while at 48 hours, the number of mortalities were 8, 8, 10, 14, 18 and 20 respectively. No mortality was recorded for 1.56 % and 3.125 % concentrations of Awba stream, 6.25 % and 12.5 % concentrations had 2 mortalities each, while 25 %



NOTE: Blank spaces indicated that no mortality was observed in the soil from Omi Adio, Awba stream, Moniya and Balewa

Figure 4.46
a): Effect of dumpsites' soil on *eudrilus euginiae* survival
b): Effect of streams' soil on *eudrilus euginiae* survival

and 50 % concentrations had 4 and 6 mortalities respectively; at 48 hours the number of mortalities were 4, 6, 10, 12, 12 and 14 respectively (Figure 4.47; Appendix 63a).

The 48hour LC_{50} values of the stream-water samples obtained using Probit method were 12.67 %, 8.63 %, 72.13 %, 33.32 %, 49.55 % and 181.07 % for Irefin, Gege, Gbagi, Odinjo, Omi Adio and Awba streams respectively (Appendix 63b).

4.9.3 Tadpoles bioassay

There was no death of tadpoles exposed to varying concentrations of stream water from Gbagi, Odinjo, Omi Adio and Awba. However, mortalities that occurred in Irefin and Gege stream water exposure to tadpoles were concentration-dependent. It was only at 100 % concentration of Irefin stream water that tadpoles' mortality occurred; At 24 hours exposure, 10 mortalities occurred while 11 mortalities were maintained from 48 hours to 96 hours. Tadpoles exposed to Gege stream had mortalities at 50 % and 100 % concentrations. The mortalities recorded at 24 hours, 48 hours, 72 hours and 96 hours of 50 % concentration were 11, 11, 13, 18 respectively. At 100 % concentration, all the tapoles died (Table 4.5). The 96 hour LC_{50} of Gege stream water using Probit method was 53.59 % with 95% lower and higher confidence limits of 47.34 % and 60.66 % respectively (Appendix 64).

4.9.4 Fish toxicity assay

4.9.4.1 *Clarias gariepinus* frys toxicity assay

Clarias gariepinus frys mortality occurred in all test chambers except the control. The mortality was concentration-dependent. For the frys exposed to the Irefin stream water: 36 mortalities were recorded in 6.25 % concentration from 24 hours to 72 hours, while it was 37 at 96 hours; 37 mortalities were recorded in 12.5 % concentration from 24 hours to 72 hours, while it was 39 at 96 hours; for 25 % concentration, 38 mortalities were recorded at 24 hours to 72 hours, while 39 was recorded at 96 hours; for 50 %concentration, 39 mortalities recorded from24 hours to 72 hours, while 40 was recorded at 96 hours; for 100 % concentration, all the frys died during the first 24 hours (Appendix 65a; Figure 4.48a). For the frys exposed to Gege stream water: frys in 6.25 % concentration had 11, 17, 26 and 33 mortalities recorded at 24, 48, 72 and 96 hours respectively; 12.5 % concentration had 19, 30, 35 and 38 mortalities recorded at 24, 48, 72 and 96 hours respectively; for 25 %

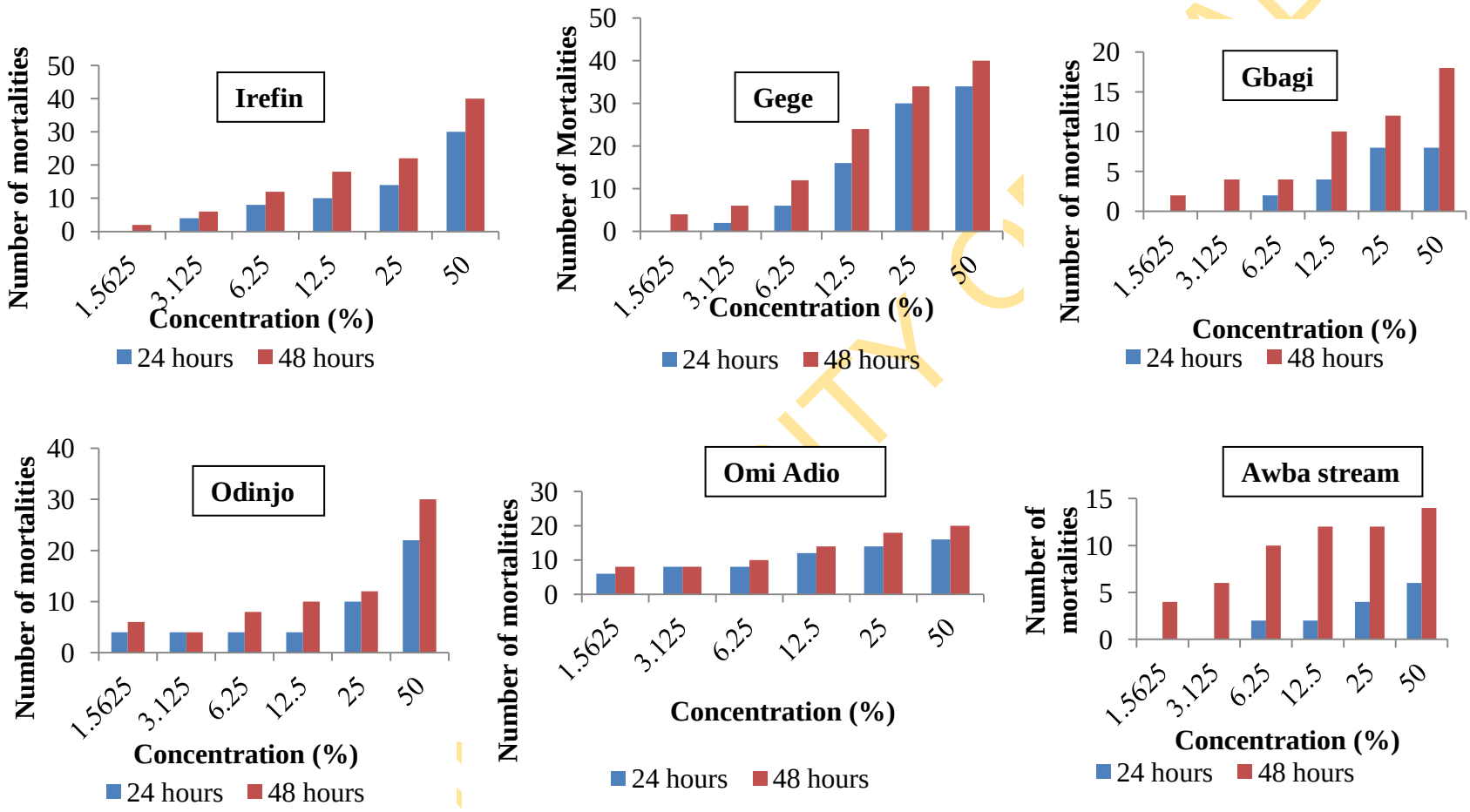


Figure 4.47: Mortalities of *Cloeon perkinsi's* larvae exposed to different concentrations of stream water

Table 4.5: Mortalities of tadpoles to different concentrations of Gege stream water

Concentration	Exposure Duration	Number of Mortalities	Concentration	Exposure Duration	Number of Mortalities
50%	24 hours	11	**100%**	24 hours	40
	48 hours	11		48 hours	40
	72 hours	13		72 hours	40
	96 hours	18		96 hours	40

concentration, 39 mortalities were recorded at 24 hours, while 40 recorded at 48 hours; for 50 % and 100 % concentrations, 40 mortalities each were recorded during the first 24 hours (Appendix 65a; Figure 4.48b). For the frys exposed to Gbagi stream water: frys in 6.25 % concentration had 17, 22, 25 and 30 mortalities recorded at 24, 48, 72 and 96 hours respectively; 12.5 % concentration had 19, 25, 29 and 33 mortalities recorded at 24, 48, 72 and 96 hours respectively; for 25 % concentration, 23, 32, 34 and 37 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 50 % concentration, 29, 35, 37 and 39 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 100% concentration, 30, 35, 38 and 40 mortalities were recorded at 24, 48, 72 and 96 hours respectively (Appendix 65a; Figure 4.48c). For the frys exposed to Odinjo stream water: frys exposed to 6.25 % concentration had 35 mortalities at 24 hours and 37 mortalities throughout 48 to 96 hours; frys in 12.5 % concentration had 38 mortalities all through 24 to 72 hours, while it increased to 39 at 96 hours; frys exposed to 25 % concentration had 39 mortalities recorded all through 24 to 96 hours; at both 50 % and 100 % concentrations, all the frys (that is, 40) died within 24 hours (Appendix 65a; Figure 4.48d). For the frys exposed to Odinjo stream water: frys exposed to 6.25 % concentration had 34 mortalities throughout 24 to 72 hours while all died (that is, 40) at 96 hours; for 12. 5 % concentration, 36, 38, 39 and 40 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 25 % concentration, 38 mortalities were recorded fir 24 to 72 hours, while 40 mortalities was recorded at 96 hours; at both 50 % and 100 % concentrations, all the frys (that is, 40) died within 24 hours (Appendix 65a; Figure 4.48e). For the frys exposed to Awba stream water: frys exposed to 6.25 % concentration had 11, 13, 14 and 16 mortalities at 24, 48, 72 and 96 hours respectively; frys exposed to 12.5 % concentration had 18, 22, 22 and 26 mortalities at 24, 48, 72 and 96 hours respectively; frys exposed to 25 % concentration had 30 mortalities at 24 hours , while 38 mortalities were recorded throughout 48 to 96 hours; frys exposed to 50 % concentration had 34 mortalities recorded at 24 hours, while 40 mortalities was recorded at 48 hours, at 100 % concentration, 34 mortalities, while 40 mortalities was recorded at 48 hours (Appendix 65a; Figure 4.48f).

The 96hour LC_{50} of all stream water obtained using trimmed Spearman-Karber method were 2.75 %, 0.8 %, 2.8 %, 0.79 % and 4.27 % for Irefin, Gege, Gbagi,

Odinjo and Awba streams respectively. The 96hour LC_{50} of the Omi Adio stream could not be calculated. However, the 72hour LC_{50} had 2.63 % (Appendix 65b).

4.9.4.2 *Clarias gariepinus* fingerlings bioassay

When fingerlings of *Clarias gariepinus* were exposed to different concentrations of test solutions, there was no mortality recorded in the exposure to the test solutions from Gbagi, Odinjo, Omi Adio streams and control. However, fish mortality occurred in test chambers of Irefin and Gege.

In the test chambers containing the varying concentrations of Irefin contaminated samples, the following mortalities were recorded: fingerlings in 3.125 % concentration had 0, 12, 16 and 23 mortalities recorded at 24, 48, 72 and 96 hours respectively; 6.25 % concentration had 3, 13, 18 and 24 mortalities recorded at 24, 48, 72 and 96 hours respectively; for 12.5 % concentration, 5, 13, 29 and 30 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 25 % concentration, 5, 15, 22 and 34 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 50% concentration, 6, 19, 30 and 35 mortalities were recorded at 24, 48, 72 and 96 hours respectively; while at 100 % concentration, 7, 20, 35 and 40 mortalities were recorded at 24, 48, 72 and 96 hours respectively (Table 4.6).

For fingerlings exposed to the varying concentrations of contaminated Gege stream samples, the following mortalities were recorded: fingerlings in 3.125 % concentration had 0, 5, 3 and 14 mortalities recorded at 24, 48, 72 and 96 hours respectively; 6.25 % concentration had 0, 9, 15 and 21 mortalities recorded at 24, 48, 72 and 96 hours respectively; for 12.5 % concentration, 2, 12, 21 and 23 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 25 % concentration, 12, 19, 29 and 33 mortalities were recorded at 24, 48, 72 and 96 hours respectively; for 50% concentration, 15, 32, 33 and 35 mortalities were recorded at 24, 48, 72 and 96 hours respectively; while at 100 % concentration, 35, 40, 40 and 40 mortalities were recorded at 24, 48, 72 and 96 hours respectively (Table 4.6).

The 96hour LC_{50} of Gege and Irefin downstream contaminated water obtained using Probit method indicated that Gege downstream had 3.327 % with 95 % lower and higher confidence limits of 1.138 % and 5.765 % respectively while Irefin downstream had 5.624 with 95 % lower and higher confidence limits of 3.045 % and 8.366 % respectively (Appendix 66).

CHECK FIGURE 4.48 IN GRAPHS FOR CHAPTOR FOUR

Table 4.6: Mortalities of *Clarias gariepinus* fingerlings to different concentrations of Gege and Irefin stream water samples

Samples	Concentrations	Mortalities			
		24 hours	48 hours	72 hours	96 hours
Irefin	3.125%	0	12	16	23
	6.25%	3	13	18	24
	12.50%	5	13	29	30
	25%	5	15	22	34
	50%	6	19	30	35
	100%	7	20	35	40
Gege	3.125%	0	5	3	14
	6.25%	0	9	15	21
	12.50%	2	12	21	23
	25%	12	19	29	33
	50%	15	32	33	35
	100%	35	40	40	40

CHAPTER FIVE

DISCUSSION

5.1 Earthworm diversity and abundance and relationship with soil factors

Earthworms are among the most widespread invertebrate animals found mainly in the soils of grasslands, woodlands, scrublands and forest, they are diverse in forms and in behaviour, and could be aquatic or terrestrial in nature (Abimbola *et al.*, 2013). Ecologically, they represent the dominant faunal biomass of the soil in many environments except the environments that are highly saline, moisture-limited or acidic (Edwards and Lofty, 1977; Lee, 1985).

The abundance and species composition of earthworm fauna at a particular site, and also the preference, avoidance or activity of individual earthworms (that is, the behavior) in contact with a soil substrate can indicate the quality of the soil (Heinz-Christian *et al.*, 2011). They have been shown to be of great importance in soil fertility, soil improvement and soil amelioration (Paoletti, 1999). They influence soil characteristics because they participate in the construction and destruction of the soil particles, as well as in organic matter transfer (Lemtiri *et al.*, 2014). The combinations of the ecological categories of earthworms together or individually are responsible for the maintenance of soil fertility (Bhadauria *et al*., 1997; Sinha *et al*., 2003; Bhadauria and Saxena, 2010).

Epigeic earthworms feed on plant debris, therefore they are mostly responsible for breaking down complex organic residues and mineralize nutrients (Ojha and Devkota, 2014). Some epigeic species maintain shallow horizontal burrows (Lee, 1985; Francis and Fraser, 1998; Ernst *et al.*, 2009). Anecic and epigeic earthworms increase water infiltration in soil (Zaller *et al.*, 2011; Spurgeon *et al.*, 2013). The lifestyle of epigeic species may likely explain their effects on water infiltration rates: Since they dwell on the surface, their activities may prevent the formation of a soil surface crust or low

permeability (Spurgeon *et al.*, 2013); the production and degradation of their casts form stable microaggregates which are important for soil moisture regulation and therefore for water affinity and conductivity (Bottinelli *et al.*, 2010); when they are exposed to adverse conditions such as drought or frost, they may burrow deeper into the soil, therefore forming temporary vertical burrows which may act as conduits for water flow (Spurgeon *et al.*, 2013).

Endogeic earthworms are known as "ecological engineers,'' or "ecosystem engineers'' because they live exclusively and build extensive nonpermanent burrows in the upper mineral layer of soil and mainly ingest mineral soil matter (Bhadauria and Saxena, 2010). They keep moving in the soil to feed on soil organic matter (Lavelle *et* al., 1997), they primarily consume soil in the upper layer of the mineral soil (Lemtiri *et al.*, 2014) and they produce physical structures through which they can modify the availability or accessibility of a resource for other organisms (Jones *et al*., 1994).

Anecic earthworms live near subsurface soil region (Ojha and Devkota, 2014). This life style helps to increase water infiltration in soil. They dig vertical burrows which are connected to the soil surface and therefore act as preferential pathways for water flow and gas diffusivity (Edwards *et* al., 1990; Clements *et* al., 1991; Capowiez *et al*., 2009; Spurgeon *et al.*, 2013). Their burrows make major contribution to soil macroporosity (Andriuzzi *et al*., 2015).

The result of the abundance and composition of earthworms collected at the streams and dumpsites indicated that all the sites had *Eudrilus euginiae* being the most abundant except at the control site for streams (Awba stream) where *Dichogaster modigliani* was the most abundant.

The occurrence of *Alma millsoni* at the bank of the streams' control site (Awba stream) was due to the fact that this species of earthworms is found in marshy environment. They are limicolous (marsh dwellers) (Dedeke *et al.*, 2010) and they thrive well in a less/non-polluted environment. Ojieze and Eghafona (2014 and 2015) also collected *Alma millsoni* from riverside of Okitipupa, Ondo state, Nigeria. *Alma millsoni* is found in the floodplain known to be high in nutrients such as phosphorus (Dedeke *et al.*, 2010). Owa and Olojo (2003) reported that such limicolous environments where they are found are high in nutrients such as phosphorus, are referred to as fertile regions that are yearly renewed by alluvial deposits resulting

from annual floods. The presence of *Alma millsoni* in Awba stream might account for the high phosphate-phosphorus present in the streamwater in the month of January, 2009; high potassium in the soil in the months of November, 2009 and January. 2010; and high sodium in all the three months that the earthworm was found. Dedeke *et al.* (2010) observed high phosphorus, potassium and sodium in *Alma millsoni* earthworms collected among banks of stream in Olabisi Onabanjo University, Ago-Iwoye, Ijebu northeast area, southwest, Nigeria. They attributed the presence of these macrominerals to the marshy environment where the earthworms were collected.

Eudrilus euginiae are epigeic earthworms that live in the uppermost moist soil litter layer and feeding mainly on organic matter of the soil (Sivasankari *et al*., 2014). They are generally referred to as African night crawlers. The presence and abundance of *Eudrilus euginiae* might be attributed to the fact that it is extremely prolific (Dominguez *et al.*, 2001), has ability to move quickly, capable of surviving in various substrates, under polluted conditions (Mainoo *et al.*, 2008) and it is capable of rapidly converting wide range of organic substrates such as sewage sludge (Graff, 1982), animal wastes (Dominguez *et al.*, 2001), cassava peel (Mba, 1996) and so on. All these were present in some of the streams and dumpsites. High-reproduction rates are being exhibited by *Eudrilus eugeniae* (Bano and Kale, 1988; Edwards, 1988) and is capable of quickly decomposing large quantities of organic wastes and incorporating them into the topsoil (Neuhauser *et al.*, 1979; Neuhauser *et al.*, 1988; Edwards 1988). Fabunmi *et al.* (2016) also collected *Eudrilus euginiae* earthworms from three dumpsites in Port Harcourt, Nigeria.

Dichogaster modigliani ia also an epigeic earthworm. It was not present in the soil from the Idi Ope dumpsite. One of the factors that aided its absence might be the cassava processing industry very close to this site. This observation was contrary to Jouquet *et al*. (2006), who found *Dichogaster modigliani* in a small area of cassava plantation. Apart from *Dichogaster modigliani* that was present in their study site, some species of earthworms were absent, which suggested that cassava cropping affected earthworm density (Jouquet *et al.*, 2006). Ogunlaja and Morenikeji (2013) observed *Dichogaster modigliani* in an oil pipeline vandalized area in Lagos state, Nigeria.

Hyperiodrilis africanus has been identified as one of the broadly distributed species of earthworms (Barois *et al.*, 1993) existing through humid tropical (Lavelle *et al.*,

1999) Central and West Africa in disturbed and undisturbed fields (Madge, 1969; Tondoh, 1998), hence its presence in the soil samples from the streams and dumpsites except from the soil from the Odinjo stream and Moniya dumpsite. It is an exotic worm that is known to be active in the burial and the decomposition of litter in various agro-ecosystems (Hauser, 1993; Hauser *et al.*, 1998; Tian 1995). Dedeke *et. al.* (2010) also observed *Hyperiodrilis africanus* in friable soils from Olabisi Onabanjo University, Ago Iwoye, Nigeria. *Hyperiodrilus africanus* were also found in soil receiving wood wastes from Isale Ake sawmill in Abeokuta, Southwestern, Nigeria (Bamidele *et al.*, 2016).

In situ observation of earthworms' biomass and population dynamics has been a means of determining long-term effects on environment (Kooch and Jalivand, 2008). They are regarded as bioindicators of soil quality (Pérès *et al.*, 2011). Due to their various activities like burrowing and casting that affect the activities of other organisms, the presence of earthworms modifies the soil quality (Kalu *et al*., 2015). Their activity is influenced by soil parameters besides feed (Edwards and Lofty, 1972). Physical and chemical properties of soil are influenced also by earthworms (Jayakumar and Natarajan, 2012). In addition, soil texture, pH and organic matter content have major influence on earthworm abundance and diversity (Edwards and Bohlen, 1996). Areas with higher soil organic carbon content sometimes have more earthworms (that is, abundance) (Hendrix, *et al.*, 1992; Poier and Richter, 1992; Nuutinen, *et al.*, 2001). However, not in all studies (Whalen, 2004; Rossi *et al.*, 2006). This could also be seen from the result of the organic matter that despite the low, medium and high levels of organic matter in the soils from the streams and dumpsites, the earthworm abundance is low. The weak inverse correlations between total organic carbon and matter with earthworms' density of the dumpsites (Appendix 68) may be due to the fact that the presence of earthworms depends on factors more important than organic carbon, and when present, organic carbon is consumed by earthworms (Mainoo *et al.*, 2008). Kale (1998) also reported that the abundance and diversity of earthworm species is affected by carbon and nitrogen content of the soil.

Inverse correlation of total organic carbon and earthworm abundance were also observed by Mainoo *et al.* (2008) in their sampling of earthworms from some site in Accra, Ghana and also Maclean and Parkinson (1997) in their observation of epigeic earthworms in a pine forest. This might probably explain the weak inverse

correlations between total organic carbon and matter with earthworms' density of the dumpsites (Appendix 68). However, Kale *et al*. (2015), observed positive correlation of organic matter with earthworm population density in their sampling of Panchase area, Nepal. Hendrix *et al*. (1992) also observed high significant correlation between earthworm populations and soil organic carbon content in their sampling of earthworms in Georgia Piedmont, USA.

The high electrical conductivity of the streams and dumpsites implicated that there are more soluble salts in the soil (Arias *et al.* 2005; Karaca, 2004 and Singer and Munns, 1999). This has implication on survival of earthworms because they cannot tolerate high salinity (El-Duweini and Ghabbour, 1965) because high salt concentrations cause dessication and eventually death (Schaefer, 2005). This probably explains the low abundance of earthworms and also the inverse correlation between the streams' earthworm density and biomass and the electrical conductivity (Appendix 67).

There is wide recognition of the importance of earthworms for heavy metal biomagnifications in terrestrial ecosystems (Karanjal *et* al., 2010). This could be seen from the inverse correlation of streams' earthworm density and biomass with lead, iron, cadmium and positive correlation with zinc (Appendix 67). Owa (1992) and Aladesida (2010) also observed positive correlation of earthworm abundance with soil iron and calcium. When lead is high, earthworms will not thrive because lead is poisonous to their immune system. This might be the reason for the low earthworms' population in soil from the streams and dumpsites, since their lead contents were high.

The low abundance of earthworms in the dry season could be attributed to changes in soil temperature and moisture (Whalen *et al.,* 1998). This was also seen from the results, even though the temperature and moisture contents were not analysed.

5.2 Physico–chemical characteristics of stream water samples

The chemical character of any water determines its quality utilization (Elueze *et al.*, 2004). The quality is a function of the physical, chemical and biological parameters to which it could have been subjected to and a particular use it is intended for (Tijani, 1994).

pH measures the degree of acidity or alkalinity of water and it determines some reactions (APHA, 1998). It is important in water quality assessment as it influences many biological and chemical processes within a water body (Chapman, 1996); low pH increases the availability of metals and other toxins for intake by aquatic life (Nartey *et al.*, 2012). The mean pH of the stream water samples fell within the range (6.5 – 8.5) recommended for surface water samples by NESREA (2011). Some of the samples were a little lower than 6.5, the Omi Adio downstream had pH of 5.48 in September, 2008. The pH values observed were related to the range (5.4 – 6.8) observed by Ewa *et al.* (2011) on their study of Omoku creek that receives industrial effluent and domestic wastes in Rivers state, Nigeria. They also fell within the range 7.6 -7.8 observed by Nartey *et al.* (2012) on their study on the impact of solid waste dumpsites on some surface water systems in Accra, Ghana.

Dissolved oxygen is a measure of the degree of organic pollution in a water body by organic matter, the destruction of organic substances as well as self purification capacity of the water body (Omole and Longe, 2008). It is a very important abiotic parameter because without it, aquatic organisms cannot survive. It is highly important for aquatic life. When it is very low, it can stress the organisms in the water; the organisms may move away, get weak or die. The dissolved oxygen content of water is influenced by the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system (WHO, 2006). Atmospheric and photosynthetic activities are sources of dissolved oxygen in the aquatic environment while respiration, decay by aerobic bacteria and decomposition of decaying sediment cause loss of dissolved oxygen (Gupta and Gupta, 2006).

During the sampling periods, there were some months that zero values of DO were observed. This might be as a result of organic pollution due to high organic contents from human faeces and domestic wastes because the rate of deoxygenation depends on dilution that occurs when wastes mix with the stream, the biochemical oxygen demand of the discharge, temperature of the discharge and the streams' DO (Raheem and Morenikeji, 2008). The months when DO were observed, the values were lower than 4.0 mg/L limit laid down by NESREA (2011) for effluent discharge and also 6.0 mg/L limit laid down for fisheries and recreation quality criteria standards, also by NESREA (2011). The values from the control site (Awba stream) showed that they can support aquatic life. There were also reports on surface water bodies with low DO

level amongst which are Lagos lagoon with human sewages and municipal wastes discharge (Lawson, 2011), Lower Ogun river caused by organic–rich abattoir effluents (Yakub, 2010). Raheeem and Morenikeji (2008) also observed zero DO values at the point at which abattoir effluent enters Alamuyo stream in Ibadan, Nigeria.

The values of BOD and COD observed during the sampling periods were higher than the limits of 6.0 mg/L and 30.0 mg/L respectively set by NESREA (2011). The low DO concentrations observed at the site may be due to high organic load as shown by the result of biochemical oxygen demand (BOD) and chemical oxygen demand (COD). This probably explains the inverse relationship between BOD and DO, COD and DO (Appendix 69). This implies that as the BOD and COD increase, DO decreases. The positive correlation between BOD and COD also justifies the fact that there is high organic load in the streams. All the stream samples have organic matter that is daily imputed into them. For instance, human and animal faecal matters are being imputed daily. The contamination of water with faeces increases the BOD because it contains mainly organic matter making oxygen less available to desirable organisms (Ekundayo, 1977 and Imevbore, 1983). Sudhi (2014) also observed high BOD in rivers polluted by faecal contamination in Kerala, India.

Conductivity is the ability of a solution to pass electric current. Conductivity values are often related to the dissolved solids concentrations (Kashiwabara and Tsude, 1994; Twort *et al.*, 1995). According to Reddy and Reddy (2011), electrical conductivity depends on concentration of ions and nutrients status. The high values of total dissolved solids (TDS) and electrical conductivity (EC) indicated that there were high concentration of anions and cations indicating the presence of inorganic materials. Since electrical conductivity of industrial wastewater, treatment plant, effluents and polluted waters is due to the presence of ionic solutes (Ademoroti, 1996), this probably explains the positive correlations of TDS and EC with total alkalinity, chloride, phosphate and sulphate. Electrical conductivity is strongly influenced by the concentration of dissolved constituents (Obire *et al.*, 2003); this probably explains an almost perfect positive correlation between electrical conductivity (EC) and total dissolved solids (TDS) (Appendix 69).

The range of TDS values obtained in the stream samples were far below the range of 1235 to 19846 mg/L obtained by Obire *et al.* (2003) in Elechi creek whose banks is

also marked with waste disposal and frequent defaecation in Port Harcourt. The mean TDS values obtained in the surface water samples were a little lower than the mean of (732±26 mg/L) and (725±75 mg/L) observed at the upstream and downstream respectively of a stream in the vicinity of a battery factory in Ibadan, Nigeria (Dawodu and Ipeaiyeda, 2008). There are no limits of EC and TDS set by NESREA (2011) but Dawodu and Ipeaiyeda (2008) claimed that there is an international acceptable level of 1000 mg/L of dissolved solids. They also claimed that since there is no limit for electrical conductivity, the values should not reflect an associated dissolved solids level. The upstream and downstream of Gege, upstream and downstream of Irefin, and upstream and downstream of Odinjo had TDS values that were more than 1000 mg/L. This might probably be due to the presence of ionic (anions and cations) solutes as seen in their results of sulphate-sulphur, phosphate-phosphorus, chloride, magnesium and calcium.

Using the mean values of TDS to classify water according to the classification of water based on TDS by Davis and DeWiest (1966) (Appendix 71), Gege stream may be useful for irrigation. Also, according to Freeze and Cherry **(**1979) (Appendix 72), all the water types are freshwater except Gege that is a little bit tending towards the brackish water type.

Using their electrical conductivity values to classify their salinity hazards according to US salinity laboratory (1954) (Appendix 73), the control stream (Awba stream) and Gbagi stream have low to medium salinity hazards; Gege stream has very high salinity hazard; Irefin stream has high to very high salinity hazard; the upstream of Omi Adio stream has a low to medium salinity hazard, its downstream has low, medium and high salinity hazards; while Odinjo stream has medium, high and very high salinity hazards.

The measure of the capacity of natural water to neutralize acid is alkalinity. It is an estimate of the ability of water to resist change in pH upon the addition of acid and it is caused mainly due to hydroxide, carbonate and bicarbonate ions (Mahananda *et al.*, 2010). There is no alkalinity limit stipulated by NESREA (2011).

Some of the mean total alkalinity values of the stream water samples were higher and some were lower than the mean alkalinity values of 369 mg/L and 119 mg/L observed by Mahananda *et. al.* (2006) from two ponds that receive municipal solid wastes and different human activities are also carried out at the banks in Bargarh District, Orissa,

India. The range of values obtained were also higher than the range of 4.1 to 18.5 mg/L by Nkwocha *et al.* (2011) from points of Otamiri river which is close to municipal solid waste dumpsite. The higher alkalinity values obtained in the streams may be due to higher concentrations of nutrients, ions and phosphate (which have acid buffering properties).

5.2.1 Anion qualities of stream water

The limit of chloride set by NESREA (2011) for effluent discharge is 300 mg/L. Using the mean chloride contents of all the streams, they were not up to the limit. However, at some particular periods of sampling, Gege, Irefin and Odinjo upstreams and downstreams were higher than the stipulated limit. The high chloride contents signified high organic pollutants present in the water bodies at the time of sampling. The origin of the pollutants may be due to origin like human and animal faeces, and also sewage inflow into the water bodies.

The range of chloride values observed were far higher than the range of 12.1 to 184 mg/L observed by Nkwocha *et al.* (2011). Their mean values were also higher than the mean of 11.78 mg/L and 7.59 mg/L observed at the upstream of Rivers Ona and Alaro respectively and 9.52 and 12.01 mg/L observed at the downstream of the rivers in Oluyole Industrial Estate, Ibadan (Osibanjo *et al.*, 2011). Chloride sources could be from soluble salts of NaCl and KCl from blood discharged into abattoir effluent (Atuanya *et al.*, 2012) especially in Gege and Gbagi streams that receive blood from abattoir.

Phosphorus is a nutrient that occurs in many forms that are bioavailable and phosphate is one of such forms of existence (Nartey *et al.*, 2012). Phosphorus occurs in natural waters and wastewaters almost solely as phosphates (APHA, 1998). It is often transported to water bodies via soil erosion because many forms of phosphorus tend to be adsorbed to soil particles. It also occurs in natural waters in low quantity as many aquatic plants absorb and store phosphorus many times their actual immediate needs (Mahanada *et al.*, 2010).

The very high values of phosphate may be due to releases of diverse composition of wastes into the stream. It may also be due to solar radiation that might have encouraged the biological degradation of the organic matter (Mahanada *et al.*, 2010). High levels of total phosphorus and other nutrients have been reported to encourage

eutrophication which could further deplete the dissolved oxygen levels of the rivers (Fakayode, 2005; Minareci *et al.*, 2009). This could also be deduced from the dissolved oxygen values obtained and the inverse correlation between phosphate and DO (Appendix 69). Phosphate may also encourage the growth of algae in the water.

Nitrate generally occurs in trace quantities in surface water (APHA, 1998). Mean nitrate values obtained were below the limit of 40.0 mg/L set by NESREA (2011) for effluent discharge. However, there were some sampling periods where the values of nitrate in the upstreams and downstreams of Gege and Odinjo and the downstream of Gbagi were higher than the set limit for fisheries and recreation but not up to limit for effluent discharge. From the point of nitrate pollution, there is no cause of alarm.

Sulphate is widely distributed in nature and may be present in natural waters in concentrations ranging from a few to several thousand milligrammes per litre (APHA, 1998). Sulphate values were far higher than 500 mg/L set by NESREA (2011) for effluent discharge. The high sulphate values could be as a result of the wastes entering the water bodies.

5.2.2 Calcium and magnesium

Calcium and magnesium occur naturally in water bodies and they are among the most highly available alkali metals in the environment (Grochowska and Tandyrak, 2009). Their concentrations in ground and surface waters increase as they are washed out from bedrock (Gałczyńska *et al*., 2013). Calcium compounds are present naturally in surface water, and their concentrations are determined mainly by the carbonate balance (Gałczyńska *et al.*, 2013) while magnesium salts are found naturally and in high concentrations in surface and ground water (Potasznik and Szymczyk, 2015).

Calcium levels in the stream water samples were not up to the limit of 180 mg/L set by NESREA (2011). So also magnesium levels were not up to the limit of 40 mg/L set by NESREA (2011), except at the upstream of Irefin in March 2009, the downstream of Gege in July 2009 and the upstream of Omi Adio in January 2010.

Potasznik and Szymczyk (2015) observed calcium content of 74.0±20.8 mg dm^{-3} in the Tolknicka Struga stream, which receives wastewater from a local wastewater treatment plant and magnesium content of 12.0±4.1 mg dm^{-3} within the same stream. Grochowska and Tandyrak (2009) observed calcium content between 47.12 and 64.97

mg/L in the waters of Miodówko Lake surrounded by the year-round houses not connected to the collective sewerage system but equipped in septic tanks. The magnesium content of the same lake varied in the range of 4.4 to 33.2 mg/L (Grochowska and Tandyrak, 2009).

5.2.3a Other metals (Pb, Cu, Fe, Zn)

NESREA (2011) did not set limit for manganese but there are limits for the other metals. The range of values of the other elements were more than the set limits by NESREA (2011) for effluent discharge, except nickel values of the upstream of Gege and Gbagi. Chromium values were also not up to the limit.

Considering their mean values, lead mean values were higher than the limit for effluent discharge except the upstream and downstream of Irefin, upstream and downstream of Gege, upstream of Omi Adio and the upstream of Gbagi.

Mean values of copper, iron and zinc were more than the two set limits. Nickel mean values were not up to effluent limit. Cadmium mean values were not also up to effluent limit except Omi Adio and the upstream of Gbagi.

Metals in trace amount may play important role in the biochemical life processes of aquatic organisms. However, their sublethal concentrations become lethal to the organisms when there is prolonged exposure duration.

The results obtained from the metal analysis showed that there was high pollution indicating that there was high magnitude of metal input from the wastes and effluents entering the water bodies. The high levels of metal in the water bodies call for concern because of the organisms inhabiting the streams and the larger water bodies that the streams feed and also human beings exposed to such environment.

The high values of metals in the control stream (Awba stream) could be as a result of the diffuse nature of lead, run-off activities in cadmium, zinc or lead containing materials (Ololade *et al.*, 2009). The presence of lead in the stream samples may be due to its discharge from petroleum products. It could also be from lead-acid batteries, plastics and rubber remnants, lead foils such as bottle closures, used motor oils and discarded electronic gadgets including television, electronic calculators and stereos (WHO, 2004). Lead in the environment is mainly particulate bound with relatively low mobility and bioavailability (Nartey *et al.*, 2012). According to WHO (1989) lead

does, in general not bioaccumulate and there is no increase in concentration of the metal in food chain. However, female animals show impact of lead toxicity by miscarriages and potent mortality (Taupean *et al.*, 2001). Fatoki *et al.* (2002) observed the development of neurological problem in fetuses and children exposed to a lead concentration of 0.1 mg/L.

Zinc is an enzyme co-factor in several enzyme systems including the carbonic anhydrase found in the red blood cells (Lawson, 2011). It has been found to have low toxicity effect in man. However, the prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia (Hess and Schmid, 2002).

Iron is important in cellular processes of plants and animals. It is found in natural waters but when the levels are elevated, it discolours materials such as clothes, plates, etc.

5.2.3b Other metals Ni, Cd, Cr, Mn

High nickel concentration may be due to its presence in wastes of diverse forms and particularly in its soluble form. Even in lower concentration, apart from being carcinogenic, it can cause allergic reactions in people (Mckenzie and Smythe, 1998).

Cadmium occurs naturally in zinc, lead, copper and other ores which can serve as sources to ground and surface waters, especially when in contact with soft, acidic waters (Ololade *et al.*, 2009). High cadmium values in the streams could be due to the closeness of the streams to roadside or washing of cars into the streams, for example, the Omi Adio and Odinjo streams. Its high concentrations lead to chronic kidney dysfunction, inducing cell injury and death by interfering with calcium regulation in biological systems in man, fish and other aquatic organisms (Woodworth and Pascoe, 1982). Its involvement in endocrine disrupts activities, which could pose serious health problem (Lawson, 2011). However, its concentrations in water are only likely to be of health concern in environments where pH is less than 4.5 (WHO, 2004).

Inhalation of high dose of manganese leads to death. The symptoms in man include problems with central nervous system, euphoria, insomnia, serious headache and palsy of feet (Lawson, 2011). It is an element of low toxicity having considerable biological significance and one of the more biogeochemical and active transition metals in aquatic environment (Evans *et al.*, 1977). It occurs in surface waters that are low in oxygen and often does so with iron (Lawson, 2011). This probably explains the positive correlation with iron. A probable source of airborne inorganic manganese pollutant in urban centres is the combustion of methylcyclopentadienyl manganese tricarbonyl (MMT), particularly in high traffic density (Sierra *et al.*, 1998). Combustion of MMT in hot car engine leads to the emission of manganese phosphates, manganese sulphate and manganese oxides that include manganese tetroxide as a minor component (WHO, 2004 and Zayed, 2001).

According to USEPA (2010), the recommended maximum level for manganese in water is 0.05 mg/L. Values from the stream water analysis were higher than this recommended level. This could be due to MMT, an antiknocking agent in petroleum products which has manganese as an active compound.

5.3 Soil contamination by domestic solid waste

An important component of the terrestrial ecosystem is soil due to its key functions in fertility, decomposition processes, nutrient and energy flows (Karanja *et al.*, 2010).

5.3.1 Particle size distribution

Soils of the banks of the streams had high percentages of sand and very little amounts of clay and silt. The soils of the dumpsites also had high percentages of sand and very little amounts of clay and silt. These corroborate the works of Oni (2010) who observed high percentages of sand in waste dump area of Aba-Eku landfill in Ibadan; Benga-Coker and Bafor (1999) observed high percentages of sand of Teboga waste dump in Benin City; Anikwe and Nwobodo observed high percentages of sand (72 – 76 %) from Abakaliki dumpsite. The authors made a conclusion that soils with sand content greater than 70 % were unsuitable for waste disposal because they had high permeabilities that would allow the leachates pass through them. From their conclusion, it could also be inferred that the soils of the study areas are unsuitable for dumping wastes. This is confirmed by the results of the groundwater analysis showing

high concentrations of some of the metals or elements in them. This means that the metals are seeping through the soil and finding their ways into groundwater bodies. This indicated that the soils of the dumpsites are unsuitable for refuse disposal.

5.3.2 Organic matter

Soil organic carbon is not a requirement for plant growth, however, the levels of organic matter in soils influence a number of soil chemical and physical processes and it is an important indicator of the soil as a rooting environment (Okalebo *et al.*, 1993). Enwezor *et al.* (1988) classified organic matter levels in soil: organic matter levels less than 2 % were considered low (values below critical limits); 2.1 – 3.0 % as medium (values above critical limits); and greater than 3.1 % as high. Based on this classification, the soils of the control site for the streams (Awba stream) and Gege stream ranged from low to medium levels of organic matter while soils of Irefin, Odinjo, Gbagi and Omi Adio streams ranged from low, medium and high levels of organic matter. The low organic carbon contents of some of the sites could be attributed to the utilisation of organic carbon by micro-organisms as a source of nutrients for mineralization (Ogbonna *et al.*, 2009).

Using this classification on soils from dumpsites; all soils from the dumpsites and their control site (Balewa) had high organic matter levels. These could be as a result of human and animal faeces. High organic matter has been reported by Oni (2010) on the analysis of soils in Aba Eku dumpsite in Ibadan. Obasi *et al.* (2012) also observed high organic matter in waste dumpsite soils along Enugu-Port Harcourt expressway.

Municipal wastes contain a lot of decomposable material that add to the soil organic matter (Ideriah *et al.,* 2006). This accounts for the high levels of organic matter in the dumpsites' soil samples since the sites contain major biodegradable wastes like domestic litters. However, increased organic matter can lead to increased soil productivity (Anikwe and Nwobodo, 2002).

5.3.3 Electrical conductivity

The soils of the streams had high range of electrical conductivity. This was also observed in the soils of the dumpsites, except the control (Balewa). Obasi *et al.* (2012) also observed high electrical conductivity from soils from Enugu-Port Harcourt dumpsite and also dumpsite from Zaria. The high electrical conductivity

may be attributed to the presence of metal scraps which is one of the constituents of the refuse dumpsite and it implicated that there are more soluble salts in the soil (Singer and Munns, 1999; and Karaca, 2004).

5.3.4 Calcium and Magnesium

Bowen (1979) stated that the World Median value for calcium was 15 000 mg/Kg. During the sampling period, the calcium values obtained for the soil samples from the banks of the streams and dumpsites were much higher than the 15 000 mg/Kg stipulated by Bowen (1979) except for some few months. There were values that were even more than twice the World Median level. Plants and animal tissues have calcium as one of the inherent constituents, therefore their decay can contribute to the elevated concentration of calcium in the environment (Oni, 2010). The vegetative constituents of the dumpsites might have also been the reason for the high contents of calcium and magnesium (Oketola and Akpotu, 2015).

Additional sources of calcium may be domestic and industrial wastes (Ademoroti, 1996). The excessive amount of calcium may indicate some anthropogenic input from the wastes dumped in the streams and on the dumpsites.

Oni (2010) also observed a wide range (18,728.60 – 42,663.85 mg/Kg) of calcium with a mean value of 29617 mg/Kg in top soils of waste dump area of Aba Eku landfill in Ibadan. Coşkun *et al.* (2006) also observed high calcium values of 1,750 – 164,700 mg/Kg with a mean value of 30,700 mg/Kg in Thrace region, Turkey.

However, Ahmed and Suleiman (2001) observed lower mean calcium value of 1,151 mg/Kg in soils of Seri-Petalangi landfill in Malaysia. Eddy *et al.* (2006) also observed a range of 100 -142 mg/Kg in their study.

Eddy *et al.* (2006) gave the range background levels for magnesium between 1,000 – 35,000 mg/Kg. The magnesium values for the soils for the banks of streams and dumpsites were within this range except in few cases of soil from stream banks**.** The magnesium contents suggest some degree of anthropogenic inputs from the wastes dumped on the sites.

Oni (2010) also observed a high range of 2,303.79 – 6,485.47 mg/Kg with mean value of 3,889.33 mg/Kg in top soil samples of waste dump area of Aba Eku landfill in Ibadan. A lower mean value of 53.61 mg/Kg was obtained by Ahmed and Suleiman

(2001) in the soil samples from Seri-Petaling in Malaysia and Eddy *et al.* (2006) obtained lower levels of magnesium (150.5 – 415.5 mg/Kg) which were lower than the values obtained in this study.

The natural limit for potassium as given by Eddy *et al.* (2006) ranged between 200 and 2,400 mg/Kg while Bowen (1979) gave a world median value of 14,000 mg/Kg. The potassium levels in the soil from the banks of the stream and the dumpsites were within this natural limit and the world median value except the Awba stream that had a value of 130 mg/Kg in January, May and July 2009 and the same value recorded at the Omi Adio stream in November 2009.

However, the concentration of potassium (8,334.79 – 14,897.29) in top soil levels of Aba Eku landfill in Ibadan was quite higher than the ones observed in this study. Eddy *et al.* (2006) also observed a higher range of 15,169 – 22,680 mg/Kg.

5.3.5 Metals

NESREA (2011) gave a limit of 164 mg/Kg of lead in soil. The results obtained showed that the values of lead in the soil samples from stream banks and dumpsites were fluctuating around this figure. This suggests a high level of lead contamination depending on the composition of the wastes that come in and some other factors such as anthropogenic inputs, lead from leaded gasoline and a host of other factors.

Navas and Machin (2002) stated that a lead range between 10 and 67 mg/Kg is frequent in soils of the world. The world median value was 35 mg/Kg as stated by Bowen (1979). However, Olade (1987) stated that the background trace element content of lead often varies depending on the underlying bedrock type but ranged from 16 – 24 mg/Kg and 35 – 150 mg/Kg in tropical soils of Nigeria with mean values of 42 and 78 mg/Kg respectively depending on the type of bedrock. The lead values in the soil from the dumpsites fell within the range given by Olade (1987), so also some of the soil samples from streams' banks, except some of them.

Tijani *et al.* (2006) gave a range of lead in the soils from Ibadan to be from 20.8 to 65.3 mg/Kg depending on the bedrock type. Anikwe and Nwobodo (2002) observed lead values of 63.4 to 72.1 mg/Kg of municipal waste dump area of Abakaliki as compared with 17.3 – 29.3 mg/Kg in the control (non-dump) site. Shomar *et al.*

(2005) obtained high concentrations of lead that ranged from 146 to 210 mg/Kg in agricultural top soils of Gaza strip located near a solid waste dumpsite.

Eddy *et al.* (2006) gave the permissible range of manganese levels in soils with a range from 200 - 9,000 mg/Kg. Bowen (1979) gave a range of 1000 mg/Kg. However, Tijani *et al.* (2006) gave the range of 77.5 to 387.5 mg/Kg in soils of Ibadan depending on the type of the bedrock. Manganese levels in the samples from the streams' banks and the dumpsites had their ranges within the limits given by the three authors.

Comparing the values with other studies indicated that the manganese levels were below the range of 2,313.50 to 3,175 mg/Kg observed in dumpsite soil by Eddy *et al.* (2006). The possibility of naturally enriched manganese levels is supported by their study, even though there are some evidences of manganese input from the wastes dumped. However, Shomar *et al.* (2005) observed a lower range of 26 to 239 mg/Kg.

Olade (1987) gave the range of 10 to 270 mg/Kg as background level of zinc in soils and the mean values of 74 to 118 mg/Kg depending on the type of bedrock while Tijani *et al.* (2006) gave values of 17.2 to 116.9 mg/Kg as the background values for zinc in Ibadan soils. The mean values of zinc obtained from the soil samples from the stream banks and dumpsites had higher values than the background values suggested by the authors except the control sites that had their mean values within the suggested background values. However, the mean values obtained from some of the sites were within the 421 mg/Kg limit stipulated by NESREA (2011) except some samples that were higher.

Plants and humans require iron which is an abundant nutrient element, and its toxicity is not common (Anikwe and Nwobodo, 2002). Bowen (1979) gave a world median value of 40, 000 mg/Kg while Eddy *et al.* (2006) gave the range of concentration in natural background as varying widely between 3,000 to 500,000 mg/Kg. All the iron values observed in the soil samples from the study sites fell within the range of natural background given by Eddy *et al.* (2006) and also their mean values fell within the world median value given by Bowen (1979) except the mean value observed at the Oremeji dumpsite. The high iron concentrations observed in the samples might be attributed to the natural concentration of iron in the environment and not only the disposed wastes since Ademoroti (1996) reported that natural soils contain significant concentrations of iron.

The reason for the high chromium content in the soils from the dumpsites might be attributed to wastes from household chemicals and cleaners, diesel engines utilizing anti-corrosive agents, rubber, candles, matches and so on (Olayiwola and Onwordi, 2015). However, Ihedioha (2016) observed low concentrations of chromium during rainy and dry seasons (3.6 mg/kg and 4.05 mg/kg respectively) in soil samples collected from a municipal dumpsite in Uyo, Nigeria.

5.4 Groundwater contamination by domestic solid wastes

Now-a-days, quality of groundwater is more important than quantity (Hem, 1985). Groundwater is protected by the filtering action of soil, but it can still be polluted by leaking municipal solid waste or landfills. When there is no access to portable water, a lot of water-borne diseases can be transmitted. According to the World Health Organization (2015), globally, at least 1.8 billion people use a drinking-water source contaminated with faeces and diseases such diarrhoea, cholera, dysentery, typhoid and polio can be transmitted through contaminated water.

Contaminated drinking-water is estimated to cause 502 000 diarrhoeal deaths each year (WHO, 2015). In 2014, forty-two (42) countries from all continents reported 190 549 cases of cholera to World Health Organization (WHO), 55% of the cases were reported from Africa (WHO, 2015). The World Health Organization reported that there were 5,853 deaths due to cholera in Africa in 1997. There was a reduction to 1, 882 deaths recorded in Africa in 2014 (Wong, 2015). This reduction could be confirmed from WHO (2015), that 91% of the world's population had access to an improved drinking-water source, compared with 76% in 1990.

The pH of groundwater samples had various ranges which fell within or outside the NESREA (2011) limits for substances and characteristics affecting groundwater for domestic use. The wells at the control site (Balewa) and after the Ojokondo dumpsite fell within the NESREA (2011) permissible level of 6.5 – 9.2. Others at a particular time had pH values that were a little less than 6.5 which showed that they were acidic, and at those times, they were not suitable for drinking. Throughout the study period, the well close to the Moniya dumpsite showed a range (5.19 – 6.76) that was outside the NESREA limit. This indicated acidic level of the water which does not make it fit for human consumption. The Duncan's multiple range tests even showed that it was

the only well that its pH values did not show any significant relationships with any of the wells. The acidic nature may be due to the fact that runoff might bring contaminants from the dumpsite since it is located downslope the dumpsite and it might also be as a result of the water treatment practiced by the owner of the well; the chemicals for treatment might not be applied in the correct proportion.

Organic pollution load of the samples were very high. This statement could be confirmed from the result of biochemical oxygen demand (BOD) and chemical oxygen demand (COD), and also from the correlation of BOD and COD (Appendix 70). NESREA (2011) did not set any limit for BOD. But according to Federal Environmental Protection Agency (FEPA, 1991) standards for drinking water quality, BOD should be 0 mg/L. Throughout the sampling period, there was no particular time that BOD was not detected in the samples. The range 18.16 to 140.62 mg/L obtained from the samples were higher than the range of -13.0 to 27 mg/L observed in groundwater samples from three locations in Ibadan by Oni (2000). It was also higher than the range 0 to 52.19 mg/L observed by Adewoyin *et al.* (2013) from groundwater samples located around mechanic workshops in Ibadan.

Compared with other works, COD range of 60.46 to 200 mg/L was much higher than the range (2.16 to 18.67 mg/L) observed by Oni (2010) on two groundwater wells around a landfill in Ibadan. It was also higher than the range of 35.0 to 51.5 mg/L observed at a well around a battery factory in Ibadan by Dawodu and Ipeaiyeda (2008).

Total dissolved solids' (TDS) limit was not stipulated by NESREA (2011) but FEPA (1991) stipulated limit of 500 mg/L for drinking water standard. The values obtained at the control site (Balewa) were acceptable by FEPA (1991). The other samples at one time or the other were fluctuating, but throughout the sampling period, the well after the Ojokondo dumpsite showed values that were higher than the FEPA (1991) limit. Since TDS is a measure of the total concentration of ionic species in a sample, that is the sum of cation and anionic concentration; this might probably explain the TDS significant positive correlations observed with electrical conductivity, chloride, nitrate-nitrogen, sulphate-sulphur, zinc, nickel, magnesium and calcium (Appendix 70). The higher values of TDS obtained may be due to leaching of contaminants from the dumpsites towards the groundwater source or the presence of higher dissolved mineral matter. The periods when TDS values were lower than the FEPA limit might

probably be due to the filtering effect of the soil as the contaminants move towards the groundwater.

The mean TDS was higher than the mean 212.13 mg/L of hand dug wells in dumpsite areas of Warri observed by Akudo *et al.* (2010). The range of TDS was lower than the range of 267 to 2345 mg/L obtained by Rajkumar *et al.* (2010) from wells close to municipal solid waste dumpsite in Erode city, India.

Groundwaters are classified depending upon their hydrochemical properties based on their TDS values (Carroll, 1962; Freeze and Cherry, 1979). Using the classification according to Freeeze and Cherry (1979) (Appendix 71), the values of the sampled groundwater showed that they are freshwater except for a brackish water occasionally. The well after the Ojokondo dumpsite might be classified as being brackish water type because it was just about three times of the sampling that it had values less than 1 000 mg/L, even those values were between 846 to 901 mg/L.

Considering the suitability of the groundwater samples for drinking, it is only the well at the control site (Balewa) that is suitable for drinking based on the FEPA limit. The well water after the Ojokondo dumpsite was not at any time suitable for drinking while the other well water samples from the other sites had times when they were fit for drinking and there were some other times when they were not fit for drinking.

Electrical conductivity is a measure of the capacity of water to convey electric current. It also signifies the amount of dissolved salts (Dahiya and Kaur, 1999). According to Carpenter *et al.* (2012), polluted groundwater is electrically conductive. There is no electrical conductivity limit stipulated by NESREA (2011), but there is limit of 440 µS/cm by WHO (1994). However WHO (1997) indicated a limit of 2000 µS/cm. Throughout the sampling period, the wells before and after the Ojokondo dumpsite had values greater than the 1994 WHO limit. However, the well before the Ojokondo dumpsite had values lower than the 1997 WHO limit while the well after the Ojokondo dumpsite had times when it was lower than 1997 limit and times when it was higher. The other wells had times when they met up with the 1994 limit and times when they were greater than the limit. It was only the well at the control site (Balewa) that met up with the1994 limit except a particular sampling month that it was a little higher (468 µS/cm). The high electrical conductivity values of the groundwater samples could be as a result of the effluent from the different wastes

indicating the presence of high amount of dissolved inorganic substances in ionized form.

Using the electrical conductivity values to classify the groundwater salinity hazard according to US salinity laboratory (1954) (Appendix 73), the well at the control site (Balewa), had low to medium salinity hazard, the wells before the Ojokondo dumpsite, the ones close to the Olodo and Idi Ope dumpsites had medium to high salinity hazards, the well close to the Moniya dumpsite had low, medium to high salinity hazard, the well at the Oremeji dumpsite had medium salinity hazard, while the well after the Ojokondo dumpsite had high to very high salinity hazards.

The range of electrical conductivity values observed in the groundwater samples was higher than the range of 344 to 1191 µS/cm observed by Saidu (2011) on groundwater close to refuse dumpsites in Minna, Nigeria.

Alkalinity is the measure of the capacity of natural water to neutralize acid and it is due to the presence of hydroxide, carbonate and bicarbonate compounds of calcium, sodium and potassium (Devi and Premkumar, 2012). This probably explains the positive correlation of alkalinity with calcium (Appendix 70). Alkalinity values in drinking water mainly reflect the bicarbonate ion concentration (Sarapata, 1994). There is no limit for total alkalinity by NESREA (2011).

The range of total alkalinity values observed in the groundwater samples during the sampling period was higher than the range of 20 to 358 mg/L observed in drinking well water in Ibadan by Onianwa *et al.* (1999).

Chloride concentration acts as an indicator of pollution by sewage (Devi and Premkumar, 2012). Chloride concentrations of the groundwater samples were not up to the highest desirable level of 200 mg/L by NESREA (2011) except the well close to the Oremeji dumpsite and the one after the Ojokondo dumpsite. However, these two wells did not show values up to the maximum permissible level of 600 mg/L also by NESREA (2011).

Considering only chloride to judge the suitability of the groundwater for domestic use, all the water samples were suitable for use. High chloride concentration gives an undesirable taste to water (Kola–Olusanya, 2011), it is corrosive to metals particularly at low alkalinity (Coode, 1997). People accustomed to higher chloride in water are subjected to laxative effects (Dahiya and Kaur, 1999). According to Souza and

Somashekar (2012), high chloride concentration in groundwater can affect the people suffering from heart and kidney disorders.

The mean of chloride values observed in the groundwater samples was lower than the mean 229 mg/L observed in groundwater samples situated around a surface water dumpsite in Ondo state (Ololade *et al.*, 2009).

There were high levels of phosphate-phosphorus in the samples. Since phosphorus is present in natural waters coupled with sources from waste and household detergent, this might be the reason for its high levels and this is also an indicator of organic pollution. Phosphate-phosphorus values were far higher than 3.5 mg/L limit by NESREA (2011) and much higher than the values observed by some authors who worked on groundwater samples close to refuse dumpsites (Kola – Olusanya, 2011- range of 0.06 to 2.09 mg/L; Adekunle, *et al.*, 2007 – highest mean of 1.49±-0.84 mg/L; Souza and Soumashekar, 2012 - range of 0 to 1.89 mg/L).

According to Golwer and Matthess (1968), the process of decomposition of organic material exhaust all available dissolved oxygen in the groundwater and give rise to a reduction of the nitrate and to a smaller extent of the sulphate, the oxygen which is used for the oxidation. This might be the reason for the lower nitrate values in the groundwater samples. The nitrate is reduced to elementary nitrogen escaping into the atmosphere or to ammonia. The sulphate is reduced to elementary sulphur and to hydrogen sulphide. The reduction in nitrate and sulphate originates into bacterial action too.

Nitrate may attain high levels in some groundwater (APHA, 1998). The presence of nitrates in groundwater is an indication of a possible bacteriological pollution, which may present some health risks (Mbonu, 1991) and can also cause severe illness in infants such as Methemoglobinemia. At very high concentrations, it can cause gastric cancer (WHO, 1997). The concentrations of nitrate-nitrogen in the samples were not up to the highest desirable level of 45 mg/L set by NESREA (2011), therefore the groundwater samples based on nitrate-nitrogen contents, they may not constitute any danger to human health. From previous works, nitrate-nitrogen values exceeding NESREA standards are not very common but there are some exceptional cases. For instance, Akinbile (2012) found 61 mg/L of nitrate-nitrogen in one of the three groundwater samples close to a landfill in Akure, Ondo state.

Sulphate-sulphur concentrations were observed at a much higher level than phosphate-phosphorus and nitrate-nitrogen. They were far higher than the highest desirable level and the maximum permissible level of 200 and 400 mg/L respectively, including the well at the control site (Balewa). Levels of sulphate act as purgative in humans (Esry and Habicht, 1986; Esry *et al.*, 1991). Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Manivaskam, 2005). The discharge of domestic sewage, refuse dumps and industrial wastes tends to increase its concentration.

5.4.1 Calcium and magnesium

NESREA (2011) indicated 75 and 200 mg/L for highest desirable level and maximum permissible level of calcium in groundwater for its suitability for domestic use. The wells at the Oremeji dumpsite and after the Ojokondo dumpsite at some periods of sampling, showed values higher than the highest desirable level but not up to the maximum permissible level.

NESREA (2011) indicated 30 and 150 mg/L for highest desirable level and maximum permissible level of magnesium in groundwater for its suitability for domestic use. It was also the wells at the Oremeji dumpsite and after the Ojokondo dumpsite that at some periods showed values higher than the highest desirable level but not up to the maximum permissible level. Using the calcium and magnesium to consider the groundwater samples for use, they are suitable for domestic purpose.

5.4.2 Other metals (Pb, Cu, Fe, Zn, Ni, Cd, Mn and Cr)

Lead, nickel, cadmium and chromium do not have highest desirable and maximum permissible levels by NESREA (2011) but they had target and intervention values also by NESREA (2011). During the sampling periods, there were times when all the four elements were not detected. However, when they were detected, their values were fluctuating.

Copper, iron, zinc and manganese have highest desirable and maximum permissible levels by NESREA (2011). There were also periods of sampling that they were not detected and the periods when they were detected, they had their values fluctuating around the highest desirable and maximum permissible levels by NESREA (2011).

Copper contents were greater than the highest desirable level of 0.05 mg/L but less than the maximum permissible level of 1.5 mg/L. Their mean values were less than the highest desirable level except the mean values of the well before the Ojokondo dumpsite and the one at the Oremeji dumpsite but the two were not up to the maximum permissible level.

The ranges of the values of iron were greater than both the highest desirable and maximum permissible levels of 0.1 and 1.0 mg/L respectively. Their mean values were also greater than highest desirable and maximum permissible levels except the wells close to the Olodo, Idi Ope dumpsites and the one after the Ojokondo dumpsite.

The ranges of values of zinc in the samples from the Idi Ope well and the well after the Ojokondo dumpsite were greater than the highest desirable level of 5.0 mg/L but not up to the maximum permissible level of 15.0 mg/L while those from other samples were not up to the two limits. The mean values of all the samples were not up to the two limits.

All the ranges of manganese values were greater than the highest desirable level of 0.05 mg/L and the maximum permissible level of 0.5 mg/L, except those of the wells at the control site (Balewa), Olodo and Idi Ope dumpsites that were less than the maximum permissible level. The mean manganese values were greater than the highest desirable level but not up to the maximum permissible level, except that of the well at the Oremeji dumpsite that was greater than the maximum permissible level.

The elevated levels of metals in the groundwater samples during some sampling periods showed that they were not completely free from metal contamination. This means that the samples are not totally suitable for drinking or use.

Heavy metals such as lead, cadmium, chromium, copper, and so on have been reported at excessive levels in groundwater due to landfill operations (Lee *et al.*, 1986; Ogundiran and Afolabi, 2008; Oni, 2010; Akoteyon, 2012; Sanusi, 2013). The migration of metals is likely a product of some parameters including soil sorption capacity, reaction rate of these elements with solid phase, water movement rate in the soil and their primary concentration (Behbahaninia *et al.*, 2010).

According to APHA (1998), the average abundance of copper in groundwater is less than 0.1 mg/L. Some compounds are toxic by ingestion or inhalation. Copper is commonly used in electrical wiring, roofing, various alloys, cooking utensils, piping

and in chemical industry. These might be the reasons for its elevated levels in the wells at the upper part of Ojokondo and Oremeji dumpsites.

Copper has been shown to have a protective effect against cadmium poisoning, and people who do not have enough copper in their diet can be more susceptible to adverse effects from lead (ATSDR, 2005). Although mammals have efficient mechanisms to regulate copper stores such that they are generally protected from excess dietary copper levels, however at high enough levels, chronic overexposure to copper can damage the liver and kidneys (EFS, 2005).

The average abundance of iron in groundwater is 0.1 to 10 mg/L (APHA, 1998). Most groundwater supplies contain some iron because iron is common in many aquifers and is found in trace amounts in practically all sediments and rock formations (Omofomwan and Eseigbe, 2009). The high levels of iron in the groundwater samples could also be as a result of the material used for covering the wells, since they were made of iron. Large quantities of iron result in toxic effect like haemochromoitosis in tissues if more iron accumulation takes place (Tambekar *et al.*, 2012). Akinbile (2006) and Shyamala *et al.* (2008) remarked that the formation of blue baby syndrome in babies and goiter in adults are the results of consumption of water containing iron above the specified quantity.

The average abundance of cadmium in groundwater is from 1 to 10 µg/L. It occurs in sulphide minerals that contain zinc, lead or copper. This probably explains the positive correlation between cadmium and zinc, and its inverse relationship with lead and copper (Appendix 70). Since cadmium is used in electroplating, batteries, paint pigments and alloys with various metals, this probably could be the reason for its elevated levels in all the samples due to wash down from paint pigments from buildings, the various metal scraps from the auto-mechanic workshops beside the well at the upper part of the Ojokondo dumpsite and also the Moniya well.

Cadmium is extremely toxic and accumulates in kidneys and livers, with prolonged intake at low levels sometimes leading to dysfunction of the kidney.

Manganese resembles iron in its chemical behavior and its occurrence in groundwater is less abundant than iron. It is found to be lower than iron. Although in deep wells, it may reach concentrations as high as 2 to 3 mg/L (APHA, 1998). When solid wastes dissolve, they usually contain abundant manganese (Hughes, 2004). Excessive

concentration of manganese would result in taste and precipitation problems (Longe and Balogun, 2010).

According to APHA (1998), the average abundance of chromium in groundwater is generally 100 µg/L. It is also used in alloys, in electroplating and in pigments. It is an essential trace element for animals. Its hexavalent compounds have been shown to be carcinogenic by inhalation and are corrosive to tissue. Their sources could also be from the wastes. Even though, chromium salts are rapidly eliminated from human body, their heavy doses could corrode the intestinal tract (WHO, 2004).

5.5 Toxicity tests

As pollution intensity increases, in most cases, there is a decrease of all biological indices of environmental health (algae, invertebrates, fish) (Cuffney *et al.*, 2000; Hill *et al.*, 2000). In heavily contaminated soil and water, there is a decrease in the population, growth and function of biota present (Kaonga and Monjerezi, 2012). This could be inferred from the results of the toxicity tests results except for the pollution tolerant species.

5.5.1 *Eudrilus euginiae* earthworms

The earthworm mortality recorded during the toxicity tests indicated the pollution level of the soil samples. Although *Eudrilus euginiae* species used as test organisms can survive in various subtrates under polluted conditions (Mainoo *et al.*, 2008), but they are sensitive to disturbances (Dominguez *et al.*, 2001). This might probably be the reason for the high mortality recorded during the test. This was contradictory to the 100 % survival recorded by Jeyanthi *et al.* (2016) when the *Eudrilus euginiae* species were exposed to different concentrations of carbaryl and lead at different exposure periods. Alemneh (2015) observed 100 %, 87.5%, 50 %, 37.5 % and 25 % survival of *Eudrilus euginiae* when exposed to 0.3, 0.6, 1.2, 2.4 and 5 mg/ml of chloroxylenol (dettol) respectively during a 7-day exposure period. He observed 87.5 % and 75 % survival when exposed to 0.6 and 1.3 mg/ml of sodium hypochlorite (parazone) respectively after seven days. He observed 87.5 %, 87.5 %, 75 % and 37.5 % survival of the earthworms when exposed to 0.7, 1.3, 2.4 and 4 mg/ml of lactic acid (Mr Muscle) respectively.

5.5.2 Mayflies (*Cloeon perkinsi's*) larvae

There have been significant effects of mayflies' diversity throughout the world due to impact of human activities (Landa and Soldan, 1995).

The genus *Cloeon* (Leach, 1815) Ephemeroptera which is one of the most common and most diversified genera of mayflies colonizes all kinds of still and standing waters, present in riparian vegetation of streams, in ponds, lakes and artificial habitats (Salles *et al.,* 2014). *Cloeon perkinsi* is the most abundant of African *Cloeon* with nymphs occurring in many types of still or slowly moving water from temporary ponds to the margin of large lakes (Gillies, 1980). They are valuable indicators of water qualities, hence their use for the toxicity assay.

The contaminated stream samples were highly toxic to *Cloeon perkinsi's* (mayflies') larvae. This is attributed to the fact that the presence of mayflies in water indicates clean water sources because they prefer cleaner waters (Science, Olympiad, 2013) and they are sensitive to chemical pollutants, decreased dissolved oxygen levels, and increases in suspended solids (erosion) (Sigurdson, 2010). They are sensitive to acidification, heavy metal contamination and low pH levels (Capinera, 2008). The reason for the high mortalities recorded during the test could probably be due to the fact that all the metals analysed did not meet up with the regulatory standards as stipulated by NESREA (2011).

Sublethal effect of pollution result in altered enzyme function, poor growth, behavioural change or lack of reproductive success (Capinera, 2008). Since they are important in the food chain, there is pollution effect on other organisms such as overgrowth of algae due to death of herbivorous nymphs, over-abundance of prey species due to scarcity of predacious nymphs (Capinera, 2008). However, mayflies help in removing pollutants from aqueous systems by processing a lot of great quantity of organic matter and transferring a lot of nitrates and phosphates to terrestrial environments when they emerge as adults from the water (Dominguez, 2006).

Ogbogu (2003) also carried out a 48 hour static bioassay exposing *Cloeon perkinsi's* larvae to 5, 10, 15 and 20 mg/L each of stock solutions of sodium chloride, sodium sulphate, sodium hydrogen phosphate and potassium nitrate. He observed that at all concentrations of phosphate solution, survival was below 10 %, survival in nitrate

solution was high (70 %) at 5 mg/L but decreased as concentration increased, reaching mimimum (7 %) at 20 mg/L. In chloride and sulphate solutions, survival varied between 40 % and 70 %. He commented that very low levels of phosphate concentration in water can impair production of low *Cloeon perkinsi* in reservoirs, higher concentrations of nitrates around 20 mg/L can also impair *Cloeon perkinsi* production. This could be observed in the very high phosphate result of the test solutions**.** Beketov (2004) observed LC_{50} value of 19.05 % for *Cloeon bifidum* larvae when exposed to a mixture of 59.0 % ammonia, 1.5% nitrite and 39.5 % nitrate.

However, *Cloeon dipterum* larvae could support water of low quality (α-β mesosaprobic) and even temporary anoxia (Nagell, 1977). There was a case of *Cloeon dipterum* larvae which were exposed to laboratory anoxic condition. About 50 % of the larvae survived 130 days of anoxia at 0 ^{o}C; the most resistant surviving 155 days. Undissociated H_2S (1.4 mg/L) in the anoxic water did not reduce the survival. Severely starved larvae survived anoxia for only 16 days (LT_{50}) (Nagell, 1977). This was due to the fact that the larvae are facultative anaerobes and will use oxygen if it is available in winter (Nagell, 1977).

5.5.3 Tadpoles (*Rana temporaria*)

Amphibians are bioindicators of environmental stress (Hall and Mulhern, 1984; Freda, 1991; Dunson *et al.*, 1992), especially due to decline of some population (Barinaga, 1990). Decline of some population has been linked to environmental contamination and potential adverse effects of chemical exposure (Blaustein *et al.*, 1994).

Tadpoles growth and survival can be affected by alterations in environmental factors such as limitation of resources, predation, crowding and dessication of habitat (Shi, 2000). Exposure of tadpoles to contaminants can lead to frogs with many types of malformation. For example, frogs without eyes, with extra or missing legs, or deadly malformations (U. S. Fish and Wildlife Service, 2000). If the tadpoles exposed to stream test solution of Gbagi, Odinjo and Omi Adio were left for more than 96 hours and the growth to frogs observed, it is possible that some of these malformations would occur.

Tadpoles of *Rana catesbeiana* collected in coal ash deposition basin (contaminated with arsenic, cadmium, chromium, copper, selenic and other elements) and a

downstream drainage swamp had a reduced number of labial teeth and deformations of labial papillae when compared with tadpoles from reference areas (Rowe *et al.*, 2014). Tadpoles with deformities were less able to graze periphyton than the normal tadpoles when tested in the laboratoty. When given periphyton as sole food, they had lower negative growth rates than the ones with normal teeth (Rowe *et al.*, 2014). Since the toxicity assay was just for 96 hours, these deformities could not be observed in the test experiments.

Juveniles of anurans accumulated greater concentrations of polychlorinated biphenyls (PCBs) compared to adults collected from the same contaminated stream locations flowing from Paducah gaseous diffusion plank in Paducah, Kentucky (De Garady and Halbrook, 2005).

High electrical conductivity impacted the growth, development and survival of various anuran tadpoles of brown tree frog, *Litoria ewingii* exposed to high saline condition (Chinathamby *et al.*, 2006). Electrical conductivity above 3 000 µS/cm had negative impacts on anurans species presence (Smith *et al.*, 2007). However, the electrical conductivity values of the test solutions were not up to 3 000 µS/cm, death of the tadpoles observed might be due to the high values of electrical conductivity.

Chronic exposure of calcium phosphate significantly reduced the survival of *Litoria aurea* tadpoles of a fertilizer-applied agricultural land in southeastern Australia (Hamer *et al.*, 2004). The death of tadpoles exposed to the contaminated-stream water of Irefin and Gege might be due to the high phosphate contents of the samples.

Endosulfan, which is an organochlorine pesticide affected *Rana temporaria* tadpoles (Denoel *et al.*, 2013). The tadpoles travelled shorter distances, swam less often at a lower speed and occupied less peripheral position than control tadpoles (Denoel *et al.*, 2015). Survival of the tadpoles was reduced after long-term exposure, which was associated with short-term behavioural dysfunctions. Therefore, endosulfan strongly affects behavioural repertory of amphibian tadpoles (Denoel *et al.*, 2015).

Furthermore, *Rana temporaria* tadpoles were developed in simulated experiments of ponds littered with metal-containing refuse ponds (Severtsova and Gutierrez, 2013). Retarded growth was observed in the tadpoles exposed to the water polluted with lead and the tadpoles were significantly smaller than the control group. However, those

developing in iron polluted water had an increased body size when compared with the control group.

5.5.4 Fishes (Frys and fingerlings of *Clarias gariepinus*)

Fishes are widely used to check the health of an aquatic body, hence the use of *Clarias gariepinus* frys and fingerlings. The link of fish to man in the food chain makes it to be a major test organism in ecotoxicological studies (Oshode *et al.*, 2008). They may provide advanced warning of the potential danger of new chemicals and the possibility of environmental pollution, if they are used for the assessment of water-borne and sediment-deposited toxins (Powers, 1989).

Clarias gariepinus is very hardy, however, the frys and fingerlings cannot tolerate pollution stress since the organs are not well developed. This led to the mortalities of the frys and fingerlings observed because of the high contamination level of the streams.

Clarias gariepinus is of commercial importance in aquaculture due to its positive attributes like resistance to diseases, high fecundity, and ease of larval production (Hogendoorn, 1980; Haylor, 1991; Kestemont *et al.*, 2007). However, there is low survival during the larval and fingerling stages (De Graaf and Jannsen, 1996) which is attributed to infectious diseases caused by parasites (Bricknell and Dalmo, 2005).

Haematology is used as an index of fish health status in a number of fish species to detect physiological changes following different stress conditions like exposure to pollutants, diseases, metals, hypoxia, and so on (Blaxhall, 1972; Duthie and Tort, 1985).

Oshode *et al.* (2008) after 96 hour exposure of fingerlings to 25 %, 35 % and 45 % concentrations of raw leachate collected from Aba Eku landfill, Ibadan, they observed 20 %, 40 % and 100 % mortalities respectively. They also observed abnormalities in the livers, gills and kidneys and physiological changes in the haematological parameters of the exposed fishes. Aderemi *et al.* (2012) also observed 20%, 40%, 60% and 80% mortality of *Clarias gariepinus* fingerlings when exposed to 1%, 2%, 3% and 5% concentrations of municipal landfill leachate respectively for 96 hours. However, no mortalities of *Clarias gariepinus* fingerlings were observed when exposed to 20 %, 40 %, 60 %, 80 % and 100 % concentrations of domestic effluent

discharge from a female hostel in Niger Delta University, Nigeria (Aghoghovwia *et al.*, 2015).

Endosulfan was highly toxic to juveniles of *Clarias gariepinus*. The 96 hour LC_{50} value obtained was 0.052 ppm, there was decrease in haematological values (PCV, Hb and RBC), which might be due to haemolysis of red blood cells leading to significant decrease in haematocrit which resulted in fish anaemia (Yekeen and Fawole, 2011).

Furthermore, fingerlings of *Clarias gariepinus* were exposed to lethal concentrations of herbicide 2,4-Dicholorophenoxyacetic acid (Shallangwa, 2011). The exposed *Clarias gariepinus* exhibited agitated swimming, loss of equilibrum, air gulping, period of quiescence and the fish turned on its flank and swarm in circles and finally died. The 96 hour LC_{50} value obtained was 86 mg/L.

In addition, adults of *Clarias gariepinus* were exposed to various concentrations of cassava effluent, death occurred at 15 ml concentration of cassava wastewater. Various heamatological responses were observed, which include anaemia, higher total white blood cell than control, and histopathological lesions which include severe necrosis, hypertrophy and vacuolation of hepatocytes (Adeyemo, 2005). According to NESREA (2011), the limit of oxygen for effluent discharged into a stream should not be less than 4 mg/L for organisms to be able to survive in it. Irefin and Gbagi test solutions had zero (0 mg/L) DO, Odinjo had 1.07 mg/L, this could be attributed to stress which eventually led to the death of the frys and fingerlings exposed to the test solutions.

In order for fish to survive in an aquatic medium, the physico-chemical qualities of the water should meet up with regulatory standard. Low quality water results in weak, sick and eventually death of fishes.

5.6 Conclusion and recommendation

The low diversity and abundance of earthworms present in the soil from the streams and dumpsites indicated that the sites were highly contaminated and polluted. This resulted from the low qualities of the soil, which could not support the existence of various species of earthworms.

There should be improvement of the soil qualities so that soil health would be better improved; all soil-dwelling fauna (not only earthworms) could be preserved and they will not go into extinction.

The results of the physico-chemical qualities of the streams showed that streams were highly polluted because the qualities could not meet up with the standard as stipulated by NESREA (2011). The low physico-chemical qualities of the streams had a negative impact on the survival of the different test organisms used for the bioassay. Therefore, efforts should be made in preserving our aquatic health and also for the survival of aquatic organisms.

The physico-chemical qualities of the groundwater samples close to the streams and dumpsites indicated that the groundwater samples were contaminated and since all their qualities did not meet up with the standards for drinking water, therefore, they were not fit for drinking.

The study showed that apart from wastes that were being dumped on the land, a lot of activities going on around the sites had negative effects on the existence of earthworms, soil, stream, groundwater and existence of aquatic organisms. Some of the activities include washing of abattoir wastes into streams without prior treatment of the effluent such as occurring in Gege and Gbagi. Auto-mechanic workshops around Ojokondo, Oremeji and Moniya, washing of cars and motor cycles as occurring in Odinjo and Omi Adio. Cassava processing as observed in Idi Ope, and food vendor around the Odinjo upstream, Gbagi and Omi Adio downstream.

In order to ensure sustainable management of conservation of soil and aquatic biodiversity as well as socio-economic importance of aquatic and soil resources of Ibadan, the following regulatory measures are therefore recommended:

There is need for waste management by waste reduction, reuse and recycling when and where appropriate. Each household should have refuse bins in front of the house and the Government should intensify more efforts on the collection of the waste from the households and the further movement to landfill sites that have been designated for dumping of wastes. There should be public enlightenment on the impacts of disposing wastes into water bodies and indiscriminately on land, such as susceptibitlity of inhabitants around the wastes sites to various diseases and infections such as cholera, typhoid and some other water-borne diseases, apart from negative

impacts on aquatic dwelling organisms. Public health officers should inspect various houses especially around the core or low income areas, for provision of toilets for defaecation.

Furthermore, abattoir owners and workers should be enlightened on the impacts of washdown of abattoir on public health, the environment and the fragility of the ecosystem. Treatment of abattoir effluent should be encouraged. There should be proper monitoring of abattoir to enhance compliance with hygienic requirements and sanitary regulations to reduce the transmission of zoonotic diseases. Regulatory bodies should strengthen the enforcement and punitive aspect of their responsibilities so that those who infract on environmental safety standards should be brought to book to serve as deterrant either in form of fines or punishment.

In addition, auto-mechanic engineers and car wash operators should be enlightened on the impact of their disposal on land and in water. Environmental friendly techniques should be employed and their wastes must be treated before disposal.

For the cassava processing site, waste water should be treated before being released

and such water can be used for irrigating crops or safely released to rivers or streams. Solid waste such as cassava peels, fibrous residue and starch residue can be disposed by land filling and can be dried to produce animal feed.

The need for further studies on the work include a longer exposure duration of earthworms for the bioassay test to check changes or alterations in the survived earthworms in their aspects of reproduction, cocoon production, alterations in newly-developed earthworms; haematological and histopathological variations in exposed earthworms. Bioremediation should also be checked.

Furthermore, there is need for increased and continued combined environmental intervention, enlightenment and awareness programmes. These should be organized through public health workers for local residents on the environmental devastations that result from indiscriminate dumping of untreated wastes into the natural water bodies and on land as well as the benefits of adequate waste management measures.

In addition to the aquatic toxicity assays, tadpoles should be exposed for a longer duration to check for the likely alterations in metamorphosised frogs. Then the survived tadpoles during the 96 hour test should also be subjected to various histopathological and haematological tests. Frogs should be collected from the sites to

check for probable biochemical alterations in their vitellogen production, like the exhibition of female characters in the male frogs.

Public health aspect of the work should be carried out to check the effects of the waste disposal sites on human beings inhabiting the areas. This should be done by the use of questionnaires to interview inhabitants close to waste disposal sites on the health challenge they are constantly faced with. Information should also be gathered from hospitals near the waste sites to check for the data on the occurrence of food-, air- or water-borne infections like cholera, dysentery, diarrhoea, typhoid, hepatitis A and E, zoonotic diseases and some other infections that have been reported.

Lastly, this study serves as a database to initiate remediation programmes for the already affected sites (soil, surface water, groundwater) and check how the natural biota can be effectively conserved.

REFERENCES

Abidemi, O.O. and Theresa, O.C. 2015. Environmental fate of heavy metals in soil of Ido-Osun waste dump site, Osogbo, Osun, Nigeria. *American Journal of Environmental Protection 3*.1: 1-4.

Abimbola, W.A., Amoo A.O.J. and Owa, S.O. 2013. Protozoan and helminth parasites of earthworms (*Alma millsoni* and *Libyodrilus violaceus*). *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 4.2: 293-295.

Ademoroti, C.M.A. 1996. *Standard methods of chemical analysis*. March Print and Consultancy, Benin.

Adekunle, I.M., Adetunji, M.T., Gbadebo, A.M. and Banjoko, O.B. 2007. Assessment of groundwater quality in a typical rural settlement in SouthWestern Nigeria. *International Journal of Environmental Research and Public Health* 4.4: 307-318.

Aderemi, A.O., Adewumi, G.A. and Otitoloju, A.A. 2012. Municipal landfill leachate characterization and its induction of glycogen vacuolation in the liver of *Clarias gariepinus*. *International Journal of Environmental Protection* 2.4: 20-24.

Adewoyin, O.A., Hassan, A.T. and Aladesida, A.A. 2013. The impacts of auto-mechanic workshops on soil and groundwater in Ibadan metropolis. *African Journal of Environmental Science and Technology* 7.9: 891-898.

Adeyemo, O.K. 2005. Haematological and histopathological effects of cassava mill effluent in *Clarias gariepinus*. *African Journal of Biomedical Research* 8: 179-183.

Agency for Toxic Substance and Disease Registry, ATSDR (2005).Toxicological profile for copper. Human Health Fact Sheet. Argonne National Laboratory, EVS. http://www.atsdr.cdc.gov/toxpro2.html.

Aghoghovwia, O.A., Aguoru, C.M. and Ohimain, E.I. 2015.Toxicity of domestic effluents to *Clarias gariepinus* fingerlings. *Journal of Advances in Biology and Biotechnology* 4.4: 1-6.

Ahmed, A.A. and Suleiman, W.N.A. 2001. Evaluation of groundwater and soil pollution in a landfill area using electrical resistivity imaging survey. *Environmental Management* 28.5: 655-663.

Akinbile C.O. 2006. Hawked water quality and its health implications in Akure, Nigeria. *Botswana Journal of Technology*, 15: 70–75.

Akinbile, C.O. 2012. Environmental impact of landfill on groundwater quality and agricultural soils in Nigeria. *Soil and Water Resources* 7.1: 18-26.

Akinbiyi, R. 1992. Improving the urban environment. *African Health* 15.1: 26-28.

Akoteyon, I.S. 2012. Evaluation of groundwater quality using contamination index in parts of Alimosho, Lagos-Nigeria. *American Academic and Scholarly Research Journal* 4.4: 35-41.

Akudo, E.O., Ozulu, G.U. and Osogbue, L.C. 2010. Quality assessment of groundwater in selected waste dumpsites areas in Warri, Nigeria. *Environmental Research Journal.*4.4: 281-285.

Aladesida, A.A. 2010. Earthworm taxonomy in southwestern Nigeria in relation to soil properties. Ph.D thesis submitted to the Postgraduate College School, Olabisi Onabanjo University, Ago – Iwoye. 152 pp.

Albaret. J and Lae, R. 2003. Impact of fishing on fish assemblages in tropical Lagoons. The example of the Ebrie Lagoon, West Africa. *Aquatic living Resources* 16: 1-9.

Alemneh, L.Y. 2015. Assessment of the robustness of biofil toilet technology for the treatment of blackwater. Dry Toilet 2015. 5th International Dry Toilet Conference. Available online www.huussi.net.

Alimba, C.G. and Bakare, A.A. 2016. In vivo micronucleus test in the assessment of cytogenotoxicity of landfill leachates in three animal models from various ecological habitats. *Ecotoxicology* 25.2: 310-319.

Alimba, C.G., Bakare, A.A. and Aina, O.O. 2012. Liver and kidney dysfunction in wistar rats exposed to municipal landfill leachate. *Resources and Environment* 2.4: 150-163.

Alimba, C.G., Bakare, A.A and Latunji, C.A. 2006. Municipal landfill leachates induced chromosome aberrations in rat bone marrow cells. *African Journal of Biotechnology* 5.22: 2053-2057.

Aliyu, B.N. 2011. Solid waste and its implications for climate change in Nigeria. *Journal of Human Ecology.* 34.2: 67-73.

Alkassasbeh, J.Y.M., Heng, L.Y. and Surif, S. 2009. Toxicity testing and effect of landfill leachate in Malaysia on behaviour of common carp (*Cyprinus carpio* L., 1758; Pisces, Cyprinidae). *American Journal of Environmental Sciences* 5: 209-217.

American Public Health Association (APHA) 1992. *Standard methods for the examination of water and wastewater*. 18th ed. Washington D.C: American Public Health Association. 1193pp.

APHA, AWWA, WEF 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th Edn. American Public Health Association, American Water Works Association, Water Environment Federation. Greenberg, A.E., Clesceri, L.S., and Eaton, A.D Wastington D.C. USA. 1213p.

Amber, I., Kulla, D.M. and Gukop, N. 2012. Municipal Waste in Nigeria Generation, Characteristics and Energy Potential of Solid. *Asian Journal of Engineering, Sciences and Technology* 2.2: 84 – 88.

Amos-Tautua, B.M.W., Onigbinde, A. and Ere, D. 2014. Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsite in Yenagoa, Nigeria. *African Journal of Environmental Science and Technology* 8.1:41-47.

Amusan, H.A., Ige, D.V. and Olawale, R. 1999. Preliminary investigation on the use of municipal wastes dump site for farming. *Paper presented at the 25th Annual Society Conference of Soil Science society of Nigeria*, 21 – 25 November, 1999. Benin City, Nigeria.

Anderson, J.M. and Ingram, J.S.I. (Eds). 1993. *Tropical soil biology and fertility*. A Handbook of Methods, 2nd Edition. CAB Int, U.K. pp 221.

Andriuzzi, W.S., Pulleman, M.M., Schmidt, O., Faber J.H. and Brussaard, L. 2015. *Plant and Soil* 397.1: 103 -111.

Anikwe, M.A.N. 2000. Amelioration of a heavy clay loam soil with rice husk dust and its effect on soil physical properties and maize yield. *Bioresource Technology* 74: 169-173.

Anikwe, M.A.N., and Nwobodo, K.C.A. 2002. Long-term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. *Bioresource Technology* 83: 241-250.

Arias, M.E., Gonzalez-Perez, J.A., Gonzalez-Villa, F.J. and Ball, A.S. 2005. Soil health - a new challenge for microbiologists and chemists. *International Microbiology.* 8: 13 – 21.

Ashbolt, N.J. 2004. Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology* 198.1-3: 229-238.

ATSDR, 2005. Agency for Toxic Substances and Diseases Registry. Toxicological profile for lead. www.atsdr.cdc>toxprofiles. Accessed on 12th December, 2013.

Atuanya, E.I., Nwogu, N.A. and Akpor, E.A. 2012. Effluent qualities of government and private abattoirs and their effects on Ikpoba River, Benin City, Edo State, Nigeria. *Advances in Biological Research* 6.5: 196 - 201.

Awolumate, O. 1977. Selected methods for soil and plant analysis. Central Analytical Laboratories. Cocoa Research Institute of Nigeria. Pp 58 – 60. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Ayoola, A.A. 2010. Replacement of fishmeal with alternative protein sources in aquaculture diets. M.Sc thesis submitted to the Department of Nutrition and Food Science, North Carolina state University, Raleigh, North Carolina. 145 pp.

Babanyara, Y.Y., Usman H.A. and Saleh, U.F. 2010. An overview of urban poverty and environmental problems in Nigeria. *Journal of Human Ecology* 31.2: 135-143.

Babayemi, J.O. and Dauda, K.T. 2009. Evaluation of solid waste generation, categories and disposal options in developing countries: a case study of

Nigeria. *Journal of Applied Science and Environmental Management* 13:83–88.

Bakare, A.A., Mosuro, A.A. and Osibanjo, O. 2005. An *in vivo* evaluation of induction of abnormal sperm morphology in mice by landfill leachates. *Mutat. Res.* 582: 28-34.

Bakare, A.A, Pandey, A.K., Bajpayee, M., Bhargav, D., Chowdhuri, D.K., Singh, K.P., Murthy, R.C and Dhawan, A. 2006. DNA damage induced in human peripheral blood lymphocytes by industrial solid waste and municipal sludge leachates. *Environmental and molecular mutagenesis* 48.30-37.

Bakare, A.A. and Wale-Adeyemo, A.R. 2004. The potential mutagenic and cytotoxic effects of leachates from domestic wastes and Aba-Eku landfill, Nigeria on *Allium cepa*. *Nature Environment and Pollution Technology* 3.4: 455-462.

Bates, R.G. 1954. Electrometric pH determinations. John Wiley and Sons, Inc., New York. In selected methods for soil and plant analysis, Institute of Agricultural Research and Training Manual.

Bamgbose, O., Odukoya O., Arowolo, T.O.A. 2000. Earthworms as bioindicators of metal pollution in dump sites of Abeokuta city, Nigeria. *Revista de Biologia Tropical* 48.1.

Bamidele, J.A., Idowu, A.B., Ademolu, K.O., Akinloye, O.A. and Bamgbola, A.A. 2016. Heavy metal accumulation and biochemical evaluation of earthworms from sawmills in Abeokuta, South-Western Nigeria. *Revista de Biologia Tropical* 63.4: 1213-1221.

Bano, K., and Kale, R. D. 1988. Reproductive potential and existence of endogenous rhythm in reproduction of earthworm *Eudrilus eugeniae*. *Proc. Zool. Soc.* (Calcutta) 38: 9-14.

Bareja, B.G. 2011. African Night Crawler (ANC), other composting earthworms described. www.cropsreview.com/night-crawler.html. Accessed on 2nd November, 2014.

Barinaga, M. 1990. Where have all the froggies gone? *Science* 247: 1033–1034.

Barois, I.P., Lavelle, M., Brossard, J., Tondoh, M.A., Martinez, J.P., Rossi, B.K., Senapati, A., Angeles, C., Fragoso, J.J., Jimenez, T., Decaëns, T., Lattaud,

K.K., Kanyoyo, K.K., Blanchart, E., Chapuis, L., Brown, G.G. and Moreno, A. 1993. Ecology of earthworm species with a large environmental tolerance and/or extended distributions . In Lavelle, P., Brussaard, L., and Hendrix, P. 1999. *Earthworm management in tropical agroecosystems*. CABI Publishing, New York. 300 pp.

Basel Convention. 1989. http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

Bates, R.C.1954. *Electrometric pH determination*. John Wiley and Sons Inc. New York pp 35-38. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Behbahaninia, A., Mirbagheri, S.A. and Nouri, J. 2010. Effects of sludge from wastewater treatment plants on heavy metals transport to soils and groundwater. *Iran Journal of Environmental Health Science and Engineering* 7.5:401–406.

Beketov, M.A. 2004. Different sensitivity of mayflies (Insecta, Ephemeroptera) to ammonia, nitrite and nitrate: linkage between experimental and observational data. *Hydrobiologia* 528: 209-216.

Benga-Coker, M.O. and Bafor, B.E. 1999. Waste management and water pollution, eds. Pickford, J.A., Proceedings of the 25th WEDC Conference, pp 12 -16, Addis Ababa, Ethiopia, Loughborough University, United Kingdom.

Bhadauria, T., Ramakrishnan, P.S., Srivastava, K.N. 1997. Population dynamics of earthworms during crop rotation under rainfed agriculture in central Himalayas, India. *Applied Soil Ecology* 6.3:205–215.

Bhadauria, T. and Saxena, K.G. 2010. Role of earthworms in soil fertility maintenance through the production of biogenic structures. *Applied and Environmental Soil Science*: 1-7. http://dx.doi.org/10.1155/2010/816073

Black, C.A. 1965. *Methods of soil analysis*. Part I, American Society of Agronomy. Madison, Wisconsin, USA. 1572 pp. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Blaustein ,A.R., Wake D.B and Souse, W.P. 1994. Amphibian declines: judging stability and susceptibility of population to local and global extinction. *Conservation Biology* 8:60–71.

Blaxhall, P.C. 1972. The haematological assessment of the health of freshwater fish. *Journal of Fish Biology* 4: 593-605.

Bottinelli, N., Henry-des-Tureaux, T., Hallaire, V., Mathieu, J., Benard, Y., Tran, T.D. and Jouquet, P. 2010. Earthworms accelerate soil porosity turnover under watering conditions. Geoderma 156. 1–2: 43-47.

Bouché, M.B., 1977. Strategies Lombricennes. In: Soil organisms as components of ecosystems, (Eds.) Lohm, U., Persson, *Ecological Bulletins (Stockholm)* 25:122-132. In: Mainoo, N.K. 2007. Feasibility of low cost vermicompost production in Accra, Ghana. A thesis submitted to the Department of Bioresource Engineering, McGill University, Montreal in partial fulfillment of the requirements of the degree of Master of Science. 103 pp.

Bowen, H.J.M. 1979. *The environmental chemistry of the elements.* London: Academic press. 333 pp.

Boyd, C. E 1982. Water quality management for pond fish culture development. *Aquaculture and Fisheries Science* 9: 34-44.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Soil Science* 59:39-45. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Bricknell, I. and Dalmo, R. A. 2005. The use of immunostimulants in fish larval aquaculture. *Fish and Shellfish Immunology* 19. 5: 457–472.

Cabrera, CL. and Rodriguez, D.M.G. (1999). Genotoxicity of leachates from a landfill using three bioassays. *Mat. Res.* 426:207-210.

Caldwell, B.A. 2007. (E: /APPENDIX B.doc). In Watershed Protection Plan Development Guidebook. Description of commonly considered Water Quality Constituents.

Canbek, M., Isikli, B., Uyanoglu, M., Demir, T.A. and Berber, A. 2005. Determination of lead accumulation in the *Lumbricus terrestris* (earthworm)

living in the roadside soils of Eskişehir, BCLF8. Meeting of the Balkan Clinikal Laboratory Federation, 35, September 20.23.2000, Romanya.

Capinera, J.L. 2008. Encyclopedia of Entomology. Springer science and Business Media. pp 4158-4165. ISBN 978-1-4020-6242.fish that feed on nymphs (Di Guilio and Hinton. 2008.

Capowiez, Y., Cadoux, S., Bouchant, P., Ruy, S., Estrade, J.R., Richard, G. and Boizard, H. 2009. The effect of tillage type and cropping system on earthworm communities, macroporosity and water infiltration. *Soil and Tillage Research* 105:209–216.

Carpenter, P.J., Ding, A. and Cheng, L. 2012. Identifying groundwater contamination using resistivity surveys at a landfill near Maoming, China. *Nature Education Knowledge.* 317: 20.

Carroll, D. 1962. Rainwater as a chemical agent of geologic processes: A Review. USGS Water Supply Paper 1535-G. 18 pp.

Cecchi, F, Pavan, Musacco, A. and Mata-Alvarez, J. 1993. Anaerobic pre-treatment of municipal solid waste before landfilling. In: Proceedings Sardinia ’93, IV International Symposium on Landfills. CISA.

Central Pollution Control Board. 2006. Ministry of Environment and Forests, Government of India, Delhi. Effects of sewage pollution on surface water bodies.

Chapman, D. 1996. *Water quality assessment. A guide to the use of biota, sediments and water in environmental monitoring*. 2nd Editon, E and FN Spon, New York. 21 pp.

Chapman, D. and Kimstach, V. 1992. *The selection of water quality variables*. *Water Quality Assessments: a Guide to the use of Biota, Sediments and Water in environmental monitoring.* Chapman, D. ed. London: Chapman and Hall. 50-199.

Chauhan, R.P. 2016. Role of earthworms in soil fertility and factors affecting their population dynamics: A review. *Journal of Recent Advances in Agriculture* 2.7: 277-284.

Chinathamby, K., Reina, R.D., Bailey, P.C.E and Lees, B.K. 2006. Effects of salinity on the survival, growth and development of tadpole of the brown tree frog, *Litoria ewingii. Australian Journal of Zoology* 54: 97–105.

Chen, M. and Ma, L.Q. 2001. Comparison of 3 aqua regia digestion methods of 20 Florida soils. *Soil Science Society of American Journal* 65: 491-499.

Chilton, J. and Chilton, K. 1992. A critique risk modelling and risk assessment of municipal landfills based on U.S Environmental Protection Agency techniques. *Waste Management and Research* 10: 505-516.

Chofqi, A., Younsi, A., Lhadi, E., Mania, J. and Veron, A. 2004. Environmental impact of an urban landfill on a coastal aquifer (El-Jadida, Morocco). *Journal of African Health Sciences* 39: 509-516.

Cabrera G.L. and Rodriques D.M.G.1999. Genotoxicity of leachates from a landfill using three bioassays. *Mutat. Res* 426:207-210.

Clark, W.M., 1923. Studies on Oxidation-Reduction. I. Introduction: *Public Health Reports* 38: 443-455

Clements, R., Murray, P. and Sturdy, R. 1991. The impact of 20 years' absence of earthworms and three levels of N fertilizer on a grassland soil environment. *Agriculture, Ecosystems and Environment* 36: 75–85.

Clements, W.H., Carlisle, D.M., Lazorchak, J.M. and Johnson, P.C. 2000. Heavy metals structure benthic communities in Colorado mountain streams. *Ecological Applications* 10:626-38.

Commons abundance network. 2015. Reducing food waste. commonsabundance.net/docs/reducing-food-waste

Commonwealth of Australia. 1996. State of the environment 1996. State of the environment advisory council and Department of the Environment, Sport and Territories. CISRO Publishing, Collingwood, Australia.

Conder, J.M., Lanno, R.P and Basta, N.T. 2001. Assessment of metal availability in smelter soil using earthworms and chemical extractions. *Journal of Environmental Quality* 30:1231 – 1237.

Coşkun, M., Steinnes, E., Frontasyeva, M.V., Sjobakk, T.E. and Demkina, S. 2006. Heavy metal pollution of surface soil in the Thrace Region, Turkey. *Environmental Monitoring and Assessment* 119.1: 545-556.

Critto, A., Carlon, C., and Marcomini, A. 2003. Characterization of contaminated soil and groundwater surrounding an illegal landfill (S. Giuliano , Venice, Italy) by principal component analysis and kriging. *Environmental Pollution* 122: 235-244.

Crillet, C. and Quetin, P. 2006. Effect of temperature changes on the reproductive cycle of loach in Lake Geneva from 1983 to 2001. *J. Fish Biol*. 69: 518-534.

Cuffney, T. F., M. R. Meador, S. D. Porter, and M. E. Gurtz. 2000. Responses of physical, chemical, and biological indicators of water quality to a gradient of agricultural land use in the Yakima River Basin, Washington. *Environmental Monitoring and Assessment* 64:259-270.

Curds, C.R. 1992. Protozoa in the water industry, Cambridge University Press, Cambridge, U.K .

Dahiya, S and Kaur, A. 1999. Physico-chemical characteristics of underground water in rural areas of Tosham subdivision, Bhiwani district, Haryana. *Journal of Environmental Pollution* 6.4: 281–288.

Darwin, C., 1881. The formation of vegetable mould through the action of worms, with observations on their habitats. Murray, London. 326 pp. In Earthworm Society of Britain. 2014. www.Earthwormsoc.org.uk/earthworm information/earthworm-info-pg.3. Accessed on 23rd August, 2015.

Davis, S.N. and DeWiest, R.J. 1966. Hydrogeology. New York: Wiley. In Abdul Saleem, Mallikarjun, N.D. and Kumar, K.V. 2012. Correlation-regression model for physicochemical quality of groundwater in South Indian city of Gulbarga. *African Journal of Environmental Science and Technology* 6.9: 353-364.

Dawodu, M.O. and Ipeaiyeda, A.R. 2008. Evaluation of groundwater and stream quality characteristics in the vicinity of a battery factory in Ibadan, Nigeria. *African Journal of Biotechnology* 7.12: 1933-1938.

Dedeke, G.A, Owa, S.O and Olurin, K.B. 2010. Macromineral profile of four species of earthworms *Hyperiodrilus africanus*, *Eudrilus eugeniae*, *Libyodrilus violaceus* and *Alma millsoni* from Nigeria. *Current Research Journal of Biological Sciences* 2.2: 103-106.

De Garaday, C.J. and Halbrook, R.S. 2006.Using anurans as bioindicators of PCB contaminated stream. *Journal of Herpetology* 40.1: 127-130.

De Graaf, G. J. and Janssen, H. 1996. Artificial reproduction and pond rearing of the African catfish, *Clarias gariepinus* in sub-Saharan Africa. *A handbook, Tech. Rep*. 362, FAO Fisheries, Rome, Italy.

Di Giuilio, R.T. and Hinton, D.E. 2008.The toxicology of fishes. CRC Press p794

Denoel, M., Libon, S., Kestemont, P., Brasseur, C., Focant, J.and De Pauw, E. 2013..Effects of sublethal pesticides exposure on locomotor behaviour : A video –tracking analysis in larval amphibians. *Chemosphere* 90.3: 945 – 951.

Department of Environment, National Working Committee (DOE, NWC). 1981. Report of the sub-committee on the disposal of sewage sludge to land: standing technical committee report 20. London: Department of Environment.

Devi, S. And Premkumar, R. 2012. Physico-chemical analysis of groundwater near industrial area, Cuddalore district, Tamilnadu, India. *International Journal of ChemTech Research* 4.1: 29-34.

Dominguez, E. 2006. Ephemeroptera de America Del sur penso ft publishers. pp17-24. ISBN 978-954-642-259-0 (Wikipedia, the free encyclopedia).

Dominguez, J. and Edwards, C.A. 2011. Biology and Ecology of earthworms species used for vermicomposting. By Taylor and Francis Group, LLC.

Dominguez, J., Edwards, C. and Ashby, J. 2001. The biology and population dynamics of *Eudrilus euginiae* (Kinberg),(Oligochaeta) in cattle waste solids. *Pedobologia* 45: 341 – 353.

Dunson, W.A., Wyman, R.L. and Corbett, E.S. 1992. A symposium on amphibian declines and habitat acidification. *Journal of Herpetology* 26: 349-352.

Duthie, G.G. and Tort, L. 1985. Effect of dorsal aortic cannulation on the respiration and haematology of the Mediterranean dogfish, *Scyliorhinus canicula*. *Comparative Biochemistry and Physiology* 87A: 879-883.

Earthworm Society of Britain. 2014. www.Earthwormsoc.org.uk/earthworm information/earthworm-info-pg.3. Accessed on 23rd August, 2015.

Echols, B.S., Currie, R.J. and Cherry, D.S. 2010. Preliminary results of laboratory toxicity tests with the mayfly, *Isonychia bicolor* (Ephemeroptera: Isonychiidae) for development as a standard test organism for evaluating streams in the Appalachian coalfields of Virginia and West Virginia. *Environ Monit Assess.*169 (1-4): 487-500. Accessed on 30th November, 2015.

Ecochem 2014. www.ecochem.com/t_compost_faq2.html. Accessed on 30th November, 2015.

Eddy, N.O., Odoemelem, S.A. and Mbaba, A. 2006. Elemental composition of soil in some dumpsites. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 5.3:1349-1365.

Edwards, C. A. 1988. Breakdown of animal, vegetable and industrial organic wastes by earthworms. In *Earthworms in waste and environmental management*, ed. C. A. Edwards and E. F. Neuhauser, 21–31. SPB, the Hague, the Netherlands. In Dominguez, J. and Edwards, C.A. 2011. Biology and Ecology of earthworms species used for vermicomposting. By Taylor and Francis Group, LLC.

Edwards, C.A., and Bohlen, P.J. 1996. *Biology and ecology of earthworms.* Chapman and Hall, UK.

Edwards, C.A. and Lofty, J.R. 1972. *Biology of earthworms*. Chapman and Hall, London. 283 pp.

Edwards, C.A. and Lofty, J.R. 1977. *Biology of earthworms.* (2nd edition). Chapman and Hall, London. 333 pp.

Edwards, W., Shipitalo, M., Owens, L. and Norton, L. 1990. Effect of *Lumbricus terrestris* L. burrows on hydrology of continuous no-till corn fields. *Geoderma* 46: 73–84.

Ekundayo, J.A. 1977. Environmental consequences of the pollution of the Lagos Lagoon. *Bulletin of the Science Association of Nigeria* 3: 290-299.

El Achheb, A. 2002. Contribution à l'étude de la minéralisation et identification des sources de contamination des eaux souterraines. Application au système aquifère du bassin Sahal-Doukkala (Maroc). Univ Chouaib Doukkali, 133, 206 pp. In Chofqi, A., Younsi, A., Lhadi, E., Mania, J. and Veron, A. 2004. Environmental impact of an urban landfill on a coastal aquifer (El-Jadida, Morocco). *Journal of African Health Sciences* 39: 509-516.

El-Duweini, A.K., and Ghabbour, S.I. 1965. Population density and biomass of earthworms in different types of Egyptian soils. *Journal of Applied Ecology* 2:271–287.

Elueze, A.A., Omidiran, J.O. and Nton, M.E. 2004. Hydrogeochemical inverstigation of surfacewater and groundwater around Ibokun, Ilesha area, Southwestern Nigeria. *Journal of Mining and Geology*. 40.1: 57-64.

Ensminger, L.E. 1954. Some factors affecting the adsorption of sulphate by Alabama soils. *Proc. Amer. Soc. Soil Sci.* 18: 259–264. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Enugu State Environmental Sanitation. 1994. In Ezeji, J. 2010. Another look at the Niger-Delta. http://joachimibeziako.blogspot.com/2010/06/another look-at-niger-delta.htm.

Environmental Fact Sheet, EFS (2005). Copper: Health Information Summary. New Hampshire Department of Environmental Services, ARD-EHP-9. www.des.nh.gov.

Enwezor, W.O., Ohiri, A.C., Opubaribo, E.E. and Udoh, E.J. 1988. *A review of soil fertility investigations in southeastern Nigeria.* Vol. II. Lagos: F.D.A.

EPA. 1986. The Environmental Protection Act. No 29 of 1986. Ministry of Environments and Forests, Department of Environment, Forests and Wildlife, Government of India, New Delhi. https://saferenvironment.wordpress.com. Accessed on 25th October, 2013.

EPA, Victoria. 2012. Illegal dumping alert. www.epa.vic.gov.au/~/media/Publications/1512.pdf.

Ernst, G., Felten, D., Vohland, M. and Emmerling, C. 2009. Impact of ecologically different earthworm species on soil *water characteristics. European Journal of Soil Biology 45.3: 207-213.*

Esry, S.A. and Habicht, J.P. 1986. Epidemiologic evidence for health benefits from improved water and sanitation in developing countries. *Epidemiologic reviews* 8: 117-128.

Esry, S.A., Potash, J.B. and Shiff, C. 1991. Effects of improved water supply and sanitation on ascariasis, diarrhea, dracunculiasis, hookworm infection, schistosomiasis and trachoma. *Bulletin of the World Health Organization* 6.5: 609-621.

European Commission. 2006. Reference document on best available techniques for waste incineration. BAT reference document (BREF). European IPPC Bureau, Seville, Spain. eippcb.jrc.es/pages/FActivities.htm..

Evans, D.W., N.H. Cutshall, F.H. Cross and 1977. Manganese cycling in the Newport estuary, North Carlifonia. Estuar. Coast. *Marine Sciences* 5: 71-80. In Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the mangrove swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research* 5.1: 08-21.

Ewa, E.E., Iwara, A.I., Adeyemi, J.A., Eja, E.I., Ajake, A.O. and Otu, C.A. 2011. Impact of industrial activities on water quality of Omoku creek. *Sacha Journal of Environmental Studies* 1.2: 8-16.

Ezeji, J. 2010. Another look at the Niger-Delta. http://joachimibeziako.blogspot.com/2010/06/another look-at-niger-delta.htm.

Fabunmi, I., Nwoko, J.C., Imhansoloeva, M.T. and Appia, Y.J. 2016. Earthworms *Eudrilus eugeniae* as bio-indicators of heavy metal contamination in Port Harcourt dumpsites. *Journal of Scientific Research and Reports* 9.4: 1-10.

Fagade, S.O. and Olaniyan, C.I.O. 1974. Seasonal distribution of the fish fauna in Lagos

Lagoon. *Bull Institution for Africa Noire Series A* 36:245-252.

Fagbami, J.A. 1976. The soils and agro-environment of the Ibadan area. Department of Agronomy, University of Ibadan. In Oyadiran, O. 2009. Landuse landcover change intraditional urban settlement. A case study of Ibadan metropolis, Nigeria. M.Sc Thesis (Internet Published).

Fagbenro, O.A. and Davies, S.J. 2001. Use of soybean flour (dehulled, solvent-extracted soybean) as a fish meal substitute in practical diets for African catfish, *Clarias gariepinus* (Burchell 1822): growth, feed utilization *Journal of Applied Ichthyology* 17.2: 64–69.

Fakayode, S.O. 2005. Impact assessment of industrial effluent on water quality of the receiving Alaro river in Ibadan, Nigeria. *AJEAM – RAGEE* 10: 1-13.

Fatoki, O.S., Lujiza, N. and Ogunfowokan, A.O. 2002. Trace metal pollution in Umtata River. *Water SA* 28.2: 183-190.

Federal Ministry of Housing and Environment (FHME). 1982. State of the environment in Nigeria. Monograph Series, No 2. Solid waste Management in 15 cities and urban areas in Nigeria. In Mshelia, A. D. 2015. Solid waste management: An urban environmental sanitation problem in Nigeria Sky Journal of Soil Science and Environmental Management 4.3: 034–039.

FEPA. 1991. National environmental protection (effluent limitation) regulations (S.I.8), FEPA, FGPL, Lagos, Nigeria.

Ficken, K.L.G. and Byrne, P.G. 2013. Heavy metal pollution negatively correlates with anurans species richness and distribution in southeastern Australia, *Austral Ecology : A Journal of Ecology in the Southern Hemisphere* 38.5: 523-533.

Finney, D.J. 1971. Probit analysis. 3rd edition. Cambridge: Cambridge University Press, xv+ 333 pp.

Florida Statutes 403.703(19). Florida Senate 2010. Proposed committee substitute by the committee on environmental preservation and conservation. Archive.flsenate.gov>Senate>bills>pdf. Accessed on 2nd March, 2012.

Food and Agriculture (FAO). 2015. Fisheries and aquaculture. Cultured aquatic species information programme *Clarias gariepinus* (Burchell, 1822). Accessed online on 1st December, 2015.

Fox, R.L., Olsen, R.A. and Rhodes, H.F. 1964. Evaluation of sulphur status of soils by plants and soil tests. *Soil Science American Procedure* 28: 243-246. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Fragoso, C. and Lavelle, P. 1992. Earthworm communities of tropical rain forests. *Soil Biology and Biochemistry* 24: 1397-1408.

Franceys, R., Pickford, J., and Reed, R. 1992. A guide to the development of on-site sanitation. 9241544430_eng.pdf.

Francis, G.S. and Fraser, P.M. 1998. The effects of three earthworm species on soil macroporosity and hydraulic conductivity. *Applied Soil Ecology 10.1–2: 11-19.*

Freda, J. 1991. The effects of aluminum and other metals on amphibians. *Environmental Pollution.* 71.(2-4):305-328.

Freeze, R.A. and Cherry, J.A. 1979. Groundwater, New Jersey: Prentice-Hall. Pg 604. In Abdul Saleem, Mallikarjun, N.D. and Kumar, K.V. 2012. Correlation-regression model for physico-chemical quality of groundwater in South Indian city of Gulbarga. *African Journal of Environmental Science and Technology* 6.9: 353-364.

Fufeyin, P. and Egborge, A.B.M. 1998: Heavy metals of Ikpoba River, Benin City, Nigeria. *Tropical Freshwater Biology* 7:27-36.

Gałczyńska, M., Gamrat, R., Burczyk, P., Horak, A. and Kot, M. 2013. The influence of human impact and water surface stability on the concentration of selected mineral macroelements in mid-field ponds. *Water-Environment-Rural Areas* 3(3/43): 41-54 (in Polish). In Potasznik A., Szymczyk S. 2015. Magnesium and calcium concentrations in the surface water and bottom deposits of a river-lake system. *Journal of Elementology* 20.3:677-692.

Gillies, M.T. 1980. An introduction to the study of *Cloeon* LEACH (Baetidae, Ephemeroptera) West Africa. Bulletin de l'I.F.A.N.T.42, series A.1: 135 – 156.

Golwer, A. and Matthess. G. 1968. Research on groundwater contaminated by deposits of solid waste. *Int. Assoc, Sci. Hydrol.* 129 -133.

Gonzalez, G. 2002. Soil organisms and litter decomposition. In: Ambasht, R.S., Ambasht, N.K. (eds) Modern trends in applied terrestrial ecology. Kluwer Academic/ Plenum Publishers, New York, pp 315–329. In: Gonzalez, G., Huang, C.H., Zou, X. and Rodriguez, C. 2006. *Biol Invasions*. DOI 10.1007/s10530-006-9023-7. Accessed online on 11th November, 2015.

Gonzalez, G., Huang, C.H., Zou, X. and Rodriguez, C. 2006. *Biol Invasions*. DOI10.1007/s10530-006-9023-7. Accessed online on 11th November, 2015.

Gonzalez, G., and Seastedt, T.R. 2001. Soil fauna and plant litter decomposition in tropical and subalpine forests. *Ecology* 82:955–964.

Gouveia, N. and Ruscitto do Prado, R. 2010. Health risks in areas close to urban solid waste landfill sites. *Rev Saude Publica* 44.5: 1-8.

Graff, O. 1982. Vergleich der Regenwurmarten *Eisenia foetida* and *Eudrilus euginiae* hinsichtlich ihrer Eignung zur Proteingewinnung aus Abfallstoffen. *Pedobiologia* 23: 277 – 282.

Greweling, T. and Peech, M. 1965. Chemical soil tests. Cornel Univ. Agric. Exp. Station, Bull 1960. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Grochowska, J. and Tandyrak, R. 2009. The infuence of the use of land on the content of calcium, magnesium, iron and manganese in water exemplifed in three lakes in Olsztyn vincinity. *Limnological Review* 9.1: 9-16.

Gupta, N. 2009. Effect of oil sands process - affected water and substrate on wood frog (*Rana sylvatica*) eggs and tadpole . M.Sc thesis submitted to the Toxicology Graduate program, University of Syskatchewan, Canada. 149pp. ecommons.usask.ca/bitstream/handle/10388/etd…/Niti_Gupta_Thesis.pdf. Accessed on 1st Dec. 2015.

Gupta, S.K. and Gupta, R.C. 2006. *General and applied Ichthyology (Fish and Fisheries).* S. Chand and Company Ltd. Ram Niger, New Delhi. 1130 pp.

Habitat (1997). In Achankeng, E. 2003. Globalization, urbanization and municipal solid waste management in Africa. African Studies Association of Australasia and the Pacific 2003 Conference Proceedings – African on a Global stage.

Hall, R.J. and Mulhern, B.M. 1984. Are anurans heavy metal accumulators? University of Kansas, Museum of Natural History, p. 123-133.

Hamer, G. 2003. Solid waste treatment and disposal: effects on public health and environmental safety. *Biotechnology Advances* 22: 71-79.

Hamer, A.J., Makings, J.A., Lane, S.J and Mahony M..J. 2004. Amphibian decline and fertilizers used on agricultural land in south-eastern Australia. *Ecosystems and Environment* 102: 299–305.

Hauser, S. 1993. Distribution and activity of earthworms and contribution to nutrient recycling in alley cropping. *Biology and Fertility of Soils* 15:16 - 20.

Hauser, S., Asawalam, D. O. and Vanlauwe, B. 1998. Spatial and temporal gradient of earthworm casting activity in alley cropping systems. *Agroforestry Systems* 41:127-137.

Haylor, G.S. 1991. Controlled hatchery production of *Clarias gariepinus* (Burchell 1922): growth and survival of fry at high stocking density. *Aquacult. Fish. Manag*. 22:405-422.

Heinz-Christian, F., Ulfert, G. and Sabina, T. 2011. Earthworms as bioindicators of soil quality. Chapter 16. Karaca, A. (ed.). biology of earthworms. *Soil Biology* 24. Springer-Verlag Berlin Heidelberg 2011. Pp 261 - 278.

Hem, J.D. 1985. Study and interpretation of the chemical characteristics of natural water. USGS. Water supply paper No 2254, pg 264.

Hendrix, P.F., and Bohlen, P.J. 2002. Exotic earthworm invasions in North America: ecological and policy implications. *BioScience* 52:801–811.

Hendrix, P.F., Mueller, B.R., Bruce, R.R., Langdale, G.W and Parmelee, R.W. 1992. Abundance and distribution of earthworms in relation to landscape factors on the Georgia Piedmont, U. S. A. *Soil Biol. Biochem.* 24.12: 1357–1361.

Henton, M.P. 1982. Waste disposal in Scotland and its effects on ground and surface waters. Effects of waste disposal in ground and surface water. Proceedings of the Exeter Symposium, July 1982. *IAHS Publ.* 139.

Hess, R. and B. Schmid, 2002. Zinc supplement can have toxic effects. *J. Paediatr. Haematol./Oncol*., 24: 582-584. In Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the mangrove swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research* 5.1: 08-21.

Hill, B.H., Willingham, W.T., Parrish, L.P. and McFarland, B.H. 2000. Periphyton community responses to elevated concentrations in a Rocky Mountain stream. *Envvirponmental Pollution* 95: 183-190.

Hogendoorn, H. 1980. Controlled propagation of the African catfish, *Clarias lazera* (C. and V.). 3. Feeding and growth of fry. *Aquaculture* 21:233-241.

Hoornweg, D. and Bhada - Tata, P. 2012. http://www.scribd.com/doc/97467178/What-a-Waste-A-Global Review-Of-Solid-Waste-Management. No 15.

Hopkins, W.A., Congdon, J. and Ray J.K. 2000. Incidence and impact of axial malformations in larval bullfrogs (*Rana catesbiana*) developing in the site polluted by a coal–burning power plant. *Environmental Toxicology and Chemistry* 19: 862-868.

Hopkins, W. and Rowe. 2010. Interdisciplinary and hierarchial approaches for studying the effects of metals and metalloids on amphibians. In Donald, W.S., Greg, L., Christine A.B. and Sherry, K. *Ecotoxicology of amphibian and reptiles*, 2nd edition, CRC press. 944 pp.

Horn, H. 1996. Measurement of overlap in comparative ecological studies. *Am Nat* 100: 419-424.

http://imnh.isu.edu/digitalatlas/hydr/concepts/surfhyd/srfwtr.htm.In https://en.wikipedia.org/wiki/Surface_water.

http://www.emro.who.int/CEHA/pdf/Pakistan.pdf

http://www.searo.who.int/ENT/Section1257/Section2263/Info-Kit/WHO-Sanitation-in Emergencies.pdf

https://en.wikipedia.org/wiki/Ibadan

https://www.geappliancesparts.com/store/parts/category/disposers

Hughes, J.L. 2004. Evaluation of groundwater degradation result from waste disposal to Alluvium Near Barstow, California. *U.S. Geological survey professional Paper* 878.

Hydrologie.org/redbooks/a078/iahs_078_0129.pdf

Ideriah, T.J.K., Omuaru, V.O.T. and Adiukwu, P.U. 2006. Soil quality around a solid waste dumpsite in Port Harcourt. *African Journal of Ecology* 44.3: 338–394.

Ihedioha, J.N., Ukoha, P.O. and Ekere, N.R. 2016. Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria. Environ Geochem Health. May 12. [Epub ahead of print]. DOI:10.1007/s10653-016-9830-4.

Ikem A., Osibanjo, O. Sridhar, M.K.C and Sobande, A. 2002. Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria. *Water, Air and Soil Pollution* 140. 1-4.

Imevbore, A.M.A. 1983. The investigation of faecal pollution in the surface water of the Niger Delta of Nigeria. Final report on vol. 3 Ed. Niger Delta Basin Development.

IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Iruruaga, E.T. 2012. Solid Waste Management in Nigeria. www.d-waste.com › New Ideas.

Jackson, M.L. 1962. Nitrogen determination from soils and plant tissues. In IITA (International Institute of Tropical Agriculture). 1979. Selected methods for soil and plant analysis. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Jayakumar, P. and Natarajan, S.S. 2012. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus: 1-26. doi: 10.1186/2193-1801-1-26

Jeyanthi, V., Paul, J.A.J., Selvi, B.K., Karmegam, N. 2016. Comparative study of biochemical responses in three species of earthworms exposed to pesticide and metal contaminated soil. *Environmental Processes* 3.1: 167-178.

John, N. M., Edem, S.O., Ndaeyo, N.U. and Ndon,B.A. 2006. *Journal of Plant Nutrition* 29 2: 189 – 194.

Jones, C.G., Lawton, J.H. and Shachak, M. 1994. Organisms as ecosystem engineers *Oikos* 69.3: 373–386.

Jouquet, P., Bottinelli, N., Mathieu, N., Orange, D., Podwojewski P, Henri des Tureaux, T. and Tran Duc, T. 2006. Impact of land-use change on earthworm diversity and activity: the consequences for soil fertility and soil erosion. In: Gebbie, L., Glendinning, A., Lefroy-Braun, R. and Victor, M. (editors). 2007. *Proceedings of the International Conference on Sustainable Sloping Lands and Watershed Management: linking research to strengthen upland policies and practices.* 12th - 15th December, 2006. Luang Prabang, Lao PDR Vientiane: NAFRI. 130 – 143.

Kabata-Pendias, A., and Pendias, H. 1984. Trace elements in soils and plants. CRC Press, Inc., Boca Raton, USA. Pp 107 -109.

Kale, V.S. 1988. Characteristics of channel fill deposits of upper Godavari river basin and their implication on the interpretation of Late Quaternary fluvial megasequences. Geology and environment. Edited by Singh, S. and Tiwari, R.C. published by Allahaba and Geographical Society, Allahabad, Pp. 171-202.

Kalu, S., Koirala, M. and Khadaka, U.R. 2015. Earthworm population in relation to different land use and soil characteristics. *Journal of Ecology and the Natural Environment* 7.5:124-134.

Kanbour, F. 1997. Generation status of urban waste management in West Asia. Paper delivered at the UNEP Regional Workshop on urban waste management in West Asia, Bahrain, 23-27 November, 1997.

Kaonga, C.C. and Monjerezi, M. 2012. Periphyton and earthworm as biological indicators of metal pollution in streams of Blantyre City, Malawi. Water Pollution. Edited by Nuray, B. ISBN 978-953-307-962-2.

Karaca, A. 2004. Effect of organic wastes on the extractability of cadmium, copper, nickel and zinc in soil. *Geoderma* 122: 297–303.

Karanjal, N., Mutua, G.K., Ayuke, F., Njenga, M., Praim, G. and Kimenju, J. 2010. Dynamics of soil nematodes and earthworms in urban vegetable irrigated with wastewater in the Nairobi river basin, Kenya. *Tropical and Subtropical Agroecosystems* 12: 521-530.

Kashiwabara, M. and Tsude, T. 1994. Relation between dissolved matter and conductivity of Ichikawa industrial water. *Kogye Yossui* 186: 44-49.

Kestemont, P., Toko, I., Fiogbe, E.D. and Koukpode, B. 2007. Rearing African catfish (*Clarias gariepinus*) and vindu catfish (*Heterobranchus longifilis*) in traditional fish ponds (whedos): effects of stocking density on growth, production and body composition. *Aquaculture* 262: 65-72.

Kiffney P.M. and Clements, W.H. 1994. Effects of heavy metals on a rocky mountain stream macroinvertebrates assemblage in experimental microcosm. *Journal of the North America Benthological Society* 13: 51 – 524.

Kiffney, P.M. and Clements, W.H. 1996. Effects of metals on stream assemblage from different altitudes. *Ecological Application* 6: 427 – 481.

King, R.P, and Jonathan, G.E. 2003. *Aquatic environmental perturbations and monitoring. African Experience*, USA 166p.

Kola-Olusanya, A. 2011. Impact of municipal solid waste on underground water sources in Nigeria. *European Scientific Journal* 8.11: 1-19.

Kooch, Y. and Jalivand, H. 2008. Earthworms as ecosystem engineers and the most important detritivores in forest soil. *Pakistani Journal of Biological Sciences* 11.6: 819-825.

Krieger, K.A.1997. Mayflies and Lake Erie: A sign of the times. Ohio States University sea grant fact sheet FS-069, Columbus, Ohio.

Landa, V. and Soldan, T. 1995. Mayflies as bioindicators of water quality and environmental change on a regional and global scale. Current directions in research on Ephemeroptera. Canadian Scholar's Press, Inc., Toronto. Pp. 21-29.

landfill leachate.htm

Lavelle, P. 1988. Assessing the abundance and role of invertebrate communities in tropical soils: aims and methods. *Journal of African Zoology* 102: 275-283.

Lavelle, P., Bignell, D. and Lepage, M. 1997. Soil function in a changing world. The role of invertebrate ecosystem engineers. *European Journal of Soil Biology* 33: 159-193.

Lavelle, P. and Brussaard, L., and Hendrix, P. 1999. *Earthworm management in tropical agroecosystems*. CABI Publishing, New York. 300 pp.

Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the mangrove swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research* 5.1: 08-21.

Leachate. www.foe.org/site1/ptp/chapter 3.html.

Lee, K.E. 1985. Earthworms, their ecology and relationships with soils and land use. Academic Press, New York. In: Gonzalez, G., Huang, C.H., Zou, X. and Rodrıguez, C. 2006. *Biol Invasions*. DOI 10.1007/s10530-006-9023-7. Accessed online on 11th November, 2015.

Lee, G.F., Jones, R.A. and Ray, C. 1986. Sanitary landfill leachate recycle. *Biocycle* 27: 36- 38.

Legrand, H. E. 1965. In Golwer, A. and Matthess. G. 1968. Research on groundwater contaminated by deposits of solid waste. *Int. Assoc, Sci. Hydrol.* 129-133. Hydrologie.org/redbooks/a078/iahs_078_0129.pdf

Lemtiri, A., Colinet, G. Alabi, T. Cluzeau, D., Zirbes, L., Haubruge, E. and Francis, F. 2014. Impacts of earthworms on soil components and dynamics. A review. *Biotechnologie, Agronomie, Société et Environnement* 18.1: 121-133.

Letsrecycle.com. 2006. "PM's advisor hails recycling as climate change action." In https://en.wikipedia.org/wiki/Recycling

Linder, G. and Grillitsch, B.2000. Ecotoxicology of metals.

Liu, Z.G, and Zou, X.M. 2002. Exotic earthworms accelerateplant litter decomposition in a Puerto Rican pasture and a wet forest. *Ecol Appl* 12:1406–1417.

Logan, T.J. 2002. Soil and environmental quality. In Anikwe, M.A.N., and Nwobodo, K.C.A. 2002. Long-term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. *Bioresource Technology* 83: 241-250.

Longe, E.O. and Balogun, M.R. 2010. Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. Res. *J.Appl. Sci. Eng. Technol*.2(1):39-44.

Lowe-McConnel R.H. 1987. *Fish Communities in Tropical Freshwater* Longman, London and New York. 137p.

Ma, W.C. 1982. Biomonitoring of soil pollution: Ecotoxicological studies of the effect of soil-borne heavy metals on 'Lumbricid earthworms'. Research Institute for Nature Management, Arnhem, Netherlands, 1982, pp. 83-97.

Maclean, M.A. and Parkinson, D. 1997. Soil impacts on the epigeic earthworm *Dendrobaena octaedra* on organic matter and microbial activity in lodgepole pine forest. *Canadian Journal of Forest Resources* 27:1907-1913.

Madeira, M, Auxtero, E. and Sousa, E. 2003. Cation and anion exchange properties of Andisols from the Azores, Portugal, as determined by the compulsive exchange and the ammonium acetate methods. *Geoderma* 117: 225–241.

Madge, D.S. 1969. Field and laboratory studies on the activities of two species of tropical earthworms. *Pedobiologia* 9:188 - 214.

Mahananda, M.R., Mohanty, B.P. and Behera, N.R. 2010. Physico-chemical analysis of surface water and groundwater of Bargarh District, Orissa, India. *IJRRAS* 2.3.

Mainoo, N.K. 2007. Feasibility of low cost vermicompost production in Accra, Ghana. A thesis submitted to the Department of Bioresource Engineering, McGill University, Montreal in partial fulfillment of the requirements of the degree of Master of Science. 103 pp.

Mainoo, N.K., Whalen, J.K. and Barrington, S. 2008. Earthworm abundance related to soil physicochemical and microbial properties in Accra, Ghana. *African Journal of Agricultural Research* 3.3: 186-194.

Manivaskam, N. 2005. *Physico-chemical examination of water, sewage and industrial effluent.* 5th Edition. Pragati Prakashan Meerut. In Devi, S. and Premkumar, R. 2012. Physico-chemical analysis of groundwater near industrial area, Cuddalore district, Tamilnadu, India. *International Journal of ChemTech Research* 4.1: 29-34.

Marine Insight News Network, 2016. www.marineinsight.com/environment/causes-and-effects-of-ocean-dumping/

Marshall, T.J., Holmes, J.W. and Rose, C.W. 1996. Soil Physics (3rd edition), Cambridge University Press, UK.

Mason, C.F. 1991. *Biology of Freshwater Pollution*, 2nd edition. Wiley, New York. 250 pp.

Matagi, S. V. 1996. The effects of pollution on benthic macroinvertebrate in a Ugandan stream. *Arch. Hydrobiol*. 137.4: 537–549.

Mba, C.C. 1996. Treated cassava peel vermicomposts enhanced earthworm activities and cowpea growth in field plots. *Resour. Conserv. Recy*. 17: 219 – 226.

Mbagwu, J.S.C. 1989. Influence of cattle feed lot manure on aggregate stability, plastic limit and water retention of three soils in North Central Italy. *Biological Wastes* 28: 257-269.

Mbagwu, J.S.C. and Piccolo, A. 1990. Some physical properties of structural aggregates separated from organic - waste amended soil. *Biological wastes* 33: 107-121.

Mbonu M. 1991 : Hydrogéologie, hydrochimie et géochimie isotopique des aquifères de socle du plateau de Jos et des plaine environnantes (Nigéria). Thèse Université d'Avignon et des Pays de Vaucluse, France, 80.

Mckenzie, H.A. and Smythe, L.E. 1998. Quantitative trace analysis of biological materials. Elsevier, Amsterdam.

McLean, M.A. and Parkinson, D. 1997. Soil impacts of the epigeic earthworm *Dendrobaena octaedra* on organic matter and microbial activity in lodgepole pine forest. *Can. J. For. Res.* 27: 1907 – 1913.

Miller, G.T. (Jr.) 1999. Environmental Science. *Working with the earth* 7th Edition. Wadsworth Publishing Company.

Miller, D.M., and Miller,W.P. 2000. Land application of wastes. In: Summer, M.E (Ed), Handbook of Soil Science, CRC Books, New York.

Minareci, O., Ozturk, M. Egemen, O. and Minareci, E. 2009. Detergent and phosphate pollution in Gediz river, Turkey. *African Journal of Biotechnology* 8.15: 3568-3575.

Morgan, J.E. and Morgan, A.J. 1988. Cadmium lead interaction involving earthworms, part 1: The effect of exogenous calcium and lead accumulation by earthworm under field and laboratory conditions. *Environmental Pollution* 54: 123-128.

Nagell, B. 1977. Survival of *Cloeon dipterum* (Ephemeroptera) larvae under anoxic conditions in winter. *Oikos* 29: 161 – 165.

Nahmani, J., Lavelle, P., Lapied, E. and van Oofort, F. 2004. Effects of heavy metal soil pollution on earthworm communities in the north of France. *Pedobologia* 47: 663-669.

Nartey,V.K., Hayford, E.K. and Ametsi, S.K. 2012. Assessment of the impact of solid waste dumpsites on some surface water systems in the Accra Metropolitan Area, Ghana. *Journal of Water Resource and Protection* 4: 605-615.

National Environmental Standards and Regulatory Agency (NESREA). National Environmental (Surface and groundwater control) regulations. 2011.

National Population Commission 2007. Provisional figure released by the National Population Commission (2007) and Survey Department of the Ministry of Lands, Housing and Survey, Ibadan.

National small Flows Clearinghouse 2007. Sewage Disposal FAQ's

Navas, A . and Machin, J. 2002. Spatial distribution of heavy metals and arsenic in soils of Aragon (Northeast Spain): controlling factors and environmental implications. *Applied Geochemistry* 17: 961 - 973.

Nelson, S. A. (2007). Lecture notes of Professor Stephen A. Nelson of Tulane University. (solid waste.htm).

Neuhauser, E.F., Kaplan, D.L., and Hartenstein, R. 1979. Life history of the earthworm *Eudrilus eugeniae*. *Rev. Ecol. Biol. Sol.* 16: 525 – 34.

Neuhauser, E.F., Loehr, R.C., and Malecki, M.R. 1988. The potential of earthworms for managing sewage sludge. In *Earthworms in Waste and Environmental Management*, ed. C. A. Edwards and E. F. Neuhauser, 9–20. SPB Academic Publishing, the Hague, the Netherlands. In Dominguez, J. and Edwards, C.A. 2011. Biology and Ecology of earthworms species used for vermicomposting. By Taylor and Francis Group, LLC.

Nigerian Institute of Safety Professionals (NISP). 2003. Contractor employee training manual, Level 3, ECNEL Ltd, Port Harcourt, Nigeria. In Omofonmwan, S.I. and Eseigbe, J.O. 2009. Effects of solid waste on quality of undergroundwater in Benin metropolis, Nigeria. *Journal of Human Ecology* 26.2: 99-105.

Noring, F. 1951. In Golwer, A. and Matthess. G. 1968. Research on groundwater contaminated by deposits of solid waste. *Int. Assoc. Sci. Hydrol.* 129-133. hydrologie.org/redbooks/a078/iahs_078_0129.pdf

Nkwocha, E.E., Pat-Mbano, E.C. and Nnaji, A.O. 2011. Effect of solid waste dump on river water: A paradigm in a Nigerian tropical environment. *International Journal of Science and Nature* 2.3: 501-507.

NRES497-3.2012. http://www.ag.unr.edu/dwj/NRES497-3 2012 Soilchemistry.pdf

NSF (National Science Foundation). 1977. Lead in the environment. NSF/RA-770214. Bogess,W.R., ed., NSF, Washington, D.C.

Nuutinen, V., Pitkänen, J., Kuusela, E., Widbom, T., and Lohilahti, H. 2001. Spatial variation of an earthworm community related to soil properties and yield in grass-clover field. *Soil Ecol.* 8: 85 – 94.

Obasi, N.A., Akubugwu, E.I., Ugbogu, O.C. and Chinyere, G.C. 2012. Heavy metals bioavailability and phyto-accumulation potentials of selected plants on burrow-pit dumpsite in Aba and Ntigha dumpsite in Isiala Ngwa of Abia state, Nigeria. *Nigerian Journal of Biochemistry and Molecular Biology* 27: 27-45.

Obire, O., Tamuno, D.C. and Wemedo, S.A. 2003. Physico-chemical quality of Elechi creek in Port Harcourt, Nigeria. *Journal of Applied Sciences and Environmental Management* 7.1: 43-49.

Obuotor, E.M. and Onajobi, F.D. 2000. Preliminary evaluation of cytotoxic properties of *Raphia hookeri* fruit mesocarp. 1. *Fitoterapia* 71.2: 190-192.

Ogbogu, S.S. 2003. Effects of different concentration of inorganic compounds on the survival of *Cloeon perkinsi* larvae (Ephemeroptera). *Research update on Ephermeroptera and plecoptera*. Gairo, E. (Ed.), University of Perugia, Perugia, Italy. pp 377-379.

Ogbonna D, Benjamin L. and Patrick O. 2009. Some physico-chemical and heavy metals levels in soils of waste dump-sites in Port Harcourt municipality and Environs. *Journal of Applied Science, Environment and Management.*13.4: 65–70.

Ogu, V.I. 2000. Private sector participation and municipal waste management in Benin city, Nigeria. *Environment and Urbanization*. 12.2: 103 – 117.

Ogundiran, O.O. and Afolabi, T.A. 2008. Assessment of the physicochemical parameters and heavy metal toxicity of leachates from municipal solid waste open dumpsite. *International Journal of Environmental Science and Technology* 5.2: 243-250.

Ogunlaja, A. and Morenikeji, O.A. 2013. Species diversity and population size of earthworms after oil spillage in a pipeline vandalized area in Lagos State, Nigeria. *African Journal of Agricultural Research* 8.8: 671-679.

Ogwueleka, T.C. 2009. Municipal solid waste characteristics and management in Nigeria. *Iranian Journal of Environmental Health Science and Engineering* 6.3: 173-180.

Ojha, R.B and Devkota, D. 2014. Earthworms: 'Soil and ecosystem engineers' – a review." *World Journal of Agricultural Research* 2.6: 257-260.

Ojiezeh**,** T.I. and Eghafona, N.O. 2014. Nutritional and physicochemical profiles of some indigenous extracts used in alternative medicine. *Journal of Intercultural Ethnopharmacology* 3.1:29-36.

Ojiezeh, T.I. and Eghafona, N.O. 2015. Humoral responses of broiler chickens challenged with NDV following supplemental treatment with extracts of *Aloe vera*, *Alma millsoni*, *Ganoderma lucidum* and *Archachatina marginata*. *Cent Eur J Immunol* 40.3: 300-306.

Okalebo, J.R., Gathua, K.W. and Woomer, P.L. 1993. Laboratory methods of soil and plant analysis: A working manual tropical soil Biology and fertility program, TSBF institute, Nairobi, Kenya.

Okecha, S.A. 2000. *Pollution and Conservation of Nigeria Environment.* T' Afrique International Associates, Owerri, Nigeria. In Omofonmwan, S.I. and Eseigbe,

J.O. 2009. Effects of solid waste on quality of undergroundwater in Benin metropolis, Nigeria. *Journal of Human Ecology* 26.2: 99-105.

Okeke, P.N. 2014. Impact of solid waste on physico-chemical properties of ferrealsol in Owerri, Nigeria. *African Research Review* 8.3: 116-122.

Oketola, A.A. and Akpotu, S.O. 2014. Assessment of solid waste and dumpsite leachate on topsoil. *Chemistry and Ecology* 31.2: 134-146.

Olade, M.A., 1987. *Dispersion of cadmium, lead, zinc in soils and sediments of a humid tropical ecosystem in Nigeria. Lead, mercury, cadmium and arsenic in the environment*. Hutchinson, T.C. and Meema, K.M. Eds. Chichester : John Wiley and sons Ltd. Pp 303-313.

Olafusi, O.R. 2004. Waste disposal and management – A case of healthy environment, Akure, Nigeria: Federal University of Technology, Department of Architecture Housing seminar report.

Olaitan, S.O. and Lombin, G. 1984. *Introduction to tropical soil science.* Macmillan Publishers Ltd., Hong Kong. Pp 66-69. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Olaniyan, C.I.O. 1975. *An Introduction to West African Ecology*. Hemernann Education Books Ltd. London. 170p.

Olaniyan, I.O., Alayande, A.W. and Bamgboye, O. 2009. Predicting surface water contamination from the Kaduna, Yola and Maiduguri landfill sites. *Research* 1.6: 63-68.

Olayiwola, O.A. and Onwordi, C.T. 2015. Environmental fate of heavy metals in soil of ido-osun waste dump site, Osogbo, Osun, Nigeria. *American Journal of Environmental Protection*. 3.1: 1-4.

Olexa, M.T., Leviten, A., and Samek, K. 2003. Florida solid and hazardous waste regulation handbook: Solid and hazardous waste disposal. EDIS document FE 457, a publication of the Department of Food and Resource Economics, Florida Cooperative Extension Service, UF/IFAS, University of Florida, Gainesville, FL.

Ololade, I.A., Adewunmi, A., Ologundudu, A. and Adeleye, A. 2009. Effects of household wastes on surface and groundwaters. *International Journal of Physical Sciences* 4.1: 022-029.

Olubori, 2011. Cities and adaptation to climate change – Solid waste management in Lagos state. Paper presented at the Resilient cities 2011 Congress Bonn, Germany.

Omofonmwan, S.I. and Eseigbe, J.O. 2009. Effects of solid waste on quality of underground water in Benin metropolis, Nigeria. *Journal of Human Ecology* 26.2: 99-105.

Omole, D.O. and Longe, E.O. 2008. An assessment of the impact of abattoir effluents on River Illo, Ota, Nigeria. *Journal of Environmental Science and Technology* 1.2: 54-56.

Oni, A.A. 2000. Physicochemical parameters and toxicity of solid wastes and leachate on selected animals at Aba-Eku landfill site, Ibadan, Nigeria. Ph.D Thesis submitted to the Department of Zoology, University of Ibadan. 330 pp.

Onianwa, P.C., Ogunniyi, O.J. and Ogunnowo, A.A. 1999. General physico-chemical quality of drinking water in Ibadan, Nigeria. *Environmental Education and Information* 18.2: 143-154.

Onibokun, A. and Kumuyi, A.J. 1999. Ibadan, Nigeria (Chapter 3). In Onibokun, A.G (Ed). Managing the Monster: Urban waste and governance in Africa. DRC, pp101-172. In Taylor, R. and Allen, A. 2006. 12 Waste disposal and landfill: Information needs.http://www.who.int/water_sanitation health//resources quality/en/groundwater 12.pdf.

Onyidor, H. 2006. Sanitation in developing nation's http://www.helium.com/tm/283643/health-wealth-popular saying.

Orewole M.O., Makinde O.W., Adekalu K. and Shittu K.A. 2007. Chemical Examination of piped water supply of Ile –Ife in South West Nigeria. *Iran Journal of Environmental Health, Science and Engineering* 4.1: 51-56.

Organization of Economic Cooperation and Development (OECD). 1997. Environmental data. Paris, France.

Oshode, O. A., Bakare, A. A., Adeogun, A. O., Efuntoye M. O. and Sowunmi, A. A. 2008. Ecotoxicological assessment using *Clarias gariepinus* and microbial characterization of leachate from municipal solid waste landfill. *Int. J. Environ. Res*, 2.4: 391 - 400.

Osibanjo, O., Daso, A.P. and Gbadebo, A.M. 2011. The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria. *African Journal of Biotechnology* 10.4: 696-702.

Oviasogie, F.E. and Oviasogie, P.O. 2014. Physicochemical properties and fungal dynamics of soils from public, reclaimed and residential wastes dumpsites. *Nigerian Journal of Agriculture, Food and Environment* 10.3:57-63.

Owa, S.O. (1992). Taxonomy and distribution of Nigeria Earthworms of the family Eudrilidae and their use as possible indicators of soil properties. Ph.D Thesis submitted to the Department of Zoology, Obafemi Awolowo University, Ile-Ife.

Owa, S.O. and F. Olojo, 2003. Limicolous earthworms of streams and river banks in Ago Iwoye, SW Nigeria. *J. Appl. Sci.* 6.3: 3726-3737.

Ozanne, F. 1990. Les lixiviats de décharge, le point des connaissances en 1990. L'Eau; Techniques sciences et Méthodes juin, 289-312. In Chofqi , A., Younsi,A., Lhadi, E., Mania, J., Mudry, J.N. and Veron, A. 2004. Environmental impact of an urban landfill on a coastal aquifer (El-Jadida, Morocco). *Journal of Environmental Quality* 30: 509-516

Pan American Health Organization (PAHO) 1995. El Manejo de Residuos Sòlidos Municipales en América Latina y El Caribe. Serie Ambiental No 15. Washington DC, United States.

Pandard, P., Devillers, J., Charissou A.M, Poulsen, V., Jourdain, M.J., Ferard J.F., Grand, C. and Bispo, A. 2006. Selecting a battery of bioassays for eco-toxicological characterization of wastes. *Science of the Total Environment* 363:114-125.

Paoletti, M.G. 1999. The role of earthworms for assessment of sustainability and as bioindicators. *Agricultural Ecosystem Environment* 74: 137-155.

Peckarsky, B.L. and Cook, K.Z. 1981. Effect of keystone mine effluent on colonization of stream benthos. *Environmental Entomology* 10: 864–871.

Pérès, G., Vandenbulcke, F., Guernion, M., Hedde, M., Beguiristain, T., Douay, F., Houot, S., Piron, D., Richard, A., Bispo, A., Grand, C., Galsomies, L., Cluzeau, D. 2011. Earthworm indicators as tools for soil monitoring, characterization and risk assessment. An example from the National Bioindicator Programme (France). *Pedobiologia* 54, Supplement: S77-S87.

Piccolo, A. and Mbagwu, J.S.C. 1997. Exogenous humic substances as conditioners for the rehabilitation of degraded soils. *Agro-Food-Industry Hi-Tech* 8.2: 2-4.

Pidgeon, B. 2001. Eriss notes. Natural causes of fish kills in top end waterways.

Pielou, E.C. 1975. Ecological diversity. New York: Wiley, C.A. General book on ecological diversity, entropy-based diversity measures models (for the distribution of species).

Poier, K.R. and Richter, J. 1992. Spatial distribution of earthworms and soil properties in an arable loess soil. *Soil Biol. Biochem.* 24: 1601 – 1608.

Pontasch, K.W. and Cairns, Jr., J.C. 1988. Establishing and maintaining laboratory-based microcosms of riffle insect communities: Their potential for multi-species toxicity tests. *Hydrobiologia* 175: 49–60.

Potasznik, A. and Szymczyk, S. 2015. Magnesium and calcium concentrations in the surface water and bottom deposits of a river-lake system. *Journal of Elementology* 20.3: 677-692.

Powers, D. A. 1989. Fish as model systems. *Science* 246: 352 – 358.

Pramer, D.E. and Schmidt, F.L. 1964. Experimental soil microbiology. Burges Publication Company, Minneapolis, U.S.A. pp 1-50. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Prati, L., Pavanello, R. And Pesarin, F. 1971. Assessment of surface water quality by single index pollution. *Water Resources* 741-751.

Rajkumar, N., Subramani, T. and Elango, L. 2010. Groundwater contamination due to municipal solid wastes disposal – A GIS based study in Erode city. *International Journal of Environmental Sciences* 1.1. Paper presented at the International Conference on Disaster Mitigation and Management, 2009.

Raheem, N.K. and Morenikeji, O.A. 2008. Impact of abattoir effluents on surface waters of the Alamuyo stream in Ibadan. *Journal of Applied Sciences and Environmental Management.* 12.1: 73-77.

Raman, N. and Narayanan, D.S. 2008. Impact of solid waste effect on groundwater quality nearer to Pallavaram solid waste landfill site in Chennai. *Rasayan J. Chem* 1.4: 828-836.

Rast, W. And Thornton, J.A. 1996. *Hydrological Process* 10: 295.

Reash, R. J. 1986. Fecundity and trace metals content of creek chubs from metals containmated stream. *Trans American Fisheries Society* 115: 346 – 351.

Reddy, P.G.P. and Reddy, G.V.S. 2011. Physico-chemical analysis of surface and groundwater of selective areas of UCIL Thummalapalli Project, YSR (KADAPA), AP, India. *African Journal of Scientific Research* 3.1: 163-178.

Reynolds, J.W. 1977. *The earthworms Lumbricidae and Sparaanophilidae of Ontario*. Royal Ontario Museum Life Sciences Miscellaneous Publications.

Robert, A.C. 1999. Standard handbook of environmental engineering. McGraw-Hill Companies, U.S.A.

Rossi, J.P., Huerta, E., Fragoso, C. and Lavelle, P. 2006. Soil properties inside earthworm patches and gaps in a tropical grassland (la Mancha, Veracruz, Mexico). *European Journal of Soil Biology* 42: S284-288.

Rowe, C.L., Kinney, O.M, Fiori, A.P. and Congdon, J.D. 2014. Oral deformities in tadpoles (*Rana catesbeiana*) associated with coal ash deposition: effectcs on grazing ability and growth. *Freshwater Biology* 1996.36:723-730.

Saidu, M. 2011. Effects of refuse dumps on groundwater quality. *Advances in Applied Science Research* 2.6: 595-599.

Salles, F.F, Gattolliat, J., Angeli, K.B., De-Souza, M.R., Goncalves, I.C, Nessimian, J.L. and Sartori, M. 2014. Discovery of an alien species of mayfly in South America (Ephemeroptera). *Zookeys* 399: 1-16.

Sang N. and Li, G. 2004. Genotoxicity of municipal landfill leachate on root tips of *Vicia faba. Mutation Research* 560: 159-165.

Sang N. and Li, G. 2005. Chromosomal aberration induced in mouse bone marrow cells by municipal landfill leachate. *Environ. Toxical. Pharmacoal.* 20:219-224.

Sanusi, A.L. 2013. Groundwater quality assessment at Olusosun landfill, Lagos, Nigeria. M.Sc Thesis submitted to the School of Environmental and Sustainability, Royal Roads University, Victoria, BC. 52 pp.

Sarapata, J.S. 1994. Bicarbonate alkalinity in drinking water. *Journal of North England Water works Association* 108: 277-287.

Schaefer, M. 2005. The landfill of TBT contaminated harbour sludge on rinsing fields-a hazard for the soil fauna? Risk assessment with earthworms. *Water, Air and Soil Pollution* 165: 265-278.

Scottish Environmental Protection Agency (SEPA) 2007. News Release Effects of Sewage.

*Science, Olympiad. 2013.*https://quizlet.com/21553008/2013-science-olympiad-entomology-orders-flash-cards

Severtsova, E.A. and Gutierrez, D.R.A. 2013. Postembryonic development of anuarans in ponds littered with metal-containing refuse (simulation experiments). *Biology Bulletin of the Russian Academy of Sciences.* 4.9: 738 – 747.

Shallangwa, S.M. 2011. **Toxicity of 2,4-Dichlorophenoxyacetic acid on African mud fish *Clarias gariepinus* (Teugals).** *Agricultural Journal* 6.4: 177 - 180.

Shomar, B.H., Muller, G. and Yahya, A. 2005. Geochemical features of top soils in the Gaza strip : natural occurrence and anthropogenic inputs. *Environmental Research* 98:372- 382.

Shpiner, R. 1997. The effect of domestic garbage grinding on sewage systems and wastewater treatment plants.Submitted to the Senate of the Technion – Isreal Institute of Technology. January 1997.

Sharma, S.P. 2002. Bypass turns into waste dump. The Tribune, February 17.

Sherman, R. 2003. Raising earthworms successfully. *North Carolina Cooperative Extension Service.*

https://www.bae.ncsu.edu/topic/vermicomposting/pubs/**earthworms**.pdf. Accessed on 29th *July, 2016.*

Shi, Y.B. 2000. *Amphibian metamorphosis: from morphology to molecular Biology*. John Wiley and sons Inc. MA, United States. 228 pp.

Short, T.M., Black, J.A., and Birge, W.J. 1991. Ecology of a saline stream: Community responses to special gradients of environmental conditions. *Hydrobiologia* 226: 167- 178.

Shreeder, G.I. 1975. Night time material balance for oxygen in fish ponds receiving organic wastes *Bamidgeh* 27: 65-74.

Shyamala R., Shanti M. and Lalitha P. 2008. Physicochemical analysis of borewell water samples of Telungupalayam area in Coimbatore District, Tamilnadu, India. *E-Journal of Chemistry* 5: 924–929.

Siddique, H.R., Gupta, S.C., Dhawan, A., Murthy,R.C, Saxena, D.k., Chowdhuri, D.K. 2005. Genotoxicity of industrial solid waste leachates in *Drosophila melanogaster*. *Environ. Mol. Mutagen* 46: 189-197.

Sierra, P.S., Chakrabarti, R., Tounkara, S., Loranger, G. and Zayed, J. 1998. Bioaccumulation of manganese and its toxicity in feral pigeons (*Columba livia*) exposed to manganese oxide dust (Mn_3O_4). *Environmental Resources* 79.2: 94-101.

Sigurdson, T. 2010. jianfreestreammovies.tk/Mayflies-2010-Movie/

Simonsen, V. and Scott-Fordsmand, J.J. 2004. Genetic variation in the enzyme esterase, bioaccumulation and life history traits in the earthworm *Lumbricus rubellus* from a metal contaminated area, Avonmouth, England. *Ecotoxicology* 13:773-786.

Singer, M.J. and Munns, D.N. 1999. Soil: An introduction. 4th Edn., Prentice-Hall, Inc., New Jersey, USA. 254 pp.

Sinha, B., Bhadauria, T.P., Ramakrishnan, S., Saxena, K.G. and Maikhuri, R.K. 2003. Impact of landscape modification on earthworm diversity and abundance in the Hariyali sacred landscape, Garhwal Himalaya. *Pedobiologia* 47.4: 357–370.

Sivasankari, B., Indumathi, S. and Anandharaj, M. 2014. A study of life cycle of earthworm *Eudrilus eugeniae*. *International Journal of Research in Pharmacy and Life Science* 1.2: 64-67.

Small Island Environmental Management. 1997. UNEP Islands website. http://islands.enep.ch/siemf2.htm.

Smith, M.J., Schreiber, E.S.G., Sgroggie, M.P., Kohout, M., Ough, K., Potts, J., Lennie R., Turnbull, D., Jin, C. and Clancy T. 2007. Associations between anuran tadpoles and salinity in a landscape mosaic of wetlands impacted by secondary salinisation. Freshwater Biology 52:75-84.

Sotolu, A.O. 2010. Feed utilization and biochemical characteristics of *Clarias gariepinus* (Burchell, 1822) fingerlings fed diets containing fish oil and vegetable oils as total replacements. *World Journal of Fish and Marine Sciences* 2.2: 93-98.

Souza, P.D. and Somashekar, R.K. 2012. Environmental impacts of an abandoned composting unit in Bangalore. *International Journal of Science and Nature* 3.3: 651-661.

Spurgeon, D. J., Keith, A.M., Schmidt, O., Lammertsma, D.R. and Faber J.H. 2013. Land-use and land-management change: relationships with earthworm and fungi communities and soil structural properties. *BMC Ecology* 13: 46. doi:10.1186/1472-6785-13-46.

St. Clair County Health Department. 2014. Open dumping what is it? www.health.co.st-clair.il.us/environmental/pollution/Documents/ODBrochure.pdf.

Sudhi, K.S. 2014. Kerala rivers polluted by faecal contamination: PCB study. www.thehindu.com/news/...polluted-by-faecal-contamination.../article6083312.ece.

Surface Water Contamination Superfund USEPA. Mht.

Tahir, M., Hussain, T., Behaylu, A. and Tilahun, A. 2015. Scenario of Present and Future of Solid Waste Generation in Metro Cities of India. *Journal of Environment and Earth Science* 5.9: 164–169.

Tabatabai, M.A. 1974. Determination of Sulphate in Water Samples. *Soil Science Society American Journal* 10**:**11-15. In IITA (International Institute of Tropical Agriculture). 1979. *Selected methods for soil and plant analysis*. IITA Manual Series, I, IITA, Ibadan, Nigeria. 60 pp.

Tambekar, P., Morey, P., Batra, R. J. and Weginwar, R.G. 2012. Quality assessment of drinking water: A case study of Chandrapur District (M.S.). *Journal of Chemical and Pharmaceutical Research* 4.5:2564-2570.

Taupean, C., Poupon, J., None, P., Lefevie, B. 2001. Lead accumulation in the mouse ovary after treatment induced follicular atresia. *Reprod.Toxicol.* 15.4: 385-391.

Taylor, R. and Allen, A. 2006. 12 Waste disposal and landfill: Information needs. http://www.who.int/water_sanitation health//resources quality/en/groundwater 12.pdf.

Tewarri, A., Chauhan, L.K.S., Kumar, D. and Gupta, S.K. 2005. Municipal sludge leachate induced genotoxicity in mice - a subacute study. *Mutat. Res*. 587:9-15.

The League of Women Voters (1993). The Garbage Primer. New York: Lyons and Burford. pp. 35–72. In https://en.wikipedia.org/wiki/Recycling.

Thorp, J.H. and Rogers, D.C. 2014. Thorp and Covich's Freshwater Invertebrates: Ecology *and General Biology. Elsevier. 886 pp.*

Tian, G. 1995. Breakdown of plant residues with contrasting chemical compositions under humid tropical conditions: effects of earthworms and millipedes. *Soil Biology and Biochemistry* 27: 277 - 280.

Tian, J, Huang, P., Feng, T., Hou, D. and Zhang, G. 2012. **Framework of** multiregional water quality management information syst**em.** *ICETCE '12 Proceedings of the 2012 Second International Conference on Electric Technology and Civil Engineering.* doi>10.1109/ICETCE.2012.348

Tijani, M.N. 1994. Hydrogeochemical assessment of groundwater in Moro area, Kwara state, Nigeria. *Environmental Geology* 24: 194-202. In Elueze, A.A., Omidiran, J.O.and Nton, M.E. 2004. Hydrogeochemical inverstigation of

surfacewater and groundwater around Ibokun, Ilesha area, Southwestern Nigeria. *Journal of Mining and Geology*. 40.1: 57-64.

Tijani, M.N., Okunola, O.A. and Abimbola, A.F. 2006. Lithogenic concentrations of trace metals in soils and saprolite over crystalline basement rocks: A case study from southwest Nigeria. *Journal of African Earth Science* 46:427-238.

Tondoh, E.J. 1998. Effect of coffee residues on growth and reproduction of *Hyperiodrilus africanus* (Oligochaeta, Eudrilidae) in Ivory Coast. *Biology and Fertility of Soils* 26: 336 - 340.

Tomori, M.A., 2008. Ibadan metropolitan area and the challenges and sustainable development. Ibadan: MACOS Urban Management Consultancy.

Tuberose.com. 2005

Twort, A.C., Raw, F.M. and Crawley, F.W. 1995. Water supply. (Edward Arnold, Rondon).

Udousoro, I.I, Umoren, I.U, Izuagie, J.M, Ikpo, C.U, Ngeri, S.F and Shaibu, E. S. 2015. Soil invertebrates as bio-monitors of toxic metals pollution in impacted soils. *Current World Environment* 10.2: 367-385.

United Nations High Commissioner for Refugees, 1999. Report of the United Nations High Commissioner for Refugees, 1999. http://www.un.org/documents/ga/docs/55/a5512.pdf

US Army Engineer Waterways Experiment Station, Environmental effects of dredging. Technical Notes Upland animal bioassays of dredged material.EEDP-02-41988, 1988.

USDA. 2013. Natural resources conservation service soils. United States Department of Agriculture.http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167. Accessed on 13th December, 2013.

Unites States Environmental Protection Agency (USEPA). 2013. Advancing sustainable materials management: Facts and figures. https://www.epa.gov/.../advancing-sustainable-materials-management-facts-and-figure. Accessed on July 8th 2016.

United States Environmental Protection Agency. 1994. EPA drinking water glossary: A dictionary of technical and legal terms related to drinking water. nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=20001QWV.TXT

Unites States Environmental Protection Agency (USEPA). 1997. EPA Probit analysis program. Version 1.5. http://www.epa.gov/nerleed/stat2.htm.

United State Environmental Protection Agency (US EPA). 2010. List of contaminants and their maximum contaminant level (MCLs). http://water.epa.gov/drink/contaminants/index.cfm#List.

Unites States Environmental Protection Agency (USEPA). 1999. Municipal solid wastes in the United States: 1999 Facts and figures. https://archive.epa.gov/epawaste/nonhaz/municipal/web/pdf/msw99.pdf.

Unites States Environmental Protection Agency (USEPA). 2012. What is non-point source pollution. http://water.epa.gov/polwaste/nps/whatis.cfm

United States Environmental Protection Agency (USEPA). 2014. Municipal solid waste generation, recycling, and disposal in the United States: Facts and figures for 2012. United States Environmental Protection Agency, Washington, DC.

U. S. Fish and Wildlife Service. 2000. Homeowner's guide to protecting frogs – lawn and garden care. U. S. Fish and Wildlife Service, Division of Environmental Contaminants. http://www.fws.gov. Accessed on December 1st 2015.

US Salinity Laboratory. 1954. Diagnosis and improvement of saline and alkali soils. U.S. Department Agricultural Handbook 60. 160 pp. United States Department of Agriculture. Agricultural Research Service. www.ars.usda.gov/Main/docs.htm?docid=10158

Uzoije, A.P., Uzoigwe, L., Otuonye, E., Kamalu, C.O. and Onunkwo-Akunne, A. 2013. Modeling lateral distribution of heavy metal and bio-accumulation

in earthworm in the varying acidic surface horizon of waste-polluted soil. *International Journal of Energy Engineering* 3.2: 45-54.

Vasanthi, K., Senthilkumari, M., Chairman, K., and Riarijit Singh, .J.A. 2013. .Influence of temperature on growth and reproduction of earthworms, *Eudrilus euginiae. International Journal of Current Microbiology and Applied Science* 2.7: 202 – 206.

Voshell, J.R. and Rees, J. Illustrated by Wright, A.B. 2002. A guide to common fresh water invertebrates of North America. Blacksburg (VA): The Mmacdonald & Woodward Publishing Company. 442pp.

Voutsa, D., Grimanins, A. and Samar, C. 1996. Trace element in vegetable grown in an industrial area in relation to soil and air in particulate matter. *Environmental Pollution* 94: 325-335.

Wassersug, R.J. 1997. Where the tadpoles meets the world – observations and speculations on biomechanical and biochemical factors that influence metamorphosis in anurans. *American Zoologist* 37:124 - 136.

Water or Rivers Commission, 1998

Whalen, J.K. 2004. Spatial and temporal distribution of earthworm patches in cornfield, hayfield and forest systems of southwestern Quebec Canada. *Appl. Soil Ecol.* 27: 143-151.

Whalen, J.K., Parmelee, R.W. and Edwards, C.A. 1998. Population dynamics of earthworm communities in corn agroecosystems receiving organic or inorganic fertilizer amendments. *Biology and Fertility of Soils* 27:400-407.

WHO 2015. Drinking-water. Factsheet. No 391. www.who.int/mediacentre/factsheets/fs391/en/

WHO, "Environmental Chemistry," 2nd Edition, WH Freeman and Co., New York, 2004. In Nartey,V.K., Hayford, E.K. and Ametsi, S.K. 2012. Assessment of the impact of solid waste dumpsites on some surface water systems in the Accra Metropolitan Area, Ghana. *Journal of Water Resource and Protection* 4: 605-615.

WHO. 1997. Guideline for drinking water quality, (2nd edition), World Health Organization, ISBN: 9241545038, Geneva. In Tamungang, N.E.B.,

Alakeh, M.N.,Niba,M.L.F and Jude, S. 2006. Physicochemical and bacteriological quality assessment of the Bambui community drinking water in the North West Region of Cameroon. African journal of environmental science and technology. 10.6: 181-191.

WHO. 1989. "Lead-Environmental Aspects," Environmental Health Criteria 85, World Health Organization, Interna- tional Programme on Chemical Safety (IPCS), Geneva, 1989. In Nartey,V.K., Hayford, E.K. and Ametsi, S.K. 2012. Assessment of the impact of solid waste dumpsites on some surface water systems in the Accra Metropolitan Area, Ghana. *Journal of Water Resource and Protection* 4: 605-615.

World Health Organization (WHO). 8. Sanitation.

www.who.int/water_sanitation_health/hygiene/emergencies/em2002chap8.pdf

World Health Organization (WHO). 2004. Guidelines for drinking water quality. 3rd. Ed. Vol. 1 Recommendation, Geneva, 515.

World Health Organization (WHO). 2006. Guidelines for drinking water quality. WHO Geneva. Pp 488-493.

Wild, A. 1993. *Soils and environment*. Cambridge University Press. 189-204pp.

Williams, D. D. and Williams, N. E. 1998. Aquatic insects in an estuarine environment: Densities, distribution and salinity tolerance. *Freshwater Biology* 39: 411–421.

Wong, K.K. 2015. Cholera in the United States. ACIP meeting of October 21, 2015. Centre for Disease Control. https://www.cdc.gov/vaccines/acip/meetings/downloads/...2015.../cholera-02-wong.pd

Woodworth, J.C. and Pascoe, V. 1982. Cadmium toxicity to rainbow trout, *Salmo gairdneri* Richardson. A study of eggs and alevins. *Journal of Fish Biology* 21: 47-57.

Woomer, P.L., Martin A., Albrecht, A., Resck, D.V.S., Scharpenseel, H.W. 1994. The importance and management of soil organic matter in the tropics. In: Woomer, P.L; and Swift, M.J (Eds). The Biological Management of Tropical Soil Fertility. TSBF and Sayce Publ, UK.

Wootton, R.J. 1996. *Fish Ecology* (2nd Ed). Blackie Academic & Professional. London Weinheim. 205p.

World Health Organization 2015. Drinking-water Fact sheet No 391 June 2015. http://www.who.int/mediacentre/factsheets/fs391/en/. Accessed on 1st August 2016.

World Health Organization. 1991. Environmental health management in emergencies. Alexandria, WHO regional office for the Eastern Mediterranean.

World Health Organization 2015. Global health observatory data. www.who.int/gho/epidemic_diseases/cholera/cases_text/en/ Accessed on 1st August 2016.

World Health Organization (WHO). 1994. Guidelines for drinking-water quality, Geneva.

World Health Organisation (WHO), 2004. Guidelines for drinking-water quality, 3rd edition, World Health Organization, Geneva.

World Health Organization (WHO). 2006. Guidelines for drinking-water quality: incorporating 1st addendum, Recommendations. Vol 1 - 3rd edition. Pp 595.

www.science.jrank.org/pages/4188/Mayflies-Ecological-economic-importance-mayflies.html. Accessed on 5th November, 2015.

Yakub, A.S. 2010. Effects of abattoir effluent on composition and distribution of insect fauna in Lower Ogun River, southwest, Nigeria. *Journal of Aquatic Sciences* 25.1: 98–104.

Yekeen, T.A. and Fawole, O.O. 2011. Toxic effects of endosulfan on haematological and biochemical indices of *Clarias gariepinus*. *African Journal of Biotechnology* 10.64:14090-14096.

Younsi, A., Mania, J., Lhadi, E.K. and Mudry, J. 2001. Influence of extreme rainfall events on an unconfined coastal aquifer (Chaouia, Morocco). *Rev. Sci. Eau* 4.2: 115-130.

Zaller, J.G., Heigl, F., Grabmaier, A., Lichtenegger, C., Piller, K., Allabashi, R., Frank, T. and Drapela, T. 2011. Earthworm-mycorrhiza interactions can affect the diversity, structure and functioning of establishing model grassland communities. PLoS ONE 6.12: e29293. doi:10.1371/journal.pone.0029293

Zayed, J., 2001. Use of MMT in Canadian gasoline: health and environmental issues. *American Journal ofIndustrial Medicine* 39: 425-433. In Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the mangrove swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research* 5.1: 08-21.

Zelinka, M. and Marvan, P. 1961.Zur prazisierung der biologische klassifikation der Reinheit fliessender Gewasser, *Archio fur hydrobiology* 57: 389 – 407. Salles, F.F, Gattolliat, J., Angeli, K.B., De-Souza, M.R., Goncalves, I.C, Nessimian, J.L. and Sartori, M. 2014. Discovery of an alien species of mayfly in South America (Ephemeroptera). *Zookeys* 399: 1-16.