ASSESSMENT OF SOME HEAVY METALS CONTENT IN LOCAL AND IMPORTED FISH IN JEMA'A LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

BY

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DECLARATION

I hereby declare that this Dissertation entitled Assessment of Heavy Metals Content in Local and Imported Fish in Jema'a Local Government Area has been carried out by me in the Department of Geography and Environmental Management. The information derived from the literature has been acknowledged in the text and references provided. No part of this Dissertation has been presented elsewhere for the award of a Master Degree in this or any other institution.

_____ _____

Date

CERTIFICATION

This dissertation titled "Assessment of Heavy Metal Content in Fish in Jema'a Local Government Area, Kaduna State, Nigeria" meets the regulations governing the award of Masters of Science in Environmental Management of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentations.

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DEDICATION

This research work is dedicated to my beloved father, Late Maj. C.L. Baba, my mother, Mrs Naomi Baba, my brothers, sisters and all those that contributed to the successful completion of this research.

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All acknowledgements, thanks and praise be to God Almighty and Jesus Christ my Savior and Lord, for His infinite mercies and grace, in whom I live, move and have my being.

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ABSTRACT

People in Jema'a Local Government Area of Kaduna State, consume both imported and local fish without adequate information of likely health consequences from contamination. This knowledge gap is filled by this study. The aim of this work was to assess the heavy metals concentration in local and imported fish, as well as river water and sediment in the study area. To achieve the aim, a total of 21 fish samples comprising of local fish (*Barbus occidentalis, Tilapia oreos, Clarias gariepinus*) and imported fish (*Ethmalosa fimbritus, Alosa fallax, Clupea harengus*), 6 water samples and 6 sediment samples from Wonderful and Magami Rivers were collected and analysed for concentration of zinc, cadmium, iron, lead and mercury using atomic absorption spectrophotometer. Degree of sediment contamination was assessed using geoaccumulation index. Target hazard quotient was used to assess human health risk in both local and imported fish. Awareness of risk associated with heavy metals in fish consumed in the study area was also examined and three hundred and eighty four copies of questionnaire were distributed to respondents using random sampling technique. Eight (8) wards namely Kafanchan A, Kafanchan B, Bedde, Kagoma, Jagindi, Asso, Kaninkon, and Gidan – Waya were chosen using purposive sampling. Data gathered from the questionnaire were summarized using simple statistics such as tabulation frequency and percentage. Forty – nine percent (49%) of respondents had some form of general awareness of risk in fish. However awareness was low on chemical specific risk in fish. People were unaware of metals in the order cadmium > iron > mercury > zinc > lead. Results of laboratory analysis shows that cadmium risk is significant in all fish species, while risk of lead is significant in *Barbus occidentalis, Tilapia oreos, Ethmalosa fimbritus* and *Clupea harengus*. Values of water samples compared with NESREA guideline showed that all water samples were above NESREA minimum acceptable standard. Geoaccumulation Index for sediments revealed that mercury (45.2 and 44.5), cadmium (2.3 and 1.6) and lead (4.47 and 3.74) are at higher

contamination in sediments. The study concludes that heavy metals in fish occur at concentrations that poses risk to human health, while in terms of awareness, depth of knowledge about risk associated with heavy metals is still limited. The study recommends among others, the need for enlightenment campaigns, periodic workshops and discussion forums, as well as establishment of task force for monitoring of river ecosystem.

TABLE OF CONTENT

Title page	i
Declaration	ii
Certification	iii
Dedication	iv
Acknowledgement	v
Abstract	vi
Table of content	viii
List of tables	xii
List of figures	xiv
List of appendices	xiv
CHAPTER ONE: INTRODUCTION	
1.1 Background to the Study	1
1.2 Statement of the Research Problem	3
1.3 Aim and Objectives	5
1.4 Scope of the Study	6
1.5 Justification of the Study	6
CHAPTER TWO: LITERATURE REVIEW	
2.1 Environmental Sources of Heavy Metals	8
2.1.1 Natural Sources	8
2.1.2 Anthropogenic sources	10
2.2 Bioavailability of Heavy Metals	17
2.3 Environmental Media of Heavy Metals	18
2.3.1. Heavy metals in surface water river system	18
2.3.2 Heavy metals in marine water body	20

2.3.3. Heavy metals in sediment 22

2.3.4 Heavy metals in fish 25

2.4 Effects of Heavy Metals in Humans 28

2.4.1 Health effects of mercury on human 28

2.4.2 Health effects of cadmium on human 29

2.4.3 Health effect of lead on human 31

2.4.4 Health effect of zinc on human 33

2.4.5. Health effect of iron 34

2.5 Risk Assessment 35

2.6 Environmental Risk Assessment of Heavy Metals 36

2.6.1. Ecological risk of heavy metals 39

2.6.2. Human health risk assessment of heavy metals 41

2.7 Environmental Awareness 42

CHAPTER THREE: MATERIAL AND METHODS

3.1 Study Area 45

3.1.1 Location 45

3.1.2 Climate 45

3.1.3 Drainage 47

3.1.4 Geology 47

3.1.5 Soil and vegetation 48

3.1.6 People and occupation 49

3.1.7 Land use 49

3.2 Methodology 50

3.2.1 Types of data 50

3.2.2 Sources of Data 50

3.2.2.1 primary data source 50

3.2.2.2 secondary data source 51

3.2.3 Sampling size and sampling technique 51

3.2.3.1 sample collection, identification and preparation 53

3.2.4 Risk assessment 56

3.2.4.1. target hazard quotient 56

3.2.4.2. total target hazard quotient 56

3.2.5 Pollution of metals in sediment 57

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Socio-demographic Characteristics of Respondents 59

4.2 Educational Characteristics of Respondents 60

4.3 Economic Characteristics of Respondents 61

4.4 Fish Consumption Information of Respondents 61

4.5 Awareness of Heavy Metal Contamination in Fish 64

4.6 Awareness of Symptom Specific Risk in Fish Consumed by Study Population 65

4.7 Fish Advisory to Study Population 65

4.8 Concentration of Mercury in Fish Samples 67

4.9 Average Zinc Concentration in Fish Samples 69

4.10 Average Lead Concentration of Fish Samples 70

4.11 Average Cadmium Concentration of Fish Samples 71

4.12 Average Iron Concentration of Fish Samples 73

4.13 Human Health Risk Assessment 77

4.14 Concentration of Metals in River Water Samples 79

4.15 Concentration of Metals in River Sediment Samples 80

4.16 Geoaccumulation Index of River Sediments 81

4.17 Test of Hypothesis for Fish Samples 84

4.18 Test of Hypothesis for Water Samples 87

4.19 Test of Hypothesis for Sediment Samples 87

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary 90

5.2 Conclusion 91

5.3 Recommendations 92

References 94

Appendices 117

Appendix I Pictures of the researcher collecting water samples 117

Appendix II Heavy metal analysis result 120

Appendix III Questionaires administered to respondents 126

LIST OF TABLES

Table		Page
3.1	Projected Ward Population of Jema'a Local Government Area	52
3.2	Scale for Risk Analysis of Total Target Hazard Quotient	57
3.3	Geoaccumulation Index for Sediment Quality	58
4.1.	Socio-Demographic Characteristics	59
4.2	Educational Characteristics of Respondents	60
4.3	Economic Characteristics of Respondents	61
4.4a	Fish Consumption	62
4.4b	Fish Consumption Pattern	63
4.5	Awareness of Heavy Metals Contamination in Fish	64
4.6	Awareness of Chemical Specific Risk in Fish	66
4.7	Fish Advisory	67
4.8	Average Mercury Concentration in Fish Samples	68
4.9	Average Zinc Concentration in Fish Samples	70
4.10	Average Lead Concentration of Fish Samples	71
4.11	Average cadmium concentration of fish Samples	73
4.12	Average Iron Concentration of Fish Samples	74
4.13a.	Target Hazard Quotient of Heavy Metals in Fish (excluding mercury)	77
4.13b.	Target Hazard Quotient of Heavy Metals in Fish (including mercury)	78
4.14	Average Concentration of Heavy Metals in Water Samples	80
4.15	Average Concentration of Heavy Metals in Sediment Samples	81
4.16	Geoaccumulation Index of River Sediments	82
4.17	Test Between Subject Effect (2-way ANOVA)	85

4.18 Independent Sample Test on Water Samples 88

4.18 Independent Sample Test on Sediment Samples 88

LIST OF FIGURES

Figure		Page
3.1:	Map of Kaduna State Showing Jema'a Local Government Area	46
4.1:	Average Mercury Concentration in Fish Samples	69
4.2:	Average Zinc Concentration in Fish Samples	70
4.3:	Average Lead Concentration of Fish Samples	72
4.4:	Average Cadmium Concentration of Fish Samples	73
4.5:	Average Iron Concentration of Fish Samples	75
4.6:	Plots from 2 – Way ANOVA	86

LIST OF APPENDICES

Plate		Page
1.0	Some important pictures	117
1.1	Researcher collecting water samples from a section of Wonderful River	117
1.2	Researcher holding a sample of water collected	117
1.3	A section of Magami River showing agricultural plants along the river bank	118
1.4	A section of Magami River showing a fisherman going into the river to collect water samples	118
1.5	One of the fishermen working on fish harvested directly from the river from where local fish samples were bought.	119
1.6	Some labelled samples of *Tilapia oreos*	119
1.7	Some labeled samples of *Clarias gariepinus*	119
2.0	Heavy metal analysis result	120
3.0	Questionnaire	126

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Fish is an important source of protein which is an element necessary for the maintenance of healthy body. It is one of the most important animal protein sources which is beneficial. It has low saturated fat, high protein content, and Omega-3 Polyunsaturated fatty acids, all of which are known to support good health (Burger and Gochfeld, 2004). Fish is highly recommended by the American Heart Association to be included in the human diet at least twice a week because it helps to lower the risk of cardiovascular diseases (AHA, 2013).

Therefore, they are consumed on the basis that they promote good health. Nevertheless, in addition to the nutrients they provide, they contain other substances that are injurious to health. These are called contaminants. Notable among such contaminants are heavy metals (Costenla, 2014). Heavy metals are stable metals with density greater than 5 to 6 g/cm^3 which can have hazardous effects when present in higher concentrations (Keepax, Moyes and Livens, 2011). Arsenic, cadmium, chromium, copper, nickel, lead and mercury are common heavy metals among others which pollute the environment.

Natural sources such as geologic weathering of the earth crust, volcanic eruptions, soil erosions as well as anthropogenic sources such as industrial and municipal wastes, as well as leakages from boats and also emissions via shipping traffic, all cause heavy metals to enter aquatic environments through the agents of wind and rain where they are ingested by aquatic organisms.

Fish accumulates substantial amounts of heavy metals in their tissues including the muscles and thus represent a major dietary source of these metals for humans. When ingested in excess amounts, heavy metals combine with the body's biomolecules, like proteins and

enzymes to form stable biotoxic compounds. These compounds mutilate their structures and hinder them from carrying out bioreaction functions. As a result, they have been considered the most dangerous category of pollutants in the aquatic environment (Kalay, Ay and Canli, 1999; Hassaan, Al-Kahali and Al-Edres, 2007).

This present a significant amount of danger due to their ability to bioaccumulate. Bioaccumulation occurs when there is an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Heavy metals are easily stored in their fatty tissues and will bioaccumulate if fish is exposed to further contamination. This means an increase in the concentration of heavy metals in fish over time. (Duruibe, Ogwuegbu and Egwurugwu, 2007). While they are not very visible in the aquatic environment, their impacts on delicate aquatic ecosystems can be large (Yilmaz, 2003), affecting both fish and human population.

Metals such as copper and zinc can leach into river water from mining industries, and has been found to affect fish population when present in water even at low doses (Saei-Dehkordi and Fallah, 2011). Higher level of copper in fish can cause diarrhea, stomach cramps and vomiting when consumed. Research has also revealed that people who eat fish contaminated with mercury will be put at risk particularly pregnant women. Because heavy metals are toxic, health impacts are likely, especially when they exceed permissible limits. These impacts are no doubt life threatening, as a result, World Health Organization (2014) observed rightly that contamination of the environment is not only a pollution issue but also a rising public health matter. This observation brings to the fore the necessity of assessing contaminants in aquatic media as well as in local and imported fish. More so that, fish contamination which also affects human health, are equally reflections of man's impact on the aquatic environment.

1.2 Statement of the Research Problem

Heavy Metals pollution in aquatic environment has become a matter of great concern over the last few decades not only because of the threat to quality of water but also the hazards posed to human health on consumption of fishes (Tanee et al, 2013). The heavy metals which fishes take up are released into river water from anthropogenic sources (point and non-point) such as industrial effluent, agriculture, sewerage, mining, waste dump, storm drainage runoff etc., where they become available for fish uptake.

Similar concern occurs for sediment. This is because, river sediment serve as secondary sources where heavy metals present are released back into the river water column. Because water serves as medium of heavy metals uptake by fish, it quality is of utmost concern, and contamination with heavy metals constitute a major problem due to it corresponding health impact on humans who consume such contaminated fish (Tyokumbor, Okorie and Umma, 2014).

Recent studies have revealed heavy metals content in humans arising from fish consumption. Such studies have shown that in the world today, there is a spate of occurrence of heavy metals in humans at higher concentrations, arising from consumption of contaminated fish. For instance, Lye, Legrand, Clarke and Probert (2013), revealed occurrence of total mercury in blood of canadians 6 - 79 years of age, at increasing concentrations commensurate with total fish and shell fish consumption. This means that mercury exposure occurs in humans via fish consumption. This could happen in any fish consumed, either those from fresh water or those from salt water bodies. The health effects of concern as a result of this exposure depend on the form of mercury and the duration as well as magnitude of exposure. If the exposure is for a long duration, all forms of mercury could cause health effects, especially in the areas of the nervous system (Wilson, 2013). Furthermore, occurrence of lead, chromium, and

cadmium has been reported in human blood samples at higher concentrations, linked to bioaccumulation of the metals arising from consumption of fishes equally contaminated with heavy metals (Akintujoye, Onumudu and Awobode, 2013).

The undesirable consequences as a result are health effects on consumers of these fishes. Effects such as deficits in neurocognitive function expressed in detectable alterations in performance on test of fine motor speed, dexterity and concentration, as well as disruption of memory and verbal learning, arising from mercury exposure associated with fish consumption have already been reported (Yokoo et al, 2003). Even an average weekly consumption of 1.2 servings of maternal fish intake, contaminated with as much as 0.02 - 2.38 ug/g mercury has been strongly associated with low infant cognition (Oken et al, 2005). Vulnerability to both lead and copper health hazard such as nervous disorders, anaemia, cardio-vascular disease, disorders in bone metabolism, renal function and reproduction in fish consumption has been reported (Ogundiran and Ojo, 2012).

In Jema'a Local Government Area, both imported and local fish are likely with heavy metals contamination. In particular, local varieties are sourced from inland rivers such as Kagoma, Magami, Kogum, Wonderful, Semes, Challo, Kudan, Zauru, Zakko, and Bakin – Kogi Rivers among others, some of which have agricultural activities, taking place within the catchment area where land based discharge occurs through surface run-off. The rivers are receptacles of effluents from sewerage, dumpsites, domestic wastes, farm drainage with pesticides, herbicides, and chemical fertilizers containing metal compounds sloping into the rivers during heavy showers yearly. Such activities place these rivers at the risk of being contaminated with heavy metals alongside the tendency of increasing the load thereof, with the problem of bioaccumulation in local fish varieties. Unlike other market products such as drugs, beverages, e.t.c. consumers of local and imported fish seldom scrutinize them before

purchase, neither do they have any means of identifying the health of aquatic media from where they are caught. The average consumer remains largely uninformed on the safety of fish purchased and consumed, as well as the consequences of eating such fish contaminated with heavy metals. Harmful effects can be immediate or delayed, leading to economic losses via loss in productive capacity in the case of death, hospitalization, and cost incurred in accessing health care services as well as intangible costs of pain, suffering, anxiety and reduction in quality of life. To the extent of accessible literature, no research work of this nature has been carried out in the study area.

i. What is the concentration of heavy metals of local and imported fish in the study area?
ii. What is the concentration of heavy metals of river and sediment in the study area?
iii. What is the health risks associated with the concentration of heavy metals in imported and local fish as well as in the water course in the study area?
iv. What is the level of awareness of risks of heavy metals in the local and imported fish in the study area?

1.3 Aim and Objectives

The aim of this study is to assess heavy metal content of local and imported fishes consumed in Jema'a Local Government Area of Kaduna State, Nigeria. This is achieved through four specific objectives which are to:

i. determine the heavy metal content in local and imported fish consumed in Jema'a LGA.,
ii. examine the heavy metal content of river water and sediment in Jema'a LGA.,
iii. examine the health risk associated with the concentration of heavy metals in fish imported and local in Jema'a LGA.

iv. assess the level of awareness of the risks by the public.

1.4 Scope of the Study

The study covers the assessment of heavy metal content. However, the assessment focuses on fishes harvested from Wonderful and Magami Rivers of Kafanchan and Godogodo areas of Jema'a Local Government Area, which was carried out within the period January – March 2016. The assessment also focuses on five parameters namely mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), and iron (Fe). The elements represents those metals whose monitoring has been designated as obligatory by WHO (1997), of which three (mercury, cadmium and lead) are non - essential and two (zinc and iron) are essential. Six species are sampled comprising of three local varieties namely *Barbus occidentalis* (Dorawa), *Clarias gariepinus* (Tarwada) and *Tilapia oreos* (Parpasa); as well as three imported fish species namely *Ethmalosa fimbritus* (Shawa), *Alosa fallax* (Mackerel) and *Clupea harengus* (Sardine), imported from Ireland, Holland and Netherland respectively. These are the widely consumed wild caught local and imported fish in the study area, available at the time of sampling.

1.5 Justification of the Study

Assessment of heavy metal content in local and imported fish has become necessary to examine it suitability for consumption and state of the local aquatic environment since there is a dearth of data in Jema'a Local Government Area. The human health risk posed by presence of heavy metals in local and imported fish in the study area calls for studies on the subject matter. This is because households consume fish as one of the main animal protein due to easy accessibility and affordability.

Awareness of health effects in the study area seems low as knowledge about fish purchased is based solely on the nutritive value that can be derived. With a potential risk of toxicity

evidenced by crop cultivation practices along the river banks and construction works, as well as domestic waste discharge from homes washed into rivers in the study area, makes adequate assessment essential in order to ascertain contamination state of the rivers and the safety of wild caught local varieties as well as ascertaining the suitability of imported frozen fish consumed in the area, to safe guard the populace from immediate and long term health effects.

This study bears relevance as it will educate the public on the safety of local and imported fish to consumers in the study area, provide information on the pollution state of rivers occasioned by anthropogenic activities, and inform policy design and decision - making on enhancing the safety of inland rivers and fish consumed (local and imported varieties). The outcome of this research will also provide a useful platform for subsequent researchers.

CHAPTER TWO
LITERATURE REVIEW

2.1 Environmental Sources of Heavy Metals

2.1.1 Natural sources

Bed rock and parent material

Heavy metals content naturally occur in the earth crust, in bedrock and geologic parent materials. (Nagajyoti, Lee and Sreekanth, 2010). High contents are found in ultrabasic igneous rocks (e.g. 150 mg/kg, 1,600 mg/kg, 2000 mg/kg for Co, Cr, and Ni respectively), and ultramafic igneous rocks have been reported to be rich in Cr, Ti, Fe, V and Ni (Robb, 2004). Ores such as arsenopyrite (capable of producing arsenic when precipitated), galena and sphalerite consists of up to 100% heavy metals such as native copper and mercury (Hans et al, 2016; Fashola, Ngoleme and Babalola, 2016). Magmatic hydrothermal fluids has been observed to carry substantial amount of metals such as copper, as well as greisens - a product of the reaction between magmatic fluids and granitic rocks – containing substantial amounts of metals like Sn (Alloway, 2013). Other means through which heavy metals enter the biotic and abiotic environment from natural sources includes weathering, erosion, volatilization e.t.c.

Weathering

Weathering liberates heavy metals from minerals within rock structure. These include Fe, Li, Al, Ti, Cr among others, which are eventually weathered and released in soils. During weathering, silicates containing Mn such as amphiboles and pyroxenes, is precipitated under aerobic conditions mainly as poorly soluble Mn(iv)oxide and Mn is released into the soil environment (Hans et al, 2016). Igneous rocks such as olivine, augite and hornblende contribute considerable amounts of Mn, Co, Ni, Cu and Zn to the soil environment through weathering action.

Within the class of sedimentary rocks, shale has highest concentrations of Cr, Mn, Co, Ni, Cu, Zn, Cd, Sn, Hg and Pb followed by limestone and sand stone (Nagajyoti et al, 2010), which are easily weathered and released into the environment by dissolution and hydrolysis. Pyroxene and amphibole of rock structures contain Fe and Mn in reduced form, and become oxidized during weathering in a process which breaks the bond in the mineral and liberates the oxidized metals Fe and Mn into the environment. Oxidation processes of rock mineral containing heavy metals promotes the degradation and subsequent release of heavy metals contained into the environment. This is same for weathering of biotite, where Fe^{2+} is released into the environment as $Fe^{3+}O$ precipitate (Hans et al, 2016).

Hydrolysis

In hydrolysis which is a chemical form of weathering, silicates are subject to hydrolysis processes during which metal containing compounds in rock minerals react chemically with H^+ and OH^- ions of water and become dissociated and available. Metals mainly bound in silicates are released by this process into the environment via transportation into rivers and streams (Stanjek, 1998).

Temperature

The role of temperature is significant in the release of heavy metals from rocks into the environment via weathering. This is because solubility rises with increasing temperature except for carbonates which drops with increasing temperature and eventually leads to the degradation of carbonate rocks along with the release of associated metals contained (Alloway, 2013).

Dissolution

In limestone areas, the marine basins in which these chemical precipitates of $CaCo_3$ accumulate also receive heavy metals with elevated concentrations. However, during weathering, when the limestone undergoes dissolution in addition to oxidation, the metals become released and dispersed in the soil and surface water environment (Alloway, 2013).

Volcanic source

Volcanoes have been identified as natural sources of metal in the environment, which are released during eruptions (He, Yun, Shi and Jiang, 2013). Tephra carry wide variety of absorbed metals Mn, Zn, Cu, Ba, Se, Br, B, Al, Si, Fe, etc., along with plumes of ash and dust which are effectively dispersed. After the tephra and ash settles on the ground, these metals get dissolved often by rain water and leach into the environment (Weinstein and Cook, 2005). Heavy metal emissions from volcanic eruptions assembled has that 1.72×10^7 kg As is released from volcanic eruption each year, and other 4.87×10^6 kg is released from the erupton of submarine volcanoes (He et al, 2013). In the 1976 eruption of Mt. Etna, daily output into the environment was estimated as 360kg of lead, 110kg of arsenic, 75kg of mercury and 28kg of cadmium (Weinstein and Cook, 2005).

2.1.2 Anthropogenic sources

Compared with natural sources, anthropogenic sources are commonly considered as the major causes for the increasing heavy metal pollution in the environment (He et al, 2013). Anthropogenic flow of heavy metals to the atmosphere accounts for about 94-97 per cent of the total heavy metal emission sources (Ginzburg and Gromov, 1999). This arises from activities such as mining and smelting operations, agriculture, traffic emission, mining,

industrialization, to mention a few (Herawati et al, 2000). Some of these anthropogenic sources are briefly discussed as follows;

Agriculture

Modern agricultural practices are significant source of heavy metals in the environment. Fertilizers and pesticides has contributed to the availability and continuous accumulation of the elements (Nouri et al, 2011; Atafar et al, 2010). Lead arsenate and arsenic containing compounds have been documented to be used in fruit orchard and banana plantations (Wuana and Okieimen, 2011), as well as cadmium in lime and phosphatic fertilizers (Kabata-Pendias and Pendias, 1999). The application of these fertiliser containing metals and biosolids, along with livestock manures, composts and municipal sewage sludge on agricultural soils leads to the availability of various heavy metals into the environment such as, Cd, Cr, Cu, Hg, Mo, Ni, and Zn (Basta, Ryan and Chaney, 2005).

Du Plessis et al, (2005) was able to trace the link between heavy metal like copper in fungicide and pesticide, and its occurrence in the environment, thus establishing use of agrochemicals as environmental source of contamination. High fertilizer applications and acid atmospheric deposition, combined with insufficient liming, increase heavy metal availability, making it readily mobilized from soil into the surface water via run-off from storm water drain (De Vries, Romkens, Van and Bronswijk, 2002). Brigden, Stringer and Santillo (2002) observed high cadmium concentration in some fertilizers with a corresponding ability to accumulate in some soil environment. In particular, lime and superphosphate fertilizer has been identified as containing trace amounts of cadmium, which posses the ability to influence cadmium availability and movement in the soil environment (Yanqun et al, 2005; Wangstrand, Eriksson and Obom, 2007).

Animal manure has also been found to enrich the soil environment of heavy metals by the addition of Mn, Zn, Cu and Co and sewage sludge by Zn, Cr, Pb, Ni, Cd and Cu (Verkleji, 1993). In some instances, increase in lead and arsenic in agricultural soils have been suggestive of over application of fertilizers as well as pesticides (Atafar et al, 2010; Parkpian, Leong, Laortanakul and Thunthaisung, 2003). Sadly, these practices only introduce and continually make available heavy metals into the environment.

Traffic Emission

Human activities result in heavy metal deposit in urban environment including soil and road dusts (Sezgin et al, 2003), and this occurs to a large extent through traffic emission (Ahmed and Ishiga, 2006). Communication routes, such as roads, railways etc., are an important source of metal pollution in the environment, especially in the case of lead and zinc. Areas located close to roads, particularly in urban centres, have heavy metals available in their environment via traffic emissions. Apart from lead and zinc; chromium, cadmium, nickel and platinum are emitted by combustion engine-powered vehicles (Indeka and Karczun, 1999); and, grease used in vehicles have been considered a source of cadmium pollution along roads (Antonkiewicz and Macuda, 2005). These are carried along storm water drains into surface waters.

According to Jin et al, (2005) the source of Cu in street dust was metallic parts of cars derived from engine wear, thrust bearing, brushing and bearing metals. High concentrations of Pb in street soil dust are often attributed to high vehicular traffic conditions, use of leaded fuels in vehicles that ply roads and non adherent to the use of diethyl lead, wear-and-tear of tyres, combustion of fuel (especially diesel) and oil/lubricants, which are also known to contain trace levels of cadmium (Atiemo et al, 2011). Moore and Attar (2011) identified

rubber tire wear, auto workshops, as anthropogenic sources of Pb, Cu, Zn, Mo and Cd deposits in the environment.

Mining

In mining, tailings are major products containing heavy metals. These wastes produced from mineral extraction not only contain high amounts of heavy metals, but represent the medium by which heavy metals get into the environment. These metals leach out in an uncontrolled manner into surrounding environments on exposure to water or through dispersal by wind (Fashola, et al 2016). The infiltration of water through sulphide- containing tailings pile and ponds, surface and underground workings, waste and development rock leads to leaching of large volumes of metals like Zn^{2+}, Ni^{2+}, Pb^{2+}, As^{2+}, $Cu2^{+}$ and sulphate ions into stream and river ecosystems (Durkin and Herrmann, 2016; Edward, Bond, Gihring and Banfield, 2000).

Armah, Obiri, Yawson, Pappoe and Akoto (2010) in a study of anthropogenic sources of heavy metals in surface water in Ghana identified that Pb derives from water carrying drainage from mine machinery maintenance yards. Hg mainly originates from artisanal small scale mining, while Cd, Zn, Fe and Mn mainly emanate from industry sources.

Chemicals used in processing mineral during mining process, are also identified source of heavy metal release in the environment. For instance, an estimated 1400 metric tons of mercury was used in 2011 by South Africa Gold Mining and an annual average of 1000 metric tons of inorganic Hg was discharged. One-third of this estimated value goes into the air and the rest is mixed up in heaps of tailings, soil where they are leached and carried by acidic into waterways (Telmer and Veiga, 2009; Nagajyoti et al, 2010).

Industrial Effluent

Wastewater streams containing heavy metals are released into the environment from different industries such as electroplating, wood processing, inorganic pigment manufacturing, petroleum refining e.t.c. without adequate treatment, where significant quantities of heavy metals such as cadmium, zinc, lead, chromium, nickel, copper, vanadium, platinum, silver, and titanium occur. Arsenic containing waste released into the environment occurs in wood processing industry (Sorme and Lagerkvist, 2002).

Studies have shown that industrial waste water released into the environment, contain heavy metals at varying levels which are toxic. For instance, Ogunleye and Izuagie (2013) has shown that industrial effluents from most industries in Ondo State of Nigeria are contaminated by nickel, selenium, mercury, and arsenic. When compared with global permissible level in industrial effluents, it showed that industrial effluents did not meet regulatory standards, and exposure to ground water resulted in contamination.

Ram, Pravin and Deepali, (2011) assessed toxic heavy metals in the industrial waste water effluents collected from Taloja industrial belt of Mumbai. The study reveals that dyes, paints, pharmaceutical and textile industries contributed to the heavy metal occurrence in the surrounding aquatic environment. Values were as much as 35.2 mg/l, 33.1 mg/l, 31.4 mg/l, 33.3mg/l and 12.8 mg/l for Cr, Zn, Pb, Cu and Fe respectively, showing industrial waste waters to be source of heavy metals in the environment. Pb and Cd concentrations from industrial waste water with values ranging from 0.78 to 1.56 mg/l and 0.19 to 0.62mg/l, exceeding permissible limit has also been reported (Hadad, Maine and Bonetto, 2006). Similar findings were reported by Abdullah, Mohammed, Anwar, Mohammed and Sallem (2013) on industrial waste water of Riyadh city, Saudi Arabia, pointing to untreated industrial effluents as other source of heavy metals in the environment.

Combustion of Fossil Fuel

Airborne sources of heavy metals include aerial emission from combustions (Wuana and Okieimen, 2011). These sources are of particular interest because, all solid particles of pollutants from emissions from factories and other sources are not only deposited on land but also on surface water like lakes, rivers and sea (Hafeburg and Kothe, 2007).

Combustion of coal and other fossil fuels are important source of heavy metals emission to the atmosphere. Compounds known as fly ash and bottom ash (collectively referred to as coal ash) are produced, containing large quantities of Hg, Cd, As, Mo, and V released into the atmospheric environment (IEA, 2012). According to SourceWatch (2015), 1.05 billion tons of coal combustion each year in the United States contains 109 tons of mercury, 7884 tons of arsenic, 1167 tons of beryllium, 750 tons of cadmium, 8810 tons of chromium, 9339 tons of nickel, and 2587 tons of selenium, revealing the extent to which fossil fuel combustion releases heavy metals into the atmosphere.

Some of these metals volatilize at high temperatures and get carried out as vapors or condense as fine particles contributing to atmospheric pollution or may remain attached to the ashes (Lopes, Pinto and Gulyurtlu, 2017). Mining also contributes to atmospheric source of heavy metals. In gold mining for instance, mercury is mixed with the ores dug from the ground or from stream beds to form an amalgam. This mercury is released into the atmosphere through the burning of the amalgam which leads to vaporization of the elemental mercury into a toxic plume released into the environment and leaving the gold behind. This process has been attributed globally, the second largest source of atmospheric mercury pollution after coal combustion (Telmer and Stapper, 2012). Metal processing has become the major source of lead emissions to the air today. The highest levels of lead in air are generally found near lead smelters (Pisupati, 2017).

Incineration

The purpose of incineration is basically to reduce the volume of the waste, to utilise the energy content and to destroy harmful organic compounds and microorganisms in the waste. As regards some of the heavy metals in the waste, incineration unfortunately rather mobilise the metals in the waste and accelerate the release of the metals to the environment (European Commission, 2002), particularly at high temperatures.

Heavy metals such as Cr, Pb, Cd are not destroyed by incineration, rather they become volatile at high temperatures (Min-Hao and LinWun-Yue, 2014). These metallic elements with high vapor pressures, get converted to vapor phase during combustion (NAS, 2000). Volatile forms of Pb, such as $PbCl_2$, might vaporize completely and become airborne, contributing to atmospheric source of lead in the environment. Pb in liquid wastes exposed to flame temperatures vaporize more than Pb in solid wastes. Pb in combustible solid wastes (e.g., paper or plastics) vaporize to a greater extent than Pb in mostly noncombustible items, such as glass in the combustion process (NAS, 2000).

Pb becomes airborne and travels long distances in the atmosphere before it settles on land or water environment. Other anthropogenic sources are sewage sludge (Fang, Wei and Liu, 2016); metalliferous ores (Kabata-Pendias and Pendias, 1999); pharmaceuticals (Hafeburg and Kothes, 2007), slaughter house discharge, meat processing centres, animal and human discharges (Mohapatra, 1993; Adeyemi, 2014) and military activities (Nwaedozie et al, 2013). All these sources contain many polluting metals and complexes, which are carried and made available to nearby water bodies and ground water (Sahni, 2011).

2.2 Bioavailability of Heavy Metals

Bioavailability involves the state of being chemically potentially available for biological uptake by an aquatic organism when that organism is encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from water as it passes through the respiratory cavity). Unlike organic compounds, metals do not suffer chemical or biological degradation, so their concentration in water can remain at very high levels even after long periods of time after their introduction in the habitats (Adriano, Wenzel, Vangronsveld and Bolan, 2004). Heavy metals circulates in the ecosystems but are never destroyed and cannot be eliminated (Bose, McCarty, Steckling and Lettmeier, 2010). They can be dispersed in soil, water and air, dissolved in ground and surface water, suspended as particulates in water.

The behavior of metals in natural waters is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. During their transport, the heavy metals undergo numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena (Akcay, Oguz and Karapire, 2003; Abdel- Ghani and Elchaghby, 2007) which influences their bioavailability (Nouri et al, 2011).

While in aquatic environment, they become bound to solids as a result of chemical, electrostatic, and hydrophobic interactions, the strength of which vary considerably. They get dissolved in aqueous or gas phases and become subject to transport processes such as diffusion, dispersion, and advection that may carry the contaminant to the surface of a living organism. These same processes can also transport contaminants still bound to small solid particles (colloids) to close proximity of potential receptors. As contaminants are being transported, they can undergo transformation reactions that can affect greatly the bioavailability and toxicity of the contaminant (NAS, 2003) for instance, transformation of

mercury into more toxic form - methyl mercury - by activities of bacteria. As a result, these contaminants becomes bioavailable to aquatic fauna such as fish via the gills and skin. Humans also become the repository of these metals via fish consumption with it attendant health implications.

2.3 Environmental Media of Heavy Metals

2.3.1. Heavy metals in surface water river system

Trace elements in surface water also referred to as metals have specific gravity that is at least five (5) times the specific gravity of water. The specific gravity of water is 1 at 4ºC (39ºF) (Dye, 2006). Some well known toxic metallic elements with a specific gravity that is 5 or more times that of water are arsenic, 5.7; cadmium, 8.65; iron, 7.9; lead, 11.34; mercury, 13.546 (Royal Society of Chemistry, 2016).

The presence of these heavy metals above specified threshold results in the pollution of surface water creating room for bioaccumulation in biological organisms. This pollution occurs through the following; contamination of surface water by atmospheric droplets (Swackhamer et al, 2004); Disposal of industrial and domestic water and sewage into surface water (Owili, 2003); Disposal of solid and liquid refuse on land which later enter the drainage system by seepage and urban stream run-off (Paul, 2011), Land development for urbanization, construction works and increasing agricultural activities (Kofoworola, 2007).

Heavy metals discharged into aquatic system by natural or anthropogenic sources during their transport are distributed between the aqueous phase and sediments. Because of adsorption, hydrolysis and co-precipitation only a small portion of free metal ions stay dissolved in water and a large quantity of them are deposited in the sediment (Gaur, Gupta, Pandey, Gopal and Misra, 2005; Varol and Sen, 2012). However, these sediments resuspend and release back

heavy metals into the water column, which can be chemically altered by organisms and converted into organic complexes, some of which may be more hazardous to animal and human life (Liu et al, 2009).

Several main sources from which surface water has been polluted with heavy metals reaching toxic levels has been researched. For instance, Adekola and Saidu (2005) determined the pollution level of Landzu River in Bida, Nigeria. Average concentrations of Fe and those of Cd and Ni at upstream sampling sites outside town were found to be higher values attributed to anthropogenic inputs resulting from activities of blacksmith and metal smelting industries in the neighborhood of the river. High Pollution load during the rainy season was as a result of storm water run-off that carried high load of anthropogenic materials into the river.

Similarly, Emoyan, Ogban and Akarah (2006) evaluated the concentration of heavy metal loadings of River Ijana in Ekpan - Warri. From the study, River Ijana had varying metal contamination. Cadmium pollution was attributed to rural - urban effluents, atmospheric precipitation, and leachate from refinery sludge lagoon containing nickel-cadmium batteries. Chromium and copper pollution was attributed to dumping of wood treated with chemicals; Iron pollution was related to run-off from rusted metallic pipes at refinery scrap metal dump sites and sludge lagoon; lead and nickel concentrations were attributed to weathering of minerals, atmospheric deposition, and industrial waste water effluent discharge.

Furthermore, Godugba, Atuwara and Ilo streams in Ado-odo Ota and Ifo Local Government Areas of Ogun State Nigeria, were analysed for heavy metals. The result showed that for all the parameters analyzed, values were high above the WHO permissible standard (for drinking water) for all three streams. Pollution of the water was attributed to industrial wastes and material rubbles from demolitions, unusable stripped soil, eroded soil and rock from several

construction operations, junked materials from homes, factories and mechanic villages, all of which resulted in pollution of the rivers with horrific, poor appearance and smelling condition (Kofoworola, 2007).

Impact assessment of dumpsite leachate on the qualities of surface water and sediment of river Eku, Ona-Ara local government, Oyo State Nigeria, revealed that the mean levels of some pollution parameters gave evidence of pollution in the River. The results confirmed that the dumpsite leachate was the source of pollutants in the river (Nubi, Osibanjo and Nubi, 2008).

Other studies such as the work of Wogu and Okaka (2011); Adefemi and Awokunmi (2010); Dan and Bichi (2010); Owamah (2013) which revealed that, water quality management and river monitoring in Nigeria has not been so sound, and the demand for advancement in various facets of living and economic development (a priority of government) which has led to presence of industries, other economic and household activities (industrialization and urbanization) has resulted in increased quantity of discharge, and wide range of pollutants are reaching surface water bodies. An idea which is consistent with Ebiare and Zejiao (2010).

2.3.2 Heavy metals in marine water body

Heavy metals availability in marine environment is related with adsorption and desorption phenomenon. Adsorption removes the heavy metal from the water and stores the metal in the sediment. Desorption sends back the metal to the water column where recirculation and bio-assimilation may take place (Conti and Cecchetti, 2001). Total solids, total dissolved solids, total suspended solids, and dissolved solids, may increase salinity and electrical conductivity, which along side decrease in redox potential and pH, increase metal concentration. (Nduka and Orisakwe, 2011).

Many pollutants coming from large rivers and coastal activities have been found to contribute to the phenomenon of metal contamination in marine ecosystem, with dire consequences (Adebowale, Agunbiade and Olu-Owolabi, 2008). Many factories have been reported with discharge of wastewater with various degrees of treatment directly into the sea (Jitar, Teodosiu, Nicoara and Plavan, 2013). Researches conducted on marine environment have revealed that the quality of marine water over time has changed and still do with increasing concentration of contaminants and a potential of being bioavailable and bioaccumulated in marine fauna.

For instance, Red Sea which is a semi-enclosed tropical body of water has been previously considered to be a relatively unpolluted marine environment. In the last few decades, however, increasing population growth and industrial activities in Suez City as well as the tourism industry and shipping of ores have been major sources of the anthropogenic input of heavy metals with increased concentrations observed (Gehan, Soaad and Abd-El-Khalek, 2012). Study of heavy metal pollution at Khomse coast in Lybia showed that the concentration of all measured heavy metals (lead, cadmium, mercury, copper and zinc) in sea water significantly increased in comparison to their concentration 17 years ago , except for cadmium which decreased (Metwally and Fouad, 2008).

Studies on heavy metal concentrations in areas of the Black Sea, have shown that the Black Sea is now rich in cadmium, cobalt, copper and nickel, as compared to other regional seas (Zeri, Voutsinou, Romanova, Ovsjanya and Moriki, 2000). The coastal zone of the marine environment in Ukraine has been highlighted to have an increase in Nickel concentrations (71.7 mg/g) (Oguz, 2008). High values have also been recorded in the Russian contaminanted areas for Nickel, and Copper in the Georgian marine environment. Levels of heavy metals in the Turkish coast showed fractions of dissolved metals in water and results when compared

with the limits of US EPA have demonstrated that the water is more polluted than other coastal areas (Coban, Balkis and Aksu, 2009).

Study on the pollution characteristics of twenty surface seawater samples were collected in Seawater of Jinzhou Bay and analyzed for copper, lead, zinc, cadmium, mercury and arsenic using the methods of Atomic Absorption and Atomic Fluorescence. The pollution was becoming more and more serious from open sea to offshore marine areas, and heavy metals distribution in the Bay was affected by hydrodynamic factors (Wang et al, 2012). So around the world, as countries strive for industrialization due to economic benefits, the environment is at the receiving end in terms of chemical contamination, and the aquatic environment (both fresh water and marine) has had it fair share.

2.3.3. Heavy metals in sediment

Sediments act both as a sink and a source for metals and are seen as sensitive indicators for monitoring contaminants in the aquatic environment (Vandecasteel, Quataert, De Vos and Tack, 2004; McCready, Birch and Long, 2006; Ololade, Lajide and Amoo, 2007; Beutel, Leonard, Dent and Moor, 2008; Malferrari, Brigatti, Laurora and Pini, 2009). Sediments receive and absorb pollutants resulting from natural weathering, erosion, and anthropogenic activities (Li et al, 2007). Pollution status in aquatic environment is also evaluated through the process of sediment analysis (Pekey, 2006). This analysis shows that sediment properties such as pH, Eh, grain size and nutrient values, properties of the adsorbed compounds, and the prevailing physicochemical conditions are well correlated with metal concentrations (Wang and Chen, 2000; Chatterjee et al, 2007; Chen, 2007). In other words, different sediments exhibit different degrees of availability of total metal concentration depending on their properties.

Heavy metals can be present in sediments in a number of chemical forms, exhibiting different physical and chemical behaviours with respect to chemical interactions, mobility, biological availability and potential toxicity (Sahuquillo, Rigol and Rauret, 2003; Singh, Malik, Sinha, Singh and Murthy, 2005; Li, Lu, Zhang, Liu and Hou, 2008; Christophoridis, Dedepsidis and Fytianos, 2009; He et al, 2011; Gao and Li, 2012). Numerous factors control their relative abundance of heavy metals such as the original heavy metal contents of rocks and parent materials, processes of soil formation, contamination by human activities, and other anthropogenic factors (Li et al, 2008).

While in the sediment environment, heavy metals are inert and are often considered as conservative pollutants but by which risk can occur (Hope, 2006). The role of sediments organic matter in accumulation of heavy metals has also been emphasized by Gonzalez, Baudrimont, Boudou and Bourdineaud (2006) and Wakida et al (2008). They hold the view that organic matter in sediments act as a major sink for trace elements due to its strong complexing capacity for metallic contaminants. In estuarine environment, complex interaction between fluvial and marine process act as geochemical trap for heavy metals. This mixing leads to a depositional acceleration of clay minerals due to salinity change, favoring the entrapment and accumulation of metal absorbed on clay particles (Vicente-Martorell, Galindo-Riaño, García-Vargas and Granado-Castro, 2009). So generally, sediment usually have higher concentration of heavy metals than fishes (Linnik and Zubenko, 2000), and concentrations are often 10 – 1000 times higher than in water (Shabanda and Itodo, 2012; Zhao et al, 2012).

A study by Abd Karim, Deraman and Mohammed (2014), observed an increase in the trend of mean heavy metals concentrations in seabed sediment of Golok Central and Golok Barat Gas Fields Sarawak, Malaysia between 2010-2012, which was attributed to anthropogenic

sources such as chemical additives like emulsifiers, biocides, lubricants, wetting agents, corrosion inhibitors, surfactants, detergents, caustic soda, salts, and organic polymers used during drilling activities.

In southeastern Nigeria, study on the Great Kwa River watershed focused on the investigation of the current level and distribution of seven heavy metals (Pb, Zn, Cu, Ni, Cr, Cd, As) collected from surface sediment. Pollution status was evaluated using Enrichment Factor (EF), and Index of Geoaccumulation (Igeo). Based on geoaccumulation index, the sediments were generally classified as unpolluted with regards to the measured heavy metals. However, The computed Enrichment Factors (EF) showed that some heavy metals (Pb, Zn, Cr, Cd) have EF values of up to 1, which indicates enrichment through lithogenic and anthropogenic sources (Bassey and Ifedayo, 2014).

Heavy metals concentrations throughout the year 2011 in bed sediment samples of the black sea were investigated. According to the quality standards for marine sediments, it was noticed that individual values of concentrations measured in some sediments had recorded slightly elevated levels of concentrations, the most important being registered for cadmium and nickel, and the lowest for lead and chromium (INCDM, 2011). A study on pollution in Port Klang coastal area of Selangor, Malaysia have revealed port activities and industrial waste water as main anthropogenic sources of heavy metal contamination identified in marine sediments (Sany et al, 2013). The occurrences of enhanced concentrations of heavy metals especially in sediments is an indication of human induced perturbations rather than natural enrichment through geological weathering (Binning and Baird, 2001; Eja, Ogri and Arikpo, 2003). As a result, Zheng, Wang, Liang and Zheng (2008) reports that the distribution of heavy metals in sediments adjacent to populated areas could be used to investigate the anthropogenic impacts on ecosystems and assess the risks posed by human waste discharges.

2.3.4 Heavy metals in fish

Fish occupies the highest trophic level of the aquatic food chain, and has the ability to absorb heavy metals within its tissues directly from water and diet. Contaminant residues may ultimately reach concentrations hundreds of times above those measured in the water (Othman and Luck, 2001; Osman, Wuertz, Mekkawy, Exner and Kirschbaum, 2007; Labonne, Basin, Othman and Luck, 2013). Its concentrations depend on the source of contamination, age, size (Beetseh and Abraham, 2013), feeding habit (Farkas, Salanki and Specziar, 2003), differences in ecological needs, swimming behaviour and the metabolic activities among the fishes (Canli and Atli, 2003).

According to Atuanya, Nwogu and Akor, (2012), the concentration of heavy metals varies with variation in fish species. This implies that heavy metal accumulation in fish is also specie dependent. For instance Salaramoli, Salamat, Razavilar, Najafpour and Aliesfahani (2012) in their study showed that warm water fish like silver carp, has the tendency to accumulate higher heavy metals content than cold water fish e.g. rainbow trout. Generally, fishes are good bio-indicators and as such are very useful for assessing and monitoring pollution status in the aquatic environment.

Fish from aquatic ecosystems associated with industrial drainage, sewage wastewater and agriculture drainage has been shown to be affected from results of metal loadings in fish muscles, gills, kidney, and liver tissues. Fish samples collected from industrial drainage and sewage canals have been shown to have the highest levels of heavy metal residues followed by agriculture drainage canals (El-Sayed, El-Ayyat, Nasr and Khater, 2011). This implies that industrial and sewage sources of contamination have higher levels heavy metals in fish than agricultural sources. Fish organs do not have uniform concentration of heavy metals. A study on the influence of heavy metals concentration in three common fish within quarry

environment in Akamkpa Local Government Area of Cross River State has established this fact. It showed that gills and liver of *Heterotis niloticus, Oreochromis niloticus Clarias gariepicus* contained the highest concentration of the studied heavy metals, while muscles appeared to be the last preferred site for the bioaccumulation of metals (Ekpo, Agu and Udoakpan, 2013). Agrahari and Gopal (2007) also noted that the gills and liver showed highest accumulation of lead and cadmium while the brain and kidney had the lowest in *C. puntatus*. Nwani, Nwoye, Afiukwa and Eyo (2009) reported significantly higher concentration of metals in the gills than that of the muscles in all the fish species studied, except in *H. odoe.*

Gills generally have the highest metal concentration due to their intimate contact with the environment and their importance in ionic and osmotic regulation. Liver in its role as a storage and detoxification organ can also accumulate much less (Kumolu, Aladetohun and Ndimele, 2009). Fish muscle always contains lower concentrations of metals than other tissues in a number of fish species in many water bodies around the world (Yilmaz, 2003; Reynders et al, 2008; Jaric et al, 2011), due to its low metabolic activity (Uluturhan and Kucuksezgin, 2007).

Skin and bones may have much higher levels of lead. Higher lead concentrations in fish scales and bones than in the other parts of the fish occurs because lead preferentially accumulates in bone and calcium structures (Rashed, 2001). Other studies on various fish organs such as gills, muscle, liver, kidney and bones includes (Etim, 2005; Metwally and Fouad, 2008; Verdouw, 2008; El-Sayed et al, 2011). Mechanisms of metal uptake in fish has been advanced forward. Availability in fish has been found to occur through absorption across the gills surface or through the gut wall tract (Obasohan, 2007). Diffusion is another mechanism observed which facilitates metal transportation in gills. Surface mucus are equally

mechanisms of uptake from water (Oguzie, 2003). Based on studies made particularly in the Nigerian environment, aquatic ecosystems have been reported with varying levels of pollution. Several of these studies have reported high level of heavy metals in fish from some Nigerian rivers such as 1.50mg/kg and 1.23mg/kg of cadmium in *Alestes nurse* and *Synodontis nigritis* from Oguta Lake (Odoemelam, 2005), 0.23mg/kg and 0.90mg/kg of cadmium in *Tilapia* fish from Makoko and Carter Bridge Rivers in Lagos Nigeria (Bolawa and Gbenle, 2010); Oronsaye, Nangboye and Oguzie (2010) who reported cadmium of 0.79mg/kg and 0.98mg/kg; and Ishaq, Rufus and Annune (2011) who reported 0.927mg/kg - 0.994mg/kg of cadmium in *C.gariepinus* and *T.zilli* respectively from River Benue, Nigeria.

Fish has not been the only aquatic fauna that has been used to bio-indicate heavy metal pollution in aquatic medium, studies have also used other aquatic fauna such as periwinkles (Ideriah, Braide and Briggs, 2006; Nwabueze, Nwabueze and Okonkwo, 2011), crabs (Maulvault, Cardoso, Nunes and Marques, 2013), molluscs (Rabaoui, Balti, El Zrelli and Tlig-Zouari, 2013), plankton (Javed, 2003), protozoans (Fernandez and Olalla, 2000), crustaceans (Allinson, Laurenson, Pistone, Stagnitti and Jones, 2000), and so on. However, fish is most useful to bio-indicate pollution status of aquatic environment due to their ability to bioaccumulate these metals as top feeders (trophic level) in the aquatic food chain (Wildianarko, Van, Verweij and Van, 2000; Zhou, Zhang, Fu, Shi and Jiang, 2008). The importance of having a healthy environment has necessitated these research works and such studies have shown that varying level of pollution ranging from unpolluted to very practically polluted have characterised aquatic ecosystems.

A comparative assessment on beneficial nutrients and contaminants in fish has shown that benefits or risks could be ascribed on the basis of which is in greater amount in fish. For instance, assessment of associations between exposure to both marine n-3 Polyunsaturated

Fatty Acids (n-3 PUFA) and methylmercury, to myocardial infarction (heart attack) using data from Finland and Sweden has shown that exposure to mercury is associated with increased risk of Myocardial Infarction. On the other hand, higher S-PUFA concentrations are associated with decreased risk of Myocardial Infarction. Thus, Myocardial Infarction risk may be reduced by the consumption of fish high in S-PUFAs and low in methylmercury but increased by the consumption of fish high in heavy metal (VKM, 2014).

2.4 Effects of Heavy Metals in Humans

Virtually all metals can produce toxicity when ingested in excessive quantities, but there are some which are particularly important, because they are either pervasive or produce toxicity as complexes or ligands with organic compounds. When in complexes with these metals, the biological molecules lose their ability to function properly, and result in malfunction / death of affected cell (Adata, Wegwu, Belonwu and Okerenta, 2015). Metal specific effect on human health is thus considered as follows:

2.4.1 Health effects of mercury on human

Mercury is considered as a non-essential element for living organism. It is among th most toxic elements to mammals. Humans are usually exposed to mercury in both chronic and low dose (Park and Zheng, 2012), and the vast majority of exposure is in the form of methyl mercury through the consumption of fish (Sarkar, 2005; Zahir, Rizwi, Haq and Khan, 2005). The health effects of concern depend on the form of mercury and the duration and magnitude of exposures. If the exposure is of elevated concentrations for a long duration, all forms of mercury may cause health effects especially to the nervous system (Wilson, 2013).

Fish from fresh and salt water, appear to be the primary source of methyl-mercury poisoning in humans. Once ingested the gastrointestinal tract readily absorbs approximately 95% of methyl-mercury (Bernhoft, 2012). The nervous system is the primary repository for mercury

exposure, however, the systemic distribution has the potential to cause symptoms in different organ systems (Gundacker, 2010), causing various effects. In the gastrointestinal system the effects of mercury may be such as abdominal pain, indigestion, inflammatory bowel disease, ulcers and bloody diarrhoea. It has also been associated with reduced resistance to pathogenic infection and can also cause kidney damage to a large extent (Miller, 2013). It is related to increased blood pressure, risk of myocardial infarction (heart attack), atherosclerosis (disease of the arteries) and risk of developing cardiovascular disease (Azevedo, 2012).

Mercury can damage the blood brain barrier and it facilitates penetration of other toxic metals and substances to the brain, causing effects in the central nervous system and immune, sensory, neurological, motor, and behavioural dysfunctions (Tchounwou, Ayensu, Ninashvilli and Sutton, 2003). Low exposure levels of mercury may affect the endocrine system by the disruption of the pituitary, thyroid, adrenal glands and pancreas (Minoia, Rinchi, Pigatto and Guzzi, 2009). The effects on the reproductive system not only affect conception but also the foetus development. Methyl-mercury can cross the placenta and cause neurological damages to the foetus and babies can be born with a variety of birth defects and cognitive delays (Bernhoft, 2012; Rice, Walker, Wu, Gillette and Blough, 2014). Children are thus considered highly vulnerable to mercury effect (Costenla, 2014).

2.4.2 Health effects of cadmium on human

Cadmium is produced as an inevitable by product of zinc. The application of agricultural inputs such as fertilizer, pesticides and biosolids (sewage sludges), industrial waste or deposition of atmospheric contaminants increases cadmium. Human exposure to cadmium is possible through a number of several sources such as emissions from mining, smelting, and manufacturing of batteries, pigments, stabilizers, and alloys (Agency for Toxic Substances and Disease Registry, 2008); consumption of certain aquatic foods such as, crustaceans and

mollusks (Satarug et al, 2003); as well as, mushrooms, shellfish, mussels, and dried seaweed. By far the highest concentrations are found in fish and shellfish (Llobet, Falcó, Casas, Teixidó and Domingo, 2003).

While in the body, highest levels of cadmium are found in the liver and kidney. Elimination from the body occurs very slowly via urine and faeces (Borchers, Teuber, Keen and Gershwin, 2010). There is increase accumulation of cadmium when in the body and the level increases with age given a long half - life greater than 20 years (Sabath and Robles-Osorio, 2012). Various epidemiological studies have demonstrated that environmental exposure to cadmium increases the risk of developing kidney injury (Sabath and Robles-Osorio, 2012). An important route of exposure is the circulatory system where blood vessels are considered to be main stream organs of cadmium toxicity. High levels of cadmium in urine have been associated with higher overall mortality and increased risk of cancer (Menke, Muntner, Silbergeld, Platz and Guallar, 2009). In addition to its nephrotoxic effect, cadmium is also associated with increased risk of developing diabetes (Schwartz, Yasova and Ivanova, 2003).

Exposure to cadmium also increases the risk of high blood pressure and it is considered a risk factor for cardiovascular mortality and morbidity (Gallagher and Meliker, 2010), and hypertension (Tellez, Jones, Dominguez-Lucas, Guallar and Navas-Acien, 2013). Cadmium is able to pass to the foetus via the placenta affecting its central nervous system. It can impair myelination (hindering proper functioning of the nervous system) in the new born child, create deficits in learning and altered behaviour. Increasing evidence has demonstrated that cadmium is a possible etiological factor of neurodegenerative diseases, such as Alzheimer's disease and Parkinson's disease (Wang and Du, 2013).

After acute ingestion of cadmium, symptoms such as abdominal pain, burning sensation, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness and

convulsions usually appear within 15 to 30 minutes (Baselt and Cravey, 1995). Acute cadmium ingestion can also cause gastrointestinal tract erosion, pulmonary, hepatic or renal injury and coma, depending on the route of poisoning (Baselt and Cravey, 1995; Baselt, 2000). In some studies, environmental cadmium exposure has also been associated with development of cancers of the prostate, kidney, liver, hematopoietic system (The bodily system of organs and tissues, primarily the bone marrow, spleen, tonsils, and lymph nodes, involved in the production of blood) and stomach (Waalkes, Misra and Chang, 1996).

2.4.3 Effect of lead on human

Lead is the most systemic toxicant. This means that it affects several organs in the body including the kidneys, liver, central nervous system, hematopoetic system (The bodily system of organs and tissues, primarily the bone marrow, spleen, tonsils, and lymph nodes, involved in the production of blood), endocrine system, and reproductive system (Agency for Toxic Substances and Disease Registry, 1999). Once it enters the blood stream, 99% of lead binds with the erythrocytes (Shafiq-ur-Rehman, 2013). In the bloodstream, it has a half-life of roughly 30 days and is excreted in urine and bile. The remaining lead binds to red blood cells, and is distributed throughout the soft tissues of the body and accumulates in the bone. Once in the bone, its half-life ranges from 20 to 30 years (Saxena, Gautam, Kaur and Gill, 2007).

Exposure to small amount of lead over a long period of time may be dangerous because once it gets into a person's system, it is distributed through out the body system. Its absorption is influenced by factors such as age and physiological status. In the human body, the greatest percentage of lead is taken into the kidney, followed by the liver and the other soft tissues such as heart and brain but, the lead in the skeleton represents the major body fraction (Saxena et al, 2007). The nervous system is the most vulnerable target of lead poisoning.

Headache, poor attention span, irritability, loss of memory and dullness are the early symptoms of the effects of lead exposure on the central nervous system.

There are many published studies such as Amodio et al, (1996); Litvak et al, (1998); Kaul, Sandhu, Depratt and Reyes (1999); United States Environmental Protection Agency (2002), that have documented the adverse effects of lead in children and the adult population. These studies have shown that in children, an association exists between blood lead poisoning and diminished intelligence, lower intelligence quotient-IQ, delayed or impaired neurobehavioral development, decreased hearing acuity, speech and language handicaps, growth retardation, poor attention span, and anti-social and diligent behaviors.

In the adult population, reproductive effects, such as decreased sperm count in men and spontaneous abortions in women have been associated with high lead exposure (Apostoli, Kiss, Stefano, Bonde and Vanhoorne, 1998; Hertz- Picciotto, 2000). Acute exposure to lead induces brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, blood pressure, kidneys, and vitamin D metabolism (Agency for Toxic Substances and Disease Registry, 1999; Kaul et al, 1999; Hertz- Picciotto, 2000). Lead binds to biological molecules and thereby interfere with their function by a number of mechanisms. It binds to some groups of enzymes, altering their configuration and diminishing their activities and alter the transport of essential cations such as calcium (Saxena et al, 2007).

Events like pregnancy, menopause or lactation increase the turnover of bone tissue and releases lead back into the bloodstream (Mason, Harp and Harn, 2014). During pregnancy, the level of lead in maternal bloodstream increases, it crosses the placenta which poses a threat to the health of the foetus. Even among the vulnerable i.e. women and children, the latter are at higher risk because they have greater gastrointestinal absorption and less

effective renal excretion and the encephalic barrier immature (Koyashiki, Paoliello, Tchounwou, 2010). Not only during the pregnancy but also during lactation, lead can pose a threat to infants. Breast milk from mothers with current exposure to lead or mothers exposed by the redistribution of bone lead has been identified as a source of exposure to the infant (Koyashiki et al, 2010). Hence nursing mothers have been advised to stay away from certain fish species known with higher tendency of heavy metal accumulation.

Neuropsychological research over the years has revealed that lead exposure can result in declines in intelligence, memory, processing speed, comprehension and reading, visuospatial, motor and executive skills. Among the cognitive deficits induced by lead toxicity, visuospatial deficits appear to be major. Lead exposure to breast milk mother can cause anxiety, depression and phobia. There is also a growing evidence of antisocial behaviour linked to early lead exposure (Mason et al, 2014). Research also indicates that cumulative environmental lead exposure is neurotoxic to adults acting as a risk factor for accelerated declines in cognition (Bakulski, Rozek, Dolinoy, Paulson and Hu, 2012).

2.4.4 Effect of zinc on human

Zinc is an essential element to human. Ingestion of zinc and it compounds can have deleterious effects on account of toxicity occasion by ingestion beyond reference values. The levels of zinc that produce adverse health effects are those much higher than the Recommended Dietary Allowances (RDAs) for zinc of 11 mg/day for men and 8 mg/day for women. If large doses of zinc (10–15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur, along with damage to the pancreas, and decrease levels of high- density lipoprotein (HDL) cholesterol (ATSDR, 2005). Complications may include gastrointestinal hemorrhage and acute pancreatitis. In more severe cases, chest tightness, excitement, coldness, unconsciousness, and coma occurs

(Nriagu, 2007). Very high levels of zinc can disturb protein metabolism, and cause arteriosclerosis (Lenntech, 2016). Zinc toxicity has also been associated with anorexia, asthma-related symptoms, blood disorders, changes in attention, bloating, constipation, diarrhea, dizziness, drowsiness, fatigue, genital or urinary complications, headache, hormone changes, immune changes, increased risk of lung or breathing disorders, indigestion, kidney inflammation, liver failure or inflammation, loss of smell, throat irritation, tingling in the nose, and tissue death (Mayo Clinic, 2016). When in high-dose zinc interferes with the uptake of copper, and as a result, induce copper deficiency. Effects arising from this include low white blood cell (affecting body immunity) risk of infections and osteoporosis (Karl, 2013). Other common effects associated with long-term, excessive zinc intakes includes wheezing, rales, rhonchi, nausea, epigastic pain, lightheadedness, listlessness, metallic taste in the mouth, anaemia, and even death (Nriagu, 2007).

2.4.5. Human health effect of iron

Iron is the most abundant transition metal in the earth's crust. Biologically it is the most important nutrient for most living creatures as it is the cofactor for many vital proteins and enzymes as well as oxygen transport and DNA synthesis (Cappellini, 2007). Humans cannot actively remove excess iron. Cumulative effects leads to significant morbidity and mortality. In the blood, labile plasma iron has been reported to be taken up by liver, cardiac and endocrine cells (Cabantchik, Breuer, Zanninelli and Cianciulli, 2005) and excess iron in the body has been associated with cardiac failure, liver failure, diabetes and eventually death. Neuro degenerative disorders and brain damage has been reported (Robert and Prem, 2012).

Chronic fatigue, joint pain, impotence, osteoporosis and diabetes have been identified as symptoms for consideration in early diagnosis of excess iron in the body (Mainous, Diaz and Everett, 2011). Hillman (2001) has identified four stages of iron toxicosis in humans.

The first stage which occurs 6hrs is marked by gastrointestinal effects such as gastro intestinal bleeding, vomiting and diarrhea. The second stage progresses within 6 to 24hrs and it is considered as the latent period, a period of apparent medical recovery. The third stage occurs between 12 to 96 hrs after the onset of certain clinical symptoms. This stage is characterized by shocks, hypotension, lethargy, tachycardia, hepatic necrosis, metabolic acidosis and sometimes death. The fourth stage occurs within 2-6 weeks of iron overdose. This stage is marked by the formation of gastrointestinal ulcerations and development of strictures.

Excess iron uptake can initiate cancer mainly by the process of oxidation of DNA molecules (Bhasin, Kauser and Athar, 2002) thereby increases the risk of cancer. It promotes DNA damage. Iron formation of free radicals is the outcome of iron toxicity (Fine, 2000). Some of these free radicals such as hydroxyl radicals are dangerous as they can inactivate certain enzymes, initiate lipid peroxidation, depolymerize polysaccharides and can cause DNA strand breaks. This can sometimes result in cell death (Jaishankar, Tseten, Anbalagan, Mathew and Beeregowda, 2014).

2.5 Risk Assessment

The term risk is the combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence (Department of Resources and Tourism, 2008). Risk and hazard are often used inter-changeably. While this is the case, hazard is the property or situation that in particularly circumstances leads to harm (Burgman, 2005). The distinction between hazard and risk can be made clearer by the use of this illustration. Heavy metals have deleterious effects on human health. It has inherent potential to cause harm. But the degree of harm caused by specific exposure will depend on specific exposure scenario (European Environmental Agency, 2008). Therefore if a human comes in

contact with specific dose of heavy metal particularly below a reference dose, the risk of harm (i.e. the probability of occurrence of hazard and it consequences) will be minimal and vice-versa, but the hazardous property of the heavy metal remains unchanged.

Risk assessment is a methodology to determine the nature and extent of risk by analysing the potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihood and the environment on which they depend (UNISDR, 2009). It incorporates a measure of likelihood of the hazard actually causing harm and a measure of the severity of harm in terms of the consequences to people or the environment (Fairman, Mean and Williams, 1999).

Risk assessment vary widely in scope and application. In broad terms, assessment of risk results in a characterization of potentially adverse human health or environmental (ecological) impacts resulting from exposure to hazardous waste, hazardous substances, or other stressors (chemical, biological, physical, etc.) (ITRC - Interstate Technology & Regulatory Council, 2008). In other words, risk assessment is carried out to examine the effects of an agent on humans (Health Risk Assessment) and ecosystems (Ecological Risk Assessment). Since this occurs in the environment, it is better viewed from an environmental perspective otherwise known as environmental risk assessment.

2.6 Environmental Risk Assessment of Heavy Metals

Environmental Risk Assessment (ERA) is an estimate of the likelihood or probability of an adverse impact on the environment, as a result of human activities (i.e., a formal procedure for identifying and estimating the risk of environmental damage) (MELP, 2000). It involves examination of risks resulting from polluting sources that threaten ecosystems, animals and people and includes human health risk assessments, ecological or ecotoxicological risk

assessments, and specific industrial applications of risk assessment that examine end-points in people, biota or ecosystems (Fairman et al, 1999).

In the environment, risk can occur in the form of discharge of mine affected water, impacting surface water quality like rivers, in relation to aquatic biology, drinking water and aesthetics in aquatic environments, spills of ores into water courses (Boulanger and Gorman, 2004), spills from transport, storage or use of hazardous materials giving rise to impacts on water quality (KPI, 2007). In the life cycle of a chemical, risks can arise during manufacture, distribution, in use, or the disposal process where they eventually become pollutants.

Four steps of environmental risk assessment has been identified. They are:

a. Hazard identification which is a process of determining whether a hazard exists
b. Exposure assessment which the process of estimating route of exposure (contact, inhalation or ingestion)
c. Toxicity assessment which is the characterization of a chemical's toxicity, including the relationship between the dose a person might receive and the occurrence of adverse health effects in the exposed population
d. Risk characterization which is a combination of the exposure and toxicity assessments into a quantitative expression of risk (ITRC - Interstate Technology & Regulatory Council, 2008).

For a risk to exist there must be a source (or hazard or pressure), a pathway and a receptor (or target) (Daly, 2004), which is the basis for the Source- Pathway-Receptor (S-P-R) conceptual model for environmental management (EPA, 2007). Potentially harmful industrial materials; emissions from automobiles, energy production and other industrial processes are some anthropogenic sources of risk to the environment (World Bank, 1997).

The pathway is a mechanism or route by which a contaminant comes into contact with, or otherwise, affects a receptor. In other words, it is one or more route, or means by or through which a substance or contaminant moves through the environment and comes into contact with, or otherwise, affects a receptor (DETR, 2000) and includes air, water and soil (via inhalation, absorption and ingestion). A pathway must exist if a hazard is to pose a risk to a receptor. The pathway thus defines the likelihood of contact with, or transport to, a receptor (EPA, 2007).

A receptor is a person, living organism (e.g. fish, livestock, crops, pets or wildlife), ecological system, controlled waters, atmosphere, structures and utilities that could be adversely affected by the source (BS, 2001). The magnitude of risk is proportional to both the rate of exposure and the inherent potency of the chemical. This is a fundamental principle known as dose – response relationship. According to the dose-response principle, as the level of exposure increases, the probability and/or magnitude of adverse health effects also increase (Wilson, 2013).

The risk to receptors is dependent on the potential for exposure to the hazard, (whether leachate, landfill gas, sewerage, agricultural wastes, storm water drain, industrial effluent, hospital waste) and is dependent on the pathway and the distance between the hazard/source and the receptor (EPA, 2007). Exposure estimates combined with chemical-specific toxicity helps to determine the likelihood of adverse health effects in potentially exposed populations. (ITRC - Interstate Technology and Regulatory Council, 2008).

The assessment of environmental conditions and indicators is summarized in terms of a risk index, and generally reported by means of a series of risk classes. As a part of the risk analysis, it may be useful to define specific thresholds, or a low risk benchmark based on best management practices (MELP, 2000).

2.6.1. Ecological risk of heavy metals

An ecological risk assessment is the process for evaluating how likely it is that the environment may be impacted as a result of exposure to one or more environmental stressors such as chemicals, land change, disease, invasive species and climate change (EPA, 2015). The degree to which metals are available to aquatic and terrestrial organisms varies depending on the site-specific geochemical conditions controlling metal speciation, and therefore also influence the degree to which organisms may be exposed to metals and experience adverse effects from such exposure (ICMM, 2005).

The basis for assessing the risk in an ecosystem is that heavy metals affect organisms directly or indirectly as it transfers to the next tropic level of the food chain. While in the aquatic environment, heavy metals in dissolved form are easily taken up by aquatic organisms where they are strongly bound with sulfhydryl groups of proteins and accumulate in their tissues. The accumulation of heavy metals in the tissues of organisms can result in chronic illness and cause potential damage to the aquatic population (Amirah, Afiza, Faizal, Nurliyana and Laili 2013).

Ogeleka et al, (2013) investigated short term effects of industrial chemicals commonly released in the Nigerian environment using laboratory toxicity test. Fish and earth worms exposed were studied using the organization for economic cooperation and development (OECD) 203 and 207 protocols respectively. Soil and water ratings indicated toxicity on the aquatic organisms, as fish exposed showed significant difference when compared with the levels measured in the control group. Heavy metal contamination may have devastating impacts on the ecological balance of natural water bodies including the loss of aquatic diversity (Vosyliene and Jankaite, 2006; Farombi, Adelowo and Ajimoko, 2007; Hayat and Javed, 2008).

For instance, in a study on the effects of lead on *Clarias gariepinus* juveniles, growth, survival and other physical parameters were monitored to ascertain the toxicity effects of lead. The results revealed that fish mortality and abnormal behaviour were more in samples with higher concentrations of lead (Falayi and Amatosero, 2014). This shows that higher concentration of heavy metals in aquatic environment can affect the juvenile population of fish, reduce fish population and create an imbalance in the river ecosystem in the long run. Even sediments soil microbes are toxicologically affected, leading to decline in fish population (Khan, Hesham, Qiao, Rehman and He, 2010).

Akan, Abdulrahman, Sodipo, Ochanya and Askira (2010) investigated heavy metals in sediments from River Ngada, Maiduguri Metropolis, Borno State, Nigeria. The extent of sediment quality deterioration was observed in all the sampling points to be higher with respect to all the metals studied. The authors concluded it is most likely that the food web in this study environment might be at highest risk of induced heavy metal contamination. Some species of fishes have been found to experience poisonous effect of chromium as echoed in the blood changes such as anemia, eosinophilia and lymphocytosis, bronchial and renal lesions (Sehar et al, 2014).

Chromium is not known to accumulate in the bodies of fish, but high concentrations of chromium, due to the disposal of metal products in surface waters, can damage the gills of fish that swim near the point of disposal (Sehar et al, 2014). Reproduction rate of aquatic organisms is affected due to exposure to heavy metals and can lead to a gradual extinction of their generations in polluted waters (Sridhara, Kamala, Samuel and Raj, 2008). Cadmium and mercury damage the kidney in fish and cause signs of chronic toxicity, including impaired kidney function, poor reproductive capacity, tumors and hepatic dysfunction (Mansour and Sidky, 2002).

2.6.2. Human health risk assessment of heavy metals

Human health risk assessment is a process that is accepted by international health agencies for evaluating the potential of chemical, biological and physical agents that causes adverse health effects in people. Although it is desirable to minimize exposures to some environmental chemical contaminants, it cannot be avoided in many circumstances. Regulatory agencies across the world have adopted risk assessment as a scientifically-defensible tool for the evaluation of potential health risks to chemicals. This risk assessment focuses on the reasonable likelihood of adverse health effects in people exposed to various environmental chemicals or physical agents (Wilson, 2013).

Risk assessment is one of fastest method which is needed to evaluate the impact of the hazards on human health and also need to determine the level of treatment which tend to solve the environmental problem that occur in daily life (Yujie et al, 2012). Several methods have been proposed for estimation of the potential risks to human health of heavy metals in fishes such as disability adjusted life years, quality adjusted life years (Becker and Petersson, 2007), benchmark dose modeling (US EPA, 2012), exposure dose and target hazard quotient. Most Studies have however adopted the target hazard quotient to assess the level of risk involved with consuming fish from contaminated environment and various findings have emerged.

For instance, the concentrations of heavy metals (Cr, Cd, Hg, Cu, Zn, Pb and As) in the water, sediment, and fish were investigated in the middle and lower reaches of the Yangtze River. Health risk analysis of individual heavy metals in fish tissue indicated safe levels for the general population and for fisherman but, in combination, there was a possible risk in terms of total target hazard quotients (Yujun, Zhifeng and Shanghong, 2011). To evaluate the health risk to people in Machilipatnam Coast, the Target Hazard Quotient (THQ) of heavy

metal was estimated on the concentrations of metal in fish muscle and risk involved in daily fish consumption. The THQ values of all the studied metals in fish samples were above 1 except Cd. The concentration of the metals in fish muscle from Machilipatnam coast was therefore adjudged to pose health hazards to the consumers (Krishna, Jyorthirmayi and Madhusudhana, 2014).

Amirah et al, (2013) researched human health risk assessment of metal contamination through the consumption of fish at selected river in Kuantan, Malaysia. Target Hazard Quotient (THQ) was used in the health risk assessment to determine carcinogenicity of the sample. The result shows that the concentration and THQ of all metal studied (Cu, Pb, Cd) are less than 1; signifying that a daily exposure at this level is unlikely to cause any adverse effects during a person lifetime. Although the THQ-based risk assessment method does not provide a quantitative estimate of the probability of an exposed population experiencing an adverse health effect, it does provide an indication of the risk level associated with pollutant exposure and has been shown to be valid and useful tool for human risk assessment. This method of risk estimation has recently been used by other researchers (Chien et al, 2002; Wang, Sato and Baosha, 2005).

2.7 Environmental Awareness

Environmental awareness is defined as knowing of, being informed or having knowledge and specific facts about the adverse impact of people's behavior on the environment (Laurian 2003; Hansla, Gamble, Juliusson, and Gärling, 2008). Man's behavior towards his environment has been driven by quest for economic development evident in activities ranging from industrialization, manufacturing, agriculture, and the likes without having a recourse to environmental protection. Hazardous waste sites, persistent toxic organic compounds, sewage, radiation, heavy metals are consequencies of these anthropogenic interference in the

environment which has been ranked the top five pollution induced anthropogenic activities (Slimak and Dietz, 2006).

In terms of pro environmental practices, peoples understanding of environmental issues determines how they utilize environmental space, with corresponding effects on the quality of the environment (Barasa, Toili and China, 2011). To what extent people understand the consequences of their actions have necessitated awareness research. Such research has shown that some form of awareness exist among study population on environmental risk only a general level but lacking on specific aspects of environmental risks.

A survey of environmental awareness among residents of Ogbomosho in Nigeria has shown that majority of respondents perceived the presence of environmental problems in the area. But despite their awareness, the people lacked much consciousness and care of environmental cleanliness and management (Eugenious, 2006). This is similar to survey findings on environmental awareness issues in Malaysia where respondents basic or general environmental knowledge are reportedly high, but low in knowledge on specific environmental issues (Khaled, Mohd and Romlah, 2016).

Worthy to note is the fact that enhancing factual knowledge about the environment often has little or no impact on behavior towards the environment (McKenzie-Mohr, 2000). This is because, awareness of the environment comprises three constituents namely; the cognitive/ knowledge-based element, affective perception-based/ emotional involvement element, and behavioral action-based element (Arlt, Hoppe and Wolling, 2011). While cognition deals with knowledge base element, it doesn't suffice in achieving the desired goal of awareness creation which is positive behavioural action. The affective element which involves the emotional base of the individual plays a key role in influencing behavioural action evident in

pro-environmental behaviour. A combination of these three constituents, influences attitudes and behaviours towards the environment.

As study by Ogunbode and Arnold (2012) has shown, people will only be most concerned about environmental issues that directly affects their daily lives. This means that the extent to which an environmental information supplied influences behavioural and attitudinal change depends on how people understands how the risks affects them personally in their daily lives. Other than this, their attitudes remains unchanged irrespective of the quality of environmental information presented and awareness sought.

Empirical review of literatures shows that in many cases, levels of environmental awareness among a population correlate significantly with educational attainment, age, and income (Inglehart, 1995). In terms of gender, irrespective of cultural and geographic differences, surveys have found a strong gender bias in environmental awareness and attitudes. In other words, females have been adjudged positive in terms of environmental behavior than males. Educational attainment has also shown that people who have received a higher level of education tend to understand risks and know how to avoid or mitigate risks, such as the risk of food additives, food contamination, pesticides in food, than people with less education (Dosman, Adamowicz and Hrudey, 2001), while low income earners are lacking in awareness on the dangers and ways of alleviating environmental problems such as traffic fumes, poor waste disposal, and pollution (Eugenious, 2006).

CHAPTER THREE
MATERIAL AND METHODS

3.1 Study Area

3.1.1 Location

Jema'a L.G.A. Kaduna State, is located between latitude 9^{o} $10^{'}$ and 9^{o} $30^{'}$ N and longitude 8^{o} $00^{'}$ and 8^{o} $30^{'}$ E. The L.G.A. is bounded in East by Kagoro in Kaura L.G.A., in the North by Zonkwa and Ungwar Rimi District of Zangon-Kataf L.G.A., in the West by Jaba L.G.A., in the South by Nasarawa State and in the South-East by Sanga L.G.A. respectively shown in Figure 3.1

3.1.2 Climate

The area is designated Koppen's Aw (Tropical wet and dry) climate with two distinct seasons. Rainfall occurs between the months of April to October with a peak in August. The mean annual rainfall is about 1800 mm, but could reach 2500 mm particularly in the forest reserve areas of Gidan – Waya (Dogo, 2014). These values give an insight into the nature of surface runoff occasioned by heavy downpour. Surface runoff carry serve as one of the mediums through which rivers receive heavy metal loadings. The release of heavy metals from natural sources such as rocks is made possible by rainwater through chemical weathering action.

The dry season is characterised by the north – east trade wind known as the harmattan. This is dusty and dry with low humidity (Abaje, Ati and Ishaya, 2009). This seasonal variations influences the concentrations of heavy metals in aquatic environments with dry season having higher concentrations in water. The mean monthly temperature is 25^{o}C, with an annual average of 30^{o}C, minimum temperature may fall to 15^{o}C during the hamattan which spans the period (December to January), and maximum temperature reaching 42^{o}C between

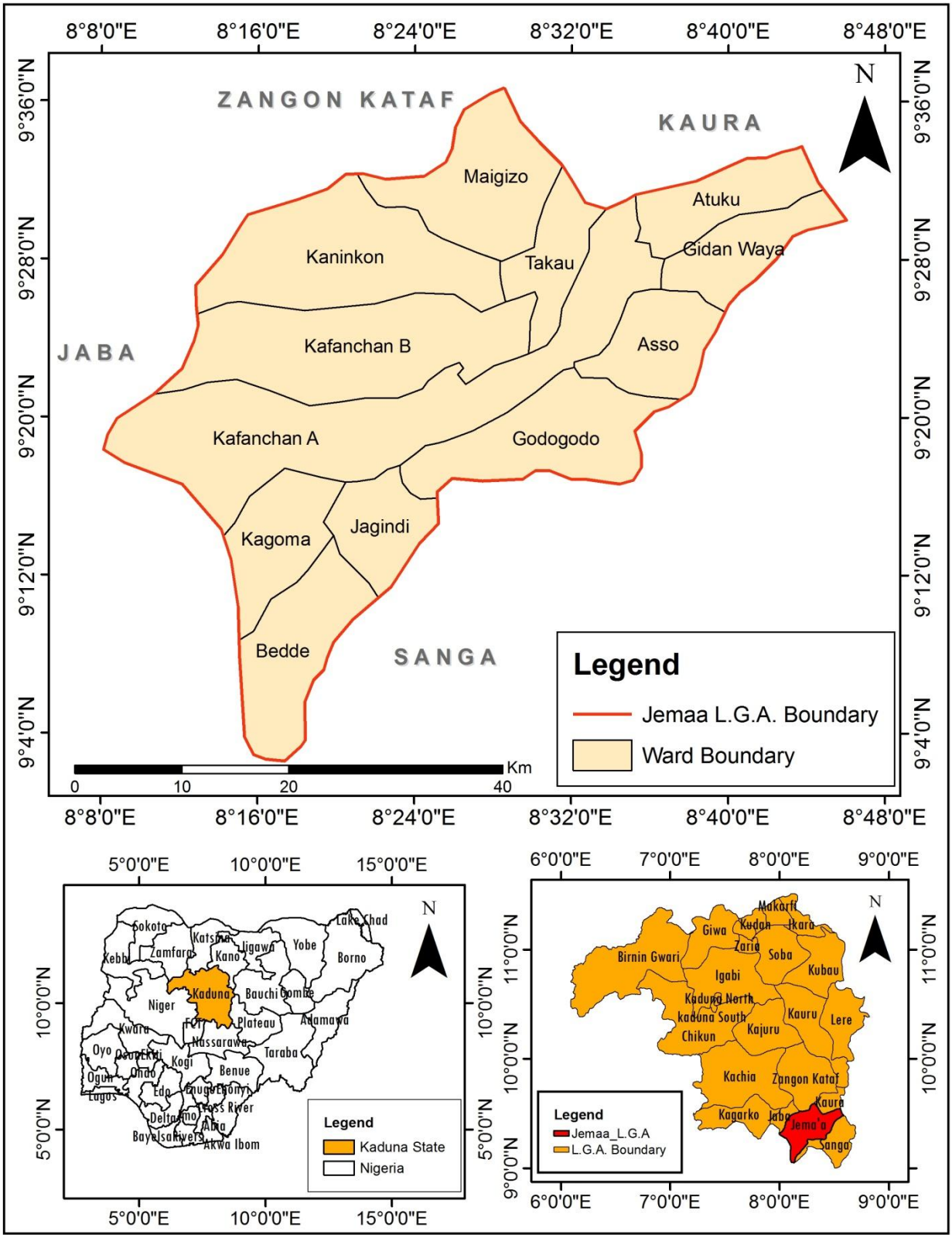


Figure 3.1: Jema'a Local Government Area, Kaduna State.
Source: Adapted from the Administrative Map of Kaduna State.

February and early April, which is the hottest period (Dogo, 2014).

3.1.3 Drainage

The area is drained by a network of rivers and streams which are mostly perennial. Rivers Kagoma, Magami, Wonderful, Semes, Challo, Kudan, Zauru, Kogum, Zakko and Bakin – Kogi among others constitute the rivers which drain the area. The north eastern part has three major rivers namely, Assob, Gimi and Sanga. These have their sources from the western escarpment of the Jos Plateau. They join southward to form the Mada River. All these rivers have tributaries, like the Dangwa, Masoyi, Jema'a and River Ojib. The north western part of the area has the Kogum and Kanock Rivers as the major rivers. These have their sources at the Kagoro and Samban hills, respectively and their tributaries include the Garti, Chori, Nok, Pyneba, Pynecho rivers. All the rivers in the area flow southward and drain into the Mada River which belongs to the Benue system. The tributaries are controlled either by master-joint pattern or the schistosity of the basement rock. The resulting drainage pattern is largely trellised and less dendritic (Hamidu and Ikpokonte, 2013). Artisanal fishing takes place in some of these rivers for both sales and domestic consumption.

3.1.4 Geology

The study area is underlain by the basement complex rock of North-Central Nigeria consisting of migmatites granites, gneiss granites, and newer basalts. Granite form the dominant rock unit in the area with three types identified namely; biotite granite, medium grained biotite granite, and biotite hornblende granite. Newer basalts occur as ridges in isolated exposures in the area (Jatau and Bajeh, 2007). The migmatite shows alternating and discontinuous dark and light coloured bandings and, the gneisses occur as ortho- and paragneisses. The former type is characterized by layered structures while the latter has bands

of light and dark alignment of minerals mostly of biotite and quartz. The basaltic rock occurs as boulders which are either vesicular or amygdaloidal. The boulders occur at the subsurface within the regolith at depths between 5–10 metres and sometimes as flow at the surface. Joints, pegmatite and aplite dykes, quartz veins and minor folds constitute some of the structural elements in the area (Hamidu and Ikpokonte, 2013). There are mineral deposits such as, sapphire, corundum, ameltyst, aquamarine, zircon, mica, chalcofyrite, topaz, crystals topaz quartz, columbite, tantalite, zinc, lead and suspected diamond, (Shanum, 2011). Bedrocks of geologic formations have been known to cause release of heavy metals in the environment like arsenic. In this case, lead and zinc forms part of the geologic formations of the study area as cadmium is known to be present and associated with zinc where the latter is found.

3.1.5 Soil and vegetation

The main type of soil is the ferruginous tropical soil which is related to the climate, vegetation, lithology and the topography of the area. The relief is relatively flat and undulating and it influences the drainage pattern of the area (Ishaya and Abaje, 2008). Alluvium stream channels contains deposit of alluvial sand derived from the area as a result of weathering of basement complex rocks. They range from fine to coarse grained sand, silts and clays. The unconsolidated gravels decompose mainly from quartzites and laterites (which could influence the presence of iron in the river sediment) (Jatau and Bajeh, 2007) Soils forms the platform for agricultural activities where use of chemical pesticides and herbicides contaminate the soils and flow into surface water. The vegetation comprises of species like *Daniella oliverii, Vitex doniana, Diospyros mespiliformis, Khaya grandifoliola and Albizia africana* (Yunana and Banta, 2014).

3.1.6 People and occupation

The study area has witnessed a tremendous growth in population in the last 30 years (Ishaya and Abaje, 2008). It has a population of 278,735 (FRN, 2006). With annual growth rate of 3% in the state (FRN, 2006), the 2015 projected population using exponential growth rate is about 365,133 people. Increasing population also translates into increase in amount of domestic waste generation with lots of contaminants. The L.G.A. has four chiefdoms under its jurisdiction namely, Ninkyob, Godogodo, Dyekpa and Fantsuwan chiefdoms (Shanum, 2011).

Presently it has twelve wards, namely: Jagindi, Godogodo, Atuku, Gidan Waya, Maigizo, Kaninkon, Kagoma, Asso, Kafanchan A, Kafanchan B, Bedde and Takau (Ishaya and Abaje, 2008). The people engage in various economic activities notably hunting, fishing, blacksmith, iron smelting, animal rearing as well as crop cultivation. Major agricultural produce are:- Maize, Guinea corn, millet, yam, cocoa yam, rice, palm, kola nut, Soya bean, hide & skin fishing, goat, pig, rearing and chicken rearing in commercial quantity (Shanum, 2011). Some of these activities have potential for the release of heavy metals into the environment through the use of pesticides and herbicides.

3.1.7. Land use

The major land use in the study area is agriculture which is the mainstay of the economy. This is as a result of the conducive atmospheric cool temperature, adequate rainfall and abundant farmland spread all over the area. Rain fed arable cropping and flood land agriculture are two systems to which the land is being used. The former has the largest hectarage of land cultivated, with little use of manure or fertilizer. The major crops are sorghum, Millet, Cassava, Maize and yam. Others are acha, cocoyam and rice. Flood land agriculture is limited to the seasonally flooded bottomlands. The most common crops in these

wet bottom lands are bambara nut, rice, maize, cabbage, spinach, oranges cassava, groundnut, beans, sweet potatoes sugar cane, banana and vegetables. Almost all the crops grown here are for subsistence uses except for cotton and peanut. This land use type is practiced by almost all the ethnic groups in the area, with the exception of cultivation of "acha" which is peculiar to Jaba, kagoma, Kagoro and Bajju ethnic groups. Since the area is tsetse fly infested there are no settled animals production systems, however, domestication of sheep, goats and Pigs by the indigenes is carried out. Sheep and goats are kept in houses and roam about freely especially during the dry season (Marcus, 2012). The land use is also evident in the modification of the natural environment into built environment.

3.2 Methodology

3.2.1 Types of data

The types of data used in this work include information on awareness of harmful chemicals in fish purchased, level of harmful chemicals in fish purchased, rate and pattern of consumption of fish, and types of fish consumed. Concentration of mercury, cadmium, lead, zinc and iron analyzed in the river water and sediment was also used.

3.2.2 Sources of data

The sources of data for this study were both primary and secondary data source.

3.2.2.1 Primary data source

Primary data were obtained from result of laboratory analysis of fish, water and sediment samples and also from the use of questionnaire to elicit information from residents of the study area. Questionnaire for the residents was divided into two sections. Section A consistsof questions designed to obtain demographic data of the respondents, while Section B

focuses on obtaining information on fish consumption pattern and level of awareness of chemical contamination of local and imported fish consumed in the study area.

3.2.2.2 Secondary data source

Secondary data were obtained from publications of NESREA, Journals, textbooks and other relevant materials. Data obtained were guideline values of heavy metals in fish, river water and sediment.

3.2.3 Sampling size and sampling technique

Jema'a local government area forms the spatial frame for this study. It has a population of 278,735 people (NPC, 2006). But with a population growth rate of 3%, the projected population for 2015 (using exponential growth rate formula) stands at 365,133. To determine the sample size of the respondents for this research, Krejcie and Morgan (1970) method of determining sample size was adopted. Since the projected population of the area stands at 365,133; therefore 384 was adopted as the sample size as presented in Table 3.1.

The local government area has twelve (12) wards however, only eight (8) were used as the sampling frame using purposive sampling technique. The selected wards are Kafanchan A, Kafanchan B, Godogodo, Gidan Waya, Asso, Bedde, Kagoma, and Jagindi. These represents major fishing areas as well as major settlements with high fish consumption pattern. Respondents were picked from homes, schools, offices, shops and farms. In each category, respondents were picked randomly, so that each member of each category is given an equal chance of being represented. Homes were selected because fish purchase, preparation and consumption is majorly carried out by households in the home. Schools were also selected on the basis that the research also sought to cover the literate segment of the study area, to ascertain their awareness as they also form the fish consuming population.

Table 3.1 Projected ward population of Jema'a Local Government Area (2015).

Wards	Projected ward population (2015)	Selected wards	Sample size
Asso	36,338	Asso	53
Atuku	23,034	Bedde	55
Bedde	37,819	Gidan - Waya	44
Gidan – Waya	30,436	Jagindi	48
Godogodo	33,382	Kafanchan A	46
Jagindi	33,386	Kafanchan B	46
Kafanchan A	31,907	Kaninkon	53
Kafanchan B	31,904	Kagoma	39
Kagoma	27,470	-	-
Kaninkon	36,344	-	-
Maigizo	21,554	-	-
Takau	21,559	-	-
Total	**365,133**	**8 wards**	**384**

$$\text{Sample size} = \frac{n}{N} \times 384 \qquad 3.1$$

where n = Sample ward population, N = Total ward population.

Offices, shops and farms were important to cover, to reach out to those absent from home for their occupations during the time of sampling, which involved office work, business and farming. Four research assistants were used in the administration of the questionnaires within the period January – March, 2016. For chemical assay in fish, the USEPA (2000) sampling protocol of minimum of 3 samples per fish specie was adopted. Following this sampling

protocol, 21 fish samples (consisting of 3 samples per specie in each location) comprising the most consumed fish in the area – were sampled.

3.2.3.1 Sample collection, identification and preparation

For fish, a total of twenty - one (21) samples were collected and properly labelled, comprising of three (triplicate) fish samples for each species according to US EPA (2000) fish sampling protocol. A total of six fish species were sampled, on the basis of most consumed fish species available at the time of study. Three local fish species (*n = 12*) were sourced from fishermen who are heavily involved in catching wild fish directly from sampling stations (Kafanchan and Godogodo areas of Wonderful and Magami River respectively). Three imported fish species (*n = 9*) were also sourced from market at retail centres in Kafanchan. Origin of imported fish was gotten from the information inscription on fish carton given as *Ethmalosa fimbritus* (Ireland), *Alosa fallax* (Holland) and *Clupea harengus* (Netherland). The retail outlets get imported frozen fish directly from cold storage facilities (called cold room) located within Kafanchan. Fish samples were placed in freezing bags below 4°C and transported in ice from the study area.

Fish samples were taken to Department of Biological Sciences for identification according to standard requirements. This was done in January 2016. Fish foreign species were identified as *Ethmalosa fimbritus* (shawa), *Alosa fallax* (mackerel), and *Clupea harengus* (sardine) and local varieties were noted as *Barbus occidentalis* (Dorawa), *Clarias gariepinus* (Tarwada) and *Tilapia oreos* (Parpasa) according to Olaosebikan and Raji (2013). The chemical assay focused on the heavy metals in the fish for Mercury (Hg), Cadmium (Cd), Lead (Pb), Zinc (Zn) and Iron (Fe). These are metals whose monitoring in fish has been designated as obligatory by World Health Organization (1997) cited in Staniškienė, B., Matusevičius, P. and Urbonavičius (2009).

Fish samples were prepared for analysis by cleaning them with de-ionized water, to free them of mechanical additives. Fish inner organs were removed and the flesh was separated from the spinal column and ribs, and dried in an oven at 250°C for 2 hours each day for 2 days. Dried fish samples were crushed into fine powder by porcelain mortar and pestle and stored in amber coloured bottles in vacuum desicators. Analysis for heavy metals was then carried out using Atomic Absorbtion Spectrometer Varian Model, by staff of mulit-user laboratory, Faculty of Science, A. B. U. Zaria.

For river water, six water samples were collected from Magami and Wonderful Rivers (*n = 6*), and analyzed for heavy metals. Both Magami and Wonderful Rivers were sampled purposively among other rivers in the study area because, anthropogenic activites such as waste (hospital and domestic) and heavy farming activities occured more along banks of Wonderful and Magami Rivers respectively.

To ensure quality control, clean bottles were used to collect water samples. Water samples were carefully collected by wading into the river to avoid stirring up of the river water. Sample bottles were lowered carefully and tilted at angle thirty degree (30°) to receive undisturbed flowing water. Touching of the lip of sample bottle and cap were avoided as much as possible. Each sample was collected at interval of 10m (Shelton and Capel, 2015) from each sample location. Water samples were collected in clean bottles. Samples were treated with nitric acid and prepared in the laboratory.

100ml of each of representative water samples were transferred into pyrex beakers containing 10ml of concentrated HNO_3. The samples were boiled slowly and evaporated on a hot plate to about 20 ml. The beakers were allowed to cool and another 5 ml of concentrated nitric acid was added. Heating was continued with addition of nitric acid as required until digestion was

complete. The samples were evaporated again to dryness (not baked) and the beakers were cooled, which was followed by addition of 5 ml of HCl solution (1:1 v/v). The solutions were warmed and 5 ml of 5M NaoH was added and then filtered. The filtrates were transferred to 100ml volumetric flasks and diluted to the mark with distilled water. The solutions were then used for elemental analysis using Atomic Absorption Spectrometer (Varian Model). Elemental analysis was carried out by staff of multi-user laboratory Faculty of Science, A.B.U. Zaria.

For sediment, six sediment samples were collected from the fishing rivers –Magami and Wonderful River ($n = 6$) and analyzed for heavy metals. Surface sediments (2 – 20cm) were collected. The fisher men in the area who engaged in harvesting wild caught fish helped in getting the river sediment as instructed. Samples were immediately placed in clean polythene bags and transported to the laboratory. Taken from -4°c temperature, samples were dried at 105°C during 24h, grinded using an agate mortar, sieved through a stainless steel mesh in order to obtain fine particle-size fractions and stored in polyethylene bottles until sequential extraction analysis.

In the sequential extractions, 1g of sediment was mechanically shaken for 16h with 40 ml 0.11 mol/L acetic acid and the extract separated by centrifugation. The residual fraction was twice heated by IR lamp with 5 ml HF 48% in a Teflon Petri dish until dryness. This procedure was repeated twice with 5 mL HNO_3 65% and the residue was lixiviated with 20 ml of 3.86 mol/L HCl by heating and magnetic agitation during 1h. The extracts collected in sequential extraction steps and in the total acid digestions were made up to 50ml, and stored at −4°C in acid washed polyethylene bottle until were analysed by AAS. Blank samples were prepared and taken account. The quality of total acid digestion of the sediment was checked by using a certified reference material.

Sediment samples were analyzed in the laboratory for mercury, cadmium, lead, iron and zinc. Laboratory analysis was carried out by staff of multi-user laboratory, faculty of science, A.B.U. Zaria. All chemical analysis for fish, water and sediment was carried out using flame atomic absorption spectrometer.

3.2.4 Risk assessment

3.2.4.1 Target hazard quotient

This was used to assess risk involved with consuming fish. It expresses the ratio between exposure dose and oral reference dose. Values greater than 1 shows that risk is significant while values less than 1 shows non-significant risk, and is given as:

$$THQ = \frac{EF \times ED \times FIR \times C}{RfD \times WAB \times TA} \times 10^{-3} \qquad 3.2$$

Where THQ is target hazard quotient, EF is the exposure frequency 365 d/yr, ED is exposure duration equivalent to average life expectancy 54.5 years, FIR is food ingestion rate which in this study is 198.4 g according to field survey, C is metal concentration in mg/kg, RfD is oral reference dose taken from US EPA table developed for ingestion as estimates of daily exposures to a substance that is likely to be without a discernable risk of deleterious effects to the general population during a life time of exposure, WAB is average body weight for adult given as 60kg in this study, while TA is exposure time given as EF x ED (i.e. 365d/yr x 54.5 years).

3.2.4.2 Total target hazard quotient

Total Target Hazard Quotient was employed because humans are often exposed to more than one pollutant and suffer combined or interactive effects. This is given as;

$$TTHQ = HQ\,(Hg) + HQ\,(Zn) + HQ\,(Cd) + HQ\,(Fe) + HQ\,(Pb) \qquad 3.3$$

where TTHQ = Total Target Hazard Quotient, HQ (Zn) = Target Hazard Quotient of Zinc, HQ (Cd) = Target Hazard Quotient of Cadmium, and HQ (Fe) = Target Hazard Quotient of Iron, HQ (Pb) Target Hazard Quotient of Lead. A scale of risk analysis presented in Table 3.2 shows that risk ranges between no hazard to greater hazard.

Table 3.2. Scale for Risk Analysis of Total Target Hazard Quotient (TTHQ)

Scale	Evaluation
0.0 – 1	No Hazard
1.1 – 10	Moderate Hazard
>10	Greater Hazard

Source: US EPA, 2011

Although the THQ-based risk assessment method does not provide a quantitative estimate of the probability of an exposed population experiencing an adverse health effect, it does provide an indication of the risk level associated with pollutant exposure. This method of risk estimation has recently been used by researchers (Chien et al., 2002; Wang et al., 2005) and has been shown to be valid and useful.

3.2.5 Pollution of metals in sediment

The geoaccumulation index (i-geo), which is defined as enrichment of metal concentration above baseline concentrations in aquatic sediment was calculated using the method proposed by Muller (1969), to assess the pollution of metals in river sediment. Igeo assess the degree of metal pollution in terms of seven enrichment classes based on the increasing numerical value of the index, and is given as:

$$\text{igeo} = \log_2 \frac{\text{Cm}}{1.5(\text{Bn})} \qquad 3.4$$

where Cm = Measured concentration of heavy metals in rivers sediment, Bn = Geochemical background value in average shale of element n, as derived from world average by Turekian and Wedopohl (1961), 1.5 = Correction factor to take care of possible variations in background values for a given environment that may be attributed to lithologic variations in the sediment.

Seven grades ranging from uncontaminated to extremely contaminated was used and presented in Table 3.3.

Table 3.3 Geoaccumulation Index for Sediment Quality

Igeo value	Igeo class	Designation of sediment quality
i-geo ≤ 0	Grade 0	Uncontaminated
$0 <$ i-geo ≤ 1	Grade 1	Slightly contaminated
$1 <$ i-geo ≤ 2	Grade 2	Moderately contaminated
$2 <$ i-geo ≤ 3	Grade 3	Moderately severely contaminated
$3 <$ i-geo ≤ 4	Grade 4	Severely contaminated
$4 <$ i-geo ≤ 5	Grade 5	Severely extremely contaminated
i-geo > 5	Grade 6	Extremely contaminated

Source: Muller, 1969

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of the respondents show the age, gender as well as tribe of respondents. In terms of age, most respondents were between 20 – 50 years. However, average age of respondents calculated was 31 years as shown in Table 4.1

Table 4.1. Socio-demographic characteristics

Age (years)	**Frequency of Respondents (*n = 384*)**	**Percentage of Respondents (*100*)**
20 and below	83	21.6
21 – 30	150	39.1
31 – 40	79	20.6
41 – 50	45	11.7
51 – 60	20	5.2
61 and above	7	1.8
Sex		
Male	193	50.3
Female	191	49.7
Tribe		
Gong	131	34.1
Ninkyob	46	12.0
Nyenkpa	23	6.0
Jaba	38	6.9
Atyab	28	7.3
Bajju	27	7.0
Other Indigenous tribes	27	7.0
Non – Indigenous tribes	64	16.7

Source: Field work, 2016.

In awareness studies, more awareness is associated with increasing age levels 25 - 39 years and highest in groups over 40 higher than lower age groups (Amirad, Zakaria and Hadi,

2011; Wiernik, Ones and Dilchert, 2013). The tribal characteristics reveals an aspect of the socio-demographic characteristics of respondents. Respondents were drawn from tribes in the wards as presented in Table 4.1 Major tribes represented in this study are Gong (34.1%), Ninkyob (12%), Nyenkpa (9.9%). These tribes are indigenous in the study area. Other tribes surveyed include Gwandara, Mada, Ninzo and Fantswam. Each of these tribes are known for agricultural practices involving the use of chemical fertilizers and manure activities (Marcus, 2012), capable of heavy metal release in the environment (Basta et al, 2005).

4.2 Educational Characteristics of Respondents

In general, the educational profile of the study population reveals that educational qualification is not uniform but occurs at varying level as shown in the Table 4.2. A meagre 5.7% of the study population acquired only primary school education, 28.6% attained only secondary education, while a larger proportion constituting 64.9% indicated tertiary levels of education. In this study, all tertiary institutions were grouped together. Most respondents engage in knowledge based activity which implies that majority of the study population are literate.

Table 4.2 Educational characteristics of respondents

Qualification	Frequency of Respondents (n = 384)	Percentage of Respondents (n = 100)
Doctor of Philosophy (Ph.D)	7	1.8
Masters Degree	9	2.3
Bachelors Degree	39	10.2
Higher National Diploma (HND)	29	7.6
Nig. Cert. in Educ. (NCE)	119	31
National Diploma (ND)	46	12
Senior Sch Cert Exam. (SSCE)	110	28.6
Primary School Certificate	22	5.7
None	3	0.8

Source: Field work, 2016.

4.3 Economic Characteristics of Respondents

The study revealed that most respondents in the study area where civil servants (29.4%) as presented in Table 4.3. Others were farmers, business persons involved in one trade or the other. With majority of respondents earning an annual income ranging between N100,000 – N200, 000 (44% and 19.3% respectively), average annual income for the study population stood at N150,278.80 which indicates that the study population can afford a minimal one serving of fish at least once a week, at the time of this study.

Table 4.3 Economic Characteristics of Respondents

Occupation	Frequency of Respondents (n = 384)	Percentage of Respondents (n = 100)
Trader	14	3.6
Civil servant	113	29.4
Farmer	61	15.9
Business person	57	14.8
Unemployed	39	10.2
Student	98	25.5
Retiree	2	0.5
Annual Income (N)		
100,000 and below	169	44
101,000 – 200,000	74	19.3
201,000 – 300,000	32	8.3
301,000 – 400,000	29	7.5
401,000 – 500,000	21	5.5
> 500,000	20	5.2
Without Income	39	10.2

Source: Field work, 2016.

4.4 Fish consumption Information of Respondents

Information on fish consumption by respondents is presented in Table 4.4 (a) covering areas such as fish source, reasons for fish consumptions and fish type consumed. A close

examination of these shows that majority of preferences exist for imported fish notably *E. fimbritus* (36.7%), *A. fallax* (24.7%), and *C. harengus* (24.2%). This can be due to the cheapness and other beneficial nutrients such as Omega 3 – Polyunsaturated Fatty Acid available for imported varieties which promotes good health. Even though local fish are caught, the study shows that preferences least occurs for the local fish caught with *C. gariepinus* (16.1%) being an exception.

Table 4.4a Fish Consumption

Fish Source	**Frequency of Respondents (*n = 384*)**	**Percentage (100%)**
Cold room	75	19.5
Market	251	65.4
Fishermen	58	15.1
Reasons for Fish Consumption		
Cheap	171	44.5
Taste	50	13.0
Healthy	163	42.4
Fish Type Consumed		
Ethmalosa fimbritus *(Shawa)*	158	24.6
Alosa fallax *(Mackerel)*	124	19.3
Clupea harengus *(Sardine)*	93	27.8
Tilapia oreos *(Parpasa)*	19	6.9
Clarias gariepinus *(Tarwada)*	27	16.1
Bagrus bajad *(Shululuwa)*	9	5.3

Source: Field Work, 2016 *n* = Total number.

Further more, Table 4.4(b) shows fish consumption pattern covering areas such as most consumed fish specie, rate of fish consumption, and fish servings consumed. Among the types of fish most consumed, imported frozen fish are consumed more than local fish, in the order *E. fimbritus* > *A. fallax* > *C. harengus* > *T. oreos* > *C. gariepinus* > *B.bajad* given as 36.7%, 24.7%, 24.2%, 7.0%, 5.0% and 2.3% respectively, of which the last three are local

species. On the rate of fish consumption, respondents consume fish once a week, twice a week, thrice a week, four times a week, five and six times a week respectively, and as much as seven times a week, 21.1%, 13.5%, 19.0%, 15.4%, 9.4%, 7.0% respectively. 0.3%, of respondents consume fish once in two weeks as 4.9% of respondents do not have any specific time of consuming fish but consume fish any time.

Table 4.4b Fish Consumption Pattern

Most consumed Fish Specie		**Frequency of Respondents (*n = 384*)**	**Percentage (100%)**
Ethmalosa fimbritus *(Shawa)*		141	36.7
Alosa fallax *(Mackerel)*		95	24.7
Clupea harengus *(Sardine)*		93	24.2
Tilapia oreos *(Parpasa)*		19	5.0
Clarias gariepinus *(Tarwada)*		27	7.0
Bagrus bajad *(Shululuwa)*		9	2.3
Rate of Fish Consumption (Weekly)			
Once		52	13.5
Two times		81	21.1
Three times		73	19.0
Four times		59	15.4
Five times		36	9.4
Six times		36	9.4
Seven times		27	7.0
Once in Two weeks		1	0.3
Anytime (undefined)		19	4.9
Fish Servings Weekly	**Grams**	**Frequency (n = 384)**	**Percentage (100)**
One	99.2	101	26.3
Two	198.4	132	34.3
Three	297.6	104	27.1
Four	396.8	45	11.7
Five	496.0	-	-
Six	595.2	1	0.3
Seven	694.4	1	0.3

Source: Field work, 2016

The study found that highest fish consumption occurs twice in a week (21.1%) among residents, with a consumption of two fish servings weekly. A value range of one to four servings of fish (99.2g – 396.8g) forms the largest proportion of fish serving consumed. However, average servings of fish consumed stands at 222.1g, equivalent to 2.3 servings. This shows that respondents are a fish consuming population. On the basis of this, there is higher tendency of human health risk issues due to exposures.

4.5 Awareness of Heavy Metal Contamination in Fish

Table 4.5 shows the general awareness of risk in fish. Respondents were asked to indicate their opinions on the presence of harmful chemicals in the fish they get and eat. Their responses indicated their various level of awareness on risk in fish ranging from strongly agree to strongly disagree.

Table 4.5 Awareness of Heavy Metals Contamination in Fish

Fish contain contaminants	Frequency	Percentage
SA	84	21.8
A	106	27.6
U	29	7.6
D	109	28.4
SD	56	14.6
Total	384	100

Source: Field work, 2016

From the survey, it is gathered that a combined 49.4% have a general awareness of chemical risk via contaminants present in fish consumed while a combined 43% indicated not having any form of awareness on chemical risk via presence of contaminants in fish. Another 7.6% undecided meaning that they could not affirm a certain pollution effect. This shows that there is some form of general awareness of risk among a sizeable portion of the study population. This is not surprising due to the fact that higher educational qualification 64.9 % is recorded.

Knowledge which is a function of education has been identified as a key factor in influencing perception and attitudes, and is a basic component towards health awareness and risk related phenomenon (Ratnapradipa, Brown, Middleton and Wodika, 2011).

4.6 Awareness of Symptom Specific Risk in Fish Consumed by Study Population

Table 4.6 shows awareness level with respect to specific symptoms that could arise as a result of contaminated fish consumption in the study area. A comparative assessment indicated that more awareness occurred for only few cases, which are for the symptoms severe vomiting and diarrhea (64.3%), as well as high blood pressure, miscarriage and memory loss (42.7%). This means that for these symptoms assessed, most respondents were aware that consumption of chemical contaminated fish yield the above symptoms in humans.

However, most respondents disagreed that symptoms notably brain effects (62%), reduced cognitive function (45%), male infertility (53.7%), deafness and blindness (50.3%), as well as chronic fatique and headache (42.2%) could arise from consuming contaminated fish. Even though the study population were literate, possible explanation for this knowledge deficiency can be attributed to the fact that information of this nature has not been disseminated to them evident by 51.6% who have not had any form of fish advisory in Table 4.7, hence the knowledge deficiency evident.

4.7 Fish Advisory to Study Population

Fish advisory involves information on safety of fish and water body where they are harvested. Such information include species of fish to avoid due to chemical contamination, specific water bodies where they are caught, as well as the categories of consumers to be at higher risk. Responses on fish advisory presented in Table 4.7 shows that only 48.4% of respondents agreed to receiving fish advisories.

Table 4.6 Awareness of symptom specific risk in fish

Frequency (*n = 384*) and Percentages (100)

Effect - Heavy Metal	SA	A	U	D	SD
Brain effects	21(5.4)	59 (15.4)	66 (17.2)	167 (43.5)	71 (18.5)
Reduced cognitive function	59(15.4)	104(27.1)	46 (11.9)	126 (32.8)	49 (12.8)
Severe vomiting and diarrhea	93(24.2)	154(40.1)	34 (8.9)	68 (17.7)	35 (9.1)
Infertility in men	32(8.3)	79 (20.8)	67 (17.4)	147 (38.3)	59 (15.4)
Deafness and blindness	38(9.8)	72 (18.8)	81 (21.1)	145 (37.8)	48 (12.5)
Chronic fatique and headache	34(8.8)	112(29.2)	73 (19.0)	122 (31.8)	43 (11.2)
High BP, miscarriage and memory loss	66(17.2)	98 (25.5)	58 (15.1)	106 (27.6)	56 (14.6)

Source: Field work, 2016. Note: Figures in bracket represent percentages

Based on this response, the study found that fish advisory was disseminated among those who receive it in the order Environmental Health Officers > Television > Fish sellers > Radio > Newspaper > Friends > Internet. Interestingly, in an age of globalization, the internet as a source had the least response and thus underutilized. This could have been an inexpensive and effective tool for information dissemination considering the fact that more people get connected to the internet in increasing numbers, and advance internet technology is being rolled out with greater improvements to gain personal access to individuals.

This study have shown that while various efforts have made some level of public awareness creation on the possibility of risks in fish consumed in the area, it has not been effective in reaching out to a wider population. Only a lesser proportion have been covered, leaving a larger proportion of the study population largely unaware.

Table 4.7 Fish Advisory

Reception of Fish Advisory	Frequency of Respondents (*n = 384*)	Percentage (100)
Yes	186	48.4
No	198	51.6
Source	**(*n = 186*)**	
TV	36	19.4
Radio	28	15.1
Newspaper	26	13.9
Fish sellers	35	18.8
Friends	17	9.1
Env. Health Officers	40	21.5
Internet	4	2.2

Source: Field Work, 2016.

4.8 Average Concentration of Mercury in Fish Samples

Mercury is one of chemical elements that is without any biological usefulness to humans but rather toxic when ingested hence its non-essential. Among the samples analyzed, mercury occur in fish samples in the order *E. fimbritus > B. occidentalis > T. oreos > C. gariepinus (RM) > A. fallax > C. harengus > C. gariepinus (RW).* Highest concentration of mercury was observed with 2.055mg/kg in *E. fimbritus*. Unfortunately, it is the fish with the highest consumption among residents in Table 4.8 All fish samples also contained mercury at high concentrations. This further means that higher risk of mercury effects occurs through *E. fimbritus* than other fish species when compared with standard permissible values. Concentration of heavy metals in all fish samples was compared with 0.1 mg/kg NAFDAC guideline value for heavy metals in food and 0.5 mg/kg WHO/FAO guideline values as well. All fish samples (local and imported) had concentrations of mercury greater than permissible limits of both NAFDAC and WHO/FAO.

Table 4.8 Average mercury concentration in fish samples

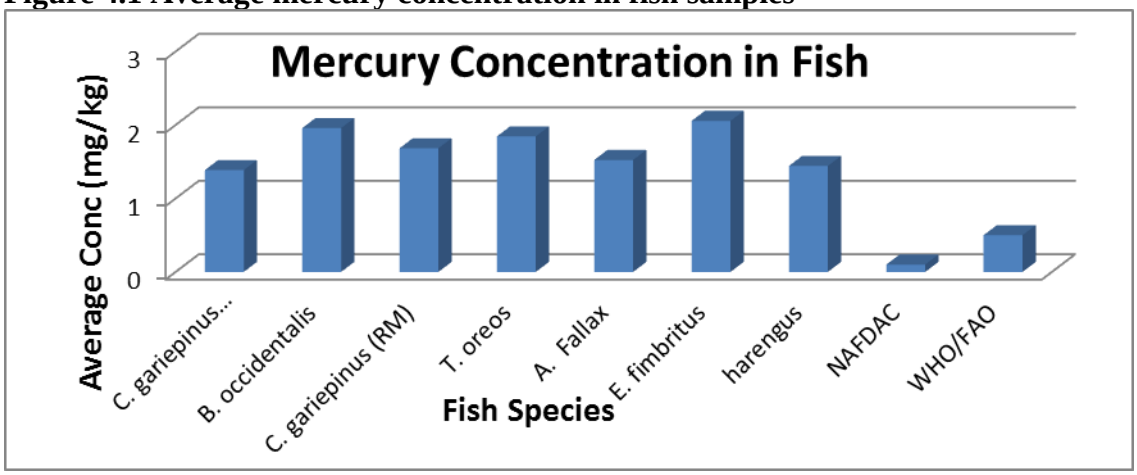
Fish specie	Mercury Concentration (mg/kg)	Nafdac std (mg/kg)	WHO/FAO std (mg/kg)
C. gariepinus (RW)	1.386	0.1	0.5
B. occidentalis	1.957	0.1	0.5
C. gariepinus (RM)	1.683	0.1	0.5
T. oreos	1.844	0.1	0.5
A. fallax	1.524	0.1	0.5
E. fimbritus	2.055	0.1	0.5
C. harengus	1.442	0.1	0.5

Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

This implies that clinical symptoms such as abdominal pain, indigestion, inflammatory bowel disease, ulcers and bloody diarrhoea among others are imminent particularly among regular consumers, with nursing mothers and children at greater risk. In fish 80% of total mercury exists as methylmercury which is the most dangerous and toxic form of mercury. With the results provided, it can be deduced that there is higher methylmercury along with it toxic capabilities in human consumers. None of the fish samples is free from methylmercury contamination and thus not fit for consumption.

The result of the study corroborates those of Freire et al (2010) who reported high mercury in fish and associated it with decrements in general cognitive scores, as well as cognitive development delay of spanish children in mediterranean region, Yokoo et al (2003) who observed that mercury exposure with values ranging from 0.56 to 13.6 mg/kg in fish consumed was responsible for detectable alterations in performance on test of fine motor speed, dexterity and concentration, as well as disruption of memory and verbal learning, and deficits in neurocognitive function, while Boalt, Dahlgren and Aroha (2012) has been able to show that metal concentrations in fish muscle of *Clupea harengus* shows a significant and positive relationship with whole fish concentrations.

Figure 4.1 Average mercury concentration in fish samples



Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

4.9 Average Zinc Concentration in Fish Samples

Zinc is one of chemical elements that is with known biological importance, hence it is regarded as essential although only when present within certain threshold. It is found in cells through out the body, and needed for the body's defence (immune system) to properly work. It plays a role in cell division, cell growth, wound healing and breakdown of carbohydrates. Zinc is also needed for the senses of smell and taste as well as growth during pregnancy, infancy and childhood (Evert, 2013). Table 4.9 shows average zinc concentration in local wild caught and imported frozen fish species. In fish samples, zinc occurred in the order *A. fallax* > *E. fimbritus* > *B. occidentalis* > *C. gariepinus (RW)* > *T. oreos* > *C. harengus* > *C. gariepinus (RM).*

Interestingly, among all fish samples assessed, zinc concentration occurred at levels below NAFDAC and WHO/FAO permissible values. This implies that clinical symptoms of zinc are not indicative according to these standards. At the concentrations recorded, zinc can only play beneficial role than toxic roles. Highest concentrations was observed in *A. fallax* (26.8mg/kg) and *E. fimbritus* (23.967mg/kg) and could still be considered for consumption. Zinc concentration in *C. gariepinus* (wonderful river) and *B. occidentalis* – 19.567mg/kg and 19.767mg/kg respectively are closer alternatives where imported fish are not available.

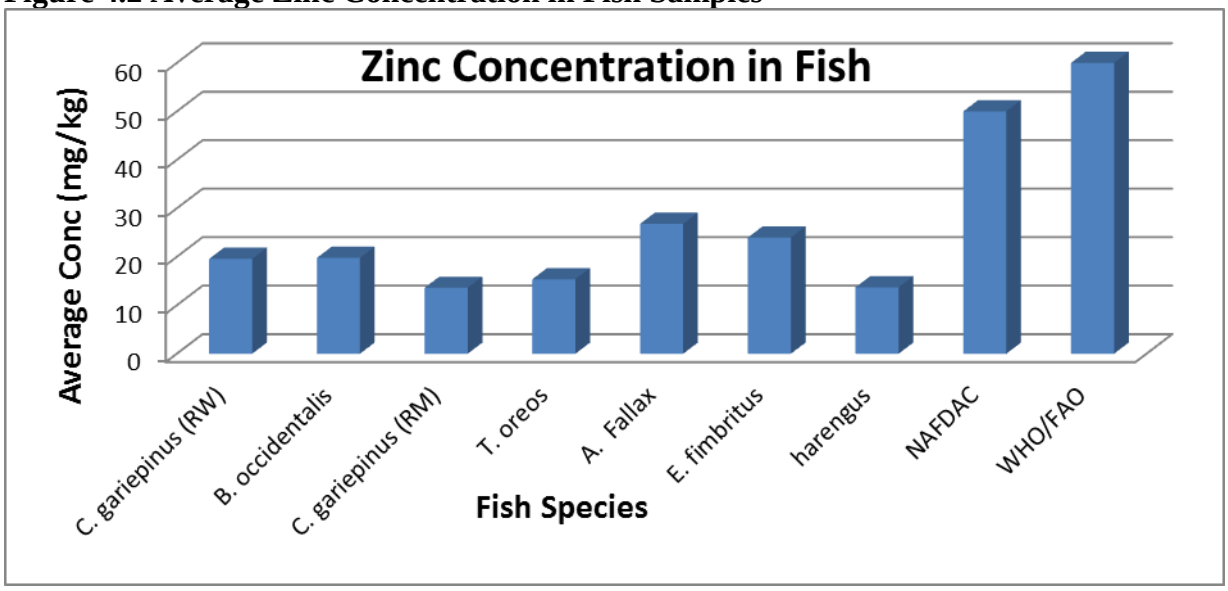
Table 4.9 Average zinc concentration in fish samples

Fish specie	Zinc Concentration (mg/kg)	Nafdac std (mg/kg)	WHO/FAO std (mg/kg)
C. gariepinus (RW)	19.567	50	60
B. occidentalis	19.767	50	60
C. gariepinus (RM)	13.600	50	60
T. oreos	15.367	50	60
A. fallax	26.800	50	60
E. fimbritus	23.967	50	60
C. harengus	13.700	50	60

Source: Field work, 2016. RW= Wonderful River, RM= Magami River

Results of this study corroborates those of Saei-Dehkordi and Fallah (2011), who reported zinc concentration (13.528mg/kg) in commercially valuable fish species from persion gulf, lower than permissible values established by WHO/FAO.

Figure 4.2 Average Zinc Concentration in Fish Samples



Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

4.10 Average Lead Concentration of Fish Samples

Similar to mercury, lead is one of chemical elements that is without biological relevance but rather toxic when present in human body, hence it is non-essential. Table 4.10 shows average

lead content in fish samples. Lead occur in fish samples in the order *C. harengus* > *E. fimbritus* > *B. occidentalis* > *T. oreos* >*C. gariepinus (RM)* > *A. fallax* > *C. gariepinus (RW).* With the exception of *C. gariepinus (RW)* – 0.78mg/kg and *A. fallax* – 0.967mg/kg, all imported and local species had values of lead concentration above 1mg/kg. All fish samples had lead concentrations greater than WHO/FAO permissible limits. However, only *C. harengus, E. fimbritus, B. occidentalis, T. oreos and C. gariepinus (RM)* were higher than NAFDAC permissible limit. Going by WHO/FAO and NAFDAC permissible limits of 0.4mg/kg and 1mg/kg respectively, clinical symptoms of lead contamination are indicative, notably decline in neurocognitive deficits, reproductive effects such as decreased sperm count and spontaneous abortions, brain damage, renal dysfunction, gastrointestinal diseases among others (Mason et al, 2014; Saxena et al, 2007).

Table 4.10 Average lead concentration of fish samples

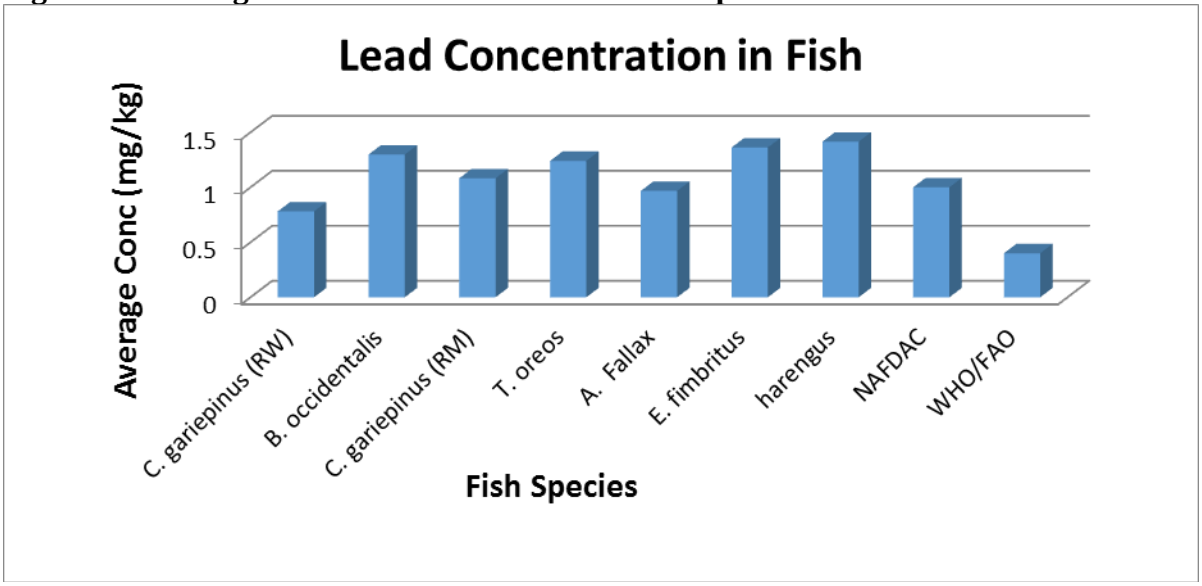
Fish specie	Lead concentration (mg/kg)	Nafdac std (mg/kg)	WHO/FAO std (mg/kg)
C. gariepinus (RW)	0.781	1	0.4
B. occidentalis	1.298	1	0.4
C. gariepinus (RM)	1.082	1	0.4
T. oreos	1.240	1	0.4
A. fallax	0.967	1	0.4
E. fimbritus	1.362	1	0.4
C. harengus	1.415	1	0.4

Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

4.11 Average Cadmium Concentration of Fish Samples

Cadmium concentration has been shown to occur in both imported and local species of fish samples Table 4.11 Cadmium occur in fish samples in the order *B.occidentalis*> *C.gariepinus (RW)*>*C.gariepinus(RM) and T.oreos* > *E.fimbritus and C.harengus* > *A.fallax.* Cadmium in fish has no benefit to humans when consumed, rather, it impacts human health negatively.

Figure 4.4 Average Lead Concentration of Fish Samples



Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

In addition to health issues that emanate, it has been further designated as a human carcinogen. A dangerous charateristic of cadmium is that it accumulates through out a life time (Omer, Elobeid, Fouad and Daghestani, 2012).

Cadmium concentration is observed to be higher in local wild caught fish samples than imported frozen fish samples. Comparison of cadmium concentration in all fish samples with 0.1 mg/kg NAFDAC guideline value for heavy metals in food and 0.1 mg/kg WHO/FAO permissive limits revealed that all fish samples (local and imported) had cadmium at concentrations greater than the permissible limits of NAFDAC and WHO/FAO. This means that health risks are indicative upon exposure.

Even though health risk of cadmium toxicity exists among all fish samples, higher risk of cadmium effects occurs more in all local fish, and clinical symptoms such as kidney injury, burning sensation, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness, and convulsions may be imminent among others.

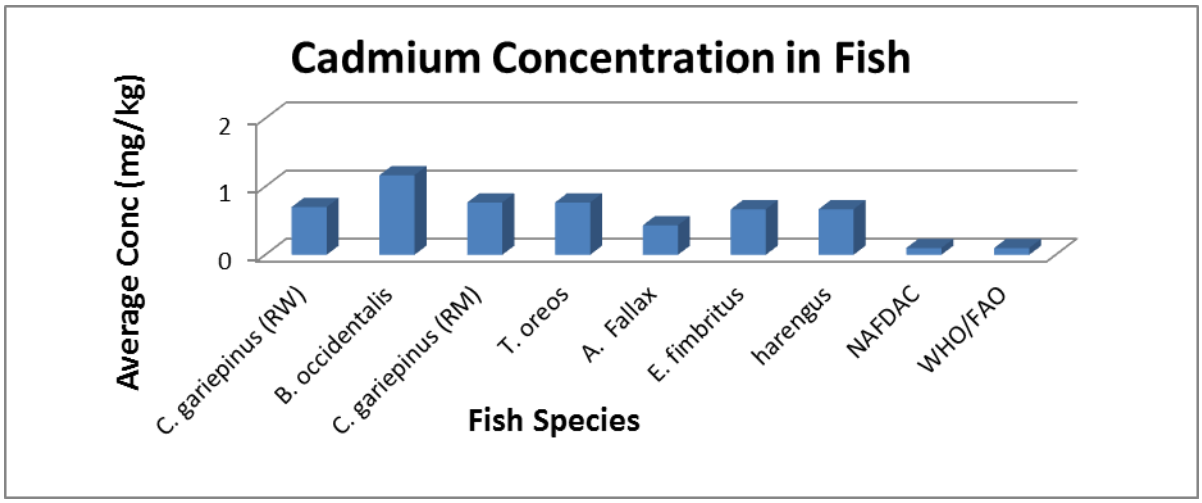
Table 4.11 Average Cadmium Concentration of Fish Samples

Fish specie	Cadmium concentration (mg/kg)	Nafdac std (mg/kg)	WHO/FAO std (mg/kg)
C. gariepinus (RW)	0.700	0.1	0.1
B. occidentalis (RW)	1.167	0.1	0.1
C. gariepinus (RM)	0.767	0.1	0.1
T. oreos (RM)	0.767	0.1	0.1
A. fallax (H)	0.433	0.1	0.1
E. fimbritus (I)	0.667	0.1	0.1
C. harengus (N)	0.667	0.1	0.1

Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

Since cadmium is a known human carcinogen, this levels of ingestion and exposures is likely to lead to development of cancers of the prostate, kidney, liver, hematopoietic system (The bodily system of organs and tissues, primarily the bone marrow, spleen, tonsils, and lymph nodes, involved in the production of blood) and stomach, depending on magnitude of exposure.

Figure 4.4 Average cadmium concentration of fish samples



Source: Field work, 2016. RW= Wonderful River, RM= Magami River.

4.12 Average Iron Concentration of Fish Samples

Table 4.12 shows average iron concentration in both wild caught and imported fish species. Among the local species, *Clarias gariepinus* caught from Wonderful River had an average

concentration of 56.533 mg/kg higher than same specie in Magami River, *Barbus occidentalis* had an average cadmium concentration of 30.966 mg/kg. Among the two species from the same location (Wonderful River), *Clarias gariepinus* showed higher iron concentration than *Barbus occidentalis*.

Table 4.12 Average Iron Concentration of Fish Samples

Fish specie	Cadmium concentration (mg/kg)	Nafdac std (mg/kg)	WHO/FAO std (mg/kg)
C. gariepinus (RW)	56.533	NA	0.8
B. occidentalis	30.966	NA	0.8
C. gariepinus (RM)	38.400	NA	0.8
T. oreos	17.866	NA	0.8
A. fallax	55.133	NA	0.8
E. fimbritus	48.5	NA	0.8
C. harengus	35.1	NA	0.8

Source: Field work 2016. RW= Wonderful River, RM= Magami River.

Clarias gariepinus caught from River Magami had an average iron concentration of 38.400 mg/kg, while *Tilapia oreos* had an average concentration of 17.866 mg/kg. A comparison of both species from the same location (river magami), shows that concentration of iron is higher in *C. gariepinus* and lower in *T. oreos*. Further comparison of local fish species from both locations (Rivers Wonderful and Magami), showed that highest and lowest values of iron concentration occur in *C. gariepinus* – River Wonderful and *T. oreos* – River Magami. A closer view of iron concentration in all local species shows that *C. gariepinus* in all locations had higher iron concentrations than other local species.

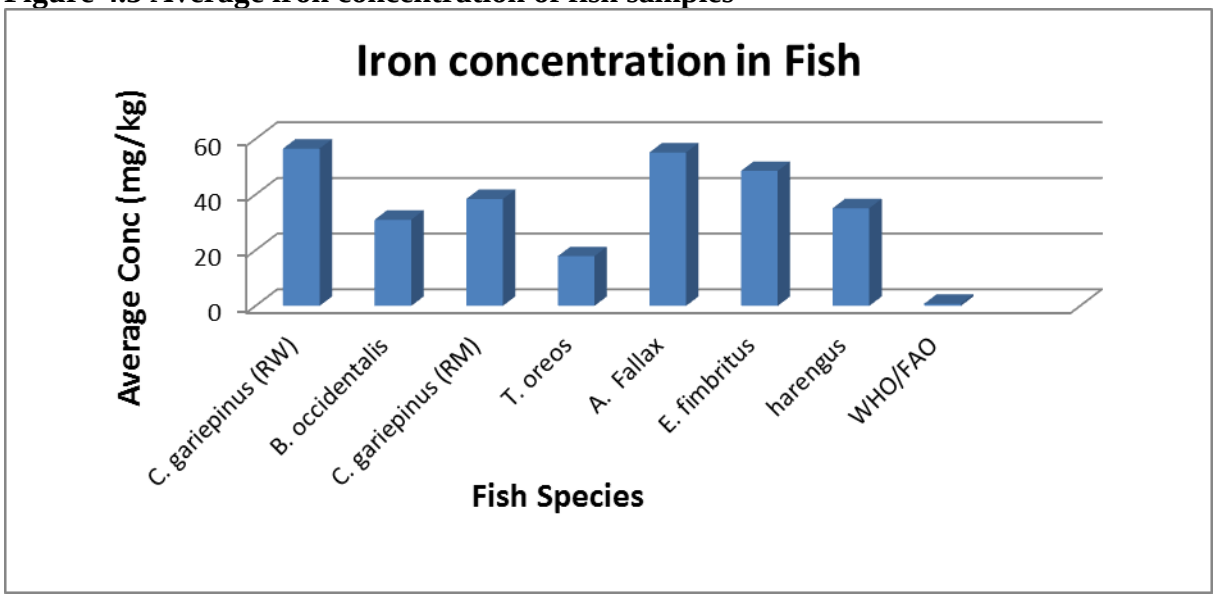
Among the imported species, Alosa fallax (mackerel) from Holland, had iron concentration of 55.133 mg/kg, *Ethmalosa fimbritus* (shawa) from Ireland had concentration of 48.5 mg/kg, while Clupea harengus (sardine) from Netherland had concentration of 35.1 mg/kg. Comparison of iron content among imported samples shows that highest concentration occurs

in *A. fallax* from Holland while least concentration occurs in *C. harengus* imported from Netherland.

Further comparison between local and imported fish samples shows that highest iron contamination occur in local fish (*C. gariepinus* – Wonderful River). Even though least concentration of iron in all fish samples is found in *T. oreos* –Magami River, values of iron in imported fish were lower than *C. gariepinus* – Wonderful River but higher than *T. oreos* – Magami River.

Concentration of iron in all fish samples was compared with 0.8 mg/kg WHO/FAO guideline values only, since NAFDAC guideline values for iron in food was not available. All fish samples (local and imported) had concentrations of iron greater than the permissible limits of WHO/FAO.

Figure 4.5 Average iron concentration of fish samples



Source: Field work 2016. RW= Wonderful River, RM= Magami River.

This means that there is likelihood of health consequences from consumption of all local and imported fish. Hence, clinical symptoms such as gastro intestinal bleeding, vomiting and diarrhea, shocks, hypotension, lethargy, tachycardia, hepatic necrosis, metabolic acidosis and gastrointestinal ulcerations among others are highly likely to occur. Chronic fatigue, joint

pain, impotence, osteoporosis and diabetes are symptoms for consideration in early diagnosis of excess iron in the body, should they occur.

The results concur with Atuanya, Nwogu, and Akor, (2012), who observed that concentration of heavy metals varies with variation in fish species. Likely contaminant sources in the river ecosystem for this study are agriculture, sewerage, municipal wastes, hospital wastes, vehicular emissions, dumpsites, mechanic workshops all within the river catchment, with storm water draining all contaminants into the rivers. Other studies within the Nigerian environment which corroborates this study in terms of metal contamination sources includes Opaluwa et al, (2012) who identified dumpsites as sources of iron, zinc, cadmium, contamination in *Clarias gariepinus* and *Synodontis schall* from Uke stream, Nasarawa State; Olele, Falodun and Wangboje (2013) who identified fumes from high vehicular traffic dense areas combined with mixed effluent sources as possible sources of zinc, lead, copper, cadmium and chromium contamination in *Clarias gariepinus* from Ekpoba river Benin-City, Edo State.

Worrisome is the fact that the law establishing regulations and compliance mechanisms for food and sea foods sold and consumed in the country has been observed according to Ladan (2008), to be slow, weak and inadequate. Officers of regulatory institutions have been alleged to be corrupt. Substitution and re-labeling of product occurs before they are imported from unsuitable aquatic environments (Ladan, 2008). All kinds of inferior and substandard foods (fish inclusive) are likely present in the consumer market many of which do not meet standards, some bear forged trade mark or even bearing no trade mark at all (Ladan, 2008).

4.13 Human Health Risk Assessment of Heavy Metals

For assessing the health risk associated with heavy metals contamination of local wild caught and imported frozen fish samples, target hazard quotients (THQ) and total target hazard quotients were estimated in this study as shown in Tables 4.13a and 4.13b, using the scale presented in Table 3.2. The acceptable guideline value for THQ is 1 (US EPA, 2011). In all fish samples in Table 4.13a, THQ value above 1 exists for cadmium (1.43 – 3.86), and lead in *B. occidentalis* (1.07), *T. oreos* (1.03), *E. fimbritus* (1.13), and *C. harengus* (1.17). This indicates that a daily exposure at this level is likely to cause adverse cadmium and lead effects during a persons life time. However, *C. gariepinus (RW)*, *C. gariepinus (RM)* and *A. fallax* are unlikely to cause lead based risk during a life time.

Table 4.13a. Target Hazard Quotient of Heavy Metals in Fish (excluding mercury)

Sample	Zn	Cd	Fe	Pb	TTHQ	Evaluation (TTHQ)
C. gariepinus (W)	0.23	*2.13	0.27	0.65	3.28	Moderate risk
B. occidentalis	0.23	*3.86	0.15	*1.07	5.31	Moderate risk
C. gariepinus (M)	0.15	*2.54	0.18	0.89	3.76	Moderate risk
T. oreos	0.17	*2.54	0.08	*1.03	3.82	Moderate risk
A.fallax	0.30	*1.43	0.26	0.80	2.79	Moderate risk
E. fimbitus	0.26	*2.21	0.16	*1.13	3.76	Moderate risk
C. harengus	0.15	*2.21	0.17	*1.17	3.70	Moderate risk

W = From Wonderful River, M = from Magami River. * means values that presents risk.

Humans are often exposed to more than one contaminant and thus combined interactive effects of heavy metals do occur (Li, Huang, Wang and Chung, 2013), which is determined by the arithmetic sum of all individual heavy metal effect called Total Target Harzard Quotient (TTHQ). The TTHQ values of the four metals (TTHQ = 2.79 – 5.31) for all fish samples implied that combined/interactive effects occurs as risk is at moderate level. Among all the heavy metals investigated, local wild caught *B. occidentalis* contaminated by Cd, and

Pb had relatively greatest potential TTHQ health risks and should be avoided as much as possible. Imported frozen *Alosa fallax* though contaminated with only cadmium has a relatively lower TTHQ health risk and may be considered if consumption must take place. Table 4.13b highlights total target hazard quotient with mercury inclusive. Mercury has an outrageous target hazard quotient value. As a result, mercury was excluded in Table 4.13a, to gain a perspective on the strength of interactive risk effects mercury poses with other heavy metals.

Table 4.13b. Target Hazard Quotient of Heavy Metals in Fish (including mercury).

Sample	Hg	Zn	Cd	Fe	Pb	TTHQ	Evaluation (TTHQ)
C. gariepinus (W)	9.17*	0.23	*2.13	0.27	0.65	12.45	Great risk
B. occidentalis	12.94*	0.23	*3.86	0.15	*1.07	18.25	Great risk
C. gariepinus (M)	11.13*	0.15	*2.54	0.18	0.89	14.89	Great risk
T. oreos	12.19*	0.17	*2.54	0.08	*1.03	16.01	Great risk
A.fallax	10.07*	0.30	*1.43	0.26	0.80	12.86	Great risk
E. fimbitus	13.59*	0.26	*2.21	0.16	*1.13	17.35	Great risk
C. harengus	9.54*	0.15	*2.21	0.17	*1.17	13.24	Great risk

W = From River Wonderful, M = from River Magami. * means values that presents risk.

All target hazard quotient values for mercury were above 1 which indicates that health risk associated with exposure is likely to occur. More importantly is the fact that the inclusion of mercury concentration with those of other heavy metals in determination of TTHQ shows that general risk involved in fish consumption increased with values soaring above 10, thus translating the risk level of combined heavy metals analysed in fish samples from moderate to great risk of the risk classes according to the scale in Table 3.2. Findings of this study agrees with previous studies such as those of Fu, Hu, Tao, Yu and Zang (2013) who reports risk of adverse health effects of Pb, Zn, and Fe, in fishes from Yangtze river and Taihu lake, as well as Yi, Yang and Zang (2011) who reports possible risk of TTHQ for the elements Cd, Hg, Zn, Pb, and As in fishes of middle and lower Yangtze river basin.

Regular consumption of fish high in mercury can accumulate in blood stream over time. Even though mercury is removed from the body naturally, it may take over a year for the levels to drop significantly upon cessation (UNEP, 2009) while 5 - 15% of ingested inorganic lead is absorbed. Once in the blood stream, lead is primarily distributed among blood, soft - tissue and mineralizing tissue. Lead distribution in the body initially depends on blood flow into various tissues and almost 95% of lead is deposited in the bone as insolube phosphate (Papanikolaou, Hatzidaki, Belivanis and Tzanakaki, 2005). since the non-essential metals (Hg, Cd, Pb) have been identified to constitute risk to human health in some fishes within a life time of exposure, it is safe to conclude therefore that effects derived from consuming fish in the study area outweighs the benefits.

4.14 Concentration of Metals in River Water Samples

Concentration of sample metals analysed reveals that heavy metals occur in river water at varying concentrations ranging 0.013 - 1.23mg/l presented in Table 4.14. In both Wonderful and Magami Rivers, heavy metals are found to occur in the order Hg > Fe > Pb > Zn > Cd. Mercury is identified as the metal with highest concentration. Possible source of mercury in river water could among others be river sediment (Table 4.15) which has been reported as a secondary source of metal contamination, where re-suspension of heavy metals absorbed, back into the water column occurs (Li et al, 2007).

Hospital wastes previously dumped into Wonderful River, as well as storm drainage run-off which drain municipal and solid wastes along with agrochemicals like pesticides from agriculture in both rivers catchment area are strong pointers to heavy metals contamination sources of both rivers. A comparison of heavy metal concentration in river water samples with NESREA guideline value for fishing waters reveal that all metals are high above

permissive values. Hence the water is not suitable for fish activities and domestic use such as drinking.

Table 4.14 Average concentration of heavy metals in water samples

Heavy Metals	RW (mg/l)	RM (mg/l)	Nesrea Std (mg/l)	Evaluation
Hg	1.231	1.116	0.001	High
Zn	0.067	0.069	0.01	High
Pb	0.371	0.459	0.01	High
Cd	0.013	0.014	0.005	High
Fe	0.415	0.688	0.05	High

Source: Field Work, 2016. RW = River Wonderful, RM = River Magami, Hg = Mercury, Zn = Zinc, Pb = Lead, Cd = Cadmium, Fe = Iron

These heavy metals which occur at high concentrations have constituted a threat to the aquatic life (such as fish) in the rivers ecosystem. Through biomagnification, they become bioavailable in the food chain ending up in human beings, and impacting their health negatively. Similary observations were raised by Lokhande, Singare and Pimple (2011) on water of Kasardi river where concentrations of Cd, Zn, Pb, Fe among other metals, occurred at concentrations higher than maximum permissible limits. Other research works which corroborates this findings includes Emoyan, Ogban and Akarah (2006), who attributed household wastes releases and urban effluents discharges along river course for cadmium contamination. Presence of iron in river water was attributed to run-off from metallic scraps dumpsites into river courses, which also supports earlier findings of Ndiokwere (2004). Other findings which agrees with this study also includes Abui, Yusuf, Shebi and Makarau (2014) especially in iron and lead contamination.

4.15 Concentration of Metals in River Sediment Samples

Concentrations of metal loadings in river sediment samples analyzed shows that heavy metals occur in river sediments at varying concentrations ranging from as little as 0.7mg/kg to a

whooping 28,517.8mg/kg, shown in Table 4.15. In Magami river sediments, heavy metals occur in the order Fe > Pb > Zn > Hg > Cd while in Wonderful river sediments, average heavy metals concentration occur in the order Fe > Pb > Hg > Zn > Cd. Slight variations in the order between both rivers sediments occur for zinc. In both rivers, iron occurs as the most abundant element.

Similar trend has been reported by Pandey and Singh (2017) in sediments of Ganga River where Fe appeared the most abundant element, which also agrees with earlier findings of Ghrefat, Abu-Rukah and Rosen (2011) of sediments at Kafrain dam, as well as those of Singh, Malik, Sinha, Singh and Murthy (2005) on sediments from Gomati River.This abundance can be attributed to (chemical) weathering action, whereby unconsolidated gravels decompose from laterite in the area (Jatau and Bajeh, 2007). Other possible sources of other metals contamination could be erosion, as well as urban releases, municipal wastes, construction wastes and agricultural activities. A comparison of heavy metal concentration in river sediment samples with NESREA guideline value reveal that only Hg and Pb occur above permissive values.

Table 4.15 Average Concentration of Heavy Metals in Sediment Samples

Heavy Metals	RWS (mg/kg)	RMS (mg/kg)	Nesrea Std (mg/kg)	Evaluation
Hg	95.3	93.5	4	High
Zn	60.5	145.6	300	Low
Pb	134.233	112.067	10	High
Cd	1.033	0.700	3	Low
Fe	7502.5	28517.8	Not fixed	-

Source: Field Work, 2016. RWS = River Wonderful Sediment, RMS = River Magami Sediment.

4.16 Geoaccumulation index of river sediments

Table 4.16 presents the geoaccumulation index (igeo) for sediments from both rivers. The geoaccumulation index was used to shows the levels of contamination of each river sediment,

via assessing enrichment of metal concentration above baseline concentrations in the aquatic sediments. These results points out that sediments from Wonderful and Magami Rivers have varying levels of heavy metal enrichment above baseline concentration. In the case of mercury, sediments from Wonderful and Magami Rivers have been shown to be extremely contaminated. However, sediments from Wonderful River has slightly higher mercury pollution than sediments from Magami River.

Possible explanation to this is the occurrence of previously established hospital wastes sites along the river course of Wonderful River, where mercury containing waste drain into the river water and settle on sediments. Other sources of this pollution are agrochemicals used in farming activities which are washed into the river through surface run-off. Results of geoaccumulation index also points out that sediments from Wonderful and Magami Rivers have occurrences of Zinc pollution, and shows that there is an enrichment of metal concentrations above baseline concentrations in the aquatic sediments..

Table 4.16 Geoaccumulation Index of River Sediments

Metals	RWS	RMS	igeo class	Evaluation
Hg	45.2	44.5	6*, 6**	Extremely contaminated
Zn	0.40	1.02	1*, 2**	Slightly contaminated*, Moderately contaminated**
Cd	2.3	1.6	3*, 2**	Moderately severely contaminated*, Moderately contaminated**
Fe	0.12	0.40	1*, 1**	Slightly contaminated
Pb	4.47	3.74	5*, 4**	Severely extremely contaminated*, Severely contaminated**

RWS = River wonderful sediments, RMS = river magami sediments *for sediments from River wonderful; ** for sediments from River Magami

The index shows that sediments from Wonderful River are slightly contaminated with zinc, while sediments from Magami River are moderately contaminated with zinc. While zinc

contaminated exist in both rivers' sediment, lithogenic and anthropogenic causes could be responsible for the higher zinc contamination in Magami River.

In the case of cadmium, *igeo* values show that contamination occurs in sediment from both rivers. Sediments from Wonderful River are moderately severely contaminated, while sediments from Magami River are only moderately contaminated with cadmium. Surface sediments of Wonderful River are thus more contaminated with cadmium than sediments of Magami River. Obvious reasons for this is the fact that anthropogenic inputs from where cadmium is sourced (such as drainage from mechanic road sites, wastes dumps with cadmium containing contents like batteries and so on) is more pronounced along the catchment area of Wonderful River than Magami River, hence the larger value in the former than in the latter.

Igeo values for iron points out to the fact that much contamination of the heavy metal does not occur in the sediment as sediment from each location only shows that there is only slight iron contamination. This shows that though iron is a naturally occurring metal in the earth crust, anthropogenic sources have made only little contribution in terms of contamination of this metal in the study area. The *igeo* values of sediments from Wonderful and Magami River for iron show that contamination occurs in both river sediments.

The igeo result shows that sediments from Wonderful River are severely extremely contaminated, and sediments from Magami River are severely contaminated with lead. Surface sediments of Wonderful River are thus more contaminated with lead than sediments of Magami River. Obvious reasons for this is similar to that of cadmium pollution, anthropogenic inputs (such as drainage from mechanic road sites, wastes dumps with cadmium and lead containing contents like batteries and so on) is more pronounced along the catchment area of Wonderful River than Magami River, hence the larger value in the former than in the latter.

Agricultural activities in the catchment area of both rivers (Wonderful and Magami) are very important sources of heavy metal enrichment in the study area. This is because, modern agricultural practices through the application of pesticides (Atafar et al, 2010) and fertilizer's such as nitrogen, potassium, phosphatic fertilizers, livestock manures, composts and municipal sewage sludge on agricultural soils are identified agricultural sources for accumulation of cadmium, mercury, and zinc (Kabata -Pendias and Pendias, 1999; Basta et al, 2005).

Being an agrarian society, with a sizeable area engaged with crop cultivation, heavy metal contamination from such activities are part of the result on the receiving environment. Hou et al (2013) reported moderate contamination for the metals Cu, Pb, Zn, and Cd in sediment of Lake Dalinouer, China. Rubio, Nombela and Vilas (2000) calculated igeo for sediments of Ria de Vigo (Spain) and showed that significant differences occur between background values used for metal concentration.

4.17 Test of Hypothesis for Fish Samples

A two-way Analysis of variance (2-way ANOVA) was conducted to explore interaction effect of heavy metals and types of fish studied. Heavy metals and fish studied were Hg, Zn, Pb, Cd, and Fe in *C. gariepinus, B. occidentalis, T. oreos, A. fallax, E. fimbritus, and C. harengus* respectively. The following hypotheses were tested:

Ho: There is no interaction effects between heavy metals and types of fish studied

Results Presented in Table 4. 1 revealed that there was a statistical significant main effects for heavy metals [F (4.161), P = 0.0001)] and statistical significant main effect for types of fish [F (140.473), P = 0.0001)]. Moreover, a statistical interaction effects was revealed [F (23.51), P= 0.0001).

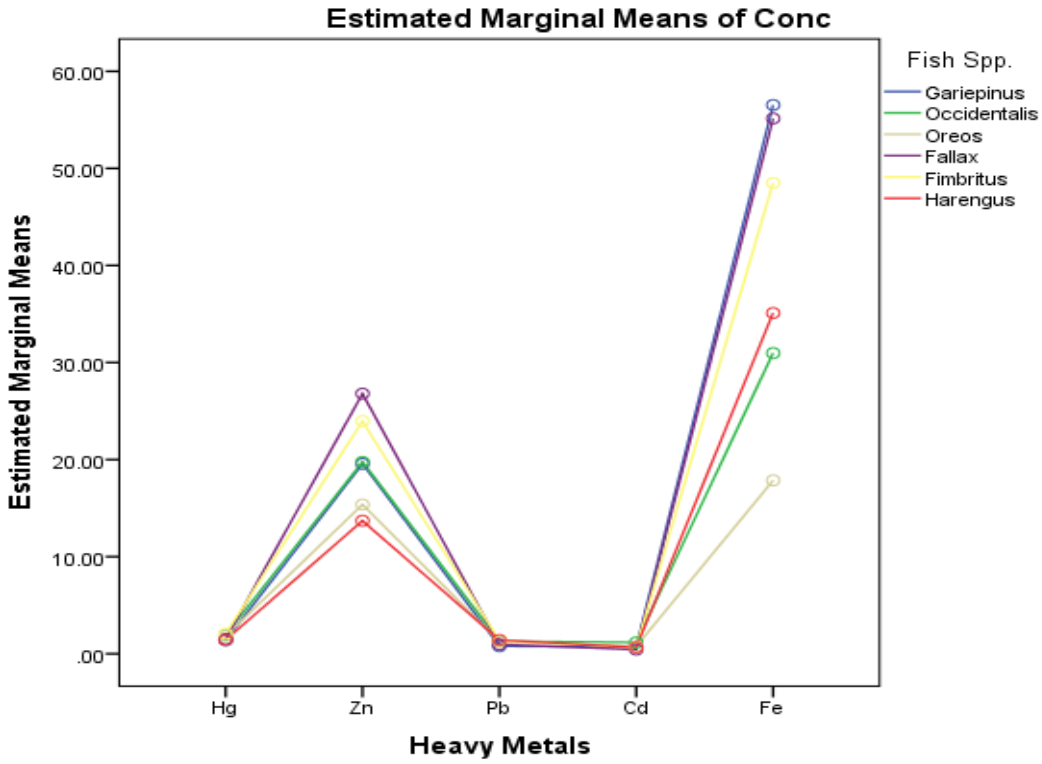
Table 4.17 Test Between Subject Effect (2-way ANOVA)

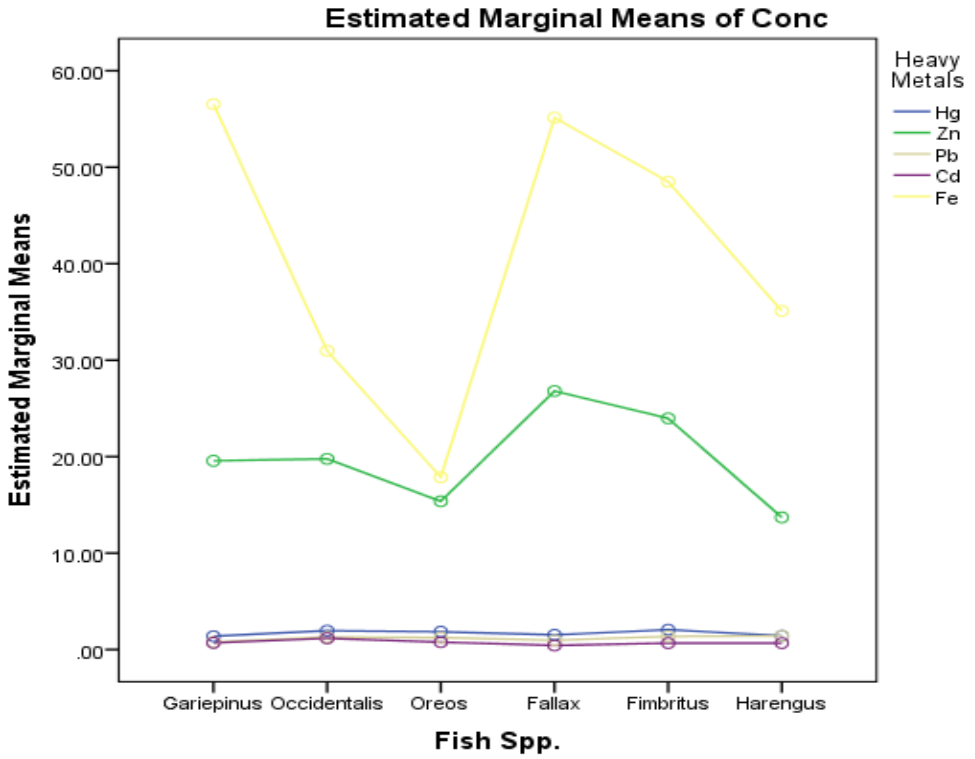
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	86792.006a	29	2992.828	103.2	0.000
Intercept	49387.289	1	49387.289	49387.28	0.000
Heavy Metals	73875.871	4	18468.968	4.1617	0.000
Fish	3511.828	5	702.366	140.473	0.000
Heavy Metals * Fish	9404.307	20	470.215	23.51	0.000
Error	0	270	0		
Total	136179.295	300			
Corrected Total	86792.006	299			

R Squared = 1.000 (Adjusted R Squared = 1.000)

Close inspections of Figure 4.6(a) showed that, *Falax* and *Gariepinus* fish species have higher concentrations of Fe followed by *Fimbritus*, *Harengus* and *Occidenalis* fish species. The least specie with the concentration of Fe is *Oreos.* The concentration of heavy metals was also revealed using plots from 2-way ANOVA. Figure 4.6(b) showed that, Fe is the highest heavy metal associated with the studied fish species followed by Zn, Hg, Pb and Cr which made insignificant contribution's with respect to the magnitude of values of other heavy metals in the fish species. The order of the concentration of heavy metals in fish species are Fe>Zn>Hg>Pb>Cd.

Figure 4.6 Plots from 2-Way ANOVA





4.18 Test of Hypothesis for Water Samples

An Independent Sample Test on water samples was conducted to explore the statistical significance differences between heavy metals in Wonderful and Magami rivers studied. Heavy metals in water samples studied were Hg, Zn, Pb, Cd, and Fe. The following hypothesis was tested:

Ho: There is no significant differences between the studied heavy metals in Magami and Wonderful Rivers

From the result available in Table 4.18, levene's test for equality of variances shows that sig. value (0.908) is greater than 0.05 i.e. P > 0.001 hence equal variances is assumed. Since t – test for equality of means sig. value (0.872) is greater than 0.05, the null hypothesis is accepted and concludes that there is no statistically significant difference in heavy metal concentrations of Wonderful and Magami Rivers. This also implies that anthropogenic influence namely agriculture, waste dumps e.t.c. have contributed to the presence of heavy metals in both rivers water at uniform pace.

4.19 Test of Hypothesis for Sediment Samples

An Independent Sample Test on sediment samples was conducted to explore the statistical significance differences between heavy metals in sediments of Wonderful and Magami Rivers. Heavy metals in sediment samples studied were Hg, Zn, Pb, Cd, and Fe. The following hypothesis was tested:

Ho: There is no significant differences between the studied heavy metals in Magami and Wonderful Rivers sediment.

Table 4.18 Independent Sample Test on Water Samples from Wonderful and Magami Rivers

	Levene's Test for Equality of Variances		t - test for Equality of Means						
	F	Sig	t	Df	Sig	MD	SE	95% Confidence Interval of the Difference	
								Lower	Upper
Equal Variances assumed	0.014	0.908	-0.167	8	0.872	-0.0498	0.29867	-0.73854	0.63894
Equal Variances not assumed			-0.167	7.966	0.872	-0.0498	0.29867	-0.73905	0.63945

Table 4.19 Independent Sample Test on Sediment Samples from Wonderful and Magami Rivers

	Levene's Test for Equality of Variances		t - test for Equality of Means						
	F	Sig	t	Df	Sig	MD	SE	95% Confidence Interval of the Difference	
								Lower	Upper
Equal Variances assumed	2.51206E +16	0.000	-0.203	2	0.858	-8.65	42.55952	-191.76882	174.46882
Equal Variances not assumed			-0.203	1.001	0.872	-8.65	42.55952	-548.27886	530.97886

From the result available in Table 4.19, levene's test for equality of variances shows that sig. value is less than 0.05 i.e. $P < 0.001$ hence equal variances is not assumed. Since t – test for equality of means, sig. value (0.872) is greater than 0.05, the null hypothesis is accepted and conclude that there is no significant difference in heavy metal concentrations of sediments from Wonderful and Magami Rivers. This implies that anthropogenic influence have contributed to the presence of heavy metals in both rivers sediments. Interestingly, the result shows that anthropogenic influence has been uniform in both locations. This is not surprising due to the fact that anthropogenic activities such as agriculture, sewerage dumpsites to mention a few are evident along the rivers catchment area.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study was carried out to assess heavy metals content in local and imported fish in Jema'a Local Government Area, Kaduna State. The studied rivers where fishing activities take place were receptacles of effluents from sewerage, dumpsites, and domestic wastes, farm drainage with pesticides, herbicides, and chemical fertilizers containing metal compounds sloping into the rivers during heavy showers yearly. Such activities placed the rivers at the risk of being contaminated with heavy metals alongside the tendency of increasing the load thereof, with the problem of bioaccumulation in local fish varieties. In view of this, the specific objectives of the study were to determine the heavy metal content in local and imported fish consumed in the study area; determine the heavy metal content of rivers and sediment in the study area and examine the level of awareness of the risks by the public.

Available literature were reviewed on issues concerning environmental sources of heavy metals, bioavailability of heavy metals, heavy metals in fresh surface water and marine water ecosystem, heavy metals in sediments, heavy metals in fish, human health effect of heavy metals, human and ecological risk assessment of heavy metals. The reviewed literatures showed that heavy metals contamination in river's is a global concern whose availability impacts river ecosystem as well as human health.

Data for this study were acquired from result of laboratory analysis of fish, water and sediment samples and also from the use of questionnaire administered using purposive sampling to a total of 384 respondents in eight wards within the study area. These wards are Kafanchan A, Kafanchan B, Kaninkon, Gidan Waya, Asso, Bedde, and Kagoma. The administration of questionnaire was carried out to get the residents' views on fish consumption pattern and level of awareness of chemical contamination of local and imported

fish consumed in the area. Also, risk assessment was carried out using target hazard quotient and total target hazard quotient. Pollution of river sediment was determined using geoaccumulation index. Results of analysis revealed that concentrations of metals occur at levels considered risk in fish, water and sediment. Mercury, lead and cadmium were at levels of concern in fish as concentrations were recorded above permissive limits of NAFDAC and WHO. Results of risk assessment via target hazard quotient and total target hazard quotient shows that mercury, cadmium, and lead have values considered risk for human health via fish consumption. In river water, results recorded showed that all metals occurred at concentration considered high according to standard permissive values. Igeo values for sediments indicate that baseline concentrations of mercury, cadmium and lead have witnessed increament of the said metals, and thus sediments have been considered to be contaminated. Agriculture, effluents from sewerage, municipal wastes, dumpsites, washing and bathing activities, are strong indicators of heavy metal pollution in the river ecosystem.

5.2 Conclusion

This work provides analysis of heavy metals in fish (local wild caught and imported frozen species), river and sediments in Wonderful and Magami River areas of Jema'a LGA- Kaduna State, Nigeria. Based on the findings of this study, it can be concluded that both local and imported fish species available in the study area are unsafe for consumption. Various metals - causal health impacts are imminent ranging from mercury induced health effects to lead as well as cadmium induced health effects. Since the non-essential metals (Hg, Cd, Pb) have been identified to constitute risks to human health in some fishes within a life time of exposure, it is safe to conclude therefore that effects derived from consuming fish in the study area outweighs the benefits. Further more, metal concentrations in both rivers water with high values makes the river water unfit for fishing and other uses. Igeo values for sediments indicates that mercury, cadmium and lead are at higher pollution in sediments. From the

findings, the study concludes that anthropogenic inputs (such as drainage from mechanic road sites, wastes dumps with cadmium and lead containing contents like batteries and so on) have made incursions into the river ecosystem. Agriculture, effluents from sewerage, municipal wastes, dumpsites, washing and bathing activities, are strong indicators of heavy metal pollution in the river ecosystem. The study also concludes that there is need for Proper management efforts of the river ecosystem in order to avoid an ecological and human health disaster in the light of these discoveries. It is also concluded that depth of knowledge about risk associated with heavy metals is still limited. Fish advisory effort which is highly important in risk communication and management is grossly lacking and insufficient.

5.3. Recommendations

Arising from the findings of this research, the following recommendations are made:

1. An environmental task force should be set up with the mandate to set up and carry out proper monitoring and management activities of the river ecosystems in the area.
2. With low awareness identified in the study, proper enlightenment should be created along side the involvement of the traditional councils of Jema'a Local Government Area for effective dissemination of knowledge, through their relevant structures.
3. Enlightenment campaigns should be carried out effectively in schools, markets and residential areas, by Kaduna State Environmental Protection Agency (KEPA), and relevant non-governmental organization.
4. In line with awareness creation, the internet as a tool should to harnessed to maximum effectiveness in information dissemination.
5. Information's on fish advisory should be holistic and disseminated effectively. Such information should combine indigenous knowledge on fish and toxicological

information on risk of chemical exposures to increase understanding and acceptability.

6. For the imported stock, efforts should be made to strengthen surveillance of institutions responsible for monitoring imported items such as the Nigeria Custom Service as well as National Agency for Food and Drug Administration and Control. Furthermore, erring personnels should be effectively dealt with to serve as deterrent to others.
7. Periodic workshops and discussion forums should also be organized by Kaduna State Environmental Protection Agency.

There are rooms for further study on actual health risk of consuming the fish investigated in this study. This should be interdisciplinary involving dieticians, nutritionists, medical practitioners and environmentalist. This will bring far reaching results that will be more convincing and authoritative.

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Appendices



Plate 1.1: The researcher collecting water samples from a section of River Wonderful



Plate 1.2: The researcher holding a sample of water collected



Plate 1.3: A section of River Magami showing agricultural plants along the river bank.



Plate 1.4: A section of River Magami showing a fisherman going into the river to collect water samples.



Plate 1.5: One of the fishermen working on fish harvested directly from the river from where local fish samples were bought.



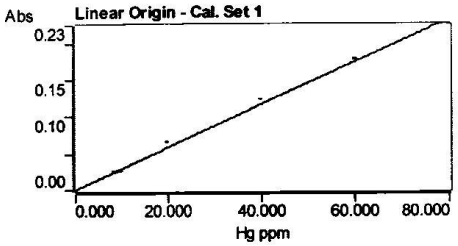
Plate 1.6: Some labelled samples of Tilapia oreos



Plate 1.7: Some labeled samples of Clarias gariepinus

Analyst	MUSRL/ABU Zaria
Date Started	10:11 AM 3/27/2015
Worksheet	Mercury 001 13
Comment	Blessed Baba
Methods	Hg
Computer name	MUSRL-PC
Serial Number:	AA0904M046

Method: Hg Water (Flame)

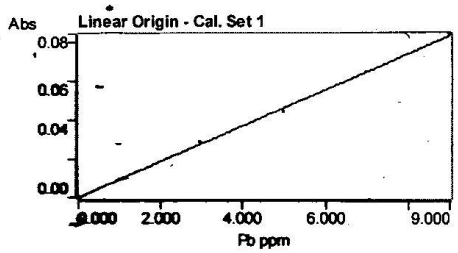


Sample ID	Conc ppm	SD	Mean Abs
Sample RMS 1	0.910	0.0011	0.0264
Sample RMS 2	0.942	0.0018	0.0273
Sample RMS 3	0.954	0.0009	0.0277
Sample RWS 1	0.955	0.0001	0.0277
Sample RWS 2	0.934	0.0007	0.0271
Sample RWS 3	0.970	0.0005	0.0282
Sample RM 1	1.080	0.0015	0.0314
Sample RM 2	1.110	0.0011	0.0322
Sample RM 3	1.159	0.0006	0.0337
Sample RW 1	1.174	0.0009	0.0341
Sample RW 2	1.239	0.0006	0.0360
Sample RW 3	1.280	0.0012	0.0372
Sample Fish 1	1.287	0.0008	0.0374
Sample Fish 2	1.351	0.0009	0.0392
Sample Fish 3	1.354	0.0004	0.0393
Sample Fish 4	1.452	0.0010	0.0422
Sample Fish 5	1.495	0.0005	0.0434
Sample Fish 6	1.520	0.0007	0.0441
Sample Fish 7	1.557	0.0006	0.0452
Sample Fish 8	1.597	0.0007	0.0464
Sample Fish 9	1.649	0.0009	0.0479
Sample Fish 10	1.677	0.0007	0.0487
Sample Fish 11	1.724	0.0006	0.0501
Sample Fish 12	1.787	0.0014	0.0519
Sample Fish 13	1.815	0.0005	0.0527
Sample Fish 14	1.820	0.0011	0.0529
Sample Fish 15	1.897	0.0009	0.0551
Sample Fish 16	1.929	0.0006	0.0560
Sample Fish 17	1.951	0.0009	0.0567
Sample Fish 18	1.927	0.0006	0.0559
Sample Fish 19	1.992	0.0017	0.0578
Sample Fish 20	2.010	0.0009	0.0584
Sample Fish 21	2.037	0.0013	0.0592
Sample Fish 22	2.117	0.0005	0.0615
Sample Fish 23	2.133	0.0016	0.0619
Sample Fish 24	2.192	0.0010	0.0636

Sample Fish 25	0.000	0.0006	-0.0053
Sample BLK	0.000	0.0005	-0.0051

Analyst	MUSRL/ABU Zaria
Date Started	1:28 PM 3/26/2015
Worksheet	Lead 001 00 1 12
Comment	Blessed Baba
Methods	Pb
Computer name	MUSRL-PC
Serial Number:	AA0904M046

Method: Pb Water (Flame)

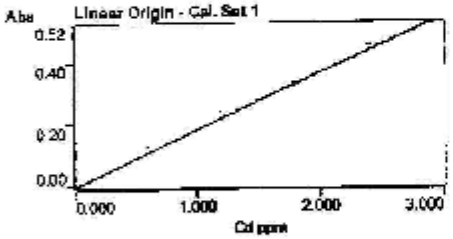


Sample ID	Conc ppm	SD	Mean Abs
Sample RMS 1	1.092	0.0005	0.0101
Sample RMS 2	1.070	0.0003	0.0099
Sample RMS 3	1.200	0.0006	0.0110
Sample RWS 1	1.265	0.0003	0.0116
Sample RWS 2	1.361	0.0004	0.0125
Sample RWS 3	1.401	0.0003	0.0129
Sample RM 1	1.307	0.0008	0.0120
Sample RM 2	-0.086	0.0007	-0.0008
Sample RM 3	0.157	0.0005	0.0014
Sample RW 1	0.319	0.0006	0.0029
Sample RW 2	0.371	0.0002	0.0034
Sample RW 3	0.424	0.0005	0.0039
Sample Fish 1	0.522	0.0005	0.0048
Sample Fish 2	0.681	0.0002	0.0063
Sample Fish 3	0.708	0.0002	0.0065
Sample Fish 4	0.953	0.0002	0.0088
Sample Fish 5	0.957	0.0003	0.0088
Sample Fish 6	0.965	0.0002	0.0089
Sample Fish 7	0.979	0.0006	0.0090
Sample Fish 8	1.003	0.0002	0.0092
Sample Fish 9	1.053	0.0003	0.0097
Sample Fish 10	1.032	0.0001	0.0095
Sample Fish 11	1.160	0.0002	0.0107
Sample Fish 12	1.251	0.0004	0.0115
Sample Fish 13	1.237	0.0004	0.0114
Sample Fish 14	1.249	0.0001	0.0115
Sample Fish 15	1.233	0.0002	0.0114
Sample Fish 16	1.256	0.0001	0.0116
Sample Fish 17	1.176	0.0005	0.0108
Sample Fish 18	1.269	0.0004	0.0117
Sample Fish 19	1.368	0.0003	0.0126
Sample Fish 20	1.367	0.0003	0.0126
Sample Fish 21	1.395	0.0004	0.0128
Sample Fish 22	1.323	0.0005	0.0122
Sample Fish 23	1.427	0.0005	0.0131
Sample Fish 24	1.393	0.0004	0.0128

Sample Fish 25	1.424	0.0005	0.0131
Sample BLK	0.000m	0.0006	-0.0019

Analyst	MUSRL/ABU Zarra
Date Started	2:34 PM 3/26/2015
Worksheet	Cadmium 051 98
Comment	Blessed Baba
Methods	Cd
Computer name	MUSRL-PC
Serial Number:	AA0604M048

Method: Cd water (Flame)



Sample ID	Conc ppm	SD	Mean Abs
Sample RMS 1	0.018	0.0007	0.0028
Sample RMS 2	0.011	0.0005	0.0019
Sample RMS 3	0.008	0.0002	0.0010
Sample RMS 1	0.015	0.0001	0.0027
Sample RMS 2	0.013	0.0005	0.0023
Sample RMS 3	0.015	0.0006	0.0028
Sample RM 1	0.015	0.0003	0.0026
Sample RM 2	0.014	0.0003	0.0025
Sample RM 3	0.013	0.0001	0.0023
Sample RW 1	0.012	0.0006	0.0021
Sample RW 2	0.016	0.0006	0.0029
Sample RW 3	0.012	0.0002	0.0022
Sample Fish 1	0.011	0.0008	0.0019
Sample Fish 2	0.008	0.0005	0.0015
Sample Fish 3	0.013	0.0004	0.0023
Sample Fish 4	0.009	0.0002	0.0017
Sample Fish 5	0.014	0.0002	0.0025
Sample Fish 6	0.010	0.0002	0.0018
Sample Fish 7	0.010	0.0001	0.0018
Sample Fish 8	0.009	0.0002	0.0016
Sample Fish 9	0.010	0.0004	0.0017
Sample Fish 10	0.012	0.0004	0.0021
Sample Fish 11	0.013	0.0005	0.0023
Sample Fish 12	0.014	0.0002	0.0025
Sample Fish 13	0.012	0.0013	0.0022
Sample Fish 14	0.013	0.0005	0.0024
Sample Fish 15	0.010	0.0003	0.0019
Sample Fish 16	0.013	0.0002	0.0024
Sample Fish 17	0.016	0.0001	0.0028
Sample Fish 18	0.015	0.0005	0.0027
Sample Fish 19	0.016	0.0003	0.0029
Sample Fish 20	0.008	0.0002	0.0014
Sample Fish 21	0.010	0.0004	0.0019
Sample Fish 22	0.014	0.0004	0.0025
Sample Fish 23	0.012	0.0004	0.0022
Sample Fish 24	0.008	0.0001	0.0015

Sample Fish 25	0.012	0.0003	0.0022
Sample BLK	0.004m	0.0010	0.0015

QUESTIONNAIRE

Dear Respondent,

I am a student of Ahmadu Bello University, Zaria, from the Department of Geography. I am undertaking a study to **assess the awareness of risks in local and imported fish consumed in Jema'a Local Government Area**, as part of the requirement for the award of M.Sc in Environmental Management. Please provide the required responses in the fields by ticking [√] the boxes provided. All information will be treated for academic purpose only.

SECTION A
(Socioeconomic characteristics of respondents)

i. Age: less than 20 years [ ] 21 – 30 [ ] 31 – 40 [ ] 41 – 50 [ ] 51 – 60 [ ] 61 and above [ ]

ii. Sex: Male [ ] Female [ ]

iii. Occupation: Trader [ ] Civil Servant [ ] Farmer [ ] Business [ ] Unemployed [ ] Student [ ] others please specify_____

iv. Income (per annum): < N100,000 [ ] N101,000 – N200,000 [ ] N201,000-N300,000 [ ] N301,000 – N400,000 [ ] N401,000 – N500,000 [ ] above N500,000 [ ]

v. Highest Educational Qualification: Ph.D [ ] M.Sc/M.A/M.Ed [ ] B.Sc/B.A/B.Ed [ ] HND[ ] NCE [ ] ND [ ] SSCE [ ] Primary School Certificate [ ] None [ ] others please specify_____

vi. Tribe: _____

SECTION B
(Information on fish consumption)

1. Where do you get the fish you eat? I buy from cold rooms [ ] I buy from market [ ] I buy from fishermen [ ] Others please specify_____
2. What type of fish do you eat always? Shawa [ ] Mackerel [ ] Sardine [ ] Parpasa [ ] Tarwada [ ] Ragon-ruwa/ Shululuwa [ ] (kindly tick as much as you eat)
3. Why do you eat these fish? Cheaper source of protein [ ] Taste [ ] Healthier than meat [ ] Others please specify_____
4. How regularly do you eat fish? Once a week [ ] 2 times a week [ ]
   3 times a week [ ] 4 times a week [ ] 5 times a week [ ] 6 times a week [ ] 7 times a week [ ] Others please specify _____
5. In terms of Size, 1 serving of fish means fish that is equal to the size of a woman's palm(🤚). What is the size of fish you eat every week? 1 serving [ ] 2 servings 🤲 [ ] 3servings🤲[ ] 4servings🤲[ ]. Others please specify_____
6. The fish you buy and eat can have harmful chemicals.
   Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

7. Eating the fish you buy can affect the brain.
   Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

8. Eating contaminated fish can result in low learning ability in children.
   Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

9. Severe vomiting and diarrhea can occur from eating contaminated fish.
   Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

10. Eating contaminated fish can also result in infertility in men.
    Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

11. Deafness and blindness could be caused by eating contaminated fish.
    Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

12. Skin rashes, tiredness, and headaches may be signs of eating contaminated fish.
    Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

13. Rise in blood pressure, miscarriages, or even memory loss can occur as a result of eating fish contaminated with chemicals. Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

14. Eating fish contaminated with chemicals can cause other sicknesses apart from the ones mentioned above? Strongly Agree [ ] Agree [ ] Undecided [ ] Disagree [ ] Strongly Disagree [ ]

15. Health information about fish tell us about the safety of fish we buy and eat. Do you receive health information about the fish you buy and eat? Yes I do [ ] No I don't [ ]

16. If yes, how do you receive health information about the safety of fish you buy and eat?

TV [ ] Radio [ ] Newspaper [ ] Fish Sellers [ ] Friends [ ] Environmental Health Officers [ ] Others_____ (please tick as much as you know).