FEDERAL UNIVERSITY OF AGRICULTURE
ABEOKUTA NIGERIA

84th INAUGURAL LECTURE

IN THE FOOTPRINTS OF THE ENVIRONMENT: EVERY CONTACT LEAVES A TRACE ON OUR COMMON FUTURE

by

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This 84th Inaugural Lecture was delivered under the Chairmanship

of

The Vice-Chancellor

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B.Sc (Agric Biology); M.Sc (Crop Improvement),
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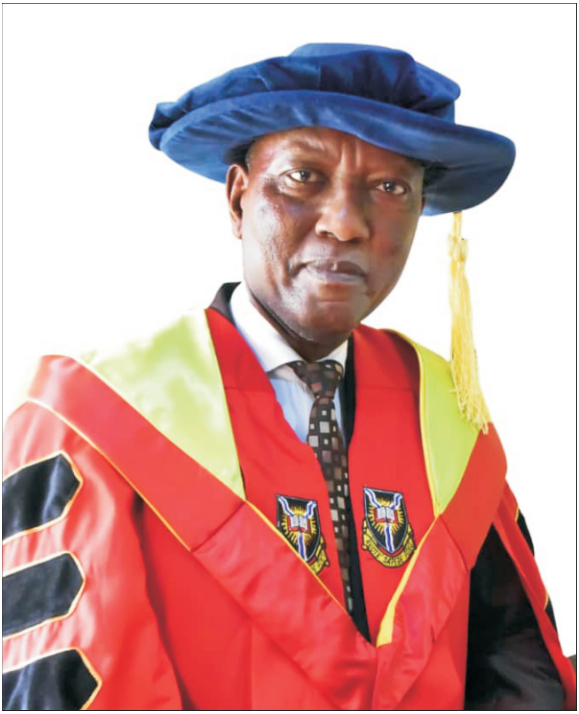

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Protocol

Mr Vice-Chancellor,

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Gentlemen of the Press,

Distinguished Ladies and gentlemen,

Great FUNAABITES,

I welcome you all, to this inaugural lecture.

PREAMBLE

Mr Vice-chancellor Sir, permit me to state very clearly that this lecture which is the 84th in the series of inaugural lectures of FUNAAB and indeed the second from the Department of Environmental Management and Toxicology, after that of my senior colleague and friend, Prof Toyin Arowolo. This lecture is to the Glory of God and I am a testimony of God's goodness and faithfulness.

With the death of my mother and burial in Feb 14, 2012, I am all but left with my father who will be 92 in a few days' time. I wish to share his response when one of my siblings on our WhatsApp platform asked- What is an inaugural lecture? He responded, thus:-
A newly appointed professor was required to give a detailed description of direction in which he intended to pilot his discipline in teaching and particularly in terms of research. At the University of Ibadan, the first set of inaugural lectures followed this pattern. At that time, there was only one professor in each Department. When the university moved into the era of multiple professorships, it became impossible for each new professor to give an inaugural lecture as soon as he was appointed. Consequently an inaugural lecture became a retrospective account of the new professor's research. This kind of lecture could be given ten or more years after his appointment. Mine is coming 16 years after.

1.0 INTRODUCTION

My research work is a modest contribution to the monumental task of monitoring and protecting the environment. Before completing my PhD at the University of Ibadan in 1988, I was a Graduate Assistant in the same University and after the completion of my PhD, I worked briefly as Lecturer II at the Lagos State University before crossing to the then Ogun State University, now Olabisi Onabanjo University in the same year and finally to the University of Agriculture Abeokuta (now Federal University of Agriculture, Abeokuta) in 1991, where, I am till date. To note that I have known only one job, I have been a teacher of Applied Chemistry. Teaching for me is an irresistible passion and I have been a professional for the past 42 years counting the days of my Graduate Assistantship. By His grace, I am a teacher of teachers and the Almighty favoured me to be elevated to the rank of Professor of Analytical/Environmental Chemistry after several years of sojourn in the academic wilderness.

This inaugural lecture is titled IN THE FOOTPRINTS OF THE ENVIRONMENT: EVERY CONTACT LEAVES A TRACE ON OUR COMMON FUTURE.

Figure 1: Footprints in the sands at the beach

1.1 What Is Our Natural Environment

The natural environment is the set of living and non-living things on earth which occur in a state substantially not influenced by humans. The term is often applied to an ecological complex which includes all the plants, animals, micro-organisms, abiotic factors such as minerals, rocks water bodies and atmospheric layers. There are extremely complex interactions between the living organism and abiotic elements as well as meteorological influences, all of which combine to form rich speciation and biodiversity in most natural systems

Figure 2: A virgin forest with a waterfall

This concept of the natural environment can be distinguished by components.

- Complete ecological units that functions as natural systems without massive civilized human intervention, including all vegetation, micro-organism, soil, rocks, atmosphere and natural phenomenon that occur within their boundaries.
- Universal natural resources and physical phenomena that lack clear-cut boundaries such as air, water and climate as well as energy, radiation, electric charge and magnetism, not originating from civilised human activity (Johnson *et al.,* 1997)

The natural environment is contrasted with the built environment which comprises the areas and components that are strongly influenced by humans belonging to a civilized (i.e. hierarchically structured, agricultural, densely populated, complexly systematized) society.

It is difficult to find absolutely natural environments and it is common that the naturalness varies in a continuum from ideally 100% natural in one extreme to 0% natural in the other. More precisely we can consider the different aspects or components of an environment and see that their degree of naturalness is not uniform (Symons, 1979).

Natural environment is often used as a synonym for habitat. For instance it's been identified that the natural environment of giraffes is the Savanah.

1.1.1 Types of Spheres of Natural Environment

Man's natural environment recognises four major spheres.

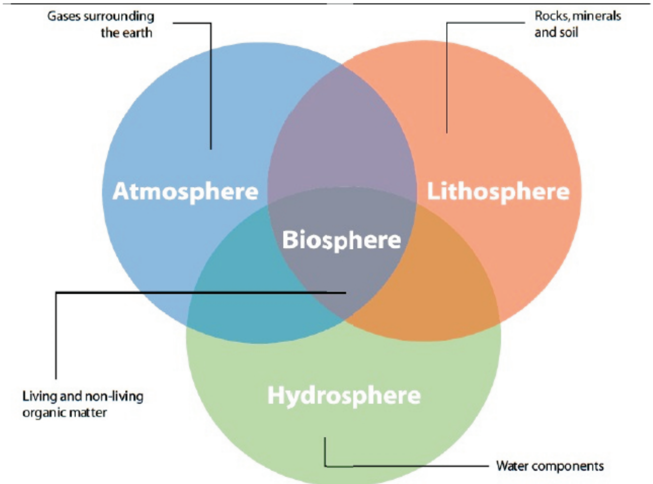

Figure 3: The major spheres of man's natural environment

1. The lithosphere
2. The hydrosphere
3. The atmosphere
4. The biosphere

1.1.1.1 Lithosphere

The earth's crust is the outermost solid surface of the planet and is chemically and mechanically different from the underlying mantle. The crust has been produced chiefly by igneous processes in which magma cools and solidifies to form solid rock. Beneath this lithosphere lies the mantle which is heated by radioactive decay. This solid mantle exists in a state of rheic convention, which process causes the lithospheric plates to move very slowly. The resulting process is known as plate tectonics. Volcanoes result primarily from the melting of subducted crust material or of rising mantle at mid-oceanic ridges and mantle plumes.

1.1.1.2 Hydrosphere

Various types of water bodies are present throughout the world, including oceans, rivers and lakes. In addition, groundwater basins are important storage areas which have their own ecosystems and can exchange flows with surface waters.

Ocean

Figure 4: The world's Ocean

An ocean is a major body of surface saline water and represents a major component of the hydrosphere. Approximately 71% of the earth's surface is inundated by oceans or seas, a continuous feature comprising five major oceans and numerous seas, gulfs and estuaries. More than half of this ocean expanse is greater than 3000 meters in depth. The major oceanic divisions are defined in part by the continents, various archipelagos and other criteria; these divisions in reducing sizes are Pacific, Atlantic, Indian, Southern and Artic Ocean.

1.1.1.3 Atmosphere

The atmosphere of the earth serves as a key factor in sustaining the planetary eco-system. The thin layer of gases that envelopes the earth is held in place by the planet's gravity. Dry air consist of 78% N_2, 21% O_2, 1% Ar and other inert gases, such as CO_2.

Figure 5: The atmosphere represented by the Clouds

The remaining gases often referred to as trace gases (Buchdahl, 2013) among which are the greenhouse gases such as water vapour, CO_2, methane, nitrous oxide and Ozone.

The Ozone layer of the earth's atmosphere plays an important role in depleting the amount of UV radiation that reaches the surface. As DNA is readily damaged by UV light, this serves to protect life at the surface. The atmosphere also retains heat during the night, thereby reducing the daily temperature extremes. Furthermore, the earth's atmosphere can be divided into 5 main layers going from the highest to the lowest. Exosphere is outermost layer of earth's atmosphere extends from the exo-base upwards, mainly composed of H_2 and He. Thermosphere is the top of the thermosphere is the bottom of the exosphere also called the exobase. Its height varies with solar activity and ranges from about 350-800 km. The international space orbits in this layer. Mesosphere is a layer where most meteors burn up upon entering the earth. Stratosphere extends from the troposphere to about 51 km. Troposphere begins at the surface and extends to between 7 km at the poles and 17 km at the equator.

BIOSPHERE

Figure 6: Various life forms of the Biosphere

Evidence suggests that life on earth has existed for about 37 billion years (history of life through time-university of California museum of palaeontology). Although there is no universal agreement on the definition of life, scientists generally accept that the biological manifestation of life is characterized by organisation, metabolism, growth, adaptation, response to stimuli and reproduction. (Definition of life, (2007). A diverse variety of living organism (life forms can be found in the biosphere on earth and properties common to these organism- plants, animals, fungi, protists, archaea and bacteria) is a carbon and water based cellular form with complex organisation and heritable genetic information.
Living organisms undergo metabolism, maintain homeostasis, possess a capacity to grow, respond to stimuli, reproduce and through natural selection, adapt to their environment in successive generations. More complex living organism can communicate through various means.

1.2 Biogeochemical Cycles

Global biogeochemical cycles (figs.7-11) are critical to life, most notably those of water, oxygen, carbon, nitrogen and phosphorus (Smil, 2010).

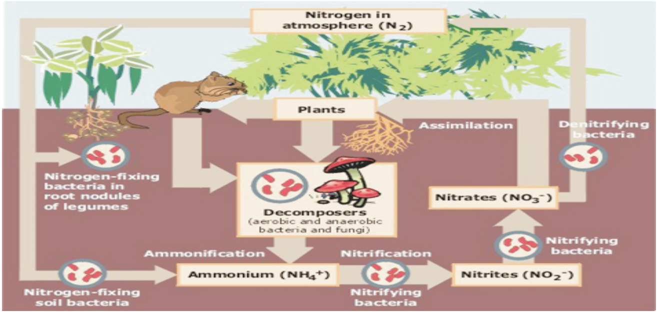

Figure 8: The Nitrogen Cycle

It is the transformation of N_2 and nitrogen containing compounds in

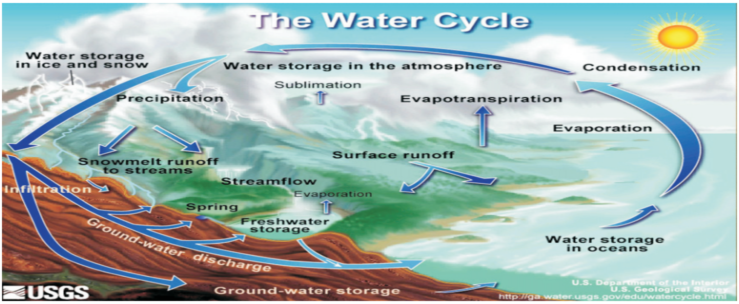

Figure 9: The Water Cycle

It is the continuous movement of water on, above and below the surface of the earth.

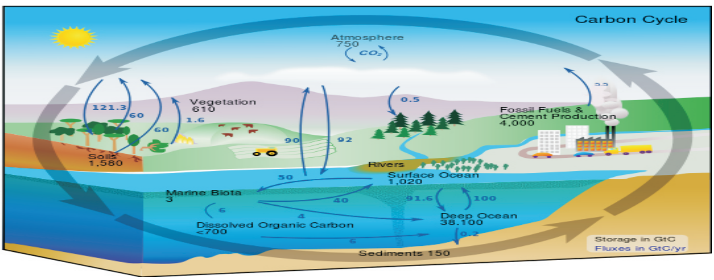

Figure 10: The Carbon Cycle

Carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere and geosphere, hydrosphere and atmosphere.

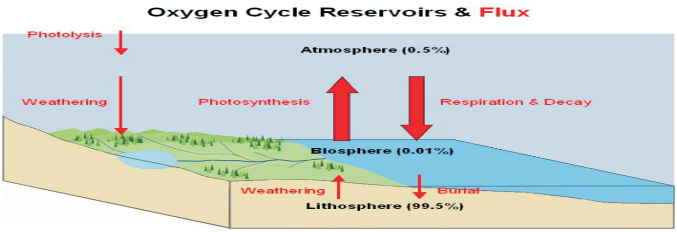

Figure 11: The Oxygen Cycle

This is the movement of oxygen within and between its 3 main reservoirs; the atmosphere, the biosphere and the lithosphere. The main dividing factor of the oxygen cycle is photosynthesis, which is responsible for the modern earth's atmosphere composition and life.

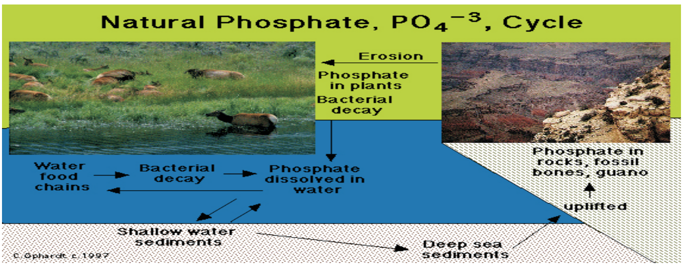

Figure 12: The Phosphate Cycle

This is the movement of phosphorus through the lithosphere, hydrosphere and biosphere. The atmosphere does not play a significant role in the movement of phosphorus because phosphorus and its compounds are usually solids at the typical ranges of temperature and pressure found on earth.

1.3 In the Footprints of Environmental Issues.

It is the common understanding of natural environment that underlies environmentalism- a broad political, social and philosophical movement that advocates various actions and policies in the interest of protecting what nature remains in the natural environment or restoring or expanding the role of nature in this environment. While true wilderness is increasingly rare, wild nature

Figure 13: The wilderness

(e.g. unmanaged forests, uncultivated grasslands, wildlife and wildflowers) can be found in many locations previously inhabited by humans.

Some of the goals expressed by environmental scientists include

i) Reduction and clean up of pollution with future goals of zero pollution
ii) Clearly converting non-recyclable materials into energy through direct combustion or after conversion into secondary fuels
iii) Reducing societal consumption of non-renewable fuels
iv) Development of alternative green, low carbon or renewable energy sources
v) Conservation and sustainable use of scarce resources such as water, land and air
vi) Protection of representative or unique pristine ecosystems
vii) Preservation of threatened and endangered species extinction
viii) The establishment of nature and biosphere reserves under various types of protection and most generally the protection of biodiversity and ecosystems upon which all human and other life on earth depends.

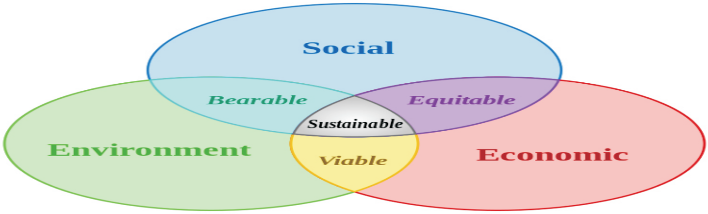

Figure 14: Interaction of the Social Environmental Factors.

Our common future as depicted is the report of the United Nations World Commission on the Environment and Development in 1987 and it is also known as Brandtland Report in honour of the Chairman of the Committee who was once the Prime Minister of Norway. It was this report, the first of its kind that drew attention from one Earth to one world.

United Nations report on the environment took its root vis-a-vis the following:

a) the 1992 Earth summit and the adoption of Agenda 21.

b) the Rio Declaration and the establishment of the commission on sustainable development.

c) Convention on Biological Diversity 1992

d) International Conference on Population and Development programme of action 1994

e) Earth charter

f) Lisbon principles

g) UN Millenium Declaration 2000

h)The Millennium Declaration and MDG's

As summarised by the chairman of the committee

The present decade has been marked by a retreat from social concerns. Scientists bring to our attention urgent but complex problems bearing on our very survival. A warming globe, threats to the earth ozone layer, deserts consuming agricultural land. We respond by demanding more details and by assigning the problems to institutions ill-equipped to cope with them.

Environmental degradation- first seen, as mainly a problem of the rich nations and a survival issue for developing nations. It is part of the downward spiral or linked ecological and economic decline in which many of the present nations are trapped. (UNWCED 1987)

Sustainable development is defined in the report as-development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

1.4 Every Contact Leaves a Trace

Figure 15: Footprints in the Sands of time

If you take your time and google the above sentence, you will find it listed as a book by Elanor, Dymott and also under forensic science particularly credited to Dr. Edmund Locard (December , 13, 1877 to 4th May 1966) who was a pioneer in forensic science and who became known as the Sherlock Holmes of France. He formulated the basic principle of forensic science "every contact leaves a trace" which later became known as Locard's Exchange Principle.

Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as a silent witness against him. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes , the glass he breaks, the tool marks he leaves, the paint he scratches, the blood or semen he deposits or collects. All of these and more bear mute witness against him.

This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence, physical evidence that cannot perjure itself, and it cannot be wholly absent. Only human failure to find it, study and understand it, can diminish its value, from Paul Kirk's book (1953) on crime investigation:- physical evidence and the police laboratory.
If I may be forgiven, by foraying into the cherished field of forensic scientists.

The ancient World lacked standardized forensic practices, which aided criminals in escaping punishment. Criminal investigations and trials relied on forced confessions and witness ceremony. However, ancient sources do contain several accounts of techniques that foreshadow concepts in Forensic Science that were developed centuries later (Scafer, (2008) Forensic Science is the scientific method of gathering and examining information about the past which is then used in a law court. It is not out of place, if as an individual present in this hall wonders, what has forensic science got to do with this inaugural lecture

A classic example is attributed to Archimedes (287-212BC), if I can assume that most of us here are familiar with Archimedes principle and the battle cry "Eureka". (Vitruvius. 'De Architectural Book ix. Paragraphs 9-12 text in English and latin-University of Chicago-retrieval 2007). According to Vitruvius, a votive crown, for a temple had been made for King Hiero II, who had supplied pure gold to be used and wanted to find out if indeed the pure Gold was used and not substituted with silver. Archimedes had to solve the problem without damaging the crown as he could not melt it down into a regularly shaped body in order to calculate its density. He used the law of displacement to prove that the goldsmith had taken some of the gold and substituted silver instead… Is this not our Analytical Chemistry at work?

2.0 MY RESEARCH CONTRIBUTIONS

Sustainable development has been defined in plain terms to mean – development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This goes to say that whatever you do, it must be done in moderate measures. If you till the soil; you must use the land resources in such a way that future generations can also use the land. This therefore applies to any other renewable or reusable resources.

I would therefore now wish to bring to the fore the title of this inaugural lecture as it reflects on my calling as a Professor of Analytical/Environmental Chemistry.
In the footprints of the environment: every contact leaves a trace on our common future.

Man's activities in the various sphere of the environment (lithosphere, hydrosphere, atmosphere, biosphere represents the four footprints on the environment and in relation to Forensic Science, all these contacts leaves a trace of various pollutions (soil, water, air, energy, heat) on Mother earth, our world, which we all must seek to protect.
I hereby stand before you as a Detective Grade1in the likes of Sherlock Holmes (Fig. 16)

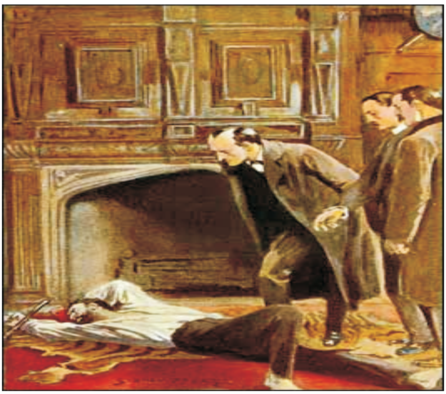

Figure 16: Sherlock Holmes at a Crime Scene

Seeking, to determine the various contacts, that man has made on the environment and to see the effect of these footprints on earth that is our common future.

For the purpose of this Inaugural lecture, I wish to present my foray into the field of Analytical Chemistry as I go down the memory lane with an eye into the future.

- My training as an analytical chemist provided the opportunity of familiarization with multifarious analytical techniques and technical know- how, with respect to analyses of various parameters in environmental samples. In this regard, my contribution to knowledge is hinged and primarily focused on application of analytical techniques to the analysis of environmental samples.

- At the onset, when I started my PhD programme under my indefatigable supervisor, Prof Oladele Osibanjo, the topical issue was the danger posed by pesticides. Along this line of study was the information presented by providing baseline data on toxic chlorinated hydrocarbons in Nigeria marine fishes and shellfishes which led to the identification of the fish species *Galeoides decadactylus* as a suitable bio-indicator for the Nigerian marine environment with respect to chlorinated hydrocarbon bio-magnifications.
- My research apart from being premised on analysis of environmental samples was also hinged on method development with the sole aim of improving known methods of analyses along with the presentation of new methods for the analyses of environmental samples.

- Due to the versatility of the atomic absorption spectrophotometry which has dove-tailed now into Inductive Coupled Plasma Spectrophotometry, it has been applied in the analyses of metals in various biota of soil, blood, saliva, human waste, adipose tissues, water and vegetation.

- The speciation of metals in soil samples is also an area of interest of which I have graduated a Ph.D student. A novel study was the influence of environmental degradation on the metal concentration in tissue of grass cutter which is a delicacy in South West Nigeria. Similarly the earthworm *Libryodrilus violaceus* had been identified as suitable to act as a bio-indicator of metal pollution in tropical dumpsites.

- More recently, I have also diversified to working on humans, due to the multi-disciplinary nature of environmental analysis and the direct interaction of humans with the environment using samples such as teeth, breast milk, urine and blood for metal analyses and pesticides.

- the dynamics of food processing and preservation is also an area of immense research interest of which many studies were carried out.

- a new emerging trend of which I had also made contributions is that of reclaiming back the land environment once it had been contaminated referred to as remediation studies of which the first Ph.D in the Department of EMT worked on.

- The study of analytical/environmental chemistry has evolved in the past decade to take cognizance of the total environment and resulting from this, is the need for multi-disciplinary environmental studies. In this vein, I have collaborated with several scientists which include- Profs Olatunde, Alegbeleye, Adeofun, Onadeko, Arowolo, Akegbejo-Samson, Sanni, Odukoya, Adamson, Ademuyiwa, Adetunji and several other PhD holders of which space and time limitations exclude them from here.

- Finally research into parameters that will make the environment sustainable remain my area of focus and motivation, which I hope in the next few years to come until am retired but not tired will form a major platform of my continuing contribution to knowledge

In this light, I would present my research contributions as assessment of the impact of man in the various spheres that I had earlier mentioned.

2.1 Footprints in the Atmosphere

2.1.1 *Assessment of vehicular pollution on occupationally exposed people in Lagos metropolis, Nigeria.*

In most urban areas, the key air pollutants are CO, PM, NOx, O_3, Pb and hydrocarbons (HC) which have varying health effects on humans. Motor vehicles are already identified as the major source of these pollutants in cities (Denison *et al.,* 2007).

The higher the number of vehicles with malfunctioning engines in any community, the higher the risk faced by humans due to high concentration of pollutants in the air. Some CO, HC, NO_{3x}, PM and SOx have direct health effects on humans, elevated CO levels is associated with the impairment of visual perception, work capacity, manual dexterity, learning ability and death (Aziz and Bajwa (2007). Lagos metropolis was the centre of a study to assess the health impacts of vehicular pollution on occupationally exposed people in particular traffic control officers. (Adeleke *et al.,* 2011).

Table1 shows the bio-social characteristics and pollution exposure of traffic officers and control.

Table 1 :Bio-Social Characteristics and Pollution Exposure of Traffic Officers and Control

Characteristics	**Traffic Officers**	**Control**
Age	35 ± 8 years	36 ± 6 years
Height	1.7 ± 0.1 meters	1.7 ± 0.7 meters
Weight	70 ± 13 kg	70 ± 14kg
Body Mass Index	25 ± 4.0	23 ± 4.0
Daily Exposure		
1-5h	2%	NAs
6-10h	74%	NA
>10h	24%	NA
Years of Exposure		
1-5y	65%	NA
6-10y	31%	NA
>11y	4%	NA
CO breath test (ppm)	1.18 ± 0.43	0.63 ± 0.59

From hospital records of 2001 to 2006, Table 2 shows reported cases of air pollution related diseases among Lagos residents.

Table 2 : Reported Cases of Air Pollution Related Diseases Among Lagos Residents

Diagnosed Ailments	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**Total**
Acute Sinusitis	57	96	54	81	3	63	356
Acute Tonsillitis	31	113	34	41	97	186	502
Pneumonia	119	146	50	73	47	100	535
Broncho Pneumonia	172	-	10	95	125	845	1413
Acute Bronchitis	24	28	6	13	4	5	80
Chronic Bronchitis	73	-	-	-	27	174	279
Asthma	269	513	231	375	226	192	1806
Obstructive Diseases	11	22	5	39	-	6	44
Pleural Effusion	52	21	40		19	23	194
Upper Respiratory Tract Infection	-	-	6363	416	841	2,997	4,323

The mean concentration of sampled pollutants at the selected locations in Lagos are shown in Table 3

Table 3: Mean Concentration of Sampled Pollutants at the Selected Locations in Lagos

Pollutants	Ikeja	CMS	Maryland	Mazamaza	Oshodi	Imota	Ikotun	UNILAG
Tsp µg/m^3	501.28 ± 218.3	503.91 ± 230.8	442.33 ± 173.7	1171.7 ± 351.1	820.53 ± 465.5	603.96 ± 458.5	800.19 ± 293.8	130.60 ± 44.5
PM_{10} µg/m^3	330.59 ± 231.1	278.95 ± 154.0	232.79 ± 119.2	617.38 ± 327.9	441.24 ± 282.8	378.45 ± 294.7	417.21 ± 139.2	85.84 ± 28.3
$PM_{2.5}$µg/m^3	147.12 ± 55.0	182.72 ± 102.7	141.68 ± 69.7	272.85 ± 105.5	257.75 ± 133.1	192.13 ± 171.5	162.43 ± 61.6	26.68 ± 15.3
CO ppm	1.70 ± 0.4	2.00 ± 0.9	2.90 ± 1.3	3.10 ± 0.88	3.00 ± 0.67	2.30 ± 0.68	3.40 ± 1.3	0.10 ± 0.00
SO_2ppb	77.20 ± 12.6	81.70 ± 12.4	79.10 ± 17.9	100.20 ± 48.1	116.3 ± 27.3	69.70 ± 13.3	81.0 ± 30.1	9.40 ± 0.97
NO_2ppb	78.40 ± 56.2	109.2 ± 55.2	98.0 ± 69.2	98.8 ± 52.2	138.6 ± 78.4	88.20 ± 54.8	172.8 ± 88.9	8.76 ± 3.3
Benzene ppb	5.57 ± 3.5	10.9 ± 2.9	11.90 ± 6.7	17.58 ± 8.8	10.47 ± 6.6	4.26 ± 0.14	11.58 ± 3.7	3.47 ± 3.84
Toluene ppb	13.30 ± 7.2	21.0 ± 8.56	25.69 ± 13.3	36.92 ± 19.6	22.94 ± 14.3	8.21 ± 1.9	27.55 ± 8.1	5.34 ± 6.0
MP-xylene Ppb	7.63 ± 4.3	12.24 ± 4.8	13.89 ± 7.9	21.57 ± 10.5	13.22 ± 7.8	4.84 ± 1.1	16.04 ± 3.3	3.37 ± 3.4
O-xylene ppb	2.80 ± 1.6	4.58 ± 1.9	5.68 ± 2.7	8.03 ± 3.9	4.94 ± 2.9	1.80 ± 0.37	5.99 ± 1.2	1.27 ± 1.5

ANOVA Result: TSP (F -10.03; α 0.001); PM_{10}(F-5.15; α 0.001); $PM_{2.5}$(F-5.77; α 0.001); CO (F-15.10; α 0.001); SO_2 (F-16.14; α 0.001); NO_2 (F-5.87; α 0.001); Benzene (F-3.049; α 0.001); Toluene (F-3.102; α 0.001); Mp-Xylene (F-3.408; α 0.008), O-Xylene (F-3.623; α 0.005).

Our findings show that the University of Lagos had the lowest levels of each of these pollutants. With the exposure of the general Lagos residents to a high concentration of these gaseous pollutants. It is not far-fetched for a high occurrence of respiratory diseases alluded to by Shun-Hwa *et al.,* (1999) and Caciola *et al.,* (2002).
The broad profile of diagnosed health problems among residents that visited the public hospital, showed high prevalence of upper respiratory tract infection (45.3%), asthma (18.9%) Broncho-pneumonia (14.8%) and pneumonia (5.6%).

A higher concentration of CO in blood of the occupationally exposed people and the prevalence of respiratory ailments among the general populace showed the negative impact of air pollution on Lagos residents.
In January 16, 2014, Beijing's skyscrapers receded into a dense gray smog as the capital saw the season's first wave of extremely dangerous pollution with the concentration of toxic small particles registering more than two dozen times the level considered safe.

The air took on an acrid odour and many of the city's commuters wore industrial strength face masks as they hurried to work.
The diversity of PM 2.5 was about 350 to 500 mg and had reached as high as 621 mg at 4am, which is about 26 times as high as the 25 mg considered safe by the world health organisation.

2.1.2 *Lead, Zinc and Copper levels in tree barks as indicator of atmospheric pollution.*

Heavy metals are natural components of the environment, but are of concern lately because they are being added to soil, water, and air in increasing amounts. This is because of the rapid growth of population, increased urbanization, expansion of industrial activities, and more. Consequently, as we move towards the end of the twentieth century, anthropogenic emissions of most trace metals now exceed or equal their natural emissions (Biney *et al.,* 1994). As a result, heavy metal pollution now poses a serious threat to the earth atmosphere by putting the natural environment, which forms the life support system of our planet, gravely at risk.

The combustion of fossil fuels and automobile exhaust emission in certain areas are the primary sources of the atmospheric metallic burden (Williamson 1973, Nriagu 1992, Biney *et al.,* 1994) For example, many reports have shown that environmental lead loadings are related to traffic volume and that lead levels in soils and vegetation rise as average daily traffic (ADT) increases (Wheeler and Rolfe 1979, Kapu *et al.,* 1989). A recent report has also confirmed automobiles as a dominant source of air pollution in many cities of Africa (Nriagu, 1992). This is because the lead contents of gasoline sold in African countries are among the highest in the world; typical concentrations of lead in regular fuel fall in the range of 0.5–1.0 g/l (Alliance 1994, Nriagu *et al.* 1996).

The levels of atmospheric trace metallic concentrations has been successfully monitored using different types of biological monitors and vegetation (Garty *et al*., 1977, Onianwa *et al.,* 1986 and Kapu *et al.,* 1991).

The use of vegetation monitors provides the cheapest and simplest indicator for monitoring trace metal levels in the atmosphere; however, trees are preferable to grasses, shrubs, mosses, and food crops (Barnes *et al.,* 1976, Osibanjo and Ajayi 1980) because they are widely distributed and remain in a fixed position over a considerable period of time, thus enabling analysis of trends over time intervals.

Osibanjo and Ajayi (1980) studied the correlation between traffic volume and concentrations of Pb, Zn, and Cu in rain trees (*Samanea Saman*) and other trees species in Ibadan, Nigeria. They concluded that a positive correlation existed between traffic volume and concentration of these metals. In a separate study by Ademoroti (1986), the results of analysis of tree barks in Benin City, Nigeria, confirm the elevated levels of trace metals in the atmosphere. Fatoki and Ayodele (1991) studied the correlation between Zinc and Copper concentrations of barks of ten tree species in the ancient city of Ile-Ife, Nigeria, and traffic volume and came to a similar conclusion. Our study investigated the levels of trace heavy metals in tree barks located near roads in Abeokuta as indicator of atmospheric pollution (Odukoya *et al.,* 2000).

The results are presented in Tables 4 and 5.

Table 4: Average concen tration of lead, copper and zinc at city high traffic and low traffic density sites for Nigerian *Azadirachta indica*

Sample no	Location	Bark features	Lead mean	SD	Copper mean	S.D	Zinc mean	S.D
S1	Lagos road (MIDGAL)	Rough hard and thick do	44.7	3.25	7.3	0.91	575.5	14.46
S2	Lagos Road near L/S feeds	do	159.8	6.15	20.7	0.25	658.1	1270
S27	Alabata junction, Ibadan Road		98.5	1.62	8.,1	0.46	68.4	6.17
S31	Tejumola plaza Adat an	“	35.3	0.84	6.9	0.16	107.5	2.20
S32	Kugba road, elega	“	55.7	1.73	6.5	0.75	141.8	2.67
S3	Neuro-psychiatric hospital Aro	“	42.2	0.87	9.8	0.43	168.6	2.68
S4	Neuro-psychiatric hospital Aro (inside-near the ward)	“	18.0	0.66	9.0	1.26	41.7	0.72
S13	NUD road (beside Atilab pharmacy)	“	13.4	0.43	7.2	0.24	66.5	1.58
S5	N/psy (near maintenance yard)	“	9.7	0.51	8.4	1.05	48.1	2.69
S20	Oke-ilewo (round about)	“	9.6	0.46	5.1	0.15	40.1	0.14
S22++	Layi Balogun Av. Ibara	“	1.9	0.33	4.7	0.67	3.29	3.32

= Dry weight of ug/g sample ** = Mean of three replicate analysis S.D = standard deviation
+= sample from Lagos Road (MIDGAL) ++ = unpolluted reference point.

Table 5: Statistical measurement of lead, copper and zinc contents of bark of Nigerian *Azadirachta Indica* (Dogonyaro) collected from two areas of different traffic density levels

Area	Pb	Cu	Zn
High traffic density sites (6 samples)			
Mean (ug g-1)	72.7	9.9	286.8
Range (ug g-1)	35.3-159.8	6.5-20.7	68.4-659.1
Standard error of the mean S.E.M)	19.7	22	105.9
Low traffic density sites (5 samples)			
Mean (ug g-1)	10.5	6.9	4.9
Range (ug g-1)	1.9-180.0	4.7-9.0	32.9-66.5
Standard error of the mean (S.E.M	2.6	0.86	5.7
T value	2.84	1.17	2.05

Barks of seven species of trees were sampled at 32 locations having different pollution levels in Abeokuta, Nigeria. The concentrations of Pb, Zn, and Cu were determined by atomic absorption spectrometry. The Pb and Zn contents, 1.9–159.8 and 16.5–659.1 $\mu g\ g^{-1}$, dry weight respectively, correlate with traffic volume, indicating pollution from anthropogenic sources. The results obtained for Cu, 4.2–20.7 $\mu g\ g^{-1}$, dry weight, though lower, were still significant but did not show any correlation with traffic density. The study also confirms the suitability of *Azadirachta indica* (Dogoyaro—a very popular local tree) as a suitable bio-indicator of aerial fallout of heavy metals.

The results of the chemical analysis of the bark samples of a popular Nigerian tree, *Azadirachta indica*, Dogoyaro, for Pb, Cu, and Zn at high traffic and low traffic density sites of Abeokuta are presented in Table 4. The results indicate the presence of lead and zinc in high concentrations (and copper in moderate concentrations) in the samples taken from high traffic density sites. For example, tree barks in an area of relatively higher traffic volume such as S_2 (Lagos Road, near L/S Feeds), S_{27} (Alabata junction), S_{32} (kugba road), S_8 (Aiyetoro Road 1), S_9 (Aiyetoro Road 2), S_{13} (Sokenu Road), and S_{16} (Isabo Junction).

This study demonstrates the suitability of the Dogoyaro tree bark as a suitable indicator of environmental pollution particularly in areas where *Terminalia catapa* and Rain Trees (*Samarea Saman*) are not readily available. The Dogoyaro is a very popular local tree of immense value to the local indigenes. The tree barks and leaves are traditionally soaked in water and the concoction made, used in the treatment of malaria. The study also confirms that the medicine made from the barks of Dogoyaro tree contain these heavy metals.

2.1.3 *Influence of environmental degradation on the concentrations of copper, lead and zinc in tissues of grascutter (Thryonomys swinderianus temminck, 1827)*

Wildlife is a valuable source of protein particularly for rural community. However, a large percentage of bushmeat from rural areas is today being sold to urban consumers at prices considered higher than that of beef or muttons. For instance, Amubode and Agossa (1985) reported that about 79,889 kg of wildlife spp were cropped and dressed for protein supply to urban consumers from five locations within a period of nine months. Among these wildlife species, grasscutter constituted more than 25%. Casual observations at bushmeat processing centres in many parts of South-West Nigeria also revealed that grasscutter constituted more than 33% of the species being wet or dry smoked for urban consumers in recent times.

A socio-biological survey of Ogun River Forest Resources in Lagos State, Nigeria (Amubode, *et al.,* 1985) clearly showed that grasscutter is largely harvested from degraded ecosystems and abandoned farmlands. The extent of degraded ecosystems is now on the increase with the creation of more states and local government areas. The resultant environmental pollution of this urbanization or industrialization has great ecotoxicological implications, especially on the resources that are cropped for consumption in such areas. Since wildlife species, particularly grasscutter is consumed as complimentary dietary protein (Frank, 1992), there is need to check the concentration of heavy metals in their tissues as they form part of the food chain in degraded ecosystems.

Heavy metal toxicity have acute, overt or chronic effects depending on retention time in some specific tissues. The toxicity of heavy metals is prone to target organs like kidney, heart, muscles, lungs and oven skin (Stanley, 1989). According to Bryan (1984), tissue concentrations of the heavy metals in general have considerable geographic variations and are also known to provide immune reactions which may result to conjunctions, asthma, urtricaria proteinuria and sometimes the effect may range from glucosuria to aminoaciduria and renal dysfunction.

This study monitored the extent to which wildlife species have been exposed to heavy metal contamination in the Kila area of Odeda Local Government, Ogun State, Nigeria using grasscutter as a case study (Bamgbose *et al.,* 1996).

Box traps were set in degraded habitats located in Kila, Odeda Local Government Areas, Ogun State, Nigeria. The trigger of the traps were initially disengaged for two weeks to enhance mass capture when triggers were subsequently engaged for ten days.
One adult and one juvenile grascutter were collected from University of Agriculture, Abeokuta (UNAAB) domestication unit and sacrificed for muscle, heart, liver and kidney samples. These samples constituted the control. Traps set were visited daily in order to collect catches. The live weight of captured grasscutter was taken before the animal was sacrificed and dissected in the laboratory. Specimen were collected from the kidney, liver heart and muscle and labeled as adults and sub-adult/juvenile, before storage at 20 ^{0}C.

After the traps have been daily visited for ten days and the grasscuter captured have been sampled, the stored specimens were sorted into groups and digested (wet digestion) for minerals according to the AOAC (1986) method of analysis as employed by Adeloju (1989).

Ten grasscutters were captured during the sampling exercise. Out of the 30 box traps baited, only 10 eventually triggered to capture grasscutter. The success rate of capture is therefore 33%. Among the ten captured grasscutters, five (5) were distinct as adult while three (3) were sub-adults and two (2) were juveniles as depicted with the descriptions of Onadeko (1996).

The concentrations of Cu, Pb and Zn in the muscle tissue of replicate analysis from control grasscutter (domesticated) is shown in Table 6. The reproducibility and reliability of the methodology is thus demonstrated to be within an acceptable limit of error (X=Cu: 13.28±0.15; Pb: 4.66±0.41 and Zn: 28.91±0.16).

Table 6: Levels of Cu, Pb and Zn in Macerated Muscle Tissue of Grasscutter

No. of replicate Analysis	Cu	Pb	Zn
1	13.35	4.90	29.72
2	13.19	4.42	29.03
3	13.54	4.65	28.97
4	13.21	4.55	28.78
5	13.48	4.63	29.12
6	13.12	4.75	29.00
7	13.33	4.71	28.88
8	13.10	4.69	29.10
9	13.22	4.51	28.85
10	13.26	4.79	28.65
Mean	13.28±0.15	4.66±0.41	28.91±0.16

Tables 7, 8, 9 and 10 respectively show the mineral concentrations as analysed in the heart, kidney, liver and muscle of the captured grasscutter. For the metal concentrations in the heart (Table 7), the control values were, in all cases, significantly (P<0.01) lower than the values from captured wild grasscutter (T_1–T_5). When means were pooled over the captured grasscutter, the concentration of copper was numerically higher in the adults ($\bar{X}$=25.25±3.26) than the sub -adults/juveniles($\bar{X}$=23.92 +2.67); but not significantly (P>0.0.5). The concentrations of lead ($\bar{X}$=53.69 ±5.33) and zinc (121.25 ±12.15) were higher (P<0.01) in adults than in the sub-adults/juveniles (X=24.59 +0.86mg kg-1). These difference significantly (P<0.01) varied between each other.

Table 8 shows that the metal concentrations in the kidney of grasscutter. The concentrations of metals in the kidney was significantly (P<0.01) higher in captured grasscutter than in the domesticated counterparts. Similarly, the tissues of adult grasscutter contained more minerals than the tissues of sub-adults/juveniles (Cu $\bar{X}$ = 6777.32±5.49 Vs 65.36±5.78; Pb $\bar{X}$ = 123.02 ± Vs 107.86±7.26 and Zn $\bar{X}$=206.27 ±21.89 Vs 178.69 ±16.58mg kg-1). The concentration of Zn, Pb and Cu in the kidney varied)P<0.01) between each other, Zn being the higher ($\bar{X}$+190.98 +3.16mg kg-1) followed by Pb ($\bar{X}$=116.34 ±2.85mg kg-1) and ($\bar{X}$=66.31±1.61mg kg -1).

The concentration of metals in the liver (Table 9) was equally significantly higher in wild captured grasscutter than in the domesticated grasscutter. Again, Zn was most concentrated (X = 134.47 + 7.32 mg kg-1) in the liver, followed by Pb (X = 92.72 +4.12 mg kg^{-1}) and Cu (X = 43.29 + 1.20 mg kg^{-1}).

Metal concentration in the muscle (Table 10) followed the same pattern obtained in the heart, kidney and liver, and the values for domesticated grasscutter was lower than in the wild captured rodent. Irrespective of age group and degree of docility, the muscle contained the least concentrations of the minerals assayed, followed by the heart, liver and kidney in that order.

Table 7: Concentration of Copper, Lead and Zinc (mg kg^{-1}) in the Heart of Grasscutter

	Copper		Lead		Zinc		Length (cm)		Weight (kg)	
Treatment A	**A**	**SB**	**A**	**SB**	**A**	**SB**	**A**	**SB**	**A**	**SB**
C	19.22	19.15	17.54	17.01	21.45	20.71	67.5	42.5	4.10	2.45
T1	30.22	27.82	49.11	44.66	140.52	120.33	69.9	4.7	3.85	2.25
T2	26.14	25.14	62.32	55.43	116.17	101.44	76.2	40.6	.60	3.10
T3	21.45	20.93	51.47	40.15	124.35	99.56	74.4	39.6	4.20	2.35
T4	23.78	22.24	0.38	43.89	110.76	84.48	66.3	40.8	4.40	3.30
T5	24.69	23.45	55.19	50.57	108.47	104.8	66.1	49.8	3.90	2.90
Mean	25.25± 3.26	23.92± 2.67	53.69± 5.33	46.94± 6.03	121.25± 12.15	104.8± 14.77	70.53± 4.61	43.6± 4.45	4.38± 0.29	2.78± 0.15

C = *Control samples*   *A = Adult Grasscutter*
T1-T5 = Trapped Samples   *SB: Sub-adult/Juvenile Grasscutter*

Table 8: Concentration of Copper, Lead and Zinc in the Kidney of Grasscutter (mg kg^{-1})

	Copper		Lead		Zinc	
Treatment A	A	SB	A	SB	A	SB
C	55.56	54.26	22.14	20.18	29.31	27.34
T_1	72.64	70.41	121.52	101.17	215.52	185.51
T_2	61.31	60.88	126.47	116.83	235.15	214.72
T_3	62.52	58.15	128.36	108.33	190.73	170.63
T_4	67.11	65.97	127.77	112.90	210.81	188.45
T_5	73.05	71.41	110.93	100.10	119.15	179.14
$\bar{X}$	67.32±5.49	65.36 ± 5.78	123.02± 7.27	107.86 ± 7.26	206.27 ± 21.89	187.69 ± 16.58

Table 9: Concentration of Copper, Lead and Zinc (mg kg-1) in the Liver of Grasscutter

	Copper		Lead		Zinc	
Treatment A	A	SB	A	SB	A	SB
C	38.43	35.82	17.93	17.73	24.55	25.19
T_1	45.22	46.11	117.84	99.57	150.72	120.12
T_2	47.13	44.76	102.16	82.41	140.13	110.07
T_3	38.77	37.34	85.22	70.22	137.38	108.72
T_4	40.22	38.97	101.58	87.54	139.77	121.43
T_5	47.91	46.45	98.82	81.85	124.55	119.78
$\bar{X}$	43.85 ± 4.13	42.7 ± 4.26	101.12 ± 11.61	84.32 ± 10.62	138.51 ± 9.35	116.02 ± 6.10

Table 10: Concentration of Copper, Lead and Zinc (mg kg^{-1}) in the Muscle of Grasscutter

	Copper		Lead		Zinc	
Treatment A	A	SB	A	SB	A	SB
C	14.01	13.28	4.89	4.66	29.47	28.91
T_1	15.71	14.68	34.54	24.43	84.50	78.47
T_2	17.62	16.36	30.70	22.14	89.17	80.29
T_3	15.78	14.51	26.29	18.19	79.80	72.35
T_4	17.23	51.53	28.88	20.02	79.18	69.45
T_5	19.79	71.81	35.38	30.19	77.25	71.26
$\bar{X}$	17.22 ± 1.67	15.77±1.35	31.19±3.85	22.99±4.65	81.98± 4.82	78.36±4.74

A success rate of 33% was obtained during the grasscutter capture exercise. This rate is lower than that of Amubode, *et al.,* (1985), probably because the grasscutter were initially introduced to the box traps before the capture trigger was set.
The metal concentrations (Cu, Pb and Zn) in the organs (heart, liver, kidney and muscle) of captured grasscutters were generally higher than the control values from domesticated grasscutter. This observation agrees with the reports of Johnson and Roberts (1978) on metal concentration in tissues of small mammals from polluted environments and the report of Anderson and Barett (1982) on meadow wolves, from sewage. Contamination of various organs of Nigeria wildlife species was demonstrated by Osibanjo and Jinadu (1989) by the occurrence of relative amounts of organochlorine pesticides.

A consistent trend of metal elevation in kidney and generally in the grass-cutter followed in the order liver>heart> muscle is in line with the report of Johnson and Roberts (1978) on the distribution of lead, zinc and copper in small mammals from polluted environments. Dietary sources were confirmed to be responsible for tissue metal elevation. The adult animals recorded higher concentrations of metals than sub-adults/juveniles suggesting that there is a buildup of metal in the body tissues with advancing age.
It turns out that the large-sized wild animals are the most favoured as bush meat. In fact, juveniles are hardly displayed for sales in the bushmeat processing centres since juveniles have no high market demand and prices are not attractive.

In terms of edibility of grass-cutter sample and its tissue metal concentrations, the levels of the metals were found lower than the permissible concentration recommended by the World Health Organisation, (1990) in particular for the muscle tissue (Wright, 1986). However, for the organs (heart, kidney and liver), even though heavy metal concentrations were within the permissible levels, the levels are high enough to warrant caution from consumers.

The results and discussion from this study indicate that wildlife species are not an exception to pollution effects. The muscle tissue is the least contaminated of the various organs analysed. There was increase in metal concentration from juvenile/sub-adult grass-cutter to the adult grass-cutter with a trend of increases following the order of Kidney> Liver. Heart >Muscle.

Heavy metals in tissues had higher concentrations in animals that were captured from the natural range than from domesticated grass-cutter under laboratory conditions of controlled diet. All these affirm that dietary sources are responsible for tissue heavy metal concentration

2.2 Footprints in the Hydrosphere

2.2.1 Galeoides decadatylus: A bio-indicator for the Nigerian Marine Environment.

The major advantages of the use of fish as biological indicator to monitor marine pollution are its direct measurement of the amount of a specific pollutant present in the marine environment and its time integration of the ambient pollution conditions at the site of collection. There is now a considerable body of evidence to suggest that some form of equilibrium exists between the levels of Chlorinated hydrocarbons (CHC) in marine water and that in marine fish. It has been reported that relationship exist between fish length, weight and pesticide concentration. Similarly positive relationship between age of fish and size, along with differences in concentration of pesticides levels between species being ascribed to differences in fat weight.

As at the time of this study no fish species had been proposed as a bio-indicator for the Nigerian marine environment with regards to monitoring of chlorinated hydrocarbons. This study was based on an earlier report by Osibanjo and Bamgbose (1990). A total of 25 samples of Galeoides decadactylus was used for the study Bamgbose *et al.,* (1993). The results for the correlation of Chlorinated Hydrocarbon Levels with Fish Weight, Fish Length and Fish Fat of Some Nigerian Fish Species analysed in this study is presented in Table 11, while Table 12 shows the concentration range and mean of the Chlorinated Hydrocarbon levels in the Fish Samples.

Table 11: Correlation of Chlorinated Hydrocarbon Levels with Fish Weight, Fish Length and Fish Fat of Some Nigerian Fish Species

Species	Correlation parameters	Weight of fish	Length of fish	Fat weight	HCB	Lidane	Heptachlor	Aldrin	DDT	PCB
Brachydeuterus auritus	FW	0.85	0.39	-0.55	-0.33	-	-	0.33	0.31	0.49
	FL	0.85	0.04	-0.67	-0.58	-	-	0.02	0.19	0.17
	FF	0.39	0.04	0.15	0.14	-	-	0.36	0.76	0.67
Vomer setapinnis	FW	0.87	0.98	0.52	0.44	-		0.77	0.93	0.93
	FL	0.97		0.89	0.76	0.61	-	0.62	0.89	0.91
	FF	0.98	0.89		0.45	0.43	-	0.73	0.87	0.88
Galeoides decadactylus	FW		0.92	0.98	0.79	0.96	0.83	-	0.91	0.86
	FL	0.92		0.90	0.59	0.93	0.58	-	0.82	0.68
	FF	0.98	0.90		0.80	0.95	0.89	-	0.96	0.91
Pseudotolytus senegalensis	FW		0.97	0.45	0.39	0.81	-	0.93	0.46	0.44
	FL	0.97		0.11	0.01	0.33	-	0.88	0.03	-0.05
	FF	0.45	0.11		0.22	0.17	-	0.74	0.71	0.66
Cynoglossus senegalensis	FW		0.92	0.88	-0.25	-0.52	0.74	0.71	0.64	-0.38
	FL	0.92		0.70	0.11	0.41	0.63	0.52	0.46	-0.08
	FF	0.88	0.70		-0.43	-0.37	-0.09	0.89	0.41	-0.59
Trichiurus lepturus	FW		0.49	0.49	-0.40	-0.88	-0.22	0.47	0.71	0.60
	FL	0.97		0.32	-0.25	-0.99	0.02	0.64	0.88	0.68
	FF	0.32	0.49		0.47	0.11	0.63	0.49	-0.06	0.29
Pomadasys jubelini	FW		0.99	0.95	0.76	0.81	0.75	-0.67	0.02	0.74
	FL	0.99		0.97	0.79	0.85	0.78	-0.17	0.03	0.71
	FF	0.95	0.97		0.92	0.93	0.92	-0.14	0.19	0.78
Ethmalosa fimbriata	FW		0.99	0.39	0.88	0.67	-	0.82	0.81	0.79
	FL	0.99		0.48	0.92	0.74	-	0.75	0.86	0.84
	FF	0.39	0.48		0.68	0.93	-	-0.16	0.86	0.86

FW = weight of fish; FL = length of fish; FF = fish fat; - = Non-detectable

It was observed that a positive correlation existed between fish weight (FW) and pesticide concentrated (FC)
For all the fish samples analysed Hexaclorobenzene (HCB), Lindane Heptachlor, Total dichlorodiphenyl tricloro ethane (ΣDDT) and Polychlorinatedbiphenyl (PCB) were detected

Table 12: Concentration Range and Mean of the Chlorinated Hydrocarbon Levels in Fish Samples in 1983 1985 Concentration (ng g-1)

Chlorinated Hydrocarbon	Range	1983 Mean	Range	1984 Mean	Range	1985 Mean
HCB	0.035-2.40	0.70	0.029-1.44	0.34	0.15-9.48	2.31
Lindane	0.089-4.76	0.93	ND-4.56	0.39	0.07-5.3	1.77
Heptachlor	ND-5.62	1.58	ND-3.06	0.20	ND-21.4	3.60
Aldrin	ND		0.045-54.60	3.99	ND-20.0	1.66
Endosulphan	ND-4.95	0.54		ND	ND-3.39	0.34
DDEpp	0.132-7.45	2.76	0.449-14.7	4.06	0.50-16.7	4.35
DDDop	ND-0.20	0.04		ND		ND
DDDpp	ND-1.05	0.38		ND		ND
? DDT	0.145-8.19	3.04	0.49-16.17	4.47	0.55-18.37	4.78
PCB	11-150	54.65	11.1-97.7	25.53	15.1-225	68.84

In all cases, the levels of chlorinated hydrocarbons indicated contamination of the fish samples and the capacity of the fish species to tolerate high levels of contamination, thereby satisfying one of the most important attribute for an organism to act as a biological indicator of marine pollutants i.e the organism should accumulate the pollutant without being killed by these levels encountered in the environment.

In conclusion, the fish *Galeoides decadactylus* was found to concentrate the CHC at contamination level, showing a high level of tolerance for the residues and as such meeting the conditions for a bio-indicator as shown in the Table 13

Table 13:-Fish Species, Feeding Habits, Highest and Lowest Concentration of Chlorinated Hydrocarbons in Nigerian Marine Fishes, 1983-1985

	Highest Level of Residue			Lowest Level of Residue		
	Concentration Feeding ($ng\ g^{-1}$)	Species	Feeding Habit	Concentration ($ng\ g^{-1}$)	Species	sFeeding Habit
HCB	9.15	*Galeoides decaductylus*	NP	0.03	*Pseudotolythus senegalensis*	NP
Lindane	5.3	*Caranx senegallus*	P	0.02	*Rhinobatus rhinbatus*	ZP
Heptachlor	21.4	*Galeoides decadactylus*	NP	0.05	*Psettodes belcheri*	ZP
Aldrin	54.6	*Pseudotolythus senegalensis*	NP	0.05	*Psettodes belcheri*	ZP
DDT	18.6	*Caranx*	P	0.5	*Aurius heudeloti*	ZP
PCB	225	*Galeoides decadactylus*	NP	4.8	*Aurius heudeloti*	NP

P = Piscivore, NP = Non -piscivore, PP = Phytoplankton, ZP = Zooplankton

The fish weight and fish length (FL), fish weight (FW) and fish fat (FF), fish length and fish fat all gave positive correlation coefficients. Similarly these parameters (FL, FW and FF) also gave positive correlation with the concentration of the CHC. As a result of these relationships the fish species Galeiodes decadactylus was presented to serve as a bio-indicator for monitoring chlorinated hydrocarbons in the Nigeria marine environment.

2.2.2 Levels of polyaromaic hydrocarbon in borehole water of selected settlements in the coastal area of Ondo State Nigeria

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic compounds with two or more fused aromatic rings. They have a relatively low solubility in water, but are highly lipophilic. PAHs can leach from soil into water. Water contamination also occurs from industrial effluents and accidental spills during oil shipment at sea. Groundwater sources of PAH contamination could also be from seepages from waste disposal sites, oil spills, surface and underground storage tank leakages, agro activities, effluents discharges, and deliberate dumping (Ogbuagu *et al.,* 2011). Contaminated groundwater sources pose potential risk to the local water consumers as well as the natural environment (Ritter *et al.,* 2002).

The environmentally significant PAHs are those molecules that contain 2 to 7 benzene rings. PAHs are divided into two groups based on their physical, chemical, and biological characteristics (Martinez *et al.,* 2004). The lower-molecular-weight (LMW) PAHs, for example, 2 to 3 rings of PAHs such as naphthalenes, fluorences, phenanthrenes, and anthracenes, have significant acute toxicity to aquatic organisms. The high-molecular-weight (HMW) PAHs, containing 4 to 7 rings, from chrysenes to coronenes, do not cause acute toxicity but are known to be carcinogenic (Neff, 1979).

Oil exploration in the Niger-Delta region of Nigeria since mid-20th century has brought about environmental degradation to this region. Few people arc fully aware of their daily dependence upon crude oil. Awareness is growing as the fragilities of modern civilization, stemming from population growth and economic expansion become recognizable not only as world and national problem but also as personal problem. However, as human dependency on crude-oil increases the dangers that accompanied it also increases. During the transportation of crude oil through tankers and pipelines, oil spills occur and can cause greater ecological damage (Burgherr, 2007). Non availability of potable water to settlements necessitates heavy reliance on rivers for domestic, agricultural or recreational purposes.

The study areas are oil producing towns of Ondo State in southern

Nigeria. The rivers in the study area empty into the Atlantic Ocean and to some other parts of the country. The river is known for sea foods (Ololade *et al.,* 2008) which mean that its pollution may have national and global health effects. It is against this suspicion and for the non-existence of research on the possible contamination of the groundwater aquifer of this area that the current investigation was conducted with objectives aimed at the determination of the presence and levels, and spatial variations of some PAHs in borehole water sources of the coastal areas of Ondo state (Terebo *et al.,* 2022)

The study areas comprise mainly selected communities in Ilaje and Ese-Odo Local Government Areas of Ondo State, comprises of thirty towns, which were divided into four districts as shown in Table 14.

Table 14: Ilaje and Ese-Odo Coasted communities divided into districts

DISTRICT 1	DISTRICT 1I	DISTRICT 1II	DISTRICT 1V
Akure Water work	Awoyre (AWY 1)	Etikan (ETK II)	Ojuala (JLP)
Ondo Water work	Ayetoro (AYT)	Etikan II (ETK 2)	Ugbotu-Zion (GTZ)
Ilesha Water works	Ikorigho (KRG)	Igbokoda (GBN)	Ugbotu Bolorunduro (GTB)
Owena-Ondo	Ilowo (ILW)	Ilara (ILR)	Igbobini (GK)
Owena-Ilesa	Ilepete (LPT)	Ipare (IBR)	Igbekebo –Okolo (GKO)
	Jinrinwo (GRW)	Mahin (MHN)	Igbekebo –Okolo Pekagba (GKO)
	Eninma (ERN)	Okoga (OG)	Sabomi I (SBM)
	Obe- Rewoye (ABR)	Palm village (PLV)	Sabomi II (SBM 2)
	Obe-Rebiminu (AWY 2)	Salen Quarter (SLQ)	Kiribo I (KRB 1)
	Obe-Nla (OBN)		Kiribi II (KRB 2)
	Ugbonla (UGB)		

The results of the thirty boreholes waters sampled within the selected communities of the coastal area are presented for the dry season in Table 15 and for the raining season in Table 16. Samples for PAH analysis were collected in amber bottles in each season of rain and dry respectively. Again, samples were taken from three different urban water supply schemes (water works) which include Owena-Ondo, Owena-Ilesa and Alagbaka-Akure as District I to serve as control, a total of two hundred and sixty four samples were taken each season in all the communities of the study area.

Table 15: Seasonal mean values of Poly Aromatic Hydrocarbon (PAHs) in borehole waters in the Coastal Areas of Ondo State during the Dry Season.

PAH (mg/L) Congeners	WET				
Districts	I	II	III	IV	Mean±S.E
Naphthalene	BDL	BDL	0.03±0.02	BDL	0.01±0.00
Acenaphthalene	0.61±0.04[a]	BDL	BDL	0.13 0.02	0.10±0.06
Acenaphthene	0.74±0.32[a]	0.42±0.07[b]	0.33±0.10[b]	0.23 0.07[b]	0.36±0.05
Flourene	6.25±1.24[a]	0.20±0.01[b]	0.07±0.04[b]	0.5±0.03[b]	0.61±0.45
Anthracene	26.64±2.32[a]	0.20±0.08[b]	0.21±0.16[b]	7.06±2.64[b]	4.89±0.31
Phenanthrene	1.03±0.03a	0.09±0.05[b]	0.22±0.02[a]	0.72±0.32[a]	0.42±0.14
Flouranthen	0.23±0.01[a]	0.01±0.01[b]	0.26±0.01[a]	0.14±0.02[a]	0.14±0.008
Pyrne	BDL	0.02±0.02[a]	0.25±0.01[a]	0.09±0.01[a]	0.14±0.09
Benzo (a) anthracene	3.52±0.24[a]	0.01±0.01[c]	0.57±0.05[a]	0.22±0.02[b]	0.55±0.30
Chrysene	8.81±0.82	10.11±0.00[a]	2.95±1.39[a]	3.00±0.21[b]	5.67±1.71

A PAH standard mixture containing 500 ppm each of fluoranthene, pyrenc, benzo (a) anthracene, chrysene, benzo (b) fluoranthene, and benzo (k) fluoranthene was added to the samples before extraction and used as internal standard. Stock solutions were used to prepare working standard solutions for calibration.
PAHs in borehole water samples were extracted according to the method of USEPA 3630C

The concentrations and descriptive statistics of the occurrence of 16 congeners of PAHs analysed in this study showed that borehole water samples in the Coastal area of Ondo state, Nigeria contain relatively low amount of PAH. During the wet and dry seasons, the mean concentrations of Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Anthraccne, Phenanthrene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)flouranthene, Benzo(a)pyrene, Dibenzo(a,h)anthrancene, Benzo (g,h,i) pyrenlene and Indeno (1,2,3) pyrene are as presented in Table 16.

Table 16: Seasonal mean values of Poly Aromatic Hydrocarbon (PAHs) in borehole waters in the Coastal Areas of Ondo State during the Raining Season.

PAH (mg/L) Congeners	WET				
Districts	I	II	III	IV	Mean±S.E
Naphthalene	BDL	BDL	0.03±0.02	BDL	0.01±0.01
Acenaphthalene	0.65±0.45	BDL	BDL	BDL	0.06±0.05
Acenaphthene	0.74±0.32[a]	0.39±0.07[b]	0.33±0.10[b]	BDL	0.35±0.05
Flourene	6.25±4.24[a]	0.03±0.01[b]	0.07±0.04[b]	0.21±0.08[b]	0.61±0.45
Anthracene	26.64±3.35[a]	0.18±0.08[b]	0.21±0.17[b]	0.05±0.03[b]	2.66±0.23
Phenanthrene	1.03±0.10[a]	0.20±0.11[b]	0.22±0.12[b]	0.37±0.02[b]	0.36±0.12
Flouranthen	0.23±0.03[a]	0.01±0.01[b]	0.26±0.03[a]	0.45±0.22[b]	0.14±0.08
Pyrne	0.02±0.00[a]	0.02±0.00[a]	0.25±0.02[a]	0.14±0.01[a]	0.14±0.08
Benzo (a) anthracene	3.35±0.25[a]	0.18±0.02[b]	0.57±0.06[a]	0.19±0.02[a]	0.53±0.29
Chrysene	8.81±0.83[a]	7.17±3.85[a]	2.95±1.39[a]	0.01±0.00[b]	7.77±1.54
Benzo (b) fluoranthene	37.01±1.45	0.48±0.04[b]	1.71±0.12[b]	3.01±0.21[b]	4.22±0.32
Benzo (k) fluoranthene	0.64±0.39[a]	0.99±0.17[a]	0.94±0.03[a]	0.71±0.05[b]	0.88±0.132
Benzo (a) pyrene	0.64±0.40	BDL	BDL	0.80±0.03[a]	0.06±0.04
Dibenzo (a,h) anthracene	19.82±11.27	0.15±0.02[b]	BDL	BDL	1.85±1.31
Benzo (g,h,i) perylene	0.03±0.00	BDL	BDL	BDL	0.002±0.00
Indeno (1,2,3-cd) pyrene	0.35±0.03[a]	BDL	0.002±0.00	BDL	0.004±0.00

The concentrations were below detection limit in some districts during the study. It can be seen that 16 out of the 16 target US EPA priority PAT-I compounds reported in this study were frequently detected in all the borehole water samples including the control samples. There were significant ($p<0.05$) differences in the concentrations of PAHs such as Acenaphthene, Fluorene, Anthracene, Phenanthrene, Pyrene, Benzo(a)anthracene, Chrysene, Dibenzo(a,h)anthracene and Indeno(1,2,3,cd)pyrene in the waters from the borehole in the coastal districts during wet season. These concentrations were significantly ($p<0.05$) higher in District I than all others during wet season. In general, the low molecular weight PAHs (LMW: 2-and 3-ring PAHs) were less dominant, accounting in some cases for as low as 2% of the total PAHs. This trend contrasted the results reported by Farooq et al., (2011) and Thavamani *et al.,* (2012), both reported that molecular weight PAHs (LMW: 2- and 3-ring PAHs) were dominant, accounting in some cases for as high as 90% of the total PAHs, for surface water samples from Greece, where Naphthalene and Phenanthrene accounted for 82% of the total PAHs. However, the low molecular weight PAHs such as Naphthalene, Fluorene, Anthrancen and Phenanthrene are toxic to aquatic organisms while the high molecular weight PAHs such as Chrysene, Benzo(b)fouran

are not, though known to be carcinogenic (Fang *et al.,* 2014; Khairy *et al.*, 2014; Griffith *et.al.,* 2015). High significant values reported in District I, control samples (urban water supply schemes) might be due to elevated concentrations in drinking water due to coal-tar lined pipes (Davi *et al.,* 1994).
Reporting on district basis, study showed that Naphthalene, Benzo (a) pyrene and Benzo (g,h,i) perylene were not detected in Districts II and IV in wet season. Significant ($p<0.05$) differences in the concentrations of Anthracene, Benzo (b) fuoran and Dibenzo(a,h)ant: 26.64±12.35 mg/L and 26.64±2.32 mg/L, 37.01±1.45 mg/L and 37.01±3.14 mg/L as well as l9.82±11.27 mg/L and 19.83±1.27 mg/L were observed in District I in both seasons.

Similar trend of PAHs distribution in borehole water was observed in both seasons with few exceptions in District IV for Anthracene (0.37±0.02 mg/L and 7.06±2.64 mg/L), Benzo (b) fuoran (0.71±0.05 mg/L and 9.79±0.90 mg/L), Beuzo (a) pyrene (0.00±0.00 mg/L and0.09±0.01 mg/L) and Dibenzo (a,h) ant (0.00±0.00 mg/L and 3.55±0.24 mg/L) for wet and dry seasons respectively. The PAH concentrations were significantly ($p<0.05$) higher in District I than all others during wet season and also for the PAHs Acenaphthene, Fluorene, Pyrene, Benzo (a) anthrac, Chrysene and Dibenzo (a,h) in District I were excessively higher than those recorded for other districts in dry season for the coastal area of Ondo State.

The results of PAHs congeners of the borehole water samples were within the WHO permissible levels with the exception of anthracene, acenaphthene, fluorine, anthracenc, chrysene, benzo(b)fuoran, dibenzo(a,h) anthracene all found in District 1 in both seasons. The results of all PAHs congeners showed no significant difference within the season except for pyrene.

2.2.3 Pollution Load of Heavy Metals in Ilupeju, Ikeja and Isolo Industrial Wastewaters and Seasonal Impacts on Quality of Water Downstream and Upstream in Lagos Metropolis

Occurrence of heavy metals in waters and biota usually indicate the presence of natural and anthropogenic sources (Papafilippaki *et al.,* 2008). The existence of heavy metals in aquatic environments has led to serious concerns about their influence on plant and animal life. Some metals such as copper, zinc and iron are biochemically classified as essential elements. Their presence in trace amounts play an important role in different physiological processes of living organisms.
All heavy metals exist in surface waters in particulate, colloidal and dissolved phases. Rivers are a dominant pathway for metals transport and this was the reason trace metals were regarded as significant pollutants of even some small riverine systems (Ipinmoroti *et al.,* 1997). Extent of mixing with water current, dilution factor, direction of water flow, synergistic effect of heavy metals and rapid industrialization are known factors that contributed to high levels of metal in water (Al-Sarawi *et al.,* 2002). The aggravated levels of metals in industrial wastes are often toxic and could persist in the environment for a long time because of slow degradation thus causing hazards to human health, living organisms and ecosystem (Hugh, 2006)

In Lagos with teeming population and diverse industrialization, levels of heavy metals in industrial wastewaters can be affected by seasonal changes. This study thus determines the impact of industrial wastewaters on upstream and downstream water quality as season changes. The choice of these three industrial areas was necessary by reason of size and diversity of industries releasing copious wastewaters into proximate streams thus causing changes in water quality. Regular assessment is necessary to check uncontrolled release from the industries and assess the performance of regulatory and supervisory bodies.

The study conducted by Akintunde and Bamgbose (2020) was in three major industrial areas of Lagos city namely: Ikeja, Ilupeju and Isolo industrial areas. Composite sample of industrial wastewater with river water at the point of discharge into the river (WMS) was collected. Composite samples of water upstream (WUS) and water downstream (WDS) were also taken at any sampling site the set of samples was used to determine heavy-metals (HMu, HMm, HMd). The samples were filtered and the filtrate treated with 3ml 1:1 HNO per litre in order to keep the metal ions in solution before analysis. The fifth set of samples was used to determine other physico-chemical parameters (OPMu, OPMm, OPMd).

Heavy metals analysis was carried out by Atomic Absorption Spectrophotometer (Perkins Elmer Model 2380). The results for the various industrial zones with respect to mean composition of heavy metals at the point of effluents discharge into waterways for Ikeja Industrial Zone is presented in Table 17, For Ilupeju in Table 18 and for Isolo industrial zone in Table 18. While Upstream and Downstream water quality parameters for the second year of sampling for Ikeja (Table 20), Ilupeju (Table 21) and Isolo (Table 22)

Table 17. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterwaysin waterways in Ikeja Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p=0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P=0.05 Ind. T-test
Cr (mg/L)	0.71±0.01	0.77±0.03	0.94	0.25±0.02	0.25±0.01	0.99
Mn (mg/L)	0.15±0.04	0.40±0.06	0.01*	2.62±0.03	0.91±0.04	0.43
Fe (mg/L)	0.92±0.06	0.64±0.03	0.31	6.23±0.31	10.23±0.10	0.34
Cu (mg/L)	0.78±0.03	0.69±0.09	0.75	0.08±0.01	0.06±0.02	0.31
Zn (mg/L)	0.75±0.03	0.28±0.08	0.26	2.54±0.05	1.76±0.06	0.70
Cd (mg/L)	0.02±0.01	0.50±0.05	0.50	0.01±0.01	0.14±0.01	0.47
Pb (mg/L)	ND	0.09±0.01	ND	0.16±0.02	ND	ND

Table 18. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterways in Ilupeju Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p=0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P=0.05 Ind. T-test
Cr (mg/L)	0.50±0.06	0.65±0.08	0.76	0.20±0.01	0.13±0.06	0.79
Mn (mg/L)	0.14±0.04	0.84±0.01	0.21	0.57±0.05	0.20±0.01	0.60
Fe (mg/L)	0.76±0.07	0.93±0.05	0.74	3.45±0.03	2.97±0.04	0.88
Cu (mg/L)	1.62±0.08	0.56±0.04	0.33	0.38±0.01	0.41±0.03	0.93
Zn (mg/L)	1.53±0.02	0.43±0.01	0.25	2.32±0.07	1.77±0.03	0.75
Cd (mg/L)	0.01±0.01	0.16±0.09	0.38	0.01±0.01	0.21±0.06	0.64
Pb (mg/L)	ND	0.18±0.01	-	0.24±0.01	ND	-

Table 19. Seasonal Mean composition of heavy metals at the point of effluents discharge into waterwaysin Isolo Industrial Zone (mean ± SD) n=3

Parameters	[1]Dry Season	[1]Rainy Season	p=0.05 Ind. T – test	[2]Dry Season	[2]Rainy Season	P=0.05 Ind. T-test
Cr (mg/L)	1.63±0.04	0.86±0.05	0.37	0.26±0.01	0.13±0.05	0.64
Mn (mg/L)	ND	5.65±0.06	-	6.37±0.08	0.85±0.09	0.42
Fe (mg/L)	0.81±0.05	0.98±0.06	0.60	3.62±0.03	4.02±0.01	0.87
Cu (mg/L)	0.53±0.03	1.37±0.02	0.13	0.26±0.05	0.07±0.02	0.39
Zn (mg/L)	0.41±0.07	0.35±0.05	0.55	2.41±0.50	1.70±0.42	0.73
Cd (mg/L)	ND	0.24±0.03	-	0.00±0.00	0.21±0.06	0.39

Note: * Independent T-test is significant at the 0.05 level (2-tailed)
[1,2]First and second year mean concentration ND: Not Detected

Manganese was not detected in the dry season of the first year of sampling in Isolo industrial zone. Evidence of significance difference (P=0.05) observed in the first year of sampling in Ikeja industrial zone showed seasonal variation. This might be accounted for by the mobility and effect of dilution during rainy season.. Higher levels of manganese at downstream point caused by effluents discharged into water ways reported in the literature corroborated findings from this study (Gasparon, and Burgess 2000).

Higher level of Iron (Fe) was observed in the rainy than dry season at the point of industrial wastewater discharge into the waterways. In the rainy season, the level of iron fluctuated from 6.23 ± 0.31

mg/L to 10.23 ± 0.10 mg/L in Ikeja; 2.97 ± 0.04 mg/L to 3.45 ± 0.03 mg/L in Ilupeju and 3.62 ± 0.03 mg/L to 4.02 ± 0.01 mg/L in Isolo industrial zones. The higher levels in the· rainy season might be attributed to iron salts in wastewater from iron and steel industries aided by water flow.

The variations of mean concentration of copper between seasons and across zones displayed some peculiarities. The low concentration at the point of wastewater discharge into the water bodies in wet seasons was in contrast with some findings in the literature (Massoud 2004)

The higher zinc concentration in the dry seasons than rainy season might be due to low dissolution of zinc as a result of water temperature. Papafilippaki *et al.,* (2008) reported the concentration of some heavy metals in dry and wet seasons. They observed that zinc levels were significantly higher in warm period than cold period due to change in river flow and water temperature.

At the point of wastewater impact with river, cadmium was estimated in lower concentration than other heavy metals. The concentration range in the three industrial zones lies between 0.0lmg/L and 0.50 mg/L which might arise from industrial and domestic activities. In support of this finding, similar study reported cadmium concentration range between 0.01 mg/L and 0.69 mg/L (Rani and AbdulAhmed, 2005) Though there was no significant difference in cadmium concentration at this point, its concentrations were generally higher in rainy than dry seasons for all industrial zones.

Slight concentration of lead was detected in the rainy seasons and dry seasons of Ikeja and Ilupeju zones in the first and second year of sampling respectively. The concentration of Lead at the point of industrial wastewater impact with water bodies range between

0.09 ± 0.01 mg/L and 0.16 ± 0.02 mg/L in Ikeja, 0.18 ± 0.01 mg/L and 0.24 ± 0.11 mg/L in Ilupeju zones. This could be attributed to some domestic and commercial activities.

Table 20. Upstream and Downstream water quality parameters for Ikeja Industrial zone in the second year of sampling (Mean ± SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO recommended limit
	IKJu	IKJd	IKJu	IKJd	
Cr (mg/L)	0.20±0.07	0.31±0.08	0.24±0.01	0.25±0.01	0.05
Mn (mg/L)	0.99±0.01	4.06±0.09	0.66±0.04	0.81±0.02	0.1
Fe (mg/L)	4.64±0.85	5.70±0.26	8.95±0.18	8.96±0.88	0.3
Cu (mg/L)	0.21±0.02	0.05±0.03	0.05±0.02	0.04±0.02	1.0
Zn (mg/L)	1.68±0.24	2.62±0.49	1.68±0.02	1.39±0.01	5.0
Cd (mg/L)	0.01±0.01	0.25±0.02	0.20±0.05	0.14±0.01	0.05
Pb (mg/L)	0.18±0.01	0.18±0.02	ND	ND	0.06

Table 21. Upstream and Downstream water quality parameters for Ilupeju Industrial zone in the second year of year of sampling (Mean±SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO Recommended LimitILPu
	ILPd	ILPu	ILPd		
Water Quality Parameters	Dry Season		Rainy Season		WHO Recommended Limit
	ILPu	ILPd	ILPu	ILPd	
Cr (mg/L)	0.27±0.05	0.29±0.09	0.12±0.06	0.12±0.05	0.05
Mn (mg/L)	1.66±0.22	1.15±0.89	0.20±0.01	0.40±0.07	0.1
Fe (mg/L)	6.94±0.08	4.66±0.81	1.40±0.17	15.94±1.56	0.3
Cu (mg/L)	0.12±0.08	0.48±0.02	0.13±0.06	0.10±0.02	1.0
Zn (mg/L)	2.05±0.60	2.43±0.06	2.17±0.09	2.52±0.07	5.0
Cd (mg/L)	0.05±0.02	0.01±0.01	0.21±0.04	0.20±0.05	0.05
Pb (mg/L)	0.09±0.04	0.29±0.01	ND	ND	0.06

Table 22. Upstream and Downstream water quality parameters for Isolo Industrial zone in the second year of sampling (Mean ± SD) n=3

Water Quality Parameters	Dry Season		Rainy Season		WHO
	ISLu	ISLd	ISLu	ISLd	Recommended Limit
Cr (mg/L)	0.26±0.06	0.21±0.02	0.13±0.04	0.13±0.03	0.05
Mn (mg/L)	6.75±0.73	4.57±0.70	0.90±0.04	0.46±0.01	0.1
Fe (mg/L)	4.89±0.16	3.63±0.65	9.10±0.64	4.98±0.76	0.3
Cu (mg/L)	0.05±0.02	0.05±0.01	0.07±0.01	0.06±0.02	1.0
Zn (mg/L)	2.59±0.06	2.64±0.09	1.95±0.07	1.37±0.04	5.0
Cd (mg/L)	0.01±0.01	0.01±0.00	0.20±0.06	0.20±0.06	0.05
Pb (mg/L)	0.08±0.04	0.18±0.01	ND	ND	0.06

In both dry and rainy seasons, across the industrial zones, the concentration range of Chromium (Cr) from water samples taken upstream was between 0.12 ± 0.06 mg/L and 1.41 ± 0.35 mg/L. This exceeded the internationally recommended desirable levels of 0.05mg/L for drinking water. Higher level of chromium in water upstream than the recommended value has been reported in support of this finding (Ali, 2004) More downstream accumulation of chromium was observed in the dry than rainy seasons of Ikeja and Ilupeju except Isolo industrial zone. This could be explained on the basis of low solubility of heavy metals as a result of less dilution of water and warm temperature. An average concentration of 3.25 mg/L chromium in warm dry and 1.44 mg/L in cold wet seasons reported was in harmony with this study. Although, chromium (III) compounds are less damaging to the health due to their limited absorption (4%) by the body, but chromium (IV) compounds are actually poisonous. When in contact with the skin, it could trigger dermatitis, allergies and irritations, thus considered carcinogenic to humans (Oniye et al., 2005).

The levels of zinc at all points of sampling were below (5.0 mg/L) the highest permissible level for drinking water. Although, this level may not pose immediate visible danger, however, when it accumulates, it becomes problematic to aquatic ecosystem

(Ogunfowokan et al., 2005).
In effect, concentration of zinc tended to accumulate downstream during dry season especially in the second year sampling. The considerable levels of zinc observed in water upstream especially in Ikeja industrial zone might be attributed to impact of nearby Olusosun landfill. According to the findings, zinc was reported as the most predominant metal in the Olusosun landfill which have tendency of leaching to nearby stream and enhancing its concentration downstream (Ogundiran and Afolabi, 2008).

Upstream and downstream levels of lead showed similar trend in seasonal variation. The levels were above the permissible level in water. Concentration of lead in water above permissible limit has been reported in the literature (Nicolau *et al.,* 2006).

However, in support of these findings, high concentration of lead upstream in the range of 0.32 ± 0.04 mg/L due to domestic activities has also been reported elsewhere (Papafilippaki *et al.,* 2008). Downstream, concentration of lead has been reported in a similar study (Dike *et al.,* 2004). They reported that the concentration was due to lead battery -based units and heavy vehicular transaction used for industrial activities. Direct use of untreated water for drinking by downstream dwellers could be detrimental to health. It has been reported that neurological damage of fetuses; abortion and other complications in children less than three years of age were major health hazards of lead (Yadav, 2006).

Lead was not detected at all in Isolo industrial zone and some seasons of Ikeja and Ilupeju zones. This might be due to absence of Pb producing industries and reduced impact of vehicular transaction to the industries. Similarly, complexation ability of Lead might reduce its availability in elemental form for detection.

In conclusion, for both seasons, there were high levels of heavy metals in discharged industrial wastewaters from all the industrial areas, however only manganese level showed seasonal impact in Ikeja. Higher levels at downstream than upstream showed that industrial wastewater was responsible for high impact on water quality. All heavy metals were higher at upstream and downstream than WHO permissible level which may limit their use for drinking and routine purposes. Thus regular assessment and seasonal treatment are required. Also, combined treatment is necessary at the points where wastewater discharges into the river.

2.3 Footprints in the Lithosphere

3.1 Phytoremediation of lead contaminated soil using Amaranthus cruentus.

Nigeria being one of the developing countries, farming is not zoned to a particular area in the cities. Individuals particularly those from low socio-economic status, farm on available land space to augment family income. Arising from the developmental pressure on limited land space in most urban areas, it has become a common practice to utilize lands previously used as dumpsites for crop production. These lands are usually cleared and connected to agrarian fields for the cultivation of crops such as vegetables, cereals and fruits without prior reclamation procedure. The detection of heavy metals such as Mn, Cu, Cd, N, Cr and Pb in soils and weeds found close to dumpsites in Nigeria and as reported by various researchers (Bamgbose *et al.,* 2000, Ebong *et al.,* 2007 and Uba *et al.,* 2008) suggest that heavy metals from this type of land use has the potential for their accumulation in food crops tissue. Conventional clean-up technology is generally expensive and after, harmful to desirable soil properties such as texture and organic matter for the restoration of contaminated sites. Phytoextraction and phytoremediation is the use of plants to remove contaminants from soil by accumulation in plant tissue and this a promising clean up technology for a variety of metal containing soil (Fuhrmann *et al.,* 2002, Lasat, 2002). In the phytoremediating process, several sequential crops of selected plants species can be cultivated to reduce the concentration of heavy metals in contaminated soil to environmentally acceptable levels (Zhen *et al.,* 2002). Vegetables have been found to absorb heavy metals from the soil as well as from surface deposits on part of vegetables exposed to polluted air (Yusuf *et al.,* 2002). This was what prompted the use of various crops and vegetables fluted pumpkin (*Telfaria occidentalis*), Cowpea (*Vigna unguiculata*), Corn (*Zea Mays*) and waterleaf (*Amaranthus cruentus*) at various times for the remediation studies.

For this study (Opeolu *et al.,* 2006) the seeds of *Amaranthus cruentus* were raised in a nursery for specified number of days. Seedlings of equal height and vigour were selected and transported into pots each having 5 replicates. Plant height and number of leaves were measured. The seedlings of *A. cruentus* were then subjected to the various treatments.

The major observations were that the control plants quickly outgrew those on the contaminated soils. Plant height decreased in the exposed plants as for EDTA amended soils than the un-amended polluted soils. This was attributed to more lead mobilization in the plants, leading to increased toxicity to plants. The results for dry matter yield of *A. cruentus* in lead Polluted Soils with and without EDTA Application is presented in Table 23, while table 24 is for the results for lead translocation from roots to shoot and table 25 represents results for total and soluble lead levels in *A. cruentus* grown in lead contaminated solution.

Table 23: Dry Matter Yield of *A. cruentus* in Lead Polluted Soils with and without EDTA Application

	Dry Matter Yield (g)			
Treatment	Leaves	Stem	Root	Total
Control	6.34	3.30	1.18	10.82
600ppm	4.70	2.46	0.96	7.12
600ppm + EDTA	3.97	2.38	0.74	6.09
1800ppm	3.06	2.02	0.74	6.03
1800ppm + EDTA	2.86	1.95	0.97	5.78

The number of leaves in the control plants was greater than those planted in contaminated soil. It was similarly noted that the dry matter yields per plot (Table 23 above) correspond to the concentration of lead in the shoots of A. cruentus in which dry matter yields decreased with increased lead concentration in shoots.
Lead levels in leaves and stems measured as the level of lead increased in the roots

Table 24 : Lead Translocation from Roots to Shoot *A. cruentus*

Treatment	Shoot to Root Ratio of Lead Concentration (T.F)	Lead Absorbed by Shoot Lead Absorbed by Whole Plant (%)
Control	1.09	52.0
600ppm	1.12	52.8
600ppm + EDTA	2.16	68.3
1800ppm	2.89	74.3
1800ppm + EDTA	4.42	81.6

Shoot = Leaves + Stems T. F. = Transfer Factor

Table 25 : Total and Soluble Lead Levels in *A. cruentus* grown in Lead Contaminated Solution

	Lead Concentration (mg/kg)				
Treatment	Leaves	Stem	Root	Soluble	Total
Control	87.0	2.0	82.0	3.5	171.0
600ppm	119.5	71.5	171.0	8.5	362.0
600ppm + EDTA	138.5	124.5	122.0	10.5	385.0
1800ppm	167.0	120.5	99.5	12.0	387.0
1800ppm + EDTA	174.5	195.0	83.5	156.0	453.0

In conclusion, *A. cruentus* has the potential to translocate above average of lead from contaminated soils to shoot since the transfer factor was greater than one- to note that phytoremediation species should be able to transport most of the contaminants to the shoots which facilitate sequestering of pollutants. (Tu *et al.,* 2002).
Hence *A. Cruentus* qualified as a hyper accumulator and a promising plant for phytoremediation. This may, however, pose a health risk to the human consumer since levels were highest in the leaves. This implies that the plants meant for human consumption must not be planted on lead contaminated soils.

2.3.2 *Heavy metal content in Playground Top soil of some Public Primary Schools in Metropolitan Lagos Nigeria.*

Soil ingestion has been recognized as an equally important exposure route of contaminants to humans (especially for children), as water and food ingestion (McKone and Daniels, 1991). Not only are children more susceptible to the negative health effects of soil contaminants because of physiological factors, but they are also closer to the ground when playing and may thereby ingest soil through mouthing dirty hands and objects, eating dropped food and even consuming soil directly. Pica behaviour includes the ingestion of several non food materials and when soil is intentionally ingested in a pica manner this is termed geophagy. Ingestion of non-nutritive substances via hand-to-mouth transfer is common in children between 18 months to 2 years (Ljung *et al.,* 2006). In a study of geophagy undertaken by Geissler *et al.,* (1997) on the ingestion of soil in 285 Kenyan school-children aged 5-18, 73% were reported to consume soil, with the prevalence decreasing with age.

Studies of metal concentrations in playground soil ingested by children via the hand to mouth pathway have been carried out in a number of places according to Watt et al., (1993) and Higgs et. al., (1997. There is substantial evidence that a high Pb level in the environment could affect blood Pb level, intelligence and behavior (Bellinger *et al.,* 1990; Lanphear *et al.,* 1998). It is especially important that soil contents of potentially harmful substances are kept low in areas frequented by children. Other metals such as Cd, Cu, Pd and Zn are good indicators of contamination in soils because they appear in gasoline, car component, oil lubricants and industrial incinerator emissions.

However, attention has not been paid to the problem of heavy metal contamination in the school playgrounds in Lagos state. To provide a healthy city environment and protect young lives from heavy metal contaminants, it is important to have a thorough understanding of the nature and extent of heavy metal pollution in playgrounds. The study by Popoola *et al.,* (2012) determined the levels of heavy metals (Pb, Cr, Cd and Mn) in 40 topsoil samples obtained from playgrounds of some public primary schools in Lagos State.

The results obtained from the analysis are shown in Tables 26 and 27 below;

Table 26: Mean, range, minimum and maximum concentrations (µg/g) of Pb, Cr, Cd and Mn in selected schools playground soils in the local government areas of Lagos state

		Mean Conc.	Max	Min	Range
Pb	HD	23.07±11.11	42.45±1.20	1.26±0.26	41.19
	LD	23.55±15.93	81.40±0.02	9.77±0.45	71.63
Cr	HD	5.99±5.79	22.31±0.49	0.33±0.19	49.66
	LD	3.80±3.83	13.83±5.36	0.02±0.33	41.30
Cd	HD	0.33±0.33	1.18±0.03	0.01±0.00	1.43
	LD	0.39±0.31	0.94±0.10	0.01±0.00	0.95
Mn	HD	1.60±0.14	1.89±0.16	1.47±0.01	7.29
LD		1.60±0.05	1.66±0.02	1.52±0.04	7.26

Min: Minimum; Max: Maximum

Table 27: Concentrations of metals in playground topsoil samples from schools in the 20 Local Government Areas of Lagos state

	Pb (µg/g)		Cr (µg/g)		Cd (µg/g)		Mn (µg/g)	
Local government areas	HD	LD	HD	LD	HD	LD	HD	LD
Badagry	19.60±0.01	20.99±0.32	2.67±0.09	2.38±0.26	0.34±0.04	0.20±0.01	1.47±0.01	1.66±0.04
OshodiIsolo	24.85±0.25	25.75 ±0.54	7.75±0.42	2.19±0.39	0.58±0.00	0.38±0.00	1.77±0.07	1.52±0.04
Shomolu	18.58±0.52	17.92±0.09	1.89±0.13	ND	0.35±0.01	0.28±0.00	1.53±0.15	1.61±0.09
Agege	31.65±0.03	36.24±1.67	6.66±0.25	ND	0.49±0.00	0.65±0.00	1.56±0.16	1.58±0.04
Alimosho	17.42±0.07	23.43±0.39	ND	3.33±0.17	0.10±0.01	0.35±0.00	1.61±0.12	1.62±0.11
AmuwoOdofin	20.02±0.24	26.33±0.15	ND	3.32±0.27	0.47±0.00	0.68±0.01	1.48±0.20	1.62±0.02
Mainland	41.34±0.30	30.02±0.66	11.14±0.05	5.55±0.10	0.28±0.00	0.28±0.00	1.61±0.09	1.58±0.12
Surulere	28.40±0.45	19.90±0.36	1.45±0.26	6.87±0.34	0.60±0.00	0.95±0.10	1.47±0.02	1.66±0.02
Lagos Island	42.45±1.20	10.36±0.11	13.32±0.37	ND	1.19±0.03	0.31±0.01	1.89±0.16	ND
Eti-Osa	25.79±0.40	15.44±0.05	ND	1.91±0.14	0.11±0.00	0.91±0.05	ND	ND
IfakoIjaiye	29.26±1.21	15.07±0.11	0.79±0.07	0.52±0.25	0.05±0.00	ND	ND	ND
AjeromiIfelodun	3.14±0.09	38.08±0.07	2.45±0.09	ND	ND	0.70±0.01	ND	ND
IbejuLekki	1.26±0.26	81.40±0.02	ND	ND	ND	0.10±0.01	ND	ND
Epe	40.00±0.46	10.98±0.49	0.33±0.19	0.02±0.33	ND	0.08±0.01	ND	ND
Kosofe	27.95±0.94	24.60±0.36	ND	5.41±1.12	ND	ND	ND	ND
Apapa	21.19±0.30	22.24±1.22	ND	0.49±0.06	ND	ND	ND	ND
Ojo	10.81±0.10	9.77±0.44	ND	13.83±5.36	ND	ND	ND	ND
Mushin	20.44±0.15	19.15±0.55	ND	ND	0.01±0.00	0.00±0.00	ND	ND
Ikorodu	15.01±0.18	7.57±0.05	ND	ND	0.02±0.00	0.01±0.00	ND	ND
Ikeja	22.31±0.49	15.65±0.11	17.46±0.49	ND	0.01±0.00	ND	ND	ND

2.3.2.1 *Lead in playground soil*

Lead concentration in playground soils show a wide range of concentrations. Mean values of high density playground soils (23.08 µg/g) are similar to the mean values of low density ones (23.55 µg/g), reflecting a general and diffuse contamination of soils in the playgrounds (Table 26). The results of lead concentrations in mg/kg in playground soils from a mining and smelting district in northern Armenia shows the Pb concentrations to be between 938 and 999 µg/g (Petrosyan *et al*., 2004). Old industrial cities like Uppsala (in northern Europe) have the mean Pb level in playground dust to be 26 mg/kg (Ljung *et.al.,* 2006) while cities such as Hong Kong which have their mean Pb level in playground dust to be 77.3 µg/g (Sai *et.al.,* 2002). These levels may reflect the long history of industrial contamination coupled with traffic emissions

(Pb in gasoline has been phased out in most of these countries) in urban environment of these playgrounds. The mean concentration obtained in this present study is lower than the range of 30-50 µg/g reported by Nriagu (1992) as the typical concentration of lead in urban soils and dusts of African cities while the lower lead levels in this study compared to Nriagu (1992) reports, still gives cause for concern since children spend appreciate time in the locations studied. Comparing the results of each sampling points, only one sample from Ibeju Lekki, low density area had the highest Pb concentration for the playground

It was also observed that a significant degree of Pb pollution exists in playground soil obtained from the Lagos Mainland high density area (41.34 µg/g). This area represents another nerve-centre of business activities on the mainland in the state as it is a very busy route in the metropolis which connects most bus stops in the state. Schools located close to these areas are subjected to metal pollution almost on a daily basis.

Relatively high concentration of 40.00 µg/g Pb was obtained for high density area in Epe (Epe is considered a rural area in Lagos state); this can also be explained as point sources. Some schools located in the low density areas (areas with minimal business, human and vehicle activities such as the government reserved areas), have been observed to have higher lead levels than their high density areas counterparts and they include areas such as Agege, Ajeromi Ifelodun, and Ibeju-Lekki. This observation may be partially due to sources from influx of imported power generating sets that have flooded the country in recent times due to poor existence of power generation.

It is expected that Oshodi-Isolo area will have one of the highest lead levels as reported by Arowolo et.al. (2000). However; the contrast was obtained in this study in which flooding episodes have been recorded in the area and indeed in many parts of the state and has worsened in the recent times (Nigerian Punch Newspapers, 2008). As expected, Ikorodu Local Government Area has the lowest Pb level for both high and low density..

The metal concentrations in the playground soils studied is characteristic of unpolluted soils, except for some areas with levels above those considered as acceptable limits for recreational and institutional environments such as Lagos Island and Mainland local Government areas. Maintaining
ground cover will however provide a margin of safety from exposure to heavy metals in playground soils

2.3.3 *Physicochemical Characteristics and Heavy Metal Levels in Soil Samples obtained from Selected Anthropogenic Sites in Abeokuta, Nigeria*

Heavy metals contamination of topsoil has been a major concern regarding their toxicity, persistence and non-degradability in the environment. Toxicity of these compounds has been reported extensively (Momodu and Anyakora, 2010; Anyakora *et al.,* 2011).

They accumulate overtime in soils, which act as a sink from which these toxicants are released to the groundwater and plants and end up through the food chain thereby causing various toxicological effects.

Effects of elevated concentrations of heavy metals to soil functions, soil microbial composition and microbial growth have long been reported under both field and laboratory condition (Tyler *et al.,* 1989).

Human activities in urban areas largely contribute to the contamination of urban soils and this is a major health concern. Iwegbu et.al. (2009) reported elevated concentration of Cd, Cr, Cu, Pb, Ni, and Zn in an automobile mechanic workshop soil while Dauda and Odoh, (2012) in their study revealed the high degree of contamination of Pb, Cd and Zn in soil from fuel filling stations in Benue state.

In addition, Ubwa *et al.* (2013) reported high levels of Cd, Zn, Ni, Cr and Pb from soil around the Gboko Abattoir. The extent of human impact is now so pervasive and profound, that there is need to investigate the levels of heavy metals in soils from different anthropogenic sites.

Olayinka *et al.*(2017) determined the physico-chemical characteristics and heavy metals in surface and sub-surface soil samples from control sites and selected anthropogenic sites (dumpsites, mechanical workshops, abattoirs, fuel filling stations and hospital incinerators) in Abeokuta, Nigeria. Sampling locations were selected based on anthropogenic activities; such as dumpsites, abattoirs, mechanic workshops, petrol stations, hospital incinerator sites and soil samples collected from the same sources in Abeokuta city and also from two control sites (uncultivated forest and lawn) in Federal University of Agriculture Abeokuta. Samples were collected at different depths (0-5 cm, 5-10 cm, 10-15 cm) using soil auger and transferred into cellophane bags, tightly sealed with minimal air space and labelled with carbon free paper outside and stored in a cool place to prevent breaking down of organic matter. Samples were air dried for 48 hours, and then sieved with 2 mm mesh to remove debris, gravel and other materials prior to analysis.

The pH of soil samples was determined according to Bamgbose *et.al.,* (2000), while organic carbon content of soils was determined by Walkey and Black (1934) and digestion method as described by Anderson and Ingram (1989). The digest was titrated with ferrous ammonium sulphate solution with end point indicating a change from greenish to brown colouration.

The organic carbon content expressed in percentage as follows was based on 77% recovery factor Mean soil pH in dumpsites was 7.13±0.94, 7.38±0.72 and 7.24±0.83 for 0-5 cm 5-10 cm and 10-15 cm depth respectively (Table 28), while in the abattoir it was 6.65 ±0.98, 6.87±0.47 and 6.74±0.74 for 0-5 cm,

For trace metal analysis sieved soil was digested with HNO_3-HCl according to USEPA method 3050B to extract the metals. The concentrations of Zn and Mn were measured using Perkin-Elmer Analyst 300 atomic absorption spectrophotometer (AAS).

Soil texture plays an important role in mobility of metals in soil. The textural class for most of the sites were sandy loamy except fuel filling station which was sandy clay and two of the hospital incinerator sites that were loamy sandy. This was similar to the report of Osakwe (2014). Soil organic carbon in dumpsites decreased from 4.80±2.65 % in depth 0-5 cm to 2.40±0.29 % in depth 10-15 cm and the mean soil organic matter ranged from 4.12±1.74 % in depth 10-15 cm to 8.25±4.56 % in depth 0-5cm. Also soil organic carbon in abattoirs decreased with depths with average of 3.27±2.10 % at 0-5 cm depth and 1.38±0.85 % at 10-15 cm depth. However, mean values of both organic carbon and organic matter across depths were significantly ($p< 0.05$) different from each other in mechanic workshops. While, organic carbon level of the hospital incinerator soils increased with depth from 2.89±1.49 at depth 0-5cm to 3.48±1.52 % at depth 10-15 cm.

Values of soil organic matter and organic carbon content obtained were higher than the control sites. This observation corroborated Oyedele et.al., (2008) who reported that polluted sites had significant higher soil organic matter and organic carbon as compared to the control site.

Table 28: **Interval of contamination/pollution index of heavy metals in soil and its significances**

Depth(cm)	0 - 5	5 - 10	10 - 15
pH	7.10 ± 0.94^b	7.38 ± 0.72^a	7.24 ± 0.3^b
Moisture density	16.11 ± 1.49^c	17.89 ± 7.27^b	18.38 ± 7.34^a
Bulk density	4.47 ± 0.12^a	1.31 ± 0.28^b	1.38 ± 0.15^b
Sand%	73.18 ± 15.76^b	73.42 ± 15.80^a	73.25 ± 15.79^b
Clay%	3.00 ± 1.83^a	2.90 ± 1.95^a	3.08 ± 1.89^a
Silt%	23.30 ± 16.15^b	23.75 ± 16.19^a	23.68 ± 16.26^a
OC%	4.80 ± 2.65^a	3.71 ± 2.54^b	2.40 ± 0.29^c
OM%	8.25 ± 4.56^a	6.38 ± 4.6^b	4.12 ± 1.74^c
Zn ($mgkg^{-1}$)	254.13 ± 114.33^c	395.43 ± 144.84^b	444.29 ± 248.06^a
Pb ($mgkg^{-1}$)	154.50 ± 71.41^a	132.00 ± 60.70^b	99.94 ± 31.85^c
Mn ($mgkg^{-1}$)	281.06 ± 72.89^c	364.94 ± 117.14^a	315.50 ± 81.13^b
Cd ($mgkg^{-1}$)	1.13 ± 0.88^c	1.38 ± 1.13^b	1.63 ± 1.38^a

Mean concentrations of heavy metals of the soil samples are shown in Tables 29 – 32. Zinc had highest average concentration across the depths followed by Mn, Pb and Cd in dumpsites. Average concentration of Pb, and Mn decreased with depths, while Zn and Cd concentrations increased with depth in dumpsites (Table 28). Increase in concentration of manganese in the dumpsites may be attributed to the metal scraps dumped around some of the sites (Idugboe *et al.,* 2014). The concentration of cadmium obtained at dumpsites may be due to the dumping of Poly vinyl chloride (PVC), nickel-cadmium batteries. Concentrations of Cd obtained at dumpsites and hospital incinerator sites were similar to concentrations reported from soil samples of industrialized environment (Chimezie *et al.,* 2013), dumpsite soil of Markudi (Wuana and Okieimen, 2011), also soils from fuel filling station (Dauda and Odoh, 2012). The highest mean concentration of Pb was obtained in dumpsites and lowest in abattoir sites. In abattoir the concentrations of Zn, Pb, Mn and Cd were 632.18±508.79 $mgkg^{-1}$, 21.88±6.72 $mgkg^{-1}$ 682.44±143.85 $mgkg^{-1}$, and 0…31 ± 0.06 $mgkg^{-1}$ respectively

Concentrations of Pb at abattoir were lower than concentration reported by Yahaya *et al.* (2009) while Zn concentrations were higher. Pb concentration decreases as the depth increases for most of the sites. Mean concentrations of Mn obtained at abattoirs were slightly higher than concentration reported by Yahaya *et al.,* (2009). Manganese concentration at abattoir may be as result of disposal of rumen which contain green grasses that are still in their early stage of digestion, this contains chlorophyll which contain manganese and iron.While in fuel filling stations Mn had highest (479.50±253.25 $mgkg^{-1}$) concentrations at depth 10-15 cm, while, highest (295.94±222.87 $mgkg^{-1}$) concentration of Zn was recorded at 5-10 cm depth (Table 4). Zn is the second most abundant in soils around the petrol stations. Pb concentrations at 0-5 cm, 5-10 cm and 10-15cm were 76.56±39.48$mgkg^{-1}$, 70.13±28.34 $mgkg^{-1}$, and 99.50±70.14 $mgkg^{-1}$ respectively.

Concentration of Pb was obtained at mechanic workshop for all depths studied show that motor vehicles constitute principal source of Pb. Lead concentration greater than 1.0 $mgkg^{-1}$ is generally indicated a local source of pollution. The concentrations of manganese at mechanic workshop were lower than concentration reported by Eddy *et al.,* (2006) and Osakwe (2014). The high Mn concentrations at mechanical workshop could be attributed to the fact that Mn forms a part of batteries, welding works and spray paintings of the vehicles. The concentration of manganese found in mechanic workshop sites were similar to level of Mn in soils that received significant impact of crude oil in Nigeria (Iwegbue *et al.,* 2009). The concentration obtained at fuel filling station may be due to regular discharge of petroleum products around these filling stations (Dauda and Odoh, 2012). The concentration of cadmium at mechanic workshop may be due to disposal of engine oil and some other automobile waste and process of vulcanization around these workshops. It was reported that the cadmium level in car tyres is in the range of 20-90 mgg^{-1} as associated with cadmium contamination in the process of vulcanization (Akpoveta *et al.,* 2010).

Table 29: Physico-chemical parameters and heavy metal levels of soil samples selected abattoirs at different depths

Depth (cm)	0-5	5-10	10-15
PH	6.65±0.98[a]	6.59±0.33[a]	6.74±0.74[a]
Moisture density	21.89±7.65[a]	17.61±4.07[c]	19.50±6.62[b]
Bulk density	1.16±0.30[c]	1.42±0.33[b]	1.81±0.37[a]
Sand%	64.55±10.48[a]	64.33±10.05[b]	64.22±10.53[b]
Clay%	5.48±3.89[b]	5.65±3.73[b]	6.50±3.49[a]
Silt%	29.98±10.63[a]	20.08±10.66[c]	29.03±10.98[b]
OC%	3.27±2.10[a]	2.70±2.41[b]	1.38±0.85
OM%	5.63±3.61[a]	4.64±412[b]	2.37±1.47
Zn($mgkg^{-1}$)	632.18±508.79[a]	191.06±108.97[b]	171.93±82.43[c]
Pb(mgk^{-1})	21.88±6.72[a]	19.75±6.50[b]	19.38±6.72[c]
Mn($mgkg^{-1}$)	682.44±143.85[a]	697.06±148.24[a]	640±148.52[b]
Cd($mgkg^{-1}$)	0.31±0.06[a]	0.25±0.02[a]	0.25±0.01[a]

OC = organic matter: Means with the different superscript along the same row are significantly ($p<0.05$) different from each other; Each value represents the mean determination ± standard deviation.

Table 30: Physico-chemical parameters and heavy metal levels of soil samples from selected fuel filling stations at different depths

Depth(cm)	0 – 5	5 - 10	10 - 15
pH	7.01±0.49[a]	6.95±0.35[a]	6.98±0.49[a]
Moisture content	11.66±3.23[b]	11.08±2.71[c]	16.46± 8.76[a]
Bulk density	1.37±2.00[a]	1.43±0.60[a]	1.49±0.13[a]
Sand%	70.55±15.66[a]	70.50±15.72[a]	70.35±15.82[b]
Clay%	8.28±9.34[a]	8.45±9.21[a]	2.90±3.48[b]
Silt%	21.18±16.55[b]	22.08±16.61[a]	20.78±15.95[c]
OC%	2.46±1.85[c]	3.30±3.02[a]	2.90±3.48[b]
OM%	4.20 ±3.19[c]	5.51±5.19[a]	4.98±5.99[b]
Zn($mgkg^{-1}$)	147.28±82.7[c]	295.94±222.87[a]	285.19±239.35[b]
Pb($mgkg^{-1}$)	76.56±39.48[b]	70.13±28.34[c]	99.50±70.14[a]
Mn($mgkg^{-1}$)	182.69±61.95[c]	266.13±85.62[b]	479.50±253.25[a]
Cd($mgkg^{-1}$)	0.25±0.01[b]	0.44±0.19[b]	1.06±0.81[a]

OC = organic carbon, OM = organic matter.; *Means with the different superscript along the same row are significantly ($p<0.05$) different from each other.
*Each value represents the mean of three determination ± standard deviation.

Table 31: **Physico-chemical parameters and heavy metal levels of soil samples from selected mechanic workshops**

Depth(cm)	0 – 5	5 - 10	10 - 15
pH	6.70±0.97[a]	6.58±1.35[ab]	6.48±1.43[b]
Moisture content	10.19±4.65[b]	11.18±7.06[a]	7.90±4.34[c]
Bulk density	1.73±0.15[a]	1.45±0.42[b]	1.50±0.34[b]
Sand%	66.98±13.77[b]	67.35±14.45[a]	66.70±13.50[c]
Clay%	7.75±3.22[c]	8.35±3.14[b]	9.38±1.21[a]
Silt%	25.28±11.96[a]	25.05±12.26[b]	25.18±12.13[ab]
OC%	5.98±3.24[a]	2.95±1.91[b]	1.52±0.77[c]
OM%	10.28±5.58[a]	5.07±3.34[b]	2.61±1.33[c]
Zn(mgkg^{-1})	406±127.62[a]	254.44±62.74[b]	122.69±30.04[c]
Pb(mgkg^{-1})	88.56±62.72[a]	58.63±34.73[b]	22.75±9.10[c]
Mn(mgkg^{-1})	304.50±84.23[b]	320.50±60.82[a]	185.63±10.58[c]
Cd(mgkg^{-1})	0.25±0.01[a]	0.25±0.02[a]	0.25±0.01[a]

OC = organic carbon, OM = organic matter.; *Means with the different superscript along the same row are significantly ($p<0.05$) different from each other.
*Each value represents the mean of three determination ± standard deviation.

Table 32: Physicochemical parameters and heavy metal levels of soil samples from selected hospital incinerator sites.

Depth (cm)	0-5	5-10	10-15
PH	6.69± 0.21[a]	6.59± 0.35[a]	6.59±0.24[a]
Moisture density	6.84±1.86[a]	11.08±2.71[c]	7.09±1.76[a]
Bulk density	1.34±0.09[c]	1.43±0.60[a]	1.36±0.25[a]
Sand%	48.85±3.35[a]	70.50±15.72[a]	48.68±3.05[b]
Clay%	3.13±0.46[b]	8.45±9.21[a]	2.98±0.91[a]
Silt%	48.25±4.33[a]	22.08±16.61[a]	48.35±4.49[a]
OC%	2.89±1.49[a]	3.30±3.02[a]	3.48±1.52[a]
OM%	4.98±2.58[a]	5.51±5.19[a]	6.00±2.62[a]
Zn(mgkg^{-1})	548.56±315.92[a]	295.94±222.87[a]	577.66±354.85[b]
Pb(mgkg^{-1})	113.94±22.95[a]	70.13±28.34[c]	114.94±73.68[b]
Mn(mgkg^{-1})	447.50±22.92[a]	266.13±85.62[b]	414.25±30.58[b]
Cd(mgkg^{-1})	0.94±0.47[a]	0.44±0.19[b]	1.13±0.71[b]

In conclusion, the concentrations of selected metals in the soils studied were generally higher than control sites, indicating some degrees of contamination. At some sites the concentrations were higher than natural ranged concentrations and stipulated values of United State Environmental Protection Agency (USEPA, 2002). Zinc and Manganese were the most abundant heavy metals in the studied sites. It was also observed that increase in pH decreases the concentration of heavy metals in the soil. Mean concentrations of heavy metals studied in the soil samples at all depths measured from abattoir, dumpsite, petrol station, hospital incinerator, and mechanic workshop were found to be in increasing order as (Mn > Zn > Pb > Cd), (Zn > Mn > Pb > Cd), (Mn > Zn > Pb > Cd), (Mn > Zn > Pb > Cd) respectively. Contamination and pollution index showed that all anthropogenic sites were moderately polluted and severely contaminated with heavy metals studied. Therefore, there is need for regular monitoring of these anthropogenic activities in order to forestall the impending health risk from heavy metals.

2.4 Footprints in the Biosphere

2.4.1 *Levels of cadmium, lead and zinc in urine of randomly selected smokers and Non- smokers residents of Abeokuta city.*

Metals get into biological fluids from various sources apart from the direct consumption of food items that contain such metals. These sources include those of partially disintegrated particles of the containers in which food are stored, exposure to fine particles of metal waste in the metals extraction industries through ingestion (drinking) and from inhalation (tobacco smoke).
It has been shown that the environmental tobacco smoke (ETS) is a complex mixture of chemicals formed in air as a specific result of smoking (side stream smoke that is released from the lit end of the cigarette and exhaled and from main stream smoke that is exhaled by the smoker after drawing on the cigarette (Richard and Proctor, 1990).

It has also been established that smoking is an important factor in the production of carcinoma of the lungs (Shaham *et al.,* 1996, WHO 1990) and as such tobacco smoke can therefore lead to cancer (Daube *et al.,* 1997). The danger of smoking has long been realised in the more developed countries with the promulgation of appropriate laws in 1962 (Farrly and Pybus, 1969). Similar law had also been made in Nigeria, particularly with the promulgation of Decree 28 of 1990 (Ajayi and Adekunle, 1991) More recently the Lagos state Governor has accented to the bill passed by the house of Assembly banning smoking in public places.

The presence of these metals in urine is regarded as a reliable index to the extent of recent metal intake and as such the determination of these metals in the diagnosis of incipient poisoning and in monitoring as reflected in Bamgbose *et al.,* (2007).

Urine samples of 200 male volunteers comprising of 100 smoker and 100 non-smokers were analysed for levels of heavy metals (Cd, Pb and Zn) in urine and with a bio-data presented in Table 33 for smokers and in Table 34 for non-smokers.

Table 33 : Biodata of Selected Smokers and Levels of Trace Metals (Cd, Pb and Zn) in Urine Samples

Sample Code	No. of Sample	Age Group	Occupational Status	Years of Smoking	Type of Cigarette Smoked	Estimated Average No. of Cig./day	Metal Ion Concentration (ppm)	
							Cd	Pb
1	4	10-19	Carpenter	6	Rothmans	3-4	0.171	0.139
2	4	10-19	Student	4	All Types	2-4	0.089	0.076
3	4	10-19	Bus Conductor	7	All Types	5-8	0.101	0.245
4	4	10-19	Unemployed	5	Benson. St. Moritz	3-4	0.078	0.118
5	4	20-29	Unemployed	12	Rothmans	5-7	0.180	0.233
6	4	20-29	Air Force Officer	16	Rothmans	>10	0.300	0.230
7	4	20-29	Mechanic	12	SM	>10	0.255	0.297
8	4	20-29	Carpenter	13	Ten-ten	8-10	0.227	0.223
9	4	20-29	Bricklayer	14	Rothmans	7-9	0.241	0.189
12	4	20-29	Labourer	12	Eric moore	8-10	0.236	0.245
13	4	20-29	Bricklayer	13	SM	7-9	0.241	0.189
14	4	20-29	Clerk	14	Benson	8-10	0.262	0.213
15	4	20-29	Student	7	Rothmans	3-4	0.095	0.105
16	4	20-29	Painter	4	Rothmans	6-8	0.075	0.113
555								
17	4	20-29	Civil Servant	16	Rothmans	5-7	0.097	0.133
18	4	20-29	Student	11	Rothmans St. Moritz	7-8	0.196	0.124
19	4	20-29	Student	11	Rothmans St. Moritz	4-5	0.186	0.101
20	4	30-39	Driver	12	Target	5-8	0.265	0.265
21	4	30-39	Baker	14	Benson	8-10	0.301	0.211
22	4	30-39	Painter	8	Target	5-7	0.091	0.133
23	4	40-49	Trader	18	Benson	8-10	0.320	0.205
24	4	40-49	Welder	20	Gold leaf	8-10	0.340	0.158
25	4	50-59	Driver	22	Benson	8-10	0.302	0.124

Table 34 : Biodata of Selected Non-Smokers and Levels of Metals (Cd, Pb and Zn) in Urine Samples

				Metal Ion Concentration (ppm)		
Sample Code	No. of Sample	Age Group	Occupational Status	Cd	Pb	Zn
26	4	10-19	Mechanic	0.034	0.179	0.438
27	4	10-19	Student	0.037	0.104	0.317
28	4	10-19	Student	0.054	0.112	0.586
29	4	10-19	Student	0.054	0.037	0.571
30	4	10-19	Student	0.048	0.177	0.319
31	4	10-19	Student	0.043	0.173	0.599
32	4	10-19	Mechanic	0.043	0.187	0.511
33	4	10-19	Painter	0.045	0.194	0.243
34	4	10-19	Painter	0.065	0.188	0.409
35	4	10-19	Student	0.038	0.168	0.341
36	4	10-19	Student	0.041	0.057	0.563
37	4	20-29	Petrol Attendant	0.065	0.251	0.576
38	4	20-29	Trader	0.050	0.038	0.660
39	4	20-29	Student	0.043	0.144	0.615
40	4	20-29	Mechanic	0.054	0.194	0.342
41	4	20-29	Trader	0.043	0.077	0.664
42	4	20-29	Tailor	0.048	0.038	0.488
43	4	20-29	Student	0.043	0.046	0.489
44	4	20-29	Student	0.054	0.123	0.235
45	4	20-29	Student	0.054	0.038	0.515
46	4	30-39	Student	0.048	0.048	0.502
47	4	30-39	Teacher	0.049	0.057	0.516
48	4	30-39	Driver	0.065	0.178	0.634
49	4	40-49	Baker	0.048	0.110	0.500
50	4	40-49	Driver	0.054	0.165	0.622

The occupational status of the respondents sampled, varied widely from students to different categories of workers (traders, mechanic, carpenter, driver, clerk, painter etc). Students however constituted 16% of the smoking population sampled and also constituted a larger percentage of the non-smoking respondents, thus indicating that a smaller proportion of this our great University, the Federal University of Agriculture, Abeokuta are involved in smoking. This was further confirmed from the questionnaire administered at this time to the year II students from which only 25% (120 out of 800) indicated having smoked at one time or the other.
Cigarette types smoked include Rothmans, Benson and Hedges, St.Morris, Target, Gold-leaf with a smoking rate of 2-4 sticks of cigarette as minimum and 8-10 at the upper level. Results from this study in Table 35 show that in general the levels of concentration of Cadmium, Zinc and Lead in the urine samples of smokers were relatively higher than those for the non-smokers. However it was

also observed that notable exceptions could arise depending on the occupational status of the respondents.

Table 35 : Mean concentration (ppm) of the metals for smokers as against non-smokers.

Metal	Non-smokers	Smokers
Cd	0.034-0.065	0.075-0.340
Pb	0.037-0.251	0.076-0.297
Zn	0.235-0.664	0.488-1.97

The main caution here is that smokers are prone to exposure of heavy metals.

2.4.2 *Organochlorine pesticides and PCBs in human milk*

Organochlorine pesticides (OCP's) with their high persistence in the environment accumulate in fatty foods and human adipose tissues. Contamination of human milk by Organochlorine pesticides and other related compounds has been extensively reported worldwide (Jensen 1983, GEMS/FOOD 1998). Breast milk containing high concentrations of organochlorine compounds is a source of contamination for the breast fed baby. The child exposure to these contaminants starts as early as in the uterus due to the long half-life of these compounds.

Human milk at the top of the food chain represents the major route of elimination of OCPs by lactating women (Rogan *et al.,* 1986, Sim and McNeil, 1992). The excretion of these compounds during lactation is much higher than their intake from their diet (Jensen and Slorach, 1991) which may imply that the tissue deposits of OCPs in women decrease with consecutive lactation.

In the course of lactation, persistent organochlorine compounds dissolved in milk fat are removed from a woman's body, thereby leading to breast fed children being subjected to higher levels of exposure to certain chemicals than adults. These may lead to immunological impairment and manifesting as reduced neurological optimality at birth, developmental delays in gross motor function during infancy, slow cognitive processing and attention difficulties, impaired intellectual function in school age children, as well as lower behavior and activity rating (Guo *et al.,* 1995, Jocobson and Jocobson, 1996).

It has therefore became necessary in a country like Nigeria where organochlorine compounds are still in use for agricultural crops, unlike in developed countries where a ban has been imposed, to monitor on continuous basis the concentration of OCP residues and metabolites in human milk.

In this study, Bamgbose and Opeolu (2007) worked on one hundred and fifty (150) samples of human breast milk (colostrum's) collected from donors patronizing a post natal center in Nigeria were they were analysed for the levels of lindane, total DDT and Total PCBs residues. Donors were stratified with respect to factors that may affect accumulation of these compounds such as age, previous lactation, parity, occupation, income and education status by use of questionnaire.

Analysis was performed by preliminary lipid extraction followed by partitioning on a column and finally by gas liquid Chromatography equipped with election capture detector.
Lindane, total DDT and PCBs were detected in all samples with a concentration range of 2-16ng/ml for lindane, 28-750 ng/ml for DDT and 16-143ng/ml for PCBs as shown in Table 36 below, mean values were 14.12 ng/ml, 186ng/ml and 468.62ng/ml respectively.

Comparison of the mean results from this study with the levels obtained from other studies in the more industrialized regions of the world showed that the residue levels in human milk in this location in Nigeria (Table 37) is higher than the worlds average. While Table 38 is a summary of multiple regression analysis.

Table 36: concentration of detected pesticides and PCBS in analyzed samples (ng / ml), and their ratio.

	Lindane	Total DDT	PCBs
N	150	150	150
Median	13.5	147	186
Mode	13	21	35
Mean	14.12	186	468.62
Range (nglml)	2-33	28-750	16-1431
Std deviation	7.43	160.3	431.3
PCB/ Lindane		33.19	
PCB/ DDT		2.52	
DDT/ Lindane		13.17	

Table 37: Comparison of pesticides and PCBs levels in human milk from other countries.

Countries	References	Lindane	Total DDT	PCBs
Sweden	Noren & Lunden(1991)	0.69	34.40	132.5
Spain	Hernandez et al. (1993)	1.48	26.32	184.6
Canada	Newsome et al. (1995)	0.39	22.1	207.3
Norway	Johansen et al. (1991s)	3.44	18.14	286.9
Ghana	Ntow (2001)	17.15	201	518.4
This study		14.12	186	468.2

Table 38: Summary of multiple repression analyses.

Variable	Lindane	Total DDT	PCB
Age of mother	0.134	0.611	0.178
Parity	0.116	0.241	0.109
Occupation	0.42	0.38	0.27
Level of income	0.101	0.132	0.223
Lindane		0.09	0.114
Total DDT	0.09		0.434
PCB	0.114	0.434	

2.4.4 *Lead levels in carious teeth of residents in three Nigerian cities*

The evaluation of human exposure to lead can be carried out by monitoring lead concentrations in the environment. The blood lead level reflects a dynamic equilibrium between exposure, absorption, distribution and elimination of lead. Lead in blood is therefore, thought to be the best indicator of recent prolonged exposure. Lead in body is rapidly transported through the blood to bones and teeth where it is stored. Lead undergoes bioaccumulation in bone and teeth throughout life. It is estimated that about 90% of the body burden of Pb is retained in these media after long time exposure. However, lead in bones is moveable and subject to loss during the re-modelling process. Therefore, out of these two major reservoirs for lead in the body, the teeth may be considered to be better assessment as an index of environmental pollution and as indicator of the body burden of lead.

Analysis of teeth has now become common in prospective and retrospective studies of lead exposures and also in relating exposure to human health. The lead levels in the teeth have the advantage of reflecting the cumulative lead burden over a given period. The aim of this study was to determine the lead level in carious teeth of some adult inhabitants of Lagos, Ibadan and Abeokuta, Nigeria in order to provide a reliable data for the assessment of the extent of environmental pollution (Arowolo and Bamgbose, 2004).

A total of three hundred and six samples of teeth extracted from men and women living in Lagos, Ibadan and Abeokuta, aged 14 to 70 years were collected from Dental Centres in these cities. Most of the teeth donors were permanent residents in these cities. The subjects were randomly selected and people who had been or still were occupationally exposed to lead were excluded from the study. For each donor, age, sex and other relevant information were recorded. The teeth samples were stored in refrigerator at $-5^{0}C$

immediately after collection until needed for analysis.

The average lead levels in the teeth of male and female living in the three cities, Lagos, Ibadan and Abeokuta, were classified according to donor's age and are presented in Table 33. The concentrations ranged from 1.91 to 26.80 for Lagos; 2.05 to 21.6 for Ibadan and 1.95 to 18.08

Table 39: Lead level in teeth (dry rot) or urban residents classified according to age groups

Age Range	Lagos		Ibadan		Abeokuta	
	Average Lead level	n	Average Lead level	n	Average Lead level	n
14-20	4.50+2.71a	27	4.24+2.38a	24	4.07+2.14a	13
21-30	5.42+2.91a	28	5.24_2.76a	34	5.01+3.01a	19
31-40	6.04_4.07a	27	6.25+3.98a	27	5.84+3.46a	33
41-50	9.25+5.28b	14	8.82+4.76b	11	8.70+4.51b	18
51-60	14.07+6.09c	11	12.61+5.89c	5	11.92+5.61c	8
61-70	19.11+7.63d	5	14.43+6.87c	4		
r*	0.83		0.90		0.87	

Table 40 : Lead level in teeth (dry root) of donors classified according to sex and age

Age Group	Male	Female
14-20	4.90+2.58	3.48+2.32
21-30	5.04+3.02	5.76+2.79
31-40	6.95+4.38	5.85+3.88
41-50	9.16+6.05	8.90+4.12
51-60	15.06+8.18	11.62+6.57

There is, therefore, a clear and urgent need for the Nigerian Government to commence the implementation of a program of planned phase out of leaded gasoline in the country. This is important because lead pollution is known to play a major role in urban areas as a result of automobiles. The latter accounts for most (about 90%) of lead pollution in urban areas of Nigeria. In addition, the removal of lead from gasoline has been associated with reduced exposure and lowered blood lead levels in the general population of many countries.

Table 41: Lead level in teeth (µg g^{-1}) and motorization rate in some countries

Country	Subjects age (years)	Lead level (Average/Range)	Motorization rate	Remarks (Ref)
Northern Treland	3-10	24-38.6	-	Whole teeth (Gil et al., 1996)
England (Sheffield)	40-72	26.6+12.4 112.5+52.9	383	Denrine Pulp (Bercovitz et al., 1993)
France (Strasbourg)	32-65	45.3+15.8	516	Inner root dentine (Frank et al., 1990)
Finland	Adults	53.5+7.8	412	Whole dry dentine Lappalainen and Knuuttila (1979)
USA (Philadephia)	Children	51.1+10.9	801	Whole Tech Needleman et al., 1972
South Africa	6-12	26.5-74.5	182	Dentine, range between urban and rural regions (Grobler at al., 1995).
Mexico City	12-29	24.1+9.3	-	Root inner denrine (Frank et al., 1990)
Israel	31-40	6.41+3.80	189	Whole roots (Bercovitz et al., 1993)
Nigeria Lagos Ibadan Abeokuta	31-40	6.04+4.01 6.25+3.98 5.84+3.46		Whole roots Whole roots (present study)

2.5 Footprints in the Inter-Related Natural Environments

The footprints of man on the environment at times cannot be strictly restricted to a particular sphere as there are interactions between these spheres.

2.5.1 *Earthworms as bio-indicator of metal pollution in dumpsites*

It has been reported (Ireland 1983) that earthworms can accumulate in their tissues heavy metals in contaminated and uncontaminated environments. As reviewed by Edwards and Lofty (1997) earthworms consume a significant amount of dirt and in this process helps in enriching the soil and improving growing condition for the plants. Dumpsites provide suitable environments for earthworm activities by increasing the degree of mixing with soil micro flora, facilitating further enzyme activity (Stafford and McGrawth 1986) and increasing the overall decomposition of organic matter. (Hamilton and Dindal 1989).

In this study (Bamgbose et.al., 2000) Ten dumpsites were selected as sampling sites, all in Abeokuta as shown in Table 42, while sites in Alabata served as control in Table 43

Table 42 : Soil pH, Organic Matter % and Metal Ion Concentration in Soil Samples from Contaminated Sites (waste dumps) in Abeokuta City, Nigeria

Sample Site	Soil pH	Organic Matter %	Zn	Pb	Mn	Cu	Cd	Cr
Adatan	9.62	6.20	95.25	96.40	187.55	39.27	6.41	11.52
Asero	8.18	7.07	67.18	57.60	86.67	23.55	4.32	9.48
Iberekodo	10.10	6.10	84.27	300.41	101.48	26.41	4.74	7.15
Ijaye	9.98	6.03	204.66	218.54	148.31	42.84	5.11	14.20
Imo	7.44	5.89	68.36	82.45	77.26	34.26	4.38	7.92
Isale-Igbein	9.85	5.79	101.74	61.38	78.82	27.81	3.71	8.31
Ita-Oshin	10.10	7.59	296.19	314.82	116.67	81.13	4.21	6.45
Kuto	8.77	6.24	207.44	443.36	132.44	35.38	5.04	7.22
Lafenwa	9.45	6.31	112.38	170.11	98.17	21.11	4.28	6.18
Obantoko	8.50	7.10	79.65	105.48	105.63	33.82	2.91	5.56

Data are in µg/g dry weights

Table 43 : Soil pH, Organic Matter % and Metal Ion Concentration from Uncontaminated Sites

Sample Site	Soil pH	Organic Matter %	Zn		Pb		Mn		Cu		Cd		Cr	
			S	E	S	E	S	E	S	E	S	E	S	E
ALA 1	6.74	3.25	5.88	6.05	45.71	4.81	10.45	10.91	1.44	1.50	0.89	0.74	0.51	0.58
ALA 2	6.25	3.40	6.54	6.96	5.68	5.77	11.36	10.83	1.70	1.60	0.71	0.88	0.42	0.47
ALA 3	5.90	3.36	7.80	8.04	4.42	4.55	9.42	9.87	1.65	1.80	0.82	0.78	0.55	0.60
Mean	6.30	3.34	6.74	7.02	4.94	5.04	10.41	10.54	1.60	1.63	0.8	10.80	0.49	0.55

S = Soil, E = Earthworm ALA $_1$: COLPLANT Farm Area, ALA $_2$: Water Reservoir Area, ALA $_3$: Students Hostel Area

Table 44 shows the metal ion concentration in the earthworm (*Libyodrilus violaceus*)

Table 44: Metal Ion Concentration in Earthworms (*Libyodrilus violaceus)* from Contaminated Sites (waste dumps) in Abeokuta City, Nigeria

Sample Site	Zn	Pb	Mn	Cu	Cd	Cr
Adatan	84.77	84.86	171.54	33.15	7.55	13.10
Asero	57.64	51.12	80.73	20.49	5.31	10.79
Iberekodo	75.51	266.35	92.36	20.67	5.72	8.20
Ijaye	182.43	185.29	137.42	36.75	6.01	16.31
Imo	62.15	73.31	72.07	29.80	5.11	8.97
Isale-Igbein	84.72	54.03	71.51	24.26	4.35	9.68
Ita-Oshin	257.44	271.89	103.33	68.19	4.89	7.43
Kuto	190.23	381.72	122.84	30.38	5.94	8.41
Lafenwa	96.18	148.95	94.13	18.47	5.01	7.12
Obantoko	72.75	90.74	99.19	28.00	4.67	6.4

Data are in µg/g dry weights

The levels showed slight variations in the metal concentrated and in nearly all cases, the concentrations in the earthworm (*Libyodrius violaceus*) being slightly higher than those of the soil samples, however for the contaminated sites (Table 44) the reverse was the case, in which the concentration of metals in the soil samples were higher than those of the earthworms and in conformity with the reported work of Weigmann (1991), irrespective of the degree of pollution the ratio of metal concentration in earthworms to soil samples is less than one (unity).

We found out that the amount of metals accumulated within earthworm tissues is partly dependent on the absolute concentration of the metal within a given soil and is strongly co-determined by physiochemical edaphic interactions of factors such as pH, organic matter content and cation exchange capacity.

This study also confirmed the widely led view that motor vehicle emission contribute to the levels of Pb in the environment. As we found out that dumpsites located on motor ways in this case the kuto market had the highest level of lead to the tune of 443.36pp

2.5.2 *Effective management of feacal sludge through co-digestion for Biogas Generation*.

The use of fossil fuels as primary energy source has led to global climate change, environmental degradation and human health problems (Adeniran et al., 2014). A lot of feedstock wastes is generated from agriculture and as such these wastes can be properly managed by conversion into useful and more environment-friendly forms called biogases. Biogas is a mixture of colourless, flammable gases obtained by the anaerobic digestion of plant-based organic waste materials (Abubakar, 2012). Bio-gas is typically made up of methane (50-70%) carbon dioxide (30-40%) and other trace gases (Cheremisinoff, 2003). A pilot study for bio-gas production was carried out by one of my PhD student in 2017 of leading to the publication of Soyingbe *et al.,* 2019.

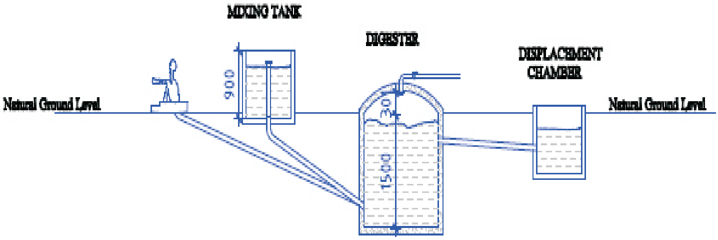

Fig. 17. Schematic diagram of Biogas production.

Plate 1. Construction of digestion dome.

Plate 2: Biogas digester construction with pipe fixings

Plate 3: Pressure gauge for gas quantity determination

Plate 4: Fixed Stock Material Mixing in the Inlet Tank

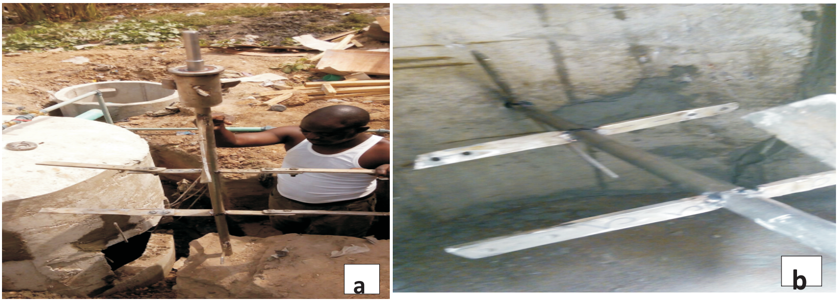

Plate 5: Stirrer constructed with antirust steel metal: a)- stirrer before installation and b)-stirrer after installation

Plate 6: Measurement of gas flow rate

2.5.2.1 Process of constructing fixed dome digester

The digester was constructed in accordance with a designed layout (Figure 17 and plates 4, 5 and 6). The foundation was casted with two bags of cement at a mixing ratio of 5 head pans of sharp sand to 7 head pans of granite per bag of cement reinforced with iron rod, the digester stand was cast with 2½ bags of cement at the ratio of 5:6 head pans of sharp sand and granites respectively per bag of cement while the dome head of the digester consumed 2¾ bags of cement in the above ratio. Two 4ft size well rings were used as inlet and outlet (slurry) units at a distance of 2ft between the digester. A water resistant iron fabricated stirrer was fixed into the digester before the dome was cast for effective mixing of the substrate. Pipe line connection to convey methane to the kitchen for utilization was also carried out (Plate 5). Both inlet and outlet tanks were covered with metal plate to reduce odour nuisance and breeding of mosquitoes.

Table 45: Financial cost of the digester construction (2 m^3) at ₦420.00/dollar as at 2016

S/N	Items	Amount (₦)
1		18,000.00
2	Granite (47 head pans) at N250.00	11,750.00
3	Labour for excavation (2 men)	12,000.00
4	Sharp sand (37 head pans) at ? 125.00	4,625.00
5	8mm iron (15pcs) at ? 800.00	12,000.00
6	Plywood (6 pcs) at 900.00	5,400.00
7	Plywood (6 pcs) at 900.00	5,400.00
8	2x2 plank (14 pcs)	3,500.00
9	3x3 plank (1 pcs)	6,000.00
10	Nails	2,000.00
11	Well ring (2 pcs) at ? 4,500.00	9,000.00
12	Inlet and outlet cover (2 pcs) at 3,000 each	6,000.00
13	Iron bender labour	7,000.00
14	Carpenter labour	15,000.00
15	Bricklayer	15,000.00
16	Plumber	20,000.00
17	Plumbing materials	35,000.00
18	Stirrer fabrication	80,000.00
19	Miscellaneous (Transport of materials to site)	3,000.00
20	Pour flush Toilet facility	4,000
21	Stove	5,000
	Total	**N274,275.00**

2.5.2.2 Monitoring of the fixed dome digester's performance

In order to monitor the performance of the digester for its efficacy, samples of substrate (feedstock) and digestrate (effluent) slurries were collected and analyzed for physico-chemical and microbial contents between October 2015 to January 2017. Three feedstock materials were used for co-digestion with feacal sludge for biogas production in the digester. The feed stock materials are; cow dung (CD), Cow intestinal waste (CIW) and mixed organic waste (MOW). The Cow Dung (CD) was sourced from Federal University of Agriculture, Abeokuta (FUNAAB) cattle cooperative farm and Cow Intestinal Waste (CIW) was sourced from Ifesowapo Asejere abattoir, Agbeloba, Abeokuta while Mixed Organic Waste (CIW) was sourced from the households and Panseke market, Abeokuta. Each of the feedstock was replaced at the end of the retention time (time between the commencement of gas production and termination of the experiment) which is average of 30 days for each feedstock material. The feedstock were thoroughly mixed with well water in the inlet mixing tank (Plate 4).

Each feedstock was fed into the digester and the readings taken accordingly until the retention time is reached before the next feedstock was loaded. Analysis of the effluent (slurry) was carried out with the intention to determine its suitability for farm application as organic fertilizer. Samples of the effluent slurry were taken after one month of retention in the digester. Proper stirring of the content inside the digester was carried out to ensure uniform decomposition, using a specially fabricated stirrer improvised with the digester (Plate 5). Digital gas detector (Plate 6) was also used to analyze the gaseous composition of the biogas and assess methane generating potential of the digester. Arising from this pilot studies the following papers had been published Soyingbe *et al.,* 2019, 2020 and 2021.

2.5.3 *Utilization of Maize (Zea Mays) cob as an absorbent for lead (II) removal from aqueous solution and industrial effluent.* Existing technologies for heavy metals removal from waters and waste waters are often expensive and unavailable in developing countries. A higher percentage of these pollutants are therefore being released into aquatic ecosystems by manufacturing companies in these countries. There is therefore the need to find alternative inexpensive and effective methods for heavy metals abatement from waters. Bio-sorption remains an emerging field in this regard. It involves the use of living and non-living biological matters for pollutants removal from aqueous solutions and industrial effluents. Although various treatment techniques have been employed to treat wastewater, most of the methods suffer some drawbacks such as expensive generation of secondary pollutants and ineffectiveness for low metal concentration (Han *et al.,* 2006). Agricultural waste materials have also attracted attention of researchers as biosorbents for the removal of heavy metals in wastewaters (Horsfall *et al.,* 2004; Khan and Wahab, 2007).

Maize (Zea mays) cob was selected for this study because of its relative abundance in Nigeria. Maize is a major staple cereal in Nigeria and therefore, produces large volume of waste. Maize is widely believed to have the greatest potential among food crops for attaining the technological breakthroughs that will improve food production (Smith *et al.,* 1997).

Almost all the different uses of maize dispose off the cobs. The cobs were therefore used as potential adsorbents for Pb^{2+} removal from wastewater particularly since conventional methods are expensive. (Opeolu *et al.,* 2009). Table 46 shows the percentage removal of Pb^{2+} by adsorbents, while Table 47 shows the result of shaking on the percentage adsorption of Pb^{2+}.

Table 46. Percentage removal of Pb^{2+} by adsorbents.

Weight of residues(g/L)	Pb^{2+} removal from solution at equilibrium (mg/L)	
	Dowex	Maize cob
0.025	74.88a	23.80a
0.05	80.89b	35.70b
0.10	81.99c	57.90c
0.20	83.74d	77.90d
0.40	85.80e	82.20e
0.60	86.16f	82.70f

Figures followed by the same letter within a column do not differ significantly according to DMRT at 5% level of probability

Table 47. Effect of shaking on percentage adsorption of Pb^{2+} in 100 mg/L standard solution and effluents at equilibrium.

Adsorbent	Pb^{2+}Standard solution		Effluents			
	Shaken	Unshaken	Battery (Shaken)	Battery (Unshaken)	Paint (Shaken)	Paint (Unshaken)
Dowex	88.92	85.77	59.82	52.68	41.07	27.83
Maize	86.90	77.90	100.00	100.00	100.00	66.13

Two adsorbents maize (*Z. mays*) cob and dowex (a synthetic adsorbent) were used to bind Pb^{2+} from standard aqueous solutions. Effects of adsorbent weight, Pb^{2+} concentration, contact time and pH were assessed to determine equilibrium conditions for adsorption.

Since maize cob have the potential to remove Pb^{2+} from aqueous solutions and industrial effluents, it implies that it may also decontaminate wastewaters containing other divalent metal ions such as Zn^{2+}, Cd^{2+}.

3.0 CONCLUSION

The exponential growth in population leading to a higher consumption of energy, food and materials opens up an astronomical increase in human prints on the environment.

It is of utmost importance that we do everything possible to ensure the preservation of a healthy environment, not only in our own interest but also in the interest of generations that will come after us and to whom ideally we should bequeath a legacy of a clean habitable and safe environment as we are all stake holder in the global village. The time is now for all of us to join the struggle for a healthy environment in order to reduce considerably the footprints of man on the environment.

4.0 RECOMMENDATIONS

Mr. Vice-Chancellor, Sir in the course of this lecture, I have attempted to show that activities of man leaves a trace on the different components of the Environment, be it the atmosphere, hydrosphere, biosphere or the lithosphere.

In achieving this lofty objective I wish to recommend as follows:

1. Government must be alive to its responsibilities of funding Universities, so that there could be sustained research in the identification of man's footprints on the environment.
2. The political terrain has created six geo-political zones and as such I wish to implore government to establish standard laboratory complexes with state of the art equipment that Universities can draw on, with the aim of achieving its mandate of tracking man's footprints on the environment.
3. It is also of utmost importance that there must be increased public awareness in the light of a greater public education so that the populace can fully understand the need to halt indiscriminate ugly and unwarranted human footprints on the environment. Nothing beats ignorance like education

positive dividend of democracy to its citizens. The high cost of fuel has hard a spiral effect on cost of living that what can assist green environment is virtually disappearing in the like of using gas, even as at now Kerosene has become an antiquity and citizens are in the bush with a heightened rise of deforestation; an increased and indelible footprints of man on the environment.

4.0 ACKNOWLEDGEMENT

Mr. Vice-Chancellor Sir, I have been specially favoured by the Almighty God "Not by might nor by power but by my spirit says the Lord Almighty" *Zechariah 4:6 (NIV).* I am indeed very grateful to God Almighty Who alone is the giver of life for his divine favour upon my life. I am what I am today by His Grace and I give him all the glory.

Starting from my immediate environment, I wish to appreciate all the former Vice-chancellors of this great University since I took up employment in November 1991, having transferred my service from the Ogun State University now, Olabisi Onabanjo University. First the foundation Vice-Chancellor, Prof. Nurudeen Nimbe Adedipe under whose leadership I joined the services of the University as Lecturer I in the Department of Environmental Management &Toxicology and as the 2nd academic staff, coming immediately after my late bosom friend, Alhaji Dr. Kolade Jinadu. I wish to thank Prof. Julius Amioba Okojie the first VC that we elected via the ASUU-FGN agreement of 1992. The rest is history. Till today Prof. Okojie still owes me for naming of the University Journal as ASSET when he threw this challenge at us at a senate meeting. I am yet to be remunerated for this effort and I throw the challenge to the sitting VC, Prof. Olusola Babatunde Kehinde to do the needful.

It was under the late Prof. Israel Folorunso Adu, that I unleased my pen on the University community. Prof. Ishola Adamson came into office as acting Vice-Chancellor when everything was about acting upside down. Then my good friend and mentor, Prof. Olaiya Balogun who I often refer to as a car in the likes of Morris minor; small frame but yet a big engine in similarity to his brain. He exposed me internationally and indeed locally when I served as the pioneer Director of the Centre for Entrepreneurial Studies which I nurtured and coined as CENTS

I am extremely grateful to Prof. Olaiya Balogun for the exposure and relationship we had when and even after his tenure. He opened my eyes to what had been there but I did not see. Thank you sir.
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Each of these VCs had at hand various Deputy Vice-Chancellors both academic and Development who had assisted them in carrying out their various responsibilities. But of all these Deputy VCs I can't but mention my very very good friend; Prof. Toyin Arowolo and my friend before, before 'Mummy' Precious, officially addressed as Prof. Bolanle Akeredolu Ale. And also Profs Mrs. Morenike A. Dipeolu, Lateef Sanni, Clement Erumosele, Yemisi Erumosele, Christopher Onwuka, Ariyo and last on the list are the current DVC, Profs Kolawole Adebayo and Christian Ikeobi.
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I have worked full time at the University of Ibadan, Ibadan, Lagos State University, Ojoo, Olabisi Onabanjo University, Ago Iwoye and presently at FUNAAB. While I had the opportunity of sabbatical appointment at OOU, Unilag and FUTA. At the University of Ibadan, I cannot forget my lecturers that put me on the path of chemical reactions vis-avis Profs Bankole, Ogunmola, Adesogan, Ajayi, Adesumoju, Kolawole, Adeleke, Odiaka, Onianwa, Remi Idowu, Faboya and last but not the least my indefatigable supervisor at the Masters and Ph.D level, Prof. Oladele Osibajo, here was the workaholic genes that I inherited from and I recollect how I acknowledged him on the completion of my PhD, "his guidance, criticisms and suggestions throughout the duration of this work, particularly his inspiring words of encouragement on this work. His attitude to work and determination to succeed in spite of all odds had inspired me in appreciating the fact that purposeful research work calls for self-discipline, hard work, patience and humility as shown by him".

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After the completion of my secondary school at GCI, the then Oyo State Government cancelled Higher School Certificate (HSC) and then created Basic Studies of which I registered for at the Ibadan Polytechnic set of 74-76. I also had dedicated teachers who saw

During this period, I also made a lot of acquaintances which time and the quest for survival would naturally had made me to forget these friends, but thanks to the creation of a Whatsapp group that has brought back all these my friends of which I cannot list all of them except a few troublesome ones like Profs Bassman Olayiwola, Victor Olumekun Kehinde Ayoola, Kayode Adedire, Abiola Aborisade, Francisca George, Jimi Adesina and the non-professorial course mates, include, Yomi Olomolaye, Lanre laoshe, Adesina Agboluaje, Sunkanmi Onadeko, Ayodeji Mosuro, Kola Kolade, Akiola Kester, Ademola Onafowokan, Sola Olokode, Toyin Taiwo, Segun Ojo, Akin Oyekola, Niyi Akande, Olusesan Ekisola, Edward Boyo, Toyin Osibodu, Bukki Layode Adekoya Sofowora, Dupe Aro, Gbemisola, Oke, Kolapo Adisa, Abike Adewole, Olukayode Alufa, Wuyi Atiba, Akin Oyekola, Biodun Adeyinka, Adewale Temowo, Segun Olumodesi and numerous others. All of these friends are now old men/women looking straight ahead to three score and 10 years.

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We have no other Union but ASUU that has sole handedly given to the Universities all the ground breaking improvement vis-a-vis salaries and emoluments like EAA, Excess work load and other allowances and the ability to stand up to dictatorial Vice-chancellors and authoritarian Governments. We must all rise up in support of our Union as no other Union can take us to the Promised Land.

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to the less brilliant students. The 2022/2023 graduating 500 level EMT toxicology option students comes to mind as a wonderful class of brilliant students. This inaugural is also a celebration of my graduate students and in this vein, I would like to acknowledge the efforts of my PhD students and a few masters students who came together to form the G15 in support of my inaugural. The Jotter's came as a complimentary gift and was solely financed by them, along with other financial support that made my personal financial commitment to the Inaugural, a walk in the park.
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Dr. Azeez Soyingbe	-	Ogun State College of Health Technology Ilese.
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Dr. Tayo Sindiku	-	Analytical/Environmental Consultant
Abudulsalam Lateef	-	9 Mobile
Charles Emuegb a	-	Environmental Consultant
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My immediate family, Prof. Mrs. Titilayo Bamgbose, Adebimpe Oluwatoyin, Fisayo Oladunni, and my children, Bukola, Gbolahan, Taiye, Kehinde, Debo and Eniola, you all, are the type of children that any parent will always be proud of. I am indeed proud of you all as I eagerly await to become a grandfather soon from Gbolahan and Smhruthi….

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And then, I cannot but thank my wife, Prof. Titilayo, Janet Bamgbose, you have undertaken this rough journey of life, through thick and thin with me in the last thirty years plus. You have been a great support in the proper training of our children to make them attain enviable status in life. Most important of all, you have survived turbulent times that ordinarily would have taken the lives of mere women and indeed academics. You stood tall, undaunted, head unbowed though bloodied, yet here you are, despite all these obstacles at the peak of your profession. I sincerely appreciate you.

In my effort at attaining this lofty academic goal, I have benefited immensely from the direction and intellectual versatility of my teacher, friend and father Prof. Ayo Bamgbose, Doyen of Linguistics in Africa, member General Assembly and the Executive Committee of the Permanent Committee of Linguists (CIPC). Honourary member of the Linguistic Society of America and past president of West Africa linguistic Society and Yoruba Studies Association of Nigeria. It is this distinguished Linguist, language planner and literally scholar in conjunction with my mother, my inestimable Jewel whose love and sacrifices know no bound that I honour with this inaugural lecture. Thank you.

To the audience and all guests from outside the University, I deeply appreciate you all and wish you journey mercies to your various destinations. I appreciate the Publications and Ceremonial committees that made this day to be.

Mr. Vice Chancellor Sir, Principal Officers of the University, Deans of Colleges, Guests, ladies and gentlemen the greatest of the greatest Unaabites, I thank you all for your patience and attention.

And before we take our leave, I seek the indulgence of the Vice Chancellor to say that may your footprints on this University environment leave a positive trace and in seeking this objective, ASUU is to be greatly counted and relied on. In this vein I would like to end this lecture with the solidarity song………SOLIDARITY FOR EVER……..Please sing along with me.

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