UNIVERSITY OF LAGOS, NIGERIA
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TOPIC:

POLLUTANTS IN THE ENVIRONMENT: PEREGRINATION OF AN ANALYTICAL CHEMIST

By
PROFESSOR KEHINDE OLOLADE OLAYINKA

Pollutants in the Environment: Peregrination of an Analytical Chemist

An Inaugural Lecture Delivered at the University of Lagos Main Auditorium on Wednesday, 9th March, 2016

By

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My Precious Students, past and present;
Gentlemen of the Press;
Distinguished Guests, Ladies and Gentlemen.

I give thanks and praises to the Almighty God, the King of Kings and Lord of Lords for making this day a reality. May His name be Glorified. Amen.

I wish to express my gratitude to the Vice Chancellor for giving his approval to deliver this lecture. Mr. Vice Chancellor, Sir, I would like to place it on record that this is the 9th Inaugural Lecture to be delivered by a Professor from the Department of Chemistry of this Citadel of Learning. This Lecture is the first Inaugural lecture in the field of Analytical Chemistry. I am by the special grace of God the first Professor of Analytical Chemistry of this great University.

INTRODUCTION

Mr. Vice Chancellor, Sir, this Lecture is titled, "Pollutants in the Environment: Peregrination of an Analytical Chemist". The lecture focuses on the role of an Analytical chemist in the accurate determination of pollutants in the environment and invariably in food which are the products of the environment.

In achieving the above objective, I consider it necessary to describe some of the key words/ concepts which are the pillars of this lecture. I appreciate the fact that my audience is made up of Chemistry and non-Chemistry students and graduates. I

acknowledge that the entire University community is represented in today's lecture. There are also visitors and well-wishers from outside the University representing the community among us. I cannot conveniently welcome you to my world of Analytical and Environmental Chemistry without a good foundation. We should be on the same page in this lecture to achieve the proper flow of thought.

Having described the key words or basic concepts, the lecture will examine the following issues:

i) Steps to be taken in analysis of samples/Analytical Instruments
ii) Some toxic pollutants of interest/Toxicological risk assessments of pollutants
iii) My works in the field of Analytical Chemistry focusing on the accurate determination of pollutants in foods, soils, waters, etc. My studies deal with foods and different environmental matrices. The study on the Environment deals majorly with Lagos State because of the many industries located in the State and the dearth of information in this area. However, the information obtained is applicable worldwide.
iv) My collaboration efforts within and outside Nigeria are also presented in this lecture.

Finally, the lecture ends with an overview of my modest contributions to the field of Analytical Chemistry, my conclusions and recommendations.

DEFINITION/BASIC CONCEPTS

1. Pollutants - These are substances that are harmful to the Environment.
2. Environment - This is our natural world. It consists of Air, Water and Soil.

   The environment is God's greatest free gift to mankind. The history of creation in the Bible shows that God created the world and it was perfect. God gave us dominion over our Environment; it was clean and pure.

Cleanliness, like we say, is next to Godliness. Today, the environment has been defiled and polluted by us.

3. Peregrination - Simply put, is a journey - a long but rewarding and fruitful journey. It is synonymous with an odyssey, globetrotting, expeditions and excursions.

Today's Lecture is the product of a journey of many years. It began in 1976 when I matriculated as an undergraduate student of Nigeria's Premier University, University of Ibadan. I graduated in 1979. Between 1980 - 1982, I was at Ahmadu Bello University, Zaria for my Master's degree. I was at Greenwich University, London, UK between 1984 - 1988 for my Ph.D degree. The journey as an Analytical Chemist includes my stay at the Federal Institute of Industrial Research, Oshodi (FIIRO) from 1982 - 1999. I joined this great University as a Senior Lecturer in 1999. The journey took me to most parts of Lagos State, other parts of Nigeria and the UK. Gathering and analysing samples of chemicals in polluted water, soils and foods are the reasons for my journey.

In the bid to ensure accurate measurement of chemicals/ pollutants in the samples collected, I had to travel and collaborate with colleagues outside Nigeria. Mr. Vice Chancellor Sir, so far it has been a journey of almost 37 years as a Chemist, out of which 32 years have been devoted to continuous research work as an Analytical Chemist. It has been a fruitful and rewarding journey, hence, the choice of the phrase "Peregrination of an Analytical Chemist" in this lecture. Permit me to say that the lecture is a presentation of the results of my various research works as an Analytical Chemist.

ANALYTICAL CHEMISTRY

Analytical Chemistry is a specialised Chemistry. A mother and child relationship exists between Chemistry and Analytical Chemistry respectively. Every child is the product of a biological mother. It is impossible to talk of a child without a biological mother. It is not possible to speak about Analytical Chemistry without reference to Chemistry. I would therefore deal with Chemistry before examining Analytical Chemistry/ Analytical chemist.

WHY IS CHEMISTRY IMPORTANT?

Any nation that must experience progress must take Science and Engineering very seriously. Chemistry is a Central Science. It is the study of how matter changes and it is applicable to Medicine, Petroleum and Solid Minerals Exploration, Drug production, Biotechnology, etc.

It is not limited to beakers, conical flasks and laboratories or people wearing lab coats. The truth is that all of us living are Chemists. Chemistry is all around us, it explains why an egg changes when it is fried, how soap and shampoo make us clean, how the petrol in our car works and why we become alert after drinking coffee, etc. As we Chemists ask: "What in the world is not Chemistry?"

WHAT ARE CHEMICALS?

Chemicals are used to make virtually every man-made product. Chemicals are made of molecules, tiny particles too small to see without a microscope. An atom as we know is the smallest particle of an element.

Chemicals are everywhere, in every area of life. Everything we breathe, see, eat or touch is made up of chemicals. Even we as human beings are made of chemicals. For example water (H_2O), diamond (Carbon, C), Gold (Au), refined sugar (sucrose, $C_{12}H_{22}O_{11}$), drugs for prevention and treatment of diseases are all chemicals. Life will not exist without chemicals!

Plate 1: Some Examples of Chemicals

Mr. Vice Chancellor, Sir, all chemicals can cause harm at a certain level. When a small concentration of a chemical is harmful, the chemical is said to be toxic. However, when a very large amount of the chemical is needed to cause damage, the chemical is considered to be relatively non-toxic. Toxic chemicals can cause acute/chronic effects or both. Some chemicals cause cancer (the uncontrolled growth and spread of abnormal cells in the body - Carcinogens).

As at 2008, about 500 chemicals were considered to be carcinogenic in humans. Some other toxic chemicals cause genetic damage. The genetic material of a cell consists of DNA, which is organised into genes and chromosomes. DNA informs the cell of how to function and reproduce (form new cells). Some chemicals may change or damage the genes or chromosomes (mutation), these are mutagens.

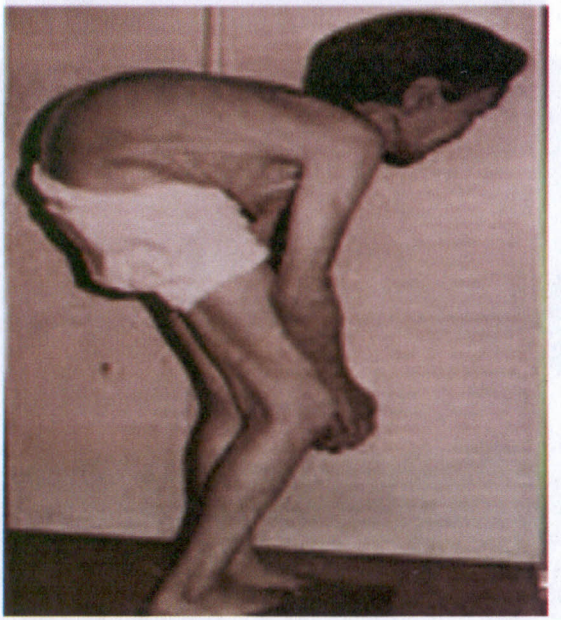


Plate 2: Cadmium Poisoning - Itai Itai Disease

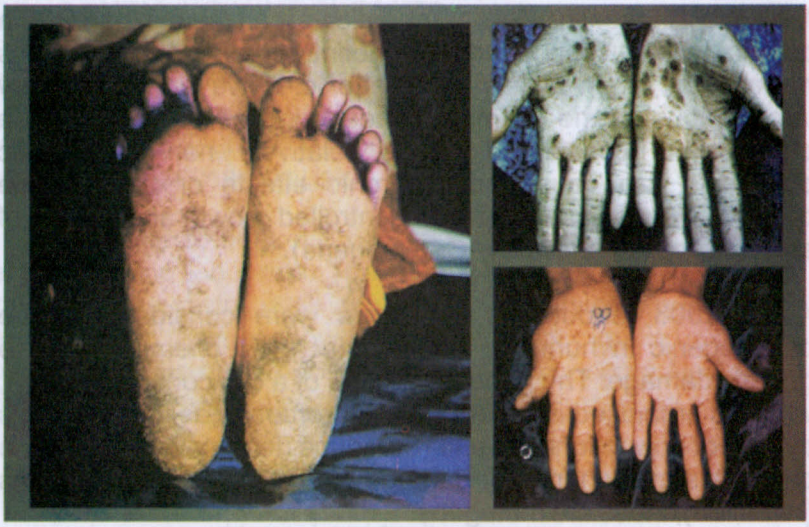


Plate 3: Arsenic Poisoning

Plate 4: Mercury Poisoning, Minamata Bay, Japan

WHAT IS ANALYTICAL CHEMISTRY?

Analytical Chemistry is unique. It is the area of chemistry responsible for the characterisation of the composition of substances both quantitatively and qualitatively. It involves separation, identification and determination of the chemical components in a sample. Analytical Chemistry plays an essential role in Medicine, Geology, Forensic Science, etc. It helps medicine to understand, diagnose and treat disease, essential for the safety of our food and water supplies, important for quality control in the manufacture of plastics, paints, fabrics, fertilizers and nearly everything that we use. If you breathe air, eat, drink, use manufactured goods or visit the doctor when you are ill, your life depends on Analytical chemistry every single day (Harris, 1995). Analytical Chemists or Analysts use different methods to investigate the chemical nature of substances.

An Analytical process usually begins with a question or problem? Is this water safe to drink? How much caffeine is in this tea, coffee or energy drink? How much active ingredients are in the drug? Is the soil or air contaminated? The Analyst then chooses or develops the procedure to solve the problem. When the measurements or analysis is complete, the Analyst must translate the result into what can be understood by the general public or end user.

STEPS TAKEN IN ANALYSIS OF SAMPLES

An analytical procedure has several steps: sampling, sample preparation, separation (extraction) and removal of interferences, statistical evaluation, decision and action (Khan *et al.,* 2005).

For analysis, most of the samples to be analysed are heterogeneous in nature. To obtain a meaningful chemical analysis, we must obtain a small, homogeneous sample that is representative of the whole sample. The component to be measured (called the *analyte*) must be transformed into a suitable form. We may also need to remove interfering species from the component so that we do not obtain a false result.

Correct sampling ensures that representative samples are obtained, etc. A laborious analysis is worthless if the sample that is analysed is not representative of the original population e.g. in analysing the iron content of seawater, taking seawater from a single depth would not give a representative sample of the entire ocean.

Sample preparation may involve grinding to reduce the particle size, mixing to ensure homogenous sample is used and storing for different lengths of time before analysis begins.
We analyse replicate samples after careful measurements. Replication improves the quality of results and gives a measure of their reliability.

Analysis can be determined on solids, solutions or gaseous samples. Conversion of the analyte component into soluble forms can be difficult, time consuming and may involve heating the sample with strong acids, strong bases, combination of solvents or extraction with organic solvents, etc.

Species other than the component that affect the final measurement are called interferences. We must devise a scheme to isolate the analyte from interference before the final measurement is made. Resolving the problem of interferences is one of the most demanding aspect of an analysis and can involve different separation techniques like chromatography (e.g. solid phase extractions (SPE, SPME, liquid-liquid extractions, etc.) or addition of reagents to mask the interfering species or selectively react with the analyte.

The Analytical chemist develops the method for the separation/extraction of sample, isolate, clean up and concentrate the component analyte (pollutant) of interest. This is the heart of Analytical Chemistry. The Analyst has to understand the chemical principles of the reactions involved in extraction, clean up, instrumentation, etc.

It is only after the cleanup that the concentration of analyte is determined using instrumental techniques like the Atomic

Absorption Spectrophotometer (AAS), Gas Chromatograph-Mass Spectrometer (GC-MS), High Performance Liquid Chromatograph (HPLC, etc.).

The results obtained from instrumental analysis are evaluated statistically to give meaning to data generated and this then indicate decisions to be taken. To obtain accurate results, painstaking efforts are required. For an Analytical chemist, the validation of experimental data requires an effort that is comparable to that involved in the initial data acquisition.

The results of an analysis may be used for treatment of patients or making vital decisions. Therefore such results must be accurate. Mr. Vice Chancellor, Sir, analytical expertise takes time to develop. It is very common to make errors in analysis and several publications abound in print with such errors. Validation of measurements is always important.

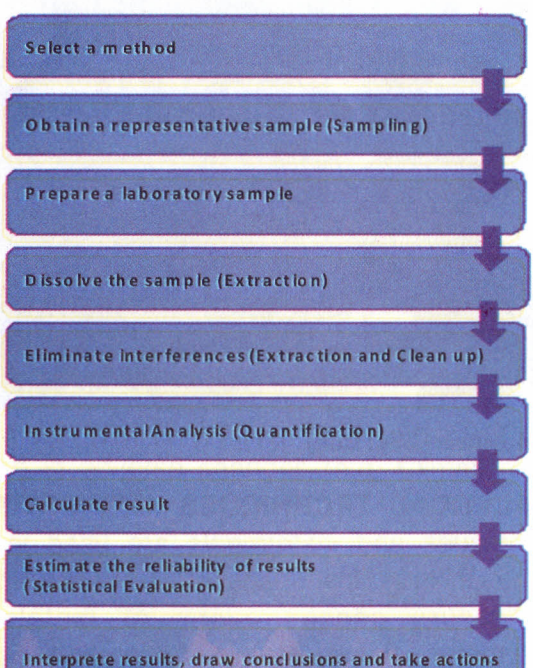


Fig. 1: Steps in Quantitative Analysis (Adapted from, Skoog & West, and Harris, 1995)

Mr. Vice Chancellor, Sir, some Scientists albeit, Chemists have erroneously suggested that Analytical chemistry is not a separate branch of chemistry but just the application of the knowledge of Chemistry. Unfortunately, the unique art of Analytical Chemistry is not in performing routine analysis on a routine sample. The Analytical chemist develops and validates appropriate, accurate and quantitative analytical methods. After its development, the routine application of the method is then the job of an ordinary Chemist.

It is after developing the method that it then becomes a routine technique that is written out as a manual as in Association of Public Health Association (APHA), The Official Methods of Analysis of AOAC International, British Pharmacopeia (BP) etc.

Fig. 2: An Analytical Laboratory

SOME ANALYTICAL TECHNIQUES AND INSTRUMENTS

Several techniques and instruments are used in Analytical Chemistry, they include Spectroscopic techniques where light is used to measure concentrations of metals i.e. UV Spectrophotometer, flame Atomic Absorption Spectrophotometer (AAS), Electrothermal Atomic Absorption Spectrophotometer (ETA-AAS), Inductively coupled plasma-

mass spectrometer (ICP-MS); Chromatographic techniques involving separation where one phase is held in place while the other moves past it (mobile phase) e.g. Gas chromatograph with flame ionisation detector (GC-FID), Gas chromatograph with electron capture detector (GC-ECD), Gas chromatograph - mass spectrometer (GC-MS), High Performance Liquid Chromatograph- UV DAD (LC-UV), High Performance Liquid Chromatograph-Fluorescence detector (LC-FLD). In Analytical Chemistry, newer equipments and techniques are developed virtually every day.

It is therefore important that equipment are not stored away in laboratories but used regularly so that they do not become obsolete before they add any value.

SOME ENVIRONMENTAL POLLUTANTS OF INTEREST

Mr. Vice Chancellor, Sir, in Genesis 1:9-10, God said, "Let the waters below the heavens be gathered into one place, and let the dry land appear and it was so. God called the dry land Earth, and the gathering of the waters He called Seas; and God saw that it was good. Then God said, Let the earth sprout vegetation: plants yielding seed ..." God made everything and saw it was good!

However, in the quest of man for better living standards, man developed Science and Technology (Industrialisation) and has continued to plunder the natural resources thereby polluting the Environment. Man degraded the lands and forests, threw toxic wastes into rivers and seas and harmful gases into the Environment. This continuous load of man-made pollutants into the Environment is referred to as "Environmental Pollution" and has resulted in adverse changes (e.g. Climate change) and human health hazards.

An Analytical Chemist studies the toxicological effect (risk) of pollutants in the Environment. Some of the toxic pollutants we studied include Persistent Organic pollutants (POPs), Heavy metals and Nutrients.

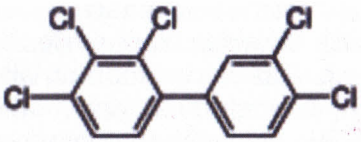


Plate 5: PCB

Plate 6: Benzo[a]pyrene

PERSISTENT ORGANIC POLLUTANTS (POPS)

These are also called Persistent, Bioaccumulative and Toxic pollutants (PBTs). They are mostly synthetic chemicals and persist (i.e. do not break down easily) in the environment, they bioaccumulate in food chains and pose a risk to human health and the ecosystem. There are three classes of POPS: Polyaromatic hydrocarbons (PAHs) Polychlorinated biphenyls (PCBs) and pesticides (UNEP, 2003).

Some of these POPs have been found in fish in concentrations that are much higher than those in the waters in which they swim. This phenomenon is called Bioaccumulation; they accumulate the pollutants from the waters and sediments through their gills into their fatty tissues and become more concentrated there. As the small fishes are eaten by the bigger fishes and eventually by humans, the concentration of the chemicals increase dramatically up the food chain. A chemical (pollutant) whose concentration increases along the food chain is said to be biomagnified. In essence, though a low concentration of pollutants is discharged into the rivers and seas, a much higher concentration is found in big fishes and humans (as much as 100 times the concentration of the original pollutant).

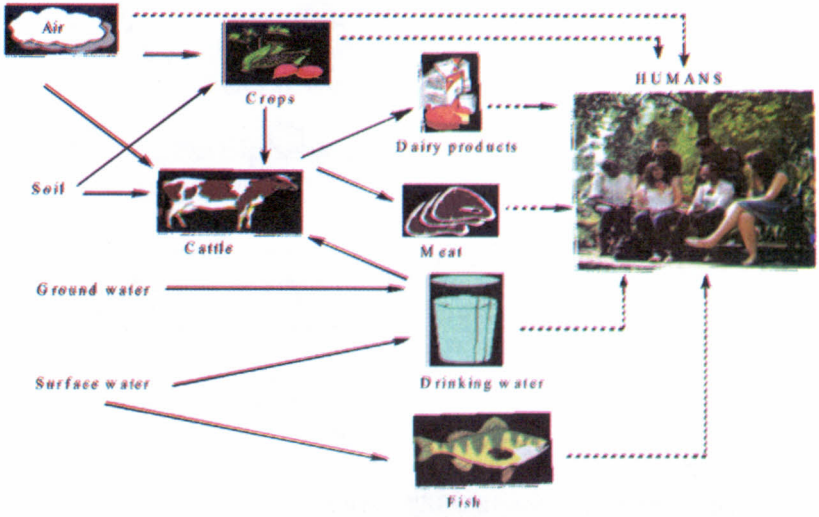


Fig. 3: Human Exposure Routes to Pollutants, courtesy SETAC (Society for Environmental Toxicology and Chemistry) culled from Alani, 2011.

PAHs

These are a group of organic compounds that have two to thirteen aromatic rings, they have two or more fused benzene rings in various arrangements. They are of environmental concern because some of the compounds are toxic, mutagenic, or suspected carcinogens. Sixteen PAHs (acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chry-sene, benzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, and pyrene) are known as priority pollutants (Messinger, 2004).

The sources of PAHs include oil spillages, incomplete combustion of organic matter (e.g. automobiles, domestic heating with coal, forest fires, etc.), industrial waste, domestic waste, municipal effluents, etc.

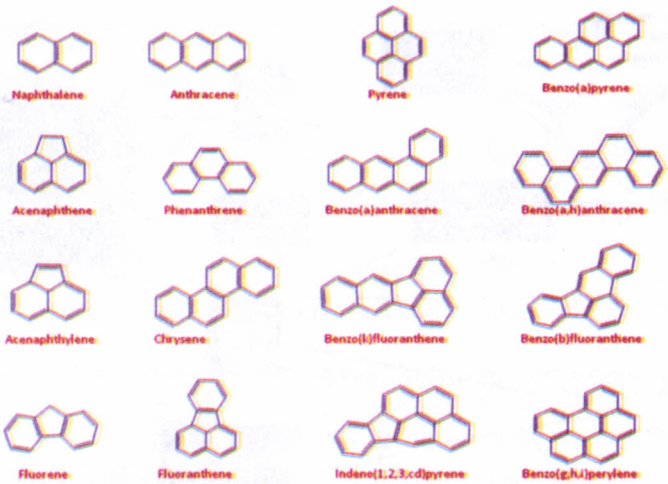


Fig. 4: Structure of the 16 USEPA Priority PAHS (Joa et al., 2009)

Pyrogenic- Barbecue, Open Fire Grilling of Fossil Fuels

Petrogenic - Incomplete Combustion of Fossil Fuels

PAHs can damage the DNA in unborn children, cause disruption of endocrine systems or transformed into other chemical species.

Pesticides

Pesticides are substances that kill or control unwanted organisms (pests). The active ingredients in most of these pesticides are Organochlorines (OC). Organochlorine pesticides are not readily biodegradable, have low solubility in

water and high solubility in fatty materials resulting in bioaccumulation through the food chain. Examples of pesticides are DDT, Aldrin, Dieldrin, etc.

PolyChlorinated Biphenyls (PCBs)

PCBs are a group of industrial organochlorine chemicals that are used as coolant fluids in power transformers, as plasticizers, de-inking solvents and heat transfer fluids in machines, etc. When released into the environment, PCBs persist for many years because they are resistant to breakdown by chemical or biological agents. They cause cancers and birth defects in humans.

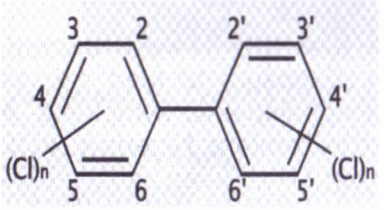


Plate 7: PCB

Plasticizer (Plastics)

Metals

Heavy metals are one of the most important pollutants of concern because of their common occurrence and public health relevance. The 'key heavy metals" are Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Lead (Pb). Others include Zinc, Copper and Nickel. Heavy metals are bioaccumulative and enter the environment through mining activities, industrial discharge and household electronic appliances, e.g. used televisions and computers (e-waste).

Metals are transported with sediments, persistent in the environment and a common pollutant in wastewater. They pose a risk to human beings and animals even at low concentration.

Electronic Waste (e-waste)

Television

Lead

Lead is extremely toxic and damages the nervous system, kidneys and reproductive system. Exposure to lead causes irreversible brain damage and encephalopathic symptoms. A case of lead poisoning was reported in Zamfara, Nigeria in 2010 where about 163 people died including 111 children and a recent incidence of poisoning was also reported in Niger State in 2014.

The investigation in Zamfara showed that illegal miners were digging for gold in an area where lead was prevalent. Initially, the villagers thought the children had contracted malaria but analysis by Médecins Sans Frontières (MSF) found unusually high levels of lead in the blood of the children.

It was later discovered that the poisonings were caused by the illegal extraction of gold ores by villagers, they take the crushed rock home with them to extract. This resulted in the contamination of soil by lead which then poisons people through hand-to-mouth contamination. Other people were contaminated by contact with contaminated tools and water.

Lead Poisoning, Zamfara State, Nigeria

Other Heavy Metals

Cadmium is reported to be the most toxic element. Even at its low concentration in the food chain, it causes itai-itai disease. It is used in the manufacture of rechargeable batteries, plastics, pigments, television sets, etc. It is toxic to human beings and animals as it causes renal dysfunction, lung cancer, increase in blood pressure, bone degeneration, liver and blood damage.

Nickel is used in several industrial applications, e.g. electroplating, automobile and aircraft parts, production of nickel–cadmium batteries, cosmetics, etc. Water soluble salts of nickel contaminate aquatic systems.

The toxicity of mercury has been recognised worldwide; mentally disturbed and physically deformed babies were born to mothers who were exposed to toxic Mercury due to consumption of contaminated fish. The sources of mercury in the Environment include mining and mineral processing, batteries and mercury fluorescent lamps. A case of mercury poisoning in Nigeria was also reported in Zamfara State, in 2010. Artisenal and small scale gold mining (ASGM) has long been practised in Nigeria and is associated with significant

environmental degradation. The use of mercury in mining operations was identified as the single largest intentional source of mercury pollution in the world. Mercury is released into the air or waters when miners heat the mercury-gold amalgams. Exposure to Mercury causes damage to the central nervous system, respiratory failure, nausea, vomitting, diarrhoea, increase in blood pressure, skin rashes, kidney damage, etc. Methyl mercury is more toxic than any other species of mercury.

Chromium (VI) is known to be more toxic than Chromium (III). Chromium is used in the leather and tanning industries, paper and pulp and rubber manufacturing industries. High levels of exposure causes liver and kidney damage, skin ulceration and also affects the central nervous system. Chromium (VI) causes greater toxicity than chromium (III) in animal and human health.

Mr. Vice Chancellor, Sir, the severe toxic effects and poisoning by heavy metals worldwide require strict regulations for discharge of solid waste and wastewater (effluents) into Aquatic bodies.

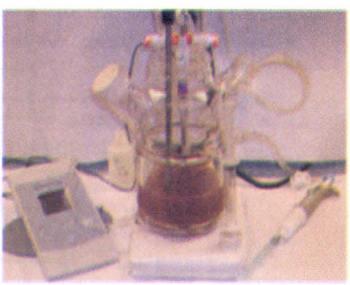
TOXICOLOGICAL RISK ASSESSMENT OF POLLUTANTS

Mr. Vice Chancellor, Sir, as Analytical chemists, we agree that the chemical form or species in which a pollutant exists affects its mobility, bioavailability and fate in the environment. We therefore realised it is important to identify not only the total pollutant concentration but also the different species of a pollutant in a sample (i.e., soil, water or food). If we only determine the total concentration of a particular heavy metal e.g. lead in a soil sample and not the different species of lead, it could give an erroneous assessment of the risk of lead in the soil sample especially if the level of bioavailable lead is low. In other words, not all the lead in that soil is bioavailable and leads to harm.

The Assessment of the risk of a pollutant in a sample matrix (e.g. soil, water or food) can be carried out by several

techniques. Some of the techniques include *in vivo* studies, *in vitro* studies, comparison of concentration of pollutants with regulatory limits or sequential extraction (SE) using different reagents for fractionation of pollutants, etc. *In vivo* studies entail testing the effects of the pollutants on whole animals including humans and plants whereas *in vitro* ("within the glass") involves testing the pollutants in a laboratory environment using test tubes, petri dishes, etc.

In vivo Studies



In vitro Studies

In Vitro Studies using Gastrointestinal Models

In vitro methods are preferred because *in vivo* studies can be difficult to interprete due to the physiological discrepancies between humans and the experimental animals used. *In-vitro* systems based on human gastrointestinal (GI) tract processing of food consists of ingestion, mastication, deglutition, digestion, absorption, peristalsis and defecation.

In vitro determines the bioaccessible fraction of a pollutant which is the fraction that is potentially available for absorption by the human or animal and can cause damage to it.

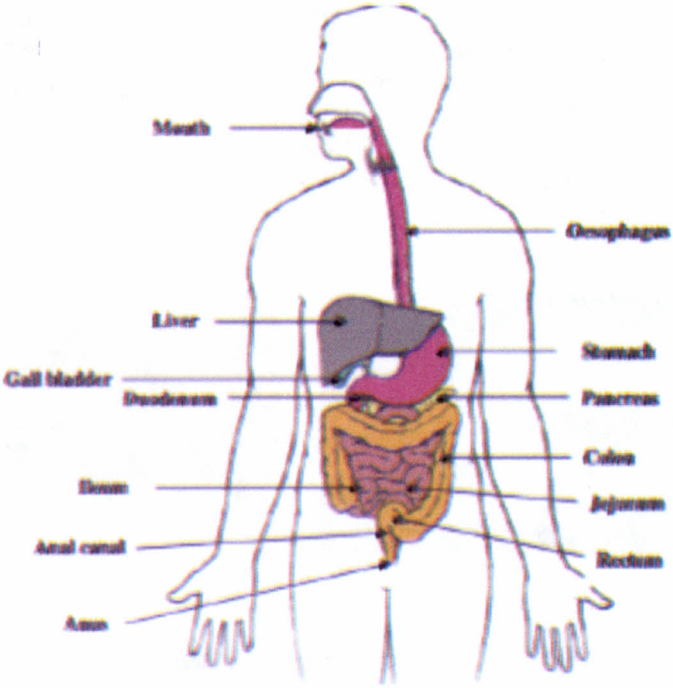


Fig. 5 The Human Digestive System (Dean and Ma, 2007)

At present, a variety of *in vitro* GI models have been developed. These include three of the GI models used in our work:

(I) The Physiologically Based Extraction Test (PBET): This is an *in vitro* test system for predicting the bioavailability of metals from a solid matrix(e.g. soil or food) and is achieved by using the mouth, stomach and intestinal digestive juices to extract the contaminant. It involves a two stage sequential extraction using various enzymes to simulate both gastric and the small intestine compartments and the extraction is carried out at 37°C (the temperature of the human body).

(ii) Fed Organic Estimation Human Simulation Test (FOREhST): This is a standard test for predicting the bioavailability of PAHs in soils.

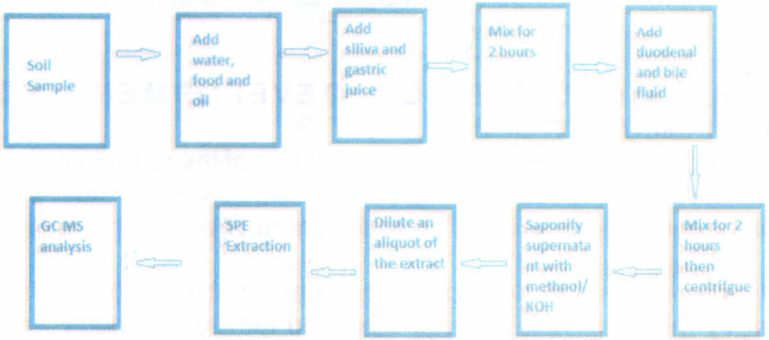


Fig. 6: Schematic Diagram of FORESHT Method

In vitro techniques saves time and cost in comparison to *in vivo* methods.

Mr. Vice Chancellor, Sir, the President of the Federal Republic of Nigeria, President Muhammadu Buhari told the Executive members of the Manufacturers Association of Nigeria (MAN) that he would gladly reverse or abandon inherited economic policies if doing so will create jobs for Nigerians. This is a welcome development. However, as Nigeria goes into industrialisation and creates employment for our teeming unemployed youths, it is important that we practise Sustainable Development. It should never be at the expense of the health of the populace. Effluents from industries must be appropriately treated before discharge so that they do not cause a problem. Cases of improper disposal of effluents and their antecedent effects abound in literature all over the world especially in the developing countries.

Mr. Vice Chancellor, Sir, having explained what Analytical Chemistry and Environmental Pollutants entail, permit me to track some of my modest contributions together with my team of Postgraduate students.

My Contributions to knowledge are in three components:

- Analytical Method Development.
- Risk Assessment of Pollutants in Foods and Soils.

- Pollution Studies of the Lagos Lagoon and Remediation of Pollutants in Effluents.

ANALYTICAL METHOD DEVELOPMENT FOR DETERMINATION OF POLLUTANTS

The importance of accurate determination of the concentration of pollutants in foods and environmental sample for policy formulation and regulatory activities cannot be overemphasised.

My interest was in developing accurate methods to determine heavy metals, PAHs, phosphates and nitrates in foods, water, soils and sediment samples using different instrumental techniques. As an Analytical Chemist, some of my researches in this area have included the following:

DETERMINATION OF LEAD AND CADMIUM IN FOODS WITH ELECTROTHERMAL ATOMISATION ATOMIC ABSORPTION SPECTROMETRY (ETA-AAS)

Heavy metals in foods especially lead and cadmium can be difficult to determine at the ultratrace levels (parts per billion level). ETA-AAS is one technique that can be used for the determination of trace metals. It involves pre-treatment (dissolution) of the sample so it is available in a soluble form prior to determination. Sample dissolution is time consuming and despite being both reliable and reproducible may be subject to errors in accuracy at the trace levels.

We developed a novel slurry technique for the determination of heavy metals in dried foods using the (ETA-AAS). The method involved direct slurry introduction of powdered foods into the ETA-AAS and in-situ ashing of the sample by infusion of oxygen to the sample to prevent the build-up of carbon residue in the graphite tube. Statistical evaluation of the slurry method using certified reference materials showed the method was accurate and comparable in precision to the traditional wet and dry ashing. Calibration was by simple standard addition techniques (Olayinka *et al.*, 1986).

GRAPH OF CADMIUM RESPONSE

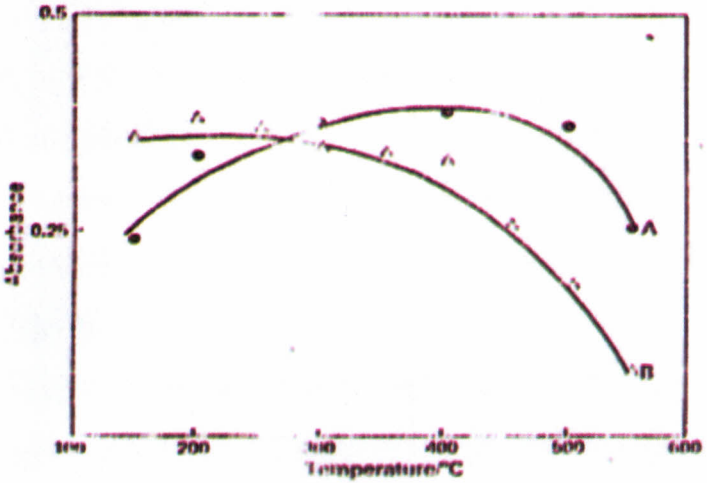


Fig. 7: Cadmium Response vs Ashing Temperature for Pig's Kidney Slurry

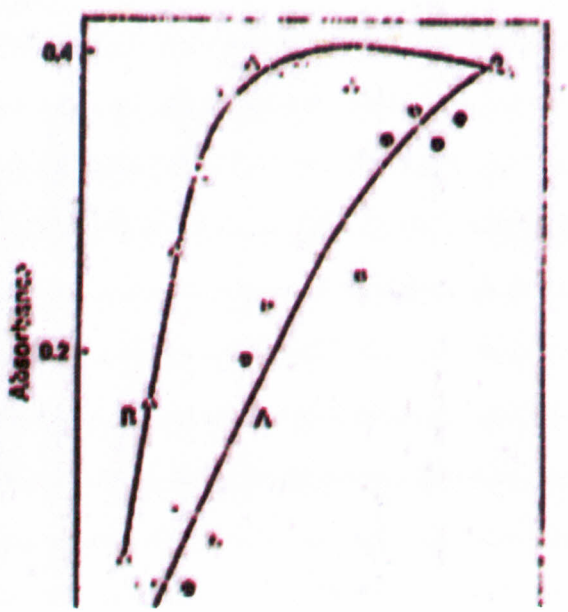


Fig. 8: Cadmium Response vs Atomisation Temperature for Pig's Kidney Slurry

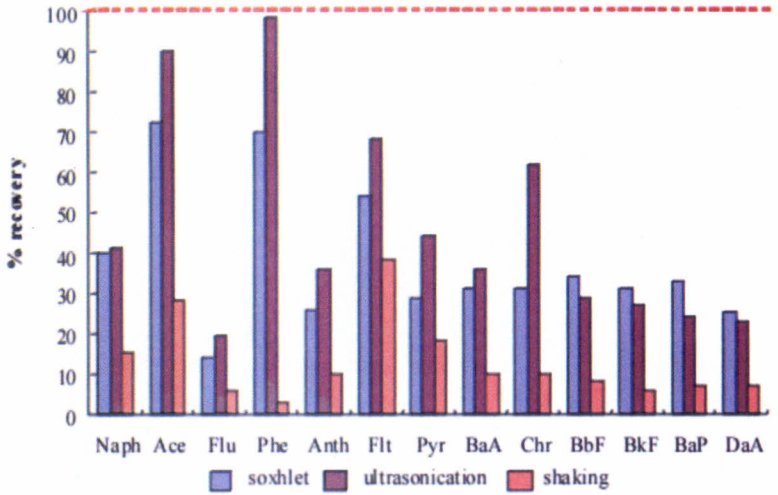


Fig. 9: Percentage Recoveries of PAHs using Different Methods of Extractions

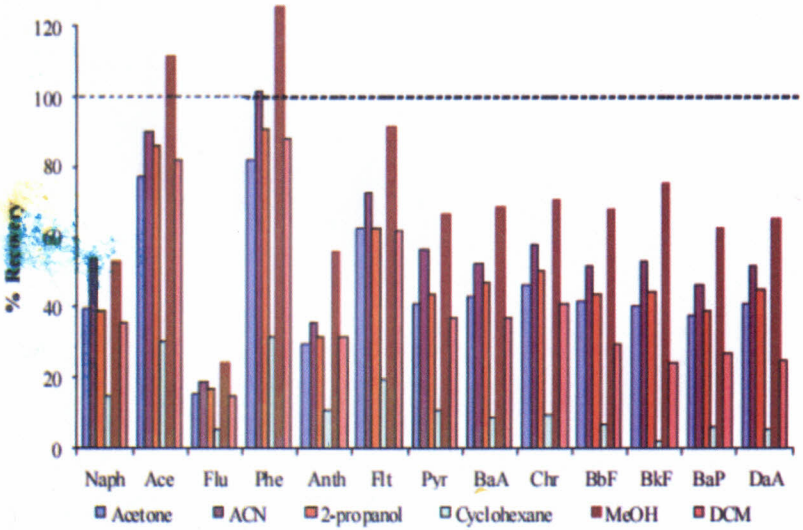


Fig. 10: Recovery of PAHs in CRM using Different Extraction Solvents

METHOD DEVELOPMENT FOR THE ANALYSIS OF PAHS IN SOILS BY GC-MS USING THE SINGLE ION MONITORING (SIM) MODE

Mr. Vice Chancellor, Sir, we noticed that peak separations of samples in HPLC analysis are often incomplete therefore GC–MS, an alternative to LC–FLD has been applied to many samples. This is because of the increased efficiency of GC due to the higher peak capacity and length of columns (the length of columns in GC is about 30m compared to 30cm in LC). We however noticed that from most of the literature, the method of analysis by GC-MS is the scan mode, unfortunately, not all the constituent PAHs are resolved in this mode. The SIM mode allows all the constituents to be resolved and quantified.

We modified a technique for the extraction, clean up and analysis of PAHs by GC-MS using the Single Ion Monitoring (SIM) mode. We ran PAHs, Alkylated PAHs and deuteriated PAHs. The mass spectrum was scanned and a temperature programme optimised for the oven between 50 °C to 300 °C at a rate of 20 °C/min. Individual PAHs, deuteriated and methylated PAHs were identified based on their masses and retention times. From these identified masses and retention times in the scan mode, they were grouped for the Single Ion Monitoring (SIM) mode for quantitative analysis.

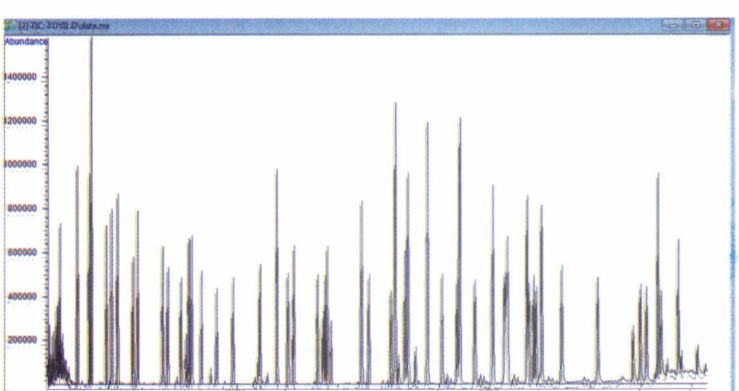
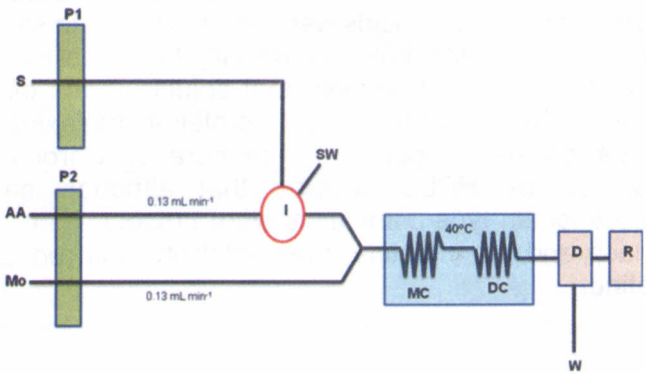


Fig. 11: Chromatogram of the Analysis of PAHs in the Scan Mode (with so much background noise)


P1
S
SW
P2
AA
0.13 mL min-1
I
40°C
D
R
Mo
0.13 mL min-1
MC
DC
W

Mr. Vice Chancellor, Sir, I have quickly run through some of my works in the field of Analytical Method Development and have shown how good quality data may be obtained.

RISK ASSESSMENT OF HEAVY METALS AND PAHS IN FOODS AND SOILS

SPECIATION OF HEAVY METALS IN FOODS

The next phase of the discussion is the risk assessment of pollutants in foods and soils. The physical and chemical forms or species in which a pollutant exists is now clearly understood to affect its mobility, availability and fate in the environment. There is the need to identify not only the total elemental concentrations but also the component species of an element. The determination of the different species of an element is called "Speciation". Speciation helps to identify the bioavailable species of an element hence the level that may be harmful to plants and animals.

The quest for the different species of metals in foods led us to use a modified two-stage enzymolysis procedure developed by Crews *et al.*, 1985 and suggested by the Analytical Methods Committee of the Royal Society of Chemistry.

We simulated an *in vitro* model gut digestive system to study cadmium bioavailability in crab meat using the reversed phase High Performance Liquid chromatography (HPLC) with ETA-AAS. The ready to eat crab was purchased from a local market. Enzymes and organic acids were used to simulate stomach and small intestinal fluids. We also used the biological membrane in the study. The result showed that soluble forms of cadmium existed in the gut however, only protein-complexed cadmium species passed through the membrane. Chromatographic separation by HPLC showed that although cadmium - metallothionein type complexes were present at the pH of the stomach and the intestine, their solubility was reduced in the intestine.

Our results showed that though the total levels of cadmium was high in the crabmeat, the level in the simulated intestine condition was low meaning that we are not at risk from eating the crab meat (Olayinka *et al.*, 1989).

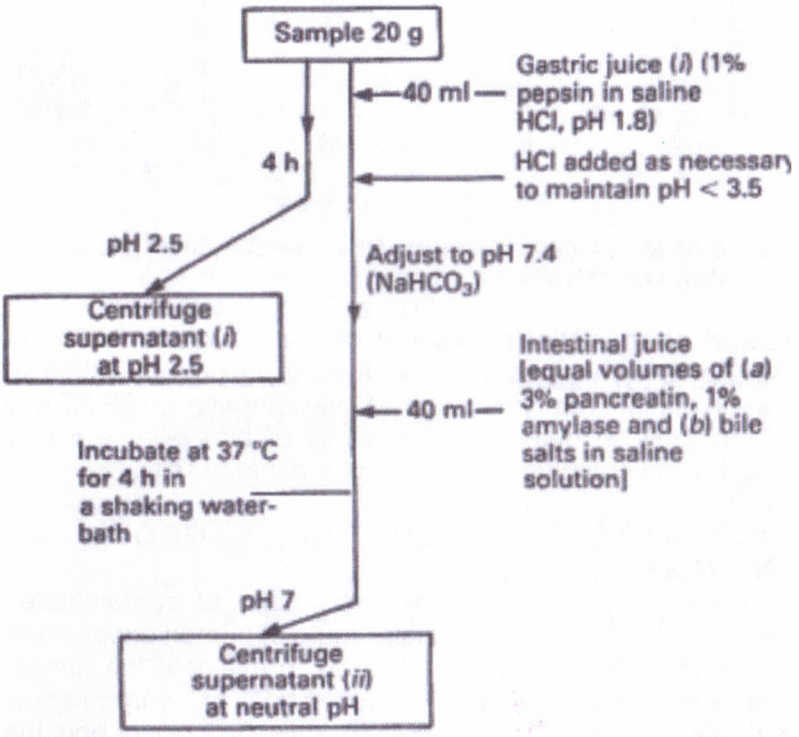


Fig. 14: Optimised Enzymolysis Procedure

Table 2: Cadmium Distribution in Gut Digestion Model

	Cadmium content/ug per 20g	
Sample	Pepsin, pH 2	Pepsin-pancreatin, pH 7.4
Whole crab (n=5)	24.5 (100%)	35.5 (100%)
Supernatant (n=4)	18.0 (73%)	15.5% (44%)
Residue (n=4)	6.5 (27%)	20.0 (56%)

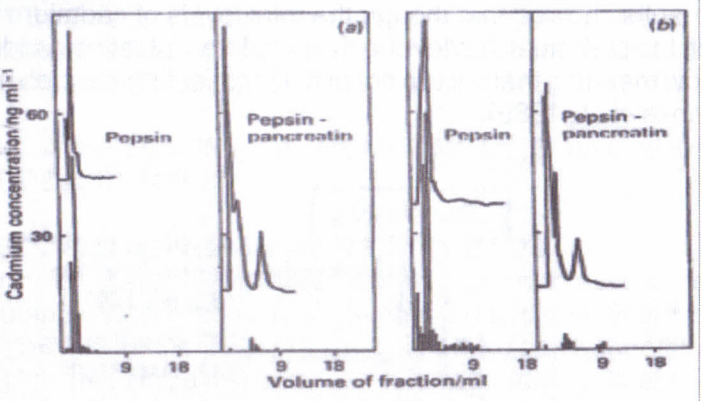


Fig. 15: Crab Meat Digest Separated with the HPLC with (a) and without (b) Dialysis Membrane

This work on speciation of metals in crab meat was carried out in 1989; however, we are at present working on Speciation of metals in our laboratory here in the University with the PBET and SBET models to determine the levels of bioavailable heavy metals from vegetables planted on contaminated soils.

HEAVY METALS IN VEGETABLES GROWN ON CONTAMINATED SOILS

It is generally agreed that the oral intake of contaminated vegetables into the body is a major route of human exposure to heavy metals. We carried out a study to evaluate the human health risk associated with consumption of leafy tropical vegetables grown on contaminated soils by considering the transfer factor from soil to vegetables. Vegetable samples were acid digested using microwave assisted digestion system and quantification of the heavy metals (As, Cd, Cr, Cu, Mn, Ni, Pb and Zn) was with the ICP-MS.

The results obtained revealed that the levels of metals in most vegetable samples exceeded the maximum tolerable limits established by FAO/WHO for edible plants. The soil samples were from contaminated sites here in Lagos including Olusosun dumpsite, Owode Onirin, the Unilag Metallurgical Dept. dumpsite, Mechanic workshops, etc. and the vegetables

planted included: *Ewedu, Ugwu, Soko* and *Tete.* The experiments were carried out at the University green house under the supervision of gardeners and botanists. The researcher went further and determined the bioavailable heavy metals in the vegetables using an in-vitro GI method (PBET and SBET models).

The results of these studies showed that though the soils were heavily contaminated with heavy metals and the levels found in vegetables after planting were higher than the recommended Food and Agricultural Organisation (FAO) limits, the bioavailable levels found in the vegetables after subjecting them to *in-vitro* extraction were very low. We can therefore confidently say that we are not at risk from consuming vegetables grown on such soils (Odujebe *et al.*, 2015a and b).

Table 3: Total Concentration of Potentially Toxic Elements in Soil Samples (dry weight) mg/Kg

Sample	As	Cd	Cr	Cu	Mn	Ni	Pb	Zn
A	1.20±0.02	0.20 ±0.01	24.0 ± 2.7	20.0 ± 1.0	132 ± 28	8.2 ± 0.8	37 ± 3	172 ± 5
B	17.0 ± 1.6	0.5 ± 0.1	2410 ± 180	580 ± 54	3050±140	1050± 20	165 ± 15	2760 ± 72
C	20.0 ± 2.4	20.0 ±2.3	193 ± 12	14910±680	951± 25	140 ± 25	6200± 170	4700 ± 190
D	4.0 ± 0.7	7.0 ± 0.4	120 ± 31	524 ± 90	637 ± 80	85 ±18	440 ±40	2600 ± 130
E	2.0 ± 0.1	< 0.09	25.0 ±1.7	14 ± 2	232 ± 14	7.0 ± 0.5	17.0 ± 1.1	72 ± 8

Mr. Vice Chancellor, Sir, we also studied the uptake of heavy metals by vegetables grown on contaminated soil and assessed their bioavailability using Sequential extraction. We used three soils and three vegetable samples - *Amaranthus viridis, Celosea argentea* and *Corchorus olitorius.* Matured plants were harvested and analysed for their metal concentration. The soil samples were analysed before and after planting. We correlated the metal accumulation of the plants with potential bioavailability using sequential extraction (SE) of the modified BCR technique. It was observed that the metal differed in uptake. Of the plants investigated, *A.*

viridis had the highest levels of Cd, Cr, Pb and Zn (Olayinka et al., 2011).

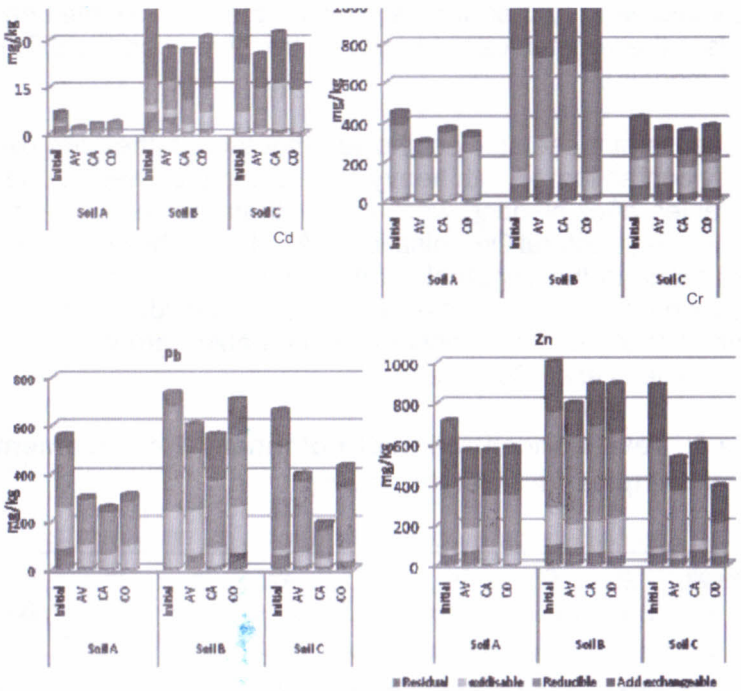


Fig. 16: Fractions of Metals in Soil before and after Planting of Vegetable Samples

From our studies, we observed that though the total levels of metals in the foods, soils, sediment and vegetable samples were high, they were not bioaccessible or bioavailable. We can therefore say that some of these chemicals may not be that toxic especially since they are not bioavailable.

Mr. Vice Chancellor, Sir, we really might not be at that much risk as we thought. I am not proposing that we go out to contaminate our waters and soils indiscriminately. However, I am only drawing attention to in-depth scientific work being done before we make assertions on pollution of the different components of the Environment. It is not sufficient to determine the total pollutants in the environment; we need to determine the bioavailable levels of these pollutants as well.

As one of my PhD graduates said during her PhD *viva* recently (she worked on the Bioavailabilty of polyaromatic hydrocarbons (PAHs) in vegetables planted on contaminated soils). During her *viva,* she constantly said "this is good news" and the External Examiner asked "What is good news about these pollutants". She explained to him that her results proved that we may not be at risk from the pollutants as we previously thought! Yes, the levels in the contaminated soils were high, but the bioavailable levels of PAHs using the "Foresht "model was very low indicating that there was no risk from the PAHs. It is cheering news indeed. We could only make this assertion by Scientific evidence!

Let me add Mr. Vice Chancellor, Sir, that these students carried out part of their work themselves (using the ICP-MS and GC-MS) in the UK at the University of Strathclyde, Glasgow and the University of Portsmouth respectively. We are fortunate as a research group to have Overseas (UK) collaborators who are willing to have our students work in their laboratories for 6-12months. These students come back with such good results and more expertise. I actually went to visit and spend time with them in the laboratories and had opportunity to learn new techniques! Mentor-mentee relationship!

Mr. Vice Chancellor, when I joined the University of Lagos, I met only one lecturer in the field of Analytical Chemistry, (the late Dr. Ladipo). Few years after, he died and I was burdened with teaching all the courses in Analytical Chemistry at the undergraduate and postgraduate levels. I had to take the research projects for all the postgraduate students of Analytical Chemistry. It was indeed a daunting task! As a Department, we had to attract lecturers on Sabbatical Leave to assist. I resolved to train doctoral students in Analytical Chemistry to ease the burden. To the glory of God, I have reproduced myself several times over. I have since produced five PhD graduates in Analytical/ Environmental Chemistry who are now lecturers in the Department. I am still producing

more doctoral students (two are about to round off and three are still on their PhD programmes).

RISK ASSESSMENT OF PAHs IN SMOKED FISH

Some years ago, there was an outcry by NAFDAC that the European Union (EU) was rejecting smoked fish samples exported from Nigeria and just recently in one of the newspapers, an Agricultural expert said Nigeria was working hard to target revenue from non-oil sector and that all efforts will be made to ensure that food items that were banned by the EU in 2015 are exported in 2016.

Smoking of foods is one of oldest technologies of food preservation and is used in fish processing. Potential health hazards associated with smoked foods are thought to be caused by carcinogenic components of wood smoke - mainly PAHs. We obtained a CRC grant from the University and investigated the levels of PAHs in smoked fish samples processed by sawdust, charcoal, firewood and oven respectively. We used three species of fishes: cat fish, sole fish and fresh stock fish and determined the 16 priority PAHs using HPLC -UV DAD. The concentration of PAHs in the oven dried method gave the least value while sawdust smoked fish had the highest concentration.

Our results showed that cat fish had the highest level of PAHs and the highest oil content (48.94mg/g) of the three fishes. There was a correlation between the fat content and the total PAHs. These findings are similar to the result from other studies, (Rey-Salgueiro et al., 2004,). They observed that the highest PAH concentrations were generated during grilling or barbecue. Smoke penetrates into the foods. Melted fat from the food drips onto the hot coals producing PAHs which is then deposited on the fish.

There was a correlation between the oil content and total PAHs in the fish sample. However, the results showed that the fish samples did not constitute a health risk as the levels of the benzo(a) pyrene (a biomarker) were below the maximum levels regulated by the European Commission (Silva *et al.*,

2011). We can therefore advise that sawdust should not be used as fuel in fish smoking.

Table 4: Concentration of (µg/Kg) of PAHs in *Arius heude Loti* (Cat fish) Smoked by Different Methods

PAHs	Sawdust	Fire wood	Charcoal	Oven dried
Naphthalene	124	109	ND	ND
Acenaphthylene	321	269	99.5	27.2
Acenaphthene	514	23.9	543	ND
Fluorene	ND	802	143	132
Phenanthrene	30.7	ND	ND	ND
Anthracene	188	30	35.5	ND
Fluoranthene	329	17.9	82.9	68.2
Pyrene	247	43.1	ND	ND
Benzo(a)anthracene	ND	ND	ND	20.4
Chrysene	23.1	5.5	ND	8.9
Benzo(b)Fluoranthene	ND	ND	ND	ND
Benzo(k)fluoranthene	18.5	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND
Dibenzo(a,h)anthracene	216	19.7	233	50.9
Benzo(g,h,i)perylene	ND	ND	ND	ND
Indeno(1,2,3,c)pyrene	47.7	2.2	ND	25
Sum PAHs	2058	1321	1137	331

*ND-Not detected ≤0.2 µg/kg

Table 5: Concentration of (µg/Kg) of PAHs in *Cynoglossus senegalensis* (Sole) Smoked by Different Methods

PAHs	Sawdust	Fire wood	Charcoal	Oven dried
Naphthalene	236	ND	ND	ND
Acenaphthylene	ND	528	12.4	18.3
Acenaphthene	630	300	98.6	ND
Fluorene	ND	142	ND	ND
Phenanthrene	ND	ND	12.0	ND
Anthracene	15.3	21.8	ND	ND
Fluoranthene	68.7	88.5	5.4	ND
Pyrene	442	78.3	30.1	ND
Benzo(a)anthracene	ND	36.1	ND	5.3
Chrysene	3.6	17.1	ND	2.5
Benzo(b)Fluoranthene	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	ND	4.9	ND
Benzo(a)pyrene	ND	ND	ND	5.6
Dibenzo(a,h)anthracene	ND	ND	ND	ND
Benzo(g,h,i)perylene	ND	10.9	ND	ND
Indeno(1,2,3-c,d)pyrene	ND	34.7	13.4	14.4
Sum PAHs	1395	1258	177	46.1

*ND-Not detected ≤0.2 µg/kg

Table 6: PAHs Concentration (µg/Kg) Found in Haake sp. Smoked by Different Methods

PAHs	Sawdust	Fire wood	Charcoal	Oven dried
Naphthalene	34.7	14.2	96.3	ND
Acenaphthylene	631	42.9	24.5	6.1
Acenaphthene	119	11.0	ND	ND
Fluorene	38.7	29	ND	3.2
Phenanthrene	29.1	22.8	ND	12.4
Anthracene	4.0	60.9	ND	11.0
Fluoranthene	ND	281	ND	0.5
Pyrene	ND	81.1	ND	4.7
Benzo(a)anthracene	ND	ND	ND	ND
Chrysene	ND	55.1	ND	ND
Benzo(b)Fluoranthene	ND	ND	ND	ND
Benzo(k)fluoranthene	ND	16.0	ND	ND
Benzo(a)pyrene	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ND	82.6	ND	ND
Benzo(g,h,i)perylene	64.1	41.5	ND	ND
Indeno(1,2,3,c)pyrene	ND	43.1	ND	ND
Sum PAHs	856	781	121	37.9

*ND-Not detected ≤0.2 ug/kg

The values of the sum PAHs showed that the *Artus heude loti* had highest level of PAHs

Realising that PAHs can get into foods during processing and only few studies have been carried out on Nigerian delicacies, we studied the effects of roasting on the Proximate composition and Levels of PAHs in Some Roasted Nigerian Delicacies (Adetunde *et al.*, 2012).

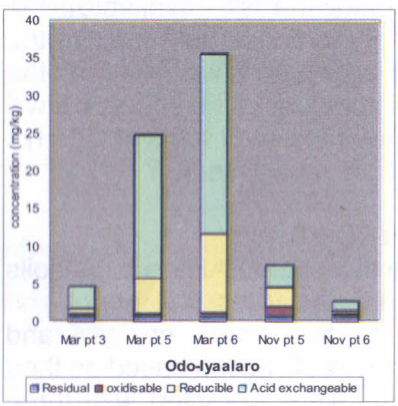
We evaluated raw and roasted samples of corn (*Zea mays*), ripe plantain, unripe plantain (*Musa paradisiaca*) and yam (*Dioscorea sagittifolia*). The samples were roasted using the open flame method of a grid placed over a pot of lighted charcoal samples roasted with occasional fanning. PAHs in the samples were extracted by ultrasonic extraction and cleaned up with nylon filter membrane.

The levels of PAHs in roasted samples were found to be higher than in the raw samples. However, roasted plantain was found to have the highest level of PAHs with a concentration of 40,330µg/Kg. The BaP_{eq} calculations showed that more risk is associated with roasted food compared with raw foods. There is no limit yet for PAHs in foods such as plantain, maize and yam but the result showed that BaP, a bio-indicator, was not

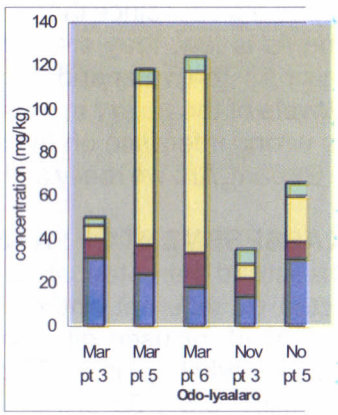
detected in the raw and roasted samples except in the roasted maize.

SPECIATION OF HEAVY METALS IN SEDIMENTS OF A POLLUTED TROPICAL STREAM USING THE BCR SEQUENTIAL EXTRACTION TECHNIQUE

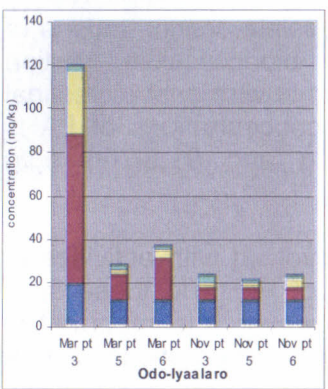
Mr. Vice Chancellor, Sir, we studied the risk assessment of heavy metals in the sediment samples from Odo Iya Alaro stream in Lagos using the modified BCR sequential extraction scheme. The scheme allows us to determine the species of the contaminants and whether they are bioavailable.



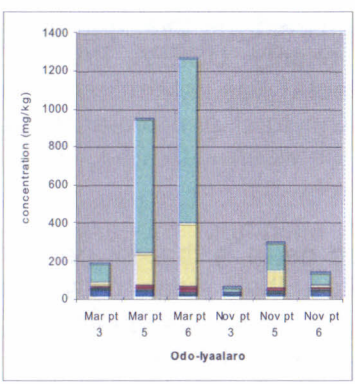
Lead



Cadmium



Chromium



Zinc

Fig. 17: Fractionation Pattern of Metals in Sediments

The results showed that lead was predominant in the organic matter/sulphide bound fraction (51.3%) while the smallest proportion was found in the water-soluble, exchangeable /carbonate fraction (0.4%). This is the bioavailable fraction. Cadmium followed a similar trend to that of lead so also Cr and Ni. However, Zinc was found to be predominant in the water soluble, exchangeable fraction (39%). Zinc was found to be the most mobile and bioavailable heavy metal determined (Oyeyiola *et al.,* 2007).

It therefore follows that the total levels of lead, cadmium, Cr and Ni may be high but since the percentage that is bioavailable in the sediments is low, they are not likely to cause any harm to the organisms in the water and by inference man. If we just report the total levels of the heavy metals without that of the species, it will give a wrong inference on the state of the sediments of Odo Iya Alaro Stream. Are we really at risk from heavy metals?

RISK ASSESSMENT OF PAHS IN SOILS

We measured the potential health risks from PAHs in eight soils impacted by different anthropogenic activities (i.e. depot and loading point for used oil, dumpsite, trailer park, car park and mechanic workshop) in the Lagos area of Nigeria based on their accessibility. 0.5 - 5g soil samples were extracted with three portions acetone: hexane cleaned up and analysed by GC/MS.

We determined the total and bio-accessible concentrations of the 16 priority USEPA PAHs. The bioaccessible fraction (bioavailable) was determined using an in vitro gastrointestinal model. The total and bio-accessible concentrations of PAHs ranged between 702-253, 922 ng/g and 91.5-760 ng/g respectively.

The good news is that for persons involved with activities at these sites, their mean daily intake of PAHs in these soils showed no observable health risk. However, it is important to reduce human exposure even to low concentrations of bio-

accessible PAHs due to their lipophilic nature and their tendency to bio-accumulate in plants, humans and other organisms (Adetunde et al., 2015).

Table 7: Concentration (ng/g) and Percentage* of the Bio-accessible Priority USEPA PAHs Found in Eight Contaminated Soil Samples in the Lagos, Nigeria

	Soil Sample							
Compound	A	B	C	D	E	F	G	H
NAP	-	92.7±9.15 (14%)	90.5±34.5 (87%)	327 ± 24.6 (45%)	316 ± 132 (30%)	100 ± 34.5 (62%)	267 ±34.5 (87%)	171 ± 8.0 (8%)
ANT	17.6±4.0 (2%)	29.7±1.2 (1%)	nd	28.5 ± 9.8 (25%)	40.1 ± 10.0 (0.1%)	28.5± 5.4 (26%)	17.0 ± 34.5 (30%)	26.2 ± 9.0 (0.7%)
BaP	nd	549 ± 3.0 (17%)	nd	nd	nd	nd	nd	273 ± 1.56 (21%)
DaH	nd	88.6 ± 55.2 (0.9%)	nd	nd	nd	nd	nd	Nd
BgP	194 ± 6.4 (17%)	Nd	nd	nd	nd	nd	nd	101 ± 2.8 (43%)
Sum Bio-accessible PAH	511 ± 4.2 (4.3%)	760 ± 23.0 (0.7%)	91.5 ±35.0 (12.9%)	356 ± 15.0 (1.7%)	356 ± 100 (0.1%)	129 ± 12.9 (3.1%)	284 ± 30.0 (41.2%)	570 ± 18.0 (0.9%)

*Percentage = Concentration of b io-accessible PAH/Total concentration PAH in soil x 100

*Percentage = Concentration of bio-accessible PAH/Total concentration PAH in soil x 100

POLLUTION STUDIES OF THE LAGOS LAGOON AND REMEDIATION OF POLLUTANTS IN EFFLUENTS OF INDUSTRIES

The Lagos Lagoon is one of Africa's largest urbanised estuarine ecosystems. The brackish coastal Lagos Lagoon is a great expanse of shallow water with depths ranging between 0.9 to 25metres (Webb, 1958). The estimated area is 150.56km^2. It is used for recreational purposes, transport, dumpsite for industrial, sewage, agricultural and municipal wastes. The lagoon is important for a wide variety of fish and marine organisms and is the major source of seafoods to the people of Lagos. Lagos State is the most heavily industrialised in Nigeria - reported to be home to between 68 and 80% of the country's medium and large-scale manufacturing industries (Oketola and Osibanjo, 2007).

Map 1: Map of Lagos Lagoon Showing the Major Industrial Zones around Lagos Metropolis

Activities around the Lagoon, Okobaba

Mr. Vice Chancellor, Sir, we studied the pollution trend of the Lagos Lagoon and adjoining rivers from 2002 till date. With this, we determined the levels of contaminants (heavy metals, PAHs, organochlorine pesticides, PCBs and nutrients- phosphates and nitrates) in the Lagos Lagoon and the rivers.

COMPARISON OF THREE SEQUENTIAL EXTRACTION PROTOCOLS AND ECOTOXICOLOGICAL IMPLICATION OF HEAVY METALS IN SEDIMENTS OF THREE RIVERS AND THE LAGOS LAGOON

We developed a modified BCR sequential method for the determination of bioavailable metals in the sediments of the

Lagos Lagoon. Sequential extraction involves the use of a series of reagents to isolate elements from solid samples. Each reagent used is more aggressive compared to the previous one and aims to solubilise the metals bound in different, operationally defined fractions of the sediment.

We modified the original BCR technique to enhance speciation and avoided using a very powerful oxidising reagent (hydrofluoric acid) for digestion of the sediments. We then compared our results with two other certified sequential extraction procedures, the 5-step Tessier's procedure and the three step original Community Bureau of Reference (BCR). We found the results obtained by the three methods to be comparable (Oyeyiola et al., 2011b).

With this study, we adopted our developed modified BCR method for all our subsequent metal speciation work (Oyeyiola et al., 2011a, 2013a and 2013b). This method has also now been adopted by other researchers and appropriately cited worldwide.

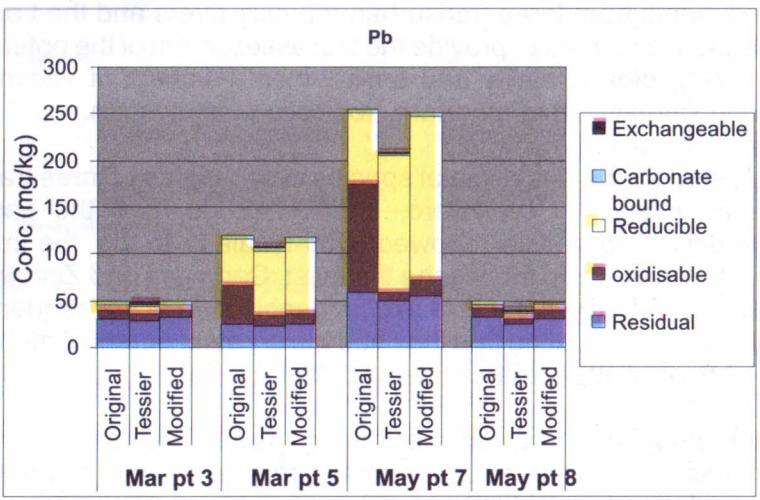


Fig. 18(a): Fractionation of Lead for the Three Extraction Schemes

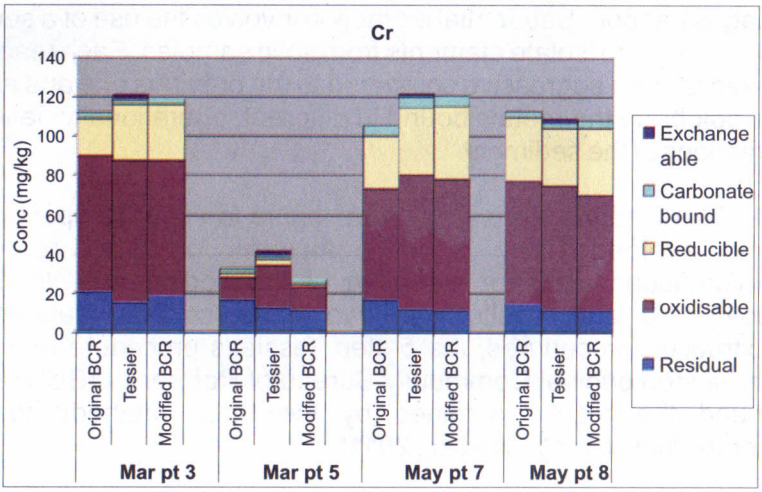


Fig. 18(b): Fractionation of Chromium for the Three Extraction Schemes

Mr. Vice Chancellor, Sir, we went further to use the modified BCR sequential extraction to fractionate Cd, Cr, Cu, Pb and Zn in sediments from three transurban tributary rivers and the Lagos Lagoon, and, hence, provide the first assessment of the potential mobility, bioavailability and environmental impact of sediment bound metals in this important, tropical aquatic system.

We studied the heavy metal species in sediments of three trans-urban rivers – Odo-Iyalaro, Ibeshe-Ikorodu, and the Lagos Lagoon. The results showed Odo-Iyaalaro to be the most contaminated and the Ibeshe the least. Cadmium and Zinc were released mostly in the acid exchangeable step of the sequential extraction, indicating that they had the greatest potential mobility and bioavailability of the metals studied.

The study also showed that during the dry season, the toxic metals accumulate in sediments in relatively labile forms that are released and can be transported or bioaccumulated in the rainy season. Application of risk assessment codes and Hankanson potential risk indices indicated that Cd was the element of greatest concern in the Lagos Lagoon system. The study indicated the need to strengthen Environmental

management and pollution control measures to reduce risk from heavy metals, but that even relatively simple strategies, such as seasonal restrictions on dredging and fishing, could be beneficial (Oyeyiola *et al.*, 2014).

Table 8: Ecological Risk Factors and Risk Indices Calculated for the Lagos Lagoon Sediments

	Site	E_r^i					RI
			Cd	Cr	Cu	Pb	Zn	
Odo-Iyaalaro	3	Mar	480	15.6	10.8	13.3	4.13	524
		Nov	*	3.27	5.86	5.79	1.40	16.3
	5	Mar	2130	3.45	27.8	35.0	20.4	2220
		Nov	690	2.80	13.5	17.8	7.84	732
	6	Mar	3440	4.65	37.0	45.3	27.4	3560
		Nov	220	2.95	9.72	12.7	4.34	250
Shasha River	7	May	*	21.5	21.2	59.4	16.8	119
		Oct	*	*	5.58	11.6	0.912	18.1
	8	May	*	17.2	6.76	13.0	2.95	39.9
		Oct	*	6.26	*	*	0.342	6.6
	10	May	*	5.26	5.60	11.5	1.11	23.5
		Oct	170	5.46	12.8	30.6	5.00	224
Ibeshe River	14	Feb	*	*	66.4	*	2.55	69
		Dec	*	*	28.6	7.74	1.14	37.5
	16	Feb	*	*	0.840	*	0.121	0.961
		Dec	*	5.29	2.84	*	0.355	8.49
	17	Feb	*	*	0.680	*	0.158	0.838
		Dec	*	3.95	13.6	*	0.724	18.3
Lagos Lagoon	19	Sep	*	5.29	7.04	9.76	6.24	28.3
		Dec	*	5.29	6.74	9.76	4.32	26.1
	20	Sep	*	5.29	3.9	5.35	3.74	18.3
		Dec	130	7.95	6	11.5	3.84	159
	21	Sep	*	3.95	8.6	11.5	6.47	30.5
		Dec	210	7.95	6.74	11.5	5.00	241
	22	Dec	*	6.62	*	*	0.389	7.01
	23	Dec	*	6.54	*	*	0.0342	6.57

*Not calculated because results were <LOD

Table 9: Ecological Risk Factors, Risk Indices and Severity of Risk

E_r^i	RI	Potential ecological risk
<40	<150	Low
$40 \leq E_r^i < 80$	$150 \leq RI < 300$	Moderate
$80 \leq E_r^i < 160$	$300 \leq RI < 600$	Considerable
$160 \leq E_r^i < 320$	–	High
≥320	≥600	Very high

BIOACCUMULATION OF PAHS, PCBS AND ORGANOCHLORINES (OCs) IN FISH AND INVERTERBRATES OF THE LAGOS LAGOON

Mr. Vice Chancellor, Sir, we studied the bioaccumulation of PAHs, PCBs and OCs in fish and invertebrates of the Lagos Lagoon and the likely effects of related risks to humans that consume the fish and invertebrates. We observed incessant burning of sawdust along the shore and indiscriminate discharge of waste into the Lagos Lagoon.

The levels of the pollutants were assessed in the water, sediment, invertebrates (crayfish, shrimps and crabs) and twelve species of fish. Fish samples were collected from six stations on the Lagoon and analysed using the GC-MS after extraction with a soxhlet extractor.

The results showed that whole-fish samples bioaccumulated high molecular weight PAHs than the lower ones. In the fish fillet tissues, the most bioaccumulated PAHs were phenanthrene (109.758-11.491ng/g d. w.) and naphthalene (62.270-11.343ng/g d. w.). Phenanthrene was found to pose high risks to young crabs, crabs eggs, and *Carranx hippos* (agaza).

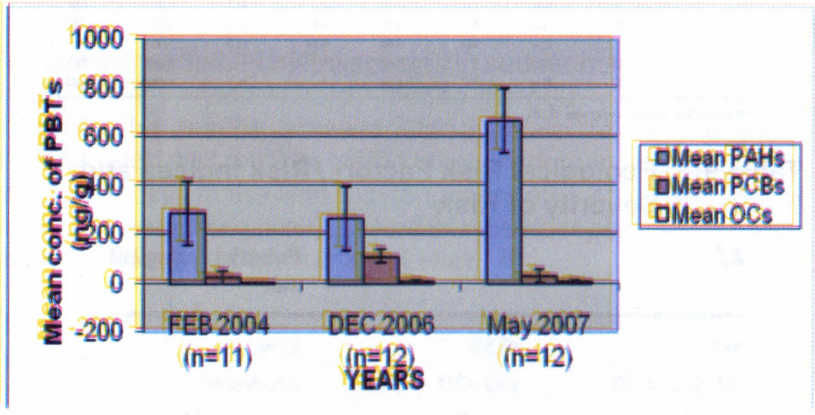


Fig. 19: Mean Concentrations of PBTs in Feb., 2004 to May 2007 Sediments

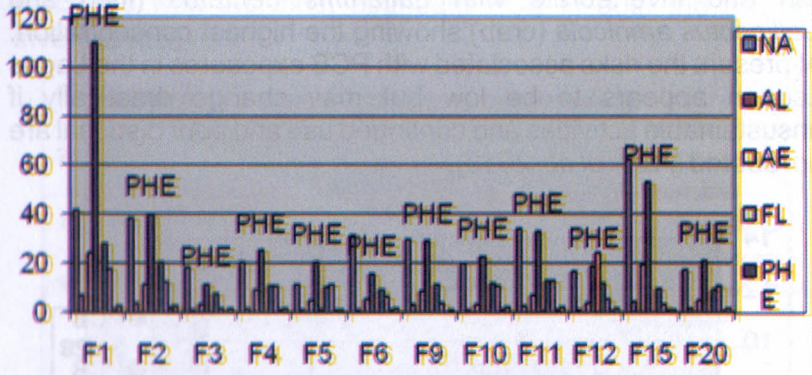


Fig. 20: PAHs (ng/g) in Fish Tissues from the Lagos Lagoon, 2007

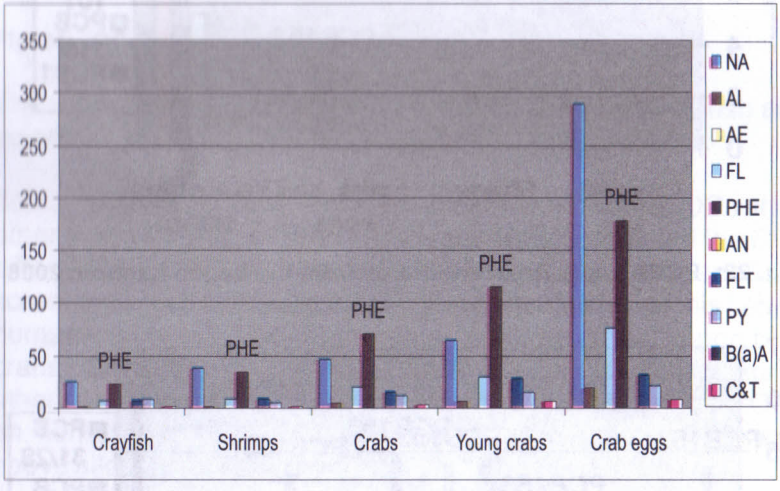


Fig. 21: PAHs (ng/g) in Invertebrates from the Lagos Lagoon, 2007

Phenanthrene was the most abundant PAH in both the fish and invertebrates. The most abundant of the organic pollutants were the PAHs, with the highest total biota concentrations of 625.44ng/g and 264.61ng/g found in blue crab eggs and young blue crabs respectively (Alani *et al.*, 2012).

Of the72 PCBs analysed, no PCBs were detected in the water. Low chlorinated PCBs were found in the sediment. PCB 153 (a known carcinogen) was found at low concentrations in the

fish and invertebrate with *Lutjamms dentatus* (fish) and *Callinectus amnicola* (crab) showing the highest concentration. At present the risks associated with PCB exposures in the Lagos Lagoon appears to be low but may change drastically if unsustainable activities and continued use and poor disposal are not abated (Alani *et al.*, 2013).

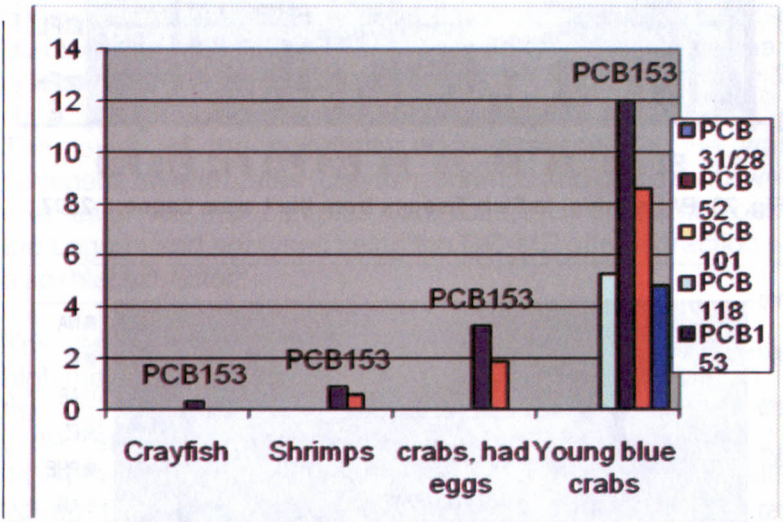


Fig. 22: PCBs (ng/g) in Invertebrates from the Lagos Lagoon, 2008

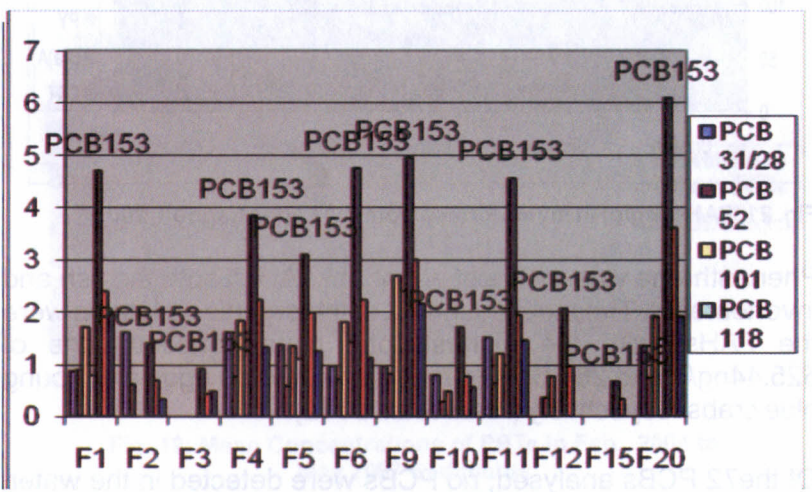


Fig. 23: PCBs (ng/g) in Fish Tissues from the Lagos Lagoon, 2008

PCB 153 was the most abundant PCB in both the fish and invertebrates.

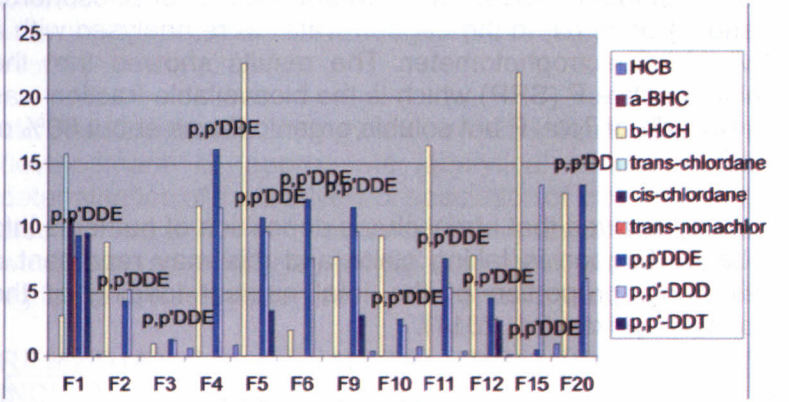


Fig. 24: OCs (ng/g) in Fish Tissues from Lagos Lagoon, 2008

The results showed the most abundant OCs in both the fish and invertebrates were b-HCH, p,p'DDE and p,p'DDT.

Young crabs and crab eggs bioaccumulated more OCs than other invertebrates. Different fish types bioaccumulated the OCs differently. The results showed some of the fishes exceeded the screening value indicating a risk in the consumption of this fish by humans. Consumption of crab eggs, matured crabs, young blue crabs (*Callinectus amnicola*), Agaza (*Caranx hippos*), and some other seafoods from the Lagos Lagoon may pose a risk from OCs on humans as these biota bioaccumulated the contaminants above allowable limits (Alani *et al.*, 2013).

ASSESSMENT OF NITROGEN AND PHOSPHORUS LOADING BY ATMOSPHERIC DRY DEPOSITION TO THE LAGOS LAGOON

Literature revealed that surface water pollution is driven by the contributions of air-borne particles, open-air waste burning, fossil fuel combustion and ammonia volatilisation from excreta and fertilizer. Atmospheric particles into the Lagos Lagoon is suspected to be a major contributor to the nutrient levels of the Lagoon. We monitored the atmospheric particulates at six

stations around the Lagos Lagoon (from January to June, 2012) to estimate the contributions of atmospheric deposits into the Lagoon's nutrient cycles. The different species of phosphorus (P) and nitrogen (N) in the Lagoon water were analysed with a UV/Visible Spectrophotometer. The results showed that the Soluble reactive P (SRP) which is the bioavailable fraction was less than 2% of Total P but soluble organic P was about 86% of Total P.

The study showed that atmospheric deposition of nutrients into the Lagos Lagoon is taking place and this may represent a considerable proportion of the total nutrient loading of the Lagoon (Olayinka *et al.*, 2014).

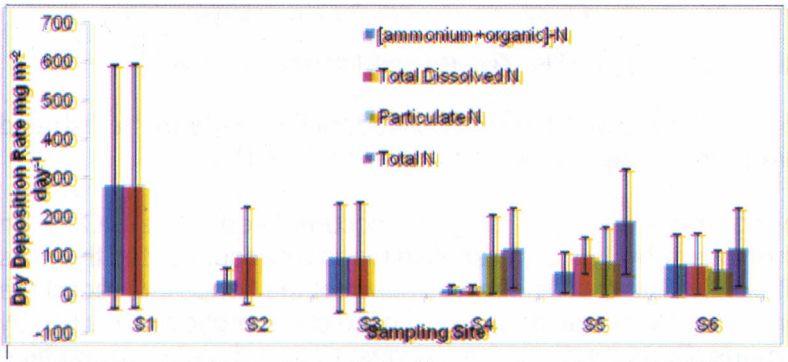


Fig. 25: Dry Deposition of the Nitrogen Species at the Sites

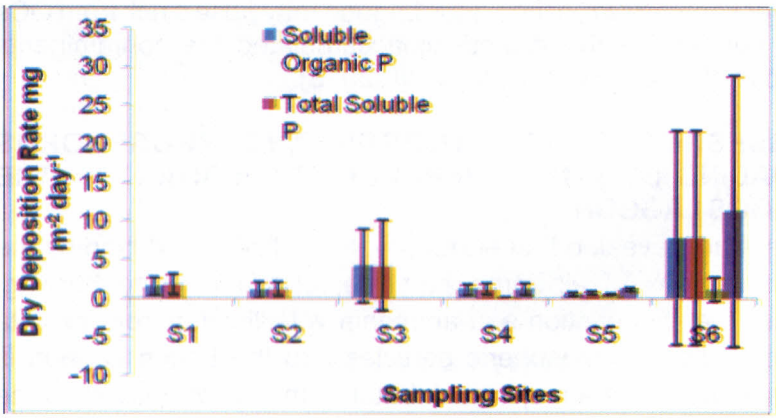


Fig. 26: Dry Deposition of the Phosphorus Species at the Sites

Mr. Vice Chancellor, Sir, a comprehensive review of our work since 2002 on the Lagos Lagoon is in a recent chapter in an Elsevier Book on Estuaries of the World: The Land/Ocean Interactions in the coastal zone of West Africa, Estuaries of the World (Alo *et al.*, 2014).

Mr. Vice Chancellor, Sir, my work on metals was not limited to the development of appropriate analytical methods for the determination of the analytes or speciation of the heavy metals. I also worked on the remediation of heavy metals from industrial wastewaters -effluents (using low cost adsorbents from agricultural waste materials) and in contaminated soils.

REMEDIATION OF METAL POLLUTANTS FROM INDUSTRIAL EFFLUENTS

Heavy metals are frequently used in industrial processes such as metal plating industries, galvanising industries, mining operations and tanneries and are usually present in high concentrations in the liquid wastes which are released directly into the environment without any pre-treatment. The remediation technologies for the removal of heavy metals from wastewater include ion exchange, reverse osmosis, electrodialysis, photocatalysis, electrocoagulation amongst others. These methods are expensive for a developing country like Nigeria, therefore I worked on the removal of heavy metals from industrial effluents using more economically favourable alternatives - low cost materials both agricultural waste materials and clay materials.

REMEDIATION OF HEAVY METALS FROM INDUSTRIAL EFFLUENTS USING CLAY MATERIALS

At FIIRO, I had the privilege of mid-wifing the Environmental section of the Chemical and Fibre Division in 1996. We realised that the Institute's Electroplating plant generated liquid wastes loaded with heavy metals. We also noticed that most of the effluents of industries in Lagos were not being treated or at best the treatment given was inefficient. We collected effluents from four different electroplating plants in Lagos, analysed and treated the effluents using cheap and locally processed

loading, pH, contact time and temperature were studied. Similar experiments were done using the unmodified coconut husk and the effect of modification compared. The results showed the HCl-modified adsorbent removed 96 ± 3.6% of Cr(VI) at a pH of 4.0 and 99 ± 0.7% of Ni(II) at a higher pH of 7.0. The unmodified adsorbent removed 90 ± 8.8% of Cr(VI) and 97 ± 1.5% of Ni(II). However, the NaOH- modified adsorbent had the lowest percentage removal of metals: 40 ± 9.9% for Cr(VI) and 80 ± 6.1% for Ni(II).

The equilibrium data for the adsorption of Cr(VI) and Ni(II) on coconut husk was tested using both the Freundlich and Langmuir adsorption isotherms. The Freundlich isotherm was found to be more suitable for Cr(VI) adsorption, while the Langmuir isotherm was observed to be better for Ni adsorption on coconut husk. The adsorption mechanism fitted the second order. The HCl modified adsorbent gave the better result and can be used by industries to remove heavy metals from effluents before discharge (**Olayinka** *et al.*, 2009a and b).

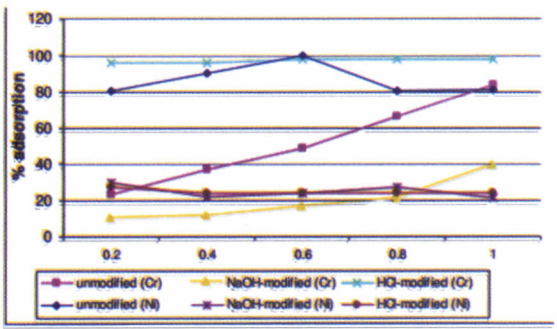


Fig. 28: Effect of Adsorbent Loading on the Adsorption of Cr and Ni.

Some other of our other research works on remediation of metals from effluents include: (i) Removal of heavy metals in Electroplating waste waters of Industries in Nigeria using precipitating agents (**Olayinka** *et al.*, 1999b). In this study, we treated electroplating effluents with lime and alum singly and as a mixture, we also used ferrous sulphate and ferric chloride with lime respectively. The results showed the treatment with ferric chloride and lime gave the best result with 100% removal

of all the metals at pH of 7.0; (ii) Treatment of Textile Effluents using alum and activated carbon (Madukasi *et al.*, 2001a and b) where we treated textile effluents which were coloured, had high pH values and high BOD values with lime and activated carbon. The results showed an optimum reduction of BOD at pH 5.0- 6.0 for all the effluents. The BOD and COD were reduced by 60% and 90% respectively for all the treated effluents. The implication of this work is that effluent treatment plants for industrial effluents can be installed in factories locally using locally sourced materials and Engineers.

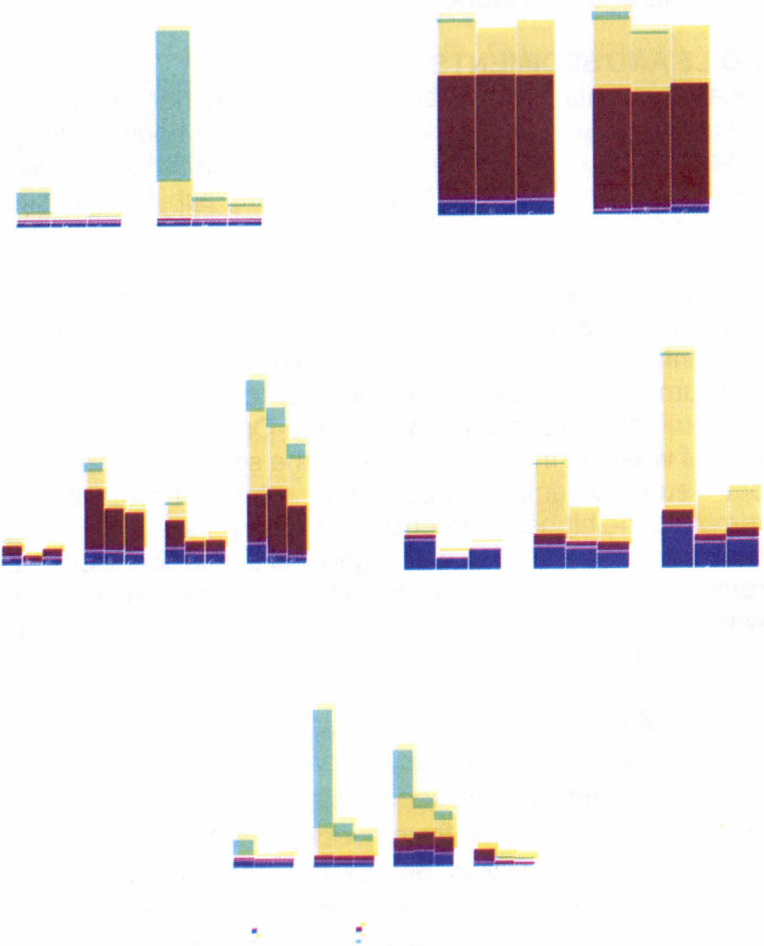
SOILS AND SEDIMENTS

Heavy metals generated during industrial activities are deposited in soils and washed into the water bodies. This poses a serious threat to the Environment. Remediation of soils and sediments from metal pollution can be achieved in-situ soil washing.

We remediated contaminated soils using different extracting reagents. We used five environmentally friendly chemical reagents (EDTA, Acetic acid, Sodium Chloride, Water, and Calcium chloride) for the remediation of lead and zinc from a contaminated urban soil (from Owode-Onirin, Lagos). This was a way of washing the pollutants from the soils and is applicable to petroleum contaminated soils. Our results showed that EDTA removed the highest percentage of heavy metals from the soils. Remediation with EDTA was highest in acidic conditions. EDTA removed 20% and 6% lead and zinc respectively. Repeated washing with EDTA is recommended to remove the metals below the accepted values (**Olayinka** and Odiwe, 2006).

REMEDIATION OF METAL POLLUTED SEDIMENTS

We compared the efficiency of batch extraction and column leaching of metals from sediments using EDTA. We collected four sediment samples from rivers in Lagos for the study. We used sequential extraction (SE) to compare the effects of batch extraction and column leaching on the fractionation pattern of metals in the sediments before and after



available or accessible to living organisms. This again tells us that the total PAHs in a soil or food does not necessarily mean it is available. Therefore, for the present we may not be at risk due to involuntary ingestion of soils (Adetunde *et al.,* 2015).

Mr. Vice Chancellor, Sir, these assertions could only be made after careful, painstaking scientific studies by an Analytical Chemist. Other *in vitro* gut digestion models used in our Laboratory for determination of risk from metal pollutants in foods and soils include the PBET and SBET models. Part of the results of these work were presented earlier in this lecture. The results all showed that the total levels of the metals were much higher than the bioaccessible fractions and there may be no risk from involuntary ingestion of the soil or consumption of the food.

Mr. Vice Chancellor, Sir, again I ask, are we at risk from pollutants in the Environment? I say, Yes we are. We can only say we are not at risk after proper bioavailability or speciation studies. Does this mean we should go about and indiscriminately pollute our environment and kill ourselves slowly? The answer is, No. The pollutants discussed in our lecture bioaccumulate in the environment since they do not readily biodegrade/break down easily, they become stored in the fatty tissues of humans and other organisms over time in much higher concentrations and therefore become harmful and carcinogenic. Therefore, we still need to be careful.

Some of our latest studies investigated the levels of PAHs in edible vegetables grown on PAH- contaminated soils. For this bioavailability study, we mixed the contaminated soils in different ratios with uncontaminated soils and added fertilizers. We planted eight different vegetables commonly consumed in Nigeria: [*Corchorus Olitorius* (Ewedu), *Celosia Argentea* (Soko), *Amaranthus cruentus L* (Tete), *Basella Alba* (White Spinach), *Lactuca Sativa* (Lettuce), *Allium* Ascalonicum (Spring Onions/Alubasa elewe), *Talinum Triangulare* (Water leaf), *Telfairia Occidentale* (Ugwu) on soils contaminated with PAHs. The contaminated soils were mixed serially with

uncontaminated soils to give a series of the different percentages of contamination i.e. 20 to 100% contaminated soils.

We found that Ugwu consistently grew on all the soils and their mixes even on 100% heavily contaminated soils with high oil contents. Lettuce gave the least growth followed by Soko. This study is important and an implication that we need to be careful where we grow our vegetables. We also found that Ugwu consistently bioaccumulated PAHs from the soils unlike the other vegetables (Adetunde O, PhD thesis, 2015).

OUR COLLABORATIVE EFFORTS

Mr. Vice Chancellor, Sir, we collaborated with several Universities in the UK, Canada and China on research work. Some of the Universities are University of Hull, UK with Prof. Steve Haswell. Steve along with Dr. Roman Greszkowiak, were my PhD supervisors in 1984. In 2001, Steve introduced me to micro fluidics work using flow injection and I am glad that I produced a PhD on this and another is almost rounding off his PhD.

At the University of Strathclyde with Dr. Christine Davidson, we worked on Speciation and Bioavailability of heavy metals in the sediments of the Lagos Lagoon using the AAS and ICP- MS. From this collaboration effort, we produced PhD graduates and jointly published several papers in International journals. At Loughborough University, UK, we worked with Prof. Roger Smith on determination of PAHs from sediments of the Lagos Lagoon using HPLC with Fluorescence detector. This effort again produced a PhD graduate and several International publications. At the University of Portsmouth with Prof. Graham Mills who recently visited Lagos as a Guest speaker at a Royal Society of Chemistry Conference, we worked on the Bioaccessibility of PAHs in contaminated soils and vegetables using the GC-MS and also produced a PhD graduate and several papers.

We worked with Prof. Ken Drouillard at the Great Lakes Research Institute, Ontario, Canada and produced a PhD graduate with several publications. We also worked on Flow Injection with Prof. Worsford at the University of Plymouth, UK. Our recent addition is to Soochow University, Suzhou, China with Prof. Anping Deng where we worked on the Speciation of macronutrients (phosphates and nitrates) from the Lagos Lagoon using the Segmented Flow Injection method.

Some of these collaborations have led to Memorandum Of Understanding (MOU) i.e. with University of Strathclyde and more are expected. We gained more grants, more International Publications and visibility, quality PhD graduates and some of our host institutions gave us small equipments like the SPE manifold and rotator used in the simulation of the GIT and some very scarce chemicals to help with further work (e.g. CRM and standards).

Mr. Vice Chancellor, Sir, most of these collaborative work were funded by grants from the Analytical Trust Fund of the Royal Society of Chemistry, UK., the Commonwealth Split-site Scholarship and the University of Lagos grant for Doctoral students.

I have also obtained grants from the Royal Society of Chemistry, UK, the Central Research Committee of the University of Lagos and TETFUND. To all these bodies, I am grateful.

EQUATORIAL AFRICA ATMOSPHERIC DEPOSITION NETWORK (EADN)

We are part of a consortium of Twelve African countries working on a Global Environmental Facility (GEF) International Waters projects on African Great Lakes to identify links between Eutrophication and Atmospheric deposition of macronutrients on lakes, create Regional cooperation and advocate for changes in National and Regional rural development programmes. The work is funded by the World Bank; the initiative started in 2006 but we obtained the grant

only in 2011. We collected monthly atmospheric deposition samples at our Nigerian station at NIHORT, Ibadan from 2013 till date and send them to Toulouse, France for analysis. The results are being compiled and will show the extent of pollution of the Equatorial Africa water bodies (lakes) by Atmospheric macronutrients deposits. However, we in our research group have also worked on the nutrient deposition on the Lagos Lagoon Environment.

INTERLABORATORY COMPARISON PROGRAMMES WITH INTERNATIONAL AGENCIES

We participate in some Interlaboratory comparison programmes to ensure the quality of analysis carried out in our laboratory. These include the Programme Interlaboratotios Control de Caudad, Spain (PICC-Metals) on metals, Interlaboratory Comparison on POPs in Food by the Norwegian Institute of Public Health, Norway, etc. Unfortunately, some of the agencies carrying out the studies are now requesting for payment and this has recently hampered our participation.

CURRENT RESEARCH AND WAY FORWARD

There has been an increased concern over pollution by Heavy metals, Persistent Bioaccumulative and Toxic pollutants (PBTs) like Polycyclic Aromatic Hydrocarbons (PAHs), Organochlorines, Polychlorinated biphenyls (PCBs) and nutrients in foods and the environment. These pollutants are a potential health risk to surface, ground waters and soils. Therefore, my research has been primarily based on the accurate evaluation of these pollutants in food, water and the soil to determine the different species of these chemicals and their bioaccessibility/bioavailability and therefore the likely risk

to health. The work also involved statistical analysis, modeling and remediation of these pollutants from waters, wastewaters and soils. Development of methodologies for the accurate determination of the species of the pollutants, were also investigated.

My current research efforts are on the Bioavailability/ Bioaccessibility of other organic pollutants - (PCBs in soils, flame retardants in soils, endocrine disruptors like phthalate esters in foods and soils) using different bioaccessibility models like Foresht. Also, more work is on-going on the monitoring and speciation of atmospheric nutrients in some water bodies and in remediation of metal and organic pollutants.

More research is also going on accurate determination of pollutants using newer and more modern equipments like ICP-MS, GC-MS/MS etc.

CONCLUSIONS AND CONTRIBUTIONS TO KNOWLEDGE

Mr. Vice Chancellor, Sir, Pollutants in the Environment and Foods can cause harm. Therefore, accurate determination is imperative. From the perspective of the Analytical Chemist, the physicochemical form or species in which a pollutant exists is more important than the total levels because the form or species affects its bioavailability and fate in the environment. It is therefore important to identify not only the total concentration of the pollutants but also the component species (speciation) of the pollutant in a sample i.e. soil, water or food. If we determine only the total concentration of a particular pollutant in a sample, it will give an erroneous assessment of the risk of that pollutant in the environment. I have carried out the assessment of the risk of pollutants using sequential extraction and *in vitro* methods. My sojourn through the field of Environmental pollution has enabled me to make contributions in the areas described.

1. Based on my research in the area of method development for the accurate determination of pollutants we made the following contributions:
   a) A simple direct slurry method of analysis with infusion of oxygen was developed by us for the analysis of heavy metals using the Electrothermal Atomisation Atomic Absorption Spectrophotometer (ETA-AAS). Also, we demonstrated the use of matrix modifiers coupled with platform atomisation to eliminate interferences in metal analysis.
   b) Our work on the analysis of PAHs and other organic pollutants developed a fast, efficient, quantitative, economic and environmentally friendly method of extraction with the High Performance Liquid Chromatograph with Fluorescence Detector (LC-FLD) and an improved Gas Chromatograph-mass Spectrometry (GC-MS) method using the Single Ion Monitoring mode (SIM) for quantification in environmental samples.
   c) Our work is the first Nigerian study on continuous flow analysis of environmental samples which demonstrated the suitability of Flow Injection Analysis for the determination of phosphorus and nitrates in water and soils.
   d) Our work on the modified four-step BCR sequential extraction is useful in the determination of the bioavailability of heavy metals in soils and sediments.

2 a) For the first time, to the best of our knowledge, based on our findings on the quantification and risk assessment of PAHs in smoked Nigerian fishes and roasted staple foods (yam, plantain and corn), we have advised that the method of smoking affects the levels of PAH (a carcinogenic pollutant) in our foods, however, our results show that at present, we are not at risk from consumption of smoked fish and roasted foods as the level of benzo(a) pyrene (a biomarker and carcinogen) inthe foods was below the maximum levels regulated by the European Commission.

b) Our work on the uptake pattern of metals and PAHs by edible vegetables planted on contaminated soils, (the first of its kind in Nigeria to the Inaugural lecturer's best knowledge) showed that though the total levels of pollutants in the soils and vegetable samples were high, they were not bioaccessible or bioavailable and are safe for consumption. However, one of the vegetables (Ugwu) consistently grew on all the PAH contaminated soils so we need to be careful where we plant our vegetables.

c) Our work on the comprehensive risk assessment of PAHs in soils in Nigeria using the estimated cancer risk (ER), annual daily dose exposure (Da), mean daily intake (MDI) and bioaccessible PAHs risk assessment methods showed that persons involved with the different anthropogenic activities may not be at risk since their mean daily intake of PAHs in these soils showed no observable health risk, however, it is still advisable to reduce human exposure since the pollutants can bioaccumulate over a period of time.

Our work on the Lagos Lagoon and its adjoining rivers:

a) Our study on the heavy metals in the Lagos Lagoon and some of the rivers adjoining has provided baseline information and the risk posed by heavy metals (Pb, Cd, Cr, Ni, Cu and Zn) using the sequential extraction. We can assert that we are not at risks from the heavy metals in the Lagos Lagoon Environment.

b) We have identified the predominant sources of organic pollutants to the Lagos Lagoon and provided baseline information on the occurrence, geographical distribution and pattern of aliphatic hydrocarbons and persistent organic pollutants such as polyaromatic aromatic hydrocarbons,

(PAHs) polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCs) as they are transported through the abiotic and biotic portions of the Lagos Lagoon.

c) Our work has helped to fill data gaps in the area of metal, nutrients, POPs pollution and modelling of pollutants for long-range transport, persistence, bioaccumulation and toxicity of the Lagos Lagoon environment and the Gulf of Guinea.

d) We have used mathematical and statistical multivariate analytical tools for data analysis for metals, nutrients, POPs (i.e. PAHs, PCB, OC) and n-alkanes from the Lagos Lagoon and the adjoining creeks.

e) Our work on the remediation of pollutants from effluents using the low cost agricultural wastes (both modified and unmodified) have shown the effectiveness of the method in removing metals from the different matrices. Also our "green" approach of remediation of PAHs and metals in sediments and soils has been recommended for restoring dredged sediments and polluted soils.

f) Our work on *in vitro* studies based on human gastrointestinal (GI) and using the PBET, SBET and FOREShT models to predict the bioaccessible metals and PAHs in foods and soils and thus predict human health risk have shown that we may not be at risk from some of the pollutants. Our studies have affirmed the need to identify not only the total contaminant concentration but also the component species as determination of only the total concentration can give an erroneous assessment of the risk of that pollutant to the Environment.

In concluding, Mr. Vice Chancellor, Sir, I have gone through the Peregrination of an Analytical Chemist as she navigates the subject of "Pollutants in the Environment". I have asked the question of whether we are killing ourselves slowly and

have attempted to answer that there are "Pollutants in the Environment" caused by chemicals, the good news is that we may not be at risk now because the concentrations of the bioavailable species of the pollutant is low. However, these pollutants do not biodegrade (break down easily) so they persist in the environment and accumulate in the fatty tissues of organisms for a long time and can then be harmful.

On this Sir, I rest my case and wait for your verdict on whether I have fully paid my debt to our great University.

RECOMMENDATIONS

Chemical pollutants in the environment do present a challenge to scientists both on the accurate determination of the concentrations and the risk associated with these pollutants. Some of the pollutants are persistent, bioaccumulative in nature and toxic to humans, plants and animals.

Newer pollutants that are more toxic are being produced everyday and some intermediate products may be more toxic than the original pollutants. These pollutants disrupt the endocrine system, the reproductive system; cause cancers, deformities to unborn children. The most vulnerable groups are pregnant women and the unborn children.

I recommend that as scientists, we carry out research not only on the determination of the total concentrations of these contaminants and emerging contaminants in our water, soils and foods but also determine the risk of the pollutants from the species present. To do this, I recommend as follows:

1. **The provision of research equipment in our Universities**

I commend the efforts of the Vice Chancellor and the entire Management of the University for the commissioning of the Central Research Laboratory (CRL) Building donated by one of the Alumni of this great University, Dr. D.K. Olukoya (the General Overseer of the Mountain of Fire and Miracles Church) in 2014. I have gone round the Universities in

Southwest, Nigeria and I make bold to say that our CRL Building is the biggest in the region (By God's grace, I am the Chairman of the Central Research Laboratory Management Committee at the University of Lagos).

Research Laboratories are expensive to fund and maintain but are a necessity for a University that wants visibility and be in world ranking of Universities in the League of Nations.

There is need for the provision of more research equipment, funding for: research, equipment maintenance and training for cutting edge researches.

2. Use of CRL Building

The CRL Building should be used exclusively as a Research laboratory. This is to avoid the problem of contamination by pollutants which can affect the integrity of results from analysis. This can also affect the accreditation of the CRL. The CRL should be developed to International Standards with Accreditation for analysis. This will improve the rating and bring respect, dignity and visibility to our University.

3. Provision of Laboratory Space for Research Students

There is the need for the provision of laboratory space for Postgraduate students in the Departments especially the Department of Chemistry. Most of the Doctoral students are overcrowded in the little laboratory space available to them. It is sometimes impossible for supervisors to check on students unannounced and actively participate in their laboratory work. The Department organised the International Year of Chemistry in 2011 to try and raise funds for the building of a research Laboratory (I was the Head of Department at this time). Unfortunately, what was raised was insufficient to do such. If we must produce first class researchers, we must also provide space for them to develop their capabilities.

4. Training of Research Students and Technologists

Training of researchers and technologists in use of modern instrumentation and maintenance should be enhanced. A situation where students or staff always send samples abroad for analysis does not develop the capacity of our researchers and technologists.

5. Constant Monitoring of our Environment and Enforcement of Standards by Regulatory Agencies

Constant monitoring of our environment for pollution is recommended. We also need legislation and enforcement by the Regulatory bodies. This is the only way to ensure that we are safe from pollutants especially emerging pollutants that have tendencies to bioaccumulate in the environment.

6. Provision of Bursaries for Non-staff Candidates Undergoing PhD Studies by the University

The University of Lagos should employ Research Fellows as well as Graduate Assistants to provide the much needed PhD graduates for our University and the newer Universities. There is still a dearth of PhD graduates for our Universities.

7. The Royal Society of Chemistry, UK constantly looks out for more members and gives grants/bursaries to PhD candidates to assist with their work. (We in my research group have benefitted extensively from this initiative) I recommend that the Chemical Society of Nigeria just like its counterpart initiates this incentive.

8. Finally, the University of Lagos should provide more modern and easy-to- understand Chemistry books in the library and students should be encouraged to use them.

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First, I will like to express my gratitude to the Lord God Almighty who was and is and is to come. He is faithful and good. I could not have made it this far without Him. To Him be all praise and honour.

I want to thank the Vice Chancellor, Prof. Rahamon Bello and the Management team of the University for their support. Special mention is made of late Prof. Babatunde Sofoluwe who was the Vice Chancellor at my Professorial interview.

I also appreciate the Dean of Science Prof. Olusoji Ilori for all his help and encouragement.

I am forever grateful to my parents Mr. Adebayo and Mrs. Olufemi Osipitan for their love and care. I am particularly grateful to my father, Mr. Bayo Osipitan. This must be one of the happiest days of his life. We lost our mother Mrs. Modupe Olayinka Osipitan when I was 10years old. My father refused to marry for another 12years, taking care of my siblings and I. He single handedly paid our school fees (school fees was not cheap at that time) even to the doctoral level. None of us used any form of scholarship; he didn't give us any reason to apply for any Federal or State scholarship. He was always encouraging me, counting the number of my publications and looking forward to my elevation to the position of Professor. Today, you have made history! I do not know of any other parent who can boast of twin-Professors employed by the same University and who have both given Inaugural Lectures in the same Auditorium (My twin brother Prof. Taiwo Osipitan SAN gave his inaugural lecture in November 2004 in this Auditorium). We your children celebrate you today! What a privilege the Lord gave you to witness this day. I am grateful to mummy Mrs. Olufemi Osipitan for your love, constant prayers and encouragement.

I appreciate all my teachers at the primary school through to the University. These all impacted my life and moulded me to

be what I am today. I remember some of my teachers at Queens School, Ibadan – Mrs. Ajayi (Maths), Mrs. Fajobi (Biology) our matron, Mrs. Adegbembo and others. They moulded us to be ladies. I appreciate my teachers at the undergraduate level: Profs Kayode Adesogan, A. Adesomoju, S.I. Ajayi, A.O. Osibanjo, T. Bamkole, J.A Oderinde and others. I must particularly mention my PhD supervisors at Greenwich University, London: Prof. Steve Haswell and late Dr. Roman Grezkowiak. They introduced me to research on Heavy metals. When Steve saw that I moved to the University from a Research Institute, he introduced me to the determination of pollutants using microfluidics (lab-on-the-chip) with Flow Injection methods. Steve has since moved from the University of Hull to the University of Deakin in Australia where he is producing sensors for analysis.

I started off at the Federal Institute of Industrial Research, Oshodi (FIIRO) where I cut my teeth in research. I want to thank my Director, Prof. S. Odunfa, my direct boss Dr. F. Osinowo, all my former colleagues.

Moving on, I joined the University of Lagos. In life, you need destiny helpers. I had mine in Profs Lekan Oyebande and Babajide Alo. They ensured that I crossed over to the University. They mentored, counselled and told me what it entailed to excel in the University system. I am grateful.

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Mr. Vice Chancellor, Sir, Let me take out time to salute all my academic children especially my PhD graduates: Dr. Ronke Oyeyiola, Dr. Temilola Oluseyi, Dr. Rose Adelani, Dr. Akeem Abayomi, Dr. Toyin Adetunde, Fausat Odujebe, Najeem Oladosu, Bilikis Folarin, etc. Five of them are now lecturers with me in the Department of Chemistry. Two of these are senior lecturers and others are working very hard and will soon be promoted! These are very important people to me, they are my jewels and I learn a lot from them. God bless and reward you all. Amen

I thank all my students, past and present at the undergraduate, Masters and PhD levels especially the Masters programmes in Analytical Chemistry, Environmental Chemistry and Masters of Environment Management programmes that I designed in 2001. I could not have had a successful academic career without you.

Outside academia, I want to thank the Federal Ministry of Environment, (FMNEV) National Environmental Standards and Regulations Enforcement Agency (NESREA), Lagos State Environmental Protection Agency (LASEPA), Standards Organisation of Nigeria (SON) and the Institute of Public Analyst of Nigeria (IPAN) for the opportunity to serve on their various committees in different capacities. These have helped me to blend the gown with the town and have a purposeful research.

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Losing a mother so early in life can be traumatic but God has been so good to us, we had several "parents" especially

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I also want to thank my other "parents", Pa & Mama S.O. Odugbesan (of blessed memory, mama was my godmother), Pa & Mama Onalaja, Otunba & late Otunba (Mrs.) Osibogun, Otunba & Otunba (Mrs.) F.I. Osikoya, Pa & Mama Odunubi, Pa & Mama Ayankogbe, Pa & Mama Adewunmi Dina, late Pa & Mama Dipe and Mrs. C.O. Badmus.

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Mr. Vice Chancellor, Sir, permit me to be factual and say some words about Taiwo, my twin brother. The foundation of today's lecture was laid during a visit by Taiwo to my office at FIIRO. He encouraged me to move to the University having served my bond at FIIRO. Thereafter, he made necessary contacts with Prof. Jelili Omotola, SAN, the then Vice Chancellor of the University of Lagos and Prof. Babajide Alo who was then Head of Department of Chemistry. My application was processed, I was interviewed and appointed a senior lecturer in the Department of Chemistry with effect from October 1999. Need I say, today, the Lord has answered your prayers! You have been a great pillar of support and I thank you.

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Mr. Vice Chancellor, Sir, all that is left is to thank my immediate family. I thank my children Olaoluwa, Opeoluwa and Ebunoluwa. I thank you for your support and understanding through my career. You have been wonderful children, my source of pride and joy. My prayer is that God Almighty will give you equally if not more wonderful and peaceful children. Given the opportunity to pick children again, I will surely pick you all again.

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Mr. Vice Chancellor, Sir, distinguished ladies and gentlemen. I thank you for your presence, patience and attention. God bless you all.

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