UNIVERSITY OF ILORIN

THE ONE HUNDRED AND THIRTIETH (130th)
INAUGURAL LECTURE

"The Heart of Science in the Service of Man"

PROF. FOLAHAN AMOO ABDULWAHID ADEKOLA
B.Sc., M.Sc. (Ife), Ph.D. (Paris), FCSN, FIPAN
Professor of Chemistry,
Department of Chemistry,
University of Ilorin, Ilorin, Nigeria.

Date: 25th April, 2013.

This 130th Inaugural Lecture was delivered under the Chairmanship of

The Vice-Chancellor
Professor Abdul Ganiyu AMBALI
DVM (Zaria); M.V.Sc., Ph.D. (Liverpool); MCVSN (Abuja)

25th APRIL, 2013

Published by
The Library and Publications Committee
University of Ilorin, Ilorin, Nigeria.

Printed by
Unilorin Press,
Ilorin, Nigeria.

PROF. FOLAHAN AMOO ABDULWAHID ADEKOLA
Professor of Chemistry

Courtesies

Bismillahir-Rahmanir-Rahim

(In the name of Allah, the Beneficent, the Merciful)

The Vice-Chancellor,

Deputy Vice-Chancellors,

Registrar and other Principal Officers of the University,

The Provost, College of Health Sciences,

Dean of Science and other Deans of Faculties, Postgraduate School and Student Affairs,

Directors, Professors and other Distinguished Members of Senate,

Head of Department of Chemistry and other Heads of Departments,

Members of Academic, Technical and Non-academic staff of the University,

Distinguished invited Guests, Friends of the University and Members of my Family,

Gentlemen of the Print and Electronic Media,

Great Students of the University of Ilorin,

Distinguished Ladies and Gentlemen

Preamble

Please permit me to start this lecture with these verses from the Glorious Qur'an: *"Read! In the name of your Lord who created - Created man from clot. Read! And your Lord is Most Bountiful - He who taught (the use of) the Pen, Taught man that which he knew not [96:1-5]"*. I am deeply honoured, humbled and privileged by your presence today to deliver the 130th Inaugural Lecture of this great University. I thank Allah for sparing my life and for bringing you here safely. This inaugural lecture is the 6th from the Department of

Chemistry and the 1st in the Analytical and Environmental Chemistry Unit of the Department. The last lecture from Department of Chemistry was delivered by Prof. G.A. Olatunji on 12th February, 2009. It was titled "Journey to the Promised Land: The Travails of an Organic Chemist". An Inaugural Lecture provides a golden opportunity for a professor to give an account of what he has contributed to the international pool of knowledge in his chosen area of specialization. Inaugural lecture means different things to different people. For instance, in France where I was trained, it is an occasion for a new Nobel laureate to present a lecture on the particular aspect of his scientific contributions which has led to his recognition.

I am proud to say that my school, *Ecole Superiure de Physique et Chimie Industrielles de Paris* (ESPCI) of Pierre & Marie Curie University, Paris, has produced over ten Nobel Prize Laureates, mainly in Chemistry & Physics. As a matter of fact, two of them, Prof. George Charpak and Prof. Pierre-Gilles de Gennes won Nobel Prize in Physics in 1991 and 1992 respectively. I was also opportuned to be physically present at the Nobel Prize inaugural lectures of these two giant scientists. One of them actually contributed to my motivation to return to Nigeria after my PhD. Prof. de Gennes said in his Inaugural lecture in Paris that while he was being invited to deliver lectures at several big national laboratories in the United States, he was surprised to find Africans as top researchers in many of these laboratories and when he asked some of them why they have not returned to Africa to contribute to the development of their continent, they responded by saying that if they returned they would not get facilities to continue their research. The Nobel laureate then concluded that it is another form of colonization to bring brilliant Africans to western countries and train them in advanced technologies without actually concentrating on the basics that will help them to contribute to solving African problems, because western countries will not solve the problem for them. I then made up my mind to return to Nigeria.

I therefore wish to thank Mr Vice-Chancellor and indeed the University for giving me this privilege and honour to present the 130th Inaugural lecture of this University. It is an opportunity for me to give account of my research activities in the last twenty-seven years since I made my '*premiere pas*' in advanced research.

Introduction

I humbly wish to state that it has not been easy for me to settle on the title of today's inaugural lecture as I have had to change it on several occasions before I finally decided on 'The Heart of Science in the Service of Man'. Chemistry is often called the central science because of its relevance to all fields of human endeavour. It is also remarkable to note that all branches of chemistry draw on the ideas and techniques of analytical chemistry and as a result, analytical chemistry occupies a central position. The importance and the breadth of its interaction with all disciplines ranging from Arts to Health sciences are illustrated in figure 1. Hence, analytical chemistry can be considered as the heart of science.

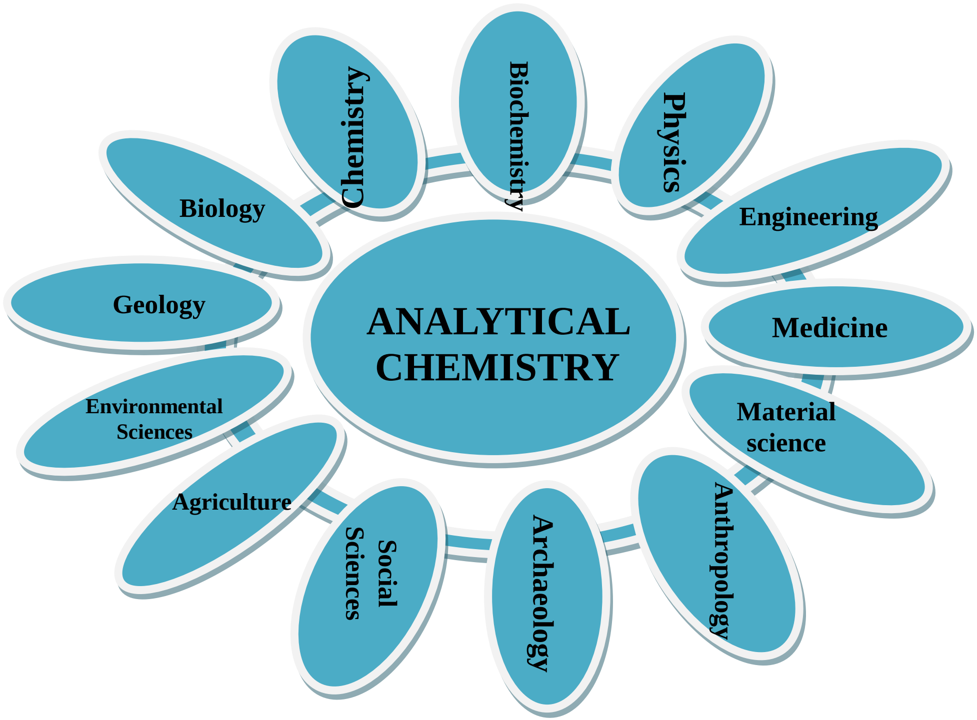

Fig 1: The Central Position of Analytical Chemistry (adapted Skoog et. al., 2005)

What is Analytical Chemistry?

Analytical chemistry is the science of obtaining, processing and communicating information about the composition and structure of matter (Harvey, 2000). In other words, it is the art and science of determining what matter is and how much of it exists. Philosophically, the general aim of analytical chemistry is to make the intrinsic but latent information about an object evident, measurable, truthful and useful (Malissa, 1995). The major keyword of analytical chemistry, which is measurement, has been mentioned several times in the Glorious Qur'an. These include the following verses: **(1)** *'Verily all things (without exception),We have created, in exact measures and proportions.'(54:49); and* **(2)** *'And there is not a thing, but its storehouse is with Us, And We send them down, But in definite ascertainable measures' (15:21).*

Analytical chemistry is all about measurement and problem solving. It integrates the knowledge of chemistry, instrumentation, computers and statistics to solve problems in all areas of science and technology (Danzer, 2006). Some of the analytical chemistry tasks include developing new ways to make measurements, interpretation of data and communication of results in a non-technical manner. For example, their measurements are used to assure compliance with environmental and other regulations; to assure the safety and quality of food, pharmaceuticals and water; to support the legal process; to help physicians diagnose disease; and to provide chemical measurements essential to trade and commerce. Analytical chemistry is also about development of new industrial processes and products. Analytical chemistry is therefore a challenging profession that makes significant contributions to many fields of science. A sound analytical chemist is expected to have solid background in chemistry, a propensity for detail, good computer skills, good laboratory facilities and problem-solving skills.

My Scientific Journey

My choice of chemistry as a profession has not been by coincidence. My interest in chemistry started from secondary school with the passionate teaching of Mr Agbemazu, a Ghanaian Chemistry teacher. On my final choice of Analytical Chemistry as an area of specialization, it was largely due to the counseling I received from Professsor Claude Poitrenaud, a distinguished Professor of Analytical Chemistry at the National Institute of Nuclear Science and Technology of Atomic Energy Commission in France, who offered me advice when I was confronted with the challenge of making a choice between Radio-Nuclear Chemistry and Analytical Chemistry for my doctoral studies. Kindly permit me to state that the road to accomplishing this feat has been rough. I encountered three major stumbling blocks during the course of my studies. The first was that my father died when I was in my final year in the University and few weeks later, my mother took ill and I had to be shuttling between Ibadan and Ile-Ife at least twice a week to visit her. Mr Vice Chancellor, sir, I want to say that in spite of this huddle, I had an ‘A’ grade in almost all my chemistry courses in the final year at the then University of Ife and ended up with a First Class Honours degree (*Alhamdulillah*).

The second obstacle was when I was doing my master’s programme at the same University. The research project was on the application of Permutation Group

Theory to generate character tables for weakly-bound polymer molecules. Unfortunately, we were not able to come-up with an acceptable expression. It was then my supervisor, Prof. J.A. Odutola, now of Alabama A & M University, USA said ‘Fola, I am sorry I cannot help you further as I don’t know the solution myself. It is your problem and I want you to think over it again. If you cannot find the solution within the next four weeks, we may have to decide on another project’. I became sad and I had to pray to Allah. On the third day, I succeeded in coming up with satisfactory mathematical expressions. The following morning, I anxiously waited for my supervisor to arrive. On his arrival I went straight to his office and I showed him my finding. He also tried to verify it by using some examples. Prof. Odutola confirmed the finding. The research work was later published in a highly-rated *American Journal of Molecular Physics* (Odutola and Adekola, 1987).

The third great challenge was when I was about to start my PhD research work in Professor Denise Bauer’s Laboratory in France. The first day I got to her office in order to obtain my research topic, she said ‘Adekola, you are welcome to the Analytical Chemistry of Industrial Processes Laboratory. The only project I have for you is an electro-analytical chemistry work. It is a project funded by three major companies in France’. I agreed with this topic and decided to settle down to work. After about five months when I was not getting good results I became worried as I might not be able to turn-in satisfactory report at the end of the year. The implication was that my scholarship would be terminated and then be asked to return to Nigeria without a PhD. As usual, I prayed to Allah for His intervention. *Alhamdulillah*, by the sixth month, I was able to establish the correct experimental conditions and develop a customized carbon paste electrode. The road then became clear. So, on the day of defense of my PhD thesis, the President of Jury, Professor Alain Storck, who was then the President of French Society of Chemical Engineers said ‘this is an excellent research and that Dr Adekola must be retained within the French universities system’. That same day, a member of the panel who was the Director of Research and Development of CLAL Precious Metals Processing Industry, one of the companies that sponsored my PhD research, broke the good news that the management of the company has decided to offer me a contract appointment as an Industrial Analytical Chemist. I resumed work in the company the following day.

At the end of the sixth month, I left for the National Research Institute for Chemical Process Metallurgy, Paris, under the supervision of Professor Michel Fedoroff as a postdoctoral researcher. About a year later, I decided to return to Nigeria to take up appointment as lecturer 1 in September, 1994 at the University of Ilorin.

Mr Vice-Chancellor sir, what follows is the account of my research in Nigeria and abroad in the last twenty-seven years. I have mostly concentrated on the application of analytical chemistry to identifying and solving problems of environmental concerns as well as developing processes that enable value-addition to diverse solid mineral resources that abound in Nigeria. The first part of my research efforts was directed at understanding the status of water and atmospheric environments as well as developing possible environmental technological solutions for the cleaning or remediating contaminated media.

Environmental pollution is the unfavourable alteration of our surrounding wholly or largely as a product of man's actions through direct or indirect effects of changes in energy patterns, radiation level, chemical and physical constitution and abundance of organisms. State of the environment is a critical factor in sustainable development. Sustainable development is globally defined as the "development that meets the needs of the present generation without compromising the ability of the future generation to meet their own needs" (WCED, 1987).

Mr Vice Chancellor, sir, it is pertinent to note from above that we all owe it as a divine duty to always strive to leave the environment at the state that we met it if not better. Unfortunately, this has always not been the case as a result of man's greed and selfishness. This is aptly described and captured by some popular Yoruba expressions: " *Se e fe je aiye omo yin maiye ni ?*" (Do you want to exhaust all the resources without leaving anything for your children?) or '*Aiye laaje ki a to je orun*" (Make maximum enjoyment in this life before you get to heaven). Economists have clearly distinguished 'want' from 'need'. What is important in sustainable development is 'need'. Let us all ask ourselves; do we need one house or many houses, one car or many cars, etc.? Are we complying with the philosophy of sustainable development or not? What follows will provide useful hints towards providing answers to some of these questions.

Professor Babatunde Alo of University of Lagos in his Inaugural Lecture (Alo, 2003) defined sustainable development in economic terms as: "a process in which the natural resource base is not allowed to deteriorate". That is, sustainable development emphasizes the previously unappreciated role of environmental quality and environmental inputs in the process of raising real income and the quality of life. From the foregoing, the two keywords 'environmental quality' and 'environmental inputs' are important for the understanding of the state of the environment. Environmental quality and inputs are related while environmental quality is simply a measure of environmental inputs which could be direct or indirect (physico-chemical and biological characteristics) in relation to the potential effects on human health or quality of life.

Environmental inputs are of two types: anthropogenic (human) and natural. However, what brings about deterioration of environmental quality is mainly 'man-made', that is 'activities of All of us'. In the Glorious Qur'an, Allah warns us all not to waste natural resources: *"O Children of Adam! Wear your beautiful apparel at every place of worship; eat and drink, but waste not by excess, for Allah does not love those who waste [7:31]."* Over time, particularly, over the past half a century, changes have been dramatic with the increasing population and consumption patterns threatening the threshold of sustainability in the balance and utilization of the environment. This has put increased pressure on the environment and the natural resources, thereby reducing the environmental sustainability index of many countries.

In Nigeria today, the legal, institutional and administrative frameworks have continually been strengthened. The integration of environmental policy in governance became reinforced in 1988 as a result of illegal dumping of 4,000 tons of toxic wastes from Italy in Koko Port, near Sapele in Delta State (Odubela et al., 1996). This unfortunate incidence led to the establishment of the then

Federal Environmental Protection Agency (FEPA), which later metamorphosed to a full-fledged 'Federal Ministry of Environment' with many parastatals. Mr Vice-Chancellor, sir, my research group has made reasonable efforts towards understanding and documenting the status of both water and atmospheric environments in Nigeria and South Africa.

Water Research

Recent survey has revealed that more than a billion people in the developing world, most of them in Africa, lack safe drinking water. As a matter of fact, 300 million people in Africa do not have reasonable access to safe drinking water and more than 400 million Africans live in water-scarce countries (UNEP, 2006).

Lack of potable water has made people to rely on heavily polluted untreated flowing river water or shallow well water. Most often, people would have to trek several kilometres before getting access to drinking water. This has resulted in preventable human suffering due to water related diseases such as cholera, typhoid, river blindness, hepatitis, cyanotoxins, arsenicosis, methaenoglobinemia (nitrate pollution), carcinogenicity, mutagenicity and endocrine disruption (disruption of the normal functioning of hormones). It is estimated that 14– 30 thousand people, mostly children and elderly die every day from water related diseases (UN-HABITAT, 2013). The world's drinking water millennium development goals target was to provide water for 89% of global world population by 2015. Out of the total water in the planet, 97.5% is salt water and 2.5% is freshwater. Of the freshwater, 1.75% is in form of ice and permanent snow in polar and mountainous regions and only 0.75% is available as liquid freshwater. Again, of the 0.75% that occurs as liquid fresh water, 97% of this is stored underground as groundwater and only 3% is accessible in rivers, streams and lakes (UN-WATER, 2013).

Some of our important research efforts have been directed on water management and water quality assessment issues. Along this line, we have established the pollution status as well as generated bankable data on the physico-chemical characteristics of the following river bodies: Asa and Oyun rivers in Kwara State, Landzu river (Bida) and Kainji Lake in Niger state, Osun, Otin and Oni rivers in Osun State.

Asa and Oyun rivers, Kwara State

Both Asa and Oyun rivers are major sources of water catchments in Ilorin city. Asa dam, the biggest dam in Kwara state, is on the course of Asa river. The practices along the riverbed such as farming, industrial effluent discharges, dumping of domestic and industrial solid and liquid wastes have been found to contribute immensely to the pollution load of heavy metals, hydrocarbon, and other pollutants in Asa river (Adekola and Eletta 2007).Nitrate and phosphate levels were also found to be higher than the permissible levels of World Health Organization. This has been attributed to urban (sewage discharge and daily washing activities) and industrial runoffs as well as runoff from agricultural lands (Eletta and Adekola, 2005). The runoff of nitrate and phosphate into rivers fertilizes them and causes accelerated eutrophication of the waters resulting in the growth of algae or aquatic weeds on the surface of the river. When ingested, nitrates are converted into nitrite in the intestine, which then combines with hemoglobin to form methemoglobin. Methemoglobin has a reduced oxygen-carrying capacity and is particularly problematic in children who are most readily affected by this "nitrite poisoning" or "blue baby syndrome." In another related study, we have reported that the Asa River sediment is contaminated. The major sources of contamination were traced to industrial discharges, domestic waste disposal and application of agrochemicals on farmlands. We have successfully used XRD technique in the monitoring of metal contaminants in sediments as evidenced from the detection of chromite and pyrite in the most polluted locations along Asa river within the urban areas of Ilorin (Adekola and Eletta, 2007).

Concentrations of some heavy metals in *Tilapia zilli* (Tilapia) and *Synodontis* membrane (Catfish) , the two common fishes in Asa River, also revealed the presence of manganese, chromium, zinc, iron and lead in the tissues of the two species while cadmium, mercury and nickel, were found to be present at ultratrace levels (less than 0.01 ppm). Concentrations of metals were found to be relatively higher at the downstream end of the river than at the upstream locations. Apart from lead, other metals did not pose any health risks in human since the calculated probable amounts being ingested by an average adult (50 kg average weight) per day were lower than WHO maximum recommended value of intake (Eletta et al., 2003). In the case of Oyun River, the river was found to have a low pollution index as most of the heavy metals analysed were within the WHO compliance levels. The Oyun river has been adjudged not to suffer from adverse impacts from both domestic and industrial activities (Adekola et al., 2003). Our studies have however revealed high concentration of iron and manganese in Oyun river and this has been attributed largely to the underlying bedrocks which consist mainly of manganiferrous aluminosilicate mineral. This was found to be more prominent between ARMTI Bridge and few kilometres after the river has traversed the University of Ilorin main campus (Adekola et al., 2008 & 2009).

Mr Vice Chancellor, sir, I am delighted to inform you that we have successfully carried out the identification of the sources of high concentration of dissolved manganese in the University of Ilorin Earth Dam. This research was commissioned by the University of Ilorin when it was discovered after the completion of the University of Ilorin water treatment plant, that the treated water exhibited some aesthetic problem of gradual changing of its initial colourless colour to brownish colour. Preliminary investigation carried out in my laboratory later revealed that the brownish colour was due to the atmospheric oxidation of dissolved manganese ion into insoluble fine particles of manganese oxide over time.

After the preliminary report on this observation was submitted to the university, I was then charged with the responsibility of leading a team of multi-disciplinary experts to investigate the possible source of manganese in Unilorin Earth Dam. The results of our investigation led to the installation of a manganese removal unit to take care of this problem. Our investigation revealed that the soil of this ecological zone is iron-manganese rich. It is well-drained and mainly sandy loam, which is an indication that leachable manganese and iron can easily be washed into the dam reservoir. The pH of the surface soil is generally acidic and this is favourable for enhancing the bioavailability of manganese and iron in the environment. In general, Fe and Mn exhibited the lowest concentrations in the water when compared to their average corresponding concentrations in both the soil and the river sediments. The highest average concentrations were however, recorded in the sediments.

In water samples, the concentration of iron was generally ten-fold higher than that of manganese. The source of both iron and manganese was found to be largely of natural origin which is geogenic. However, the study also indicated some contribution from human activities arising from the use of manganese based agrochemicals such as fertilizer, herbicides and pesticides (Adekola et al., 2008).

Landzu river, Niger State

The level of pollution of Landzu river, a major river passing through Bida in Niger state was assessed by monitoring the concentrations of some physico-chemical parameters during the wet and dry seasons of 2003 in both water and sediment samples. The organics load of the river was low while some heavy metals (Cu, Ni, Zn, Fe, Co) measured concentrations were higher than the WHO maximum desirable limits for drinking water. The sources of heavy metals were found to be diffused in nature. The presence of heavy metals was attributed to the run-offs from blacksmithing and smelting activities and agricultural lands in Bida (Adekola and Saidu, 2005).

Kainji Lake, New Bussa, Niger State

Sequential extraction was carried out to determine the concentrations of some trace metals (Mn, Cu, Fe, Pb and Cd) in the Kainji lake sediments in four fractions:

exchangeable, bound to iron and manganese oxide, bound to organic matters and residual. This was undertaken to assess the environmental fate of these trace metals. The proportion of the mean metal concentrations of the bioavailable metals follows the order Fe>Cu>Pb>Mn>Cd. Generally, Fe was the most abundant metal in the sediment and about 40% was found in its bioavailable form. Although cadmium contributed least to the bioavailable content, more than 60% of it was found in the bioavailable fraction. This suggests that cadmium is highly mobile and, since it is known to be toxic, its concentration in the bioavailable form constitutes an environmental threat (Adekola, et al 2010).

Heavy metals in Run-Offs and Road dusts in Urban environment

On the road surface, most heavy metals become bound to the surfaces of road dust or other particulates. During rainfall, the bound metals become soluble (dissolved) or are swept off the roadway with the dust, or stick to our shoes and dresses. Road dust represents a significant source of heavy metals. In order to have a better understanding of the contribution of activities in the urban environment to the total heavy metal concentrations in the river waters passing through urban areas, we have carried out studies on the measurement of concentrations of trace metals in urban run-offs and road sides dusts; zinc, cadmium, lead and iron were measured in urban run-offs rainwater and sediments in both Ilorin and Lagos, Nigeria. These heavy metals exhibited relatively high levels in the urban run-offs from these cities.

Of all the metals, Iron has the highest while cadmium has the lowest concentration. The level of zinc was significantly higher ($p<0.05$) in Lagos than in Ilorin. The analytical results also indicated a strong correlation ($r = 0.9597$) between lead and cadmium in Ilorin run-off and between cadmium and zinc ($r =0.9661$) in Lagos run-off. This suggests a most probable common source for cadmium (Cd) and lead (Pb) in Ilorin. It therefore appears that other sources apart from automotive emissions might account for Pb and Cd levels in Lagos unlike in Ilorin for which Pb and Cd might likely originate mainly from automobile emissions. In the case of run-off sediments, a significant correlation was obtained between iron and zinc in Lagos ($r =0.8820$) and in Ilorin ($r = 0.9937$).

Our results have provided evidence for a preferential sorption behavior of the iron oxides in the sediment for dissolved zinc in the run-off water. (Adekola, et al., 2001 & 2002; UNEP, 2006). Mr Vice Chancellor, sir, it gives me a great honour to inform you that our analytical data on the urban run-offs in Lagos and Ilorin have been used by United Nations Environment Programme (UNEP) as a reference source on urban run-offs sediments in Lagos and Ilorin (UNEP, 2006).

Cape Town Harbour, South Africa

In conjunction with my research collaborators at Cape Peninsula University of Technology (CPUT), South Africa, we have carried out studies on characterization of some endocrine disrupting chemicals in the marine environment of Cape Town harbour. Some of these endocrine disrupting chemicals include heavy metals and organotin compounds (trimethytin, tributyltin, triphenyltin).

Endocrine disrupting chemicals (EDC) are hormone-mimicking chemicals that are very toxic and some of these chemicals have been shown to act as either female hormones or male hormones. Thus, endocrine disrupting chemicals have been shown to change a male frog to a female frog or a he-fish to a she-fish (Okoro et al., 2011a & b). These days, there is growing evidence linking some of these chemicals to the problems in human health. These include breast cancer, infertility, low sperm counts, genital deformities, early menstruation and even diabetes and obesity.

The organotin compounds such as TBT and TPT are used mainly as antifouling paints, fungicides, pesticides, wood preservatives and stabilizing agents in polymers. Human exposure to organotin compounds (OTCs) may have adverse effects on the skin, eyes, liver and so on and on the organ systems such as cardiovascular, gastrointestinal, etc. These effects and other associated environmental impacts of OTCs are the reasons why the authorities of many countries have had to restrict the use of TBT as antifouling agents in ship paints and thus target tributyltin (TBT) regulation (Abbot et al., 2000). For instance, in our studies, we have detected a substantial concentration of tributyltin and triphenyltin compounds in sea water, sediment and mussels collected from Cape Town Harbour using a novel analytical method based on Gas Chromatograph – Flame photometric detector (GC-FPD) (Fatoki et al., 2012).

Atmospheric Environment

Atmospheric pollution means the presence in the outdoor atmosphere of one or more contaminants, such as dust, fumes, gas, odour, smoke or vapour in quantities, of characteristics, and of duration such as to be injurious to human, plant, animal or human life or to property, or which unreasonably interferes with the comfortable enjoyment of life and property (Perkins, 1974). Air pollution has become knowingly or unknowingly part of our modern life. The major cause of air pollution is combustion which is an essential part of man's life. Our technological society is mainly powered by the combustion of fossil fuels in order to meet our domestic and industrial energy requirements. Other gaseous pollutants that are released alongside carbon dioxide are carbon monoxide, sulphur oxides, nitrogen oxides, particulates, trace metals and hydrocarbons. Flaring of associated gases during hydrocarbon processing is a common occurrence in the Niger Delta (Figure 2).The basic challenge to an analytical chemist is to develop methods that enable measurement of a wide range of environmental pollutants and to measure their concentrations over time and space. The generation of accurate and reproducible analytical data would serve as useful tool for the prediction of future concentrations and will also assist environmental policy makers in formulating the right decisions on environmental issues affecting humanity.

Fig. 2 :A typical vertical gas flaring in the Niger Delta of Nigeria

Mr Vice chancellor sir, some of my research efforts in atmospheric pollution studies have been directed at identification and quantification of gaseous pollutants in the atmospheric environment. We have been able to put into evidence the use of bark of trees along the road sides in urban cities as bio-indicators of level of urban air pollution. *Gmelina arborea* and *Prosopis Africana* were found to be good bio-accumulators of heavy metals and so could be said to possess excellent characteristics for monitoring the concentration of heavy metals in the atmospheric environment (Adekola and Afolayan, 2000).

In another related study, we have linked high concentration of zinc and sulphur measured in the needles of Scots Pine (*Pinussylvestris L.*) to intense urban and industrial activities (Adekola et al, 2002). As toxic house dust is a threat to small children at crawling stage who play on floors, crawl on carpets and regularly put their fingers in their mouths. The aerosol particles readily infiltrate or penetrate buildings through doors and windows, and cracks in building structures. The possible high risk of exposure of small children as well as adults, though to a small extent, to indoor dusts or fine particulates has motivated us to assess the environmental quality of household dusts at eighteen locations within Ilorin during the harmattan period of 1998. Important average concentrations were measured for lead, cadmium, copper and iron in residential houses and public buildings that were located along heavily traveled vehicular roads and area of intense human activities (Adekola and Dosumu, 2003). The use of human hair as bio-indicator of environmental and occupational exposure has also been explored (Adekola et al., 2004). The concentrations of some heavy metals (lead, zinc and copper) were determined in the scalp hair of children (1-15 years) and active adults (16-40yrs) in Ilorin and Ibadan. While the level of zinc was higher in children than in adult; the level of lead was higher in adults than in children. The levels of these heavy metals have been attributed to urban activities including vehicular emissions and automobile traffic (Adekola et al., 2004). It is important to note that the average lead concentrations measured in gasoline used in Nigeria is 0.66gPb/L and this results in the deposition of an estimated total of 2800 metric tons of vehicular gaseous lead emissions on the urban areas in Nigeria annually (Alo, 2003).

My research group has undertaken the assessment of the level of ozone and its precursors using a combination of field measurements, empirical and theoretical modeling. The overall average concentration level of ozone, nitrogen oxides and sulphur dioxide for the two cities of Ilorin and Lagos have been reported (AbdulRaheem, Adekola & Obioh, 2009a &b) The values in parts per billion are summarized in Table 1.

Table 1: Average concentrations (ppb) of ozone, nitrogen oxides and sulphur dioxide in Ilorin and Lagos

Trace gases	Ilorin	Lagos
Ozone	27.15± 3.80	23.05± 3.38
Nitrogen oxides	2.67± 0.32	4.87± 0.38
Sulphur dioxide	4.23± 0.52	9.61± 1.12

Results from this study have confirmed the role of nitrogen oxides as a strong precursor of ozone formation and this was found to be more pronounced at the peak of dry season when photochemical activity was at its highest level. Both nitrogen oxides and sulphur dioxide were found to vary significantly (p=0.05) with traffic density. We have also suggested an interconversion of nitrogen oxides into ozone due to inverse relationship between ozone and nitrogen oxides (AbdulRaheem, Adekola & Obioh, 2009).

Characterisation of some hazardous materials in the environment

For sustainable development, it is important to minimize or eliminate human exposure, especially involuntary exposure to carcinogens and other toxic chemicals found in air, water, foods and consumer products. My research group has made significant contribution in this area by carrying out compositional analysis and toxicological studies of some materials such as indigenous mineral dyes, coals and bitumen.

Mineral dyes

The *Yombo-fitta* and *Yombo-tumtum* are mineral dyes originating from southern part of Ghana and sold at various local markets in Ilorin. These two dyes are used by some people in Nigeria to dye their grey hair so that they can continue to look young, as well as to dye clothing materials. These dyes are freely sold at Emir's market in Ilorin among other places. Our research results have revealed the presence of highly toxic metals (lead and arsenic) and a carcinogenic organic compound (*p*-phenylenediamine, 21% w/w) in these two dyes (Adebayo et al., 2005 & 2007).

Coals

Coal is a major source of energy**.** Coal has played this important role for centuries – not only providing electricity, but also as an essential fuel for steel and cement production, and other industrial activities. The coal reserves in Nigeria are estimated to be in excess of 2.5 billion tonnes (RMRDC, 1994). The levels of inorganic elements in coal are important in view of the impacts of these elements on coal combustion systems in their operational and environmental performances. The results of our investigation provided evidence that some Nigerian coals have lower degree of minerals (inorganic elements) when compared with some foreign coals. The low level of toxic metals such as Cr, Pb, Cu, and Zn measured in Nigerian coal minerals as compared to foreign coals makes Nigerian coals more environmentally-friendly than other foreign coals. Porphyrins were also isolated from Nigerian coal minerals and characterized by means of infrared and UV-visible spectrophotometric techniques (Olajire et al., 2007). The presence of these metalloporphyrins in fossil plant materials is important because they provide information on the geochemical transformations of chlorophyll and hence serve as important biological markers in sediments and sedimentary rocks (Baker and Louda, 1986).

Bitumen

A major contribution made in this area is on the effect of solar irradiation on the natural bitumen of Agbabu, Ondo State of Nigeria. Our studies have revealed a significant modification of the polycyclicaromatic hydrocarbon (PAH) profile of Agbabu bitumen after prolonged exposure to sunlight. We found some carcinogenic polycyclic aromatic hydrocarbons (pyrene, benzo anthracene, etc) which were not found in the unirradiated sample (Olabemiwo et al., 2010 & 2011).

Contribution in the Area of Environmental Technology

Mr Vice Chancellor sir, what follows constitute the second part of my research efforts. Having identified the problems, I think it is even more important to discuss environmental technological solutions for containing these problems within the context of sustainable development.

Automotive Post Combustion Catalysts (APCC)

An automotive post-combustion catalyst, also known as catalytic converter is a purification device that uses the basic reduction-oxidation reactions principle. It helps to reduce the pollutants emanating from vehicles (Adekola, 1993). It converts greater than 98% of the obnoxious gases produced by a car engine into less harmful gases. The automotive post-combustion catalysts (APCC) contain the platinum group elements as a deposit on a substrate consisting mainly of ɣ-alumina, it is a deposit itself on a Cordierite matrix. This device is normally incorporated into the exhaust chambers of motor vehicles.

There are two major types of automotive catalysts: oxidation catalysts (also known as two-way catalysts) which, as the name implies, oxidize carbon monoxide and the products of incomplete combustion of hydrocarbon fuel, and tri-functional catalysts, otherwise called three-way catalysts, which are capable of reducing the oxides of nitrogen into nitrogen, carbon dioxide and water, in addition to the oxidation role that is common to both. Platinum-bearing catalysts have the ability to transform atmospheric pollutants such as carbon monoxide, the products of incomplete combustion of hydrocarbon fuel and the oxides of nitrogen into non-toxic products (carbon dioxide, nitrogen and water) (Adekola et al, 1992b & c). Based on this important role, these catalysts have attracted attention mostly from the automobile industries. My PhD research at Pierre and Marie Curie University, Paris focused on the application of carbon paste electrode to the study of electrochemical behavior of platinum, palladium and rhodium compounds and their corresponding post-combustion automotive catalysts. The electro-analytical determination of the chemical/redox form and concentration of precious metals contained in the new and spent catalytic converters revealed the presence of platinum as platinum (IV) or Pt(II) (depending on the method of preparation of the catalytic converter), palladium as palladium (0) and rhodium as rhodium(0) depending on the type of catalytic converter (2-way or 3-way catalyst). In the spent catalysts, the precious metals were converted mainly into metal oxides (Adekola et al., 1992a& 1993).

Adsorption Science and Technology

Adsorption underlies an alternative technology for the removal of pollutants from the environment with respect to other methods such as chemical reduction, precipitation, ion exchange, reverse osmosis, and membrane separation. When the appropriate adsorbent is selected, the adsorption process can become a promising and effective technique for the removal of certain types of contaminants such as heavy metals and dyes from aqueous and gaseous effluents (Adegoke and Adekola, 2005, 2010 & 2011). Adsorption has been found to be superior to other techniques for water purification re-use in terms of initial cost, simplicity of design and use of operation (Meshko et al., 2001). Adsorption has been used extensively in industrial processes for separation and purification. Adsorbents can either be inorganic or organic. The inorganic adsorbents include alumina, silica and zeolite while the organic adsorbents are activated carbon and polymers. Pollution has seeped into the fiber of human society all over the world ranging from domestic to industrial pollutions. The routes taken by pollutants to reach water can range from being direct to being quite tortuous. The need to reduce the concentration of these pollutants from industrial effluents has been of great concern to the environmental scientist. Adsorption onto activated carbon appears to be the most interesting from the point of view of large-scale application, simple technology and cost effectiveness (Adekola & Adegoke, 2005).

Activated carbon has been produced from a wide range of carbon-rich raw materials of animal, mineral or agricultural wastes origins (Adekola & Adegoke, 2010). These include coconut shell, wood, fruit stones, rice husk, bones, nutshells, coal and peat.The surface properties and pore size distribution that result from any activated carbon are a function of both the initial material used and the exact preparation procedures (Fatoki et al., 2012). We have also synthesized a series of macroporous, ion-exchanger and nanomaterials for use in the treatment of heavy metals-laden aqueous solutions.

Macromaterials

In this regards, we have proposed suitable biosorbents, notably activated charcoals prepared from waste agricultural materials such as coconut shell, coirpith, rice husk, shear butter wood and bark for the removal of blue dye (Adekola and Adegoke, 2005) and heavy metals (Adegoke and Adekola, 2011); natural bentonite for the bleaching of palm oil (James et al., 2008), natural goethite for the removal of cadmium (Salami and Adekola, 2002) and lead and zinc from aqueous solution (Abdus-Salam and Adekola, 2005).

We have also proposed some novel synthetic ion-exchanger macro-materials for the treatment of heavy metals laden aqueous effluents. Interesting results were obtained when copper hexacyanoferrates were used to remove silver ions from aqueous solution (Adekola et al., 1997), mixed potassium divalent (copper, zinc & nickel) metallic hecaxyanoferrates used for the removal of mercuric ion (Adekola et al., 2002) and manganese hexacyanoferrates for the removal of cadmium from aqueous solution (Adekola et al., 2007). The divalent hexacyanoferrates materials were all prepared by localized growth technique (Fedoroff et al, 1990).

Nanomaterials

Nano oxides are sized between 1 and 100 nm. Conventional metal oxides typically have grain sizes that fall within the micrometre range. As part of my contribution in nanomaterials research, I have successfully supervised two PhD candidates in this area. One of the studies is concerned with the tailored synthesis of goethite, hematite and magnetite nanoparticles by acid hydrolysis, sol gel, transformation of ferrihydrite and precipitation methods (Adegoke, 2012). The nanoparticles exhibited various morphologies such as hexagonal, plate-like, nanocubes sub-rounded and spherical depending on the method of synthesis. Examples of some of these nanoparticles are shown in figure 3. The sizes were in the range of 15.69 to 85.84 nm. The prepared nanoparticles have been found to exhibit great potential for the removal of chromium (VI) (Adegoke and Adekola, 2012), arsenic (V) and manganese (II) from aqueous solutions under various conditions. We have equally established that the adsorption process chemistry of chromium, arsenic and manganese from aqueous solution using the synthesized nanoparticles was pH, Ionic strength and temperature dependent (Adegoke, 2012).

The second aspect was directed at understanding the potentials of nanoparticles material hybridized with macromaterials such as bamboo, activated carbon, fly ash and silica for the remediation of toxic trace metals (arsenic, chromium and manganese) (Adegoke, 2012) and organotin compounds (Ayanda, et al., 2012) in aquatic systems. Our results have also revealed that the composition of the activated carbon and nanometal oxides increased the surface and micropore areas of nano metal oxides due to the large number of micropores and crevices on the surface of the hybrid materials (Fatoki et al., 2012).

The overall results of our research have shown that the synthesized nano-structured iron oxide/hydroxides and their hybrids are very effective for the removal of As(V), Cr(VI), Mn (II) and organotin compounds from aqueous solutions. These materials therefore offer great potential for environmental technological applications in industries.

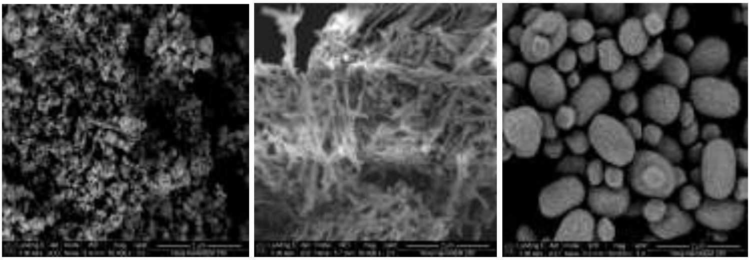

Fig 3: SEM of (a) Magnetite, (b) Goethite and (c) Hematite nanoparticles

Mr Vice-Chancellor sir, before establishing a nanomaterial chemistry group in the Department of Chemistry of University of Ilorin, I had earlier received training and participated in a European Union-sponsored research project in 2005/2006 academic session in France. The project involved six leading laboratories in nanomaterial engineering research across Europe (Paris, Germany, Sweden, Spain, UK and Hungary). I was purposely invited in 2005 by Prof. Michel Fedoroff who incidentally was my postdoctoral research supervisor in 1994 (the co-group leader with Prof. Joannes Lutzenkirchen of Karlsruhe Institute of Technology, Karlsruhe, Germany), to his laboratory in France. The project was directed at finding answers to some fundamental and controversial scientific concepts in colloid and interface chemistry which are important for optimizing the conditions for the storage of radioactive contaminants in the underground storage systems. The physico-chemical characteristics of mineral surfaces are of great importance in environmental systems. Transport of toxic and radioactive species in surface and sub-surface water is, to a large extent, governed by adsorption and desorption processes on mobile and immobile solid phases. Accurate sorption data and modeling are crucial for predicting migration in natural aquatic systems.

Due to a number of contradictions in the results reported in the literatures on the acido-basic characteristics of mineral surfaces that are commonly utilized for constructing engineered landfilled systems for the storage of radioactive materials and the attendant fear in the failure, European Union had to commission an interlaboratory research project to unravel all the questions surrounding these contradictions which could lead to system failure. Two different gibbsites; one commercial and one synthetic were studied in different laboratories; an attempt to gain insight into the origin of widely contradictory reports on gibbsite acid–base surface properties. In addition to a thorough characterization of the two solids, several methods relevant to the interfacial charging were applied to the two samples: potentiometric titrations to obtain the ‘‘apparent” proton related surface charge density, zeta-potential measurements characterizing the potential at the plane of shear, and Attenuated Total Reflection Infrared Spectroscopy (ATR-IR) to obtain information on the variation of counter-ion adsorption with pH (using nitrate as a probe).

Applying multiple procedures in different laboratories demonstrates that the differences between these samples are not connected to experimental errors but rather linked to the nature of the solids (Adekola et al., 2011). In another related study, we have provided detailed explanation on the influence of kinetics on the determination of surface reactivity of colloidal suspensions of hematite, alumina, goethite and silica nanoparticles by acide-base titration (Duc et al., 2006). It is important to note that within the last 10 years, governments around the world had spent about $70bn in nanotechnology research (Scientifica Ltd 2011). Therefore, the immense potential impact of nanotechnology on both the economy and on the quality of life means that research activities in this area will continue to grow.

Hydrometallurgical Processing of Solid Minerals

Mr Vice Chancellor, sir, what follows constitute the third major aspect of my research, which is hydrometallurgical processing of solid minerals. Hydrometallurgy is an analytical chemistry approach for obtaining valuable metals from their ores. It is a technique which requires the use of aqueous chemistry for the recovery of metals from ores, concentrates, and waste or spent materials. Hydrometallurgy process consists of leaching, solvent extraction of the metals of interest in a selective manner, stripping of the metals from the organic extractants and metal recovery in a marketable form. Solvent extraction has found extensive application in mineral processing. The organo-thiophosphorus ligands have attracted great attention by many researchers in hydrometallurgy (Cote and Bauer, 1986; Sole and Hiskey, 1992). The stripping of metals previously extracted into an organic phase is an important step in industrial applications. It enables the recovery of extracted metals on one hand and regeneration or recycling of the extractant for subsequent use on the other hand. This is necessary from the point of view of economics and also to ensure minimal wastes disposal.

As part of my contribution in this area, we have developed a practical solution for the stripping of copper from CYANEX 301 extractant using an aqueous solution composed of thiourea, hydrazine and sodium hydroxide. We have also established operational conditions for the efficient reuse of the extractant, CYANEX 301, after stripping of copper (Facon et al., 2007). This procedure is now being solicited by many hydrometallurgical plants engaged in copper ores processing.

On the beneficiation of gold ore deposit in Atakumosa local government area of Osun state, we have been able to establish hydrometallurgical conditions based on cyanidation process for the extraction of gold from the gold ore deposit. The maximum yield of gold recovered was 33 mg per 100 g of gold ore and the purity of the extracted gold was 96 % or 23 carat (Mesubi et al., 1999). This is much safer than the dry milling operation being practiced by the illegal miners of gold ore in many villages in northern Zamfara State of Nigeria which has claimed more than 400 deaths and most of them children. This is considered to be the worst lead poisoning epidemic in modern history (WHO, 2011).

Recovery of zinc, lead and sulphur from sphalerite, galena and waste materials

Sphalerite (ZnS), which associates mainly with other metal sulphide minerals, such as chalcopyrite ($CuFeS_2$), galena (PbS) and pyrite (FeS_2) in nature which serve as the principal source from which zinc is produced commercially. In mineral processing engineering, they are collected in separate concentrates through selective conventional froth flotation applied to separate each other. Sphalerite concentrates usually contain more than 50% zinc (Chen and Dutrizac, 2004).

Galena, the chief ore of lead and one of the most widely distributed of the metallic sulphides, occurs in both igneous and sedimentary rocks. It is commonly associated with other sulphide minerals such as sphalerite (ZnS), pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and arsenopyrite (FeA_SS) (Deer et al., 1999). Generally, lead-zinc deposit occurs in Nigeria along the North-South East belt, cutting through the eastern flank of the country, and extending through the Benue Trough (MMSD, 2010). The principal consumption of lead is for lead-acid batteries which are used in vehicles, and in emergency systems (e.g. hospitals) as well as in industrial batteries found in computers and forklift trucks. Lead is also used in remote access power systems and loading levelling systems as well as in compounds in the glass and plastics industries and for radiation (Hall and Heyl, 1968). Zinc is mainly consumed by the galvanizing of steel which accounts for half of the western world consumption of zinc.

As part of my contribution in this area, we have focussed our research on the beneficiation and recovery of zinc and lead from sphalerite, galena, spent dry cell batteries and automobile tyres using a combination of leaching, solvent extraction, cementation and stripping techniques. The effects of temperature, particle size, stirring speed, solid-liquid ratio and leachant concentration on the kinetics of dissolution of sphalerite, galena and the waste materials have been established (Baba and Adekola, 2010). The leachants used in the study include hydrochloric acid, ferric chloride and hydrogen peroxide, while the solvent extractions of zinc and lead in Hydrochloric acid medium were carried out using organophosphorus extractants.

Solvent extraction of synthetic solutions of Zinc and Lead showed that the extraction of metal ions increased with increasing pH, extractant concentration, salting out agent and temperature. The stripping of metal ions from the extractable species in the organic phase was successfully carried out by 0.1M HCl. Of all the extractants investigated, Cyanex 272 stood out as the extractant of choice for the extraction of zinc (Baba and Adekola, 2011).

Our studies led to the recovery of 95% Zinc and 92% Lead from 10g/L leach liquor of Abakaliki (Nigeria) Sphalerite and Galena Minerals within 30 minutes. Iron which constituted the principal impurity was effectively removed by precipitation prior to extraction using ammoniacal solution at pH 3.5, while lead and other trace elements were quantitatively separated from zinc by cementation process prior to Iron removal and Zinc extraction. The hydrometallurgical conditions established for the minerals have been found suitable for the recovery of Zinc from Spent dry cell batteries ash and automobile tyres (Baba et al., 2009). The concentrations of sulphur recovered from Abakaliki sphalerite and galena ores were

17% and 21% respectively. Sulphur is an important raw material in pharmaceutical industries.

Conclusions and Recommendations

Obviously, we can see from this lecture that Analytical Chemistry is indeed the toolbox embedded in the heart of science for delivering practical solutions that improve the quality of life of people and their environment. There are still many challenges ahead and our capabilities will continue to improve through research and identification of emerging problems that need to be solved.
Mr Vice-Chancellor, sir, please kindly permit me to make the following recommendations as it is customary in a public lecture of this nature.

1. The analytical chemistry being a laboratory-oriented discipline, hands-on experience is critical to producing graduates that are readily employable. Modern analytical chemistry facilities should be provided for the training of students in science-based disciplines. It is rather sad to note that most universities in Nigeria today do not run laboratory in electrochemistry and electro-analytical chemistry due to lack of facilities. This is rather unfortunate as it is an area that is critical to research and development in the areas of renewable energy, drug delivery, biosensors, etc.

2. All universities should be provided with adequate fund for research, teaching and training of postgraduate students. Presently, most registered PhD and Masters Students are allowed to fend for themselves. This does not augur well for productive

research as some of these postgraduate candidates would not put their mind fully into research. I want to recommend that each university should have a postgraduate fellowship scheme in order to attract brilliant postgraduate students.

3. There is the need for paradigm shift in the way we handle research in Nigeria. We need to see research as a precursor for development. In order to get good output in research, the inputs must be outstanding. It is important to note that good research practice requires adequate funding and access to state of the art facilities; qualitative supervision and training of both undergraduate and postgraduate students; openness including interaction with industries and timely dissemination of results; excellent health, safety and environment (HSE) best practice in research laboratories; high quality outputs and good publication in high impact factor journals that enjoy patronage from researchers in leading laboratories worldwide.
4. Governments at all levels (Federal, State and Local) should, as a matter of strategic concern, pay a special attention to the safeguard of freshwater resources (surface and underground) in Nigeria. The relevant agencies of government including National Environmental Standards and Regulations Enforcement Agency (NESREA) and National Water Research Institute (NWRI) should be mandated to engage in regular monitoring of endocrine disrupting compounds and other

persistent organic pollutants in both fresh and marine water bodies/ catchments of Nigeria.

5. Key Research laboratories should be established by the Federal Government of Nigeria in each geopolitical zone where advanced and state of the art equipment would be available for the use of scientists in the area of cutting edge research. The positive impact of the establishment of key research laboratories on the economy and quality of research in countries such as China, South Africa, India and Pakistan is evident for all and sundry.

6. Government would need to be proactive in the development of solid mineral sector. This will, no doubt, save the significant proportion of the country's hard-earned foreign currencies on importation of refined metals and their products. Relevant government agencies, professional bodies and non-governmental organizations should be encouraged to enlighten people on the alternative safer process of mining.

7. The Federal Government of Nigeria should grant procurement waiver to our universities and research institutes for timely, quality and cost-effective procurement of research facilities. Researchers should be able to order for their research needs directly from the manufacturers, on-line, right from their laboratories/offices without passing through the bureaucratic bottleneck of government.

8. It is also important that the government, through the National Universities Commission (NUC)/Federal Ministry of Education, should, as a national policy, institute a rewarding process for motivating productive researchers/academics who are able to publish in NUC accreditedtop international research journals in various disciplines as well as those who are able to supervise successfully master and doctoral candidates.

Mr Vice-Chancellor sir, please permit me to share these words of wisdom from Nelson Mandela with the audience. *"Education is the great engine of personal development. It is through education that the daughter of a peasant can become a doctor, that the son of a mine worker can become the head of the mine, that the child of a farm worker can become the president of a great nation."* (Nelson Mandela). I will therefore like to add “that the son of a farmer (whom I am) can become a Professor of Chemistry”, *Alhamdulillah*. I will like to end this lecture with this verse from the Glorious Qur’an: “*High above all is Allah, the King, and the Truth. Do not be in haste with the Qur'an before its revelation to you is completed, but say, "O my Sustainer! Increase my knowledge [20:114]."*

Acknowledgements

All praises and adoration belong to Allah for sparing my life to attain the position of Professor. I thank the University of Ilorin for entrusting me with this professorial chair.

I thank my late Father, Pa Sunmonu Amoo Adekola for his prayer, love and wisdom. I am highly indebted to my dear Mother, Late Mrs Ajeigbe Awero Adekola (née Sangorin) who sacrificed everything she had inorder to ensure that I had good education. Mama, Allah who knows best will reward you bountifully. I thank the Olori-ebi of Adekola Family of Isale-Alfa, Ibadan, my senior brother and mentor, Elder Thomas Oladosu Adekola and his wife, Deaconess Funmilayo Adekola for your love, guidance, prayers and support in the pursuit of my career. I thank my In-Laws, Mr Mojeed Babalola and Late Mrs Morili Babalola for your parental care, prayer, support and guidance. Unfortunately, my mother in-law passed on in 2010, just a year before I was pronounced full Professor. I also thank other family members, Mr Yekeen Adewuyi, Late Mrs Teniola Raji, the Adekolas and the Babalolas.

I wish to acknowledge the role of my mentors, Professor A.M. Salau (former VC, LAUTECH, Ogbomoso), Professor O.A. Afolabi (former Head of Service of the Federation), Prof. R.A. Raji (former Chief Imam, Unilorin) and Prof. S.A. Adediran (USA) for their guidance and mentorship. I appreciate Sheikhs Jibreel Sha'ban and Uthman Erubu, Prof. A.G.A.S. Oladosu (Chief Imam, Unilorin) and his wife and Prof. Segun Odunola and his wife for your prayers and support. I thank Prof. Y.A. Quadri for his advice and editorial assistance.

I want to appreciate all my teachers from primary school to the university. I wish to single out the following: Profs. J.A. Odutola, C. A. Obafemi, Jide Ige, C.O. Fakunle, I.A. Ojo, J.F. Ojo and I.A. Asubiojo. I thank Professors Denise Bauer (my PhD supervisor), Claude Poitrenaud, Gerard Cote and Michel Fedoroff of ENSCP/ Pierre & Marie Curie University, Paris, France.

I acknowledge all my research collaborators and students both at the University of Ilorin and Cape Peninsula University of Technology, South Africa. I wish to single out the following: Prof. O.S. Fatoki and Dr B.J. Ximba of CPUT. I thank all Professors (serving & retired), Academic, Technical and Non-academic staff and students of Department of Chemistry, University of Ilorin, Colleagues and friends in Chemistry Department of LAUTECH, Ogbomoso and Obafemi Awolowo University, Ile-Ife. I appreciate the support of all staff of Faculty of Science, General Studies Division and Academic Support Services of University of Ilorin, Ilorin.

I thank all my present and past students and in particular, my former Ph.D students (Drs N. Abdus-Salam, O.A. Eletta, G.B. Adebayo, O.M. Olabemiwo, Alafara A. Baba, A.M.O. Abdul Raheem, H.I. Adegoke, H.K. Okoro, and O.S. Ayanda), some of them are present here.

I thank all members of UNIFEMGA, COMPANION, Club 82 Prime of Ibadan, IPAN, CSN Kwara Chapter, Muhydeen Association of Nigeria, Old students of Islamic High School Ibadan and Igbo-Owu Tanke Landlords and Residents Association. I thank all our family friends from Ile-Ife, Ibadan and Lagos.

Last but not the least, I want to specially thank my darling wife, *Cherie*, Dr (Mrs) Fatimo Olabisi Adekola for

her understanding, fasting, prayers and kind words at all times. I thank Allah for your life. You are indeed a rare gift from Allah. I also thank Allah for blessing us with wonderful children; Ibrahim, Khadijat, Kamaldeen, Mariam, Abdullahi and AbdulRahman.

I thank you all for your attention and may the God Almighty bless you all.

References

Abbott A., Abel P.D., Arnold D.W. and Milne A (2000) Cost benefits analysis of the use of TBT: The case for a treatment approach, *Science of the Total Environment*, 258, 5-19.

Abdul Raheem A.M.O., **Adekola F.A.** and Obioh I.B. (2009) The Seasonal Variation of the Concentrations of Ozone, Sulfur Dioxide, and Nitrogen Oxides in Two Nigerian Cities, *Environmental Modelling and Assessment*, 14, 497-509.

Abdus-Salam N. and **Adekola F.A.** (2005) The influence of pH and Adsorbent concentration on adsorption of lead and zinc on a natural goethite, *African Journal of Science and Technology (Science and Engineering Series)* 6(2), 55-66.

Adebayo G.B., **Adekola F.A.** and Olatunji G.A. (2007) Chromatographic separation and spectro-analytical characterization of a natural African mineral dye, *Bulletin of Chemical Society of Ethiopia*, 21(2), 159-170.

Adebayo G.B., Sunmonu T.O., **Adekola F.A.** and Olatunji G.A. (2005) Effect of white African mineral hair dye on the activities of phosphatases and malondialdehyde level in tissues of albino rats, *Toxicological and Environmental Chemistry,* 87(3), 399- 406.

Adegoke, H.I. (2012) Sorption Characteristics and Mechanisms of Arsenic (V), Chromium (VI) and Manganese (II) on Nano-structured Hematite, Goethite and Magnetite, *Ph.D Thesis*, Dept. of Chemistry, University of Ilorin (361pp)

Adegoke H.I. and **Adekola F.A.** (2005) Activated carbons produced from shear butter wood and bark as adsorbent for blue dye from aqueous solution, *Science Focus*, 10(2), 90-95.

Adegoke H.I. and **Adekola F.A.** (2010) Removal of Phenol from Aqueous Solution by Activated Carbon Prepared from Some Agricultural Materials *Advances in Natural and Applied Sciences*, 4(3): 293-298.

Adegoke H.I. and **Adekola F.A.** (2011) Adsorption of lead(II) ion from aqueous solution using activated carbon prepared from coconut coirpith, *Journal of Chemical Society of Nigeria*, 36(2)134-138.

Adegoke H.I. and **Adekola F.A.** (2012) Equilibrium sorption of hexavalent chromium from aqueous solution using synthetic hematite, *Colloid Journal of the Russian Academy of Sciences*, 74(4), 441-447.

Adekola, F.A. (1993) Etude du comportement électrochimique des composés du platine, du palladium et du rhodium par l'électrode à pâte de carbone. Application à la caractérisation des catalyseurs de post-combustion automobile, *Ph.D Chemistry Thesis*, Pierre & Marie Curie University, Paris, France (119pp). Available online: https://fondsdoc.espci.fr/alexandrie-7/dyn/portal/index.seam/adekola

Adekola F.A., Abdus-Salam N., Bale R.B. and Oladeji I.O. (2010) Sequential extraction of trace metals and particle size distribution studies of Kainji Lake Sediment, Nigeria, *Chemical Speciation and Bioavailability*, 22(1), 43-49.

Adekola F.A. and Adegoke H.I. (2005) Adsorption of blue dye on activated carbon produced from rice husk, coconut shell and coconut coirpit, *Ife Journal of Science,* 7(1), 151-157.

Adekola F.A. and Afolayan O.B. (2000) Assessment of levels of some heavy metals in the bark of street trees in Ilorin City, Nigeria, *Bioscience Research Communication* 12(2), 133-137.

Adekola F.A., Baba A.A., Bale R.B., Abdus-Salam N., Eletta O.A.A. and Olayide F.T. (2009) Lixiviation of Manganiferrous aluminosilicate mineral (MASM) in hydrochloric acid. *African Journal of Pure and Applied Chemistry*, 3(10), 183-188.

Adekola, F.A., Bale, R.B., Abdus-Salam, N., Eletta O.A.A., Olaniyan, J.O. and. Baba, A.A.(2008) Manganese pollution of the University of Ilorin Dam Water: Source Identification and Geochemistry, A Report submitted to Senate Research Grant Committee, University of Ilorin, Nigeria. 50pp.

Adekola F. A., Colin C. and Bauer D., (1993) Electrochemical studies of some rhodium compounds at a carbon paste electrode with electrolytic binder, *Electrochimica Acta,* 38, 1331-1335.

Adekola F.A and Oloruntoba K., (2000) Seasonal variation and the heavy metals distribution in the roadside soils and vegetation in Ilorin City and its environs, Nigeria, *Bioscience Research Communication* 12(2), 111-118.

Adekola F.A., Colin C. and Bauer D.(1992a) A study of electrochemical behaviour of some platinum compounds at a carbon paste electrode with electrolytic binder, *Electrochimica Acta,* 37, 507-512.

Adekola F.A, Colin C. and Bauer D. (1992b) Electrochemical Study of some automotive catalysts at a carbon paste electrode with electrolytic binder, *Electrochimica Acta,* 37, 2009-2014.

Adekola F.A., Diaw M., Colin C. and Bauer D. (1992c) Electrochemical behaviour of some palladium compounds at a carbon paste electrode: Application to the determination of palladium in oxidation automotive catalyst, *Electrochimica Acta,* 37, 2491-2495.

Adekola F.A. and Dosumu O.O. (2003) Determination of heavy metals in household dusts in Ilorin city, Nigeria, *Nig. J. Pure & Appl. Sci.,* 18, 1413-1417.

Adekola F.A, Dosumu O.O and Olaleye G.A. (2004) Comparative study of the age and location dependence of some heavy metals in human hair from two Nigerian cities, *Toxicological and Environmental Chemistry*, 86(4), 191-196.

Adekola F.A, Fédoroff M., Geckeis H., Kupcik T., Lefèvre G., Lützenkirchen J., Plaschke M., Preocanin T., Rabung T. and Schild D. (2011) Characterization of acid-base properties of two gibbsite samples in the context of literature results, *J. Colloid and Interface Science* , 354, 306-317.

Adekola F.A. Eletta O.A. and Atanda S.A. (2002) Determination of the level of some heavy metals in urban run-off sediments in Ilorin and Lagos, Nigeria, *J. Appl. Sci. Environ. Mgt,* 6(2), 23-26.

Adekola F.A., Eletta O.A.A and Atanda S.A. (2001) Some heavy metals concentration in rain water run-offs on paved roads in Lagos and Ilorin cities, *Academy Journal of Science and Engineering*, 1(1), 88-94.

Adekola F.A. and Eletta O.A.A. (2007) A Study of Heavy Metal Pollution of Asa River, Ilorin, Nigeria: Trace Metal Monitoring and Geochemistry, *Environmental Monitoring and Assessment,* 125, 157-163.

Adekola F.A., Fedoroff M., Ayrault S., Loss-Neskovic C., Garnier E. and Yu L.T. (1997) Interaction of silver ions in solution with copper hexacyanoferrate (II), *J. Solid State Chem.* 132, 399-406.

Adekola F.A., Mesubi M.A. and Abdulsalam A. (2002) Fixation of Mercury on some mixed insoluble Solid Hexacyanoferrate (II) compounds, *J. Chem. Soc. Nigeria,* 27(1), 99-104.

Adekola F.A., Nwaogu N.G. and Abdus-Salam N. (2007) Removal of cadmium from aqueous solution using manganese hexacyanoferrates (II)/(III), *Bulletin of Chemical Society of Ethiopia*, 21(2), 221-228.

Adekola F.A. and Saidu M.M. (2005) Determination of pollution level of water and sediment samples of Landzu River, Bida, Nigeria, *Journal of Chemical Society of Nigeria,* 30(2), 181-186.

Adekola F.A., Salami N. and Lawal K.A.(2002) Assessment of the Bioaccumulation capacity of scots pine (*Pinus Sylvestris L.*) for Zinc, cadmium and sulphur in Ilorin and Ibadan cities (Nigeria) *Nig. J. Pure & Appl. Sci.,* 17, 1297-1301.

Adekola F.A, Salami N. and Lawal S.O. (2003) Some trace elements determination in surface water and

sediments of Oyun river, Kwara State, *Nig. J. Pure & Applied Sciences,* 18, 1418-1422.
Alo, B.I. From the Enigmatic to the metaphoric: Transactions with Heterocycles and Environment, 4th Inaugural Lecture (2002/03 Session)delivered on 25th June 2003 at University of Lagos, Lagos.
Ayanda O.S., Fatoki O.S., **Adekola F.A.**, Ximba B.J. (2012) Activated Carbon – Fly ash – nano Metal Oxide Composite Materials: Preparation, Characterization and Tributyltin Removal Efficiency, *Journal of Chemistry* (in press)
Baba A.A. and **Adekola F.A.** (2011) Beneficiation of a Nigerian Sphalerite Mineral: Solvent extraction of zinc by Cyanex 272 in hydrochloric acid, *Hydrometallurgy*, 109, 187-193.
Baba A.A., **Adekola F.A.** and Bale R.B. (2009) Development of a combined pyro- and hydro-metallurgical route to treat spent Zinc-Carbon batteries, *Journal of Hazardous Materials,* 171(1-3), 838-844.
Baba A.A and **Adekola F.A.** (2010) Hydrometallurgical Processing of a Nigerian Sphalerite in hydrochloric acid: Characterization and dissolution kinetics, *Hydrometallurgy*, 101, 69-75.
Baker E W and Louda J W. (1986) Porphyrins in the geological record. In: Johns R K Ed. *In Biological markers in the sedimentary record*, 125, Amsterdam, Elsevier.
Chen, J. Dutrizac, J.E. (2004) Mineralogical changes occurring during the fluid-bed roasting of zinc sulphide concentrates. *J. of Mining*, 56, 46-51.

Cote, G., Bauer, D. (1986) Extraction of non-ferrous metals by thiophosphorus extractants. *Chemistry and Industry (London)*, 22, 780–784.

Danzer K. (2006) Analytical Chemistry-Theoretical and Metrological Fundamentals, Springer-Verlag, Berlin, Germany (309pp).

Deer,W.A. and Howie, R.A. and J. Zussman (1999) An introduction to the Rock-forming minerals. 2nd ed., Longman, England: 603-605, 676-677.

Duc M., **Adekola F.A**, Lefevre G. and Fedoroff M. (2006) Influence of kinetics on the determination of the surface reactivity of oxide suspensions by acid-base titration, *Journal of Colloid and Interface Science,* 303, 49-55.

Eletta O.A., **Adekola F.A.** and Omotoso J. (2003) Determination of concentration of heavy metals in two common fish species from Asa river, Ilorin, Nigeria, *Toxicological and Environmental Chemistry,* 85(1-3), 7-12.

Eletta O.A.A. and **Adekola F.A** (2005) Studies of physical and chemical properties of Asariver water, Kwara State, Nigeria, *Science Focus,* 10(1), 72-76.

Facon S., **Adekola F.A** and Cote G. (2007) Stripping of copper from bis(2,4,4-trimethylpentyl) phosphinodithioic acid extract with thiourea-hydrazine-sodium hydroxide solution mixture, *Hydrometallurgy*, 89, 297-304.

Fatoki O.S., Ayanda O S., **Adekola F.A.**, Ximba B.J. and Opeolu B.O. (2012) Preparation and Characterization of Activated Carbon-nFe3O4, Activated carbon-nSiO2 and Activated CarbonnZnO Hybrid Materials, *Particle and Particle Systems Characterization*, 29, 1-14.

Fatoki O.S., Okoro H.K., **Adekola F.A.**, Ximba B.J. and Snyman R.G. (2012) Bioaccumulation of metals in black mussels (Mytilusgalloprovincialis) in Cape town Harbours, South Africa. *The Environmentalist*, 32, 48-57.

Fedoroff M., Loos-Neskovic C., Abousahl S.,**Adekola F.**, Rouchaud J.C., Boisseau N., Garnier E., Jackwerth E., Dierkes M., Rostek U. and Kaeschagen M.(1990) Summary Reports of the R & D Programme on the Recycling of Non-ferrous Metals Projects (1986-89). Commission of the European Communities, Edited by M. Donato. P. 145-169.

Hall, W.E. and Heyl, A.V. (1968) Distribution of minor elements in ore and host rocks, Illinois-Kentucky Fluorite district and Upper Mississipi Valley Zinc-lead district. *Econ. Geol.* 63(6), 655-670.

Harvey D. (2000) Modern Analytical Chemistry, McGraw Hill, Boston, USA (798pp).

James O.O., Mesubi M.A., **Adekola F.A.**, Odebunmi E.O., Adekeye J.I.D and Bale R.B. (2008) Bleaching performance of a Nigerian (Yola) Bentonite, *Latin American Applied Research*, 38(1), 45-50.

Malissa H. (1995) Philosophical definition of Analytical chemistry. Paper presented at the Symposium on Philosophy and Education in Analytical Chemistry, WPAC, Vienna.

McGraw Hill (1976) Encylopedia of Sc. and Tech, 19(7), 655-669, 620-628.

Meshko V., Markovska L., Minchev M. and Rodrigues A.E. (2001). Adsorption of basic dyes on granular activated carbon and natural zeolite, *Water Research*, 35(14), 3357.

Mesubi M.A., **Adekola F.A.**, Bello A.A., Adekeye J.I.D and Bale R.B.(1999) Extraction of gold from Igun gold ore deposit in Atakumosa Local Government Area, Osun State, Nigeria, *Nig. J. of Pure & Applied Sci.* 14, 935-945.

MMSD (2010) Lead-Zinc Exploration Opportunities in Nigeria, Ministry of Mines and Steel Development, Abuja, Nigeria (13pp).

Odubela, M.T. , Soyombo O., Adegbite, F. and Ogungbuyi, K,(1996) Transboundary Illegal Shipments of Hazardous Waste, Toxic Chemicals contraband chlorofluorohydrocarbons: The Nigerian Experience, 4th International Conference on Environmental Compliance and Enforcement, 21 April-26 April, 1996

Odutola J.A. and **Adekola F.A.**, (1987) Computation of character tables for the permutation group of weakly bound polymer molecules. *Mol. Phys.*, 60, 1395-1413.

Okoro H.K., Fatoki O.S., **Adekola F.A.**, Ximba B.J. and Snyman R.G. (2011a) Sources, Environmental levels and Toxicity of Organotin in Marine Environment – A Review. *Asian J. of Chem.*, 23(2), 473-482.

Okoro H.K., Fatoki O.S., **Adekola F.A.**, Ximba B.J., Snyman R.G. and Opeolu B. (2011b) Human Exposure, Biomarkers and Fate of Organotin in the

Environment. *Reviews of Environmental Contamination and Toxicology (RECT)*, 213, 27-54.

Olabemiwo O.M., Adediran G.O., **Adekola F.A.** and Olajire A.A. (2010) Aliphatic and Polycyclic aromatic hydrocarbons profiles of photomodified natural bitumen of Agbabu, Southwestern Nigeria, *Bulletin Chemical Society of Ethiopia*, 24(3), 461-466.

Olabemiwo O.M., Adediran G.O., **Adekola F.A.**, Olajire A.A. and Adedeji O.S. (2011) Impacts of simulated Agbabu bitumen leachate on haematological and biochemical parameters of Wistar Albino Rats, *Research Journal of Environmental Toxicology,* 5(3), 213-221.

Olajire A.A., Ameen A.B., Abdul-Hammed M. and **Adekola F.A.** (2007) Occurrence and Distribution of metals and porphyrins in Nigerian coal minerals, *J. of Fuel Chem. and Technol.*, 35(6), 641-647.

Perkins, H.C.(1974) Air Pollution, McGraw Hill Inc., Tokyo, Japan. p.3.

Salami N. and **Adekola F.A.** (2002) A Study of Sorption of Cadmium by Goethite in Aqueous solution, *Bull. Chem. Soc. Ethiop.*, 16(1), 1-7.

Skoog, D.A., West, D.M., Holler, F.J. and Crouch S.R.(2005) Fundamentals of Analytical Chemistry, 8th Edition, Brooks and Cole, New Delhi, India.

Sole, K.C. and Hiskey, J.B. (1992).Solvent extraction characteristics of thiosubstituted organophosphinic acid extractants. *Hydrometallurgy*, 30, 345–365.

UNEP (2006) The state of the Marine Environment – Regional Assessments (Part 1) Eds (C. Gordon & C. Ibe), The Hague 50pp.

UN-HABITAT (2013) Water and Sanitation for cities. The 19th session of the Governing Council, www.unhabitat.org . Retrieved on 21st March, 2013.

UN-WATER (2013) Statistics on world water resources. www.unwater.org/statistics. Retrieved on 21st March, 2013.

United Nations (1997) Comprehensive Assessment of the Freshwater Resources of the World. Commission on Sustainable Development, United Nations, New York, 1997

World Commission for Environment and Development WCED (1987) 'Our Common Future' (Oxford: Oxford University Press)

World Health Organisation (WHO) (2011) Nigeria: mass lead poisoning from mining *www.who.int/csr/don/2011_11_11/en/index.html/*. Retrieved on 12th November, 2012.