UNIVERSITY OF PORT HARCOURT

CHEMISTRY AND HEAVY METALS ARE JANUS-FACED

An Inaugural Lecture

by

PROFESSOR MICHAEL HORSFALL Jnr
BSc, MSc, PhD (UPH)
Department of Pure & Industrial Chemistry, Faculty of Science
University of Port Harcourt, Port Harcourt, Nigeria

INAUGURAL LECTURE SERIES

NO. 81

NOVEMBER 10TH, 2011

DEDICATION

This inaugural Lecture is dedicated

to the

Blessed Memory

of my late Parents

Pastor Michael Horsfall

and

Mrs. Norah Horsfall

ACKNOWLEDGEMENT

Before I start this lecture, I wish to appreciate the Almighty God for this moment in my life. Thank you, my Heavenly Father, Thank you, my Lord Jesus, Thank you, my dear Holy Ghost for all that you have done and continue to do in my life.

I would like to express my gratitude to a number of people. My journey started with my parents, especially my mother who has never sat in a classroom but has a strong faith and desire for school. I would like my late parents; Pastor and Mrs. Michael Horsfall to share this moment of joy with me in the full knowledge that they have been part of this from the beginning, I say from the bottom of my heart, thank you.

I would like to thank my senior brother Mr Ibinabo Michael Horsfall, who has not only been an inspiration to me from a very young age, but has supported me in ways I cannot enumerate; Mine-Bro, thanks a million.

I would like to express my gratitude to my family members, friends, colleagues and associates, some of whom are Mr Peaceman Batubo, Hon. Abiye M. Horsfall, Hon. E. O. Dakoru, Mr. Somieari D. Wokoma, Dr. Leo Osuji, Dr. P. Jackreece, Dr. D. Wankasi, Dr. O. Abiola, Dr. T. Tarawou, Prof. T. Akphorhonor, Dr. I. C. Howard, Mr Fatai Aborode, Dr. B. S. Kinigoma, Mr. I. Princewill, Dr (Mrs). K. Orubite, Dr. M. Iwegbue, Dr. Eva Krupp, Mr. Ken Omaye, Late Mr & Mrs A. J. Jenewari, Rev. B. P. Adowei, and a host of others

Pere, *mon cherie*, I say thank you. Otis, Doris, Evita, Laveta, Oscar, David and Elvin, I love you all.

There are many people who have influenced my life as a chemist, too many to list here; they are my lecturers. Some of them are Prof. Oladele Osibanjo, Prof. A. C. I. Anusiem and Prof. (Mrs) P. Manilla (my BSc project supervisors), Prof. C. M. Ojinnaka (my MSc project supervisor), Prof. Ayebaemi I. Spiff and late Dr. Fred E. Ogban (my PhD project supervisors), Prof. A. A. Abia and late Dr. Ph Dah (my advisers) and Prof Bene Willey-Abbey (my encourager). I cannot think of a better way to show them honour and respect than to say thank you.

Nobody comes this far without the hard work of graduate students, who, in spite of limited facilities, have made excellent contributions to my research. To those of you here and those who couldn't be here, I thank you.

Finally, I wish to acknowledge my numerous collaborators both home and abroad. In no chronological order at the international arena are Prof. (Dr.) J. D. Lee and Dr. Tony Edmonds, Loughborough University, UK, Prof. (Dr.) Jose Vicente, University of La Plata, Argentina, Prof. Jorg Feldman, University of Aberdeen, Scotland; Dr. Mohammad Courti, University of Zimbabwe, Harare, The Third World Academy of Sciences (TWAS) Italy; National Research Council (CONICET) of Argentina; UNESCO office, Kenya, Royal Society of Chemistry, UK, Organization of Prohibition of Chemical Weapons (OPWC) The Hague, Trace Element Speciation Laboratory (TESLA) Research Group members.

In the national arena are the University of Port Harcourt, the World Bank Office at NUC – Abuja, Nigeria; National Agricultural Research Project (NARP) Team led by Prof. F. D. Sikoki, the River State Government, Fugro Nigeria Ltd headed by Dr. G. C. Ofunne, and finally Prof. (Barr.) Bio. L.

Nyananyo who despite the wide difference in academic experience accepted to be my orator. I was humbled; I say thank you sir.

I wish to end this acknowledgement by giving a special thanks to the former Director of the Institute of Petroleum Studies (IPS), Prof. A. J. Ajienka (now Vice Chancellor) for encouraging and supporting the Journal of Applied Sciences and Environmental Management (JASEM), while he was at IPS.

CHEMISTRY AND HEAVY METALS ARE JANUS-FACED

Vice-Chancellor,

Member(s) of the University Council present,

Deputy Vice-Chancellors,

Registrar and other Principal Officers,

Provost, College of Health Sciences,

Dean, School of Graduate Studies,

Deans of Faculties,

Heads of Administrative and Academic Departments,

Other University Colleagues,

Distinguished guests,

Students,

Friends,

Members of my family and relatives,

Ladies and Gentlemen

PREAMBLE

Dear Vice-Chancellor, at the very onset, let me thank God Almighty for sustaining me all these years to present this professorial lecture. Without God's love, I would not have become eligible to stand here today.

I wish to thank the incubent Vice Chancellor for this honour and opportunity of presenting my inaugural lecture.

I also wish to express a special gratitude to my Big Mummy, Professor (Mrs.) Ayebaemi Ibuteme Spiff who consistently encouraged me to deliver an inaugural lecture as soon as my Professorial assessments are concluded.

Immediately the Professorial assessments were over, I searched various sources to find what a Professorial Inaugural lecture is supposed to be. In the process I came across a lot of very enlightening information, but the one I liked most is from the website of University of Edinburgh. I have quoted it here to show you what has guided me in preparing this lecture:

"The Inaugural Lecture is an opportunity for ***newly****-promoted or appointed Professors to inform colleagues in the University and the general public, about their research career so far; and update colleagues on their current and future research directions. The lecture is intended to emphasize both the significance of research and its implications for the discipline. Moreover, the inaugural lecture is a public event and should be designed both in its title and its scope to be accessible to interested members of the public".*

With this in mind, I spent several days imagining of what I thought would be an appropriate title for this lecture. Then, I remembered my early contact with chemistry in Class 3 of my secondary school days.

The first Chemistry teacher told us that "Chemistry is corrosive, so beware of chemists"; a second chemistry teacher later said to us "A world without chemistry would be a world without cinema, a world without aspirin or soap, or paper; if you want to understand chemistry, you must first love chemistry". At this point several things went through my mind, the rest is history but I said to myself this is double standard.

Another incident was during my PhD research work; which was titled "*Heavy Metal Pollution: the impact of industrial activities on the baseline levels in the New Calabar River, Nigeria*".

In the process of that research, I came to know that "in small amount, heavy metals are essential to maintain the metabolism of the human body"; however, "at higher concentrations they can lead to poisoning". Another double standard.

I then searched everywhere to capture a word that can best describe two opposing sides or two different opinions for a single entity; and that was *Janus*.

Dear Vice Chancellor, because of the twin-opposite incidence during my early contact with chemistry and heavy metals, I have titled my inaugural lecture today as "*Chemistry and Heavy Metals are Janus-Faced*"

INTRODUCTION

In ancient Roman religion, *Janus* [Varo, 1449] is the god of beginnings and transitions. Janus is often depicted as having two heads, facing opposite directions, symbolically looking simultaneously into the past and the future (Fig 1).

Fig.1: A statue representing *Janus*.

Chemistry is Janus-Faced

I have therefore described the science of chemistry as Janus-faced. One face embodies the countless services it provides for mankind; the other, pollution and industrial disasters.

One Face of Chemistry

Chemistry is the science of matter and the changes that matter can undergo.

In the broadest possible terms, chemists take one form of matter and conjure from it a different form. In many cases, they take more sophisticated forms of matter and convert it into materials suitable for use or to substances needed for high technology.

Take water, for instance, the absolute essential enabler of life. Chemistry has made communal living possible by purifying water to remove pathogens by a process called chlorination [Darnell, 1911].

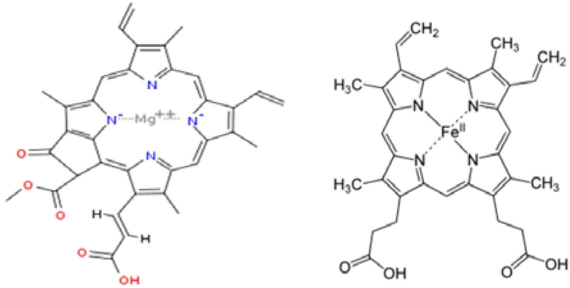
As the global population grows and the productive land area is eroded, so it becomes more and more important to coax crops into greater abundance. The traditional way to encourage abundance is to apply fertilizers. Chemists harvested the skies, taking the nitrogen of the atmosphere and converting it into fertilizer and ensuring that these can be assimilated by plants.

After water and food, we need energy. Nothing happens in the world without energy. Civilizations would collapse if it ceases to be available.

Chemists contribute at all levels and to all aspects, of developing both new sources and more efficient applications of current sources of energy. Petroleum is one of the legacies of the past, being the partially decomposed residue of organic matter, that sank to the bottom of lakes and seas and was later subjected to heat and pressure. Chemists have long contributed to the refinement of crude oil into various useable fractions.

Where do chemists currently look for new sources of energy? The Sun. Chemists have already developed moderately efficient photovoltaic materials to capture energy from the sun.

Chemists are designers; Look at plants – their leaves are green because of chlorophyll. Blood is red because of haemoglobin. Those molecules are actually almost the same, except the one in leaves has magnesium (Mg) in the centre; the one in blood has iron (Fe) in the centre.



Structure of Chlorophyll 1c

Structure of Hemoglobin

Fig. 2: Structures of Chlorophyll and Hemoglobin

Chemists can change the molecule at the centre of leaves with a different metal and produce a dye which can be used in colouring jeans.

Plastics are but one face of the materials revolution [Fenichel, 1996] that has characterized the last one hundred years and is continuing vigorously today, chemists were the brains behind it.

Chemists developed the semiconductors that lie at the heart of computation and the optical fibres that are increasingly replacing copper for the transmission of signals [Sariciftci, et al 1992].

One of the great contributions of chemistry to human civilization has been the development of pharmaceuticals [McGuire et al 2007]. Chemists can be justly proud of their contribution to the development of chemical agents against diseases.

Chemistry also contributes to the understanding of nanotechnology, biotechnology, medicine, engineering, and several other challenging scientific endeavours.

Chemists have already helped to produce the mobile sources, such as laptops, telephones, vehicles and monitoring devices of all kinds and the batteries, which drives them.

The benefits of chemistry research can be appreciated if we take a close look at the components of a mobile phone (Fig 2).

Fig. 3: The Benefits of Chemistry Research

The components of a mobile phone are:

1. *Bag*: LDPE (low density polyethylene)
2. *CD-ROM Sleeve*: Polycarbonate acrylic, paper, LDPE, metal
3. *Manual*: paper
4. *Keys*: Polypropylene
5. *Circuit Board*: Fibre-glass epoxy composite, metals, ceramics
6. *Charger*: acrylonitrile-butadiene-styrene polycarbonate housing, PVC coated copper wire, metal conductor, ceramics
7. *Housing case*: acrylonitrile butadiene-styrene polycarbonate
8. *Data Cable*: PVC coated copper wire, metal connectors, and
9. *Box*: card board interior; moulded polystyrene

The Other Face of Chemistry

At the same time, however, no other science is connected with more bad emotions and anxiety across wide sectors of society than chemistry. The achievements in Chemistry have come at a price: our collective human health and the global environment are threatened. Our bodies are contaminated with a large number of synthetic industrial chemicals, many of which are known to be toxic and carcinogenic. Some dangers of chemistry research include industrial emissions leading to fish kills, air pollution and oil pollution (Fig 4).

Fig. 4: Some Dangers of Chemistry research

In some dreadful cases, accidents have killed and maimed thousands. The explosion at the Union Carbide plant in Bhopal in India in 1984 [Weisman, 1985], the Minnamata [George, 2001] and Itai-itai [Almeida Stearns, 1998] diseases due to mercury and cadmium pollution in Japan between 1912 and 1968, several major and minor incidents of oil disasters in the Niger Delta region between 1960 to 2011; and the recent major oil disaster in the Gulf of Mexico in 2010 are also worthy to be mentioned.

These disadvantages and horrors have also made me to believe that chemistry is corrosive.

Heavy Metals are Janus-Faced

I have also described the science of heavy metals as Janus-faced. One face embodies the essentiality of heavy metals; and the other, pollution and toxicity.

Metals occupy the bulk of the periodic table of elements. The most current periodic table (Table 1) contains 118 elements, of which 18 are non-metals, 10 are metalloids and 90 are metals. Out of the 90 metals, 35 metals are of concern to us because of occupational or residential exposure; 23 of these are described as the *heavy metals* [Daffus, 2002].

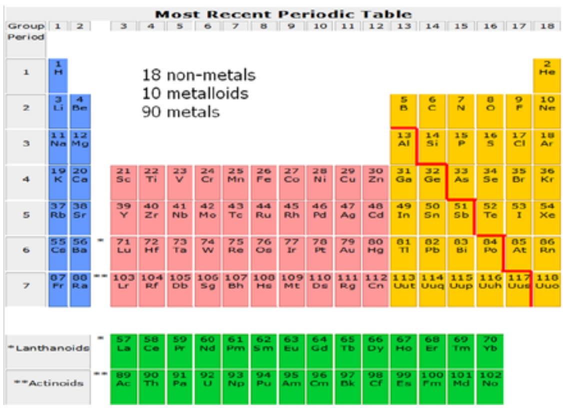


Fig. 5A: The Most recent Periodic Table of Elements

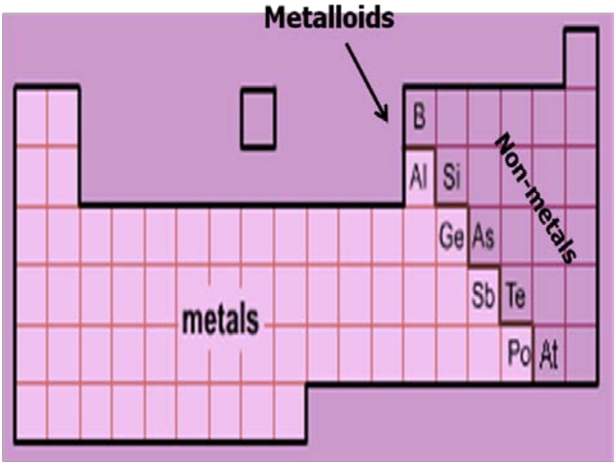


Fig 5B: Skeletal periodic arrangement for the elements showing metals, non-metals and metalloids

Many different definitions have been proposed for heavy metals —some based on density, some on atomic number or atomic weight, and some on chemical properties or toxicity [Daffus, 2002].

In this inaugural lecture, I have defined heavy metals following Lide (1992) as a subset of chemical elements with a specific gravity that is at least 5 times the specific gravity of water. This definition includes metals and methalloids.

The heavy metals include antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc [Glanze, 1996].

One Face of Heavy Metals

In small quantities, certain heavy metals are nutritionally essential for a healthy life. These elements, or some form of them, are commonly found naturally in foodstuffs, in fruits and vegetables, and in commercially available multivitamin products [IOSHIC, 1999].

Some are used in diagnostic medical applications such as direct injection of gallium during radiological procedures, the use of lead as a radiation shield around x-ray equipment and the use of silver and mercury amalgam for tooth filling [Roberts 1999].

Essential heavy metals also have normal physiological regulatory functions. Heavy metals are also common in industrial applications such as in the manufacture of pesticides, batteries, alloys, electroplated metal parts, textile dyes, steel, catalysis and so forth [IOSHIC, 1999].

The other Face of Heavy Metals

Essential heavy metals become toxic when their amount exceeds those required for correct nutrition.

For some heavy metals, toxic levels can just be a little above the background concentrations naturally found in nature.

Long-term exposure to heavy metals may result in slowly progressing physical, muscular, and neurological degenerative processes. Allergies are also common and repeated long-term contact with some metals or their compounds may even cause cancer and eventual death [IOSHIC, 1999].

Since the dawn of civilization, metal pollutants have been a part of human history. However, toxic metal pollution of the biosphere has intensified rapidly since the onset of the industrial revolution, posing major environmental and health problems.

Sources of Heavy Metals

The sources of heavy metals are diverse and specific to each element. Heavy metals may be released into the environment by industrial, domestic and transportation processes.

When released into the environment, they are washed into the soil by rain, and are taken up by plants, which are eventually consumed by grazing animals.

Heavy metals may also enter a water body such as streams, lakes, rivers, boreholes and groundwater by industrial and domestic effluents as well as from acid rain.

Such metals find their way into parts of the body such as liver, lung, gizzards, kidney, and brain tissue, thereby compromising human health. Therefore, due to health concern, humans should consume less liver, gizzard, kidney and lungs of animals, chicken and fish.

In general, the major sources of heavy metals in our environment may include:

- Oil and gas activities
- Industrial emissions and domestic applications
- solid waste combustion
- Agricultural applications and
- transportation processes

It has been established that roadways and automobiles (Fig 6) are now considered to be one of the largest sources of heavy metals in our environment [Ferner, 2001].

Fig 6: A Road Transportation

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. Some common heavy metals present in road runoff are listed in Table 1 [IOSHIC, 199].

Table 1: The common metals in road runoff are

Metals	**Sources from road transportation**
Lead	leaded gasoline, tire wear, lubricating oil and grease, bearing wear
Zinc	tire wear, motor oil, grease, brake emissions, corrosion of galvanized parts
Iron	auto body rust, engine parts
Copper	bearing wear, engine parts, brake emissions
Cadmium	tire wear, fuel burning, batteries
Chromium	air conditioning coolants, engine parts, brake emissions
Nickel	diesel fuel and gasoline, lubricating oil, brake emissions
Aluminum	auto body corrosion

Toxicological symptoms of some Heavy Metals in Humans

Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs of the body. The toxicological Symptoms of Some Heavy Metals are presented in Table 2.

Table 2: Toxicological Symptoms of Some Heavy Metals

Metal	**Toxicological Symptoms**
Aluminum	degenerative muscular conditions, Alzheimer's disease, Parkinson's disease and cancer, senility, and presently dementia
Arsenic	breathing problems; death if exposed to high levels; decreased intelligence; known human carcinogen: lung and skin cancer; nausea, diarrhea, vomiting; peripheral nervous system problems, skin pigmentation, abdominal pain
Bismuth	Renal failure
Cadmium	kidney damage and hypertension and all forms of cancer in human
Chromium	acute renal failure, Pulmonary and lung cancer
Cobalt	Goiter
Copper	Blue vomitus, shortage of blood, irritation
Iron	Vomiting, hemorrhage, stomach ulcer, liver failure and death
Lead	Behavioral problems; high blood pressure, anemia; kidney damage; memory and learning difficulties; miscarriage, decreased sperm production; reduced IQ and aggressiveness
Manganese	Parkinson-like syndrome, respiratory problems and , neuropsychiatric disorder
Mercury	blindness and deafness; brain damage; digestive problems; kidney damage; lack of coordination; mental retardation, autism, Parkinson's disease, Eczema
Nickel	Dermatitis, Eczema, acute lung injury, reduced sperm count, headache
Silver	bone marrow suppression, pulmonary edema, blue-grey discoloration of skin, nails, mucosae
Thallium	Vomiting, diarrhea, pain, coma,
Zinc	vomiting, diarrhea, abdominal pain, anemia,

Exposure some heavy metals to Humans

Exposure to toxic heavy metals is generally classified as acute, 14 days or less; intermediate, 15-354 days; and chronic, more than 365 days [Dupler, 2001]. These classifications indicate that humans are constantly exposure to heavy metals throughout their life-time. The major routes of exposure of five metals are discussed below:

Arsenic

For Environmentalists and some public health experts, one of the most puzzling practices of modern agriculture is the addition of arsenic-based compounds to chicken feed. The point of the practice is to promote growth, kill parasites that cause diarrhea, and improve pigmentation of chicken meat (Fig 7).

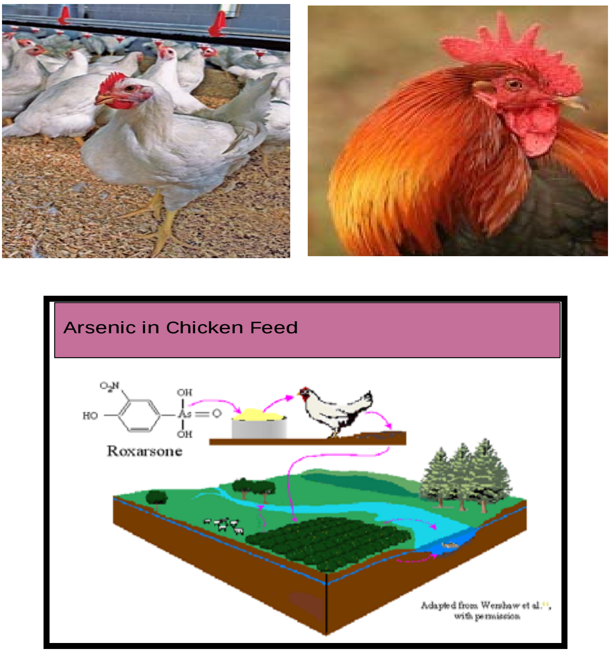


Fig 7: Chicken fed with roxarsone containing feed

Roxarsone (4-hydroxy-3-nitrobenzenearsonic acid) is the most common arsenic-based additive used in chicken feed. In its original organic form, roxarsone is relatively gentle. It is less toxic than the inorganic forms of arsenic-arsenite [As (III)] and arsenate [As (V)]. However, roxarsone in chicken converts into inorganic arsenic within the bird, and the rest is transformed into inorganic forms after the bird excretes it.

Chicken litter containing arsenic finds its way to the soil as organic fertilizer and are consumed and concentrated in the tissues of cow and goat, which are then ground into hamburger and corned beef to be consumed by humans.

Symptoms of acute arsenic poisoning are sore throat from breathing, red skin at contact point, or severe abdominal pain, vomiting, and diarrhea. Other symptoms are fever, mucosal irritation, cardiovascular collapse, progressive peripheral and central nervous changes, numbness and tingling, and muscle tenderness. Long-term exposure to inorganic arsenic can cause bladder, lung, skin, kidney, and colon cancer, as well as harmful immunological, neurological, and endocrine effects, partial paralysis and diabetes.

There may also be excessive darkening of the skin in areas that are not exposed to sunlight. Arsenic poisoning range from

- Pigmentation (white and dark spots on skin)
- Skin hardening and development of nodules (keratosis)
- Skin cancer and other forms of cancer such as bladder, lung and kidney
- Peripheral vascular diseases (Black foot disease), resulting in gangrene
- Hypertension and ischemic heart disease
- Liver damage, anemia and diabetes mellitus

Fig. 8: Arsenic lesions on hands, legs and head and acute skin pigmentation due to arsenic pollution

The chronology of arsenic exposure may be determined by the white lines on the fingernails (Fig 9).

Fig 9: White lines on the Finger showing Arsenic Exposure

Lead

Acute exposure to lead is also more likely to occur in workplace, particularly in manufacturing processes that include the use of lead such as battery manufacture and in petrol filling stations. Also printing ink, paint, and fertilizer contain lead (Fig 10).

Fig 10: Distribution and Some Sources of lead into the Environment

Symptoms include abdominal pain, convulsion, and hypertension, and renal dysfunction, loss of appetite, fatigue, and sleeplessness. Other symptoms are hallucinations, headache and numbness, lack of concentration, arthritis. Chronic exposure to lead may result in birth defects, mental retardation, autism, allergies, hyperactivity, weight loss, shaky hands, muscular weakness, and aggressiveness. Children are particularly sensitive to lead and are prone to ingesting lead because they chew anything that comes handy even though not intended for human consumption (Fig 11).

Fig 11: Some Effects of lead

Mercury

Acute mercury exposure may occur in the mining industry and in the manufacture of fungicides, thermometers, and thermostats. Liquid mercury is particularly attractive to children because of its beautiful silver color and unique behavior when spilled.

Children are more likely to incur acute exposure in the home from ingesting mercury from a broken thermometer or drinking medicine that contains mercury (Zayas et al. 1996).

Dental fillings constitute the most important source of silver and mercury to humans (Fig 12).

Interestingly, the metallic mercury used by dentists to manufacture dental amalgam is shipped as a hazardous material to dental offices.

Fig. 12: Silver-Mercury amalgam filling in a tooth

Therefore as chemists, we do not support the use of mercury amalgam fillings for teeth; but rather support research to develop new materials that will prove to be as safe as dental amalgam. Other sources of mercury are from gold mining, natural gas and fish consumption.

Symptoms of acute exposure are cough, sore throat, and shortness of breath; metallic taste in the mouth, abdominal pain, nausea, vomiting, headache, weakness, visual disturbances, and hypertension.

Chronic exposure to mercury may result in permanent damage to the central nervous system (Ewan et al. 1996) and kidneys.

Mercury can also cross the placenta from the mother's body to the fetus and bioaccumulate; resulting in mental retardation, brain damage, blindness, seizures, autism, Parkinson’s disease and inability to speak.

Fig 13: Effect of mercury on children

Cadmium

Acute exposure to cadmium generally occurs in the workplace, particularly in the manufacturing processes of batteries and color pigments used in paint and plastics, as well as in electroplating and galvanizing processes.

Apart from cadmium; cigarette smoke contains several different toxins, all of which increase the amount of free radicals in our lungs and throughout our bodies (Fig 14).

In Nigeria, cow and goat are free rangers and graze on road sides which may contain high Cd levels from Car exhaust dust

The symptoms of cadmium include kidney and lung damage, kidney stones, chest pain, cough and hypertension and all forms of human cancer.

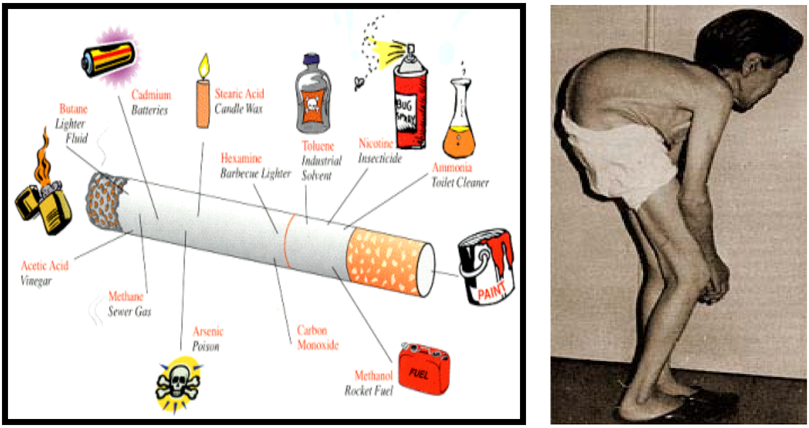


Fig 14: Chemical components in a stick of cigarette and Itai-ita Diseases due to cadmium pollution

Aluminum

Aluminum is not a heavy metal, however, environmental exposure is frequent, especially through aluminum pots and spoons (Fig 15), leading to concerns about accumulative effects. Acute exposure is more likely in workplace by inhaling airborne aluminum dust and handling aluminum parts during assembly processes.

At home, we are in constant contact with aluminum in foods and in water; from cookware and soft drink cans; from consuming items with high levels of aluminum such as antacids, aspirin, or treated drinking water; or even by using nasal sprays, toothpaste, and antiperspirants.

Fig 15: Aluminum pot and spoon

Symptoms of aluminum toxicity include memory loss, learning difficulty, loss of coordination, disorientation, mental confusion, colic, heartburn, flatulence, headache and Parkinson’s disease.

Bioaccumulation of Heavy Metals

Heavy metals are dangerous because they may bioaccumulate. Bioaccumulation means an increase in the amount of a chemical in a biological organism over time, compared to the amount present in the environment.

When a heavy metal gets dumped into the environment, the organisms absorb it into their structure. Land and aquatic plants may absorb it by uptake from the roots. Animals may absorb it by eating the plants. Seafood may filter it directly from the seawater.

Through the food chain, heavy metals move from one trophic level to another and bioaccumulate in the organism at the top of the food chain (Fig 16).

Humans occupy the top of the food chain; this is because man eats more than one type of food. Therefore bioaccumulation is a significant health concern for man.

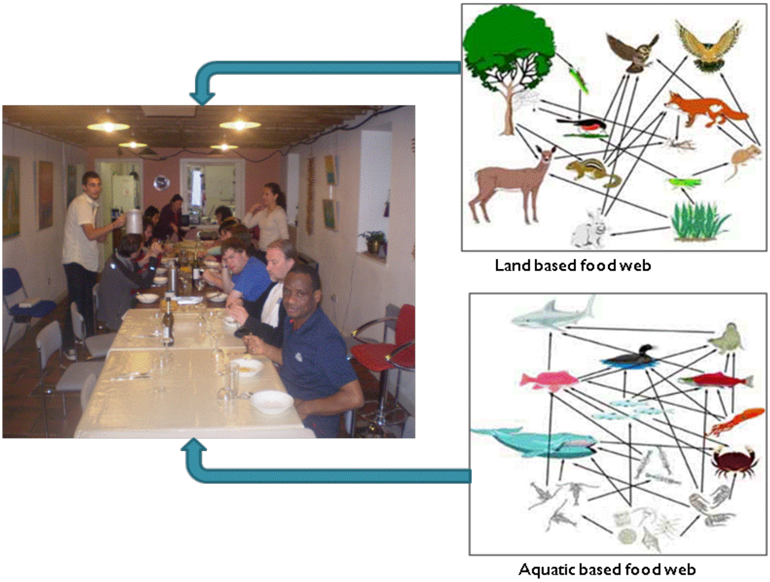


Fig. 16: Bioaccumulation of heavy metals

Some Biggest Disasters of Heavy metals

Minamata disaster in Japan (1950s – 60s) due to mercury pollution: In the 1950s and early 1960s, hundreds of children around Japan's Minamata Bay were born with horrific birth defects after their mothers ate seafood contaminated with mercury compounds, which had been discharged into the bay since the 1930s.

Itai-itai disease in Japan (1912 -32) due to cadmium pollution: The victims ate seafood and rice with high cadmium levels.

Arsenic Disaster in Bangladesh: Natural arsenic contamination of groundwater has become a high-profile problem in recent years due to the use of boreholes and tube wells for water supply in Bangladesh, causing serious arsenic poisoning to large numbers of people. A 2007 study (Smedley et al, 2007) found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water.

Lead Disaster in Nigeria due to Illegal mining activities in Zamfara State: More than 400 children have died and many more at risks. The local imams allow women to contribute by grinding the ore inside their houses. But the ore contain up to 20 percent lead.

Once they had extracted the gold they threw the waste residue into the backyard where kids would pick it up, then put their fingers in their mouths (Fig 17). At such high levels it is fatal to the children (UN report, 2010). The situation is so bad that parents are now afraid to go their houses for fear of killing their children.

Fig. 17A: Illegal Ore Processing for Gold

Fig. 17B: Children are more at risk of lead pollution due to their pica-pica play

My Research Career So Far

Dear Vice Chancellor, I am concern with heavy metals pollution because, their toxicity can produce symptoms that sometimes are mistaken for other chronic disease conditions.

Metals can directly and indirectly damage DNA and that means an increased risk of cancer (we call this genotoxicity). There are also possibly non-genotoxic pathways, due to irritation or immuno-toxicity. Sure enough, a number of metals are known to be carcinogenic.

Secondly, heavy metals pollution of our environment is less visible and direct; but its effects on the ecosystems and human health are intensive and very extensive.

I am aware that everyone in Nigeria talks about oil pollution. This is because, oil pollution is visible, therefore clean-up and remediation processes can commence immediately after spillage (Fig 18) except in the fragile Niger Delta ecosystem.

Fig. 18: (A). Beach cleanup of an oil spill and (B) abandoned oil spill sites in Nigeria.

On the other hand, heavy metals pollution of our environment is less visible and direct; but its effects on the ecosystems and human health are intensive and very extensive (Fig 19).

Fig. 19: Heavy metal pollution is not visible. If the rivers and sachet water in these pictures are polluted with some heavy metals, they may not be visible.

Whether unrecognized or inappropriately treated, heavy metal toxicity can result in significant illness and reduce the quality of life.

Therefore, it is important for us to inform ourselves about heavy metal pollution and take proactive and protective measures against excessive exposure.

In Nigeria, heavy metal exposure is common. However, health conditions have never been associated with heavy metal pollutions.

Tobacco is an important source of cadmium in Nigeria. We therefore set out to investigate the levels of cadmium present in cigarettes smoked in Nigeria (Spiff *et al*., 1999), our results show that a stick of cigarette contains 1-2 µg Cd and that Nigerian smokers would absorbs about 5 to 10 times the amount of cadmium absorbed from their average daily diet.

Therefore, our people continue to perish because they have not been provided with the knowledge.

Heavy metal pollution is like signing a pact with the devil. Millions of families in the world exist today, that are struggling to survive in heavy metal hazardous conditions.

Dear Vice Chancellor, it is worth-while to mention here that after creation (*refer Genesis 1: 31*) God looked at the environment He has made and said “it was very good”.

Therefore, the environment made by God, which fostered man when he was created on this earth was a hospitable one, tender with him, considerate of his health, and affording him means to live and prosper.

However, man has caused a serious change and dangerously harmful alterations in the structure, texture and composition of the environment as a result of rapid civilization and the breathless pace of industrialization witnessed on this earth. This harmful alteration is called *pollution*.

Pollution became a popular issue after World War II. In the U.K after the Great Smog of 1952 that killed at least 8000 people in London. In the US, pollution began to draw major public attention between the mid-1950s and early 1970s, when Congress passed the Noise Control Act, the Clean Air Act, the Clean Water Act and the National Environmental Policy Act [Wikipedia].

In Nigeria, the issue of pollution became noticed after the dumping of 3,880 tons of toxic waste at Koko Town in part of the Niger Delta in 1988.

An important aspect of public health protection is the prevention or reduction of exposures to environmental agents that contribute to premature deaths, diseases, discomfort or disability (Ottis and Roberts, 1998).

Heavy Metals Speciation

Knowledge of human exposure to environmental contaminants is an important component of environmental risk assessment.

Most of the environmental management structures around the world rely directly on the total measured contaminants in various media to judge quality, infer risk and interpret compliance.

However, total contaminant concentration provides no information on the fate of the contaminant in terms of its interaction with environmental matrices, bioavailability or its resultant toxicity.

Elemental speciation is the key to evaluate the eco-toxicological potential, the extent of bioavailability and the fate/ or mechanism of contaminants reactions.

Professor Osibanjo and his research team started heavy metal study in Nigeria by investigating the total concentration present in environmental matrices in the 1980s, while Horsfall and Spiff led the way for elemental speciation in Nigeria by investigating heavy metals speciation in environmental matrices beginning from 1994.

In environmental chemistry, metal speciation is the qualitative identification; and the quantitative determination, of the individual chemical species (or forms) which together constitute the total concentration of a given element in an environmental matrix [Tessier et al 1979].

The significance of speciation is that; it can be used to determine the toxicity of metals, biogeochemistry of metals, functionality of bio-metallic species, the potential environmental risks, the bioavailability, bioaccumulation or biodimunition of metals.

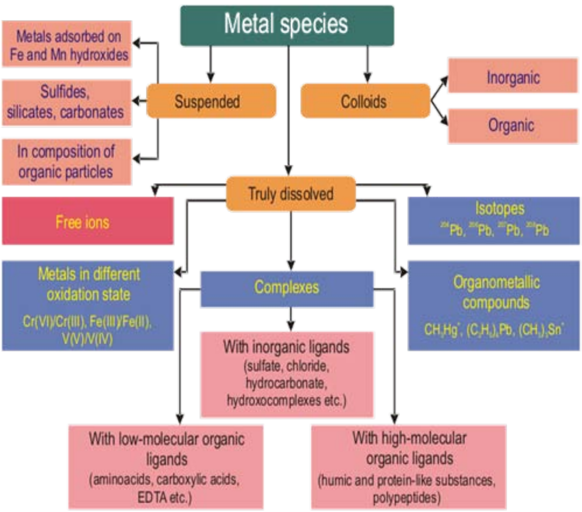


Fig 20: Heavy metal speciation analysis

Our foremost research is heavy metal speciation analyses, which are the analytical activities of identifying and/or measuring the quantities of one or more individual chemical species in a sample.

The Science Citation Index Expanded (SCI-Expanded) is the most important and frequently used database for a broad review of scientific information and accomplishments in all fields. A literature survey in the SCI-Expanded on African aquatic environments by Biney et al [1994], shows that, the waters and sediments of the known river systems in the Niger Delta region of Nigeria are not known especially from the heavy metal speciation point of view.

Consequent upon the non-availability of information on heavy metals speciation in the Niger Delta area, our research group initiated series of research projects to quantify and study the speciation of several heavy metals in some of the known river systems of the Niger Delta region.

In our series of investigations, we were able to study, the speciation of lead (II), zinc (II), cadmium (II), cobalt (II), copper (II), and nickel (II) in sediments from some coastal waters in the Niger Delta area, using sequential extraction techniques.

Specifically, Horsfall and Spiff [1999] reported the heavy metal speciation and total concentrations; of some environmentally toxic heavy metals in inter-tidal flat sediments of the Okrika River System in Rivers State as well as other known chemical variables related to the retention/ or release of heavy metals by sediment.

The behaviour of each metal based on their speciation in the Okrika river system revealed a higher environmental risk for cadmium and lead and a lesser degree for zinc due to their higher percentages in the more easily remobilized fractions.

The distribution of heavy metals in sediments of the lower reaches of the New Calabar River was also investigated together with their chemical speciation in five geochemical phases [Horsfall and Spiff 2002].

The result obtained show that the total metal content of sediments in the lower reaches of the New Calabar River system was depended on anthropogenic inputs as well as the natural physico-chemical characteristics of the sediments. Data from this investigation reveals that the sediment at the bottom of the New Calabar River is a *reservoir* for heavy metals and *not a sink.*

Therefore, heavy metal flux across the sediment-water interface in either direction may readily occur depending on changes in the environmental ambient conditions.

Humic and Fulvic Acids

To the environmental chemists, humic and fulvic acids (Fig 21) are organic ligands found in the aquatic ecosystem as well as in soil. They play a prominent role in the fate, transport, cycling and accumulation of heavy metals in soils and sediments [Nriagu and Coker 1972]. Both ligands are capable of binding metals and can be used to predict the potential environmental risks and transport mechanisms of heavy metals in the aquatic ecosystem.

The environmental contamination risks and the transport mechanism of heavy metals based on their selective extractions from humic and fulvic acids in sediments of the New Calabar River system was evaluated [Horsfall and Spiff, 2005].

In this investigation, it was observed that the principal metal in the New Calabar River system is iron (Fe). The cycling of Fe has been recognized to play a fundamental role in the transport of trace metals in aquatic environment.

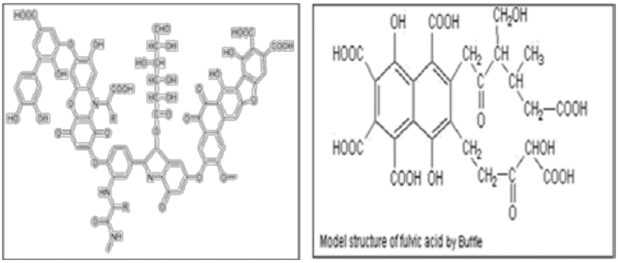


Fig. 21: Structure of typical Humic and Fulvic acids

Research has revealed that metals in aquatic system are scavenged by either the particulate or colloidal hydrous iron oxides, thus transferring heavy metals to the particulate phase. Once formed, the particulate fractions may settle to the sediment and may release trace metals to the overlying waters [Taillefert and Gaillard, 2000].

The large amount of Fe found in the New Calabar River in this investigation supports our earlier observation and confirms the sediments of the New Calabar River as reservoir for heavy metals.

The distribution and chemical speciation of heavy metals in inter-tidal flat sediments of the Brass River Estuary was also investigated [Horsfall and Spiff, 2004]. Inter-tidal flats (Fig 22) are margins of the sea that are located next to the terrestrial land. They have sufficient sediment, but limited strong wave action and are occasionally covered by the flow and ebb of the river's tidal regime.

These transitory environmental conditions may lead to changes in the redox potential of the river system; and therefore may affect the distribution of heavy metals in the river.

The speciation and distribution patterns of heavy metals in the Brass River Estuary suggests that the inter-tidal flat sediments of the estuary is a reservoir; and could release metals into the water column, which could be detrimental to aquatic filter feeders.

Fig. 22: Examples of Inter-tidal Flat sediment

Bioavailability of Heavy Metals

In environmental chemistry, bioavailability is defined as the extent to which a toxic contaminant is present in a form or species which will be available for biologically mediated transformations in an aquatic environment.

In order to estimate effects and potential risks associated with elevated elemental concentrations, the species of total elemental abundances in water, sediment, and soil that are bioavailable need to be identified.

Bioavailability studies indicate that both aquatic and terrestrial organisms take up free metal ions from solution more efficiently than via direct particulate matter ingestion [Luoma, 1983].

Elevated chloride contents tend to enhance chloride complex formation, which decreases the adsorption of heavy metals on sediment, and results in greater solubility and mobility [Bourg, 1988].

Also, acidic and oxidizing conditions tend to release large amounts of heavy metals into solution due to decreased sorption capacity of all metal species.

In the Niger Delta area; acidic conditions have been created due to industrial activities. Also there is high chloride content due to sea water intrusion. The combination of these two factors may enhance the release of heavy metal ions from soil and sediment to overlying water system for ingestion by filter feeding organisms [Howard and Horsfall, 1995].

A combination of metal speciation and potential bioavailability was employed to predict the degree of contamination risk of the Ntawogba Creek in Port Harcourt [Horsfall and Spiff, 2005]. The prediction revealed differential polluting potentials in the different sampling zones due to the non-point source nature of heavy metals input into the river.

The speciation study confirms that the predominant species of heavy metals in the Ntawogba Creek is the reducible fraction; which is a potential risks to aquatic life.

Accordingly, it was suggested that, regulatory agencies should prevent the over flow of the Ntawogba creek into farm lands to prevent uptake of heavy metals in tuber crops such as cassava and yam [Horsfall and Spiff, 2005].

Dear Vice-Chancellor, our intention was to investigate the heavy metal profiles and undertake their speciation in sediments of the Niger Delta coastal region beginning from Benin River up to Andoni River (Fig 23).

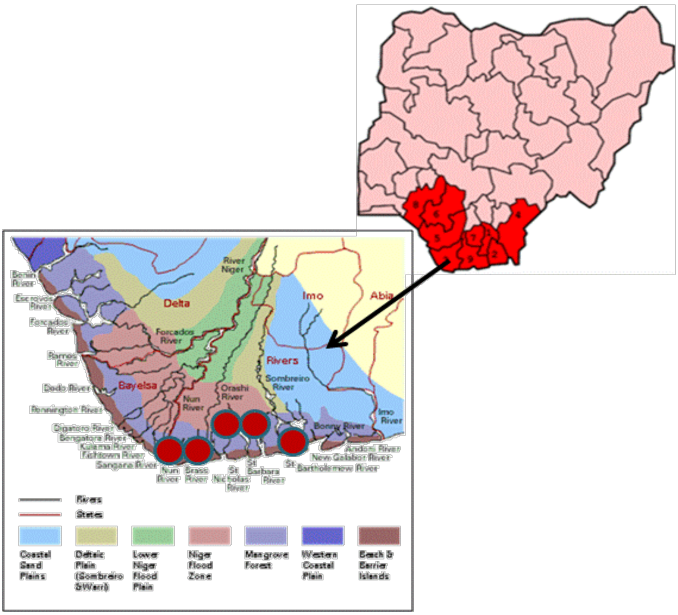


Fig. 23: Major coastal Rivers in the NDDC defined Niger Delta area with Nigeria insert

However, we were able to study only five rivers out of the eighteen coastal rivers of the region.

The reason was because; the Niger Delta struggle which started about 1951 during the Colonial period and has traversed several phases reared its ugly head after the destruction of Odi in Bayelsa State in 1999.

Day after day, the emergence of social movements in the Niger Delta and the militarization of the regions and the subsequent conflict between these social movements and Government agents took a different dimension.

It was unfortunate for us, because we could no longer go to the creeks to carry out research in the Niger Delta region. However, for our research group, we re-designed our research projects to continue the work on heavy metals; but this time in the area of adsorption studies.

Adsorption Studies of Heavy Metals

Adsorption study is capital intensive; faced with the dwindling University research grants; a research proposal on the use of agro-wastes for the adsorption of heavy metals from aqueous solution was made to the International Foundation for Science (IFS), Sweden. Our proposal was accepted and we had an international research grant for this work.

Adsorption is a surface reaction, where atoms, ions, biomolecules or molecules of gas, liquid, or dissolved solids stick to a surface. The process creates a film of the adsorbate on the surface of the adsorbent (Fig 24).

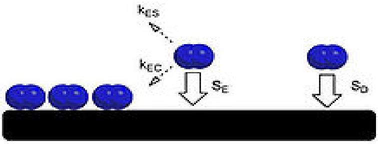


Fig 24: Two adsorbate molecules adsorbing onto a surface

It differs from absorption, in which a fluid permeates or is dissolved by a liquid or solid. The term *sorption* encompasses both processes, while *desorption* is the reverse of adsorption.

$$\text{Adsorbate} + \text{Adsorbent} \underset{\text{desorption}}{\overset{\text{Adsorption}}{\rightleftharpoons}} \text{Adsorption}$$

$$A + B \rightleftharpoons AB$$

The mechanism of the adsorptive process may be represented as follows:

$A_{(g)} + S \rightleftharpoons AS$

$A_{(g)} + AS \rightleftharpoons A_2S$

$A_{(g)} + A_2S \rightleftharpoons A_3S$ and so on

In Nigeria, several industrial processes such as paint manufacturing, battery, food, plastics, tire, cement and fertilizer, tanning, textile dyeing, steel fabrication, metal processing, auto-body works, agricultural runoff and oil and gas activities are on-going.

These industries generate large amount of contaminants, which in many cases are discharged into the environment without any form of treatment; because conventional wastewater treatment techniques are not economically feasible for most small- and medium-scale industries operating in Nigeria.

It is therefore, necessary to search for low –cost techniques that may be effective, environmentally friendly and economical, which may be utilized by these industries.

The adsorption processes using agricultural waste products were becoming the new alternative technique for wastewater treatment.

Materials investigated include Sago waste, [Quek et al 1998]; Banana pith, [Low et al 1998]; coconut husk, [Manju et al 1998]; medicago sativa (alfalfa) [Gardea-Torresdey el al 1998], ground nut husks [Okiemen et al 1998]; saw dust, [Malik, 2004] just to mention a few.

In our investigations, we have employed several pure unmodified agro-wastes biomass for the removal of some heavy metal ions and organic contaminants in aqueous solution. Our various results showed that pure unmodified biomass of agro-waste could remove between 25 – 54% of metal ions in aqueous solution.

The agro-waste biomass used in our investigations include *cassava waste* [Horsfall, and Abia, 2003, Horsfall, et al 2003; Abia et al, 2003, Horsfall, et al 2004, Horsfall et al 2006, Horsfall et al 2007], *fluted pumpkin stem waste* [Horsfall and Spiff, 2005a, Horsfall and Spiff, 2005b, Horsfall and Spiff, 2005c, Horsfall and Spiff, 2005d references], *unedible (wild) cocoyam* [Horsfall and Spiff, 2004, Horsfall and Spiff, 2005,], *Rhizophora tree waste* [Horsfall et al 2005], *Nypa palm petioles* [Wankasi et al 2005,], *Almond tree (Terminalia catappa L.) leaves waste* [Horsfall and Vicente, 2007], *water hyacinth* [Tarawou, et al 2007], and *water spinach* [Tarawou and Horsfall 2008] (Figs 25A - H)

Fig 25A - : Cassava plant (Left) and tuber (Right) (Tapioca, *Manihot sculenta* Cranz)

Fig 25B: Fluted pumpkin (*Telfairia occidentalis* Hook) leaf

Fig 25C: Ornamental cocoyam (*Caladium bicolor)*

Fig 25D.   Red mangrove (*Rhizophora mangle*) tree roots and leaf

Fig 25E: Almond tree (*Terminalia catappa* L.) leaves and fruit shell popularly called "fruit" in Nigeria.

Fig 25F Nipa palm (*Nipah fruticans* Thumb Wumb).

Fig 25G: Water spinach (*Ipomoea aquatic*).

Fig 25H: Water hyacinth (*Eichornia crassipes*) plant

Chemical Modification of the Agro-waste Biomass

Chemical modifications by esterification of the pure agro-waste biomass have been known to alter the physicochemical and surface characteristics of these materials, thus enhancing their sorption capacities [Gardea-Torresdey et al 1998].

In our investigations, we have successfully modified cassava waste [Abia et al 2003, Horsfall et al 2004], fluted pumpkin stem waste [Horsfall and Spiff 2005, Horsfall et al 2005], *Rhizophora mangle* (red mangrove) [Ayawei and Horsfall 2005] and water hyacinth [Tarawou et al 2007] and use same for the removal of heavy metals and organic contaminants in aqueous solutions.

Chemically modified biomass was able to remove between 87 – 99% of heavy metals ions from solution at pH 5.5; which was an improvement over the unmodified biomass.

The chemical modifications were achieved using sulphanylacetic acid as exemplified in the scheme for hydroxylated biomass (Fig 26).

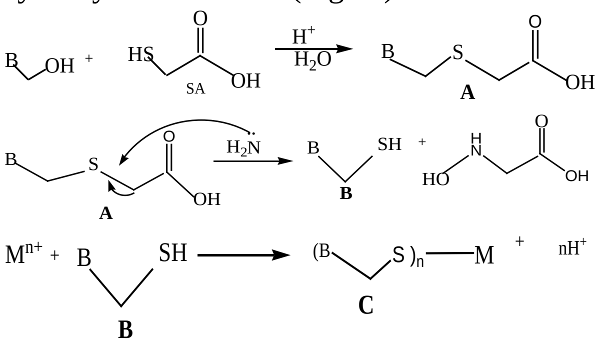


Fig 26 (Scheme I): Mechanism of chemical modification by sulphanylacetic acid

In the scheme, sulphanylacetic acid reacted with the hydoxylated biomass and produced A. The resulting substitution product A can be cleaved with hydroxylamine to afford the S – modified biomass B, and the latter may then be metallated with divalent ions (M^{2+}).

Effect of Reaction Conditions in Adsorption Process

Reaction conditions exert a lot of influence on the efficiency of the adsorption process. In our various investigations, we have studied the effects of temperature, pH, surface area, particle size of adsorbent, agitation speed, contact time, and metal ion concentration on the removal of heavy metals from aqueous system.

From the various investigations, we have established optimal reactions conditions for the various agro-wastes used [Horsfall and Spiff 2005a, b, c, d; Horsfall et all 2006; Horsfall and Vicente 2007].

This process is environmentally friendly; and may provide affordable technology for small- and medium-scale industry in Nigeria, generate employment and enhance local entrepreneurship.

Surface Characterization of Agro-waste Biomass

Even though the agro-waste biomass possesses the potential ability to remove contaminants from aqueous system, we observed differential sorption behavior of a particular metal on different biomass surface. Therefore, it became necessary to study the surface characteristics of these biomasses.

Due to the apparent lack of basic analytical instrumentation, we made a proposal to the United Nations Educational Scientific and Cultural Organization (UNESCO), Italy for collaborative research on the surface characterization of the agro-waste and we got a fellowship grant to the Research Institute of Theoretical and Applied Physical Chemistry (INIFTA), University of La Plata, Argentina.

This research fellowship enabled us to determine the properties of the fluted pumpkin stem waste biomass using Scanning-Electron-Micrograph (SEM) imagery. The different magnifications of the SEM were employed to show the pore size of the biomass (Fig 27).

The imagery reveals that microscopic pores are prevalent on the biomass surface [Horsfall and Vicente, 2007].

the spent biomass [Horsfall et al 2005] in a fixed-bed column using different concentrations of acidic, basic and neutral solutions as eluting agent.

The data obtained showed that the ease of metal ion recovery from metal-loaded biomass require slightly acidic solutions. Also, macroscopic changes on the regenerated biomass were observed with increase in recovery reagent concentration.

Activated Carbon for Removal of Heavy Metals

Agro-wastes biomass have been widely used as effective removers of metal ions from aqueous solution, however, agro-wastes have low resistance to mechanical abrasion making them suitable only for a “once-and-for-all” application.

Again, most biomass in its native form may not be suitable for industrial process applications as they may disintegrate under the harsh conditions of wastewater processing. Also, the shelf-life of agro-waste biomass was observed to be short.

In order to overcome these problems, much emphasis has been given to the treatment of wastewaters through adsorption technology using activated carbons [Juang et al 2002].

Due to the success of our initial work on the adsorption of heavy metals from aqueous solution using pure agro-waste biomass; a second research grant proposal on converting the agro-waste into activated carbon for removal of heavy metals from aqueous solution was presented to the International Foundation for Science, Sweden and our proposal was accepted.

This second proposal was funded by the IFS in partnership with the Inter-Islamic Network on Water Resources

Development and Management (*INWRDAM*), Islamabad, Pakistan and the Committee for Scientific and Technological Cooperation (*COMSTECH*), Jordan.

In this series of research work, we successfully carbonized and activated the following agro-wastes at temperatures ranging from 350 – 800^{O}C (Fig. 28): fluted pumpkin stem waste [Ekpete and Horsfall 2010], water hyacinth [Tarawou and Horsfall 2007 and water spinach waste [Tarawou and Horsfall 2010a and b].

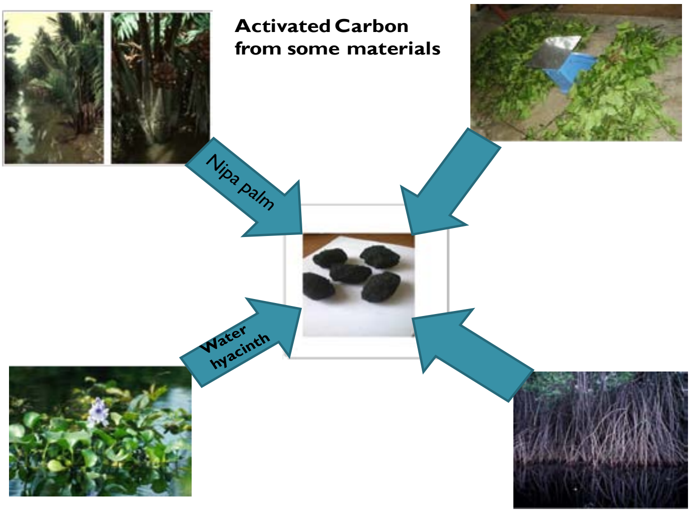


Fig 28: Activated carbon from some agro-wastes and non-useful materials

The activated materials produced were used for the removal of heavy metals and organic contaminants in aqueous systems; in a downward flow packed column arrangement.

The adsorptive capacities of these investigations show that, there were no significant differences between the activated carbon we produced from agro-waste and the commercial grade imported activated carbon.

The effects of column design parameters, such as bed height, initial contaminant concentration and flow rates were also investigated.

The breakthrough profiles for the sorption of the contaminants in the column were analyzed using the bed depth service time (BDST).

The pilot scheme for activated carbon production from agro-waste is ready and available. We invite indigenous investors to seize the opportunity for local production of activated carbon and save the industries from huge foreign exchange from importation of activated carbon.

Current and Future Research Plans

Dear Vice Chancellor, for the past forty-five to fifty minutes, I have tried to take every one through the rigorous path of my research journey so far by looking into the past. In the next ten to fifteen minutes, I shall introduce my current and future research directions.

Current Research

Our current and on-going investigations are focused on the quantification and speciation of heavy metals in Nigerian seafood found in the Niger Delta region.

Previously, we have investigated the levels of heavy metal in Land Crab *(Gecarcinus quadratus),* Edible water Crab (*Pachygrapsus marmoratus),* Mudskipper fish (*Periophthalmus papillio*), and the Black mud fish *(Neochanna diversus*) (Figs 29).

Fig. 29A: Land Crab *(Gecarcinus quadratus)* called Olu in Kalabari

Fig. 29B: Edible water Crab (Pacygrapsus marmoratus) *called Ikooli* in Kalabari

Fig. 29C: Mudskipper fish *(Periophthalmus papilio)* called Isila in Kalabari

Fig. 29D: Black mud fish *(Neochanna diversus)* called Ikili in Kalabari

Our results [Horsfall and Acholonu 1998, Howard el al 2006a and b] showed that, heavy metals in the tissues of some of this seafood are consistently higher than recommended levels for human consumption.

Generally speaking, continuous monitoring of the coastal marine waters, and sediment conditions and seafood health in terms of heavy metals in the Niger Delta region has become very essential because greater percentage of the population of this country are resident in this region and depend on seafood as their source of protein.

You will agree with me that, research of this nature is capital intensive and require highly sensitive and high-resolution analytical instrumentation.

For our initial investigations, we relied heavily on Perkin Elmer Atomic Absorption Spectrophotometer (AAS). However, the limitation of the AAS is that it cannot detect below the parts per million (ppm) levels.

Again, we are concerned that seafood are consumed by our people since the pre-industrialization of the region; therefore this information requires equipment with significantly high detection limits, which can detect parts per billion (ppb), eliminate interferences and produce reliable data which can be presented anywhere in the world and validate the integrity of our findings.

Armed with our initial findings, we made a proposal to the Royal Society of Chemistry, UK for a fellowship to "*investigate the levels and speciation of selected heavy metals in seafood, predominantly found in the Niger Delta coastal waters"*.

The aim of this research is to generate knowledge for the first time on trace elements speciation in Nigerian seafood using inductively coupled plasma – mass spectrometry (ICP-MS).

Our proposal was accepted and a Research Fellowship tenable at the Trace Element Speciation Laboratory (TESLA), Department of Chemistry at the University of Aberdeen, Scotland; was awarded.

The four (Fig 30) Nigeria seafood samples collected from the Niger Delta region for this research were; Periwinkle

(*Tympanotonus fuscatus*), Whelk (*Buccinum undatum*), Edible Clam (*Mercenaria mercenaria),* and *Oyster (Crassostrea gigas).*

Fig. 30A: Periwinkle (*Tympanotonus fuscatus)* called isam in Kalabari

Fig. 30B: Whelk (*Buccinum undatum*) called ngolo in Kalabari

Fig. 30C: Edible Clam (*Mercenaria mercenaria)* called ofingo in Kalabari

Fig. 30D*: Oyster (Crassostrea gigas)* called ngbe in Kalabari

At the Trace Element Speciation Laboratory (TESLA), University of Aberdeen, the seafood samples were freeze-dried and ground into fine powder.

This investigation is dear to my heart; because, this is the source of protein I grew up with and this is the first time in Nigeria, that the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and the more sophisticated High-Resolution Electron-Spray - Mass Spectrometry (HRES-MS) (Fig 31) has been used to investigate heavy metal speciation in Nigerian seafood.

Precision and accuracy were determined by replicate analyses, recovery of added heavy metals and standard reference materials (CRM) for seafood (DORM-4, DORT-3 and BCR) were used. Indium and Gallium were used as internal standards. Results obtained from regression analysis for the coefficient of determination or "goodness of fit" was all above the acceptable 0.80 level.

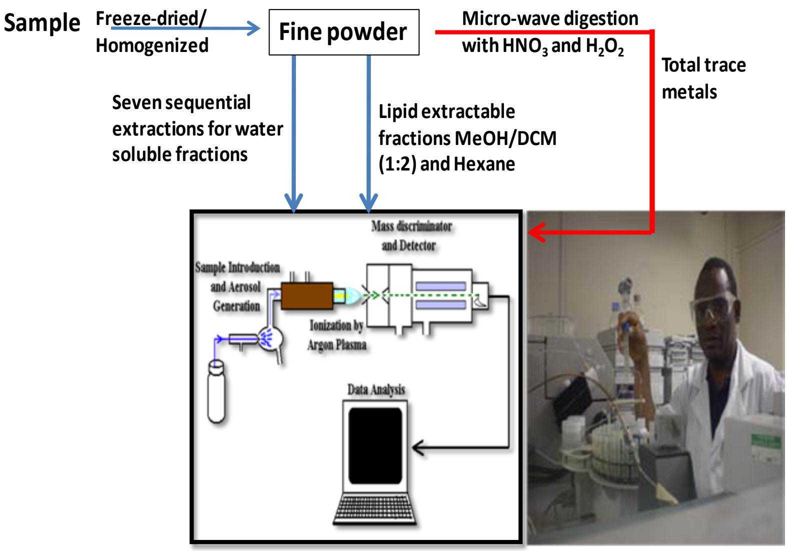


Fig 31: Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)

Currently at the institute of Trace Element Speciation Laboratory (TESLA), we have quantified fourteen (14) (Fig 32) elements (Cd, Pb, Hg, Cr, As, Zn, V, Cu, Co, Mn, Mo, Ni, Fe, and Se) in the four Nigerian seafood using the state of the art environmental analytical instrumentation – the Inductively Coupled Plasma Mass Spectrometry (ICP-MS). We have also started the speciation of arsenolipds in the seafood.

The results obtained within this research will be of importance to national and international food authorities in their evaluation and risk assessment of the consequences of Nigerian seafood.

Furthermore, the results will also be of value for seafood aquaculture industry and the fishery sector in Nigeria

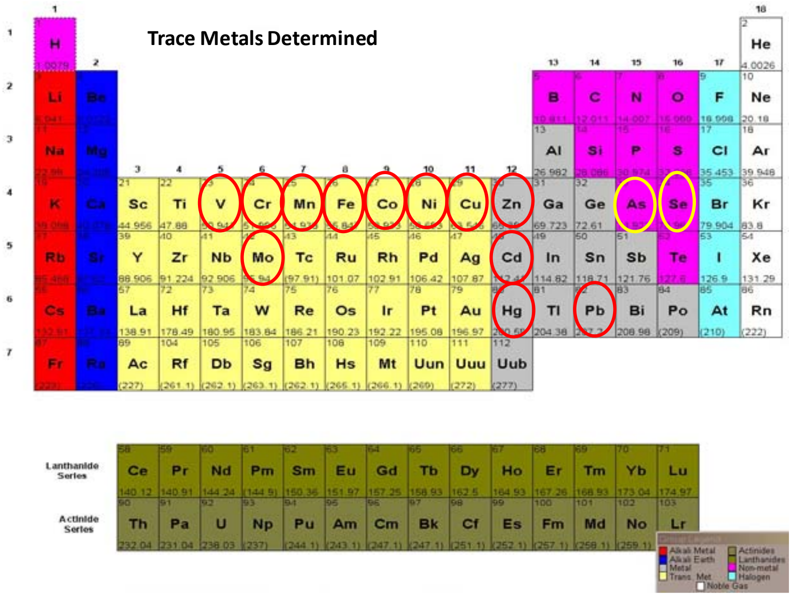


Fig 32: The circled 14 trace elements has been quantified

Future Research Plans

Dear Vice Chancellor, seafood constitutes an important source of protein for many people throughout the world, and their consumption has increased among health-conscious Nigerians because it provides a healthy and cheap source of protein and other nutrients.

Fish consumption is generally very healthy. They contain high quality protein and other essential nutrients; low in saturated fat, and contain omega-3 fatty acids, a type of essential fatty acids that promotes healthy cardiovascular systems.

At the same time, levels of heavy metals and other contaminants in seafood are of considerable interest because of potential effects on the fish themselves or the organisms that consume them, including man (*Seafood is Janus-faced*).

There are a lot of health risks in the consumption of some shellfish. Shellfish are filter feeders; they generally accumulate heavy metals and marine biotoxins in the process of feeding.

Filter feeders such as oyster can filter up to 30L/hr and clams can store toxins over 1yr after being exposed [Pomati, 2004].

While attention has focused on self-caught fish, presently most of the fish eaten by the Nigerian public comes from imported commercial sources.

Therefore, our future research strategic plan is to continue the research on speciation of heavy metals in Nigerian seafood and various species of imported seafood commonly available in supermarkets, open markets and fish markets in the Niger Delta Region.

Collaborative Research

Research is the backbone for the development of a nation and it is important that Government should give it a priority in their national budgets.

Collaborative and strategic partnerships between academia and industry are also crucial to enhance the two-way flow of knowledge between these sectors. This is because, the economic impact of fundamental chemistry research reaches far beyond any single sector and therefore Government and the private sector should not allow funding in this area to diminish.

It will be necessary to add here that, even though, chemistry is the most enabling science; in the process of research, discovery and innovation, chemistry works in tandem with other science disciplines including physics, biology, medicine, pharmacy, biotechnology, material science and engineering.

Therefore, it is our desire to collaborate with experts from other disciplines to carry out holistic investigations on trace element speciation in Nigerian seafood as well as imported fish species.

Our research group is called *The Environmental Chemistry Group (TECG).* TECG collaborates with other research laboratories around the world in trace element speciation research.

Conclusion

Dear Vice Chancellor, in conclusion, I want to say that the aim of this inaugural lecture is to provide an overview of the health hazards and sources of exposure of heavy metals to humans, introduce my contributions and future plans in heavy metals speciation research.

In order to protect the population, legislative control measures to minimize the presence of heavy metals in food should be put in place by establishing an environmental regulatory agency.

In 1999, the Federal Government of Nigeria established the Federal Ministry of Environment and scrapped the Federal Environmental Protection Agency (FEPA). It is important to make it clear that Ministry of Environment is meant for policy formulation while FEPA is supposed to serve as a regulatory and enforcement organ of the Government. The scrapping of FEPA has done more harm to our environment than good. I therefore call on the Federal Government to re-establish the Federal Environmental Protection Agency (FEPA) with a renewed charge to enforce environmental laws.

If your job or living circumstances expose you to heavy metals, you would do well to minimize or eliminate your exposure as much as possible. Be aware that there are many ways these toxins can be absorbed into your body--through foods and beverages, skin exposure, and via the air you breathe and the water you drink. So, whenever possible, wear gloves, use protective breathing apparatus, and be sure to obtain fresh air ventilation. Such preventative measures are worthwhile and important, but ultimately avoiding heavy metal exposure is impossible. The inescapable reality is that it is impossible in this day and age not to be exposed to heavy metals. It is only a matter of how much and how often.

The economic and social returns we enjoy today reflect the fruits of many years of investment in chemistry research. All over the world, chemistry research initiatives are adequately funded by Government and its agencies and the private sector. This year alone the UK Government under the Higher Education Funding Council (HEFC) budgeted the sum of £1.5 billion (₦375 billion) for research to be shared among the first fifteen (15) research rated Universities in the UK (RSC Newsletter, 2011).

Some Nigerian Universities are endowed with skilled and innovative academic workforce and is well placed to adopt and advance new ideas, successfully exploit new technologies and develop new and better products and services.

I therefore call on the Nigerian Government and its agencies and private sector to recognize that fundamental research in Chemistry is indispensible to the search for answers to some of the most important scientific, medical, technological and societal challenges facing this country.

Energy is an indispensible component line of any country's research output. With the present epileptic power outage, scientific and technological breakthroughs may elude Nigeria, if the situation is not urgently addressed. In order to address the present energy crises of this University, Government should seek to acquire gas turbine from the numerous gas fields around the University, so that the effort made by the present University administration towards research will be meaningful and sustained.

Once research becomes a priority for the Government, the private sector would be encouraged to follow. In this way, the benefits of Research and Development will be achieved.

Ladies and Gentlemen, in ending this lecture, I want you to go home with the news that the ordinary meaning of *Janus-faced* is *two-face* but in opposite direction.

Therefore; *If Chemistry is Janus-faced;*
And Heavy Metals are Janus-faced,
Then Everything is Janus-faced;
And Everybody is Janus-Faced.

Thank You

REFERENCES

Abia, A. A., **Horsfall, M. Jnr** and Didi, O (2003). The Use of Chemically Modified and Unmodified Cassava Waste for the Removal of Cd, Cu and Zn ions from Aqueous Solution. *Bioresource Technol, UK* 90 345 – 348

Almeida, P and Stearns, L (1998). "Political opportunities and local grassroots environmental movement: The case of Minamata". *Social Problems* 45 (1): 37–60.

Atkins, P (2011). A World of Science 9 (1) 2 - 7

Ayawei, N.; **Horsfall, M. Jnr** and Spiff, A. I. (2005). *Rhizophora mangle* Waste as Adsorbent for Metal ions removal from Aqueous Solution. *European Jour. of Scientific Res. Vol. 9 (1) pp 6- 21.*

Biney, C; Amuzu, A. T; Calamari, D; Kaba, N; Mborne, I. A; Naeve, H; Ochumba, P. BO; Osibanjo, O V and Saad, M. A 1994. Review of heavy metals in the aquatic environment. Ecotox. Environ. Safety, 28 123-159

Bryan, G. W; M. Waldichuk, R. J. Pentreath and Ann Darracott Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences © 1979 The Royal Society.

Clark RF, Williams SR, Nordt SP, Manoguerra AS (1999). "A review of selected seafood poisonings". *Undersea Hyperb Med* 26 (3): 175–84. PMID 10485519. http://archive.rubicon-foundation.org/2314. Retrieved 2008-08-12.

Daffus, John H. (2002). ""Heavy metals" a meaningless term? (IUPAC Technical Report)" Pure and Applied Chemistry, 2002, Vol. 74, pp. 793-807. doi:10.1351/pac200274050793

Darka, James (2006). Metals at your service. University of Johannesburg Press pp1-18

Darnall C.R. (1911), "The Purification of Water by Anhydrous Chlorine", American Journal of Public Health; 1: 783–97

Glanze, W.D. Mosby Medical Encyclopedia, Revised Edition 1996. St. Louis, MO: C.V. Mosby.

Deeds, J. R.; Landsberg, J. H.; Etheridge, S. M.; Pitcher, G. C.; Longan, S. W. Non-traditional vectors for paralytic shellfish poisoning. Mar. Drugs 2008, 6, 308-348.

Dupler, D. Heavy metal poisoning. Gale Encyclopedia of Alternative Medicine 2001. Farmington Hills, MI: Gale Group.

Ekpete,O A; **Horsfall, M. Jnr** and T. Tarawou (2010). Potential of fluted and commercial activated carbons for phenol removal in aqueous systems ARPN Journal of Engineering and Applied Science, USA September 2010. Vol. 5 No. 939 – 47

Epoch Times, Wednesday 6, 2010

Ferner, D.J. (2001). Toxicity, heavy metals. *eMed. J.* 25; 2(5): 1

Forstner, U 1985 in R. Lescheber, R. D Davis and L. P Hermite (eds), Chemical forms and reactivities of metals in sediments in Chemical Mehtods for Assessing Bioavailable Metals in Soils, Elsevier, London pp1-30.

Fenichell, Stephen (1996). *Plastic: The Making of a Synthetic Century*, HarperBusiness, , ISBN 0887307329 p. 17

Gardea-Torresdey, J.L., Tiemann, K.J., Gonzalez, J.H., Henning, J. A., Townsend, M.S., (1996b). Ability of Silica-Immobilized *Medicago sativa* (Alfalfa) to Remove Copper ions from Solution J. Hazard Mater. 57, 29 - 39

Gardea-Torresdey, J.L., Gonzalez, J.H., Tiemann, K. J., Rodrignuez, O., Gamez, G (1998). Phytofiltration of Hazardous cadmium, chromium, lead and zinc ions by biomass of *Medicago sativa* (Alfalfa). J. Hazard. Mater. 48, 191 – 206.

Gardea-Torresdey, J.L., Tiemann, K..J., Gamez, G., Dokken, K., (1999). Effect of Chemical Composition for Multi-Metal Binding by *Medicago sativa* (Alfalfa). J. Hazard. Mater. B 69, 41 – 51.

Gardea-Torresdey, J. L., Tang, L., Salvador, J.M., (1996a). Copper adsorption by esterified and unesterified fractions of Sphagnum peat moss and its different humic substances. J. Hazard. Mater. 48, 191 – 206.

Galvão JA, Oetterer M, Bittencourt-Oliveira MC, Barros SG, Hiller S, Erler K, Luckas B, Pinto E, Kujbida P. Saxitoxins accumulation by freshwater tilapia (Oreochromis niloticus) for human consumption. Toxicon 2009, 54(6), 891-894.

GESAMP 1988. Review of potentially harmful substances – arsenic and selenium Rep. Study. 28. 1-192 and UNEP Reg. Seas. Rep. Stud. 92. 1-172

Graham Lappin, Malcolm Rowland, R. Colin Garner. *The use of Isotopes in the Determination of Absolute Bioavailability of Drugs in Humans.* Expert Opin. Drug Metab. Toxicol. (2006) 2(3)

George, Timothy S. (2001). *Minamata: Pollution and the Struggle for Democracy in Postwar Japan*. Harvard University Asia Center. ISBN 0-674-00785-9.

Glanze, W.D. Mosby Medical Encyclopedia, Revised Edition 1996. St. Louis, MO

Haber, Fritz. “Enriching the Earth: Carl Bosch, and the Transformation of World Food Production by Vaclav Smil (2001) ISBN 0-262-19449-X

Ho, Y. S. (2003). Removal of copper ions from aqueous solution by tree fern. *Wat. Res* Vol 37 (5) 2323 – 2330.

Ho, Y. S., John Wase, D. A., Forster, C. F., (1995). Batch Nickel Removal from Aqueous Solution by Spagnum Moss Peat. *Wat. Res* Vol 29 (5) 1327 – 1332.

Horsfall, M. Jnr, Spiff, A.I. and Ogban, F.E. (1994). Petroleum hydrocarbon pollution: The distribution in Sediment and Water of the New Calabar River, Port Harcourt, Nigeria. *Journal of Science of Total Environment:* 141, 217 - 221.

Horsfall, M. Jnr and Acholonu, P. (1998). Total Hydrocarbon Content in the Tissues of Gastropod- *L.littorea* From the Niger Delta of Nigeria. *Environ. Review* 2 (2): 29 – 31.

Horsfall, M. Jnr; Howard, I.C. and Spiff, A.I. (1998). Tissue Distribution of Heavy Metals in Mudskipper (*Periophthalmus papillio*) from the Mangrove Swamps of the Coastal New Calabar River, Nigeria. *J. Appl. Sci. Environ. Manage.1 (1):50 -54.*

Horsfall, M. Jnr and Spiff, A.I. (1999). Speciation of Heavy Metals in inter-tidal Sediments of the Okrika River System, Rivers State, Nigeria. *Bull. Of Chemical Soc. of Ethiopia Vol. 13, (1) 1 – 9*

Horsfall, M. Jnr; & Spiff, A. I. (2002). Distribution and Partitioning of Trace Metals in Sediments of the Lower Reaches of the New Calabar River, Port Harcourt, Nigeria. *Environ. Monitoring & Assessment*, *The Netherlands* ***78:*** *309-326.*

Horsfall, M. Jnr; Abia, A. A; and Spiff, A.I. (2003). Removal of Cu (II) and Zn (II) ions from wastewater by Cassava (*Manihot esculanta Cranz)* waste biomass. *Africa Journ. Biotech.* ***2*** *(10) 360 -364*

Horsfall, M. Jnr and Abia, A. A (2003). Sorption of Cd(II) and Zn(II) ions from Aqueous solutions by Cassava Waste Biomass (*Manihot sculenta* Cranz). *Water Research* 37 4913 – 4923

Horsfall, M. Jnr and Spiff, Ayebaemi I. (2004). Studies on the Effect of pH on the sorption of Pb^{2+} and Cd^{2+} ions from aqueous solutions by *Caladium bicolor* (Wild Cocoyam) biomass. *Elec. Journal of Biotechnology*, Vol 7 (3), pp 310 – 320.

Horsfall, M. Jnr; A. I. Spiff and A. A. Abia (2004). Studies on the Influence of Mercaptoacetic Acid (MAA) Modification of Cassava *(Manihot esculenta* Cranz*)* Waste Biomass on the Adsorption of Cu^{2+} and Cd^{2+} from Aqueous Solution. *Bull. Korean Chem. Soc.* Vol. **25** (7), 969 – 976.

Horsfall, M. Jnr and Spiff, Ayebaemi I. (2004). Adsorption of Metal ions from Mixed Solutions by *Caladium bicolor* (Wild Cocoyam) Biomass. *Journal of Corrosion Sci. & Techno*l. Vol. **2,** pp 120 – 126.

Horsfall, M. Jnr and Spiff, Ayebaemi; I. (2005). Speciation and Bioavailability of Heavy Metals in Sediments of Diobu River, Port Harcourt, Nigeria. *European Journ. of Sci. Res. Vol. 6, (3) pp 20 – 36*

Horsfall, M. Jnr and Ayebaemi I. Spiff (2005). Effect of Temperature on the Sorption of Pb^{2+} and Cu^{2+} from Aqueous Solution by *Caladium bicolor* (Wild Cocoyam) Biomass. *Elec. Journal of Biotech. Vol. 8 (2); pp 162-169*

Horsfall, M. Jnr; and Spiff, A. I. (2005)d. Effect of 2- Mercaptoethanoic Acid Treatment of Fluted Pumpkin Waste (*Telfairia occidentalis* Hook f) on the Sorption of Ni^{2+} ions from Aqueous Solution. *J. Sci. & Ind Res. Vol. 64; pp 613 – 620.*

Horsfall, M. Jnr; Spiff, Ayebaemi I.; and Ogban, Fred E. (2005). Physicochemical Evaluation of the Sorption Process of Cu (II) on Pure and Activated Fluted Pumpkin (*Telferia occidentalis)* Waste Biomass. *European Journal of Sci. Res. Vol. 6, (5) pp 47 – 59.*

Horsfall, M. Jnr and Ayebaemi Ibuteme Spiff (2005)c. Adsorption of Transition metals in Aqueous Solutions by Fluted Pumpkin (*Telfairia occidentalis* HOOK f) Waste. *Chemistry & Biodiversity The Netherlands Vol. 2 pp 1266 – 1276*

Horsfall, M. Jnr and Ayebaemi I. Spiff (2005). Distribution of Trace Metals and Fulvic Acids in Sediments of the New Calabar River, Port Harcourt, Nigeria. *Asian Journal of Water, Environment & Pollution; pg. 75 – 79.*

Horsfall, M. Jnr and Spiff, Ayebaemi Ibuteme (2005). Effect of metal ion concentration on the biosorption of Pb^{2+} and Cd^{2+} by *Caladium bicolor (*wild cocoyam). *African Jour. of Biotech. Vol. 4 (2) pp 191-196.*

Horsfall, M. Jnr and Spiff, Ayebaemi; I. (2005). Kinetic Studies on the **Sorption** of Lead and Cadmium Ions from Aqueous Solutions by *Caladium bicolor (Wild* Cocoyam) Biomass. *Bull. Chem. Soc. Ethiop.19(1),89– 102.*

Horsfall, M. Jnr, F E. Ogban, and E. E. Akporhonor (2005). Effect of Heat Treatment on the Proximate Chemical Composition of African Pear (*Var. edulis*) Seed Flour. *European. J Sci Res. Vol 8 No 2 12 - 21*

Horsfall, M. Jnr and Spiff, Ayebaemi; I. (2005)b. Sorption of Lead, Cadmium, and Zinc on Sulfur-Containing Chemically Modified Wastes of Fluted Pumpkin (*Telfaria occidentalis)* HOOK f.). *Chem. & Biodiversity; The Netherlands Vol. 2; pp 373 – 385.*

Horsfall, M. Jnr and Spiff, Ayebaemi; I. (2005)a. Equilibrium sorption study of Al^{3+}, Co^{2+} and Ag^{+} in aqueous solutions by fluted pumpkin *(Telferia occidentalis* HOOK f*)* waste biomass. *Acta Chim. Slov. Vol. 52 pp 171 – 181.Slovakia*

Horsfall, M. Jnr, F. E. Ogban, and E. E. Akporhonor (2005). Sequential Fractionation of Trace Elements in Inter-Tidal Flat Sediments of the Brass River Estuary, Nigeria. *European J Scientific Research* Vol 7 (4) July 2005, 64 - 74

Horsfall, M. Jnr, F. E. Ogban, and E. E. Akporhonor (2005). Biosorption of Pb^{2+} from Aqueous Solution by *Rhizophora mangle* Aerial Root Waste Biomass. *Chemistry & Biodiversity, The Netherlands* Vol 2 No 9 1246 – 1255.

Horsfall, M. Jnr, Fred E. Ogban, and E. Akporhonor (2006). Recovery of lead and cadmium ions from Metal-loaded Biomass of Wild Cocoyam (*Caladium bicolor)* using Acidic, Basic and Neutral Eluent Solutions. *Elec. Journal of Biotechnology* , Chile Vol. 9 No 2 152 – 156, 2006

Horsfall, M. Jnr, Abia, A. A.; and Spiff, A. I. (2006). Kinetic studies of Adsorption of Cd^{2+}, Cu^{2+}, and Zn^{2+} ions from Aqueous solutions by cassava (*Manihot sculenta* Cranz) tuber bark waste. *Bio Resource Tech. UK 97, pp 283 – 291*

Horsfall, M Jnr and Vicente, J. L. (2007). Kinetic study of liquid phase adsorptive removal of heavy metal ions by almond tree (*Terminalia catappa* L.) leaves waste. *Bulletin of Ethiopian Chemical Society Volume 21 (3) 249 – 262.* Ethioppia

Horsfall, M Jnr; Ogban, F and Akporhonor, E. E (2007). Sorption of Chromium (VI) from Aqueous Solution by Cassava (Manihot sculenta CRANZ) Waste Biomass. *Chemistry & Biodiversity, The Netherlands Vol 3; 161 – 174*

Huot RI, Armstrong DL, Chanh TC (June 1989). "Protection against nerve toxicity by monoclonal antibodies to the sodium channel blocker tetrodotoxin". *J. Clin. Invest.* **83** (6): 1821–6. doi:10.1172/JCI114087. PMC 303901. PMID 2542373.

Howard, I. C; Gabriel, U. U and **Horsfall, M. Jnr** (2008). Trace metals in the tissues and shells of Tympanotonus fuscatus var. Radula from the Mangrove Swamps of the Bukuma Oil Field, Niger Delta. *European Journal of Scientific Research*. Vol 24 No 4. 468 - 476

Howard, I C; **Horsfall, M Jnr**, A. I. Spiff and S. C. Teme (2006). Variation of heavy metal levels in the tissue of *Periophthalmus papillio* from the mangrove swamps of the Bukuma oilfield, Rivers State. *Global Journal of Pure and Applied Sciences Vol 12 No 1 89 – 92*. Nigeria

Howard, I. C; **Horsfall, M. Jnr**; Spiff, A. I; Teme, S. C (2006). Physicochemical Characteristics of the Surface Water in an Oil – flow Station and its Environs in the Niger Delta Area, Nigeria. *African Journal of Science* Vol. 7 No 1 1513 - 1523

Howard, I. C; **Horsfall, M. Jnr**, Spiff, A. I and Teme, S. C (2006). Heavy metals levels in surface waters and sediments in an oil- field in the Niger Delta, Nigeria. *Global Journal of Pure & Applied Sci. Vol 12 (1)*

IOSHIC, (1999). International Occupational Safety and Health Information Centre. Metals. In Basics of Chemical Safety, Chapter 7, 1999 Sep. Geneva: International Labour Organization.

IUPAC, (1993). International Union of Pure and Applied Chemistry, Glossary For Chemists of Terms Used in Toxicology: Pure and Applied Chemistry, v. 65, no. 9, p. 2003-2122.

Juang, R. S. F. C; Wu, F. C; Tseng, R. L (2005). Characterization and use of activated carbon from bagasse for liquid phase adsorption. Colloid. Surfaces A: Physicochem. Eng. Aspects 210: 191-199

Kpee, F; **Horsfall, M. Jnr** and Spiff, A. I. (2000). Determination of Trace Metals in the Shellfish Dogwalk (*Thai haemostoma*) from Brass River, Nigeria. *J. Appl. Sci. Environ. Mgt. 4 (2) 91 - 94.*

Kumar P and Dara S S. (1982). Utilization of agricultural for decontaminating industrial/domestic wastewaters from toxic metals, *Agric. Wastes* 4 213 – 23.

Lagos, N.; Onodera, H.; Zagatto, P. A.; Andrinolo, D.; Azevedo, S. M.; Oshima, Y. The first evidence of paralytic shellfish toxins in the fresh water cyanobacterium Cylindrospermopsis raciborskii, isolated from Brazil. Toxicon 1999, 37, 1359-1373.

Landsberg JH, 2002. The effects of harmful algal blooms on aquatic organisms. Reviews in Fisheries Science, 10(2): 113–390.

Landsberg, J. H.; Hall, S.; Johannessen, J. N.; White, K. D.; (2006). Saxitoxin puffer fish poisoning in the United States, with the first report of Pyrodinium bahamense as the putative toxin source. Environ. Health Perspective 2006, 114, 1502-1507.

Leung, F.Y. Trace elements that act as antioxidants in parenteral micronutrition. Can. J. Nutr. Biochem. 1998; 9(6): 304-7.

Lide, D. CRC Handbook of Chemistry and Physics, 73rd Edition 1992. Boca Raton, FL: CRC Press.

LOW, K. S., LEE, C. K., and LEO, A. C. Removal of metals from electroplating wastes using banana pith. *Bioresource. Technology*, 1995, vol. 51**,** p. 227 – 231

Lupton, G.P., Kao, G.F., Johnson, F.B., Graham, J.H., Helwig, E.B. Cutaneous mercury granuloma. A clinicopathologic study and review of the literature. J. Am. Acad. Dermatol. 1985 Feb; 12(2, Pt. 1): 296-303.

Manju, G N; Raji, C and Aniruhan, T S (1998). Evaluation of coconut husk carbon for the removal of arsenic from water. Water Research. Vol 32, No. 10. 30662-30670

Malik, P K (2004). Dye removal from wastewater using activated carbon from saw dust: adsorption equilibrium and kinetics. J. Hazard. Mater., B113: 81-88

Maranon E and Saatre H, (1998). Heavy metal removal in packed beds using apple wastes, *Bioresour Technol*. 38: 39 – 43

McGuire, John L., Horst Hasskarl, Gerd Bode, Ingrid Klingmann, Manuel Zahn "Pharmaceuticals, General Survey" Ullmann's Encyclopedia of Chemical Technology" Wiley-VCH, Weinheim, 2007

Nriagu, J. O and Cooker, R. D 1980. Trace elements in humic and fulvic acids from Lake Ontario sediments. Environ Sci. Technol 6: 443-446

Nurnberg, H. W. Anal. Chem. Acta 1984 164 1-21

Okiemenn, F. E., Maya, A. O.and Oriahkhi, C. O.,(1998). Sorption of cadmium, lead and zinc ions on sulphur-containing chemically modified cellulosic materials. Int. J. Environ. Anal. Chem. 32: 23 - 27

OKoye, B. C. O 1991a. Heavy metals and organisms in the Lagos Lagoon Int. J. Environ. Stu.37, 265-292

Ottis WR, Roberts JW. Everyday exposure to toxic pollutants. Sci Am 1998; 2: 1-7

Pardo, R; Barrade, E; Perez, L and Vega M .1990. Determination of heavy metals in the sediments of the Pisuerga River. Wat. Res. 24 (3) 373-379

Pardo, R; Barrade, E; Perez, L and Vega, M. 1990. Determination and Speciation of heavy metals in the sediments of the Pisuerga River. Water Research 24 (3) 9-12

Pomati, F.; Burns, B. P.; Neilan, B. A. Identification of an Na(+)-dependent transporter associated with saxitoxin-producing strains of the cyanobacterium Anabaena circinalis. Appl. Environ. Microbiol. 2004, 70, 4711-4719.

Purves, D. Trace elements contamination of the environment, Elsevier. Amsterdam; 1985

Randall J M, Hautala E and Waiss A C. Removal and cycling of heavy metal ion from agricultural byproducts, *Proc. 4th Mineral Waste Utilization Symp*., Chicago, IL, USA (1974).

QUEK, S. Y, WASE, D.A.J and FORSTER, C. F. The use of Sago Waste for the Sorption of lead and Copper. Water SA, 1998, vol. 24, no. 3, p.251 –256

Randall J M, Reuter F C and Waiss A C, (1974). Removal of cupric ions from solution by contact with peanut skins, *J. Appl. Polym. Sci.*19 156 – 71.

Roberts, J.R. Metal toxicity in children. In Training Manual on Pediatric Environmental Health: Putting It into Practice 1999 Jun. Emeryville, CA: Children's Environmental Health Network

Sariciftci, N. S.; Smilowitz, L.; Heeger, A. J.; Wudl, F. (1992). "Photoinduced Electron Transfer from a Conducting Polymer to Buckminsterfullerene". *Science* **258** (5087): 1474.

Salau, A T (1993). Environmental crisis and development in Nigeria. University of Port Harcourt Inaugural lecture series No 13.

Sato, S.; Kodama, M.; Ogata, T.; Saitanu, K.; Furuya, M.; Hirayama, K.; Kakinuma, K. Saxitoxin as a toxic principle of a freshwater puffer, Tetraodon fangi, in Thailand. Toxicon 1997, 35, 137-140.

Shimizu, Y.; Norte, M.; Hori, A.; Genenah, A.; Kobayashi, M. Biosynthesis of saxitoxin analogs: the unexpected pathway. J. Am. Chem. Soc. 1984, 106, 6433-6434.

Silver, Mary Wilcox (2006), "Protecting Ourselves from Shellfish Poisoning", *American Scientist* **94** (4): pp.316–325

Smedley, P. E; J. Knudsen and D. Maiga (2007). Arsenic in groundwater from mineralised Proterozoic basement rocks of Burkina Faso Applied Geochemistry, Volume 22, Issue 5, May 2007, Pages 1074-1092

Smith, E. A.; Grant, F.; Ferguson, C. M.; Gallacher, S. Biotransformations of paralytic shellfish toxins by bacteria isolated from bivalve molluscs. Appl. Environ. Microbiol. 2001, 67, 2345-2353.

Spiff, A. I; **Horsfall, M. Jnr** and Dairo D. I. (1999). Determination of Cadmium levels in Cigarettes smoked in Nigeria. *J. of Appl. Sci. Environ. Manage*. Vol. 2, (1), 43-45

Sun, Gang and Weixing Shi. (1998). Sunflower as Adsorbents for the Removal of Metal ions from Wastewater. *J Industrial Engineering and Chemical Research*, 37. 1324 – 1328

Tarawou, T; Wankasi, D; **Horsfall, M. Jnr** (2010). Sorption of Ni^{2+} on Acid and Base Modified Cassava (Manihot esculenta Cranz) Peelings Waste Biomass. *Inter. J.Physic. Sci. Benin Republic* Vol 2 No. 4 116 - 124

Tarawou, T. and **Horsfall, M. Jnr** (2007). Adsorption of Methylene Blue Dye on Pure and Carbonized Water Weeds. *Bioremediation Journal USA, Vol 11 No 2,1 – 8.* USA

Tarawou, T; Wankasi, D; **Horsfall, M. Jnr,** (2010). Column Removal of methylene blue using activated carbon derived from water spinach (Ipomoea aquatic) *Int. J. Biol. Chem. Sci Cameroon***,**. Sci Vol 4. No 3. 535 – 545

Tarawou, T; Wankasi, D; **Horsfall, M. Jnr,** (2010). Sorption kinetic study on the removal of basic blue-9 dye using activated carbon produced from water spinach. *Int. J. Biol. Chem. Sci Cameroon,* Vol 4. No 3. 703 – 709

Tarawou, T; **Horsfall, M. Jnr** and Vicente, J L (2007). Adsorption of Methyl Red using Water hyacinth (*Eichornia crassipes*) Biomass. *Chemistry & Biodiversity, The Netherlands* Vol. 4: No. 22 :36 – 2245.

Tarawou, T; Wankasi, D; **Horsfall, M. Jnr,** (2010). Sorption of manganese (II) and chromium (III) ions from aqueous solution using water hyacinth biomass (Eichhornia crassipes) J. *Environmental Sci. & Engineering USA* Vol 4. No 11.Serial No. 36. 38 - 43

Tessier, A; Campell, P. G. C and Bisson, M. 1979. Sequential extraction procedure for the speciation of partition of particulate trace metals. *Anal. Chem*. 51 844 – 581

Varro apud Augustine (1449). De Civitate Dei VII 9 and 3; Servius Aen.

Weisman, Steven R.(1985). "Bhopal a Year Later: An Eerie Silence". *The New York Times*. p. 5.

Winterbourn, M.J., McDiffett, W.F and Eppley, J.S. (2000). Aluminium and iron burdens of aquatic biota in New Zealand streams contaminated by acid mine drainages: effects of trophic level. *The Science Total Environment, USA*. 254, 45 – 54.

Wankasi, D; **M. Horsfall Jnr** and A. I. Spiff (2006). Sorption Kinetics of Pb^{2+} and Cu^{2+} ions from Aqueous Solution by Nipah palm (*Nypa fruticans* Wurmb) Shoot Biomass. *Elec. Journal of Biotechnology Chile,* Vol. 9 No 5, 587 – 592

Wankasi, D.; **Horsfall, M. Jnr** and Spiff, A. I. (2005). Desorption of Pb^{2+} and Cu^{2+} from Nipah palm (*Nypa fructicans* Wurmb) Biomass. *African J. Biotechnology, Vol. **4** (9) pp 923 – 927*

Wankasi, Donbebe; **Horsfall, M. Jnr** and Spiff, Ayebaemi I. (2005). Retention of Pb (II) from Aqueous Solution by Nipah Palm (*Nypa fructicans, Wurmb)* Biomass. *J. Chil. Chem. Soc. Chile 50, No. 4; pp 691– 696.*

Wikipedia http:/ en.wikipedia.org/ wiki/Mina Mata disease

World Health Organization (WHO), 2000 Arsenicosis Bulletin, volume 78, (9):pp 1096.

Yakubu, A. F.; Sikikoki, F.D. and **Horsfall, M. Jnr**. (1998). An investigation into the Physiochemical conditions and Planktonic organisms of the lower Reaches of the Nun River, Nigeria. *J. Appl. Sci. Environ. Mgt. Nigeria (1) 38 – 42.*

ZHOU, J. L, HUANG, P. L and LIN, R. G. Sorption and Desorption of Cu and Cd by macroalgae and microalgae. *Environmental Pollution*, 1998, 101, 6 – 75

CITATION

ON

PROFESSOR MICHAEL HORSFALL Jnr

Our 81st inaugural lecturer, Professor Michael Horsfall Jnr was born on the 11th of November, 1965 at Buguma City in the ASARI-TORU local Government area of Rivers State, Nigeria. He attended Baptist State School Buguma, from 1971 – 1977, Kalabari National College, Buguma 1977 – 1982, University of Port Harcourt Port Harcourt 1982-1992, where he obtained a BSc (Chemistry) 1986, MSc (Analytical Chemistry) 1989 and PhD (Environmental Chemistry) 1992. On the 17th of July 1992, Horsfall was employed as a lecturer II in the same department where he rose steadily to the rank of Professor at the age of 45 in 2011.

In 1994, he was granted an NUC-World Bank Staff Development scholarship for a post – doctoral research fellowship at the Loughborough University of Technology, Loughborough, England where he worked with the World's foremost inorganic chemist – Prof. (Dr). J. D. Lee and Dr Tony Edmunds, on trace elements speciation and biogenic amines in wines produced in Nigeria.

Due to his expertise in the area of environment, Horsfall was appointed Special Assistant in 1999, by the Rivers State Government to serve the newly created Ministry of Environment and Natural Resources.

In 2000, the Rivers State Government sponsored Michael Horsfall to the University of Maryland, Maryland, USA, Offshore Environmental Systems of Florida, Miami USA and Fresh-kills Waste Management Company, New York, USA on the Proposed

Waste to Energy Recovery Plant Project of the Rivers State Government.

In 2001, our inaugural lecturer was granted a travel fellowship to Kenya by the United Nations Environment Programme (UNEP) to attend the 5th Global Training Program in Environmental Law and Policy.

In 2004 – 2005, he served as a visiting senior lecturer in the Delta State University, Abraka, Nigeria.

He is also a reviewer to several national and international journals and Executive Editor of the World Bank assisted Journal of Applied Sciences and Environmental Management based in the University of Port Harcourt for about 12 years now.

For three years, (2006 – 2009) our Inaugural Lecturer today was a UNESCO fellow. He spent three months every year within the period working with Prof. (Dr). Jose. L. Vicente at the Institute of Theoretical and Applied Physical Chemistry, University of La Plata, La Plata, Argentina on Gas Phase Adsorption of activated carbon from the vegetable (Ugwu) *Telfairia occidentalis*, fluted pumpkin waste (waste to wealth in the entrepreneurial spirit).

Horsfall had attracted two International Research Grants from the International Foundation for Science (IFS), Sweden in partnership with the Inter-Islamic Network on Water Resources Development and Management (INWRDAM), Islamabad, Pakistan and the Committee on Scientific and Technological Cooperation (COMSTECH), Jordan in 2004 and 2006 respectively. He is currently serving as one of the consultants to the International Foundation for Science (IFS) in Africa.

In September 2007, a travel fellowship was granted to Professor Michael Horsfall Jnr by the Organization for Prohibition of

Chemical Weapons (OPWC) to present a lead paper on the Fractal Dimension of Liquid-Phase Adsorption at the First Annual Congress of the Federation of African Societies of Chemistry at the University of Addis Ababa, Ethiopia.

Prof. Michael Horsfall Jnr hosted two scientists in 2007; one from the University of Zimbabwe, Harare-Zimbabwe and the other from University of Agriculture, Abeokuta-Nigeria under the sponsorship of the International Foundation for Science (IFS), Sweden.

In 2011, our inaugural lecturer was awarded a Royal Society of Chemistry research fellowship at the Trace Element Speciation Laboratory (TESLA), University of Aberdeen, Scotland, U. K

Service to the University

He has served the University of Port Harcourt in several capacities including Acting Deputy Vice Chancellor (Research and Development), Head, Department of Pure & Industrial Chemistry, Editorial Member of Graduate School Publications Committee, University of Port Harcourt Book and Journal Publications, Member, Curriculum Review Committee for Science Laboratory Technology Programme (SLTP), which successfully upgraded it to d Degree awarding status. Member of several committees in the Department, Faculty of Science and School of Graduate Studies. In 2009, he served as Senate Representative on the Publications Board of the University of Port Harcourt.

Our inaugural lecturer has supervised several undergraduate and graduate research projects and has over eighty (80) publications in international and national refered scientific journals. Horsfall has attended several international and national conferences. He is a member of the Royal Society of Chemistry, New York Academy of Science, Nigerian Environmental Society, Chemical

Society of Nigeria, International Chemistry Society of Africa, American Chemical Society, South African Chemical Society and Tribology Society of Nigeria.

He is currently the external examiners to the Undergraduate programmes in the Department of Chemistry of the Universities of Uyo, Madonna and Niger Delta University. In April 2005 and July 2006, he was appointed external examiner by the Annamalai University, Annamalainagar, India, where he served as eternal eaminer to assess PhD Thesis.

Horsfall was appointed Professor of Environmental Science and Health in 2006, by the University of Science & Technology, Bulawayo, Zimbabwe (declined) and Professor of Environmental Chemistry in 2011 by the University of Port Harcourt, Port Harcourt, Nigeria.

Professor Michael Horsfall Jnr has been appointed as a member of the Technical Committee on Environmental Systems by the International Association of Science and Technology for Development (IASTED), Canada for a three year term 2011-2014.

His current research area is trace element speciation in Nigerian seafood and currently the recipient of a Royal Society of Chemistry fellowship at the Trace Element Speciation Laboratory (TESLA), University of Aberdeen, Scotland, U. K, working with Professor Jorg Feldman.

Vice Chancellor Sir, I hereby present to you, the 81st Inaugural Lecturer of the University of Port Harcourt, Professor Michael Horsfall Jnr who will be celebrating his 46th birthday tomorrow, November 11, 2011.

Professor (Barrister) Bio L. Nyananyo