FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

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INAUGURAL LECTURE SERIES 66

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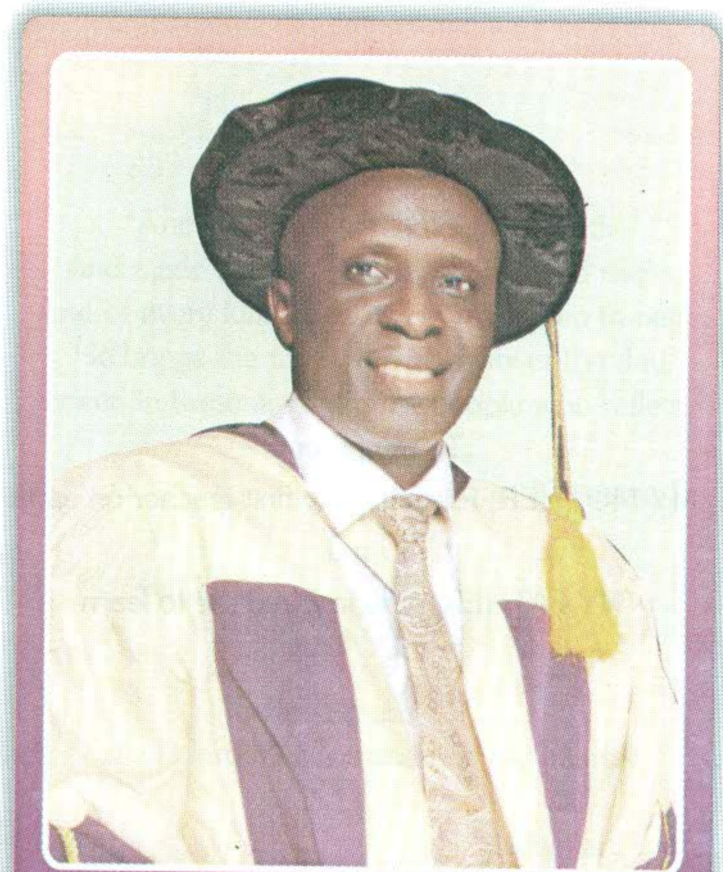

Yahaya Ahmed, IYAKA

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Professor of Chemistry

To my parents –

MY MOTHER, for being my first teacher on earth

and

MY FATHER, who inspired me to learn

EPIGRAM

"And He (God) spread out the earth,
And made therein firm mountains and rivers,
And of every kind of fruits He made two in pairs,
He brings the night as a cover over the day,
Indeed in these are signs for people who reflect."

Quran 13: Verse 3

"Living nature ....
shall plan my ways and rule my heart."

(Newman)

PROLOGUE

My beginning

I was born in a learning environment; I started by learning and completing the recitation of the holy Quran at the tender age of seven. My late father was an Alim and a merchant who believed strongly that "only men of knowledge can be leaders of mercy to their people" and he wanted that for his child. I never experienced the pastime and frivolities of little children; my childhood was rather engaged in learning. In exchange to learning my father gave me exceptional privilege a child could enjoy and loved me very tremendously to the envy of my siblings and step mothers. Perhaps, because I was also his first surviving male child; verily my father was my **best friend**.

The Unseen Hands of Destiny in the choice of my Career

As a child I was endowed with an unusual intellect; always in the first position throughout my primary school days and a college scholar at the prestigious Federal Government College, Ilorin. After my secondary education, I was admitted into the School of Basic Studies, Zaria with my Mock result. However, when the GCE (O level) result was released my **Chemistry** was not included; by implication I was not to continue with my subjects' combination of Biology, Chemistry and Physics. Nevertheless, when the team of the staff registering us saw my result, they argued that a candidate with such distinctions in his result, coupled with the standard of my Secondary School, they were confident that my Chemistry result would be released and I would pass. Yes, that was how **the unseen hand of destiny intervened**; I offered chemistry at "A" level **without** "O" level Chemistry result (of course with all Glory to Allah my Chemistry result was later released with a distinction grade).

Moreover, I came by vicissitude, an accident of time which is said to be the greatest misfortune of life; I had three years of unsuccessful academic life which again only my late father understood best. To the glory of God those three years were the best formative years of my life and existence.
Alhamdulillah (All praise is due to Allah)!

My Choice of Chemistry
Yes, I wrote to a very close uncle and friend:

> *"You may probably not like the course of my choice, but I am at an end; at a point where I have to choose **the best** before me, though I am not alone in this and that is my only consolation".*

These were my words, when I ventured into Chemistry as a career and a profession. Consequently, to the Glory of the Lord (my Creator) I graduated as the best graduating student in **Pure Chemistry** in my set.

For the Sake of my Friend: Usman Nda – Umar
In our undergraduate days, we had teachers that gave their commitment and time; the best was Prof. L. G. Hassan – my Organic Chemistry teacher and my project supervisor. Hence, the only option before me at the Postgraduate level was Organic Chemistry. However, my good friend and faithful comrade Usman turned me away, to study Analytical Chemistry. Today, by the Mercy of Allah, I am a Professor of Chemistry with specialization in Analytical Chemistry; the **best place** I ought to be. Alhamdulillah!

INTRODUCTION

1.1 Inaugural lecture

Mr. Vice-Chancellor Sir, in these days that the best academic practice is to interact and take the ownership of learning, coupled with information surge I really marvel whether this assembly is really necessary. My only hope is that this professorial inaugural lecture at the end of it, may perhaps accord me an exceptional privilege and a feeling of immense humility for the following reasons:

- ✓ inaugural lectures are a part of an important research and a valued tradition in the University system;
- ✓ it will provide an opportunity for me to appreciate the loved ones, my mentors and colleagues, whose support over a lifetime, has led me to this remarkable day;
- ✓ perhaps my lecture may be plausible enough to inspire a young concessive mind to see the beauty of chemistry as a "worthy profession";
- ✓ it will provide me a moment to tell the world (concisely) what I have learnt and done as an academician; in the words of Bammera Pothanna:

"What I have heard or learnt (or seen)
From many a scholar,
A pious hope it has been,
To render it crystal clear"
Unsornii ya Allah (So help me God)!

1.2 The title of my inaugural lecture

"I find purer philosophy in a Poem than
*In a conclusion of Geometry, a **Chemical analysis**, or*
In a Physical law"

(Wilfred Owen)

At the prime University of Ibadan, the erudite Prof. O. Osibanjo planted the seed for <u>my quest</u> for the **fascinating Elements in Soils** and the eminent Prof. S. E. Kakulu at my PhD level increased <u>my concern</u> for them, while they both <u>nurtured my inspiration and deep love</u> for **Analytical Chemistry**.

As to my question, I derived my inspiration from the words of Bill Nye who stated thus:

"Everyone you will ever meet,
knows something you don't."

Hence, the theme of my Inaugural Lecture:

"The Fascinating Elements in Soils:
Are you seeing what I am seeing?"

Subhanaka wa bi ahmdik (Glorified be you [Allah] and unto you be the praise)!

Mr. Vice - Chancellor Sir and distinguished audience in my lecture I will talk about:

- ✓ Chemistry
- ✓ Analytical Chemistry

- ✓ The Chemical Elements
- ✓ The Heavy Metals
- ✓ Soils
- ✓ My Contributions
- ✓ Conclusion and Recommendations
- ✓ Acknowledgements.

CHEMISTRY

"What in the world isn't chemistry?"
(Anonymous)

Chemistry is an experimental science that deals with the **study of matter**, including its composition, structure, physical properties, and reactivity. The practice of chemistry is not limited to chemistry books or laboratories: **It happens** whenever someone is involved in changes in matter or in conditions that may lead to such changes.

Attempts to understand the behaviour of matter extend back to more than 2500 years. The Greek postulate claimed that matter consists of four elements; air, earth, fire, and water.

2.1 The Age of Alchemy

It was not until about 320 BCE, at the time of Alexander the Great, that the alchemists made serious studies of **chemical changes**. Alchemy encompassed Greek and Egyptian as well as Arabian and Chinese concepts of **matter and energy**. The early alchemists were not scientists, and they also did not use scientific procedures, but they were philosophical and theological about their trial-and-error procedures (Figure 1). They were **unable to decipher the nature of chemical reactions**, but they did **make some discoveries that advanced knowledge.**

Most early alchemists are **unknown**, considering that they were very **secretive** about their methods and left little in the way of written history. Their goals were mystical, economic, secret, unpublished, and unshared. The alchemists' main search was for

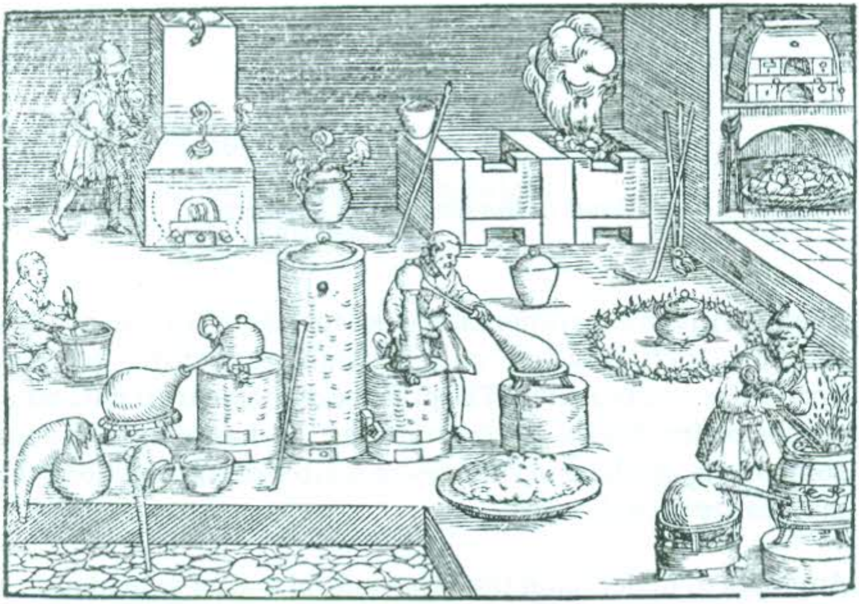

Figure 1: An alchemist's workshop circa 1580 [Although alchemy made some useful contributions to how to manipulate matter, it was not scientific by modern standards (credit: Chemical Heritage Foundation)]

the "philosopher's stone" that could unlock the secrets of transmutation — that is, the secrets of how to transform base metals and chemicals into different, more useful and valuable products, such as gold and silver. This also led to the futile search over many centuries for the *elixir vitae* that would be both the universal "cure" for all illnesses and the way to achieve "immortality".

For over 2,000 years, alchemy was the only "chemistry" studied. Alchemy was the predecessor of modern chemistry and contributed to the slow growth of what we know about the Earth's chemical elements. For example, the alchemists' interest in a common treatment for all diseases led to the scientific basis for the art of modern medicine. In particular, the alchemist/ physician Paracelsus (1493–1541) introduced a new era of medicine known as iatrochemistry, which is, chemistry applied to medicine. In addition, alchemists' elementary understanding of how different substances react with each other led to the concepts of atoms and their interactions to form compounds.

2.2 The Age of Modern Chemistry

It is both difficult to determine an exact date for the beginning of modern chemistry and impracticable to bestow the designation of "father of chemistry" on any one individual. Some historians date the end of alchemy and the beginning of modern chemistry to the **early seventeenth** century. Over the years many men and women of different races have contributed to our current knowledge and understanding of chemistry. A few examples include:

In 1661 ***Robert Boyle*** (1627–1691), an early chemist from Great Britain, published a book titled ***The Skeptical Chymist,*** which was the beginning of the end of alchemy. His book ruled the perceptions and behavior of early scientists for almost 100 years. Two of his contributions were the use of experimental procedures to determine properties of the chemical elements and the concept that an element is a substance that cannot be changed into something simpler.

Robert Boyle is best known for Boyle's Law, which states that the volume of a gas varies inversely with the pressure applied to the gas when the temperature remains constant.

Most historians credit the French chemist, **Antoine-Laurent Lavoisier** (1743–1794) with the death of alchemy and the birth of modern chemistry. His many contributions to the profession included the important concept that one must make observational measurements and keep accurate written records. Lavoisier mixed substances, burned common materials, weighed and measured the results. His work led to the discovery of more than 30 elements.

He described **acids, bases,** and **salts** as well as many organic compounds. Through a unique experiment with water (H_2O), he determined that it is made up of the gases hydrogen and oxygen, with oxygen having a weight eight times that of hydrogen. This led to a later theory of the Law of Definite Proportions, which states that a definite weight of one element always combines with a definite weight of the other(s) in a compound. (It should be noted that Lavoisier was unaware that two atoms of hydrogen combine with one atom of oxygen to form a water molecule. Therefore, the actual ratio of weight [atomic mass] is 1:16 instead of 1:8).

Jöns Jakob Berzelius (1779–1848), a Swedish chemist, is also considered one of the founders of modern chemistry. He prepared, purified, and identified **more than 2,000 chemical elements and compounds**. He also determined the atomic weight (mass) of several elements and replaced pictures of elements with symbols and numbers, which is the basis of our chemical notations today.

2.3 Chemistry: The Central Science

Chemistry is sometimes referred to as "the central science" due to its interconnectedness with a vast array of other STEM disciplines (STEM stands for areas of study in the Science, Technology, Engineering, and Mathematics fields). Chemistry and the language of chemists play vital roles in biology, medicine, material science, forensics, environmental science, and many other fields (Figure 2).

- The basic **principles of physics are essential for understanding** many aspects of chemistry, and there is extensive overlap between many sub disciplines within the two fields, such as chemical physics and nuclear chemistry.
- Mathematics, computer science, and information theory provide important **tools** that **help us** calculate, interpret, describe, and generally **make sense of the chemical world**.
- Biology and chemistry converge in biochemistry, which is crucial to understanding the many complex factors and processes that keep living organisms (such as humans) alive.
- Chemical engineering, materials science, and nanotechnology combine chemical principles and empirical findings to **produce useful substances**, ranging from gasoline to fabrics to electronics.
- Agriculture, food science, veterinary science, brewing and wine making help to provide sustenance in the form of food and drink to the world's population.
- Medicine, pharmacology, biotechnology, and botany identify and produce substances that help keep us healthy.
- Environmental science, geology, oceanography, and atmospheric science **incorporate many chemical ideas** to help us better understand and protect our physical world.
- Chemical ideas are further used to help understand the universe in astronomy and cosmology.

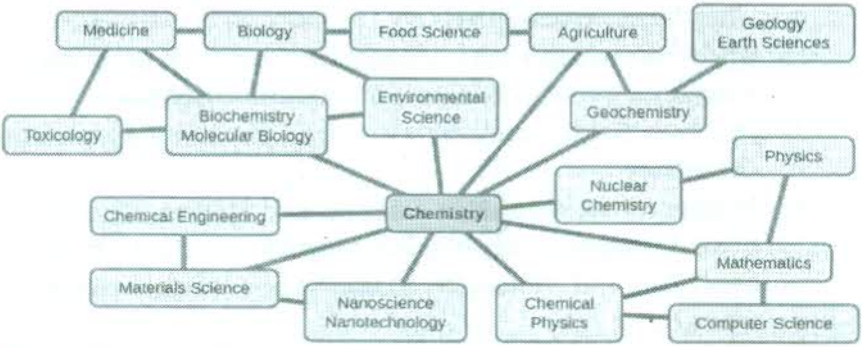

Figure 2: Some of the interrelationships between chemistry and other fields

At its core, chemistry explains how the world around us works. After all, everything including ourselves is made out of **atoms** and **chemical compounds** which implies that knowing the basics of chemistry helps us to understand how everything in the world interacts.

Plate 1: The relevance of Chemistry

Though, there are many approaches to studying chemistry, but, **historically and arbitrarily as well as for convenience** sake, we can **traditionally divide chemistry into five fields**: organic, inorganic, physical, biochemical, and **analytical** chemistry.

THE EVOLUTION OF ANALYTICAL CHEMISTRY

"**Chemical analysis** is based directly on general chemistry, and .... at the same time it must be regarded as one of the **fundamental pillars**, upon which the **entire scientific edifice rests**; ......and its usefulness to doctors, pharmacists, mineralogists, enlightened farmers, technologists, and others requires no discussion."

(Fresenius, 1866)

The term "analysis" appears explicitly for the first time around the turn of the **nineteenth century** in the title of the book **"Handbook for the Chemical Analysis of Minerals".** Robert Bunsen is rightfully acknowledged as the harbinger of "modern analysis", but much of discipline's distinctive scientific character was provided by Wilhelm Ostwald (1894) building on the activities of Van't Hoff and Walther Nernst.

3.1 Analytical Chemistry

"Analytical Chemistry is what Analytical Chemists Do"

(Charles N. Reilly on the occasion of his Fisher Award Address in April, 1965)

Analytical Chemistry can be defined in four simple ways as the:

i. discipline in *charge* of "**Analysis**"
ii. discipline in charge of the ***production*** of so named "(bio)chemical information" or "analytical information";
iii. discipline of **(bio)chemical *measurements***; and

iv. **chemical metrological discipline**, which is related to the previous definition.

The (above) four general definitions have been used to formulate various more **conventional definitions** such as the following:

- □ *"Analytical Chemistry is a metrological discipline that develops, optimizes and applies measurement processes intended to produce quality (bio)chemical information of global and partial type from natural and artificial objects and systems in order to solve analytical problems derived from information needs"*

  (Valcárcel, 2000)

- □ *"Analytical Chemistry is a scientific discipline that develops and applies methods, instruments and strategies to obtain information on the composition and nature of matter in space and time"*

  (Kellner et al., 2004)

3.1.1 Aims of Analytical Chemistry

Analytical Chemistry has two essential **aims**:

i. The **intrinsic**, is the obtainment of as high metrological quality as possible (i.e. of as true as possible analytical information with as low as possible uncertainty).

ii. The **extrinsic** aim is solving analytical problems derived from (bio) chemical information needs posed by "clients" engaged in a great variety of activities (health, general and agrifood industries, and the environment).

3.1.2 The Main Objectives of Analytical Chemistry

I. The magnifying; to obtain a large amount of (bio) chemical information of a high quality,

ii. The reducing; to use less material (sample, reagents), time and human resources with minimal costs and risks for analysts and the environment.

The aims and objectives of Analytical Chemistry share two sides (basic and applied); these are usually in contradiction and require appropriate harmonization. Thus, ensuring a high metrological quality may be incompatible with obtaining results in a rapid and economical manner. In fact, obtaining more and better (bio) chemical information usually requires spending more time, materials and human resources, as well as taking greater risks. Balancing the previous two aims and objectives requires adopting quality compromises (Valcárcel and Lendl, 2004) that should be clearly stated before specific analytical processes are selected and implemented.

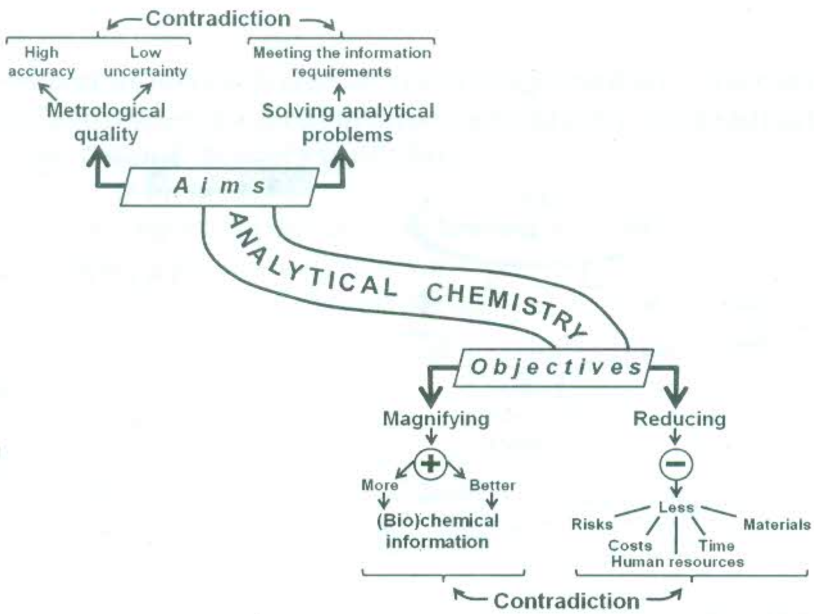

Figure 3: Aims and Objectives of Analytical Chemistry

3.1.3 Research and Development in Analytical Chemistry

The basic side of Analytical Chemistry encompasses a variety of Research and Development (R& D) activities aimed at **improving existing methods and/or developing new ones** in response to new and challenging information needs. These activities can produce both tangible and intangible tools as illustrated in Figure 5 (Valcárcel *et al.*, 2007).

Typical **tangible analytical tools** include instruments, apparatus, certified reference materials, immobilized enzymes and engineering processes adapted to the laboratory scale (e.g. supercritical fluid extraction, freeze-drying).

The **intangible analytical tools** are analytical strategies, basic developments (e.g. calibration procedures) and chemometric approaches (e.g. new raw data treatments, experimental design of analytical methods).

Transfer of technology in this context is more closely related to **tangible** Research and Development tools, whereas **transfer of knowledge** is mainly concerned with **intangible** Research and Development analytical tools; in any case, the two are difficult to distinguish.

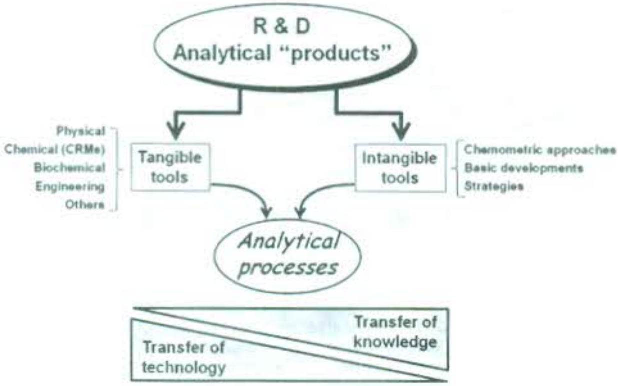

Figure 4: Main outputs of research and development in Analytical Chemistry

3.1.4 Social responsibility of Analytical Chemistry

Social Responsibility of Analytical Chemistry, SRAC (Valcárcel and Lucena, 2012) is directly related to the impact of (bio) chemical information or knowledge from objects and systems to society, in general, and to human and animal health, the environment, industry and agrifoods, among others, in particular.

SRAC encompasses **two basic requirements**, namely:

- producing reliable data, information and knowledge by using sustainable procedures in the framework of so named "green methods of analysis" (Armenta and Garrigues, 2008); and
- ensuring consistency of delivered data, information and knowledge with the facts to avoid false expectations and unwarranted warnings.

Analytical Chemistry can therefore provide society with signals (data), results (information) and knowledge (reports) which can have a rather different impact. As can be seen in Figure 5, SRAC has **two complementary connotations**:

- The **internal connotation** is the sustainable production of reliable data and results, and their appropriate transfer — which can be made difficult by contextualization and interpretation errors if left in the hands of nonexperts.

- The **external connotation** is the appropriate delivery of reports (knowledge) to provide society with accurate information about the composition of natural and artificial objects and systems.

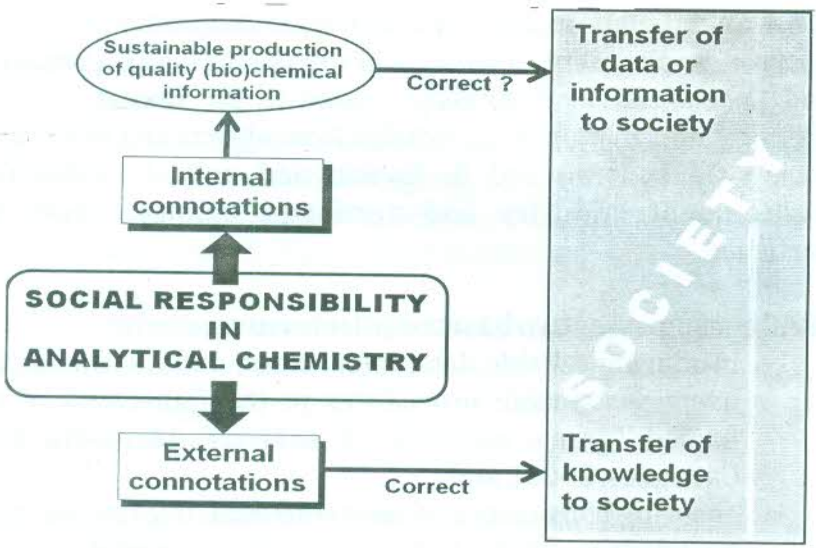

Figure 5: Connotations of Social Responsibility in Analytical Chemistry and ways to transfer data, information and knowledge to society

THE CHEMICAL ELEMENTS

*"...Analyse me that I may learn to know myself and that I emerge a **pure element**, worthy to be included in the group of elements already free from the bonds of their earthly life..."*

(A Chemist's Prayer – Therese Southgate, 1946)

The elements are the **basic units of all types of matter** and their number has grown from **four** in the days of the Greeks to **118** at present. In 1800, only 31 elements were known. By 1865, the number of identified elements had more than doubled to 63. Up until 1939 only 88 naturally occurring elements had been discovered. It took a dramatic modern technique (based on Ernest O. Lawrence's Nobel-prize-winning atom smasher, the cyclotron) to synthesize the most recently discovered elements. **Efforts to synthesize new elements are continuing.**

During the passage of scientific history, the very idea of "element" has undergone several great changes. Empedocles, the Greek natural philosopher, poet and physician proposed the theory of the **four elements**; earth, air, fire, and water calling them the *"rhizomata"(or radices, stoicheia or elementa),* the roots of all things (Freeman, 1962). Aristotle considered these as being combinations of four properties: hot, cold, dry, and moist. However, Boyle contends that earth, air, fire, and water cannot be elements because they are not universally distributed (Togeas, 2006). Lavoisier relaxes the strict postulate of universal distribution by observing that, for a simple substance to be an element, it is:

"………also necessary for it to be abundantly distributed in nature and to enter as an essential and constituent principle in the composition of a great number of bodies."

(Guerlac, 1973)

There is a table of thirty – three (33) simple substances in the Elements of Chemistry by Lavoisier (1743 – 1794); twenty – six (26) of which appear in the Modern Periodic Table of Elements. Furthermore, in 1769, Lavoisier and others published a book titled *"The Methods of Chemical Nomenclature" that* proposed a logical systematic language of chemistry. Even with modifications by the Geneva System of 1892 and additional reforms by the International Union of Pure and Applied Chemistry (IUPAC) in 1930, Lavoisier's nomenclature of chemical names and symbols is still in use today.

It is also apparent that our present knowledge of the elements stretches back to:

- the first discovery of a true element phosphorus by Dr. Brand of Hamburg, in 1669;
- the discovery of aluminum, barium, boron, calcium, magnesium, potassium, sodium, and strontium by Davy when in 1807 he applied the method of electrolysis, using a development of Volta's pile as a source of current;
- the German physicist W. K. Roentgen and his discovery of x rays in 1895;
- a once unknown Swiss patent clerk, Albert Einstein, and his now famous theories;
- Poland's Marie Curie who, in 1898, with her French husband Pierre laboriously isolated polonium and radium;
- the Dane Niels Bohr and his 1913 idea of electron orbits;
- England's Ernest Rutherford, who in 1919 proved that,

occasionally, when an alpha particle from radium strikes a nitrogen atom, either a proton or a hydrogen nucleus is ejected;

$$_7N^{14} + {_2He^4} \rightarrow {_1H^1} + {_8O^{17}}.$$

- the element Francium - 87; the last of the natural or original 92 elements discovered in 1939 by French Scientist Marguerite Perey;
- the French scientist H. A. Becquerel, who first discovered something he called a "spontaneous emission of penetrating rays from certain salts of uranium"; and
- still further.

4.1 The Modern Periodic Table

The modern Periodic Table is arranged in order of increasing atomic number, which is also the number of protons in the nucleus of an atom. The lightest atom is Hydrogen; with an atomic number of 1 and the **heaviest naturally occurring element** is Uranium, with an atomic number of 92. The **heaviest human - made element** has atomic number of 118 and its discovery was announced on October, 2006, as a result of collisions between Californium - 249 atoms and calcium - 48 ions; it is believed to be a semi - conducting noble gas.

Most of the elements in the Periodic Table are metals (Figure 6); the metals begin on the left - hand side and extend until the stair - step line, where the metalloids(semi - metals) come in, before the fewer non - metals on the right - hand side. The representative elements are Groups 1 - 2, and 13 - 18, while the transition metals are Groups in - between, 3 and 12. The two rows of elements below the main table are the inner transition metals; the first row consist of the Lanthanides (atomic numbers 58 - 71) because their first member is Lanthanum, and the second row is made up of Actinides (atomic numbers 90 - 103), so named because their first member is called Actinium.

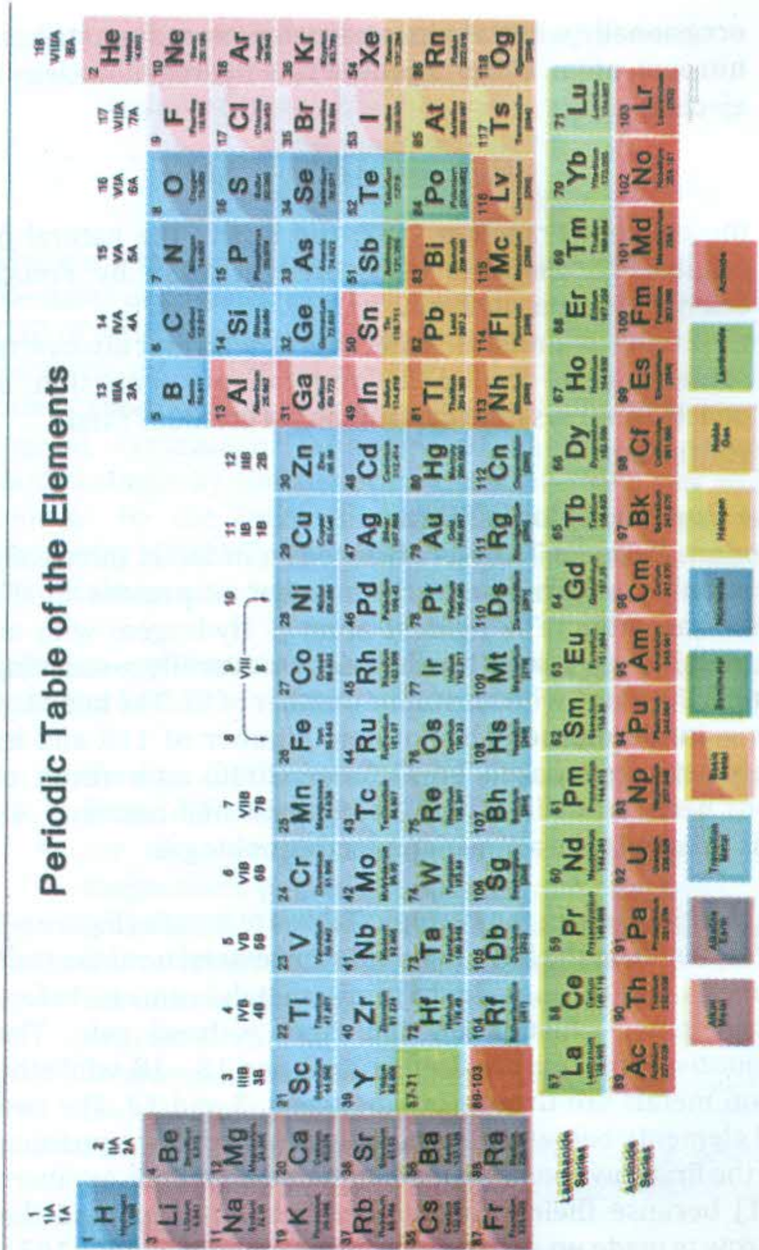

Figure 6: Modern Periodic Table

Source: Sciencenotes.org

4.2 Names and Symbols of the Elements with Atomic Numbers 113, 115, 117 and 118

In 2005, a Joint Working Party (JWP) of independent experts drawn from IUPAC and the International Union of Pure and Applied Physics (IUPAP) was appointed by the presidents of these organizations to determine priority of claims to the discovery of new chemical elements. The JWP reports on the claims of priority of discovery of elements with atomic numbers 113, 115, 117, and 118 were submitted in 2015; prior to the publication, each of the claimant laboratories was asked to check the contents and findings in these drafts for technical accuracy. The reports were also reviewed by independent expert referees. Finally, the findings were accepted by the Division Committee of the IUPAC Division of Inorganic Chemistry (Division II) and by the Executive Committees of the two Unions. The reports were subsequently published in *Pure and Applied Chemistry* (Karol *et al.*, 2016a; Karol *et al.*, 2016b).

4.2.1 Element 113

The name **nihonium** and symbol **Nh** are proposed for the element with $Z = 113$. Nihon is one of the two ways to say "Japan" in Japanese. The name is proposed to make a direct connection to the nation where it was discovered and also to celebrate the fact that it is the very **first element** in the history of the Periodic Table to be discovered in, and to be named after, an Asian country.

4.2.2 Element 115

It is proposed that the name **moscovium** and symbol **Mc** are given to element 115. Moscovium is recommended in recognition of the Moscow region and to honour the ancient Russian land that is home to the Joint Institute for Nuclear Research, where the discovery experiments were conducted with the Dubna Gas-Filled Recoil Separator in combination with the heavy-ion accelerator capabilities of the Flerov Laboratory of Nuclear Reactions, JINR.

4.2.3 Element 117

The name **tennessine** and symbol **Ts** are proposed for element 117. Tennessine is recommended in recognition of the contribution of the Tennessee region (state, USA), including Oak Ridge National Laboratory, Vanderbilt University, and the University of Tennessee at Knoxville, to super heavy element research, including the production and chemical separation of unique actinoid target materials for super heavy element synthesis. Actinoid materials from Oak Ridge have contributed to the discovery and/or confirmation of nine super heavy elements. As element 117 belongs to Group 17, the ending of the name is "-ine".

4.2.4 Element 118

The collaborating teams have proposed the name **oganesson** and the symbol **Og** for element 118. Oganesson is proposed in recognition of Prof. Yuri T. Oganessian who was born in 1933 for his pioneering contributions to transactinoid elements research, over an extensive period of time. His many achievements include the discovery of super heavy elements and significant advances in the nuclear physics of super heavy nuclei, including experimental evidence for the "island of stability". As element 118 belongs to Group 18, the ending of the name is "-on".

4.2.5 Summary

The (above) provisional recommendations of the names and symbols were made available for review and comment in May 2016. The final recommendations were approved by the IUPAC Bureau in November 2016, as authorized by the Council at its meeting in 2015. This final part of the process followed the statutory period during which the recommendations were open for public comment for a period of five months.

HEAVY METALS

*"......there is **no chemical basis** for deciding which metals should be included in this category (heavy metals)"*

(VanLoon and Duffy, 2000)

The term "heavy metals" has been used inconsistently, which reflects inconsistency in the scientific literature. Prior to 1936, the term was used with the meanings *"guns or shot of large size"* or *"great ability"* (Ogilvie, 1884; Williams, 1930).

The **oldest scientific** use of the term to be found in the English literature, according to the *Oxford English Dictionary*, is in Bjerrum's *Inorganic Chemistry*, 3rd Danish edition, published in London (Bjerrum, 1936). It is worth noting that no comparable inorganic chemistry textbook published since seems to have used Bjerrum's classification, and it has not been included in the IUPAC *Compendium of Chemical Terminology* (McNaught and Wilkinson, 1997), which is the **gold standard in terminology for chemists**.

However, there is a tendency, unsupported by the facts, to **assume** that all so-called "heavy metals" and their compounds have highly toxic or ecotoxic properties. This implies that the **pure metal and all its compounds have the same** physicochemical, biological, and toxicological properties, which is untrue and has no basis in chemical or toxicological data. Thus, the term "heavy metals" is both **meaningless and misleading** (Duffus, 2002).

Furthermore, despite the consensus in the literature that the term "heavy metal" is **badly defined and be best avoided**, the plant scientists feel otherwise (Appenroth, 2010). Rather they suggested that three groups from the Periodic Table should be considered heavy metals:

- transition elements
- rare earth elements (lanthanide and actinide series)
- p – block elements that are either metals or metalloids and that Ge, As and Te be included ("lead group").

Nevertheless, the term "heavy metals" is often used as a group name for metals and semimetals (metalloids) that have been **associated** with contamination and potential toxicity or ecotoxicity. At the same time, legal regulations often specify a list of "heavy metals" to which they apply.

5.1 Effects of Heavy metals on Humans and Animals

Although toxicity and the resulting threat to human health of any contaminant are, of course, **a function of concentration**, it is well known that chronic exposure to heavy metals and metalloids at relatively low levels can cause adverse effects (ATSDR, 2007, 2008; Castro-González & Méndez-Armenta, 2008). However, irrespective of the origin of their disequilibria, the health effects of trace metals in humans and animals are manifestations of their deficiency or excess syndromes (Table 1), which are determined by several factors such as soil geochemical components, metal bioavailability in a given diet, inter – elemental interactions, the health status of the concerned subjects, and special conditions (e.g. life at high altitudes). All these factors are interlinked and should be considered in context with anthropogenic pollutions, nutritional factors and related metabolic effects (Iyengar and Gopal – Ayenger, 1988).

There are only few reported cases of acute poisoning in the general population by heavy metals and the most familiar examples are:

- Itai – itai disease in Japan, which was caused by ingestion of rice contaminated with cadmium (Jellif and Jellife, 1982).

- The Zamfara (Nigeria) lead multiple heavy metal mortality and morbidity that caused the death of more than four hundred children (Bartrem *et al.*, 2014) living in small scale mining communities; it was referred to as the worst of such case in the modern history.

Table 1: Health effects associated with deficiency or excess of some heavy metals

Heavy metal	**Health effects**	
	Deficiency	**Excess**
Cu	Anaemia and changes in ossification.	Wilson's disease.
Zn	Growth retardation, hypogonadism, metal lethargy, poor appetite, skin lesions.	Nausea, anaemia, neutropenia.
Cd		Human carcinogens, hypertension, renal and lung damage, osteomalacia, anosmia (no sense of smell).
Pb		Affect every organ in the body; impaired haemesynthesis, insomnia, miscarriage, brain and kidney damage, nervous system, damage of organs responsible for sperm production and death in extreme cases.

Source: Ward, 1995; CHSR, 2009

SOILS

"The Soil: The real Source of Health
*A **healthy soil**, full of "life" itself, will yield up to the plants*
all they need for healthy, diseases – resistant growth.
*Such **plants** eaten raw and fresh can likewise*
*produce healthy, diseases – resistant **animals**,*
and these healthy plants and animals in turn can
***alone** provide the true nutrition of **healthy humans**.*
***Without a healthy living soil**, how can the medical*
and allied professions escape from the prophylactic
treatment of symptoms?
The foundation of health is the mother earth!"

(S. B – I. Sweeny)

There are several definitions of soil, depending on the discipline; we have definitions based on geological, traditional, component, soil taxonomy and as a portion of the landscape.

However, (to me) as an Analytical / Environmental Chemist, soil is one of the most diverse habitats on earth and the most complex ecosystem in nature. It constitutes a vital component of rural and urban environments (USDA, 2001), that serves as an ultimate sink for elements and plays a significant role in their environmental cycling (Kabata and Pendias, 1992).

Soils generally contain trace elements of various origins that include:

- ***Lithogenic*** elements which are directly inherited from the lithosphere i.e. natural rocks or parent material;

- ***Pedogenic*** elements are also from lithosphere, but their **concentrations and distributions** in soil particles / layers are altered through **weathering processes**.
- ***Anthropogenic*** elements are those deposited into soils due to direct or indirect human activities.

Table 2: Mean contents of some heavy metals in earth's crust and their common ore minerals

Heavy Metal	Content in Earth's crust ($mgkg^{-1}$)	Ore mineral
Cadmium	0.1	ZnS
Chromium	100	$FeCr_2O_4$
Copper	50	$CuFeS_2$; Cu_5FeS_4; Cu_3AsS_4; Cu_2S; CuS; native Cu
Lead	14	PbS
Nickel	80	$(Ni, Fe)_9S_8$; $NiAs$; $(Co, Ni)_3S_4$
Zinc	75	ZnS

Source: Adapted from Alloway and Ayres, 1997

Table 3: Natural heavy metal concentrations of surface soils

Heavy Metal	Concentration ($mgkg^{-1}$ dry weight) Mean	Range
Cadmium	0.25	0.01 - 2.5
Chromium	60	5 - 1100
Copper	15	6 - 60
Lead	20	1.5 - 80
Nickel	20	1 - 120
Zinc	60	17 - 125

Source: Ward, 1995

The term "trace metals" is the **theoretical acceptable name** for heavy metals, and the natural concentrations of some heavy metals (often used and discharged industrially) in the earth's crust and their common ore minerals as well as in the surface soils are as indicated in Tables 2 and 3 respectively.

Soil contamination by metal - containing constituents may generate from either farm initiated (deliberate) pollution or from inadvertent pollution (point) sources as given in Table 4. Thus, the relative role of these various sources and their importance in relation to the natural background levels in different areas need **careful assessment and monitoring**.

Table 4: Anthropogenic sources of heavy metals in soils

Various sources (of inputs)	
Non – point (deliberate)	**Point (accidental)**
Agricultural chemicals and fertilizers	Fossil fuels of power generation and motor vehicles
Dredged sediments and Irrigation	Minning, Smelting and metal processing
Waste products e.g. sewage sludge	Urban industrial

Source: Tiller, 1989

6.1 Soil dissolution for elemental analysis

Quantitative analytical methods for elemental analysis of soils require a homogenous solution. The sample needs to be decomposed into soluble forms and dissolved completely using either **fusion with an alkali flux** or **digestion with a single acid or combination of acids**.

6.1.1 Digestion with acids

Digestion with acids is preferred to fusion decomposition and is probably the most widely used method because it:

- avoids the introduction of extraneous material or salts in the final solution
- has less interference in the determination of the elemental content
- is less time consuming and inexpensive.

Some researchers (Hossner, 1996; Sawhney and Stillwell, 1994) reported that strong inorganic acids or their mixtures such as HCl, HNO_3 and $HClO_4$ are the acids of choice for decomposition. Hani (1996) argued that aqua regia and HNO_3 are best known for dissolving heavy metals anthropogenically brought into soil, while Merry *et al.* (1983) claimed that concentrated HNO_3 and aqua regia are used to determine total metal contents in contaminated soils. Furthermore, other researchers (Amacher, 1996; Baker and Amacher, 1982) suggested that digestion with HNO_3 - H_2O_2 – HCl (USEPA, 1986) gives a reliable measure of total metal contents added to soils as nonsilicates. However, if the most complete soil sample dissolution and total metal recovery is intended then HF is included in the digestion sequence.

Usually, HF reacts with Si to form SiF_4 (destruction of silicate minerals), while H_2O_2 or $HClO_4$ oxidizes the organic matter and HNO_3 is added in small amount to oxidize the more reactive constituents of the organic matter at low temperature to prevent the explosive reaction of $HClO_4$. Moreover, H_2SO_4 is not commonly used for the digestion of soil samples because of the low solubility of some inorganic sulphates; in few cm^3 it can be added to digestion mixture to prevent the dryness of the sample.

6.1.2 Analytical Methods

There are various instrumental techniques for elemental analysis of soils and environmental samples. However, following decomposition and dissolution of samples, atomic spectroscopic analyses still remain the most well – established technique for

Table 5: Most common methods for determination of heavy metals

Techn ique	Principle	Application
Atomic absorption Spectrometry (AAS) - Flame - Graphite furnace - Hydride generation - Cold vapour	Absorption of radiant energy produced by a special radiation source, by atoms in their electronic ground state	widely used
Inductively Coupled Plasma Atomic Emission Spectrometry (ICP- AES)	Measures the optical emission from excited atoms	widely used; multielement analysis
Inductively Coupled Plasma Mass Spectrometry (ICP- MS)	Separation of ions based on their mass-to – charge ratio	widely used; isotope determination
Atomic Fluorescence Spectrometry (AFS)	Measures the light that is reemitted after absorption	determination of Hg, As & Se; Complementary to AAS
X – ray Fluorescence (XRF)	X – rays primary excitation source; elements emit secondary X – rays of a (solid)	suitable for very thin/flat and homogenous
	characteristic wavelenght	samples; *in situ* analysis
Neutron activation Analysis (NAA)	Conversion of stable nuclei of atoms into radioactive ones; measures the characteristic	appropriate for materials that are difficult to
convert	nuclear radiation emitted by the radioactive nuclei	into a solution for analysis; most elements can be determined
Electro (analytical) chemical Methods - Polarography - Potentiometry - Stripping voltammetry	Controlled voltage or current	determination of different ions of metals and metalloids

Source: Adapted from Draghici et al., 2010 quantitative analysis. The advantages of atomic absorption spectrometry (AAS) technique are good detection limit, controllable matrix and chemical effects, analytical specificity, relative low cost, simplicity of instrumental handling, excellent accuracy and precision as well as sensitivity (Zurera - Casano, 1997; Johnson, 1997).

Several AAS can be distinguished depending on the **mode of sample introduction and atomization**. Flame (FAAS), graphite furnace (GFAAS), hydride generation (HGAAS), and cold vapor (CVAAS) systems have been described extensively. FAAS and GFAAS are applicable for quantitative analysis of nearly 70 and 60 elements respectively; detection limits of GFAAS are approximately 100 times lower than those of FAAS. In HGAAS, the analyte is reduced to its volatile hydride and it is only applicable to elements Ge, As, Se, Sn, Sb, Te, Bi and Pb that form covalent gaseous hydrides. CVAAS applies solely to Hg being the only analyte that has an appreciable atomic vapour pressure at room temperature (Ortega, 2002). Table 5 shows the optical, radiochemical and the electrochemical methods applied for the determination heavy metals.

MY CONTRIBUTIONS

*"I wanted to understand the <u>secrets</u> behind **my chemical experiments** and behind **the process in nature**"*

(Richard Ernest)

Mr. Vice-Chancellor Sir and distinguished audience, my contributions for this Inaugural lecture are focused on the three most widely world researched elements in soils that I termed "fascinating elements"; they include ***Copper, Lead and Zinc***. My study has been centered principally on **urban surface soils** due to my interest as an Analytical/Environmental Chemist on the anthropogenic input of trace metals into soils, and their possible effects on plants, animals and humans through the food chain. Earlier, most researched studies on the elemental contents of soils in Nigeria had focused primarily on the micronutrients status of soils and plants (Udo and Fagbami, 1979; Lombin, 1983a, 1983b; Kpamwang *et al.*, 2000).

7.1 Soil Quality Guidelines

Soil quality guidelines or standards (**baseline values and typical contents**) for trace metals in soils are not available for Nigerian soils, thus comparisons in my contributions have been based on the concentrations of control soils (background soils), world soil standards and guideline values for some other countries.

Logan and Miller (1983) suggested that soil contamination may be considered when concentrations of an element in soils were **two – to - three times greater than the average background level**.

7.2 Cultivated farmlands in the vicinity of abandoned industrial sites

Concentrations of **copper and zinc** in soil samples collected from cultivated farmlands in the vicinity of abandoned industrial sites of Minna and Bida were determined using Flame Atomic Absorption Spectrophotometer. The obtained concentrations were 12.0 – 89.0 $mgCukg^{-1}$ and 2.8 – 41.0 $mgZnkg^{-1}$ for Minna, as well as 2.4 – 6.5 $mgCukg^{-1}$ and 0.57 – 36.0 $mgZnkg^{-1}$ for Bida (Iyaka and Kakulu, 2009a).

The Copper levels in Minna cultivated farmlands in the vicinity of abandoned industrial site were substantially higher than in control sites, with an average copper value of almost five times that of the control content; thus indicating contamination.

Furthermore, the highest obtained total copper content of 89ppm was higher than the Agricultural Acceptable Limit of 63ppm in Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 1999).

However, the very low zinc concentrations obtained from all the soils of the cultivated farmlands in the vicinity of abandoned industrial sites in our study could probably be ascribed to much less application of fertilizers and other agrochemicals as well as potential leaching due to sandy soil texture of the studied areas. Several researchers (Andreu and Gimeno, 1996; Alloway and Ayres, 1997; Iyaka *et al.*, 2009b) had stated that agricultural chemicals or materials such as impurities in fertilizers, pesticides and wastes from intensive poultry production constitute the very essential non – point sources of metal pollutants, such as zinc in soils.

7.3 Surface Soils around Ceramic and Pharmaceutical industrial sites

Mean concentrations for all soil sample locations for the Ceramic and Pharmaceutical industrial sites of our study were 18.0 ± 7.5 $mgkg^{-1}$, 15.0 ± 5.7 $mgkg^{-1}$ and 28.0 ± 22.0 $mgkg^{-1}$ for lead, copper and zinc respectively (Iyaka and Kakulu, 2012a). The obtained values were of higher contents than the background levels measured in control soil samples, thereby showing that studied trace metals are mainly accounted for by anthropogenic activities. Honk and Lock (2000) recognized ceramic industry as an important source of lead pollution, thus the obtained values for lead from the vicinity of the ceramic industrial site showed that the lead levels generally decreased with distance from the factory, thus suggesting dispersion from a point source.

The higher zinc contents obtained for the pharmaceutical industrial site than in the ceramic industrial site could probably be due to more agricultural activities observed in the vicinity of the pharmaceutical industrial site.

7.4 Topsoil of a Local Brass Industrial Area

Copper pollution may arise from brass manufacture and major uses of zinc have also been associated with the production of non – corrosive alloy; brass, galvanized steel and iron products, while zinc may also contain small amount of lead as impurities (Alloway and Ayres, 1997; Elindar, 1986). The obtained results from the surface soils of the vicinity of the local brass industrial area from a major city in Niger State revealed significant average values of 467 ± 455.0 $mgCukg^{-1}$, 181± 201$mgPbkg^{-1}$ and 181 ± 44 $mgZnkg^{-1}$(Iyaka and Kakulu, 2012b).

Up to 85% of the analyzed soils from this local industrial site had total copper concentrations that exceeded the Residential Acceptable Limit of 63ppm in Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (CCME, 1999). The zinc contents were generally higher than the normal concentration range of 17 – 125 $mgZnkg^{-1}$ for top surface soils suggested by Ward (1995). However, in 23% of the soil samples studied, the 250 $mgPbkg^{-1}$ levels were exceeded; this value applies to worst cases scenario in which children below five years often repeatedly use an area without grass cover and mouthed objects frequently.

Moreover, ATSDR (1988) claimed that a soil lead concentration of 250ppm would add an estimated 2 $\mu gPb\,dm^{-3}$ to the blood lead level of children and further argued that there may be no level of blood lead that is not toxic; children are particularly sensitive to lead because of their more rapid growth rate and metabolism, with critical effects in the developing central nervous system (ATSDR, 2007; Castro – González and Méndez – Armenta, 2008).

Juberg *et al.*, (1997) observed that children absorb about 30 – 40% of ingested lead, while adults absorb only 5 – 15% and retain less than 5% of what is absorbed. Furthermore, Viverette *et al.*, (1996) and Calabrese *et al.*, (1997) observed that the Total Tolerable Daily Intake (TTDI) of 6$\mu gPb\,day^{-1}$ may easily be exceeded, especially for lead accumulated in soils of outdoor play environment.

The location of local brass industrial site within a residential area has undermined the public concern with regard to the possible potential health implications that could arise from such environment. Consequently, the obtained results further indicate the need for immediate remediation of local brass industrial site.

7.5 Roadside Topsoils

In our study of roadside topsoil of two major cities in Niger State of Nigeria, the mean contents of all sample locations were 15 ±

5.0 $mgkg^{-1}$, 53 ± 33 $mgkg^{-1}$ and 53 ± 32 $mgkg^{-1}$ for copper, lead and zinc respectively (Iyaka and Kakulu, 2011); these values were higher than the background levels measured in control soil samples, thereby indicating some extent of contamination. The average copper content was about three times the background soil sample level, the lead total contents in all the background soil samples were too low to be detectable and the zinc mean concentration was about five times the background soil sample level.

The universal phase – out of leaded gasoline has been attained, particularly in developed nations. However, copper, zinc and especially lead in surface soils have been of great concern because they are not **biodegradable and usually poorly mobile** (Chang *et al.*, 1996); half – lives of copper and lead ranged between 310 – 1500 years and 740 – 5900 years respectively, depending on the soil type and their physicochemical properties (Alloway and Ayres, 1997).

7.6 Total and Bioavailable Lead levels in Urban Rice Paddy Soils

Urban soils are often contaminated with lead because of its ubiquitous nature in the environment (Mielke, 1994; Nriagu, 1998), and reduction in soil fertility and agricultural outputs have been associated with high lead contents (Lokhande and Kalkar, 1999). In urban gardens, fruits, vegetables and crops grown in contaminated soils may also become contaminated as a result of plant uptake of lead from soils or direct deposition of leaded dust onto plant surfaces (Rahlenbeck *et al.*, 1999). Consequently, when the leaded contaminated plants are consumed by animals and humans, acute exposures to lead may cause gastrointestinal disturbances, hepatic and renal damage, hypertension and neurological effects that may aptly result in convulsions and death (IPCS, 1995).

Currently, the use of acidic or chelating agents to dissolve trace metals from solids has been on focus. Since most pollutant inputs in urban surface soils are not silicate bound (Nomeda *et al.*, 2004), a pseudo – total digestion methods of strong acids that do not involve dissolution of silicates by hydrofluoric acid are used. Using aqua regia for this type of analysis is considered adequate (Hseu *et al.*, 2002; Loncaric *et al.*, 2010) and is found useful in the estimation of the maximum element available to plants (Vercoutere *et al.*, 1995). Furthermore, among the chelating agents used for heavy metal extraction from polluted soils, EDTA has been considered to be the most effective in solubilising soil – bound lead that is available for phytoextraction (plant available fraction) because of its strong complexing ability (Samani *et al.*, 1998; Haag – Kerwer *et al.*, 1999; Zeng *et al.*, 2005; Nascimeto *et al.*, 2006). Polettini *et al.* (2006) asserted that EDTA can effectively remove 65 – 85% lead from contaminated/polluted soils.

Using aqua regia for digestion and extraction with EDTA respectively for forty composite soil samples from eight cultivated rice paddy soils, total and plant available lead concentrations were determined. Varying lead contents were obtained; the overall total lead average value was 12.6 ± 13.1mgkg^{-1}, while the EDTA extracted lead had mean concentration of 5.0 ± 3.1mgkg^{-1}. This study indicated a considerable contamination that could serve as baseline data for lead level in rice paddy soils in Niger State (Iyaka and Umar, 2015).

7.7 Total and Plant available Copper and Zinc Concentrations in Urban Cultivated Rice farmlands

In order to boost production, rice farmers use varieties of agro – allied chemicals such as chemical fertilizers, herbicides, pesticides and soil amendments. However, the continuous use of these chemical farm inputs not only deprives the soil from its being natural (Prakongkep *et al.*, 2008), but also constitutes major sources of pollution particularly of trace metals in agricultural soils (Yadav *et al.*, 2009; Olatunji *et al.*, 2013). Trace metals such as copper and zinc in very low concentrations are essential microelements for the survival of plants and animals, but their accumulation in high concentrations in soils could result in significant phytotoxicity problems that may impact negatively on the food chain (Ward, 1995; Alloway, 2004); soil → plant →animal →man or soil →plant →humans.

In this study, zinc contents were greater than copper concentrations in all the soil samples. The overall total copper and zinc mean values were 9.8 and 35.8 mg/kg respectively, while the plant available copper and zinc average concentrations were 3.5 and 8.5 mg/kg respectively (Iyaka *et al.*, 2015). Although, lower copper contents were obtained in this study, the overall order of relative availability showed that copper was extracted in the highest relative amount than zinc.

The geo - accumulation index also revealed that the studied urban cultivated rice farmlands were uncontaminated to moderately contaminated using the ranges given by Müller (1981) for interpretation. Furthermore, the percentage Enrichment Factors confirmed the moderate contamination for most locations except for fewer values that could be ascribed to higher anthropogenic effects.

7.8 Total Lead Content in Soils: A Comparative evaluation of three Wet Digestion Methods

Soon and Abboud (1993) observed that for an assessment of soil contamination with trace metals, digestion method(s) that probably dissolve(s) most metal oxides and other mineral phases excluding silicates should be most preferred. Other research scientists (Frank *et al.*, 1976; Merry *et al.*, 1983; Hani, 1996) however, claimed that nitric acid and aqua regia are the most well known acids for dissolution of trace metals anthropogenically brought into soil or for determination of total metal contents in contaminated soils.

The soil samples of this study were collected from a major motor park in Niger State, Nigeria. The average soil lead contents obtained for all locations were 70.29ppm, 68.23ppm and 37.39ppm for 1:1HNO_3, concentrated HNO_3 and aqua regia (HNO_3 - HCl) procedures respectively (Iyaka, 2006). The obtained results clearly showed that the two nitric acid procedures are better dissolution reagents for total lead content in soils than the aqua regia procedure. This probably could be ascribed to the observation that nitric acid method does not differentiate between anthropogenic and natural soil contents (Hani, 1996). Furthermore, there was a manifest correlation in the obtained total lead contents from 1:1HNO_3 and concentrated HNO_3 especially at low soil lead concentrations.

7.9 Copper and lead levels in Soils of Occupational Sites

Contents of copper and lead in soils of five occupational sites that include storage battery repair, car radiator repair, welding, car spray painting and car repair were determined. The copper concentrations varied widely from 1.2 ppm in car repair site to 929 ppm in car radiator repair site (Iyaka *et al.*, 2009c). However, copper occurs in soils as an essential trace element, whose increase in concentration could give rise to hazardous effects on ecological system (Ebbs and Kochian, 1997; Iyaka and Kakulu, 2005).

The lowest and the highest lead average values of 32 ppm and 2181 ppm were from car repair site and storage battery repair locations respectively (Iyaka *et al.*, 2009c). The high lead contents from storage battery repair locations could probably be ascribed to the fact that battery manufacturing or recycling is one of the main sources of lead in the environment (Alloway and Ayres, 1997; Iyaka, 1998).

Of great health risk concern was the mean lead contents obtained from some sampling points within the storage battery repair and car radiator repair locations, with values higher than 1000ppm soil lead which correlates with the critical blood lead level of 7mcg/*dl* in children (USEPA, 1994).

7.10 Sequential Extraction

Sequential extraction schemes are the best means of evaluating forms of chemical association of trace metals with crystalline soil phases, and indirectly their bioavailability (Harrison *et al.*, 1981). Generally, for every phase sequence the subsequent one tends to contain less trace metals in terms of mobility and availability. The soluble – exchangeable fraction and sometimes the organics are the plant – available forms (Petruzelli, 1989; Shuman, 1991); these fractions are also the most mobile and could have harmful impacts on ground water (Li and Shuman, 1996) and consequently on ecosystems and humans.

Our **developed Sequential extraction scheme** was used for copper, lead and zinc speciation of selected contaminated soil samples, and the obtained results were dominantly in the non – residual fractions, thus reflecting control by anthropogenic sources (Iyaka, 2006) that are more easily mobile and potentially more phytoavailable than the lithogenic and pedogenic heavy metals in soils. The percentages of the studied heavy metals in each fraction were in the following order:

Copper: organic > carbonate > oxide > residual > exchangeable
Lead: carbonate > oxide > residual = organic
Zinc: carbonate > oxide > organic > residual > exchangeable.

CONCLUSIONS AND RECOMMENDATIONS

"The more I study Science the more I believe in God."

(Albert Einstein)

Mr. Vice-Chancellor Sir and the distinguished audience, you would all agree with me that my elements of interest and concern are indeed fascinating and that I have only seen them perhaps as an analytical chemist or environmental analyst. Thus, I want to conclude with the following recommendations:

i. Site or location is an important factor that determines the levels or accumulation of heavy metals in urban soils in relation to the associated activit(y)/ies, particularly for copper, zinc and lead.

ii. There is a significant enrichment of the concentrations of copper, zinc and lead above background levels in Niger State urban soils, but not as alarming as found in most Western world probably due to insignificant industrialization and low application of fertilizers in the cultivated farmlands.

iii. For urban contaminated/polluted soils, copper, zinc and lead speciation indicated dominant non - residual fractions, thus indicating that anthropogenic heavy metals are more easily mobile and potentially more phytoavailable than lithogenic and pedogenic heavy metals in soils.

iv. There is need for frequent remediation or clean – up measures for some locations within the urban soils, especially storage battery repair and car radiator repair locations as well as local brass or related industrial sites.

v. To achieve an environmental safe nation, constant monitoring or watch on levels of heavy metals in urban soils is inevitable, in order to assess their possible potential risks to life and environment.

vi. How can we as a nation achieve economic development without quality and genuine **scientific discoveries and technological innovations**? We have the obligation of **rethinking our education**:

- We must show commitment to **build research universities** (universities that transcend historical models); universities that are not limited by their entrenchment in obsolete institutional ideology, lack of scalability, and residual elitism.

- Restoring sufficient levels of public investments and desired standards in higher education are challenges that policy makers and we as citizens alike must address.

- The Government must accept that open and equitable access to quality education and the role of government to make that happen should be an integral part of our nation's political culture and governance.

- If we must excel in **scientific discoveries and technological innovations**, then it is critically important that we must key into interrelationships termed by Etzkowitz as the "triple helix" of "university – industry – government innovation"; whereas industry is the "key actor as the locus of production" government serves as the "source of contractual relations that guarantee stable interactions and exchange, while "the role of the university in this triad is pre - eminent."

vii. In conclusion, I also submit that as lecturers we have the onus of making our institutions not mere citadels of abstract learning, but institutions intended to serve the direct needs of the society.

viii. Furthermore, the ambiguity surrounding the training of our technologists has led to two distinct problems; a problem of efficiency and a problem of equity. At stake is the loss in productivity that comes with a work force lacking advanced skills. We must as higher institutions and as a nation re - define the role of technologists and their significance.

ix. I also do strongly recommend the urgent need for us to have standard laboratories with state of the art equipment in atleast each of our political regions with well trained technologists that possess required expertise; it is only through this that in my thinking, we can come up with research products that are worth universal patent.

x. Our students, particularly in Chemistry and other related research - based courses must know how to research, how to analyze, how to synthesize and how to communicate well. They must know how to gather data, to test and refine them, or how to throw them out when necessary and start over. As **sincere scientists** they must do all these and in addition learn to develop a culture of knowing the difference between figures and results.

Mr. Vice - Chancellor sir, as we get embedded in our search for "glory" in this ephemeral world permit me to end this lecture by these verses of the holy Quran:

In the Name of Allah,
the Most Gracious, the Most Merciful
*"When the **earth** is shaken with its (final) earthquake*
*And when the **earth** throws out its burdens*
And man will say: "What is the matter with it?"
That day it will declare its information,
Because your Lord will inspire it,
That day mankind will proceed in scattered groups that they may be shown their deeds,
*So whoever does **good** equal to the weight of an atom shall see it, And whosoever does **evil** equal to the weight of an atom shall see it"*

(Quran 99; 1 – 8)

I will only add that henceforth:

"Whenever one of my students comes to me with a scientific project (topic), I will ask only one question:
"Will it bring you nearer to God?"

Adapted from: I. I. Rabi

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"Gratitude is not only the greatest of the virtues, but the parent of all the others."

(Cicero)

All the praises and thanks are to Allah, the Lord of all that exist in whose benevolence good things attain perfection. Glory be to my Lord, the most high, who created me, predestined for me and guided to me to whom/what I am. I sanctify Allah Who has taught me by the pen, taught me to read and granted me expressive speech.

I thank my parents late Alhaji Muhammad Ibrahim (Baba) Iyaka and Hajiya Fatimatu Umaru Iyaka may "**My Lord! Bestow on them Mercy as they did bring me up when I was young**". I also appreciate the contributions of my siblings particularly Hajiya Hauwa Iyaka and Alhaji Umar Ahmed Iyaka as well as my life - long friend and maternal uncle Alhaji Ndagi Maaji (the current Principal of Government Vocation Training Centre, Minna). I want to thank my parental in-laws: Alhaji Muhammad Jamiu Oyejobi Diekola and Hajiya Mistura Diekola for their care, prayers and support.

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Martins Luther King said "**A man becomes a living person (only) when he leaves his narrow confinement for the broader concern of humanity**". Hence, I will be remiss when I count the favours and blessings of ALLAH on me without expressing my appreciation to my **administrative mentors**.

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Mr. Vice-Chancellor Sir, distinguished invited guests, ladies and gentlemen, I thank you all for listening.

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A BRIEF PROFILE OF PROFESSOR YAHAYA AHMED IYAKA

Yahaya Ahmed Iyaka is a native of the ancient Bida city; the cradle of Nupe culture and civilization. He was born exactly five decades ago to the family of Alhaji Muhammad Ibrahim (Baba) Iyaka and Hajiya Fatimatu Umaru Iyaka. He had his primary education at the then Government Model Primary School, Bida from 1976 to 1980 and as a promising young lad he gained admission into the famous Federal Government College, Ilorin where he was a College Scholar from 1981 to 1985. He obtained his Bachelor of Science (Honours) Degree in Chemistry from Usmanu DanFodiyo University, Sokoto in 1992, his Master of Science in Analytical Chemistry from the premier University of Ibadan, Ibadan in 1998 and his Doctor of Philosophy (PhD) in Analytical Chemistry from University of Abuja, Abuja in 2006.

Professor Iyaka joined the services of Federal University of Technology, Minna in **2000 as an Assistant Lecturer** in the Department of Chemistry and steadily rose through the ranks to the position of a **Professor of Chemistry in 2015.** He has served as **chairman and member** of many committees in the University; currently he is a member of University Governing Council. Professor Iyaka has held several administrative positions within the Department, the School and the University at large; he served as Chemistry Coordinator for the present Centre for Preliminary and Extra Mural Studies (CPES) from 2004 to 2006, Postgraduate Programme Coordinator for the Department of Chemistry from 2006 to 2010 – a position he held concurrently as a Deputy Dean of Students.

Professor Iyaka became a substantive Dean, Students' Affairs Division of the University from October, 2010 to January, 2013 and was appointed Head of Department, Department of Chemistry, Federal University of Technology, Minna from June, 2015 to April, 2017. He served as Deputy Vice-Chancellor (Administration) from April, 2017 to February, 2018 when he was redeployed to his current position of the Deputy Vice-Chancellor (Academic).

As a Professor of Chemistry, he has contributed immensely to the field of Chemistry by his committed involvement in the teaching, research and supervision of students both at undergraduate and postgraduate levels. He has several publications in reputable journals at the International and National levels. He has also participated effectively in several community services and has served as member of NUC Accreditation Panel to various Universities in Nigeria. Furthermore, he has contributed enormously to many Universities in Nigeria either in visiting capacity or as external examiner for both undergraduate and postgraduate programmes, and had his Sabbatical appointment at the Department of Pure and Applied Chemistry, Usmanu DanFodiyo University, Sokoto during 2013/2014 academic session.

Professor Iyaka is well travelled and has attended many seminars, training and workshops within and outside the country in South Africa, Ghana, Rwanda, UAE Dubai, France and United States of America on Educational Policies, Administration and Management of Tertiary Institutions, Leadership and University Lecturers' Skills Enhancement Training Programme as well as on the Art and Science of Fundraising.

He is a member of Chemical Society of Nigeria (CSN) and his hobbies include reading, walking and travelling. Professor Yahaya Ahmed Iyaka is happily married with children.

Note