UNIVERSITY OF PORT HARCOURT

THAT METALS MAY LIVE LONGER

An Inaugural lecture

By

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ORDER OF PROCEEDINGS

2.45P.M. GUESTS ARE SEATED

3.00P.M. ACADEMIC PROCESSION BEGINS

The procession shall enter the CBN Centre of Excellence Auditorium, University Park, and the Congregation shall stand as the procession enters the hall in the following order:

ACADEMIC OFFICER
PROFESSORS
DEANS OF FACULTIES/SCHOOL
DEAN, SCHOOL OF GRADUATE STUDIES
PROVOST, COLLEGE OF HEALTH SCIENCES
LECTURER
REGISTRAR
DEPUTY VICE-CHANCELLOR [ACADEMIC]
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
VICE CHANCELLOR

After the Vice-Chancellor has ascended the dais, the congregation shall remain standing for the University of Port Harcourt Anthem.
The congregation shall thereafter resume their seats.

THE VICE-CHANCELLOR'S OPENING REMARKS.

The Registrar shall rise, cap, invite the Vice-Chancellor to make his opening remarks and introduce the Lecturer.

The Lecturer shall remain standing during the Introduction.

THE INAUGURAL LECTURE

The Lecturer shall step on the rostrum, cap and deliver her Inaugural Lecture. After the lecture, she shall step towards the Vice-Chancellor, cap and deliver a copy of the Inaugural Lecture to the Vice-Chancellor and resume her seat. The Vice-Chancellor shall present the document to the Registrar.

CLOSING

The Registrar shall rise, cap and invite the Vice-Chancellor to make his Closing Remarks.

THE VICE-CHANCELLOR'S CLOSING REMARKS.

The Vice-Chancellor shall then rise, cap and make his Closing Remarks. The Congregation shall rise for the University of Port Harcourt Anthem and remain standing as the Academic [Honour] Procession retreats in the following order:

VICE CHANCELLOR
DEPUTY VICE-CHANCELLOR [ADMINISTRATION]
DEPUTY VICE-CHANCELLOR [ACADEMIC]
REGISTRAR
LECTURER
PROVOST, COLLEGE OF HEALTH SCIENCES
DEAN, SCHOOL OF GRADUATE STUDIES
DEANS OF FACULTIES/SCHOOL
PROFESSORS
ACADEMIC OFFICER

PROTOCOL

Vice-Chancellor, Sir,

Members of the Governing Council of the University,

Principal Officers of the University,

Provost, College of Health Sciences,

Dean, School of Graduate Studies,

Deans of Faculties and Directors of Centres,

Heads of Departments,

Distinguished Professors,

Staff and Students of the University,

Members of the Press,

Distinguished Guests,

Ladies and Gentlemen

DEDICATION

My children and co labourers in Christ.

ACKNOWLEDGEMENTS

“Guard your heart diligently, for out of it flows the issues of life (Proverbs 4: 23)”. Whatever we allow to into our hearts, affects our actions either negatively or positively. I sincerely and deeply appreciate God Almighty for enabling me over the years to diligently guard my heart and hold on to positivity around my life. He guided me to conceive the idea and topic for this Inaugural lecture at a time when the ‘issues of life’ crowded me and I was “almost sinking deep”; LORD I AM GRATEFUL!

My profound gratitude goes to the Vice Chancellor. Prof. Owunari A. Georgewill and the Inaugural Lecture Committee set up for effective delivery of Inaugural lectures of which I am a beneficiary. Thank you for finding this lecture worthy of presentation, without your thorough scrutiny and approval we would not be seated here.

I am filled with deep appreciation for the former Vice Chancellor Prof. J. Ajieka, former acting Vice Chancellor, Prof. Steve Okodudu, who was instrumental in facilitating my promotion to the esteemed position of Professor. He played the role of a guiding figure, much like Moses, leading many of us out of our previous limitations. The final decision and approval were made by our diligent and visionary Vice Chancellor, Prof. Owunari Georgewill, without whom all other previous efforts would have been in vain. I pray God’s blessings continue to shine upon you. Thank you.

Special appreciation to the following persons (all of blessed memory): Firstly my parents Chief George Lawson Jack and Tiya Sokari Ojuka - the vehicles that brought me to this world. Secondly my uncles Benibo Sokari Ojuka (whom I called 'Father') and Justice Adolphus Karibi Whyte your interest in my education brought me this far. Thirdly of exceptional mention is my grandmother, Moruta Gogo Berein, the pretty princess of the Royal Bereyin house of Ifoko. Though without formal education, her constant inquisitive questions, wanting to know what I learnt at school, started the first student – teacher relationship in my life.

I passed through a lot of teachers from primary, secondary and tertiary levels some of whom are late. I sincerely appreciate all their effort in molding me to what I am today. Of special mention is my primary school teacher, Mr. F. F. Whyte (late), who took interest in that 'small girl from Lagos' and maintained the high standard ("Sir, I wish you can hear me I did not disappoint you"), Dr I. I. Samuel, (Prof. Felix Okieimen former Deputy Vice Chancellor, University of Benin) my supervisor and academic adviser in my undergraduate days at the University of Benin always referred to me as one of his 'first generation' students. He was more of a father to us, ready to listen and proffer solutions to our many students' problems. Late Prof. N.C Oforka supervised my Masters and Ph.D work and other lecturers I met at the University of Port Harcourt.

I sincerely appreciate my academic mentors, Prof. Ibiba R. Jack, Prof Onyewuchi Akaranta, Prof Mike Horsfall all renowned professors of Chemistry whose guidance and efforts led me to join them in the professoriate club. My special friend, super mentor, senior colleague Prof Gloria Ukalina Obuzor (first female president of the Chemical Society of Nigeria and many other caps) and Prof. Victor Ukaegbu a Geologist who had so much interest in my academic progress and contributed immensely to the realization of my presentation this day.

I have fantastic friends who are worthy of mention. They are always around me in thick or thin. My dear Margaret Apaemi Briggs Kamara (an Associate Professor), Prof. Charity Ogunka – Nnoka, Akens Hamilton (Associate Professor), Prof. Emylia Jaja, Prof. Nedie Akani they are 'my gang'.

My colleagues at the Department of Pure and Industrial Chemistry, University of Port Harcourt, Drs O. Oriji, Uche Chuku, Naemeka Ngobiri, , Chidi Obi, Dr Duru, Dr Obi, Profs L C Osuji, M. Horsfall, Charles Osu, A. James, M. Ibezim Ani. The administrative staff at the departmental office, Madam Esther, Mary, Blessing, Joy I appreciate you all.

My Baptist family is worthy of mention here, Dn.K. Orukotan, Prof and Dns M. M. Egein, Revs. N. Chibuogwu, R. Okparanta, and the TRUTH Family Baptist Church. Your prayers have become testimonies in my life.

I acknowledge the assistance and contributions of my in- laws. Special mention is Chief V. Aliezi and Dr (Mrs) E V. Aliezi, Chiakabi Aliezi, Comfort Ogunka (Momsi) may heaven's

blessing be your portion for all you are doing for me and my children.

My cousins and siblings, His Royal Highness King Emmanuel Stephen the Amayanabo of Ifoko, Dr Daerego Jack, Opiri Alex, Belema Harry, Mr Ngo Lawson Jack, Ibifuro Lawson Jack, Komabo Lawson, Barr. Opiri West, our aunty Mrs Nnenna D. Lawson among others. Thank you for being there for me. God bless you. Out of sight is not out of mind, my dear brother, late Monima Lawson Jack; I miss you today as always.

The unparalleled support by my immediate family has been a huge source of strength. My children, their spouses -Beleki and Stanley, Anyimba and Churchill, Ojuka and Ahni, , Ngo and Eseosa , my bestie - Kulabibi Boma, my grandchildren who bring me joy each day, and their late father and grandfather, Prof. A. K. Okorosaye – Orubite . I do not wish for a better family. From the bottom of my heart I appreciate you all.

I specially acknowledge Dr Ngo Woghiren for preparing these beautiful slides for presentation, my Personal Assistant, thank you and God bless you.

For all who touched my life in one way or the other, even if you are not mentioned here, you are appreciated and I pray God Almighty rewards you all.

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PREAMBLE

I have grown up to love nature and always intrigued by its transformation from one form to another. As a young primary school girl, I was attracted to a type of grass growing around our house its flowers had whitish exudates (gum like liquid that comes out of the flower); I had found pleasure in fiddling with those flowers with a view of finding use for the exudates. I would try them as gum for torn Exercise books or Text books with little success because I lacked knowledge on how to prepare a gum from such plants. I had an inquisitive mind-attribute of scientists, and often asked questions to which I rarely found answers; like why did peak milk not form ice block in the freezer the same time with water? I had thought I could make a different kind of ice block, something we liked licking but hide from our parents. Years later while in secondary school, these answers were provided by my able and hardworking Science/Chemistry teachers (the milk would not form ice block same time with water because they have different freezing points). My interest in Science was kindled by the then Mr. I. I. Samuel (now Dr I. I. Samuel) -our General Science teacher who did 'some magic' during our first class when he demonstrated the Law of Gravity. He had filled a clean glass with water, covered the glass with a white sheet of paper, then turned the glass upside down, Lo and behold the water did not pour and the sheet of paper remained intact! He explained that there is a balance between the force of gravity pushing the water up and the force pulling it down. It was not magic after all; we students tried it and observed same. Other experiments like show "one fifth of air is oxygen" and many more made the General Science class interesting and paved my way to studying science. We nicknamed him ‘Operation General Science ‘and eagerly waited for the next General Science class. Most of us turned out studying science related courses.

In the higher classes dedicated teachers like Mr. Ikenna Onyido (now Prof Ikenna Onyido former Vice Chancellor Nnamdi Azikiwe University, Awka), Mr Shode (now Prof. Shode) and Mr Charles Obunwo (now Prof. Charles Obunwo), who at the School of Basic Studies did not only teach us Chemistry but discipline and time consciousness. Lateness to ‘Charlie boy’s’ class was prohibited. These teachers perfected my choice of Chemistry as a course of study in the University.
Esteemed Vice Chancellor, sir, my resolve to read Chemistry in the university was not by default. I loved to do experiments gets results to improve man and society. Therefore my joy was full when I was offered admission to the University of Benin to read Industrial Chemistry. While growing up, I had the task of explaining to my grandmother what I learnt at school every day. When I gained admission she asked ‘what is Industrial Chemistry’, I told her, I will be studying how to use natural materials like plants etc., to make useful product for the society and humanity with the possibility of working in an Industry. Her response was a resounding applause accompanied by prayers for my success. Here I am today giving an inaugural lecture related to metals, plants, industry and humanity. As an inaugural lecturer, I know my task is to professionally stimulate and entertain this mixed audience

while I share my achievements in research, teaching activities and other engagements in the university.

I am a Professor of Inorganic Chemistry, a Chemist, member Chemical Society of Nigeria (CSN), member, Institute of Chartered Chemists of Nigeria (ICCON), member Women In Chemistry (WIC) and member Organisation of Women Scientists in Developing Countries (OWSD).

I have taught chemistry to various levels of students for over a period of 30 years. Chemistry is a central science which cuts across all science related courses and has always been a controversial subject among students from Secondary, College to University. However many still wade through the hurdles to become successful graduates.

Definition of chemistry

Chemistry is the science of matter and its components. It is divided into 3 major divisions

- ✓ Inorganic
- ✓ Organic
- ✓ Physical

These three are further subdivided into many different branches. I will briefly explain what Inorganic Chemistry is.

What is Inorganic Chemistry

Inorganic Chemistry is concerned with properties and behavior of Inorganic compounds which include metals, minerals and organometallic compounds. **Inorganic means not Organic**.

While Organic connotes living or natural (these days we hear of organic fruits, vegetables and foods etc.) inorganic literally means little or no chemicals added.

In Chemistry we define ‘Inorganic’ as substances that contain no Carbon or insignificant amount of carbon. So while Inorganic Chemistry is the study of compounds that do not contain carbon, Organic Chemistry is the study of compounds that contain Carbon. However it is difficult to completely alienate the two branches from each other as they are interwoven. Hence we have branches like Organometallic Chemistry, study of metals in organic molecules.

As Professor of Inorganic chemistry, I still work with Organic and Inorganic compounds. My research is centered on metals, their interactions in our environment, how organic materials can enhance the usefulness and longevity of metals and metallic materials. I have dealt majorly on Corrosion Inhibition of metals using organic materials, specifically waste bio materials, hence the title of this inaugural lecture, **‘That Metals may live longer’.**

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INTRODUCTION

Everyone who has invested in a construction, building or installation expects them to last long for effective use. When they are made of metals, the issue of corrosion must be put into serious consideration. Metals hold great value in any high energy society. They constitute approximately 90% of all construction materials and implements utilized in our environment. Corrosion is a natural phenomenon that happens to metals albeit at different rates; if left unabated corrosion leads to the deterioration of the metal and eventual breakdown. Metal deterioration ultimately shortens the lifespan of the metal. The economic and technical problems due to corrosion are so enormous and have plagued various industrial sectors worldwide. According to the US Federal High way Administration (FHWA) study the direct global cost of corrosion as at 2016 is estimated to reach 2.5 trillion, approximately 3.4% of GDP. When the metal is used in a place where it comes in contact with water or moisture, oxygen, air, ions or electrolytes, it is bound to react with these substances. One effective method to combat corrosion and make metals live longer is application of corrosion inhibitors on the metal surface or its environment. Synthetic corrosion inhibitors are gradually giving way to green inhibitors that are more ecofriendly, readily available and cheaper. Biowaste materials are also finding use as corrosion inhibitors. Inhibitors create protective barrier around metal against corrosive compounds thereby enabling metals live longer.

What are metals?

Metals are materials that are mined from ores for use in buildings, constructions like pipelines, bridges and other metallic gadgets in our world. From industries to homes, offices metals are in use. Metals can be identified by their properties

1. Conductivity. Metals conduct electricity and heat.

These properties can be demonstrated in a simple illustration; if you hold a metal spoon in a pot of boiling water, the heat or hotness from the pot travels down to your hand very quickly and you want to drop the spoon. On the other hand if a wooden spoon is in the same pot the heat is not transferred same way so you can hold the spoon for a long time without feeling the heat (metals conduct heat). Again, if you touch an electric source with a metal, electricity is transferred to your body and quickly you want to drop it due to the shock felt (sometimes the person may not survive the shock). Holding a wooden material or plastic does not produce such shock. Hence you see many electrical materials being insulated with wood or plastic material.

2. Shining (or lustrous) appearance

When polished or fractured metals show shining surfaces

3. Ductile and malleable

Metal have the capacity to stretch, bend or spread in response to stress. They can be hammered, pressed or rolled into thin sheets without breaking.

4. Magnetic properties

Metals are attracted to a magnet. When you bring a magnet close to a wooden or plastic material, there is no attraction but close to a metal, the metal is attracted to the magnet.

5. Sound

Metallic substances produce this resonating sound if you hit them with another hard substance. This sound is quiet different form the sound made by a wooden material or plastic. (in your seated position, hit the seat and observe the sound (please, don't hit yet; do that after the lecture), if there is any plastic around you, hit with same substance, observe the metallic substance does not have same sound with wood or plastic material.

These properties of the metal are as a result of metallic bond formed by atoms and molecules of the metal. Their valence shell accommodates only few electrons that are easily given off during chemical reactions to obtain a stable configuration.

If you look around where you are seated you can identify a metal or a metallic substance. Approximately ¾ of all known chemical elements are metals. Most abundant among them are **Aluminum, Iron, Calcium, Potassium, Sodium** and **Magnesium.** Chemists have arranged all known elements in the PERIODIC TABLE, which groups every element according to their properties, hence the division into metals and non metals.

Where are metals from?

Metals are found in nature as minerals in rocks or in ores. Ores are solid materials found on the earth's crust. Mining operations are necessary to extract metals from the earth (mines). People who work in the mines are called miners. Metals have to pass through extraction processes to become useful materials. Apart from the earth's crust, metals are found in our body e.g.

- ❖ Cobalt - used to make red blood cells in our body,
- ❖ Iron (Fe) - found in hemoglobin(blood)
- ❖ Zinc – helps our immune system
- ❖ Calcium – found in bones.

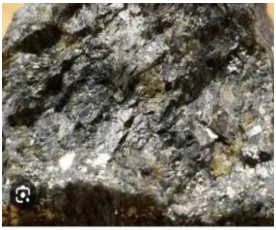
However metals discussed in this lecture are those naturally occurring in ores.

Table 1. Some metals and their ores

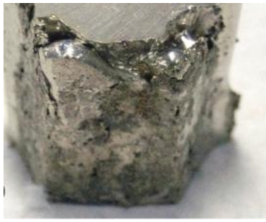
S/N	**Metal**	**Ore**
1.	Iron	Haematite, Magnetite, Limonite
2.	Aluminum	Bauxite
3.	Copper	Chalcopyrite
4.	Tin	Casserite
5.	Silver	Argentite
6.	Zinc	Sphaelerite or Zinc blende
7.	Nickel	Pentandite

Iron ore (haematite)

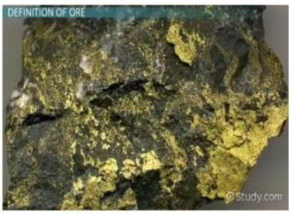
Aluminium ore



Zinc ore



Nickel ore



Gold ore

Cobalt ore

Plate1: Photos of some ores (photo credits: https://geologyscience.com, Alamy and Wikipedia)

Extraction of metals from ores

Metals are extracted from their ores either by reduction, oxidation or electrolysis. Extraction means removing unwanted materials from the ore to obtain a pure and useful product. The method employed depends on how the metal can react with the environment or type of ore.

Generally speaking, every ore passes through the following steps to separate metal from gangue (unwanted material). These steps are,

i. Concentration of ore to remove unwanted particles leaving a mass that contains higher percentage of the metal.

ii. Depending on the type of ore, concentrated product is subjected to roasting if it is a sulphide ore, e.g.

$$2ZnS_{(s)} + 3O_{2_{(g)}} \rightarrow 2ZnO_{(s)} + 2SO_{2_{(g)}} \qquad \text{(Equ.1)}$$

If ore is a carbonate, calcinations which is heating the concentrated product in the absence of limited supply of air

$$CaCO_{3_{(s)}} \rightarrow CaO_{(s)} + CO_{2_{(g)}} \qquad \text{(Equ.2)}$$

iii. Reduction and electrolytic reduction
Metal oxides obtained from roasting and calcinations are subjected to reduction to produce the impure metal, e.g.

$$ZnO_{(s)} + C_{(s)} \rightarrow Zn_{(s)} + CO_{2_{(g)}} \qquad \text{(Equ.3)}$$

Or $$CuO_{(s)} + H_{2\,(g)} \rightarrow Cu + H_2O_{(s)} \qquad \text{(Equ.4)}$$

iv. Highly reactive metals like Na. K, Mg are isolated by electrolytic reduction of their molten salts. Hence electrolytic cells are used to obtain the molten metal e.g., Molten sodium chloride is reduced to Na metal using electrolysis.

Further refining processes produces the pure metal.

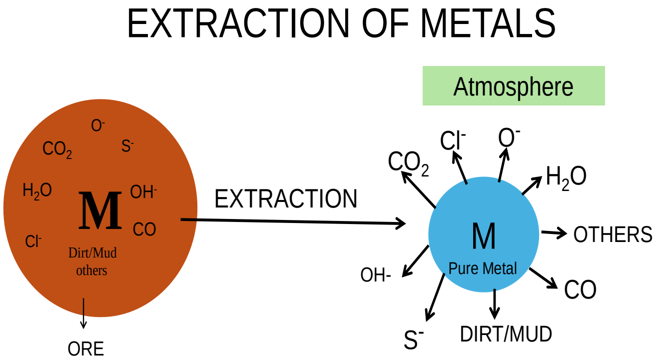


Fig 1. Extraction of metal

Once produced in their pure form, some metals can be used on their own e.g. Gold, Silver, Platinum, while others need to be combined with other elements to become useful in their pure state. Combining pure metals with other elements to obtain more stable and useful property is the process of making alloys. So alloys are mixtures of metal with one or more elements to improve the property of that metal. Alloys are stronger, harder and more durable than the pure metal. E.g. Aluminum (Al) is obtained as a molten mass, soft, malleable with low density. However its properties are enhanced when combined with elements such as Copper (Cu), Magnesium (Mg), and Manganese (Mn) to form alloys. Likewise pure Iron (Fe) is too soft for many uses, some other elements are added to increase its strength and make it more useful.

Table 2. Examples of Alloys

S/N	Name of alloy	Composition
1.	Duralumin	Al (95%) Cu, Mn and Mg
2	Bronze	Al (90%) Cu + Ag
3	Carbon steel	Fe (95%) , 2 – 4% C
4.	Stainless steel	Fe (64 -74%) >2% C , Cr, Ni
5.	Mild steel	Fe (98%), 0.15 – 0.25% C
6.	Brass	Zn (34%), Cu (66%)
7.	22 karat Gold	Au (92%), other metals (8%)

Importance of metals and their uses

Metals are important to any high energy society. They provide many services such as

- Transporting electricity in electrical grid
- Transport petroleum crude (pipelines)
- Biomedical applications (implants in human body).
- Household utensils
- Building construction
- Making Jewelries like Gold, silver etc
- Marking furniture (metal seats like the one we are sitting on in this auditorium) to mention but a few.

Table 3: Some metals and where they are used

S/N	Name of metal	Uses
1.	Gold / Silver	Ornaments of jewelries
2.	Copper	Electric wire
3.	Iron/steel	Buildings/construction/pipelines
4.	Lead	Car batteries
5.	Mild steel	Car bodies, solders
6.	Liquid mercury	Thermometers
7.	Stainless steel, cobalt, titanium	Body implants

The uses of metals as shown in Table 3 form the basis of some industries. Metals or their alloys could be raw materials, equipments or implements in such industries.

What is an industry?

An industry is a particular sector of economy that is either involved in manufacture of goods or providing services. The industry is the economic activity that converts resources to useful materials. Industries are grouped as either primary, secondary or tertiary. A primary industry is one involved in the extraction of raw materials from nature e.g. mining, fishing and livestock, while a secondary industry is one that turns raw material into finished goods. Provision of goods and services are the concern of a tertiary industry. When an **industry** is registered under company act Incorporated and pays tax, it is called a **company**.

Major types of industries

Some major industries are,

- Agriculture
- Banking
- Utility – Electricity
- Information technology
- Entertainment
- Health care
- Car manufacturing
- Construction
- Oil and Gas

Table 4: Metals used in some industries.

S/N	Industry	Metal used	Where metal is used
1.	Agriculture	Steel	Implements , rakes, hoes, shovels, tractors
2.	Car manufacturing	Mild steel, Aluminum Titanim Iron based alloys Copper	Car bodies Brake, rotors wheels, crankshaft, Exhaust pipe
3.	Construction	Steel and alloys of Iron. Carbon steel	Bridges, buildings,
4.	Oil and Gas	Aluminum, steel, iron and copper	Stainless steel, carbon steel, alloys of iron
5.	Building construction	Carbon steel	Making columns, decking, railings etc

Corrosion attacks on some industries

1. Agriculture

Agricultural implements and machinery are exposed to wear and tear. Rakes, shovels, tractors all suffer serious corrosion attacks

Plate 2. Corroded Agricultural implements and Machinery

Photo credit: Alamy stock photos

2. Construction

Corrosion is a major source of destruction in the construction industry. Corrosion causes bridges and other building constructions collapse and cause huge losses. (Al-Sherrawi et. al 2018).

Corroding car part corroding pipe

Corroded metal door

corroding storage tank

Plate 3. Corrosion in construction industry

Oil and Gas

The main materials used in this industry are Iron and its alloys like steel. Total annual cost of corrosion in the oil and gas industry in the United State according to report is estimated to be 1,372,600 US dollars (Simmons 2008). In Nigerian oil and gas industry, millions of Naira is lost each year to corrosion of equipment (Atanmo and Nwankwo (2017). Corrosion has caused perforation of pipelines, damaged separator vessels, pump elbows to mention but a few. So many measures have being and are still in place but the problem of corrosion persists.

Plate 4. A corroding Oil and Gas installation. Photo: credit appmfg.com

3. Building Industry

Rods are often used to reinforce concrete in a building. Corroded rod can weaken the structure and cause subsequent collapse.

Corrode rod in a building

Corroded railing

Corroded steel bridge (photo credit: @2023 Globe Media Partners, LLC)

Plate 5. Corrosion in building industry

Life expectancy of metals

The life expectancy of a metal is interpreted here as, how long a metal can be useful from the time of extraction (from ore) especially while used in metallic construction to when it strength fails. Strictly speaking, the life expectancy of a metal depends on

1. The nature of the metal
2. Its position in the reactivity series
3. The environment of use
4. Proper design

1. Nature of metal

Some metals are so reactive by nature that they cannot really exit unaccompanied. Examples are Sodium, Potassium, and Lithium they react so fast when exposed to the atmosphere to be in combined state. Sodium can remain stable as sodium chloride for instance. When a metal is very reactive its life expectancy in any construction material is very low. On the other hand a less reactive metal has high life expectancy. Liquid metal like mercury are not used in building construction but in other industries - making of thermometers and the likes.

2. The position of the metal in the reactivity series clearly determines its life expectancy.

Scientists have prepared a scale showing metals according to their reactivity and stability called the Electrochemical Series (ECS) or Reactivity series. The reactivity of a metal is measured in terms of electrical conductivity or Electrode potentials, E^0. Metals with lower electrode potentials (top of the scale) are more reactive than those with higher electrode potentials (bottom of the scale). Hence reactivity decreases down the scale.

Table 5. Electrochemical Series (ECS)

S/N	Name	Symbol	Electrode potential (E^0)
1.	Potassium	K	-2.925
2.	Sodium	Na	-2.714
3.	Magnesium	Mg	-2.37
4.	Aluminum	Al	-1.66
5.	Manganese	Mn	-1.18
6.	Zinc	Zn	-0.763

7.	Iron	Fe	-0.44
8.	Nickel	Ni	-0.25
9.	Tin	Sn	-0.14
10.	Lead	Pb	-0.12
11.	Hydrogen	H	0.00
12.	Copper	Cu	+0.337
13.	Silver	Ag	+ 0.799
14.	Platinum	Pt	+1.20
15.	Gold	Au	+ 1.50

As shown in table 5. The most stable metals are gold and platinum with the highest electrode potentials of +1.20 and + 1.50

3. Another overriding condition to the life expectancy of a metal is the environment in which the metal is or being used.

- Environment with moisture can spark off reaction and reduce usefulness of the metal
- Acidic environment. Metals are generally very reactive when in acidic environment. this can reduce their life expectancy
- Humid atmospheres help in dissolution of gases and do spark off reaction between metal and environs.
- Sea water contains a lot of salt that affects the life expectancy of metals.

4. **Sometimes the life expectancy of a metal is affected by other metals or substances in its surrounding.** For instance metals above hydrogen in the reactivity series will displace metals below hydrogen. In this wise Zinc will

displace Copper when in the same material and lead to deterioration'.

5. The longevity of a metal can also be influenced by proper design during construction.

Proper design of a structure could mean a design that takes into consideration the purpose of the construction. For instance designing a structure where water will accumulate, requires a drainage situated at a point where water can easily run off (fig 6)

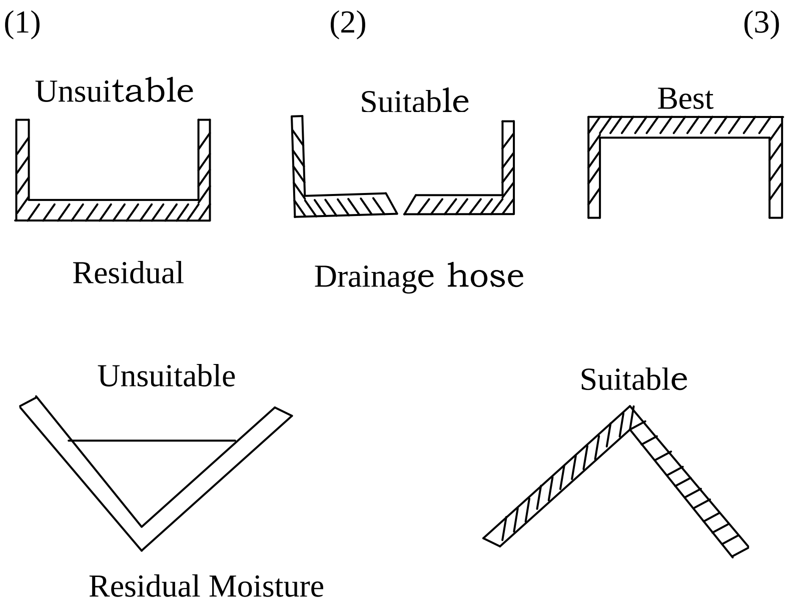


Fig. 2. Suitable and unsuitable designs in construction (Basic Principles of Corrosion, **Orubite** et al., 2018 first Edition)

The problem of metals

As valuable as they are, almost every metal has the problem of corrosion and rusting which affects their life expectancy or longevity. The tendency to corrode or rust and the rate these happen depend on the type of metal and its environment.

Why do metals corrode?

One basic reason why metals corrode is their tendency to revert back to their original environment– the earth (the form in which they were mined). Metallic ores occur as oxides, sulphides, carbonates etc. To obtain pure metals, other components in the ore are separated leaving the metal unaccompanied. So once in use these metals combine with the environment (oxygen, hydrogen, water, moisture) to become oxides, sulphides, carbonates and so on. This reaction gives rise to deterioration or degradation of the metal which eventually leads to breakdown of the metal. This is what we call **electrochemical corrosion.**

Corrosion

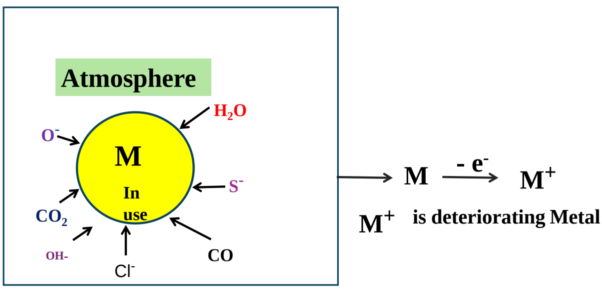


Fig. 3. An illustration of how corrosion occurs. Metal M+ gradually goes into solution and eventual break down

Corrosion and rusting

Corrosion simply put is the deterioration of a metal as a result of its interaction with the environment or surrounding which if not abated can lead to serious damage. It is a natural phenomenon and an electrochemical process, that is, during corrosion; current is produced as electrons move from anode to cathode. The most stable metals are Gold and platinum, their corrosion rates are so minimal and almost insignificant that they appear not to corrode. A pure gold trinket can remain the same for so many years while in use not so with same made of copper, Nickel or Zinc.

All metals corrode but only Iron and its alloys rust. Rusting is the oxidation of iron in the presence of air and moisture (that reddish brown substance that forms on the metal)

$$4Fe + 3O_2 \rightarrow Fe_2O_3 + \mathrm{x}H_2O \rightarrow \begin{matrix} Fe_2O_3.\mathrm{x}H_2O \\ (rust) \end{matrix} \qquad \text{(Equ.5)}$$

The product known as rust is a complex compound formed when iron reacts with air or moisture, only iron gives that reddish brownish product and no other metal. Rusting is a form of corrosion peculiar to iron and its alloys.

Examples of corrosion

1. Tarnishing of surface of silver or other metals
2. Rust which appears on iron surface
3. Blue-green coating on copper coins

How corrosion affects the life expectancy of a metal

Everyone who has invested in a construction, building or installation expects them to last long for effective use. When they are made of metals, the issue of corrosion must be put into serious consideration. If metallic corrosion is unabated, the metal deteriorates and eventually breaks down causing great damage to the construction. Corrosion is an extremely costly problem that leads to collapsed buildings, bridges, pipeline leakages and the like. The economic and technical problems due to corrosion are so enormous and have plagued various industrial sectors worldwide. According to the US Federal High way Administration (FHWA) study the direct global cost of corrosion as at 2016 is estimated to reach 2.5 trillion, approximately 3.4% of GDP. When the metal is used in a place where it comes in contact with water or moisture, oxygen, air, ions or electrolytes, it is bound to react with these substances. This reaction is the corrosion that happens to the metal or the metallic construction. Metals are rarely used in places where water or moisture, oxygen, air, ions or electrolytes do not exist. In other words metals and corrosion are inseparable. Corrosion can attack the entire surface area of the metal which is referred to as Uniform corrosion or Localized corrosion that attacks just a part of the metal. Either way the damage is extensive.

Elongating the life expectancy of metals

This is the subject of this lecture. Metals are prone to corrosion where ever they are used. The issue of how to make metals live longer brought scientists to the subject of corrosion inhibition. Corrosion inhibition is the practice of reducing, slowing down or stopping the deterioration of a metal by protecting the metal from getting in contact with reactants (water, moisture, oxygen, air) which will cause them to corrode. Various forms of corrosion control or prevention methods abound such as,

1. Proper designing of a metallic construction
2. Good material selection using less corrosive metals
3. Modification of the environment in which the metal is used
4. Addition of corrosion inhibitors to the environment

This inaugural lecture will dwell on control method (4), addition of corrosion inhibitors

Corrosion inhibitors

Corrosion inhibitors are materials that suppress metal deterioration when present in minute quantity in a corroding environment. They can slow down, reduce and stop the degradation of the metal thereby elongating the life of the metal. Many corrosion inhibitors have been discovered by scientists and they are grouped according to their mode of inhibition. Generally speaking, they act by forming a kind of barricade between metal and corrosive environments. Initial corrosion inhibitors discovered were mostly **synthetic organic or inorganic** compounds that contain S,N,O hetero atoms in their molecules. These hetero atoms researchers revealed, reacts with metal ions (from the corroding metal) to form a protective film over the metal. Such films are often hydrophobic (waterproof), formed by weak chemical bonds that can break down at high temperatures. On the other hand inhibitor molecules can diffuse into the metal surface due to chemical adsorption to form a protective film which is stronger and stable at higher temperature. More still inhibitors can protect metal by reacting with a potentially corrosive substance in the environment. Corrosion inhibitors are a solution to huge amount of money spent by industries to combat corrosion.

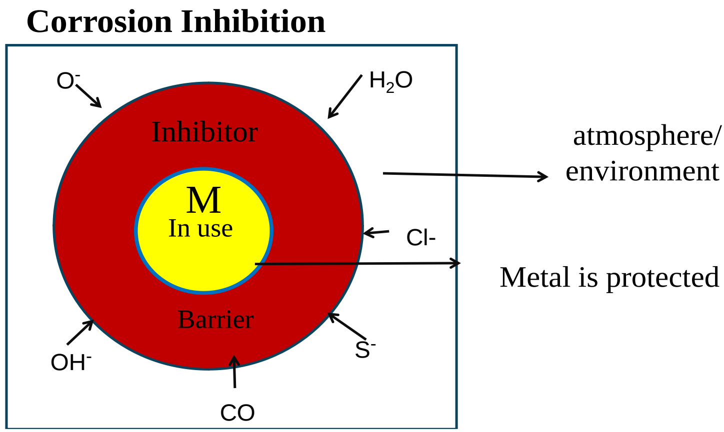


Fig 4. Illustration of corrosion inhibition

Table 6. Examples of synthetic corrosion inhibitors

Organic	Authors	Inorganic	Authors
Imidazoline Derivatives	Ghanbari et.al (2010	Molybdate	Mu et al (2006)
Adenosin	(Sin et.al (2017),	Tungstate	Mu et al (2006)
Diphenyl carbazones	(**Orubite and Oforka 2004**; Abiola and Oforka 2009)	Chromate	Ilevbare and Burstein (2003)
Pyrazolones	Chaouiki et al (2020)	Zinc oxide	Loto et. al (2016)
Some drugs	Gece G. 2011; Ngobiri N C and **Okorosaye-Orubite, K.** (2017	Phosphate	Bastos et. al (2005)

Green corrosion inhibitors

Most of these synthetic corrosion inhibitors are not without various environmental hazards. Some of them are non biodegradable; constitute environmental toxicity, expensive and not readily available (Winston et al 2020).

In line with the current industrial legislation and the striving for green environment, scientists resorted to finding non toxic, environmentally friendly and readily available corrosion inhibitors.

Over the years the resolve to go green has fueled research in identifying natural products such as leaves, plant extracts and other biodegradable materials suitable to suppress metal degradation and corrosion.

Green corrosion inhibitors are natural, eco- friendly inhibitors produced from bio materials which are cheap and readily available (Amitha and Bharanti 2012; Hongyu et.al 2020).

Plant products are organic in nature; they contain phytochemicals (tannins, amino acids, alkaloids) which have heteroatoms such as P, O N, and S atoms capable of forming protective film as barrier to prevent metal corrosion.

Plant extracts as corrosion inhibitors

Many plant extracts have been reported as efficient corrosion inhibitors for metals such as,

- Vernonia Amygdalina leave extract (bitter leaf) – Loto (2003)
- Eucalyptus leaf extract – Abdel and Rahal (2020)

- Aqueous extract of Camellia sinensis- Abd El – Aziz et.al (2013)
- Euphoria heterophylla L extract – (Odejobi and Olatunde (2019)
- Green tea, Nayem Hossain et al (2020)
- Bamboo leaves- (Xianghong Li et al 2017)
- Ruta Graveolens Extract- (Anupama et al 2016)

Plate 6. Vernonia Amygdalina leaves (Bitter leaf)

Plate 7. Eucalyptus leaves

Plate 8. Camellia sinensis plant

Plate 9. Euphoria heterphylla

How efficiency of a corrosion inhibitor is measured

The efficiency of a corrosion inhibitor measures the extent of protection it can afford a metal in a particular environment. This further translates to the longevity of that metal. The efficiency of the inhibitor is presented as corrosion inhibition efficiency in percentage (Inhibition efficiency, I.E %). This property of the inhibitor is obtained from experimental procedures. Hence any plant extract reported as effective or good corrosion inhibitor was experimentally confirmed to have inhibition efficiency between 70 -95%.

Mathematically, I.E % is expressed as,

$$I. \quad E\ \% = \frac{Wo - Wi}{Wo}\ x\ 100 \qquad \text{(Equ.6)}$$

Where, Wo = weight loss without inhibitor and Wi = weight loss with inhibitor

Table 7. Inhibition Efficiencies obtained for some plant inhibitors

S/N	Plant	Author (s)	Title	Inhibition Efficiency ($I.E$ %) at 30^{O}C
1.	Bamboo leaves	Xianghong Li *et al*.,(2016)	Inhibition effect of bamboo leaves extract on cold rolled steel in Cl_3CCOOH solution	95%
2.	Ruta graveeous extract (RGE)	Anupama *et al*., (2016)	Investigating the effectiveness of Ruta graveeous extract (RGE) for corrosion	95%

			inhibition of mild steel in 1M HCl RGE,	
3.	Theobroma Cacao plant extract	YuliYetri*et al*.,	Theobroma Cacao plant extract as corrosion inhibition for mild steel HCl medium	96.3 -95%
4.	Vernonia Amygdalina extract	(Eyu *et al*., 2013).	Effect of Vernonia Amygdalina extract on corrosion inhibition of Mild steel in simulated sea water	75%
5.	Andrographis paniculata	Ambrish *et al*., (2012)	Corrosion inhibition of Carbon steel in HCl solution by some Plant extracts	98%

The gap in some of the researches on plant corrosion inhibitors

Most of these plants proposed as corrosion inhibitors are also useful for other purposes. The competitive use of these plants may hinder productivity and prevalent use of such inhibitor.

Table 8. Selected plants and their dual usage

S/N	Plant	Author (s)	Where used as inhibitor	Other uses of plant
1.	Bitter leaf ((*Vernonnia amygdalina***)** and honey	M. A. Abba-Aji, B. Muhammad and D. Onwe (2020).	Corrosion inhibition of mild steel determined using blended Bitter leaf (*vernonnia amygdalina*) extract and honey in dilute H_2SO_4 And HCl acid solutions	Bitter leaf is used food and medicinal purposes. Honey also has variety of uses
2.	Theobroma Cacao plant extract.	Yuli *et al*., (2015).	Corrosion inhibition of mild steel by polar extract of Theobroma Cacao peels in HCl solution.	Theobroma cacao provides raw material for chocolate industry. Treatment for various ailments such as anemia, mental fatigue
3.	Rutagraveeous extract (RGE)	Anupam a *et al*., (2016)	Excellent Anticorrosion Behaviour of *RutaGraveolens Extract* (RGE) for mild Steel in Hydrochloric acid: Electro Analytical Studies on the effect of time, temperature and inhibitor concentration;	Has therapeutic uses such as treatment of inflammatory conditions, Eczemas , ulcers, antidote for venoms, etc.

4.	Bamboo leaves extract	Xiangho ng *et al*., (2016)	Inhibition effect of bamboo leaves extract on cold rolled steel in Cl_3CCOOH solution	Bamboo leaves serve as herbal teas, antibacterial activity, and the tall trees are used as support for building constructions.

My Fascinating Journey of exploration and discovery of Green Corrosion inhibitors

My fascinating journey into the world of corrosion inhibition anchored me in under taking preliminary studies on the exploration of bio waste or less useful materials as corrosion inhibitors. This was intended to bridge the existing gap in using plants which are handy for medicinal, therapeutic or culinary purposes. I resorted to using bio waste materials for the following reasons.

- They are ecofriendly
- Readily available
- Reduce filthiness of the environment
- Economical/Cheap

Metals studied were those commonly used in our environment (mild steel, Aluminum, Copper and Zinc). The first Bio material used was *Nypa fruiticans wurmb* in our work **Orubite** and Oforka (2004). Corrosion inhibition of mild steel in HCl using extracts of *Nypa fruiticans wurmb.* We explored the use of Nypa Palm as a corrosion inhibitor for mild steel in acidic medium (HCl). *Nypa fruiticans wurmb* is that palm that grows along the coastal areas of the Niger Delta. Nypa was introduced during the colonial era as an assumed remedy for shore protection and agriculture but it has actually not been useful for that purpose. As at the time we found this use for *Nypa fruiticans wurmb* many scholars including Government saw it as nuisance and called for its eradication (Ukoima 2000). At best *Nypa fruiticans wurmb* was used for making thatches and roofing by the local (Orubite and Oforka 2004). The rate it was ravaging the mangrove forest was alarming hence the call for eradication (we can all attest to this fact especially those of us who travel along the coastal areas). Even in the present, *Nypa fruiticans wurmb* is still wiping out the more useful Mangrove trees. (Ukong et. al. 2015, Nwobi et. al 2020; Numbere 2023)

Plate 10. *Nypa fruiticans wurmb* growing among Mangrove trees along a coastal area.

The leaves extract was tested and found suitable as a corrosion inhibitor for mild steel in Hydrochloric acid medium.

Why Hydrochloric medium?

We considered Hydrochloric acid as the medium because in urban areas where air pollution is caused by oil exploration and heavy vehicular activities, there is a chance of acid rain occurring in the form of Hydrochloric acid when it rains.

Mild steel was chosen on its merit as being the most used metal especially for car bodies. So the aim was to find an inhibitor for mild steel that can save car bodies from corrosion. You can agree with me that car bodies corrode faster in this city (Port Harcourt, Rivers State) than elsewhere with less air pollution. The inhibition study was done alongside a synthetic organic inhibitor, 1, 5 Diphenyl carbazone (DPC) as comparism.

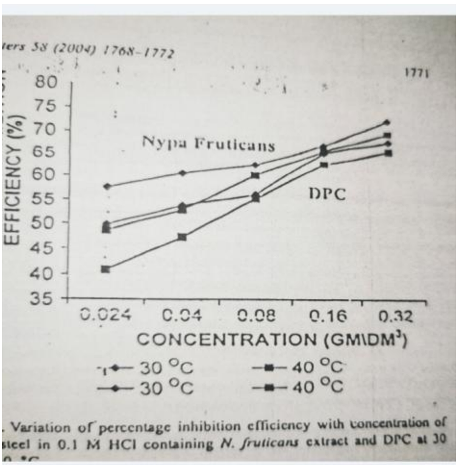


Fig. 5. Inhibition efficiency of *Nypa fruiticans wurmb* and DPC

Our result showed the highest inhibition efficiency of 75.11% for *Nypa fruiticans wurmb* and 70.18% for DPC at $30^{O}C$ suggesting the leaves extract of *Nypa fruiticans wurmb* as good corrosion inhibitor and comparable to a synthetic inhibitor.

In another study (**Okorosaye-Orubite** and Oforka. Corrosion inhibition of Zinc by leaves extracts of *Nypa fruiticans wurmb* in HCl medium) the same extract was tested as inhibitor for Zinc in Hydrochloric acid and also compared with same 1,5 Diphenyl Carbazone (DPC). The optimum inhibition efficiency for both *Nypa fruiticans wurmb* and DPC was 36.43 and 40.70 % respectively. Although Nypa did not inhibit Zinc's corrosion in this study, evidence was provided once more *Nypa fruiticans wurmb* and DPC show comparative inhibition properties.

Still testing the usefulness of *Nypa fruiticans wurmb* in corrosion inhibition, our research moved to synergistic studies (addition of other substances to the inhibitor to improve its performance) in another work ,**Okorosaye-Orubite et.al**. (2016) Synergistic effects of potassium iodide on corrosion inhibition of mild steel in Hydrochloric acid solution by leaves extract of *Nypa fruiticans wurmb* the effect of adding Potassium iodide (KI) to *Nypa fruiticans wurmb* was investigated in 0.1M and 0.5M HCl. The results showed a more effective *Nypa fruiticans wurmb* extract. In 0.1M HCl, an inhibition efficiency of 77.31% was obtained for only *Nypa fruiticans wurmb* while addition of potassium iodide to *Nypa fruiticans wurmb* extract increased inhibition efficiency to

95.36% at the same temperature of 30^{O}C. The observations clearly established that the addition of KI improved the corrosion inhibition power of *Nypa fruiticans wurmb* leaves extract.

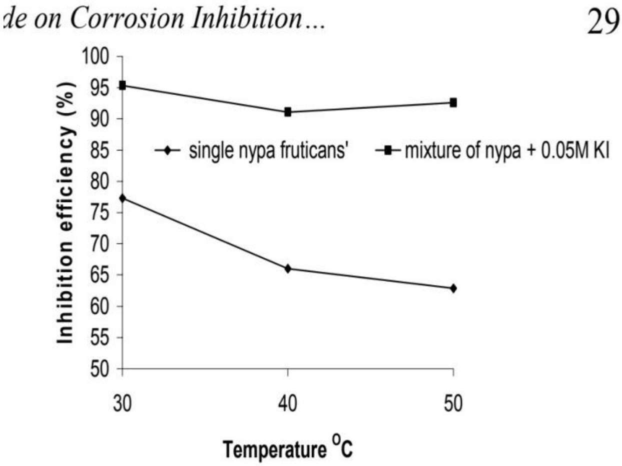


Fig 6. Variation of inhibition efficiency with Temperature (^{O}C) in synergistic study with KI (Orubite et al 2005).

Other parts of *Nypa fruiticans wurmb* were also tested for corrosion inhibition properties. Specifically the fruits were used; **Okorosaye-Orubite** and Hamilton (2005) Inhibition of corrosion of mild steel in hydrochloric acid medium by extract of *Nypa fruiticans wurmb* Fruits.

Nypa fruiticans wurmb produces fruits clustered in a bunch as shown below. When the fruits are ripe, they detach from and float away on the tide and often germinate while still on water. Germinated seeds are dispersed into mangrove soil to start its life circle.

Plate 11. *Nypa fruiticans wurmb* fruits. Photo credit wikipidea

Extracts of the fruits retarded the dissolution of mild steel in HCl medium and the inhibition power was relative to concentration and temperature studied (30 and 40 ^{O}C). Inhibition was more effective at higher extract concentration and lower temperature. In this same study we reported that the fruits extract as well as the leaves extracts inhibit mild steel corrosion comparatively.

We decided to use another medium to test corrosion inhibition power of *Nypa fruiticans wurmb* on mild steel, NaOH and NaCl. Sodium Hydroxide (NaOH) also known as caustic soda or lye does not occur naturally but has been manufactured as raw material for numerous industrial uses including manufacture of soap. In agriculture, it is a valuable chemical for weed control, raise pH of soils to acceptable levels and also in pest control chemicals, Muley and Parihar (2022) When in contact with metals (Aluminium, Lead , Zinc , Iron) in the presence of acids (from acid rain, fertilizers, industrial chemicals and other farm chemicals), water or moisture, it releases a flammable and explosive gas called Hydrogen gas. The resolve to test in Sodium Hydroxide medium was hinged on this fact.

On the other hand, Sodium Chloride (NaCl) which is known as common salt is found in nature and responsible for the salinity of the sea among other ions. These ions are present in environment as (Na^+, K^+, Cl^-, NO_3^-etc.). They serve as vehicles to transport electrons and contribute to corrosion of metals, the more their concentrations in the environment, the faster the corrosion rate. This is the reason metals corrode faster in sea water than fresh water. Sea water has species like Na^+, Ca^{2+}, Cl^-, SO_4^{2-}, etc. in higher concentrations than they are in fresh water.

In the two mediums (NaOH and NaCl) our work **Okorosaye-Orubite** et al (2009) observed the following,

- Mild steel corrodes in NaOH and NaCl mediums
- *Nypa fruiticans wurmb* leaves extract facilitated the corrosion of mild steel in NaCl solutions
- *Nypa fruiticans wurmb* aided the formation of a thick product which covers the surface of the metal to limit further dissolution of the metal (passivation) in NaOH.
- Inhibition efficiency values obtained were negative for the extract in NaCl but positive for NaOH

- An increase in temperature (30-40^{O}C) accelerated the corrosion of Mild steel in NaCl but caused only slight dissolution of metal in NaOH.

The research therefore provided information that *Nypa fruiticans wurmb* leaves extract is not an effective inhibitor for mild steel corrosion in NaCl medium but in NaOH solution, can improve the protection of Mild steel through passivation. Passivation is a process through which a metal can be protected from its corrosive environment. The end result is longer life span for the metal.

These pioneer studies on *Nypa fruiticans wurmb* opened up other researches on the use of *Nypa fruiticans wurmb* as corrosion inhibitor for metals; Onen (2010), Mohd Zaidi Mat Sater et al (2012) corrosion inhibition of Aluminum by using Nipa (Nypa Fruticans) extract solutions in Hydrochloric (HCl) media. Muhammad Saliu Azreen Ismail (2015), corrosion inhibition of mild steel in Hydrochloric acid solutions by the extracts of *Nypa fruticans wurmb*. Shetata et al (2018). Kinetic studies of selected corrosion inhibitors of Aluminum and Mild Steel in Acid medium. Green corrosion inhibitors, past, present and future; Dave P N and Macwan PM. (2024). Phytochemicals /plant extracts as corrosion inhibitors for Brass in various electrolytes, Nwigwe U S and Nwoye C I. (2022) The efficacy of plant inhibitors as used against structural mild steel corrosion: A review.

These research all found *Nypa fruticans wurmb* extracts as good corrosion inhibitor and recommend its use in industries as a clean, safe and economic corrosion inhibitor.

The search for eco friendly corrosion inhibitor led our research to another plant called *Xanthosoma Spp* an aquatic weed. Literature has it that it is a native of tropical America but widely cultivated and naturalized in other tropical areas. This plant grows as an aquatic weed in the swampy environment of Bonny Island in Rivers State, Nigeria. From information, not much use is made of this plant by the locals both for domestic or other purposes.

Plate 12. Xanthosoma plant in Bonny Island

In another research with my colleagues, Hart, **Okorosaye-Orubite** and James (2016) Corrosion inhibition of copper in sea water by *Xanthosoma spp* leaf extract (XLE**).** The leaf extract of this sea weed was tested as corrosion inhibitor of copper. Sea water prepared artificially according to known standards (Axelrod Glen S 2005) was the medium used for the testing. *Xanthosoma Spp leaf* extract was found to inhibit corrosion of Copper in sea water. An optimum inhibition efficiency of 85% was obtained at temperature of $30^{O}C$. Once more a common sea weed was confirmed as corrosion inhibitor for a metal (Copper) in a corrosive environment.

Table. 9. Composition of Stimulated Sea water used

Salt	Concentration (mg/l)
Sodium Chloride (NaCl)	55
Sodium Sulphate (Na_2SO_4)	10
Potassium Chloride (KCl)	4
Sodium bicarbonate ($NaHCO_3$)	1
Boric Acid (H_3BO_3)	0.010
Magnesium Chloride ($MgCl_2.6H_2O$)	32
Calcium Chloride ($CaCl_2.2H_2O$)	4

Source: Axelrod Glen (2005)

Why stimulated Sea water?

- To have a laboratory form of sea water.
- Sea water out of the sea depreciates or loses potency every hour and would not be the same concentration for the period of the experiment (7 days).
- To have a consistency in measurement of corrosion parameters.
- Minimize biological effects
- To have a reproducible solution of known concentration

Another sea weed along the Bonny River (Nymphae *pubscens*) was also tested as corrosion inhibitor in our work, Hart, **Okorosaye-Orubite** and James (2018) Corrosion inhibition of Mild steel in stimulated sea water by *Nymphae pubscens* Leaf Extract (NLE). Commonly known as water lily, the plant is a native to the temperate and tropical parts of the world. It grows in the fresh water environment of Bonny Island. In this study, mild steel was again used in stimulated sea water. From literature, phytochemical investigation shows it contains the hetero atoms (N, O, and S) and availability of pi electrons.

Plate 13. *Nymphae pubscens* (water lily) along the Coast of Bonny River

Table: 10. Calculated values of corrosion rate (mmp y^{-1}) and inhibition efficiency for mild steel corrosion in stimulated sea water in the absence and presence of various concentrations of NLE at different temperatures.

Inhibitor Concentration (v/v%)	Corrosion rate (mmp y^{-1}) x 10^3				Inhibition Efficiency (I.E %)			
	303K	313K	323K	333K	303K	313K	323K	333K
0 (blank)	0.34	0.37	0.41	0.45	-	-	-	-
1	0.31	0.34	0.38	0.41	30.71	28.09	24.8	24.51
2	0.24	0.28	0.32	0.37	33.64	30.13	29.56	27.04
3	0.19	0.24	0.28	0.32	54.3	51.7	50.56	48.74
4	0.13	0.18	0.23	0.28	69.2	66.43	66.06	61.68
5	0.07	0.12	0.18	0.24	85.91	84.05	79	77.36

As shown in Table 10, using *Nymphae pubscens* extract shows an inhibition efficiency of 85.91% at $30^{O}C$ (303K) with concentration of 5v/v%. Thus NLE can be exploited as corrosion inhibitor for mild steel to enhance its longevity.

In search for more natural and ecofriendly corrosion inhibitors we considered a seasonal bio waste that litters our environment – **corn silk.** The effectiveness as corrosion inhibitor was investigated in our work, **Okorosaye-Orubite** and Ngobiri (2017), Corn silk as corrosion inhibitor for mild steel in 0.1M HCl medium. Corn silks or hairs are a bundle of long and yellowish strands on top of the corn fruit. They appear brownish on a matured corn. Although some traditional uses of corn silk have been reported (Maksimovic 2003) they rarely find use around us but mostly discarded when corn is prepared as a meal.

Plate 14. Corn with the silk or hairs

The effectiveness of corn silk water extract as corrosion inhibitor for mild steel in 0.1 M HCl was confirmed to be between 72-77.7 % at 30 ^{O}C. inhibition efficiency was found to increase with increase in concentration of the extract. Hence the highest concentration of 20%v/v gave the highest inhibition efficiency. The graphical presentation of the result is as shown in Fig. 17

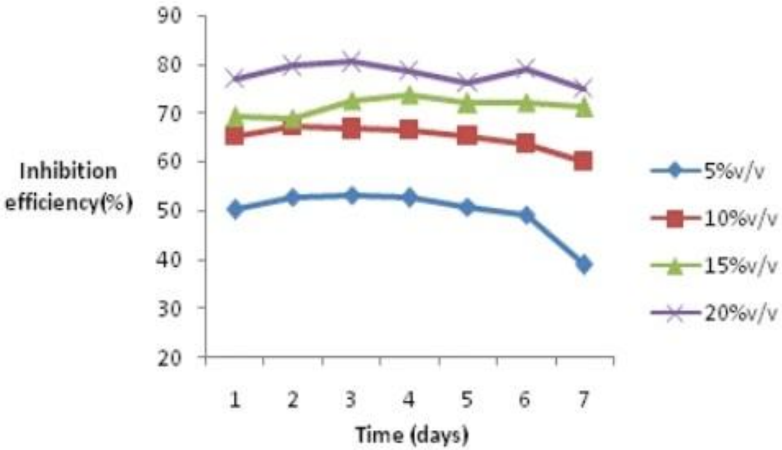


Fig.7. Inhibition efficiency of corn silk water extract at 30 ^{O}C

The corn silk extract used was obtained using de ionized water. We decided to use another solvent (methanol) for the extraction. A comparison of the effect of both solvents on corrosion inhibition of mild steel in 0.5M HCl was also studied.

The result showed inhibition efficiency of 95.07% for the methanol extract and 79.43% for the aqueous (water) extract. It was obvious that methanol extracted more components of the corn silk which provided better protection for mild steel in the acidic medium.

We concluded that in terms of extraction method the methanolic extract gives better inhibition than water or aqueous extract. Using corn silk (hair) extract as corrosion inhibitor was a pioneer research by us since it was not cited or published in any referred journal before our work.

After this research some other authors studied corrosion inhibition of metals using corn silk and ascertained its effectiveness. Sefrilita et al (2023) reported in their work, corn hair extract as corrosion inhibitor for ST37 steel in 3% HCl media the inhibitor significantly impacted the the morphological characteristics of ST steel. They also observed that higher concentration of corn silk extract lowered the corrosion rate better. In conclusion the research asserted that the potential use of corn hair extract (a waste material) as corrosion inhibitor is effective for reducing the corrosion rate of ST 37 steel. These researchers also recommended the future manufacture of corn hair as inhibitor for reducing the corrosion rate for ST 37 steel. Indeed bio waste can elongate the lives of metals to grow our industries.

The Niger Delta region is involved with oil exploration activities, crude oil and the like are transported through metal pipelines which are buried underground. Corrosion of pipelines is a regular occurrence and a menace to the oil industry. Broken pipelines lick crude oil into water bodies and farm lands, the effect on the community is well known to us.

Our next research Ngobiri N C and **Okorosaye-Orubite K.** (2018) used another bio waste Brassica oleracea (cauliflower) outer leaves and Citrus paradise (Grapefruit) mesocarp or peel extracts as corrosion inhibitor for pipeline steel. The extracts were prepared by peeling off the mesocarp of Citrus paradise and outer leaves of Brassica oleracea.

Plate 15. Brassica oleracea showing the leaves

Plate 16. Citrus paradise with the peels

Outer leaves of Brassica oleracea (BO) and Citrus paradise mesocarp (CPM) are both parts of the fruits which are discarded while other parts are eaten. These parts are therefore considered as waste materials. They are usually discarded as waste in most homes and food drink industries.

Steel pipelines are used to transport domestic and industrial fluids are also prone to internal corrosion as these fluid pass through them which can affect their life span if left uncontrolled or prevented. Our research confirmed that corrosion was a continuous process in this closed system and using the extracts as corrosion inhibitors can be a relief. Brassica oleracea (BO) and Citrus paradise mesocarp (CPM) showed near equivalence corrosion inhibition efficiency of 91.45% and 89.44% respectively at the concentrations studied.

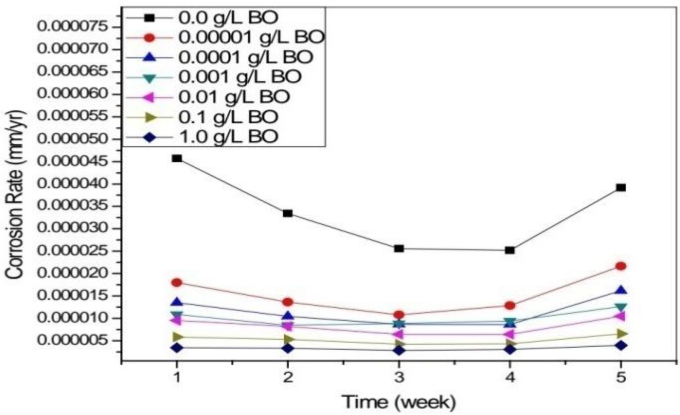


Figure 2. Variation of corrosion rate (mm/year) with time (weeks) of the pseudo anaerobic corrosion inhibition of pipeline steel in petroleum pipeline water with various concentrations of *Brassica oleracea* extract (BO).

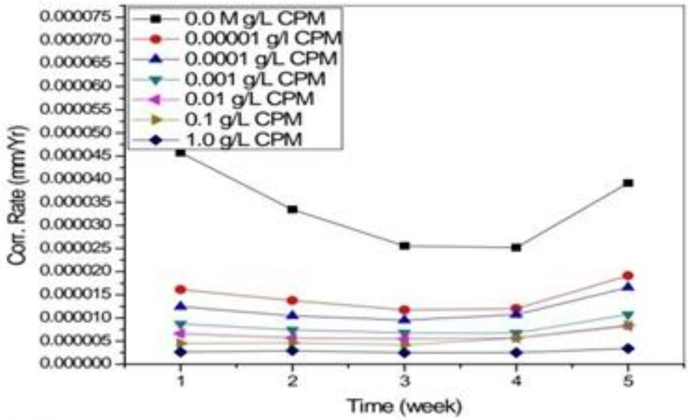


Figure 3. Variation of corrosion rate (mm/year) with time (weeks) of the pseudo anaerobic corrosion inhibition of pipeline steel in petroleum pipeline water with various concentrations of *Citrus paradise* mesocarp extract.

Fig.8. Inhibition efficiency of BO and CPM on pipeline steel.

Table 11. Inhibition Efficiencies (at 30^{O}C) obtained for plant inhibitors used in my researches

S/N	Plant	Author (s)	Title	Inhibition Efficiency ($I.E$ %)
1.	*Nypa fruiticans wurmb*	**Okorosaye-Orubite** (2004)	Corrosion inhibition of mild steel in HCl using extracts of *Nypa fruiticans wurmb* leaves**.**	75.11%
2.	*Nypa fruiticans wurmb*	**Okorosaye-Orubite** and **Oforka** (2004)	Corrosion inhibition of Zinc by leaves extracts *Nypa*	36.43%

			fruiticans wurmb in HCl medium.	
3.	*Nypa fruiticans wurmb* extract)	**Okorosaye-Orubite** e and Hamilton (2005)	Inhibition of corrosion of mild steel in hydrochloric acid medium by extract of *Nypa fruiticans wurmb* Fruits.	68.0%
4.	*Nypa fruiticans wurmb*	**Okorosaye-Orubite** et.al. (2007).	Synergistic effects of potassium iodide on corrosion inhibition of mild steel in hydrochloric acid solution by leaves extract of *Nypa fruiticans wurmb* .	77.34%
5.	Xanthosoma Spp leaf extracts	Hart, **Okorosaye-Orubite, K.,** James A O (2017). .	Corrosion Inhibition of copper in sea water by Xanthosoma Spp leaf extracts (XLE**).**	83.0%
6.	Corn silk	**Okorosaye-Orubite** and Ngobiri (2017).	Corn silk as corrosion inhibitor for mild steel in 0.1M HCl medium	77.2%
7.	*Brassica Oleracea* (outer leaves)	Ngobiri, N. C. and	Corrosion pattern of	91.45%

		Okorosaye-Orubite, K. (2018).	pipeline steel in petroleum pipeline water in the presence of biomas derived extracts of *Brassica oleracea and citrus paradise mesocarp*.	
8.	*Citrus paradise* mesocarp.	Ngobiri, N. C. and **Okorosaye-Orubite, K.** (2018	Corrosion pattern of pipeline steel in petroleum pipeline water in the presence of biomas derived extracts of *Brassica oleracea and citrus paradise mesocarp*.	89.44%
9.	*Nymphae Pubscens*	Hart Kalada , **Okorosaye-Orubite, K.** and James A.O (2018)	Corrosion inhibition of Mild steel in stimulated sea water by *Nymphae pubscens* Leaf Extract	77.36%
10.	Methanolic Extracts of Corn Silk	Eyah, Okorosaye-**Orubite** and James (2018).	Methanolic and Aqueous Extracts of Corn Silk as Corrosion Inhibitor for Mild Steel in 0.5M HCl	95.07%

11.	Aqueous Extracts of Corn Silk	Ayah, **Okorosaye-Orubite** and James (2018).	Methanolic and Aqueous Extracts of Corn Silk as Corrosion Inhibitor for Mild Steel in 0.5M HCl	79.43%
12.	*Chrysophyllum Albidum*	Othaki, Ngobiri, **Okorosaye-Orubite** (2021)	Corrosion inhibition of pipeline steel using seed pericap of *Chrysophyllum albidum* in 0.5 M H_2SO_4	88..0% (cotyledon) and 78.80% (pericap)

Ongoing and future Research

The research outlined above is all preliminary steps to identifying bio waste materials as corrosion inhibitors for metals. One will ask how they are applied to the metal for protection and subsequent longevity of the metal. Our ongoing research is aimed at achieving that objective which introduces us to the use of anti corrosion paints.

What are anti corrosion paints?

These are paints sprayed on metals to create protective barriers between the metal surface and the corroding environment. Such barriers are often water resistant and impermeable to other agents that assist corrosion. These anti corrosion paints are composed of pigments, binders and other additives to effect protection of the metal. They are different from oil paints which are often times misunderstood for anti corrosion paints; although the oily nature of oil paints can protect the metal surface from water and other climate conditions, however oil paints may have issues in effective protection of metal surface from chemicals or industrial gases.

An anti corrosion paint because of its specific chemical composition creates a barrier between metal surface and any chemical compound. Therefore the distinction between oil paints and anti corrosion paints is basically in their chemical composition. While the oil paints protect by mere covering or barrier between metal surface and environment (water, moisture, air), anti corrosion paints have the added advantage of inhibiting metal surface in contact with chemical compounds which are corrosive. For instance chromate-type pigments release a chemical that interfere with the electrolyte (corrosion environment) and disrupts the corrosion reaction (Felhosi et al 2023; Jaydutt 2017).

Composition of an anti corrosion paint

Several anti corrosion paints, domestic and industrial, are available and in use, their composition consists of

1. Corrosion resistant pigments such as

- Chromates of zinc and lead (zinc chromate, lead chromate)
- oxides of zinc
- zinc dust
- Red lead.

2. Binder in form of oil
3. Drying Agent to impute quick drying characteristics to the paint.
4. Solvent

Corrosion is an electrochemical reaction, so any substance that inhibits this electrochemical reaction is sure to protect metals. The chemicals in the pigments interfere with the electrolyte and disrupt the electrochemical reactions thereby effecting protection of the metal surface.

In some other cases the pigments added act as sacrificial coating and are corroded instead of the metal of interest. Example is zinc coating.

The following factors are considered among others while developing an effective anti corrosion paint for metals,

- environment in which the metal is used (fresh or salt water)
- possible corrosive contaminants in the environment
- Chemistry of the soil in the environment i.e. whether soil is acidic, alkaline or contains reactive salts.
- Electrical conductivity of soil
- factors that may cause stray currents
- Exposure to reactive substances like acid rain, alkaline or acidic compounds, radiation, solvents, sewage and so on.

Basically an anti corrosion paint is formulated taking into consideration the nature of the environment in which the metal is to be used for effective protection.

Many scholars have reported the preparation of anti corrosion paints (Ross and Wolstenholme (1977), David et al 2018, Tadros and Abd El Nabey (2000), Lazorenko et al (2021), Popoola (2014, to mention but a few.

However in the formulation of these paints synthetic pigments are used which still boil down to the issue of toxicity of the environment. Lazorenko et al (2021) in their work "Anti corrosion coatings for protection of steel railway structures exposed to atmospheric environments" reiterated the global trend to reduce volatile organic compounds VOCs) and toxic corrosion inhibitors.

Therefore to maintain an eco friendly environment, anti corrosion paints must contain less of synthetic pigments and more of organic, bio degradable and non toxic materials. Only a few works on preparation of anti corrosion paints from eco friendly corrosion inhibitors are reported in literature like (Izadi et.al 2018 and Wan Nik, et.al 2017). This is the reason our present work is interested in developing anti corrosive paints from bio waste materials having found them effective corrosion inhibitors.

How anti corrosion paints are applied on metal for protection

Anti corrosion paints are applied on metal surface by several layers of paint after sandblasting or preparing metal surface. This forms the coating which serves as a barrier between metal and corrosive environment to protect and elongate life span of the metal. For effective performance an anti corrosion coating must adhere efficiently to the metal surface and have flexibility and strength to withstand load and stress when exposed to the environment.

Still working on how Metals can live longer, our team considered microbial corrosion in which we isolated and identified some microbes that attack Aluminum, Zinc and Copper surfaces (Gbarakoro, **Okorosaye – Orubite** 2021; Gbarakoro, **Okorosaye – Orubite** 2022). One of our ongoing research is aimed at identifying natural Biocides that will limit the growth of microbes on metal surfaces, reduce corrosion and make them live longer.

A Biocide is a chemical substance or biological product used to kill, control the growth of or repel a specific organism (Virginia et al 2022).

My other research on metals and Bio wastes

Apart from corrosion studies I have done research on alternative sources of obtaining some metals other than their ores that I wish to mention here.

Natural sources of metals (ores) are deleting hence the exploit to find alternative sources of some technologically important metals. Recycling is one way of achieving this. Silver was our metal of interest. Silver is one of the noble metals whose natural source is the Argentite ore. Apart from ores its being reported that 25% of the world's silver needs are obtained from recycling of which 75% are from photographic wastes (Mekurialem Demelash 2014). Silver finds use in the photographic industry as well as in making ornaments, batteries and mirrors.

In our work **Okorosaye-Orubite, K** and Jack, I. R., (2011) an attempt was made at recovering Silver from waste X- ray films. Unripe plantain bark (a bio waste) was used as extractant. Silver was successfully stripped from the X- ray films. The paper presented an evidence of a cheap and environmentally safe reagent for silvery recovery from waste X-.films.

Further work was done to estimate Silver content in other photographic wastes like spent photographic solution, photographic films and stabilizer solution; **Okorosaye-Orubite, K**. and Jack, I. R., (2012). These photographic wastes were found to have high concentrations of silver ions.
It is common knowledge that photographic solutions are disposed to the environment as waste water. However the free silver ion in these wastes is very toxic even in trace concentrations, thus the removal of silver ions from the wastes is for both economic and environmental benefit.

In another work, **Okorosaye-Orubite, K.** and Don - Lawson, C (2016). Red mangrove bark was used as extractant for reducing silver ion concentration in photographic wastes before discarding same to the environment. Red mangrove bark aqueous was presented as effective stripping solution for this purpose.

Okorosaye-Orubite K and Don-Lawson C. **(**2018**)** considered the effect of pH on the extraction of Silver from X- ray films using Red mangrove Ash Solution. It was established that the extraction process yields better result in alkaline Red mangrove Ash solution.

Another bio waste, Cocoa Husk Ash, showed competence in stripping photographic wastes of silver ions.

Okorosaye-Orubite, K. and Gbarakoro, S. L. (2018) reported the **e**xtraction of Silver from Photographic Waste (waste X-ray films) Using Cocoa Husk Ash Solution. The work recommended Cocoa Husk Ash Solution for stripping X-ray films and obtaining silver metal.

Still exploring alternate means of obtaining metals, my research team determined the potassium ion concentration in Red mangrove bark presented in the paper, Determination of Potassium ion concentration red mangrove (Rhizohora Mangle L) bark aqueous extracts (RMBAE) in buffer media; George, Waribo, **Okorosaye-Orubite** and Bills, U. S. (2014).

Potassium is one of the body's important nutrients; its deficiency causes a variety of health problems. Potassium is also needed in chemical industries to produce fertilizers.

Okorosaye-Orubite, K., Chukwu U J and Clement T O (2016). Synthesis of Nano Zero-valent Iron using magnetic and decantation separation techniques was investigated for alterative source of Iron.

As a Chemist I am an advocate of Chemical Safety and Chemical Security. Haven gone through workshops organized by the Civilian Research and Development Foundation (CRDF) Global and Chemical Society of Nigeria on Chemical Security program (CSP) for South- South Zone, Port Harcourt in 2018 and another one by CSP / Oak Ridge National

Laboratory sponsored by the United States Department of State (2020).

I am also part of the book **‘ Modernity in Health and Disease Diagnosis: the account from STEM women’** .put together by the OWSD University of Port Harcourt branch and published by Springer Nature in which I authored Chapter 13 titled ‘Chemical Safety and Chemical Security: A guide to preventing Health Hazards’. This chapter highlights some of the hazards caused by chemicals to health and provides a simple guide to ensure safety and security in the application of chemicals. We come across chemicals every day not only in the laboratories but also in our homes, from dishwasher, bleaches, soaps, medicines, pesticides, alcoholic beverages, cigarettes and so on.

Mr Vice Chancellor sir, permit me to share some excerpts of the book on ‘**Guides to preventing Health Hazards in our homes’** below,

i. Always label home used chemicals properly.
   For instance, Salt and granulated sugar has same appearance, differentiate them by labeling their containers.
ii. Make sure rodenticides and pesticides are not kept near food or food materials.
   A lot of persons use them in homes to keep off rodents and pests
   When rodents or insects are killed make proper disposal of them by digging a hole, they could be

poison to other animals in the environment if carelessly disposed of.

iii. Let everyone in the home know about the dangers of dual-use chemicals (chemicals used for more than one purpose) e.g. Hypo - bleach camphor balls etc. available in the home.

iv. Do not take chemicals (hazardous or not) out their original containers. If you must, properly label the container or inform family members.

v. Always wash hands or parts of your body with soap and water after using chemicals.

vi. When you buy chemicals, read the labels, there are usually directions for use and warning about their hazardous nature.

vii. Keep chemicals out of the reach of children. For older children explain the dangers of hazardous chemicals to them.

viii. Keep chemicals in original containers, if you must switch containers, please label properly.

Contribution to knowledge

a. Bio waste materials, such as *Nypa fruticans wurmb*, Corn silk, outer leaves of cauliflower, grapefruit peels, *Nymphae Pubscens* leaf extract, *Xanthosoma Spp* leaf extract can be utilized as corrosion inhibitors for metals in different corrosion environments.

b. *Nypa fruticans wurmb* extracts, Corn silk extract, outer leaves of cauliflower, grapefruit peels extract, *Nymphae Pubscens* leaf extract, *Xanthosoma Spp* leaf extract can be used as additives in formulation of anti corrosion paints.

c. These easily affordable, available, cheap and non toxic corrosion inhibitors from bio wastes can make metallic structures live longer.

d. In addition to protecting metals, utilizing bio waste as corrosion inhibitors can contribute to a cleaner environment.

e. Recycling Silver from photographic waste with bio wastes such as unripe Plantain bark, Red mangrove, and cocoa husk ash solutions can be another source of obtaining Silver metal.

f. Chemical safety and chemical security not only valuable in the laboratory but also in our homes.

Conclusion

Mr Vice Chancellor sir, in this lecture, I have addressed the fundamental issue concerning metals, which is corrosion. Metals hold great value in our Industries as they constitute approximately 90% of all construction materials and implements utilized. Every metallic structure is prone to corrosion, which, if left unabated, leads to the deterioration of the metal and eventual breakdown. This ultimately shortens the lifespan of the metal. One effective method for preventing metallic corrosion is the application of corrosion inhibitors on the metal surface or its environment in order to create a protective barrier between the metallic surface and the corrosive elements thereby enabling metal to live longer.

Corrosion inhibitors are either synthetic or natural (organic). While synthetic corrosion inhibitors can be toxic and harmful to the environment, natural or organic inhibitors are eco friendly, they present minimal or no toxic effect on the environment. Plant extracts as corrosion inhibitors are extensively reported in literature. Although some plant extracts may have competitive use in the society; this lecture focuses on utilizing plant extracts derived from bio wastes as efficient corrosion inhibitors for metallic corrosion.

Mr V C sir I have presented experimental evidence from my research that, *Nypa fruticans wurmb*, Corn silk, outer leaves of cauliflower, peels of the grapefruits among others, all bio waste materials are effective corrosion inhibitors for the metals studied. Utilizing these bio wastes materials which are readily available, non toxic and cheap, will create a cleaner environment and most importantly enable metallic structures live longer to grow our industries.

The formulation of anti corrosion paints with these bio waste extracts is my ongoing research. Plant based anti corrosion paints will be a perfect replacement for synthetic anti corrosion paints.

RECOMMENDATIONS

My recommendations based on this lecture are as follows:

1. *Nypa Fruticans wurmb* trees should be recognized as a potential cottage industry. A proper setup can be established to utilize its parts in the production of corrosion inhibitors.
2. In Waste management, bio wastes can be segregated and used as raw materials for manufacturing corrosion inhibitors for metals.
3. Considering that the University of Port Harcourt is located in an area prone to metallic corrosion, I suggest the establishment of a Corrosion Research center. This center would facilitate studies on metallic corrosion inhibition.

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CITATION

PROFESSOR KAINE OKOROSAYE-ORUBITE
B.Sc (Benin). PGDE, M.Sc. Ph.D (UPH)

Kaine Okorosaye-Orubite (nee George Lawson Jack) was born on 24th November, 1960 in Abonnema to the family of Chief George Lawson –Jack and Tiya Sokari Ojuka. She is the only survivor of that marriage after five infant deaths. For fear of losing this only survivor, her maternal uncle Benibo Sokari Ojuka opted to raise her as his child in Lagos. She started her Primary education in Surulere Baptist School, Lagos 1967 with little and no interference by the civil war. In 1970 when Rivers State and Nigeria became peaceful she was brought back home to continue primary school in St. James State School Ifoko. Her brilliancy earned her double promotions and she finished her primary school at St. James State School in 1971.

In January 1972 she passed the then compulsory common entrance examination with flying colours was admitted into St. Scholarsticas' Girls High School, Bakana, with the Rivers State Government scholarship. The school calendar changed from January – December to May – June and so in June 1976 she wrote and obtained the West African School Certificate.

With the active support of her uncle as guardian, she attended the Rivers State School of Basic Studies to obtain the IJMB (Interim Joint Matriculation Examination) certificate in 1978. In 1979 she gained admission into the University of Benin through Direct Entry and was offered again the Rivers State Government Scholarship to read Industrial Chemistry she graduated in 1982 with a second class degree. She did her mandatory National service at the Teacher Training College Ndele. She also had a brief service with the Rivers State Government Secondary School.

She obtained the following post graduate degrees - PGDE (1987), M.Sc (1994) and Ph. D (2003) from the University of Port Harcourt.

In January 1996 she was employed by the Rivers State University of Science and Technology as an assistant lecturer and grew to the position of a Senior Lecturer. She held many positions while in the service of the Rivers State University of Science and Technology, Departmental examination officer 1997-1998. Departmental seminar coordinator 2001 -2010, Member, Centre for Special Project Board 2004 -2011.

In 2014 she transferred her services to the University of Port Harcourt and was appointed a Professor with effect from October 2018.

In University of Port Harcourt she has also served in various capacities, Member, departmental accreditation exercise, 2014 Member, University of Port Harcourt 40th Anniversary

Celebration 2015 Associate Dean, Faculty of Science .2016 - 2018, Member, Research Ethics Committee 2017 -2023 .She had taught as a part time lecturer in Science Laboratory Technology. University of Port Harcourt 2002-2004, Facilitator, National open University, Bayelsa/Rivers State 2006 -2008.Adjunt lecturer, Veritas University, Abuja, Obehie campus 2012-2013.

She has supervised many undergraduate and post graduate students. Her researches over 40 are published in reputable journals both local and international.

She is an active member of the Organisation of Women in Developing countries (OWSD) and one of the authors in the book '**Modernity in Health and Disease Diagnosis: the account from STEM women'** put together by the OWSD University of Port Harcourt branch and published by Springer Nature. A member of Institute of Chartered Chemists of Nigeria (ICCON) and Chemical Society of Nigeria (CSN) professional bodies of all chemists. In 2016 she was the chairman of the Local Organising Committee of the 36th International Conference of CSN held in Port Harcourt Rivers State, 'Garden City' 2016.

Prof. Kaine Okorosaye Orubite is a practicing Christian of the Baptist denomination, the mother of Beleki, Ibiosiya, Ojuka , Ngo, Boma, a mother in law and a proud grandmother .

I present to you a strong character that has successfully combined academics, social and family life to get to the apex of your profession, a chemist and chemistry teacher par excellence.

Professor Owunari A. Georgewill,
Vice- Chancellor