UNIVERSITY OF PORT HARCOURT

THE LIFEBLOOD OF SUSTAINABLE INDUSTRIAL PROCESSES

An Inaugural Lecture

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INAUGURAL LECTURE SERIES

No. 210

9th April, 2026

University of Port Harcourt Printing Press Ltd.
University of Port Harcourt,
Port Harcourt,
Nigeria.
E-mail: uniport.press@uniport.edu.ng

ISSN: 1119-9849
INAUGURAL LECTURE SERIES NO. 210
DELIVERED: 9TH APRIL, 2026

Designed, Printed and Bound By UPPL

ORDER OF PROCEEDINGS

2.45 pm. Guests are seated

3.00pm. 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
University Librarian
Registrar
Deputy Vice Chancellor Research and Development
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:

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Deputy Vice Chancellor Administration
Deputy Vice Chancellor Academic
Deputy Vice Chancellor Research and Development
Registrar
University Librarian
Lecturer
Provost, College of Health Sciences
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- Cherished Friends and Guests
- Unique Students of UNIPORT
- Members of the Press
- Distinguished Ladies and Gentlemen.

DEDICATION

Dedicated to the Holy family of Nazareth, and families of Ibezim-Ezeani, Ochuonu, Mbonu and Omeonu.

ACKNOWLEDGEMENTS

My endless praises and reverence to the Blessed Trinity for the gift of life and countless blessings.

Superb appreciation goes to our capacity-extraordinaire9th Vice-Chancellor (VC) of the University of Port Harcourt (UPH), Professor O.A. Georgewill for granting the approval to my inaugural lecture presentation. I equally remain ever grateful to our digital VC for my professorial elevation, appointment as Director of Central Instrument Laboratory–University of Port Harcourt (CIL) and series of remarkable contributions to my professional development. May the Faithful God be your shepherd forever.

I specially thank the team of fittingly chosen principal officers: Prof. C.O. Onyeaso (Dep. VC-Admin.), Prof. R. Ogu (Dep. VC-Acad.), Prof. A.I. Frank-Briggs (Dep. VC-Research and Dev.), Dr. G.O. Chindah (Registrar), Dr. G.W. Obah (Bursar) and Prof. H.U. Emasealu (University librarian). May God be glorified in all your activities.

My profound gratitude goes to Prof. D. Baridam(6th VC) for providing the response that led to my employment through the recommendation of the Department of Pure and Industrial Chemistry, University of Port Harcourt in 2005. Very many thanks to Prof. J. A. Ajienka (7th VC) for his quality suggestions that impacted on my directorship and the advancement of CIL. Bountiful thanks to Prof. N. E. S. Lale (8th VC) who appointed me the Coordinator, Department of

Biochemistry/Chemistry Technology–School of Science Laboratory Technology, University of Port Harcourt in 2019, under the remarkable deanship of Prof. M. Horsfall (Jnr). Immense thanks go to Prof. S. A. Okodudu (Former Acting VC) who translated my hope by HIS grace into full testimony of readership promotion during his tenure. May the Omnipotent God be with you all on every side.

Grateful acknowledgement to Prof. O. Akaranta (a versatile scientist and academia-industry facilitator) for his extraordinary mentorship capacity from my postgraduate days till date. May the Lord influence times and seasons in your favour.

Immeasurable gratitude to my highly esteemed lecturers and mentors (Profs. C.M. Ojinnaka, R.E. Ogali, M. Horsfall, L.C. Osuji, M. Onyekonwu, G.U. Obuzor, N. Frank-Peterside, E.C. Chukwuocha, E.B. Essien, A.I. Spiff, O. Abumere, E. Nduka, I.P. Okoye, H. Fawehinmi, M.O. Monanu, F. Nduka, G.O. Abu, L.O. Odokuma, R.I. Ngochindo, O.J. Abayeh, G. Avwiri, P. Nnabuo, Msgr. S. Udoidem, etc.); and colleagues (Profs. C.N. Ehirim, C.J. Ogugbue (Dean, Faculty of Science), A.O. James, K. Okorosaye-Orubite, T. Egbuchunam, K.O. Monago, M.C. Onojake, A.N. Ikot, U.J. Chukwu, O. Achugasim, C.I. Osu, A.M. Ekwonu, O. Ndukaku, N.C. Ngobiri, O.M. Onyema, Drs. K. Sofolabo,U.S. Okorie,O.G. Oriji, R.U. Duru, P. Adowei, I. Orji, T.N. Chikwe, I.E. Ekpo, G. Iwuoha,C.O.Victor-oji, S. Anuchi, T. Douglas, etc.). May the ever-loving God stand by you always.

I sincerely appreciate the assistance received from Academic-technologists, laboratory and administrative staff of Pure and Industrial Chemistry (Y.O. Johnson, N.E. Okike, A.R. Mumuni, G.I. Airuehia, S.N. Nwosu, E.E. Okon, C. Okele, J. Nwakamma, E. Nwogu, E. Agommuo, M.C. Okor, Dr. M. Amacha, J. Onobun, U. Ojenamah, S.C. Uchendu, Dr. N. Nde, A.O. Amadi, E. Nwogu, N.T. Ilili, B. Onyekaonwu, P. Eleonu, V. Nwokoma, M.P. Leera, R. Ogbuka, I. Ogwudire, C.O. Eze, S.N. Amadi, C.G. Agbaruoka, M. Asiol, T. Semenibipi, V. Amesi-Sunday, E. Obodagu, B. Ogbara, J. Derefaka, M. Worlu, B. Martins); and the staff of Faculty of Science (K.O. Wogwu (Fac. Officer), P. Chinah, B. Uko, B. Ariwodo, etc.). May the Almighty remain instrumental to your day-to-day progress.

Hearty thanks to my colleagues and connections at the School of Science Laboratory Technology, UPH (Profs. H.O. Nwankwoala, S. Abrakasa, O. Loveday, M.O. Ifeanacho, N. Egesi, Drs. V.J. Aimikhe, S. Omeodu, R.C. Ohiri, G.C. Onwugbuta, O.C. Nwankwo, H.O. Asuzu-Samuel, J.C. Isirima, A.D. Osayande, O.N. Akoma, J.I. Nwosu, B. Boogbara, E. M. Sam, A.T. Nnadiukwu, A.O. Ojeabulu, C.O. Wodu, G.O. Udoakang, A.N. Wuga, C.E. Agbo, P.C. Ichendu, B.A. Ibisa S.E. Nagi, S. Amadi, S. Kpaduwa, J. Offor, T. Ibisabo, S. Mgbahuru, D. Aniekpon, J. Samuel, S. Madaki, U.M. Ebere, Late R.S. Aride, S. Oladele, A.C. Dimkpa, F.T. Fibmesima, U.D. Okon, P.C. Onwubu, A. Adabayo, V.E. Okpere, C. Obioha, etc.). May God be gracious and bless your efforts.

It is well with the soul of my departed lecturers and mentors: Profs. A. C. I. Anusiem (iconic mentor and graduate supervisor), A.A. Abia (exceptional mentor and undergraduate supervisor), N.C. Oforka, B.A. Uzoukwu, G.O. Ibeh, P.N. Manilla, J.O.E. Otaigbe, S.E. Ofodile, and beloved colleagues: Profs. N.H. Okoye, C. Obi, F. Anacletus, U.C. Chukwulobe, P.E. Ijente, E. Akalonu, C. Mathias, R. Chukwu, and U. Emordi. Thank you very much, and rest-on in the bliss of Christ.

I deeply appreciate the contributions and encouragement received from the diligent staff of CIL and Int'l Conf. on Laboratory Research & Technopreneurial Innovations (2024, 2025 and 2026) organizing committee members (Prof. O. Lawal, Drs. L. Oghenekaro, O. Frank, P.O. Onyagbodor, C. O. Victor-oji, R. C. Ugonwa, G. Suotor, O.C. Ihunwo, A.L. Eke, O. Nnodim, N.T. Peter, E. Nwulu, E. Nwogu, G. Ogwueli, A. Gbogim, J. Nsirim, A. Amadi, A.C. Ekeocha, I.D. Dennis and V.A. Francis); awesome presentations by the conference's guests, speakers and participants (Profs. C. O. Onyeaso, E. Laws, B.B. Babatunde, T. Blanchard, V.I. Anireh, B.O. Omijeh, P.J. Kpolovie, R. Ekechukwu, Engr. O. Akoma, Drs. E. Daniel, Engr. I. Edeh, N.J. Maduelosi, Engr. A.A. Udoh, P. Ugwu, etc.); and collaborators (Pst. Dr. R. Antai, Engr. C.J. Nnadi, R. Nasir, Dr. & Dr. Mrs. D. Isiavwe, R. Okeugo, Laser Engineering and Resources Consultants Ltd., GGI Int'l (Nig.) Ltd., INTEX Incredible Shopping Paradise, Rainbow Specialist Medical Centre, HONIPOD Nig. Ltd., Helena Haven Hotels Ltd., RealGreen-Environments Ltd., Tropical Naturals Nig. Ltd., ISGRABACHEM GLOBAL

ENGINEERING, etc.). May GOD immeasurably bless you all the time.

The sense of responsibility and characteristic dedication put in by the Chairman and members of the University Inaugural Lecture Screening Committee toward ensuring excellent presentation is priceless and are thankfully acknowledged. Plenty of thanks to the Director of Academic Affairs (Mr. G. Ijah) and team for their support. May God honour you all in unique ways.

My deep gratitude goes to my project students, research team members, mentees and other students of Pure and Industrial Chemistry (Drs. D.C. Ike, F.A. Okoye, F.U. Wokobia, C.I. Otobrise, C.C. Imaga, I. Orji, J.N. Obowu, C. Onyeogulu, I.I. Agha, S.O. Orjiocha, U. Ezechinyere-Otuka, A. Pat-Okunbor, T. Jim-Halliday, O.M. Otokpa, A.M. Onyesom, F.M. Amukalu, F.C. Anioke, R. Okah, D.E. Iladebi, K.M. Eshiet, E.E. Aiyebo, A.C. Akobundu,etc.) for their cooperation which contributed to my academic growth. May God bless you with more opportunities to thrive.

The committed prayers of religious and laity catalysed my all-round lifting up. Worthy of note are the beloved brave Rev. Frs. P. Amadi, I.E. Peter, J. Visan, Faithful of St. Mary's Catholic Church, Alakahia, Catholic Women Organization, Catholic Men Organization, Catholic Youth Organization, Association of Sacred Heart of Jesus and Immaculate Heart of Mary, and so on. May God remarkably shower HIS love on you all forever.

I joyfully recognize and appreciate my professional activities with the Chemical Society of Nigeria (Profs. C. Obunwo, G.A. Cookey, N. Boisa, J. L. Konne, N.J. Maduelosi, C. Ayozie, H. Wegwu, G. I. Ndukwe, E. Ogbonda-Chukwu, C.C. Umeileka, etc.), Institute of Chartered Chemists of Nigeria (E. Okonkwo, S. Egwuchim, Drs. E.A. Daniel, O. Frank, etc.), Organization for Women in Science for the Developing World (Profs. F. Nduka, U.O. Georgewill, E.O. Nwachi, C.B. Chikere, A. Henri-Ukoha, Rev. Sr. M.A. Ozah, M.P. Iwundu, Drs. U.A. Okengwu, I. Ugiomoh, K. Oterai, Engr. S. Orakwe, etc.), Women in Chemistry (I.A. Kalagbor, H. Orlu, T. Uchechukwu, I. Ogbonna, C. D. Don- Lawson, etc.),AASDU-Education Team (Profs. E. Achalu, C. Uche, Drs. O.C. Nwankwo, R.C. Ugonwa, C. Mezie-Okoye, U. Anekwe, S. Chidube, N. Ilomuonso, etc.), and my numerous beloved colleagues and friends (that I couldn't mention due to time constrain) who have contributed to the achievement of my desired career goal. May the Lord lead you ever upward.

My thankful heart goes to my parents, Chief A.N. and Ezinne P.U. Ochuonu (blessed memory) for the pivotal and pioneering role they played which have gone a long way in the actualization of my higher education and progress. Eternal rest grant them O! Lord, and let perpetual light shine on them; and may their blessed souls rest in perfect peace.

I sincerely treasure the patriotic zeal and charismatic commitment demonstrated towards the success of my career by my beloved families and in-laws: Chief A. Ibezim (blessed memory) & Chief (Mrs) R.O. Ibezim-Ezeani, Cyril Ezeani,

Mike & Florence Ezeani, George & Calista Ezeani, Augustine & Uchenna Ezeani, Martin & Pharm. Dr. Chidozie Ibezim, Chika (Mayor) & Uju Ezeani, Oluchi Ezeani, Barr. & Barr. (Mrs) G. Ezeani, Dr. B. Okolo, Chief Sir J.O. Udoji (blessed memory), Mr. Ernest (blessed memory) & Mrs. C. Ochuonu, Mr. & Mrs. V. Ochuonu (blessed memory), Sir & Lady E. Ochuonu, Mr. & Mrs. Emeka O. Ochuonu, Chief & Mrs. I. Mgbobukwa, Mr. & Mrs. Ebuka Ochuonu, Pastor (Prof) & Mrs. A. Osuala, Chief Raphael (blessed memory) & Mrs. Ngadi, Mr. & Mrs. S.N. Ibeto, Super-aunty F. Amadi, Super-aunty D. Ekezie, Mr. & Mrs. Okagbue, Bro. A. Ezekwe (blessed memory), Rev. Fr. B. Ochuonu (blessed memory), Mr. & Mrs. O. Okeugo, Dr. and Mrs. D. Ogbonna, Mrs. R. Omeonu, Pastor and Deaconess Okey-Omeonu, Pastor P. Omeonu, Pastor N. Omeonu, Ifeoma, N. Ozegbe, Mr. I. Dimkpa, etc. May God magnificently bless and perfect your concerns.

I most affectionately thank my husband, Mr. A.I. Ibezim-Ezeani for his prayers, love and benevolent contributions which facilitated the attainment of this feat. In fact, your admirable composure in everything, thoughtful proofreading of my write-ups, valuable inputs to my works, sharing of ideas, etc. reminds me daily of how fortunate I am to have you as my God-given partner. To our beloved children (Clement, Emmanuel and Charles), your unwavering support and prayers have been a true blessing to my upliftment; and I cherish you all greatly. May God continue to illuminate your paths and HIS Joy remain your constant strength, Amen.

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1. Preamble

Knowledge grows when shared. Thank you, our capacity-extraordinaire VC and distinguished audience, for sharing this moment with me as I present the 210th inaugural lecture in this unique citadel of learning. During my days at the Women Training College Primary School Enugu, while trekking to school particularly after a downpour; I kept wondering as I moved through the wet streets where the assorted dirts of plastics, clothes, paper, sandy mud, greasy liquid waste, stones, painted items and other waste materials flowing alongside the water were heading to and the distance they will cover.

Plate 1: Trekking to school after a downpour

My curiosity on this matter as I grew up led me to understand that over time, these discarded materials thus released, travel kilometres further away into water bodies and could become harmful to the ecosystem. The memories of this and other related experiences lingered on into my secondary education at the prestigious Queens School Enugu (headed then by Rev. Sister Agbasiere). “Laborare Uno Animo” is the motto of Queens School Enugu, which means “working together with one mind towards a common goal”, and I think this continues to influence my harmonious working relationship with colleagues which earned me in December 2022 the “*Award of Most Outstanding Team Player for Dedication and Team Spirit Consciousness in the Faculty of Science*”. Queens School Enugu was renowned for having qualified and experienced teachers who were gifted in knowledge delivery. I carried the rudimental knowledge gained beyond secondary school; and embraced my admission into the Department of Pure and Applied Chemistry, University of Port Harcourt (UPH) with enthusiasm having understood that chemistry is everyday science that studies matter and the transformations they undergo at different conditions.

At the undergraduate level, I appreciated the branches of Chemistry (Physical, Analytical, Materials, Biochemistry, Organic, Inorganic and Theoretical) taught by leading minds in Chemistry, some of who are present here like Professors Ojinnaka, Akaranta, Ogali, Monanu, Onyeike, etc.(https://www.expii.com/t/branches-of-chemistry-examples-overview-11023).

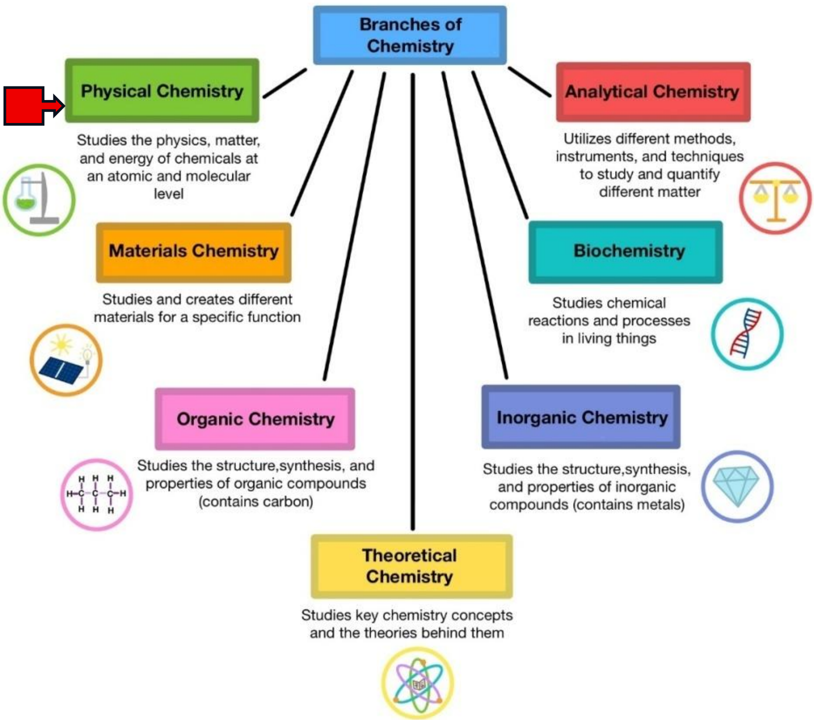


Figure 1: Branches of Chemistry

However, the period of carrying out my final year undergraduate project work (supervised by Late Prof. A.A. Abia – Professor of Physical Chemistry) on the "Kinetics of ethylethanoatesaponification followed conduct metrically" became the major spark for interest in Physical Chemistry. The clarity with which the use of Physical Chemistry models and graphical representations provided insight into the resolved experimental data by revealing the rates and steps of the molecular interactions was an eye-opener. This evolved into personal fascination for further studies in Physical Chemistry at the graduate level, which led to my lecturing appointment; as well as rose through ranks to becoming the first female Professor of Physical Chemistry in Department of Pure and Industrial Chemistry, and first to present inaugural lecture in the field of Physical Chemistry from the University of Port Harcourt.

My academic and scientific exploration were marked with many tours to industrial and laboratory facilities. I spent the National Youth Service Corps year at the Laboratory Services Department, Research and Quality Control Section-Delta Steel Company-Aladja (Delta State) where I gained the initial industrial work experience. Atgraduate level, my research work (supervised by Late Prof. Anusiem–Professor of Biophysical Chemistry) was centred on formulating surface-active collectors for metal ore beneficiation; while I continued further research as a staff with Prof. Akaranta (Professor of Industrial Chemistry) and some supervisees on repurposing agro waste materials. Hence, my passion for upcycling plant-based waste with advantageous impact on nature has led to today's inaugural lecture titled"**The Lifeblood of Sustainable Industrial Processes**".

2. Introduction

The development of novel and innovative industrial products has significant influence on job creation, quality of life, societal empowerment, economic advancement and ecosystem wellness. The growing trend in process industries for the use of different classes of surface-active agents is crucial in raising the gross domestic product of nations. However, most of the conventionally applied surface-active agents are derivatives of fossil fuels and are often toxic to man and his environment. These agents influence every industrial process from promoting food security through storage stabilisers in agrochemicals, to enhancing light absorption through film-morphology improver in solar energy system, to ensuring smooth engine operation through lubricant in automobiles, to healing of body system through drug delivery agents in pharmaceuticals, to achieve neat surfaces through soil removers in detergents, and so on. Given today's worldwide shift away from fossil-derived systems toward natural product-based, regenerative, and renewal-oriented approaches; renewable surface-active agents embody this shift.

2.1. Lifeblood: The Essential Element

The Lifeblood is the actual blood required to sustain life's processes (https://www.teachoo.com/15903/3515/What-are-life-processes-/category/Concepts/). In the present context, lifeblood refers to the essential element needed for continuous industrial process survival and optimization alongside environmental conservation.

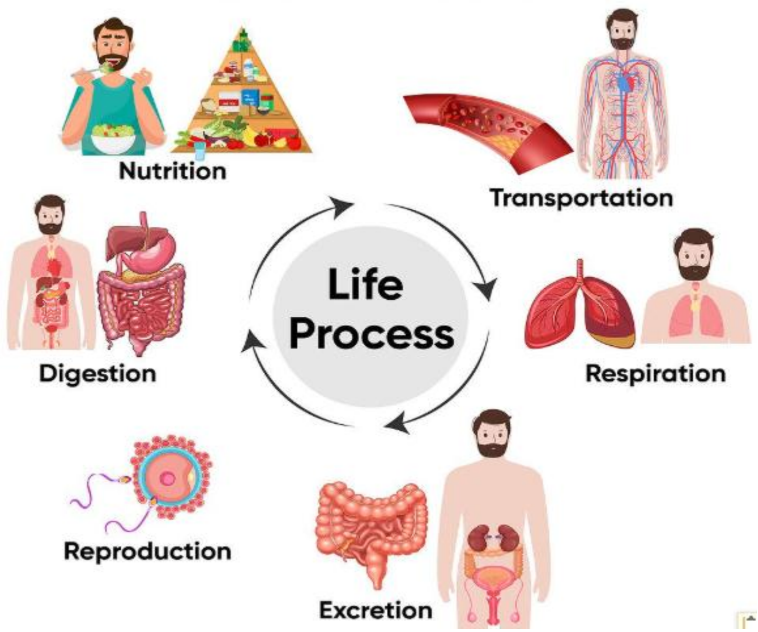


Plate 2: Life's processes

The efficacy of these essential elements is based on their structural flexibility and compatibility with other production components of industrial processes. Some lifebloodinfluence of surface-active agents at different stages of manufacturing, maintenance and preservation of industrial processes are presented in Table 1.

Table 1: Some lifebloodinfluence of surface-active agents at different stages of industrial processes

S/ №	Industry	Some lifebloodinfluence of surface-active agents
1.	Pharmaceutical	Permeation enhancer, drug delivery improver, wetting agent, suspension stabilizer, solubility improver, inhalation therapy aid, antimicrobial action
2.	Furniture production	Adhesion improver, degreaser, antistatic booster, emulsifier, dispersant, wetting promoter, foam stabilizer, cleaning and flow agent, moisture repeller
3.	Institutional detergent	sanitizer, fabric softeners, disinfectant, antistatic agent, suspension stabilizer, soil remover, antimicrobial action, fabric softener, wetting agent, emulsifier
4.	Automobile	Fuel detergent, lubricant, coolant, anti-fog agent, rust protector, degreaser, adhesion enhancer, dispersant, mould release agent, appearance improver
5.	Solar energy	Film-morphology improver, charge transfer enhancer, interfacial modifier, stability enhancer, electrodes work function booster, crystallization controller
6.	Oil and gas	Interfacial modifier, stabilizing emulsifier, demulsifier, corrosion inhibitor, dispersant, flow assurance improver, wettability adjuster, antiscalant
7.	Lubricant processing	Emulsifier, detergent, dispersant, wetting and spreading agent, rust inhibitant, friction modifier, stabilizer, anti-wearing agent, defoamer, additives solubilizer
8.	Construction	Air-entraining agent, plasticizer, wetting agent, dispersant, soil stabilizer, corrosion inhibitor, emulsifier, adhesion improver, water retention controller
9.	Metallurgical	Collector, frother, depressant, activator, surface modifier, Interfacial reaction controller, leachant, coolant, dispersion stabilizer, corrosion protector
10.	Agrochemicals	Penetration enhancer, wetting and spreading agents, emulsifier, solubility improver, adhesion promoter, performance booster, storage stabilizer
11.	Paper and pulp	wetting agent, dispersant, emulsifier, de-inking aid, coating stabilizer, sizing enhancer, foam controller, paper quality improver, release agent, softener
12.	Food processing	emulsifiers, foaming agent, texture enhancer, defoamer, dough conditioner, dispersants, crystallization modifiers, shelf-life extenders, wetting promoter
13.	Instruments making	cleaning agent, lubricant, emulsifier, dispersant, wetting agent, coating aid, corrosion preventer, sealant, foam control agent, antistatic agent,
14.	Paint and coatings	wetting agent, dispersant, emulsifier, defoamer, durability stabilizer, adhesion promoter, flow agent, levelling aid, rheology modifier, tinting strengthener

Certainly, these lifebloodeffects of surface-active agents are imperative to the survival of industrial operations. Thus, necessitating eco-conscious approach for their preparation and applications in industrial processes, so as to deliver performance with toxic-free outcomes.

This inaugural lecture therefore, focuses on the use of renewable and eco-friendly surface-active agents as the indispensable lifeblood in process industries for sustained efficiency, profit and growth. Industries require renewable surface-active agents the way we need the lifeblood to complete their production processes and manufacturing cycles. The role of these surface reaction enablers and conditioners makes them the lifeblood of sustainable industrial processes, as well as eco-friendly accompaniments in production pathways.

2.2. Surface-active agents

Surface-active agents are amphiphilic molecules with functional versatility at surfaces or interfaces, where they alter interfacial interactions, thereby facilitating a wide range of industrial processes. Surface-active molecules(Figure 2)acquire stability through the peculiar inclination at the surface or interface of colloidal systems; with the polar (water-loving, hydrophilic, lipophobic or oleophobic) head portion and nonpolar (water-hating, hydrophobic, lipophilic or oleophilic) tail portion aligning towards aqueous and organic phases respectively (Ibezim-Ezeani, 2024).

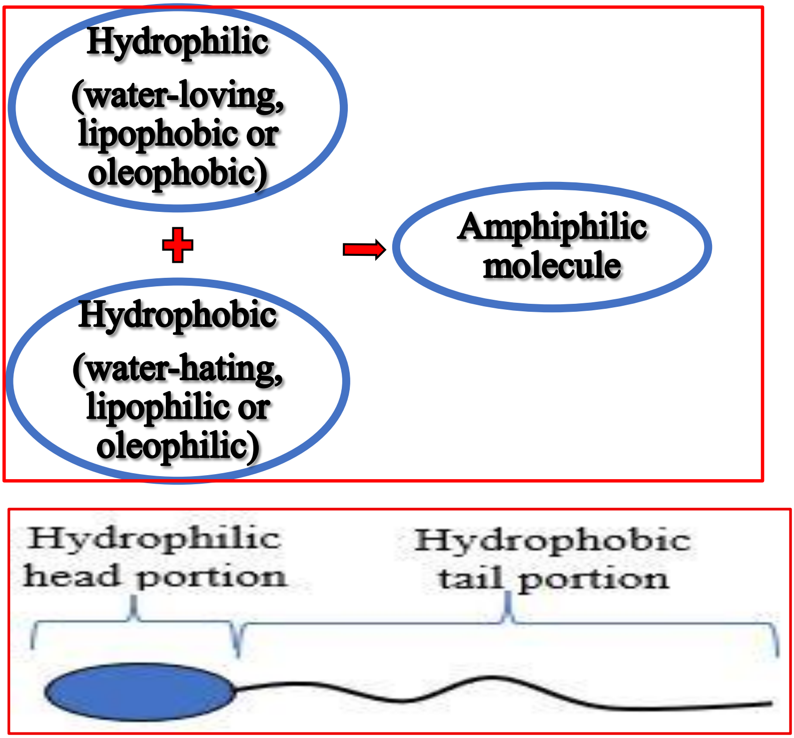


Figure 2: Schematic representation of surface-active molecule

Generally, the categorization of this dual natured molecule is in accordance with the inherent behavior of the water-loving moiety in dispersion medium. The four major classes of surface-active agents (SAAs) are the cationicsurface-active agents (CSAAs), anionicsurface-active agents (ASAAs), nonionicsurface-active agents (NSAAs) and zwitterionic surface-active agents (ZSAAs)(Schramm *et al*., 2003; Sharma, 2014; Ibezim-Ezeani, 2023) as illustrated in Figure 3. These classes of SAAs and some applied examples in industrial processes are presented in Table 2.

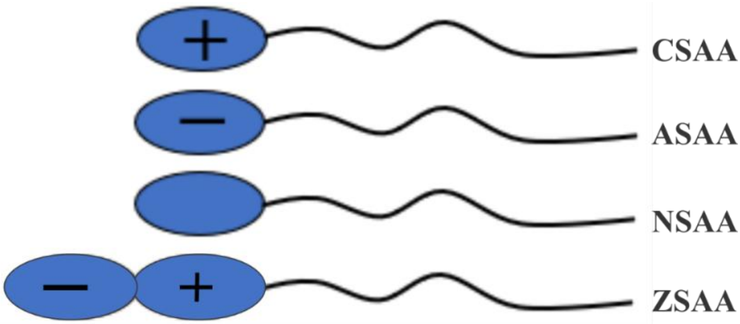


Figure 3: Classes of SAAs represented schematically

Table 2: Classes of surface-active agents and some applied examples in industrial processes

Classes of surface-active agents	Example	Application
CSAAs are those SAAs which in aqueous medium bear positively charged head portion. Structurally, their water-hating parts align preferentially at the immiscible interface of matter, where they exhibit the potency to drive back similar charged positive groups while attracting unlike charged surfaces	2-substituted imidazolines	Corrosion inhibitors to prevent rusting on metallic surfaces, and protect steel reinforcement in concrete
	Benzalkonium chloride	Sanitizers, disinfectant cleaners and antisepticsoapsto provide antistatic and antimicrobial activities
	Cetrimonium chloride	fabric softeners to impart smoothness, pliability and antistatic properties intextiles
ASAAs are SAAs which possess negatively charged water-loving part in dispersion phase.	Lignosulfonates	dispersants and adhesion improvers in wettable powder and dry flowable formulations for agrochemicals
	Sodium stearoyl lactylate	Doughstrengthener in baking,

		emulsifier in dairy/creamers, stabilizers in sauces,cosmeticsand personal care products
	Linear alkylbenzenesulphonates	soil remover, foaming agents, stabilizing emulsifiers for detergents, laundry powders and liquid washers
The water-loving component of NSAAscarry no charge and do not undergo ionization in dispersion medium; they rather manifest their water-loving attributes mainly through hydrogen bonding and weak forces of attraction	Polyether-modified silicones	anti-fog coatings for windshields, mirrors, and interior plastics in automotives
	Propylene glycol monooleate	stabilizing emulsifiers and anti-staling agents for shortenings, margarine, and bakery products in food processing
	Polysorbate 80	Solubilizers of hydrophobic drugsfor parenteral formulations in pharmaceuticals
ZSAAs have both positive and negative centers in their water-loving portion, with the positive part of the hydrophile serving as the link to the water-hating part. Depending on the interaction condition, ZSAAs can act as a cationic, anionic or neutral SAAs	Lauryl betaine	wettability enhancer and stabilizing emulsifiersin chemical flooding to convert reservoir rock from oil-wet to water-wet for enhanced oil recovery
	Sulfobetaine	Wetting and levelling agents in electroplating bathsto prevent pitting and improve surface quality
	Cocamidopropyl betaine	Foam stabilizers and emulsifiers for shampoos, body washes, liquid soaps, cosmetics, baby products, toiletries

Thus, surface-active agents exhibit their lifeblood capabilities to alter the properties of systems through the preferential orientation of the water-loving and water-hating regions for optimal interactions at surfaces or interfaces in numerous processes by industries (such as oil and gas, institutional and household detergents, bakery, pharmaceutical, personal care and laundry products, paint and coating, construction, mineral processing and mining, confectionery, leather, agrochemical, adhesive, paper, food processing, lubricant and grease processing, plastic, textile, fibre processing, etc.) (Hassanzadeh *et al*., 2012).

2.3. Sustainable Industrial processes

The important aspect of the economy with the role of manufacturing goods, providing services or natural resources extraction is referred to as industry. Businesses or organizations are grouped as industry depending on the similarity in the type of their economic activities. For instance, the construction industry (covers businesses that build, repair, adjust, or maintain physical structures and infrastructure), pharmaceutical industry (concerns organizations that discover, develop, manufacture or distribute drugs and therapies for human or veterinary use), and agrochemical industry (includes businesses tied to the manufacture, distribution, or marketing of chemicals applied in agriculture to enhance soil fertility, improve crop yields and protect plants).Industrial processes are the procedural stages (mechanical, physical, thermal, chemical, biotechnological or electrical) undertaken in large-scale progression to convert raw materials into intermediate components or finished commodities under controlled conditions (https://Oasdom.com/pes-of-manufacturing-industries/).

Plate 3: Industrial processes

Sustainable industrial processes therefore, are industrial processes developed with renewable materials or non-depletable resources, and their technological systems operated in formulating products by international best practices. Thereby, ensuring the process efficacy with favourable output, healthy ecosystem and effective circular economy. Hence, this can be achieved mainly by incorporating renewable surface-active agents made from eco-conscious materials into industrial processes.

3. Renewable Surface-Active Agents

Renewable surface-active agents (RSAAs) are fortifying organic molecules or compounds derived from natural product materials with versatile water-loving and -hating capacities at the surfaces or interfaces of two or more insoluble states of matter. These RSAAs could be applied as raw materials or separable components (extracts / filtrates / exudates / isolates /distillates / concentrates / fermentates / residues) or in formulations with non-petrochemical solvents to give products with marked speciality (Ibezim-Ezeani, 2024).Natural product is a complex organic structured compound produced by living organisms (plants, animals, microorganisms and marine organisms).Those derived from plants are termed phytochemicals; and have applications in medicine, research, cosmetics, biotechnology, food and environmental quality. Amino acids, alkaloids, steroids, tannins, glycosides, lipids, phenolics, flavonoids etc. are some phytochemicals inherent in parts of plant (trunk, flower, leaf, stem, seed, branch, bark, fruit, root, peel, husk, shell and so on). These phytochemicals contribute to their lifeblood efficacies when applied as RSAAs for industrial processes. Renewable surface-active agents therefore, exhibit lifeblood capabilities to modify the properties of systems through preferential adsorption (Salager, 1994) of amphiphilic molecules (water-loving and water-hating regions) at surfaces or interfaces, thereby optimizing interfacial interactions and underpinning a broad spectrum of industrial processes and products (Figure 4).

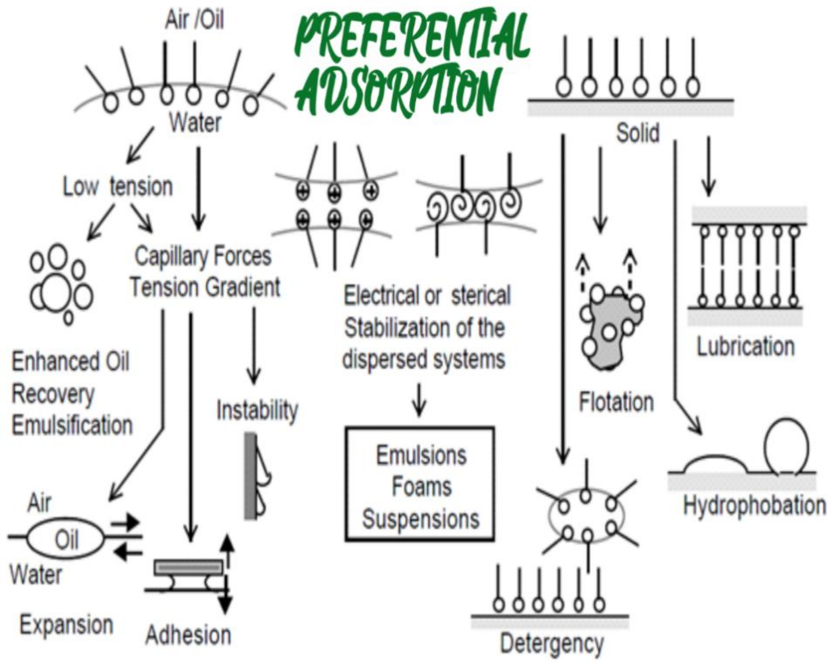


Figure 4: Preferential adsorption of amphiphilic molecules at surfaces or interfaces

The following are some of my works on the utilization of RSAAs as the lifeblood in processes for sustained industrial advancement with favourable impression on the ecosystem. These include RSAAs as: collector for metal ore beneficiation, emulsifier in drilling mud formulation and ion exchanger for industrial effluent treatment.

3.1. Collector for Metal Ore Beneficiation

A complex mineral material or rock which contains valuable metals and gangue in its natural form is known as metal ore. Galena(https://www.google.com/search?q=galena+pdf&sca_es

v=e73d2a95), hematite (https://www.google.com/search?q= hematite&sca_esv=e73d2a95759) and cassiterite (https://www. google.com/search?q=cassiterite&sca_esv=e73d2a95759f60) were investigated as they are some of the metal ores available in large quantities in parts of Nigeria.

Plate 4: Metal ores

Metal ore beneficiation is the selective process of purifying desired higher-grade metallic concentrate from the earthy waste in the mining and metallurgical industries prior to smelting and refining processes. After the purifying process with collector reagents, the major valuable metals recovered from galena, hematite and cassiterite are Lead, iron and tin respectively. These metals have high economic value and are useful in industries such as battery, radiation shielding, alloys, electronics, construction, chemical, electrical, printing and ammunition for lead (https://files01.core.ac.uk/download/ 154408274.pdf); steel production, machinery, transportation, power, cast iron products, defence, chemical, household and consumer goods for iron (https://initube.es/en/iron-in-historyand-its-uses-in-the-industry/); and tin plating, alloys, automotive, electronics, printing, medical, construction, chemical, packaging, electrical, aerospace, energy and emerging tech for tin (Muderawan *et. al*., 2024).

With global emphasis on sustainable development as regard to the quality of life in general, RSA collectors are speedily replacing petroleum-based collectors due to their friendliness to the environment and ability to degrade. Some of these RSA collectors utilized in this investigation are formulated with palmitic and lauric acids(obtained from palm and coconut oils respectively)which are plant-based fatty acids by modified saponification method. The potential of modified sodium-palmitate and sodium-laurate as RSA collectors for metal ores (galena, hematite and cassiterite) beneficiation was assessed with the micelle formation studies on their interfacial tension measurements at different concentrations in aqueous phase (Ibezim-Ezeani and Anusiem, 2011a). Micelles are geometrically structured assemblage of definite quantity of water-loving and -hating components which are initiated at a particular concentration of the SA molecules termed the critical micelle concentration (CMC). Micelle formation is a key behaviour of SAAs, and it is the point from which SA molecules begin to form micelles.

3.1.1.Froth flotation

The purification process often employed in separating solid ores of similar densities (preferably between 35and 100μm) which cannot be separated by gravity method using jigging and tabling is performed with froth flotation method.

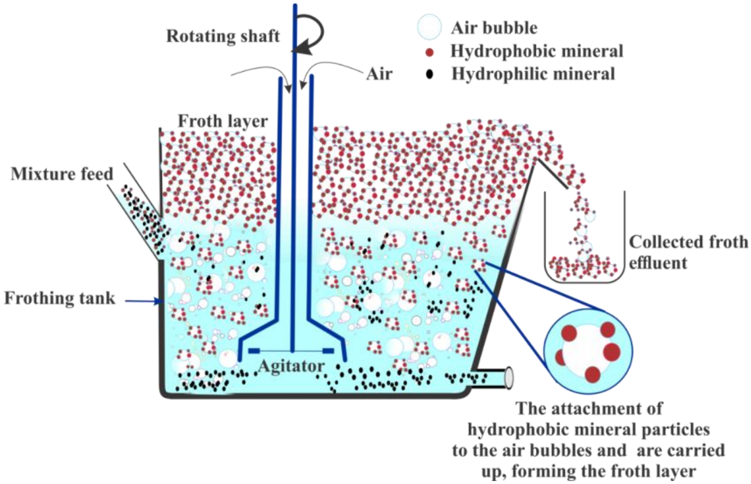


Figure 5: Representation of Froth flotation apparatus

The mixture of RSA collector reagent(modified sodium-palmitate / sodium-laurate) and metal ore (galena / hematite / cassiterite) was fed into the tank of the froth flotation apparatus (Figure 5) with agitator which provided continuous recirculatory mixing of the solids and solution. Air was introduced through the rotating shaft and exited into the solution at the bottom of the sub-aerated agitator. The RSA collectorsimpartthelifeblood on the desired metallic particles by their adhesion to the air bubbles. Due to density differences, the air bubbles rise to the surface of the solution where they are collected as a froth layer which spilled over into the froth collection tray. The froth containing the desired metallic particles can be mechanically skimmed off; while the water-loving particles remain in solution, which is eventually decanted off as the tailing stream (Ibezim-Ezeani and Anusiem, 2009; 2010a).The measurements of interfacial tension were taken at different concentrations of RSA collector, and applied in evaluating the CMC of RSA collector. The concentration of RSA collector which coincides with the point of deviation from the slopy-line plot reveals its CMC (Figures 6 and 7).

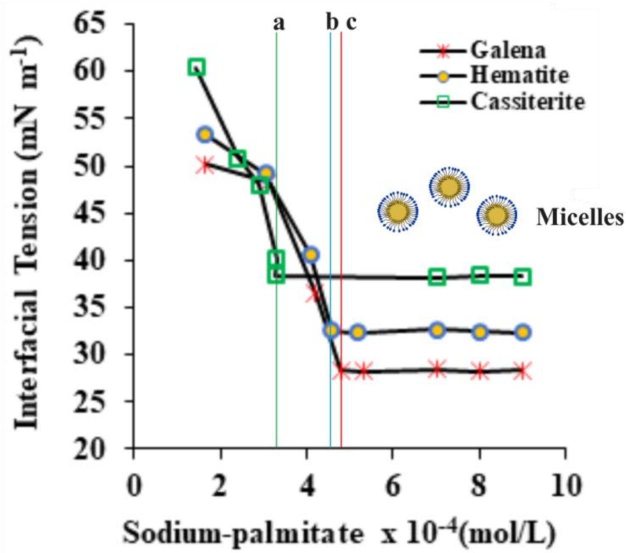


Figure 6: Plot of interfacial tension versus modified sodium-palmitate concentration

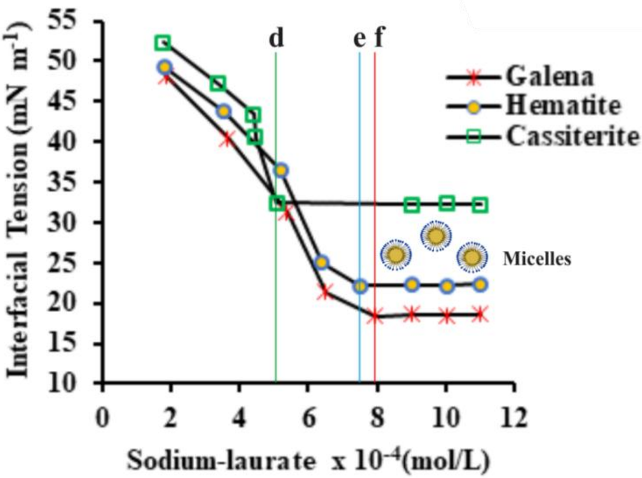


Figure 7: Plot of interfacial tension versus modified sodium-laurate concentration

The pre-micellar region in Figure 6 and 7 denotes the interval of preferential orientation of RSA molecules at the interface with increase in its quantity, followed by the attendant degree of reduction of interfacial tension in this circumstance. Thus, with further increase in concentration and as time progresses, the saturation of RSA collector concentrations at the interconnection point of the phases is reached when the self-generation of micelles begins to occur which is depicted as CMC [(a) 4.78, (b) 4.58 and (c) 3.31x 10^{-4} mol/L for sodium-palmitate; and (d) 7.95, (e) 7.49 and (f) 5.08 x 10^{-4} mol/L for sodium-laurate]. The post-CMC (plateau) region signifies the period in which more micelles are formed with further addition of RSA compounds; followed by abrupt change in the physicochemical properties with relatively no noticeable variation in interfacial tension.

3.2.Emulsifier in Drilling Mud Formulation

Emulsifiers are SA organic molecules or compounds which fortify and stabilize two or more incompatible fluids by increasing their kinetic energy at the interface. For e.g. Native salad (Abacha &Ugba) is prepared by leaching palm bunch ash with water (google.com/search?q=show+me+potash+palm+bunch+ash+sauce). The phytochemicals in the liquid extract are then applied as the emulsifier for mixing the oil to bind the Native salad sauce. The lifeblood factor exhibited by the extracted emulsifier to bind the Native salad sauce, is applied in involving the phytochemicals in the leaves extracts for developing drilling muds. Drilling mud is one of the crucial components of the complex process of extraction of hydrocarbon reserves which play a key role in enabling efficient and safe wellbore drilling in the oil and gas industry. Drilling mud represents about 15-18 % of the total cost of petroleum well drilling. To increase the productive value and enhance sustainability, the process of drilling should conform with major factors such as easy application, efficient utilization, cost effectiveness and environmental friendliness (Onyeogulu*et al*., 2021a).

We investigated three alkaline solutions (NaOH, Na_2CO_3 and $K_2CO_3.H_2O$) applied to extract the phytochemicals present in three dried plant materials [namely: Pawpaw (*Carica papaya)* (news-medical.net/health/Papaya-Health-Benefits.aspx), Bitter (*Vernonia amygdalina)* (agronigeria.ng/interesting-facts-about-bitter-leaf-by-ify-mgbemena/) and Almond (*Terminalia mantaly)* (google.com/search?q=almond+tree+showing+leaves) leaves] using Soxhlet extraction method(Onyeogulu *et al*., 2021b).

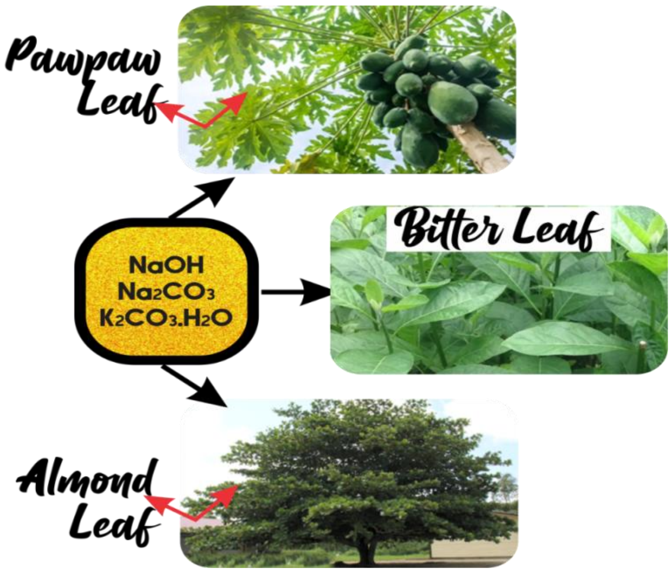


Plate 5: Alkaline solutions for the extraction of phytochemicals in pawpaw, bitter and almond leaves

These alkaline extracts were utilized as emulsifiers with other components in the formulation of water-based mud which yielded bitter leaves extract mud (BLEM),pawpaw leaves extract mud (PLEM) and almond leaves extract mud (ALEM) as RSA muds. The control mud was supplied by an Exploration and Production Company (Yunita*et al*., 2015; Orji *et. al*., 2016b, c; Orji *et. al*., 2018; Onyeogulu *et. al*., 2021b).The adsorption of the injected RSA drilling mud into the reservoir system at the interface establishes the lifeblood influence, byaligning the water-hating and water-loving portions of the RSA mud molecules with the adhered crude oil and aqueous phases respectively. The attraction of the RSA molecules to the crude oil lowers the interfacial tension thereby changing the oil-wet to water-wet rock's surface so as to displace the oil, and facilitate crude oil mobilization and extraction process.

3.2.1.Filtration Volume Studies

The filtrate volume was evaluated in order to determine the filtration characteristics of the muds. American Petroleum Institute fluid loss apparatus Fann High Pressure High Temperature filter press was used at 93 °C and 500 psi, and the loss in filtrate volume was recorded from the graduated cylinder at the end of 30 minutes and results presented in Figure 8 (Onyeogulu *et. al*., 2021b).

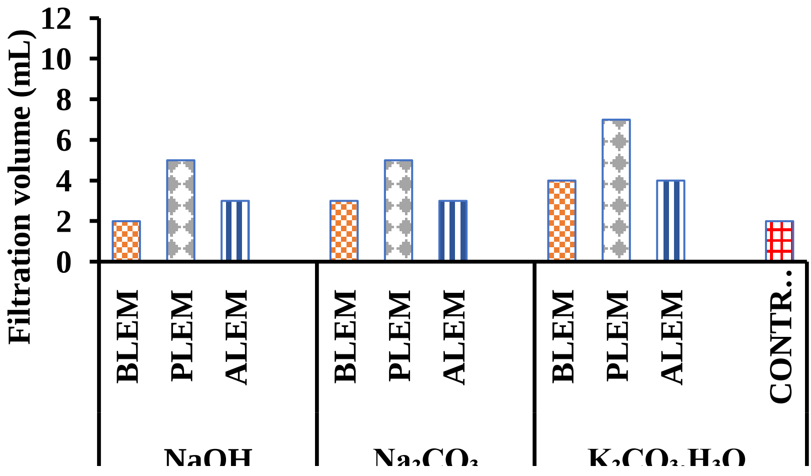


Figure 8: Filtration volume for the drilling muds

The actual fluid that could invade a permeable formation through deposited mud solids is termed filtration or fluid loss; while filtration volume refers to the total volume of fluid that passes through the filter medium during the filtration test. This test gives information on drilling mud filtration into the formation under static condition over a certain period. In this research work, filter cake refers to the deposited solids on the filtration medium, while filtrate refers to the separated liquid during filtration test. High value of filtration volume indicates permeable filter cake with more filtrate invasion into the formation, which can damage reservoir productivity; while low value of filtration volume indicates low-permeability filter cake, with minimal invasion of formation fluids. Thus, the relatively low filtration volume (Figure 9)resolved in this research signifies that the drilling mud loses only small amount of fluid to the formation, which is highly desirable for better well productivity. The performance of the formulated muds (especially $BLEM_{(NAOH)}$) in reference to the control mud is due to the lifebloodfeatures of the phytochemicals in the plant extracts which are responsible for the relative improvement in the formulated muds.

3.3.Ion Exchanger for Industrial Effluent Treatment

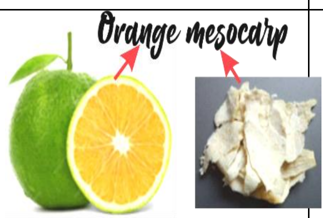
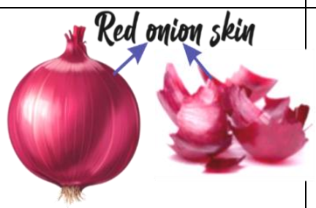
Water is the carrier-solvent of the components of all industrial effluents. The wastewater generated from manufacturing, factory or industrial plant processes that contains waxy and oily substances, suspended particulates, dyes, heavy metals, toxic species and chemicals is termed industrial effluent (google.com/search?sca_esv=06655e5bf07ee195&sxsrf=ANbL: assessed Jan, 2026).

Plate 6: Iindustrial effluent

Thus, the sustainability of aquatic ecosystems and safeguarding human health depends on treating industrial effluents to acceptable standards before discharge into water ways. Sustainable exchangers are preferred for remediation of ions from effluents because they are biodegradable, cost-effective, selective, stable, widely available, environmentally friendly and regenerable (Ibezim-Ezeani and Akaranta, 2016; Ibezim-Ezeani and Ihunwo, 2020a, b; Ibezim-Ezeani *et al*., 2020a, b; Ihunwo *et al*., 2020; Okorie *et al*., 2020, 2021; Ibezim-Ezeani and Ihunwo, 2021a, b; Ihunwo and Ibezim-Ezeani, 2021; Ihunwo *et al*., 2021; Ihunwo and Ibezim-Ezeani, 2022; Ihunwo *et al*., 2022a, b).

In our studies, RSA exchangers were developed from the by-products of orange, red onion and *cola lepidota* (monkey kola). These materials are of biological, horticultural, economical, phytochemical, nutritional, medicinal and healthful values to mankind.Their by-products (orange mesocarp, red onion skin and *cola lepidota* seed respectively) are in most cases discarded as waste from eating and cooking activities in schools, playgrounds, offices, kitchen, eateries, market garden, food processing industries, etc. Description of these agro-waste materials with their phytochemicals and applications are presented in Table 3.

Table 3: Agro-wastes with their phytochemicals and applications

Agro-waste	Description	Phytochemicals	Applications
	Whitishfibrous layer between the outer-colored peel and edible segments	Phenolicacids, flavonoids, dietary fibre, phytosterols, triterpenoids, carotenoids and ascorbic acid	Bioenergy, food, cosmetic, beverages, health, pharmaceuticals, personal care, animal feed, nutraceuticals, industrial, fermentation, agricultural and environmental
	Brownish-red outermost papery part on the fleshy bulbous layers	Quercetin, anthocyanins, flavonoids, phenolic acids, sulphur-containing compounds, tannins and other polyphenols	Naturaldye, crafts, health, agriculture, household, industrial, research, eco-friendly and sustainable development

	Innermost brownish part of the fleshy edible pulp	Saponins, flavonoids, tannins, terpenes, phenolics and alkaloids	agricultural, personal care product, nutritional, medicinal, economic, traditional, pharmaceutical, nutraceutical, cosmetic, industrial and cultural

The phytochemicals present in the milled samples (100 – 120 μm size) were extracted with acetone at 50 – 55 ºC by the Soxhlet extraction method. The extracted samples were recovered by expelling acetone from the acetone-extract mixture using rotor evaporator. Spectrophotometry of these materials and their extracts revealed that they consist of polar hydroxyl groups which enhance their susceptibility to chemical modification (Ibezim-Ezeani and Okon, 2016; Orji *et al*., 2016; Orji and Ibezim-Ezeani, 2017; Ibezim-Ezeani and Orji, 2017; Ibezim-Ezeani *et al*., 2017c; Onyeogulu and Ibezim-Ezeani, 2019; Onyeogulu *et al*., 2019; Adesanmi*et al*., 2019; Pat-Okunbor*et al*., 2019a, b; Ibezim-Ezeani *et al*., 2020b; Obi *et al*., 2020b; Ansa *et al*., 2021; Aimikhe*et al*., 2022).

3.3.1. Ion Exchange Process

Ion exchange process is based on the principle of diffusion and is the stoichiometric chemical reaction in which the interchange of equivalent ions at the phase boundary is reversible(Ibezim-Ezeani *et al*., 2010).The lifeblood attributes of the RSA exchangers are exhibited during the interchange of equivalent ions between the exchanging ions and exchangeable species at the active internal surfaces of the resin particles.

Thus, for a particular medium, the rate at which species diffuse in or out of the system and its surrounding depend on variable parameters like concentration, pressure, temperature, effective surface area, dissociation strength, agitation rate, particle size, characteristics of exchanging ions and exchanger, ionic radius and density with change in distance and time (Ibezim-Ezeani and Akaranta, 2017). Some of my findings on the interchange of mobile hydrated H^+ ions with RSA exchangers for equivalent metal ions at different conditions are presented in Table 4.

Table 4: Agro-wastes and their modified forms as metal ion exchangers

Agro-waste	**RSA exchanger**	**Metal ion exchanged (%)**	**Condition for optimal exchange**	**Reference**
Orange mesocarp 	Carboxylated-toluene di-isocyanate orange mesocarp extract resin	Zn^{2+} – 70.5 Cu^{2+} – 72.7 Ni^{2+} – 76.4 Co^{2+} – 84.2	≈ 40-45min, 29 °C, pH 7.2	Ibezim-Ezeani *et al*., 2010; 2012a, b
	Sulphonated-toluene di-isocyanate orange mesocarp	Zn^{2+} – 78.1 Cu^{2+} – 84.0 Ni^{2+} –		

	extract resin	88.0 Co^{2+} – 93.8		
Red onion skin 	Unmodified red onion skin extract	Pb^{2+} – 85.9 Cd^{2+} – 59.3	≈ 50-55 min, 28 °C, pH 6.3	Orji *et al*., 2016c; Orji & Ibezim-Ezeani, 2017; Ibezim-Ezeani & Orji, 2017
	Phosphoric acid red onion skin extract resin	Pb^{2+} – 96.8 Cd^{2+} – 94.0		
	Citric acid red onion skin extract resin	Pb^{2+} – 97.8 Cd^{2+} – 92.0		
	Maleic acid red onion skin extract resin	Pb^{2+} – 98.6 Cd^{2+} – 76.0		
	Succinic acid red onion skin extract resin	Pb^{2+} – 99.3 Cd^{2+} – 98.5		
	Carboxylated-epichlorohydrin red onion skin extract resin	Mn^{2+} – 86.7 Fe^{2+} – 77.0 Pb^{2+} – 66.3	≈ 35-40 min, 29 °C, pH 6.4	Ibezim-Ezeani & Okon, 2016; Ibezim-Ezeani & Akaranta, 2016; Ibezim-Ezeani & Akaranta, 2017
	Citric acid red onion skin extract resin	Cr^{6+} – 98.9	≈ 30-35 min, 30 °C, pH 4.0	Onyeogulu*et al*., 2019;Onyeogulu & Ibezim-Ezeani, 2019
	Maleic acid red onion skin extract resin	Cr^{6+} – 98.3		

*Cola lepidota*seed 	unmodified *Cola lepidota*seed extract	Pb^{2+} – 75.3 Cd^{2+} – 80.1	≈ 30-40 min, 30 °C, pH 6.0	Pat-Okunbor*et al.*, 2019a, b
	ethanedioic acid-modified *Cola lepidota*seed extract resin	Pb^{2+} – 89.4 Cd^{2+} – 83.5		

The proposed mechanism of exchange of metal ion for hydrogen ions on carboxylated-epichlorohydrin red onion skin extract resin (CERR) is presented in Figure 9 (Ibezim-Ezeani and Okon, 2016).

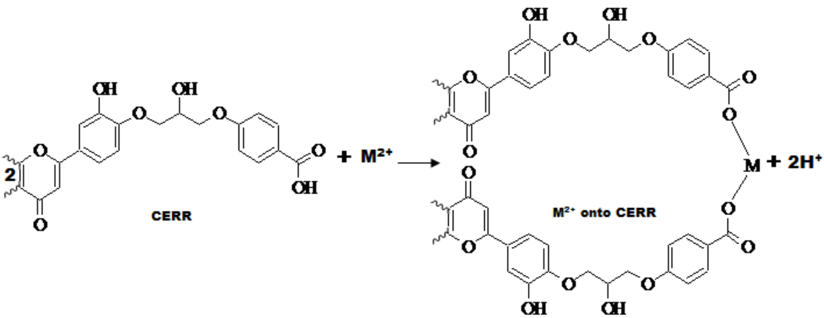


Figure 9: Proposed mechanism of metal ion (M^{2+}) exchange for hydrogen ions (H^{+}) on CERR

4. CONCLUSION

This lecture has shown that RSAA is an irreplaceable factor in manufacturing and thus, is the lifebloodof sustained industrial process advancement. I then conclude as follows:

(i) The palmitic and lauric acids applied in the formulation of the RSA collector reagents used for the metal ores beneficiation occur naturally as fatty acids found in high quantities in the edible palm and coconut oils, respectively. The micelle formation assessment showed that the RSA collectors displayed their lifebloodqualities by boosting the attachment of mineral particles to the surface of air bubbles for the achieve optimum separation.

(ii) The innate phytochemicals present in the plant extracts were responsible for the variations and relative improvement in the properties of the formulated mud. On the overall assessment, bitter leaves extract mud gave the closest fitting filtration loss to the control mud and could serve as an alternative RSA emulsifier in the formulation of water-based drilling mud.

(iii) The application of these formulated RSA exchangers that were churned from agro-wastes and by-products, will reduce the drudgery in the deionisation procedures of many industries, and develop the pathway to wring out ecofriendly effluents with economical and less cumbersome treatment trajectory.

4.1. FUTURE RESEARCH

Our team's future research focus is on developing renewable surface-active:

(i) Demulsifiers for breaking crude oil emulsions in order to meet refinery and export requirements.

(ii) Descalers to prevent scale build up on the surfaces of industrial facilities.

4.2. RECOMMENDATIONS

The roles of RSAAs in interfacial and multimedia operations in the industry make their development and harnessing an economic window for revenue generation. Hence, the following recommendations:

(i) Industries that use conventional resins in their water treatment ion exchange basins should see the RSA exchange resins as the formidable substitute and an element of cost benefit mechanism for optimal results.

(ii) Municipal waste managers should tap the potential of the RSAAs to improve the efficiency of their plants. The accelerated function of the eco-friendly produced materials will enhance environmental remediation and sustainability.

(iii) Having ascertained the lifebloodpotency of the phytochemicals in different formulations, industries should minimize their foreign exchange expenses by replacing the commercial SAAs with the RSA formulations of characterized compositions.

4.3. FINAL WORDS

Finally, my research works over the years in the University with the application of renewable surface-active agents for different formulations have demonstrated their life blood qualities; and exhibited high-performance efficacy giventhe green synthetic pathways.

I am available for consultation with individuals or corporate bodies that are interested in developing renewable surface-active agents or search for economically feasible alternative to conventional surface-active agents for application in sustainable industrial processes with ease of operation and maintenance.

Our capacity-extraordinaire VC and distinguished audience, **there is no life without surface-active agents**. The world is hungry for better tomorrows, companies want safer materials, communities desire cleaner ecosystems, Governments anticipate resilient economies, and people look forward to an industrial landscape that aligns with sustainable values. Thus, renewable surface-active agents provide a pathway toward sustainable industrial advancement, while promoting enhanced ecosystem services. This is the moment to advance their efficient use and establish **renewable surface-active agents as the lifebloodof sustainable industrial processes that benefit humanity and the long-term economic profiles of nations**.

Thank you.

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APPENDIX

Some pictures of my research works, and team tours to industrial and laboratory facilities

Plate 7: UPH team with the tour guides at Port Harcourt Refining Company, Alesa-Eleme, PH

Plate 8: Sample analysis with Gas Chromatography-Mass Spectrometer at Laser Environmental Laboratory

Plate 9: Application of Ion Selective Electrode for electrolytes analysis at University of Port Harcourt Teaching Hospital (UPTH)

Plate 10: Operation of Automated Full Chemistry Analyser at UPTH

Plate 11: UPH team with the tour guides at UPTH

Plate 12: Multiple viewing point microscope at work in the Microbiology Lab., UPTH

Plate 13: UPH team listening to the introductory & safety

Plate 14: UPH team at the Ammonia Control Room of NOTORE Chemical Industries, Onne

Plate 15: UPH team with the tour guides at NOTORE

Plate 16: UPH team heading to Fertilizer production plant of NOTORE

Plate 17: Oven drying of bitter leaf samples at Central Instrument Laboratory, UPH

Plate 18: Sample analysis with Microwave Plasma Atomic Emission Spectrometer at Laser Environmental Laboratory

CITATION

Professor Millicent Uzoamaka Ibezim-Ezeani

Professor of Physical Chemistry

B.Sc., M.Sc., Ph.D. (UPH)

FCSN, FICCON, MWIC, MOWSD

Millicent Uzoamaka Ibezim-Ezeani (nee Ochuonu) was born the first child of four children on 6th July, 1967 into the family of Late Chief Alphonsus N. Ochuonu and Ezinne Philomena U. Ochuonu of Egbema-Ozubulu, Egwusigo Local Govt. Area, Anambra State, Nigeria. She is the first professor of Abor-ani Awgbu (Orumba North Local Govt. Area, Anambra State) through her deep marital ties to the family of Late Chief Augustine Ibezim and Chief (Mrs) Rebecca O. Ibezim-Ezeani. She attended Women Teachers Training College Primary

School, Enugu from 1972-1978; and Queens School, Enugu, Enugu State from 1978-1983. She proceeded to University of Port Harcourt, Rivers State, where she graduated with B.Sc (Hons) Pure and Applied Chemistry in 1988; M.Sc (Physical Chemistry) in 2003; and Ph.D (Physical Chemistry) in 2008.

Right after her National Youth Service Corps (at Research and Quality Control Section, Laboratory Service Department of Delta Steel Company Ltd., Aladja, Warri, 1989-1990),she taught Chemistry and Mathematics (at PUMO GCE/WAEC/JAMB Preparatory School No. 6 Umuedafe St., off Alegbon Primary School, Effurun, Delta State, 1990-1996) before taking up a role as Safety Instructor, Chase Technology Ltd. (Old Training School Block, SPDC–Warri, 1997-2000). She subsequently became a Part-time Teacher-Demonstrator, Department of Pure and Ind. Chemistry University of Port Harcourt (2000-2003), and assumed duty as an Assistant Lecturer, Department of Pure and Industrial Chemistry University of Port Harcourt (2005-2007). She rose to the rank of Lecturer II–2007, Lecturer I–2011, Senior Lecturer–2014, Reader–2017 and Professoriate in 2020.

As a Professor of Physical Chemistry, her subject lectures are in Physical-, Surface-, Radiation-, Colloidal-, and Electro-Chemistry at both undergraduate and graduate levels in the University of Port Harcourt. Millicent's research works have proffered solutions in the: identification of kinetic, thermodynamic and equilibrium conditions which are conducive to produce optimum results in the elimination of metal ions from effluents with resins formulated from agro waste; investigations on the spatiotemporal distribution and risk assessment of heavy metals and polycyclic aromatic hydrocarbons in surface water, sediment and living organisms in water bodies; electrochemical studies on the mixing tendencies of organic electrolytes for high energy density batteries; formulation and characterization of renewable surface-active agents from agro-wastes and by-products, and their modified derivatives for oilfield applications, etc.; and have many scholarly articles published in these areas. She is the co-author of the books: Fundamentals of Solution Thermodynamics, Introduction to Physical Chemistry, Fundamentals of General Chemistry, Rudiments of Radiation Chemistry, Modernity in Health and Disease Diagnosis, and Natural Products in Oilfield Operations. She is an External Assessor (for the ranks of Reader and Professor) and Examiner (for Postgraduate and Undergraduate Programmes) in many Universities; and has supervised over 162 undergraduate and graduate research projects.

Millicent is a Fellow–Chemical Society of Nigeria (FCSN), Fellow–Institute of Chartered Chemists of Nigeria (FICCON), Member–Organization for Women in Science for the Developing World (MOWSD) and Member–Women in Chemistry (MWIC); and has attended many conferences and capacity building workshops at home and abroad. She was the Chairperson, Communiqué Committee for the 8th Mandatory Continuing Professional Development Workshop by ICCON (May, 2016); and Chairperson, Welfare and Accommodation Sub-committee of the Local Organizing Committee, 39th CSN International Conference (2016). As the staff adviser to

Students' Chemical Society of Nigeria (UPH Chapter, 2010-2014), she recorded among other achievements, the initiation and publication of ChemSite Magazine; for which she wrote the "Greener Scope" column in 2nd and 3rd editions. She applies her cheerful disposition, brilliant mind and experience in counselling and mentoring the young ones, in a characteristic manner that acts as a wonderful boost for their morale and rich source of inspiration for creating innovative works, and in the overall, make them top achievers.

Millicent has served the University in various capacities including: Member, Faculty of Chemical Sciences Representative–Appointments and Promotions Committee, Academic (2015), Member, Committee for Development of Post-Graduate Degree Programme and Course Curricular for Science Laboratory Technology (2018); Member, School of Graduate Studies Results Verification Committee (2015-2021). She represented UPH as a subject matter expert at the Teacher Education Program Review Workshop (March, 2016) by African Virtual University, Kenya; where she reviewed modules on Physical Chemistry and Separation, Electroanalytical and Spectrochemical Techniques; and peer reviewed those on Volumetric Chemical Analysis and Environmental Chemistry.

She also served as: Member, Committee for Development of Post-Graduate Degree Programme and Course Curriculum for Science Laboratory Technology (2018); Associate Editor, Scientia Africana–An international Journal of Pure and Applied Sciences, (2018-2021); Chairperson, Faculty of

Science Welfare Committee (2018-2021); Coordinator–Department of Biochemistry/Chemistry Technology, School of Science Laboratory Technology (2019-2020); Academic Supervisor and Assistant Research Group Leader –Niger Delta Aqua Research Group, Department of Biochemistry and Chemistry Technology, School of Science Laboratory Technology(2019-2025); Editor-in-Chief, BioChemTechazine – An Annual Publication (1st& 2nd editions; ISSN 2714-4909) of the Department of Biochemistry / Chemistry Technology (2019-2020); Faculty Debate Coordinator–School of Science Laboratory Technology (2019-2020); Faculty of Science Homecoming and Science Day Celebration Committee (2020); Faculty of Science Seminar and Exchange-Linkage Committee (2021-2023); Research Collaboration and Infrastructural Development Committee, University of Port Harcourt (2021-2025); Member, Strategic Research Plan Review Committee, University of Port Harcourt (2023-2025); etc.

She is currently the first female Director of Central Instrument Laboratory – University of Port Harcourt (CIL). Under her directorship, CIL organized the 1st and 2nd International conference on Laboratory Research and Technopreneurial Innovations in commemoration of World Laboratory Day, 2024 and 2025 respectively. She is the Editor-in-Chief of the International Journal of Research and Technopreneurial Innovations {(a multidisciplinary biannual publication (Volume 1 & 2; ISSN 3043-5722)} and CILAZINE {an annual publication (1st& 2nd editions; ISSN 3043-5714), purchased Ultraviolet-Visible spectrometer from internally generated revenue, organized hands-on training workshops, hosted annually the Students Industrial Work Experience Scheme among other achievements.

Millicent is a devout Catholic; and belongs to the Catholic Women Organization, Association of Sacred Heart of Jesus and Immaculate Heart of Mary, and Divine Mercy prayer group, Nigeria. She is a certified instructor of Billings method of natural family planning. She is eternally grateful to Almighty God for her lovely marriage to Mr. Anthony I. Ibezim-Ezeani and gift of children (Clement, Emmanuel and Charles).

Prof. Owunari Abraham Georgewill
Vice-Chancellor