UNIVERSITY OF ILORIN

THE TWO HUNDRED AND EIGHTY-SIXTH (286TH) INAUGURAL LECTURE

"WASTE STREAM AND EMISSIONS MANAGEMENT FOR SUSTAINABLE DEVELOPMENT"

By

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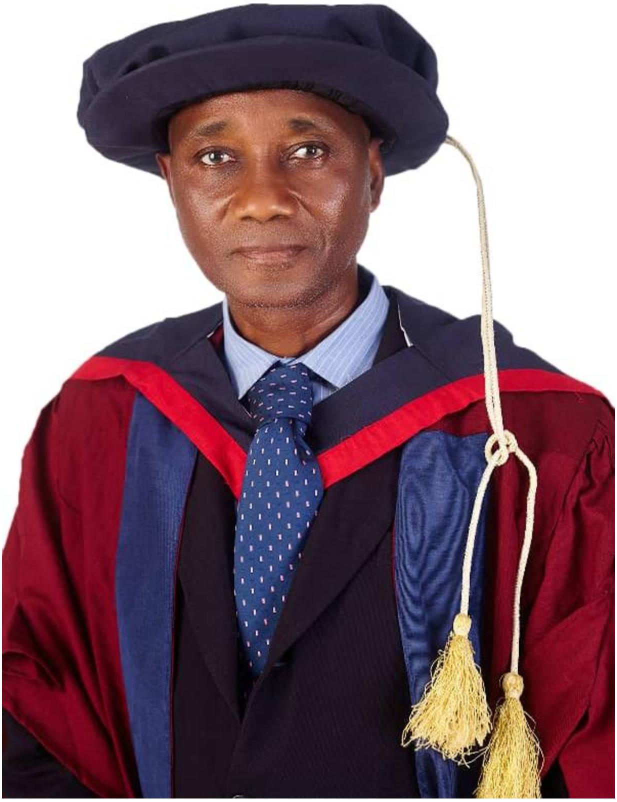

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Members of Academic Staff,
My Lords Spiritual and Temporal,
Distinguished Students of Chemical Engineering,
Members of my Nuclear and Extended Families,
Esteemed Guests,
Gentlemen of the Print and Electronic Media,
Great students of the University of Ilorin,
Distinguished ladies and gentlemen.

Preamble

"Auzu billahi minna shaytani rajeem, Bismillahi Rahmani Raheem"

I seek refuge in Allah against the accursed devil. I begin the delivery of this inaugural lecture in the Name of Allah, the Gracious, ever Merciful. Allah! You are the Omnipotent and the Omnipresent, the First and the Last, the First without any beginning and the One to ever exist without any point of termination. It is with much gratitude to the Almighty Allah that I am here today, before this distinguished audience from far and wide, to deliver the 286th Inaugural Lecture of this great citadel of learning, the University of Ilorin, which is the 3rd by a

Professor of Chemical Engineering from the Department of Chemical Engineering. The first lecture was delivered by Prof. Omodele A.A. Eletta on September 2, 2021 titled *Bad, Yet Good: Rummaging and Combatting for Future Water and Land Security*. The second lecture was delivered by Prof. Temitope E. Odetoye on April 4, 2024 titled *Symphony of Biomass, Bioenergy and Bioproducts for Sustainability*.

Today's lecture marks a significant milestone in my career as I deliver the 286th Inaugural Lecture of the University of Ilorin as a Professor of Chemical Engineering in the Department of Chemical Engineering. This occasion is a great personal achievement and an opportunity to reflect on the contributions I have made to the field of waste streams and emissions management both in Nigeria and beyond. I hope that by sharing my insights and experiences, I can inspire future generations of engineers to champion sustainable development and advocate for responsible environmental management.

I was born many years ago in Nkawkaw, Eastern Region of Ghana. I started my education at St. Stephen's Anglican Primary and Middle School (1960-1969). In my final year at the middle school, I took the Middle School Leaving Examination and passed with distinction. I then took the Ghana Common Entrance Examination and was admitted to two secondary schools and one technical school. They were the Tema Secondary School, Tema, Greater Accra Region, Ahmadiyya Secondary School, Kumasi, Ashanti Region and the Sunyani Technical Institute, Sunyani, Brong-Ahafo Region. As fate would have it, some 'wise' men advised my father against sending me to secondary school and that I should be made to learn a trade. That was how I became an apprentice WATCH REPAIRER in August 1969.

Fortunately, fate intervened again in that same year when the government of Prof. K.A. Busia asked all foreigners without resident permit to leave Ghana within two weeks in the middle of November. It was a period of total chaos. On December 14, 1969, my family left Ghana and got to Offa on December 16, 1969 spending the nights of 14th and 15th

December in Aflao and Abeokuta, respectively. I wanted to continue my education based on the strength of my common entrance examination result and letters of admission but another ‘wise’ man in Offa told my father that there are differences in the education systems of Ghana and Nigeria and so advised him that I should spend another year in a Nigerian primary school to get familiarised with the Nigerian educational system.

I was then enrolled at Iyeru-Okin African School, Offa in 1970, from where I sat for the National Common Entrance Examination. I passed and was admitted at the famous Offa Grammar School, Offa in 1971. A week to resumption, I received a letter of award of full scholarship for my secondary education based on my performance in the common entrance examination. That was the beginning of my many scholarships. In 1975, I passed the West African School Certificate Examination with distinction again. I was in the School of Basic Studies (SBS) of the Kwara State College of Technology from 1975-1977, where I sat for the GCE-Advanced Level examination (Mathematics, Physics and Chemistry) moderated by the University of Cambridge.

I applied to three universities offering Chemical Engineering at the time-the University of Lagos, University of Benin, and the University of Ife (now Obafemi Awolowo University), in that order of preference and was eventually admitted to UNILAG in 1977 from where I graduated in 1981. Following my graduation, I completed the National Youth Service Corps (NYSC) at West African Breweries Ltd, Abeokuta, where I gained invaluable hands-on experience in industrial operations, further solidifying my interest in Reaction Engineering and Process Design.

After my National Youth Service in 1982, I began my career with the Kwara State Education Management Board and worked there for three years. On July 17, 1985, I reported to the Nigerian Paper Mill Ltd, Jebba as a Paper Production Superintendent. Exactly forty years later, I am standing before this distinguished audience as a Professor of Chemical/

Environmental Engineering. *Which of the favours of Allah will I deny?*

I left the Nigerian Paper Mill Ltd and joined the Cement Company of Northern Nigeria (CCNN) Plc, Sokoto, as a Senior Production Engineer, and eventually got promoted to Principal Production Engineer and Shift Manager. I resigned in 2001 to embark on an academic career, joining Ladoke Akintola University of Technology (LAUTECH), Ogbomoso as an Assistant Lecturer. In 2008, I moved to the University of Ilorin as Lecturer II upon the establishment of her Department of Chemical Engineering. My decision to study Chemical Engineering was no accident, but a dream fulfilled and a struggle tenaciously pursued.

Back in 1973 when Chemical Engineering was first introduced at the University of Lagos (UNILAG), I was in Form Three at Offa Grammar School, Offa. It was then that I saw an image-later to be revealed to be a Fluid Catalytic Cracking (FCC) unit of a refinery that showcased where a chemical engineer works. There and then, I made up my mind to study the discipline so that I could work in a refinery. (I NEVER DID BY THE WAY!) That was my original plan, but Allah had other plans for me. The closest I came was attending an interview in 1991 where I was asked, "*Who sponsored you?*". By then, I was working at the then Cement Company of Northern Nigeria Plc, Sokoto (now BUA Cement).

Introduction

Mr. Vice-Chancellor, my academic journey began at the University of Lagos, where I obtained my Bachelor's degree in Chemical Engineering in 1981. The knowledge and training that I received during this period under the guidance of esteemed professors including Prof. A. F. Ogunye, Prof. A. A. Susu and other lecturers in the Department, laid a promising foundation for my passion for environmental conservation and management. Their tutelages emphasized the practical applications of scientific theories and the manipulation of natural phenomena, thus, sparking my interest in sustainable practices.

My undergraduate project, titled *"Possible Energy Derivation from Lagos Municipal Refuse"*, was undertaken under the supervision of the late Prof. J. O. Edewor, whose mentorship inspired my journey into academia. In 1998, while working at the Cement Company of Northern Nigeria (CCNN) Plc, Sokoto, I progressed with my education by enrolling at Usmanu Danfodiyo University, Sokoto, where I earned a Postgraduate Diploma in Management. This programme honed my administrative skills and highlighted the importance of effective management in engineering projects. Building on this foundation, I pursued a Master degree programme in Chemical Engineering at the Obafemi Awolowo University, Ile-Ife, which I completed in 2008 with distinction. My Master research under late Prof. B. O. Solomon focused on the bioremediation of tannery wastewater. This work deepened my appreciation for the indispensable role of microorganisms in environmental remediation. During the period, I had the privilege of practical Environmental Engineering under the tutelage and mentorship of Prof. S. O. Adeyemi of CIWAT Engineering, where I actively contributed to the design of an Industrial Wastewater Treatment Facility in Kaduna and an Integrated Solid Waste Management (ISWM) facility in Ilorin.

In 2013, I reached a significant milestone by completing my Ph.D. in Environmental Engineering at the Universiti Teknologi Malaysia, Johor Bahru**.** My doctoral research focused on methane emission inventory and forecasting, equipping me with the needed expertise to deal with sustainable emission mitigation strategies, greenhouse gas chemistry, and climate change impacts. By the end of my Ph.D. programme, I had gained comprehensive knowledge and practical exposure in sustainable waste management across various media like land, water, and air, and their respective control systems. My progression at the University of Ilorin through various academic ranks is proudly peaked by my current role as a Professor of Chemical Engineering. As acting Head of Department, I was a key member of the committee that developed the curriculum, and spearheaded the establishment of postgraduate programmes.

Despite many hurdles, the experiences have merely enriched my administrative capabilities.

Vice-Chancellor, Sir, I have led pioneering projects aimed at addressing environmental challenges, including research on the *bioremediation of contaminated soils* and *air quality assessments* across Nigerian industries. My breakthroughs in utilising local microbial strains for waste treatment have advanced both academic knowledge practical solutions to community environmental issues. Additionally, my active participation in numerous national and international conferences has enabled collaborations and promoted knowledge exchange, which in turn enriched my research portfolio, and amplified my impact in the field of environmental engineering. As I reflect on this journey, I remain eternally grateful to Allah for His divine guidance towards receiving support and mentorship from heavenly-sent mankind along the way. I am committed to further exploring the field of environmental engineering to promote sustainable development.

Methane Emission and Renewable Energy

The rising trend in the temperature of the earth has become a global threat. This is as a result of global warming. Global warming is caused by the emission of greenhouse gases into the atmosphere and which has had a significant impact on the world's climate. The major greenhouse gases are carbon dioxide, methane and nitrous oxide. Records show that only carbon dioxide received detailed investigation but not methane; hence a detailed study of methane emission sources was carried out. The principal sources of methane emission were identified as crude oil production, livestock rearing, wastewater, municipal solid wastes, coal mining and rice production.

Mr. Vice-Chancellor, comprehensive methane emission inventories for both Malaysia and Nigeria were developed (as shown in Figs. 1-4) and these have informed national greenhouse gas mitigation policies (**Yusuf** *et al.,* 2012; **Yusuf** *et al.,* 2016). A similar work on livestock methane emission forecast from five decades of livestock production in Nigeria is shown in Table 1.

The study employed diverse methodologies, including the Intergovernmental Panel on Climate Change (IPCC) guidelines-the global standard for methane emission estimation. These methodologies have been adapted to develop region-specific emission inventories suitable for different industrial contexts, particularly in Malaysia and Nigeria.

A key innovation in the research has been the application of the Auto-Regressive Integrated Moving Average (ARIMA) model for forecasting methane emissions (**Yusuf** *et al.*, 2014). This statistical tool enables precise projections based on historical data, making it an invaluable resource for policymakers. Furthermore, biogas estimation models have been used that incorporate waste composition analysis, thereby enhancing the accuracy of methane generation potential assessments. The research has produced significant insights into the potential reduction of methane emissions through improved waste management practices.

A notable example is the study on historical and projected methane emissions in Malaysia (1980–2020) **(Yusuf** *et al.*, 2015**),** which revealed that the highest emissions originated from the oil sector and livestock production, with substantial contributions from municipal solid waste. The findings emphasized the critical role of methane recovery systems in landfills. By adopting these systems, methane emissions can be mitigated, and the captured gas can also be harnessed as a renewable energy source, thereby offering a dual benefit of reducing environmental impact while addressing energy needs.

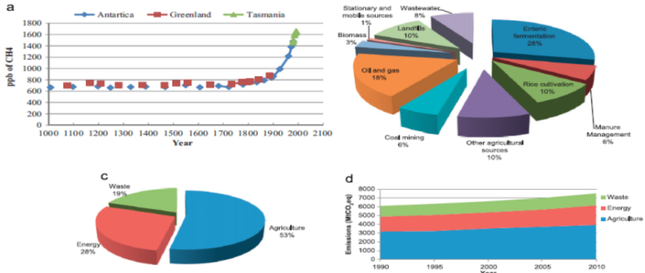
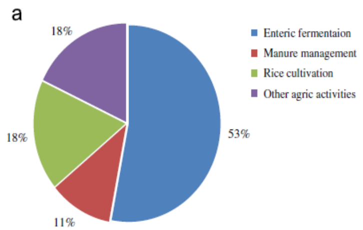


Fig. 1: (a) Methane concentration in the atmosphere, (b) Anthropogenic methane emissions by source in 2010. (c) Anthropogenic methane emission by sectors in 2010 (d). Methane emission trends by sectors from 1990–2010.



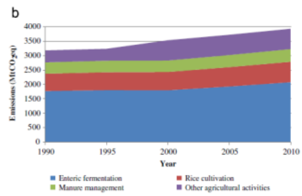


Fig. 2: (a) Methane emissions from agriculture (b) Methane emissions trend from the agricultural sector (1990–2010)

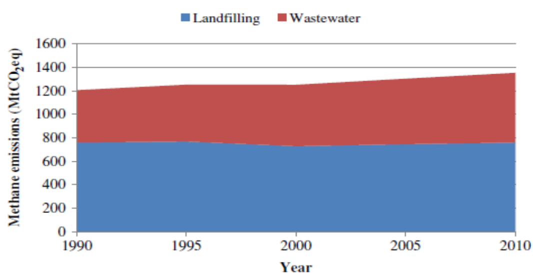


Fig. 3: Total emissions from the waste sector (1990-2010)

Table 1: Methane emission forecast from livestock (2013-2025)

Model		2013	2014	2015	2016	2017	2018	2019/12	2023	2024	2025
Cattle	F	620.20	627.65	635.10	642.55	650.00	657.45	664.90	694.69	702.14	709.59
	UCL	646.54	662.75	677.25	690.79	703.70	716.16	728.27	774.42	785.56	796.57
	LCL	593.85	592.54	592.94	594.30	596.29	598.73	601.52	614.97	618.73	622.62
Sheep	F	204.34	208.26	212.18	216.10	220.01	223.93	227.85	243.52	247.44	251.35
	UCL	209.64	217.93	226.95	236.63	246.89	257.69	268.99	318.63	332.04	345.82
	LCL	199.05	198.60	197.41	195.57	193.14	190.17	186.71	168.41	162.83	156.88
Goats	F	302.94	305.16	307.38	309.60	311.83	314.05	316.27	325.16	327.38	329.61
	UCL	308.27	315.99	324.76	334.45	344.96	356.22	368.17	422.09	436.94	452.30
	LCL	297.60	294.33	290.00	284.76	278.69	271.88	264.37	228.24	217.82	206.91
Camels	F	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	UCL	1.05	1.06	1.08	1.09	1.11	1.12	1.13	1.17	1.17	1.18
	LCL	0.89	0.87	0.85	0.84	0.83	0.82	0.81	0.77	0.76	0.75
Horses	F	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34	4.34
	UCL	5.00	5.27	5.48	5.66	5.81	5.95	6.08	6.52	6.62	6.71
	LCL	3.68	3.41	3.20	3.02	2.87	2.73	2.60	2.16	2.06	1.97
Asses	F	14.16	14.24	14.28	14.29	14.30	14.31	14.31	14.31	14.31	14.31
	UCL	15.13	15.97	16.68	17.27	17.79	18.25	18.67	20.04	20.33	20.61
	LCL	13.19	12.50	11.88	11.32	10.81	10.36	9.95	8.58	8.29	8.01
Pigs	F	24.47	25.19	25.91	26.63	27.35	28.08	28.80	31.68	32.41	33.13
	UCL	25.46	26.62	27.84	29.12	30.44	31.80	33.21	39.19	40.77	42.38
	LCL	23.47	23.76	23.98	24.15	24.27	24.35	24.39	24.17	24.04	23.87
Chicken	F	9.12	9.44	9.76	10.10	10.45	10.81	11.18	12.80	13.24	13.69
	UCL	9.71	10.31	10.88	11.44	12.00	12.58	13.17	15.70	16.39	17.09
	LCL	8.56	8.62	8.74	8.88	9.05	9.23	9.42	10.32	10.57	10.83

F: Forecast, UCL: Upper confidence level, LCL: Lower confidence level

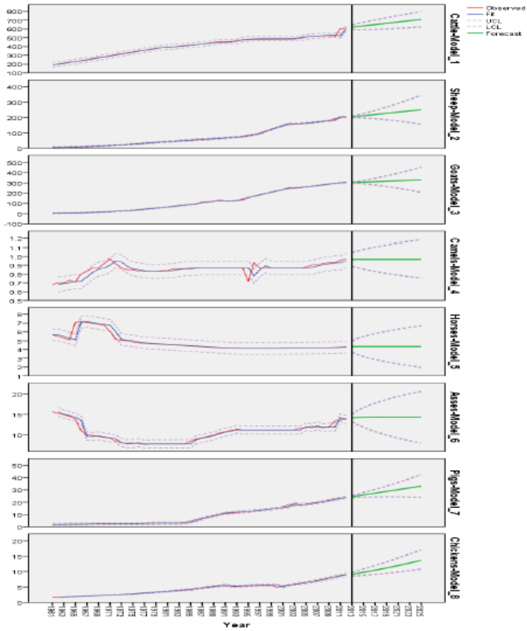


Fig. 4: Observed, fitted, and predicted values of methane emission projection (1961-2025)

Table 2: Methane emission from 2012-2020 (Gg)

Model		2012	2013	2014	2015	2016	2017	2018	2019	2020
Rice-Model_1	Forecast	50.6	50.6	50.6	50.6	50.6	50.6	50.6	50.6	50.6
	UCL	53.2	53.8	54.3	54.8	55.2	55.5	55.9	56.2	56.5
	LCL	48.0	47.4	46.9	46.5	46.1	45.7	45.4	45.0	44.7
Livestock-Model_2	Forecast	129	130	132	133	134	136	137	1395	140
	UCL	137	141	145	149	152	155	158	161	164
	LCL	121	119	118	117	117	117	116	116	117
Coal-Model_3	Forecast	2.6	2.8	3.1	3.4	3.6	3.89	4.2	4.4	4.8
	UCL	3.0	3.4	3.8	4.3	4.8	5.26	5.8	6.3	6.8
	LCL	2.2	2.3	2.4	2.4	2.5	2.52	2.5	2.5	2.5
Oil-Model_4	Forecast	332230	342947	353663	364376	375092	385809	396521	407238	417954
	UCL	350115	367223	382984	398011	412552	426751	440686	454410	467963
	LCL	314349	318671	324339	330745	337632	344863	352360	360065	367946
Wastewater-Model_5	Forecast	680	699	719	738	758	777.19	796.7	816	836
	UCL	749	775	801	827	852	876.99	902	926	950
	LCL	610	623	636	649	663	677.39	692	706	721
MSW-Model_6	Forecast	143	146	149	152	155	157.92	161	164	169
	UCL	144	148	151	155	156	163.86	168	173	177
	LCL	143	145	145	149	150	151.98	154	155	156

UCL: Upper control limit; LCL: Lower control limit

Similarly, in Nigeria, my research on observed and projected trends in livestock methane emissions from 2012–2020 presented in Table 2 revealed that cattle, sheep, and goats collectively accounted for over 95 % of total emissions (**Yusuf.** *et al.*, 2016). This finding pointed out the need for sustainable livestock management practices to mitigate emissions while simultaneously supporting agricultural productivity.

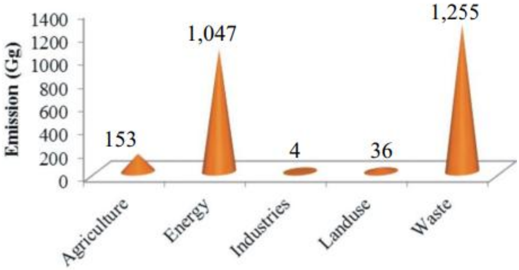


Fig. 5: Methane emission from each sector in Malaysia (1990-2007)

Fig. 5 shows the work on methane emission inventory from each sector in Malaysia between 1990 and 2007. These interdisciplinary efforts emphasized the value of collaborative approaches to tackling complex environmental challenges, particularly in developing nations like most countries in sub-Saharan Africa. In summary, my work on methane emissions has advanced both academic knowledge and practical sustainability solutions for waste management. As I continue to engage in this vital research area, even as I am preparing to retire from active service, I remain committed to interdisciplinary collaborations that could drive innovation and policy-relevant for a sustainable future.

Non-Methane Gaseous Pollutants from Liquefied Natural Gas Operations

Vice-Chancellor, Sir, the environmental impacts of non-methane gaseous pollutants (NMGPs) from liquefied natural gas (LNG) operations was extensively examined. This area is essential for understanding the broader implications of LNG production and consumption on air quality and climate change (Adeniran, **Yusuf,** Jimoda, Adesanmi & Sonibare, 2016). Key pollutants investigated include carbon monoxide (CO), volatile organic compounds (VOCs), and nitrogen oxides (NO_x) that are emitted during LNG processing and transportation. Beyond emissions characterization, the study predicted maximum ground level concentrations impact of air pollutant on ambient air quality using different scenarios as presented in Table 3 and modelled the dispersion of annual pollutants concentrations of CO, NO_x and VOCs as shown in Fig. 6 (Adeniran, **Yusuf,** Jimoda, Adesanmi & Sonibare, 2016). The study assessed their health and environmental impacts, and examined how these emissions interact with climate change to propel effective mitigation strategies. As LNG gains prominence as a "cleaner" fossil fuel, my works critically evaluate its environmental footprint to ensure alignment with sustainability goals.

In the studies on NMGPs, comprehensive methodologies were used to quantify emissions and assess air quality impacts. One notable approach involved the use of air quality modelling techniques, particularly the American Meteorological Society-Environmental Protection Agency Regulatory Model (AERMOD), which has been instrumental to predicting ground-level pollutant concentrations across various operational scenarios. This framework has provided robust assessments of the potential impacts of LNG facilities on surrounding communities (Adeniran, **Yusuf,** Jimoda, Adesanmi & Sonibare, 2016). Additionally, innovative emissions inventory methods have been developed by integrating real-time monitoring data with predictive modelling, to enhance the accuracy of emissions assessments. This includes using scenario-based analyses to predict emissions under different operational conditions, such as maximum capacity scenarios that consider the simultaneous operation of multiple processing units.

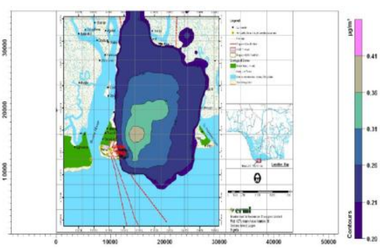
Mr. Vice-Chancellor, Life Cycle Assessment (LCA) techniques were also adopted to evaluate the full environmental impact of LNG operations, encompassing resource extraction, processing, and eventual disposal. This holistic approach provides a deeper understanding of the cumulative environmental burden of LNG production and use. The research has produced significant findings concerning NMGP emissions from LNG operations. In one particular study, it was noted that the predicted maximum ground-level concentrations of CO, VOCs, and NO_x in Nigerian LNG facilities were of particular concern under maximum operational scenarios. CO concentrations, in particular, were interestingly found to exceed national and international air quality standards during peak operations. These results present the urgent need for stringent monitoring and enforcement of air quality regulations in the LNG sector to safeguard public health and the environment. Furthermore, my research has contributed to the growing body of informed literature advocating for advanced emissions control technologies in LNG facilities through the development of feasible frameworks. Another key finding from my research demonstrated the relationship between operational efficiency and emissions reduction. By analysing operational data from LNG facilities, I showed that optimizing processes could significantly reduce NMGP emissions, offering a viable pathway to improving air quality without compromising production outputs.

Table 3a: Predicted Maximum Ground Level Concentrations Impact on Ambient Air Quality

Air Pollutant	Averaging Period	Scenario 1		Scenario 2		Scenario 3	
		Conc. ($\mu g/m^3$)	% of Set Limit	Conc. ($\mu g/m^3$)	% of Set Limit	Conc. ($\mu g/m^3$)	% of Set Limit
CO	1 – hour	7.53	0.03	11.14	0.04	4.21	0.01
	8 – hour	3.78	0.04	4.77	0.05	1.4	0.01
	24 – hour	2.48	0.02	3.13	0.03	0.75	0.01
	Annual	**0.17**	-	**0.25**	-	**0.07**	-
VOCs	1 – hour	4.46	-	As in Scenario 1		None Expected	
	8 – hour	2.59	-				
	24 – hour	1.66	0.03				
	Annual	**0.08**	-				
NO_X	1 – hour	11.44	5.72	18.63	9.32	7.42	3.71
	8 – hour	5.48	-	7.87	-	2.59	-
	24 – hour	3.48	2.32	5.23	3.49	1.59	1.06
	Annual	**0.24**	-	**0.39**	-	**0.15**	-

Table 3b: Predicted maximum ground level concentrations impact on ambient air quality

Air Pollutant	Averaging Period	Scenario 3		Scenario 4		Scenario 5	
		Conc. (μg/m^3)	% of Set Limit	Conc. (μg/m^3)	% of Set Limit	Conc. (μg/m^3)	% of Set Limit
CO	1 – hour	4.21	0.01	12.17	0.04	15.87	0.05
	8 – hour	1.4	0.01	5.41	0.05	6.49	0.06
	24 – hour	0.75	0.01	3.82	0.03	4.48	0.04
	Annual	**0.07**	-	**0.33**	-	**0.41**	-
VOCs	1 – hour	None Expected		5.67	-	As in Scenario 1 or Scenario 2	
	8 – hour			2.99	-		
	24 – hour			2.05	0.03		
	Annual			**0.16**	-		
NO_X	1 – hour	7.42	3.71	18.61	9.31	25.13	12.57
	8 – hour	2.59	-	7.76	-	10.35	-
	24 – hour	1.59	1.06	5.49	3.66	7.01	4.67
	Annual	**0.15**	-	**0.47**	-	**0.62**	-



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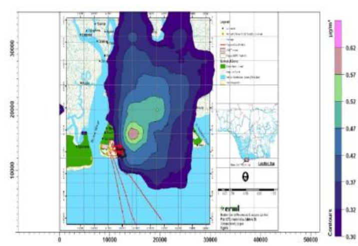

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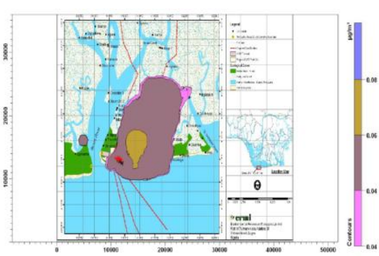

(c)

Fig. 6: Expected Annual Averaging Period Pollutants Concentrations from Scenario 5 (a) CO (b) NO_x (c) VOCs

Urban Air Pollution

Vice-Chancellor, Sir, my study on urban air pollution has fostered extensive collaboration across disciplines and institutions, cutting across several areas of interest which encompass measurement, monitoring, modelling, and management of air pollutant emission such as gaseous pollutants (CO, NO_2, SO_2, NH_3, TVOCs, and ground level O_3) and Particulate Matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}& TSP), Heavy Metals (also known as potentially toxic elements – PTEs), Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorinated Biphenyls (PCBs) from urban traffic, University campus, markets, scrap-iron industry and thermal Plant. Furthermore, my work has contributed to the quantification and prediction (forecasting) of sectoral pollutant emissions in Nigeria from 1980 to 2050 and the understanding of air quality trends during COVID-19.

Traffic Related Air Pollutants (TRAPs)

Concentration variations of Traffic Related Air Pollutants (TRAPs) at traffic intersections (TIs) in Ibadan, Nigeria were investigated, as shown in Fig. 7. Odediran, Adeniran, and **Yusuf** (2023a) investigated the concentration variations of gaseous pollutants (CO, NO_2, SO_2, NH_3, TVOCs, and ground level O_3) and Particulate Matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10}& TSP) during the rainy and dry seasons at and around twenty-five (25) Traffic Intersections (TIs) which are major traffic hotspots within Ibadan metropolis (Figs. 8 and 9). The daily rush and non-rush hour concentrations of pollutants were monitored. Cancer risks (CR_{inh}) and epidemiology based mortality estimates using Relative Risk (RR) and Attributable Fractions (AF) linked with $PM_{2.5}$ and PM_{10} exposure were evaluated. The non-cancer risks via inhalation for CO, NO_2, SO_2 and ground level O_3 were assessed using Hazard Quotient (HQ). The mean concentrations of $PM_{1.0}$, $PM_{2.5}$, PM_{10} & TSP in the dry season were higher than rainy season. Health risk assessment over the study period showed that cancer risks via inhalation (CR_{inh}) of $PM_{2.5}$ were tolerable while Hazard Quotient via inhalation (HQ_{inh}) of SO_2 was above 1, indicating significant non-cancer risks at TIs in Ibadan.

Odediran, Adeniran and **Yusuf** (2023b) reported seasonal variation and health risks of particulates ($PM_{1.0}$, $PM_{2.5}$, PM_{10} & TSP) at the 25 TIs in Ibadan metropolis. The 24h mean concentration of $PM_{1.0}$, $PM_{2.5}$, PM_{10} and TSP sampled at 25 TIs in Ibadan during the dry season were 1.57, 2.29, 4.19 and 4.09 times their corresponding values during the rainy season. Statutory Limit Breach (SLB) values were above the set standards of regulatory agencies at several TIs. Total Respiratory Deposition Doses (TRDD) of $PM_{1.0}$, $PM_{2.5}$, PM_{10} were higher during the dry season by 35.15%, 56.89% and 78.27% than those during the rainy season. SLB and TRDD estimates of the study showed that road users are significantly at risk of exposure to particulates from traffic-related sources.

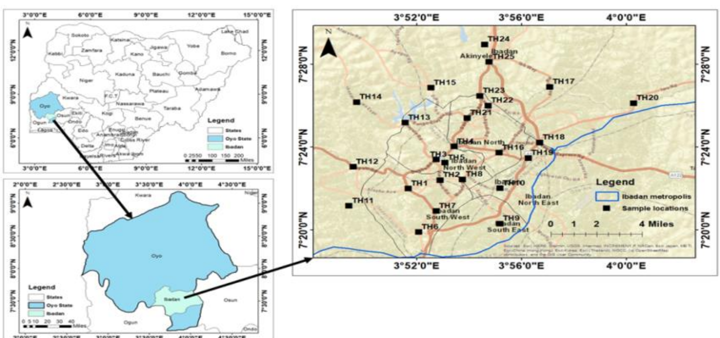

Figure 7: Map of Study Area –Ibadan

Odediran, Adeniran and **Yusuf** (2024) employed AERMOD model to examine TRAPs dispersion at 25 selected TIs, considered as volume sources. Seasonal concentration distributions of six pollutants (CO, NO_2, SO_2, TVOCs, $PM_{2.5}$, and PM_{10}) were determined using meteorological, topographical, and pollutants' emission rates in AERMOD. Estimated peak concentrations of the studied pollutants were generally higher in the rainy season than dry season, surpassing the air quality standards set by World Health Organization (WHO) and Nigeria's National Environmental Standards and Regulations Enforcement Agency (NESREA) during the rainy and dry seasons except SO_2 (24 h) concentration which did not exceed the NESREA standard. This study highlighted TIs as significant contributors to air quality degradation in both seasons studied in Ibadan and showed AERMOD's suitability for air dispersion studies.

Similarly, Odediran, Adeniran, **Yusuf,** Abdulraheem, Adesina, Sonibare and Du (2021) studied the contamination levels, sources and health risks of ten PTEs (Fe, Pb, Zn, As, Co, Cr, Cu, Cd, Mn and Ni) at twenty-five traffic hotspots (sites) of Ibadan during the rainy and dry seasons. The possible sources of PTEs were identified and quantified by combining positive matrix factorization (PMF) with existing and new contamination indices. PMF results shown in Fig. 10 identified six main sources (factors) each contributing to PTEs pollution during the rainy and dry seasons. The contamination levels of Cd and Pb were more serious than that of other PTEs during the two seasons studied. Non-carcinogenic risks posed by Pb and Cd were significant in Children and Adults at few sampling sites (Fig. 11). Carcinogenic risks of Cd were unacceptable at some sites during both seasons. This study showed that Children were more prone to both non-carcinogenic and carcinogenic hazards (Fig. 12). This study provided information to prevent and control exposure to road dust PTE pollution in a typical African city.

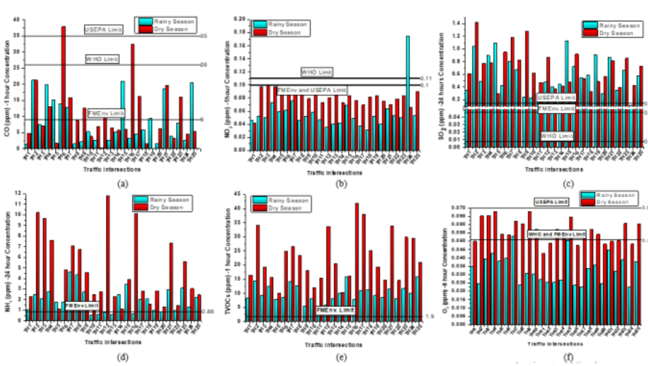

Fig. 8: Seasonal concentration levels of gaseous pollutants at 25 traffic Intersections (a) CO (b) NO_2 (c) SO_2 (d) NH_3 (e) TVOCs (f) O_3

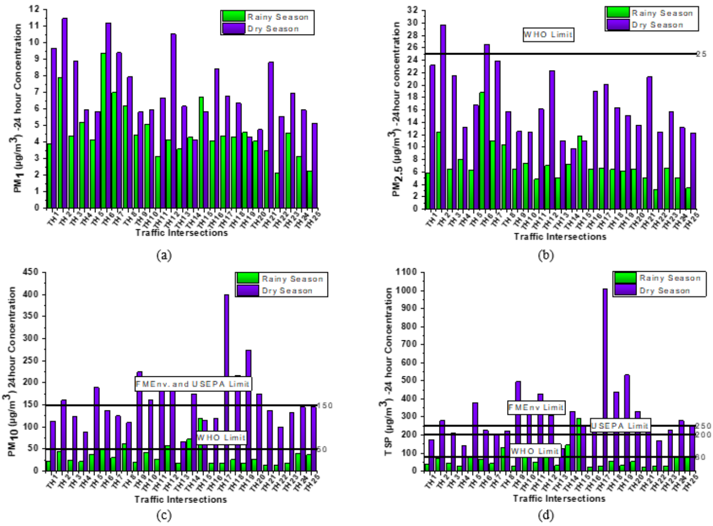

Fig. 9: Seasonal concentration levels of particulate matter at 25 traffic Intersections (a) PM_1 (b) $PM_{2.5}$ (c) PM_{10} (d) TSP

Moreover, **Yusuf** *et al.* (2022) explored the spatial and seasonal pattern, sources and related cancer health risks of PAHs in the road dusts sampled at ten traffic intersections (TIs) of a model African city. Mixed PAHs sources were ascertained using the diagnostic ratios and Positive Matrix Factorisation (PMF) model. The results showed that three–ring PAHs were the most abundant PAHs with Anthracene (Anth) being the predominant pollutant in Ibadan. Benzo(k) Fluoranthene (BkF), which is a pointer of traffic emission was the most dominant among the seven carcinogenic PAHs considered, Seasonal variation results showed that PAHs concentrations were 20% higher during the dry season than the rainy season. The seven sources of PAHs identified by PMF model are shown in Fig. 13. Employing the incremental lifetime cancer risk (ILCR) model, the city's cancer risk was more than the satisfactory risk baseline of ILCR$\leq 10^{-6}$ and higher in adults than in children.

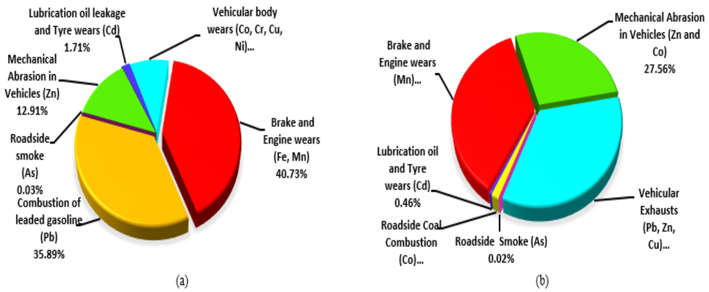

Fig. 10: Percentage factor contributions of PTEs during (a) rainy season and (b) dry season

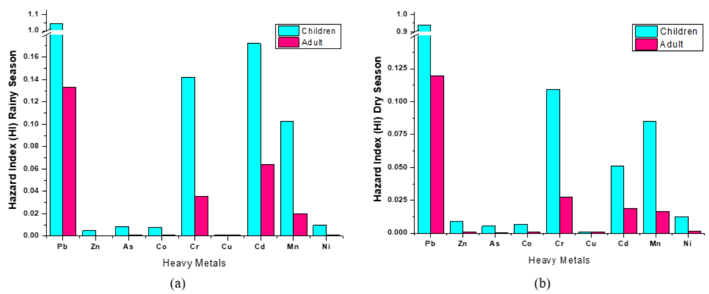

Fig. 11: Non- carcinogenic risk for adults and children in the study area (a) Rainy Season (b) Dry Season

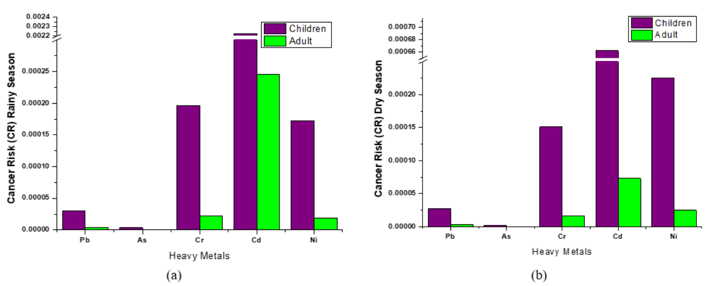

Fig. 12: Carcinogenic risk for adults and children in the study area (a) Rainy Season (b) Dry Season

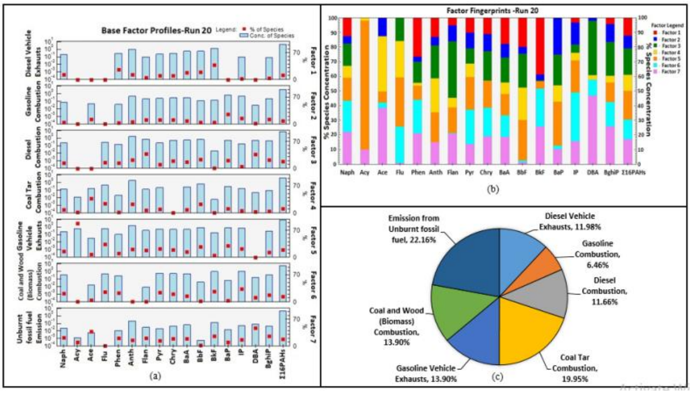

Fig. 13: (a) PMF model source profiles, (b) Fingerprints of PAHs in Ibadan road dust and (c) Percentage factor contributions of PAHs.

Quantifications and Predictions of Air Emissions

Abdulraheem, Adeniran, Aremu, Yusuf, **Yusuf,** Odediran, Sonibare and Du (2023) developed a comprehensive sectoral emission inventory using the emission factor approach to estimate various pollutant emissions from different sources. Five major sources of pollutant emissions were identified which include transportation, energy, municipal solid waste, wood fuel, and agricultural sectors. An increasing trend in emissions from 1980 to 2020 was observed for total emission of CO, NO_x, $PM_{2.5}$, PM_{10}, SO_2, NH_3 and NMVOC in Nigeria (See Figure 14). This study reported that wood fuel, transportation, and municipal waste sectors are the major sources contributing 63%, 16%, and 15% of the total CO emissions, respectively. Three mitigation scenarios for emission reduction for the future were analysed. CO emission reductions of 38%, 24%, and 38% will be obtained from the liquefied petroleum gas (LPG) intervention, waste to energy (WTE) technology, and vehicle inspection and maintenance (VIM) policy scenarios, respectively, through to the year 2050.

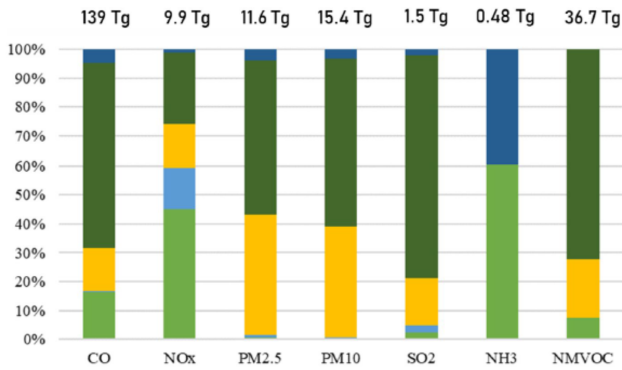

Figure 14: Total air emission estimates across major sectors for Nigeria (1980–2020)

Air Pollution during COVID-19 Pandemic

Mr. Vice-Chancellor, Odediran, **Yusuf** and Adeniran (2022) investigated the trends and sources of air pollution at Traffic Intersections (TIs) before and during the COVID-19 lockdown in Ibadan, Nigeria. The relationships among climatic parameters, vehicular counts and ten air pollutants which include particulate matter ($PM_{1.0}$, $PM_{2.5}$, PM_{10} & Total Suspended Particles-TSP) and gaseous pollutants (CO, NO_2, SO_2, NH_3, total volatile organic compounds-TVOCs, and ground level O_3) measured simultaneously at TIs were analysed. Results indicated significant decrease in mean concentrations of all pollutants studied except NO_2 with 212% increase during the study period. Concentrations of gaseous pollutants CO, SO_2, NH_3, TVOCs and ground level O_3 reduced by 7.92%, 24.80%, 1.58%, 44.08% and 4.28%, respectively while particulates concentrations of $PM_{1.0}$, $PM_{2.5}$, PM_{10} and TSP concentrations decreased by 49.64%, 60.79%, 81.21% and 84.17%, respectively during lockdown. An integrated source apportionment approach using Pearson's Correlation, Airflow backward trajectories arriving in the study area (HYSPLIT) and Principal Component Analysis (PCA) identified vehicular emission as the primary source of studied air pollutants at TIs before and during the lockdown in Ibadan.

In addition, Adeniran, Mohammed, Muniru, Oloyede, Sonibare, Yusuf, Abdulraheem, Odediran, **Yusuf**, and Sonibare (2021) explored indoor transmission dynamics of expired SARS-CoV-2 virus in a model African hospital ward by studying the cough and sneeze droplets' interactions with indoor air of a typical hospital clinic that are mostly found in developing African countries. The work investigated the effectiveness of existing guidelines/protocols being adopted in the control of the spread of corona virus disease (COVID-19) transmission. The influences of indoor air velocity, the type, size distribution, residence time in air, and trajectory of the droplets, were all considered while investigating the effectiveness of physical distancing measures, the use of face covers, cautionary activities of the general public, and the plausibility of community spread of the SARS-CoV-2 virus through airborne transmission as shown in Fig. 15. A series of 3-D, coupled, Discrete Phase Models (DPM) were implemented in the numerical studies. Based on DPM concentration maps as a function of particle positions and particle residence times that were observed under different droplet release conditions, the virus-laden droplets were found to travel several meters away from the source of release (index patient), with smaller-sized particles staying longer in the air. The behaviour of indoor air was also found to indicate complex dynamics as particle transports showed no linear dependence on air velocity.

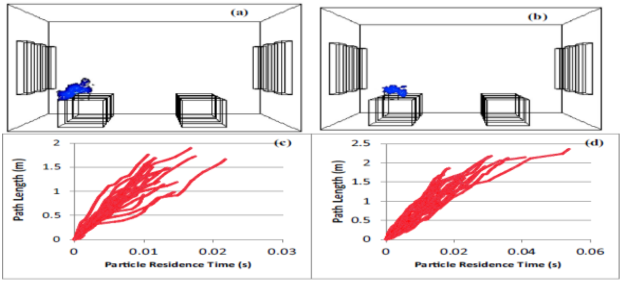

Fig. 15: Transport of cough droplets at air velocity of 1 m/s showing (a) & (b) 3-D concentration maps at residence times of (c) 0.0215589 s (100 iterations); and (d) 0.0533417s (2,000 iterations). Max. Path length: 1.88 m; 2.32 m, respectively

Air Pollutants from Scrap-Iron Recycling Plant

Vice-Chancellor, Sir, the growing demand for ferrous metals and abundant scrap materials has fuelled Nigeria's scrap-iron smelting industry, leading to hazardous pollutant emissions. Therefore, Ogunlade, Adeniran, Abdulraheem, Odediran, Atanda, Oyeneye, Akapo and **Yusuf** (2024) investigated pollution levels, sources, and health risks of ten potentially toxic elements (PTEs) (Fe, As, Cd, Zn, Cu, Mn, Pb, Cr, Co, and Ni) in indoor and outdoor areas surrounding a major scrap-iron recycling plant in north-central Nigeria. The potential sources of studied PTEs pollution during the rainy and dry seasons were evaluated using Positive Matrix Factorization (PMF) model. Ecological risk assessments of studied PTEs were conducted using different pollution indices. Out of the 10 PTEs studied, cadmium (Cd) had the highest pollution level and exhibited a high potential to cause cancer in children during the two seasons considered. Fig. 16 presents the identified sources of PTEs for rainy and dry seasons. This study contributes to the understanding of the environmental impact of scrap-iron smelting operations and advocate for the implementation of sustainable practices that protect both human health and the environment.

Mr. Vice-Chancellor, in this quest again, Adeniran, Ogunlade, Odediran, **Yusuf** and Sonibare (2024) studied the concentrations, seasonal and indoor-outdoor variations, origins, and health impacts of Polycyclic Aromatic Hydrocarbons (PAHs) in dust samples around a scrap-iron smelting facility. Analyses of dust samples revealed that high molecular weight PAHs (HMWPAHs) dominated during both seasons, with 5-ring PAHs (34%) contributing most during the rainy season and 3-ring PAHs (36%) during the dry season as shown in Figure 17. Carcinogenic PAHs were more prevalent in the rainy season compared to the dry season. Seven PAH sources were identified, with gasoline combustion being the dominant source during the rainy season and iron and steel production during the dry season. Incremental lifetime cancer risk (ILCR) assessments showed PAH concentrations within safe limits, with dermal contact identified as the primary exposure pathway for both children and adults in the study area.

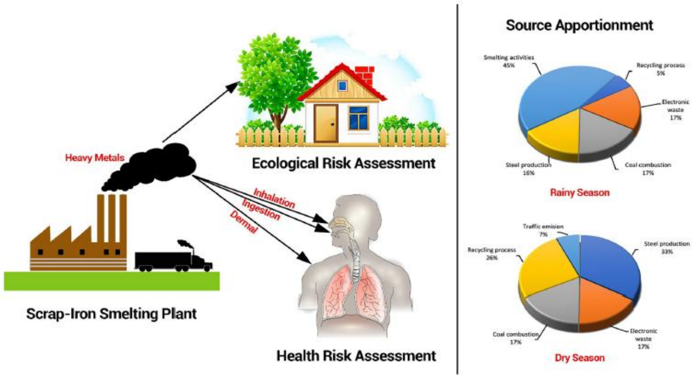

Fig. 16: Exposure Dynamics and percentage factor contributions of PTEs around a major scrap-iron recycling plant during rainy season and dry season

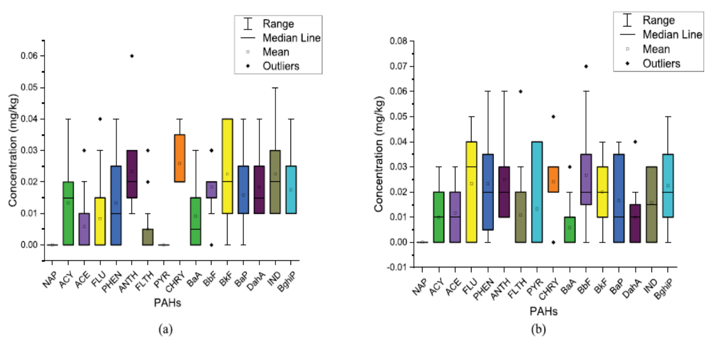

Fig. 17: PAH concentrations in the (a) rainy season and (b) dry season

Air Pollutants from Thermal Plants

Vice-Chancellor Sir, Adesanmi, Adeniran, Fakinle, Jimoda, **Yusuf** and Sonibare (2016) carried out studies on air pollutants from thermal plants, focusing primarily on emissions characterization and their implications for air quality and public health at both local and national levels. This area of study is particularly critical given the reliance on thermal energy generation in Nigeria and globally. Key pollutants investigated include sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOCs). The sources and chemical composition of these pollutants, their atmospheric dispersion dynamics, and their effects on human health and the environment were rigorously examined. The research focused on providing regulatory frameworks governing thermal plant emissions, aiming to inform policymakers and industry stakeholders on effective pollution control and management strategies. Various methods were used including atmospheric dispersion modelling, field measurements, and laboratory tests. The AERMOD model, a reliable air quality prediction tool, has been essential in estimating ground-level pollutant concentrations from thermal plants. By simulating different operational scenarios, the possible effects of emissions on nearby communities have been evaluated.

The research uncovered several critical insights into air pollutants emitted from thermal plants. In one notable study, the ground-level concentrations of key pollutants emitted from natural gas-powered thermal power plants in Nigeria were analysed. The findings revealed alarmingly high levels of sulphur dioxide (SO_2) and nitrogen oxides (NO_x) in the vicinity and surrounding areas of these facilities, with concentrations exceeding both national and international air quality standards. These findings reiterate the pressing need for more rigorous monitoring and control measures to mitigate the health and environmental risks associated with thermal plant emissions. Enhanced regulatory enforcement, coupled with the adoption of advanced emissions reduction technologies, is essential to safeguard public health and ensure compliance with air quality standards.

Another main study in the research focused on assessing particulate matter (PM) emissions from thermal plants. The results revealed a strong correlation between elevated PM levels and respiratory health issues among the local populace, thus, highlighting the critical public health implications of thermal plant emissions. This research has been valuable for the advocacy of stricter emissions regulations and the adoption of cleaner technologies in energy production. Additionally, the evaluation of emission control technologies has shown that implementing best practices, such as flue gas desulfurization and selective catalytic reduction, can significantly reduce SO_2 and NO_x emissions. These findings provided actions for the energy sector, as they offer a viable pathway to improve air quality while maintaining energy generation efficiency.

Bioremediation of Polluted Soil

Mr. Vice-Chancellor, the studies conducted on bioremediation were focused on characterization and restoring polluted soils contaminated by anthropogenic activities that include petroleum spills, industrial discharges, and agricultural runoffs (Olu-Arotiowa, **Yusuf** & Adelowo-Imoekparia, 2008; Agarry,Durojaiye, **Yusuf**, Aremu, Solomon & Mojeed, 2008; Agarry, Owabor & **Yusuf**, 2010a; Agarry, Owabor & **Yusuf**, 2010b; Agarry, Owabor & **Yusuf**, 2012; **Yusuf** *et al.*, 2022). This area is critical for addressing environmental degradation and promoting sustainable land use practices. The studies concentrated on the application of microbial and phytoremediation techniques to restore contaminated sites effectively. Microbial remediation utilizes either naturally occurring or engineered microorganisms to degrade pollutants, while phytoremediation involves the use of specific plants capable of absorbing, accumulating, and detoxifying contaminants. With the integration of these approaches, practical and environmentally friendly solutions for managing soil contamination related to a wide range of pollutants have been developed.

The investigations into bioremediation techniques have employed a range of methodologies specifically aimed at addressing diverse contaminants and varying soil conditions. One of the key innovations in my research has been the development of microbial consortia designed to enhance the degradation of petroleum hydrocarbons and other toxic substances in contaminated soils. This process involves isolating and characterizing native microbial strains that demonstrate a high tolerance to specific pollutants, followed by optimizing environmental conditions to maximize their growth and bio-degradative activity.

Additionally, successful bio-augmentation and bio-stimulation techniques have been adopted to accelerate natural biodegradation processes. The former involves introducing selected microorganisms into contaminated environments to supplement existing microbial populations, while the latter enhances the activity of indigenous microbes by providing essential nutrients or co-substrates. These approaches have proven highly effective in improving pollutant degradation rates.

Another major milestone reached in the research works is the integration of phytoremediation with microbial bioremediation (**Yusuf**, Amoloye, Adeniran, Abba & Busari, 2022) (See Table 4 and Fig. 18). This hybrid approach is quite interesting as it employs specific plants to stabilize, extract, and detoxify contaminants, while simultaneously leveraging microbial activity in the rhizosphere to degrade pollutants. I have studied different plant species that enhance the bioavailability of contaminants to microbial communities, thereby facilitating more efficient remediation processes. This integrated strategy has much proven to improve clean-up efficiency and provide a sustainable and environmentally friendly alternative for managing contaminated sites.

Table 4: Microbiological and Physicochemical Properties of Soil and Animal Manure

Parameters	Soil	Poultry manure	Piggery manure	Goat manure
pH	6.60 ± 0.2	7.2 ± 0.3	7.8 ± 0.2	6.9 ± 0.3
Total organic carbon (%)	2.45 ± 0.03	24.3 ± 0.5	21.2 ± 0.3	18.2 ± 0.2
Total nitrogen (%)	0.29 ± 0.04	2.2 ± 0.2	2.0 ± 0.1	1.8 ± 0.1
C:N ratio	8.4:1	11:1	10.6:1	10:1
Available phosphorus (%)	0.11 ± 0.05	0.39 ± 0.03	0.32 ± 0.04	0.23 ± 0.02
Potassium (%)	0.07 ± 0.04	1.25 ± 0.03	1.16 ± 0.02	1.10 ± 0.01
THB ($CFU \cdot g^{-1}$)	$0.1 \pm 3.7 \times 10^6$	$0.2 \pm 4.8 \times 10^6$	$0.1 \pm 4.2 \times 10^6$	$0.2 \pm 2.9 \times 10^6$
THDB ($CFU \cdot g^{-1}$)	$0.2 \pm 0.8 \times 10^4$	$0.2 \pm 1.3 \times 10^4$	$0.1 \pm 1.0 \times 10^4$	$0.1 \pm 0.4 \times 10^4$

Note. Each value is a mean of three replicates and ± indicates standard deviation among them.

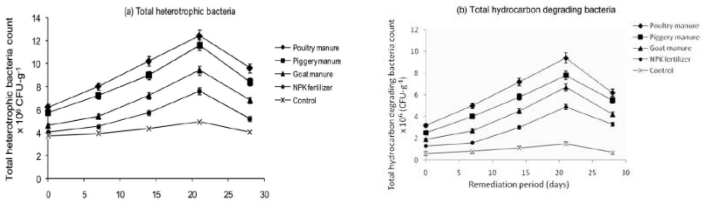

Fig. 18: Growth profiles of bacterial population as a function of remediation period (a) Total heterotrophic bacteria; (b) total hydrocarbon-degrading bacteria. Measurements the standard are average of three determinations and error bars represent the standard deviation

The research in the bioremediation field has yielded several notable findings that progress solutions, while offering practical application to soil pollution. In one of my notable studies on the bioremediation of petroleum-contaminated soils, it was found that the application of oriented microbial consortia significantly increased the rate of hydrocarbon degradation compared to natural attenuation. The study demonstrated that using specific strains of bacteria resulted in over 90% reduction of total petroleum hydrocarbons within a short time frame. In addition, the work on integrating phytoremediation with microbial bioremediation revealed that certain native plant species, when paired with microbial treatments; significantly enhance the overall efficiency of soil clean-up. This synergy highlights the potential for sustainable, cost-effective remediation solutions that gained the natural interactions between plants and microorganisms. Furthermore, my research has highlighted the importance of understanding the interactions between soil properties, microbial communities, and plant growth in developing effective remediation strategies. Key factors such as soil pH, organic matter content, and the availability of specific nutrients were found to strongly influence the success of bioremediation efforts.

Solid Waste Management for Energy and Material Recovery

Mr. Vice-Chancellor, my research on solid waste management primarily focuses on addressing the growing challenges associated with waste generation, particularly in urban areas, while equally promoting key components of the United Nations Sustainable Development Goals (SDGs) (Abba, Noor, **Yusuf**, Din & Hassan, 2013; Lee, Noor, **Yusuf**, Ali, Talib & Ho, 2017; Noor, **Yusuf**, Abba, Hassan & Din, 2013; Othman, Noor, Abba, **Yusuf** & Hassan, 2013). These works encompass several key areas that include:

1. Waste characterization: Analysing the composition of solid waste to identify opportunities for energy and material recovery
2. Energy recovery technologies: Exploring methods such as anaerobic digestion, incineration, and gasification to convert waste into energy.
3. Recycling and material recovery: Investigating efficient recycling processes to recover valuable materials from waste streams.
4. Policy and regulatory frameworks: Evaluating existing waste management policies and recommending improvements to promote sustainable practices.

Many innovative solutions have been developed through these research areas that conform to the principles of the circular economy, where waste is minimised, and resources are recovered and reused. In the investigations of solid waste management for energy and material recovery, I have employed diverse methodologies streamlined to specific waste types and recovery technologies. One significant innovation has been the development of comprehensive waste management frameworks that integrate waste characterization, energy recovery, and recycling processes. This holistic approach ensures the efficient use of resources and minimizes environmental impacts. The life cycle model of sulphuric acid (cradle to gate) is presented in Fig. 19.

Life Cycle Assessment (LCA) methodologies have also been adapted to evaluate the environmental implications of various waste management strategies (Othman, Noor, Abba, **Yusuf** & Hassan, 2013; Adeniran, **Yusuf** & Adetoro, 2017; Adeniran, Mustapha, **Yusuf** & Baruwa, 2020). This approach enables decision-makers to assess the benefits and drawbacks of different waste recovery technologies and select the most sustainable options.

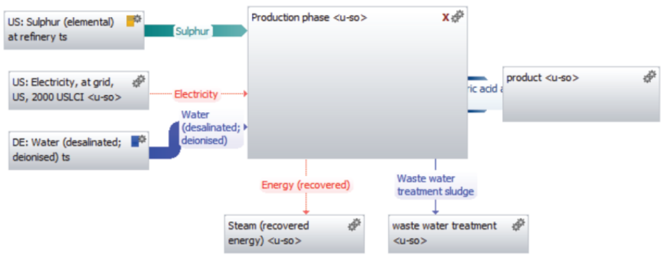

Fig. 19: Life cycle model of Sulphuric acid (cradle to gate)

Additionally, I have utilised data analytics and modelling techniques to optimize waste management processes. For example, I developed predictive models to forecast waste generation rates and their potentials for energy recovery based on historical data and socio-economic trends (**Yusuf** & Oyewunmi, 2008; **Yusuf** *et al*., 2008; Noor, **Yusuf**, Ali, Talib & Ho, 2017; Noor, **Yusuf**, Abba, Hassan & Din, 2013; Abba, Noor, **Yusuf**, Din & Hassan, 2013; Lee, Noor, **Yusuf**, Ali, Talib & Ho, 2017). These models provide valuable knowledge for urban planners and waste management authorities in designing efficient systems. Another area of focus has been the optimization of anaerobic digestion processes to enhance biogas production from organic waste (**Yusuf** *et al*., 2019; **Yusuf** *et al*., 2019a). My research presented the yearly and cumulative gas production rates and cumulative gas production as shown in Fig. 20. By exploring various feedstock combinations and process parameters, I have identified strategies to maximize energy recovery while minimizing greenhouse gas emissions.

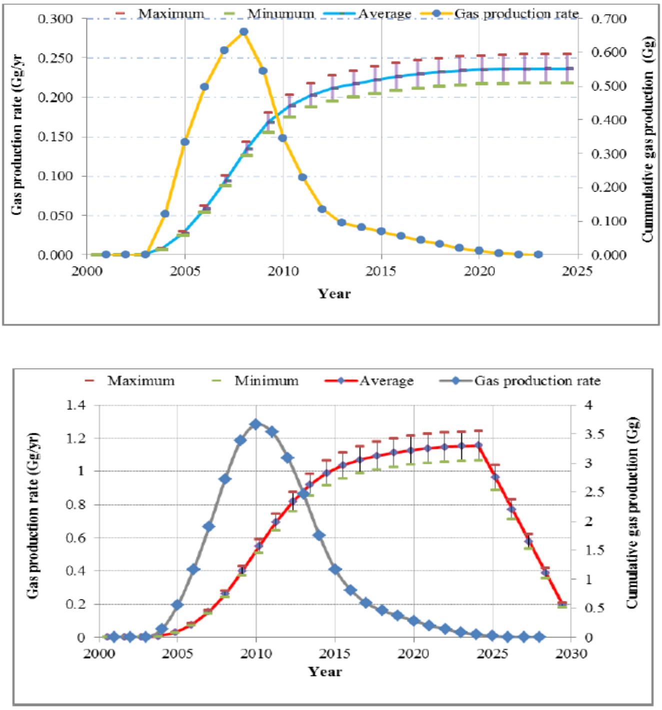

Fig. 20: (a) Yearly and cumulative gas production rates, (b) Cumulative gas production

Solid Waste Management for Energy and Material Recovery

Mr. Vice-Chancellor, my research on solid waste management has led to several critical findings that have contributed to the field of solid waste management, particularly its role in energy and material recovery. One notable study on waste characterization in urban settings revealed that a substantial portion of municipal solid waste (MSW) comprises organic materials. This presents a significant opportunity for energy recovery through anaerobic digestion, while laying much emphases on the need for improved segregation and processing of organic waste types (**Yusuf** & Oyewunmi, 2008; **Yusuf** *et al*., 2019). Further studies on energy recovery technologies demonstrated that anaerobic digestion is a very effective method for reducing waste volume and a sustainable source of renewable energy. Several case studies revealed that well-designed anaerobic digestion systems could achieve over 70 % energy recovery from organic waste, consequently, contributing to local energy demands while reducing dependence on fossil fuels.

Additionally, works on recycling practices highlighted the much-needed role of public awareness and community participation in improving material recovery rates. It was found that community engagement initiatives significantly increased recycling rates and reduced contamination in recyclable materials, thus enhancing the overall efficiency of recycling programs. These studies on solid waste management have significantly advanced the understanding and application of sustainable practices, while promoting environmental sustainability and improving resource recovery.

Environmental Impact and Life Cycle Assessment of Processes

The research in this area has significantly focused on Environmental Impact Assessment (EIA) and Life Cycle Assessment (LCA) methodologies, particularly concerning industrial processes in areas such as methane emissions, air pollutants from thermal plants, bioremediation of polluted soil, and solid waste management. These methodologies are important for understanding the environmental consequences of industrial activities and identifying opportunities for improvement and mitigation. In these investigations, comprehensive frameworks that integrate EIA and LCA to holistically assess the sustainability of industrial processes were developed. This allows for simultaneous evaluation of resource utilization and environmental impacts, therefore, offering a clearer understanding of environmental performance. Standard LCA methodologies such as the ISO 14040 series were reviewed to reflect the unique contexts of industries both in Nigeria and Malaysia. Additionally, advanced modelling techniques were employed with the aid of simulation software, to analyse emissions from complex industrial systems. This has been particularly beneficial in sectors like oil and gas, where multivariate interactions occur to influence emissions.

Another innovation is the incorporation of stakeholder engagement into the EIA process. By involving local communities and other relevant parties, it is ensured that environmental and social concerns are identified and adequately addressed, which ultimately improve the overall effectiveness of EIA processes. The research has yielded several significant findings that have advanced the field of environmental impact and life cycle assessment. In the study on Environmental Impact Assessment Challenges in Nigeria, it was found that a considerable proportion of EIA projects submitted to the Federal Ministry of Environment were from the oil and gas sector, highlighting the need for robust environmental monitoring and regulation in this critical industry. The findings emphasized the necessity for improved coordination among governmental bodies to enhance EIA effectiveness and public participation.

The research has yielded several impactful findings such as:

1. Environmental Impact Assessment Challenges in Nigeria: A significant proportion of EIA projects submitted to the Federal Ministry of Environment are from the oil and gas sector. This reveals the critical need for robust environmental monitoring, improved coordination among governmental agencies, and greater public participation (**Yusuf** *et al*., 2008).

2. Life Cycle Assessment of Sulphuric Acid Production: My LCA research identified key hotspots within the production process, particularly in raw material extraction and processing, which contribute substantially to CO_2 emissions. These findings suggest that emissions reduction efforts should focus on these stages to achieve significant sustainability gains. These findings also have critical implications for the chemical manufacturing sector,

suggesting that emissions reduction efforts should prioritize these stages to achieve meaningful sustainability gains (Adeniran, **Yusuf** & Adetoro, 2017; Adeniran, Mustapha, **Yusuf** & Baruwa, 2020).

3. Energy Recovery from Waste Management: The studies on municipal solid waste management highlighted the potential for energy recovery through improved waste segregation and anaerobic digestion processes. (Othman, Noor, Abba, **Yusuf,** & Hassan, 2013). When these practices are fully optimized, municipalities can significantly reduce landfill use while generating renewable energy. This greatly conforms with circular economy principles.
4. Sustainability Studies: Investigating sustainable practices in sectors like waste management, energy production, and industrial processes (Lee, Noor, **Yusuf**, Ali, Talib & Ho, 2017).

Research Impact

The researches directly address contemporary societal challenges related to environmental sustainability and public health. Much focus is put on solid waste management and waste-to-energy conversion. It is aimed at mitigating the environmental impacts of waste disposal while offering renewable energy solutions to support energy security. In addition, the bioremediation studies address soil contamination challenges while contributing to public health by reducing risks associated with polluted environments. Findings from my research on methane emissions and air quality assessments provide policymakers and industry stakeholders with executable information, especially enriched data to implement more effective environmental regulations and practices. This emphasis on sustainable practices supports global initiatives to combat climate change and promote cleaner energy sources. With the provision of data-driven recommendations for waste management and emissions reduction, this work supports a global transition toward sustainability.

Future Research Direction

Vice-Chancellor, Sir, forging ahead in this evolving research, it is planned to incorporate emerging technologies and methodologies that further promote environmental sustainability. In half a decade to come (God willing), it is aimed to expand the research scope to include the following focus areas:

1. Innovative Waste-to-Energy Technologies: A plan to investigate advanced waste conversion technologies, such as gasification and pyrolysis, to optimize energy recovery from waste materials. In collaboration with industry partners, I plan to pilot these technologies in real-world scenarios to assess their scalability and effectiveness.
2. Integrated Environmental Management Systems: I intend to develop frameworks that integrate waste management, air quality control, and bioremediation into cohesive systems that address multiple environmental challenges simultaneously. This holistic approach will greatly improve the sustainability and resilience of urban environments.
3. Community Engagement and Education: I aim to incorporate community engagement into my research, by developing educational programs that raise awareness of sustainable practices in waste management and pollution control.
4. Policy Advocacy and Implementation: It is planned to collaborate with governmental and non-governmental organisations to advocate for evidence-based policies that promote sustainable waste management practices and pollution reduction. My research will inform these efforts, ensuring that scientific findings translate into actionable policies.

Broader Academic Contributions

Mentorship

Mr. Vice-Chancellor, throughout my academic career, I have prioritised mentorship as a crucial component of my career as an academic, even before assuming my latest role as a professor. I have had the privilege of guiding numerous students, junior researchers, and colleagues, helping them navigate their academic paths and develop their skills in the engineering field. One specific success story involves mentoring a group of undergraduate students who participated in a project on solid waste management strategies in Ilorin. Under my guidance, they conducted a comprehensive waste characterisation study that not only contributed to their academic growth but also led to practical recommendations for local waste management practices. Many of these students have since pursued advanced degrees in environmental science and engineering, attributing their interest to the hands-on experience gained during this project. Additionally, I have actively supported the professional development of junior faculty members by guiding them in designing appropriate research methodologies, writing award-winning grants, and discussing publication strategies. I believe that providing a conducive environment where junior researchers can excel is essential for capacity building within the academic community.

Teaching Philosophy

My teaching philosophy centres on creating an interactive and inclusive learning environment that encourages critical thinking and active participation. I believe that education should not only impart knowledge but also cultivate skills that enable students to tackle real-world challenges. To achieve this, I employ a variety of teaching methods, including project-based learning, case studies, and collaborative group work. For example, I usually incorporate field trips to local waste treatment facilities and research laboratories in the courses I teach on waste management and environmental engineering. These experiential learning opportunities allow students to see the practical applications of their studies and engage with professionals in the field.

Another notable course is Technology of Pulp and Paper Production, where my six years of active work in the Nigerian Paper Mill Ltd., Jebba comes in handy by mixing theory with practice. The same scenario applies to my course on Cement Production Technology where my ten years' experience in the cement industry became evident in my method of lecture delivery. I always emphasized the importance of integrating sustainability principles into engineering practices. By incorporating discussions on environmental ethics and social responsibility into my curriculum, I aim to prepare students to become not only skilled engineers but also conscientious global citizens.

Service to the University and Society

Mr. Vice-Chancellor, I have actively contributed to institutional development and community engagement initiatives throughout my tenure at the University of Ilorin and beyond. My service to the university includes participation in various committees such as the Faculty of Engineering and Technology's Academic Monitoring Committee and the Faculty of Engineering Mock Accreditation Committee. In these roles, I have worked to enhance academic standards, ensure compliance with accreditation requirements, and promote faculty development. Beyond the university, I have engaged with professional organizations. My involvement in these professional bodies has provided me with opportunities to contribute to the development of guidelines and policies that promote sustainable practices within the engineering community. These bodies include the Nigerian Society of Chemical Engineers (NSChE), where I have served as a member of various committees focused on advancing the practice of Chemical Engineering in Nigeria.

I served as a member of the Member of the NSChE/NCDMB Collaboration Project Team from 2019–2021. I was a member of the LOC of the 52nd Annual Conference/AGM of the NSChE held in Ilorin in 2022. I am presently the Kwara State Coordinator, Oyo/Osun/Kwara/Ekiti Chapter of the NSChE since 2023 and also a member of her Technical Committee. I was the Secretary, Education and Research Sub-Group, NSChE (2019–2021). I have also served diligently in some committees of the Nigerian Society of Engineers. I served as Assistant Auditor, NSE, Sokoto Branch (1997-2001), a member of the NSE Investment and Properties Committee (2003), Welfare and Growth Committee (2004). I am currently the Kwara State representative of the Association of Environmental Impact Assessment in Nigeria.

Additionally, I am committed to community engagement initiatives that address local environmental challenges. I have organised workshops and awareness campaigns in collaboration with local NGOs aimed at educating community members about sustainable waste management practices and pollution reduction strategies. These initiatives not only enhance community awareness but also foster partnerships between academia and local stakeholders. I am a passionate lover of football and I have had the rare honour of being a football captain at various levels of my amateur career and a seasoned unregistered coach who led the NSE, Ilorin Branch to win the National Engineering Games football cup in 2023 after being runners-up in 2021 and 2022.I am also the Deputy State Coordinator, Islamic Welfare Foundation, Kwara State since 2021.

In summary, my broader academic contributions encompass mentorship, innovative teaching practices, and active service to both the university and society. By nurturing the next generation of engineers and engaging with the community, I strive to make a lasting impact in the field of environmental engineering and promote sustainable development practices.

Scholarly Impact and Citations

My research has received much recognition within the academic community, as demonstrated by a strong citation record. To date, my publications have accumulated over 2,500 citations, as it reflects the relevance and impact of my works on environmental practices and policies. My *h-index* (a metric that attempts to measure both the productivity and the impact of a researcher’s publications; calculated by finding the largest number *h* such that *h* publications have at least *h* citations each) which quantifies both productivity and citation impact, further indicate my influence in the field, positioning me as a thought leader in environmental engineering, particularly in areas related to waste management and emissions reduction.

Recognition and Awards

I have been honoured with several accolades for my contributions to academia and the field of environmental engineering. These include:

i. International Doctoral Fellowship from Universiti Teknologi Malaysia (awarded twice) for publications in high-impact (Q1) journals.
ii. awards from the Nigerian Society of Chemical Engineers (NSChE) for outstanding contributions to environmental sustainability.
iii. recognition from various professional bodies for my role in advancing research and policy in waste management and environmental protection.
iv. honours from academic institutions for excellence in teaching and mentorship, reflecting my commitment to nurturing the next generation of engineers.

Conclusion

In the course of this lecture, I have shared the highlights of the milestones of my academic journey and the significant contributions I have made to the field of Environmental Engineering. From methane emission studies and air quality assessments to bioremediation and solid waste management for energy recovery, my researches, carried out over a span of over three decades have been focused on tackling some of the most pressing environmental challenges of our time. Beyond providing scientific insights into emissions reduction, waste-to-energy technologies, and sustainable industrial practices, my work has influenced policy development and industry standards.

With ongoing projects, I shall continue to find ways to improve sustainability via innovative waste management practices and renewable energy solutions. While beaming brighter hopes into the future, I envision the Department of Chemical Engineering at the University of Ilorin being at the forefront in environmental sustainability and climate action, nationally and globally. I shall continue to expand the impact of my works both in Nigeria and on a global scale with my colleagues.

To the students, early-career researchers, and fellow academics here today, I urge you to engage boldly with the transformative potential of Environmental Engineering. The challenges we face-climate change, pollution, and resource depletion-are undeniably complex, but they also present unparalleled opportunities for innovation and progress. I urge you to re-imagine waste management, energy production, and environmental protection by collaborating across disciplines, and contribute to building a more sustainable future. You must remember that science and engineering are fundamentals tools for solving technical problems-they are instruments for building a better world. Join this mission. Push boundaries. Be the generation that delivers lasting, positive change.

Recommendations

1. The field of environmental engineering, particularly in waste management, bioremediation, and emissions control, is faced with several key challenges that directly impact my research. One of the most significant challenges is funding constraints. Government and the private sector should be ready to fund projects in this for large-scale research projects, pilot studies, and the implementation of waste-to-energy technologies.
2. Technological barriers also pose a significant challenge in my field. Infrastructures should be provided to hasten the implementation of cutting-edge technologies, such as advanced bioremediation techniques or energy recovery

systems which often require substantial infrastructure and technical expertise.

3. The mechanism for enforcing environmental regulations should be strengthened as enforcement remains inconsistent and policies often lag behind technological developments. This regulatory gap can undermine efforts to implement sustainable waste management and emissions reduction practices, particularly in the industrial and energy sectors.
4. Sustainable solutions should be found to address environmental issues such as climate change and the negative impacts of waste and emissions. With rising global temperatures, there is an increased urgency to find sustainable solutions, but the lack of coordination among various stakeholders and industries creates significant barriers to progress.
5. Government should intensify efforts in the several emerging trends and technological advances which present exciting opportunities for growth in the field of environmental engineering. One of the most promising trends is the shift towards the circular economy. This concept, which emphasizes resource recovery, waste minimization, and the creation of closed-loop systems is much relatable to my work on energy and material recovery from solid waste.
6. Advances in waste-to-energy technologies should intensify so as to increase the immense potential for expanding energy recovery efforts**.** These technologies include anaerobic digestion, gasification, and pyrolysis. They provide a sustainable way to manage waste while contributing to renewable energy generation.
7. There should be encouragement in the use of big data and machine learning as they present another interesting opportunity. By integrating data analytics with environmental monitoring, we can improve the efficiency and accuracy of waste management systems. Predictive models can be used to forecast waste generation, optimise

recycling processes, and predict the environmental impacts of various industrial activities.

8. There is a need for innovative solutions to reduce greenhouse gas emissions, particularly in developing countries like Nigeria. The researches on methane and non-methane gaseous pollutants place me in a unique position to contribute to these efforts. As I look forward to a continued collaboration with policymakers, industry leaders, and other researchers, I aim to develop more robust strategies that would reduce emissions and provide sustainable energy and material recovery solutions.

9. I call on the Kwara State government specially to revisit the design carried out by CIWAT Engineers on the construction of an Integrated Solid Waste Management Facility for Ilorin with Gbagede chosen as the site for the proposed facility. This will go a long way in reducing the reckless dumping of wastes all over the city. The factors considered then remain the same except the increase in population with the attendant increase in amount of waste generation.

Mr. Vice-Chancellor Sir, please permit me to quote the speech of Sir Winston Churchill *at the Lord Mayor's Day Luncheon on November 10, 1942* while celebrating the victory at the Second Battle of El Alamein. He said

> "*This is not the end, it is not even the beginning of the end, but it is, perhaps, the end of the beginning*."

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I began with *Bismillah-ir Rahman-ir Raheem* LLAAHLLAH, kindly allow me to end with these verses from the Glorious Qur'an (Surah Yunus, Qur'an 10:10 and Surah As-Soffat, Qur'an 37:180-182).

> *"Their call therein will be, "Exalted are You, O Allah," and their greeting therein will be, "Peace." And the last of their call will be, "Praise to Allah, Lord of the worlds*!"
>
> *Glorified is your Lord-the Lord of Honour and Power- above what they claim!"Peace be upon the messengers, And praise be to Allah-Lord of all words".*

References

Abba, A. H., Noor, Z. Z., **Yusuf, R. O.,** Din, M. F. M., & Hassan, M. A. A. (2013). Assessing environmental impacts of municipal solid waste of Johor by Analytical Hierarchy Process**.** *Resources, Conservation and Recycling, 73*, 188–196.

Abdulraheem, K. A., Adeniran, J. A., Aremu, A. S., Yusuf, M. N. O., **Yusuf, R. O.**, Odediran, E. T., Sonibare J. A., & Du, M. (2023). Quantifications and predictions of sectoral pollutants emissions in Nigeria from 1980 to 2050. *Environmental Monitoring and Assessment, 195*(3), 398.

Adeniran, J. A., Ogunlade, B. T., Odediran, E. T., **Yusuf, R. O**., & Sonibare, J. A. (2024). Polycyclic aromatic hydrocarbons within the vicinity of a scrap-iron smelting plant: indoor-outdoor and seasonal pattern, source, and exposure risk assessment. *International Journal of Environmental Health Research*, 1–19.

Adeniran, J. A., Mohammed, I. A., Muniru, O. I., Oloyede, T., Sonibare, O. O., Yusuf, M. N. O., Abdulraheem, K. A., Odediran, E. T.**, Yusuf, R. O.,** & Sonibare, J. A. (2021). Indoor transmission dynamics of expired SARS–CoV–2 virus in a model African hospital ward. *Journal of Environmental Health Science and Engineering, 19*, 331–341.

Adeniran, J. A., Mustapha, S. L., **Yusuf, R. O.,** & Baruwa, M. O. (2020). Life cycle assessment of a petroleum-contaminated soils thermal desorption unit. *Journal of Experimental Research, 8*(3), 8–15.

Adeniran, J. A., **Yusuf, R. O.**, & Adetoro, M. A. (2017). Life cycle engineering case study: Sulphuric acid production. *Journal of Engineering and Technology, 8*(2), 1–19.

Adeniran, J. A., **Yusuf, R. O.**, Jimoda, L. A., Adesanmi, A. J., & Sonibare, J. A. (2016). Atmospheric loading of non-methane gaseous pollutants from a liquefied natural gas operation. *Journal of Research Information in Civil Engineering, 13*(2), 940–955.

Adeniran, J. A., **Yusuf, R. O.**, Mustapha, S. I., & Sonibare, J. A. (2017). Exposure to total volatile organic compounds (TVOCs) from household spray products. *Environmental Research, Engineering and Management, 73*(4), 21–30.

Adesanmi, A. J., Adeniran, J. A., Fakinle, B. S., Jimoda, L. A., **Yusuf, R. O**., & Sonibare, J. A. (2016). Ground level concentration of some air pollutants from Nigeria thermal power plants. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 38*(16), 2426–2432.

Agarry, S. E., Durojaiye, A. O., **Yusuf, R. O.**, Aremu, M. O., Solomon, B. O., & Mojeed, O. (2008). Biodegradation of phenol in refinery wastewater by pure cultures of *Pseudomonasaeruginosa* NCIB 950 and *Pseudomonas fluorescence* NCIB 3756. *International Journal of Environment and Pollution, 32(*1), 3–11.

Agarry, S. E., Owabor, C. N., & **Yusuf, R. O.** (2010). Bioremediation of soil artificially contaminated with petroleum hydrocarbon oil mixtures: Evaluation of the use of animal manure and chemical fertilizer. *Bioremediation Journal, 14*(4), 189–195.

Agarry, S. E., Owabor, C. N., & **Yusuf, R. O.** (2010). Studies on biodegradation of kerosene in soil under different bioremediation strategies. *Bioremediation Journal, 14*(3), 135–141.

Agarry, S. E., Owabor, C. N., & **Yusuf, R. O.** (2012). Enhanced bioremediation of soil artificially contaminated with kerosene: Optimization of biostimulation agents through statistical experimental design. *Journal of Petroleum and Environmental Biotechnology, 3*(3), 2–8.

Agarry, S. E., **Yusuf, R. O.,** & Ajani, A. O. (2010). Biodegradation of anthracene and naphthalene in soil. *Journal of the Nigerian Society of Chemical Engineers, 25(*1&2), 55–63.

Edewor, J. O., & **Yusuf, R. O.** (1983). Wastes recycle management innovation and environmental improvement in Nigeria. In *Alternative Energy Sources V, Part E: Nuclear/Conservation/Environment,* T.N. Veziroglu, editor. (pp. 269–276).

Lee, C. I. S., Noor, Z. Z., **Yusuf, R. O.**, Mohd Ali, M. R., Talib, S. M., & Ho, C. S. (2017). Development of SIs on solid waste management through selection: A review. *Chemical Engineering Transactions, 56,* 535–540.

Noor, Z. Z., **Yusuf, R. O.,** Abba, A. H., Hassan, M. A. A., & Din, M. F. M. (2013). An overview for energy recovery from municipal solid waste (MSW) in Malaysia scenario. *Renewable and Sustainable Energy Reviews, 20,* 378–384.

Odediran, E. T., Adeniran, J. A., & **Yusuf, R. O**. (2023b). Seasonal variation and health risk assessment of gaseous and particulate pollutants around traffic hotspots of a densely populated African city. *1st Faculty of Engineering and Technology Conference (FETiCON 2023)*, Jun. 5–7, 2023, University of Ilorin, Nigeria.

Odediran, E. T., Adeniran, J. A., & **Yusuf, R. O**. (2024). Assessment of seasonal variations in vehicular emissions at traffic intersections in Ibadan using AERMOD dispersion model. *Environmental Quality Management*, *34*(1), 1–15.

Odediran, E. T., **Yusuf, R. O.**, & Adeniran, J. A. (2022). Impacts of COVID-19 lockdown on concentration levels of traffic-related air pollutants in Ibadan-a West African city. *Nigerian Journal of Technological Development, 19*(3), 206–222.

Odediran, E. T., Adeniran, J. A., & **Yusuf, R. O**. (2023a). Seasonal variation and health risks of particulates at and around traffic hotspots in Ibadan - A model African metropolis. *Journal of the Nigerian Society of Chemical Engineers, 38*(1), 30–39.

Odediran, E. T., Adeniran, J. A., **Yusuf, R. O.**, Abdulraheem, K. A., Adesina, O. A., Sonibare, J. A., & Du, M. (2021). Contamination levels, health risks and source apportionment of potentially toxic elements in road dusts of a densely populated African City. *Environmental Nanotechnology, Monitoring & Management, 15*, 100445

Ogunlade, B. T., Adeniran, J. A., Abdulraheem, K. A., Odediran, E. T., Atanda, A. S., Oyeneye, A. K., Akapo R. A., & **Yusuf, R. O.** (2024). Heavy metals analysis in the vicinity of a North-central, Nigeria major scrap-iron smelting plant. *International Journal of Environmental Research, 18(*6), 1–16.

Olu-Arotiowa, O. A., **Yusuf, R. O.,** & Adelowo-Imoekparia, F. (2008). Kinetic model for bioremediation of crude oil polluted soil using *Pseudomonas aeruginosa* as biodegrader. *International Journal of Soft Computing, 3*(4), 333–337.

Othman, S. N., Noor, Z. Z., Abba, A. H., **Yusuf, R. O.,** & Hassan, M. A. A. (2013). Review on life cycle assessment of integrated solid waste management in some Asian countries. *Journal of Cleaner Production, 41,* 251–267.

Yusuf, R. O., & Oyewunmi, M. O. (2008). Qualitative assessment of methane generation potential from municipal solid waste. A case study. *Environmental Research Journal, 2*(4), 138–144.

Yusuf, R. O., Adeniran, J. A., & Eletta, O. A. A. (2016). Observed and projected trends in livestock methane emission: Analysis of five decades of data from Nigeria. *Journal of Research Information in Civil Engineering, 13*(3), 996–1013.

Yusuf, R. O., Adeniran, J. A., Mustapha, S. I., & Sonibare, J. A. (2019). Energy recovery from municipal solid waste in Nigeria and its economic and environmental implications. *Environmental Quality Management, 28*(3), 33-43.

Yusuf, R. O., Adeniran, J. A., Sonibare, J. A., & Noor, Z. Z. (2019). Application of the Triangular Model in quantifying landfill gas emission from municipal solid wastes. *Pollution, 5*(1), 71–80.

Yusuf, R. O., Amoloye, M. A., Adeniran, J. A., Abba, A. H., & Busari, I. B. (2022). Phytoremediation of contaminated soil using maize (*Zea mays*) and mycorrhiza inoculation. *FUOYE Journal of Engineering and Technology, 7*(2), 236–239.

Yusuf, R. O., Durojaiye, A. O., & Agarry, S. E. (2008). Designing an integrated framework for solid waste management in Nigeria. *Journal of Resources, Energy and Development, 5(*1), 1–9.

Yusuf, R. O., Noor, Z. Z., & Hassan, M. A. A. (2015). Historical and projected methane emission determination in Malaysia (1980-2020), *Sustainable Environment Research, 25*(1), 37–45.

Yusuf, R. O., Noor, Z. Z., Abba, A. H., & Hassan, M. A. A. (2014). Predicting methane emissions from livestock in Malaysia using the ARIMA model. *Management of Environmental Quality: An International Journal, 25*(5), 585–599.

Yusuf, R. O., Noor, Z. Z., Abba, A. H., Hassan, M. A. A., & Din, M. F. M. (2012). Methane emission by sectors: A comprehensive review of emission sources and mitigation methods. *Renewable and Sustainable Energy Reviews, 16*, 5059–5070.

Yusuf, R. O., Odediran, E. T., Adeniran, J. A., & Adesina, O. A. (2022). Polycyclic aromatic hydrocarbons in road dusts of a densely populated African city: Spatial and seasonal distribution, source, and risk assessment. *Environmental Science and Pollution Research, 29*(29), 44970–44985.