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Environmental Remediation

Dr. Vincent Nnadi, *FNSChE*

Agric Value Chain

Prof. Akuma Oji

Leadership

Engr. AbdulRasheed Babalola, *FNSChE*

SAFETY CONCERNS & SUSTAINABILITY OF CNG RETROFITTED VEHICLES IN NIGERIA

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"To be the Center of excellence for the Chemical Engineering Profession in Africa and the Prime Mover of Industrialization in Nigeria".

NSChE MISSION

"To organize the Nigerian Society of Chemical Engineers into a virile professional body capable of promoting the relevance and versatility of the profession, achieving better training and updating of Chemical Engineers through its activities. Fostering of relationships with the academia, research institutes, industries, other professional bodies and government will be the basis for stimulating accelerated industrialization of the country and improving the quality of life of the Nigerian people".

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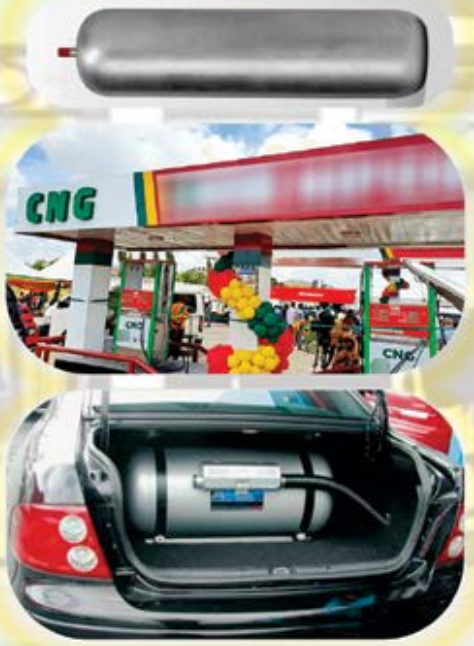

Dr. Vincent Nnadi

Prof. Akuma Oji

Engr. AbdulRasheed Babalola

FROM THE *Editorial* SUITE

Engr. Donatus Uweh, *FNSChE*
(Editor-in-Chief)

In this Information Age, we are to pay attention to the right and relevant type of information. **NSChE's magazine** publication policy prioritizes valuable and relevant information to stakeholders in the engineering industry and the reading public in general. There are contemporary issues in **Science & Technology.** Engr. Anthony Ogheneovo, FNSChE, FNSE, Executive Secretary of NSChE, shares valuable and relevant information covering emerging technologies and allied matters that serve as food for thought, particularly in ethical and other considerations. The details in this edition are worth the readers' attention.

As a Society deeply concerned with ENERGY matters, the Nigerian Society of Chemical Engineers delegation paid a visit to Nigerian National Petroleum Company Limited (NNPCL). A brief on the visit and some memorable photos are presented. Another event is the 33rd Fellows Confab of NSChE in 2025 on the theme: "Consumption to Production Economy in Nigeria – The Pathways". Memorable photos are also served.

Nigerians have found themselves in the era of adoption of Compressed Natural Gas (CNG) as an alternative fuel to petrol and diesel. In this edition, an experienced Chemical Engineer, Engr. Elizabeth Ekanem, has taken the bull by the horn by communicating to the reading public the safety concerns in the use of vehicles retrofitted with CNG cylinders.

This is not meant to be an alarm. The matter is professionally addressed in this edition in a manner that should not be ignored by all stakeholders.

"...Compressed Natural Gas (CNG) as an alternative fuel... an experienced Chemical Engineer... communicating to the reading public the safety concerns..."

Still on the issue of safety, specifically, environmental safety a renowned scholar and a practising engineering consultant, Engr. Dr. Vincent Nnadi, FNSE, FNSChE, presents a vivid treatise on the topic, **"ENVIRONMENTAL REMEDIATION - USE OF LOCAL MATERIALS FOR CLEAN-UPS"**

The mitigation measures unveiled by the expert with the use of local materials are instructive.

The growing population of Nigeria calls for innovative approaches in addressing food insecurity.

How can Chemical Engineers come to the rescue? The answer is provided by an erudite professor in University of Port-Harcourt, Prof. Akuma Oji in his article entitled, **"CHEMICAL ENGINEERING: A CATALYST FOR AGRICULTURAL TRANSFORMATION AND VALUE CHAIN ENHANCEMENT IN NIGERIA".** Seeking solutions from experts should continue to occupy the attention of government and other stakeholders.

We now look at the issue of LEADERSHIP. Success depends on leadership and followership but more on leadership. How can a leader lead to the promised land filled with prosperity, peace, joy, comfort, happiness. A renowned scholar, Engr. Dr. AbdulRasheed Babalola, FNSE, FNSChE, shares knowledge on LEADERSHIP in this edition. His presentation comes in series. Enjoy Volume 1.

Finally, we deeply appreciate our esteemed contributors to the success of this publication.

Relax and enjoy your reading!

Engr. Donatus Uweh, FNSChE
Editor-in-Chief

CONTEMPORARY ISSUES IN SCIENCE AND TECHNOLOGY

This presentation is a summary of contemporary issues in science and technology. It has highlighted opportunities for Scientists and Engineers.

1. ARTIFICIAL INTELLIGENCE (AI) AND AUTOMATION

Opportunities: Smart manufacturing, predictive healthcare, robotics

Issues: Job displacement, algorithmic bias, deepfakes, ethics of autonomous weapons

2. CLIMATE CHANGE AND RENEWABLE ENERGY

Opportunities: Green hydrogen, wind/solar, energy storage

Issues: Fossil fuel dependence, slow energy transition, and climate migration

3. BIOTECHNOLOGY AND GENETIC ENGINEERING

Opportunities: Clustered regularly interspaced palindromic repeats (CRISPR) gene editing, personalized medicine, bio-farming

Issues: Human cloning ethics, genetically modified organisms (GMOs), biosecurity

4. CYBERSECURITY AND DATA PRIVACY

Opportunities: Blockchain for secured transactions, cloud computing

Issues: Ransomware, hacking, digital identity theft, and government surveillance

5. SPACE EXPLORATION AND MILITARIZATION

Opportunities: Space mining, Mars missions, satellite internet

Issues: Space debris, weaponization of orbit, private vs. government space race

Engr. Anthony Ogheneovo*, FNSChE, FNSE*
(Executive Secretary, NSChE)

6. HEALTH AND PANDEMIC PREPAREDNESS

Opportunities: AI in diagnostics, mRNA vaccines, and telemedicine

Issues: Inequality in healthcare, misinformation, and global vaccine access

7. NANOTECHNOLOGY AND ADVANCED MATERIALS

Opportunities: Nano-drug delivery, desalination, supercapacitors

Issues: Safety concerns, lack of regulation

8. ETHICS OF EMERGING TECHNOLOGIES

Issues: Transhumanism, human cloning, AI consciousness

Debates: Should machines have rights? How far should human enhancement go?

9. DIGITAL DIVIDE AND TECH INEQUALITY

Opportunities: Online learning, fintech, remote work

Issues: Limited access in rural areas, cost barriers, gender gap in STEM

10. SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY

Opportunities: Waste-to-energy, biodegradable plastics, green chemistry

Issues: Overconsumption, plastic and e-waste crisis

11. QUANTUM COMPUTING

Opportunities: Breakthroughs in cryptography, drug discovery, materials science

Issues: Extremely high cost, global tech race, risk of breaking current cybersecurity systems

12. 5G, 6G AND NEXT-GEN CONNECTIVITY

Opportunities: Smart cities, autonomous vehicles, IoT growth.

Issues: Infrastructure cost, privacy concerns, digital surveillance fears

13. FOOD SECURITY AND AGRICULTURAL TECHNOLOGY

Opportunities: Precision agriculture, hydroponics, lab-grown meat

Issues: Land degradation, overuse of fertilizers, ethical debates around artificial foods

14. WATER SCARCITY AND TECHNOLOGY

Opportunities: Desalination, wastewater recycling, AI-driven irrigation

Issues: High energy use in desalination, unequal access to clean water

15. MISINFORMATION, SOCIAL MEDIA, AND SOCIETY

Opportunities: Fast global communication, activism

Issues: Fake news, deepfakes, cyberbullying, social polarization

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NSChE DELEGATION VISITS NNPC LIMITED

On August 13, 2025 at the NNPC Towers in Abuja, Engr. Bashir Bayo Ojulari, Group Chief Executive Officer of NNPC Limited received a delegation from Nigerian Society of Chemical Engineers (NSChE) led by Engr. Bayo Olarewaju-Alo, National President of NSChE. Discussions centered on strengthening collaboration to advance Nigeria's Energy Sector, with a focus on process safety, refinery upgrades, industrialization and sustainable development. NSChE shared its initiatives including the Process Safety Initiative of Nigeria (PSIN) and efforts to improve academia-industry partnership.

Both parties expressed mutual commitment to fostering innovation, supporting capacity building and delivering long term value creation for the industry, the engineering profession and the nation.

Engr. Bayo Ojulari, GCEO of NNPCL (R) and Engr. Bayo Olarewaju-Alo, National President of Nigerian Society of Chemical Engineers, exchanging pleasantries during the Courtesy visit of the leadership of Nigerian Society of Chemical Engineers to NNPCL HQ in Abuja

Group photograph of the leadership of NNPCL and NSChE

A cross-section of the NSChE team at the meeting with the leadership of the NNPCL

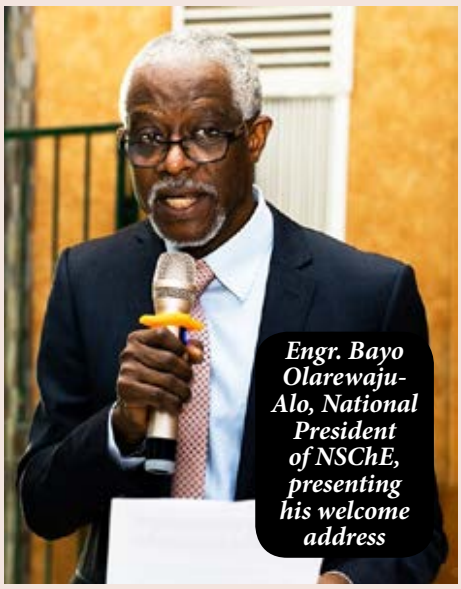
NSChE'S 33RD FELLOWS CONFAB

THEME:

CONSUMPTION TO PRODUCTION ECONOMY IN NIGERIA – THE PATHWAYS

VENUE: Nigerian Society of Engineers Auditorium, Abuja | **DATE:** October 9, 2025

Engr. Anthony Ogheneovo, Executive Secretary of NSChE presenting a Safety Brief at the start of the event



Engr. Bayo Olarewaju-Alo, National President of NSChE, presenting his welcome address

Engr. Abubakar L. Yar'Adua, Chairman of the Confab, addressing the participants

A group photograph of some participants

Prof. Oyebanji Oyelaran-Oyeyinka, Guest Speaker at the Confab

Engr. Bayo Olarewaju-Alo, NSChE President, presenting appreciation award to Prof. Oyebanji Oyelaran-Oyeyinka

Engr. Bayo Olarewaju-Alo, NSChE President, presenting appreciation award to Engr. Abubakar L. Yar'Adua

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SAFETY CONCERNS AND SUSTAINABILITY OF CNG RETROFITTED VEHICLES IN NIGERIA

1.0 INTRODUCTION

Nigeria's transportation sector relies heavily on petrol to drive public buses, private cars and commercial fleet vehicles. However, the removal of fuel subsidy on May 29, 2023, saw petrol and diesel prices rise sharply, putting significant financial strain on both households and businesses across the country.

Engr. Elizabeth Ekanem, *MNSE, MNSChE, MNIM (Senior Process Engineer, NETCO, subsidiary of NNPCL)*

In response, the government pivoted towards Compressed Natural Gas (CNG) as a strategic alternative. CNG is not just cleaner, it is also far more cost-effective, with the potential to cut transport costs by up to 60%. This move aligns with Nigeria's broader push for energy transition, leveraging the country's substantial natural gas reserves to reduce costs and support sustainability goals. Fig. 1 shows a typical CNG fuel station.

To accelerate the large-scale penetration and adoption of CNG, the Federal government launched the Presidential Compressed Natural Gas Initiative (PCNGI) in August 2023. This initiative aims to rapidly expand CNG adoption in both public mass transit and private vehicles, focusing on infrastructure development, vehicle retrofitting, and increased engagement across the public and private sectors. The program represents

Fig. 1: A CNG Fuel Station

a coordinated effort to modernize Nigeria's transportation landscape and create a more resilient, cost-effective system for businesses and consumers alike.

2.0 CNG AS AN ALTERNATIVE FUEL FOR TRANSPORTATION

The introduction of Compressed Natural Gas (CNG) as an alternative automobile fuel in Nigeria is not a new concept. Its entry dates back to 1996, when the Federal Government identified CNG as one of the viable gas monetization options alongside Liquefied Natural Gas (LNG) and Liquefied Petroleum Gas (LPG) under the Gas Master Plan policy.

To promote CNG adoption, a pilot project was launched in Benin City, Edo State in 2006, where eight (8) CNG fueling stations were established and were supplied with gas from Escravos via the West African Gas Pipeline, WAGP. These stations were intended to serve as proof of concept for CNG-powered vehicles, create public awareness, and lay the foundation for broader deployment across the country. However, despite this early initiative, large-scale adoption did not materialize due to setbacks ranging from low public awareness and acceptance, lack of regulatory framework, and infrastructure (gas supply pipelines, refueling stations, conversion centers), and high conversion costs. The renewed push under PCNGi seeks to overcome these challenges, but as Nigeria accelerates CNG penetration, safety concerns and sustainability challenges surrounding retrofitted vehicles must be carefully addressed.

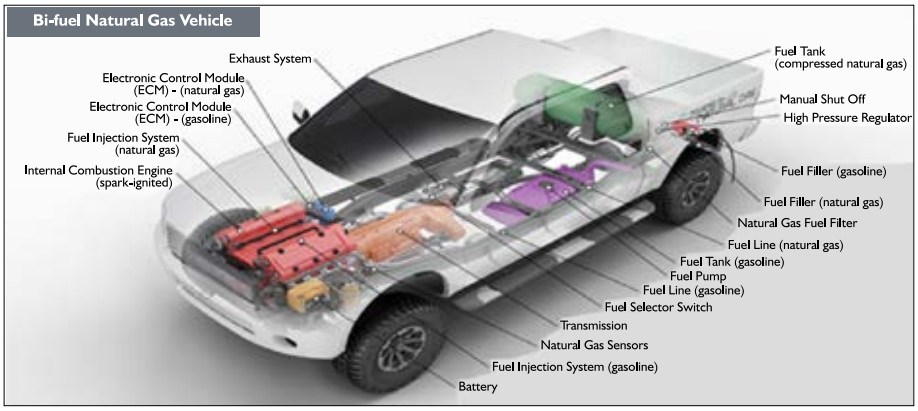

Fig. 2: The components of a CNG fuel system

Compressed natural gas, primarily methane compressed to high pressures of 200-250 bar (20000 - 25000 kPa) and reduced to one-hundredth of its original volume, offers compelling advantages over conventional automobile fuels. Its comparative affordability, lower flammability tendencies in open spaces, and higher dissipation rate compared to petrol and diesel make it an attractive alternative. CNG retrofitting process involves installing specialized conversion kits in originally designed gasoline or diesel vehicles, transforming them into bi-fuel or dual-fuel systems capable of running on CNG.

3.0 CNG VEHICLE RETROFIT AND COMPATIBILITY

The complexity of CNG conversion becomes apparent when examining the required components. A complete conversion kit comprises high-pressure cylinders with valves and brackets, pressure regulators, electronic control modules, solenoid valves, gas-air mixers, and crucial safety devices including temperature-pressure relief valves and non-return valves. See Fig. 2. At the heart of every CNG system lies the storage cylinder, designed to withstand pressures up to 250 bar (25,000 kPa) and constructed from high-strength steel or composite materials. These robust vessels are significantly more durable than conventional fuel tanks and has a service lifespan of 15-20 years with regular routine checks and mandatory requalification every five (5) years.

Vehicle compatibility for CNG conversion varies significantly across different types and conditions. Private cars, light commercial vehicles, tricycles, and certain bus types in good mechanical condition, particularly those less than ten (10) years old with modern engine systems, typically offer the best conversion outcomes. See Fig. 3. However, high-performance vehicles, turbocharged engines, and older vehicles often prove incompatible with CNG systems. Diesel vehicles present particular challenges, as their engine design prevents full conversion to CNG, allowing only partial switching to operate on approximately 50% diesel and 50% CNG blends.

Fig. 3: The classes of automobile suitable for CNG retrofitting

Type	Construction	Market Share (%)	Weight (Kg/l)	Weight Reduction (%)	Indicative cost US $/l	Service life (year)
Type-I	All metal (aliuminium or steel)	93	0.80-1	-	3-5 $	20
Type-II	Metal liner reinforced by composite wrap (glass or carbon fibre) around middle (hoop wrapped)	4	0.52-0.68	15-35%	5-7 $	20
Type-III	Metal liner armored by wrapping (Carbon or glass fibre) around the complete cylinder (fully wrapped)	<2	0,41-0.45	44-48%	9-14 $	15
Type-IV	Plastic (HDPE) gas-tight liner reinforced by composite wrapo around entire tank (fully wrapped)	<2	0.30-0.39	51-66%	11-18 $	20

*Table 1: Showing...**XXX***

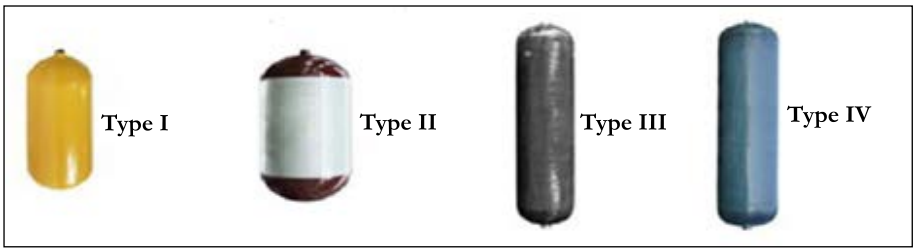

Fig. 4: The available CNG cylinder designs

4.0 CYLINDERS FOR CNG VEHICLES

The safety challenges associated with CNG retrofitting in petrol and diesel vehicles in Nigeria are multifaceted and require careful consideration from different perspectives. The fundamental concern begins with the high-pressure CNG cylindrical vessels operating at about 200-250 bar (20,000 – 25,000 kPa), which contains extremely high mechanical and chemical energy. Studies have shown that most CNG vehicle accidents are linked to the failure, damage or improper installation of these cylinders. In cases where explosion occurs due to overpressure, fire, or on impact, these cylinders can become high-velocity projectiles, posing severe threats to vehicle occupants, other road users and bystanders. Hence, it is important to consider the types of cylinder suitable for CNG storage in automobiles and their design requirements.

A CNG storage vessel is a cylinder with hemispherical domes at both ends. Fig. 4 shows the types of CNG cylinder designs. They are constructed from thick-walled, high-strength materials such as steel, aluminum, or composites to safely withstand high gas pressures. These cylinders are engineered to handle pressures higher than their normal service pressures and are designed with a safety factor typically greater than 2. However, they must never be filled beyond their maximum allowable pressure, which is generally limited to 1.25 times the service pressure.

CNG cylinders are classified into four types. Type I cylinders are all-metal (steel or aluminum), inexpensive, durable, and widely used, but they are the heaviest. Type II and Type III cylinders use metal liners reinforced with composite wraps. Type II has partial (hoop) wrapping, making it up to 35% lighter than Type I but also more expensive, while Type III is fully wrapped and preferred for weight-sensitive applications, with its strength largely dependent on the composite filament. Type IV cylinders use a non-loadbearing plastic liner fully wrapped with carbon fiber, making them the lightest design, though their durability relies entirely on the composite material. See Fig. 4.

5.0 SAFETY CONCERNS ASSOCIATED WITH CNG RETROFITTED VEHICLES

The adoption of Compressed Natural Gas (CNG) as an alternative fuel brings significant economic and environmental benefits. However, vehicles retrofitted with CNG systems also introduce safety concerns highlighted below, that must be carefully addressed to ensure public safety and sustainability.

i. **High-pressure CNG Storage System:** In automobiles, CNG is stored in cylinders at very high pressures, typically between 200 and 250 bar, which make the storage cylinder a critical safety component. See Fig. 5. In the event of an accident or improper installation, a damaged cylinder can rupture or explode, releasing a large amount of stored energy. This could potentially turn the cylinder into a high-velocity projectile, posing severe risks to passengers, bystanders, and

Fig. 5: A CNG retrofitted vehicle

property. The risk is compounded if the cylinder is not properly shielded from a heat source (such as a car exhaust pipe) or not routinely inspected for defects such as corrosion, fatigue cracks, or mechanical damage.

In 2017, a CNG bus explosion in Charsadda District, Pakistan, was traced to a corroded and poorly maintained cylinder that ruptured under pressure during refueling, causing fatalities. Similar incidents have been reported in India where tanks were not periodically tested or re-certified.

ii. **Substandard Conversion Kits and Cylinder Integrity:** The quality of the retrofit kit and cylinder integrity play a central role in safety of the CNG fuel system. The use of substandard or uncertified components can result in malfunction, leaks, or even catastrophic failure during operation. Low quality cylinders may not withstand repeated pressurization cycles, leading to premature degradation. This increases the likelihood of rupture, endangering both the vehicle occupants and surrounding road users. Furthermore, frequent component failures create additional cost burdens for vehicle owners due to recurrent repairs and replacements, which discourage proper maintenance and undermines confidence in CNG adoption. Fig. 6 shows a typical CNG conversion kit.

In October 2024, a tragic CNG car explosion occurred during refueling at a NIPCO station located at Aduwawa, Benin City, Edo State, leaving three people severely injured. Investigations traced the incident to the use of a substandard storage cylinder that ruptured under pressure. The poorly fabricated cylinder had not been certified for high-pressure service, highlighting the dangers of counterfeit or substandard components entering the market.

iii. **Limited Regulatory Oversight and Enforcement of Safety Standards:** A major hazard in many developing countries, including Nigeria, is inadequate

Fig. 6: A CNG conversion kit

regulatory oversight of CNG retrofitting. Without strict enforcement of installation and operational standards, retrofits may be conducted by unlicensed workshops or poorly trained technicians. Improper installation increases the risk of gas leaks, faulty piping, poor electrical integration, and mechanical failures. Inadequate inspections and certification processes also allow unsafe vehicles to remain in operation, creating systemic risks across the transportation network. The current CNG adoption drive under the Presidential Compressed Natural Gas Initiative (PCNGi) highlights this concern that while demand is growing, there is still limited framework nationwide for certifying conversion workshops and enforcing maintenance standards, unlike in countries such as Argentina or Brazil where strict codes exist.

iv. **Low Public Awareness of CNG Handling and Safe Practices:** Safe operation of CNG vehicles requires both technical compliance and user awareness. In Nigeria, a significant percentage of the general public and fueling station attendants still lack adequate training on CNG safe handling procedures. Improper refueling practices, such as over-pressurization, can damage CNG cylinders and valves, leading to hazardous leaks. The problem is worsened by the lack of regular pump recalibration at CNG stations, which can result in defective pressure readings during refueling. Faulty gauges or miscalibrated pumps may overfill the cylinder, increasing the risk of explosion from overpressure. Moreover, common driving practices such as vehicle overloading, reckless driving, combined with poor road conditions can place abnormal stress on CNG piping, fittings, and mounts. Vibrations or impacts from potholes can loosen joints and cause leaks, while sudden shocks may compromise cylinder integrity.

v. **CNG Ignition and Combustibility:** Compressed Natural Gas (CNG) is highly combustible when mixed

"...adoption of CNG retrofitting in Nigeria faces a number of infrastructural and operational challenges..."

with air within its flammability range of 5 – 15% by volume. In the event of a leak inside the passenger cabin or luggage compartment, the confined space can quickly accumulate an explosive gas-air mixture. Ignition sources such as cigarettes, lighters, matches, or even faulty electrical equipment carried by passengers may trigger an explosion or fire. The risk is compounded during the dry seasons, where high ambient temperatures are more prevalent and increase the volatility of CNG leaks. Lack of passenger awareness and poor enforcement of "No Smoking" rules inside public CNG vehicles can further amplify the hazard.

vi. **Maintenance and Inspection Gaps:** The safety of CNG retrofitted vehicles depends heavily on strict maintenance routine and periodic inspection of both the fuel system and storage cylinders. Degradation of seals and fittings such as rubber O-rings and gaskets can harden and crack over time. If not replaced, these weak points can allow gas leaks at high pressure. CNG cylinders undergo repeated pressurization and depressurization during daily refueling and use. Combined with thermal stresses from Nigeria's tropical climate, this creates fatigue and accelerates wear. Without periodic inspections (such as hydrostatic testing every 3 – 5 years, as recommended globally), early signs of pitting, corrosion, or minor dents can go unnoticed. These may escalate into catastrophic rupture during refueling, when the typical service pressure between 200 -250 bar is achieved. A small pinhole leak from a corroded cylinder wall may go undetected until it worsens into a jet release, which could ignite and cause explosions, particularly at filling stations.

vii. **Vehicle weight Distribution and Structural Modifications:** The structural implications of CNG retrofitting often receive insufficient attention despite their significant impact on vehicle safety and performance. Retrofitting alters the structural and dynamic balance of vehicles not originally designed for CNG use. A typical steel Type-1 CNG cylinder weighs 60 - 80 kg when full, and when installed in a vehicle's boot, this additional weight shifts the center of gravity, affecting vehicle handling, braking distance, and cornering stability. This weight distribution change increases rollover and skidding risks during emergency maneuvers. Besides, retrofitting frequently involves modifying the boot floor of a vehicle and removing some factory reinforcements to make room for cylinder brackets. These changes weaken the vehicle's crash energy absorption capability known as 'Crashworthiness', particularly in rear-end collisions. In such cases, the CNG cylinder itself may be directly exposed to impact forces, magnifying the consequences of an accident. Standard suspensions are not designed for the added static load of the cylinder and dynamic stresses from bad road conditions. Over time, this can lead to suspension failure, tire blowouts, or misalignment, further undermining safety.

6.0 INFRASTRUCTURE AND OPERATIONAL SUSTAINABILITY CHALLENGES

Beyond safety concerns, the adoption of CNG retrofitting in Nigeria faces a number of infrastructural and operational challenges that hinder long-term sustainability.

i. **High Conversion Costs for Vehicle owners:** The initial cost of converting vehicles from petrol or diesel to CNG is prohibitively high for the average Nigerian. Conversion cost of petrol or diesel engines for commercial transporters falls in the range between N1.2 and N1.5 million. For private car owners and small fleet operators this can be slightly higher depending on the car model, cylinder size and conversion center. For vehicle owners already grappling with the high fuel prices, such upfront costs can be a major setback. Without government subsidies, financing schemes, large-scale adoption of CNG remains unrealistic.

ii. **Limited availability of CNG Fueling stations** Currently, Nigeria has very limited CNG fueling outlets, most of which are concentrated in the major cities like Lagos, Abuja and Port Harcourt. Vehicle owners often travel long distances

"Several factors contribute to the depreciation of CNG-retrofitted vehicles..."

and the inability to find a fuel station, outside the abovementioned areas makes daily use inconvenient and impractical. This discourages adoption by both private car owners and commercial operators, as fueling reliability is essential for transport operations.

iii. **Pressure and Supply Inconsistencies:** CNG vehicles require gas delivered at a consistent high pressure (around 200 bar) for proper storage and performance. However, defective or poorly maintained compressors/pumps at refueling stations often result in inconsistent supply pressure. This leads to longer refueling times, reduced driving ranges, and overall driver dissatisfaction, undermining the appeal of CNG as a reliable fuel alternative.

iv. **Logistics and Gas Transportation Challenges:** Nigeria's gas pipeline infrastructure is underdeveloped and fragmented, with most pipelines focused on industrial hubs and export terminals rather than domestic distribution network. Many regions have no direct pipeline access, making it difficult to consistently supply refueling stations. As a result, reliance on virtual pipelines (CNG cascades mounted on trailers) becomes necessary. These are both expensive and limited in capacity, creating bottlenecks in the supply chain and reducing efficiency.

v. **Limited Spare parts and Diagnostic tools:** The maintenance of CNG vehicles requires specialized spare parts and diagnostic tools that are not readily available in Nigeria. Few workshops have the right equipment to service CNG systems and detect potential leaks or damage to components, leading to long downtimes, high maintenance costs, and operational inefficiencies. This discourages both commercial transporter and private vehicle owners from considering CNG retrofits.

vi. **Public acceptance and Cultural adoption:** Beyond technical and infrastructural challenges, public perception remains a significant barrier. Misconceptions about the safety of CNG cylinders and fears of explosion create reluctance among potential users. In addition, Nigerians are deeply accustomed to petrol and diesel as the dominant automobile fuels, with strong trust in their reliability and resale value. Mechanics and drivers alike tend to favor conventional fuels, as they are more familiar and require no learning curve. Without effective public education and trust-building, widespread adoption of CNG will remain slow.

vii. **Lack of Resale Value of CNG-Retrofitted Vehicles:** One of the overlooked sustainability challenges associated with the adoption of CNG retrofitted vehicles in Nigeria is the low resale value of such vehicles in the secondary automobile market. Vehicle owners considering conversion weigh not only the immediate benefits of fuel savings but also the long-term financial implications, including the ability to resell the vehicle at a fair price.

Several factors contribute to the depreciation of CNG-retrofitted vehicles:

a. Market Perception and Buyer Skepticism: Many prospective buyers remain skeptical of CNG technology due to misconceptions about safety, fears of cylinder explosions, or concerns about engine performance. This lack of trust significantly lowers buyer interest.

b. Limited Technical Knowledge: As CNG systems are not yet mainstream, mechanics and technicians in the used-car ecosystem are less familiar with the retrofitted technology. Buyers often avoid these vehicles, fearing high maintenance costs and difficulty finding qualified service providers.

c. Uncertainty of Conversion Quality: In Nigeria, where substandard kits and unauthorized workshops exist, buyers cannot easily verify the integrity of the retrofitted system. The uncertainty discourages them from purchasing such vehicles at competitive market prices.

d. Durability of Conversion Kits and Cylinders: CNG cylinders have a finite lifespan (typically 15 – 20 years, with periodic inspections), and conversion kits are subject to wear and tear. Used car buyers worry about inheriting components that may soon require expensive replacements.

"...owners of CNG-retrofitted vehicles often experience steeper depreciation rates compared to conventional vehicles."

e. Cultural familiarity with conventional fuels: Petrol and diesel vehicles have long dominated the Nigerian automobile market, creating a deep-rooted trust and a well-established resale ecosystem. In comparison, CNG-retrofitted vehicles remain niche, with limited demand from second-hand buyers.

As a result, owners of CNG-retrofitted vehicles often experience steeper depreciation rates compared to conventional vehicles. This perception of poor resale value discourages many individuals and fleet operators from investing in conversion, thereby undermining the long-term sustainability of CNG adoption.

7.0 MITIGATION MEASURES FOR THE SAFETY AND SUSTAINABILITY CHALLENGES WITH CNG RETROFITTED VEHICLES

The widespread adoption of CNG retrofitted vehicles in Nigeria requires not just technical solutions, but also institutional, economic, and social interventions. To ensure both safety and sustainability, the following practical measures should be prioritized:

i. Public Awareness Campaigns and Continuous Education

a. Launch nationwide sensitization programs to dispel myths around CNG usage and promote its safety, environmental, and cost-saving benefits.
b. Train vehicle owners, drivers, and fuel station attendants on proper refueling procedures, safe handling practices, and emergency response.
c. Incorporate CNG-related modules into vocational and automotive technical training institutes to build long-term technical capacity.

ii. Local production of Conversion Kits and Maintenance Spares

The Nigerian government has introduced supportive measures to ease the financial burden of CNG adoption. Through the Presidential CNG Initiative (PCNGi), commercial drivers now benefit from a 50% discount on conversion costs, while the Credit Access for Light and Mobility (CALM) Fund provides credit financing for CNG conversion with flexible repayment durations of 1 – 3 years. Despite these interventions, conversion kits and key components remain largely import-dependent. Hence, the prices of these items are directly tied to foreign exchange fluctuations, creating volatile and unpredictable costs for vehicle owners. This price instability discourages many private vehicle owners and small fleet operators from converting, as they struggle to plan long-term investments.

Also, the high and fluctuating cost of conversion reduces the resale value of CNG retrofitted vehicles, since second-hand buyers are often unwilling to pay for vehicles with uncertain long-term maintenance costs and potential safety concerns. This undermines the sustainability of adoption, as owners may hesitate to invest in retrofits without the assurance of value retention. To achieve true cost stability, subsidies should be complemented with policies to localize the production and assembly of CNG kits and spare parts. Developing domestic supply chains will reduce reliance on imports, shield prices from currency volatility, and build long-term confidence in the CNG market.

iii. Regulatory Enforcement of CNG Retrofitting Standards

a. The National Automotive Design and Development Council (NADDC), working with Standards Organization of Nigeria (SON) and Nigerian Institute of Transport Technology (NITT), should develop and strictly enforce national standards for retrofitting practices.
b. Establish clear penalties for unlicensed workshops and uncertified kits to eliminate unsafe retrofits.
c. Enforce compliance through regular monitoring of conversion centers.

"The safety and reliability of CNG retrofitted vehicles largely depend on the quality of the conversion process."

iv. **Mandatory Certification for Kits and Technicians**
   a. Only certified technicians should be authorized to install and maintain CNG kits.
   b. Certification programs should be developed in collaboration with polytechnics, engineering bodies, and international partners to ensure global best practices.
   c. All imported kits must carry proof of quality certification before being cleared for use in Nigeria

v. **Routine Inspection and Recertification of CNG Vehicles**
   a. Introduce mandatory periodic inspection of CNG vehicles (i.e. every 2 – 3 years) to check for cylinder integrity, gas leaks, and wear of key components.
   b. Develop a digital registry for all converted vehicles to track inspection history and cylinder lifespan.
   c. Adopt international best practices by requiring cylinder hydrostatic testing every 3 – 5 years, depending on design type.

vi. **Expansion of CNG Refueling Infrastructure**
   a. Expand CNG stations nationwide through public-private partnerships (PPP), especially along major highways and urban centers.
   b. Invest in mother stations, daughter stations and pipeline interconnectivity to ensure consistent gas supply and eliminate reliance on costly virtual pipelines (trailer cascades).
   c. Incentivize oil marketing companies and independent retailers to incorporate CNG pumps in existing fuel stations.

vii. **Policy Alignment and Long-Term Incentives**
   a. Establish a comprehensive national CNG policy that clearly outlines targets, safety standards, and fiscal incentives.
   b. Align policies across energy, transport, and environment ministries to avoid fragmented implementation.
   c. Provide long-term incentives such as reduced road taxes, priority licensing, and fleet procurement mandates for CNG vehicles to build sustained market confidence.

viii. **Boost Secondary Market Value of CNG Vehicles**
   a. Encourage insurance companies and financial institutions to recognize the residual value of certified CNG vehicles.
   b. Develop resale assurance programs backed by government or automakers to give buyers confidence in used CNG vehicles.
   c. Promote standardization and certification of retrofitted vehicles to reduce buyer skepticism in the secondary market.

8.0 BEST PRACTICES FOR SAFE CNG VEHICLE RETROFITTING

The safety and reliability of CNG retrofitted vehicles largely depend on the quality of the conversion process. Adhering to best practices ensures that vehicles remain roadworthy, efficient, and free from undue risks throughout their service life.

i. **Use of Certified Components:** Only certified CNG conversion kits and cylinders approved by regulatory authorities should be used. Substandard or counterfeit components compromise safety and increase the risk of leaks, malfunctions, or cylinder explosions. Cylinders must meet international standards (such as ISO 11439 or ECE R110) and be traceable to verified manufacturers.

ii. **Professional Installation by Trained Technicians:** Retrofitting should only be carried out by authorized workshops with trained and certified technicians. Improper installations such as poor mounting of cylinders, inadequate piping connections, or faulty electrical wiring can create safety hazards. Mandatory certification programs for technicians help ensure competence and adherence to safety protocols.

iii. **Proper Cylinder Mounting and Positioning:** Cylinders should be mounted securely

"Adequate ventilation of the cylinder compartment is necessary to avoid gas accumulation in case of minor leaks."

with approved brackets that can withstand mechanical shocks, vibration, and rear-end collisions. Adequate ventilation of the cylinder compartment is necessary to avoid gas accumulation in case of minor leaks. Positioning should also account for vehicle balance and minimize impacts on crashworthiness.

iv. **Leak Testing and Pressure Validation:** After retrofitting, all joints, valves, and fittings should undergo leak detection tests using certified methods (e.g., soap solution, electronic detectors). The cylinder must also be filled and tested under operating pressure (~200 bar) and not exceed the maximum fill pressure (typically 1.25 times normal operating pressure), to validate its integrity before the vehicle is released for use.

v. **Electrical and Safety Integration:** Conversion kits should include safety devices such as pressure relief valves, excess flow valves, and automatic shut-off solenoids. Electrical wiring must be properly insulated, routed away from heat sources, and protected against short circuits that could ignite leaked gas.

vi. **Documentation and Certification:** Every retrofitted vehicle should be issued a certificate of compliance after inspection by regulatory agencies such as the Presidential Compressed Natural Gas Initiative (PCNGI). This ensures the vehicle meets national safety standards and can be legally operated.

viii. **Insurance:** Insurance companies play a crucial role in driving adherence to safety and quality standards in the CNG retrofitting industry. Since insurers are ultimately exposed to financial risks in the event of accidents or explosions, they have a vested interest in ensuring that conversions are carried out in line with approved practices.

*a. **Risk Assessment and Certification Requirements***
Before providing coverage, insurers would require proof that the vehicle was retrofitted in an authorized workshop and that all components (cylinders, valves, regulators) are certified by relevant regulatory bodies (e.g. PCNGI, NADDC). This acts as a filter against unsafe retrofits using substandard kits or unlicensed technicians.

*b. **Incentivizing Compliance through Premiums***
Insurance policies are structured to reward vehicle owners who comply with safety standards. For example, vehicles with valid CNG retrofit certificates, routine cylinder inspection records, and maintenance logs may attract lower premiums. On the other hand, uncertified or poorly maintained retrofits would face higher premiums or outright denial of coverage.

*c. **Mandatory Inspections Before Coverage Renewal***
Annual renewal of insurance policies is tied to inspection reports of the CNG system. This not only ensures continued compliance but also encourages regular maintenance and early detection of faults such as leaks, corrosion, or valve malfunctions.

*d. **Promoting Industry Accountability***
Insurance companies, in collaboration with regulators, maintain a database of certified CNG retrofit workshops and approved kit manufacturers. Vehicle owners seeking insurance would be compelled to use providers on this list, thereby raising the overall standard of retrofitting practices.

*e. **Risk Mitigation and Compensation***
In the unfortunate event of an accident, insurance must provide financial coverage for damages, medical costs, or third-party liabilities. However, insurers can also use such incidents to audit the root cause and push for stricter compliance measures, creating a feedback loop that strengthens industry-wide safety culture.

*f. **Driving Public Confidence in CNG Adoption***
By making insurance coverage contingent on safe and standardized retrofitting, insurers reassure the public that certified CNG vehicles are not only cost-effective but also safe. This helps reduce the cultural resistance

and misconceptions about the dangers of CNG-powered vehicles. Insurance companies function as a gatekeeper, ensuring that only vehicles converted according to best practices are road-legal and financially protected. This alignment of financial incentives with regulatory enforcement helps build a safer and more sustainable CNG ecosystem.

"CNG retrofitted vehicles offer Nigeria a cost-effective and cleaner transport option, leveraging the nation's abundant natural gas resources. However, their success depends on strict enforcement of safety standards, proper training of technicians, and public education to build confidence in CNG use."

ix. **Routine Inspection and Maintenance:** CNG systems should undergo routine inspection every 3–5 years, including hydrostatic testing of cylinders, inspection of seals, O-rings, and valves, and recalibration of pressure regulators. Neglecting maintenance increases the risk of leaks, pressure build-up, or sudden failures during refueling.

x. **Public and Driver Awareness**
Drivers and vehicle owners should be trained on safe CNG practices such as refueling protocols, early detection of leaks (by smell or hissing sounds), and emergency shutdown procedures. Awareness reduces the risk of unsafe handling by untrained individuals.

9.0 CONCLUSION

CNG retrofitted vehicles offer Nigeria a cost-effective and cleaner transport option, leveraging the nation's abundant natural gas resources. However, their success depends on strict enforcement of safety standards, proper training of technicians, and public education to build confidence in CNG use. Long-term sustainability further requires investment in refueling infrastructure, consistent policies, and reliable regulatory oversight. With these measures in place, CNG adoption can become a safe, trusted, and transformative step towards a more affordable and sustainable transportation system in Nigeria.

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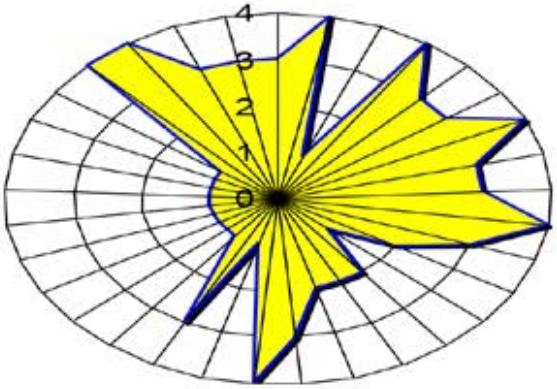

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ENVIRONMENTAL REMEDIATION: USE OF LOCAL MATERIALS FOR CLEAN-UPS

1.0 INTRODUCTION

One of the major problems of the oil industry is the issue of pollution of the environment. Pollution may be due to operational challenges, accidents/ incidents, discharge of wastes, sabotages and more recently illegal artisanal refining of petroleum as is the case in the Niger Delta of Nigeria. It is estimated that about 3million metric tons of oil and its products are dumped into water bodies annually . This is huge.

Engr. Dr. Vincent G. Nnadi *FNSE ,FNChE, FNIM*
(Chairman/CEO, MetierForte Ltd)

The Niger Delta of Nigeria is regarded as one of the most polluted regions of the world (See Fig. 1). According to reports, about 16,476 spills were recorded between 1976 and 2015 with about 3 million barrels dumped into the environment and worse still about 70% of this spill was not recovered. Pollution poses very serious problems for people and environment including health and damage to the ecosystem.

As these issues cannot be completely prevented, humanity is left with no option than to provide measures to remove these pollutants from the recipient bodies.

2.0 METHODS OF CLEAN-UPS

Some of the classic methods used in clean-ups include the following:

i. **Manual Method:** This is the oldest form of clean-up and the most commonly used. It involves a lot of manual labour using teams of workers with tools such as buckets, rakes, shovels, drums. The collected oil is transferred to a processing station or stored in reservoirs and tanks. Hoses and pumps are also used to recover the spilled oil.

Before a manual method could be applied, it may be necessary to restrict the spill within an area. This containment prevents the spill from spreading to other areas. An alternative is to divert the spill where recovery is possible.

While manual recovery may be cheap, it is, however, labour intensive. A second disadvantage is in its poor efficiency of recovery. This process may only succeed in the recovery of visible oil leaving a lot of films unrecoverable.

ii. **Booms:** A boom is a floating barrier used to contain spills on marine environment. It includes a containment partition that floats and extends

Fig. 1: Polluted Environment in the Niger Delta of Nigeria

"The performance of sorbents is measured in terms of the weight of the total oil recovered compared to its original weight."

above the water surface and a curtain that sinks into the water to prevent oil escaping underneath. It is supported at several points by tensioned ropes or steel cables. Booms are usually about 15 to 30m long. To ensure buoyancy, floats are located at several points. The floats are usually made of polyurethane or polyethylene materials. Booms can be self-inflating or inflatable from an external source.

Sorbent booms are specialized containment and recovery booms equipped with other materials such as polypropylene which absorb the oil while it is being contained. They are mainly used when the oil slick is thin.

There are other special purpose-built booms designed for specific conditions. While booms have served as good containment and recovery equipment, its use may be limited by the weather and other extraneous factors.

iii. **Skimmers:** Oil Skimmers are mechanical devices that are designed to remove oil from water for purposes of recovery or remediation. Skimmers are classified according to the area of use (onshore or offshore) or sometimes by the viscosity of the oil to be skimmed (heavy or light) or according to the operating principle (disk, brush, weir).

The effectiveness of a skimmer is rated according to the quantity of oil it recovers as well as the amount of water in the recovered oil. This effectiveness, however, depends on such factors as the quantity of spill, viscosity of the oil, thickness of the slick, sea conditions including waves and ambient temperature. Most skimmers function well when the quantity of spill is much. They are, therefore, deployed downstream of booms. They are sometimes fitted with screens to prevent debris.

Skimmers are also classified according to operating principles. They include oleophilic, weir, suction, vacuum, submersible, vortex or centrifugal skimmers.

Oleophilic skimmers are equipped with surfaces that are made of fabric, steel, plastics such as polyurethane or polyvinylchloride. These surfaces provide some adhesion to oil making it very effective. A wiper blade wipes off the oil and transfers it to a container from where it can be pumped as recovered oil.

While skimmers are largely in use for recovery of oil on polluted water environment, their use is still limited by environmental factors, thickness of oil, and presence of debris. Again, its efficiency in terms of oil-in-water recovered is also limited. A lot of work has been done and is still being done to improve the observed limitations.

iv. **Sorbents:** Sorbents are products that recover petroleum products through absorption or adsorption. They are mostly used in the recovery of final traces of spills especially in confined spaces where booms or skimmers cannot be deployed.

Sorbents are classified as natural or synthetic. Natural sorbents are organic such as wood products or inorganic materials such as clay.

Sorbents can be used in various ways including cleaning of surfaces, wiping of booms after a clean-up operation. They can be used and re-used by simply squeezing out the absorbed oil.

The capacity of sorbents depends on the exposed surface area to which oil can adhere and on the type of surface. To improve performance, some sorbents are treated with oleophilic (oil attracting) and hydrophobic (water repelling) materials to improve its ability to segregate clean-up of oil instead of water.

The performance of sorbents is measured in terms of the weight of the total oil recovered compared to its original weight. Synthetic sorbents are much more efficient. They can recover up to 30 times its original weight compared to inorganic sorbents that can handle only thrice its weight.

While the use of sorbents has proved to be very efficient in the circumstances in which they have been deployed, its main disadvantage remains in the regeneration process. The transfer of loaded sorbents from sites to regeneration can result in other spills.

v. **Natural Methods:** Natural actions of the sun, weather and wave can promote the breakdown of oil spilled on water surfaces. If oil spill does not threaten wild life or close to populations, the tendency is usually to leave it and let natural actions take care of the spill especially if the

"One of the commonly used processes of clean-up is based on the old aged principle of adsorption."

quantity spilled is small. Lighter oils will disperse faster than heavier oils.

When oil breaks down as a result of natural actions, they mix with water, sand and other particles to form tar balls. Tar balls eventually scatter over the coastal surfaces. The disadvantage of this process is that the weathered oil may create secondary films on water surfaces that may require further clean-up through other processes.

vi. **Use of Dispersants:** Dispersants are chemicals that are sprayed on oil spill surfaces to cause a breakdown of the oil into smaller droplets. Dispersants contain certain surfactant chemicals that contain both water and oil compatible ends. At a certain concentration of mixtures, the surfactant molecules attach to the oil and reduce the interfacial tension between oil and water. This reduction allows oil droplets to break off from the slick and minimizes the tendency to re-coalesce.

The use of dispersants over the years has been discouraged due to high toxic effects observed when degreasers were applied to the "Torry Canyon oil spill". This was one of the world`s most serious oil spills when the super tanker ran aground and spilled over 160 million litres of crude oil off the south west coast of the UK in 1967. The impacts to communities were very extensive. Though research has produced dispersants with less toxic effects, its use as a means of oil spill clean-up is highly regulated and, in some cases, actually banned.

vii. **Burning:** Controlled (in-situ) burning refers to the burning of oil slick at sea or close to site of the spill. Controlled burning burns off the oil in water, thereby reducing the quantity of oil-in-water. This system is only possible under low windy conditions.

There is a limited use of this process due to the problems and issues generated by it including the air pollution from heavy smoke and respiratory problems it can cause. It also leads to the formation of extremely viscous and dense residue which sinks at sea, including the safety concerns from this method.

viii. **Bioremediation:** Bioremediation in oil spill clean-up refers to the addition of materials to contaminated environments resulting in an acceleration of the biodegradation process. It is becoming a promising method of oil spill clean-up with little impact to the habitat. The process uses decomposers or their enzymes to improve the condition of the contaminated environment. For example, Bacteria can be introduced to remove specific contaminants such as hydrocarbon present in crude oil and its products. There are several types of Bioremediations which include the following;

- Addition of native microbes to increase populations
- Encouraging the growth of native microbes by adding substrates/nutrients which creates a favourable environment for hydrocarbon organisms to degrade toxic compounds present in oil. This is also known as 'Bio stimulation'.
- Addition of microbes that are not native to the environment. This is known as 'Bioaugmentation'.

Bioremediation has the advantage of utilizing natural processes with minimal equipment; its main drawbacks include being a very sensitive process with respect to toxicity and environmental conditions of temperature and pH.

A lot of research has been carried out in finding the most efficient and cost-effective ways to remove these pollutants.

3.0 TECHNOLOGY

One of the commonly used processes of clean-up is based on the old aged principle of adsorption. Adsorption is a surface process that leads to transfer of a molecule from a fluid bulk to a solid surface. This occurs because of physical forces or by chemical bonds. Usually, it is reversible (the reverse process is called desorption); In most of the cases, this process is described at the equilibrium stage by means of some equations that quantify the amount of substance attached on the surface given the concentration in the fluid. These equations are called isotherms (the most famous are the Langmuir and the Freundlich equations) because of the dependence of their parameters on the temperature, which is one of the most important environmental factors affecting adsorption.

"The history of clean-up of oil spill started with natural and manual methods."

Adsorption is an efficient separation method used in chemical, petrochemical and pharmaceutical industries.

4.0 LOCAL MATERIALS FOR CLEAN-UPS

The history of clean-up of oil spill started with natural and manual methods. As these methods could not completely remove traces of oil in water, researchers focused on developing chemical and synthetic products to improve the efficiency of clean-ups. This led to the development of synthetic organic sorbents such as polyurethane, polypropylene and polyethylene materials. To improve their oleophilic and hydrophobic properties, other products were added by copolymerization. Though their sorbent characteristics improved greatly, the use of these synthetic products had a major disadvantage. They are not biodegradable and also very expensive.

In a world now more sensitive to its environment, research pushed further to develop eco-friendly products. This led researchers to focus on the development of clean-up materials from natural and agricultural products.

4.1 CLAY

Clay is a soft, loose, earthy material containing particles with a grain size of less than 4 micrometers (μm). It forms as a result of the weathering and erosion of rocks containing the mineral group feldspar. It is an earthy material that is plastic when moist but hard when fired, that is composed mainly of fine particles of hydrous aluminum silicates and other minerals, used for brick, tile, and pottery.

Clay had been discovered as a product good for adsorption and so research focused into the use of natural clay and later modified clay as a substitute for the synthetic products.

Natural clays are widely used in this process but the hydrophilic surface of natural clays usually affects the removal efficiency leading to poor results. This has led to more interests in modifying raw clays in order to enhance its adsorption capacity. The structural and surface properties of raw clay could be modified by a thermal and/or a chemical process. This way, the hydrophilic surface is made hydrophobic by embedding cations into the clays through an ion exchange process which improves the adsorption affinity.

Various combinations of clay with other agricultural products are capable of enhancing performances in remediation of oil spill. They include: Clay modified with surfactants, mixture of Clay and Sawdust. Clay mixed with agricultural products such as Rice husks, Cotton, Kapok, Mixture of Clay, Plantain & Banana stems.

5.0 RECENT ADVANCES

More recent advances includes the use of rice husk ash as oil sorbents for oil spill cleanup. The rice husk ash is prepared through a thermal process. The thermal treatment improves the structure of the husk particles especially in terms of porosity. In one of the researches,, the rice husks were thermally treated at 700oC to obtain a modified structure with higher porosity compared to the virgin husks. This, therefore, demonstrates the possibility of obtaining effective oil adsorbents from rice husks which are currently considered as agricultural waste. About 7million metric tons of rice is consumed annually in Nigeria with a local production of about 3.9million metric tons. 20% of all local production of rice is husk. This generates a lot of waste. Rice waste from husks could be useful for oil spill clean-up.

Other local combinations that have been developed for clean-ups include the following: Clay + Saw Dust, Clay + Cotton, Clay + Plantain + Banana Stem.

6.0 COST OF CLEAN-UPS

Getting the global cost of clean-up of oil-polluted site is a huge challenge. Available data is often extrapolated from specific cases of pollution. For example, the cost of the clean-up of the Gulf of Mexico in 2010 was estimated at $65billion making it one of the most expensive case.

A report indicates that it may cost up to $12billion to clean up years of oil pollution in Bayelsa State.

The United Nations Environmental Program (UNEP) estimated that it could cost up $1billion to clean up the Ogoni polluted environment over a 30yr period. This is currently being implemented by the Hydrocarbon Pollution Remediation Project

Fig. 2: Environmental Remediation by HYPREP in Ogoni, Rivers State, Nigeria

"Local materials developed from clay and organoclays have the advantages of being biodegradable and also less expensive. The petroleum industry should take advantage of this as the country just launched its "Nigeria First" program."

(HYPREP). See Fig. 2.

The pain is that most of these costs go for the importation of the clean-up chemicals. If we cannot prevent pollution, can we invest locally and create an industry out of remediation and save costs in foreign exchange? This is the direction of this article.

7.0 CONCLUSION

This article was motivated by the need to substitute the foreign materials used today with local materials developed by research. The foreign materials have the disadvantages of being non-biologically degradable and also very expensive.

Local materials developed from clay and organoclays have the advantages of being biodegradable and also less expensive. The petroleum industry should take advantage of this as the country just launched its "Nigeria First" program.

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CHEMICAL ENGINEERING: A CATALYST FOR AGRICULTURAL TRANSFORMATION AND VALUE CHAIN ENHANCEMENT IN NIGERIA

ABSTRACT

Nigeria's agricultural sector, a cornerstone of its economy, grapples with significant challenges including low productivity, substantial post-harvest losses, and limited value addition. This paper posits that chemical engineering, often overlooked in the agricultural discourse, holds immense potential to catalyze a transformative shift in the sector. We delve into specific applications of chemical engineering principles and technologies across the entire agricultural value chain in Nigeria, from optimizing input utilization and crop production to advanced processing, preservation, and the creation of high-value products. By integrating sustainable practices and fostering innovation, chemical engineering can significantly contribute to food security, economic diversification, and rural development in Nigeria.

Keywords: *Chemical Engineering, Agriculture, Value Chain, Nigeria, Food Security, Post-Harvest Loss, Agro-processing, Sustainable Agriculture.*

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1. 0 INTRODUCTION

Agriculture plays a key role in generating employment, particularly, in rural farming communities in Nigeria. Despite its prominence, the sector faces myriad challenges, including reliance on rain-fed agriculture, rudimentary farming techniques, inadequate access to quality inputs, severe post-harvest losses (estimated at 20-50% for various crops), and limited processing capabilities. These issues collectively hinder food security, exacerbate poverty, and constrain the sector's contribution to national income and export earnings.

While various interventions have focused on direct agricultural practices, the critical role of chemical engineering in addressing these systemic challenges often remains understated. Chemical engineering, with its foundational principles in process design, optimization, separation, and material science, offers a robust framework for enhancing efficiency, sustainability, and value creation within the agricultural value chain. This paper aims to highlight how chemical engineering expertise can be leveraged to unlock the full potential of Nigeria's agricultural sector.

2.0 THE NIGERIAN AGRICULTURAL VALUE CHAIN: AN OVERVIEW AND GAPS

The Nigerian agricultural value chain typically encompasses:

- Input Supply: Seeds, fertilizers, pesticides, machinery
- Production: Cultivation, harvesting
- Post-Harvest Handling: Cleaning, sorting, grading, initial preservation
- Processing: Transformation of raw produce into finished or semi-finished goods
- Marketing and Distribution: Storage, transportation, sales
- Consumption: End-user utilization

The following significant gaps exist at various stages:

- Upstream: Inefficient fertilizer utilization, reliance on imported agrochemicals, and limited access to improved seed varieties
- Midstream: High post-harvest losses due to poor storage, inadequate preservation techniques, and rudimentary transportation

"Agriculture is the largest contributor to Nigeria's Gross Domestic Product (GDP), employing a significant..."

Fig. 1: Solar air dryer | *Source: radhasolar.com*

- Downstream: Low levels of industrial processing, leading to limited value-added products, minimal export potential, and a high dependency on raw material sales

These gaps underscore the urgent need for technological interventions, precisely where chemical engineering can provide transformative solutions.

3.0 CHEMICAL ENGINEERING INTERVENTIONS ACROSS THE VALUE CHAIN

Chemical engineering principles and technologies can be strategically applied at each stage of the agricultural value chain to boost productivity, reduce waste, and enhance value.

3.1 ENHANCING AGRICULTURAL PRODUCTION (UPSTREAM)

i. Fertilizer production and smart application are intervention opportunities. Chemical engineers are crucial in designing and optimizing processes for local fertilizer production, reducing Nigeria's reliance on imports. This includes developing novel formulations like slow-release and coated fertilizers that minimize nutrient runoff and improve absorption efficiency. Precision agriculture techniques, guided by chemical principles, enable targeted application, reducing waste and environmental impact.

ii. Pesticide and Herbicide Formulation: Development of less toxic, biodegradable, and highly effective agrochemicals is in chemical engineering domain. Encapsulation technologies can ensure controlled release of active ingredients, enhancing efficacy while minimizing environmental exposure and human health risks. Research into biopesticides derived from natural sources also falls within this scope.

iii. Soil Amendment and Remediation: Chemical engineers contribute to developing solutions for improving soil fertility and remediating contaminated lands. This involves formulating soil conditioners, biochar, and other amendments to enhance soil structure, water retention, and nutrient availability, particularly critical in areas affected by erosion or pollution.

iv. Water Treatment for Irrigation: With erratic rainfall patterns, efficient water management is vital. Chemical engineering expertise is essential in designing and implementing water purification and treatment systems for irrigation, including the safe reuse of treated wastewater. This ensures water quality for crops and minimizes the spread of pathogens.

3.2 OPTIMIZING POST-HARVEST HANDLING AND PRESERVATION (MIDSTREAM)

i. **Advanced Drying and Dehydration:** Post-Harvest losses of perishable crops (fruits, vegetables, grains) are staggering. Chemical engineers can design and optimize efficient drying technologies (e.g., solar dryers with enhanced collectors, mechanical dryers with heat recovery systems, osmotic dehydration) that reduce moisture content effectively while preserving nutritional value and sensory qualities. See Fig. 1.

ii. Improved Storage and Preservation Technologies: This involves developing and

"Chemical engineers can design and optimize efficient drying..."

implementing controlled atmosphere storage (CAS), modified atmosphere packaging (MAP), and smart cold chain solutions. See Fig. 2. Chemical engineers contribute to designing hermetic storage facilities, developing anti-microbial coatings for packaging materials, and optimizing refrigeration cycles to extend the shelf life of produce, thereby reducing spoilage and increasing market access.

iii. Sorting and Grading Technologies: While often mechanical, chemical sensing technologies can enhance precision sorting and grading based on ripeness, sugar content, or spoilage indicators, ensuring quality consistency for further processing.

Fig. 2: Nitrogen controlled grain storage | *Source: grainsilo.com*

3.3 DRIVING VALUE ADDITION AND PRODUCT DIVERSIFICATION (DOWNSTREAM)

i. Food Processing and Fortification: This is a core area for chemical engineers. From basic processing (e.g., cassava into garri, starch, flour; maize into grits, syrup) to advanced food product development (e.g., fruit juices, concentrates, dairy products, baked goods), chemical engineers design and optimize the entire processing line. See Fig. 3. This includes thermal processing (pasteurization, sterilization), separation (filtration, centrifugation), mixing, and formulation to ensure product quality, safety, and shelf stability. See Fig. 4.

Fig. 3: Fruit juice production | *Source: 5.imimg.com*

Fig. 4: Milk pasteurization plant | *Source: pranamjiengineering.com*

"Fortification processes, adding essential vitamins and minerals to staple foods, are critical for addressing malnutrition in Nigeria."

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ii. Biofuels and Bioenergy Production: Agricultural residues and surplus crops can be converted into valuable bioenergy. Chemical engineers are central to designing processes for ethanol production from starchy crops (e.g., cassava), biodiesel from oilseeds, and biogas from organic waste through anaerobic digestion. These initiatives offer sustainable energy alternatives and create additional income streams for farmers.

iii. Bioplastics and Bioproducts: The conversion of agricultural waste (e.g., rice husks, cassava peels) into biodegradable plastics and other biopolymers is a promising avenue for sustainable development. Chemical engineers develop the extraction, polymerization, and processing techniques for these novel materials, reducing environmental pollution and creating new industries.

iv. Nutraceuticals and Pharmaceuticals: Nigeria's rich biodiversity offers immense potential for extracting high-value compounds from plants and agricultural by-products. Chemical engineers are key in developing efficient extraction, purification, and formulation processes for nutraceuticals (e.g., functional food ingredients) and pharmaceutical precursors, establishing a sophisticated agro-allied industry.

4.0 CHALLENGES AND OPPORTUNITIES IN NIGERIA

4.1 CHALLENGES

i. Inadequate Infrastructure: Limited access to reliable electricity, good roads, and modern processing facilities hinders the adoption of chemical engineering technologies.

ii. Funding and Investment: Insufficient capital for research and development (R&D) and for scaling up innovative technologies pose as bottleneck in agro initiatives.

iii. Human Capital Development: A gap exists in specialized chemical engineering skills tailored to agricultural and agro-allied industries.

iv. Policy and Regulatory Gaps: Inconsistent policies, lack of standardization, and weak enforcement can impede industrial growth and investment.

v. Market Linkages: Poor market access and inefficient distribution of channels reduce the incentive for farmers to produce more or for processors to invest in advanced technologies.

4.2. OPPORTUNITIES

i. Large Domestic Market: Nigeria's growing population presents a vast consumer base for processed food products.

ii. Abundant Raw Materials: Diverse agricultural resources (cassava, maize, palm oil, cocoa, etc.) offer significant feedstock for various agro-allied industries.

iii. Government Focus on Diversification: Current government policies emphasize agricultural transformation and value chain development, including initiatives like the Special Agro-Industrial Processing Zones (SAPZs).

iv. Technological Advancements: The advent of smart agriculture, Internet of Things (IoT), and Artificial Intelligence (AI) can be integrated with chemical engineering solutions for enhanced efficiency and data-driven decision-making.

v. Youth Engagement: Opportunities exist to attract and train young chemical engineers and entrepreneurs in the agro-allied sector, addressing youth unemployment.

5.0 POLICY RECOMMENDATIONS AND FUTURE OUTLOOK

To fully harness the potential of chemical engineering in transforming Nigeria's agriculture, the following recommendations are crucial:

i. Strategic Investment in Agro-allied Industries: Government and private sector investment in modern processing plants, cold chain logistics, and R&D facilities specifically for chemical engineering applications in agriculture are necessary.

ii. Curriculum Development and Capacity Building: Revamping chemical engineering curricula in universities to include specialized courses in

"Chemical engineering is not merely an auxiliary discipline but a fundamental enabler for agricultural transformation in Nigeria."

food processing, biochemical engineering, and sustainable agricultural technologies should be implemented as part of the solution. Vocational training and re-skilling programs for existing professionals should be promoted.

iii. Enabling Policy Environment: There is a need to develop clear, consistent, and supportive policies that incentivize local manufacturing of agricultural inputs and value-added products, including tax breaks, access to credit, and export promotion schemes as well as enforcement of quality standards. Specifically, regulatory agencies which include NAFDAC and SON should ensure product competitiveness.

iv. Research and Innovation Hubs: Government should establish and adequately fund national research institutes and university centers focused on chemical engineering solutions for agricultural challenges, fostering collaboration involving academia, industry, and farming communities.

v. Public-Private Partnerships (PPPs): Policy makers should encourage strong PPPs for infrastructure development, technology transfer, and market linkages, allowing for shared risks and benefits in developing the agricultural value chain.

vi. Promote Sustainable Practices: Chemical engineering solutions should be integrated in a way that prioritizes environmental sustainability, such as waste valorization, green chemistry, and energy-efficient processes.

6.0 CONCLUSION

Chemical engineering is not merely an auxiliary discipline but a fundamental enabler for agricultural transformation in Nigeria. By applying its core principles to optimize processes, develop novel materials, enhance preservation, and facilitate value addition, chemical engineers can significantly reduce post-harvest losses, improve food quality and safety, create new markets, and drive economic diversification. A concerted national effort, driven by strategic investments, robust policy frameworks, and sustained human capital development, is imperative to fully leverage chemical engineering expertise for a food-secure and economically prosperous Nigeria.

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THE ART OF EFFECTIVE LEADERSHIP: NAVIGATING THE PATH TO SUCCESS

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As the saying goes, "A great leader is not born, but made." And indeed, the art of effective leadership requires a combination of skills, traits, and experiences that can be cultivated and honed over time. Whether you are a seasoned executive or someone who aspires to take on a leadership role, understanding the essential elements of effective leadership is crucial in navigating the path to success.

First and foremost, an effective leader must possess a clear vision and a strong sense of purpose. It is the ability to articulate this vision and inspire others to work towards it that sets apart a great leader from an average one.

A vision should be aspirational, realistic, and align with the organization's values. It should also be effectively communicated to all team members, creating a sense of shared purpose and direction.

Another crucial aspect of effective leadership is setting the right example. A leader's behavior and actions are closely observed by their team, and it is essential to lead by example.

This means displaying integrity, accountability, and empathy in all interactions and decisions. A leader's words must also be backed up by their actions, as this builds trust and credibility within the team.

Effective communication skills are also 'a must-have' for any leader. The ability to communicate clearly, actively listen, and provide constructive feedback are essential in creating a cohesive and productive team. Good communication also fosters transparency, encourages collaboration, and ensures that everyone is on the same page, working towards the common goal.

In today's fast-paced and ever-changing business landscape, adaptability and agility are critical traits for a leader. The ability to pivot, make quick decisions, and embrace change is crucial for an organization's success.

A leader must keep abreast of industry trends, be open to new ideas, and be willing to take calculated risks. They must also be able to lead their teams through change effectively.

In addition to these skills and traits, an effective leader must possess emotional intelligence. This encompasses self-awareness, self-regulation, motivation, empathy, and social skills. A leader who is emotionally intelligent can manage their emotions and effectively navigate through conflicts, build strong relationships, and inspire their team to achieve greatness.

Furthermore, a leader must prioritize continuous learning and development. In today's competitive business landscape, a leader who is not constantly seeking to improve is at risk of becoming stagnant. An effective leader must continuously seek new knowledge, develop new skills, and be open to feedback. This not only allows them to stay relevant but also sets an example for their team to follow.

In conclusion, the art of effective leadership is a continuous journey that requires a combination of skills, traits, and experiences. It is a delicate balance between setting a clear vision, leading by example, effective communication, adaptability, emotional intelligence, and continuous learning. As a leader, it is your responsibility to cultivate these qualities within yourself and inspire others to reach their full potential.

By doing so, you will not only pave the way for your organization's success but also build a legacy of effective leadership that will inspire future generations.

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