FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

ENVIRONMENTAL CHEMICAL POLLUTION: HOW SAFE IS SAFE ENOUGH?

By

PROFESSOR JONATHAN YISA
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PROTOCOL

The Vice Chancellor, The Deputy Vice Chancellor (Academics), The Deputy Vice Chancellor (Admin), The Registrar, and other Principal Officers of the University; Deans, Members of Senate; My Professional and Academic colleagues; My Precious Students, past and present; Distinguished Guests, Ladies and Gentlemen.

1.0 INTRODUCTION

Looking at the environment as a life supporting system for human existence and survival, it provides much of the physical milieu and the raw materials required for socio-economic progress. Humanity has no choice but to interact with it. Unfortunately, human interactions are putting very high pressure and negative impact on the quality of our environmental conditions. Chemical pollution, in particular, is currently one of the most critical issues facing mankind, animals, plants, bacteria, and others, which in turn depend on the air, land and water environments. The cost of producing a risk-free society is practically impossible as solving one problem creates another. What is now essential is to derive the knowledge on the safety of these substances and to answer the question - how safe is safe enough?

In view of the above, I have therefore, titled my Inaugural Lecture "Environmental Chemical Pollution: How safe is safe enough?"

2.0 CHEMICALS AND MODERN SOCIETY

Chemicals are essential elements of modern society. Humans in general, are totally dependent on chemicals: agrochemicals, medicine, pharmaceuticals, colorants, the list is almost endless. They are used as processing aids or as integral part in the production of materials needed for daily living. They shape economic activities, from agriculture, construction and textiles to high tech industries such as aerospace, automotive, health care and electronics, more than any other manufacturing sector. Due to their role in the value chain, they serve all sectors of the economy and contribute to our well-being.

Chemicals are not just 'chemical products' (paint, glue, detergents, solvents, pharmaceuticals); they are virtually all materials (metals, plastics, paper, glass). The millions of articles used everyday (electronics, toys, clothing, vehicles, and buildings) are either manufactured using chemicals, consist of chemicals or treated with chemicals (e.g., coatings, preservatives). As at 2018, the number of industrial chemicals in commerce globally was estimated to be between 40,000 and 60,000 with 6000 of these chemicals accounting for more than 99 per cent of the total volume. The global chemical industry's production capacity (excluding pharmaceuticals) almost doubled from about 1.2 to 2.3 billion tones. If pharmaceuticals were included, global sales totaled 5.68 trillion United States dollars (USD) in 2017, making the chemical industry the second largest manufacturing industry in the world (UNEPA, 2019).

Chemical production in Africa is limited. South Africa's chemical industry is the largest in Africa. In Northern Africa, there are strong presence of chemical industries in Algeria, Egypt, Libya, Morocco and Tunisia. While in West Africa, Nigeria is the primary producer and major user of chemicals. To meet their developmental needs, African countries import chemicals for industrial, domestic, and agricultural purposes. Trade liberalization and creation of free trade industrial zones facilitate chemical trade across borders and continents. At the same time, many African countries lack the capacity and knowledge to assess and monitor the risks associated with the trade of chemicals and products containing chemicals. There are also concerns that African countries import chemicals that have expired or rejected by the industrialized countries. Trans-boundary trade of hazardous chemicals, such as: mercury and heavy metals in e-waste, has heightened public health concern due to the lack of knowledge on environmentally sustainable alternatives and proper quality control of chemical products (European Commission, 2017).

3.0 ENVIRONMENTAL CHEMICAL POLLUTION

Environmental chemical pollution is characterized by the presence or increase of chemical contaminants in the environment that are not naturally present or are found in quantities greater than their background levels (Estival, 2019). It is one of the most annoying of several mournful consequential reasons, which include:

i. The substances involved have a high toxic potential and in most cases, these substances do not usually occur alone.
ii. Many are characterized by their persistence and potential to bioaccumulate and cause biomagnification through the trophic chain.
iii. Chemical pollutants do not know frontiers, so they can travel long distances and spread widely, thus becoming a planetary problem.
iv. The vast majority of the chemicals created and produced for various purposes do not only fulfill the objectives for which they were designed.
v. One of the great disadvantages of chemical pollution is that it usually goes unnoticed.

3.1 Global Chemical Pollution

Environmental chemical Pollution became a popular global concern from the 1950s, after World War II. This was due to radioactive fallout from nuclear warfare and testing. International catastrophes have demonstrated the universality of environmental chemical pollution and the scale at which efforts to address them needed to engage. These catastrophes include: The Great Smog of 1952 in London that killed at least 4000 people, Polychlorinated biphenyl (PCB) dumping in the Hudson River resulted in a ban by the EPA on the consumption of its fish in 1974, Long-term dioxin contamination at Love Canal starting in 1947 which became a national news story in 1978, Legal proceedings in the 1990s that helped bring to light Chromium-6 releases in California the champions of whose victims became famous, DDT was banned in most of the developed world after the publication of Rachel Carson's Silent Spring, the Bhopal disaster in 1984. The borderless nature of atmosphere and oceans inevitably resulted in the implication of pollution on a planetary level with the issue of global warming (Birnbaum, 2008).

Various UN agencies and their subsidiaries have been established to stem chemical pollution through the management of chemicals and wastes. Most especially, UNEP, OPCW, UNFCCC, WHO, FAO, UNIDO, lAEA, World Bank, etc.

Several Multilateral Environmental Agreements (MEAs), international conventions and protocols also address the management of chemicals and wastes to achieve sustainability in "green" economies. Nigeria is signatory to most of these conventions. Presently, the focus of advanced technological societies has shifted from local and regional scale activities to global scale environmental problems.

3.2 Nigeria Chemical Pollution

Chemical pollution issues did not gain official prominence in

Nigeria until the 1988 Koko toxic waste dumping saga which also brought to the fore the exigent need to establish the Nigeria Federal Environmental Protection Agency (FEPA), Federal Ministry of Environment and other relevant agencies, ostensibly to tackle environmentally related issues, in the country.

According to a World Bank Report, over 80 percent of industries in Nigeria discharge solid, liquid, and gaseous effluents directly into the environment without any prior treatment especially in the states that contain about 80 percent of the nation's industries: Lagos, Rivers, Kano, and Kaduna (World Bank, 1995). The report indicated that only a few percent undertake even rudimentary recycling prior to disposal of wastes. This situation points to a growing industrial pollution problem which affects Nigeria's ecosystems and threatens the health of its population. Toxic emissions from industries that burn fuels have devastating effects on life when inhaled. Acid rains are a nightmare to those who live in the vicinity of industries that generate toxic emission. It has been reported that more than 11 million hectares of forest are destroyed by acid rain. Today they situation is worse - off.

The effect of illegal artisanal mining, pipeline explosion and vandalism, and the resultant impact on the dwelling communities around such sites are mournful problems. Nigerian farmers have greatly increased the use of chemical-based insecticides, herbicides, and fungicides. Persistent Organic Pollutants are still being used or stocked in make-shift stores where the dangers and risks due to exposure are enormous. Oil producing areas in Nigeria have been identified as danger zones of pollution arising from toxic wastes.

The problem of chemical pollution became exacerbated as many factories in Nigeria are located on river banks and uses the rivers as open sewers for their effluents. In some cases, wastewater was directly applied to land through the use of holding and evaporation ponds. The establishment of industrial estates beside residential areas in most state capitals and large urban centres are environmentally unacceptable and pose serious threats to public health. Major industries responsible for environmental pollution in Nigeria include petroleum, mining (for gold, tin and coal) wood and pulp, pharmaceuticals, textiles, plastics, iron and steel, brewing, distillery fermentation, paint and food. Of all these, the petroleum industry presents the greatest threat to chemical pollution. Occasionally, accidental oil spillages occur which endanger local sources of water supply, land and freshwater living resources, especially in the rural areas (Anukam, 1997).

Other reasons for the magnification of chemical pollution problems in Nigeria include:

i. Unsafe use of chemicals.
ii. Lack of appropriate regulatory measures or the impossibility of enforcing them.
iii. Chemical dumping and waste sites adjacent to populated areas.
iv. Lack of awareness about risks and cultural aspects.
v. Lack of interest because of other urgent and immediate health priorities.
vi. Despair at the magnitude of the problem.

Driven by safety concerns and achieving safety goal, Nigeria has established regulatory frameworks for chemicals. Despite differences in purposes and scope, a common component of this regulatory framework is an inventory of chemicals manufactured in, imported into, and/or used in the nation. This approach is effective only to a certain extent, as many chemicals manufactured or used in the country may enter through trade (e.g., in the form of imported goods and articles) and/or environmental transport via air, water and land.

Therefore, in order to effectively manage chemical risks within a country, there is a need to address not only chemicals manufactured in, imported into, and/or used in the country, but also those manufactured, used, disposed, and released from other countries. A noteworthy finding is that the identities of many chemicals remain publicly unknown because they are claimed as confidential or ambiguously described (Wang *et al.,*

4.0 CATEGORIZING CHEMICAL POLLUTION

4.1 Natural and Anthropogenic

Categorizing chemical pollution of the Nigerian environment is not much different from other places only the degree and specifics differ. In general, multitudes of chemical pollution originate both from natural processes and anthropogenic sources, including synthesis-by-design of new molecular entities and inadvertent formation of by-products from these syntheses or from the molecule's destruction. Sometimes, the chemicals produced by humans are the same as those produced in nature.

4.2 Order of Priority

Chemical pollution can be categorized into one of the following:

- i. High priority for regulatory risk management.
- ii. High priority for data generation and assessment.
- iii. Low priority for further regulatory action.

4.3 Chemical Structure of the Pollutant

Based on chemical structure of the pollutant, pollution could be categorized into the following sources:

i. **Inorganic pollutants**

Inorganic pollutants are released into the environment due to activities of mining, industry, transportation and urban activities. Environmental risks associated with inorganic pollutants vary widely due to several complex interactions at both intracellular and extracellular levels. Toxic heavy metals and metalloids interact quite strongly with soil constituents when compared to salts of alkali metals, rate of which however, depend on the element and their speciation.

ii. **Organic pollutants**

Man is daily exposed to most of the organic compounds used in industries and medical fields. They are used for drugs and cleaning applications and as solvents in a wide range of products such as fuels, paints, inks, preservatives and pesticides, therefore causing more pollution. As such, they can have serious impacts on human health, and many can be absorbed through contact with skin and absorbed into the bloodstream.

iii. Nuclear (Radiation) pollutants

This is the increase in the natural radiation levels caused by human activities. The human activities that can release radiation involve activities with radioactive materials, such as: mining, handling and processing of radioactive materials, handling and storage of radioactive waste, as well as, the use of radioactive reactions to generate energy (nuclear power plants), along with the use of radiation in medicine (e.g. X-rays) and research. But what about microwaves, cell phones, radio transmitters, wireless devices, computers, and other common commodities of today's life? Based on the frequency with which it occurs, radioactive pollution can be continuous, occasional or accidental.

4.4 Modern and Traditional Pollution

The pollution from chemicals can be categorized as modern and traditional. Modern pollution results from industrialization and urbanization and includes ambient air pollution, soil and water pollution, and pollution in the workplace. These forms of pollution are increasing. Traditional pollution refers to indoor air pollution, largely caused by poor ventilation and smoke from cooking stoves and heating fires, and water pollution from unsafe sanitation. Traditional pollution, which closely correlates with poverty, improves as economies grow and living standard rises.

5.0 THE BURDEN OF DISEASE FROM CHEMICAL POLLUTION

The adverse effects of hazardous chemicals include deaths from acute poisonings involving heavy metals or pesticides, intellectual disability from exposure to lead, cancer caused by exposure to asbestos or dioxins, and endocrine disruption from various chemicals (Figure 1). Chemical pollution has been identified as a significant and "almost certainly underestimated" contributor to the global burden of disease (UNEPA, 2019).

The World Health Organization estimated that disease burden preventable through sound management and reduction of chemicals in the environment at around 1.6 million lives and around 45 million disability-adjusted life years in 2016 (Figure 2). These are likely to be underestimated, given that they are based only on exposures to chemicals for which reliable global data exist (including lead causing intellectual disability, occupational carcinogens such as asbestos and benzene, and pesticides involved in self-inflicted injuries).

The 2016 Global Burden of Disease study published in the *Lancet* estimated that in 2015 almost 500,000 deaths were attributable solely to lead exposure. In addition, chemical accidents in facilities continue to result in high human fatalities, adverse environmental impacts and high economic costs (WHO, 2018). The report further stated that workers are typically subject to disproportionally high exposures to hazardous chemicals, particularly in small and medium-sized enterprises (SMEs) in developing countries and economies in transition and in the informal economy, where they may not be sufficiently informed and protected.

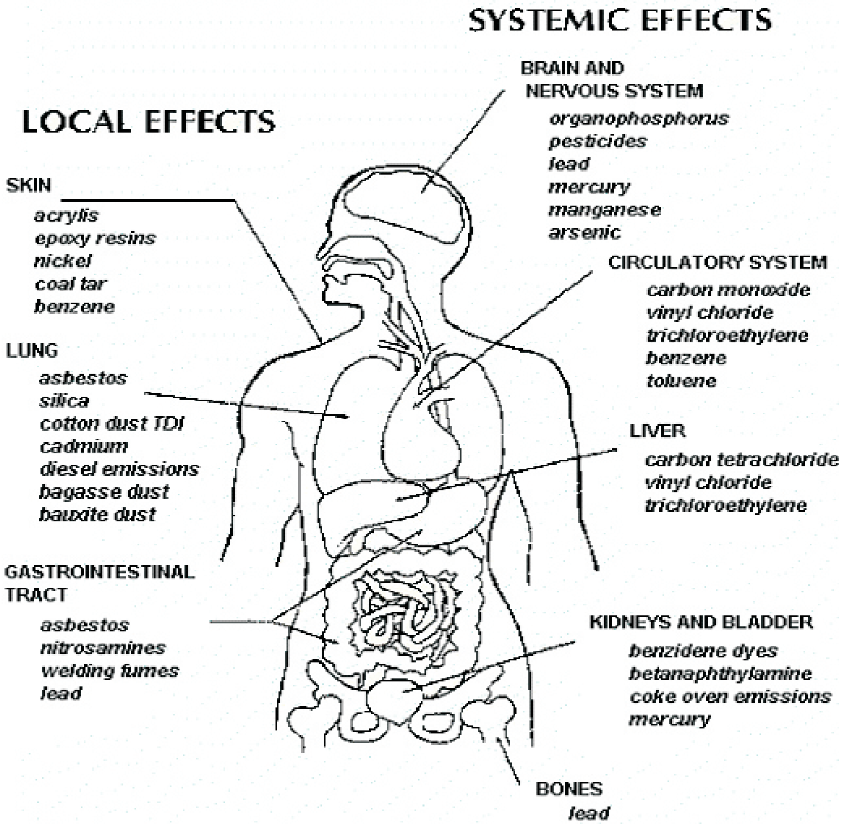

Figure 1: Effects of Exposure to Chemical Pollutants

Source: *Tricker and Tricker, 1999*

Workers are exposed to hazardous chemicals throughout the supply chain, from extraction, to manufacturing, to recycling and disposal. In 2015, almost 1 million workers died from exposure to hazardous substances, including dusts, vapours and fumes (WHO, 2018).

Foetuses, infants, children, pregnant women, the elderly and the poor are among the most vulnerable to the adverse effects of chemicals and waste. For example, the foetal brain is especially vulnerable to methylmercury. The poor may be disproportionally exposed because they frequently live near sources of hazardous chemical releases, such as hazardous waste dumpsites and manufacturing facilities. Vulnerability and exposures of women and men to chemicals may also differ. In general, women are often more likely to be exposed to hazardous chemicals in certain cosmetics, while men have significantly higher occupational exposures in certain sectors. Tragic as it is, it is not surprising to see Nigeria among the top ten in Total Annual Premature Pollution-related Deaths in the world, ranking 18 in the number of deaths per 100,000 people as shown in Table 1 (Global Alliance on Health and Pollution, 2019). Zamfara lead poisoning is the worst and most recent heavy metals incidence in Nigerian records that claimed the lives of over 500 children within seven months in 2010 (Galadima and Garba, 2012).

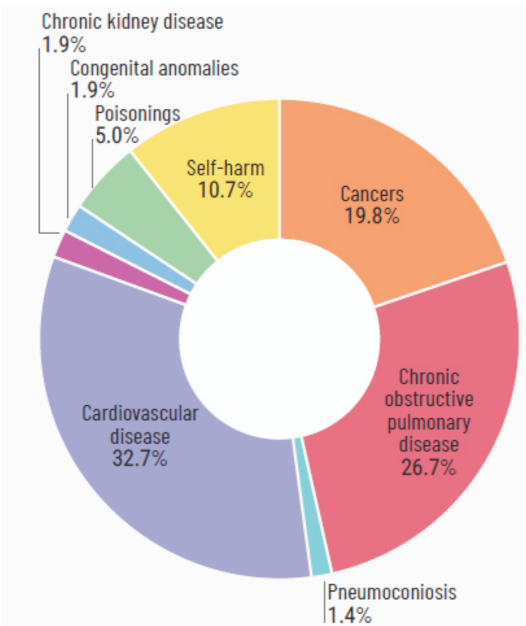

Figure 2: Deaths Attributed to Selected Chemicals
Source: WHO, 2018

Table 1: Premature Pollution-related Deaths per Year

No.	Country	Pollution Death Rate	Death Rate Ranking	Total Pollution Deaths	Air Pollution Deaths	Water Pollution Deaths	Occupation Pollution Deaths
1	India	174	10	2,326,771	1,240,529	698,597	153,528
2	China	135	22	1,865,566	1,242,987	9,585	255,580
3	Nigeria	146	18	279,318	114,115	159,777	2,088
4	Indonesia	88	75	232,974	123,753	60,040	16,331
5	Pakistan	114	38	223,836	128,005	60,213	8,787
6	Bangladesh	126	25	207,922	122,734	33,583	13,558
7	USA	61	132	196,930	107,507	1,628	59,536
8	Russian Fed.	82	86	118,687	99,392	685	9,634
9	Ethiopia	106	46	110,787	40,614	63,454	1,931
10	Brazil	52	146	109,438	66,245	7,152	14,462

Source: *Global Alliance on Health and Pollution (2019)*

6.0 THE CHALLENGES OF MANAGING CHEMICAL POLLUTION IN NIGERIA

The ultimate objective of managing environmental chemical pollution is to achieve a chemical-safe future and a non-toxic environment. This can be achieved by strengthening key elements of an enabling framework to accelerate the needed transformation. It is in the context of the implementation of the 2030 Sustainable Development Agenda, that international discussions on sustainable chemistry are placed (Figure 3).

The following key gaps have been identified to explain why pollution is still an issue:

i. Inadequate awareness, data and information on pollution
ii. Poor institutional and technical capacity.
iii. Absence of infrastructure to manage and control pollution.
iv. Limited scope and scale of finance and industry leadership on pollution matters.
v. Mispricing and invisibility of ecosystem values and absence of internalization of pollution costs.
vi. Limited understanding of pollution's social dimension.

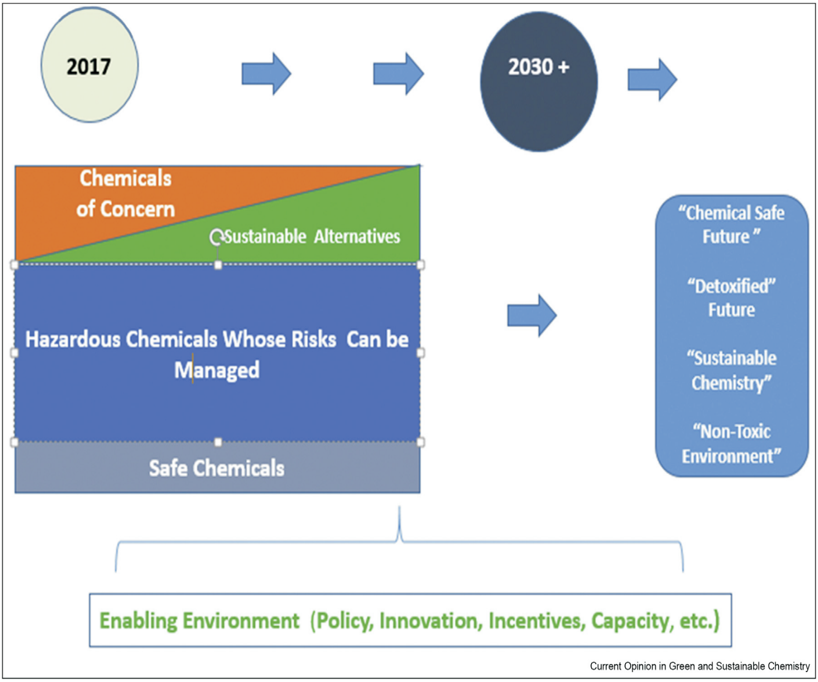

Figure 3: Vision for the Sustainability of Clean Environment
Source: *Halpaap and Dittkrist, 2018*

vii. Lack of funding and technologies.
viii. Behaviour of citizens, the profit motivation of industry and the short termism of governments result in choices that have pollution consequence.

7.0 SUSTAINABLE SOLUTIONS FOR THE CHEMICAL POLLUTION MANAGEMENT

Sustainable Solutions for the Chemical Pollution management means satisfying our present needs without compromising the right of future generations to meet theirs (Elleuch *et al*., 2018). In order to prevent complex threats to human health, habitats and major costs to national economies, sound control of chemicals during their lifecycle is crucial. Additionally, to optimize the potential benefits of their contribution to human well-being, sound management of chemicals and waste is important; either as an input to or consequence of act. A fundamental challenge to be addressed is the prioritization of chemicals and waste management, which is often less prominent than headline issues, such as poverty eradication and climate change, but key to achieving progress towards the development of any nation. The potential way to achieve a sustainable chemical pollution management is to reduce the production of waste and the use of hazardous chemicals, to avoid pollution. This can be achieved through:

i. Understanding how waste is generated and how it can be reduced or even avoided.
ii. Preventing chemical pollution from being produced in the first place is the best way to manage chemical pollution.

Chemical pollution control management can be subdivided into physical, chemical, and biological treatment systems. Most treatment systems use combinations of any of these three technologies.

8.0 ADSORPTION TECHNOLOGY

Several methods have been developed to remove heavy metals ions from aqueous solution before discharge into the water bodies. These methods include, reduction, precipitation, ion exchange reverse osmosis dialysis and adsorption by coated carbon. Most of these methods are expensive and therefore are not affordable for a developing country like Nigeria. They also have limited applications as they cannot remove metals at low concentrations (Ahalya *et al.,* 2005). With increasing environmental awareness and legal constraints imposed on the discharge of effluents, the needs for cost – effective alternative technologies are essential for the removal of heavy metal ions from industrial wastewater. Different types of adsorbent such as activated carbon from agricultural waste, graphene-based, chitosan, clay, polymer biopolymers, metal oxides, nanocomposites, and multiwalled carbon nanotubes have been used for the removal of toxic substances from wastewater. Among the aforementioned adsorbents, agricultural wastes are characterized by ready availability, affordability, eco-friendliness and high uptake capacity for heavy metals due to the presence of functional groups which can bind metals to effect the removal of heavy metal from effluents. Complexation, coordination, chelation, ion exchange, precipitation, electrostatic interaction and/or a combination of these processes occur when adsorbing heavy metals using various adsorbents, as shown in Figure 4

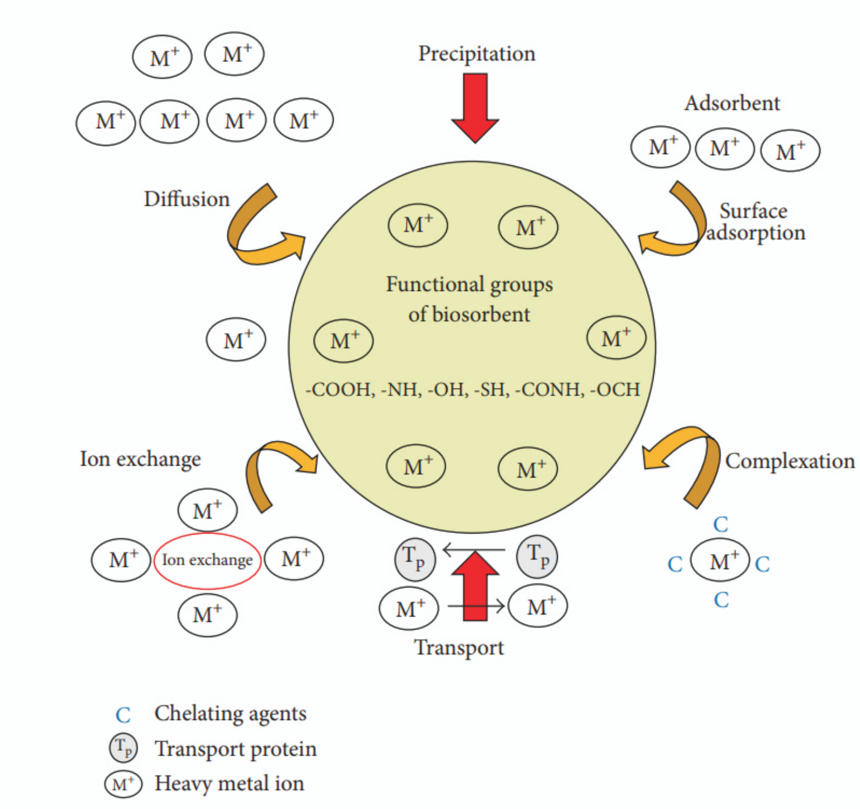

Figure 4: Adsorption mechanisms based on research

Source: *Praveen and Vijayaraghavan, 2014*

9.0 MY RESEARCH CONTRIBUTIONS TO KNOWLEDGE

The Vice-Chancellor Sir, distinguished ladies and gentlemen, let me highlight some of my research contributions to the field of chemical pollution and remediation:

9.1 Environmental Impact Assessment

Studies on a number of Industrial pollution hotspots as well as non-hotspot locations in Nigeria revealed alarming results. For example, Environmental Impact Assessment of Tannery Operations on Challawa River in Kano showed that except pH, Mn and Cd contents, high levels of trace metals, physical and chemical parameters (Table 2) of were observed to exceed apparent safe standard limit for effluents discharge into surface water for all categories of industries in Nigeria (Yisa *et al.,* 2004). This may impact negatively on the health of the aquatic biota and of the rural community that uses the river water directly for domestic use without treatment (Yisa *et al.,* 2009).

9.2 Water Quality Index

The qualities of a number of surface and ground water resources including sediments which represent long time conditions and better indicator of quality of surface and groundwater bodies in various parts of Nigeria were studied (Yisa, 2010; Yisa *et al.,* 2011[a & b], 2012[a, b & c]). Of particular interest and importance is in the study of surface water pollution of River Landzu in Bida, Niger State. Effluents from cottage industries, municipal sewage, agricultural and urban run-off are discharged into it bringing about considerable change in the water quality. The study was aimed at using the application of Water Quality Index (WQI) in evaluating the quality of River Landzu for public usage. This was done by subjecting the 120 water samples collected to comprehensive physicochemical analyses using APHA standard methods of analysis. The overall WQI for the samples was 171.85.

Table 2: Summary Statistics for all Tanneries Sampling Sites

	Median	Maximum	Minimum	Mean	Std. Deviation
pH	8.11	12.92	4.21	8.39	2.17
T(°C)	27.00	40.00	24.00	27.20	3.01
TS (mg/cm³)	8019.50	23030.00	2766.50	8758.57	3663.16
TDS (mg/cm³/)	5258.50	11710.00	1280.00	5139.02	2524.14
TSS (mg/cm³)	2463.50	11573.00	104.60	3083.03	2140.10
Conductivity (μS/cm)	10454.00	22410.00	1970.00	10587.15	4156.06
Chloride (mg/cm³)	1701.34	9489.00	0.00	2209.82	1961.99
Sulphide (mg/cm³)	200.00	1140.00	14.00	274.79	235.88
TKN (mg/cm³)	40.94	1526.53	2.10	133.48	223.28
Alkalinity (mg/cm³)	30.00	1140.00	0.00	170.55	282.83
BOD (mg/cm³)	3506.50	9500.00	742.95	3808.66	1971.44
COD (mg/cm³)	5195.51	10177.65	965.55	5172.72	2324.27
Na (mg/cm³)	230.05	508.40	107.10	247.81	82.29
K (mg/cm³)	46.04	310.10	4.07	65.14	64.95
Ca (mg/cm³)	93.86	977.00	4.89	162.66	192.53
Mg (mg/cm³)	8.21	36.92	1.96	11.82	9.18
Mn (mg/cm³)	0.07	0.33	0.00	0.08	0.07
Fe (mg/cm³)	5.19	33.90	0.00	6.40	6.63
Cu (mg/cm³)	0.33	2.07	0.00	0.54	0.55
Pb (mg/cm³)	0.14	10.06	0.00	0.88	1.84
Zn (mg/cm³)	0.29	6.30	0.00	0.70	1.04
Cd (mg/cm³)	0.01	2.04	0.00	0.04	0.26
Ni (mg/cm³/)	0.36	4.96	0.00	0.47	0.66
Cr (mg/cm³)	36.14	489.90	0.00	80.73	103.97

T = Temperature, TS = Total Solids, TDS = Total Dissolved Solids TKN = Total Kjedahl Nitrogen, BOD = Biochemical Oxygen Demand, COD = Chemical Oxygen demand .

Source: *Yisa et al., 2009*

The high value of WQI (Table 3) had been found mainly from the higher values of iron, chromium and manganese, COD and turbidity. The results of the analysis when compared with World

Health Organization (WHO) and Nigerian Industrial Standard (NIS) permissible limit indicated that the river was heavily polluted and the water is not safe for domestic use and would need further treatment.

Table 3: Computed WQI Values for River Landzu, Bida

Parameter	Standard Permissible value (S_i)	Wi	Qi	qiWi
pH	6.50 - 8.50	0.13	86.66	11.50
Turbidity (NTU)	1.00	1.00	3350.00	3350.00
Total acidity	100.00	0.01	18200.00	182.00
Total hardness	200.00	0.01	4690.00	23.45
TDS	500.00	0.00	52000.00	104.00
Total solids	500.00	0.00	158000.00	316.00
Nitrate	10.00	0.10	1430.00	143.00
Nitrite	1.00	1.00	5.00	5.00
Phosphate	5.50	0.18	271.00	49.27
Chloride	250.00	0.00	3170.00	12.68
Sulphate	500.00	0.00	997.00	1.99
DO	5.00	0.20	420.00	84.00
COD	10.00	0.10	8090.00	809.00
Manganese	0.05	20.00	74.00	1480.00
Chromium	0.05	20.00	32.00	640.00
Iron	1.00	1.00	305.00	305.00

Si = Recommended Standard, Wi = Relative Weight, qi = Quality rating scale, Qi = Quality rating, DO = Dissolved Oxygen, COD = Chemical Oxygen Demand.

Source: *Yisa and Jimoh, 2010*

The percentage of water samples that fall under different quality are indicated in Table 4. The high value of WQI has been found mainly from higher value of turbidity, COD, manganese, chromium and iron in the water sample. The study demonstrated application of water quality index in estimating/understanding the quality of river water and appeared to be promising in the field of water quality management (Yisa & Jimoh, 2010).

Table 4: Water Quality Classification Based on WQI Value

WQI value	Water quality	Water samples (%)
<50	Excellent	20
50-100	Good water	36
100-200	Poor water	30
200-300	Very poor water	0
>300	Water unsuitable for drinking	14

9.3 Metal Pollution Index and Factor Analysis

In river systems, surface water has been widely used as environmental indicators and their chemical analysis can provide significant information on the assessment of anthropogenic activities. The study evaluated the pollution status of Imo River with reference to heavy metal enrichment. The mean concentration of the ten metals used in this study was slightly higher than the recommended maximum permissible limit by the Nigerian Standard for Drinking Water Quality except zinc. The results of metal pollution index (Table 5) revealed that the river is slightly too moderately polluted with metals.

The application of factor analysis on the data-set identified three factors which imply that these metals enter the river through three possible sources. As seen, in Table 6, factor one comprises of pH, nickel, lead, iron and cadmium and accounts for 34.46% of the total variance. Factor two has a moderate loading of 25.89%

Table 5: Calculated Heavy Metal Pollution Index for the Groundwater of Imo River

Parameters (mg/dm^3)	HMPI	Value Rating
Arsenic	2.10	Moderately polluted
Cadmium	3.33	Moderately polluted
Chromium	1.40	Moderately polluted
Copper	1.02	Moderately polluted
Iron	3.40	Moderately polluted
Lead	3.00	Moderately polluted
Manganese	2.50	Moderately polluted
Mercury	2.00	Moderately polluted
Nickel	3.50	Moderately polluted
Zinc	0.55	Lightly polluted

< 0.01 = Very lightly polluted; 0.01-0.99 = Lightly polluted; 1.0-4.99 = Moderately polluted; 5.0-10.0 = Highly polluted; > 10.0 = Very highly polluted

Table 6: Factor loading of the dataset after varimax rotation

Parameters	Factor-1	Factor-2	Factor-3
Arsenic	0.002	**0.517**	0.216
Cadmium	**0.502**	0.301	0.116
Mercury	0. 235	**0.505**	0.149
Chromium	0.360	**0.517**	0.334
Copper	0.134	-0.005	**0.549**
Iron	**0.850**	0.391	0.288
Lead	**0.520**	0.353	0.091
Manganese	0.002	**0.659**	0.114
Nickel	**0.531**	0.142	0.336
Zinc	0.257	0.056	**0.520**
pH	**0.705**	0.380	0.345
Eigenvalues	2.446	1.832	1.1060
% of Variance	34.459	25.890	16.638
Cumulative %	34.459	60.349	76.987

Source: *Amadi et al., 2016*

of the total variance with arsenic, mercury, chromium and manganese as contributors. Factor three had the least loading from copper and zinc which constitutes a total variance of 16.64%. The enrichment of these heavy metals in the river may be attributed to the dumping of waste into the river as well as the discharge of untreated industrial effluent into the river. The prohibition of dumping of waste into the river is strongly advocated. The present study demonstrated application of metal pollution index and factor analysis in understanding the quality of river water and appeared to be promising in the field of water quality management. (Amadi *et al*., 2016).

9.4 Enrichment Factor and Chemical Fractionation

Copper and Manganese contents and their chemical forms in the surface soils of the Abuja Streets were investigated to quantitatively assess their contamination, mobility, and potential bioavailability. Thirty surface soil samples were collected and analyzed for total contents and chemical forms of Cu and Mn. The results (Table 7) revealed that the total contents of Cu and Mn in the soils ranged from 4.93 to 9.67 mg/Kg and 23.67 to 85.33 mg/Kg respectively. The Enrichment Factors (EF) of Cu and Mn in some soils were lower than 1.0 with the exception of Ayingba Street, Aminu Kano, Lagos Street, Landoke Boleuvard, and Tafawa Balewa Streets where EFs were more than 1 for Mn, indicating that Mn has anthropogenic origin. Less than 2% and more than 60% of total Cu and Mn contents in the soil at most sampling sites were associated with the exchangeable fraction and residual fraction, respectively, showing their low mobility and bioavailability. The major sink for anthropogenic Cu was organic matter and carbonates, while for Mn was carbonates and reduceable phase (Yisa *et al*., 2011[c]).

Table 7: Enrichment Factor of Cu and Mn in Soils of Abuja Street

Street name	Cu	Mn
Moshood Abiola	0.10	0.20
Ademola Adetokunbo	0.20	0.80
Ahmadu Bello	0.040	0.90
Anyigba	0.10	1.30
Aminu Kano	0.10	1.50
Gimbia	0.040	0.60
Lagos	0.10	1.50
Landoke Boulevard	0.10	1.90
Ibrahim Kashim	0.010	0.40
Tafawa Balewa	0.10	3.40

Source: *Yisa et al., 2011*[c]

9.5 Evaluation of Pollution Patterns

Multivariate methods of data analysis were used to describe patterns of soil contamination with heavy metals in Lokoja city dumpsites. Groups of metals and dumpsites were identified using cluster analysis. Score plot was used to group dumpsites into four; Group I consists of Pata and Cinima dumpsites, while groups II, III and IV consist of Caturgo, High Court and New Market dumpsite respectively. The loading plot shows that Cu, Co, Cr and Cd have less significant contribution than the other five elements with positive value on the principal components. The bi-plot sketch shows the correlation between site samples and metals, in which Group I sample sites, consisting of sample 1 and 3, does not really correlate with particular metal, making it exceptional in terms of contamination. It is probably, the least contaminated among the sample site groups. Group II, consisting of sample site 4, is characterized by Zn and Cu. Group III, the group of sample site 5, has Co, Fe and Mn as main metal contaminant. Ni and Pb are dominant contaminants of Group IV.

Strong and positive correlation co-efficient of element pairs indicate common source. This can be observed in the cases of Fe and Mn, Zn and Mn, Zn and Fe, Co and Mn as well as Cd and Cr, whereas, Ni and Pb, originate from different pollution source. The cluster analysis gives pattern recognition based on the similarity and closeness of dump sites and the nature of the contaminants. The result reveals the closeness of sites 1, and 2 in terms of pollution level (Olukoya *et al*., 2019).

9.6 Metals Speciation in Municipal Waste

Management of waste is one of the most important environmental problems today in Nigeria. Heavy metal ions in the refuse sediment are always partitioned between the various solid phases present (Yisa and Idoga, 2009).

Studies using single and sequential procedures for the speciation of copper (Cu), Tin (Sn), Lead (Pb), Manganese (Mn) and Iron (Fe) in the refuse dump from Bida metropolis, Nigeria, indicated that the mean of the exchangeable, acid extractable, reduceable, oxidisable and residual fractions were 33.02, 42.46, 43.67, 48.27 and 20.95 mg/Kg respectively. The oxidasable fraction provided more binding sites for heavy metals than other phases and that competition for the binding phase occurs for acid exchangeable, reduceable and oxidizable (Yisa *et al*., 2006).

It was observed that the municipal waste was not highly contaminated. Most metal concentrations were below the permissible levels for the application to agricultural land as regulated by the USEPA (1995).

9.7 Abstraction of Cu and Pb Ions from Aqueous Solution

The physicochemical properties (Table 8) and adsorption performance of activated carbon prepared from sandal fruits (*Santalum Album)* for the removal of lead and copper from aqueous solution was investigated using batch adsorption process. The influence of important parameters like initial metal concentration, temperature, pH, adsorbent dosage and contact time were studied. The result indicated that adsorption capacity increased with increase in the initial metal concentration, pH, adsorbent dosage and contact time up to an equilibrium point when adsorption stabilizes or decrease with further change in those parameters. The sorption process either decreases with increased temperature or does not change with changes in temperature. FTIR analysis results of the adsorbent includes; 3250-3400 cm^{-1}; 1640-1670 cm^{-1}; 1000-1260 cm^{-1} which revealed the presence of functional groups such as the carboxylic acid or alcoholic O-H bond stretching, amine (N-H) bond stretching, C=O bond of carbonyl or amide groups, C-O and O-H bond stretching of alcohol and ethers. The surface area, iodine number, bulk density, particle density, ash content and porosity of the adsorbent determined were; 649.5 m^2/g, 614.7 mg/g, 0.921g/cm^3, 0.72g/cm^3 and 26.4% respectively The equilibrium sorption data proved that the process fitted well into Freundlich better than Langmuir isotherm model as indicated with high correlation coefficients ? 0.95. The results obtained in this study indicated the high adsorption ability of sandal fruit for Pb and Cu, proving it to be excellent biosorbent (Jibrin *et al.*, 2015).

Table 8: Physicochemical properties of Sandal fruit adsorbent

Parameter	Adsorbent Values
Bulk density (g/cm^3)	0.92
Ash (%)	4.45
Iodine number(mg/g)	649.50
Surface area(m^2/g)	615.00
Particle density (g/cm^3)	1.25
Porosity (%)	26.40

Source: *Jibrin et al., 2015*

9.8 Equilibrium and Adsorption Study

The aim of the study was to produce activated carbon using melon seed shell which is harmless, cheap and abundant. This agricultural raw material when activated with HNO_3 as an activating agent to remove malachite green from aqueous solution, two step processes which involve carbonisation of the powder melon seed shell followed by activation of the carbon were used for the production of the activated carbon. Experimental data were analysed using Langmuir, Freundlich, Temkin and Harkin's-Jura adsorption isotherms. Characteristics of the activated carbon values produced is as shown in Table 9.

Isotherm parameters obtained for Langmuir are R^2 = 0.9461, 0.9183, 0.9653 and RL= 0.0468, 0.4640, 0.0712 for AC1, AC2 and AC3; for Freundlich are R^2 =0.9288, 0.8991, 0.9705 and n = 0.25, 0.41, 0.65 for AC1, AC2 and AC3; for Temkin are R^2 = 0.8273, 0.8430, 0.9019 for AC1, AC2 and AC3; for Harkin's-jura are R^2 = 0.8538, 0.8345, 0.8244 for AC1, AC2 and AC3. Adsorption capacity at equilibrium tends to increase as the initial concentration increases. Langmuir adsorption isotherm best described the adsorption processes because of the higher R^2 values (Idris *et al.*, 2013).

Table 9: Characteristics of the Activated Carbon (AC) Prepared from Melon Seed

Parameters	AC1	AC2	AC3
% Burn off	43.41 ± 0.01	77.73 ± 0.04	86.50 ± 0.02
% Yield	56.63 ± 0.02	22.32 ± 0.01	13.54 ± 0.03
Bulk density (g/cm^3)	9.76 ± 0.01	9.15 ± 0.06	8.34 ± 0.01
pH	6.18 ± 0.02	7.24 ± 0.01	7.12 ± 0.01
Conductivity (µS/cm)	1.50 ± 0.01	1.60 ± 0.01	1.80 ± 0.01

Source: *Idris et al., 2013*

9.9 Kinetics and Isotherm Study

The potential of chemically modified Bombax buonopozense Calyx to adsorbed Cr^{6+}, Mn^{2+} and Cd^{2+} ions from aqueous solutions are of prime intent in batch experiments. In this study, chemically modified activated carbon (AC) functionalized with H_2SO_4 (ACH) and KOH (ACK) were used in batch absorption process. The pseudo first, pseudo second, Natarajan and Khalaf first, Bhattacharya and Venkobachar first, Elovcih and intraparticle diffusion model rate equations were tested on kinetic data. The adsorption data followed the pseudo second order rate kinetics (Table 10).

Table 10: Kinetic Parameters for Adsorption of Cr^{6+}, Mn^{2+} and Cd^{2+}

Kinetic Model	Parameter	Cr^{6+} ACH	Cr^{6+} ACK	Mn^{2+} ACH	Mn^{2+} ACK	Cd^{2+} ACH	Cd^{2+} ACK
Pseudo first Order	R^2	0.807	0.606	0.954	0.841	0.821	0.790
	k_1 (min^{-1})	0.029	0.029	0.039	0.044	0.032	0.035
	q_e,(exp)(mg/g)	0.935	0.914	0.921	0.920	0.934	0.914
	q_e,(cal) (mg/g)	0.233	0.219	0.581	1.064	0.382	0.229
	SSE (%)	0.314	0.311	0.151	0.064	0.247	0.306
Pseudo second order	R^2	0.997	0.990	0.990	0.997	0.997	0.994
	k_2($mg.g^{-1}min^{-1}$)	0.143	0.084	0.089	0.062	0.107	1.022
	q_e,(exp)(mg/g)	0.935	0.914	0.921	0.920	0.934	0.914
	q_e,(cal) (mg/g)	0.995	1.011	1.014	1.033	1.010	0.977
	SSE (%)	0.027	0.048	0.042	0.050	0.034	0.028
Natarajan and Khalaf first Order	R^2	0.611	0.567	0.584	0.857	0.724	0.746
	k (min^{-1})	0.009	0.009	0.009	0.009	0.009	0.007
Bhattacharya And Venkobachar	R^2	0.852	0.865	0.975	0.924	0.855	0.674
	k_B (min^{-1})	0.037	0.039	0.046	0.053	0.037	0.018
Elovich	R^2	0.780	0.732	0.867	0.919	0.846	0.683
	a ($mg.g^{-1}min^{-1}$)	3.319	0.346	0.294	0.269	1.057	1.415
	β ($mg.g^{-1}min^{-1}$)	8.621	5.882	5.649	5.682	7.246	7.752

Source: *Musa et al., 2018*

The isotherm data were analysed for possible agreement with the Halsay model than Hurkins-Jura, Radlich-Peterson and Dubinin-Radushkevich models (Table 11). Correlation coefficient (R^2) values obtained ranged from 0.799 to 0.997. The results indicated high prospect of chemically modified Bombax buonopozense Calyx for Cr^{6+}, Mn^{2+} and Cd^{2+} ions removal (Musa *et al*., 2018).

The aforementioned adsorbents obtained from agricultural wastes are characterized by ready availability, affordability, eco-friendliness and high uptake capacity for heavy metals. Activated carbon from agricultural waste such as; Dum palm leaves and fronds, Poultry Waste, Dattock (*Detarium microcarpum*) Sweet

Table 11: Isotherm Constants for the Adsorption of Cr^{6+}, Mn^{2+} and Cd^{2+}

Isotherm Model	Parameter	Cr^{6+}		Mn^{2+}		Cd^{2+}	
		ACH	ACK	ACH	ACK	ACH	ACK
Hurkins-Jura	A_H (g^2/L)	1.071	1.021	0.968	1.011	1.202	1.238
	B_H (mg/L)	1.109	1.144	1.027	1.085	1.000	1.060
	R^2	0.826	0.832	0.879	0.799	0.823	0.897
	RMSE	4.612	4.942	4.329	3.962	4.369	7.207
	χ^2	17.88	4.942	14.68	12.97	12.82	43.59
Halsay	K_{HA} (mg/L)	0.876	0.755	0.886	0.867	1.049	0.851
	n_{HA}	1.996	1.996	1.812	1.934	1.176	2.062
	R^2	0.983	0.982	0.998	0.974	0.983	0.975
	RMSE	0.001	0.057	0.028	0.039	0.216	0.070
	χ^2	0.000	0.003	0.001	0.001	0.031	0.004
Radlich-Peterson	G	0.498	0.497	0.446	0.482	0.135	0.514
	K_R (L/g)	0.931	0.868	0.934	0.929	0.997	1.081
	R^2	0.982	0.981	0.997	0.970	0.659	0.977
	RMSE	0.001	0.049	0.018	0.049	0.223	0.066
	χ^2	0.000	0.002	0.000	0.002	0.034	0.004
Dubinin-Radushkevich (D-R)	B_D (mol^2/KJ^2)	0.946	0.997	0.909	1.057	1.245	0.925
	Q_D (mol/g)	3.597	2.175	3.789	3.846	6.606	3.432
	E_D (KJ/mol)	0.727	0.708	0.742	0.688	0.634	0.735
	R^2	0.970	0.962	0.946	0.987	0.993	0.915
	RMSE	0.229	0.294	0.044	0.211	0.095	0.335
	χ^2	0.044	0.074	0.092	0.037	0.006	0.094

***Source:** Musa et al., 2018*

Orange (*Citrus sinensis*) have been prepared for the removal of selected heavy metals (Idris *et al.,* 2012; Jimoh *et al.,* 2013; Yisa *et al*, 2011[d] & 2016).

10.0 CONCLUSION AND RECOMMENDATIONS

The era of environmental dormancy in overlooking the environmental chemical pollution and its effect is over. There is no doubt that chemical pollution has done a fair share of damage to the environment. Therefore, to control the deleterious effects of pollution and to minimize it, the following recommendations are made:

i. Government should promote integrated waste management with recycling, as well as cleaner technologies in production, and sound chemicals management.

ii. Government and various bodies should create a greater awareness and enforcing legislative control measures and policies as to the need to protect the environment.

iii. As a signatory to many Multilateral Environmental Agreements (MEAs), international conventions and protocols, Nigeria should address the sound management of chemicals and wastes to achieve sustainability in "green" economies and ensure the minimization of significant adverse effects of chemical pollution on human health and the environment.

iv. The need for collective responsibility to protect the environment for present and future generations, and adopt sustainable consumption and production strategies so that posterity may commend rather than condemn us.

v. Consumer demand, as well as green and sustainable chemistry education and innovation (e.g. through startups), are among the important drivers of change. They can be scaled up through enabling policies, reaping the potential benefits of chemistry innovations for sustainable development.

vi. Developing a database of assessed and classified chemicals for information-sharing and promoting harmonization of classifications.

vii. Setting targets to fill data gaps to fully understand the hazards of substances in commerce, and assessing progress.

viii. Developing harmonized approaches across sectors to share chemical information and to advance full material disclosure across supply chains, including chemical-intensive industry sectors and the recycling/waste sector.

ix. Strengthening collaboration by all actors in the supply chain in designing and using safer chemicals and sustainable products.

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PROFILE OF THE INAUGURAL LECTURER

Jonathan Yisa is a Professor of Chemistry in the Department of Chemistry, School of Physical Sciences. He was born in January 30, 1965 to the family of late Mr. Jeremiah Audu Yisa and Mrs. Elizabeth Nnadzwa Yisa (popularly known as Kedigi) in PatiShabakolo, Lavun Local Government Area of Niger State, Nigeria.

He commenced his educational pursuit at L. E. A. Primary School, Pati-Shabakolo in 1973 and completed his primary education in 1979. On completion, he gained admission to Government Technical College, Kontagora for his secondary education in 1979 but was later transferred to Government Science College, Kutigi in 1981 where he successfully completed the secondary education in 1984. He got admission into School of Basic Studies, Ahmadu Bello University, Zaria and obtained IJMB in 1985 upon which he was admitted to the Department of Chemistry, Ahmadu Bello University, Zaria the same year. He earned a B.Sc. Degree in Chemistry in 1988, M.Tech. Degree in Analytical Chemistry from The Federal University of Technology, Minna (1999) and PhD degree in Chemistry from Ahmadu Bello University, Zaria (2004).

Prof. Jonathan Yisa had his National Youth Service in Oyo State between 1988 and 1989 and thereafter began his academic career as an Assistant Lecturer with the Niger State College of Education, Minna in 1989. In 1990, he joined the service of The

Federal Polytechnic, Bida, lecturing in the Department of Science Laboratory Technology. He later transferred his services to Federal University of Technology, Minna as a Senior Lecturer in the Department of Chemistry in 2007, where he currently holds the rank of Professor of Chemistry Since 2013.

In maintaining an active research interest, Professor Yisa's interest focuses on: Development and application of analytical techniques in environmental studies; Chemical studies of local fruits, vegetables and indigenous plants as basis for their further utilization; Assessment and remediation of Industrial and Agricultural Wastes and analysis of industrial products to ensure conformity with standards. He has conducted externally-funded research and publishes regularly with his research students in reputable journals.

Prof. Yisa has supervised several undergraduate, M. Tech and PhD students. He has assessed many candidates for promotion to professorial ranks at many universities.

He has held several administrative positions in Polytechinic and University system. Some of which include:

- Director, School of Preliminary Studies, Federal Polytechnic, Bida, 2006 –2007.
- SIWES Coordinator, School of Science and Science Education, Federal University of Technology, Minna 2008 – 2010.
- Head, Department of Chemistry, Federal University of Technology, Minna 2010 – 2013.
- Industrial Liaison Officer/SIWES Coordinator, Federal University of Technology, Minna 2018 – 2019.
- Dean, School of Physical Sciences Federal University of Technology, Minna, 2019 – Date.

Prof. Yisa also served in a number of committees at the Federal University of Technology, Minna :

- Member, Junior Staff Disciplinary Committee, 2010 – 2012.
- Member of Professional and Academic Board of CPES, 2010 – 2013.
- Member, Staff Welfare Committee, School of Physical Sciences, 2011.
- Member, Committee to Look into the Operation of Academic Staff Taking up Visiting Appointment in other Universities, 2015.
- Member, School of Physical Sciences Committee to review the Condition of Service of Senior Staff, 2015.
- Chairman, Committee to investigate the case of illegal mining in the Main Campus, Gidan Kwano of Federal University of Technology, Minna, 2015.
- Member, Search Team for the Appointment of a New Vice-Chancellor for The Federal University of Technology, Minna, 2017.
- Senate Representative, Postgraduate School Board, 2018 – 2019.
- Member, Committee of Deans, 2019 – Date.
- Member, Senate Estimate and Budget Committee, 2019 – Date.
- Member, Promotions and Appointments Committee, 2019 – Date.
- Member, Senate Business Committee, 2019 – Date.
- Member, West African Science Service Centre on Climate

Change and Adapted Land Use (WASCAL) Board, 2019 – Date.

- Member, Directorate for Research, Innovation and Development Board, 2019 – Date.

While at The Federal Polytechnic, Bida, he served in the Department of Science Laboratory Technology as:

- Seminar Coordinator, 2004 – 2005.
- Examination Officer, 2005 –2006.

His contributions to national development are equally very impressive. He has served as Chairman and or member (Resource Person) of National University Commission in Accreditation Visitation Team to several Nigerian Universities.

Professor Yisa has also contributed to the development of other Polytechnics and Universities through the participation as External Examiner to:

- Niger State College of Agriculture, Mokwa, 2006 – 2010.
- Kogi State Polytechnic, Lokoja, 2007–2011.
- Ahmadu Bello University, Zaria, 2010 to Date.
- Federal Polytechnic, Bida, 2010– 2011, 2013 – 2016.
- Niger State Polytechnic, Zungeru, 2010 – 2016.
- Nile University of Nigeria, Abuja, 2012 – 2014.
- Baze University, Abuja, 2016 – Date.
- Ibrahim Badamasi Babangida University, Lapai, 2018 – Date.
- Nile University of Nigeria, Abuja, 2018 – 2019.
- University of Abuja, 2019.

Apart from the professional achievements, Prof. Yisa devoted considerable effort to community service as he served as:

- Member Senior Staff Football Team and Gold Medallist in Football at Yabani 1991 Federal Polytechnic, Nasarawa, 1991.
- Financial Secretary, PatiShabakolo Development Association, 1998 – 2003.
- General Secretary, PatiShabakolo Development Association, 2004 – 2008.
- Coordinator of Monotechnics, Polytechnics and Colleges of Education Matriculation Examination (MPCM) in Bida, 2006 – 2007.
- Vice Chairman, Chemical Society of Nigeria, Niger State Chapter, 2006 – 2010.
- Adviser, Fellowship of Christian Students, PatiShabakolo, 2010 – Date.
- Member, World Bank/CSDP Electrification Project of Patishabakolo Community, 2012 – 2016.
- Member local organizing committee of the 36th Annual International Conference of Chemical Society of Nigeria, 2013.
- Chairman, Chemical Society of Nigeria, Niger State Chapter, 2015 to 2018.
- Council Member, Chemical Society of Nigeria, 2015 to 2018.

Professionally, He is a fellow of the Chemical Society of Nigeria

(FCSN), Member of the Institute of Chartered Chemists of Nigeria (MICCON). He enjoys reading, writing, and watching football.

He is happily married to Mrs. Felicia Lami Yisa and they are blessed with three children: Nathaniel, Mercy, Nehemiah and a foster child, Naomi.

Note