FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

ENVIRONMENTAL POLLUTION MONITORING: MY UNIQUE CONTRIBUTIONS

By

PROF. JOHN OLUSANYA JACOB
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INAUGURAL LECTURE SERIES 86

28TH JULY, 2021

ISSN 2550 - 7087

2550 7087

global links communications
✆: 08056074844, 07036446818

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Published by:
University Seminar and Colloquium Committee
Federal University of Technology, Minna

28TH JULY, 2021

Professor Abdullahi Bala, **PhD, FSSSN**
Vice-Chancellor
Federal University of Technology, Minna
Chairman of the Occasion

Professor John Olusanya Jacob

B. Sc. (Ibadan), M. Sc., PhD (Abuja), C. Chem., MICCON, FCSN

Professor of Chemistry

1.0 INTRODUCTION

1.1 Chemistry and Mankind

It is not an overstatement to say that God created life and the universe and gave Chemists the right to explore and maintain it. Hence, the popular saying *Chemists recreate nature*. A Chemist is a person trained in the art of Chemistry. He performs experiments, verity laws and discovers new things through laboratory analysis.

Chemistry is the branch of science concerned with the composition of matter, the investigation of their properties and reactions, and the use of such reactions to form new substances. Matter is anything that has mass and takes up space (has volume). All matter is made up of chemical substances. A chemical substance is a material with known chemical composition. These include elements, compounds and mixture. Everything around us, including us is made up of chemicals. The Earth and all matter in it and on it are made up of chemical substances. Everything you hear, see, smell, taste or touch involves chemistry and chemicals. Hearing, seeing, tasting and touching all involve intricate series of chemical reactions and interactions in our body. Chemistry is the study of all things and everything, including you.

Chemistry is not limited to beakers and laboratories. It is all around us, and the better we know chemistry, the better we know our world. The knowledge of chemistry is applied in various fields of human endeavor. These includes; Agriculture, Medicine, Mining, Textile Industries, Military, Housing, Transportation, etc.

Hardly can anybody in this world live without going through the products of chemistry. Starting from time, you woke up from bed to the time you go back to bed. Therefore, the importance of chemistry and Chemists in our society cannot be over emphasized.

It is deductible that chemistry is the basis of all the chemical raw materials, the gas-phase reactions and the principal factors in the manufacture of drugs. The traditional medicine and its origin is traceable to the discipline of chemistry, being the only discipline that provides a scientific foundation for drug analysis. Chemistry is the basis of plastics and metal industries, and it forms the bedrock of geo-sciences. In the detoxification of waste and chemical analysis, a sound knowledge in chemistry is a *sin qua non.* The application of chemicals has not only improved the yield of crops but has helped to regulate harvest time, the shape as well as storage life of crops.

The conversion of wood and other cellulose bearing materials into pulp and paper and the production of inks and pigments, chalks, tapes by chemists have helped in global mass education and mass communication. Household materials such as toothpaste, soaps, detergents and cosmetics are products of Chemistry. Construction materials, such as steel and cement are also products of chemistry.

In Nigeria today, the greater percentage of our national income comes from petroleum and natural gas. Those behind these are Chemists. There is hardly any aspect of life that Chemists are not involved. I thank God that I am a Chemist!

1.2 The Environment

Environment can be defined as a system comprising the earth, living things, non-living things and the water, air and soil where they live. The basic components of the Earth environment are the

Atmosphere (or the air), the Lithosphere (rocks and soil), the Hydrosphere (or the water), and the living component called the Biosphere (Plate 1).

Plate 1: The Earth Environment

In a broader form, the environment is an inseparable whole and is constituted by the interacting systems of physical, biological and cultural elements, which are interlinked individually as well as collectively in myriad ways. Physical elements (space, land-forms, water bodies, climate, soils, rocks and minerals) determine variable characters of the human habitat, its opportunities as well as limitations. Biological elements (plants, animals, micro-organisms and man) constitute the biosphere. Cultural elements (economic, social and political) are essentially man-made futures. Since human inhabits the natural world as well as the technological, social and cultural world, all constitute the environment.

Environmental knowledge is a multi-disciplinary one, whose fundamental aspects have a direct significance to every segment of the planet. Its main characteristics include:

i. Conservation of natural resources
ii. Maintenance and management of biological diversity
iii. Controlling and managing environmental pollution to permissible limits.
iv. Stabilization of human population and environment
v. Development of alternative sources of renewable energy system.
vi. Providing new dimension to national security through conversation, protection, management and maintenance of environment.

It also deals with vital issues like safe and clean drinking water, hygienic living conditions and pollution free fresh air, fertility of land, healthy food and development of sustainable environmental laws, administration and environmental protection. The relationship between organism and environment are highly complex and multidimensional. No organism can live alone without interacting with other organisms or other biotic/abiotic forms. So each organism has other organisms as a part of its environment. Each and everything with which we interact or which we need for our sustenance forms our environment.

1.3 Environmental Chemistry

Environmental Chemistry is the study of the chemical and biochemical phenomena that occur in nature. It involves that understanding of how the uncontaminated environment works, and which naturally occurring chemicals are present, in what concentrations and with what effects. Without this it would be impossible to study accurately the effects that humans exert on the environment through the release of chemical species. It is a multi-disciplinary science that, in addition to chemistry, involves physics, life sciences, agriculture, material science, public health, sanitary engineering, and so on. More or less, it is the study of the sources, reactions, transport, effects, and fate of chemicals species in the air, water and land, and the effects of human activities upon the various environmental segments, such as atmosphere, hydrosphere, lithosphere and biosphere.

Many environment issues exist that have grown in size and complexity day by day, threatening the survival of mankind on earth. The various incidences of such environmental issues include de London Smog of 1952 killing about 4,000 people, the Mediterranean seas turning into Dead Sea in the 1950s, unable to support aquatic life, death of a number of Japanese because of eating fish from the Minamata Bay in the 1960s, historical movements and statues in Greece and Italy getting damaged by the effect of polluted rainwater, while marble of Taj Mahal in India becoming yellow by the action of sulphur dioxide fumes, leakages of methyl isocyanate vapour at Bhopal in India in 1984 and the hazardous effects of nuclear weapons and radiations on the people of Hiroshima and Nagaski (Gupta *et al*., 2015). More recently we have the nuclear explosion and pollution of water bodies in Japan in 2011. In Nigeria contamination of land and water bodies by oil spills and lead from mining sites is well known.

2.0 ENVIRONMENTAL POLLUTION MONITORING AND CONTROL

2.1 Environmental Pollution

> *"Be it known to all within the sound of my voice, whoever shall be found guilty of burning coal shall suffer the loss of his head."*
>
> *– King Edward II*

Environmental Pollution is not a new problem; as King Edward II of England (1307-1327) tried to abate what his wife Eleanor of Aquitaine called 'Britain's unendurable smoke' by prohibiting the burning of coal while parliament was in session. (Peirce *et al*., 1998).

Environmental Pollution can be defined as introduction of waste matter or toxic substance into the environment, which directly or indirectly causes damage to man and his environment. It is an undesirable change in chemical, physical, and biological characteristics of air, water and soil, which causes health problem to living beings (Gupta *et al*, 2015).

A pollutant is a substance or effect which adversely alter the environment by changing the growth rate of species, interferes with food chain, toxic and hence interfere with health, comfort and properties. Sources of pollutant could also be natural e.g. volcanic eruption, flooding, earthquake, etc. The environment has been polluted by various chemicals, such as, oxides of carbon, oxides of sulphur, oxides of nitrogen, hydrocarbons, metal dust, smoke, agro chemicals, e-waste, radionuclides, etc (Plates 2 – 4).

Plate 2: Air Pollution from industrial activities

Plate 3: Water Pollution as a result of indiscriminate dumping of refuse

Plate 4: Land Pollution as a result of indiscriminate dumping of refuse

2.2. Causes of Environmental Pollution

The most striking reason of the environmental degradation and hence global environmental crisis is the fact of deteriorating relationship between man and his environment because of rapid rate of exploitation of natural resources, technological development and industrial expansion. The rate of environmental change and resultant environmental degradation caused by human activities has been so fast and widespread.

The impact of man on environment through his economic activities are varied and highly complex as the transformation or modification of the natural condition and process lead to a series of changes in the biotic and abiotic component of the environment.

The impact of man on the environment falls into two categories:

i. Direct or Intentional Impacts, and
ii. Indirect or Unintentional Impacts.

Direct or Intentional impact of human activities are preplanned and premeditated because man is aware of the consequence, both positive and negative. The effects of anthropogenic changes in the environment are noticeable within short period and these effects are reversible.

On the other hand the indirect impact of human activities on the environment are not premeditated and preplanned and these impact arise from those human activities which are directed to accelerate the pace of economic growth, especially industrial development. The indirect impact are experienced after long time when they become cumulative. These indirect effects of human economic activities may change the overall natural environmental system and the chain effects sometimes degrade the environment to such an extent that this becomes suicidal for man (Appannagari, 2017).

The problem of environmental pollution is a complex consequence of forces connected with various interrelating factors. These are clearly a number of divergent and conflicting views of what could be the basic factors underlying the environmental crisis. No single cause can be considered as the root cause of environmental impairment. However, the following causes could be pointed out as the general underlying factors though each of these too could be operating simultaneously and their balance may vary from place to place and though time.

Population Growth: Increase in population will have a multiplier effect requiring proportionate increase in all requirements necessary for the existence of human beings. Some pollution problems increase more or less in step with population growth, such as the amounts of human waste. The concentration of population is a very important factor. Natural processes are capable of handling the wastes from a population of sufficiently low density, while higher densities put more and more strain on these processes.

Technological Development: The nature of productivity technology in recent years is closely related to the environmental crisis. This factor has been largely responsible for the generation of synthetic and non-biodegradable substances such as plastics, chemical nitrogen fertilizers, synthetic detergents, and synthetic fibres, petrochemical and other environmentally injurious industries. Thus, environmental crisis is the inevitable result of a counter ecological pattern of productive growth (Appannagari, 2017).

Deforestation: Forests are invaluable property of a nation because they provide raw materials to modern industries, timber for building purposes, habitats for numerous types of animals and micro-organisms. It is a matter of serious concern that the present economic man has forgotten the environment and ecological significance of natural vegetation mainly forests and grasslands and has destroy the forest so rapidly and alarmingly that the forest areas as global, regional and local levels have so markedly decreased that several serious environmental problems such as accelerated rate of soil loss through rain splash, sheet wash, rill and gully erosion, increase in the frequency and dimension of floods, incidence of drought, due to decrease in precipitation, etc. have plagued the modern human society (Appannagri, 2017).

Agricultural Development: Bids to improve on agricultural activities in order to meet up with the ever widening quests for food have led to the use of different chemicals, adoption of technologies which can elicit odours, dust, smokes and allergic pollens. Pollution form agricultural activities may come from a variety of sources. Once in the environmental, the pollutants can have direct effects in the surrounding ecosystem. Pesticides and herbicides are applied to agricultural land to control pests that disrupt crop production. Soil contamination can occur when pesticides persist and accumulate in soils, which can alter microbial processes, increase plant uptake of the chemical, and are toxic to soil organisms. Fertilizers are used to promote plant growth and increase crop yields, they can also disrupt natural nutrients and mineral biogeochemical cycles and pose risks to human and ecological health.

The major input of heavy metals and radioactive elements into agricultural soil are fertilizers, organic wastes such as manures and industrial product wastes. Heavy metals present in the environment can be taken up by plants, which can pose health risk to humans in the event of consuming affected plants. Steel industry wastes, which are often recycle into fertilizers due to their levels of zinc, essential to plant growth, can also contain toxic metals, such as arsenic, lead, mercury, cadmium, chromium and nickel (Leticia *et al*., 2016).

Industrial Development: All organisms are mainly affected directly or indirectly by environmental pollution resulting from rapid industrialization. Environmental pollution by industrial revolution is a major problem facing the world today and there is an increasing awareness of the fact that a clean environment is necessary for better health of living organisms. Industrial projects have a profound influence on society and the environment not only in terms of benefits but also in risks and hazards.

It is exact to say that the industrial revolution of the 19^{th} Century is mainly responsible for environmental pollution. This environmental pollution added by different industries is causing a great threat to human, animals as well as to plants. Development of new technologies and anthropogenic activities has affected environmental quality in many ways. Industrial wastes are disposed into the environment with no proper monitoring and management.

Environmental pollution by different types of industries occurs in different forms but can usually be thought of gaseous and particulate pollutants that are discharged from different industries and become part of the earth's atmosphere. The gaseous pollutants of industrial polluted environment consist of sulphur dioxide (SO_2), different oxides of nitrogen (NOx), ozone (O_3), carbon monoxide (CO), hydrogen sulphide (H_2S), and hydrogen fluoride (HF) (Kabir *et al.,* 2020).

Such contaminants are released from large industrial estate, such as fossil fuel fired power plants, smelter, industrial boilers, petroleum refineries and manufacturing facilities. These are toxic substances which cause damage to environmental balance, cause injury to living organisms, producing respiratory diseases and reduce visibility. Different contaminants occur as toxic substances in the earth crust or biosphere and anthropogenic activities such as mining, industry, agriculture and other such activities support their release into the environment, leading to toxicity (Lohchab & Saini, 2017).

Urbanization: One of the major threats to the Nigeria environment is urbanization (Ohwo & Abotutu, 2015). Urban development can magnify the risk of environmental hazards such as flash flooding, elevated lead levels in urban air from automobile exhaust, large volumes of uncollected wastes, and concentrated energy use, which leads to greater air pollution. A lot of pollutants are created by factories which are concentrated in the urban areas. They release smoke into the air, harmful waste into water streams and surrounding land, and also make a lot of noise because of their machines. The trends towards urbanization in most countries of the world are aggravating pollution problems. The rising standard of living in most of the countries of the world has been accompanied by increased industrial production, increased motor fuel consumption and similar increase in other pollution producing activities.

Pollution of the ecosystem by toxic pollutants during man's activities is aggravated in the urban centers and pose serious problems. These pollutants are concentrated due to physical, chemical and biological processes and these have a substantial societal impact of a contaminated system.

The greatest catastrophe of the 21st century is the over-exploitation of natural resources, by the growing population, which has severely strained their limited quantity. Consequently, adverse environmental effects like species extinction, loss of forest systems, acid rains, global warming, ozone depletion, and hazardous waste disposal problems, frequent and intense eco-accident are on the rise. Too many cars, too many factories, too much detergents, too much pesticides, multiplying contrails, inadequate sewage treatment plants, too little water, too much carbon dioxide, all can be traced to too many people (Cho & Choi, 2014). Tables 2.1 and 2.2 show major sources and effects of some pollutants in the environment.

Table 2.1: Sources and Effects of Some Atmospheric Pollutants

S/No	Pollutant	Major Sources	Effects
1	Sulphur dioxide	domestic fires, oil refineries, electricity generation, combustion of fossil fuels iron and steel works, etc.	damage to materials and properties, fading of fabrics, accelerates corrosion of materials, yellowing of leaves, acid rain
2	Hydrocarbons	vehicle emission, petroleum refineries	eye irritation, irritation of mucous membranes of the lungs, inhibition of plant growth
3	Oxides of carbon	combustion of fuels, motor vehicle emissions	CO_2 is a greenhouse gas, CO reduces oxygen-carrying capacity of blood
4	Oxides of nitrogen	vehicle emissions, nitric acid plant, electricity generation, iron and steel works, fertilizer plants, animal and human wastes	corrosion of metals, involved in photochemical air pollution N_2O is a greenhouse gas causing global warning, NO is involved in ozone depletion
5	Mercaptan (Thiols – SH)	oil refineries	specifically toxic to red blood cells
6	Ammonia	ammonia production and usage, manufacture of nitrogenous fertilizer	causes damage to respiratory muscles
7	Metals and other particulates	specific metal works, vehicle emissions, domestic firers, electricity generation, incineration of wastes, ceramic manufacture, cement works, oil refineries, volcanic eruptions	carcinogenic e.g. As, Be, Cd, Ni and Cr (VI), low IQ, asthma, kidney damage, copper causes Wilson's disease, liver damage, heart problems, brain damage e.g. mercury, skin irritation etc.

Source: Ghorain-Azam *et al*., 2018; Mani-Salidis, *et al*., 2020

Nitrogen dioxide is formed by the reaction of nitrogen monoxide with oxygen. It is therefore a secondary pollutant.

$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$

The toxic effects of CO on human beings and animals arise from its combination with haemoglobin (Hb) in the blood.

$HbO_2 + CO \rightarrow HbCO + O_2$

Table 2.2. Sources and Effects of Some Water Pollutants

S/No	Pollutant	Major Sources	Effects
1	Oxygen Demanding Waste	urban environment, domestic and industrial food processing	depletion of oxygen level, eutrophication, decrease water quality
2	Organic chemicals e.g. pesticides, detergents, and petroleum wastes	agricultural activities oil spills, sewage disposal, industrial processes	environmental destructions, eutrophication, destruction of aquatic life
3	Chemical carcinogens and pathogens	uncontrolled waste and sewage disposal	cancer, dysentery, typhoid, etc.
4	Sediments	leaching, wind, solid wastes	decrease water quality, adverse health effects on aquatic organisms
5	Inorganic chemicals and minerals, heavy metals, organometallics, etc.	industrial activities, commercial activities, leaching, refuse dumps, mining	reduced water quality, adverse health effects on aquatic organisms
6	Radionuclides	nuclear power stations, nuclear explosion, waste disposal, mining	adverse health effect on aquatic organisms and man when he feeds on the aquatic organisms
7	Thermal effluents	power stations, industrial effluents, urban activities	high temperature of water decrease level of dissolved oxygen, reduced photosynthesis in aquatic plants

Source: Pathak, 2013; Singh and Gupta, 2016

2.3 Environmental Pollution and Global Warming

Global warming is an increase in the Earth's surface temperature with potentially disastrous climatic effects. Major causes of global warming include depletion of ozone layer and greenhouse effect.

Depletion of ozone layer: The release of certain chemicals, such as CFCs and oxides of Nitrogen, into the atmosphere depletes the ozone layer as they form radicals which react with ozone to form diatomic oxygen. The thinning of the ozone layer results in more U.V radiation of wavelength below 320 mm reaching the Earth's surface. When this radiation is absorbed in tissues by nucleic acids may affect genetic formations, leading to increased levels of skin cancer in humans, especially people with fair skin, with no pigments that help to screen out the U.V rays. Crop yields will also be reduced to cell damage. Larvae of fish, shrimps and crabs, zooplanktons are in turn eaten by fish. The fish are then eaten by other animals and man. Therefore, effects of an upset in the ecological balance of planktons would be passed up the food chain. Destruction of phytoplanktons would also lead to more CO_2 in the atmosphere, as photosynthesis is reduced and this will lead to greenhouse effect and global warming.

Green House Effect: The presence in the atmosphere of certain pollutant gases called green-house gases, such as CO_2, CH_4, N_2O, O_3 and CFCs will lead to global warming. The incoming radiation from the sun is re-emitted from the Earth's surface in form of infrared (IR), in order to keep the Earth's surface temperature constant. However, part of this IR radiations are absorbed by the green-house gases in the atmosphere and are re-emitted back to the Earth, keeping the Earth's surface relatively warm (Ramanathan & Feng, 2009).

2.4 Environmental Pollution Monitoring

Environmental pollution monitoring is the processes and activities that need to take place to characterize and monitored the quality of the environment. Environmental monitoring is used in the preparation of environmental impact assessments, as well as in many circumstances in which human activities carry a risk of harmful effects on the natural environment. All monitoring strategies and programmers have reasons and justifications which are often designed to establish the current status of an environment or to establish trends in environmental parameters.

Air quality monitoring is challenging to enact as it requires the effective integration of multiple environmental data sources, which often originate from different environmental networks and institutions. These challenges required specialized observation equipment and tools to establish air pollutant concentrations. Air quality monitors are operated by regulatory agencies and researchers to investigate air quality and the effects of air pollution. Interpretation of ambient air monitoring data often involves a consideration of a spatial and temporal representativeness of the data gathered and the health effects associated with exposure to the monitored levels.

Soil monitoring involves the collection and/or analysis of soil and its associated quality, constituents and physical status to determine or guarantee its fitness for use. Soil faces many threats, including compaction, contamination, organic material loss, biodiversity loss, slope stability issues, erosion, salinization and acidification. Soil monitoring helps characterize these threats and other potential risks to the soil surrounding environments, animal health and human health. Assessing these threats and other risks to the soil can be challenging due to a variety of factors, including soil's heterogeneity and complexity, scarcity of toxicity data, lack of understanding of a contaminant's fate and variability in levels of soil screening.

Soil monitoring has historically focused on more classical conditions and contaminants, including toxic elements, e.g. mercury, lead and arsenic and persistent organic pollutants. Historically, testing for these and other aspects of soil, however, has had its own set of challenges as sampling in most cases is destructive in nature, requiring multiple samples over time.

Additionally, procedural and analytical errors may be introduced due to variability among references and methods, particularly over time. However, as analytical techniques evolve and new knowledge about ecological processes and contaminant effects disseminate, the focus of monitoring will likely broaden over time and the quality of monitoring will continue to improve (Cachada, *et al.,* 2017).

Water of good quality is crucial to sustainable socio-economic development. Aquatic ecosystem is threatened on a world-wide scale by a variety of pollutants as well as destructive land use or water management practices. Gross organic pollution leads to disturbance of the oxygen balance and is often accompanied by severe pathogenic contamination. Accelerated eutrophication results from enrichment with nutrients from various origins, particularly domestic sewage, agricultural run-off and agro-industrial effluents. Lakes and impounded rivers are especially affected.

Agricultural land use without environmental safeguards to prevent over-application of agro chemicals is causing widespread deterioration of the soil/water ecosystem as well as the underlying aquifers. The main problem associated with agriculture are salinization, nitrate and pesticide contamination and erosion leading to elevated concentrations of suspended solid in rivers and streams and the situation of impoundment. Direct contamination of surface waters with metals in discharges from mining, smelting and industrial manufacturing is a long-standing phenomenon. However, the emission of airborne metallic pollutants has now reached such proportions that long-range atmospheric transport causes contamination, not only in the vicinity of industrialized regions, but also in more remote areas. Similarly, moisture in the atmosphere combines with some of the gases produced when fossil fuels are burned and falling as acid rain, causes acidification of surface waters, especially lakes. Contamination of water by synthetic organic micro pollutants results either from direct discharge into surface waters or after transport through the atmosphere. Today, there is trace contamination not only of surface water but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites.

A pressing need for comprehensive and accurate assessments of trends in water quality has emerged, in order to raise awareness of the urgent need to address the consequences of present and future threats of contamination and to provide a basis for action at all levels. Reliable monitoring data are the indispensable basis for such assessments (UNEP/ WHO, 1996).

2.5. Pollution Control

Changing or eliminating a process that produces a pollutant is often easier than trying to trap the pollutant. A process or product may be necessary but could be changed to control emissions. For example, automobile exhaust once caused high lead levels in urban air. Elimination of lead from gasoline which was needed for proper catalytic converter operation, reduced lead pollution in the environment. Similarly, removal of sulphur from coal and oil before the fuel is burned has reduced the amount of sulphur dioxide emitted. In these cases, the source of pollution was corrected. Process may also be modified to reduce pollution. Odours from municipal incinerators may be controlled by operating the incinerator at a high enough temperature to effect more complete oxidation of odour-producing organic compounds, while sewage must be treated before their discharge into water bodies. In summary, the three technical methods for controlling pollution in order to meet emission standards are:-

i. Process change.
ii. Raw material substitution.
iii. Equipment modification.

These are known as controls. In contrast, abatement refers to all devices and methods for decreasing the quantity of pollutants once it has been generated by the source.

2.6 Monitoring of Heavy Metals Pollution

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. They are non-biodegradable and persistent environmental contaminants. They also include metalloids, such as arsenic, which are able to induce toxicity at low level of exposure (Hassan, *et al*., 2016). Heavy metals occur in the environment in both free as well as bound forms. Although they are found naturally in the earth crust, they become concentrated in the environment as a result of human activities. Other metals which do not fall into the above definition but of environmental importance are often roughly refer to as heavy metals by Environmental Chemists (Duffus, 2002).

Monitoring and analysis of heavy metal concentrations in the environment are necessary for pollution assessment and control. The levels or concentrations of potentially toxic metals and metalloids should be regularly monitored in the different environmental media such as air, water, sediments and soils as well as in the resident biota. Such environmental analysis will provide useful information about distribution, principal sources and fate of these elements in the environment and their bioaccumulation in the food chains. Such analysis is also used to assess the risk posed by these elements to wildlife and human health.

A more meaningful assessment of the impact of metal pollution may be obtained by measuring metal concentrations in selected species of the resident biota. Different plant and animal species have been used as bio-indicators to assess and monitor heavy metal contamination and pollution in the environment. Different environmental biomarkers are also used to assess and monitor pollution pertaining to heavy metals in the environment (Broadley *et al*., 2006).

2.6.1 Importance of heavy metals

Heavy metals such as copper, chromium, iron, manganese, molybdenum, nickel, selenium and zinc are essential nutrients that are required for various biochemical and physiological functions. Inadequate supply of these micro-nutrients results in a variety of deficiency diseases or syndromes. They are also considered as trace elements because of their presence in trace concentrations in various environmental matrices. Their bioavailability is influenced by physical factors such as temperature, phase association, adsorption and sequestration. It is also affected by chemical factors that influence speciation at thermodynamic equilibrium, complexation kinetics and lipid solubility. Biological factors such as species characteristics, trophic interactions and biochemical/physiological adaptation also play an important role (Stern, 2010).

The essential heavy metals exert biochemical and physiological functions in plants and animals. They are important constituents of several key enzymes and play important roles in various oxidation-reduction reactions. Copper for example serves as an important co-factor for several oxidative stress related enzymes, including catalase, superoxide dismutase, peroxidase, cytochrome oxidases, ferroxidases, monoamine oxidase and dopamine β-monooxygenase. Several other excessive elements are required for biological functioning; however, an excess amount of such metals produces cellular and tissue damage leading to a variety of adverse effects and human diseases (Tchounwou, *et al*., 2014).

For some heavy metals including chromium and copper, there is very narrow range of concentrations between beneficial and toxic effects. The ability of copper to cycle between an oxidized state, Cu(II), and reduced state, Cu(I), is used by cuproenzymes involved in redox reactions. However, it is this property of copper that also makes it potentially toxic, because the transitions between Cu(II) and Cu(I) can result in the generation of superoxide and hydroxyl radicals. Excessive exposure to copper has also been linked to cellular damage leading to Wilson's disease in humans. Other heavy metals such as arsenic, cadmium, lead, mercury, barium, platinum, silver and gold have no established biological functions and are considered as non-essential. (Wang & Shi, 2001).

In biological systems heavy metals have been reported to affect cellular organelles and components such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei and some enzymes involved in metabolism, detoxification, and damage repair. Metal ions have been found to interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis. Because of the high degree of toxicity of arsenic, cadmium, chromium, lead and mercury, they rank among the priority metals that are of great public health significance. They are all systemic toxicants that are known to induce multiple organ damage, even at low levels of exposure (Tchounwou, *et al*., 2014).

Heavy metals have been found useful in golf clubs, cars, antiseptics, self-cleaning ovens, plastic manufacture, solar panels, mobile phones and particle accelerators. However, they get their way into the environment as a result of improper use of materials and incriminate disposal of waste materials.

Although some heavy metals called essential heavy metals play important roles in biological systems, they are generally toxic to living organisms depending on dose and duration of exposure. Non-essential heavy metals such as Cd, Pb, Hg and As may be toxic even at quite low concentrations. Essential heavy metals are required in trace quantities in the body but become toxic beyond certain limits or threshold concentrations. For some elements, the window of essentiality and toxicity is narrow. The toxicity is primarily due to their reaction with Sulfhydryl (SH) enzyme systems and their subsequent inhibition, e.g. those enzymes involved in cellular energy production. Plate 5 shows the reaction of a heavy metal (M) with glutathione (GSH), an important antioxidant in the body. Here the metal replaces H atoms from SH groups on two adjacent glutathione molecules. The engagement of the two glutathione molecules in formation of strong bond with the metal deactivates prevent them from further reactions.

$$2\,\text{glutathione} + \text{metal ion}\,(M^{2+}) \rightarrow M(\text{glutathione}) + 2H^{+}$$

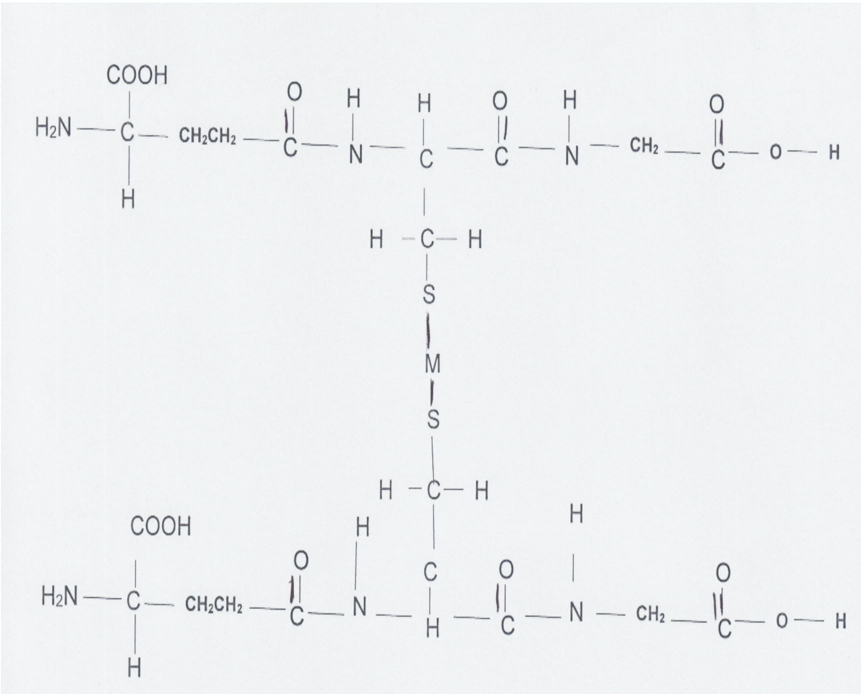

Plate 5: Metal - glutathione complex

Plates 6 – 11 and Table 2.3 show major health effects of some toxic heavy metals.

Plate 6: Effect of Pb poisoning: *Damage to teeth* and gum

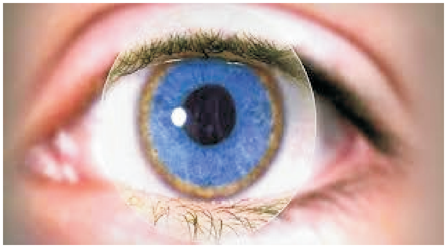

Plate 7: Effect of Cu poisoning: *Wilson disease*

Plate 8: As poisoning: *Damage to the skin*

Plate 9: Effect of Ni poisoning: *Skin cancer*

Plate 10: Effect of Cd poisoning: *Bone deformation (itai itai disease)*

Plate 11: Effect of Hg poisoning: *Minamata disease*

Table 2.3: Health Effects of Some of the Most Toxic Heavy Metals

Metal	Human Health Effects
Arsenic	Damage to kidneys, CNS, digestive and skin system. Causes nausea, anemia and cancer
Lead	Damage to bones, brains, blood, kidney and thyroid gland
Mercury	Damage to brain and kidney causes anxiety, hearing loss and depression
Cadmium	Damage to liver, placenta, kidneys, lungs, brain, and bones, causes hypertension, anemia and cancer
Nickel	Chronic bronchitis, cancer, ear problem, liver damage and skin irritation.
Chromium	Chronic exposure of Cr (VI) is mutagenic. It can also lead to asthma.
Copper	Nausea, vomiting, abdominal pain, breakdown of red blood cells and Wilson's diseases in children.
Zinc	Vomiting, diarrhea, bloody urine, liver failure and anemia

Source: Duffus, 2002

2.6.2 Common sources of heavy metals in the environment

Sources of heavy metal in the environment can be both natural and anthropogenic. The natural sources of heavy metals in the environment include weathering of metal-bearing rocks and volcanic eruptions. The global trends of industrialization and urbanization on earth have led to an increase in the anthropogenic share of heavy metals in the environment. The anthropogenic sources of heavy metals in the environment include mining and industrial and agricultural activities. These metals are released during mining and extraction of different elements from their respective ones. Heavy metals released to the atmosphere during mining, smelting and other industrial processes return to the land through dry and wet deposition. Discharge of waste waters such as industrial effluents and domestic sewage add heavy metals to the environment. Application of chemical fertilizers and combustion of fossil fuels also contribute to the anthropogenic input of heavy metals in the environment. Combustion of fossil fuel in industries, homes and transportation is anthropogenic source of heavy metals. Vehicle traffic is among the major sources of heavy metals such as Cr, Zn, Cd and Pb. High concentrations of environmentally important heavy metals have been reported in soils and plants along roads in urban and metropolitan areas (Ali *et al*, 2019).

The anthropogenic sources of chromium include electroplating industries, leather tanneries, textile and steel industries. Battery production is a good source of lead in the environment. Heavy metals are also introduced into the environment by the manufacture and use of materials containing heavy metals, as well as the disposal of these wastes. Soil is contaminated by materials from the air and by direct deposition of pollutants. Chief among these manufactured materials are electronic wastes. The dumping of carcasses of old or damage vehicles on land occurs in all towns and villages. Military ammunitions are also major worldwide sources of soil heavy metals contaminants, which wind or rain can sometimes disperse to great distances from their point of use or disposal (Ali *et al*., 2019).

Domestic and industrial waste waters, sewage discharge and urban run-off also contribute large quantities of metal pollution to the aquatic environment. Incineration is a major contributor of air-borne cadmium; however, emissions from incinerators are largely dependent on the composition of the waste material. Researchers have reported emissions of arsenic, beryllium, cadmium, copper, iron, mercury, manganese, nickel, lead, antimony, titanium, vanadium and zinc from municipal incinerators over a wide concentration range (Lee & Duffield, 1999). Table 2.4 shows the industrial sources of some of the most toxic heavy metals.

Table 2.4: Industrial Sources of Some of the Most Toxic Heavy Metals

Metal	Manufacturing Industries
As	phosphate fertilizer, metal hardening, paint and textile
Pb	paint, battery
Hg	chlor-alkali, scientific instruments, chemicals
Cd	phosphate fertilizer, electronics, pigments, paints and Ni-Cd batteries
Ni	electroplating, iron and steel
Cr	metal plating, tanning, rubber and photography
Cu	electroplating, rayon and electrical materials
Zn	galvanizing, electroplating, iron and steel

Source: Mahurpawar, 2015

2.6.3. Remediation of Heavy Metal Contamination in the Environment

In general, it is very difficult to eliminate metals from the environment. They are non-biodegradable and hence once they are introduced and contaminate the environment, they will remain. Remediation methods can be classified as mechanical (physical), chemical or biological. Most treatment procedures use combinations of these methods (Song, 2003).

Mechanical or physical methods of remediation include high temperature treatment to produce a vitrified, granular and non-leachable materials, washing process to leach out contaminants, draining of wet soil to improve soil aeration and allow metals to oxidize, making them less soluble and less available (except for chromium), contaminated soil can be evacuated from the site and placed in a sanitary land fill, etc.

Chemical remediation methods include stabilizing and somewhat detoxifying the metals *in situ* using chelators. An example is the addition of phosphate to soils contaminated with lead, forming an insoluble pyromorphite compound that remains inert in soil. Care should be taken with phosphorus applications because high levels of phosphorus in soil can result in water pollution. Active organic matter is also active in reducing availability of chromium. Various types of adsorbents, such as, activated carbon from agricultural waste, grapheme-based chitosan, clay, polymers, metal oxides and nanocomposites have been used for the removal of toxic substances from water. Agricultural wastes are particularly useful because they are readily available, affordable, eco-friendly and high capability for heavy metal uptake due to the presence of functional groups which can bind metals for their effective removal.

Bioremediation involves the use of micro-organisms, fungi, green plants (phytoremediation) or their enzymes to return the natural environment altered by contaminants to its original condition. The need for greater priority to be given to research into bioremediation could be better appreciated if it takes cognizance of the fact that, in recent time, there had been a rapid expansion and increasing sophistication of the chemical and electronic industries, with the applied consequence of an increasing amount and complexity of toxic waste effluents and electronic wastes. Bioremediation is not only a clean-up process, but also an avenue for material recovery and recycling. Phytoremediation is the most popular bioremediation technique. It involves de-polluting contaminated soils, water or air with plants that are able to contain, eliminate, or render harmless, metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants, from medial that contain them (Okonkwo, 2008).

3.0 MY UNIQUE CONTRIBUTIONS TO ENVIRONMENTAL POLLUTION MONITORING AND CONTROL

3.1 Why Are My Contributions Unique?

They are unique in the sense that no any researcher had contributed exactly what I have contributed, in terms of content, time and place. Similarly, no any other researcher would ever contribute exactly what I have contributed, in terms of content, time and place. These contributions include training, research and creating awareness. Majority of these contributions are in the area of monitoring toxic heavy metal pollutants in the environment.

3.2 My Specific Investigations

Several research work were done in monitoring toxic heavy metals in air, water, sediment and fish and as well as in agricultural soils and food crops. Because of time constrain, we shall look at a few of them. In these investigations, I acknowledge the roles and collaborations of some of my mentors, mentees, students and research assistants.

3.2.1 Monitoring Heavy Metals in Air

(i) Assessment of atmospheric concentration of Pb, Zn and Cd in Kudenda Industrial Layout, Kaduna, using Moss as bio-monitor (Jacob, 2008). The moss was identified by expert as *Funnaria hygrometric*.

Analysis of biological materials has been found useful in evaluating the concentrations and effect of trace heavy metals in the environment. This is related to the biotransformation and bio-accumulation of heavy metal in living system.

The usual procedure is to prepare the sample by removing or breaking down the organic matrix to release the metal ions into solution either by the use of hot oxidizing acid(s) singly or as a mixture (Wet Digestion), or in the dry state with atmospheric oxygen using or muffle furnace at 500°C to leave only non-combustible ash and subsequent dissolution of the mineral constituents with acid (Dry Ashing).

In wet digestion, the choice of acid mixtures is very important. Common acids used are H_2SO_4, HNO_3, HCl, $HClO_4$ and HF. H_2O_2 is also used in some cases. Heating devices include hot plate, water bath, heating mantle and microwave oven.

Solution of digests is then subjected to instrumental analysis to determine the heavy metal concentrations. Techniques used include AAS, ICP-AES, ICP-MS, XRF spectroscopy, Neutron Activation Analysis (NAA), Voltammetry and Colorimetric. Control samples and certified reference materials were also subjected to the same procedure. Results obtained are usually compared with that of control samples and international standards. Summary of results for Kudenda industrial area is shown in Table 3.1.

Table 3.1: Mean and Range of Pb, Zn and Cd Concentrations (mg/kg dry weight)

Metal	Study Site	Control Site	Accumulation Factor
Pb	$88.2 \pm 37.9_a$ $(48 - 168)_b$	26.5 ± 3.5 (24 – 29)	3.3
Zn	85.8 ± 23.4 (52 – 126)	14.0 ± 2.8 (12 – 16)	6.1
Cd	0.62 ± 0.13 (0.41 – 0.81)	0.43 ± 0.04 (0.40 – 0.45)	1.4

a = mean ± sd, b = range

Findings and Implications: The values for Pb and Zn were higher than the internationally accepted values of 3.6 and 15 mg/kg for unpolluted atmosphere. Water and soil are sinks for air borne heavy metals. Soil, water and food crops in this area are at the risk of being polluted by these metals.

(i) Monitoring atmospheric heavy metal depositions in Abuja municipality using an epiphytic moss *Polytricum formosum* (Kakulu & Jacob, 2007). Summary of results is shown in Table 3.2

Table 3.2 Summary of Heavy Metal Concentrations (mg/kg dry weight) in Moss Samples from all sites

Metal	Industrial Sites	Residential Sites	Control Sites
Cd	0.58±0.05	0.57±0.09	0.33±0.14
Cu	16.8±2.8	17.4±4.4	14.7±0.3
Ni	14.3±3.8	13.6±3.5	8.8±1.3
Pb	71.5±9.6	53.2±9.7	22.1±2.2
Zn	48.6±23.4	41.1±20.5	13.9±1.2
Fe (mg/g)	6.8±1.0	6.2±1.9	13.9±1.2

Findings and Implications: Generally the samples from the municipal area accumulated more metals than those from areas of low population and human activities. A continuous monitoring is required as the population of the city grows.

3.2.2 Monitoring of Heavy Metals in Sediment, Water and Fish

Several investigations have been carried out in this regard to ascertain the safety of fishes consumed in various localities.

(i) Determination of heavy metals concentrations in some fresh water fishes of Niger State (Jacob, *et al*, 2011).

Summary of results is shown in Table 3.3. The concentrations of selected heavy metals were determined in various organs of the fish (flesh, intestine and gills) in addition to the whole fish.

Table 3.3 Range of Heavy Metal Concentrations (mg/kg fresh weight)

Source	Pb	Cu	Zn	Cd	Ni
This Study	0.03 – 0.88	3.75 – 13.99	7.59 – 13.88	0.02 – 0.09	0.01 – 0.20
WHO Max Limit	1.5	120	150	0.2	0.4
FAO Max Limit	0.5	–	30	0.5	0.4

Findings and Implications: Concentrations of the studied metals were generally below the WHO and FAO maximum permissive limits. However, a continuous monitoring was recommended.

(i) Heavy metal concentration in water and fish from fishing sites in Federal Capital Territory and four selected states in North Central Nigeria (Akoma *et al.*, 2018). Summary of results is shown in Tables 3.4 & 3.5.

Table 3.4 Summary of Heavy Metal Concentrations (mg/dm^3) in Water Samples

State	Cu	Zn	Ni	Cr	Pb	Cd
Kwara	0.073	0.132	0.012	0.028	0.011	0.009
Benue	0.041	0.348	0.018	0.014	0.019	0.006
Niger	0.056	0.262	0.008	0.061	0.007	0.009
Kogi	0.055	0.164	0.031	0.018	0.018	0.005
FCT	0.358	0.255	0.006	0.014	0.009	0.007
WHO Standard (2013)	2.0	3.0	0.07	0.05	0.01	0.003

Findings and Implications: Values were generally lower than the WHO permissive limit, except for Cd which was generally higher. Cd is highly poisonous. Major sources of Cd contamination include mining, batteries, PVC plastics, motor oil, insecticides and fertilizer. Indiscriminate dumping of wastes into these water bodies should be avoided.

Table 3.5: Summary of Heavy Metal Concentrations (mg/kg) in Fish Samples from Fishing Sites

State	Cu	Zn	Ni	Cr	Pb	Cd
Kogi	2.68±0.20	49.34±3.95	0.50±0.05	0.31±0.05	1.80±0.21	0.84±0.22
Benue	1.88±0.25	51.55±4.31	0.54±0.06	0.33±0.05	0.76±0.28	0.53±0.11
Kwara	3.25±0.09	52.13±3.48	0.44±0.06	0.48±0.05	1.72±0.26	0.28±0.06
Niger	2.42±0.29	51.37±5.41	0.36±0.06	0.44±0.04	1.62±0.20	0.36±0.05
FCT	2.30±0.29	48.40±3.45	0.48±0.06	0.38±0.06	1,76±0.19	0.36±0.08
FAO/WHO	3.0	60	0.5	0.5	0.4	0.5

Findings and Implications: The concentrations of Pb were generally higher than the permissive limit and could pose a potential health risk to the consumers. It is pertinent to note that Pb rank high among the most toxic heavy metals and is of no known biochemical importance. A continuous monitoring of the level of toxic heavy metals in fish from the fishing sites was recommended.

3.2.3. Monitoring of Heavy Metals in Agricultural Soils, Municipal, Dumpsites and Roadsides Soils

(i) **Assessment of heavy metal bioaccumulation in soil, spinach, jute mallow and tomato in farms and gardens within Kaduna metropolis** (Jacob & Kalulu 2012).

In this study, the city was divided into 20 zones and composite samples of soil and the vegetables were collected from farms and gardens located within the city of Kaduna. Control samples were also collected from a rural village 30 km from the city.

The samples were digested using 3:1 mixture of HNO_3 and $HClO_4$, while the concentrations of Pb, Cd, Ni, Cr, Cu and Zn were determined in the digest using Atomic Absorption Spectrophotometer. Control and Certified Reference Materials were similarly treated.

Table 3.6: Summary of Mean Concentrations (mg/kg) of Heavy Metals in Samples of Soil and Vegetables

Sample	Site	Pb	Cd	Ni	Cr	Cu	Zn
Soil	Study Site	134±94	3.2±1.6	36±40	58±39	46±26	227±86
	Control	14.7±4.6	1.3±0.1	3.3±1.1	15.7±2.8	9.6±6.6	62±14
	Site WHO/FAO	100	3.0	75	400	100	300
Vegetables	Study site	19.2±4.9	3.2±1.0	9.6±2.5	14.1±2.3	25.6±4.2	185±23
	Control	4.5±2.4	1.6±0.2	3.7±0.2	4.7±3.1	8.6±2.8	77±26
	Site WHO/FAO	0.3	0.2	10	100	40	100

Table 3.7: Pollution Load Index (PLI) of Study Site

	Pb	Cd	Ni	Cr	Cu	Zn
Soil	9.14	2.46	10.82	3.69	1.79	3.65
Spinach	2.00	2.29	1.71	1.94	4.32	2.95
Jute Mallow	3.45	1.53	5.70	4.94	2.80	2.51
Tomato	4.24	1.53	5.70	4.94	2.80	2.51

Table 3.8: Mean of Soil-Plant Transfer Factors (TF) of Vegetables

	TF (pb)	TF (ca)	TF (Ni)	TF (G)	TF (Cu)	TF (Zn)
Spinach	0.19±0.14	1.47±0.54	0.59±0.21	0.33±0.13	0.96±0.44	1.28±0.37
Jute Mallow	0.40±0.53	1.40±1.1	0.32±0.16	0.34±0.20	0.74±0.36	0.87±0.38
Tomato	0.14±0.11	0.87±0.24	0.22±0.12	0.19±0.06	0.91±0.45	0.79±0.31
Mean TF value	0.24	1.25	0.38	0.29	0.87	0.98

Findings and Implications: The concentration of Pb and Cd in the city farm soils and vegetables were generally higher than he WHO/FAO maximum permissive limits. These heavy metals have no known biochemical importance and pose a potential health risk to the consumers of the vegetables. The results of the PLI show that the city is greatly enriched with the studied metals as a result of anthropogenic activities, while that TF analysis show that the TF differs between the vegetable species and sampling zones. The difference in sampling zones for the same vegetables could be attributed to the differences in soil properties. Cd had the highest TF in all the vegetables due to its high mobility. Spinach generally have the highest TF for all metals followed by jute mallow, which could be attributed to their relative transpiration rate.

(ii) **Investigation of the Bioavailability of Pb and Cd in Soils of Kaduna Urban Farms** (Jacob & Kakulu, 2011)

The total amount of the heavy metals in agricultural soil is not as important as the amount that is bioavailable to plants. Bioavailability depends on certain soil properties (such as pH, organic matter content, % clay and Cation Exchange Capacity), speciation (or forms) in which the metals exists, and the interactions of these metals with one another. Some interactions could be antagonistic while others could be synergistic. Generally, low pH, low organic matter content, low clay content and high Cation Exchange Capacity, enhance metal mobility and bioavailability.

Table 3.9: Total and Bioavailable Concentrations (mg/kg dry weight) of Pb and Cd in soil Samples, obtained from Speciation Studies.

		Pb			Cd	
Zone	**Total**	**BA**	**%BA**	**Total**	**BA**	**%BA**
1	73.2	24.2	33.1	6.5	4.8	73.8
2	217	64.2	29.6	3.4	2.9	85.3
3	230	73.1	31.8	3.9	3.5	89.7
4	438	191	43.7	4.3	3.8	88.4
5	30.5	68.0	22.3	11.3	9.9	87.6
6	52.9	12.9	24.4	2.4	2.1	87.5
7	41.1	15.9	38.7	2.9	2.6	87.5
8	262	117	44.8	5.6	5.1	91.1
9	113	35.7	31.6	4.1	3.5	85.4
10	40.4	13.5	33.4	2.9	2.4	82.8
11	27.4	12.5	45.6	2.9	2.6	89.7
12	51.1	19.6	38.4	3.6	3.3	91.7
13	35.8	16.9	47.2	2.3	1.9	82.6
14	33.3	7.8	23.4	5.6	4.3	76.8
15	496	219	44.1	13.8	10.5	76.1
16	119	52.4	44.0	2.8	2.4	85.7
17	84.4	20.7	24.5	2.9	2.3	79.3
18	172	45.2	26.2	3.6	3.3	91.7
19	31.3	15.6	49.8	2.8	2.3	82.1
20	58.0	20.3	35.1	3.2	2.7	84.4
Mean	**114**	**52.3**	**35.6**	**4.5**	**3.8**	**85.1**

BA = Bioavailable Concentration

Findings and Implications: The concentrations of Pb and Cd in the soil samples were generally above the WHO/FAO maximum permissive limits, however, the generally high soil pH was expected to be helpful in reducing the bioavailability of the metals. The high percentage bioavailability of Cd (85.1%) could be due to other factors, as mentioned earlier, and the nature of the metal itself.

(iii) **Determination of Heavy Metals Concentrations in Soils and Vegetables Irrigated with Wastewater in Chanchaga Area of Minna.** (Jacob *et al.,* 2012).

Table 3.10: Mean Concentrations (mg/kg dry weight) of Heavy Metals in Soil and Vegetables from all Farms in the Study Site

	Pb	Cd	Cr	Cu
Soil	16.9±16.1	0.4±0.2	6.2±4.5	11.8±6.8
Spinach	9.9±4.8	1.6±0.5	7.4±2.8	19.8±6.1
Jute Mallow	5.3±4.1	0.6±0.3	4.5±1.8	17.5±7.4
Tomato	3.7±2.0	0.4±0.3	3.6±1.6	9.1±3.8
WHO/FAO (Soil)	100	3.0	400	100
WHO/FAO (Vegetable)	0.3	0.2	2.3	40

Findings and Implications: The concentrations of the studies metals in the vegetables were generally higher than the WHO/FAO permissive limits, except for Cu. The higher concentrations of Pb, Cd and Cr in the vegetables could be detrimental to human health and calls for concern especially in the case of Pb and Cd which are highly toxic and of no known biochemical use. The treatment of the wastewater before use for irrigation purpose was recommended.

(iv) **Analytical Assessment of Heavy Metal Concentrations of Common Vegetables Sold in Major Markets of Minna City** (Jacob *et al.,* 2014)
Composite samples of the studied vegetables were collected

from six major markets within Minna city on a daily basis for seven days in the month of January, March and May. The samples were prepared for AAS analysis using standard procedures.

Table 3.11: Mean Concentrations (mg/kg dry weight) of Heavy Metals in Vegetables from all Markets and for all Months

Sample	Pb	Cu	Zn	Ni	Cr
Spinach	0.93	10.64	57.61	1.14	1.75
Jute Mallow	1.05	10.89	38.39	1.97	2.14
Cabbage	0.94	10.28	42.10	2.00	2.33
Cucumber	0.85	13.69	58.08	2.03	2.39
Tomato	1.18	12.17	53.30	2.08	2.44
WHO/FAO Standard	0.3	40	100	10	2.3

Findings and Implications: There were generally no critical contaminations of the vegetables by the studied metals, with mean concentrations of Cu, Zn and Ni in vegetable samples generally below established permissive limits, however, those of Pb and Cr were generally higher. Pb is highly poisonous and its accumulation in food crops could be detrimental to the consumers of such food crops.

(v) **Determination of Heavy Metal Concentrations in Top-Soil of Some Residential Areas of Kaduna, using Energy Dispersive X-Ray Fluorescence (EDXRF)** (Jacob, *et al.,* 2015)

Table 3.12: Mean Concentrations (mg/kg dry weight) of Heavy Metals in Residential Soil

Area	As	Pb	Cd	Ni	Cr	Cu	Zn
Barnawa	1.00±0.00	1600±88	1.50±0.10	753±39	273±41	467±46	320±72
Narayi	2.00±0.00	467±46	1.02±0.12	607±82	300±26	457±33	31±9
Sabo	10.67±9.67	1834±132	1.45±0.10	583±18	267±27	407±15	257±28
Paso (control)	1.00±0.00	41±9	1.00±0.10	33±11	21±4	16±3	52±4
WHO/FAO	25	100	3.0	75	100	100	300

Findings and Implications: Only Pb, Ni and Cu concentrations were generally higher than the permissive limits. This could be as a result of industrial and domestic activities in the areas. These metals pose a potential risk to the health of the residents, especially children. A continuous monitoring of the concentration of these metals was recommended.

(vi) **Determination of the Concentrations of Selected Heavy Metals in Soil in the Vicinities of Two Major Municipal Dumpsites in Minna, Nigeria** (Lawal *et al.,* 2019).

The dumpsites were Gurusu (along Minna-Sarkin Pawa Road) and Kuyi (Along Minna-Zungeru Road).

Table 3.13: Mean Concentrations (mg/kg dry weight) of Heavy Metals at Various Distances around the Gurusu Dumpsite

Distance from dumpsite (m)	Pb	Cd	Ni	Cu	Zn
0	17.43	2.27	28.66	28.39	11.57
50	19.51	2.80	24.77	50.37	55.73
100	0.71	2.23	23.55	19.47	44.56
150	BDL	2.22	30.44	17.33	55.68
200	BDL	2.38	45.39	16.74	9.52
700	BDL	2.52	24.31	24.35	BDL
WHO Limit	50	3.0	50	100	300

Table 3.14: Mean Concentrations (mg/kg dry weight) of Heavy Metals at Various Distances Round the Kuyi Dumpsite

Distance from Dumpsite (m)	Pb	Cd	Ni	Cu	Zn
0	38.52	4.33	8.53	34.24	BDL
50	39.81	4.19	10.52	40.78	1.05
100	50.04	4.67	3.21	33.22	BDL
150	54.29	4.20	2.83	25.13	6.71
200	37.35	4.46	2.91	29.11	22.42
700	53.91	4.41	4.55	24.36	BDL
WHO Limit	50	3.0	50	100	300

Findings and Implications: The concentrations of the heavy metals, Pb and Cd, in both dumpsites soils were found to be generally higher than the WHO permissive limits, hence, water, vegetation and food crops in the vicinity of the dumpsites stand the risk of been contaminated with these metals due to leaching and runoff.

(vii) Effects of Cadmium, Copper and Zinc Interactions in Soils on their Phytoavailability in *Curcurbita maschata* (pumpkin) (Nlemadim, *et al.,* 2019)

In this investigation, 0.1 mg/kg of Cd, Cu and Zn were added separately to three plastic pots, containing 20 kg of soil each. Similarly, four combined treatments namely, Cd/Cu, Cd/Zn, Cu/Zn and Cd/Cu/Zn were also carried out. Pumpkin seeds were sown into the pots and reduced to 2 plants stands per pot after two weeks. Matured plants were harvested after 30 days of planting and the heavy metal accumulation determined.

Table 3.15: Mean Concentrations (mg/kg) of Heavy Metals in Pumpkin from Single Metal Treated Soil

Treatment	Cd	Cu	Zn
Cd	11.00	13.67	43.33
Cu	14.00	17.00	44,67
Zn	16.67	20.33	52.00
Untreated soil (Control)	15.67	22.00	51.67

Table 3.16: Mean Concentrations (mg/kg) of Heavy Metals in Pumpkin from Combined Metal Treated Soil

Treatment	Cd	Cu	Zn
Cd/Cu	13.33	19.00	45.00
Cd/Zn	12.67	15.67	53.67
Cu/Zn	12.67	12.33	46.33
Cd/Cu/Zn	12.67	16.00	36.67
Untreated soil (control)	15.67	22.00	51.67

Findings and Implications: Generally, there exists a predominant inhibitory or antagonistic effect of the metals on their uptake by pumpkin. Although Cu and Zn are essential elements, this antagonistic effect will prevent their excessive accumulations in the vegetable.

4.0 CONCLUSION, RECOMMENDATIONS AND APPRECIATIONS

4.1 Conclusion and Recommendations

(i) The danger posed on the environment by toxic heavy metals cannot be over emphasized.

(ii) The negative impacts of these metals on living and non-living things in the environment are alarming.

(iii) Most heavy metal pollutions are caused by uncontrolled disposal of industrial and domestic waste materials into the environment.

(iv) Proper regulations, monitoring and effective control of the illegal mining, industrial and general human activities should be put in place.

(v) Attitudinal change and discipline of individual stakeholders in the environment must be monitored and regulated.

(vi) Adequate fund for research, development and sustainability of friendly environment should be provided by all tiers of government.

(vii) Collaborations between all stakeholders and environmental researchers is needed, as a matter of urgency, to save the only habitable planet…

(viii) There is need for deliberate policies to utilize research outcomes to cub environmental and food contaminations.

4.2 Current Research Efforts

(i) Monitoring of toxic heavy metals in industrial effluents and treatment by adsorption processes.

(ii) Expanded work on the interactions of metals in soil and the effects on their mobility, phytoavailability and uptake by food crops.

APPRECIATION

God Almighty: My profound gratitude goes to the Almighty God for his sustenance, mercy and grace for me to go through the various stages of my academic endeavour. May his name be praised for ever, Amen.

My Parents: Mr. and Mrs. Olayemi Jacob. I cannot thank them enough for their unflinching support and sacrifice.

My Wife and Children: I want to thank them for their sacrifices and prayers. They are always there for me. My wife, Mrs. Janet Idowu Jacob (She is my friend, companion and prayer-partner) and my children, God'sfavour, God'smercy, God'spower and God'sgift. Thank you and God bless you all.

My Friends and Relations: I appreciate the love and support of my friends and relations, too numerous to mention. I acknowledge the love and role of my childhood friends including, Mr. Solomon Rowland (Abana), Mr. Tayo Olure (Vasco), Bishop Ayodele Olushina, Dr. Ezekiel Sodiya (Dr. Show) and others. God bless you all.

My Spiritual Fathers: I thank all my spiritual fathers for their support. Rev. M. K. Omodanisi, Pastor (Engr.) God'spower Ikutegbe, Dr. D. K. Olukoya, Pastor Gabriel Olamidotun and others, too numerous to mention.

The Vice-Chancellor: Prof. Abdullahi Bala Sir, I want to thank you for the challenge and encouragement. I cannot thank you enough. Thank you Sir and God bless.

Former Vice-Chancellors: I want to appreciate all the former Vice-Chancellors of this great University. They all contributed to my getting to the level that I am today.

Principal Officers of the University: Both past and present. I say thank you to you all.

My Departmental Family: My special regard goes to my departmental family; the elders, and all other colleagues. Prof. B. E. N. Dauda, Prof. M. A. T. Suleiman, Prof. J. Yisa, Prof. Y. A. Iyaka, Prof. A. Mann, Prof. S. S. Ochigbo, Prof. M. M. Ndamitso, Prof. Y. B. Paiko, Dr. A. I. Ajai, Dr. L. A. Fadipe, Dr. R. B. Salau, Dr. R. A. Lafia-Araga, Dr. F. Ibikunle, Dr. J. O. Tijani, Dr. S. O. Salihu, Dr. M. T. Bankole, Mr. S. Idris, Mr. E.Y. Shaba, Mrs. Z. Abdullahi, Mr. M. T. Bisiriyu, Miss. C. N. Nwakife, Miss. A. Andrew, Mr. M. A. Salihu, Mr. S. Anyanwu, Mr. B. Amedu, Mrs. K. A. Tajudeen, Mrs. H. Tanko, Mr. A. Shehu, Mr. J. O. Salami, Mrs. A. Mamma and Mrs. R. Yisa.

My SPS Family: I thank my SPS family for the enabling environment, love and unity.

My Academic Mentors and Hand-Lifters: My profound gratitude goes to my academic mentors and hand-lifters at all levels, including Prof. S. E. Kakulu, Prof. O. D. Jimoh, Prof. A. J. Odofin, Prof. M. K. A. Adeboye, Prof. H. O. Akayan, Prof. I. K. Olayemi, Prof. R. O. Olayiwola, Prof. A. N. Saidu, Prof. A. A. Jigam, Prof. A. Y. Kabiru, Prof. Isah Audu, Dr. Henry Adeyemi, Dr. U. S. Onoduku, Dr. A. N. Amadi, and others too numerous to mention.

My Academic Mentees: I appreciate all my students, academic mentees and research assistants at all levels. I say thank you to you all.

Grant Awarding Institutions: I appreciate the following organizations for partly sponsoring some of the researches. They include, Federal University of Technology, Minna, Federal Scholarship Board, Education Trust Fund (E.T.F), World Bank/STEP-B, and TETFund.

Chairman and Members of US&CC: I will like to express my appreciation to Prof. B. Ayanwale and other members of the University Seminar and Colloquium Committee for organizing this lecture.

Everyone Present: Finally, I thank everyone that is present here today. God bless you all.

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PROFILE OF THE INAUGURAL LECTURER

Professor John Olusanya Jacob was born on the 9th of November, 1966, in Okeri, Yagba West Local Government Area of Kogi State, to the family of Mr. and Mrs. Olayemi Jacob. He attended Oyi Local School Management Board Primary School, Okeri, and the famous Titcombe College, Egbe, both in Yagba West Local Government Area of Kogi State. He obtained his B.Sc. Degree in Chemistry (with Second Class Upper Division) from the University of Ibadan (1990), M.Sc. Analytical Chemistry (2004) and PhD Analytical Chemistry (2012), both from the University of Abuja.

Professor John Olusanya Jacob is a Chartered Chemist, a member of the Institute of Chartered Chemists of Nigeria (ICCON) and a Fellow of the Chemical Society of Nigeria (CSN). He was one time General Secretary of the Chemical Society of Nigeria, Niger State Chapter, and currently a member of the National Award Committee of the Society.

Professor John Olusanya Jacob is an author of international repute. His bestseller is *Modern Practical Chemistry for Senior Secondary Schools and Colleges*. This book can be found in all English speaking countries of West Africa. He has won several research grants, which include Federal Scholarship Board grant for postgraduate research (2003), Education Trust Fund (ETF) grant for PhD laboratory work (2009), World Bank/STEP-B Innovator of Tomorrow Award (2010) and TETFund-IBR grant (2019). His area of research is Environmental Toxicology. He is the Principal Researcher of the Environmental Toxicity Research Group, F.U.T., Minna.

Professor John Olusanya Jacob has worked with various organizations, practicing Chemistry. He joined the services of the Federal University of Technology, Minna, in 2005, as Lecturer II, and rose through the ranks to become a Professor of Chemistry in 2019. He had served the University in various capacities, including Level Adviser, Examination Officer for the Centre for Preliminary and Extramural Studies (CPES), Departmental Examination Officer, School Examination Officer, Seminar Coordinator, PG Coordinator, member of numerous committees, among others. He had supervised and graduated numerous B. Tech. students, 15 M. Tech. and 2 PhD students. He is a Reviewer to many national and international journals, and External Examiner to other universities. He has numerous national and international journal publications to his credit.

Professor John Olusanya Jacob is married to Mrs Janet Idowu Jacob, and are blessed with four wonderful children.