**Analysis of Analytical Methods in Environmental Pollution Control: A Case Study of Some Nigerian Environmental Laboratories**

Von der Fakultät für Umweltwissenschaften und Verfahrenstechnik

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**Declaration**

I here by declare that my Doctoral Thesis

**Title:**   
   
**Analysis of** **Analytical Methods in Environmental Pollution Control: A Case Study of Some Nigerian Environmental Laboratories**

was written independently, under the supervision of Professor Dr. rer. nat. J. Ertel and Professor Dr.-Ing. Werner Witt. All sources used for the writing of this dissertation have been adequately referenced.

**Signed**

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Dedication

To my Lord and Saviour Jesus Christ who gave his life that I (and all that believe in him) shall be saved. He is the strength and sustainer of my life.

To my darling husband Lonis Abdu Salihu, who has given me all the support, encouragement and comfort that I needed to make this work a reality.

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**Acronyms/Abbreviations**

AAS Atomic Absorption spectroscopy

ADWG Australian Drinking Water Guidelines

AES Atomic Emission Spectrometer

APCI-MS Atmospheric Pressure Chemical Ionization

Mass Spectroscopy

APHA American Public Health Association

ASTM American Society for Testing and Materials

AWWA American Water Works Association

BBC British Broadcasting Corporation

BImSchV BundesImmissions Schutz Verordnung

BIS British Standard Organization

BOD Biochemical Oxygen Demand

BPSD Barrels Per Stream Day

BRICs Brazil, Russia, India, and China

BTEX Benzene, Toluene, Ether/benzene and Xylene

CAA Clean Air Act

CCREM Canadian Council of Resource and  
Environment Ministers

CEC Cation Exchange Capacity

CEM Continuous Emission Monitoring

CERCLA Comprehensive Environmental Remediation

Compensation and Liabilities Act

CIA Central Intelligence Agency

COD Chemical Oxygen Demand

CPC Condensation Particle Counter

CWA Clean Water Act

DIN Deutsches Institut für Normung

DWSNY Drinking Water Standards for New Zealand

DWQS Drinking Water Quality Standards

DBCP 1, 2-Dibromo-3-chloropropane

DDT Dichlorodiphenyltrichloroethane

DO Dissolved Oxygen

DOE Department of Environment

DOM Dissolved Organic Matter

EAAS Electro Atomic Absorption Spectroscopy

EC European Commission

EDXRF Energy –Dispersive X-Ray Fluorescence

EIA Environmental Impact Assessment

EPA Environmental Protection Agency

ERA’s Ecological Risk Assessment

FAAS Flame Atomic Absorption Spectroscopy

FAO Food and Agriculture Organization

FCT Federal Capital Territory

FEPA Federal Environmental Protection Agency

FIA Flame Ionization Analysis

FID Flame Ionization Detector

FIR Far Infrared

FTIR Fourier Transforms Infrared

GC Gas Chromatography

GCFIR Gas Chromatography Fourier Infrared

GC-MS Gas Chromatography – Mass Spectroscopy

GC-IRMS Gas chromatography-Isotope Ratio Mass

Spectrometers

GC-NPD Gas Chromatography with Nitrogen-Phosphorus   
 Detector

GDP Gross Domestic Product

GFC Gas Filter Correlation

HAAS Haloacetic Acids

HCB Hexachlorobenzene

HCH Hexachlorocyclohexane

HM Humic Materials

HPLC High Performance Liquid Chromatography

HPLC/ID High Performance Liquid Chromatography/

Iron Detector

IC Ion Chromatography

ICP Inductively Couple Plasma

IDF Infrastructural Development Fund

IPCC Intergovernmental Panel on Climate

Change

IMF International Monetary Fund

IR Infrared

ISE Ion-Selective Electrode

ISO International Organization for Standardization

KRPC Kaduna Refining and Petrochemicals Corporation

LAB Linear Alkyl Benzene

LPG Liquefied petroleum Gas

LOD Limit of Detection

LOQ Limit of Quantification

LTGC Low Temperature Glassy Carbon

MCERTS Monitoring Certification Scheme

MCL Maximum Contaminant Level

MCLG Maximum Contaminant Level Goal

MS Mass Spectrometry

NCTL Nembe Creek Trunk Line

NEEDS National Economic Empowerment Development

Strategy

ND Not Determined

NDE National Directorate of Employment

NDIR Non-Dispersive Infrared

NESREA National Environmental Standards and Regulations

Enforcement Agency

NGOs Non Governmental Organizations

NH Northern Hemisphere

NIP National implementation plan

NIR Near-Infrared

NMR Nuclear Magnetic Resonance

NNPC Nigerian National Petroleum Corporation

NRL National Reference Laboratory

NZWWA New Zealand Waste Water Guidelines

OLS Ordinary Least Square

OM Organic Matter

OPA Oil Pollution Act

OPEC Organization of Petroleum Economic

Countries

PAHs Polycyclic Aromatic Hydrocarbons

PAM Purge and Membrane

PCBs Polychlorinated Biphenyls

PCDD Polychlorinated Dibenzodioxins

PCDF Polychlorinated Dibenzofurans

PCNs Polychlorinated Naphthalene

PDMS-PVA Polydimethyl Siloxane- Poly Vinyl Alcohol

PEG Polyethylene Glycol

PID Photo ionization Detector

PH Potential of Hydrogen

PH-ORP Potential of Hydrogen ions-Oxygen

Reduction Potential Meter

PLE Pressurized Liquid Extraction

PMCEM Particulate Matter Continuous Emissions

Monitoring

PN Particles Number

POPs Polycyclic Organic Pollutants

PPMV Parts Per Million by Volume

PSAP Particle Soot Absorption Photometer

PT Proficiency Testing

P&T Purge and Trap

P&T –GC/MS Purge and Trap Gas Chromatography/Mass

Spectroscopy

PT Petroleum Trust Fund

PTMOS-MTMOS **P**henyl**t**ri**m**ethy**o**xy**s**ilane-

**M**ethyl**t**ri**m**eth**o**xy**s**ilane

PVC Polyvinyl Chloride

RCRA Resource conservation & Recovery Act

SDWA Safe Drinking Water Act

SON Standard Organization of Nigeria

SPME Solid-phase Micro Extraction

SPM Suspended Particulate Matter

SS Suspended Solids

TCE Trichloroethylene

TCF Trillion Cubic Feet

THC Total Hydrocarbon

TLC Thin Layer Chromatography

TLV Threshold Limit value

TN Total Nitrogen

TOC Total Organic Carbon

TP Total phosphorus

TRS Total Reduced Sulphur

TSCA Toxic Substances Control Act

TS Total Solids

TTHMs Total Trihalomethanes

UN United Nations

UNDP United Nations Development Programme

UNICEF United Nations Children’s Fund (formerly United

Nations International Children’s Emergency Fund)

UNEP United Nations Environment Programme

VDI Verein Deutsche Ingenieure

VOCs Volatile Organic Compounds

UV Ultraviolet

(UV/Vis) Ultraviolet/Visible spectrophotometer

WEF Water Environment Federation

WHO World Health Organization

WLSn Weighted Least Squares

WPCA Water Pollution Control Act

WSWQ Water Supply Water Quality

XRF X-ray Fluorescence

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**Abstract**

Scientific data and results have to be accurate, precise and reliable and are subject to ever increasing scrutiny by regulators in industry, the environment and medicine, in validation and also in research and development. Given our numerous environmental problems, the need for accurate, precise and reliable results can not be overemphasized in environmental pollution control. In the light of this analytical environmentalists believe that there is need for a hierarchical scheme of methods to be used in environmental assessment studies. In this research the state and role of analytical instruments in environmental pollution control in Nigeria were studied with a focus on the state of the Nigerian environmental pollution control laboratories. A theoretical background of this work gives an overview of the state of the art of the environment globally and that of Nigeria. This work has established that, because mankind have put thousands of chemical substances to use in this century, there are many chemicals that have found their way into the natural environment in large quantities. Because of the nature of the environmental problems mankind is facing now, many researchers and manufacturers are dedicated to using and providing quality new and reliable instrumentation methods to ensure a healthy environment in our world.

A brief study of Nigeria as the country of research is made to establish the background of possible problems. From the facts gathered in the literature Nigeria has the economic tools that it needs to put a good environmental management scheme in place, which includes good standards, laws, regulations and good analytical laboratories for compliance and monitoring. However the research has established that these economic tools are not effectively used in the management of environmental pollution control, especially monitoring of environmental pollutants.

The research was undertaken by visiting four analytical laboratories involved in environmental pollution control in Nigeria, and three organizations that are the main environmental regulatory bodies in Nigeria. The analytical laboratories visited are those of Nigerian National Petroleum Corporation (NNPC) Kaduna, Ashaka cement factory, regional laboratory of the Federal Ministry of Water Resources Gombe, and the National Reference laboratory Lagos. In these laboratories and the organizations, results were collected in the laboratories, interviews were carried out and analytical instruments available were documented. It was discovered that, in these laboratories many standard analytical instruments needed for quality environmental pollution control and monitoring are lacking. Comparison of results generated in these laboratories with some from developed countries, revealed that many parameters measured in laboratories in developed countries are not measured in the research laboratories. The results obtained in these laboratories met Nigeria’ maximum limits in some cases, but exceeded it in many cases. It is the position of this work that the gap between the environmental analytical instruments found in literature and developed countries, and that found in Nigeria is very large and calls for concern.

The environmental regulatory bodies in Nigeria have many laws, rules, regulations and standards for environmental pollution control. These regulations, standards, laws and rules were compared with what is obtained in other countries of the world, especially developed countries and found to be lacking in many areas. The way and manner the analytical methods are stated in the Nigerian regulations and standards are way below the developed countries standard. This research concludes that the regulations and standards have big influence on the kind of environmental analytical instruments found in the environmental analytical laboratories in Nigeria.

The final conclusion this study has reached is that analytical methods, equipments, and standards on ground in Nigeria are not sufficient for the purpose of good environmental pollution control and monitoring. The situations as regards analytical instruments, analytical methods, standards and guidelines used in environmental pollution control in Nigeria do not favourably compare to international situations. It is therefore recommended that the need for validity and reliability in data collection, analysis, guidelines, standards and use of data in environmental pollution control needs to be addressed by the Nigerian Government if monitoring of the Millennium Development Goals and environmental pollution control in general is to be effective.

**Kurze Zusammenfassung**

Wissenschaftliche Daten und Ergebnisse müssen genau, richtig und zuverlässig sein und unterliegen immer stärkeren Prüfungen durch Kontrollorgane in Industrie, Umwelt und Medizin, bei der Validierung und auch in Forschung und Entwicklung. Aufgrund unserer zahlreichen Umweltprobleme kann die Notwendigkeit von genauen, richtigen und verlässlichen Ergebnissen in der Kontrolle der Umweltverschmutzung nicht überbetont werden. In Anbetracht dessen glauben die mit der chemischen Analyse betrauten Umweltschützer, dass es eines gut aufgebauten Systems von Methoden bedarf, das in Studien zur Umweltbewertung Anwendung finden soll. In dieser Forschungsarbeit wurden der Zustand und die Rolle des Analyse-Instrumentariums zur Kontrolle der Umweltverschmutzung in Nigeria untersucht. Das Hauptziel dieser Arbeit ist die Untersuchung des Zustand der nigerianischen Laboratorien zur Kontrolle der Umweltverschmutzung. In einem theoretischen Teil dieser Arbeit wurde ein Überblick über den Zustand der Umwelt insgesamt und der von Nigeria gegeben. Eine gesicherte Erkenntnis dieser Arbeit ist die Tatsache, dass die Menschheit im vergangenen Jahrhundert Tausende von chemischen Substanzen verwendet hat und dadurch viele Chemikalien in großen Mengen in die natürliche Umwelt gelangt sind. Wegen der Art der Umweltprobleme, vor denen die Menschheit heute steht, sind viele Forscher und Industrielle bemüht, ein qualitativ hochwertiges Instrumentarium und neue Methoden zur Verfügung zu stellen, um eine gesunde Umwelt zu sichern.

Eine kurze Studie über Nigeria, dem Land der betreffenden Forschungsarbeit, wird dargelegt. Aus den Fakten in der entsprechenden Literatur ergibt sich, dass Nigeria über die entsprechenden Wirtschaftsmittel verfügt, die es für die Umsetzung von guten Planungen für die Umwelt benötigt. Sie schließen gute Standards, Gesetze und Verordnungen sowie gute Analyselabors für deren Einhaltung und Überwachung ein. Jedoch hat diese Forschungsarbeit nachgewiesen, dass wegen Korruption diese Wirtschaftsinstrumente in der Handhabung der vielen Umweltprobleme nicht effektiv genutzt werden. Ein weiteres Problem als erwiesene Behinderung in der Anwendung der Wirtschaftsinstrumente liegt in der Tatsache begründet, dass, obwohl Nigerias Wirtschaft Wachstum zeigte, dieses Wachstum wegen der raschansteigende Inflation keine Wirkung hat.

Im Rahmen diese Forschungsarbeit wurden sowohl vier Analyselabors besucht, die an der Kontrolle der Umweltverschmutzung in Nigeria beteiligt sind, als auch drei Organisationen, die als die hauptsächlichen Umweltbehörden in Nigeria anzusehen sind. Die besuchten Analyselabors sind die Nigerianische Nationale Ölgesellschaft NNPC Kaduna (Nigerian National Petroleum Corporation Kaduna), die Ashaka Zementfabrik (Ashaka Cement factory), das Regionallabor des Bundesministeriums für Wasserwirtschaft Gombe (Regional laboratory of the Federal Ministry of Water Resources Gonbe) und das Nationale Referenzlabor Lagos (National Reference laboratory Lagos). Festgestellt wurde, dass in diesen Laboratorien viele Standard-Analyse-Instrumente fehlen, die für eine qualitätsgerechte Kontrolle der Umweltverschmutzung benötigt würden. Ein Vergleich der Messungen aus diesen Labors mit denen aus entwickelten Ländern enthüllte, dass viele Parameter schlicht nicht gemessen wurden. Die Messergebnisse aus diesen Laboratorien erfüllten Nigerias Grenzwerte in einigen Fällen, übertrafen sie aber auch in vielen Fällen. Diese Forschungsarbeit zeigt, dass der Abstand zwischen dem Umwelt-Analyse-Instrumentarium aus Literatur und entwickelten Ländern zu dem in Nigeria vorhandenen sehr groß ist und Anlass zu Besorgnis gibt. Die Umweltbehörden in Nigeria verfügen über viele Gesetze, Regeln, Verordnungen und Standards zur Kontrolle der Umweltverschmutzung. Alle diese wurden mit denen verglichen, die in der internationalen Gemeinschaft, insbesondere in den entwickelten Ländern üblich sind; auch hier mangelt es in Nigeria in vielen Bereichen: Die Art und Weise, wie die Analyse-Methoden in den nigerianischen Verordnungen und Standards festgelegt sind, liegt beträchtlich unter dem Standard in den entwickelten Ländern. Aus dieser Forschungsarbeit ergibt sich also die Schlussfolgerung, dass Verordnungen und Standards einen großen Einfluss auf die instrumentelle Ausstattung der Umwelt-Analyse-Laboratorien Nigerias haben.

Die Gesamtstudie kommt zu der Schlussfolgerung, dass Analyse-Methoden, Ausrüstung und Standards in Nigeria zum Zwecke einer guten Kontrolle und Überwachung der Umweltverschmutzung unzureichend sind. Es wird daher das Folgende nachdrücklich empfohlen: die nigerianische Regierung muss es sich zur Aufgabe machen, Gültigkeit und Verlässlichkeit in der Datensammlung, der Analysetechnik, den Richtlinien und Standards und der Auswertung der Daten zu sichern, wenn die Überwachung der Millenniums-Zielsetzung und die Kontrolle der Umweltverschmutzung im Allgemeinen wirkungsvoll werden sollen.

Section 1

Theoretical part: GENERAL introduction and Literature review

**Chapter 1 General Introduction**

**1 Introduction**

Mankind has put thousands of organic compounds to use in the past and in this century, often in large quantities. In the 1960s it became increasingly obvious that certain chemicals had found their way into the natural environment in large quantities. Some of them came to be known as environmental poisons; animals exposed to them often displayed symptoms of illness or injury. Certain pollutants e.g. DDT, POPs, can, acting over long periods, harm living organisms even in low concentrations. This means that pollutants that are stable and thus persistent have a great ability to act as environmental poisons. Their stability means not only that their effects are long-lasting, but also that they are dispersed over large areas before being broken down. (Claes Berns, 2005, http://www.Internat.naturvardsverket.se) The introduction of these poisons into the environment by mankind thus endangers human health, harms living resources and ecosystems, and impairs or interferes with amenities and other legitimate uses of the environment. There is a large growing public concern worldwide over these potential and actual deleterious effects on the environment and human health and this call for concern and search for solutions. Environmental analytical laboratories are important part of the solutions; as such quality environmental analytical instruments are needed in these laboratories. This research is focused on the state of the art of Nigeria’ environmental analytical laboratories involved in environmental pollution control, but the situations in developed countries will be used to compare the Nigerian situations.

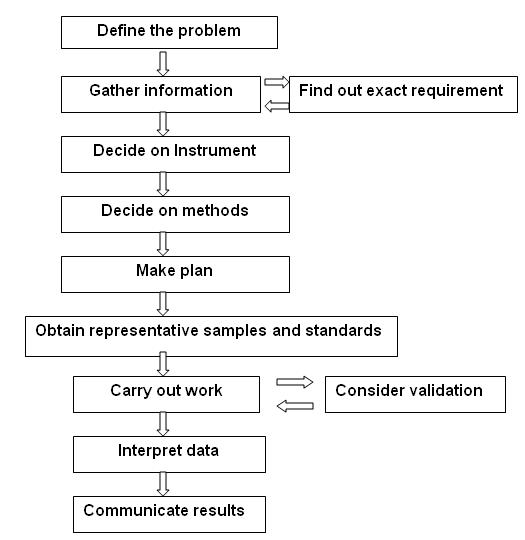
There are many sources and causes of environmental pollution. In Nigeria, principle, stationary pollution sources include chemical plants, oil spillage, oil refineries, petrochemical plants, waste disposal activities, incinerators, large animal farms, PVC factories, metal production factories, plastic factories, other heavy metal industries, etc. The common pollutants from these sources include hydrocarbons, heavy metals, herbicides, pesticides, chlorinated hydrocarbons, etc. These pollutants are mainly produced by industries in Nigeria and human activities especially related to the consumption of these industries products. Nigeria’s industries that contribute to environmental pollution include: gas and oil, chemical, food and beverages, hide and skin, cement, iron and steel, paper and pulp, agro-allied, motor assembly etc. As mentioned above industrial activity is a major contributor to many of the environmental pollutions. However, it has the potential to make a strong contribution towards achieving a sustainable society. The oil explo-ration in the Delta region in Nigeria is already causing serious environ-mental pollution problems. For example, Shell Petroleum Development Corporation; the Nigerian arm of Royal/Dutch Shell, reported that 50,200 barrels of oil were spilled in 1998 and 123,377 barrels in 1999, citing sabotage as the cause for 70 percent of the volume spilled in 1999 (Dr. E. A. Akpofure et al). This spillage constitutes a large amount of oil intro-duced to the environment, i.e. to air, water, and soil hence posing a great danger to the environment.

Since environmental pollution has become a major concern, many scientific tools have been developed world wide to help environmental managers in the assessment and remediation of these problems. In addition to the scientific tools to protect the environment from these adverse effects of pollution, many nations worldwide have enacted legislation to regulate various types of pollution as well as to mitigate the adverse effects of pollution. This applies to environmental analytical instruments, many countries have inserted into their laws, regulations and standard, specific types of instruments to be used for monitoring specific pollutant.

In Nigeria, the responsible agency for environmental pollution was the Federal Environmental Protection Agency (FEPA) which was created by decree 58 of 1988. Its task was to manage and monitor environmental standards and ensure sustainable development of natural resources and the protection of the environment. The Environmental Impact Assessment (EIA) Act (1992) reaffirmed the powers of FEPA and defined the minimum requirements for an EIA. The agency has finally metamorphosed into a full pledge ministry when in June 1999; the Federal Ministry of Environment was created (Imevbore, 2001). The Nigerian national environmental policy act requires that anyone undertaking any project that may have some impact on the environment, prepare detailed analyses of any of their actions that significantly affect the quality of the environment. This is meant to help the environmental managers to monitor what is happening to the environment.

For successful monitoring and policing of environmental pollution, excellent methods of assessment are needed. But there is confusion over the concept of methods for pollution studies, especially in oil spill often believed to be limited to the analysis of some specific polynuclear aromatic hydrocarbons by gas chromatography-mass spectroscopy. Analytical environmentalists believe that there is need for a hierarchical scheme of methods to be used in environmental assessment studies. Burns. K.A (1993) illustrated the importance of using several complementary analytical methods in oil spill studies; she did this in tandem with examples from the results of the Buhia Las Minas oil spill study. In her work Burns went ahead to present further reasons why methods must continue to be developed for an expanded range of polar oxidation products. Whether new analytical methods as in Burns studies or old known ones, analytical methods can be divided into three as follows; separation technologies, molecular analysis and elemental analysis instrumentation. Common separation technologies instruments include Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), Ion Chromatography (IC) and Electrophoresis. Molecular analysis instruments include Ultraviolet/Visible (UV/Vis) Spectrophotometer, Infrared (IR) Spectrophotometer, Raman Spectrophotometer, Mass Spectrophotometer, Nuclear Magnetic Resonance (NMR), volta metric instrumentation and moisture analysis instrumentations (Analytical Instruments, LLC; http://www.aibltd.com). For elemental analysis, instrumentations include Atomic Absorption Spectrometers (AAS), Atomic Emission Spectrometers (AES), X-ray instrumentation, surface analysis instrumentation, potential of hydrogen ions (pH) and ion-selective measurement instrumentation (Analytical Instruments, LLC; http://.aibltd.com/detail.cfm?autonumber=77363). All these aspects are applied in environmental pollution monitoring in a standard environmental laboratory, therefore this research will deal with them in detail in the later chapters.

Many researchers and manufacturers are dedicated to using and providing quality new and reliable instrumentation methods to ensure a healthy environment in our world. Of recent Jayaratne et al (2007) used fast-response monitors instrumentation, particularly they used TSI 3025A condensation particle counter (CPC) to measure particle numbers (PN) emitted by on-road vehicles. Another work on trying some new efficient methods was done by Jasdeep Kaur et al (2007) where they used immunochromatographic dipstick assay format using gold nanoparticles labelled protein-hapten conjugate for the detection of antrazine in water. This shows how much efforts the science world is putting into analytical methods in environmental pollution control. Another person’s work on analytical instruments is that of Gillian (2007), he showed that the analytical process is the science of taking measurements in an analytical and logical way to solve different problems such as in environmental pollution control. In matrix like environmental samples, identifying or quantifying an analyte in a complex sample becomes a serious excise in problem solving. To be efficient and effective, an analytical scientist must know the tools that are available to tackle variety of different problems. Gillian (2007) describes these processes as shown in Figure 1.1 below where he showed that the analytical process is a logical sequence of steps that may take the form of a flow chat. In this chat Gillian place importance on all the steps including validation which many laboratories don’t take serious.



**Figure 1.1** Analytical Processes

(Source; Created from Gillian 2007)

This thesis focuses on the role of analytical instruments in environmental pollution control as already mentioned, in doing this, an overview of the state of the art in terms of environmental pollution globally and in Nigeria is done, pollutants that are found in the environment and appropriate analytical instruments for monitoring them are reviewed globally and then finally assesses what is obtained in Nigeria both theoretically and by field work, identifies deficiencies, and make suggestions on how to mitigate these deficiencies and assist in knowledge transfer to Nigeria in the area of the application of analytical instruments in environmental pollution control.

This study will basically be concerned with the analytical instruments situations in environmental and related analytical laboratories in Nigeria using the study areas as point of reference. An intensive literature review is done to find out what is obtained in the international level which will be used to compare the findings in Nigeria. Interviews will be carried out, analytical instruments in the laboratories will be observed, and available data on the analytical instruments will be taken for analysis using statistical methods. The expected results should show the state of the art of analytical instruments used in the Nigerian environmental pollution control and it will help stakeholders to find solutions to mitigate the problems arising from the results.

The work is mainly divided in three sections as follows;-

Section 1 is a theoretical section and it comprises chapters 1, and 2; in chapter 1 a detail study proposal is given which outlines study Aims and objectives, methodology, study questions and expected outcome. In chapter 2 which is the literature review the state of the art of the environment is discussed in details from the international to the Nigerian situations. This is done to establish that environmental pollution is becoming a threat to the ecosystem including human beings, animals and plants. Also to be able to discuss what analytical instruments are use in environmental pollution control, the environmental pollutants are reviewed, i.e. air, water and soil pollutants. In the review an in-depth study is made of the types of analytical instruments found in the literatures that are applied in environmental pollution control and monitoring. Comprehensive lists of these analytical instruments can be seen in subsection 2.4. Subsection 2.7 gives a review of environmental standards, laws and regulations as obtained in the literatures, this include international and the Nigerian laws and regulations. The country Nigeria is discussed briefly as found in literature, the geographical country, the types of industries found there and the pollutions these industries produce.

Section 2 is the field work, results and discussion, it comprises chapters 4, 5 and 6; in chapter 4 the results obtained from the laboratories and the regulatory bodies are given and this include description of the organizations, laboratory results, the analytical instruments found in the research laboratories and guidelines found in the field. In chapter 5 the results obtained from the field are discussed in details, efforts are made to analyze the laboratory results in the light of the analytical instruments used, also comparisons of some results are made with some international results and the limits found in the Nigerian guidelines. Chapter 6 focuses mainly on comparing the Nigerian standards and environmental pollution monitoring with what is obtained in the developed countries.

Section 3 is the concluding section which contains only chapter 7 as the closing chapter, this gives a summary of the work, draws some conclusions from the results and gives some recommendations to stakeholders.

**1.1 Justification of the Study**

There appeared to be a widespread confusion and misunderstanding about the purpose and mechanisms of environmental regulations. The primary basis for setting standards for environmental control has been scientific. The goal of any environmental control is sustainable development; even though there are various tensions with respect to sustainable development, one thing is clear; there is a wide acceptance that sustainable development is about meeting the needs of the present without compromising the ability of future generations to meet their own needs (World commission on Environment and Development 1986). Sustainable development thus requires a balance between improving the conditions of human life in an equitable way, now and in the future, and the long term conservation of the natural environment and in doing this; quality analytical instruments will be needed in monitoring environmental pollution control. To have sustainable development environmental pollution control must be part of the solution, therefore analytical methods used in ensuring environmental standards are met, must be very reliable and accurate if we are to have a sustained environment. These methods must be reliable because standards are often the most tangible and precise expression of the judgments that underlie environmental policies. As such for any effective environmental control which will ensure sustainable development, good, accurate and reliable analytical methods must be employed in all sectors of environmental pollution control. That is why this study is crucial especially for Nigeria, as it will put the methods obtained in Nigeria in the context of world wide methods, so as to see where to improve upon.

The study area Kano, Kaduna, Gombe and Ashaka have been chosen because they are representatives of big and small industrial cities in Nigeria. The industries in these towns represent the major types of industries found in Nigeria i.e. oil and gas, metal, food and cement industries. This research has been provoked by the conditions that prevailed in River Kaduna due to the treated waste water discharged into it from the NNPC. The waste water which has been treated should have been monitored to ascertain it has reached specifications to be discharged into water bodies. Therefore the point of concern becomes the analytical instruments used for this control. The fisher men who used River Kaduna as their livelihood have almost been displaced, most agricultural activities carried out there using the river’s water are suffering from the water quality.

In Ashaka the air is almost all the time dense due to air pollution from the industry. Air leaving the industry should normally be monitored to make sure air pollutants are not allowed into the environment, but this doesn’t seem to work well and the monitoring instruments can also be put into question. There are many factors which may contribute to the above given conditions, such as personnel, finances, etc, but even if all these factors are perfect without good up to date analytical instruments, pollutants will still be let into the environments unchecked. In the light of the above and given the fact that environmental concerns are in the increase, and the environment is hard to restore once destroyed, analytical instruments used in environmental pollution control have to be of international standards in Nigeria. Therefore baseline scientific information on the state of analytical equipments in the environmental laboratories in Nigeria is needed, if the environment is to be sustained into the next century, for the future generations. That is why this study is needed, so that environmental standards can be monitored with the best analytical instruments available in the science world as a base for proper enforcement.

**1.2 Problem Statements and Research Questions**

In advanced countries, environmental quality monitoring is compulsory and there are effective environmental laboratories well equipped for this purpose. Environmental laws hence are followed strictly. Industries make efforts to use good, accurate and reliable analytical methods since there are good monitoring laboratories on ground. The situation is quite different in many developing countries. Although industrial growth and its associated environmental problems are fast increasing in these developing countries; the monitoring of pollution is mostly not taken serious. Nigeria is not an exception, monitoring pollution control by both the industries and the government monitoring organizations are not taken serious. Treated wastes are dumped into rivers or land without proper control, as such the maximum limits of the pollutants are mostly exceeded; therefore this thesis addresses the need for good, accurate and reliable analytical methods for the purpose of monitoring pollution control, setting good standards and remediation of polluted areas. The problems of this research can be summarised as follows;

* Environmental pollution in Nigeria
* The state of the art of environmental pollution control in Nigeria
* The state of art of the environmental laboratories in Nigeria
* Need for reliable analytical instruments in the existing environmental laboratories
* The role of analytical instruments and methods in the environmental laws, regulations, guidelines and standards
* The conditions of general pollution control monitoring in Nigeria as compared to international standard

Nigerian Federal Government has been trying to build National Environmental laboratories in Kano, Kaduna, FCT Abuja, Benin city, Lagos and Port Harcourt for the purpose of monitoring. The Federal Ministry of water resources also has six monitoring laboratories located in Kano, Minna, Gombe, Lagos, Akure and Enugu. These laboratories were supposed to perform mainly monitoring of pollutants for general environmental pollution and water pollution. But of these laboratories only Lagos is so far functioning to a certain level as given in the literature and some have not even taken off at all. In general very little information exists in the literature about Nigeria’s environmental laboratories. These laboratories remain largely neglected; most of them are ill-equipped. In the light of these and the importance of environmental analytical laboratories in environmental pollution control, this calls for worries and concern, also given the alarming rate of environmental degradation and related problems. There is hence the need to undertake targeted studies aimed at letting stakeholders see the magnitude of our environmental problem and how analytical instruments is part of the solution. The state of the art of analytical instruments technology worldwide will help to find ways to mitigate problems arising from the study in Nigeria’s environmental laboratories.

The main questions this study will answer as related to; Air pollution by industries in Ashaka, Water pollution by Nigerian National Petroleum Corporation (NNPC) in Kaduna and other human activities, Land and soil pollution by Shell in Port Harcourt where possible, are formulated as:

1. What is the status and trend of environmental analysis and environmental standards in Nigeria compared to the international state of the art?
2. What are the main constraints in analytical instruments in environmental laboratories in Nigeria? How can they be solved or bypassed?
3. Do laboratories in Nigeria have documentary evidence that their methods have been validated?

In undertaking the case studies the following detailed questions will be answered;

1. In Ashaka and Kano: does the cement industry have a chemical monitoring laboratory? What types of analytical instruments are found there, do they do good air quality control? What types of air pollution measurement instruments are obtained in Kano and Ashaka? What can be done to improve on what is available?
2. In Kaduna, looking at NNPC wastewater treatment and its effect on Kaduna River: What analytical instruments do they have in the laboratory? How efficient does the analytical instruments measure pollutants in the treated waste water before discharging into Kaduna River? What is the effect of the treated wastewater discharge on River Kaduna? What can be done to improve on the situations?
3. In Port Harcourt: What types of analytical methods does Shell use for soil and land pollution control? What types of analytical instruments are available in their laboratory?
   * In general are the research laboratories participating in proficiency testing (PT) programs?

* + Do these laboratories have calibration data for their instruments?
  + Do they do calibration in terms of initial calibration, monthly validation, and recalibration? Are there calibration curves available?
  + What calibration models are used in the available laboratories? E.g. Ordinary Least Square (OLS) or Weighted Least Squares (WLS) etc?
  + Do the results of their analysis indicate that maximum limits have not been exceeded?
  + Is there any body in Nigeria like DIN (in Germany) that is responsible for standards? And what standards are available?
  + How do standards found in Nigeria, e.g. standard methods for sampling, analysis and maximum limit values, compare with the international standards?
  + Any record of inventory of pollutants into the environment with the regulatory bodies?
  + Any Study on the concentration of oil products (hydrocarbons) in surface water?

**1.3 Aims and Objectives of the Study**

This work is focused on pollution monitoring, assessment and remediation of pollution using standard analytical instruments. This is to be done by providing a common framework and scientific tools for the consistent scientifically defensible assessment and remediation of pollution and providing an overview of the state of the art of analytical instruments used in environmental pollution control internationally and in Nigeria. Therefore the aims of the study are:

1. To identify problems with the current situation of analytical instruments used in environmental pollution control in Nigeria. Study the state of the art of environmental analytical instruments in developed countries,
2. To analyse the present inadequate standards of environmental analytical instruments in Nigeria as compared to what are obtained in the developed countries and see where technology transfer can help the Nigerian situation,
3. Explore the factors that influence good practise as regards envi-ronmental analytical instruments used in environmental pollution control in developed countries and make suggestions to the Nigerian environmental stakeholders.

To achieve the above mentioned aims the following objectives will be pursued:

* Find out the major pollutants that can be measured from industries to monitor pollution, this will include taking a survey of the sources of these pollutants,
* Study analytical instruments and standards used in developed countries, especially Germany to use it as a basis of analyzing what is obtained in Nigeria,
* Find out what are the environmental analytical instruments and standards found in Nigeria using the study area,
* Identify key limitations of the environmental analytical instruments in respect to pollution control,
* Analyze the environmental analytical instruments obtained in Nigeria in the light of what is obtained in the developed countries,
* Come out with recommendations and suggestions for stakeholders to use to mitigate any arising problems,
* At the end make data available to environmental planners, managers and all stakeholders.

The bigger goal of this study is to establish that the analytical methods, equipments, and standards on ground in Nigeria are sufficient for the purpose of environmental pollution control and monitoring using the study areas: also that Nigerian environmental standards are comparable to international standards, otherwise make suggestions to stakeholders to find ways of mitigating the problems. Thus this work shall support the assessment and remediation of pollution and decision making on envi-ronmental standards by policy makers in Nigeria.

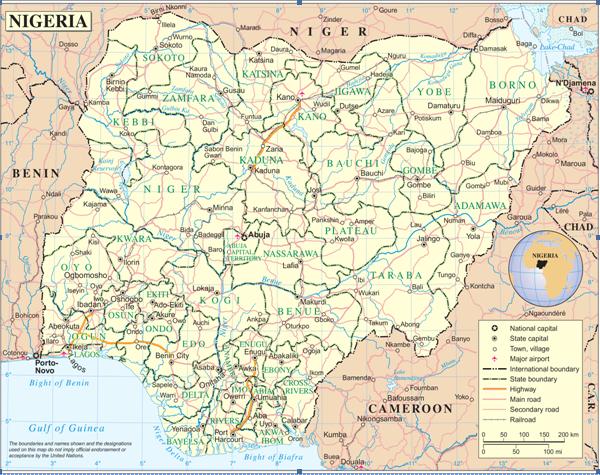
**1.4 Methodology**

The methods that are used in this research are mainly three: first is theoretical method using secondary sources, here an in-depth literature review is done to establish the state of the art of environmental pollution globally and in Nigeria, establish the state of art of analytical instruments used in pollution control and what is obtained in Nigeria in the literature. Study environmental pollution control laws, regulations, guidelines and standards to identify how they affect the choice of analytical instruments used in environmental pollution control. Second method is field work, which is done by person to person interview in collaboration with the environmental laboratories and organizations in the study area. The third method is the use of analytical laboratory results obtained from the environmental laboratories in the study area; these results are analysed using statistical methods and by comparison with results from developed countries.

**1.4.1 Study Area**

The study is intended to be carried out in seven cities as follows; Abuja, Ashaka, Gombe, Kaduna, Kano, Port Harcourt and Lagos, the location and positions of these cities in Nigeria can be seen in the map given in Figure 1.2. From this map it can be seen that the study areas are located in all the political-geographical regions in the country i.e. North-East, North-West, South-East and South-West. In these cities the organizations and companies that the research is intended to be carried out in are: The Federal Ministry of Environment, Housing and Urban Development in Abuja, Standard Organization of Nigeria (SON) Abuja, National Environmental Standards and Regulations Enforcement Agency (NISREA) Abuja, Ashaka Cement factory Gombe State, Federal Ministry of Water Resources Regional Monitoring Laboratory Gombe, Kaduna Refining & Petrochemical Company (KRPC) of the Nigerian National Petroleum Corporation (NNPC) Kaduna, Kano city air quality control, Shell Oil Company Port Harcourt and National Reference laboratory Lagos.

Abuja is located in the central part of Nigeria as can be seen in the map in Figure 1.2 below, it is the federal capital territory and the seat of power where all administration work are being done including environmental pollution control policies. Ashaka is located near Bajoga in Gombe state with a population of 7239, Ashaka cement factory is one of the big cement industries in Nigeria which contribute significantly in polluting the air of the area. Gombe is the state capital of Gombe state in the north east region of Nigeria, it has very few industries but it is located near big industries like sugar industry in Numan which is a big source of water pollutants. Kaduna is the state capital of Kaduna’s state, according to the 2006 census the population of the state stands at 6,066,562 with Kaduna city alone having 1,652,844.00 (www.population.gov.ng/pop\_figure.pdf). It is one of the big cities in Nigeria as can been seen from its population given in chapter 2. It is located on the Kaduna River, in the north-central part of Nigeria. It is a trade centre and a major transportation hub for the surrounding agricultural areas with its rail and road junction. Kaduna is an industrial city, it manufactures products like textiles, machinery, steel, aluminium; A big NNPC refinery and petrochemical is located in Kaduna with a lot of adverse effects on the Kaduna River.



**Figure 1.2** Map of Nigeria Where the Study Areas Gombe, Abuja, Ashaka (in

the near of Bajoga), Kano, Port Harcourt and Lagos can be Seen.

(Source; http://mapsof.net/Nigeria/static-maps/png/un-nigeria)

Kano is located in Kano state and is the second populous city in Nigeria after Lagos, with a population of 3,848,885 from the 2006 census. Kano is the centre of prosperous, densely populated agricultural region in which millet, sorghum, peanuts, livestock, grains and other types of food from the surrounding area are brought in for trade. Kano is one of Nigeria’s leading industrial centres; Tanning, oilseed processing, meat packing, and the production of furniture and enamelware are long established industries. Newer factories are always being established, such as factories that produce textiles, flour, pesticides, farm machinery, steel furniture, and various consumer goods. Port Harcourt is the capital of Rivers sate located in the Niger Delta south eastern part of Nigeria. Port Harcourt is a major industrial centre; it has a large number of multinational firms as well as other industrial concerns particularly business related to petroleum industry. Lagos has a population of above 8 million people; it is the most populous city in Nigeria and second in Africa. It is the major business city in Nigeria with a big concentration of industries and it has the major sea port in the country.

**1.4.2 Criteria for Choosing Research Laboratories and Organizations**

The country Nigeria is a Federal Republic with Abuja as the federal capital. The country is divided into four political-geographical regions as follows; North-East, North-West, South-East and south-West. The activities of the Federal Government are always located based on these regions, at least one in each region. The choice of the study area was based on this political-geographical division, at least one town from each region and the Federal Capital Territory which is the seat of power, therefore the choice of Ports Harcourt in the south-east, Lagos in the south-west, Kaduna and Kano in the north-west, Ashaka and Gombe in the north-east and Abuja as the Federal Capital Territory.

The Federal Ministry of Environment, Housing and Urban Development is in charge of environmental issues in Nigeria. Policies, laws and regulations concerning environmental pollution control are made directly or indirectly by the ministry or organizations under the ministry. Therefore all issues regarding standards and limits in environmental pollution control as it’s relate to the use of analytical methods can best be studied under this ministry.

The next organization in this study is Standard Organization of Nigeria (SON); this is the only organization in Nigeria directly responsible for drafting or approving any environmental standard in Nigeria. SON is also responsible for accrediting laboratories in Nigeria. It is therefore the right organization to give details about environmental laboratories in Nigeria.

The National Environmental Standards and Regulations Enforcement Agency (NISREA) was chosen because the Agency is directly responsible for enforcing environmental standards and regulations. The Agency took over the duties of the former Federal Environmental Protection Agency (FEPA) and therefore the national reference laboratories are directly under the Agency which they should use to monitor other laboratories. The Agency is the right organization to approach with issues of environmental laboratories in Nigeria.

The major polluters of the Nigerian environment are the oil industries found in Nigeria, the big ones being Shell and NNPC. The choice of Shell in Port Harcourt was based one on the fact that it is one of the big polluters and the location takes care of the south-east region of the country. NNPC Kaduna is located in the North-west and is one of the big polluters. Also the pollution of river Kaduna by the treated waste water from the company has been an issue of concern, as such the choice of this company. These two oil companies are very important in the environmental pollution control in Nigeria as such they were chosen for this research.

The choice of Ashaka and Kano were mainly due to the type of pollution expected to be studied there. The location of Ashaka in Gombe State is in the north east region of the country, therefore Ashaka as a cement company was chosen to take care of the north-east and also the fact that air quality control is being done there. Since the research covers all environmental pollutants i.e. air, water and soil, it was very important to have a cement company for the air pollution laboratory. Kano was chosen in the same light as Ashaka, but with different type of air pollution. As it will be seen later in chapter 2 Kano is one of the big cities in Nigeria with populations in millions and it is also an industrial town. This makes Kano to be chosen for air pollution control in big industrial city in Nigeria. Gombe regional water pollution control laboratory was selected based on the location and also being a regional laboratory which covers all states in the region. This laboratory covers water pollution by many types of industries in the states under the region, such as sugar factory in Numan, food and beverage factory in Jos, meat industries in Gombe, Bauchi, etc.

These organizations and companies were assessed based on the data collected during personal interview with the responsible persons in the organizations and companies. Guiding points to the interview are;

1. The types of laboratories directly control by the organization
2. Types of pollutants they produced/ monitor
3. Types of analytical instruments they used
4. The results they obtained
5. The personnel that managed the laboratories
6. The standards, laws, regulations and guidelines they used
7. The quality of results they obtained in terms of how they meet limits and how accurate and precise they are

**1.4.3 Research Strategy**

The research will be implemented in close collaboration with laboratory workers in the oil and gas industries, cement industries, chemical industries, national laboratories, and Government arms in the environmental sector in the study areas and the Federal capital. Environmental law enforcement agencies will be contacted to find out what types of standards there are in Nigeria.

The first part of the research is an extensive literature review to establish the theoretical background. This literature review established the background of environmental pollution both internationally and in Nigeria specifically. Having established that environmental pollution is a problem, the types of pollutants are reviewed so as to help in looking at what types of analytical instruments can be used to monitor these pollutants. Part of the theory work is to establish what types of industries are found in Nigeria, what are the pollutants they generate, as such determine what are expected to be analyzed in the environmental laboratories. The types of analytical instruments used in the literature in environmental pollution control are reviewed; this establishes the state of the art of environmental analytical instruments. A detailed study of advances in environmental analytics and monitoring is carried out. Information’s generated here is used to discuss laboratory findings and to compare the international state of the art of analytical instruments and standards in environmental pollution control with that of Nigeria. The literature review is followed by extensive field observations, person to person interviews and where possible technical data are collected. Then finally these technical data are analyzed using statistical methods and comparison. The findings are then used to draw conclusions and make recommendations to stakeholders.

**1.4.4 Methods for Technical Studies**

The technical studies will be mainly by participatory study as mentioned above. The environmental laboratories are visited in person, the analytical instruments in the laboratories are examined with the help of the laboratory workers, analytical results are taken, and then questions are asked to get more information on the laboratory activities. This will be done through interview using some questions that will help get the needed information. These questions include the following:

* What types of environmental analysis are done in their laboratories? i.e. in the area of air, water and soil pollution control
* What types of analytical methods are available? What informed the choice of the analytical methods being used? What is the suitability of methods being used?
* What is the quality control parameters monitored?
* What are the areas of the application of their results?
* Who benefits from their results?
* What standards are used e.g. ISOs, EPAs etc?
* How is the validity of the results being established? Is there any documentary evidence that the method has been appropriately validated?
* Do the laboratories have ISO 15189 accreditation standard
* How do Stakeholders know if the results in a certain laboratory can be relied upon or not?

At the end of the participatory study efforts will be made to get calibration data for the equipments found in the laboratories. As already mentioned some results of typical environmental analysis carried out by these laboratories are collected and used to examine the analytical instruments especially to see if they have good reproducibility. These results will be analyzed using suitable statistical methods to establish the quality of the instruments found in these laboratories.

In the study area Kaduna where the Nigerian National Petroleum Corporation (NNPC) is located, apart from visiting the laboratory like in other study areas, the waste water treatment plant there is visited to get information and data on the parameters of the treated waste water before being discharge into River Kaduna and sample analytical results are also collected here.

**1.4.5 Statistical Analysis**

Accuracy and precision of analytical instruments relies partly on calibrations which are performed by manufacturer-trained and certified technicians. Calibration provides documented evidence that your analytical instrument is working within manufacturer’s specifications. Calibration can be used to accurately represent the performance of the instrument at low concentration values. Accuracy of an analytical method is the extent to which test results generated by method and the true value agree. Therefore in this study calibration values and analytical results obtained from the technical data collection will be used to test the performance of the instruments using statistical methods such as standard deviation.

**1.5 Expected Outcome**

At the end of the study, one should be able to have a picture of what is obtained in other countries of the world as compared to what is obtained in Nigeria in terms of analytical methods in environmental pollution control.

At the end of this work environmental pollution managers in Nigeria will have a wider scope of analytical methods that can be used in monitoring remediation of polluted sites and for the control of guidelines. Industries should be able to use the results that will be obtained here to improve on their environmental pollution control and to adhere to world wide standards. This study will be carried out with the purpose of making analytical information on environmental pollution in Nigeria as reliable as possible, also to show to stakeholders that quality control and quality assurance play particularly important roles in environmental pollution control. After this work it is expected that Government will see reasons why the National laboratories should be well equipped with analytical instruments of international standards and very qualified staff hired to mine these labs. Where there is no standards setting body and where there are no environmental standards as compared to international standards, Government should be able to see this clearly and make effort to bring the situation to international level.

One result that will be achieved in this work is the types of environmental pollutants that are produced in Nigeria, particularly those that are hazardous to human and living things in general including plants. There is a lot of assumption that the Nigerian environment has only soil pollution from the oil companies, this study will point out the types of pollutants that are discharged into the Nigerian environment, especially air pollution which seems to get very little attention from the environmental stakeholders in Nigeria. Therefore after this study, it will be clear if the Threshold Limit value (TLV) of air pollutants have been adhered to or not.

**1.6 Summary of Research Work**

Figure 1.3 below is a summary of the research work and the interrelationship among the different aspects of the research. This interrelationship shows that the analysis of analytical instruments in environmental pollution control is interwoven with many factors such as the fact that the environment is polluted. Scientific evidence to this pollution is given in this work and this leads to the parameters to be monitored which are mainly determined by regulations. The regulations also determine the types of analytical instruments and methods that are used to analyzed the monitored parameters. The field research and the interrelations with the other aspects of the research formed the core practical part of this work which leads to the results and recommendations.

**Substances to Monitor**

**Scientific Evidence**

**of Pollution**

**Regulations/Standards**

**Environmental Pollution Control**

**Measurement Techniques**

**Crucial/peculiar items**

* **Sampling strategy**
* **Sampling techniques**
* **Separation**
* **Interpretation**

**Appropriate** **Equipments**

**Lab Assignments**

**Lab equipments**

**Personnel**

* **Role in network of labs**
* **Responsibilities**
* **Regional, branch, etc.**

**Costs, Sensitivity,**

**Maintenance, Operational**

**Skills, Quality Assurance**

**Headcount, Education**

**Training, Experience**

**Budget/Financing**

**Legal relevance**

**Results and**

**Recommendations**

**Figure 1.3** Different Aspects of the Research Work

**Chapter 2 Literature Review**

**2.1 Introduction**

There is probably no one who can testify with any degree of accuracy (although there is always someone who can testify with a high degree of uncertainty) as to the last time earth was pristine and unpolluted. Yet to attempt to return the environment to such a mythical time might have a severe effect on current indigenous life, perhaps a form of pollution in reverse. However, there is the possibility that through the judicious use of resources and application of the principles of environmental analysis, environmental science, and environmental disciplines involved in the study of the environment, we can come to a state where pollution is minimal and not a threat to the future. Such a program will involve not only well-appointed suites of analytical tests but also subsequent studies, that range from the effects of changes in the environmental conditions of a region to the more esoteric studies of animals in the laboratories (Speight, 2005).

Environmental pollution has been defined by many, the business dictionary defined it as presence of matter (gas, liquid, solid) or energy (heat, noise, radiation) whose nature, location or quantity directly or indirectly alters characteristics or processes of any part of the environment, and causes (or has the potential to cause) damage to the condition, health, safety, or welfare of animals, humans, plants or property. In chemistry dictionary it is defined as an undesirable change in the physical, chemical or biological characteristics of the natural environment, brought about by man’s activities. In wikipedia it has been defined as, the introduction of substances or energy into the environment, resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impairs or interferes with amenities and other legitimate uses of the environment. From these definitions it can be said that environmental pollution if not tackled can become a big threat not only to human lives but the whole ecosystem. Recent happenings such as those; in Germany, the flooding of Dresden’s historic old town by the river Elbe in August 2002, in Asia the Tsunami in 2004 and in the US New Orleans flooding in 2006 are examples of such threats to human lives and the ecosystem at large. The effects of flooding on the balance of nature have recently become far more serious due to human intervention in the environment and the natural hydrological regime.

It is understandable then, that there is a large growing public concern worldwide over potential environmental and human health - related effects associated with environmental pollution. Roden et al (2004; 2005) in their papers titled; “properties of particles generated by traditional wood burning cook stoves” showed that indoor air pollution from burning of solid fuel kills 1.6 million people per year. Particulate emissions from this source are poorly characterized and not taken as a serious threat to humans and the environment, but these emissions have serious climate and health effects. According to Roden et al (2005) up to about 2.4 billion people use biofuel for heating and cooking, and a large percentage is used in wood burning cook stoves. The major threat though seems to be the pollution from industries, but that from bio fuels should also be taken serious, more importantly the particulate emissions from such source such as wood burning cook stoves should be characterized properly using very good analytical methods.



**Figure 2.1** An Industrial Flare in China

(Source, Blacksmith Institute’s Report 2007)

The World has experienced rapid industrial development and population growth and this has resulted into rapid pollution and degradation of the environment. As such industrialization has come with a high price; an industrial flare shown in Figure 2:1 above is an example of how greenhouse gases are being released into our environment from our industries. Since we are at the age of high technology, which involved the use of such different types of industries and the introduction of so many types of waste into the environment, there is no wonder then that environmental pollution is increasing so rapidly such that most people are worried and wondering what will befall our planet in the near future if drastic measures are not taken. Some of the drastic measures needed to tackle such pollutions are the use of analytical instruments to detect what types of pollutants we are releasing into the environment and how to remedy the problems.

Some environmental problems can be felt globally but the polluting sites or country may also experience severe environmental problems within their own boundaries. One will expect that in the developing countries, where there are less industries as compared with the developed countries, there will be less environmental pollution problems. Unfortunately, in some developing countries, the situation is even worse than the developed countries, example is that found in Sudan. The UNEP spokesperson in Geneva on the 22nd of June 2007 said there are five million internally displaced people and refugees in Sudan. Environmental degradation is one of the driving forces of displacement and the environment is being further undermined by the sheer scale of displaced people and refugees in some areas. The rapidly eroding environmental services in several key parts of Sudan e.g. land degradation, desertification, deforestation, decline in rainfall, rise in temperature, etc, are among root causes of decades of social strife and conflict (http://www.unep.org/sudan).

According to Blacksmith Institute’s report in 2007, pollution is a major cause of death, illness and long term environmental damage in poor countries. The Institute equally believed that, in these parts of the world, pollution shortens lives, damages children’s development and growth, causes chronic illnesses and kills thousands of people indiscriminately (www.blacksmithinstitute.org). The problem in the poor countries, unlike the richer countries who can afford to enforce high standards of environmental protection, is that these poor countries can not afford these high standards. In developing countries, in most cases, there is not the understanding, the commitment or the resources to apply high standards of environmental protection. Therefore environmental pollution problem is not only in industrialized countries, but it is a global problem without any exception, and need to be tackled also globally. For the problems to be properly tackled, efficient measurements of pollutants so as to meet standards, control, and remediation of polluted sites, is a vital part of the solution and for these, good and accurate analytical methods are needed.

Environmental pollution measurements of any kind are mainly for monitoring the system as to have early warning for any serious pollution or chemical accidents, set standards for productions and to ensure standards are meet. Monitoring helps to protect natural sensible resources such as water, air, plantation, etc. Monitoring requires first the right measurement and secondly reliable instruments with low maintenance. Right measurement means a guarantee of correct measurement, with results that are accurate and reproducible. Measurement, in essence is a function of accuracy, precision, reliability, repeatability, sensitivity, and response time. That is why the choice of analytical instruments used in environmental protection is very important and can affect the judgment of all stakeholders in environmental pollution control.

The increase in industries as mentioned above means disposal of a wide variety of chemical contaminants into the environment. Therefore it is essential that the necessary tests be designed to detect the pollution and its effect on the environment. In environmental pollution control chemical analysis must be involved at all stages such as; Recognition of the pollution problem; Monitoring to determine the extent of the problem; Determination of control procedures; Legislation to ensure the control procedures are implemented and monitoring to ensure the problem has been controlled. Legislation is very often drafted in terms of analytical concentrations. A large proportion of current monitoring is to ensure compliance with legislation e.g. monitoring of discharges from industries. It can be said therefore that chemical analysis is a necessary component of almost all environmental pollution control stages. These make it essential that the most appropriate analytical methods are selected from a comprehensive list of methods and techniques that are used for the analysis of environmental samples.

There are many criteria to be considered for the selection of a measurement method and the realization of the method. These criteria include;

1, Sensitivity/Detection limit of the equipment

2, Response time

3, Reagents consumption

4, Environmental pollution caused by the reagent during operation

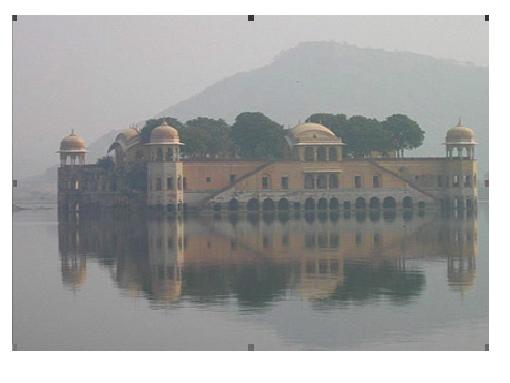
5, Danger for the Operator

This work is going to look at the state of the art as regards environmental pollution, analytical methods involved in the developed countries vis-à-vis

that of Nigeria. Effort will be made to look at some methods used in Nigerian oil industries, cement industries, and monitoring laboratories to measure pollution control, monitor production or to set standards and make recommendations where necessary. In doing this an intensive literature review is done here to establish the scientific background of these criteria for measurements of environmental pollutants. To demonstrate that analytical instruments are very important parts of environmental pollution control, first this research will show from the state of the art of the environment that pollution is a real problem and also show that the types of pollutants in the environments need good reliable analytical instruments to detect them and control their remediation.

* 1. **The State of the Environment**
     1. **General State of the Environment**

The picture below in Figure 2.2 is that of the Jal Mahal (Water Palace) in Jaipur, India. The appearance of fog suggests the photo was taken in the morning or in the evening, that is not the case, it was taken in the afternoon, and the 'fog' is actually pollution (Paul Coffey, BBC News). This is just an example of the state of the environment with regards to pollution. Climate change is one big extreme situation of the state of the environment, and this is becoming a great concern in the minds of all right thinking human beings.



**Figure 2.2** Water Palace India(Source; Paul Coffey, Hong Kong 2005)

There is growing evidence that climate change is occurring and having so much effect on the world environmental conditions. One need only to listen to the news on the television or in the radio and one can clearly see that climate change is already a global problem. For example, on the 15.09.2007, Euro News reported that the arctic ice is record low since 30 years; millions of cubic meters have melted. According to this news, arctic ice may completely disappear by 2040 if it’s continued to melt at the present rate.

Climate change and other environmental challenges impact every corner and community on the planet. Our generation is witnessing the early stirrings of extreme weather events, melting ice and other climatic manifestations. Long-lived greenhouse gases like carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are in the increase, such releases as seen in Figure 2.3 below are responsible for such greenhouse gases. If an industry with a chimney such as the one in Figure 2.3 have good gas analytical instruments in the plants for process monitoring and pollution control, such types of emissions can not be discharged into the environment, but rather retreated to reduce the greenhouse gases.



**Figure 2.3** A Typical Industrial Chimney Emitting Some Greenhouse Gases into the Atmosphere

(Source; http://www.gettyimages.de/detail/86736464/Photographers-Choice)

The Intergovernmental Panel on Climate Change (IPCC) in its 4th report gave a very comprehensive report on the state of the art as regard climate change (Solomon, S. et al; IPCC report 2007). They reported that, the concentration of atmospheric CO2 has increased from a pre-industrial value of about 280ppm to 379ppm in 2005. The annual CO2 growth rate is reported to be larger during the last 10yrs (as of time of report i.e. 1995-2005). It is estimated according to their report that about 2/3 of anthropogenic CO2 emissions have come from fossil burning and about 1/3 from land use. The effects of this increase in CO2 emission are many, one of which is the uptake of this CO2 by ocean, seas and rivers resulting in changes in chemical equilibrium. Dissolved CO2 forms weak acid, so as dissolved CO2 increases, pH of the waters decreases. This has drastic effect on aquatic lives and some uses of sea and river water. More threatening is the effect on ozone layer; CO2 as a greenhouse gas caused depletion of ozone layer leading to global warming, which is a serious problem as reported by Solomon et al in the IPCC report. The trend with methane (CH4) is similar, because the abundance of CH4 in 1995 of about 1774ppb is more than double its pre-industrial value. N2O concentration in 2005 was 319ppb, about 18% higher than its pre-industrial value. This increase can be attributed to human activities, particularly agriculture and associated land use.

The same report also showed that eleven of the last 12years (as of the time of report i.e. 1995 to 2005, with the exception of 1996) rank among the 12 warmest years on record since 1850. They concluded that the rate of warming averaged over the last 50years is nearly twice that for the last 100years. The greatest warming has occurred in the northern hemisphere’s (NH) winter and spring. Average arctic temperatures have been increasing as almost twice the rate of the world in the past 100 years. Heat waves have increased in duration beginning in the later half of the 20th century. The record breaking heat wave over western and central Europe in the summer of 2003 is an example of an exceptional recent extreme. In the tropics and sub-topics, longer droughts have been observed since the 1970s, and get worst with time. The Sahara desert is getting wider and wider.

According to the report of the state of the environment in Germany 2005 by the Umwelt Bundes Amt, the concentration of CO2 has risen by about 30% since 1750 and now exceeds a value of about 370 PPMV due to man made emission, with industrial emissions as seen in Figure 2.3, this increase is expected. According to their report the present CO2 concentration has not been reached in the last 42000 years, or probably in the last 20 million years. The last current annual rate of increase has been given as the highest in the last 2000 years. Nitrous oxide (NO2) concentration also has risen since 1750 by around 17% and is still rising. The current concentration of NO2 is the highest in the last 100 years. The trend is similar in SF6 concentration, which has risen by two orders of magnitude since its industrial production began in 1953. This report has a good degree of agreement with the IPCC report quoted above and with many other researchers’ results. Environmental pollution has been proved, by all these reports, beyond reasonable doubt to be real and serious.

The Ministry for Environment in Germany always carries out a study every two years to see how people’s sensitivity to environmental issues is doing. The last study carried out in 2006 (Kuckariz U; Rädiker S and Rheingans H, 2006 Marburg) showed that one third of Germans rate the quality of the German environment as very bad, and 91% rate the global environment as very bad. This is almost double the number in the same study carried out in 2004. People are now taking environmental pollution very serious as such this reflects on their opinion on the environment. In the same study many people believed that environmental pollution is responsible for world’s health problems, especially particulate matter in the atmosphere, but also chemicals in our day to day products as well as harmful substances in food which is posing a great risk to human health. This study shows that environmental protection is becoming more and more important in the minds of people. It is a general believe that the world is heading for an environmental catastrophe if human beings continue in the present pattern of destruction to the environment. On the weekend of 14-16 September 2007 about 35 million people across the planet took part in community-based action on climate change. This confirms the awareness that is being created in our society and hence a good percentage of our communities are well informed about the state of the environment. (Clean up the World at: http://www.cleanuptheworld.org/en/NewsandMedia/cuw---unep-global-release.html). This action is in agreement with the findings of the German studies given above, people world wide are now very conscious of the environmental problems around them and are making every effort to see how they can contribute. Figure 2.4 below is an example of these community involvements, people at the grass root willing to contribute their part in keeping our environment safe and healthy. Apart from physical cleanup, many communities focus on limiting the impacts of environmental pollution through activities such as waste reduction and recycling, water and energy conservation and planting of trees. A good lesson that should be learned from such community involvement is that each human being on the face of the earth should be ready to clean up, fix up and conserve his/her environment, and the industries should do even more especially in making sure they have reliable analytical instruments for pollution control.



**Figure 2.4** One of the Community Involvements Activities on the Environment

(Source: <http://www.cleanuptheworld.org/PDF/en/botswana--debswana-diamond-mining-company--waste-activity.jpeg>)

Blume et al (1983) reported that erosion, sedimentation process, translocation of waste gases, and leachates changed the soil around the landfills and the soil composition of the adjacent areas in a Berlin landfill. His report shows that the effect mentioned above is not affecting only our atmosphere and water, but even the soil.

In Nigeria the environmental pollution has been mainly due to the oil exploration, spillage of oils, refineries activities for oil production, other industrial activities such as fertilizer industries, mining industries, cement production, etc (John 2001). Several studies have been conducted on the impact of industrial wastes and chemical contaminants on soil both in Nigeria and else where. Ogoke (1980) reported that crude oil pollution significantly reduced weed weight and increased organic matter content, nitrogen and pH of the soil. Odu (1977) reported on the impact of oil spillage on soil microbial population. Tripathi (1990) reported that effluents discharged from a chemical fertilizer factory in India affected the physio-chemical properties of soil, its mineral composition and germination of wheat. The study showed that the concentration of Na was 40 times higher in the effluent than in the nearby well water. The effluent Na showed a positive significant correlation and significantly negative correlation with K and Ca. The soil cation exchange capacity (CEC), porosity and water holding capacity were reduced in effluent-polluted soils. In a related study, Manoylovic (1989) reported that fertilizers were considered as possible pollutants of soil, water and plants, Kudeyarava (1989) also reported that excessive phosphorus fertilization as used in Moscow, Leningrad and other areas of the Russian Republic led to soil degradation and water pollution by the leached soil constituents. Studies on the effects of industrial pollution on soil trace elements indicated that the solubility of salts increased from 0.5 to 2.2% in subtropical semi-desert solon chalk and gray-brown soils and enriched Pb 2.9, Cr 2.9. Cu 1.8, B and V1.7, CO 1.6 and Zn 1.3 fold, whereas Sr decreased 0.7 fold while Ba, Mn, Na as well as Ni were not altered. Godson et al (2004) also carried out similar studies in Nigeria on the impact of chemical fertilizer industrial wastes on the quality of soil in the vicinity of a fertilizer industry located in Port Harcourt. Their results showed very high contents of metals, some heavy metals and other elements in the soil.

From all these results above, one can confidently say, the threat due to environmental pollution is not limited to our climate, but it is all encompassing. Therefore the state of the environment is not looking good from all the studies given above and this deserve urgent action by all, from individuals, industries, NGOs, scientists, governments, communities, etc.

**2.2.2 State of the Nigerian Environment**

Nigeria like many developing countries with some kind of industrialization faces severe environmental degradation that appears to be threatening the long term development prospects. This is mainly due to the fact that Nigeria relies mainly upon the use of natural resources in its growth and development process. The use of these natural resources is not done in a sustainable manner, hence threatening the future generation’s ability to meet their own needs. In general there is no proper record of developments that indicate the degrading state of the Nigerian environment like the study by Umweltbundesamt in Germany; only pockets of isolated cases are reported in the literature, such as pollution by the oil industries in the Niger Delta area. A proper study such as to show certain general trend of indicators are on the increase, showing the degree of environmental degradation, is basically lacking in Nigeria’s environmental studies. As such to give the state of the Nigerian environment, only such individual cases will be mentioned here.

Industrial activity in Nigeria is a major contributor to many of the environmental and social problems facing the country. Some industries that are found in Nigeria include gas and oil, chemical, food and beverages, hide and skin, cement, paint industries, iron and steel, paper and pulp, agro-allied, motor assembly etc. These industries all contribute to the environmental pollution in various ways; common amongst them is the drainage of their effluents into open drains and water channels. Some go to the extent of burying their expired and hazardous chemical waste in the ground. The oil industries have some peculiar problems such as breakdown and canalization of oil pipelines causing a lot of water and soil pollution. This has become a threat to the environment, aquatic and human lives (CIA World Factbook-Nigeria).

The oil industries have the bigger effects on the environment compared to the other industries in Nigeria, therefore a review of some specific cases of these pollution will be done here. Most of the oil exploration has thus far been carried out in the Niger Delta area as such most of the reports found in literatures are on the damage done in this area. Greg Campbell quoted the spokesman for the Jesse Town council of elders in the Niger Delta area saying, up to 1000 people were involved in a fuel fire accidents at one time. Pipelines carrying both gas and oil rupture with alarming effects in Nigeria, either at the hand of saboteurs or through human and equipment error. Shell Nigeria reported that up to 50,200 barrels of oil were spilled in 1998 due to human saboteurs. In December 2000, a pipe that had leaked for weeks exploded in Atlas cove, near Lagos, killing about 50 people. On the side of the highway leading to the town of Besini in the Niger Delta, two separate 2years-old oil spills turn the jungle black, these oil spilled formed small lakes of oil affecting all forms of life in that area. The Shell Oil Company reported in its environmental performance that in 2006, it recorded 241 oil spill incidents compared to 224 incidents in 2005. Two examples of such cases quoted by Shell itself are those at Nembe creek trunk line (NCTL) at Krakrama estimated to be up to 7,000 barrels and the second Nembe-IV estimated to be 2,500 barrels. If for only two cases so high quantity was discharged into the environment, it is not difficult to conclude that the environment in the Niger Delta with the quoted 241 cases of spills are heavily polluted. A lot of fire disasters are associated with many of these spills, for example the ERA’s report in late June 2000 gave incidents where such a spill leads to a fire disaster. The spill which was due to a leaking pipe which covered up to 30 kilometers was left to continue leaking until in July when the pipe exploded causing a huge fire. According to this report more than 3000 people were burnt to death. A similar incident has earlier on occurred in Jesse village where many lives were equally lost. There are many records of such disasters, such as near Adeje village, Elume-Ibada, etc. The effect of such disaster is not only the loss of lives, but pollution of the air, soil, river and water bodies around these spill sites. The Niger Delta area of Nigeria has been discussed and studied to a large extent, that one may think this is an overemphasis, but if the 1994 Draft of the Geneva group declaration (Geneva Declaration UN paper 1994) of principles on human rights and the environment should be considered, then the people in this area have the right to cry out loud (Soji 2006). Since the declaration says in part I Nr. 4 that “All persons have the right to an environment adequate to meet equitably the needs of the present generations and that does not impair the rights of future generations to meet equitably their needs”. Part II of the same declaration says “All persons have the right to freedom from pollution, environmental degradation and activities that adversely affect the environment, threaten life, health, livelihood, well-being or sustainable development within, across or outside national boundaries”. Nr. 6 says “All persons have the right to protection and preservation of the air, soil, water, sea-ice, flora and fauna, and the essential processes and areas necessary to maintain biological diversity and ecosystems”. One can agree that the people living in the Niger Delta to a large extent have many of their rights violated by the big oil companies operating there. At the rate at which oil is been spilled in the area, is clear that the future does not look good if nothing is done to check these pollutions. These spills introduce a lot of organic pollutants in the environments in varying degrees, such as PCBs, persistent organic pollutants, VOCs, hexachlorobenzene (HCB), PAHs; etc which may be ignored after the oil has been removed from the soil (Agha 2004). That is why analytical methods are very important in remediation to be able to ascertain the effectiveness of the remediation.

Another environmental problem caused by oil production in Nigeria is the contribution to global warming, because the country flares more gas than any other country, apart from Russia (John 2007). The methane produced has a much higher global-warming potential than carbon dioxide.

Having given the short over view of the pollution due to the oil in Nigeria mention must be made of some other industrial pollutants. Sayo (2005) made an impact assessment of the industrial effluent on water quality of a receiving river Alaro in Ibadan, Nigeria. He assessed the water quality of the river upstream and down stream after the point of effluent discharged. The results of his study revealed that the water qualities of Alaro River was adversely affected and impaired by the discharge of industrial effluent. According to him, the water of the river became gray-black, stagnant with offensive odor after the point of discharge. The studied parameters like BOD had poor values after the point of discharge. Another means of pollution in Nigeria is domestic solid waste management; it is one of the critical environmental problems in urban cities of Nigeria. This could be attributed to the increase in urbanization (population increase), haphazard urban planning, poverty and weak enforcement of environmental laws (Ajao et al). The results of such pollution is wide spread cases of different disease. Adelegan (2003) reported that there are estimated 4 million cases of guinea worm in West Africa with a large contribution from Nigeria. According to him hospital records have confirmed high incidence of typhoid, cholera, dysentery, infectious hepatitis and guinea worm in urban settlements of Nigeria, and these are highly associated with environmental pollution.

* 1. **Environmental pollutants**

**2.3.1 General**

Here attempt is made to discuss what constitutes environmental pollutants, to be able to measure efficiently; it should be clear what the pollutants in questions are. The matrices in which these pollutants are found influence the choice of analytical methods for their analysis and so they’re also very important. Pollutants can come from many different sources and they can pollute air, water and land in a variety of ways. In this section pollutants will be discussed under the three categories, air pollutants, water pollutants and soil pollutants. A bulk of environmental pollutants is organic based, but there are also a number of other sources of environmental pollutants. The Helsinki convention (The Helsinki Convention http://www.helcom.fi) gave a list of some substances they called priority groups of harmful substances, which include other categories apart from organic pollutants. These are;-

a) Heavy metals and their compounds

b) Organo halogen compounds

c) Organic compounds of phosphorus and tin

d) Pesticides, such as fungicides, herbicides, insecticides, slimicides and chemicals used for the preservation of wood, timber, wood pulp, cellulose, paper, hides and textiles.

e) Oils and hydrocarbons of petroleum origin

f) Nitrogen and phosphorus compounds

g) Radioactive substances, including wastes.

These pollutants can be found in air, water or soil, these are discussed below as they relates to the different environments they can be found

**2.3.2 Air Pollutants**

An air pollutant is any substance in the air that can do harm to humans or the environment in general. Air pollutants may be natural or man made, organic or inorganic and may take the form of solid particles; liquid droplets or gases. Six common air pollutants (also known as "criteria pollutants") are normally found all over. They are particle pollution (often referred to as particulate matter), ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can harm human health and the environment, and cause property damage. Of the six pollutants, particle pollution and ground-level ozone are the most widespread health threats. In America the EPA calls these pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting standards. The set of limits based on human health is called primary standards. Another set of limits intended to prevent environmental and property damage is called secondary standards (http://www.epa.gov/).

Atmospheric particles have numerous effects, such as reduction and distortion of visibility, enhancing atmospheric chemical reactions, hence affecting weather in many ways. They can also get into respiratory tract as such damaging health in many ways. These particles in the atmosphere, which range in size from about one-half millimeter down to molecular dimensions, are made up of a large variety of materials and discrete objects that may consist of either solids or liquid droplets as shown in Table 2.1 below. Particulate matter make up the most visible and obvious form of air pollution. Such particulate pollutants especially within the range of 0.001 to 10μm are commonly suspended in the air near sources of pollution such as the urban atmosphere, industrial plants, highways and power plants (Christopher Roden 2005). Table 2.1 gives some examples of classes of particulate matter and their description. Generally some examples of very small particles of the classes given below include carbon black, silver iodide, combustion nuclei, etc. An example of large particles is cement dust, and that of mist includes raindrops, fog and sulfuric acid mist. Aerosols consist of carbonaceous material, metal oxides and glasses, dissolved ionic species and ionic solids. Asbestos is of concern as an air pollutant, because when inhaled it may cause asbestosis (tumor of the mesothelial tissue lining the chest cavity adjacent to the lungs), and bronchogenic carcinoma (cancer originating with the air passages in the lungs).

**Table 2.1 particulate matters**

|  |  |
| --- | --- |
| **Types of particulate** | **Description** |
| Aerosol | Colloidal-sized atmospheric particle |
| Condensation aerosol | Formed by condensation of vapors or reactions of gases |
| Dispersion aerosol | Formed by grinding of solids, atomization of liquids, or dispersion of dusts |
| Fog | Term denoting high level of water droplets |
| Haze | Denotes decreased visibility due to the presence of particles |
| Mists | Liquid particles |
| Smoke | Particles formed by incomplete combustion of fuel |

(Source; Guidelines for drinking water quality; 2nd Edition; WHO; Geneva; 1993)

Some metals found predominantly as particulate matter in polluted atmospheres are known to be hazardous to human health. These are mainly heavy metals; lead is the toxic metal of the greatest concern in the urban atmosphere because of the concentration in which it occurs, this is followed by mercury, others include beryllium, cadmium, chromium, vanadium, nickel and arsenic (a metalloid). In the 1970s leaded gasoline was commonly used, as such a lot of lead was entering the atmosphere through this route. With the reduction of leaded fuels, atmospheric lead is of less concern than it used to be. Atmospheric mercury is of concern because of its toxicity, volatility and mobility. Atmospheric mercury comes mainly from coal combustion and volcanoes.

Some of the "classic" environmental pollutants such as DDT, toxaphene, chlordane and hexachlorocyclohexane (HCH) are insecticides. These have been deliberately dispersed over agricultural land. Their use has gradually been phased out in industrial nations, but some of these agents continue to be used elsewhere especially in the developing countries. Substances of this kind remain present in the environment. Industrial chemicals never intended for dispersal outdoors can also leak into the environment. PCBs (polychlorinated biphenyls) are the best-known example; other compounds of this kind are polychlorinated naphthalene (PCNs), chloroparaffins and brominated flame retardants. Some stable industrial chemicals are no longer manufactured. The use of PCBs has been gradually banned completely in many countries. It has been found to be more difficult to replace some other chemicals with less hazardous substitutes, the use of brominated flame retardants continues almost unabated for this reason. Aromatic organic particles contain polycyclic aromatic hydrocarbons. These polycyclic aromatic hydrocarbons (PAH) in atmospheric particles have received a great deal of attention because of the known carcinogenic effects of some of the compounds, e.g. benzo(a)pyrene, acephenanthrylene, benzo(j)fluoranthene and indenol, the whole group of these compounds are commonly known as POPs (persistent organic pollutants).

A third category of persistent organic pollutants occur mainly as by-products of various manufacturing or combustive processes, these include hexachlorobenzene (HCB), polycyclic aromatic hydrocarbons (PAHs) and dioxins. Elevated levels of PAHs are most likely to be encountered in polluted urban atmospheres and in the vicinity of natural fires such as forest, also coal furnace and cigarette smoke may contain some levels of PAHs. To a limited extent many of these compounds can also be formed naturally, but anthropogenic emissions have now declined substantially, thanks to a number of steps that have been taken.

Renewable energy resources are in the moment’s very good alternative to fossil fuel, but not all of them are environmentally friendly. The use of biofuels especially in form of fire wood causes a lot of air pollution, as such can not be considered as good alternative for fossil fuel except where the emissions are being taken care of. Emissions from Biofuels combustion include the following pollutants and some effects they cause (Roden 2005):

CO2 – green house gas

CO – health concerns

NOx – ozone precursor

VOC- health concerns and ozone precursor

Carbonaceous particles (Such as Black carbon, organic carbon) - health concerns

Polyaromatic hydrocarbons (PAH) – health concerns

**2.3.3 Water Pollutants**

Water pollutants can be defined as follows: a water pollutant is a substance or effect which adversely alters the environment by changing the growth rate of species in the water, interferes with the food chain, is toxic, or interferes with health, comfort, amenities, or property values of humans and all living in and around the water (http://www.cpe.mrt.ac.lk/leve1/Leture11/  
ENVIRONMENTAL%20POLLUTION.ppt%20\_Compatibility%20Mode\_.pdf). This definition implies a need to set standards or guidelines in order to indicate that water, whose chemical properties exceed the limits of the standards, may cause a particular environmental alteration or interference.

There are many materials that constitute water pollutants such as organic compounds, organic matter, heavy metals, inorganic salts, etc. Organic compound in water is of environmental importance for several reasons: e.g. particular compounds may be toxic in varying degrees to living organisms, including human beings. Aqueous organic matter (OM), in particular the bulk residues of plants and animals or some industrial discharges, can be oxidized by oxygen and other oxidizing agents in water. When released into a water body, the bulk OM degrades, consuming oxygen and leaving the system in oxygen deprived state. The loss of oxygen creates stress on many aquatic organisms including fish. These conditions are frequently observed down stream from points where high OM waste water or industrial water is discharged. These OMs when present in high concentration can create anoxic conditions in water. Humic material (HM) is another form of environmental organic matter pollutant. They constitute half of dissolved organic matter (DOM) in surface water (Total Hardness, Calcium Hardness and Magnesium Hardness in Raw and Portable Waters by EDTA Trimetry London; 1981).

Polyaromatic hydrocarbons, polychlorinated biphenyls, and dioxins are all well known because of their contribution to environmental problems. Residues of pesticides and their metabolic products can also be carried into water (Linear Alkylbenzene Sulphonates: 1993). The pesticides used today in developed countries in agriculture are all degradable to varying degrees. However, locally at least, these agents too may be unintentionally dispersed beyond the fields. Low but not insignificant concentrations of pesticides and pesticide residues sometimes occur in streams draining agricultural areas and also sometimes in groundwater. But generally the dispersal of organic pollutants is less effective in water than in the atmosphere (air). Owing to their low solubility in water, persistent organic pollutants mainly occur adsorbed to particles, which subsequently settle on the bottom. In the Baltic Sea, which is almost cut off from other seas and oceans, organic pollutants have accumulated in higher concentrations than in most other marine areas. Organic pollutants can seep back into the water from contaminated sea and lake beds many years after emissions themselves have ceased. With time, however, the contaminated layer of sediment will become buried under new sediment.

Table 2.2 below is a list of some elements and compounds that can be found in water as pollutants, most of them metals. Of all environmental issues involving water, contamination by toxic metals is one of the most visible, referred to as heavy metal pollution. Example is the widespread contamination of groundwater in Bangladesh and eastern India by semi-metal arsenic (Singh 2004). Metals exist in the aqueous environment in a variety of forms such as aqua-complexes that are fully protonated or partially deprotonated, as complexes with inorganic ligands such as chloride and carbonate, and as complexes with naturally occurring organic molecules including discrete molecules. Of all the metals that poise environmental pollution, mercury is the most extensively studied, because of the several incidents of poisoning by mercury resulting in chronic illness and death. Perhaps the best known case is that which occurred in Minamata, a Japanese fishing village, during the middle of the twentieth century. During this accident, hundreds of people died from eating fish that contained more than 100μgg-1 of mercury. The source of the mercury was from waste Hg2+ catalyst from polyvinyl chloride manufacture that was discharged into the ocean bay (Allchin, Kugler 2004). Inorganic tin undergoes alkylation’s in aquatic environments to form compounds such as monomethyl tin (CH3Sn3+) and diethyl tin ((CH)2Sn2+) (www.oup.com). These organotin products are more toxic to aquatic biota than are the original inorganic tin compounds, and toxicity become greater as the number of organic groups increases in the series RnSn (4-n) 6, (n) from 1 to 3, R Stands for methyl groups,(n) the number of methyl groups (www.oup.com/uk/orc/bin/9780199274994/vanloonCh-12.pdf). Another form of metal pollutant is in the form of suspended matter. In some water, metals or some other pollutants exist as suspended particulate materials and not dissolved in solution. These suspended particulates are responsible for the distinct milky appearance of water.

**Table 2.2 Some Minor, Trace Elements and Compounds that can be Found in Water as Pollutants.**

|  |  |
| --- | --- |
| Name of the element/compounds | Name of the element/compounds |
| Arsenic | Boron |
| Cadmium | Fluorine |
| Chromium | Benzene |
| Cobalt | Atrazine |
| Copper | Lindane |
| Iron | DDT |
| Lead | Monochoramine |
| Manganese | Chloroform |
| Molybdenum | TCE |
| Nickel | Mercury |
| Selenium(IV) |  |
| Uranium |  |
| Zinc |  |

(Source; Guidelines for Drinking Water Quality; 2nd Edition; WHO; Geneva; 1993)

Typical measured properties that can indicate pollution in water include the following; - Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids (TS), Suspended Solids (SS), Total phosphorus (TP), Total Nitrogen (TN), Conductivity, Sodium hazard, Alkalinity, Potential of Hydrogen (pH) etc. The importance of these parameters can be illustrated using sodium hazard, pH and alkalinity. High sodium ions in water affects the permeability of soil and causes infiltration problems, this is because sodium can replace calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles. If the soil has calcium and magnesium predominantly adsorbed on the soil exchange complex, the soil will be easily cultivated and will have a permeable and granular structure. But if sodium caused dispersion in the soil, this will results in breakdown of soil aggregates with the results that the soil becomes hard and compact when dry and reduces infiltration rates of water and air into the soil affecting its structure (Anderson et al 1989). As with sodium hazard explained above, pH vs. alkalinity also affects water quality in that, alkalinity is a measure of the resistance of water to a reduction in pH when hydrogen ions are added. Any weak acid or base can act as a buffer, e.g. carbonate or carbonic acid. Since pH level of water is very important for the aquatic lives in the water, the alkalinity of the water is therefore very important and should be maintained.

**2.3.4 Soil Pollutants**

Past and present economic activities have resulted in the pollution of the underlying soil where these activities took place. Apart from direct pollutants on soils, there are many other environmental problems that are associated with soil such as erosion, leaching, acidification, etc. In any human society bulk solid wastes are produced as by product of normal and fundamental activities of living. These wastes can be as rudimentary as food scraps, ash from fires and excreta from humans and animals, but with industrialization the wastes are more than rudimental both in quantity and variety. The amounts of waste produced by intensive agriculture and modern industry are very alarming. Also in wealthy countries there are so much wastes generated by ordinary citizens in a consumer-oriented urban setting, and related to this are the increasing populations which have led to the rapid expansion of existing urban areas and the development of new ones. As such areas used by industries in the past have often become valuable land for the development of domestic housing in many parts of the world. Therefore many substances, which are well known toxicants or carcinogens from the former industries, are present in relatively high concentrations in the soil in some urban areas. Some of these areas have been sited and tagged as contaminated sites by many environmental activists. So many contaminated sites such as love canal, the Picello farm and the Valley of Drums have become so popular (Amdur et al, 1991). In many countries the problem of management of these contaminated sites is of considerable magnitude. For example, in the Netherlands, over 100,000 sites have been indentified as being potentially contaminated, with 10,000 sites confirmed as being contaminated. Likewise in Germany, over 50,000 potentially contaminated sites have been indentified. In the U.S. there are an estimated 100,000 sites that have been nominated as contaminated, with 10,000 of these designated as priority areas (Connell, 2005).

The most common toxic soil pollutants include metals and their compounds, organic chemicals, oils and tars, pesticides, explosive and toxic gases, radioactive materials, biological active materials, combustible materials, asbestos and other hazardous materials. These substances commonly arise from the disposal of industrial and domestic waste products in designated landfills or uncontrolled dumps. Soil contaminants do not fall into a single, or several simple classes of chemicals, but are very diverse in nature and can be harmful to the natural environment or human health. For example, from the metals, lead originating from motor vehicles is a very common soil contaminant in urban areas. Lead can also originate from smelters and mining operations. Lead is no longer used in paint, but the old paints that have already been used before the ban can contribute to lead in the environment. Copper and chromium are also common heavy metal soil pollutants and primarily originate from tanneries and wood-preserving plants. Other heavy metals pollutants include cadmium, arsenic, zinc and mercury; they are mainly due to industrial activities, waste incineration, agricultural activities, combustion of fossil fuels and road traffic.

Organic liquids are used as solvents in many industrial processes and products such as paints, petroleum products, including gasoline, naphtha, toluene, and xylene, they are common solvents too. In addition, chlorohydrocarbons such as dichloroethylene and carbon tetrachloride are commonly used as solvents. Volatile organic compounds (VOC) such as benzene, toluene, xylenes, dichloro-methane, trichloroethane, and trichloroethylene, may occur as soil contaminants in industrialized and commercialized areas, particularly in countries where enforcement of regulations is not very stringent. One of the common sources of these contaminants is leaking underground storage tanks or transport pipes as is common in Nigeria. Also improperly discarded solvents are also significant sources of soil VOCs. Almost all of the organic substances used in industry and society in general can constitute soil contaminants.

Waste coal tar produced in many places in time past was disposed into wells and pits. Coal tar consists of highly complex mixture of aromatic hydrocarbons, phenols, and PAHs. As a result, many cities contain sites with very high levels of these soil contaminants. Contamination of soil with artificial radionuclide e.g. cesium-137, strontium-90 and some plutonium isotopes also do occur in some areas where they are used in industries.

* 1. **Types of Analytical Methods Applied in Environmental Pollution Control**

**2.4.1 General**

As seen in the state of the environment we are facing countless aspects of environmental crisis today. Efforts to fight and reduce these environmental pollutions call for high-precision, higher-sensitivity analytical technologies for quantification and control of environmental pollution. The ability of a measurement system to accurately monitor an environmental variable or to detect and analyze a specific pollutant and its concentration over time is crucial if scientists are to successfully measure and control pollutants and preserve the health and safety of the environment. One of the big areas of environmental pollution that needs assessment is the studies of oil spill. So many areas from land, water to air are affected by oil pollution in different forms. Burns (1993) in her study restated the need for a hierarchical scheme of methods to be used in environmental assessment studies. Her arguments were based on the fact that there is confusion over the concept of legally defensible methods for oil spill studies. Many people limit these studies to the analysis of specific polynucear aromatic hydrocarbons by gas chromatography-mass spectroscopy. Traditionally gas chromatography – mass spectrometry has been the methods of choice, but recently the research focus has been shifted towards hyphenated chromatographic and many other combinations of methods up to bioanalytical techniques which increase in general resolution, detection sensitivity and specificity of measurement. Chemical analyses of environmental pollutants are generally expensive or slow due to the types of matrices they are found in, therefore, the development of cost-effective methods is necessary. In this area and many other analytical aspects of environmental chemistry a lot of research works are going on and there are many advances in techniques for environmental analysis which reflect the scope and the complexity of environmental analytical chemistry. Some of the advance techniques for environmental analysis have been mentioned briefly in chapter 1 in the introduction, but some more will be discussed later in details.

The scope and the complexity of environmental analytical chemistry have put analytical chemists in the forefront of the problems of mankind’s effect on the environment. These mankind’s effects on the environment has been discussed in detail under the state of the environment and it was demonstrated to be numerous, therefore without the efforts of analytical chemists to develop new measurement techniques and instrumentation, human beings would be unaware of some significant environmental problems. For example, the development of the electron-capture detector for gas chromatography in the early 1960s enable the measurements necessary for the discovery that organochlorine pesticides and polychlorinated biphenyls (PCBs) were present both in wildlife and the food that they eat (Stephen et al 2006). Similarly the development of specialized extraction techniques and high-resolution gas chromatography-mass spectrometry (GC-MS) enabled environmental scientists to assess and better manage the effect of dioxins and other contaminants in the environment (Stephen et al 2006). Analytical chemists have also developed techniques that enable concentration of many liters of water into an extract of a few micro liters, which are then analyzed so that scientists can measure parts per quadrillion or even lower. Without these developments by analytical chemists, it would not be possible to detect many harmful compounds at the levels at which they have a biological effect on human being and the environment at large (Stanley 2000). As already mentioned, environmental pollutants occur mostly in complex matrices, and that means there is need also for research in extraction methods. Analytical chemists have developed methods that have the ability to extract and enrich compounds of interest from extreme complex matrices, such as wastewater, soil, sediment, air particulate matter, etc. The development has made extraction faster and more environmentally friendly, by requiring less solvent than traditional soxhlet extraction. Examples of these extraction methods include microwave-assisted extraction and pressurized-solvent extraction etc. Passive extraction techniques, for example solid-phase micro extraction (SPME), have changed the very concept of extraction and are used for sampling systems as well as for extraction, detail description of the use of SPME and the different types of coating will be discussed later.

* + 1. **Uses of Analytical Methods in Environmental Chemistry**

There are many uses of analytical methods in environmental chemistry; some applications are driven by process control, health and safety, environmental regulations and rules, compliance with International Organization for Standardization (ISO), stringent regulatory requirements, quality system control, etc. For example, continuous emission monitoring (CEM) is being used and installed in order to monitor atmospheric emissions from combustion units, and many other types of process plants. Many of the techniques developed for correlation of crude oils and suspected source rocks, or other oils are used routinely in forensic applications for correlation of spilled products, for both crude oils and refined products. The safe destruction or containment of pollutants like PCBs requires special measures and high-tech equipment. Another use is in the field of new pollutants, there is a continuous need for identification and characterization of new environmental pollutants. Soils that are suspected to have been polluted need to be screened with methods that have been well validated and are reliable so as to arrive at the correct conclusion on the state of the soil in question. Therefore the use of a hierarchy of analytical methods would enhance the screening of contaminated sites considerably. In the industries online measurements are becoming a routine part of their culture, they are used for process control, process verification, and health and safety systems.

**2.4.3 Examples of Analytical Methods and their Applications in Environmental Pollution Control**

A general overview of some basic and advanced analytical methods are given in Table 2.4 below, here a few examples of these instruments and their applications are discussed, few examples for air pollutants, water pollutants and soil pollutants.

Air pollutants of most common regulatory interest include SO2, NOx (oxides of Nitrogen including NO, N2O and NO2) and CO2. Others are particulate matter, ozone and lead, also total reduced sulfur (TRS), HCl, NH3, and Total Hydrocarbon (THCs). SO2 istypically measured with UV absorption, UV fluorescence, or IR absorption. IR analyzers are some times called NDIR (i.e. nondispersive infrared) and are often enhance by gas filter correlation (GFC). Oxides of nitrogen are measured by a method that incorporates an O3-based chemiluminescent method and an NO2 to NO converter, the emission produced is measured by a photomultiplier tube (AOAC 1980). CO and CO2 are usually measured using IR which uses a combination of NDIR and GFC measurement techniques. Electrochemical cells can also be used to measure SO2 and NOx. Catalytic sensor is another gas detection technique; it is commonly applied in continuous emission monitoring (CEM). If measurements of HCl, HF, NH3, or heavy hydrocarbons are required among other gases, it is expected that a hot, wet extractive system would be required. Examples of instruments used with hot, wet systems include NDIR/GFC, UV, and FTIR (Fourier transform infrared). NH3 is a very difficult gas to measure using extractive techniques. It has a high propensity to stick to almost any surface at reasonable temperatures and is highly reactive and soluble. Chemilumescent analyzers and NOx differential measurement are used at times for the measurement of NH3. An example of gas measurement instrument development was that by Roden, et al, they designed and built a portable, battery-operated emission sampling cart. They used the sampling cart measures of real-time data with particle soot absorption photometer (PSAP), a nephelometer, a CO and CO2 sensors

GC/MS to analyze samples containing unknown volatile and semi volatile organic compounds, chlorinated herbicides, PCBs, and pesticides. Semi volatile organic compounds in gaseous samples can also be measured with REMPI –TOF. For instance, due to its selective ionization, REMPI –TOF is applicable to a specific detection of PAH compounds in gas samples with varying concentration of other interfering compounds. Portable field analytical equipments are also being developed and used for on-site detection and identification of organic and inorganic contaminants in air, water and soil. E.g. portable gas chromatographies such as the HNU model 311 are used for characterization of volatile organic compounds, semi volatile organic compounds, PAHs and PCBs (Paul et al 2005).

Another instrument of interest used in extraction is solid phase micro extraction (SPME) mentioned already briefly above. SPME was developed to address the need for rapid sample preparation both in the laboratory and on site. It has a lot of advantage over traditional sampling methods, because it combines sampling, sample preparation, and direct transfer of analytes into a standard gas chromatograph. Since its commercial introduction in the early 1990s, as a new sampling and sample-preparation method, SPME has been successfully applied to the sampling and analysis of environmental samples. SPME is used in Gaseous matrices and liquid matrices, in solid matrices it has to be combined with other techniques. It is a simple and effective adsorption/absorption and desorption technique which eliminates the need for solvents and combines sampling, isolation, and enrichment in one step.

**Table 2.3 Applications of Sol-Gel Coated Fibers SPME in Environ-**

**mental Analysis**

|  |  |
| --- | --- |
| **Coating** | **Analytes** |
| PEG | BTEX, Phenols, diesters and pesticides |
| Carbowax | BTEX |
| PDMS-PVA | Pesticides, PCB |
| PTMOS-MTMOS | Benzene, toluene, ethybenzene, 2-octanone, dimethylphenol and tridecane |
| LTGC | BTEX, monohalogenated benzene |
| Calix arene | Organochlorine pesticides, chlorophenols, phenolic compounds |
| Crown ether | Phenols, organochlorine, pesticides, aromatic amines, BTEX, chlorobenzenes, Arylamines |

(Source; Ganfeng et al 2006)

Several SPME fiber coatings based on sol-gel technology, including PEG, carbowax 20M modified silica, and PDMS-PVA, LTGC, etc have been developed for the determination of environmental pollutants in their complex matrices (Ganfeng et al 2006). These SPME coatings can be used for different pollutants as given in Table 2.3 above that means the choice of the coating is very important depending on the type of pollutant to be sampled and analyzed.

**Table 2.4 A General Overview of Analytical Methods**

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipments used** | **Basic Principles** | **Example of uses** | |
| Ion Chromatography (IC) | Separation between two phases (Stationary and mobile phases) | Determination of ionic solutes, e.g. inorganic anions and cations, carboxylic acids plus organic phosphonic and sulfuric acids, including detergents | |
| Inductively Couple Plasma (ICP) | Very high temperature excitation source that efficiently vaporizes, excites, and ionizes atoms | Used for the detection of trace metals and elements in environmental samples, e.g. analysis of elements not readily identified by AAS such as Sulfur, Boron, Phosphorus, Titanium, and Zirconium | |
| Mass Spectrometry (MS) | Based on the fact that a charged particle passing through a magnetic field is deflected along a circular path on a radius that is proportional to the mass to charge ratio, m/e. | Useful for quantization of atoms or molecules and also for determining chemical and structural information about molecules | |
| Raman Spectrophotometers | Based on energy differences between vibrational states of molecules and solids using a laser source of frequency | | Used to identify a compound, or individual groups like CO, SO43- |

|  |  |  |
| --- | --- | --- |
| Atomic Emission Spectrometer (AES) | Uses quantitative measurement of the optical [emission](http://www.chem.vt.edu/chem-ed/spec/emission.html) from excited atoms to determine analyte concentration | Used widely for the chemical analysis of metals, including many that are of environmental importance e.g. mercury, lead, etc. |
| Gas Chromatography (GC). Can also be two dimensional (GC+GC) | Separation between two phases | Separation of organic compounds, e.g. VOCs, PCBs, etc. |

**Table 2.4 Continued**

|  |  |  |
| --- | --- | --- |
| Radiometer Autotitrator | Titration method | Measurement of the rate of acid- or alkali-producing reactions at constant pH in the absence of buffers |
| Electrophoresis | Is based on the motion of [dispersed particles](http://en.wikipedia.org/wiki/Dispersed_particles) relative to a fluid under the influence of an [electric field](http://en.wikipedia.org/wiki/Electric_field) that is [space](http://en.wikipedia.org/wiki/Space) [uniform](http://en.wikipedia.org/wiki/Uniform)ly. | Used for simultaneous concentration and separation of proteins |
| Ultraviolet/Visible(UV/Vis)  Spectrophotometers | Is based on the measurement of UV absorbed, emitted, or reflected | Used in continuous emission monitors, Ambient point source monitors |
| Thin Layer Chromatography (TLC) | Separation between two phases, solid and liquid phases | For identifications of analyte e.g. organic pollutants |
| Nuclear Magnetic Resonance (NMR) spectrometers | Is based on the fact that nuclei of many elemental isotopes have a characteristic spin and an external magnetic field is needed | Used for atomic and molecular level structure elucidation |
| Volta metric Instrumentation | method for electrochemical analysis of elements in solution based on voltage and controlled current source | Determination of the concentration of analytes like herbicides, metals like Hg, Cd, Pb, etc in water samples |
| Atomic Absorption Spectrometer (AAS) | Base on absorption of spectroscopic energy | Commonly used to identify and quantify the concentration of metals in the environmental samples |
| Infrared (IR) and NIR (Near-Infrared) Spectrometry | Is based on the measurement of infrared radiation absorbed, emitted, or reflected | Used for elucidation of molecular structure e.g. in air emission monitoring |
| High Performance Liquid Chromatography (HPLC) | Separation between two phases | Is used for isolation and purification of compounds, separation, identification |

**Table 2.4 Continued**

|  |  |  |
| --- | --- | --- |
| X-ray Instrumentation | Based on diffraction of the X-rays at a fixed angle by the crystal and the intensity of the diffraction | Commonly used to determine structures of crystals |
| Potential of Hydrogen Selective Measurement  (pH) | pH is a measure of the [acidity](http://en.wikipedia.org/wiki/Acid) or [alkalinity](http://en.wikipedia.org/wiki/Base_%28chemistry%29) of a solution | In pollution control, e.g. water pollution control. Also used a lot in the health sector |
| Pressurized Liquid extraction (PLE) | Based on high temperature and pressure. Solvents inside the PLE cartridge are near their supercritical region | Used in the analysis of Dioxins, PCBs, pesticides, PAHs in environmental samples |
| Time of Flight MS  ( GCxGCMS) | Based on ionization of atoms, electrical field, electrical pulse, and mass-to-charge ratio of the ion | Used in analysis of organic compounds |
| Gas chromatography-Isotope Ratio Mass Spectrometers (GC-IRMS) | Gas chromatography, on-line coupled with isotope ratio mass-spectrometry (GC-IRMS) | Used in detecting and measuring organic compounds such as hydrocarbon gases |
| GC-MS | A combination of Gas chromatography with Mass Spectroscopy | Used to analyze samples containing unknown volatile and semi volatile organic compounds |
| GC-NPD | A combination of GC with Nitrogen-Phosphorus Detector | Used in screening organic compounds |

(Source; Randy D Down; Shriver and Atkins 1999)

Table 2.4 is a comprehensive list of environmental analytical instruments with some examples of their uses. These analytical instruments in Table 2.4 are instruments that are applied in all areas of environmental pollution control. Some examples for air pollution and sampling have been discussed above and a few for water and soil pollution are discussed here. Quality control of both drinking water and waste water has become more and more important lately, due to lack of pure groundwater in many places, natural water has to be treated to get portable water. Purification of drinking water is sometimes done using chlorine, producing various toxic chlorinated compounds. Purge and trap gas chromatography/mass spectrometry (P & T - GC/MS) are used in the chlorinated pollutants in water. MIMS is used to measure VOCs in drinking water. APCI – MS is used for liquid samples, such as an effluent from liquid chromatography. Phosphorus is a key element in several classes of compounds of environmental significance e.g. detergents, fertilizers, pesticides, chemical and biological weapons. Phosphorus-31, the NMR active form of phosphorus, readily leads itself to NMR analyses to a wide range of samples, including waste water, ground water, etc. The ability to selectively resonate 31P coupled with excellent chemical shift resolution makes compound/contaminant identification by 31P NMR highly effective. A HPLC proton NMR for the analysis of contaminated ground water samples has been described by Godejohan et al (1997). According to them this method is very effective in the analysis of contaminated water.

**Table 2.5 Conventional Methods for Analysis of Inorganic Anions in Drinking Water**

|  |  |
| --- | --- |
| **Analyte** | **Conventional Analytical Method** |
| Fluoride | Ion-Selective electrode (ISE) |
| Chloride | Potentiometric titration |
| Nitrite | Automated (FIA) Sulfonamide |
| Nitrate | Automated (FIA) Cadmium reduction |
| Phosphate | Automated (FIA) ascorbic acid |
| Sulfate | Turbidimetric |

(Source: Peter E. Jackson, Ph.D. 2005)

NMR spectroscopy is one of the most powerful experimental methods available for atomic and molecular level structure elucidation. It is noninvasive and is used to identify individual compounds and in determining the structures of large molecules and examine the kinetics of certain reactions. NMR’s ability to analyze a variety of sample types, from simplest molecules to the intact human body, makes NMR a powerful tool for the environmental analyst. Albaret et al (1997) used proton 3P, and analyze extracted soil samples contaminated with organophosphorus from chemical weapons. In combining 1H and 3P analyses into a series of two-dimensional analyses, the sensitivity of the 1H analyses and the resolution of the 3P facilitated the identification of the organophosphorus contaminants. Whole-soil analysis by NMR is uniquely suited to observing contaminant material, both organic and inorganic. Apart from NMR there are many instruments for inorganic ions in water samples; Table 2.5 above gives some examples of methods and instruments for inorganic anions, it can be seen that these are conventional methods used in most analytical laboratories for such analysis.

Energy–dispersive X-ray fluorescence (EDXRF) is a relatively new analytical technique that began with the development of lithium-drifted silicon detector. With EDXRF samples can be analyzed for metals nondestructively and utilized for additional measurements of organic compounds or inorganic ions. EDXRF can perform rapid analysis of a wide variety of environmental samples. For soil analysis a few nearly real-time and online instruments and methods have been developed. One of these methods employs a membrane interface connected to a purge and trap technique called purge and membrane (PAM) technique. The soil sample is flushed with inert gas and the flushed eluent is analyzed with the membrane interface to obtain sensitivity in the direct measurement. In this way is possible to reach detection limits of 2-250μg/Kg for many organic compounds, which are low enough when analyzing contaminated landsite. Another technique applied to soil analysis is two-step laser mass spectrometry, suitable ionization wavelength can be chosen and PAH compounds in soil can be analyzed using this technique. The most serious problems with hazardous waste sites involve contamination of the soil and migration of toxic organics into the surrounding groundwater. GC detector using photoionization (PID) have been used extensively in contaminated sites, e.g. at love canal USA, to determine the extent and nature of the contamination of the soil and ground water. Some lower cost field screening methods to supplement laboratory analytical methods have been developed. There are some rapid and simple methods for screening organics in water and soil using photoionization analyzers and many other types of analyzers. Total contaminant levels can be screen by using instruments such as screening/survey gas chromatographic instruments (Roger Reeve 2002). When dealing with certain types of environmental applications, the best means available has to be used to obtained accurate and reliable measurement of pollutant constituents and concentrations. Locations where measurement must take place may not be readily accessible and the cost of installing and maintaining multiple stationary instruments can be high. In such cases, it may make more sense to use a portable instrument rather than a permanently installed instrument at each location. Table 2.6 gives examples of such portable analytical instruments that can be used in the field. Combination meters, often referred to as multimeters, can be a cost-saving approach to acquiring the portable instruments needed to perform certain types of measurement. Examples are; - pH-ORP-oC meter which combines three instruments that are used in the analysis of water quality. The combination thermometer-hygrometer-velometer-light meter combines four instruments that are used to analyze the ambient environment. These portable instruments listed in Table 2.6 are common in industries where they have to do field testing of some samples for environmental pollution control or process control.

**Table 2.6 Examples of Portable Instruments**

|  |  |
| --- | --- |
| Portable gas analyzers | velometers |
| Clamp – on (non intrusive) liquid flow meters | Anemometers |
| Data loggers | Manometers |
| Turbidity meters | Barometers |
| TDS (Total dissolved solid) meters | Altimeters |
| Conductivity meters | psychrometers |
| PH meters | Luminescence (light) meters |
| DO (dissolved oxygen) meters | Range (distance) meters |
| ORP (oxygen reduction potential) meters | Colorimeters |
| CO (carbon monoxide) monitors | Salinity (Salt content) meters |
| Thermometers | Tensiometers (soil moisture) |
| Hygrometers | Metal detectors |
| Pressure gauges |  |

(Source: Randy D. Down, P.E.)

* + 1. **Choosing the Right Analytical Instrument**

In environmental analytical chemistry, the right choice of an analytical instrument is very important. To make a decision on the right choice, one must consider which instrument is best to use for the job at hand. To make a correct choice, the analyst needs to know about the different types of analytical instruments available. As well as the general working knowledge of what instruments are capable of doing the job, the analyst also needs to understand the problem, the plan for solving it and the money involved. If a number of instruments are available for use, the analyst will need to know what the priorities are, is it sensitivity, is speed the most important factor or does cost play a role? Also is limit of the detection of the instruments very important? This will help the analyst to decide which equipment can best do the job. Hence, in choosing the right instrument, there are two sets of performance criteria to be considered according to Gillian (2007). They are:

1. The performance criteria affecting quality of the result, these include
   * Accuracy
   * Precision (Repeatability and Reproducibility)
   * Sensitivity (LOD and LOQ)
   * Selectivity
   * Linearity
   * Dynamic range
   * And Stability
2. The performance criteria for the economics include

* Cost of purchase, installation and maintenance
* Analysis time
* Safety aspects
* Running costs- supplies, gases. Consumables
* Training
* Sample throughput

Wise decisions need to be made when purchasing or choosing to use one instrument over another. In answering the question, what analytical instrument should I use? The following points must be put into consideration, it must be selective for the compound of interest over the required concentration range, it must exhibit acceptable accuracy, precision and levels of sensitivity, it should be reliable, robust and easy to use, the frequency of measurement and speed of analysis must be suitable and the cost per sample should not be prohibitive.

In the Nigerian situation, the choice of which analytical instrument to buy or use may be largely due to the cost as the prices of these instruments maybe very high some times. In Table 2.7 below some analytical instruments are listed and some have their prices given, also Figures 2.5 to 2.9 are some examples of these analytical instruments and their prices. Given these prices, one can see that to be able to have a completely well equipped analytical laboratory it can cost quite a lot of money especially for a country like Nigeria. Nigeria’s entire economy revolves around oil, with large reserves, meaning the country has, in theory, the potential to build a very prosperous economy. But this wealth of oil in Nigeria has not improved the economic state of the country due to the fact that the country is long hobbled by political instability, corruption, inadequate infrastructure and poor macroeconomic management. As such the prices of these analytical instruments may be very unaffordable to the Nigeria environmental laboratories due to poor economic management and corruption. The state of the Nigerian oil industry is a prototype of how other industries have been mismanaged; as such most of these equipments will to be very expensive for the laboratories to buy.

**Table 2.7 Examples of Analytical Instruments and their Prices**

|  |  |  |
| --- | --- | --- |
| **Name of Analytical Instruments** | **Company** | **Price** |
| AAS Zeenit 600 | Analytik Jena | 26,180.00**€** |
| Perkin Elmer AAS 5000, with Autosampler AS 70 | Perkin | 5,280.00**€** |
| DR 820 Colorimeter | HACH Lange-United for Water Quality | 1,400.00**€** |
| DR 5000 UV/VIS Spectrophotometer | HACH Lange-United for Water Quality | 8,020.00**€** |
| G8 HPLC Analyzer, FID & TCD detector | Tosoh | $9,050.00 |
| Waters 600 Semi-Prep HPLC; | Waters | $12,500.00 |
| Shimadzu AA 6800 Flame AAS | Shimadzu | $9,900.00 |
| Leeman Labs HYDRA AF Gold + Mercury Analyzer | Teledyne Leeman Labs | $19,500.00 |
| [AS400 Mhz Oxford NMR](http://www.labx.com/v2/adsearch/detail3.cfm?adnumb=392096) | [VARIAN INOVA](http://www.labx.com/v2/adsearch/detail3.cfm?adnumb=392096) | $140,000.00 |
| [D500 XRD X-ray Diffractometer](http://www.labx.com/v2/adsearch/detail3.cfm?adnumb=389761) | Siemens Bruker | $35,000.00 |
| [Phoenix 8000 TOC Analyzer](http://www.labx.com/v2/adsearch/detail3.cfm?adnumb=390369) | Tekmar Dohrmann | $12,500.00 |

(Source; Created from http://www.labx.com/v2/newad.cfm?catID=32 & HACH Lange-United for Water)



**Figure 2.5** Total Hydrocarbon Analyzer Model HC-404 with the Price

(Source;http://monitoring.environmentalepert.com/STSE\_resulteach\_

product.aspx?cid=2502&idprofile=5969&idproduct=15493 Accessed

13.07.2009)



# Figure 2.6 Waters 600 Semi-Prep HPLC; Price $12,500.00

# (Source; http://www.aibltd.com/detail.cfm?autonumber=77363 Accessed 13.07.2009)

a b

**Figure 2.7** a & b Combination of FID & TCD Detector GC; Prices $12,500.00 and $9,050.00 Respectively

(Source; Cole-Parmer; https://www.coleparmer.com/Catalog/product\_index.asp?cls=379 Accessed 13.07.2009)



**Figure 2.8** Perkin Elmer AAS 5000. With Auto Sampler AS 70. Programmer AS

40. Zeeman HGA 500. Programmer HGA 500. Analysis Unit Shimadzu

Chromatopac C-R6A.

(Source; http://www.labx.com/v2/newad.cfm?CatID=1&Page=4 Accessed 20.07.2009))

The analytical instruments given here, such as Hydrocarbon Analyzer, HPLC, AAS; are analytical instruments that are commonly used in environmental analysis in the literature. Therefore is expected that they be found in many environmental laboratories in Nigeria if not for the problems of mismanagement and corruption already mentioned. But for the environmental laboratories to function properly and have good environmental pollution control some of these instruments are needed instruments especially when considering the types of pollutants found in the Nigerian environment. In Figure 2.5 a total hydrocarbon analyzer is given, and in Figure 2.6 a HPLC, these two instruments are suitable for the oil companies as such is expected that they have these instruments. Even AAS given in fig 2.9 is an important instrument, not only for the oil industries but also for the regional drinking water monitoring laboratories.



**Figure 2.9** AAS Zeenit 600 with Graphite Tube Control

(Source; Analytik Jena)

* 1. **Recent Advances in Analytical Instruments**

In chapter 1 under introduction some recent works in the area of environmental analytical instruments were mentioned briefly, research works of people like Jayaratne et al (2007), Jasdeep Kaur et al (2007) and that of Gillian (2007) were cited. Here some advances in the field of environmental analytical instruments are discussed in detail.

Practically in environmental analysis every area is undergoing rapid changes in a positive direction. The approaches followed now are more elegant, the data gathering has become easier, the detection limits lower, and the instrumentation is more advanced and powerful. With this advances and a surer control of selectivity, specificity, lower levels of detection, more and different determinations are possible. Environmental analysts are experimenting with many new approaches such as fast GC, two-dimensional GC, chiral separations, and with different new detectors or advanced version of classical detectors, including inductively coupled plasma mass spectrometers, time of flight mass spectrometers, and many versions of portable instruments.

Examples of improvements in the extraction techniques include subcritical water extraction (SWE) and pressurized liquid extraction (PLE). These techniques have advantages such as increased speed of sample preparation, a more efficient extraction and a lower solvent consumption. These two methods i.e. SWE and PLE have been reviewed by Ramos et al (2002) and they conclude that PLE combines good recoveries and adequate precision with rapid and rather selective extraction in less time than classical procedures such as conventional Soxhlet. They also demonstrated that with SWE it is possible to perform the entire sample preparation and the analysis in a close system. Another advanced method which is the use of pressurized hot water extraction coupled on-line with liquid chromatography-gas chromatography was used by Kuosmana et al (2002) to determine brominated flame retardants in sediment. A new extraction method was developed by Luque-Garcia and Luque de Castro (2003); they developed an automatic focused microwave-assisted dual soxhlet extraction system which they applied to the extraction of Aroclor 1242 from soil. According to their report this approach reduced the classical soxhlet extraction time from 24hrs to 70min. These advances in extraction methods have improved sample preparation and made it less time consuming, it has also reduced sample lost.

In Gas analysis instrumentation, Seeley et al (2001) used comprehensive two-dimensional gas chromatography with a high resolution as a good alternative to GC-MS. They used a Perkin-Elmer Autosystem XL gas chromatograph with electronic pneumatics and dual flame ionization detectors; they mounted a 6-pot diaphragm valve in the location normally reserved for the second sample inlet and replaced the 100nF filtering capacitors on each FID electrometer with an 8nF capacitor. Hydrogen was used as the carrier gas with a flow of 0.75ml/min in the primary column. Use of a complex temperature program permitted the use of this system to analyze mixtures of 130 volatile organic compounds (VOCs). The authors pointed out that their system is well suited for analyzing samples containing oxidized or halogenated compounds.

In the area of water analysis, Cai et al (2009) developed automated electronic tongue instrumentation for in-situ concentration determination of trace heavy metals in water. The electronic tongue contains two parts: first part is sensor part, this consists of a silicon- based Hg-coated Au microelectrodes array, for the detection of Zn(II), Cd(II), Pb(II), and Cu(II), and a multiple light-addressable potentiometric sensor for the detection of Fe(III) and Cr(VI). The second part is the control part which employs pumps, valves and tubes to enable the pick-up and pretreatment of aqueous sample. According to these authors this instrument achieved the ppb level of measurement without manual operation. The advantage of the instrument is a wide application in quick monitoring and prediction of heavy metals in water samples. In the same manner Wen et al (2009) reported a construction of a new portable atomic absorption spectrometer for the determination of copper, chromium, lead and cadmium in environmental water pollution control. They used coil atomizer and a handheld CCD detector for their construction and the major instrumental parameters were optimized, such as the carrier gas flow rate, the position of hollow cathode lamp, the height of the atomizer, and ashing and atomization current. They achieved a flow rate of 600/300ml/min for Cd, Cr, and Pb. They also achieved limits of detection for Cu, Cr, Pb, and Cd as low as 2μg/L, 5μg/L, 9μg/L, and 0.5μg/L respectively. According to the authors, the instrument has a promising future in the analysis of environmental water for trace elements. Classical methods, although they are normally reliable, require extensive preparation steps and at times are time consuming and require highly skilled operation and data interpretation. The advanced instruments mentioned above are mostly less time consuming and are moistly easy to read and interpret. Therefore these advances have great effects in the environmental analysis especially sample preparations advances like extraction, since the environmental samples are mostly from complex matrixes.

Many industries are working with researchers to bring these results into the market, example is Oxford Instruments Designs ( Oxford Instruments Designs; http://www.oxford-instruments.com) who supplies and supports high-technology tools, processes and solutions with a focus on, amongst others environmental applications. Example of their high technology analytical instruments is the latest benchtop NMR analyzer which offers fast, easy quality control measurements in compact, up-to-the minute package. It requires no external PC, as a standard windows PC motherboard is built inside, with USB access, internet connection and a hard disc for data storage. A second example of advanced analytical instruments from Oxford Instruments Designs is Lab-X 3500 (LabX;http://www.labx.com/v2/adsearch/ detail3.cfm?adnumb=393151). It is a robust, easy-to-use benchtop XRF analyzer. It is designed to perform in a wide range of flexible environments e.g. in the laboratory, on-site or wherever analysis is required. For the petroleum sector Lab-X 3500 conforms to ASTM D4294, ISO 20847, and ISO 8754. It can be used to measure liquids and powders and it has flexible software for user customization and method development. These superior instrumentations assure quality measurement in shorter time and with much easy for compliance and screening.

In the developed countries following the Gillian (2007) flow chat in fig 1.1 on page 6 is made easy by these advances giving analysts a wide range of instruments to choose from. But even in developing countries like Nigeria the processes of analysis as a logical sequence of steps must be taken serious and efforts should be made to choose the instrument that gives the most reliable results amongst the small range of choice available. Also even with classical instruments performance criteria affecting quality of results enumerated in sub chapter 2.4.4 above should be observed. This research is not going to focus on these advances in analytical instruments, but on the state of the art of environmental analytical instruments, since the focus country is Nigeria where the issues of availability of even classical instruments is still a problem.

* 1. **Economic Tools for Environmental Management in**

**Nigeria**

Environmental management in Nigeria is directly the responsibility of the Federal Government using Federal Ministry of Environment, Housing and Urban Development. The major source of funds for environmental planning and development comes through statutory allocation in national development plans; at the Federal level this allocation comes directly to the Federal Ministry of Environment, Housing and Urban Development which is further allocated to the responsible organizations and agencies. In Nigeria budgetary allocations are not only made by the Federal Government but are made by all levels of government for urban and regional planning activities in spite of environmentally related activities funded in other sectional allocations (Ade et al 2005). According to Don C. Okeke in his paper titled

“Government Efforts in Environmental Management in Nigeria” over the years there has been a progressive increase in financial allocation to town planning from 1.2 percent of national allocation in the second plan period (1970 -74) to 2.3 percent of national allocation in the third plan. According to him the fourth plan (1975-80) allocated 6.23 percent of its capital expenditure to town planning. However, these increases are less than proportional increases in national investments which rose from 1,025.369 million Naira in the second plan to 32,854.616 million Naira in the third plan and to 70,276.225 million Naira in the fourth plan (Don, 1997). Urban planning are normally responsible for waste management in Nigeria’ towns and cities, therefore their allocation means indirectly allocation for urban waste management. Apart from direct allocation to the Ministry government also makes fund available through project funding programs. According to Don Government adopted Ecological Fund in the 1980s to finance mitigation measures for ecological disasters; Infrastructural Development Fund (IDF) in 1985 for financing urban development projects; National Housing Fund in 1991 to facilitate the National Housing Policy and also Petroleum Trust Fund (PTF) in 1995 for infrastructural development. In 1992 Urban Development Bank was set up by the Federal Government to source fund through the insurance of bonds, loans from capital markets and banks and other revenue yielding-activities for urban development. The Urban Development Bank of Nigeria (UDB) compliments the services of the Federal Mortgage Bank established to finance housing projects.

Funds are also sourced through international finance organizations such as the World Bank through bilateral agreements. Many environmental projects in Nigeria are financed from such bilateral agreement where the Nigeria Government provides counter part funding and the World Bank provides the rest of the fund needed. Developmental Organizations such as UNDP, UNICEF, Water aid, etc are also engage in funding a lot of environmentally related projects in Nigerian. They engage funds in projects directed at resolving environmental problems of flooding, erosion, desertification, guinea worm infection, etc. To this end environmental management hitherto provided by the government as social services now attracts subjection to competitive market economy.

Looking at these tools at the disposal of environmental management, one should expect that the Nigerian environmental pollution control in all directions should be doing well. As Don went ahead to analyze the government interventions as follows; the array of government interventions and responses to environmental issues is laudable. At least in terms of making policy statements, government has demonstrated reasonable concern to monitor the trend in environmental development with intent to curb undesirable impacts on sustainable development. The need for government action is apparent; more so with the growing magnitude of environmentally related problems emanating from the peculiar circumstances that surround our development process. There is no gainsaying the fact that the government is yet to develop the political will to survive economically as a nation. The prevailing syndrome of self-centeredness manifests techno centric tendencies that identify a society of environmental manipulators. This can be seen from the fact that since the inception of the many policies and legislation on environment, government has remained rather passive in fulfilling its obligation in implementing the laws. The life time of FEPA, who was then responsible for the National Reference laboratories, was spent in the shadow of manipulated incapacitation that reflects its inability to implement controls on the use of environment. Otherwise, the agency, within the period of its existence, ought to have curbed the flaring of natural gas, establish functional reference laboratories amongst other problems of the environmental pollution control in Nigeria. This is more obvious, when one look at the subsidiary offices, they have not been fully set up. The example of the national reference laboratories earmarked to be set up in the country, only Lagos was fully set up. Even then it functioned only for a while, no wonder FEPA could not perform.

The same complacency is demonstrated in the implementation of environmental pollution standards, industries are left on their own to dispose their waste in a manner not meeting the requirements because there is no control. Government can not pretend to be serious with environmental protection, with so much financial allocation if it shies away from facilitating logistic support to establish functional institutional tools, such as laboratories, required to conduct good environmental monitoring (Don 1997). The analytical laboratories as tools for good monitoring need to be equipped with quality analytical instruments. As can be seen from the sample prices of these analytical instruments given in sub section 2.4 above, they are affordable by the Nigerian government. If money allocated for environmental pollution control is used for the same purpose, these analytical instruments can be purchased by the environmental analytical laboratories for efficient monitoring.

* 1. **Environmental Standards, laws and Regulations**

**2.7.1 Standards**

In setting standards that are requisite to protect public health and welfare, as provided in the environmental laws of almost all countries, the environmental law maker’s task is to establish standards that are neither more or less stringent than necessary. In selecting a margin of safety, the environmental law maker must consider so many factors such as the nature and severity of the health effects, the size of the sensitive populations at risk, and the kind and degree of the uncertainties that must be addressed. This is well demonstrated in Table 2.8 below which shows drinking water quality requirements from the U.S Environmental Protection Agency (EPA), where they set the standards and give the health effects. From these standards it can be seen that if the standards are not complied with some serious health problems can arise from the consumption of such water.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Contaminant** | **MCLG (mg/L)-**  maximum contaminant level goal | **MCL or TT (mg/L)**  maximum contaminant level | **Potential Health**  **Effects from**  **Ingestion of Water** | **Sources of**  **Contaminant in**  **Drinking Water** |
| [Bromate](http://www.epa.gov/safewater/mdbp/qrg_st1.pdf) | zero | 0.010 | Increased risk of  cancer | By products of drinking water disinfection |
| Chlorite | 0.8 | 1.0 | Nervous system  effects | By products of drinking water disinfection |
| Haloacetic acids (HAAS) | n/a | 0.060 | Increased risk of cancer | By products of drinking water disinfection |
| Total Trihalomethanes (TTHMs) | none | 0.10 | Liver, Kidney, or central nervous problems; increased risk of cancer | By products of drinking water disinfection |
| Chloramines  (As Cl2) | MRDLG 4 Maximum Residual Disinfectant Level Goal | MRDL4.0 | Eye/nose irritation, stomach discomfort, anemia | Water additive used to control microbes |
| Chlorine (As Cl2) | MRDLG 4 | MRDL 4.0 | Eye/nose irritation, stomach discomfort | Water additive used to control microbes |
| Chlorine dioxide (ClO2) | MRDLG0.8 | MRDL 0.8 | Nervous system effects | Water additive used to control microbes |
| Antimony | 0.006 | 0.006 | Increase in blood cholesterol; decrease in blood sugar | Discharge from petroleum refineries; fire retardants; etc |
| Arsenic | 0 | 0.010 | Skin damage or problems with circulatory systems; increase risk of cancer | Runoff from orchards; glass and electronic production wastes |
| Asbestos | 7MFL | 7MFL | Increase risk of developing benign intestinal polyps | Decay of asbestos cement in water mains; |
| Barium | 2 | 2 | Increase in blood pressure | Discharge of drilling wastes; discharge from metal refineries; |

**Table 2.8 Drinking Water Quality Standards from U.S Environmental**

**Protection Agency (EPA)**

**Table 2.8 Continued**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Beryllium | 0.004 | 0.004 | Intestinal lesions | Discharge from metal refineries; coal burning factories; electrical, aerospace, and defense industries. |
| Cadmium | 0.005 | 0.005 | Kidney damage | Discharge from metal refineries; runoff from waste batteries and paints |
| Chromium (Total) | 0.1 | 0.1 | Allergic dermatitis | Discharge from steel and pulp mills |
| Copper | 1.3 | - | Gastrointestinal distress; liver or kidney damage | Corrosion of household plumbing systems |
| Mercury (inorganic) | 0.002 | 0.002 | Kidney damage | Discharge from refineries and factories; runoff from landfills and croplands |
| Nitrite (as Nitrogen) | 1.0 | 1.0 | Shortness of breath in infants and blue-baby syndrome | Runoff from fertilizer use; leaching from septic tanks, sewage |
| Selenium | 0.05 | 0.05 | Hair or fingernail loss, numbness in fingers or toes | Discharge from petroleum refineries and from mines |
| Thallium | 0.0005 | 0.002 | Hair loss, kidney, intestine or liver problems | Leaching from ores processing sites, discharge from glass, electronics, glass and drugs industries |
| Cyanide | 0.2 | 0.2 | Nerve damage or thyroid problems | Discharge from steel/ metal factories, also from plastic and fertilizer factories |
| Fluoride | 4.0 | 4.0 | Bone disease | Water additive; discharge from fertilizer and aluminum factories |
| Lead | zero | 0.05 | Kidney problems; high blood pressure | Corrosion of household plumbing systems |
| Nitrate | 10 | 10 | Shortness of breath in infants and blue-baby syndrome | Runoff from fertilizer use; leaching from septic tanks, sewage |

(Source: EPA; http://www.epa.gov/safewater/contaminants/index.html)

**Table 2.8 Continued**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Benzo(a)pyrene (PAHs) | zero | 0.0002 | Increased risk of cancer | Leaching from linings of water storage tanks and distribution lines |
| Carbon tetrachloride | zero | 0.005 | Increased risk of cancer; liver problems | Discharge from chemical plants and other industrial activities |
| Chlorobenzene | 0.1 | 0.1 | liver and kidney problems | Discharge from chemical and agricultural chemical factories |
| 1,2-Dibromo-3-chloropropane (DBCP) | zero | 0.0002 | Increased risk of cancer | Runoff/leaching from soil fumigant used on soybeans, cotton, etc |
| O-Dichlorobenzene | 0.075 | 0.075 | Liver and kidney problems | Discharge from industrial chemical factories |
| P-Dichlorobenzene | zero | 0.005 | Anemia, Liver, kidney or spleen damage | Discharge from industrial chemical factories |
| 1,1- Dichloroethylene | 0.007 | 0.007 | Liver problems | Discharge from industrial chemical factories |
| Cis-1,2 Dichloroethylene | 0.07 | 0.07 | Liver problems | Discharge from industrial chemical factories |
| Dioxin (2,3,7,8-TCDD) | zero | 0.00000003 | Increased risk of cancer | Emission from waste incineration and others |
| Heptachlor | zero | 0.0002 | Increased risk of cancer; liver damage | Breakdown of heptachlor |
| Toluene | 1 | 1 | Liver; kidney nervous system problems; | Discharge from petroleum industries |
| Acryamide | zero | - | Nervous system problems; Increased risk of cancer | Added to water during wastewater/sewage treatment |
| Alachlor | zero | 0.002 | Eye, liver, kidney or spleen problems; Anemia; etc | Runoff from herbicides used on row crops |

(Source: EPA at http://www.epa.gov/safewater/contaminants/index.html)

According to the U.S. EPA the maximum contaminant level (MCL) is set as close to maximum contaminant level goal (MCLG) as feasible using the best available technology. This is because MCLG is the level of contaminant in drinking water below which there is no known or expected risk to health. MCLGs therefore allow for a margin of safety and are public health goals. The requirement that primary standards include an adequate margin of safety is intended to address uncertainties associated with inconclusive scientific and technical information available at any time of standard settings. It is also intended to provide a reasonable degree of protection against hazards that research has not yet identified. For example, environmental regulators worldwide require continuous particulate monitoring for the following reasons; 1) To enforce particulate emission limits in milligrams per cubic meter 2) To provide feedback that pollution abatement equipment is working correctly, to make sure the level of safety is maintained. (EPA <http://www.epa.gov/safewater/contaminants/index.html>)

Generally environmental protection is a complex objective, and potentially in conflict with many other objectives in the economy of the world, all environmental policies involve making judgments about the acceptability of current or prospective modifications to the environment resulting from human activities. Standards are often the most tangible and precise expression of the judgments that underlie environmental policies. There are many kinds of standards such as standards related to pollution, which involves the introduction into the environment of a substance or biological agent or form of energy, also some standards relate to management of species, interference with habitats or method of cultivation. Standards can be legally enforceable numerical limit e.g. that of WHO Ground Water quality in Table 2.9 below, or not mandatory but contained in guidelines, codes of practice or sets of criteria for deciding individual cases; some standards are not set by governments but carry authority for other reasons, especially scientific eminence or market power of those who set them; some standards are not numerical, but numerical standards have come to occupy a central position in a much expanded system of environmental regulation.

**Table 2.9 WHO Ground Water Quality Limits**

|  |  |  |
| --- | --- | --- |
| Parameters | Acceptable limit | Max permissible Limit |
| pH | 7.0 -8.5 | 6.5 – 9.2 |
| Total solids (mg/L) | 500 | 1500 |
| Total Hardness (mg/L) | - | - |
| Suspended Solids (mg/L) | 100 | - |
| Chlorides (mg/L) | 200 | 600 |
| Sulphate mg/L) | 200 | 400 |
| Oil & Grease (mg/L) | 0.01 | - |
| Iron (mg/L) | - | 1.0 |
| Manganese (mg/L) | 0.05 | 0.5 |
| Zinc (mg/L) | 5.0 | 15.0 |

(Source: Oshibanjo et al 1988; FEPA 1991)

Numerical standards seemed to be the most obvious and convenient way of summarizing and codifying scientific understanding of human impacts on the environment in order to make it readily usable by policy makers and regulators. An environmental standard has been defined by British Royal Commission on Environmental Pollution as any judgment about the acceptability of environmental modifications resulting from human activities which fulfils both the following conditions;

* It is formally stated after some considerations and intended to apply generally to defined class of cases
* Because of its relationship to certain sanctions, rewards, or values, it can be expected to exert an influence, direct or indirect, on activities that affect the environment (Royal Commission on Environmental Pollution 1998)

Therefore standards can be said to be a crucial element in the environmental policy process. The New Zealand’s air quality standards (www.mfe.go-vt.nz) put standards in this way; “standards are mandatory technical environmental regulations. They have the force of regulation, and are implemented by agencies and parties with responsibilities under the environmental management Acts”. This implies standards go hand in hand with policies and regulations, standards therefore are the means in which regulators and policy makers can measure compliance with their rules and regulations. Standards are therefore very important in environmental pollution control, but as important as standards may be there is no point in setting them unless there is a method available to confirm compliance with them. Analytical methods therefore are very important as they may set the limit of a standard based on their detection limits. There are cases where the detection limit of the available analytical techniques has been adopted as an environmental standard, e.g. the basis for the 0.1μg/L limit value for some pesticides set in the 1980 in the EC Drinking water Directive was based on the detection limit of the analytical techniques available then. Availability of appropriate analytical techniques was also a major consideration in setting the limit value for emissions of dioxins to air from incineration plants at 1ng TEQ/Nm3 (Royal Commission on Environmental Pollution Twenty First Report 1998). One can say that decisions about environmental policies and standards can be crucially affected by the scope of the analytical methods or techniques available, which every government should take serious. Numerical standards for concentrations and the like of substances, gases, etc should therefore always incorporate protocols for analytical techniques or methods by which compliance is to be measured.

**2.7.2 Laws and Regulations**

The past years have seen a significant evolution in environmental policy, with new environmental legislation and substantive amendments to earlier laws. Also significant advances in environmental science and changes in the treatment of science have led to a lot of discussions of important issues in environmental law and policy. Environmental laws and regulations are necessary to protect and enhance the quality of the natural resources including the environment, so as to promote public health and welfare and productive capacity of humans around the globe. Therefore the big goal of environmental laws and regulations is to influence human behavior in order to avoid or limit damage to the environment.

As already mentioned there are numerous environmental laws and regulations in different forms at different levels, some are very similar from one country to the other, and some are international so they apply to all nations. Example, continuous particulate monitoring is becoming required in the large and most environmentally sensitive industrial stacks. The situations in the United Kingdom, Germany, and the United States are cited here as examples (Averdieck J. William 2005).

In the U.K. the less polluting processes such as Roadstone plant, foundries, animal feed plant, combustion plant < 50MW are regulated for air emissions by local authorities and generally require;

* Continuous measurement in stacks with air flow greater than 300m3/min
* Qualitative monitoring and broken-bag detection in stacks with air flow greater than 50m3/min
* No monitoring in stacks with air flow below 50m3/min

For more polluting processes like chemical plants, steel mills, cement industry, utility boilers, they are regulated by the U.K. Environmental Agency and are subject to individual inspector discretion. With the introduction of Monitoring Certification Scheme (MCERTS), the standards to which continuous monitors must perform are defined. Under this scheme instruments obtain a certificate for specific processes and measurement ranges based on laboratory and field test overseen by an independent test body. ISO-10155 is used as a basis for the test standards.

In Germany continuous measurement is required based on local air pollution issues i.e. position of stack, e.g. stack close to residential area or on stacks when the total mass emissions of particulate are likely to exceed defined limits. These limits depend on the toxicity of the particulate. The regulations in Germany impacting the use of particulate monitors are;

* BIsmSchV 13: combustion plant > 50MW
* BImSchV 17: incineration plant
* BImSchV 27: qualitative monitoring of particulate after filter plant

A type approval scheme exists in Germany. In this scheme importance is placed on field testing and quality assurance issues such as instrument checks. Particulate monitors are tested by independent test authorities (e.g. TUV) against standards and for measurement ranges defined by each of the above regulations (William Averdieck 2005).

In the United States interest in particulate monitoring has grown due to some regulatory changes from the clean Air Act of 1990 amendments. The standard PS-11 is being used to define the performance of particulate monitors. This standard uses the same performance approach as ISO-10155 and as such is similar to the U.K. and Germany type approval scheme. A significant difference is that each PM, CEM will require validation in the specific stack in which it is being used.

As already mentioned, some regulations, laws or guidelines are national and some are international, but they are mostly similar or inter related. Some examples of environmental laws and regulations are given here just as representative of laws and regulations found in environmental pollution control;

* Toxic Substances Control Act (TSCA)
* Water Pollution Control Act (WPCA)
* Public Health Service Act
* Clean Air Act (CAA)
* Noise Control Act
* Solid Waste Disposal Act
* Radiation Protection Guidance
* Radiation Guidance Pursuant to the Atomic Energy Act
* Marine Protection, Research, and Sanctuaries Act
* Clean Water Act (CWA)
* Oil Pollution Act (OPA)
* Resource conservation and Recovery Act (RCRA)
* Safe Drinking Water Act (SDWA)
* Superfund, Comprehensive Environmental Remediation
* Compensation and Liabilities Act (CERCLA)

Environmental Analysts need knowledge of the various environmental laws and regulations which is always helpful in determining the analysis that must be performed that is why they are very important in this work. In looking at the analytical methods used in environmental pollution control the knowledge of these laws and regulations will help in assessing the methods whether they are adequate or lacking in helping stakeholders to comply with these laws.

**2.7.3 Environmental Legislations, Regulations, and Guidelines in Nigeria**

As shown by the state of the environment above, Nigeria as an oil rich country have petroleum products as one of the major source of air, water and land pollution. World wide petroleum refineries are generally considered a major source of pollutants in areas where they are located and are regulated by a number of environmental laws related to air, water, and land. There are so many hazardous substances in petroleum such as Benzene, which in times past were disposed along side other petroleum waste without serious treatment and monitoring. But now as a result of evolving environmental awareness, petroleum refinery operators face more stringent regulations of treatment, storage, and disposal of hazardous wastes. In Nigeria the Federal Arm of the Government responsible for environmental issues is the Federal Ministry for Environment which was created from the Federal Environmental Protection Agency (FEPA). Some laws and regulations have been promulgated by the Colonial masters and earlier leaders which include:

* Oil Pipeline Act 1956
* Public Health Act 1958
* Oil in Navigable waters Acts 1963
* Petroleum Refining Regulation Act 1974
* Factories Act 1987
* States Edicts on Environmental Sanitation

But FEPA also has done much to set laws and regulations concerning environmental pollution control. The regulations promulgated or issued by FEPA include the following (FEPA 1991a):

* S.1.8 of 1991: National Effluent limitation official Gazette Federal Republic of Nigeria No 42, Vol. 78 August 1991 (2)
* S.1.9 of 1991: Pollution Abatement in Industries, industries Generating wastes, official Gazette, Federal Republic of Nigeria No 42, Vol. 78, 20th August 1991 (4)
* S.1.15 of 1991: Management of Hazardous and solid wastes official Gazette, Federal Republic of Nigeria, No 102, Vol. 78, 31st December, 1991
* National Guidelines and Standards for environmental pollution control in Nigeria
* Environmental Impact Assessment (EIA) Decree 86, 1992 with its

sectorial guidelines for Agricultural and Rural development; Oil and Gas; Manufacturing; Mining, Beneficiation and Metallurgical processes; and Infrastructures.

Analytical methods commonly used for determination of significant variables in pollutants control are prescribed in Nigeria, by FEPA (which is now Federal Ministry of Environment) for all parties involved in the monitoring and applications of all environmental standards. Well tested standard methods for water and waste water analysis used in the United States Environmental Protection Agency (EPA), U.K. Department of Environment (DOE), the American Society for Testing and Materials (ASTM) were adopted in many situations for monitoring purposes. For reporting purposes, the analytical methods used have to be specified. A few selected water quality criteria for irrigational waters are given below in Table 2.10: the table shows a comparison of the Nigeria limits with those of FAO and Canada. But these good limits will not help in pollution control if they are not enforced and complied with, that is why FEPA created an inspectorate and enforcement department and vested it with the authority to enforce environmental protection laws. Their duties include checking and effecting compliance of industries with the regulations and laws related to industrial pollution.

**Table 2.10 Selected Water Quality Criteria for Irrigational Waters (mg/L)**

|  |  |  |  |
| --- | --- | --- | --- |
| Elements | FAO Limits | Canada Limits | Nigerian Limits |
| Aluminum | 5.0 | 5.0 | 5.0 |
| Arsenic | 0.1 | 0.1 | 0.1 |
| Cadmium | 0.01 | 0.01 | 0.01 |
| Chromium | 0.1 | 0.1 | 0.1 |
| Copper | 0.2 | 0.2-1.0 | 0.2-1.0 |
| Manganese | 0.2 | 0.2 | 0.2 |
| Nickel | 0.2 | 0.2 | 0.2 |
| Zinc | 2.0 | 1.0-5.0 | 0.0-5.0 |

(Source: Rhett A. Butler; FAO Report 2005; CCREM, 1987; FEPA, 1991)

The Inspectorate and Enforcement Department have different arms such as:

* Standards, Regulations and Registration section responsible for setting or reviewing standards, formulating regulations and issuing permits as well as accrediting environmental consultants and contractors
* Chemical tracking section responsible for chemical notification procedure, hazardous waste traffic control and monitoring of imported chemicals from cradle to grave
* Compliance monitoring section responsible for checking and effecting compliance of industries with standards and pollution abatement strategies
* There is a public complaints unit attached directly to the office of Head of Enforcement for prompt actions in addition to these three divisions.

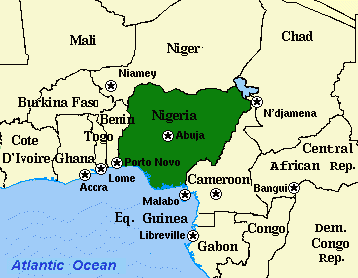
At a time when environmental health and ecosystem damaging is worsening in many cities, careful quantification of environmental pollution can be a good help to policy makers to combine environmental and health decisions with sound economic principles. If this will be achieved then appropriate instruments and techniques for environmental pollution measurement especially ones that take into consideration damage to the value of natural ecosystems and human health must be fully developed and maintained. With out the proper instruments for environmental measurements, it would be difficult to speak of attaining both a balance and compatibility between resource conservation and economic growth. In trying to address the issues of analytical methods of measuring environmental pollution and controlling it, FEPA has established National Environmental Reference laboratories in the country; The Lagos national environmental reference laboratory complex is currently serving the environmental monitoring activities of Lagos state and the Federal capital Territory. These laboratories provide FEPA with the capability to generate reliable data for determining compliance with the National environmental guidelines and standards to monitor and control domestic and industrial pollution. In spite of this effort by FEPA a survey carried out by British Geological survey team in January 2003 (Bradford et al) showed that measurement equipments are limiting quality control in Nigeria’s water sector (Bradford T. and Cook M.N 2003). Water Aid Nigeria observed that the ability of local governments and water boards to test for drinking water quality has been limited by the availability of suitable equipments and the absence of a sector wide standard that all testing bodies must adhere to (WaterAid Nigeria: http://www.wateraid.org).

The observations by WaterAid Nigeria add to the justification of this research, there is a need for a comprehensive study of the available analytical equipments and their suitability for effective pollution control. Without the proper equipments it will be difficult to ensure compliance with the environmental laws, regulations and standards.

* 1. **General Overview of Nigeria’s Industries and Environ-mental Pollutants**

**2.8.1 The Country Nigeria**

The country Nigeria is officially known as The Federal Republic of Nigeria with Abuja as the federal capital. It is located in West Africa; Figure 2.10 shows Nigeria with the neighboring countries, it is boarded to the north by the Republics of Niger and Chad, to the south by the Atlantic Ocean, to the east by the Republic of Benin, and to the west by Cameroon. According to the last census, Nigeria has a population of about 140 million, spread unevenly over a national territory of 923,768 km2, as can be seen in table 2.11 below, the population are concentrated in few big cities, e.g. one big city like Lagos has a population of above 8 million people. The country runs a three tier of government structure; Federal; State; and Local Government. There are 36 states and the Federal Capital Territory which is the seat of government; the states consist of 774 local Government Area Councils. There are about 521 different languages spoken across the country, with three major ones spoken across the three regions of the country:

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**Figure 2.10** A Map of Nigeria Showing the Neighboring Countries

(Source:http://www.appliedlanguage.com/maps)

Hausa is spoken in the northern region, Ibo, spoken in a part of the eastern region, and Yoruba, spoken in the southern part. Nigeria has a growing economy; according to the IMF projection it has a growth rate of 9% in 2008, which makes Nigeria one of the fastest growing economies in the world. The growing Nigerian economy was recognized by Goldman Sachs Investment Bank when in 2005 they listed Nigeria in the “Next Eleven”. According to them these eleven countries (which Nigeria is one) are countries having high potential of becoming the world’s largest economies along with the BRICs (Brazil, Russia, India, and China).

**Table 2.11 Population of Big Nigerian Cities**

|  |  |
| --- | --- |
| **City** | **Population** |
| Lagos | 8,029,200.00 |
| Kano | 3,848,885.00 |
| Ibadan | 3,078,400.00 |
| Kaduna | 1,652,844.00 |
| Port Harcourt | 1,320,214.00 |
| Benin City | 1,051,600.00 |
| Maiduguri | 1,044,497.00 |
| Zaria | 1,018,827.00 |

(Source:http://en.wikipedia.org/wiki/Nigeria)

Petroleum plays a large role in the Nigerian economy, accounting for 40% of Nigeria’s GDP and 95% of foreign exchange. But before the oil boom Nigeria’s main source of foreign exchange used to be agriculture, in the 1960s, Nigeria was one of the biggest food exporters. Even with the oil boom, till now a big percentage of Nigerians are employed in the agricultural sector. Apart from oil, there are a lot of other mineral resources, which are present in Nigeria, although they are not fully exploited; these include coal, tin, iron ore, limestone, niobium, lead and zinc. Despite these available minerals, the mining industries in Nigeria are very much under developed. Nigeria has a booming leather and textile industry, with industries located in some big cities given in Table 2.11 above such as Kano, Lagos, etc.

As mentioned above, Petroleum plays a large role in the Nigerian economy due to its large proven reserves. Nigeria is the largest oil producing country in Africa, the eleventh largest producer of crude oil in the world and sixth largest amongst the OPEC countries. In 2005 Oil and Gas journal ([www.mbendi.co.za](http://www.mbendi.co.za)) estimated that Nigeria has proven oil reserves totaling 35.2 billion barrels and the government plan to expand its proven reserves to 40 billion barrels by 2010. Because of the large oil reserve Nigeria is very attractive to large international companies, with the major stake holder being Shell. According to the same source quoted above, Nigeria contains 176 trillion cubic feet (Tcf) of proven natural gas reserves. Unfortunately a large part of this gas reserves is being flared into the atmosphere due to lack of gas infrastructures and this forms a huge source of environmental pollution. But the government has set 2010 as a zero flare target and to raise earnings from the natural gas export. The government has since established liquefied petroleum gas (LPG) companies to help achieve this goal by harnessing the natural gas resources. In general it can be said that the Nigerian economy has fairly improved in the last few years, this is indicated by the fact that in 2006 Nigeria became the first African country to fully pay off her debt owed to the Paris club (Wikipedia; http://en.wikipedia. org/wiki/Economy\_of\_Nigeria).

**2.8.2 Industries in Nigeria**

There are four main sectors of industries in Nigeria, which are; primary, secondary, tertiary and research and development sectors. Primary sector, these are mainly raw material extraction e.g. mining, crude oil extraction, etc. The secondary sector involves refining and manufacturing e.g. NNPC refineries. The tertiary sector deals with services and distribution of manufactured goods. The fourth sector focus on technology, research and development. The Nigerian industrial sectors are not completely developed, in 1999 the manufacturing industries accounted for only less than 5% of the country’s GDP, but by 2000 it experienced 4.9% growth mostly due to the oil and gas industrial sector (Index Mundi; http://www.indexmundi.com/nigeria/gdp\_real\_  
growth\_rate.html). The textile industry is still in the early stages of development due to lack of adequate infrastructures. Most of the raw materials used in the textile industry come from local farmers. There are some few steel industries such as the Delta Steel Plant at Aladja, Oshogbo steel rolling mills, steel complex at Abeokuta, etc. Other industries that are much in the developing and growing stages are cement, sawmills, cigarette factories, pharmaceutical plants, tire factories, paint factories, and assembly plants. Nigeria has five state owned motor vehicle assembly plants for Volkswagen, Peugeot, and Mercedes products. The CIA world Fact book of May 2008 gave a list of Nigeria’s industries based on rank ordering of industries starting with the largest by value of annual output as follows; crude oil, coal, tin, columbite, palm oil, peanuts, cotton, rubber, wood, hides and skins, textiles, cement and other construction materials, food products, foot wear, chemicals, fertilizer, printing, ceramics, steel, others. In the same Fact Book of 2008 by CIA the rate of industrial production growth was given as shown in Figure 2.11 below. It can be seen from this rate of production growth that the Nigerian industries are very much under developed, with the rate of growth of production going as low as into the minus in 2007 (Figure 2.11).

**Figure 2.11** Nigeria’s Industrial Production Growth Rate in Percentage

(Source: created from CIA World Fact book May 2008)

Another classification of industries in Nigeria is that found at [www.mbendi.co.za](http://www.mbendi.co.za), where they made attempt to give the exact numbers of the types of industries in Nigeria, this is shown in Figure 2.12, this list is not conclusive, but just to give a picture of the proportion of the Nigeria’s industries that belong to oil and gas. This shows the major source of environmental pollutants that has to be dealt with, and it can be seen that it is mainly from oil and gas or petroleum.

**Types of Industries**

1= Oil and Gas, 2 = Food, Beverages and Tobacco, 3 = Chemicals, 4 = Agriculture, 5 = Building, construction and civil Engineering, 6 = Leather, 7 = Textiles & clothing, 8 = Mining, 9 =Packaging, 10 = pulp & paper and 11 = Automobile

**Figure 2.12** Nigeria’s Industries Both Facilities and Organizations

(Source: created from www.mbendi.co.za)

Nigeria has always had industry planed as the engine for its economic growth; therefore one can anticipate that the number of industries in Nigeria will increase with time. But the problem is that, the environmental records of the industries are not encouraging as they simply discharge their untreated wastes directly into the environment without due considerations to health and the environment. The country therefore faces serious health and environmental hazards such as contamination of ground and surface waters, land and air pollution (Imevbore, 2001), that is why effort should be made to have well equipped environmental laboratories for good monitoring and control of pollution caused by industries in Nigeria.

**2.8.3 Types of Environmental Pollution Caused by Industries in Nigeria**

Environmental pollutants have been discussed extensively under literature review and the types of pollutants found in Nigeria are not different from what are obtained in the literature. From the types of industries found in Nigeria and their proportion to each other (Figure 2.12 above), is easy to figure out the types of environmental pollutants that are found in the country. The major source of environmental pollution is petroleum and it’s by products, both from the industries and the use of the finished products.

Crude petroleum may consist of various gases, solids, and trace minerals mixed in with it. Petroleum derived contaminants constitute one of the most prevalent sources of environmental degradation in Nigeria. In large concentrations, the hydrocarbon molecules that make up crude oil and petroleum products are highly toxic to many organisms, including humans. It is a well known fact that this crude form of petroleum has been released into the Nigeria’s environment so many times and at times in a large volume which is really a great environmental concern (Olu et al 2004). Apart from the hydrocarbons in this crude that can be toxic, petroleum also contains trace amounts of sulfur and nitrogen compounds, which are dangerous by themselves and can react with the environment to produce secondary poisonous chemicals.

Petroleum refineries are a major source of hazardous and toxic air pollutants such as benzene, toluene, ethylbenzene and xylene (BTEX) compounds. Therefore these pollutants are major sources of air pollutants in Nigeria from the three big refineries in the country. These pollutants are major source of what EPA calls criteria air pollutants which are particulate matter (PM), nitrogen oxides (NOx), carbon monoxides (CO), hydrogen sulfide (H2S), and sulfur dioxide (SO2). From the refineries one expect also less toxic hydrocarbons such as natural gas (methane) and other light volatile fuels and oils to be released to the environment. Some of the light hydrocarbon compounds like VOCs can combine with NOx in sunlight to create O3 which cause urban smog and create human health problems when present at lower atmosphere. In Kano, Lagos and many big towns in Nigeria where the car traffic are almost always high, urban smog seems to be all the time heavily present in these towns. Petroleum-fueled transportation is considered the chief cause of CO2 in Nigeria, since CO2 is a main constituent of petroleum fuel exhaust. Methane and NH3 although usually associated with natural gas, is also emitted whenever crude oil is extracted, transported, refined, or stored, therefore they are prevalent in Nigeria. The air in most Nigerian towns is therefore contaminated with petroleum by products from motorized vehicles, i.e. contaminants such as Volatile organic compounds (VOCs), soot, PM, carbonaceous particles, etc. Other air pollutants in Nigeria apart from those from petroleum include those from other industries such as cement dust from cement industries, heavy metals such as lead from metal industries, Aerosols, carbon black etc from other industries given in Table 2.12.

Refineries are potential major contributors to ground water and surface water contamination. Most refineries in Nigeria dispose of wastewater generated inside the plants into water bodies or inject into deep wells, and some of these wastes end up in aquifers, groundwater and surface water bodies. This wastewater may be process water from desalting, water from cooling towers, storm water, from distillation, or cracking units, therefore it may contain oil residuals and many other hazardous wastes. Large amount of sulfides, ammonia, suspended solids and other compounds in the end wastewater may end up in water resources.

Common water pollutants found in Nigeria mainly from, Oil and Gas, Food, Beverages and Tobacco, Chemicals, Agriculture, Textiles & Clothing, Mining, Pulp and Paper industries are as follows; organic compounds, aqueous organic matter (OM), polyaromatic hydrocarbons, polychlorinated biphenyls and dioxins. Others include organic industries discharges, humic materials (HM), dissolved organic matter (DOM), and toxic metals

Pipelines and oil well accidents, unregulated industrial waste, and leaking underground storage tanks are very common in Nigeria and these can all permanently contaminate large areas of soil making it dangerous to the health of organisms living in and around them including human beings. With the large number of leaks, spills and well accidents very common in Nigeria, one can expect soil contamination with many pollutants including some hazardous wastes, organic compounds of different forms, spent catalysts or coke dust, tank bottoms and sludge from the treatment processes, to constitute some problems to the ecosystems.

Other soil pollutants from the above given industries found in Nigeria include, metals and their compounds, organic compounds, chemicals, oils and tars, pesticides, biological active materials, asbestos. Copper and chromium are common heavy metal soil pollutants found in Nigeria mainly from tanneries and wood- preserving plants. Other heavy metals pollutants like cadmium, zinc, mercury and arsenic are mainly due to industrial activities, waste incineration, combustion of fossil fuels, etc.

**Table 2.12 Summary of Pollutants Released by Industries in Nigeria**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Petroleum & petrochemicals** | **Textiles & clothing** | **Mining, Cement & Tanneries** | **Food & Beverage** | **Chemicals** | **Others** |
| **Sulfur** | **Dyes** | **Particulates** | **Organic Waste** | **Pesticides** | **Soot** |
| **Nitrogen Compounds** | **Surfactants** | **Mine Tailings** | **Suspended solids** | **Spent catalyst** | **Oil & tars** |
| **Benzene, Toluene, Ethylbenzene, Xylene (BTEX)** | **Oxidizing & Bleaching agents** | **Cement dust** | **Humic Matter** | **Toxic metals e.g. Arsenic** | **Coke dust** |
| **VOCs** | **Reducing agents** | **Particulate Matter** | **Dissolved organic matter** | **Waste Chemicals** | **Asbestos** |
|  | **Silicates** | **NOx** |  |  |  |
| **Organic Pollutants** | **Inorganic salts** | **CO, CO2** | **Sludge from processes treatment** | **Furans** | **Sulfides** |
| **Oil & Grease** | **Oil, greases** | **Suspended Solids** |  | **Herbicides** | **Smog** |
| **Cyanides** | **Metal e.g. Zinc, lead** | **Sulphides** |  | **Mercury** | **H2S** |
| **Heavy metals** | **Fibers & dust** | **Heavy metals** |  | **Lead** | **NH3** |
| **Phosphorus** | **Volatile synthetic fibers** | **Acids** |  | **Inorganic Tin** | **Sulfur** |

**Table 2.12 Continued**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Polychlorinated biphenyls (PCBs)** |  | **Aerosols** |  | **Organic liquid solvents such as toluene** | **PM** |
| **Oil residuals** |  | **Dioxins** |  |  | **PAHs** |
| **Polyaromatic Hydrocarbons (PAHs)** |  |  |  |  | **VOCs** |
| Hydrocarbons |  |  |  |  | **NOx** |

**Table 2.12 above gives a summary of the pollutants found in Nigeria due to industries and human activities. It can be seen in the table that some pollutants are produced by many industries, some produced by industries and other sources such as human activities. These pollutants are very complex in the matrix that they are found as such they need high quality analytical instruments to detect them and to control them in treated waste and the environment.**