

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

Von der Fakultät für Umweltwissenschaften und Verfahrenstechnik  
der Brandenburgischen Technischen Universität Cottbus  
zur Erlangung des akademischen Grades eines Doktor-Ingenieurs (Dr.-Ing.)  
genehmigte Dissertation

vorgelegt von

B.Sc Chemistry, M.Sc Ren. Energy, M.Sc Chemistry;  
Bertha Abdu Danja

aus Kaltungo Gombe State Nigeria

Gutachter: Prof. Dr. rer. nat. Jürgen Ertel

Gutachter: Prof. Dr.-Ing. Werner Witt

Tag der mündlichen Prüfung: 26.03.2010



## **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**

-----  
**Bertha Abdu Danja**

Faculty of Environmental Sciences and Process Engineering  
Chair of Industrial Sustainability, BTU Cottbus Germany

## 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.



## Acknowledgements

I am colossally obliged to Prof. Dr. rer. nat. J. Ertel, whose guidance, advice, support and constructive criticism are behind the successful completion of this work I am very grateful, Sir. I must acknowledge here that Mrs Kay Ertel, you have been part of this work in many ways, time and space will fail me to numerate them, thank you for all the support and encouragement you have given me during the period of this work. My thanks go to Professor Dr. –Ing. Werner Witt, who willingly accepted to be one of my supervisors, your acceptance, support, advice and guidance, gave me a lot of courage to continue, thank you. I owe Visiting Professor Dr. –Ing. Otmar Deubzer a lot of gratitude, at a point I was in doubt you gave me hope, thank you very much for your effort in correcting this work, advising and guiding me as one of my supervisors, I am very grateful.

I am indebted to my husband, Mr. Lonis Abdu Salihu, who has allowed me to spend so much time in Germany to pursue this PhD, your concerted support in all areas of my life before, during and even after this work is my stronghold, I am very grateful. Dr Agnes Klingshirin you have been a mother in deed both to me and my husband, your support during our studies can not be overemphasized, we owe our success to you in all directions, i.e. financially, morally, emotionally and psychologically, you have been truly a help in time of our needs, thank you. Prof Hermann Jungrathmyr you have been a real father indeed to me and my husband, you were always there when we needed your help, you provided for us financially, visited us, visited my parents, the list goes on, thank you very much. I wish to express my gratitude to Frau Müller Gudrun, thank you very much for all your love, care and help during my studies in Germany.

I wish to thank my family members from my father side, my sister Emily Madina you have been more than a sister, you have been my best friend who I can call any time and talk over my problems with, thank you very much for all the times we have shared and your encouragement for this

work. All my siblings, Robert Danja, Reniya Yunana, Solomon Danja, Gerson Danja, Augustine Danja and Late Nehemiah Danja, you have all supported me financially, morally and otherwise, I am really proud of all of you, thank you very much. My father Mr. Danja Laufun and my mother Mrs. Monje Danja are the reasons why I am what I am today, you spent your little money to give me the education that I needed to come to this point even to dream of a PhD, I lack the words to use to say thank you, God keep you and give you good health in old age, thank you especially for your prayers for me. All my relatives at home, in-laws and friends, you have all been very supportive of me during my studies, your phone calls and e-mails gave me strong encouragement to go on, thank you.

My thanks also go to the entire working group of the Chair of Industrial Sustainability, BTU Cottbus Germany, without the cooperation, support and help of all of you in the working group I will have had a lot of problems during the period of this work, thank you all. Susann, Bert, Marek and Nele thank you very much for helping me in one way or the other, Bert I appreciate your many hours on my computer problems, thank you. I must say here the kindness, willingness to help and financial support of the Akademisches Auslandsamt BTU Cottbus has really contributed to my success, I am indebted to the AAA BTU Cottbus, all of you staff members of AAA BTU Cottbus you make the university really home to foreign students and I really felt so much at home, thank you.

My friends in Berlin so many to list here, have all stood behind me during this work, I am very grateful. Mention must be made here of Bro Olayinka Shitu and Herr Weirauch, who spent so much time translating my abstract into German language, and also in editing this work, thank you very much. The entire family of the current Nigerian Ambassador His Excellency Mr Rimdap, have been a great support to me during this work, I am very grateful to the Ambassador His Excellency Mr Abdul Rimdap, his wife Hajiya

Halimatu Rimdap, Samson Rimdap and the entire family, thank you very much.

This work would have not been possible without the help and cooperation of the staff members of Nigerian National Petroleum Corporation (NNPC:KRPC) Kaduna, Ashaka Cement factory, Regional Laboratory Gombe, Standard Organization of Nigeria Abuja, National Reference Laboratory Lagos, National Environmental Standards and Regulations Enforcement Agency Nigeria, Federal Ministry of Environment Housing and Urban Development. I am grateful to all of you who assisted in taking the laboratory results, giving interview and making documents available to me, thank you very much.

I wish to acknowledge that I am bound to the state Government of Gombe Nigeria, who accorded me the time and the study leave I needed to undertake this research, I remain indebted to you my state.

Above all, praises to the Lord, who dwelleth in Zion, who maketh the storm in my life calm, so that the waves therefore are still. The name Jesus has been my strength and my strong tower, to whom I have always ran to and I was always saved, I am forever grateful.

<b>List of Figures</b>	<b>Page</b>
Figure 1.1 Analytical Process -----	6
Figure 1.2 Map of Nigeria Where the Study Areas Gombe, Abuja, Ashaka (In the Near of Bajoga), Kano and Lagos Can be Seen.-----	18
Figure 1.3 Relations of Different Aspects of the Research-----	26
Figure 2.1 An Industrial Flare in China-----	29
Figure 2.2 Water Palace India-----	33
Figure 2.3 A Typical Industrial Chimney Emitting Some Greenhouse Gases into the Atmosphere-----	34
Figure 2.4 One of the Community Involvements Activities on the Environment -----	37
Figure 2.5 Total Hydrocarbon Analyzer Model HC-404 -----	67
Figure 2.6 Waters 600 Semi-Prep HPLC-----	67
Figure 2.7 a & b Combination of FID & TCD Detector GC; -----	68
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. -----	68
Figure 2.9 AAS Zeenit 600 with Graphite Tube Control; Analytik Jena-----	69
Figure 2.10 A Map of Nigeria Showing the Neighboring Countries -----	90
Figure 2.11 Nigeria's Industrial Production Growth Rate in Percentage -----	93
Figure 2.12 Nigeria's Industries Both Facilities and Organizations -----	94
Figure 3.1 Waste Water Treatment Tank of NNPC Kaduna -----	103
Figure 3.2 Outlet of Treated Waste Water to Receiving River-----	104
Figure 3.3 Dissolved Oxygen (DO) Meter) from NNPC Kaduna -----	105
Figure 3.4 PH Meter from NNPC Kaduna-----	105
Figure 3.5 Total Dissolved Solid Meter NNPC Kaduna-----	107
Figure 3.6 Conductivity/ COD/ PH Meter from NNPC Kaduna Chemical laboratory -----	109

Figure 3. 7	Double Beam Spectrometer from NNPC Kaduna Chemical Laboratory -----	111
Figure 3.8	IR Spectrophotometer from Ashaka Cement Factory -----	112
Figure 3.9	X-Ray Fluorescence (XRF) Spectroscopy from Ashaka Cement Factory -----	113
Figure 3.10	HACH Colorimeter DR/890 from Gombe Regional Laboratory -----	114
Figure 3.11	Electrical Conductivity Meter from Gombe Regional Laboratory -----	116
Figure 3.12	Dissolved Oxygen Meter from Gombe Regional Laboratory-----	117
Figure 3.13	Chemical Oxygen Reactor from Gombe Regional Laboratory -----	118
Figure 3.14	Biochemical Oxygen Demand (BOD) Reactor from Gombe Regional Laboratory -----	118
Figure 3.15	Flame Photometer from Gombe Regional Laboratory-----	119
Figure 3.16	UV 500 from Gombe Regional Laboratory -----	119
Figure 3.17	Total Organic Carbon Analyzer (TOC) from Gombe Regional Laboratory -----	123
Figure 4.1	Number of Analytical Instruments Shown in the Literature Review Compared with those Found in the Research Laboratories -----	136
Figure 4.2	Comparison of Nigerian Effluents Limits with NNPC Results -----	139
Figure 4.3	Comparisons of Gombe Regional Laboratory Results with Nigeria' Standards Limits -----	142
Figure 4.4	Flame from Gas Flaring in Nigeria (Ebocha) -----	148
Figure 4.5	Comparison of a Result from Germany with One of the Research Results from Gombe -----	157
Figure 5.1	Structure of New Zealand Wastewater Monitoring Guidelines -	164
Figure 5.2	Number of Parameters in Nigerian Drinking Water; Guidelines Compared with some Developed Countries-----	173
Figure 6.1	Recommended Procedures for Guidelines, Standards, and Laws Drafting-----	192
Figure 6.2	Monitoring of Drinking Water by Both the Suppliers and the Regulatory Bodies-----	194

<b>List of Tables</b>	<b>Page</b>
Table 2.1 Particulate Matters-----	44
Table 2.2 Some Minor, Trace Elements and Compounds that can be Found in Water as Pollutants -----	49
Table 2.3 Applications of Sol-gel Coated Fibres SPME in Environ- mental Analysis -----	57
Table 2.4 A General Overview of Analytical Methods -----	58
Table 2.5 Conventional Methods for Analysis of Inorganic Anions in Drinking Water-----	61
Table 2.6 Examples of Portable Instruments -----	63
Table 2.7 Examples of Analytical Instruments and their Prices -----	66
Table 2.8 Drinking Water Quality Standards from U.S Environ- mental Protection Agency -----	77
Table 2.9 WHO Ground Water Quality Limits-----	81
Table 2.10 Selected Water Quality Criteria for Irrigational Waters (mg/L) ---	87
Table 2.11 Population of Big Nigerian Cities -----	91
Table 2.12 Summary of Pollutants Found in Nigeria -----	98
Table 3.1 Result Obtained from NNPC (KRPC) Kaduna Environ- mental Pollution Control in 2007 -----	106
Table 3.2 Result Obtained from NNPC (KRPC) Kaduna Environ- mental Pollution Control in 2008 -----	108
Table 3.3 NNPC Kaduna Month end Analysis Report- November 2008-----	110
Table 3.4 Water Quality Analytical Results from Gombe Regional Laboratory. Date of Analysis: 29.06.2008-----	115
Table 3.5 Water Quality Analytical Results from Gombe Regional Laboratory Date of Analysis: 15.07.2008-----	120
Table 3.6 Water Quality Analytical Results from Gombe Regional Laboratory Date of Analysis: 06.08.2008-----	121
Table 3.7 Water Quality Analytical Results from Gombe Regional Laboratory 02.12.2008 -----	122

Table 3.8	Nigerian Effluent Limits for Discharged into Water (mg/l Unless Otherwise Stated)-----	129
Table 4.1	Summary of Analytical Instruments Found in Research Laboratories-----	131
Table 4.2	Appropriate Analytical Instruments for Pollutants Found in Nigeria ---	134
Table 4.3	Standard Deviation of Waste Water Treatment Monitoring Results NNPC Kaduna Obtained in 2007-----	138
Table 4.4	Standard Deviation of Waste Water Treatment Monitoring Results NNPC Kaduna Obtained in 2008-----	138
Table 4.5	Nigerian Limits for some Gaseous Emission from Petroleum Refinery which are not Monitored in NNPC Kaduna -----	140
Table 4.6	Comparison of Treated Effluent Values of NNPC Kaduna and Nigeria Effluent Limits-----	141
Table 4.7	A Typical Result from the Chemistry Laboratory of Ashaka Cement Factory. Date taken 13.11.2008 -----	143
Table 4.8	The Nigerian Ambient Air Quality Standard-----	145
Table 4.9	An Example of a Drinking Water Analysis Laboratory Results from Germany-----	156
Table 5.1	Comparison of Nigerian Limits for Drinking Water with some Developed Countries-----	166
Table 5.2	Comparison of Nigerian Limits for Drinking Water with that of New Zealand-----	169
Table 5.3	Emissions from Cement Kilns Monitored in Germany -----	175
Table 5.4	Threshold Values for Mandatory Reporting on 19 Air Pollutants Covered by the European Pollutant Emission Register (for Cement Industries) -----	177

## **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	<b>Phenyltrimethoxysilane- Methyltrimethoxysilane</b>

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

# Table of Content

Title Page .....	I
Declaration .....	III
Dedication .....	IV
Acknowledgement.....	V
List of Figures.....	VIII
List of Tables.....	X
Acronyms and Abbreviation .....	XII
Table of Content.....	XIX
Abstract.....	XXIII
Chapter 1 General Introduction .....	2
Introduction .....	2
1.1 Justification of the Study .....	8
1.2 Problem Statements and Research questions .....	11
1.3 Aims and Objectives of the Study .....	14
1.4 Methodology.....	16
1.4.1 Study Area .....	16
1.4.2 Criteria for Choosing Research laboratories and Organizations .....	19
1.4.3 Research Strategy .....	21
1.4.4 Methods for Technical Studies.....	22
1.4.5 Statistical Analysis .....	24
1.5 Expected Outcome .....	24
1.6 Summary of the Different Aspects of the Research .....	25

Chapter 2 Literature Review	-----	27
2.1 Introduction	-----	27
2.2 The State of the Environment	-----	32
2.2.1 General State of the Environment	-----	32
2.2.2 State of the Nigerian Environment	-----	39
2.3 Environmental pollutants	-----	42
2.3.1 General	-----	42
2.3.2 Air Pollutants	-----	43
2.3.3 Water Pollutants	-----	47
2.3.4 Soil Pollutants	-----	50
2.4 Types of Analytical Methods Applied in Environmental Pollution control	-----	52
2.4.1 General	-----	52
2.4.2 Uses of Analytical Methods in Environmental Chemistry	-----	54
2.4.3 Examples of Analytical Methods and their Applications in Environmental Pollution Control	-----	55
2.4.4 Choosing the Right Analytical Instrument	-----	64
2.5 Recent Advances in Environmental Analytical Instruments	-----	70
2.6 Economic Tools for Environmental Management in Nigeria	-----	73
2.7 Environmental Standards, laws and Regulations	-----	76
2.7.1 Standards	-----	76
2.7.2 Laws and Regulations	-----	82
2.7.3 Environmental Legislations, Regulations, and Guidelines in Nigeria	-----	85
2.8 General Overview of Nigeria's Industries and Environmental Pollutants	-----	89



2.8.1 The Country Nigeria -----	89
2.8.2 Industries in Nigeria-----	92
2.8.3 Types of Environmental Pollution Caused by Industries in Nigeria -----	95
 Chapter 3 Results from Field Work in Nigeria -----	 101
3.1 Nigerian National Petroleum Corporation (NNPC) Kaduna -----	101
3.2 Ashaka Cement Factory -----	111
3.3 Regional Laboratory Gombe, Federal Ministry of Water Resources -----	114
3.4 National Reference Laboratory Lagos-----	123
3.5 National Environmental Standards and Regulations Enforcement Agency (NESREA) Nigeria -----	124
3.6 Federal Ministry of Environment Housing and Urban Development-----	125
3.7 Standard Organization of Nigeria (SON) -----	127
 Chapter 4 Discussion of Research Results -----	 130
4.1 The State of the Analytical Instruments in the Research Laboratories --	130
4.1.1 Availability of the Instruments -----	130
4.1.2 Quality of the Research Laboratories Analytical Instruments ---	137
4.1.3 Air Pollution Quality Control in the Research Areas-----	143
4.2 Monitoring Organizations in Nigeria -----	151
4.2.1 The Reference Laboratory-----	151
4.2.2 The Federal Ministry of Environment, Housing and Urban Development -----	152
4.2.3 The Standard Organization of Nigeria (SON)-----	154
4.3 The Limitations of this Research-----	158

Chapter 5	The Nigerian Standards and Pollutants Monitoring Compared with International Situations -----	160
5.1	General Comparison -----	160
5.2	The Role of Analytical Instruments in Developed Countries’ Guidelines as Compared to Nigeria -----	162
5.3	Numbers of Parameters in Developed Countries’ Guidelines as Compared to that of Nigeria-----	171
5.4	Comparing the Cement Pollution Control in the Research Labora- tory with Developed Countries -----	174
Chapter 6	Summary, Conclusions and Recommendations -----	180
6.1	Summary-----	180
6.2	Conclusions -----	186
6.3	Recommendations-----	189
6.4	Outlook -----	199
References	-----	202

## **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 exploration in the Delta region in Nigeria is already causing serious environmental 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 introduced 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.

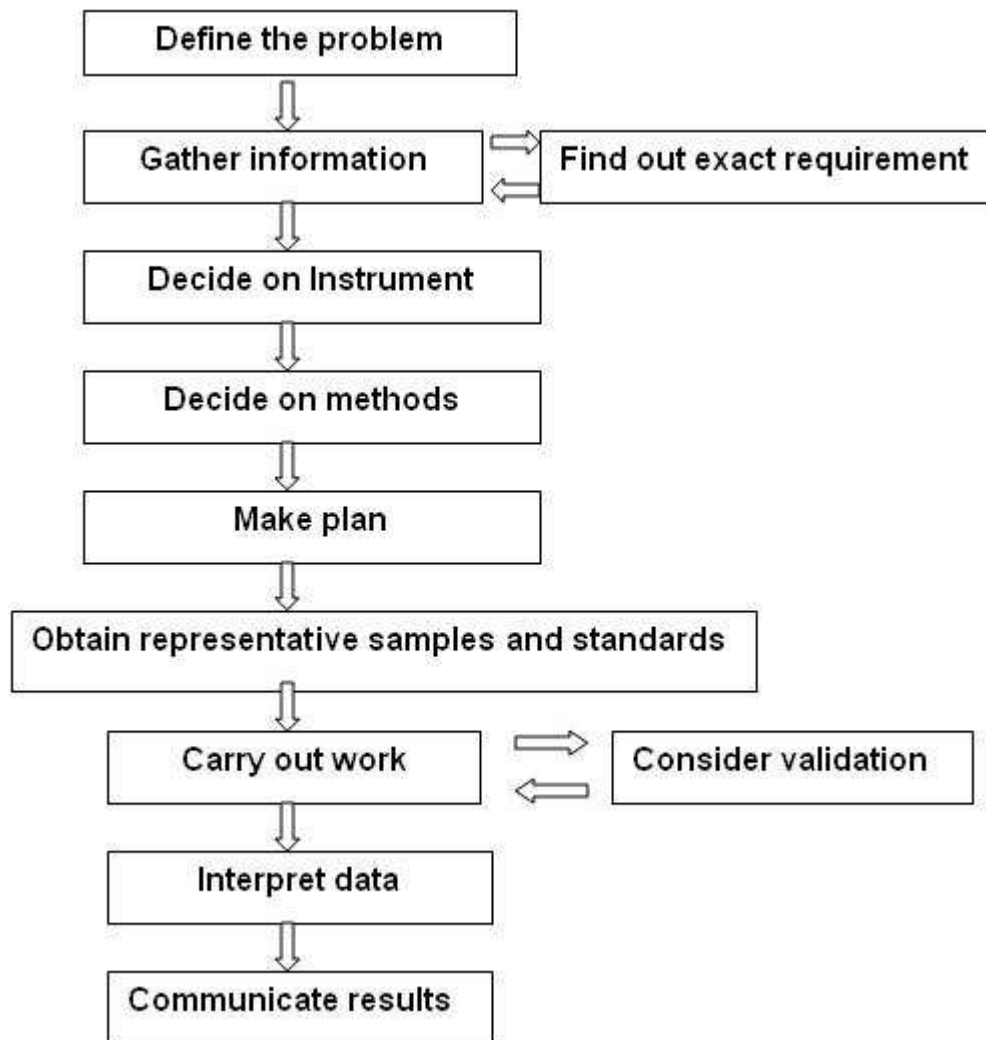
In Nigeria, the responsible agency for environmental pollution was the Federal Environmental Protection Agency (FEPA) which was created by decree 58 of 1988. Its task was to manage and monitor environmental standards and ensure sustainable development of natural resources and the protection of the environment. 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 effi-

cient 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;

- a) 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?
- b) 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?
- c) 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 environmental 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 assess-

ment and remediation of pollution and decision making on environmental 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.

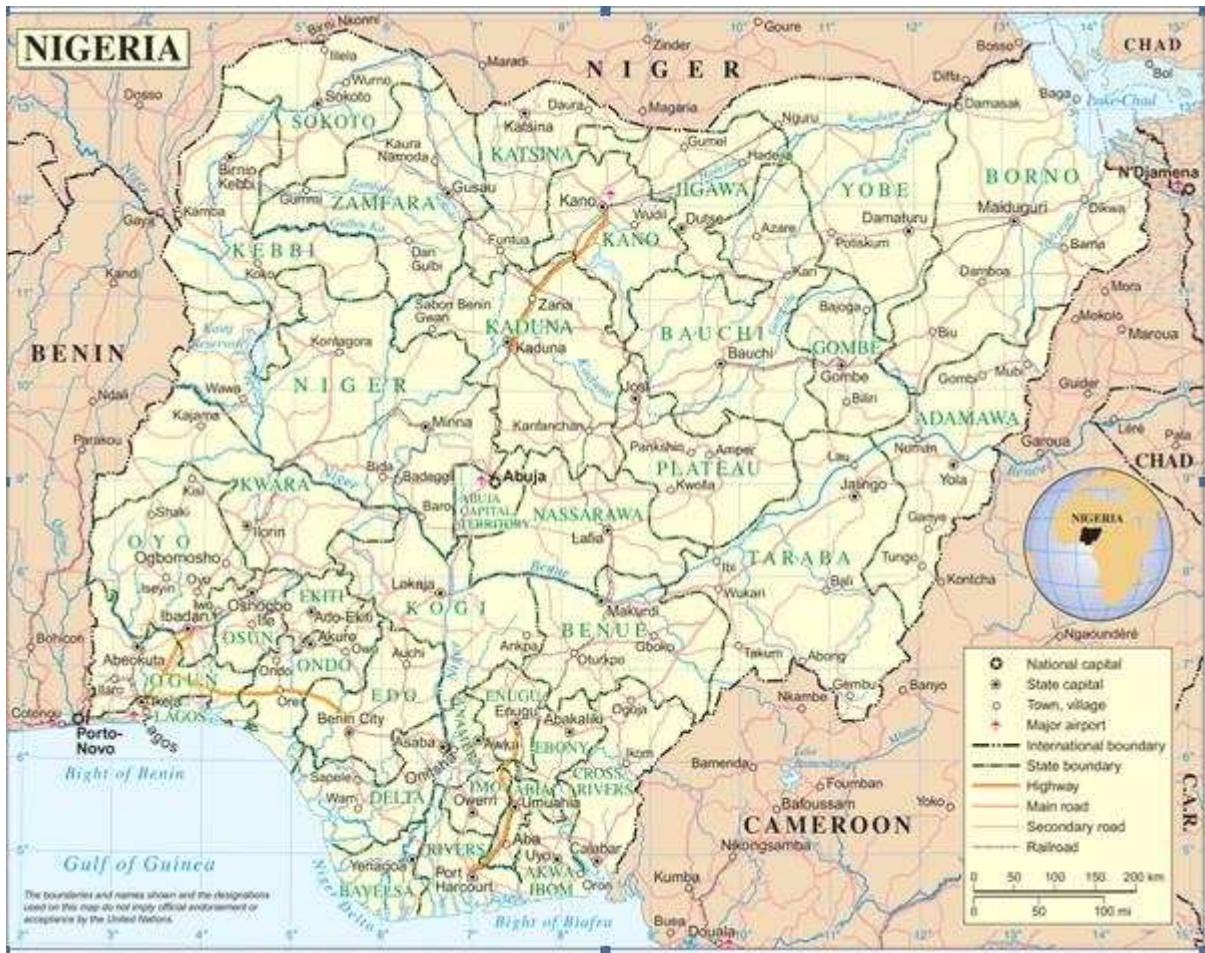
### **1.4.1 Study Area**

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 Re-



sources 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](http://www.population.gov.ng/pop_figure.pdf)). It is one of the big cities in Nigeria as can be 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 state 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 inter-

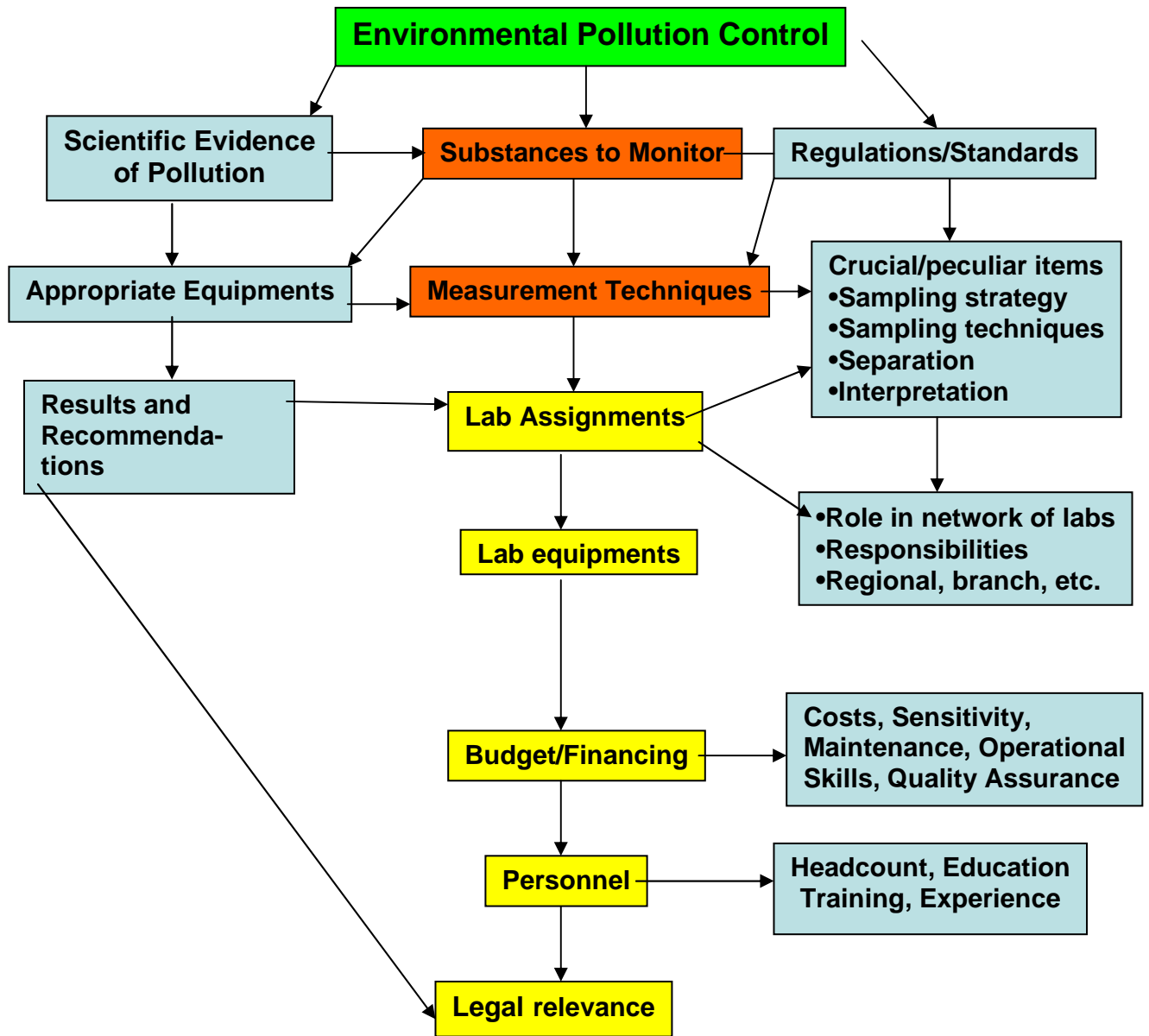


national standards and very qualified staff hired to mine these labs. Where there is no standards setting body and where there are no environmental standards as compared to international standards, Government should be able to see this clearly and make effort to bring the situation to international level.

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.



**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 22<sup>nd</sup> 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](http://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.

## **2.2 The State of the Environment**

### **2.2.1 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 ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ) and nitrous oxide ( $\text{N}_2\text{O}$ ) 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 4<sup>th</sup> 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 CO<sub>2</sub> has increased from a pre-industrial value of about 280ppm to 379ppm in 2005. The annual CO<sub>2</sub> 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 CO<sub>2</sub> emissions have come from fossil burning and about 1/3 from land use. The effects of this increase in CO<sub>2</sub> emission are many, one of which is the uptake of this CO<sub>2</sub> by ocean, seas and rivers resulting in changes in chemical equilibrium. Dissolved CO<sub>2</sub> forms weak acid, so as dissolved CO<sub>2</sub> in-

creases, 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; CO<sub>2</sub> 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 (CH<sub>4</sub>) is similar, because the abundance of CH<sub>4</sub> in 1995 of about 1774ppb is more than double its pre-industrial value. N<sub>2</sub>O 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 12 years (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 50 years is nearly twice that for the last 100 years. 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 20<sup>th</sup> 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-tropics, 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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 (NO<sub>2</sub>) concentration also has risen since 1750 by around 17% and is still rising. The current concentration of

NO<sub>2</sub> is the highest in the last 100 years. The trend is similar in SF<sub>6</sub> 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 elsewhere. 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 V 1.7, 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 encompass-

ing. 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 being spilled in the area, it 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 overview 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 downstream 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.

## **2.3 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**

<b>Types of particulate</b>	<b>Description</b>
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; 2<sup>nd</sup> 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 bio-fuels 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):

CO<sub>2</sub> – green house gas

CO – health concerns

NO<sub>x</sub> – 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/Lecture11/ENVIRONMENTAL%20POLLUTION.ppt%20\\_Compatibility%20Mode\\_.pdf](http://www.cpe.mrt.ac.lk/leve1/Lecture11/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 Titrimetry 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 pose 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  $100\mu\text{g}\cdot\text{g}^{-1}$  of mercury. The source of the mercury was from waste  $\text{Hg}^{2+}$  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 ( $\text{CH}_3\text{Sn}^{3+}$ ) and diethyl tin ( $(\text{CH}_2)_2\text{Sn}^{2+}$ ) (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  $R_nSn^{(4-n)}$ , ( $n$ ) 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](http://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; 2<sup>nd</sup> 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 result 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 rudimentary 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.

## **2.4 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 polynuclear 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.

#### **2.4.2 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  $\text{SO}_2$ ,  $\text{NO}_x$  (oxides of Nitrogen including  $\text{NO}$ ,  $\text{N}_2\text{O}$  and  $\text{NO}_2$ ) and  $\text{CO}_2$ . Others are particulate matter, ozone and lead, also total reduced sulfur (TRS),  $\text{HCl}$ ,  $\text{NH}_3$ , and Total Hydrocarbon (THCs).  $\text{SO}_2$  is typically 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  $\text{O}_3$ -based chemiluminescent method and an  $\text{NO}_2$  to  $\text{NO}$  converter, the emission produced is measured by a photomultiplier tube (AOAC 1980).  $\text{CO}$  and  $\text{CO}_2$  are usually measured using IR which uses a combination of NDIR and GFC measurement techniques. Electrochemical cells can also be used

to measure  $\text{SO}_2$  and  $\text{NO}_x$ . Catalytic sensor is another gas detection technique; it is commonly applied in continuous emission monitoring (CEM). If measurements of HCl, HF,  $\text{NH}_3$ , 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).  $\text{NH}_3$  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. Chemiluminescent analyzers and  $\text{NO}_x$  differential measurement are used at times for the measurement of  $\text{NH}_3$ . 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  $\text{CO}_2$  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 Environmental Analysis**

<b>Coating</b>	<b>Analytes</b>
PEG	BTEX, Phenols, diesters and pesticides
Carbowax	BTEX
PDMS-PVA	Pesticides, PCB
PTMOS-MTMOS	Benzene, toluene, ethylbenzene, 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**

<b>Equipments used</b>	<b>Basic Principles</b>	<b>Example of uses</b>
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 $\text{CO}$ , $\text{SO}_4^{3-}$
Atomic Emission Spectrometer (AES)	Uses quantitative measurement of the optical emission 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 relative to a fluid under the influence of an electric field that is space uniformly.	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 electro-chemical 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 or alkalinity 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 ele-

ment 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 lends itself to NMR analyses to a wide range of samples, including waste water, ground water, etc. The ability to selectively resonate  $^{31}\text{P}$  coupled with excellent chemical shift resolution makes compound/contaminant identification by  $^{31}\text{P}$  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  $^{31}\text{P}$ , and analyze extracted soil samples contaminated with organophosphorus from chemical weapons. In combining  $^1\text{H}$  and  $^{31}\text{P}$  analyses into a series of two-dimensional analyses, the sensitivity of the  $^1\text{H}$  analyses and the resolution of the  $^{31}\text{P}$  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 2-250 $\mu\text{g}/\text{Kg}$  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 constitu-

ents 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-°C 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.)

#### 2.4.4 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 concentra-



tion 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 mis-managed; 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**

<b>Name of Analytical Instruments</b>	<b>Company</b>	<b>Price</b>
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	VARIAN INOVA	\$140,000.00
D500 XRD X-ray Diffractometer	Siemens Bruker	\$35,000.00
Phoenix 8000 TOC Analyzer	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](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](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)

## 2.5 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 devel-

oped 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 micro-electrodes 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 mostly 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.

## **2.6 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 direc-

tions 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.

## **2.7 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.

**Table 2.8 Drinking Water Quality Standards from U.S Environmental Protection Agency (EPA)**

<b>Contaminant</b>	<b>MCLG (mg/L)- maximum con- taminant level goal</b>	<b>MCL or TT (mg/L) maximum contami- nant level</b>	<b>Potential Health Effects from Ingestion of Water</b>	<b>Sources of Contaminant in Drinking Water</b>
Bromate	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 Cl <sub>2</sub> )	MRDLG 4 Maximum Residual Disinfectant Level Goal	MRDL4.0	Eye/nose irritation, stomach discomfort, anemia	Water additive used to control microbes
Chlorine (As Cl <sub>2</sub> )	MRDLG 4	MRDL 4.0	Eye/nose irritation, stomach discomfort	Water additive used to control microbes
Chlorine dioxide (ClO <sub>2</sub> )	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 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.govt.nz](http://www.mfe.govt.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/Nm<sup>3</sup> (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 300m<sup>3</sup>/min
- Qualitative monitoring and broken-bag detection in stacks with air flow greater than 50m<sup>3</sup>/min
- No monitoring in stacks with air flow below 50m<sup>3</sup>/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;

- BlmSchV 13: combustion plant > 50MW
- BlmSchV 17: incineration plant
- BlmSchV 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. TÜV) 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, 20<sup>th</sup> August 1991 (4)
- S.1.15 of 1991: Management of Hazardous and solid wastes official Gazette, Federal Republic of Nigeria, No 102, Vol. 78, 31<sup>st</sup> 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. Without 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.

## **2.8 General Overview of Nigeria's Industries and Environmental 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 km<sup>2</sup>, 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:



**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**

<b>City</b>	<b>Population</b>
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.

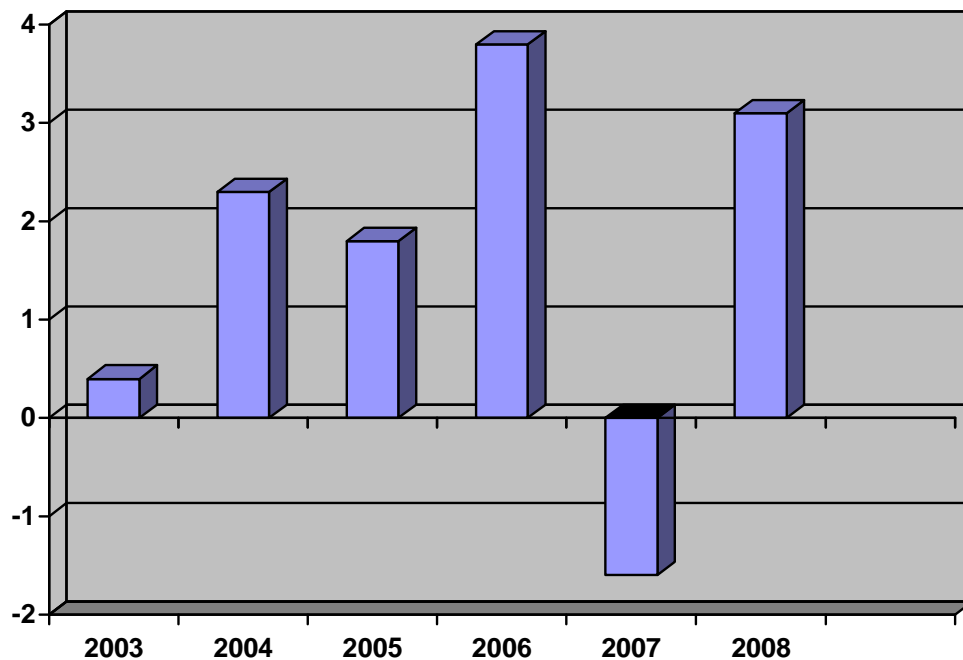
As mentioned above, Petroleum plays a large role in the Nigerian economy due to its large proven reserves. Nigeria is the largest oil producing country in Africa, the eleventh largest producer of crude oil in the world and sixth largest amongst the OPEC countries. In 2005 Oil and Gas journal ([www.mbendi.co.za](http://www.mbendi.co.za)) 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](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 and tertiary 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](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).

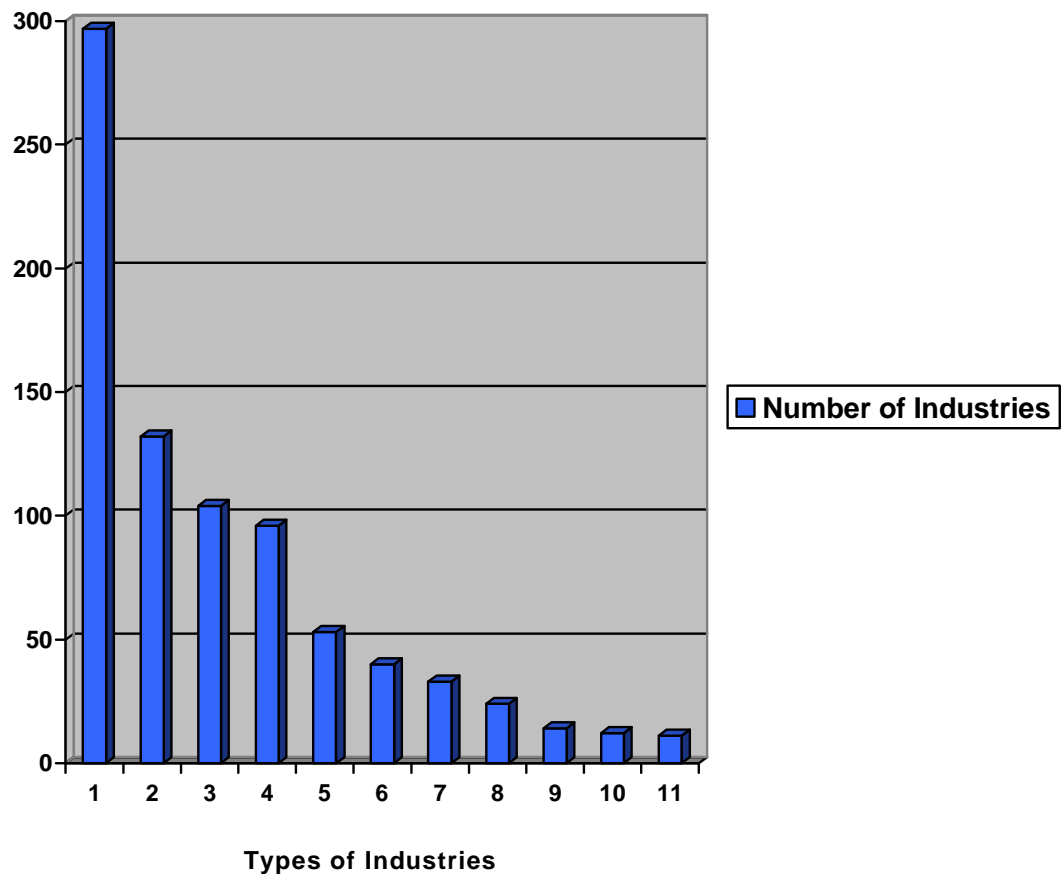


**Figure 2.11** Nigeria's Industrial Production Growth Rate in Percentage

(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.



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](http://www.mbendi.co.za))

Nigeria has always had industry planned 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 re-

cords 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 ( $\text{NO}_x$ ), carbon monoxides (CO), hydrogen sulfide ( $\text{H}_2\text{S}$ ), and sulfur dioxide ( $\text{SO}_2$ ). 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  $\text{NO}_x$  in sunlight to create  $\text{O}_3$  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  $\text{CO}_2$  in Nigeria, since  $\text{CO}_2$  is a main constituent of petroleum fuel exhaust. Methane and  $\text{NH}_3$  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**

<b>Petroleum &amp; petrochemicals</b>	<b>Textiles &amp; clothing</b>	<b>Mining, Cement &amp; Tanneries</b>	<b>Food &amp; Beverage</b>	<b>Chemicals</b>	<b>Others</b>
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, CO <sub>2</sub>	Sludge from processes treatment	Furans	Sulfides
Oil & Grease	Oil, greases	Suspended Solids		Herbicides	Smog
Cyanides	Metal e.g. Zinc, lead	Sulphides		Mercury	H <sub>2</sub> S
Heavy metals	Fibers & dust	Heavy metals		Lead	NH <sub>3</sub>
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.

## SECTION 2

# FIELD WORK, RESULTS AND DISCUSSION

## **Chapter 3 Results from Field Work in Nigeria**

Seven organizations were visited in Nigeria; they are Ashaka Cement Factory; NNPC (KRPC) Kaduna; National Reference Laboratory Lagos; Regional Monitoring Laboratory of Federal Ministry of Water Resources, Gombe; Federal Ministry of Environment, Housing and Urban Development; Standard Organization of Nigeria (SON); and National Environmental Standards and Regulations Enforcement Agency (NESREA) Abuja. From the seven organizations visited, four of them are laboratories two of which are industrial laboratories, one reference laboratory and one regional monitoring laboratory. All the seven organizations are directly involved with analytical instruments used in environmental pollution control in Nigeria, they will be introduced subsequently. The findings in each organization are going to be given under this chapter, after which the following chapter will discuss the results in general.

### **3.1 Nigerian National Petroleum Corporation (NNPC) Kaduna Now known as Kaduna Refining and Petrochemicals Corporation (KRPC)**

The Nigerian National Petroleum Corporation, NNPC, was established on April 1<sup>st</sup> 1977, under the statutory instrument Decree No 33. This decree established NNPC, a public organization that would, on behalf of government, adequately manage all government interests in the Nigerian oil industry. In addition to its exploration activities, the Corporation was given powers and operational interests in refining crude, petrochemicals and products transportation as well as marketing. Between 1978 and 1989, NNPC constructed refineries in Warri, Kaduna and Port Harcourt and took over the 35,000 barrel Shell Refinery established in Port Harcourt in 1965. In 1988, the NNPC was commercialized into 12 strategic business units, covering the entire spectrum of oil industry operations such as exploration and production, gas development, refining, distribution, petrochemicals, engineering, and commercial investment. This research was carried out in one of

the refineries of the NNPC, and that is the Kaduna refinery which later becomes Kaduna Refining and Petrochemicals Corporation (KRPC).

Kaduna Refining and Petrochemicals Corporation (KRPC) was commissioned in 1980 as NNPC Refinery Kaduna. Its initial capacity was 100,000 barrels per stream day (BPSD). As the third refinery in the country, it was established to cope with the growing demand for petroleum products, especially in the northern part of the country. The refinery was designed to process both Nigerian and imported crude oils into fuels and lubes products. In December 1988, the Linear Alkyl Benzene (LAB) petrochemical plant was commissioned, since then the NNPC Kaduna Refinery is known as KRPC. The petrochemical plant, being a downstream plant of the refinery, derives its entire raw materials including utility supplies from the refinery. The laboratory in the corporation serves both the refinery and the petrochemical units of the KRPC. There is also an environmental and pollution control unit under the fire and safety department, this unit monitor activities related to environmental pollution control.

In this company the first interview was carried out with the head of environmental and pollution control unit who holds a B.Sc in Chemical Engineering. According to him, they do insitu measurements of waste water of the industry at four points as follows:

- A) Before the waste water gets to the treatment tank
- B) In the treatment tank (Figure 3.1)
- C) Before the treated water leaves to receiving river i.e. at the point where the treated water goes out (Figure 3.2)
- D) In the receiving river at the point of entrance (The receiving rivers are River Kaduna and Romi River).

Pictures of two of these points are shown in Figure 3.1 and Figure 3.2. The waste water from the Refinery process plant is sent directly to the treatment tank, where physical treatment like taking off of scum on top is done and then treated further.



**Figure 3.1** Waste Water Treatment Tank of NNPC Kaduna

After the treatment plant, the treated waste water is pumped to a section where it leaves to the receiving river as shown in Figure 3.2. In between these two points are three different stages where the treatment is controlled before the treated water finally gets to the outlet.



**Figure 3.2** Outlet of Treated Waste Water to Receiving River

In the insitu test they used very basic analytical instruments such as dissolved oxygen (DO) meter given in Figure 3.3, PH meter incorporated with thermometer, conductivity meter given in Figure 3.4 and total dissolved solid meter given in Figure 3.5. Some results taken at these different treatment points are given in Table 3.1 and Table 3.2 below.





**Figure 3.3** Dissolved Oxygen (DO) Meter) from NNPC Kaduna



**Figure 3.4** PH Meter from NNPC Kaduna (KRPC)

**Table 3.1 Result Obtained from NNPC (KRPC) Kaduna Environmental Pollution Control in 2007**

<b>Date Results Taken: 10:08 2007</b>			
<b>Points</b>	<b>PH</b>	<b>Conductivity</b>	<b>Temperature</b>
A	7.48	28.7	29.4
B	7.51	32.5	30.2
C	7.40	31.2	30.1
D	7.17	34.5	27.8
<b>Date Result Taken: 13:08 2007</b>			
A	7.36	16.80	27.9
B	7.37	16.84	27.6
C	7.26	19.10	28.1
D	6.76	31.70	29.7
<b>Date Result Taken: 15.08. 2007</b>			
A	7.62	19.38	28.70
B	6.07	39.40	29.20
C	7.22	40.20	28.60
D	6.95	34.20	26.20
<b>Date Result Taken: 116.08 2007</b>			
A	7.32	18.90	28.20
B	7.16	43.40	31.70
C	7.33	40.70	31.10
D	7.20	35.50	28.10



**Figure 3.5** Total Dissolved Solid Meter NNPC Kaduna



**Table 3.2 Results Obtained from NNPC (KRPC) Kaduna Environmental Pollution Control in 2008**

<b>Date Results taken: 12:08 2008</b>			
<b>Points</b>	<b>PH</b>	<b>Conductivity</b>	<b>Temperature</b>
A	8.13	1.00	29.10
B	7.97	0.76	38.40
C	7.72	1.22	35.90
D	7.28	2.00	33.30
<b>Date Result taken: 13:08 2008</b>			
A	8.10	0.80	27.20
B	7.80	0.60	36.20
C	7.62	1.10	35.70
D	7.16	1.72	33.00
<b>Date Result taken: 14.08. 2008</b>			
A	10.96	1.80	31.60
B	10.88	1.26	35.50
C	11.08	1.36	34.50
D	7.82	1.82	34.40
<b>Date Result taken: 15.08 2008</b>			
A	7.64	1.21	30.30
B	7.65	0.86	36.6
C	7.44	1.20	34.70
D	-	-	-

A = Waste water before its get to treatment tank

B = Waste water in treatment tank

C = Treated water before its leaves to receiving river

D = Treated water at the point of entrance into the receiving river

The next unit visited in NNPC Kaduna (KRPC) was the chemical laboratory. Here they do general control of the process, products and the environmental pollution. They have water laboratory, oil laboratory and general laboratory. The water laboratory is where environmental pollution control is mostly carried out; they monitor the waste water, treated waste water and the receiving river. Interview was granted here by the head of the laboratory who is a chemist, subsection head of the water lab who is a laboratory

technologist and another staff who is also a laboratory technologist. Some instruments in the water laboratory include PH meter shown in Figure 3.6, also used as chemical oxygen demand (COD) meter/turbidity meter and double beam spectrometer shown in Figure 3.7.



**Figure 3.6** Conductivity/ COD/ PH Meter from NNPC Kaduna Chemical Laboratory

**Table 3.3 NNPC Kaduna Month End Analysis Report- November 2008**

Parameters Analyzed	Kaduna River		Romi River			Refinery Effluent	
	Design Spec	Results	Design Spec	Up	Down	Design Spec	Results
In ppm or mg/l except stated							
PH	7.0-7.3	7.61	7-7.5	6.86	7.00	7-8.5	7.61
Conductivity (µs)	13-105	89.90	220-370	71.60	230.10		89.9
Total solids	38-3328	281.81	200-350	295.10	208.11		281.81
Suspended solids	18-3000	57.34	20-50	130.16	38.99	10.0mg/l	57.34
Turbidity (NTU)	20-3000	15.96	20-50	19.26	40.95	50.0	15.96
Alkanity M	20-62	44.00	62	40.00	42.00		44.00
Total Iron	0.02-5.5	ND	1.0	ND	ND	0.3mg/l	ND
Total Hardness	12-38	26.00	38	22.00	30.00	500 mg/l	26.00
Ca Hardness		16.00		16.00	20.00		16.00
Chloride	0.2-24.8	21.7	27.8	18.80	26.3		22.3
Silica (SiO <sub>2</sub> )	0.8-9.3	12.49	1.7				12.49
Sulphate		7.00	3.0	25.00	52.00	200mg/l	7.00
Phosphate		7.44		8.44	17.60		7.44
B.O.D.(5days)		92.80		76.50	103.40	25 mg/l	220.00
C.O.D		170.00	38.40	96.80	113.00	60.0 mg/l	170.00
Dissolved Oxygen		7.20		7.50	6.50	Nil	7.10
Total dissolve solids	70-326	224.47	350	164.94	169.22	2000 mg/l	224.47
Oil		ND		ND	ND	0.3 mg/l	ND
Hydrocarbons		ND		ND	ND	0.1 mg/l	ND
Phenols		ND		ND	ND		ND
Nitrate		0.30		0.04	1.00		0.30
Ammonia-N (mg/l)	1.0 as N	0.22		0.20	0.52	1.0	ND
Sulphide (H <sub>2</sub> S) (mg/l)	0.2	0.01		0.01	0.04	0.2	ND
Zinc (mg/l)	5.0	ND		ND	ND	5.0	ND
Lead (mg/l)	0.05	ND		ND	ND	0.05	ND
Arsenic (mg/l)		ND		ND	ND	0.05	ND
Cyanide (mg/l)	0.05	ND		ND	ND	0.05	ND
Cadmium (mg/l)		ND		ND	ND	0.05	ND
Boron (mg/l)		ND		ND	ND	0.05	ND
Selenium (mg/l)		ND		ND	ND	0.01	ND
Mercury (mg/l)		ND		ND	ND	0.000	ND
Temperature (°C)	36	28.8		25.6	28.1	36	28.3
Hexa Chromium	0.03	ND		ND	ND	0.03	ND

ND = Not Determined due to lack of equipment (instrument) and also faulty equipment (instruments)

There was a gas chromatography in the oil laboratory which was not in used as of the time of interview. In the water laboratory, they normally carry out a comprehensive month end analysis of the refinery effluent and water

from the receiving rivers, an example of such test result is given in Table 3.3. above.



**Figure 3.7** Double Beam Spectrometer from NNPC Kaduna Chemical Laboratory

## **3.2 Ashaka Cement Factory**

Ashaka Cement Factory is located in Funakaye Local Government Authority of Gombe State Nigeria. The factory was officially opened by the Chief of Staff Supreme Headquarters, Major General Shehu Musa Yar'Addua on Thursday 19<sup>th</sup> Feb 1979. Ashaka Cement is the largest cement producer in northern Nigeria; it is able to produce 850,000.00 tons of cement a year. This company is now a subsidiary of Lafarge Company. In this factory interview was carried out in the chemical laboratory. The head of the laboratory, who is a chemist, asked one of the laboratory subhead, who himself is



also a chemist to grant the required interview. The laboratory carries out mainly quality control of their products. Responding to the question, where they do their environmental control test, he said there is an environmental control subunit and the head of this subunit was not at the moment available for interview during all the days of visit, and efforts to get in touch with him failed.

Equipments seen in the chemical laboratory are X-ray machine, IR spectrophotometer as shown in Figure 3.8, viscosity meter, rapid moisture analyzer, fusion machine, and an X-ray fluorescence (XRF) spectroscopy are shown in Figure 3.9, and other small instruments for preparations of samples. They carry out mainly inorganic salts and elemental analysis for quality control of their cement.



**Figure 3.8** IR Spectrophotometer from Ashaka Cement Factory



Some of the inorganic salts analyzed could be of interest in terms of water quality and soil quality control. Examples of inorganic salts they analyzed are:  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{SO}_3$ ,  $\text{CaCO}_3$ , etc. These analyses are carried out mainly using their XRF machine. Some results from the XRF were collected during this research, but since they are not directly environmental pollution control analyses they are not shown here, but may be used for discussions. According to the head of the subunit, they carry out air pollution analysis only incase of accident and they give out major environmental pollution analysis to external laboratories.



**Figure 3.9** X-Ray Fluorescence (XRF) Spectroscopy from Ashaka Cement Factory

### 3.3 Regional Laboratory of the Federal Ministry of Water Resources Gombe

The regional laboratory in Gombe is one of the four regional laboratories established by the Federal Ministry of Water Resources. The aim is for these laboratories to monitor pollution in these regions of the country, pollutions due to human and industrial activities. They are also to carry out quality control in the regions, for example, is a source of water to be used for sinking a bohlo for drinking fit for such purpose? Gombe regional laboratory is responsible for monitoring pollution in about eleven states. One outstanding industry in this region is Savannah Sugar Company, which produced a lot of effluent which need to be treated before disposing into any water body; the regional laboratory monitors their effluent periodically.



**Figure 3.10** HACH Colorimeter DR/890 from Gombe Regional Laboratory

The Gombe Regional Laboratory has six staff members, including a chemist, a microbiologist and others are technical assistances. The laboratory is headed by the chemist, who granted the required interview in regard to the laboratory's analytical instruments.

**Table 3.4 Water Quality Analytical Results from Gombe Regional Laboratory. Date of Analysis: 29.06.2008**

S/ NO	Parameter	Unit	Method used	Result	Nigeria NSDWQ Guided level	Re- marks
1	Appearance	-	Visual	Clear	Un-Obj	O.K
2	Color	Pt-co	Color Filtration	0.0	15.0	O.K
3	Odor	NT	Sensory Organs	Un-Obj	Un-Obj	O.K
4	Taste	-	Sensory Organs	Un-Obj	Un-Obj	O.K
5	Temperature	O <sup>c</sup>	Thermometer	29.8	Ambient	O.K
6	PH-Value	PH	PH Meter	7.35	6.5 -8.5	O.K
7	Conductivity	µS/cm	Conductivity meter	180	1000	O.K
8	Turbidity	NTU	Turbidity meter	11.29	5.0	Not O.K
9	TDS	Mg/l	Conductivity meter	90.0	500	O.K
10	DO	Mg/l	DO Meter	4.36	7.0	O.K
11	Chlorine (Free)	Mg/l	DPD Method	-	0.25	-
12	Chloride	Mg/l	DPD Method	-	250	-
13	Nitrate (NO <sub>3</sub> )	Mg/l	Nitra Ver 5 RPP	22.3	50	O.K
14	Nitrite (NO <sub>2</sub> )	Mg/l	Nitri Ver 2 RPP	-	0.2	-
15	Sulfate (SO <sub>4</sub> )	Mg/l	Sulfa Ver 4 RPP	33.0	100	O.K
16	Phosphate(PO <sub>4</sub> )	Mg/l	Phos Ver 3 RPP	0.25	5.0	O.K
17	Fluoride	Mg/l	Spands method	0.125	1.5	O.K
18	Hardness (CaCO <sub>3</sub> )	Mg/l	Calmagite	-	150	-
19	Aluminum	Mg/l	Ascorbic acid	0.02	0.2	O.K
20	Iron (Total)	Mg/l	Ferro Mo/DR890	0.01	0.3	O.K
21	Copper (Cu <sup>2+</sup> )	Mg/l	-	-	1.0	-
22	Manganese (Mn <sup>2+</sup> )	Mg/l	Oxidation	0.019	0.2	O.K
23	Arsenic	Mg/l	Comparison	-	0.01	-
24	Total Coli Form	Cfu/100 ml	Membrane filtration	0.0	0/100ml	O.K
25	E.Coli		Membrane filtration	0.0	0/100ml	O.K

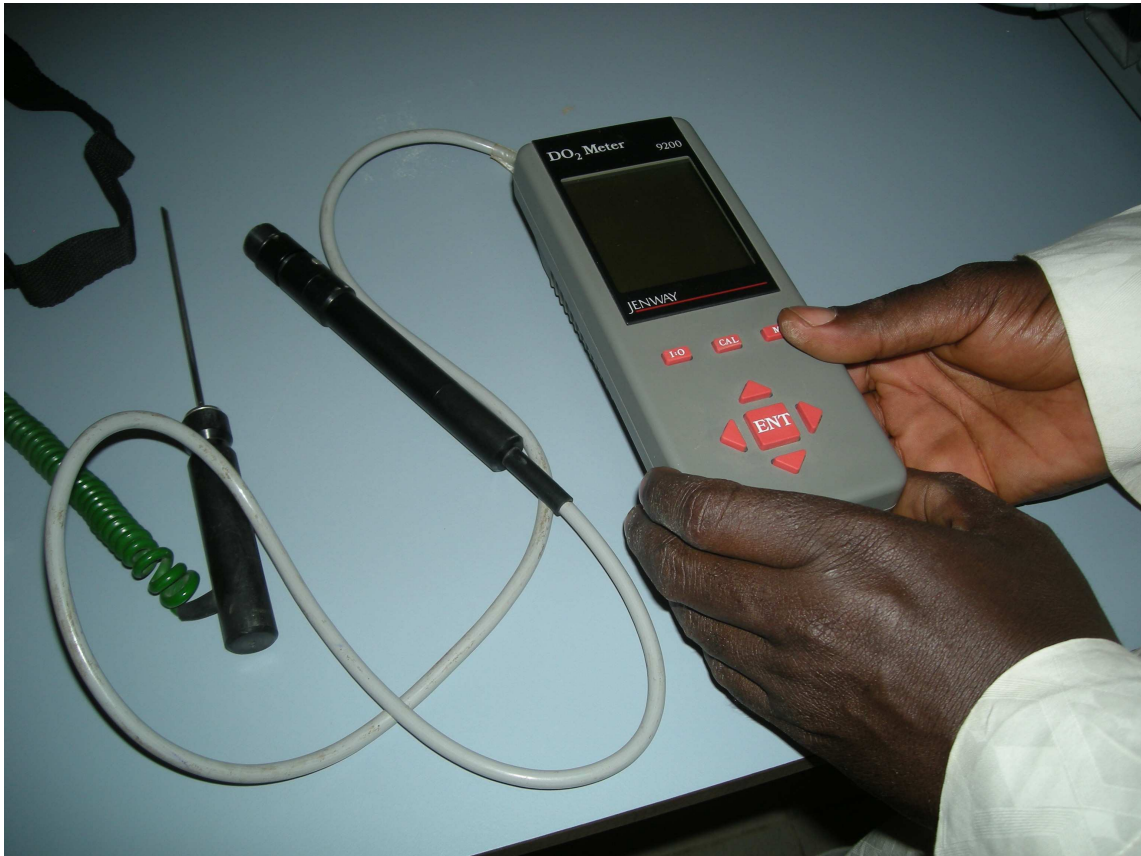
Sample: Borehole water from Gombe



**Figure 3.11** Electrical Conductivity Meter from Gombe Regional Laboratory

The analytical instruments found in this laboratory include the following: HACH colorimeter DR890 shown in Figure 3.10, according to the head of the laboratory this is use for many tests such as testing for AL, B, Br, Cl, Cr, COD, PH, etc, it is also use to measure a lot of inorganic salts. They have other instruments such as conductivity meter shown in Figure 3.11, dissolved oxygen meter shown in Figure 3.12 and COD reactor shown in Figure 3.13, BOD reactor given in Figure 3.14, and also flame photometer shown in Figure 4.15, UV 500 shown in Figure 3.16, and total organic carbon analyzer shown in Figure 3.17.





**Figure 3.12** Dissolved Oxygen Meter from Gombe Regional Laboratory

At the end of the research work in this laboratory some analytical results were taken and they are given here in Table 3.4 to Table 3.7. The results will be used to analyze the quality of the laboratory's analytical instruments.



**Figure 3.13** Chemical Oxygen Reactors from Gombe Regional Laboratory



**Figure 3.14** Biochemical Oxygen Demand (BOD) Reactors from Gombe Regional Laboratory



**Figure 3.15** Flame Photometer from Gombe Regional Laboratory



**Figure 3.16** UV 500 from Gombe Regional Laboratory

**Table 3.5 Water Quality Analytical Results from Gombe Regional  
Laboratory Date of Analysis: 15.07.2008**

S/NO	PARAMETER	UNIT	METHOD USED	Result	NIGERIAN (NSDWQ) GUIDED LEVEL	REMARKS
1	Appearance	-	Visual	Clear	Un-Obj	O.K
2	Color	Pt-co	Color Filtration	30.0	15.0	Not O.K
3	Odor	NT	Sensory Organs	Un-Obj	Un-Obj	O.K
4	Taste	-	Sensory Organs	Un-Obj	Un-Obj	O.K
5	Temperature	O <sup>c</sup>	Thermometer	28.8	Ambient	O.K
6	PH-Value	PH	PH Meter	6.65	6.5 -8.5	O.K
7	Conductivity	µS/cm	Conductivity meter	440	1000	O.K
8	Turbidity	NTU	Turbidity meter	13.70	5.0	Not O.K
9	TDS	Mg/l	Conductivity meter	220	500	O.K
10	DO	Mg/l	DO Meter	0.85	7.0	O.K
11	Chlorine (Free)	Mg/l	DPD Method	-	0.25	-
12	Chloride	Mg/l	DPD Method	-	250	-
13	Nitrate (NO <sub>3</sub> )	Mg/l	Nitra Ver 5 RPP	24.30	50	O.K
14	Nitrite (NO <sub>2</sub> )	Mg/l	Nitri Ver 2 RPP	-	0.2	-
15	Sulfate (SO <sub>4</sub> )	Mg/l	Sulfa Ver 4 RPP	15.0	100	O.K
16	Phosphate (PO <sub>4</sub> )	Mg/l	Phos Ver 3 RPP	0.46	5.0	O.K
17	Fluoride	Mg/l	Spands method	0.19	1.5	O.K
18	Hardness (CaCO <sub>3</sub> )	Mg/l	Calmagite	-	150	-
19	Aluminum	Mg/l	Ascorbic acid	0.02	0.2	O.K
20	Iron (Total)	Mg/l	Ferro Mo/DR890	0.82	0.3	Not O.K
21	Copper (Cu <sup>2+</sup> )	Mg/l	-	-	1.0	-
22	Manganese (Mn <sup>2+</sup> )	Mg/l	Oxidation	0.13	0.2	O.K
23	Arsenic	Mg/l	Comparison	-	0.01	-
24	Total Coli Form	Cfu/100ml	Membrane filtration	0.0	0/100ml	O.K
25	E.Coli		Membrane filtration	0.0	0/100ml	O.K

Sample: Borehole Water from Gombe



**Table 3.6 Water Quality Analytical Results from Gombe Regional  
Laboratory Date of Analysis: 06.08.2008**

S/NO	PARAMETER	UNIT	METHOD USED	Result	NIGERIAN (NSDWQ) GUIDED LEVEL	REMARKS
1	Appearance	-	Visual	brown	Un-Obj	Not O.K
2	Color	Pt-co	Color Filtration	10.0	15.0	Not O.K
3	Odor	NT	Sensory Organs	-	Un-Obj	Not O.K
4	Taste	-	Sensory Organs	S.Salty	Un-Obj	Not O.K
5	Temperature	O <sup>c</sup>	Thermometer	26.8	Ambient	O.K
6	PH-Value	PH	PH Meter	6.77	6.5 -8.5	O.K
7	Conductivity	µS/cm	Conductivity meter	7680	1000	Not O.K
8	Turbidity	NTU	Turbidity meter	412.85	5.0	Not O.K
9	TDS	Mg/l	Conductivity meter	3930	500	Not O.K
10	DO	Mg/l	DO Meter	0.12	7.0	O.K
11	Chlorine (Free)	Mg/l	DPD Method	-	0.25	-
12	Chloride	Mg/l	DPD Method	-	250	-
13	Nitrate (NO <sub>3</sub> )	Mg/l	Nitra Ver 5 RPP	24.3	50	O.K
14	Nitrite (NO <sub>2</sub> )	Mg/l	Nitri Ver 2 RPP	-	0.2	-
15	Sulfate (SO <sub>4</sub> )	Mg/l	Sulfa Ver 4 RPP	80	100	O.K
16	Phosphate (PO <sub>4</sub> )	Mg/l	Phos Ver 3 RPP	0.11	5.0	O.K
17	Fluoride	Mg/l	Spands method	1.26	1.5	O.K
18	Hardness (CaCO <sub>3</sub> )	Mg/l	Calmagite	-	150	-
19	Aluminum	Mg/l	Ascorbic acid		0.2	
20	Iron (Total)	Mg/l	Ferro Mo/DR890		0.3	
21	Copper (Cu <sup>2+</sup> )	Mg/l	-	-	1.0	-
22	Manganese (Mn <sup>2+</sup> )	Mg/l	Oxidation	0.004	0.2	O.K
23	Arsenic	Mg/l	Comparison	-	0.01	-
24	Total Coli Form	Cfu/100ml	Membrane filtration	0.0	0/100ml	O.K
25	E.Coli		Membrane filtration	0.0	0/100ml	O.K

Sample: Borehole water from Gombe

**Table 3.7 Water Quality Analytical Results from Gombe Regional Laboratory Date of Analysis 02.12.2008**

S/NO	PARAMETER	UNIT	METHOD USED	Result	NIGERIAN (NSDWQ) GUIDED LEVEL	REMARKS
1	Appearance	-	Visual	Clear	Un-Obj	O.K
2	Color	Pt-co	Color Filtration	90.0	15.0	Not O.K
3	Odor	NT	Sensory Organs	Un-Obj	Un-Obj	O.K
4	Taste	-	Sensory Organs	Slightly salty	Un-Obj	Not O.K
5	Temperature	O <sup>c</sup>	Thermometer	29.0	Ambient	O.K
6	PH-Value	PH	PH Meter	6.77	6.5 -8.5	O.K
7	Conductivity	µS/cm	Conductivity meter	680	1000	O.K
8	Turbidity	NTU	Turbidity meter	57.3	5.0	Not O.K
9	TDS	Mg/l	Conductivity meter	340	500	O.K
10	DO	Mg/l	DO Meter	3.40	7.0	O.K
11	Chlorine (Free)	Mg/l	DPD Method	-	0.25	-
12	Chloride	Mg/l	DPD Method	-	250	-
13	Nitrate (NO <sub>3</sub> )	Mg/l	Nitra Ver 5 RPP	7.40	50	O.K
14	Nitrite (NO <sub>2</sub> )	Mg/l	Nitri Ver 2 RPP	1.68	0.2	-
15	Sulfate (SO <sub>4</sub> )	Mg/l	Sulfa Ver 4 RPP	47.0	100	O.K
16	Phosphate (PO <sub>4</sub> )	Mg/l	Phos Ver 3 RPP	0.16	5.0	O.K
17	Fluoride	Mg/l	Spands method	0.25	1.5	O.K
18	Hardness(CaCO <sub>3</sub> )	Mg/l	Calmagite	2.40	150	O.K
19	Iron (Total)	Mg/l	Ferro Mo/DR890	0.05	0.3	O.K
20	Copper (Cu <sup>2+</sup> )	Mg/l	-	-	1.0	-
21	Manganese (Mn <sup>2+</sup> )	Mg/l	Oxidation	0.008	0.2	O.K
22	Arsenic	Mg/l	Comparison	-	0.01	-
23	Total Coli Form	Cfu/100ml	Membrane filtration	0.0	0/100ml	O.K
24	E.Coli		Membrane filtration	0.0	0/100ml	O.K

Sample: Borehole water from Gombe



**Figure 3.17** Total Organic Carbon Analyzer (TOC) from Gombe Regional Laboratory

### **3.4 National Reference Laboratory Lagos**

In this laboratory, discussion was held with the head of the laboratory who is a chemist. Since the laboratory was not functional the workers have been dispersed into other branches of the ministry for environment and so no information about the number and qualification of the workers were obtained. The functions of this laboratory amongst many are to verify compliance with regulatory requirements, to perform monitoring and surveillance studies, check imported chemicals, confirm industries claim to pollution treatment such as cleaning up of oil spillage on impacted sites, etc.

The laboratory is divided into different sections as follows: Gas laboratory, microbiology laboratory, wet analytical laboratory, soil laboratory and instrumentation laboratory. The major analytical instruments in this laboratory are HPLC, GC, AAS, flame photometer, FIR, etc. They have other commonly needed instruments such as COD reactor, conductivity meter, PH meter, turbidity meter, etc. The laboratory was under the then Federal Environmental Protection Agency (FEPA), after the establishment of NESREA, FEPA does no longer exist, and hence its activities were handed over to NESREA. Since NESREA took over this reference laboratory the instruments have not been set up due to Government bureaucracy. As such this research could not proceed further in this laboratory.

### **3.5 National Environmental Standards and Regulations Enforcement Agency (NESREA) Nigeria**

The National Environmental Standards and Regulations Enforcement Agency (NESREA) was established in 2007. It is an agency of the Ministry of Environment Housing and Urban Development, of the Federal Government of Nigeria and is charged with the responsibility of enforcing environmental laws, regulations and standards with the aim of deterring people, industries and organizations from polluting and degrading the environment. NESREA coordinate and liaise with relevant stakeholders within and outside Nigeria on matters of enforcement of environmental standards, regulations, rules, laws, policies and guidelines. The Act establishing NESREA was signed into law by President Umaru Musa Yar'Adua, GCFR, and this has been published in the Federal Republic of Nigeria Official Gazette No. 92, Vol. 94 of 31st July, 2007. After the establishment of NESREA it was asked to take over the assignment of the former Federal Environmental Protection Agency (FEPA).

In this organization discussion was held with the Head of Laboratories. According to him the organization is structured into one service department

and three technical departments. The departments are Administration & Finance, Planning & Policy Analysis, Inspection & Enforcement, and finally Environmental Quality Control. The unit Laboratory Services which deal with standard and monitoring are directly under the office of the Director General. According to him there are three national reference laboratories which are located in Lagos, Kano and Photo Harcourt, amongst these three only the one in Lagos took up and was functional, the other two never came up. But even the functional one in Lagos, since NESREA took over the laboratories from FEPA it has not been operating due to technical problems. So NESREA has not been able to restore the Lagos laboratory and put the other ones to function, since they have been dormant under FEPA for some time before NESREA took over. At as the time of interview NESREA has put down regulations including standards for monitoring, but they have not yet been approved as working documents, therefore it was not possible to have access to it. The standards being used are those from Ministry of Environment namely, National Environmental Guidelines and Standards for Environmental pollution Control in Nigeria, National Environmental Protection (Effluent Limitation) Regulations 1991 S.I. 8, and National Environmental Protection (Pollution Abatement in Industries and Facilities Generating Wastes) Regulations 1991 S. I. 9. These standards and regulations were obtained and will be used in the following chapter for discussing the findings in the field.

### **3.6 Federal Ministry of Environment Housing and Urban Development**

The Federal Environmental Protection Agency (FEPA) was established in 1988 through Decree 58. In 1999, FEPA and other relevant Departments in other Ministries were merged to form the Federal Ministry of Environment. The responsibilities of the Federal Ministry of Environment, Housing and Urban Development amongst others are:

- The monitoring and enforcement of environmental quality standards and regulations
- The regular assessment of environmental conditions and trends in rural areas and identification of programs and actions needed to reduce or avoid further environmental degradation and pollution
- The application of the national environmental assessment guidelines and procedures for all development policies and projects likely to have adverse environmental impacts within state and local governments
- The development of contingency plans and capabilities to respond quickly and effectively to environmental emergencies
- The collection, analysis and distribution of data of relevance to environmental impact assessments, policy analysis and environmental monitoring within the State and Local governments
- The preparation of periodic public reports on the state of the environment.

In this ministry interview was granted by a head of Environmental Auditing. In his words, the ministry works to see that all arms involved in environmental protection and control do their parts. Most of the environmental-related laws, regulations and standards are either directly made by the ministry or made under its supervision. Some laws, regulations and standards were collected from the ministry which will be used to analyze the activities of the laboratories visited and their results. Environmental problems such as violation of limits, discharge of waste in an inappropriate way and place, etc are monitored by the ministry. According to the officer, the ministry carries out periodic monitoring of compliance with limits of pollutants in treated

wastes. It was clear during this interview that the laboratories play very important roles in environmental law enforcement, such as inspectors from the ministry in charge of drinking water quality surveillance shall conduct regular verification of water quality tests and sanitary inspections to determine whether water utilities owners meet standard for drinking water quality. To do this tests effectively they need good quality laboratories, which in the case of water, the regional laboratories are to fulfill this function.

### **3.7 Standard Organization of Nigeria (SON)**

SON was established by Act No 56 of 1971 and amended three times in 1976, 1984 and in 1990. It relates closely with some International standard organizations e.g. British Standard Organization (BIS) and it is a member of ISO. The organization has the sole responsibility of national policy on standards, standards specification, quality control and metrology. The functions of SON include:

- To investigate the quality of facilities, materials and products in Nigeria, and establish a quality assurance system, including certification of factories, products and laboratories
- To control analytical laboratories in the country, in terms of personnel and analytical instruments and grant accreditation to laboratories that deserve it and to make sure only accredited laboratories are allowed to carry out analysis of any sort
- To ensure reference standards for calibration and verification of measures and measuring instruments
- To develop methods for testing materials, supplies and equipment, including items purchased for use by state and federal departments and private establishments

- To undertake preparation and distribution of standard samples
- To establish and maintain laboratories or other institutions, as may be necessary for the performance of its functions.

The organization is divided into eight directorates as follows: Standards; Quality Assurance; Laboratory Services; Planning, Research & Information; Management Systems; Technical Services; Finance and Supply; Human Resources. Interview was granted in this organization by the laboratory services directorate. In the area of environmental pollution control, SON works closely with state laboratories involved in environmental pollution control. These laboratories are trained by SON using ISO 14001 (Environmental Management Systems 2004) and their laboratories are certified when they demonstrate compliance with standards for analysis in Air quality, water quality and soil quality control. According to SON, most of the laboratories feel discouraged because they feel the standard laboratory instruments are expensive. So far SON has been using standards developed by FEPA and they have developed some case specific standards for different purposes, some samples have been obtained and will be used in the analysis of the laboratory results collected during this research. An example of this is the limits for effluents given in Table 3.8 below, these limits are general for all categories of industries. This gives the idea of what types of pollutants the industries are expected by SON to monitor and to ensure compliance with the limit. Other limits are then added for specific industries, depending on what types of pollutants the industry discharges. It will be later shown in the following chapter how most of these pollutants are not tested for in the research laboratories, even where tested some exceed these limits.



**Table 3.8 Nigerian Effluent Limits for Discharged into Water**  
(in Mg/l unless otherwise stated)

Pollutants	Petroleum Refinery	All categories of industries	Limit for land application
PH (PH unit )	6.5-8.5	6-9	6-9
BOD <sub>5</sub> at 20°C	10	50	500
Total Suspended Solids	30	30	-
Total Dissolved Solids		2,000	2,000
Chloride as Cl <sup>-</sup>		600	600
Sulphate as SO <sub>4</sub> <sup>2-</sup>	(Sulphides) 0.2	500	1,000
Cyanide as CN <sup>-</sup>	<0.01	0.1	-
Oil and grease	10	10	30
Nitrate as NO <sub>3</sub> <sup>-</sup>	(NH <sub>3</sub> ) 0.210	20	-
Phosphate as PO <sub>4</sub> <sup>3-</sup>		5	10
Arsenic as As		0.1	-
Barium as Ba		5	5
Tin as Sn		10	10
Iron as Fe		20	-
Manganese as Mn		5	-
Phenolic compounds	0.5	0.2	-
Chlorine as free		1.0	-
Cadmium, Cd	<0.01	<1	-
Chromium	0.3 (Chromium IV<0.1)	<1	-
Copper		<1	-
Lead	0.05	<1	-
Mercury		0.05	-
Nickel		<1	-
Selenium		<1	-
Silver		0.1	-
Zinc		<1	-
Total metals		3	-
Calcium as Ca <sup>2+</sup>		200	-
Magnesium as Mg <sup>2+</sup>		200	-
Boron		5	5
PCBs		0.003	0.003
Pesticides Total		<0.01	<0.01
VOCs		0.6	-

## **Chapter 4 Discussion of Research Results**

### **4.1 The State of the Analytical Instruments in the Research Laboratories**

#### **4.1.1 Availability of the Instruments**

In the laboratories visited, the common analytical instruments found there are the basic ones like pH meter, conductivity meter, total solid meter, dissolved solid meter, turbidity meter, etc. Some few of these instruments are fairly advanced ones; example is the HACH DR/890 which is one of HACH company's well advertised colorimeter. There were few standard instruments found in some laboratories, example are spectrophotometer, gas chromatography, flame photometer, etc. These analytical instruments if well maintained and operated can be of immense help in environmental analysis. A critical component of environmental monitoring is the type of analytical instruments used to analyze samples. Normally the choice of these analytical instruments is dictated by the environment monitored, the parameters of interest and the data quality requirements. And one must select a scientifically sound method, approved by a regulatory agency, for example the Nigerian Federal Ministry for Environment. The laboratories visited just use instruments that are available and not so much dictated by the regulatory agency nor the environment or parameters to be monitored as can be seen from what are obtained in these laboratories. This is an unfortunate situation because analytical measurements are the foundation for determining pollutants and their effects in the environment and to ultimately formulate appropriate risk management policies and laws.

**Table 4.1 Summary of Analytical Instruments Found in the Research Laboratories**

<b>NNPC (KRPC) Kaduna</b>	<b>Ashaka Cement Factory</b>	<b>Regional Laboratory Gombe</b>	<b>National Reference Laboratory Lagos</b>
DO Meter	IR Spectrophotometer	Thermometer	HPLC
PH Meter	X-Ray Fluorescence (XRF)	PH Meter	GC
TDS Meter	viscosity meter,	Conductivity Meter	AAS
Conductivity/COD/PH Meter	rapid moisture analyzer,	Turbidity Meter	Flame photometer
Double Beam Spectrometer	fusion machine	DO Meter	FIR
GC		DR890 Colorimeter	COD reactor
		UV	Conductivity Meter
		Flame Photometer	PH Meter
		BOD Reactor	Turbidity Meter
		COD Reactor	

In chapter two of this dissertation, some common pollution caused by industries in Nigeria were enumerated, such as: oil spill, trace minerals, BTEX compounds, PM, VOCs, sulfides, ammonia and suspended solids, OM, PHA, PCB and dioxins. Some of these pollutants can be very hazardous to human health and need sharp control by laboratories. Also in chapter 2, particularly 2.4.3, analytical methods used for environmental pollution control were enumerated and their applications. Some air pollutants like SO<sub>2</sub> is typically measured using UV absorption, UV fluorescence or IR ab-

sorption spectrophotometer. Carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>) are usually measured using IR which uses a combination of NDIR and GFC measurement techniques, catalytic sensor is another gas detection technique used in continuous emission monitoring, chemiluminescent analyzers are used at times for the measurement of NH<sub>3</sub>. GC/MS is used to analyze samples containing unknown volatile and semi-volatile organic compounds, PCBs, etc. There are some portable GC used in many laboratories for characterization of VOCs, PAHs, and PCB, GC/MS is also used for the water analysis. NMR is used in a wide range of samples including waste water, ground water, etc. In the light of the types of pollutions produced by industries in Nigeria and the types of instruments available for environmental pollution control given in chapter 2, one expects to find many of these types of instruments in the research laboratories. Oil company like NNPC in particular should have most of these instruments if not all, but they did not have even a working GC. An instrument like NMR that is used for a lot of measurements was expected in at least the reference laboratory, but none of the research laboratories have this.

Generally the research laboratories lack most of the classical analytical instruments as enumerated early in the theoretical part of this work, talk less of the high technology instruments discussed in chapter 2.5. The gap between the analytical instruments given in the theory and what was found in the research laboratories is big. This can be seen when one compares Table 4.1 above which contains the analytical instruments found in the research laboratories with Table 4.2 which contains appropriate analytical instruments for the pollutants found in Nigeria, the gap is big. Figure 4.1 is a comparison of these analytical instruments in the theoretical part of this work and the ones available in the research laboratories. From this figure the gap can be seen more clearly and shows there is a big room for improvement. With such serious lack of analytical instruments, the monitoring of pollutants by these laboratories can not be done efficiently. Some of the pollutants enumerated early need very good analytical instruments to control them, because when dealing with certain types of pollutants like BTEX,

dioxins, etc, the best means available need to be used to obtain accurate and reliable measurements.

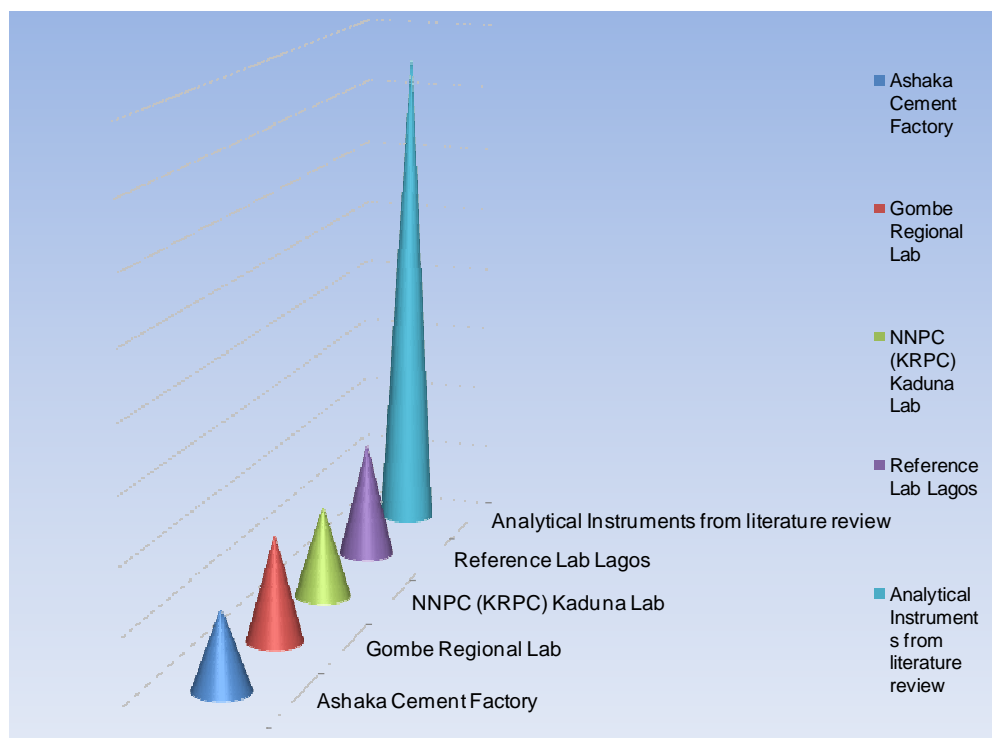
The lack of instruments mentioned above can be supported by the results collected from these laboratories. In the Regional Laboratory Gombe the results shown in Table 3.4 to 3.7 were taken using only a few from the available instruments, such as PH meter, conductivity meter, turbidity meter, DO meter and DR890. This could mean some of the few analytical instruments seen in the laboratory are not functional or are not yet put in use due to one reason or the other. In NNPC chemical laboratory, the results given in Table 3.3 showed many tests were not done because the needed instruments were not available or not in use. In front of many tests is given ND, according to the chemist in the laboratory this means “not determined” due to lack of equipment (instruments) and also faulty equipment. Pollutants like oil, hydrocarbons, phenols, zinc, lead, arsenic, cyanide, cadmium, mercury, etc are not determined in the results collected for lack of instruments. That means the treated wastewater is discharged into the receiving river regardless of how much of these pollutants are found inside. Some of these pollutants not tested in NNPC Kaduna treated wastewater before its being discharged into River Romi are hazardous and should be determined to make sure it does not exceed allowed limits.

In the Nigerian Guidelines and Standards for Environmental Pollution Control, some significant wastewater parameters for some selected industries are given. These parameters are mandatory to be tested to show that it has not exceeded allowed limits in the treated wastewater before discharging into the receiving water body. For the petroleum refining industries these parameters are given in Table 3.8, this includes oil, phenol, lead, cyanide, chromium and zinc. Some of them have limits that are really very small such as lead has allowed maximum limit of 0.05mg/L. But for lack of instruments they are not even tested, which means a large amount could be going into the receiving river, which is a serious problem both to animals and plants.

**Table 4.2 Appropriate Analytical Instruments for Pollutants Found in Nigeria**

<b>Pollutants</b>	<b>Analytical Instruments</b>
PCBs	GC/MS, Portable GC
SO <sub>2</sub>	Electrochemical cells, UV absorption, UV Fluorescence, NDIR
NO <sub>x</sub>	Chemiluminescent, Photomultiplier tube
CO, CO <sub>2</sub>	IR (NDIR & GFC) techniques, Raman Spectrophotometer
PM	GC/MS, Catalytic Sensor
HCL	NDIR/GFC, UV, FTIR
NH <sub>3</sub>	NDIR/GFC, UV, FTIR, Chemiluminescent analyzers
Hydrocarbons	NDIR/GFC, UV, FTIR
VOCs (air)	GC/MS, Portable GC
Pesticides	GC/MS
PAHs	REMPI-TOF, Portable GC, Two step laser Spectrometry
Oil Spills	GC, EDXRF, GC/PID, NMR, GC-NPD, GC-IRMS
Chlorinated Pollutants	Purge & Trap GC-MS
VOCs (in water)	MI MS
Waste Water	NMR/HPLC, APCI-MS
Sulfur	Inductively Couple Plasma (ICP),
BTEX	Pressurized Liquid extraction (PLE), GCxGCMS, Time of Flight MS
Cement dust, soot, Aerosols	UV/VIS Spectrophotometers
Heavy Metals and metals geberally	<sup>1</sup> H & <sup>3</sup> P NMR, EDXRF, Inductively Couple Plasma (ICP), AAS, AES
Inorganic salts	EDXRF, Ion Chromatography (IC)
Organic compounds,e.g. like proteins	Electrophoresis, TLC
Dioxins	Pressurized Liquid extraction (PLE),GC-IRMS

What has been said earlier in this work can be reemphasized here, i.e. 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. Therefore one can conclude that without good analytical instruments and good new measurement techniques, the Nigerian people would be unaware of some significant environmental problems, hence endangering the health of human beings, animals, plants and the planets at large. This supports the Physicist Lord Kelvin as quoted by Matthias (2004) when he identified the general need for quantification by saying "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you can not measure it, when you can not express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thought, advanced to the stage of science, whatever the matter may be". This is particularly true in environmental pollution monitoring, as such the Nigerian laboratories must be made to play their important role if the environment will be watched over and protected.



**Figure 4.1** The Number of Analytical Instruments Found in Literature Compared with those Found in the Research Laboratories.

The solution for the lack of appropriate analytical instruments is within the reach of the Federal Government as seen from chapter 2.6 “The economic tools for environmental management in Nigeria”. In this chapter it was seen that the statutory allocation to the Federal Ministry of Environment can improve the state of art of the Nigerian environment if the Government is committed to doing this. The monitoring laboratories should be equipped with appropriate analytical instruments and qualified personnel hired to mine these instruments. If there is good monitoring from the Government side, and laws are properly enforced, the industries will be forced to equip their laboratories with appropriate analytical instruments and they will monitor their waste treatment properly before discharging it to the environment.



#### 4.1.2 Quality of the Research Laboratories' Analytical Instruments

During this work, results were collected from the laboratories; some of these results are analyzed here to see how accurate they are. Attempt was made to obtain validation data from the research laboratories, although each claimed to do periodic validations of their equipments, none could make one validation data available for this work. The most reliable method to look at the quality of the laboratory's analytical instruments in the research laboratory would have been to look at the validation data as is known that to be fit for the intended purpose, a method must meet certain validation characteristics, such as selectivity, linearity, range, accuracy, precision, limit of detection and quantization, but since validation data were not available in the research laboratories, the normal laboratory results are used here to discuss the quality of the instruments. In NNPC the results from the environmental control unit will be used as the results were obtained always from the same point of the treatments. To study how good these results are, standard deviation is used here to check the agreement between the results, since standard deviation is a measure of variability or dispersion of results. Low standard deviation will indicate that all the data points are very close to the same value, which is the mean. High standard deviation will indicate that the data are spread out over a large range of values.

Standard Deviation ( $\sigma$ ) is given by the formula

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2},$$

**Equation 4.1**

Where N = Number of data

$x^i$  = Value for each data

$\mu$  = Average of the data

The results of NNPC Kaduna environmental units are used here, standard deviations calculated are given in Table 4.3 and 4.4 and they show the agreement between the waste water monitoring results.

**Table 4.3 Standard Deviation of Waste Water Treatment Monitoring  
Results NNPC Kaduna Obtained in 2007**

Points	Standard Deviation ( $\sigma$ )	
	pH	Conductivity
A	0.12	4.58
B	0.32	10.13
C	0.07	8.77
D	0.18	1.96

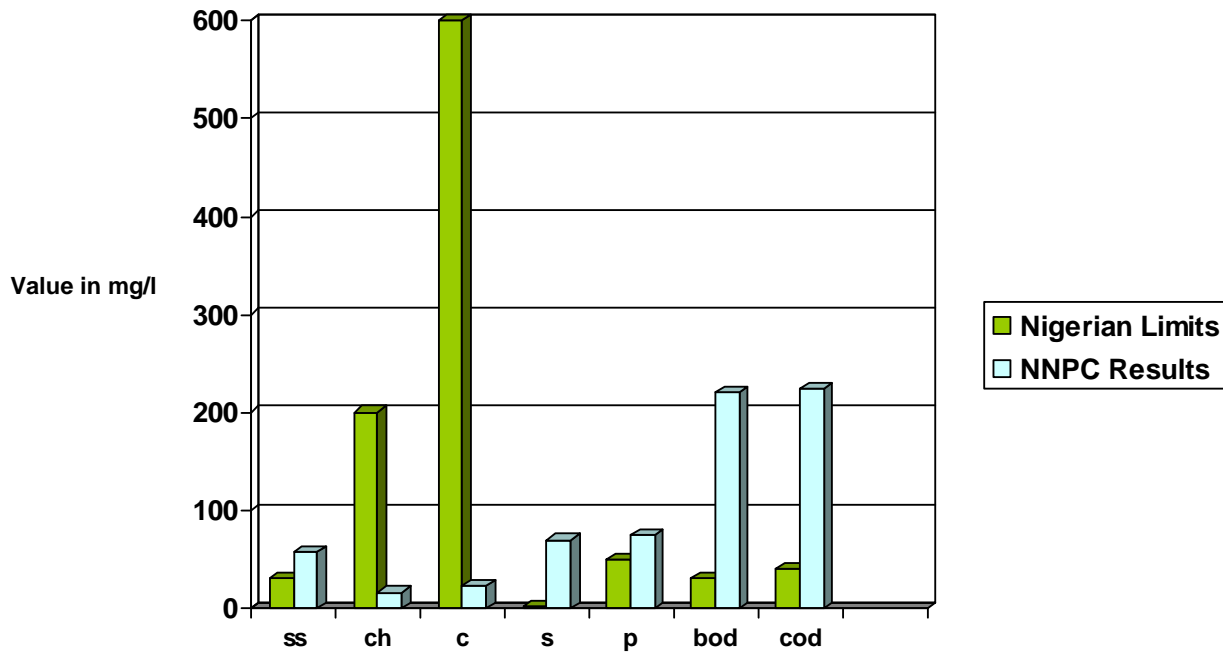
**Table 4.4 Standard Deviation of Waste Water Treatment Monitoring  
Results NNPC Kaduna Obtained in 2008**

Points	Standard Deviation ( $\sigma$ )	
	pH	Conductivity
A	1.31	0.56
B	0.57	0.24
C	1.51	0.09
D	0.29	0.01

The large standard deviations obtained especially in the results of conductivity monitoring do not show good agreement between the results. This may not lead to the conclusion that the equipments are not good since there could be many factors responsible, such as truly the water treatment did not meet specifications, or the personnel were careless, etc. But a strong factor could be the instrument being used, which could mean the instrument used is not in a good condition.

To evaluate the NNPC waste water treatment, a comparison of their treated effluent values is done with the given limits in the Nigerian Guidelines and Standards for environmental pollution control (S.1.15 1991; S.1.8 1991; and S.1.8. 1991). This comparison is shown in Figure 4.2 and in Table 4.6 below where the NNPC treated effluents values are shown in blue in Figure

4.2 and the given limits in the Nigerian Guidelines and Standards for Environmental Pollution Control shown in green.



Parameters measured

SS= Suspended Solids, CH = Ca Hardness, C = Chlorides, S = Sulphate, P = Phosphate, bod =BOD, cod = COD

**Figure 4.2** Comparison of Nigerian Effluents limits with NNPC Results

In the comparison above it can be seen that in Ca Hardness and Chlorides, the Nigerian limits are much higher which is good because that shows the NNPC results are below limits. But in the rest, in about 71% of the results, the NNPC results are all well above the given limits, which is bad for the receiving river and the environment. Parameters like BOD and COD can drastically affect aquatic lives in the receiving river, since the loss of oxygen in the river can create stress on many aquatic organisms including fish. Therefore this result does not show good environmental pollution control for the company which will end up destroying the river and its aquatic inhabitants. In Table 3.3 on page 111, one can see how many parameters have not been measured due to lack of analytical instruments or the instrument is faulty, this does not allow for efficient monitoring of the pollutants that may end up in the receiving river. This violate one of the principles of the

Guidelines and Standards for Environmental Pollution Control in Nigeria which says, “It is mandatory for all industries to have industrial pollution monitoring capabilities with in their own set up”. For NNPC as one of the biggest oil producing company in the country to lack capability to measure parameters like oil in treated wastewater, phenols, etc is very damaging for the environment. These parameters that are not measured can be present in the effluent in a large quantity, which will go directly to the receiving river; this is unhealthy for humans, animals, plants and the environment at large. Another issue is the air pollution control in NNPC Kaduna; Table 4.5 gives some Nigerian limit for gaseous emission from petroleum refinery. But these parameters in Table 4.5 were not measured in NNPC Kaduna, they are therefore just emitted into the environment, this shows the degree of lack of analytical instruments in air pollutants control in the research areas.

**Table 4.5 Nigerian limit for Some Gaseous Emission from Petroleum Refinery which are not Monitored in NNPC Kaduna**

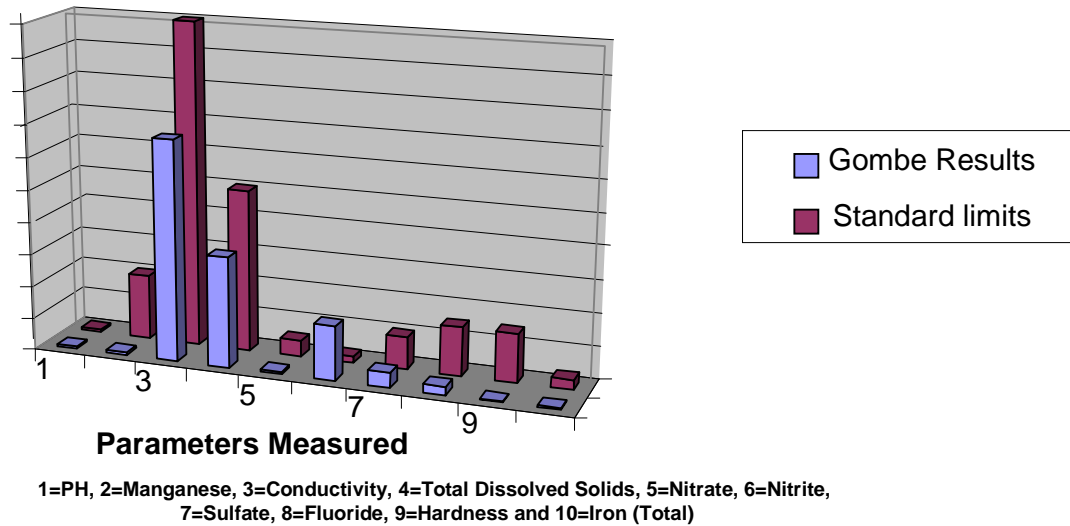
Parameter	NNPC (KRPC) Kaduna' Result	Nigerian Limit
Particulate	ND	500 $\mu\text{g}/\text{m}^3$
Sulphur Dioxide (SO <sub>2</sub> )	ND	830 $\mu\text{g}/\text{m}^3$
NO <sub>x</sub>	ND	500
H <sub>2</sub> S Vapor	ND	30
NH <sub>3</sub>	ND	30
Hydrocarbons Vapors	ND	5000
VOCs	ND	6000 $\mu\text{g}/\text{m}^3$
CO	ND	5000 $\mu\text{g}/\text{m}^3$

In Table 4.6 below where the treated effluents values of NNPC are given alongside the Nigerian effluent limits, some parameters measured by NNPC exceeded the Nigerian maximum limits, but more noticeable is the number of parameters that are not measured at all, as much as 45% of the parameters given in the Nigerian limits are not measured in the NNPC effluent.

**Table 4.6 Comparison of Treated Effluent Values of NNPC Kaduna and Nigeria Effluent Limits**

<b>Parameters Analyzed</b> ( ppm or mg/l except stated)	<b>Nigeria Limits</b>	<b>NNPC Results</b> ND=Not Determined
PH	6.5 -8.5	7.61
Conductivity (µs)	-	89.9
Total solids	-	281.81
Suspended solids	30mg/l	57.34 mg/l
Turbidity (NTU)	-	15.96
Alkanity M	-	44.00
Total Iron	20mg/l	ND
Total Hardness	-	26.00
Ca Hardness	200mg/l	16.00 mg/l
Chloride	600mg/l	22.3 mg/l
Silica (SiO <sub>2</sub> )	-	12.49
Sulphate	0.2mg/l	7.00 mg/l
Phosphate	5mg/l	7.44 mg/l
B.O.D.(5days)	30mg/l	220.00 mg/l
C.O.D	40mg/l	170.0mg/l
Dissolved Oxygen	-	7.10
Total dissolve solids	2,000.mg/l	224.47 mg/l
Oil	10mg/l	ND
Hydrocarbons	5,000mg/l	ND
Phenols	0.5mg/l	ND
Nitrate	20mg/l	0.30
Ammonia-N (mg/l)	0.210mg/l	ND
Sulphide (H <sub>2</sub> S) (mg/l)	0.2mg/l	ND
Zinc (mg/l)	< 1mg/l	ND
Lead (mg/l)	0.05mg/l	ND
Arsenic (mg/l)	0.1mg/	ND
Cyanide (mg/l)	< 0.01	ND
Cadmium (mg/l)	< 0.01	ND
Boron (mg/l)	5mg/l	ND
Selenium (mg/l)	< 1mg/l	ND
Mercury (mg/l)	0.05mg/l	ND
PCBs	0.003	ND
Hexa Chromium mg/l	< 0.01	ND

Values in mg/L



**Figure 4.3** Comparison of Gombe Regional Laboratory Results with Nigeria' Standards limits

In Figure 4.3 a comparison of the Gombe Regional Laboratory result is made with the Nigerian Standard for Drinking Water Quality maximum limits allowed. The results showed good agreements with the standards because the results' values except for nitrite are much below the maximum allowed limits. In Table 3.4 found on page 116 where the result compared here is taken, one can see that the laboratory personnel made a comment that this value is not okay, this means the high value is actually from the sample and not a failure from the instruments. But good as this result may look like; there are many parameters that are not measured by this laboratory. In the Drinking Water Standard quoted above so many inorganic constituents are given and most of them have very low limits parameters like Arsenic 0.01-mg/l, Barium 0.7mg/l, Chromium 0.05mg/l, Cyanide 0.01mg/l, Lead 0.0-1 mg/l, Hydrogen Sulphide 0.05mg/l, etc. These low limits shows how important it is to make sure such pollutants are not found in drinking water, but most of them have not been measured by the Gombe Regional Laboratory. If they are available in such water it means they are being consumed by human beings and animals to the detriment of their health. In section 2.3.3 of this work, water pollutants relevant for this research were enumerated such common water pollutants includes organic compounds like polyaro-

matic hydrocarbons, polychlorinated biphenyls, dioxins, etc. Also residues of pesticides and their metabolic products were given as common water pollutants in the section mentioned above. Looking at the Gombe laboratory results in Table 3.4 to Table 3.7 these pollutants and many others are totally absent from their test results, which could mean these pollutants where available, are being consumed in drinking water. The reason for not carrying out these analyses gathered from the laboratory chemist is lack of instruments or where they are available they are non functional.

#### 4.1.3 Air Pollution Quality Control in the Research Areas

One of the results collected from the Ashaka Cement Factory are given in Table 4.7. In this results air pollutant tests are completely absence.

**Table 4.7 A Typical Result from the Chemistry Laboratory of Ashaka Cement Factory. Date taken 13.11.2008**

Parameter	Result	Unit
SiO <sub>2</sub>	14.238	%
Al <sub>2</sub> O <sub>3</sub>	3.881	%
Fe <sub>2</sub> O <sub>3</sub>	1.854	%
CaO	43.234	%
MgO	0.467	%
SO <sub>3</sub>	0.381	%
K <sub>2</sub> O	0.799	%
Na <sub>2</sub> O	0.053	%
P <sub>2</sub> O <sub>5</sub>	0.118	%
Mn <sub>2</sub> O <sub>3</sub>	0.127	%
TiO <sub>2</sub>	0.170	%
Silica Ratio	2.483	-
Aluminum Ratio	2.094	-
Calcium Carbonate	77.164	%

The results seen in Table 4.7 are only those for products quality control. According to the environmental pollution control officer, they always contract their environmental pollution control analysis out. The chemist in the laboratory commented on this in response to the question, don't they control the air quality around the company? He said they do this only incase they happened to have an accident. This is not in agreement with the Nigerian Guidelines and Standards for Environmental Pollution Control, which state that "Guidelines for emission limits from stationary sources represent maximum allowable levels of pollutants from a site, process, stack, vent, etc with the objective of achieving a desired air quality for the environment". According to the same guideline, emission from industries and other sources have impact on ambient air. It is therefore of utmost importance to have guidelines for safe levels of air pollutants tolerable to humans, aquatic organisms and vegetation. In cement industry pollutants like dust, SO<sub>2</sub>, NO<sub>2</sub> and particulates should be monitored to ensure they don't discharge above the tolerable levels to humans and the environment. In the guidelines given in Table 4.8 air pollutants are to be measured several times a day to build the daily averages of these daily values for each of the pollutants, such as SO<sub>2</sub>, NO<sub>2</sub>, etc. Ashaka cement factory do air analysis only incase of accident which contradicts this guideline.



**Table 4.8 The Nigerian Ambient Air Quality Standard**

Pollutants	Time of Average	Limit
Particulates	Daily average of daily values 1 hour	250 $\mu\text{g}/\text{m}^3$ *600 $\mu\text{g}/\text{m}^3$
Sulphur Oxides (Sulphur Dioxides)	Daily average of hourly values 1 hour	0.01ppm (26 $\mu\text{g}/\text{m}^3$ ) 0.1ppm (260 $\mu\text{g}/\text{m}^3$ )
Non-methane Hydrocarbon	Daily average of 3-hourly values	160 $\mu\text{g}/\text{m}^3$
Carbon Monoxide	Daily average of hourly values 8-hourly average	10ppm (11.4 $\mu\text{g}/\text{m}^3$ ) 20ppm (22.8 $\mu\text{g}/\text{m}^3$ )
Nitrogen Oxides (Nitrogen Dioxides)	Daily average of hourly values (Range)	0.04ppm – 0.06ppm (75.0 $\mu\text{g}/\text{m}^3$ -113 $\mu\text{g}/\text{m}^3$ )
Photochemical Oxidant	Hourly values	0.06ppm

(Source: FEPA Guidelines And Standards for Environmental Pollution Control in Nigeria 1991)

As can be seen in Table 4.8 above, air pollution control is not a one time business when there is accident, but as often as even hourly. Suspended Particulate matter (SPM), dust, fumes, CO, etc from cement production can result in a range of health effects to households living around the factory and even workers in the factory (Henrik et al 2004). Therefore pollutions from cement factories are not to be taken for granted as they can be pretty severe and are not safe for human beings and the environment. The Ashaka cement factory may be doing some green practices, but this is not a guarantee and so the need for the ambient air quality control in and around the factory can not be overemphasized.

To underpin the necessity of continuous air pollution control in a cement factory like Ashaka, it must be mentioned that wastes are fired in such cement kilns for energy recovery and substitution of fossil fuels or substitution of minerals. In some cases even hazardous wastes are disposed of in these installations. The manufacturing process includes the decomposition of calcium carbonate ( $\text{CaCO}_3$ ) at about 900 $^{\circ}\text{C}$  to calcium oxide (CaO, lime)

followed by the clinkering process at about 1450<sup>o</sup>c in a rotary kiln. The clinker is then grounded together with gypsum and other additives to produce cement (Van Oss 2002). The combustion process in the kiln has the potential to result in the formation and subsequent release of chemicals listed in the Annex C of the Stockholm Convention, example PCDD/PCDF (Karstensen 2006 a & b). Looking at this process, it becomes clear that continuous measurement in a cement factory is necessary. The European Commission in 2001 recommended for the cement industries continuous measurements for the following parameters: pressure, temperature, O<sub>2</sub> content, NO<sub>x</sub>, CO, SO<sub>2</sub>, control of mercury and dust. The document also recommended regular periodical monitoring in kiln with best available technique for the following substances: metals and their compounds, total organic carbon/organic components, HCL, HF, NH<sub>3</sub>, and PCDD/PCDF. It is also recommended that occasionally the following should be measured; destruction and removal efficiency, in the case of destruction of persistent organic pollutants (POPs) in cement kilns, Benzene, Toluene, Xylene, Polycyclic Aromatic Hydrocarbons (PAHs), Chlorobenzenes, PCBs, etc. Therefore Ashaka cement needs to do some continuous air pollution measurement and some periodic not only occasional.

During this research, it was observed that it is not only Ashaka Cement Factory that doesn't have air pollution control instruments on ground, but all the laboratories visited. This is a serious problem, because air pollution in Nigeria is a real issue found every where, and not only in industrial areas. For example, as a result of dwindling power supply from the nation's public power source which has persisted over the years, most households, business centers, etc, especially in urban areas have resorted to the use of generating sets. The use of these generating sets is done for reasons of necessity, but it produces huge amount of air pollutants on daily basis. A Nigerian news paper Daily Trust on 6. Feb 2009 (Editorial Daily Trust 2009) reported that many Nigerians have died from the fumes emitted into the atmosphere by these generating sets. An example was given of a prominent community leader in Ihogbe in Oredo Local Government Area of Edo State, who himself, his wife and four children were killed in Jan 2009 by fumes

from a standby generator. Just entering any commercial area in Abuja, the Federal Capital, the quality of air there confirms the extent of pollution happening in Nigeria due to these generators. On daily basis the business people in a given area all put their generators at the same time, when one enters the area it feels unbearable, but the business people are sitting there the whole day and taking it for granted that it is okay, until they take ill, then they will noticed is from the fumes they have been inhaling day in day out. This is a problem that the Federal Ministry of Environment should take serious; at least the National Reference laboratory should have some good air quality control instruments to be able to monitor ambient air quality not only in Industries but even in towns.

During the visit to the NNPC chemistry Laboratory, there were no air analysis reported and no analytical instruments for gas analysis were seen in the laboratories. Friends of the Earth Nigeria reported that over 3.5 billion standard cubic feet (scf) of associated gas was produced in Nigeria in 2000, of which 70% was burnt off, i.e. flared. Even though the NNPC is part of the company that flares this huge amount of natural gas, air pollution control is not done on a routine basis in the laboratory. According to the report of Friends of the Earth Nigeria quoted above, Nigeria has become the world's biggest gas flarer, both proportionally and absolutely, with around 2 to 2.5 billion scf a day being flared of. Figure 4.4 is a typical gas flare in Nigeria; there is a recent report that shows Russia has since 2004 become top offender in gas-flare emissions but Nigeria is still flaring much making it the second offender. This recent report by the World Bank which was from a US study as reported by John Donnelly (2007) estimated Russia flares 50 billion cubic meters of natural gas, or roughly one third of the world's output. Nigeria's estimate by the same report stood at 23 billion cubic meters. The World Bank estimates that the 150 billion cubic meters of natural gas that bubbles up at oil wells worldwide adds some 400 million tons of carbon dioxide to the atmosphere each year as well as more methane. These 400 million tons of CO<sub>2</sub> according to the report, is equivalent to the emissions from all the vehicles in Great Britain, France and Germany. These flares normally contain a lot of environment pollutants some of which are toxins,

such as benzene, POPs, etc. In theory these flares are suppose to have a complete combustion producing only carbon dioxide and water, however flares do not always provide complete combustion as can be seen in the flame in Figure 4.4 which has a lot of black smokes. As a result unburned hydrocarbons and carbon monoxide are also often emitted. This shows air pollution is not only a problem with industries like cement factory but the oil companies as well, as such NNPC should also do some air pollution analysis as they do in water pollution.



**Figure 4.4** Flame from Gas Flaring in Nigeria (Ebocha)  
(Source: Ofeibea Quist- Arcton)

Speight (2005) seems to agree with the fact that NNPC as a refinery needs to take air pollution control as serious as water pollution control. In explaining the types of waste refineries produced, he said the chemicals in petroleum vary from simple hydrocarbons of low to medium molecular weight to

organic compounds containing sulfur, oxygen, nitrogen, etc. According to him waste treatment processes also account for a significant area of the refinery, particularly sulfur compounds in gaseous emission. During petroleum refining, refineries use and generate an enormous amount of chemicals, some of which are present in air emissions, waste water, or solids. A large source of air emission is generally process heaters and boilers which produce carbon monoxide, sulfur oxides, and nitrogen oxides leading to pollution and formation of acid rain. In addition, some processes create considerable amounts of particulate matter and other emissions from catalyst regeneration or decoking processes. Volatile chemicals and hydrocarbons are also released from equipment leaks, storage tanks and wastewaters. Petroleum refineries are a source of hazardous and toxic air pollutants, such as BTEX compounds (benzene, toluene, ether/benzene and xylene) (Speight 2005). They are also major source of criteria air pollutants like particulate matter (PM), etc as already mentioned. This is the more reasons why NNPC should have very good air pollution control instruments in the laboratory.

The lack of air pollution control in the research laboratories call for serious concern. Nigeria is one of the party members of the Stockholm convention, which was ratified, accepted and approved by Nigeria on 24 May 2004 (Stockholm Convention:[www.gefoline.org/projectDetails.cfm](http://www.gefoline.org/projectDetails.cfm)). This convention was largely on POPs which are toxic, persistent and bioaccumulative and undergo long range transport. Bioaccumulative chemicals are usually fat soluble and build up in higher trophic levels, including in humans. That means they can be agent for serious sicknesses like cancer that is why the Stockholm convention took them very serious. These chemicals are mostly semi-volatile compounds, so they undergo a series of evaporations and condensations in the environment, making them mobile. To show how serious these class of air pollutants are the United Nations have been carrying out workshops for assessment of the existing capacities and capacity building needs to analyze POPs in developing countries (United Nations Environment Program 2006). Activities of these workshops include training course at the pilot laboratory, analysis of national exchange samples, par-

icipation in intercalibration study with selected POPs and matrices, needs of equipment upgrade with respect to sample handling and analysis. Nigeria also try to show how serious POPs are as pollutants, on 14 November 2001 the Federal Government approved a project titled enabling activities to facilitate early action on the implementation of the Stockholm convention on POPs in Nigeria. The objective of the project was to strengthen national capacity and enhance knowledge and understanding amongst decision makers, managers, the industry, NGOs, and the public at large on POPs, so as to develop and formulate a National implementation plan (NIP). The project is meant to make Nigeria to achieve the Stockholm objectives and meet the obligations of the convention so as to manage the elimination of POPs. The project should specifically allow Nigeria to meet its reporting obligations under the convention; prepare the ground for the implementation of the convention in Nigeria; strengthen national capacity to manage POPs and strengthen chemicals management capacity in general; maximize government commitment and facility ratification of the Stockholm convention (Stockholm convention; [www.gefonline.org](http://www.gefonline.org)). This project sounds great but definitely can not be achieved without proper analytical instruments in the chemical laboratories especially with a nonfunctional reference laboratory the Federal Government can do less. But the intensity of some serious problems that some air pollutants can cause can not be ignored for lack of analytical instruments, therefore the Federal Government needs to look into the issues of analytical instruments for air pollutants and in general for the monitoring of environmental pollution.

## **4.2 Monitoring Organizations in Nigeria**

### **4.2.1 The Reference Laboratory**

Operation of quality monitoring network based on automatic monitors will normally require the establishment of a National Reference Laboratory (NRL), which can take up the following responsibilities:

- Auditing
- Measurement Standard Methods
- Reference Standards
- International Comparison studies.

The objectives of the reference laboratory are to contribute to the assurance of quality of the specified analyses, tests and measurements, by assisting the monitoring institutions in matters concerning quality assurance and quality of measurement including the provision of external quality control services. The reference laboratory should advise the authorities by assuring the quality of measurement provided by monitoring institutions and conducting audits of the activities of the monitoring institutions. Certified reference materials have to be made available to reference laboratory and all procedures have to be traceable. The reference laboratories have to participate in international proficiency tests, calibrate the reference standards at internationally recognized laboratories as well as conduct national proficiency tests. (Sivertsen B 2002)

The above given functions of reference laboratories place them in an important position in environmental pollution control, because they control the monitors of the environment. In Nigeria the National Reference Laboratory, which was formerly under Federal Environmental Protection Agency but now under NESREA has not been functional for some years now. This means the monitoring laboratories in the industries, states or even local governments are not been controlled. These laboratories which are involved in the analysis of official samples, who should work in accordance with internationally approved procedures, are left to work as they want. No one can ascertain if they use methods that are well validated or equipments

that enable the correct determination of standards. As already mentioned, national reference laboratories are very important because they should normally contribute to a high quality and uniformity of analytical results in their countries. This is normally done by activities such as the application of validated analytical methods, ensuring that reference materials are available, the organization of comparative testing and offering training to the staff from other laboratories. With a nonfunctional national reference laboratory the monitoring of other laboratories involved in monitoring environmental pollution control in the industries can not be done efficiently. The Federal Ministry of Environment and its agencies that should rely on the reference laboratory for data to effectively monitor the environment are not able to do this.

#### **4.2.2 The Federal Ministry of Environment, Housing and Urban Development**

It is the Federal Ministry that is responsible for monitoring environmental issues in general. All other federal government agencies should be monitored by the federal ministry or at least they should liaise with them to ensure environmental issues are carried out correctly and in time. The Ministry is doing a lot of environmental policing in different fields, but when it comes to using laboratories to monitor environmental conditions and to ensure compliance with standards and limits, this is really lacking and as such is a real problem. NESREA is the Federal Ministry of Environment's agency that is responsible for monitoring the environmental limits and standards. As earlier mentioned, NESREA took over the function of the then Federal Environmental Protection Agency. In the Federal Republic of Nigeria official Gazette, the functions of the Federal Environmental Protection Agency in waste management were enumerated to include provide for surveillance and monitoring of dangerous and extremely hazardous wastes; monitor and ensure that industries, factories and other institutions which discharge waste shall treat such wastes in the manner prescribed in the Nigerian regulations; employ scientific and human resources to monitor and control all phases of life cycle of all substances likely to have an adverse effect on



human health and environment. FEPA was supposed to use the National Reference Laboratory to fulfill these roles and more. The National Reference laboratories are therefore directly under NESREA now, but till the time of interview, NESREA was busy trying to develop policy statements and the like, and as such the laboratories are still left nonfunctional. This also means no industry in the country is monitored in terms of limits and standards of effluents and waste disposal. This might account for some results discussed above which were above the Nigerian limits and were not a source of worry to the industry. NESREA seems to be more involved in some basic environmental pollution control that are no longer issues in developed countries like Germany, such as indiscriminate dumping of wastes, desertification, etc. They seem to be busy getting people to take collective responsibility for a clean environment by creating public awareness, but issues like good monitoring laboratories with good analytical instruments are not yet seriously in view.

In his paper titled "Influence of Regulatory Requirements on Instrumentation Design" Randy (2005) reported that Federal, State and Local regulatory requirements have long played an important role in driving the advancement of new technologies for the measurement and control of environmental pollution. They will continue to do so; however regulations and competitive technological development ultimately work hand in hand to influence the future of environmental instrumentation and pollution control. This means Nigeria's Federal Ministry of Environment, who has the sole responsibility of policing the environment must also influenced the types of analytical instruments that are found in the environmental laboratories by making sure the laboratories are well monitored. If the regulations in terms of limits have to be met, the instruments used will have to be specified to the laboratories so that they don't just use any instruments that don't produce reliable results. From the information gotten in the field the Federal Ministry of Environment in Nigeria seems to have very little if at all to do with the types of instruments found in the laboratories. This is clearly demonstrated by the absence of so many analytical results due to lack of instruments or faulty instruments. Khopkar in his book "Environmental Pollu-

tion Monitoring and Control” stressed the importance of analytical instruments for environmental monitors like the Federal Ministry of Environment Nigeria. According to him one can not think of control measures unless one knows what the extent of pollution is. He continued by saying monitors can not effectively control pollution in the absence of authentic data about air pollution, water pollution, industrial effluents, sewage management, land and pesticides pollution. Such measures can be effective only if we have reliable data on levels of pollution. And such reliable data can only be generated with reliable analytical instruments. In another words the problem of scanty or outdated data in Nigeria are invariably a problem of analytical instruments for data generation.

#### **4.2.3 The Standard Organization of Nigeria (SON)**

Standard Organization of Nigeria (SON) has the sole responsibility for national policy on standards, standards specification, quality control and metrology. This involves certifications of the laboratories involved in monitoring environmental pollution. SON also monitors the compliance with International Standards that are adopted by Nigeria, e.g. that from ISO (SON: <http://www.sononline.org/main/preg.php>). To be able to investigate the quality of facilities, materials and products in Nigeria, and establish a quality assurance system, including certification of factories, products and laboratories, SON will definitely need the service of the National Reference Laboratories which are not functioning in the moment. SON should also ensure reference standards for calibration and verification of measures and measuring instruments, but all the laboratories visited none could supply any calibration data for their instruments. This may indicate SON is not fairing well in this area of its function. Since the National Reference laboratories are not functioning, SON should have had to establish and maintain laboratories or other institutions, as may be necessary for the performance of its functions, but apparently they have not done this and so they are depending on the National Reference laboratories and this does not allow for good monitoring. If the industries and monitoring organizations at the state

and local government levels have to stick to standards and limits, then everything should be put in place to make SON function very well.

Another observation that can be made on the role of SON as a monitoring organization is the current standard being used in Nigeria. The current guidelines and standards for environmental pollution control in Nigeria were developed since 1991 by the Federal Environmental Protection Agency (FEPA). In developed countries like Germany standards are updated regularly since environmental problems are becoming more complicated with many new pollutants entering the environment or being discovered from research. SON has not updated these guidelines and standards, and that means all the analytical methods in the guidelines are those old methods with less accuracy unlike the situations in developed countries where new analytical instruments with high accuracy and low limit of detections in the nanograms are being used. In the quoted standard of 1991 being used by SON, it is mentioned that “ideally, standards are set based on nationally generated environmental baseline data which are scanty in the present circumstance“. In their report, Artiola et al (2004) said that, nonindustrial countries have limited environmental research and few if any environmental monitoring programs relative to industrialized countries. Therefore, critical intermediate scale information is scarce and often outdated. This agrees completely with the lack of baseline studies to be used by the Standard Organization of Nigeria to set standard. This does not mean this situation should remain like this, but if it will be change then the role of analytical instruments in environmental monitoring will have to be taken serious by the Federal Government of Nigeria. In the absence of such baseline study, an alternative approach is to adapt standards adopted by world health organization (WHO) and the developed nations of Europe and America. This shows that FEPA who prepared the said standards acknowledged that there is problem with environmental data found in Nigeria, which is demonstrated from the given state of the environmental monitoring laboratories. The situation can only be changed if monitoring laboratories like the National Reference laboratories will begin to function properly.

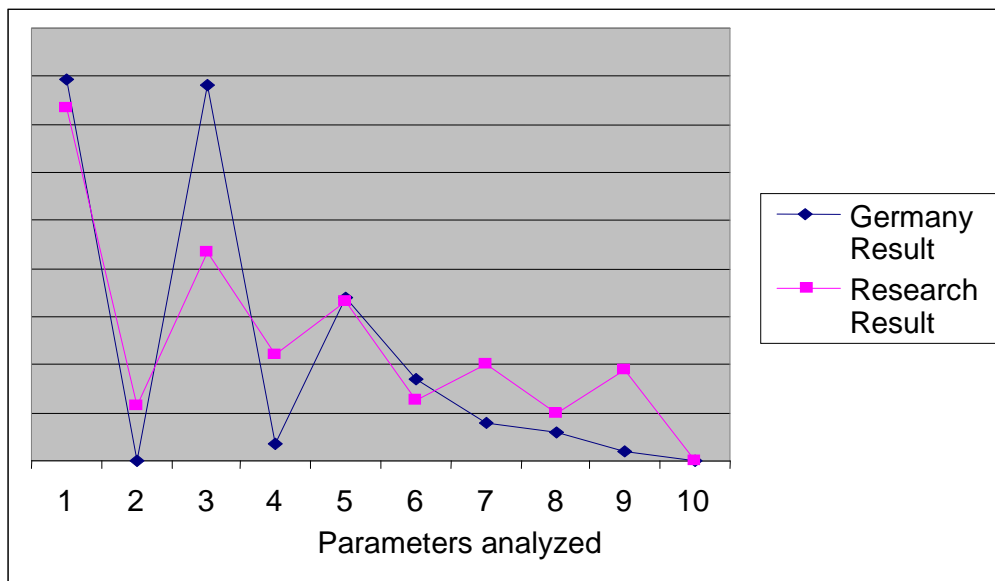
**Table 4.9 An Example of a Drinking Water Analysis Laboratory Results from Germany**

Parameter	Unit	Result	Maximum Limits	Standard used
Turbidity	NTU	0.07	1.0	DIN EN 27027 C2
Total Iron	mg/l	0.006	0.2	DIN 38406-E32-5
Calcium	mg/l	48.6	-	14911, ber ü Harte
Soluble Aluminium	mg/l	0.008	0.2	DIN EN ISO 12020
Ammonium	mg/l	< 0.01	0.5	DIN 38406 E5-1
Nitrite	mg/l	< 0.005	0.5	DIN EN 26777 D10
Sulphate	mg/l	34.0	240	DIN EN ISO 10304-1 D19
Magnesium	mg/l	16.2	-	DIN EN ISO 14911
Nitrate	mg/l	3.6	50	DIN EN ISO 10304-1D19
Benzene	µg/l	< 0.7	1	DIN 38407- F9
Boron	mg/l	< 0.02	1	DIN 38405- D17
Chromium	mg/l	< 0.001	0.05	DIN 1233 E10
Cyanide	mg/l	< 0.01	0.05	DIN 38405- -D14-1
1,2, Dichloroethane	µg/l	< 3	3	DIN 38407- F5
Fluoride	mg/l	0.17	1.5	DIN 38405- D4-1
Mercury	mg/l	< 0.0002	0.001	DIN EN 12338-E31
Trichloroethane	µg/l	< 0.3	-	DIN 38407- F5
Arsenic	mg/l	< 0.0009	0.01	DIN EN ISO 11969 D18
Nickel	mg/l	< 0.002	0.02	DIN 38406 E11-3

(Source: [http://www.stadtwerke-bad-reichenhall.de/wasser/Anal\\_2004.pdf](http://www.stadtwerke-bad-reichenhall.de/wasser/Anal_2004.pdf))

Table 4.9 is part of a result of Drinking water analysis done in a laboratory in Germany. The analyses were made based on specific standards as can be seen in the table. These standards do not only give the limit but also the analytical methods to be used, methods of calculations where necessary even formulas to be used. If we compare this with the results obtained from the research laboratories, there was no one quotation of any standard used in the analysis. If results from the Nigerian laboratories will have to meet certain standards, not only the maximum allowed limits should be given but specific analytical methods for specific analysis have to be given in the Nigerian standard or international standard with these specifications will have to be adopted. The complete result where Table 4.9 was taken from given in [http://www.stadtwerke-bad-reichenhall.de/wasser/Anal\\_2004.pdf](http://www.stadtwerke-bad-reichenhall.de/wasser/Anal_2004.pdf), there

were 102 parameters in the results, but in the research laboratory drinking water analytical results only 25 parameters were given. This makes only 24.5% of the parameters analyzed in the drinking water in the German example above. A class of pollutants seen in the German drinking water analysis, namely organic pollutants was completely absent in the drinking water research laboratory result. Seen from the German laboratory results the detection limits of the analytical instruments used are very low. This class of pollutants needs advanced instruments to be able to achieve such low limit of detection e.g. Benzo fluoroethane was measured with an instrument with detection limit of  $0.001\mu\text{g/l}$  (Hermann 1992). The large gap that is seen from the German example of a drinking water analysis and the research laboratory drinking water analysis is a matter of analytical instruments; many pollutants were not analyzed due to the lack of such instruments and the Standard Organization of Nigeria did not include these instruments in their standards.



**Figure 4.5** Comparison of a Result from Germany with one of the Research Results from Gombe  
 (On the X-axis are parameters analyzed: 1= PH, 2= Turbidity, 3= Dissolved Oxygen, 4= Nitrate, 5= Sulphate, 6= Fluoride, 7= Aluminium, 8= Iron (Total), 9= Manganese and 10= Total Coli form)  
 In Figure 4.5 some parameters from Gombe research laboratory are compared with the example result from Germany from Reichenhall quoted already above in Table 4.9, only ten parameters are used since they are the

ones common to both laboratories. The pH values are almost the same in both cases with that of Reichenhall Germany a little higher than that of Gombe Nigeria. The highest value of dissolved oxygen (DO) in the Reichenhall value is rather positive, since that determines how good the water is, higher DO means less oxygen demand by some pollutants in the water. Sulphate value is a bit higher in the Reichenhall than in Gombe but the difference is not so big. Out of the ten parameters, nine of which should be small values five of the Gombe results are higher than the Reichenhall result, things like turbidity, nitrate, iron (total) and manganese are pretty higher and they are very important parameters in determining drinking water quality. One will keep in mind that 75% of the parameters analyzed in Reichenhall laboratory were not analyzed in Gombe laboratory and of those analyzed 50% were poorer compared to another laboratory in a developed country. It can be seen that the use of standards not only in limits but with methods is necessary for good environmental pollution control.

### **4.3 Limitations of this Research**

The scope of this work was to cover Shell in Photo Harcourt and Kano. In Shell the head of chemical laboratory department would not allow access into Shell for this particular research except the research topic was changed to analyse plants in polluted areas. In Kano the research was to be carried under the State Environmental Protection Agency (SEPA) and the major area of research in Kano was to be air pollution control. The Kano's State Environmental Protection Agency does not have air quality control laboratory, so Kano was not visited. Some of the research questions intended to be answered includes the following;

In general are there laboratories participating in proficiency testing (PT) programs in Nigeria?

- Do the laboratories have calibration data for their instruments?
- Do the laboratories do calibration in terms of initial calibration, monthly validation, and recalibration? Are there calibration curves available?
- Any record of inventory of pollutants into the environment?
- Any study on the concentration of oil products (hydrocarbons) in surface water?
- What calibration models are used in the available laboratories? E.g. ordinary least square (OLS) or weighted least squares (WLS) etc?
- Do laboratories in Nigeria have documentary evidence that their methods have been validated?

Some of these questions could not be answered, as there was no calibration data available in any of the research laboratories visited and some other questions were answered in the negative. It was the intention of this research to use the calibration data of the laboratories to carry out some statistical analysis of the laboratory's results; this could not be done since the calibration data were not available. As such the analysis of the laboratory results using statistical methods was limited to standard deviation only, since analysis like accuracy, precision, etc will need calibration data. The used of the NNPC Kaduna results for standard deviation has the limitation that they are not results obtained on one sample but samples obtained on the same points, this was the best possible way to look at the quality of the results.

# **Chapter 5 The Nigerian Standards and Pollution Monitoring Compared with International Situations**

## **5.1 General Comparison**

Standards and guidelines for environmental pollutants in different areas, like wastewater, drinking water, air pollutants, etc. have been developed by many national and international regulatory and advisory bodies, including the World Health Organization (WHO). In this chapter some few standards of developed countries and environmental monitoring situations are being discussed so as to see how Nigeria is fairing compared to these developed countries. Since in the research laboratories mainly only water analysis results and water analytical instruments were available this comparison will focus more on water in the international communities.

The WHO guidelines do not have any legal force, but are used as the scientific point of departure for setting national standards. They also provide a means of determining the implications for health of a substance that is identified at a concentration above the standard. The WHO guidelines for drinking water quality are probably the most influential source of information available for establishing drinking water quality. The guidelines are intended to provide the basis for developing national standards but this also requires that local needs and constraints are taken into account. Consequently, they are the benchmark for drinking water standards in most part of the world, as WHO guidelines are health-significant and the values normally represent the concentration of a substance that does not result in any significant risk to health over the lifetime of consumption with few exception of short-term exposure. Some values in the WHO guidelines need continuous review that is why the guidelines are regularly updated by a process of rolling revision. Although WHO guidelines are used as the benchmark in most part of the world, WHO emphasizes that guideline values should not be included in national standards unless there is an adequate reason to do



so (Dawn et al 2008). In Nigeria the WHO guidelines play an important role in how other guidelines are made, in some cases they are adopted as they are.

In the report of Dawn et al (2008) an overview of how guidelines are updated in some countries is given. According to their report drinking water standards applied in the UK are largely derived from the European Directive on the quality of water for human consumption, published in 1998. This EU directive is transposed into legislation through the water supply (water quality) regulations 2000 (WSWQ). The EU directive includes strict requirements for monitoring to demonstrate compliance with standards. In Australia, the latest edition of the Australian Drinking Water Guideline (ADWG) was released in December 2004. An updated version of the ADWG latest edition was released in late 2006. The major edition of ADWG was published in 1996 and a rolling revision process was instituted for future updates. The most recent rolling revision was done in 2007. In New Zealand the current drinking water standards came into effect in December 2005, which means the old edition is no longer in used. As mentioned in the discussion under Federal Ministry of Environment, some standards used in Nigeria are the original edition from FEPA which came into effect since 1991 and they have not been updated. In the light of the other countries discussed above one can see that Nigeria is using very obsolete standards which need to be updated or even new editions need to be published.

In the test results obtained from one of the research laboratories, only 25 parameters were listed for testing in the drinking water samples collected, this is really very low in comparison with the developed countries. In New Zealand, the Drinking Water Standards for New Zealand (DWSNZ) specify the maximum acceptable values for more than 140 parameters. In the US the first EPA list contained 50 chemicals and microbial contaminants, but in 2005 EPA published the second contaminates candidate list of 51 parameters. In Japan the Drinking Water Quality Standards (DWQS) cover 50 parameters. Other items apart from the 50 parameters are called complementary targets and there are 27 parameters under this category and another

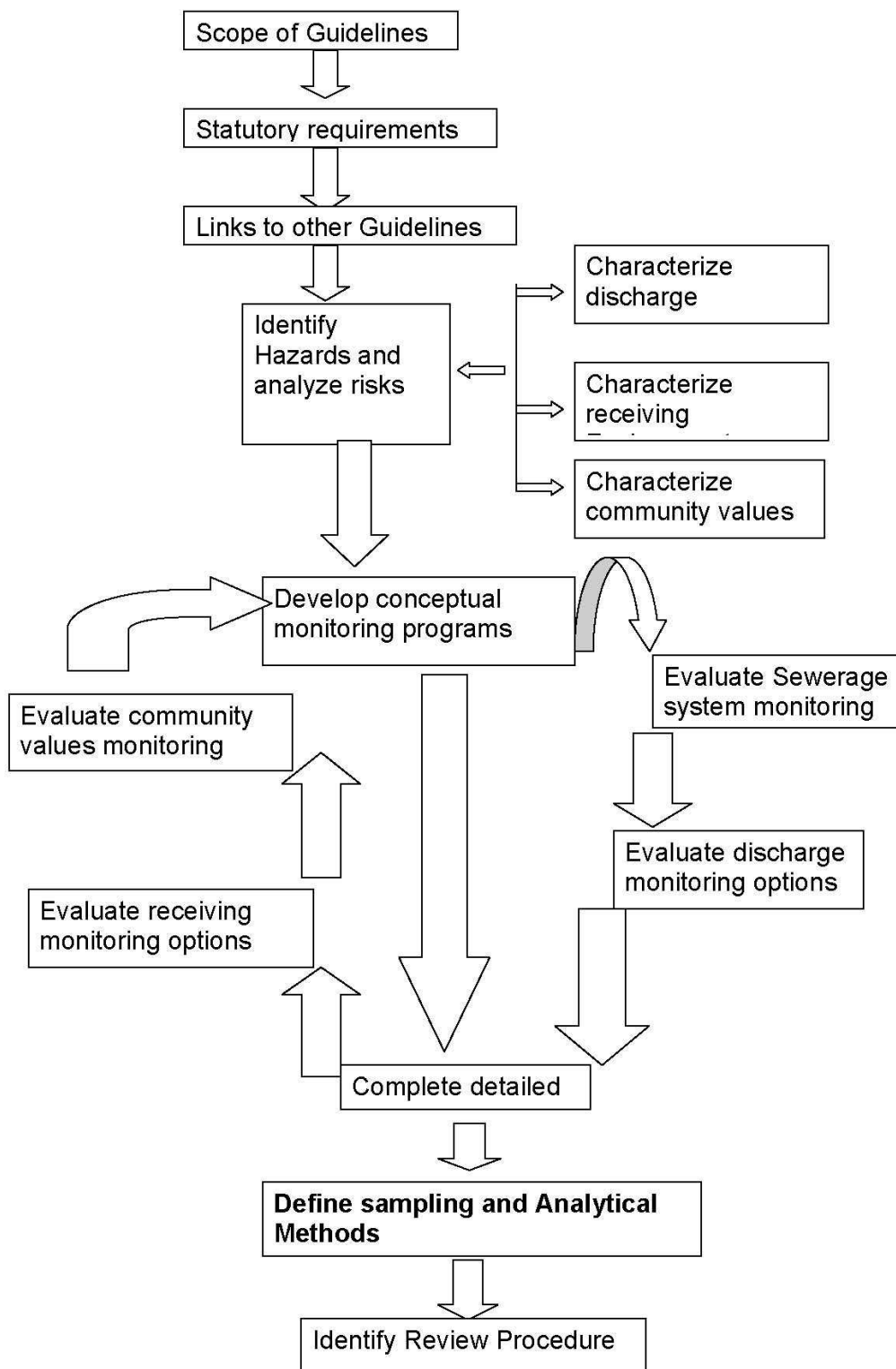
40 items are listed for studies. Pesticides are listed alone and there are 101 parameters under pesticides. The guideline for Canadian drinking water quality covers 165 microbial, physical, chemical and radiological contaminants (Dawn et al 2008). In Germany the drinking water guidelines according to a recent water quality report released by Bundesministerium für Gesundheit (Ministry for Health) and Umweltbundesamt (Federal Environmental Agency) (Press Release April 2009), about 50 parameters were tested in the drinking water results published, covering microbial, physical, chemical, etc. Finally, in the water quality results from Germany used to compare to those from Gombe Nigeria, 102 parameters were tested. It can be seen that the Nigerian parameters tested by the research laboratories are really very few in comparison with the few examples quoted here. Although in the Nigerian Industrial Standard NIS 554 2007, which is the Nigerian standard for drinking water quality many parameters, up to 48 are given for monitoring, from physical/organoleptic, chemical, to radioactive parameters, the research laboratory had only 25 listed even the 25 listed not all were tested. This may not be unconnected with the lack of instruments. Apart from looking at updating of guidelines and the number of parameters tested effort will be made here to compare the role of the analytical instruments in the International guidelines and to compare maximum limits allowed in some Nigerian standards with those of the developed countries.

## **5.2 The Role of Analytical Instruments in Developed Countries' Guidelines as Compared to Nigeria**

In the WHO Guidelines for Drinking Water, chapter 8 deals with chemical aspects of the guideline. In this chapter the whole of section 8.3 deals with analytical aspects of the guideline. It is noted in the WHO guidelines that guidelines values are not set at concentrations of substances that cannot reasonably be measured, but values are set at the reasonable analytical limits. This shows that a nation can not set guidelines without putting the

analytical methods or analytical instruments into considerations. The WHO guidelines give a list of suggested methods for measuring different parameters ranging from volumetric titration, colorimetry, UV absorption, atomic absorption (AAS), flame absorption (FAAS), electrochemical absorption (EAAS), inductive coupled plasma/atomic emission (ICP/AES), chromatography (GC, GC/PD, GC/MS, HPLC, HPLC/FD) etc. This section on analytical aspects covers up to 10 pages in the WHO guidelines, and deals mainly with the analytical instruments suitable for different types of tests. This shows how important WHO placed analytical instruments in environmental pollution monitoring.

In the New Zealand Wastewater Guidelines (NZWWA: 2002, 2003), a whole chapter, i.e. Chapter 14, is dedicated to sampling and analytical methods. In their guidelines Section 14.2 of chapter 14 which contains 15 pages deals with analytical methods from analytical instruments, auditing, to record keeping. They adopt standard analytical methods that are widely used; these are standardized analytical procedures from international and national bodies. This includes Standard Methods for the Examination of Water and Wastewater 20<sup>th</sup> edition 1998 produced by APHA, AWWA, WEF, Washington DC, US. But in adopting these standard analytical methods they did not just mention that environmental monitors should use these standards, but for every analysis they give a specific analytical procedure from these organizations. For example for testing ammonia they give APHA 4500-NH<sub>3</sub> and when one goes to APHA4500-NH<sub>3</sub> the analytical methods are given such as UV-spectrophotometric screening, etc. This is inline with the structure of their guidelines shown in Figure 5.1 below which said the analytical methods to be used should be defined clearly and given as much importance as the other parameters.



**Figure 5.1** Structures of New Zealand Wastewater Monitoring Guidelines  
(Source: Created from New Zealand Municipal Wastewater Monitoring Guidelines (2002))

The structure of New Zealand Wastewater Guidelines is given in Figure 5.1, in this structure one can see that analytical methods have a very important role to play, because for all the other steps one can not avoid defining analytical methods for the guideline. Regulatory bodies have to define analytical methods to be used in complying with guidelines, so that environmental monitors have standards for measurement, which will make results to be reliable and easily comparable. As earlier mentioned in this work the main reason for monitoring whatever environmental parameters in question and their effects on environment is to help environmental scientists to manage human activities and natural resources in an effective and sustainable manner. Like many areas of resource management we can not manage what we can not measure, so analytical methods have a very important role to play if we want to manage our environmental resources effectively and in a sustainable manner. According to the New Zealand biosolids guidelines (NZWWA 2003), the selection of an appropriate analytical laboratory, indirectly analytical instruments, is a very important but often overlooked aspect of any monitoring program in environmental pollution control. Analysis of environmental pollutants is a complex process because of the heterogeneous nature of the pollutants and matrices. Therefore a well equipped analytical laboratory is a must in environmental pollution control.

In comparison to the above quoted cases of how analytical methods are stated in the guidelines, Nigerian Standard for Drinking Water Quality by the Nigerian Industrial Standard NS 554 2007 takes only two sentences to give the analytical methods to be used “Analytical methods shall comply with ISO or WHO guidelines. Field test kits may be used by surveillance agency to conduct routine test” Here no mention is made of which particular ISO or WHO guideline they refer to or for what test. Monitors are not going to go out of their way to look for the ISO or WHO that is relevant to their analytical need. The result is what was obtained in the field where only few

tests are done and they are done with obsolete analytical instruments that may not give any reliable results.

The developed countries place analytical instruments in their environmental pollution control as an important aspect of environmental monitoring. The example of a drinking water result from Germany used in chapter 4 to compare to the drinking water result from Gombe Nigeria, quoted for each parameter the method they used by giving the number of DIN guideline where this method is given. This shows how important the analytical method used is for a result to be fully accepted. Nigeria should really learn from these developed countries to place analytical methods in a very important position in their environmental guidelines and define clearly what method should be used for what parameter. Another thing worth comparing in the guidelines found in the international community to that of the Nigerian guideline is the maximum limit for contaminants, and this is done in Table 5.1 below.

**Table 5.1 Comparison of Nigerian limits for Drinking Water with Some Developed Countries**

Parameters	Germany	US	WHO	Nigeria
Color	No abnormal Change	-	-	15TCU
Conductivity	2500 $\mu$ S/cm at 20 <sup>oc</sup>	-	-	1000 $\mu$ S/cm
PH	$\geq 6.5$ and $\leq 9.5$	-	N/Established	$\geq 6.5$ and $\leq 8.5$
Iron	200 $\mu$ g/l	0.3mg/l	N/Established	0.3mg/l
Manganese	50 $\mu$ g/l	0.03mg/l	0.4mg/l	0.2mg/l
Odor	No abnormal change	-	-	Not abnormal
Oxidizability	5.0mg/IO <sub>2</sub>		-	

**Table 5.1 Continued**

Parameters	Germany	US	WHO	Nigeria
Escherichia coli (E.Coli)	0/100ml	5.0%	0/1000ml	0/100ml
Enterococci	0/100ml	0	0/1000ml	0/100ml
Acrylamide	0.10µg/l	-	0.5µg/l	-
Antimony	5.0µg/l	0.006mg/l	20µg/l	-
Arsenic	10µg/l	0.010mg/l	0.01mg/l	0.01mg/l
Benzene	1.0µg/l	-	10µg/l	-
Benzo[a]pyrene	0.010µg/l	-	0.7µg/l	-
Boron	1.0mg/l	No limit listed	0.5mg/l	-
Bromate	10.0µg/l	0.010mg/l	10µg/l	-
Cadmium	5.0µg/l	0.005mg/l	0.003mg/l	0.003mg/l
Chromium	50.0µg/l	0.01mg/l	0.05mg/l	0.05mg/l
Copper	2.0mg/l	1.3mg/l	2000µg/l	1mg/l
Cyanide	50µg/l	0.2mg/l	0.07mg/l	0.01mg/l
1,2-Dichloroethane	3.0µg/l		30µg/l	-
Epichlorohydrin	0.10µg/l		0.4µg/l	-
Fluoride	1.5mg/l.5	4.0mg/l	1.5mg/l	1.5mg/l
Lead	10µg/l	0	10µg/l	0.01mg/l
Mercury	1.0µg/l	0.002mg/l	0.006mg/l	0.001mg/l
Nickel	20µg/l	-	70µg/l	0.02ml/l
Nitrate	50mg/l	10mg/l	50mg/	50mg/l
Nitrite	0.50mg/l	1mg/l	0.2mg/l	0.2mg/l
Pesticides	0.10µg/l	for individual substances	for individual substances(31)	0.01mg/l
Pesticides total	0.50µg/l	As above	As above	0.01mg/l
PAHs	0.10µg/l		-	0.007mg/l
Selenium	10µg/l	0.05mg/l	0.01mg/l	-
Tetrachloroethene and Trichloroethene	10µg/l	-	40µg/l and 20µg/l	-
Trichloromethanes total	100µg/l	0.1mg/l	-	-
Vinyl chloride	0.50µg/l		0.3µg/l	-
Aluminum	200µg/l	0.05-0.2mg/l	N/Established	0.2mg/l
Ammonium	0.50mg/l		N/Established	-
Chloride	250mg/l	-	N/Established	0.003mg/l
Clostridium perfringens	0/100ml	-	0/1000ml	-

**Table 5.1 Continued**

Parameters	Germany	US	WHO	Nigeria
Sulfate	250mg/l	-	N/Established	100mg/l
Sodium	200mg/l		0.4mg/	
Taste	No abnormal change	-	-	Not abnormal
Total Organic Carbon	-	-	N/Established	5mg/l
Coli form Bacteria	0/100ml	0		0/100ml
Ca, dissolved	100mg/l	-	N/Established	150mg/l
Turbidity	-	5NTU	-	5NTU
Chlorine	-	-	5mg/l	0.2 - 0.25mg/l
Total Dissolved Solids (TDS)	400mg/l	-	N/Established	500mg/l

(Source: Created from Kleiböhmer W. (Ed); WATERTIGER; Nigerian Industrial Standards)

In the comparison above in Table 5.1, the Nigerian Standard contains many parameters that have same values as in Germany, US or WHO. This confirms what was earlier said that in Nigeria some WHO values are adopted as they are. The biological parameters in the case of Germany, WHO and Nigeria are the same with 0/100ml, only the US has a different value. Some parameters like Arsenic have the same values for all the countries given in Table 5.1, and Nigeria and Germany have the same value for mercury. In the value of cyanide Nigeria has the lowest value compared to the other two countries and WHO. In terms of the maximum limits adopted for the parameters in the Nigerian guidelines, the values are not bad at all; in most cases they are either the same or even lower than those of the developed countries or the WHO. These values according to the WHO are set at concentrations of substances that can be reasonably measured, that is to say values are set at the reasonable analytical limits. It is therefore no wonder that some of these parameters even though they are given in the Nigerian guideline with low maximum limits allowed, they are not measured by the regional laboratory visited, which can not be unconnected with the lack of suitable analytical instruments.



**Table 5.2 Comparison of Nigerian Limits for Drinking Water with that of New Zealand**

<b>Parameters</b>	<b>New Zealand Limits (Maximum Acceptable Values)</b>	<b>Nigerian Limits (Maximum Limits)</b>
Escherichia coli (E.Coli)	Less than 1 in 100ml of sample	0/100ml
Enterococci	Less than 1 in 100ml of sample	0/100ml
Acrylamide	0.0005 mg/l	-
Antimony	0.02mg/l	-
Arsenic	0.01 mg/l	0.01mg/l
Benzene	0.01 mg/l	-
Benzol[a]pyrene	0.0007 mg/l	-
Boron	1.4 mg/l	-
Bromate	0.01 mg/l	-
Cadmium	0.004 mg/l	0.003mg/l
Chromium	0.05 mg/l	0.05mg/l
Copper	2 mg/l	1mg/l
Cyanide	0.08 mg/l	0.01mg/l
1,2-Dichloroethane	-	-
Epichlorohydrin	-	-
Fluoride	1.5 mg/l	1.5mg/l
Lead	0.01 mg/l	0.01mg/l
Mercury	0.002 mg/l	0.001mg/l
Nickel	0.02 mg/l	0.02ml/l
Nitrate	50 mg/l	50mg/l
Nitrite (Long Term)	0.2 mg/l	0.2mg/l
Pesticides	-	0.01mg/l
Pesticides total	-	0.01mg/l
PAHs	-	0.007mg/l
Selenium	0.01 mg/l	-
Tetrachloroethene and Trichloroethene	0.08mg/l	-
Trichloromethanes total	-	-
Vinyl chloride	0.0003 mg/l	-
Aluminum	0.10 mg/l	0.2mg/l
Ammonium	1.3 -0.3 mg/l	-
Chloride	250 mg/l	0.003mg/l
Clostridium perfringens	-	-
Color	10TCU	15TCU
Conductivity	-	1000 µS/cm
PH	7.0 -8.5	≥6.5 and ≤8.5
Iron	0.2 mg/l	0.3mg/l
Manganese	0.04 – 0.10 mg/l	0.2mg/l
Odor	Odor should be acceptable	Not abnormal
Oxidizability	-	

**Table 5.2 Continued**

Sulfate	250 mg/l	100mg/l
Sodium	200 mg/l	
Taste	Acceptable to most people	Not abnormal
Total Organic Carbon	-	5mg/l
Coli form Bacteria	-	0/100ml
Hardness	200 mg/l	150mg/l
Turbidity	2.5NTU	5NTU
Chlorine	0.6 -1.0 mg/l	0.2 -0.25mg/l
TDS	1000 mg/l	500mg/l

(Source: Created from the Guidelines for Drinking Water Quality Management for New Zealand October 2005 and Nigerian Industrial Standard)

In Table 5.2, the Nigerian limits are compared with those of New Zealand, and the Nigerian limits are seen to be relatively comparable with that of New Zealand. They have many parameters where the maximum limits are the same such as nitrite, nitrate, nickel, fluoride, arsenic, chromium and lead. In few cases Nigeria either have a bit lower than New Zealand or a bit higher limits such as cadmium, cyanide and mercury, Nigeria have a little lower limits for these pollutants than New Zealand. With aluminum Nigeria has a value higher than New Zealand. This agrees with the comparison done with Germany, US and WHO. So the maximum limits allowed in the guideline are not a problem in Nigeria, they compare very well with international situations.

### **5.3 Numbers of Parameters in Developed Countries' Guidelines as Compared to that of Nigeria**

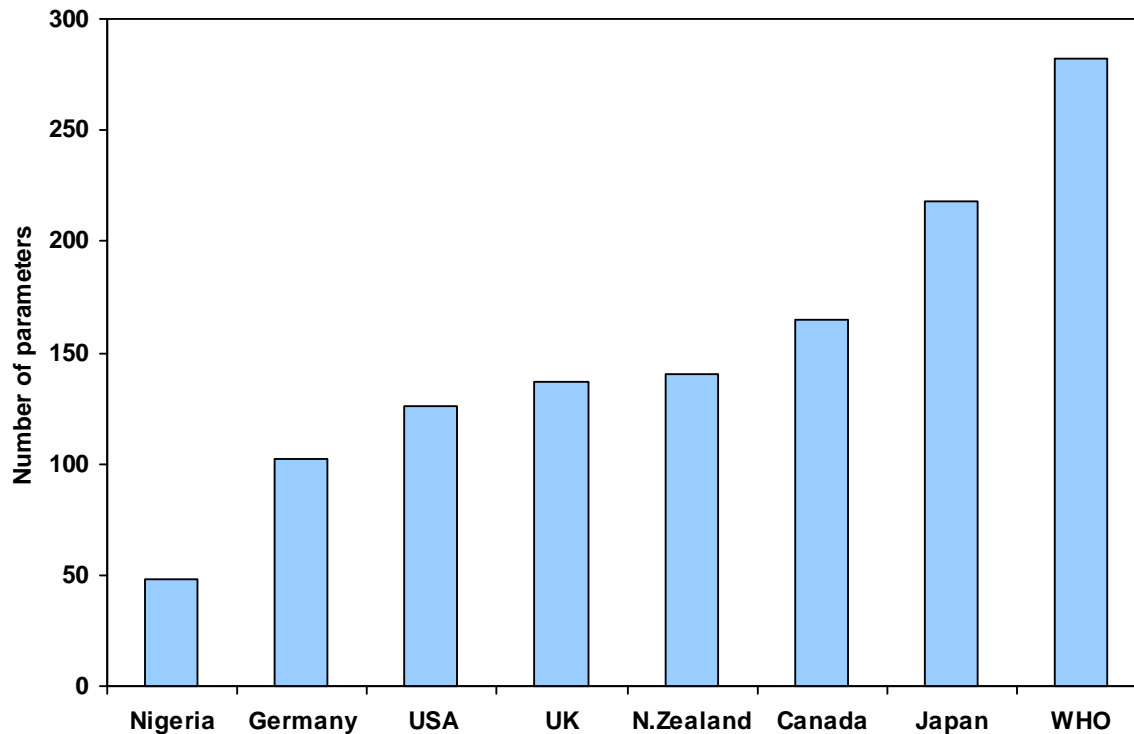
Looking at the results obtained in the research regional laboratory, many parameters were not analyzed, and some were not even listed by the laboratory. Some parameters like arsenic, cyanide, lead, mercury, nickel, etc. have very low values in the guidelines compared above which show that they are serious health related parameters which should be carefully controlled, but they were not measured in the regional laboratory results due to lack of analytical instruments. In the Nigerian guidelines many parameters are missing such as organic pollutants like benzene, dichloroethene, tetrachloromethanes, and vinyl chloride, if these parameters are not even given in the guidelines, then monitors can not even try to make effort to analyzed them. Nigeria uses chlorine in water purification and a lot of pesticides are used in the country, but byproducts from such activities are not included in the guidelines. Nkono et al (1998) used the WHO guideline in their study of trace metals in drinking water in southern part of Nigeria; another study was carried out by Musa et al (2007) they also used the WHO guideline for their study; this confirms that the Nigerian guidelines don't have all the parameters needed for drinking water analysis. In the study carried out by Musa et al (2007) Cd was found in many drinking water samples they collected, but Cd was not amongst parameters measured by the research laboratory. If a regional laboratory does not check for the presence of Cd in drinking water sample and an academic analysis detected this metal in many water samples, then there is a serious gap left between the quality of water people are drinking and the results the monitoring laboratories are providing.

The parameters for New Zealand compared with that of Nigeria, more than 100 parameters are not shown here because Nigeria don't have them so does not play any role in the comparison, but this confirms what has been said earlier that Nigerian water laboratories measure very few parameters. In the Nigerian guidelines, even though there are more than 25 parameters,

compared to what were measured by the regional laboratory; they are not up to 50 parameters in total. The Australian Drinking Water Guidelines 2003 said that guidelines are intended to provide a framework for good management of drinking water supplies, if implemented, will assure safety at point of use. If in the Nigerian guideline so many parameters are not given, this does not provide a framework for good management and can therefore endanger the lives of the end users. In the same vein the Australian guideline values are based on a consideration of the following:

- i) The limit of determination based on the most common analytical method
- ii) The concentration, calculated by WHO using a risk assessment model, that could give rise to a risk of one additional cancer per million people, if water containing the compound at the given concentration were consumed over a lifetime
- iii) Quality controlled system for management of drinking water should be supported by appropriate testing and monitoring methods
- iv) All chemicals used in treating water should be tested in portable water.

These and many other factors are being put into considerations by WHO and developed countries to arrive at many parameters for drinking water. A factor like the risk assessment can not be overlooked because a laboratory does not have the needed analytical instrument, since these are very important parameters for human health (National Guidelines on Environmental Health Practice 2007). And also so many parameters that relate to chemicals use for treating water are missing in the Nigerian guideline, this should not be so since it has to be confirmed that these chemicals have been completely used up in the treatment or have been removed..



**Figure 5.2** Numbers of Parameters in Nigerian Drinking Water Guidelines Compared with Some Developed Countries

(Source: derived from Nigerian Industrial Standards NIS 554, 2007; DVGW 2001; UK Drinking Water Inspectorate; Kleiböhmer W. (Ed); WHO Drinking water Guidelines)

Figure 5.2 is an attempt to compare how the total numbers of parameters given in the Nigeria drinking water guidelines differ from developed countries. The numbers here are approximate as they are counted directly during this work from the found guidelines of the countries from the sources quoted and they have not been confirmed from the individual regulatory bodies of the countries, but the parameters can not be less than the numbers given here, if any mistake the number of parameters can only be more than what is quoted here. So this is enough to have an idea that there are so many parameters that can be monitored in drinking water if the monitoring laboratory has the needed analytical instruments. In the WHO guideline which is the baseline for many countries guidelines, the parameters are just a little below 300 and the Nigerian guidelines have less than 50 parameters. If the guidelines give already few parameters, then it is not surprising that the field water laboratory visited has recorded only 25 parameters.

There are so many parameters which WHO terms very sensitive as health risk but are not even given in the Nigerian guideline.

#### **5.4 Comparing the Cement Pollution Control in the Research Laboratory with Developed Countries**

According to the Umweltbundesamt (2006), (German Federal Environmental Agency) they are providing quick and up to date information on exceeding of limit values for fine particulate matters at measuring stations in the Federal Republic of Germany. One of the new features is the collection of links to clean air and action plans of German states, towns and municipalities, which contain information on what needs to be done when air quality limit values are being exceeded. Elisabeth Rosenthal said “making cements means making pollution in the form of carbon dioxide emissions”. According to whom cement plants account for 5% of global emissions of carbon dioxide, the main cause of global warming and cement do not have any recycling potential, each new road, and each new building needs new cement. The work just quoted above showed that the greenest technologies can reduce carbon dioxide emissions by only about 20%. This shows how serious cement pollution control should be taken by all cement companies. The German environmental agency is not controlling particulate matter only in the cement factory and its surrounding, but practically in all cities and towns. The air pollution by cement industries are not taken lightly in the developed countries, unlike in Nigeria where the company itself does not have a good monitoring method on ground and the regulatory bodies don't have either. In September 2001 the German Cement Works Association presented the environmental data of the German Cement Industry. According to their report, the erection and operation of cement works in Germany are subject to the provisions of the federal Ambient Pollution Protection Act. Different specifications for the emission concentrations to be complied with are laid down based on the type of fuel used. If standard fuels are used exclusively, the regulations of the clean Air Act (TA Luft) are decisive. In

Germany, the competent authorities can order measurements for special reasons, such as first-time and recurrent measurements to be carried out by accredited measuring bodies. According to the same report, emissions from cement works given in Table 5.3 can be determined both by continuous and discontinuous measuring methods, which are described in corresponding VDI guidelines and DIN standards. Dust, NO<sub>x</sub> and SO<sub>2</sub> are measured in Germany continuously. If one compares this with what was obtained in the cement research laboratory in Nigeria, where there is no air quality control measurement on regular basis, then there is a lot to learn here. Also in Table 5.3 the parameters are given with their measurement methods showing that analytical instruments used in this pollution control are very important. Even though most of the standard quoted here are European standards, they have been adopted and the corresponding German standards are quoted along side. The Nigerian Standard Organization (SON) need to improve on the standards used in Nigeria, by using our own standard along side international standards as used in Germany and many other countries.

**Table 5.3 Emissions from Cement Kilns Monitored in Germany**

<b>Object of measurements (Emissions)</b>	<b>Standard, Guideline</b>
Total dust	ISO 10155 VDI 2066, Sheet 4 VDI 2066, Sheet 6
Heavy metals -Sampling -Analysis	DIN EN 13211 VDI 3868, Sheet 1,2 VDI 2462, Sheet 1-4
Sulfur dioxides	VDI 2462, Sheet 4
Nitrogen oxides	VDI 2456, Sheet 6
Carbon monoxide	VDI 2459, Sheet 6 and 9
Gaseous inorganic chlorine compounds	VDI 2470, Sheet 1
Dioxins, furans, -Sampling -Analysis	DIN EN 1948, part 1 DIN EN 1948, part 2-3
Polycyclic aromatic hydrocarbons -Sampling -Analysis	VDI 3499, Sheet 1E, 2E DIN EN 1948, part 1 VDI 3873, Sheet 1
Organically bound carbon	DIN EN 12619
Benzene, toluene, ethylbenzene, xylene	VDI 3482, Sheet 4

(Source: Verein Deutscher Zementwerke e.V. 2001)

The Verein Deutscher Zementwerke gave 37 parameters for mandatory reporting on by cements industries in Germany. The limits values are given in Table 5.4; here only 19 out of the 37 parameters for mandatory reporting are given. In the Nigerian Standard (FEPA (1991a), chapter three contains "Interim Gaseous Emission and Ambient Air Quality Control Limits". In this chapter there are only three types of air pollutants given for the cement industries, these are dust, SO<sub>2</sub>, and NO<sub>2</sub>. If we look at the 19 out of the 37 air pollutants from cements given in Table 5.4, we can say that many of these pollutants are important health risk parameters which need to be controlled by cement industries. The limits given here are for a year, which will be an average of all the measurements made in the year, in this way is difficult to compare it with the Nigerian value given per m<sup>3</sup>. Van Oss et al 2003 gave a world overview of CO<sub>2</sub> emission from cement industries. According to their review Nigeria have very small value compared to American, Europeans and Asian countries, but this is only relative to how many cement industries Nigeria have in comparison to these other countries. The many parameters not measured in Nigeria may not be high in total but high for a single industry emission. Therefore Nigeria needs to make these parameters found in the mandatory list of other countries also mandatory for cement industries in Nigeria if ambient air quality control has to be done successfully in Nigeria.



**Table 5.4 Threshold Values for Mandatory Reporting on 19 Air Pollutants Covered by the European Pollutant Emission Register (for Cement Industries)**

Pollutant	Threshold value Kg/year
Carbon monoxide (CO)	500,000
Carbon dioxide (CO <sub>2</sub> )	100,000,000
Non-methane volatile organic compounds (NMVOC)	100,000
Nitrogen oxides (NO <sub>x</sub> )	100,000
Sulfur dioxide (SO <sub>2</sub> )	150,000
Arsenic	20
Cadmium	10
Chromium	100
copper	100
Mercury	10
Nickel	50
Lead	200
Zinc	200
Dioxins and furans (PCDD/F)	0.001
Benzene	1,000
Polycyclic aromatic hydrocarbons (PAH)	50
Chlorine and inorganic chlorine compounds (HCL)	10,000
Fluorine and inorganic fluorine compounds (HF)	5,000
Fine dust (PM <sub>10</sub> )	50,000

(Source: verin Deutscher Zementwerke e.V. 2001)

The cement company in Ashaka is owned by Lafarge, which is a leader in cement production world wide. Earthjustice reported that cement manufacturers have invested millions of dollars in green programs, like cement sustainable initiative and Lafarge is a leader in doing so. This was demonstrated by the improved efficiency by decreasing emissions to 655 pounds of carbon dioxide for each ton of cement in 2006 emissions from 763 pounds in 1990 in the USA. Its goal is to get to 610pounds for each ton of cement by 2010. But even with the reduction Lafarge acknowledges that its total emissions are growing each year due to growing production of cements, which may eventually be the case in Nigeria as the country is developing and the need for cements is in the increase. Lafarge can only give the above report due to regular measurements of emissions, but these

kinds of measurements for control and planning, to reduce emission is lacking in the cement companies in Nigeria, which Lafarge is one. One will have to accept here that Lafarge is doing some green chemistry practice in Ashaka, as such the former dense dust, CO<sub>2</sub> and PM over Ashaka is not apparently seen like before, but all the same regular measurements of emissions in the factory is a necessity.

Earthjustice and the Environmental Integrity project (EIP) made a new study in the US which shows mercury pollution in the US is double what EPA claimed. According to their results Lafarge North America Inc. shows up on the top of the polluting cement Kiln list twice, at rank four with 400 pounds of mercury per year and rank five with 360 pounds of mercury per year, with its plants in New York and Michigan, US, respectively. This study shows that the cements companies are making reports of their air pollutants control regularly and even when the pollutant limit is exceeded. Earthjustice just did this study to confirm if the reported results are right. In Nigeria even the monitoring by the regulatory bodies is lacking, as such there is no record of how much emissions these companies are emitting per year. Pollutants like mercury, in the Nigerian situation, in the absence of emission monitoring and emission controls in cement Kilns; will be released into the environment. Pollutants like mercury are a great health risk to human beings. The situation in Nigeria now seems to be the one that cement plants have no obligation to control or even measure their air pollution continuously, therefore there is no way of knowing exactly how much of pollutant like mercury these facilities actually emit, which is contrary to what is obtained in the US and other developed countries.

# SECTION 3

## CONCLUDING SECTION:

### SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

# Chapter 6 Summary, Conclusions and Recommendations

## 6.1 Summary

The summary of findings in this work is done briefly here to give a recap of some important points. This covers findings from the literature review, field results and discussions. Some of the main points include the following:

Environmental pollution as the introduction of substances or energy into the environment with the result of deleterious effects on animals, humans, plants and property is a fact in our time. From the research it can be summarized that environmental pollution is a big threat to the whole ecosystem of our planet. As a result, there is a large growing public concern world wide over the effects of this environmental pollution on human health. Environmental pollution is no longer a problem of the industrialized countries only; the developing countries are fast overtaking the industrialized countries. This is partly because the industrialized countries unlike the poor developing countries can afford high standards of pollution control. In the developing countries in most cases, there is not the understanding, the commitment or the resources to apply high standards of environmental protection.

Nigeria like many developing countries with some kind of industrialization has its own share of environmental pollution problems. The oil industries in Nigeria are the biggest polluters of the Nigerian environment. Incidences like oil leakage, oil pipeline damage or even complete breakage, fire out break at oil leakage sites, gas flare, etc have been discussed in this work as some ways the oil industries contribute in polluting the Nigerian environment. Environmental pollutants are enumerated in this work to include air, water and soil pollutants such as PCBs, VOCs, DDT, HCB, Heavy metals and their compounds, PM, NO<sub>x</sub>, CO<sub>2</sub>, oil in water, etc. In the literature many analytical methods are used in environmental pollution control, these

have been enumerated in detail in this work. The scope and the complexity of environmental pollution demands that analytical instruments be chosen carefully for the purpose of effective pollution control. It has been shown in this work that the choice of analytical instruments in environmental pollution control is largely guided by laws and regulations. In the developed countries environmental standards specify analytical methods to be used in meeting these standards. Standards are therefore crucial element in environmental monitoring process.

Similarly environmental laws and regulations are necessary to protect and enhance the environment. In this work so many laws and regulations from different countries have been discussed so as to see how the Nigerian laws and regulations are doing compared to those of developed countries. This comparison is done because to be able to determine correctly what analytical instrument is to be used, the knowledge of the various environmental laws and regulations is necessary.

In looking at the Nigerian regulations, first the Nigerian environmental legislations, regulations, guidelines and standards were studied as found in literature. These regulations, guidelines, standards were mainly those from the then FEPA, but some few are found that were drafted under the supervision of Standard Organization of Nigeria (SON). These laws were then studied under field work when the regulatory bodies were visited. Types of industries found in Nigeria are discussed in this work so as to see what types of pollutants are found in Nigeria. There are four main sectors of industries in Nigeria which are:

- i) Primary sector e.g. crude oil extraction,
- ii) Secondary sector e.g. NNPC Refineries,
- iii) Tertiary sector e.g. distribution of manufactured goods
- iv) Research and Development.

Amongst these industries crude oil production has the largest value of annual output.

From the types of industries found in Nigeria, some environmental pollutants from these industries can be expected to constitute some problems in Nigeria, such as pollutants from oil production e.g. BTEX, VOCs, PM, etc. These pollutants are listed in this work in details so as to help in looking at analytical instruments needed for their analysis.

During the field work in Nigeria, seven organizations were visited, two of which are industries, two regulatory monitoring laboratories, and three are regulatory bodies. Industries visited are Nigerian National Petroleum Corporation (NNPC) Kaduna later known as Kaduna Refining Petrochemicals Corporation (KRPC) and Ashaka cement factory. Regulatory laboratories visited are National Reference Laboratory Lagos and Federal Ministry of Water Resources Regional Laboratory Gombe. Regulatory bodies visited are Standard Organization of Nigeria (SON), Federal Ministry of Environment, Housing and Urban Development, and National Environmental Standards and Regulations Enforcement Agency (NESREA).

The findings in NNPC show they have an environmental pollution control unit. This unit has some field hand held analytical instruments for insitu analysis. These analytical instruments and the sample results obtained using these instruments indicate that some pollutants in the treated waste exceed maximum allowed limits and only few basic analytical instruments are available in the laboratory. NNPC also has a big chemistry laboratory, and the main environmental pollution controls are done in the water laboratory section. Here they control basic parameters like BOD, COD, conductivity, heavy metals, inorganic compounds, etc. Sample results obtained from this laboratory give the picture of the types of parameters analyzed and the quality of the results in regards to limits. In the sample results 33 parameters were recorded, where some are not analyzed for lack of analytical instruments, with the consequences that many pollutants could be discharged into the receiving rivers above allowed limits. In the NNPC chemistry laboratory analytical instruments found there include different types of spectrometer, meters for pH, DO, conductivity, etc. A gas chromatography

was found in the oil laboratory but it was not in used as of the time of this research.

In Ashaka cement factory, they have a chemistry laboratory which was mainly use for process control. The analytical instruments found there were those suitable for testing cement quality. There was no gas laboratory section for air analysis. It was gathered that the air quality control is contracted out.

The National Reference laboratory Lagos has some good analytical instruments such as HPLC, GC, AAS, flame photometer, etc. But the laboratory has been out of use for so many years and until the time of this research it was not functional.

The Federal Ministry of Water Resources Regional laboratory Gombe has some analytical instruments for monitoring drinking water quality. The analytical instruments found there include HACH colorimeter DR 890, meters for PH, DO, and conductivity, flame photometer, BOD reactor, total organic carbon analyzer, etc. Sample results analyzed using these equipments were collected and they were analyzed in this work in detail. The results revealed that most of the parameters analyzed in the samples meet required standards, but there are many parameters that were not tested for in the samples. The regulatory bodies visited are those responsible for monitoring pollution control in the Nigerian environment and in industries. The standards obtained were those from FEPA, or those drafted under the supervision of SON. NESREA have drafted some standards and regulations, but they were not yet in used as of the time of this research.

The Federal Ministry of Environment, Housing and Urban Development are directly involved in monitoring environmental pollution control done by the other agencies. The laws, standards and regulations written by the agencies are done directly or indirectly under the ministry's supervision.

In the discussion section of this work, the laboratories analytical instruments seen and results collected were used to discuss the laws and standards. The summary of the analytical instruments found in the laboratories is that there are mostly only basic instruments available in both the industrial and regulatory laboratories. In comparison with the types of analytical instruments found in the literature and the developed countries, the research laboratories are lacking many of the needed analytical instruments.

The laboratory results were analyzed to see how good the instruments and the analysts did those measurements. The standard deviations of the results were calculated and they show that these results differ very largely from each other, which shows that the results were not precise. Another way used to see how good the results were, was to compare them with the Nigerian maximum limits, the NNPC results were higher than the maximum limits in many cases. The Gombe regional laboratory results compared fairly well with the Nigerian maximum limits for drinking water.

Air pollution quality control analytical instruments were lacking in the research laboratories. Even in NNPC as a big oil industry, there was no air quality control unit in the laboratory. In Ashaka cement factory the air quality control is done occasionally by outside contractors, and this does not agree with the Nigerian ambient air quality control standard.

The monitoring laboratories in general were either grossly underequipped or does not function at all. The role of the National reference laboratory is important in environmental pollution control, but the national environmental reference laboratories in Nigeria are not functional which calls for concern.

The regulations, laws, and standards obtained in Nigeria have been discussed in the light of what are obtained in developed countries. In doing this, some results obtained from the research laboratories are compared with some results obtained in developed countries to see what role the laws and regulations played in choice of analytical instruments. The results showed that while developed countries specify in laws, guidelines and



standards what analytical instruments should be used for each set of parameters, the Nigerian laws, standards and guidelines do not. Therefore the Nigerian standards for pollutants monitoring, compared to developed countries standards need to be updated or even new editions need to be written.

In the international standards and guidelines, analytical instruments play very important role as limits are set based on measurement abilities of analytical instruments. Suitable analytical instruments for particular pollutant are always given in the standards and guidelines; this is demonstrated by the sample results from developed countries where they always quote what instruments according to what guideline they used in their analysis. In the Nigerian guidelines analytical instruments are not specified sufficiently, and therefore the laboratories can not quote what types of instruments they used according to what standard. Measurements even of the same laboratory over time or across the country thus may not be comparable.

One of the deficiencies of the Nigerian guideline is that many pollutants are not addressed in the guideline. Compared with the developed countries, Nigerian guidelines contain fewer parameters. In the Nigerian guideline, environmental pollution by the cement industries are not taken serious, but in developed countries pollution caused by cement industries are taken serious, so much that the industries have to do regular pollution control and report the same to the regulatory bodies.

## 6.2 Conclusions

After looking at the state of the environment both globally and in Nigeria, the role of analytical instruments in environmental pollution control, and from what was obtained in the research areas; one can draw some conclusions as follows:

- **The State of the Nigerian Environment**

The UN Geneva Declaration on the right to development recognizes that the right to development is an essential human right and that the human person is the central subject of development. The Declaration also recognizes that sustainable development links the right to development and the right to a secure, healthy and ecologically sound environment. They were also convinced that the potential irreversibility of environmental harm gives rise to special responsibility to prevent such harm. It can therefore be concluded that the state of the Nigerian environment violets human rights in a lot of ways. The Niger Delta situations calls for concern, but much more than this is the water that Nigerians drink and the air they breathe daily, which can not be proved by analytical results to have met standard. The Nigerian government through its regulatory bodies in environmental pollution control has the duty to protect and preserve the environment. And for the Nigerian government to do this, efficient measurements of pollutants so as to meet standards, do proper control and remediation of polluted sites is a vital part of the solution and for this, accurate and reliable analytical tools and methods are needed in environmental monitoring laboratories.

- **Industries in Nigeria and Pollution Control.**

The major source of environmental pollution in Nigeria is petroleum and it's by products, from petroleum industries. Petroleum refineries are a major source of hazardous and toxic air, water and soil pollutants such as benzene, toluene, ethylbenzene and xylene (BTEX) etc. It has been established in this work also that other industries such as cement industries, metal industries, food, beverages and tobacco, chemicals, agriculture, tex-

tiles & clothing, mining, pulp and paper industries all contribute in the types of pollutants found in Nigeria. Therefore environmental pollution is a real problem in Nigeria and it affects air, water and the soil. Even though pollution is a real problem in Nigeria the pollution control in the industries are not taken serious both by the industries themselves and the monitoring organizations.

- **The State of the Analytical Instruments Found in Environmental Monitoring Laboratories in Nigeria**

It has been established in this work that, a critical component of environmental monitoring is the type of analytical equipments used to analyze environmental samples. It has been shown also that the choice of methods is usually dictated by the environment monitored, the parameter to be monitored, and data quality required either for legal purpose or maintenance. For any of the given reasons, an analyst must select a scientifically sound method, approved by a regulatory body. Several national and international agencies provide guidelines and approval of analytical methods for use in environmental monitoring. In Nigeria the situation is not very ideal and the analytical instruments used in the laboratories visited are not up to standard compared with what are obtained in the developed countries. Therefore the following conclusions on the state of the analytical instruments in environmental pollution control in Nigeria are made:

1. Most instruments found are basic instruments for measurements of basic parameters like BOD, pH, Turbidity, etc. The high tech, sophisticated analytical instruments or even many of the classical instruments used in developed countries to test for parameters like VOCs, heavy metals, PAHs, PCHs, etc are lacking in the visited laboratories.
2. In Ashaka, one can conclude that air pollution control is not done on daily basis; as such the chemical laboratory found in the industry is only for products control and not for environmental pollution control.

3. The results obtained from the research laboratories do not show the equipments used by the laboratories are working very well as indicated by the standard deviations calculated and from comparison with results from developed countries.
4. None of the visited laboratory showed a proof of their participation in proficiency testing (PT) programs. Therefore it can be concluded that proficiency testing is hardly done in Nigeria in environmental monitoring laboratories.
5. No single calibration and validation data was obtained from the laboratories, this can lead to the conclusion that the laboratories do not carry out calibration of their analytical instruments with time; they used all the time the initial calibration from the suppliers of the analytical instruments.

- **The Nigerian Environmental Pollution Control Regulatory Bodies**

The environmental regulatory bodies in Nigeria are: i) The Federal Ministry of Environment, Housing and Urban Development; ii) The Standard Organization of Nigeria (SON); iii) National Environmental Standards and Regulations Enforcement Agency (NESREA); iv) The States Ministries of Environments. SON have developed or supervised developments of some guidelines and standards. These guidelines and standards need to be updated or even new editions need to be written in the light of what obtained in the developed countries. Analytical methods needed to meet these guidelines are not specified in the laws, regulations and guidelines. The National Environmental Reference laboratories are not functioning as such it can be concluded that NESREA and the other monitors are not able to monitor any analytical results from any environmental laboratories even those from the industries. The result is that many pollutants are being disposed into the Nigerian environment such as receiving rivers, air, soil, etc, above allowed maximum limits. Comparing the Nigerian environmental standards with what is obtained in developed countries, the Nigerian standards have less

parameter included in it, and analytical methods are not given in details as in developed countries' standards. The Nigerian standards and guidelines used have not been updated and the editions found are mostly old editions that have been written long ago. The conclusion here is that the monitoring and regulatory bodies in Nigeria have standards, guidelines and regulations that are obsolete in comparison to the developed countries.

The bigger 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 favorably compare to international standards.

### **6.3 Recommendations**

Agha et al in their paper titled "The Development of Environmental Guidelines and Standards for the Petroleum Industry in Nigeria; A systematic Approach and Future Challenges" said as part of its statutory functions, the department of Petroleum resources is charged with the responsibility of ensuring safe and environmentally friendly oil and gas production. They said in order to achieve this responsibility the department has been developing environmental guidelines and standards covering all aspects of oil and gas operations since 1981. The departments has since then updated and produced guidelines and standards for the industry with a latest edition issued in 2002 (Environmental Guidelines and Standards for Petroleum Industry in Nigeria 2002). In this latest edition of the guidelines and standards there exist the philosophy of zero discharge in respect of some categories of wastes resulting from the exploration and production activities of oil companies. One of the objectives of this new edition is to standardize the environmental pollution abatement and monitoring procedures, including the analytical methods for various parameters. It is recommended here that

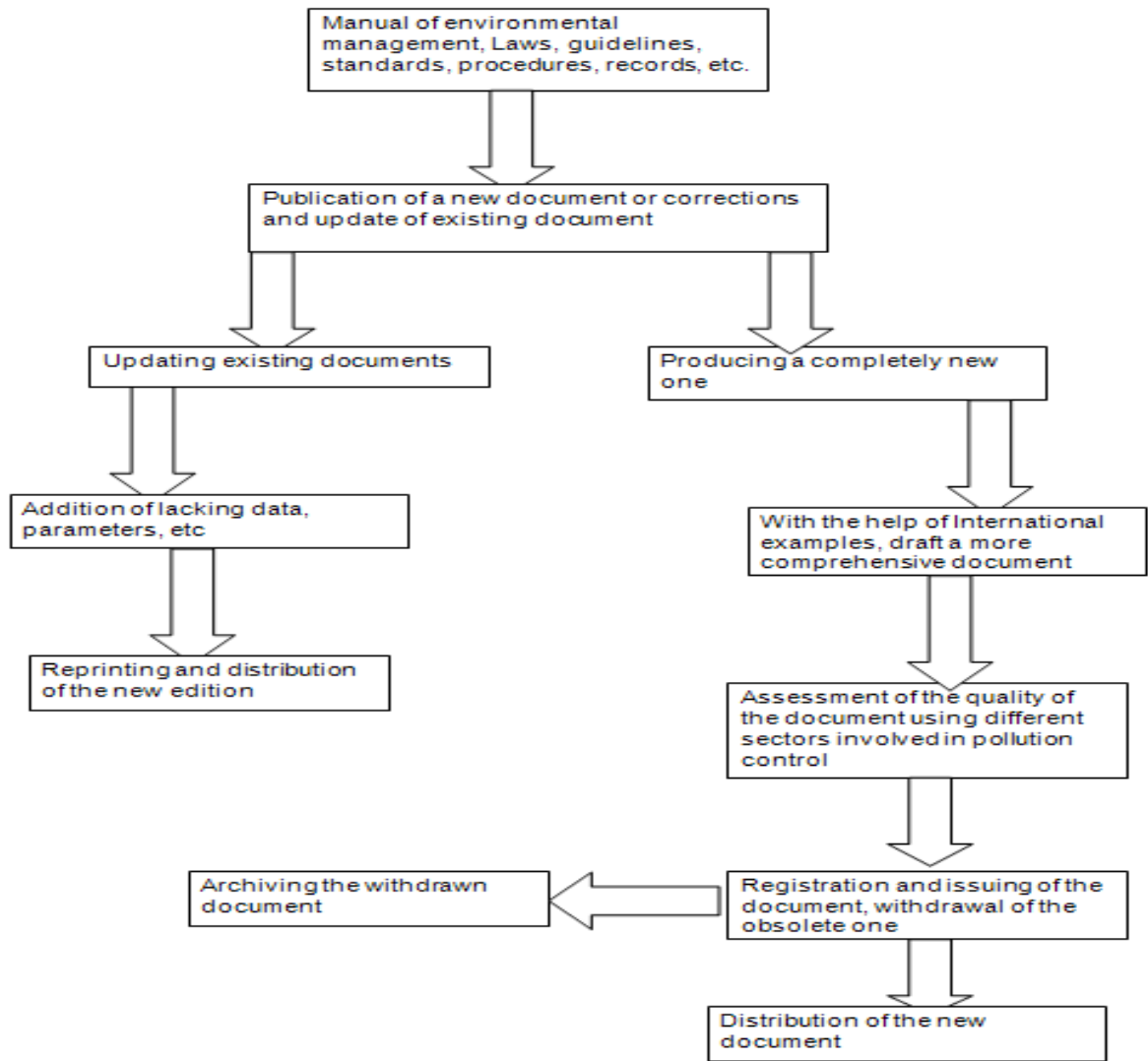
SON should do the same standardization of its laws, standards and regulation to include the analytical instruments and methods for various parameters so as to ensure zero discharge in respect of some dangerous pollutants.

Nigeria WaterAid has seen that the ability of local governments and water boards to test for drinking water quality has been limited by the availability of suitable equipment and the absence of sector wide standards that all testing bodies must adhere to. In the past in Nigeria, the World Health Organization drinking water quality guidelines have loosely formed the basis for testing but it been difficult to measure the full range of parameters because of equipment shortages. This findings by WaterAid Nigeria has been established in this work that analytical instruments in environmental monitoring is a problem in Nigeria and the standards, laws and regulations are not adequate for proper monitoring. The Millennium Development Goals (MDGs) represent a renewed commitment to overcome persistent poverty and to address many of the most enduring failures of human development. The MDGs agreed by the international community in 2000 comprise 8 goals, 18 targets and 48 indicators. Water is interconnected with all 8 MDGs goals and basic sanitation was added to the list at the 2002 World Summit on sustainable development in Johannesburg. Halving by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation is one of the quantified and time bond targets defined for the MDGs. Therefore there is the need to monitor progress towards achieving these goals on water and sanitation. To achieve this there is the need for background information and reliable statistics about the sector. The criteria to describe what is meant by good monitoring and valid, reliable data relate to questions such as: is the data accurate? Does it reflect what is supposed to be measured? Are the measurements and data collection procedures reliable? Can the information obtained be compared favorably with others from different sources? In the light of the above concerns and the findings from the research laboratories and organizations, it can be generally recommended that the need for validity and reliability in data collection, analysis, guidelines, standards and use of data 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. Therefore the following recommendations are made for the consideration of the Nigerian environmental stake holders:

### **Regulatory Bodies in Nigeria**

- The regulatory bodies in Nigeria need to have a method in which their environmental regulations, standards, guidelines and laws are updated regularly. In this vein the following procedure in Figure 6.1 is recommended; starting from auditing all existing documents in respects of the laws, regulations, guidelines and standards, then looking into the need whether to update or draft new documents, etc. as shown in Figure 6.1. From what has been seen in the field many of the environmental guidelines, standards and laws need to be recast from time to time to take care of the so many parameters missing and to include the scope of analytical methods that can be used in monitoring environmental pollution. Use of some International guidelines such as that of DIN Germany, EPA USA, Canada's guidelines, etc are recommended as guide in drafting new environmental guidelines in Nigeria. It is recommended here that new editions of these guidelines should be made rather than updating. Making new editions will make room for including the necessary parameters and analytical instruments and methods.
- As has been established in this research, many parameters that have health risk to humans and even to animals are lacking in the Nigerian guidelines, which means they are not tested for in drinking or waste water, with the consequence that people can be consuming some pollutants without knowing they are even there in their water. For drinking water guidelines the WHO guidelines is recommended to be used to add more parameters to the Nigerian guidelines. Other developed countries like Japan, Canada, etc have many parameters included in their guidelines, these can be of help in drafting new guidelines and regulations in Nigeria.



**Figure 6.1** Recommended Procedures for Guidelines, Standards, and Laws Drafting

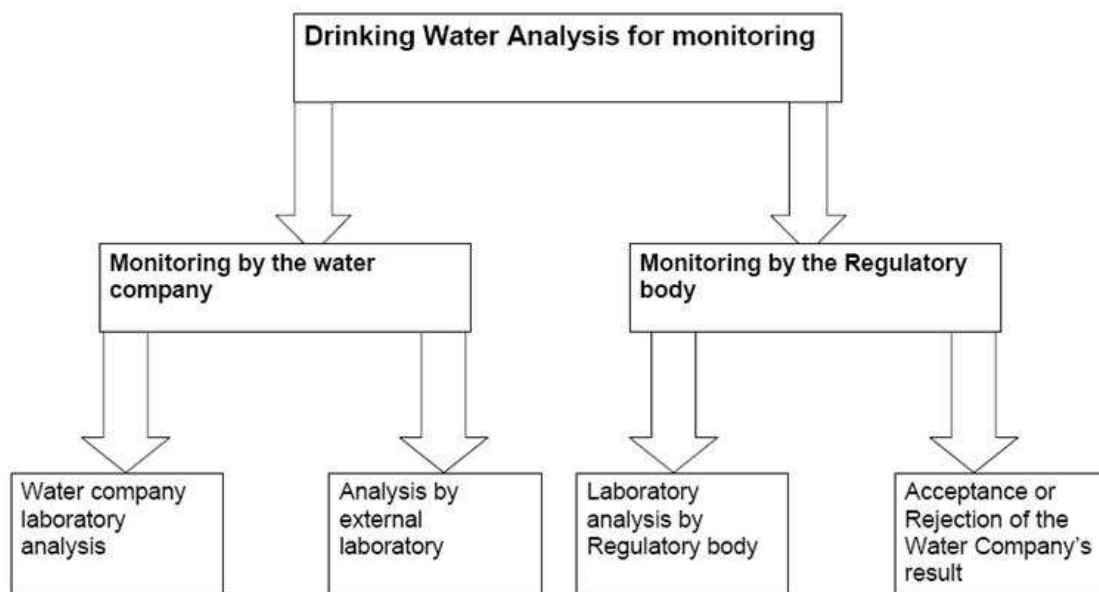
- Parameters like chlorine by products should be included in guidelines since Nigeria uses chlorine in water treatments and many organic byproducts like pesticides, as they are used a lot in farming in Nigeria.
- The Guideline for Drinking Water (2001) in Germany demands that every three years a report over the drinking water quality is to be published. This was done recently in 2008 by the German Environmental Agency, they did this using reports submitted to them and the



Ministry of Health by 16 states in the period from 2005 to 2007 (Germany's Water Quality Report 2008). From this report the Environmental Agency showed to the public that 99% of the biological to the chemical parameters measured by the water suppliers met requirement and did not exceed the maximum limit. The water suppliers themselves periodically publish their results on line for the public to have a look. This system of regular systematic reporting and making the results public is strongly recommended for the Nigerian environmental pollution control stakeholders.

- Analytical instruments in the Nigerian guidelines: It has been established in this work that the values in pollution control monitoring are set at the reasonable analytical limits. As such analytical methods or analytical instruments are very important part of any standard, guidelines or law in environmental pollution control. It is therefore recommended here that regulatory bodies in Nigeria define in details in the guidelines, standards and laws what analytical instruments and methods are to be used to comply with these guidelines, standards and laws so that results can be reliable and comparable to other laboratories. It is also recommended here that in laboratories' results they should not only give the maximum allowed limits but also the specific analytical methods used for specific analysis according to what standard. Before the Nigerian standard can be updated to include specific analytical methods for specific analysis, it is recommended that international standards with these specifications should be adopted; a good example here is DIN from Germany. Also US EPA has developed a large number of standard analytical procedures, many of which parallel that of APHA standard methods, other international and country specific standard methods which cover procedures and methods for sample collection and analysis for environmental parameters are available which can be used in setting the Nigerian standard methods. It should also be indicated in these laws, standards and guidelines that they should be reviewed, in like three or four years.

- National Reference Laboratory: The environmental National Reference Laboratory is a vital tool in the hands of the regulatory bodies, where they are able to see what is happening in the industrial laboratories in terms of pollution monitoring. Without their own laboratories, the regulatory bodies can not make good judgment on the quality of measurements and on whether limits have been exceeded or complied with. They will not have routine check on the values submitted by the industries and other pollution monitors.



**Figure 6.2** Monitoring of Drinking Water by Both Suppliers and Regulatory Bodies

Figure 6.2 illustrates the proposed monitoring of drinking water by both the water suppliers and the regulatory bodies as an example of the role of regulatory bodies in monitoring using their own laboratory. Here it can be seen that for the regulatory bodies to be able to accept the results of the water companies they need to make laboratory analysis themselves. As such National Reference laboratory is very important for the regulatory bodies to make correct judgment. It is strongly recommended that the National

Reference laboratories in Nigeria be activated and equipped with good analytical instruments for control of the other environmental pollution monitors.

- The regulatory bodies in the environmental pollution control in Nigeria need to cooperate very strongly between themselves for effective control. There are many environmental regulators with similar and identical responsibilities in Nigeria. Harmonization and clear allocation of responsibilities are recommended here. If this is done with a strong cooperation between the environmental regulators, they can be able to work more effectively. Regulators should be able to set up good databank and provide baseline data for any further work on the environment and for their own good coordination. Above their cooperation there should be political commitment at the higher levels within and among administrators related to policy making on environmental protection.
- Cement industries in Nigeria: The regulatory bodies in Nigeria should look at limits for cement producers with the view to update it and to add many missing cement pollutants seen in the developed countries. There is a need for strong regulations that satisfy the long-standing but long-ignored federal mandate to control pollution from the cement industries. Cement industries should be requested to install pollution control monitoring instruments in their laboratories, not only process monitoring analytical instruments. Continuous Emissions Monitoring system (CEMs) should be installed to monitor emissions at every kiln. Most importantly the regulatory bodies should have a means of routinely testing cement kiln emissions. According to the Verein Deutscher Zementwerke, there are 37 parameters for mandatory reporting on by cements industries in Germany. The kind of regular mandatory reporting as in Germany and the USA cited earlier on should be done in Nigeria by the cement companies and the results should be controlled periodically by the monitoring organizations to establish that the industries are really doing the monitoring of their pollutants.

### **NNPC Refinery Kaduna**

During this research it has been established that many test are not made in NNPC chemical laboratory due to lack of analytical instruments. The company needs to look into its analytical capacity vis a vis the pollutants they need to control. There are many standard analytical instruments that the company can use to monitor some pollutants effectively. As already mentioned the chemical composition of petroleum and petroleum products is complex and may change over time following release into the environment. These factors 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. These methods can be found in the theoretical parts of this work in chapter two, but other methods such as EPA 600 series; methods for organic compounds analysis of waste water, SW-846 series; Test methods for evaluating solid waste, EPA Method 8015B; GC methods for determining the total petroleum hydrocarbons in a sample, etc. are recommended to NNPC for their test. The most widely utilized text of standardized analytical procedures for waste water and aqueous environmental samples is the standard methods for the examination of water and waste water by APHA, 1998, these methods can also be used by NNPC. The company should also do its best to adhere to maximum limit of waste water pollutants so that they don't discharge treated waste water with higher levels of pollutants into the receiving river. The monitoring organizations in Nigeria should also make sure that NNPC and any industry for that matter adhere to maximum limit of pollutants in their treated waste before discharging it into the receiving environment.

### **Ashaka Cement Factory**

The priority in Ashaka cement industry should be to minimize the increases in ambient particulate levels by reducing the mass load emitted from the stacks, from fugitive emissions, and from other sources. Collection and recycling of dust in kiln gases is required to improve the efficiency of the operation and to reduce atmospheric emissions. If Ashaka cement industry can have units that are well designed, well operated, and well maintained they can normally achieve generation of less than 0.2 kilograms of dust per metric ton of clinker, using dust recovery systems, this seems to be done to some extent already in Ashaka, but can be improved upon. But even with well maintained units, the industry needs to do a daily check on its pollution, to ensure that the emissions to the environment are not above required limits. In the developed countries, most cement industries are involved in green programs like cement sustainable initiative, some plants have installed scrubbers to control sulfur dioxide, and mercury emissions should decrease as a co-benefit. But the greenest technologies can not replace effective control by testing for the pollutants in the emissions to the environment, because it is believed that the greenest technology can reduce for example carbon dioxide emissions by only about 20%. Therefore Ashaka cement needs to equip its chemical laboratory with air pollution control analytical instruments to ensure that Threshold Limit Value (TLV) of air pollutants have been adhered to in the company.

### **Federal Ministry of Water Resources Regional Laboratory Gombe**

Many parameters recorded in the laboratory test form were not measured for lack of analytical instruments; other hazardous, toxic and high risk parameters were not even recorded for testing. The regional laboratories are controlling pollution that gets into drinking water, which makes their work very important and serious since it affects people's health directly. Without good standard analytical instruments and measurement techniques in these regional laboratories, the Nigerian people can be drinking toxic chemicals in their water which can lead to untimely death especially in children. For example mercury is not tested in the research regional laboratory, but we know that if mercury is present in drinking water at concentrations above

1ng/L, it is considered unfit for human consumption, but when such drinking water is not tested for mercury then people can be consuming mercury in the water at a higher amount than 1ng/l. The Drinking Water Guidelines of the WHO should be used in these regional laboratories because they contain as many parameters as are possible and the analytical instruments needed for these tests should be supplied to these laboratories. Since Primary Drinking Water standards are protective of human health, every effort should be made by the Nigerian governments to give these laboratories all they need to function well otherwise these lack of analytical instruments can be causing people their health even their lives. Since the costs of these analytical instruments are not above the Nigerian government, effort should be made to make them available to the laboratories.

### **Analytical Instruments in the Environmental Laboratories in Nigeria**

As already said analytical instruments play very important role in environmental pollution control if limits have to be met and met effectively. Therefore all environmental laboratories in Nigeria need to seek to use the best current practice of environmental analysis. The comprehensive list in chapter two of this research and other developed countries analytical methods should be adopted in Nigeria. This research has established that the environmental analytical instruments used in Nigeria are mostly obsolete; they are at times completely absence. The requirements for any good environmental practice are minimum QA/QC activities and good analytical instruments are the major condition for success. Therefore the analytical community in Nigeria should continue to press for standards and guidelines that will ensure effective control of pollution in the analytical laboratories. Analytical instruments should be periodically calibrated apart from the initial calibration from the manufacturer, there should be periodic recalibrations done in the laboratories. The instruments used in environmental monitoring and analysis are often extremely sophisticated, but without a proper calibration, their measurements have no meaning. Thus most instruments require calibration with a point of reference because measurements are essentially instrument response comparisons. The instruments should also be validated in certain intervals to establish they are still functioning as ex-

pected. The analytical laboratories should have the chance to participate in proficiency testing programs to keep them up to date in their practice. Also reference material should be made available to the environmental laboratories for use to calibrate the analytical instruments.

## **6.4 Outlook**

The research has provided a picture of what is obtained in Nigeria in the environmental analytical laboratories using the study areas. This is a first attempt in looking at the role of analytical instruments in environmental pollution control in Nigeria. It has been established that in developed countries, analytical instruments play very important role in environmental pollution control. Results are written quoting what environmental standards or regulations were used for the analysis. This study has a lot of limitations to venture into covering all environmental laboratories in Nigeria, limitations like time, financial resources, etc. Environmental pollution management in Nigeria are done in many levels like Federal Government level, State and Local Government levels, private and industrial sectors. This research has revealed many areas where deeper investigation can be made in the future. Therefore future researchers are advised to explore the following areas to develop and improved environmental management in Nigeria through the environmental analytical laboratories.

As already discussed in this research, 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. The laboratory results obtained did not show that these kind of measurements are being achieved in the research area. But it should be noted here that the number of collected results in this research

was too small to serve as a representative of all the environmental laboratories' results, it might be even worse in some laboratories. Therefore follow up research should venture into comprehensive studies of all laboratories involved in environmental pollution control in Nigeria, to assess the state of their analytical instruments if proper monitoring is to be done. This should include, all national laboratories involved in environmental pollution control, state laboratories, local government laboratories, industrial laboratories and private ones.

The prerequisite for good quality monitoring laboratories is good regulations which defined methods that can be used in environmental pollution control to comply with rules and regulations. This research has shown that International environmental guidelines and regulations define measurement methods to be used in complying with guidelines so as to have standards for measurement. If our environmental regulators want the Nigerian environment to be managed effectively and in a sustainable manner, then they should consider defining clearly and in details measurement methods that should be used in environmental pollution control. Although effort has been made in this research to show guidelines that have defined clearly and in details measurement methods, further research that can focus mainly on this is needed. A comprehensive study of other International guidelines in comparison with that of Nigeria may convince Nigerian environmental regulators to see the role of analytical instruments in environmental pollution control and insert this into the guidelines.

In the Nigerian guidelines many parameters are missing such as organic pollutants like Benzene, Dichloroethene, Tetrachloromethanes, and Vinyl Chloride, if these parameters are not even given in the guidelines, then monitors can not even try to make effort to analyze them. Nigeria uses chlorine in water purification and a lot of pesticides are used in the country, but byproducts from such activities are not included in the guidelines. In the light of this, a further research is needed first to show that these pollutants are present in our environment and so need to be monitored; secondly the research should make it clear that the guidelines need to be improved on



by adding these many missing pollutants. In conclusion, this research has revealed many areas where deeper investigations could be made. The few mentioned here are just some few examples of the many dearly needed researches in this area of environmental monitoring; a careful study of the recommendations can reveal more future research areas.

## References

- Ade. A; Kanayo.O and Friday O.  
Econpapers; 22.08.2005 <http://129.3.20.41/eps/othr/papers/0508/0508009.doc>  
(Accessed 13.10.2007)
- Adelegan J. Akinkugbe (2003)  
[http://www.schusterweb.com/lsee/papers/8008\\_AdeleganJA.doc](http://www.schusterweb.com/lsee/papers/8008_AdeleganJA.doc)  
(Accessed 18.12.2007)
- Agha G.U, Irrechukwu D.O, and Zagi M. M (2004)  
<http://www.nioc-hse.net/Download/pdffiles/papers/spe86640.pdf>  
(Accessed 13.10.2008)
- Ajao.E.A; Okoye B.C.; and Adekanbi E.O.  
<http://iodeweb1.vliz.be/odin/bitstream/1834/269/1/Ajao.pdf>  
(Accessed 14.08.08)
- Akpofure E. A (Dr.); Efere M. L. (Chief); Ayawei Prosper (Dr.)  
[http://www.waado.org/environment/petrolpolution/oilspills/oilspillsimpact\\_titlepage.html](http://www.waado.org/environment/petrolpolution/oilspills/oilspillsimpact_titlepage.html) (Accessed 13.07.2007)
- Albaret C.; Loeillet D.; Auge P.; and Fortier P.L.;  
Application of Two-Dimensional <sup>1</sup>H-<sup>31</sup>P Inverse NMR spectroscopy to the Detection of Trace Amount of Organophosphorus compounds Related to the chemical weapons convention; Anal. Chem. 69, 2694 – 2700 (1997)
- Albion Water Company (ALB)  
UK Drinking Water Inspectorate Annual Report London 2008
- Allchin Douglas  
<http://www1.umn.edu/ships/ethics/minamata.htm>  
(Accessed 10.06.2009)
- Amdur M.O and Duoll J.  
[www.hanford.gov/dqo/project/level5/Ecoasr.pdf](http://www.hanford.gov/dqo/project/level5/Ecoasr.pdf) (Accessed 10.03.2007)
- Analytical Instruments, LLC ;  
<http://www.aibltd.com/detail.cfm?autonumber=77363> (Accessed 13.07.2007)
- Analytik Jena;  
[http://www.analytik-jena.de/en/Products\\_\\_3694/](http://www.analytik-jena.de/en/Products__3694/) (Accessed 13.07.2009)
- Anderson, J.M. and Ingram, J.S.I.(1989).  
Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International, UK. 1-100.
- AOAC (1980).  
AOAC methods of analysis. 13<sup>th</sup> edition.2.021-2.104.

- APHA (1992). Standard methods for the Examination of Water and Wastewater. 17<sup>th</sup> edition. American Public Health Association, Washington, DC
- Artiola J.F, Pepper I.L, Brusseau M.L (Editors) Monitoring and Characterization of Environment, Elsevier Academic Press 2004.
- Australian Drinking Water Guidelines, Australian Government  
Endorsed by NHMRC 10-11 April 2003
- Averdieck, J. William, C. Eng., ImechE. Continuous Particulate Monitoring; Environmental Instrumentation and Analysis Handbook; pp 329; Wiley (2005)
- Blacksmith Institute's Report 2007  
<http://news.bbc.co.uk/2/hi/americas/6995621.stm> Accessed 12.10.2008
- Blume, H. P, Hotman,I, Mouimou, D. and Zingki, M. (1983).Soil Association upon and near a waste disposal site. (Inst: Quekol Tech. Univ. Berlin; Berlin Fed. Rep.) Z. Flangemernaehr Bodenkl, 146 (1) 62 –71.
- Bradford. T and Cook M.N. (2003)  
<http://www.cee.vt.edu/ewr/environmental/teach/smprimer/icp/icp.html>
- Burns, KA 1993 Marine Pollution Bulletin [MAR. POLLUT. BULL.]. Vol. 26, 2, pp. 68- 72
- Business Dictionary  
<http://www.businessdictionary.com/definition/environmental-pollution.html>  
Accessed 02.07.2007
- Cai Weil; Li Yi; Gao Xiaoming; Guo Hongsun; Zhao Huixin; Wang Ping; American Institute of Physics Conference Proceedings (2009) 1137, 493-496
- Chemistry Dictionary  
[http://www.answers.com/topic/pollution#Chemistry\\_Dictionary\\_ans](http://www.answers.com/topic/pollution#Chemistry_Dictionary_ans) Accessed 02.07.2007
- Christopher Roden; March 2005  
<http://www.atmos.uiuc.edu/course/atms> Accessed 10.04.2007
- CIA world Factbook; May 2008;  
<http://www.enotes.com/world-fact-book/nigeria-ni> Accessed 10.03.2009
- CIA World Factbook-Nigeria;  
<https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html>  
Accessed 27.07.2009

Claes Berns, 2005, <http://www.internat.naturvardsverket.se>  
Accessed 17.08.2008

Clean up the World.

<http://www.cleanuptheworld.org/en/NewsandMedia/cuw---unep-global-release.html>

Cole-Parmer; [https://www.coleparmer.com/Catalog/product\\_index.asp?cls=379](https://www.coleparmer.com/Catalog/product_index.asp?cls=379)  
Accessed 17.05.2009

Connell W. Des (2005)

Basic Concepts of Environmental Chemistry. CRC Press, USA

Dawn Maycock; John Fawell; Graham Merrington; and Chris Watts  
Final Report; Review of England and Wales Monitoring Data for which  
a National or International Standard has been set. England March 2008

Don C. Okeke (1997) "Government Efforts in Environmental Management in  
Nigeria "National Workshop on Management of Environmental problems  
in Nigeria; 4<sup>th</sup> June 1997, Enugu Nigeria. Edited by H. Chike Mba;  
Smart N. Uchegbu; C.A. Udeh and Leonard N. Muoghalu.

Earthjustice

Cementing a Toxic legacy? How the EPA has failed to control mercury  
pollution from cement Kilns. Earthjustice & Environmental Integrity pro  
ject, Washington, DC 2008

Editorial; Daily Trust Nigeria 6. Feb 2009

<http://allafrica.com/stories/200902060078.html> Accessed 12.04.2009

Elisabeth Rosenthal

The New York Times 26.October 2007

Environmental Guidelines and Standards for the petroleum Industry in  
Nigeria (EGASPIN) Lagos 2002

Environmental management systems; Requirements with guidance for use.  
ISO 14001. 2004 Geneva Switzerland

EPA <http://www.epa.gov/safewater/contaminants/index.html>

Accessed 07.08.2008

ERA' Report on Elume River Fire Disaster

<http://www.waado.org> Accessed 27.03.2007

ERA's report on Egborode fire disaster and pipeline fire Nigeria.

<http://www.waado.org> Accessed 18.09.2007

Euro news; 15.09.2007

- European Commission 2001. Reference Document on Best Available Techniques in the cement and lime manufacturing Industries. BAT Reference Document (BREF). European IPPC Bureau, Seville, Spain
- FEPA (1991a) Guidelines and Standards for Environmental pollution control in Nigeria, Federal Environmental Protection Agency, Lagos
- Friends of the Earth Nigeria  
[www.foe.co.uk/resource/reports/gas\\_flaring\\_nigeria.pdf](http://www.foe.co.uk/resource/reports/gas_flaring_nigeria.pdf)
- Ganfeng Ouyang; Janusz Pawliszyn,  
Analytical and Bioanalytical Chemistry (2006); 386; 1059-1073
- Geneva Declaration (UN Paper 1994); The 1994 Draft of the Geneva group Declaration of principles on Human Rights and the Environment.  
<http://fletcher.tufts.edu/multi/www/1994-decl.html> Accessed 17.05.2007
- Germany's water quality Report from 2005 to 2007, Bonn/ Dessau 2008  
<http://www.umweltdaten.de/publikationen/fpdf-l/3616.pdf> Accessed 30.06.2009
- Gillian McMahon (2007); Analytical Instrumentation; A Guide to Laboratory, Portable and Miniaturized Instruments; Wiley & Sons Ltd England
- GodeJohann M.; Press A.; Mugge C.; and Wunsch G.  
Application of on-line HPLC-<sup>1</sup>H NMR to Environmental samples: An analysis of Groundwater near former Ammunition plants. Anal. Chem. 69, 3832-3837 (1997)
- Godson R. E. E Ana & Mynepali K. C. Sridhar May 2004  
<http://www.ajeam-ragee.org/vol8p19t26.htm>. Accessed 02.07.2009
- Goldman Sachs Investment Bank; 2005  
<http://www.newyork.com/Economy/The-Next-Eleven-largest-economies-in-21st-century-6/> Accessed 12.04.2008
- Greg Campbell  
These Times Magazine, June 2001  
[http://www.thirdworldtraveler.com/Oil\\_watch/Killing\\_Fields.html](http://www.thirdworldtraveler.com/Oil_watch/Killing_Fields.html) Accessed 19.09.2007
- Guidelines for drinking water quality; 2<sup>nd</sup> Edition; WHO; Geneva; (1993)
- Guidelines and Standards for Environmental Pollution Control in Nigeria  
FEPA 1991

HACH Lange-United for Water; [http://www.hach-lange.de/shop/action\\_q/shop\\_products/SA\\_ID/7/lkz/DE/spkz/de/TOKEN/lyVcxpVnlx4\\_Fny9CfCkcL545WU/M/oQqb-w](http://www.hach-lange.de/shop/action_q/shop_products/SA_ID/7/lkz/DE/spkz/de/TOKEN/lyVcxpVnlx4_Fny9CfCkcL545WU/M/oQqb-w) ( Accessed 13.07.2009)

Henrik Madsen; Poul Thyregod; Florin Popentiu; and Grigore Albeanu  
Computer Aided Modeling and Pollution Control in Cement Plants.  
Fourth Annual Meeting of ENBIS Copenhagen, 2004.

Hermann H. Dieter  
German Drinking Water Regulations, Pesticides, and Axiom of concern.  
Environmental Management Vol. 16, No 1 PP 21-31 Springer Verlag  
New York Inc 1992

<http://www.appliedlanguage.com/maps> (Accessed 17.09.2008)

<http://www.epa.gov> (Accessed 17.11.2007)

[http://www.stadtwerke-bad-reichenhall.de/wasser/Anal\\_2004.pdf](http://www.stadtwerke-bad-reichenhall.de/wasser/Anal_2004.pdf)  
(Accessed 07.04.2009)

<http://www.gettyimages.de/detail/86736464/Photographers-Choice>  
(Accessed 07.11. 2009)

<http://mapsof.net/Nigeria/static-maps/png/un-nigeria>  
(Accessed 21.07.2007)

<http://www.unep.org/sudan> (Accessed 07.09.2007)

[http://monitoring.environmental-expert.com/STSE\\_resulteach\\_product.aspx?cid=2502&idprofile=5969&idproduct=15493](http://monitoring.environmental-expert.com/STSE_resulteach_product.aspx?cid=2502&idprofile=5969&idproduct=15493) (Accessed 13.07.2009)

<http://www.aibltd.com/detail.cfm?autonumber=77363> Accessed 13.07.2009

Imevbore, A. M. A. (2001)  
[http://www.unep.org/roa/docs/Ms\\_word/AfricanIndustryReviewfinal.doc](http://www.unep.org/roa/docs/Ms_word/AfricanIndustryReviewfinal.doc)  
(Accessed 18.05.2007)

Index Mundi; [http://www.indexmundi.com/nigeria/gdp\\_real\\_growth\\_rate.html](http://www.indexmundi.com/nigeria/gdp_real_growth_rate.html)  
(Accessed 27.07.2007)

Jayarathne E.R.; Moraeska L.; Ristovski Z.D; and HE C. Environmental Science  
and Technology. 2007, 41, 5022-5027

Jasdeep K.; Vikas S.K.; Robin B.; Thampi K.R.; Manoj R.; Grish C. V.; and  
Raman S. C; Environmental Science and Technology. 2007,

John Adeoti

Technology Investment in Pollution Control in Sub-Saharan Africa: The case of the Nigerian Manufacturing Industry. PhD Thesis 2001 Maastricht, The Netherlands and Tokyo Japan.

John Donnelly 21 June 2007

[http://www.boston.com/news/world/articles/2007/06/21/russia\\_top\\_offender\\_in\\_gas\\_flare\\_emissions/](http://www.boston.com/news/world/articles/2007/06/21/russia_top_offender_in_gas_flare_emissions/) Accessed 02.07.2007

John R. Kucklick; Paul A. Helm

Anal Bioanal Chem (2006); 386: 819-836

Karstensen K. H. 2006a. Cement production in vertical shaft kilns in China: Status and opportunities for improvement. Report to the United Nations Industrial Development Organization, 31 January 2006

Karstensen K. H. 2006b. Formation and Release of POPs in the cement Industry. Second edition, January 2006. World Business Council for Sustainable Development/ SINTEF

Khopkar S.M

Environmental Pollution Monitoring and Control. New Age International Publishers 2004 India

Kleiböhmer W. (Ed) Environmental Analysis Handbook of Analytical Separations, Vol 3. 2001 Elsevier Science Amsterdam

Kuckartz, Udo; Stefan, Rädiker; Anke, Rheingans-Heintze: Umweltbewusstsein in Deutschland, Marburg 2006.

Kudeyarava, A. Y. (1989). Possible Changes in Environment connected with application of Phosphorus containing fertilizers. Inst. Soil Sc. and Photosynthesis, Puschinoi, USSR) Izv. Akad, Nauk, ISSR. Ser. Bol (4) 589-604

Kugler Mary R.N. (2004)

<http://rarediseases.about.com/od/rarediseases1/a/102304.htm>  
Accessed 07.12.2007

Kuosmanen K; Hyotyhinen T; Hartonen K; Riekkda M.-L; Journal of Chromatography 943(2002) 113-122

LabX; <http://www.labx.com/v2/adsearch/detail3.cfm?adnumb=393151>  
Accessed 13.07.2009

LabX <http://www.labx.com/v2/newad.cfm?CatID=1&Page=4>; Accessed 15.07.2009

LabX <http://www.labx.com/v2/newad.cfm?catID=32> Accessed 20.07.2009

Linear Alkylbenzene Sulphonates (LAS) and Alkylphenol Ethoxylates (APE) in waters, Wastewaters and Sludges by High performance Liquid Chromatography 1993. Methods for the Examination of Water and Associated Materials. HMSO London 1993

Luque-Garcia L.; Luque de Castro M.D.; Journal of Chromatography A 998 (2003) 21-29

Manoylovic, S. (1989). Soil pollution by fertilizers and regulation of the soil fertility and fertilizer use or protection of the agro ecosystem. Environment and the biosphere. Faculty of Agric Univ. Novisad, Nov. Sad. Yugoslavia (Vodopiređa) (21)3 – 4, 351 – 36

Mathias A.D.

Environmental Monitoring and Characterization: Edited by J.F. Artiola; I.L. Pepper and M. Brusseau Elsevier Amsterdam 2004 pp 163-181

Musa. H, Yakasai. I. A., Musa. H. H., Musa K. Y. & Gwarzo M.S. Journal of Applied Sciences Volume 7 No 22, PP 3572-3575 Asian Network for Scientific Information 2007

National Guidelines on Environmental Health Practice in Nigeria. Issued by Environmental Health Officers Registration Council of Nigeria August 2007

Nigerian Industrial Standard NIS 554: 2007. Nigerian Standard for Drinking Water Quality. Standard Organization of Nigeria Lagos 2007

Nkono N. A. & Asubiojo O. I.

Journal of Radioanalytical and Nuclear Chemistry; Volume 227, Number 1-2 Jan 1998 PP 117 – 119

NZWERF 2002. New Zealand Municipal Wastewater Monitoring Guidelines. (Edited by Ray D.E) NZ Water Environment Research Foundation. Wellington, New Zealand Accessed 02.05.2009

NZWWA (2003) Guidelines for the Application of Biosolids to Land in New Zealand <http://www.waternz.org.nz/bookshop.html> Accessed 12.06.2009

Odu, C T I. (1977). Oil Pollution and the Environment. Bull. Sci. Assoc. Nigeria. Vol No. Nigerian National Committee of Scope: Environmental Problems in Nigeria. Pg286



- Ofeibea Quist- Arcton  
<http://www.npr.org/templates/story/story.php?storyId=12175714>  
Accessed 12.04.2008
- Ogoke, N J. (1980). Rehabilitating Crude Oil Polluted Land. FEPA monograph 5: The Petroleum Industry and Environmental Impact in Nigeria. Pg 180.
- Olu Okotoni; J. Hum. Ecol; 15 /1):13-17(2004)  
<http://www.krepublishers.com/02-Journals/JHE/JHE-15-0-000-000-2004-Web/JHE-15-1-001-084-2004-Abst-PDF/JHE-15-1-013-017-2004-Okotoni/JHE-15-1-013-017-2004-Okotoni.pdf> (Accessed 27.07.2009)
- Oxford Instruments Designs; <http://www.oxford-instruments.com>  
(Accessed 27.07.2009)
- Oshibanjo O.; Faniran J.A.; Adeleke B.B; and Oderinde R.A (1988)  
Hdrogeological and Chemical Basic Data Acquisition from NNPC operational areas, Technical report, 187pp
- Paul Coffey, Hong Kong BBC News your changing  
World.[http://news.bbc.co.uk/2/shared/spl/hi/picture\\_gallery/05/sci\\_nat\\_your\\_changing\\_world/html/7.stm](http://news.bbc.co.uk/2/shared/spl/hi/picture_gallery/05/sci_nat_your_changing_world/html/7.stm) Accessed 07.11.2007
- Paul J. Gammatteo, John C. Edwards  
Environmental Instrumentation and Analysis Handbook, p  
John Wiley & Sons Inc New Jersey, 2005
- Peter E. Jackson, Ph.D.  
Ion Chromatography for the Analysis of Inorganic Anions in Water  
Environmental Instrumentation and Analysis Handbook; pp 371; Wiley (2005)
- Press Release April 2009  
[http://www.umweltbundesamt.de/uba-info-presse-e/2009/pe09-018\\_germanys\\_drinking\\_water\\_rates\\_good\\_to\\_very\\_good.htm](http://www.umweltbundesamt.de/uba-info-presse-e/2009/pe09-018_germanys_drinking_water_rates_good_to_very_good.htm)  
Fall Meeting 2005, abstract #A11A-0848 Accessed 23.04.2009
- Ramos L; Kristenson E.M; Brinkman U.ATh; Journal of Chromatographya  
975 (2002) 3-29
- Randy D Down  
Environmental Instrumentation and Analysis Handbook pp 3-12, 2005  
John Wiley & Sons Inc. New Jersey U.S.A
- Randy D. Down, P.E.  
Portable versus Stationary Analytical Instruments,  
Environmental Instrumentation and Analysis Handbook; pp 237; Wiley (2005)

- Rhett A. Butler; FAO Report 2005;  
<http://news.mongabay.com/2005/1117-forests.html> Accessed 02.07.2009
- Roden, C. A.; Bond, T. C.; 2004  
American Geophysical Union, Fall Meeting 2004, abstract Nr A23C-0819
- Roden, C.A.; Bond, T.C.; Conway, S.; Osorto Pinel, B.; Maccarty, N.; Still, D.  
(2005) American Geophysical Union, Fall Meeting 2005, abstract Nr 11A-0848
- Roger Reeve;  
Introduction to Environmental Analysis; Wiley & Sons LTD; UK; 2002.
- Royal Commission on Environmental Pollution; Twenty First Report; Setting  
Environmental Standard; October 1998  
<http://www.rcep.org.uk/reports2.htm> Accessed 07.09.2008
- Sayo. O. F 2005.  
AJEM-RAGEE Volume 10, March 2005, p1-13
- Seeley J. V; Kramp F.J; Sharpe K.S; Journal of Separation Science 24(2001)  
444-450
- Shell Nigeria Environmental Performance; Oil Spills  
[http://www.shell.com/home/content/nigeria/news\\_and\\_library/publications/2007/environmental\\_performance/report2006\\_environmental\\_performance\\_oil\\_spills.html](http://www.shell.com/home/content/nigeria/news_and_library/publications/2007/environmental_performance/report2006_environmental_performance_oil_spills.html) Accessed 13.09.2007
- Shriver Duward and Atkins Peter;  
Inorganic Chemistry; Third Edition; Freeman (1999)
- Singh A.K.  
Proceedings of National Seminar on Hydrology Nov 2004 Roorkee India
- Sivertsen B (2002)  
Air Quality Monitoring and Management; Training course, WHO/NILU  
workshop Lagos Nigeria (15-28 February 2002.)
- Speight G. James;  
Environmental Analysis and Technology for the Refining Industry; Volume  
168; Wiley- Interscience, USA, 2005.
- Soji Awogbade, 09 Nov 2006.  
<http://www.worldservicesgroup.com/publications.asp?action=article&artid=1597> (Accessed 07.04.2007)

Solomon, S., D.Qin, M. Maming, R.B. Alley, T.Bermtsen, N.L. Bindoff, Z.Chen, A.Chldthaisong, J.M.Gregory, G.C.Hagerl, M.Heimann, B.Hewitson, B.J.Hoskins, F.Joos, J.Jouzel, V.Kattsov, U.Lohmann, T.Matsuno, M.Mollna, N.Nicholls, J.Overpeck, G.Raga, V.Ramaswamy, J.Ren, M.Rusticucci, R.Somerville, T.F.Stocker, P.Whettan, R.A.Wood and D.Wratt 2007; Technical summary in climate change, Fourth Assessment Report of the Intergovernmental Panel on Climate Change(**IPCC**); Cambridge University Press UK 2007.

SON: <http://www.sononline.org/main/preg.php> Accessed 01.02.2009

Standard Methods for the Examination of Water and Wastewater  
<http://www.standardmethods.org/Store/ProductList.cfm?EPAApproved=1> (Accessed 02.08.2008)

Standard Methods for the Examination of Water and Wastewater (APHA) 2006  
<http://www.standardmethods.org/Store/ProductView.cfm?ProductID=206> (Accessed 25.04.2009)

Stanley E. Manahan;  
Environmental chemistry, Seventh Edition; Lewis Publishers; Michigan USA; 2000.

Stephen A. Wise; Damia Barecioj; Philippe Garrigues; Richard Turie  
Analytical Bioanalytical Chemistry (2006); 386; 765-767

S.I.8 National Environmental Protection (Effluent Limitation) Regulations 1991. Federal Environmental Protection Agency of Nigeria

S.I.9 National Environmental Protection (Pollution Abatement in Industries and Facilities Generating wastes) Regulations 1991. Federal Environmental Protection Agency of Nigeria

S.I.15- National Environmental Protection Management of Solid and Hazardous Wastes Regulations 1991. Federal Environmental Protection Agency of Nigeria

Taras, J.M.(1950). "Phenoldisulfonic Acid method of determining nitrate in water". Journal of Analytical Chemistry. Vol.22, 8. 1020-1022.

The Guidelines for Drinking Water Quality Management for New Zealand October 2005. <http://www.moh.govt.nz/moh.nsf/238fd5fb4fd051844c256669006aed57/5a25bf765b400911cc25708f0002b5a8?OpenDocument> (Accessed 20.04.2009)

The Helsinki Convention. ([http://www.helcom.fi/Convention/en\\_GB/convention/](http://www.helcom.fi/Convention/en_GB/convention/) Accessed 21.12.2007)

- Total Hardness, Calcium Hardness and Magnesium Hardness in Raw and Potable Waters by EDTA Titrimetry. HMSO London 1981
- Tripathi, B. D., Durvedi, R. K., Tripathi, A. (1990). Influence of Industrial Wastes on Physicochemical Properties of Soil and Germination and Mineral Composition of Wheat, India Water, Air, Soil Pollution 49 (1-2).
- Umwelt Bundes Amt  
The state of the Environment in Germany 2005 edition
- United Nations Environmental Programme Geneva Feb 2006  
<http://www.chem.unep.ch/Pops/laboratory/Minutes%20of%20the%202nd%20core%20group%20mtg.pdf>. Accessed 22.04.2008
- United Nations Environmental Programme Amsterdam 2007  
[http://www.chem.unep.ch/Pops/laboratory/Minutes%20of%20the%203rd%20Core%20Group%20Meeting\\_2007-03-19.pdf](http://www.chem.unep.ch/Pops/laboratory/Minutes%20of%20the%203rd%20Core%20Group%20Meeting_2007-03-19.pdf) Accessed 07.02,
- Van Oss H. G. and Padovani A.C. 2003. Cement manufacture and the environment, part II: Environmental Challenges and Opportunities. Journal of Industrial Ecology. 7(1), pp 93-126
- Van Oss, H.G. and Padovani, A.C. 2002. Cement manufacture and the environment, part 1: Chemistry and Technology. Journal of Industrial Ecology 6(1):pp 89-105
- Verein Deutscher Zementwerke e.V.  
Environmental Data of the German Cement Industry, Düsseldorf, 2001: [www.wbcscement.org/pdf/tf4/Wmw01e.pdf](http://www.wbcscement.org/pdf/tf4/Wmw01e.pdf)
- Water Aid Nigeria  
[http://www.wateraid.org/international/what\\_we\\_do/where\\_we\\_work/nigeria/4245.asp](http://www.wateraid.org/international/what_we_do/where_we_work/nigeria/4245.asp) Accessed 07.10.2008
- WATERTIGER; Drinking Water Quality Guidelines; Adopted from the Guidelines for Canadian Drinking Water Quality Sixth Edition, 1996.  
<http://www.watertiger.net/resources/guidelines.htm> (Accessed 12.04.2009)
- Wen Xiao-Dong; Wu Peng; He Yi-Hua; Xu Kai-Lai; Lu Yie; Hou Xian-Deng; Fenxi Huaxue (2009) 37(5) 772-775
- WHO; Guidelines for Drinking Water Quality; Third Edition; World Health Organization; Geneva 2008
- Wikipedia  
<http://en.wikipedia.org> (Accessed 27.02.2009)

Wikipedia; Nigerian Macro-economic trend;  
[http://en.wikipedia.org/wiki/Economy\\_of\\_Nigeria#Macro-economic\\_trend](http://en.wikipedia.org/wiki/Economy_of_Nigeria#Macro-economic_trend). (Accessed 27.07.2009)

William Averdieck (2005)  
[www.pcme.co.uk/.../Improving\\_environmental\\_performance\\_and\\_satisfying\\_regulator.pdf](http://www.pcme.co.uk/.../Improving_environmental_performance_and_satisfying_regulator.pdf) (Accessed 24.09.2009)

World Commission on Environmental Development; Our Common Future (The UN Brundtland Report 1986). <http://www.un-documents.net/ocf-02.htm> (Accessed 12.11.2008)

[www.blacksmithinstitute.org](http://www.blacksmithinstitute.org) (Accessed 14.06.2007)

[www.gefoline.org/projectDetails.cfm](http://www.gefoline.org/projectDetails.cfm) (Accessed 12.11.2007)

[www.mbendi.co.za](http://www.mbendi.co.za) (Accessed 02.08.2007)

[www.mfe.govt.nz](http://www.mfe.govt.nz) (Accessed 04.06.2008)

[www.population.gov.ng/pop\\_figure.pdf](http://www.population.gov.ng/pop_figure.pdf) (Accessed 11.09.2008)

[www.cpe.mrt.ac.lk/.../ENVIRONMENTAL%20POLLUTION.pdf](http://www.cpe.mrt.ac.lk/.../ENVIRONMENTAL%20POLLUTION.pdf)

[www.oup.com/uk/orc/bin/9780199274994/vanloon\\_ch12.pdf](http://www.oup.com/uk/orc/bin/9780199274994/vanloon_ch12.pdf)