**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**

|  |  |  |  |
| --- | --- | --- | --- |
| **NNPC (KRPC) Kaduna** | **Ashaka Cement Factory** | **Regional Laboratory Gombe** | **National Reference Laboratory Lagos** |
| 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 SO2 is typically measured using UV absorption, UV fluorescence or IR absorption spectrophotometer. Carbon monoxide (CO) and carbon dioxide (CO2) 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, chemilumescent analyzers are used at times for the measurement of NH3. GC/MS is used to analyzed 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 use 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 obtained 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 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 used due to one reason or the other. In NNPC chemical laboratory, the results given in Table 3.3 showed many test 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**

|  |  |
| --- | --- |
|  **Pollutants** | **Analytical Instruments** |
| PCBs | GC/MS, Portable GC |
| SO2 | Electrochemical cells, UV absorption, UV Fluorescence, NDIR |
| NOx | Chemiluminescent, Photomultiplier tube |
| CO, CO2 | IR (NDIR & GFC) techniques, Raman Spectrophotometer |
| PM | GC/MS, Catalytic Sensor |
| HCL | NDIR/GFC, UV, FTIR |
| NH3 | NDIR/GFC, UV, FTIR, Chemilumescent 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 | 1H & 3P 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 support 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.

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**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 obtained 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 most 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 use here to check the agreement between the results, since standard deviation is a measure of variability or dispersion of results. Low standard deviation will indicates that all the data points are very close to the same value, which is the mean. High standard deviation will indicates that the data are spread out over a large range of values.

Standard Deviation (σ) is given by the formula

 **Equation 4.1**

Where N = Number of data

 χi = Value for each data

 μ = 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 (σ) |
| 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 (σ) |
| 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.

**Value in mg/l**

**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 μg/m3 |
| Sulphur Dioxide (SO2) | ND | 830 μg/m3 |
| NOx | ND | 500 |
| H2S Vapor | ND | 30 |
| NH3 | ND | 30 |
| Hydrocarbons Vapors | ND | 5000 |
| VOCs | ND | 6000 μg/m3 |
| CO | ND | 5000 μg/m3 |

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**

|  |  |  |
| --- | --- | --- |
| **Parameters Analyzed**( ppm or mg/l except stated) | **Nigeria Limits** | **NNPC Results**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 (SiO2) | - | 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 (H2S) (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 |

1

3

5

7

9

**Parameters Measured**

**Values in mg/L**

Gombe Results

Standard limits

**1=PH, 2=Manganese, 3=Conductivity, 4=Total Dissolved Solids, 5=Nitrate, 6=Nitrite,**

 **7=Sulfate, 8=Fluoride, 9=Hardness and 10=Iron (Total)**

**Figure 4.3** Comparison of Gombe Regional Laboratory Results with Ni-

 geria’ 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 polyaromatic 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** |
| SiO2 | 14.238 | % |
| Al2O3 | 3.881 | % |
| Fe2O3 | 1.854 | % |
| CaO | 43.234 | % |
| MgO | 0.467 | % |
| SO3 | 0.381 | % |
| K2O | 0.799 | % |
| Na2O | 0.053 | % |
| P2O5 | 0.118 | % |
| Mn2O3 | 0.127 | % |
| TiO2 | 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, SO2, NO2 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 SO2, NO2, 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 | 250µg/m3\*600 µg/m3 |
| Sulphur Oxides (Sulphur Dioxides) | Daily average of hourly values 1 hour | 0.01ppm (26 µg/m3)0.1ppm (260 µg/m3) |
| Non-methane Hydrocarbon | Daily average of 3-hourly values  | 160 ug/m3 |
| Carbon Monoxide | Daily average of hourly values8-hourly average | 10ppm (11.4 µg/m3) 20ppm (22.8 µg/m3) |
| Nitrogen Oxides (Nitrogen Dioxides) | Daily average of hourly values (Range) | 0.04ppm – 0.06ppm(75.0µg/m3 -113µg/m3) |
| 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 (CaCO3) at about 900oC to calcium oxide (CaO, lime) followed by the clinkering process at about 1450oc 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, O2 content, NOx, CO, SO2, 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. NH3, 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), Chlorobenzens, 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 its 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 CO2 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). 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 strophic 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, participation 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 advice 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 Pollution 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 at 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>)

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>, 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 absence 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 0.001μg/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.

1

2

3

4

5

6

7

8

9

10

Parameters analyzed

Germany

Result

Research

Result

**Figure 4.5** Comparison of a Result from Germany with one of the Re-

 search 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.

* 1. **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 Exanimation of Water and Wastewater 20th 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-NH3 and when one goes to APHA4500-NH3 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 obsoletes analytical instruments that may not give any reliable results.

The developed countries place analytical instruments in their environmental pollution control as 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 | 2500μS/cm at 20oc | - | - | 1000 μS/cm |
| PH | ≥6.5 and ≤9.5 | - | N/Established | ≥6.5 and ≤8.5 |
| Iron | 200μg/l | 0.3mg/l | N/Established | 0.3mg/l |
| Manganese | 50μg/l | 0.03mg/l | 0.4mg/l | 0.2mg/l |
| Odor | No abnormal change | - | - | Not abnormal |
| Oxidizability | 5.0mg/lO2 |  | - |  |

**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 OrganicCarbon | - | - | 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**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **New Zealand Limits****(Maximum Acceptable****Values)** | **Nigerian Limits****(Maximum Limits)** |
| 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 mostpeople | 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.

* 1. **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 para-meters 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:

1. The limit of determination based on the most common analytical method
2. 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
3. Quality controlled system for management of drinking water should be supported by appropriate testing and monitoring methods
4. 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.

* 1. **Comparing the Cement Pollution Control in the Research Laboratory with Developed Countries**

According to the Umweltbundesamt (2006), (German Federal Environ-mental 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, NOx and SO2 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**

|  |  |
| --- | --- |
| **Object of measurements (Emissions)** | **Standard, Guideline** |
| Total dust | ISO 10155VDI 2066, Sheet 4VDI 2066, Sheet 6 |
| Heavy metals-Sampling-Analysis | DIN EN 13211VDI 3868, Sheet 1,2VDI 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 1DIN EN 1948, part 2-3  |
| Polycyclic aromatic hydrocarbons-Sampling-Analysis | VDI 3499, Sheet 1E, 2EDIN EN 1948, part 1VDI 3873, Sheet 1 |
| Organically bound carbon | DIN EN 12619 |
| Benzene, touelene, 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, SO2, and NO2. 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 m3. Van Oss et al 2003 gave a world overview of CO2 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 Pollu-**

 **tants Covered by the European Pollutant Emission Register**

 **(for Cement Industries)**

|  |  |
| --- | --- |
| Pollutant | Threshold valueKg/year |
| Carbon monoxide (CO) | 500,000 |
| Carbon dioxide (CO2) | 100,000,000 |
| Non-methane volatile organic compounds (NMVOC) | 100,000 |
| Nitrogen oxides (NOx) | 100,000 |
| Sulfur dioxide (SO2) | 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 (PM10) | 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, CO2 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, NOx, CO2, 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:

* + 1. Primary sector e.g. crude oil extraction,
		2. Secondary sector e.g. NNPC Refineries,
		3. Tertiary sector e.g. distribution of manufactured goods
		4. 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, textiles & 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.

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**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 expected. 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.

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