GIVING THE EARTH A FUTURE: CHEMICALS, WASTES AND POLLUTION RISK FACTORS

An Inaugural Lecture delivered at the University of Ibadan

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By

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The Vice-Chancellor, Deputy Vice-Chancellor (Administration), Deputy Vice-Chancellor (Academic), Registrar, Librarian, Provost of the College of Medicine, Dean of the Faculty of Science, Dean of the Postgraduate School, Deans of other Faculties, and of Students, Directors of Institutes, Distinguished Ladies and Gentlemen.

Introduction

I give honour and glory to God for giving me this special privilege and opportunity to deliver the 10th in the 2008/2009 series of inaugural lectures on behalf of the Faculty of Science. Today's event is of special significance as this is the first inaugural lecture to be delivered by the Analytical and Environmental Chemistry Unit of the great Department of Chemistry of the nation's premier university. It is equally historic that this period falls within the celebration of the 60th anniversary of Chemistry Department, Faculty of Science and the university itself and the 20th year of my appointment to the Chair of Analytical and Environmental Chemistry. It is divine providence that makes today's event a reality. The Department of Chemistry gave the 6th inaugural lecture for this session in November 2008. It is unusual for a department to give two inaugural lectures in a session. The Dean of Faculty of Science, a reputable international scholar, Professor T.I. Odiaka, made a special case to the university administration to accord me the rare privilege of giving a second inaugural lecture this session on behalf of the Faculty of Science—because he felt my contributions deserve to be recorded as I might have retired before another opportunity comes round. There is a hand of God in this—as the university administration granted the request.

Before embarking on the story of the journey of my life through analytical chemistry as an academic at the University of Ibadan for thirty two years, it is pertinent to reminisce on a fire disaster that occurred on 21 February 1983 and almost truncated my academic career. My personal office, research equipment, materials and research data were destroyed and

my end of the Analytical Research Laboratory wrecked by the inferno. Most people felt all was lost and there was no basis for remaining in the university system. But God gave me hope, courage and inspiration to continue. I therefore consider myself extremely lucky and divinely favoured—for His goodness and the grace to present aspects of my contributions to research nationally and internationally to this great university community of scholars and eminent persons.

Analytical Chemistry

Chemistry department is one of the foundation departments of the University of Ibadan in 1948. Chemistry as a discipline has many branches including organic, physical, inorganic, industrial and analytical chemistry. Analytical chemistry is a branch of chemistry that deals with the chemical characterization of matter, providing valuable information such as what components exist? and how much of each component is present in a substance or material? In other words, analytical chemistry is the soul of quantitative chemistry. It is one of the oldest branches of chemistry from the days of alchemy when chemists who could identify correctly precious stones (gold, silver etc) in the courts of kings were highly regarded as noble scientists. Wrong results were regarded as blasphemy leading to severe punishments including death by stoning and/or beheading. Such was the importance of analytical chemistry in ancient times.

Analytical chemistry plays an important role in all aspects of chemistry including agricultural, clinical, environmental, natural product, forensic, industrial, metallurgical, pharmaceutical and toxicological chemistry. Hence a good analytical chemist is a jack of all trade and master of all! Such is the importance of analytical chemistry that two serving Vice-Chancellors today, Professor A.M. Balogun (Federal University of Technology Akure, FUTA) and Professor A.I. Essien (University of Uyo, UNIYO) did part of their PhD research work in animal science/animal nutrition in

the Faculty of Agriculture, in our analytical chemistry research laboratory resulting in joint publications (Balogun A.M. et al. 1988 and Essien A.I. et al. 1989). Their research supervisor then, Professor B. L. Fetuga, who is a personal friend, is a great apostle of multidisciplinary research. Mr. Vice-Chancellor Sir, those were the days when facilities were adequate and functioning well. But thank God, the good days seem to be coming back during your administration—with your visionary and dynamic leadership.

The great German analytical chemist Wilhelm Ostwald (American Chemical Society 1977), wrote in the preface of his classical book in 1894 on the scientific fundamentals of analytical chemistry:

> Analytical chemistry or the art of recognizing different substances and determining their constituents, takes a prominent position among the applications of science, since the questions it enables one to answer arise wherever chemical processes are employed for scientific or technical purposes. Its supreme importance has caused it to be assiduously cultivated from a very early period in the history of chemistry, and its records comprise a large part of the quantitative work which is spread over the whole domain of science.

The analytical chemistry programme at Ibadan started in 1963 with the introduction of the postgraduate diploma degree in analytical chemistry under the inorganic chemistry unit with Dr. D.R. Goddard, a Briton, as the unit head. The programme was established in response to a request from the industrial sector of a dire need for capacity development in industrial quality control. The first graduate of the programme in 1964 was the late Dr. I.I.O. Allinson of blessed memory. At the departure of Dr. Goddard back to the United Kingdom in 1975, the headship of the analytical chemistry group fell on

Dr. S. O. Ajayi who later became the first Professor of Analytical and Environmental Chemistry in the department. The diploma programme was upgraded to a fully-fledged Msc. degree programme in Analytical Chemistry in 1976 when I joined as an analytical chemist, and Lecturer II, from the University of Birmingham, Edgbaston, United Kingdom. The Research School of Analytical Chemistry in Birmingham was a 'Mecca' of some sort as the Head of the School then, Professor Ronald Belcher of blessed memory, was the Doyen of Analytical Chemistry in the United Kingdom having trained many analytical chemists dispersed in Europe, Canada and the United States of America. The analytical chemistry unit at Ibadan was strengthened incrementally with the appointments of Dr. O. O. P. Faboya (specialist in food chemistry) as Lecturer II in 1977; Mr. P.C. Onianwa as Assistant Lecturer in 1980; Dr. O. R. Idowu (specialist in drug analysis) as Lecturer II in 1982.

I became the Head of the Analytical/Environmental Chemistry Unit in 2000 when Professor S. O. Ajayi was appointed the Head of Chemistry Department. Based on my extensive interaction in advisory capacity with Federal Government of Nigeria on environmental matters since 1978 and the industrial sector, and driven by continual requests from these sectors for Ibadan to mount Msc. Courses in Environmental Chemistry, I introduced two new postgraduate courses in analytical and environmental chemistry. These are the Msc Programme in Environmental Chemistry and Pollution Control (Academic) and Masters in Environmental Chemistry and Pollution Control (MECPC–Professional/-Terminal Masters Programme) designed for environmental protection manpower in industry and government. In other words, the Analytical/Environmental Chemistry Unit runs and awards annually three Msc degree programmes: Msc Analytical Chemistry, Msc Environmental Chemistry and Pollution Control; and Masters in Environmental Chemistry and Pollution Control (MECPC). These courses are popular and attract students from all over the country.

The strength of the analytical chemistry unit has increased steadily from academic staff strength of two in 1976 to ten in 2008 including a Visiting Professor on sabbatical leave with us from University of Agriculture Abeokuta, Professor F.O. Bamiro; and yet more staff are needed because the bounds of Analytical Chemistry are very wide.

My Journey into Analytical Chemistry

My interest in analytical chemistry grew during my undergraduate studentship days at Ibadan. Analytical chemistry was taught as part of inorganic chemistry by Dr. D.R. Goddard who was a strict lecturer, dreaded by students for his no nonsense posture. I enjoyed his lectures, did well in his tutorials and examinations; and developed a likeness for him. Some of my senior colleagues in secondary school were also running the Diploma in Analytical Chemistry programme under Dr. Goddard, which made me visit the analytical laboratory frequently. The observation of the analysis of diverse chemical substances and industrial materials using different analytical instruments fascinated me. My ambition on graduation though was to go to the United States of America for Msc/PhD programmes in chemical engineering. While processing my postgraduate admissions, I was offered Laboratory Manager's job by Lever Brothers Nigeria Limited, Apapa, Lagos in 1971. This job exposed me to the importance of analytical science in industrial quality control, water/wastewater analysis and new analytical methods development. By divine grace University of Birmingham, UK offered me admission into the Msc/PhD Analytical Chemistry programme.

The Birmingham experience was very wonderful. It exposed me to the principles and diverse applications of analytical chemistry, discoveries in analytical chemistry and uninhibited interactions with renowned analytical chemists. I was privileged to be part of the pioneering work, for my PhD thesis, on the development of a new flame analytical method—Molecular Emission Cavity Analysis (MECA) at

Birmingham in the mid-1970s. Professor Belcher encouraged me as a graduate student to attend international conferences in Europe in analytical chemistry and within the United Kingdom. I was privileged for his special interest in me as the best student in the Msc Analytical Chemistry programme in the graduating class of 1973. When I was about to return home in 1976 to take up the appointment in Ibadan, he gave me one of his textbooks and inscribed on it "Dele you have seen how it is done here, go and do the same in your country, Best of Luck". Those words inspired me up till today because my world renowned Professor believed so much in me.

Research in Analytical Chemistry

Research in analytical chemistry can be divided into fundamental or basic research and applied research. Fundamental research entails development of new analytical methods or improvement of existing methods making them faster and more sensitive. Applied research is the application of analytical chemistry to unlock the mystery of the content of substances through analysis and use of analytical data to shape policy and regulatory measures nationally and internationally.

My research at Ibadan has been an admixture of fundamental and applied research in many spheres. I will attempt to highlight some of the key ones around some of the topical environmental issues of our time, while also devoting a little time to the earlier works on MECA at Ibadan. The Vice-Chancellor, Molecular Emission Cavity Analysis (MECA) is a flame molecular emission technique in which samples are deposited in a cavity at the end of a small rod. The cavity is introduced into a hydrogen diffusion flame (cool flame) in line with the detector and the subsequent emissions are recorded (fig. 1). It can analyse both solid, liquid and with a modified cavity, gas samples. The emissions can be used for both qualitative and quantitative analysis.

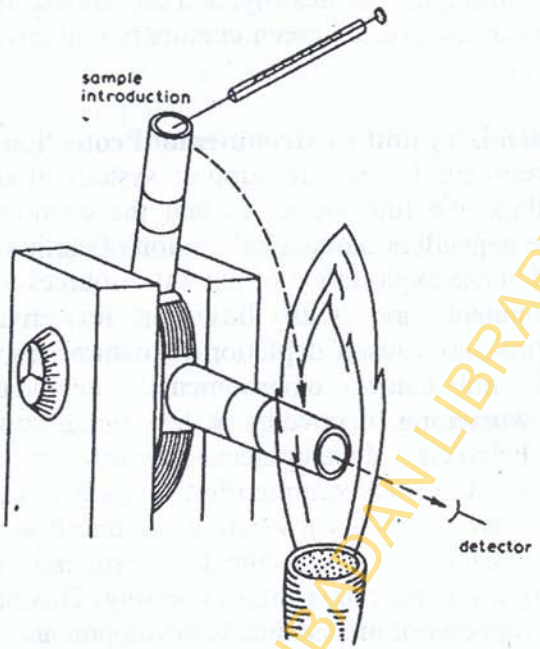

Fig. 1: Molecular Emission Cavity Analysis (MECA) sample holder assembly showing sample introduction by injection with a syringe

The analytical validity is that the emission intensity (E.I) is directly proportional to the concentration of the emitting compound. This technique can be used for the determination of none metals such as sulphur, phosphorus and halides at trace and ultrace levels. This makes the technique complementary to Atomic Absorption Spectrometry (AAS) which is not suitable for none metals determination. The research at Ibadan produced 3 publications (Belcher *et al* 1977; Osibanjo and Ajayi 1980; and Osibanjo et al 1989) in international peer reviewed journals and a PhD graduate (Dr. Adebayo O. Bankole of blessed memory). New flame analytical methods for trace halides determination using a copper cavity, as well as the determination of trace phenols in water were reported for the first time. The fire incident of 1983

terminated the MECA research in Ibadan and Africa as the research instrument was destroyed. This shifted my research focus more in the area of green chemistry and environmental protection.

Green Chemistry and Environmental Protection

The environment is our life support system in the present global village we find ourselves and the economies of all nations are dependent on the exploitation of earth's resources. However intense exploitation of natural resources in the name of development and with little or no environmental consideration has caused depletion of natural resources and ecological imbalance, environmental degradation and pollution, worsening of poverty in developing countries and conflict between development proponents including industries and the host communities. A good example is the Niger Delta area of Nigeria where economic boom from oil and gas has resulted in environmental doom; and the people now see oil as a curse rather than a blessing. This need not be within the framework of sustainable development.

Man's destruction of earth resources in the name of development has not been sustainable. Sustainable development has been proffered as the panacea to the development pathways and patterns of the past which neglect environmental consideration in projects lifecycle. The Brundtland Commission's 1987 report *"Our Common Future"* has defined sustainable development as the "development that meets the need of the present without compromising the ability of future generations to meet their own needs". In other words sustainable development is development without environmental destruction.

God gave man dominion over the earth and its resources; but requests him to be a manager of earth resources (Genesis 1:27-30) and not destroy them. The unsustainable development pathways and activities of the past in Nigeria since independence which focus on economic and social elements to the neglect of the environment have caused serious

ecological and human health problems and worsened poverty in the country. Major environmental challenges facing the country are soil degradation, rapid deforestation, industrial pollution, urban air and water pollution, desertification, chemical and oil pollution, loss of arable land and rapid urbanization accompanied by unsustainable waste management.

Environmental Pollution—Industrial Pollution Perspective

Industrialization is the engine that drives national economies and has increased quality of life to levels previously unimagined. Yet it has caused adverse impacts on the environment and human health when not properly managed because industries produce unwanted harmful by-products and hazardous wastes (effluents, sludge, gaseous emissions, etc) which contribute significantly to environmental pollution. Nigeria has undergone relatively rapid industrialization over the last four decades as a result of huge revenue from oil and gas export. However industrialization was not guided by comprehensive environmental awareness, efficient regulatory systems, enforced planning regulations and environmentally sound waste management practices. Employment generation and local manufacture of import substituted products were the overall goals of industrialization which unfortunately were not sustainable as the nation discovered with great pains later on. Industries are sometimes sited close to residential houses and other centres of human activities thereby exposing nearby human populations to great health risk from pollution.

There are almost 10,000 industries in Nigeria with different polluting potentials (primary, secondary and tertiary industries). About 70% of the industries are located in Lagos while about 80 to 90% of all industries are located close to the coast because of the proximity to surface water sources for multifarious industrial uses, easy access to bring in imported machinery and raw materials through the ports

while the latter also provides easy access for exporting manufactured goods. Typology of industrial pollution includes the following:

- ***Noise pollution*** (e.g. noise from industrial machines, turbines, generators, religious houses, music players, etc);
- ***Thermal pollution*** (e.g. hot effluent from thermal power stations and manufacturing industries such as textile mills, heat from gas flaring in the oil and gas sector, heat from industrial furnaces and machines, etc);
- ***Air pollution*** (e.g. dust/particulate matter, soot, smoke etc from factory chimneys, open burning of refuse, gas flaring etc); indoor air pollution is pronounced by the World Health Organization (WHO) as a major problem in Nigeria and other developing countries.
- ***Surface and ground water pollution*** (e.g. from untreated or partially treated industrial effluents, oil spill from leaking underground storage tanks from petrol stations and tank farms, domestic sewage septic tanks, etc).
- ***Hazardous waste pollution*** from manufacturing and the oil and gas sector (e.g. in case of the petroleum industry : drilling mud, formation water, sludge, dredged spoils etc) are either disposed in burrow pits or co-disposed in local dumps and landfills or improperly dumped in wetland or surface waters.
- ***Chemical pollution*** (e.g. release and presence of harmful chemicals at concentrations into the environment which appear to pose directly or indirectly a real threat to human health and the environment).

Over 90% of industries do not install pollution abatement equipment, and where such facilities exist most of them are grossly inadequate to cope with the volume of waste generated, or are not functional and might have broken down for a long while without repairs. Consequently raw or partially treated industrial effluents containing hazardous substances are discharged continuously (non-compliant with national/international effluent limitation standards) into nearby gutters or drains which end up in streams, rivers, and wetlands thereby leading to gross pollution of the ecosystems.

In the late 1960s and early 1970s, environmental consciousness started to grow in the developed countries because of devastating ecological and human disasters largely caused by chemical and industrial pollution as well as environmental activism by public pressure groups such as Green Peace and Friends of the Environment in the USA and United Kingdom. This led to the establishment of the first ever environmental protection agency (United States Environmental Protection Agency, USEPA) in 1970.

Analytical chemists are eminently placed to undertake environmental studies and research from the perspective of physico-chemical parameters as well as the determination of the levels and environmental fate of priority/hazardous substances and chemical pollutants in environmental media (water, land, air and even contaminants in biota). My senior colleague Dr. S. O. Ajayi had initiated research work on physico-chemical water quality parameters of Ogunpa River in Ibadan metropolis and Awba dam within the university before my arrival in the unit. We expanded the scope of work to look at the quality of major rivers in the old south western Nigeria (Ogun, Osun, Ekiti, Ondo and Oyo) as well as Kwara state to obtain some baseline environmental data on surface waters in Nigeria (Ajayi and Osibanjo 1981).

Environmental baseline data from these surveillance studies would be useful for future policy and regulatory interventions on environmental management in the country which was non-existent at the time. In 1978 I approached the Director, Environmental Planning and Protection Division

(EPPD) of the defunct Federal Ministry of Housing and Environment, late Dr. Raimi Ojikutu (of blessed memory) to sponsor a study on industrial pollution in Nigeria. He kindly sponsored the study entitled "Wastes Management at the Sugar Factory, Bacita; Paper Mill, Jebba; Nigerian Brewery Ltd. Iganmu; Guinness (Nig.) Ltd, Ikeja; Nigerian Bottling Company and Union Beverages Nigeria Ltd, Ibadan; and Selected Textile Mills throughout the Federation. The study also covered the streams and rivers receiving effluents from the industries. The report of the research study undertaken by us for the Federal Ministry of Housing and Environment; Lagos was published as the first ever "The State of the Environment in Nigeria—Monograph Series No. 1: Industrial Waste Management in 1982 (Ajayi, S.O and Osibanjo, O. 1979). The cover page of the monograph is shown in fig. 2. Some effluent and surface water data from the study are shown in tables 1 and 2.

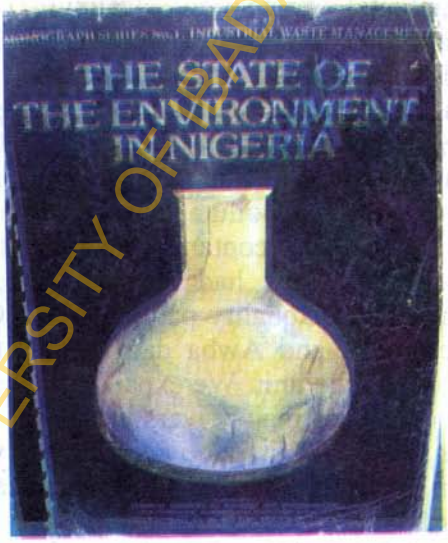

Fig. 2: Monograph Series No. 1: Industrial Waste Management (FMHE 1982)

Table 1: Chemical characteristics of effluents from the soft-drinks bottling factories visited compared with industrial effluent standard and quality parameters for some Nigerian Rivers

Parameters (mg per litre)	Pepsi-Cola Factory	Coca-Cola Factory	1st India Effluent Standard	Quality Parameter for Nigeria Rivers
pH	9.0	11.1	5.5 – 9.0	5.5 – 7.5
Total Solids	770	3,000	-	50 – 500
Dissolved solids	760	2,980	-	50 – 450
Settleable solids	6	14	-	20
Suspended solids	10	20	100	20
Conductivity	990	1,850	-	-
Alkalinity	322.5	350	-	-
Hardness	105	308	-	-
Calcium	39	94.8	-	1.6 – 4.4
Magnesium	1.3	7.6	-	-
Potassium	22	9	-	-
Sodium	124	170	-	-
Chloride	11	47	-	-
Phosphate	1.0	10.5	-	-
Zinc	0.4	0.11	1.0	0.03 – 11
Copper	0.01	0.05	1.0	0.1
Lead	0.05	0.05	1.0	0.1

Note:

1. Extracted from India standards for effluents discharged into surface water.
2. The main pollutant here is pH-especially since the receiving streams are small. Neutrialization to pH 7 is recommended before discharge.
3. Range for 21 rivers in South-Western Area of Nigeria discharging into River Niger and the Lagos Lagoon network.

Table 2: Water Quality of Streams Polluted by Textile Waste Water

Parameters	1st Polluted stream	2nd Polluted stream	3rd Polluted stream	Polluted stream in Kaduna
pH	6.1	11.0	6.5	1.5
Conductivity (umhos/cm)	155	1510	550	3300
Alkalinity	-	-	-	987
Total Solids (mg/l)	1191	1550	800	2685
Total Suspended solids	50	73	165	145
Turbidity	-	-	-	-
Colour	Green	-	-	Purple/Green
COD ($mg^0 2/l$)	150	330	750	425
BOD ($mg^0 2/l$)	10.4	80	230	-
Nitrite	-	-	-	-
Ammonia	80	-	-	-
Sodium (mg/l)	122	3,800	1,100	800
Magnesium (mg/l)	30	2.5	5.1	1.3
Calcium (mg/l)	18	1.1	3.6	7.2
Chromium	0.2	-	-	-
Manganese (mg/l)	0.25	0.04	0.16	-
Iron (mg/l)	1.5	4.9	4.8	-
Chloride (mg/l)	-	-	-	235
Zinc	-	-	-	0.7
Potassium (mg/l)	-	200	300	20

Note:
1st stream: A stream in Iganmu Industrial Estate
2nd Stream: A stream in Ikeja Industrial Estate (Iya-Alaro Stream)
3rd Stream: Another stream in Ikeja Industrial Estate (Shasha Stream)
Source: Ajayi, S.O. and Osibanjo, O. 1979.

A clear message from the foregoing study is that most if not all the surface waters in the major urban industrial cities of Lagos, Port Harcourt, Kano and Kaduna are colored, odiferous, non-drinkable, non-swimmable, non-fishable and not hygienic, nor useful to the poor people in society who hitherto use these water sources for drinking and other domestic chores. This situation worsens the problem of

scarcity of good quality water for public use in Nigeria. Hence the popularity of sachets water—"pure water" or is it "poor water "as I call them—as many are not hygienically fit for drinking (because there is water everywhere yet there is very little to drink because of pollution). Nigerian *ThisDay* newspaper of 30 April 2008 (fig. 3) with the caption "In search of water as taps dried up'' and the *Guardian* newspaper of Friday 13 March 2009 (p11), under the caption "Tears for Water" carried photographs of Nigerians in desperate search for water to drink from any source—good or bad. Have we ever spared a thought to the fact that it is cheaper to fuel your car than purchase a bottle of potable water in Nigeria today! Petrol costs ₦65 per litre and a bottle of potable water costs between ₦75 to ₦300 or more depending on the place of purchase. This is not sustainable you will all agree with me. Nigeria may not meet the Millennium Development Goals for water and sanitation by 2015. Furthermore, industrial pollution has potential adverse implications for human health such as cancer, birth defects and neurological disorder.

Fig. 3: A Nigerian in desperate search for water in an urban centre (*ThisDay* 30 April 2008).

Environmental governance commenced in Nigeria in 1988 by the establishment of the Federal Environmental Protection Agency (FEPA, but was replaced by National Environmental Standards and Regulations Enforcement Agency (NESREA) in July 2007) by Decree 58 of 30 December 1988 as the apex body for natural resources conservation and environmental protection in Nigeria. This was the federal military government (in power then) response to the illegal dumping of about 3888 tons of toxic wastes from ltaly in Koko port in the old Bendel State and now Delta State. This issue will be revisited later in the lecture.

After analysing and helping the federal government to identify the true identity of the waste as assorted hazardous industrial wastes and toxic chemicals, and not radioactive waste as initially publicized , the pioneer Director General of FEPA Dr. Evans Aina collected some of the Koko waste samples from me and sent the samples for independent analysis in the United Kingdom accompanied by a former Commissioner of Police, Alhaji Kwajafa (Special Investigation Panel on Koko toxic waste) and Mr. Akin Awobamise, a senior officer in FEPA and now Director NESREA for South Western zone of the Country. After confirmation that the United Kingdom analysis results tallied with mine, I was appointed FEPA Resident Consultant, on national assignment, from 1st January 1990 for three years. This appointment was a great honor to the University of Ibadan, the Faculty of Science and the Department of Chemistry of this great university.

I assisted the young agency in foundation building initiatives such as staff recruitment, development of programmes and activities, and the establishment of the National Environmental Reference Laboratory in Surulere, Games Village Lagos among other tasks. FEPA after a review of environmental problems in Nigeria over the years identified industrial pollution as a priority environmental problem to be addressed immediately. Then I was given a

major assignment in 1991 to produce National Guidelines and Standards for Environmental Pollution Control in Nigeria within ten days. It was a tall order but to the glory of God, the task was achievable because of the environmental baseline data Professor S.O. Ajayi and myself had obtained over the years through our researches. See Tables 1 and 2 for typical effluent quality in the late 1970s in Nigeria. The cover page of the First Nigerian Environmental Guidelines and Standards 1991 by FEPA is shown in fig. 4. Some of the guidelines were being reviewed by NESREA last year. Several federal environmental protection regulations thereafter emanated from this document.

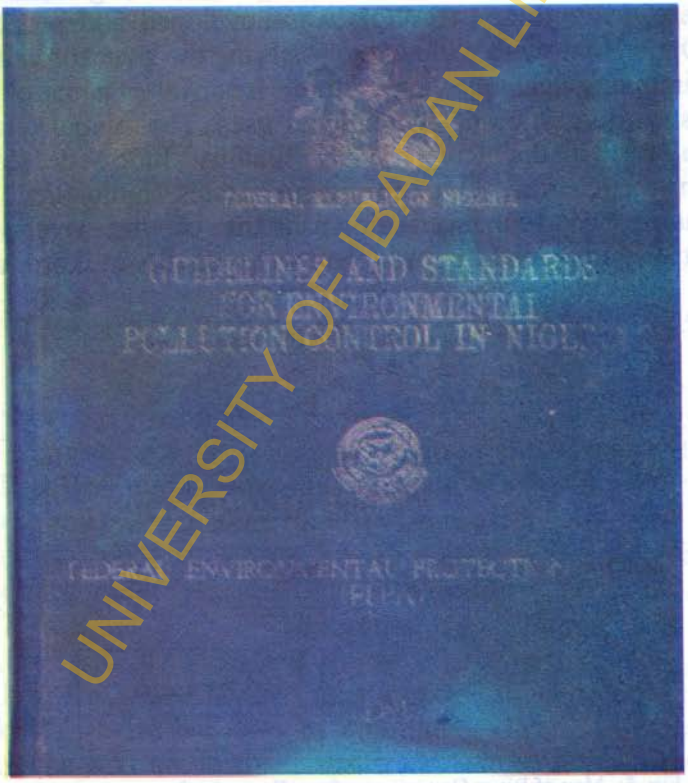

Fig 4: FEPA Guidelines and Standards for Environmental Pollution Control in Nigeria ("FEPA Green Book")

Ogun River A case study of River Pollution caused by unplanned Human Activity around the Cattle Market, Isheri along Lagos-Ibadan Express Road

One of my PhD students began in 1991 to investigate the quality assessment of Ogun River and its impact on the Lagos lagoon (Udousoro 1997). Ogun River traverses three states namely Oyo, Ogun and Lagos respectively. The objective of the study was to assess coastal and marine pollution from land based sources and other anthropogenic activities. The sampling started from its source in Eruwa in Oyo State through locations in Abeokuta and outskirts of Sagamu in Ogun State to Akute, Isheri, Majidun, Ikorodu Bridge and the Lagos Lagoon at Ikorodu all in Lagos State (fig. 5). River Water Quality Index (RWQI) was developed and proposed for Ogun River with a view to classifying the river for various requirements, namely, agriculture, freshwater aquatic life, industry, domestic and recreational uses. The spatial quality revealed that the River Water Quality Index decreased downstream from Oyo to Lagos states indicating that pollution was enhanced downstream of the river and negatively impacted Lagos lagoon water quality at Ikorodu.

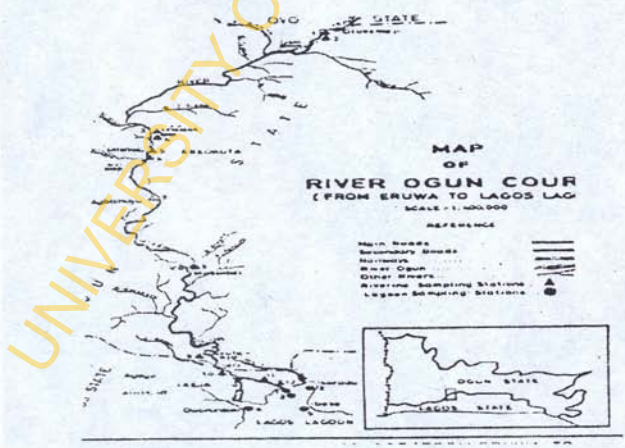

Fig 5: Map of River Ogun course from Eruwa in Oyo State to Lagos State.

Then in the late 1990s a cattle market was moved from Apapa in Lagos to the banks of Ogun River at Isheri without Environmental Impact Assessment study. We started periodic monitoring study of Ogun River at Isheri near the cattle market from 2000 to date to establish any environmental impact.

Table 3: Mean concentration of selected physico-chemical parameters (concentration in mg/l except pH) in River Ogun at Isheri on Lagos–Ibadan Express Road around the Cattle Market

Year/ parameter	1992/1994 Mean	2000	2005	2006	2008
Suspended solid	19.8	77.8	92.5	175	-
Oil and grease	10 .0	650.6	1,287	1,320	-
Dissolved oxygen	6.6	4.35	4.89	4.5	
COD	43.6	106.0	140	733	1,520
pH	7.55	6.68	7.18	7.27	6.45

The results of gross organic pollution parameters from 1992 to 1994 pre-location of the cattle market to post cattle market era from 2000-2008 indicated that the pH has decreased from near neutral 7.55 to slightly acidic 6.45 value; suspended solids increased almost 8 fold from about 20 mg/l to 175 mg/l in 2006; oil and grease had increased over 100 fold, while COD increased almost 35 fold from 44 mg/l to 1520 mg/l in 2008. These results (table 3) show that the cattle market at Isheri is a source of pollution of Ogun River and the Lagos Lagoon into which the river discharges at Ikorodu (Oketola et al. 2006). Ogun and Lagos state governments should take urgent action to halt pollution from the cattle

market at Isheri to prevent Ogun River (inter state water body) from slow death which would be an ecological disaster.

Estimating sectoral Pollution load by Industrial Pollution Projection System (IPPS)

Industrial pollution monitoring poses serious challenges to environmental regulators in developing countries because of the resource requirements, expertise needed and lack of competent staff to undertake reliable pollution monitoring studies. The World Bank developed a model, known as Industrial Pollution Projection System (IPPS) to estimate pollution load in ton/yr (with respect to staff employment). The IPPS was developed to exploit the fact that the scale of industrial activity, its sectoral composition, and the process technologies employed in production, heavily affect industrial pollution. IPPS gives regulators and environmental monitoring agencies in developing countries knowledge about the most polluting industrial sectors, thus reducing cost and time while increasing the level of enforcement. Consequently, more time can be spent on the few polluting sectors identified by IPPS. IPPS is cheaper and less time consuming when compared to running scientific monitoring data gathering and analysis.

The IPPS model was employed in estimating sectoral pollution in Lagos state (Oketola and Osibanjo 2007). From the cumulative ranking of the pollution load (ton/yr) estimate to all media (i.e. air, land, and water), Chemical and Pharmaceutical (CPH) sector is the highest polluting sector, followed by Basic Metal (BML), Domestic and Industrial Plastics (DIP), and Food, Beverage and Tobacco (FBT) sectors. Some of these sectors have the highest number of employees, and also appeared as the most polluting sectors in Lagos. We recommend IPPS as a valuable planning and enforcement tool for environmental ministries and agencies in Nigeria and other developing countries.

Oil Pollution Studies in the Niger Delta

The oil and gas sector is the crown jewel of industrialization in Nigeria. This sector is the mainstay of the Nigerian economy now and in the foreseeable future. Yet it has been a "sweet and sour story". The oil and gas industry activities take place predominantly in the Niger Delta area of the country which is an ecologically sensitive area. The main environmental concerns are multimedia in nature and include the adverse impacts on coastal and marine resources especially fisheries, with incessant oil spills which cause fish kills, pollute natural drinking water sources and destroy farmlands. These have resulted in restlessness of the youths who are largely unemployed, and elicited loud protests from inhabitants in host communities as their livelihood is threatened by oil pollution. According to the National Oil Spill Detection and Response Agency (NOSDRA) there are over 1000 oil spill sites in the Niger Delta. Pipeline vandalization has worsened oil spill incidents of crude and petroleum products in recent years.

Gas flaring has also been a nightmare problem in the Niger Delta. According to the World Bank, Nigeria holds a world record in gas flaring from the oil fields and is one of the important contributors to green house gases emission and global warming. Nigeria is losing on average between $ 1.73 billion and $2.43 billion annually from the flaring of associated gas. It is our expectation that the ever shifting gas flare-out deadline set by government would be firmed up this time by the new target date of 2012.

Mr. Vice-Chancellor, I was opportuned to be the Editor of the Proceedings of the First Biennial Seminar on the Petroleum Industry and the Nigerian Environment held in Port Harcourt in 1979, which was organized by the Department of Petroleum Resources (DPR) and EPPD of the defunct Federal Ministry of Housing and Environment (but the seminar is organized solely by DPR now). Participation in this national seminar sparked my research interest in the Niger Delta.

Our study of environmental problems in the Niger delta began in the early 1980s with the study of heavy metals in Nigerian crude oil types (Osibanjo et al. 1984), baseline heavy metals including mercury in fish and sediments (Kakulu and Osibanjo 1986), trace metal content of fish and shell fishes of the Niger Delta (Kakulu et al. 1987) and trace heavy metal pollution status in sediments of the Niger Delta (Kakulu et al. 1988). With the exception of high lead level in some shellfishes, the levels of the heavy metals were generally low compared with values from other parts of the world showing that the degree of metal pollution was low in the Niger Delta then. Furthermore the levels of metals studied were much lower than the World Health Organization acceptable limits in foods. The sediments too were generally found to have low heavy metals with the exception of lead which had elevated concentration in areas around the refineries in Port Harcourt and Warri. With the exception of lead the concentration of heavy metals in effluents from petroleum refineries in the Niger Delta were within the range found for European refineries. The heavy metals found in surface waters in the area were found to be generally lower than international levels in freshwaters and international drinking water standards.

The heavy metals levels reported in our studies and published in international reputable journals represent baseline levels in the 1980s in the Niger Delta. Exponential expansion of upstream petroleum activities has most likely increased pollution load in the last two decades since the 1980s, more so with great international demand for Nigerian crude oil. Obviously the heavy metals status could have changed in parts of the Niger Delta especially around flow stations and loading terminals. This would have to be confirmed from recent studies in the area.

I am aware that the Federal Government has invited UNEP to come and carry out environmental post impact studies in Ogoni land as an independent arbiter on the claim by Ogoni people of ecological genocide in Ogoni land. The

environmental scientists in the University of Ibadan should look out for participation in this international study when it comes on stream. A survey of petroleum hydrocarbons levels in Nigerian waters, sediments, fish and shell fish around Lagos and the Niger Delta Area of Nigeria was also carried out in collaboration with NNPC and Nigerian Institute of Marine Research and Oceanography (NIOMR), by two of my PhD students between 1984 and 1989 namely: Adekambi, O.E. 1989 (of blessed memory) and Jinadu, A. 1989. The petroleum hydrocarbon levels presented as range followed by mean value in bracket were: Lagos and Lekki lagoons 1.64 – 11.40 (5.6) mg/l; Niger Delta ND-70.70 (6.18 mg/l) while Ibadan surface water samples (served as control) showed no detectable levels of hydrocarbons.

The corresponding hydrocarbon levels (on dry weight basis) in sediment samples were Lagos and Lekki lagoons ND-99.54 (30.33) µg/g and the Niger Delta ND -74.05 (9.09) µg/g. The baseline results we obtained in the 1980s showed that Lagos Lagoon was more polluted than the Niger Delta in terms of petroleum hydrocarbons. Highest values of petroleum hydrocarbons were recorded close to oil activity points such as Ogharife field effluent canal, Chanomi creek at Egwa field, and Orughene creek in the Niger Delta area; or near human settlements such as Obotebe and Bakana or in industrial areas like Lever Brothers effluent discharge point and National Oil jetty in Ijora in the Lagos Lagoon. These studies have to be revisited after two decades to ascertain the status of environmental quality in the Niger Delta and the Lagos Lagoon arising from intensive offshore oil exploration activities and massive importation of petroleum products through the ports in Lagos.

Air Pollution Studies

Good air quality is strategically important for healthy living and enjoying fullness of life. Transportation is a major cause of low urban air quality while industrial emissions may adversely affect ambient air quality around industrial

facilities and neighborhood settlements. The conventional atmospheric pollutants for regulatory purposes include particulate matter, nitrogen oxides, sulphur dioxide and volatile organic carbons (VOCs). The particulate matter may be laden with hazardous substances such as heavy metals (lead, mercury, nickel etc) and carcinogenic organics such as Polyaromatic hydrocarbons (PAHs). The World Health Organization (WHO) has indicated that indoor air pollution, is a major cause of mortality in Africa. Somehow air quality study is largely a neglected area of research in the country.

Some studies in Nigeria have however tried to infer the presence of pollutants in air through the study of heavy metals in biological indicators using plants; tree barks (Osibanjo and Ajayi 1980) and mosses (Onianwa et al. 1986a, 1986b). Some used multi-elemental determination of trace metals (e.g. Ogunsola et al. 1993, 1994) while others used ambient air sampling by means of state-of-the-art analysers (e.g. Akeredolu, Sonibare and Osibanjo 2000; Sonibare, Akeredolu, Osibanjo and Latinwo 2005). Mr. Vice-Chancellor, the collaborative paper Akeredolu, Sonibare and Osibanjo (2000) entitled: "Air pollution problems in five Nigerian manufacturing industries: The need for workers' safety, awareness and effective management'' won the best Technical Paper Award at the 2000 Annual Conference of the Nigerian Society of Engineers.

Chemical Pollution and Sound Chemicals Management

Chemicals are important to mankind and the sustenance of life on earth in the modern world we live in with multifarious uses in agriculture, medicine, food preservation and processing, industrial manufacturing, and public health/vector control, etc. Chemicals are essential requirements of modern society that need to be managed in a safe and sound manner in order to achieve a sustainable level of agricultural, industrial and industrial development, and a high level of environmental and human health protection. Although a substantial use of chemicals is essential for social and

economic development, exposure to hazardous chemicals may threaten sustainable development through negative effects on health and the environment. The potential socio-economic impacts and costs of toxic chemicals are large and are borne disproportionately by poor communities and vulnerable groups (children, old people and pregnant women) in the society thereby worsening poverty. According to the World Health Organization (WHO) unintentional poisonings by chemicals lead to about 300,000 deaths annually while over 70,000 deaths occur in children up to 14 years old.

Hazards caused by toxic chemicals through improper handling and releases into the environment are worst for the Nigerian populace that have little chance of avoiding exposure risk and protecting themselves. In addition, due to poor education, low awareness, and lack of information, Nigerians are generally unaware of existing hazards of chemicals and have little access to timely and proper medical care. Abuse and misuse of hazardous chemicals is therefore rampant especially pesticides being used for toothache and head lice control, and electrical transformer oils containing carcinogenic polychlorinated biphenyl (PCB) being used as hair cream. Accidental or occupational exposure and food contamination still remain as the major risks.

The nexus has been established between chemicals and some of the major global environmental problems of today, in particular, Stratospheric Ozone Layer Depletion, Climate Change and Global Warming, Acid Rain, Loss of Bio-diversity and the Transboundary Movement of Toxic and Hazardous Wastes. Developing countries like Nigeria are seriously at risk from chemicals hazard due to lack of National Policy on Sound Chemicals Management, weak regulatory framework and infrastructure for sound chemicals management. The extant piece meal regulations are weakly enforced. International concern based on scientific and toxicological evidence about the dangers to human health and the environment by persistent toxic substances (PTS) and their wastes influenced the UNEP Governing Council

decision in February 1997 (Decision 19/13 C) that immediate international action should be initiated to protect human health and the environment through measures which will reduce and/or eliminate the emissions and discharges of an initial set of twelve persistent organic pollutants (POPs). These series of negotiations have resulted in the adoption of the Stockholm Convention in 2001. The initial 12 substances fitting these categories that have been selected under the Stockholm Convention are: Aldrin, Endrin, Dieldrin, Chlordane, DDT, Toxaphene, Mirex, Heptachlor, Hexachlorobenzene, PCBs, Dioxins and Furans.

In 2001 the Global Environment Facility (GEF) and UNEP organized for the first time a global study on the Regionally Based Assessment (RBA) of Persistent Toxic Substances (PTS) in the environment and the threat their releases pose to human health and the environment itself. Other PTS studied apart from POPs chemicals were : Endosulfan, Hexachlorocyclohexane (HCH), Phthalate esters, Polyaromatic hydrocarbons (PAHs), Pentachlorophenol, Organic lead, Organic tin and Organic mercury compounds, Atrazine, Chlordecone, Hexabromobiphenyl, Polybrominated biphenyl ethers, Chlorinated paraffin's, Octylphenols, and Nonylphenols. PTS have the following characteristics, they are (i) persistent, (ii) bioaccumulative, (iii) prone to long-range transboundary atmospheric transport and deposition, and (iv) are likely to cause significant adverse human health or environmental effects near to and distant from their sources. Fig. 6 shows adverse health symptoms of human exposure to PTS while fig. 7 is the photo of a Japanese victim of PCB poisoning known as YUSHO patients. The symptoms include dizziness, hypertension, various cancers, abortion, abnormal behavior and even death. Unfortunately Nigerians translate these adverse reactions of exposure to chemicals to unscientific insinuations such as "Spiritual attack'' or "The wicked have done their worst''.

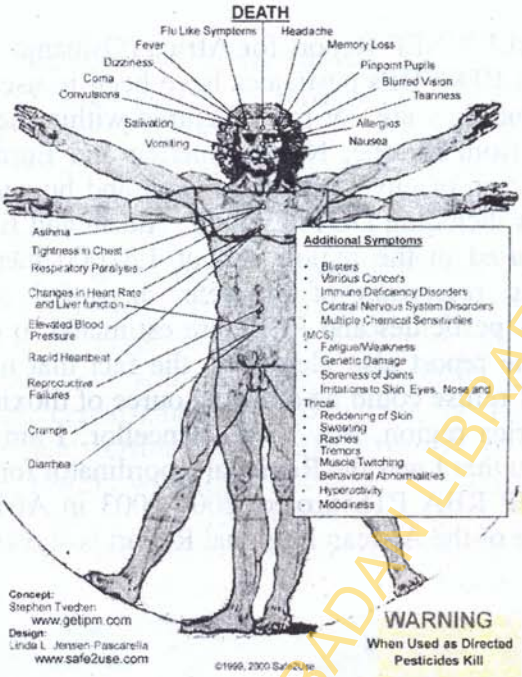

Fig. 6: Body health symptoms of exposure to toxic chemicals

Fig. 7: Japanese Victim of PCB Poisoning

The GEF/UNEP Report for Africa (Osibanjo et al. 2003) found that PTS/POPs pesticides have been in use for several decades and they are not manufactured within the region but imported from Europe, North America and Europe. Gross contamination of environmental media and humans by some PTS/POPs including DDT, Lindane, Aldrin and Endosulphan were reported in the region. About 120,000 metric tons of stocks and reservoirs of obsolete, discarded and banned PTS/POPs pesticides and PCBs are estimated to exist in the region. The report also alerted on the fact that uncontrolled burning of refuse could be a major source of dioxin and furan in the Africa region. Mr. Vice-Chancellor, I am pleased to inform you that I was the Regional Coordinator for this novel GEF/UNEP RBA PTS project 2001-2003 in Africa and the cover page of the African Regional Report is shown in fig. 8.

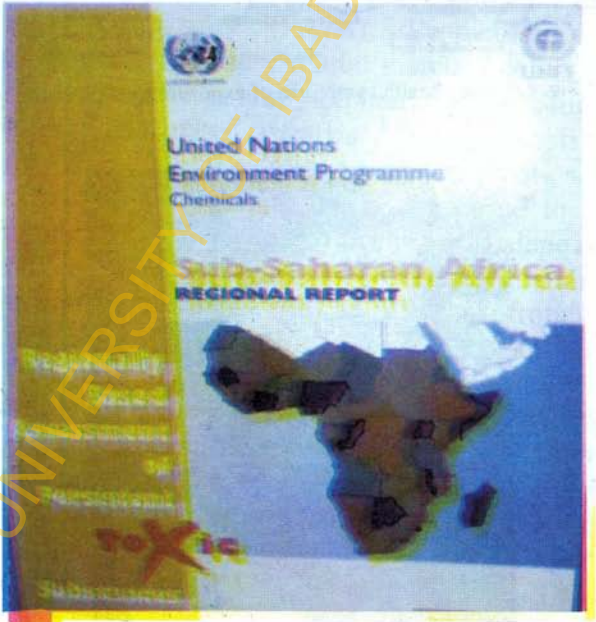

Fig. 8: GEF/UNEP Sub-Saharan Africa Report on PTS

POPs in the Nigerian Environment

Mr. Vice-Chancellor, I established a Persistent Organic Pollutants (POPs) laboratory in Chemistry Department in 1981 on my return from sabbatical leave in Sweden in the Wallenberg Laboratory, Stockholm University of Professor Soren Jensen, the Swedish Analytical Chemist who discovered Polychlorinated Biphenyls (PCBs) in the environment in 1966. We have since continually assessed POPs levels in environmental samples in Nigeria. Our studies have established contamination of Nigerian foodstuffs—vegetables, cereals, nuts, etc (Osibanjo and Adeyeye 1995; Adeyeye and Osibanjo 1999); livestock (Osibanjo and Adeyeye 1992), wildlife (Osibanjo 2002)—let bushmeat lovers beware; rivers (Nwankwoala and Osibanjo 1992), marine fish (Osibanjo and Bamgbose 1991); human blood (Osibanjo 2002) and mothers breast milk (Osibanjo 2002). Mr. Vice-Chancellor we may therefore add a caveat to WHO's slogan that "Mothers breast milk is best'', provided it is not contaminated beyond tolerable levels by POPs and other xenobiotics (table 4). We are all lovers of roasted cow skin or "*Ponmo*" as a delicacy in soup. Let me warn the nation that the present practice of roasting fresh cowskin by burning vehicular used tyres, is a high health risk because it is a major source of dioxins and furans (potent carcinogens) in the "*Ponmo*" meat. This practice is shown in fig. 9 where roasting of cow and goat carcass is done in Bodija market, Ibadan.

Fig. 9: Roasting of cow skin and goat carcass with vehicle tyres at the Bodija market abattoir, Ibadan, Oyo State

Mr. Vice-Chancellor Sir, we have joined the international debate through our research results on the ban of DDT, a cheap and effective insecticide for malaria control especially in developing countries. The chemical was banned for its persistence ($t_{1/2}$ up to 16 years in temperate weather countries), bioaccumulation and causing near extinction of the American bald eagle. Our research here at Ibadan in a tropical weather environment (Ajewole 1998, Ajewole and Osibanjo 2000) has shown the half life ($t_{1/2}$) of DDT to be 7.86 weeks (55.02 days) in uncropped soils and 8.72 weeks (61.04 days) in cropped soils depicting low persistence of DDT in a tropical soil condition. This underscores the importance of local, national and regional research before far reaching global actions are taken. Happily WHO has now given waiver for developing countries who may wish to use DDT for malaria control only.

Table 4: Concentrations of chlorinated hydrocarbons and POPs (μg/g fat weight) in human breast milk from Nigeria and from other countries in Europe and Asia

	Nigeria	Sweden	Great Britain	West Germany	Hong Kong	South Africa*
DDE	1.95 (0.18 – 9.01)	1.64 (1.15 – 2.83)	1.6 (<0.01 – 7.3)	1.51 (< 0.01 – 12.8)	11.67 (4.07 – 22.96)	8.65 (0.5-46.9) exposed people; 0.65 (ND-4.73) non-exposed people
$DDT_{p,p}$	1.27 (<0.01 – 11.90)	0.26 (0.21 – 0.33)	0.11 (<0.01 – 1.2)	-	2.17 (0.67 – 4.04)	6.77 (0.42-28.8) exposed people 0.04 (ND-0.36) non-exposed people
Aldrin	0.04 (<0.01 – 0.40)	-	-	-	-	
Dieldrin	-	0.02 (0.01 – 0.03)	0.08 (<0.01 – 0.55)	-	0.24 (0.04 – 0.80)	
HCB	0.33 (<0.01 – 4.87)	0.14 (0.11 – 0.20)	0.14 (<0.01 – 1.0)	0.72 (<0.01 – 5.38)	0.05 (<0.01 – 0.29)	
α,β-BHC	0.03 (<0.01 – 0.30)	0.17 (0.14 – 0.22)	0.22 (<0.01 – 4.4)	0.44 (<0.01 – 9.10)	15.96 (2.91 – 27.24)	
Lindane	0.46 (<0.01 – 6.55)		-	-	-	
Heptachlor	0.06 (<0.01 – 0.38)	-		-	-	
Endosulfan	0.64 (<0.01 – 10.03)	-	-	-	-	
PCBs	0.02 (<0.01 – 0.30)	1.44 (1.22 – 2.00)	0.5 (<0.1 – 2.1)	2.04 (<0.01 – 12.0)	0.64 (0.25 – 1.43)	

Source: Osibanjo 2002

Waste Management

Waste is an inevitable by-product of anthropogenic activities. Most developing countries including Nigeria, practice waste disposal which is environmentally unsustainable, rather than waste management (collection, sorting, recycling). Nigeria generates over 50 million tons of solid wastes annually with less than 10% waste management capacity (Wamason 2009). Waste management problems in Nigeria are varied and complex with infrastructural, political, technical, socio-economic, organizational, management, regulatory and legal issues and challenges to be addressed. Municipal solid waste management has therefore continually been an intractable problem beyond the capacity of the local governments and most state governments due to inefficient garbage collection (less than 40% collection), poor public compliance to waste segregation, uncontrolled open burning, and tolerated presence of open dumpsites (e.g. Ibadan city), inadequate resources, dismal law enforcement and lack of coordination among the various units of government.

Land availability is also a major constraint for new waste dumpsites due to competitive demand for the limited land available. This has been a driver for the building of houses and markets on refuse dumps especially Lagos and Port-Harcourt in Nigeria (a chemical time bomb!) which indicates the low level of awareness of the adverse environmental and human health impacts of poor waste management at all levels (fig. 10). Leachates from refuse dumps pose surface/ground water pollution (Ikem, Osibanjo, et al. 2002) and public health problems (Bakare et al. 2003, Bakare et al. 2005).

Fig. 10: New house under construction on a refuse dump in Port-Harcourt.

Hazardous waste is of special concern because of the harmful effects of exposure of humans and biota to the toxic and ecologically damaging contents of the waste. About 400 million tons of hazardous waste are produced annually (globally) with inadequate infrastructure to effectively handle them apart from the high costs of disposal especially in the developed countries coupled with enlightened citizenry and strict enforcement of hazardous waste control laws. This is the genesis of the toxic waste invasion—from developed countries—of developing countries and economy in transition countries with huge debt burdens, low public awareness of environmental issues, as well as lack of or weak hazardous waste laws in the 1980s.

You will all recall that Nigeria was a victim, with the discovery of the illegal dumping of 12,000 drums of assorted toxic wastes (3888 tons) from Italy in Koko port in the then Bendel State. This situation led to the beginning of environmental governance in Nigeria with the establishment

of FEPA (now Federal Ministry of Environment) by Decree 58 of 1988. The University of Ibadan was rewarded for my service in helping government to analyse the Koko toxic wastes with the establishment in 1994 of the FEPA (now Federal Ministry of Environment)—University of Ibadan Linkage Centre for Cleaner Production Technology and Hazardous Waste Management. The Federal Government also appointed the linkage centre as the Basel Conventional Regional Coordinating centre for Africa for Training and Technology Transfer in Hazardous Waste Management, while also coordinating the Basel Convention Centres in Egypt, Senegal and South Africa respectively. The next figure shows Dr. Evans Aina, the Director of EPPD (later Pioneer Director General of FEPA), Analytical Chemists from USEPA and Dr. Osibanjo discussing strategy at the Koko dump site (fig. 11). The Basel Convention Regional Coordinating Centre for Africa building on campus donated by the Federal Ministry of Environment and commissioned in August 2004 is shown in fig. 12.

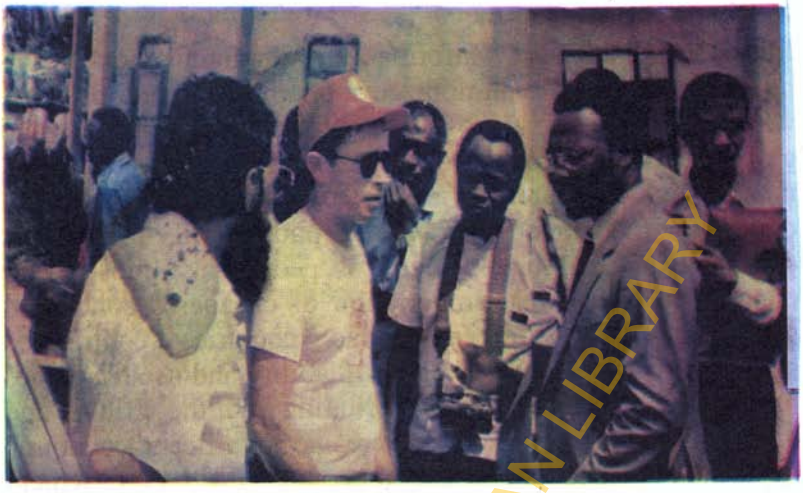

Fig.11: Analytical chemists from USEPA, Dr Osibanjo and Dr. Evans Aina (Director EPPD, later Pioneer Director General EPPD) at Koko dump site in 1988

Fig. 12: Basel Convention Regional Coordinating Centre Building, University of Ibadan. Nigeria.

Electronic Waste Tsunami- A Global Environmental Problem

Mr. Vice-Chancellor, Information Communication Technology (ICT) has revolutionized modern living and business with fast communication gadgets, international business and global governance with e-commerce, e-banking, e-government, the global system of mobile communication (GSM) and other recent innovations. Mobile phones fill a need for communication among billions of people in almost every country on the planet. Importation of cheaper second-hand sets (fig. 13) from developed countries contributed significantly to the widespread availability and use of phones by all segments of the society including both the affluent and the common man. They have created significant economic expansion in national and global economy, with employment creation and poverty alleviation (Nnorom and Osibanjo 2008).

Fig. 13 : Assorted second-hand mobile phone handsets

Most developing countries are currently undergoing rapid advancement in ICT through the use of computers. A very

significant proportion of ICT users including Internet services in developing countries rely on second-hand equipment from developed countries, primarily from Europe and North America. In view of the short life span of mobile phones and computers, rapid innovations with new models and features, falling prices and rapid product obsolescence, unprecedented large volumes of e-waste are produced globally. Worldwide, about 500 million personal computers (PCs) reached the end of their life (EoL) in the decade between 1994 and 2003 and these contain approximately 2,870,000 ton of plastics, 718,000 ton of lead, 1,363 ton of cadmium and 287 ton of mercury. Most of these EoL will end up as waste in developing countries releasing their hazardous constituents, endangering the environment and human health (Nnorom and Osibanjo 2007).

Consequently electronic waste (e-waste) is one of the topical environmental issues of the 21st century. It has been identified as the fastest growing waste stream in the world, forecast to reach soon 50 million tonnes a year, while its generation is estimated at three times the rate of municipal solid waste. With the globalization of trade in e-waste, there is high level of trans-boundary movement of electrical and electronic devices as second-hand or end-of-life electronic equipment from developed countries into developing countries in an attempt to bridge the 'digital divide'.

E-wastes contain several persistent, bioaccumulative and hazardous substances (PBT) including heavy metals such as lead, nickel, chromium, mercury and organic pollutants such as polychlorinated biphenyls (PCBs) in capacitors in the older models which are still in the market, and the brominated flame retardants (BFR). Thus, globalization of e-waste has adverse environmental and health implications in the downstream end of the EEE supply chain entailing disposal of waste, as developing countries are economically challenged, lack the infrastructure for sound hazardous waste management including recycling, or effective regulatory framework for hazardous chemicals and wastes management.

However e-waste also contains valuable ferrous (e.g. iron), non-ferrous (e.g. aluminium, copper) and precious and special metals (e.g. gold, palladium, silver, indium, gallium) metals that can be obtained from dismantling of computer cases, frames, wires, cables and other components. The rising value of these materials makes recycling more economically viable and attractive.

The recent Basel Action Network(BAN) coordinated study in Nigeria with Basel Centre Nigeria collaborating in 2005 titled—Exporting Reuse and Abuse to Africa—revealed the level of transboundary movement of second-hand and scrap electrical and electronic equipment into developing countries exemplified by Nigeria. Estimated 5 million PC units, with a weight estimated at 60,000 metric tons is imported annually into Nigeria through the major sea port of Lagos only. The BAN study observed that about 25–75% of the imported second-hand computer wares are unusable junk that are non-functional or unrepairable. This amounts to an importation of 15,000–45,000 tons of scrap recyclable electronic components, which may contain as much as 1000–3,600 tons of lead. In Nigeria, there is virtually no capacity for material recovery operations for electronic waste, as a result of which these items become discarded in local dumps. Assuming this trade continues unabated, with an annual increase of 10%, then an estimated 40 million units of PCs or monitors (or 468,000 metric tons of e-scrap) would have been imported over the period 2005–2010 (Osibanjo and Nnorom 2007). This will amount to an importation of about 40,000 metric tons of Pb for the period under consideration or 77,000 tons of e-scrap/year. Second-hand computer wares are also imported through donations by charities to organizations and educational institutions (a minor source of import) which imports have also been found to contain 20-80% junk.

Computers, monitors, televisions, etc, are disposed by thousands in open dumpsites for example in Computer Village, Ikeja and Alaba market Lagos, Nigeria waiting to be

burned after some months. In addition, informal recycling processes are taking place, including open burning resulting in the pollution of soil, atmosphere and underground water and in increasing health problems, an ominous heritage that will hinder development of Nigeria for generations. Beside the environmental and health problems, the resource efficiency which is achievable by these backyard practices is very low. This means lost chances for thousands of people in Nigeria because scrap metal prices on the world market have soared in recent years due to increasing demands and even shortages of a couple of raw materials. A Cathode Ray Tube (CRT) in computer monitors which is a major source of lead in the environment if improperly disposed is shown in fig. 14. Printed wire boards (PWBs) in computers and cell phones is shown in fig. 15; a scene at a second-hand computer market in Lagos is captured in fig. 16; while fig. 17 shows open burning in refuse dumps of unserviceable used-computers in Lagos.

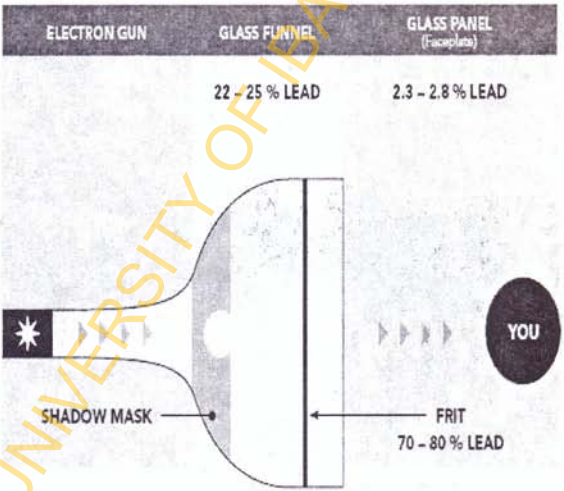

Fig 14: Cathode Ray Tube, CRT: A Major Source of Lead in E-waste: contains 2-4kg

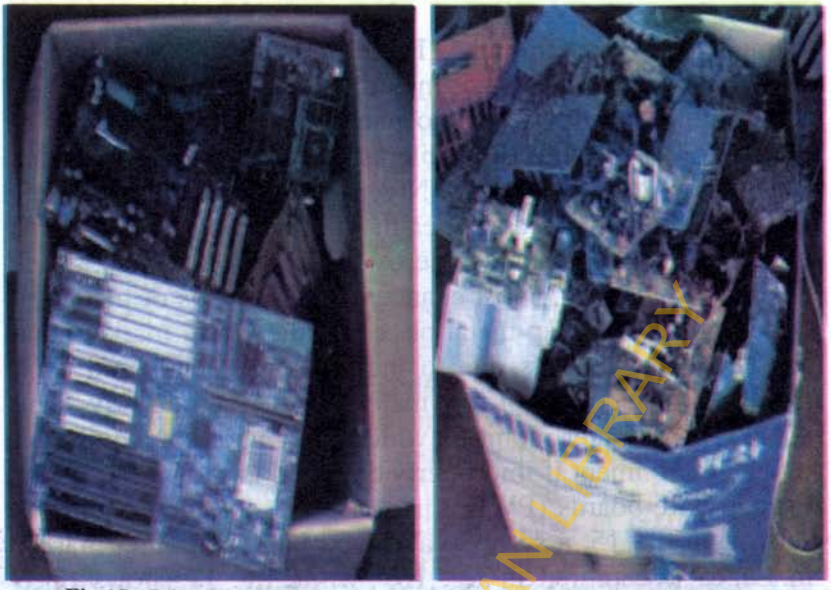

Fig 15: Printed Wire Board (PWB) in mother board of computers and cell phones.

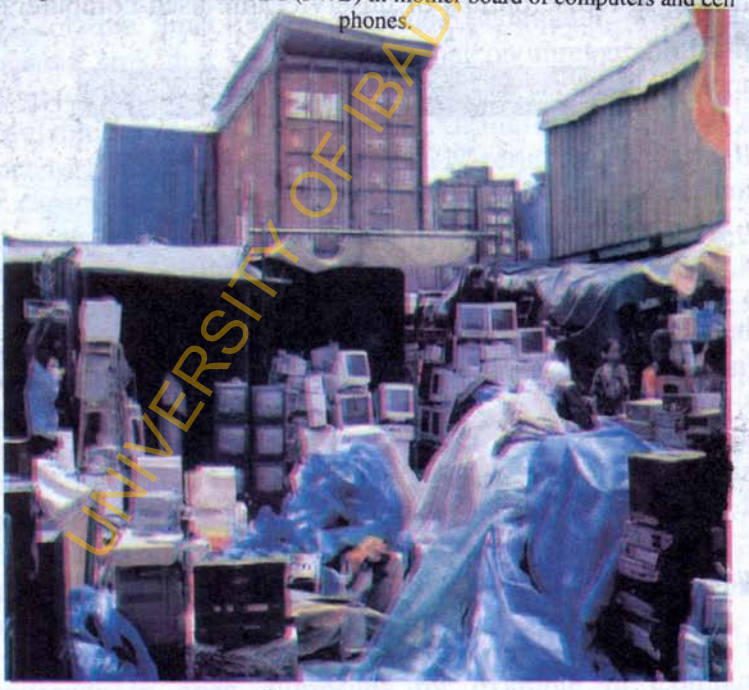

Fig. 16: Second-hand computer market in Computer Village, Ikeja, Lagos.

Fig. 17: Open burning of unserviceable used-computers in Alaba market, Lagos State.

Our studies have shown that heavy metals in used computers and cell phones (fig. 18) imported into Nigeria are much higher than threshold limits set in developed countries (Nnorom and Osibanjo 2009, Ogunkeyede 2008, etc). Post impact environmental studies have shown that there is heavy metals contamination of soils, plants and ground water around e-waste disposal and burning sites (Nnorom and Osibanjo 2009, Osibanjo and Bankole 2009).

The Federal Government, through the Federal Ministry of Environment, should as a matter of urgency enact a national Policy on e-waste, develop guidelines for testing second-hand Electronic and Electrical Equipment (EEE), introduce legislation to control dumping of e-scrap in Nigeria, build the capacity of the informal capacity for repair and refurbish used

and end-of-life EEE, set up collection and sorting centres for e-waste and promote private sector investment and active participation in e-waste recycling.

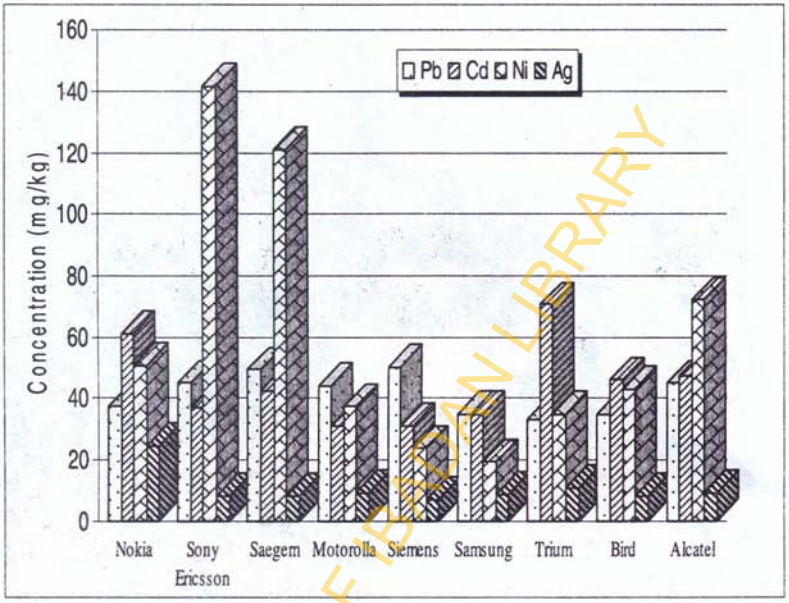

Fig. 18: Concentrations of metals in mobile phone plastic according to brand (geometric mean values)

Mr. Vice-Chancellor, e-waste is one of the four emerging global environmental issues for discussion at the Second International Conference on Chemical Management ($ICCM_2$) holding in Geneva in May 2009. I have been appointed the facilitator to collate and present the present status of e-waste globally at this global meeting and I have also been elected Co-chair global Partnership for Action on Computing Equipment (PACE) of the Basel Convention in January this year.

Improper disposal of used Dry Cell Batteries and used Lead Acid Batteries—Chemical Time Bomb in Nigeria

Dry Cell Batteries

Mr. Vice-Chancellor, Nigeria imports over 11,000 metric tons of dry cell batteries to power radios, torch lights, clocks etc largely from Asia and less from Europe and North America. Most of the dry cell batteries from China are short lived with a useful life of some days and weeks. They end up in refuse dumps and are burnt openly with thrash. In a Nigerian study of imported dry cell batteries 1980 – 1998 (Nnorom and Osibanjo 2006), the mean Pb and Cd content of the dry cell batteries were 1051 mg/kg (range 42-3170 mg/kg) and 107.7 mg/kg (range 4.6-410 mg/kg) respectively which values are much higher than threshold limits for concentration of restricted substances in articles/products in developed countries. This is a challenge for Standards Organization of Nigeria (SON) to monitor and control heavy metals in dry cell battery imports into Nigeria; while the Federal Ministry of Environment and NESREA should develop guidelines for the environmentally sound management of used/spent dry cell batteries in Nigeria.

Slag waste from Lead Acid Battery manufacture

Slag is a solid hazardous waste from auto battery manufacture containing up to 12% lead which is a highly toxic heavy metal affecting the intelligence quotient of children. West African Battery (Exide) which was the largest auto battery manufacturer closed down in 1990 and left a toxics legacy as the slag was dumped in open land and farm lands in six different villages on the outskirts of Ibadan including Olodo and Lalupon villages. An environmental assessment study was conducted by us at a site abandoned by Exide in Lalupon, near Ibadan. Lead, Cd, Cr, Ni and Zn were present in the slag waste with Pb being the predominant metal, followed by Zn. Lead levels ranged from 120–124000, 25.4–4300 and Zn from 223–2100, 16.5–319 and 35.0–80.6 mg/kg in the waste and surrounding soil respectively.

Selected samples that were tested for Toxicity Concentration Leaching Procedure (TCLP) had leachable lead exceeding 5.0 mg/L which indicates the waste as hazardous. Bioavailable Pb ranged from 63.5–73.5 %. The levels of Pb in the plants in the vicinity of the waste ranged from 13.6–15400 mg/kg as against its levels in uncontaminated plants (0.5–10 mg/kg). Phyto and chemical remediation of the site were investigated with potential success (Ogundiran et al. 2008, Ogundiran et al. 2009). The villages where Exide slag was dumped almost two decades ago remain chemical time bombs and potential threats to human health and the environment.

In line with our ongoing research on waste to wealth, the slag has been recycled into bricks and ceramic tiles (fig. 19) for potential low cost building; and in the process create employment and alleviate poverty (Adie Gilbert PhD thesis 2008).

Fig. 19: Battery slag recycled into bricks and ceramic tiles

Lead for car batteries poisons in an African town—Lesson for Nigeria

Mr. Vice-Chancellor, a disaster occurred in a village on the outskirts of Dakar, Senegal's capital early this year. Lead waste from crude processing of Used Lead Acid Battery (ULAB) was dumped carelessly on refuse dumps, a practice which is common in Nigeria's urban centres including Ibadan, Lagos, Kaduna, etc. What happened? According to Associated Press (AP) Writer Ms Heidi Vogt, "First it took the animals. Goats fell silent and refused to stand up. Chickens died in handfuls, then en masse. Street dogs disappeared. Then it took the children. Toddlers stopped talking and their legs gave out. Women birthed stillborns. Infants withered and died. Some said the houses were cursed. Others said the families were cursed. The mysterious illness killed 18 children in this town on the fringes of Dakar, before anyone in the outside world noticed. When they did—when the TV news aired parents' angry pleas for an investigation, when the doctors ordered more tests, when the West sent health experts—they did not find malaria, or polio or AIDS, or any of the diseases that kill the poor of Africa". They found excessive levels of lead in environmental and clinical samples. Nigeria and in particular the Federal Ministry of Environment, NESREA and the State Ministries of Environment should learn lessons from this and prevent avoidable deaths from crude ULAB processing in Nigeria. We don't know how many deaths have occurred due to similar incidents in Nigeria, with people thinking it is a curse or witchcraft!

Conclusion and Recommendations

Mr. Vice-Chancellor, I have taken us on a journey through the national and global environmental space and attempted to show the relevance and importance of Analytical and Environmental Chemistry in environmental protection. Let me thank you in a special way for the beautiful ambience and conducive learning environment your administration has

created on campus; and the improved support for teaching and research, although we need more funding from government. This lecture has demonstrated that, intense fossil fuel use, increasing CO_2 emissions, unsustainable industrialization, multimedia environmental pollution, poisoning and deaths from human exposure to hazardous chemicals, environmentally unsound waste management are risk factors in giving the earth a future. Unless we decouple economic growth from environmental degradation, we will still not be able to alleviate poverty and sustain good levels of quality of life. We cannot protect the environment in a data vacuum, hence the need to fund environmental research by government and the private sector. A percentage of the Ecological Fund should be allocated to universities for strategic environmental research in the geopolitical zones of the country.

Government should promote integrated waste management with recycling, as well as cleaner technologies in production, and sound chemicals management. As a signatory to the Strategic Approach to Sound Chemicals Management (SAICM) and in accordance with the Johannesburg Plan of Implementation, Nigeria should aim to achieve, by 2020, sound management of chemicals to ensure the minimization of significant adverse effects on human health and the environment. The country must domesticate and implement all the Multilateral Environmental Agreements (MEAs) it has ratified, especially those MEAs on chemicals and wastes including the Kyoto protocol on climate change. Furthermore, the educational system should promote green chemistry while greening of the Business Schools and Engineering Programmes is also important for sustainable development in the country.

Before resting my case as the lawyers say, let me remind all of us that the environment is not a gift from our parents but a loan from our children. It is our collective responsibility to protect the environment for present and future generations, and adopt sustainable consumption and production

strategies—so that posterity may commend rather than condemn us.

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