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THE EFFECTS OF ENVIRONMENTAL ASSAULTS ON HUMAN PHYSIOLOGY (2)

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GUEST LECTURE delilvered at the 25th Annual Scientific Conference and Silver Jubilee Celebrations of The Physiological Society of Nigeria

1.0 Introduction

The central theme of this conference is most appropriate, for today there is so much talk about adverse effects of the environment on health. Indeed one of the Millennium Development Goals (MDGs) is to ENSURE ENVIRONMENTAL SUSTAINABILITY and the target set for the year 2015 is to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation. It is of particular significance that this conference is holding in one of the nine states of the Niger Delta Region, which has some degree of environmental pollution.

The New Webster's Encyclopaedic Dictionary of the English Language of 1997 defined the environment as follows: *The aggreate of surrounding things, conditions or influences; The air, water, minerals, organisms and all other external factors surrounding and affecting a given organism at any time; The social and cultural forces that shape the life of a person or population*

In this presentation, I will utilize principally the first two definitions, particularly the second and focus on the effects of adverse changes in the environment on the functional processes and activities of the human body and while doing so I will pay special attention on the effects on children.

2.0 GENERAL CONSIDERATIONS:

2.1 The Magnitude of the Problem

This is examined in the next slide. As shown, data from Africa on the whole are not available, however in Nigeria there are pockets of information of increased frequency of respiratory infections among certain category of workers. For example workers in cement factories and tyre manufacturing factories are reported to present with frequent complaints of cough and dyspnoea. In Paediatric practice in Nigeria and other developing countries, the top three causes of morbidity and mortality are malaria, acute respiratory infections and diarrhoeal disease. All three can be linked to unfavourable environmental situations. Malaria through the presence of breeding grounds of the vector brought about by an unhealthy environment, respiratory infections through air pollution and diarrhoeal disease through contaminated water. On a wider scale, Nigeria faces several environmental challenges from air pollution and desertification, with the encroachment of the Sahara Desert in the north and severe air pollution in overcrowded cities such as Lagos and Port Harcourt. In the Niger Delta, the main environmental challenges result from oil spills, gas flaring and deforestation.

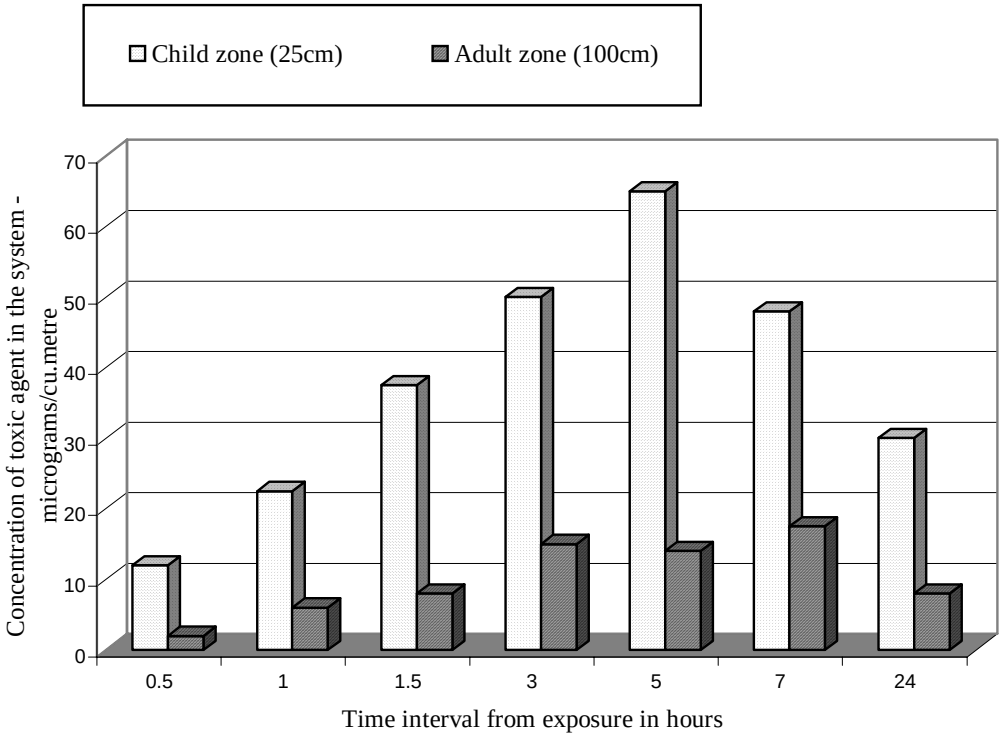
2.2 Pattern of Exposure in Adults and Children

Generally, exposures are due to chemical, physical and biological agents, but in the case of children, exposure could occur during pregnancy as well since some toxic agents are known to cross the placenta.

Overall, children are more vulnerable to environmental insults due to their large surface area relative to size and their stage of development:

For example, young children engage in normal exploratory behaviors including hand-mouth, object-mouth behaviors, and non-nutritive ingestion which may dramatically increase exposure compared to adults. Their physical differences also cause them to reside in a different location in the world—closer to the ground so heavy pollutants like mercury and lead will concentrate in their breathing zone. Children have a high surface area to volume ratio and can have dramatically increased absorption through dermal contact compared to adults. They are less likely to quickly move away from dangerous situations because of their inability to appropriately assess such situations and their inability to react quickly enough. A few examples will suffice. This is presented in Fig. 1

Fig. 1: Child and Adult Breathing Zones (Reproduced from Guzelian Ed, Similarities and Differences between Children and Adults, International Life Sciences Institute, 1992)



The breathing zone for an adult is typically 4 to 6 ft above the floor. For a child it is closer to the floor, depending on the height and mobility of the child. Within lower breathing zones, chemicals heavier than air, such as mercury, may concentrate. As shown in this figure, the concentrations of toxins are much higher in children than in adults and remain so for several hours post exposure. The surface area to body mass ratio is several times higher in newborns and toddlers than in adults. Minute ventilation in infants is three times the values in adults.

2.3 Aspects of Dynamic Developmental Physiology

Children have a dynamic physiology that is at a high level because of growth demands, but also vulnerable to damage during differentiation and maturation of organs and systems. Xenobiotics or **"***chemicals foreign to the biological system***"** utilize metabolic pathways intended for processing of nutrients and bodily waste. Some xenobiotics are dangerous as ingested and need to be detoxified by metabolism. Others are not dangerous when ingested but become so when metabolized.

Absorption is different and frequently increased because kids are anabolic and active. However, some enzyme systems are still not fully mature and therefore some toxic agents may remain longer in their system. Distribution and elimination are also different from those in adults. Examples are the blood-brain barrier, which is porous to some substances and the glomerular filtration rate, which is much lower in children.

Children breathe more air per kg body weight than adults at rest as shown in Fig. 2 and 3. An infant has triple the minute ventilation of an adult and a 6 year old has double. Children also tend to be more physically active than adults. It is clear then, that environmental toxicants found in the air, both indoor and outdoor, will be delivered to children at higher internal doses than to adults.

Fig. 2 Surface area to body mass ratios at different ages

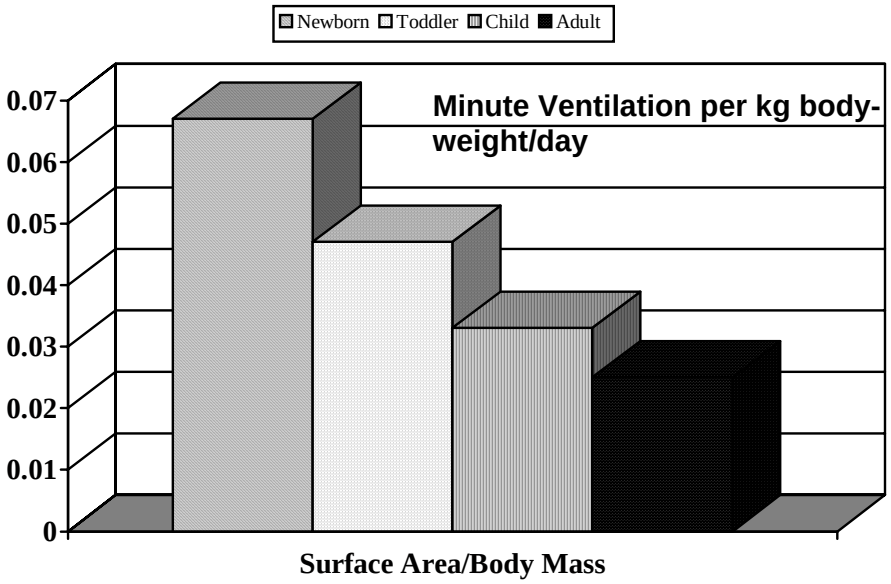
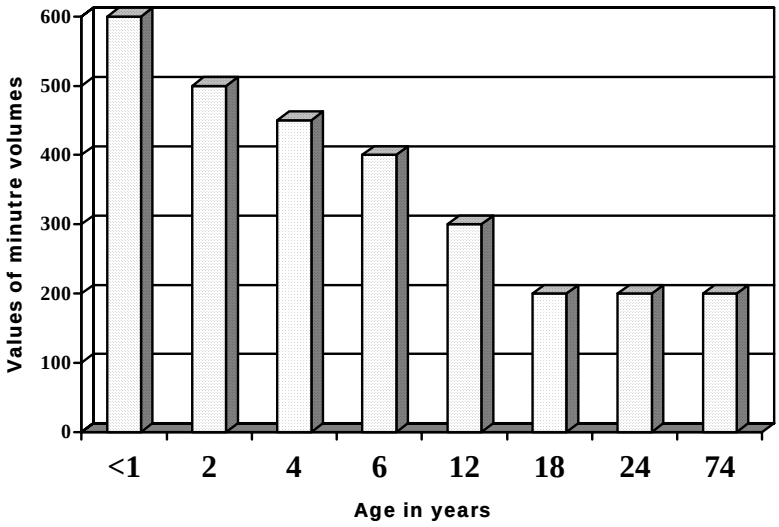
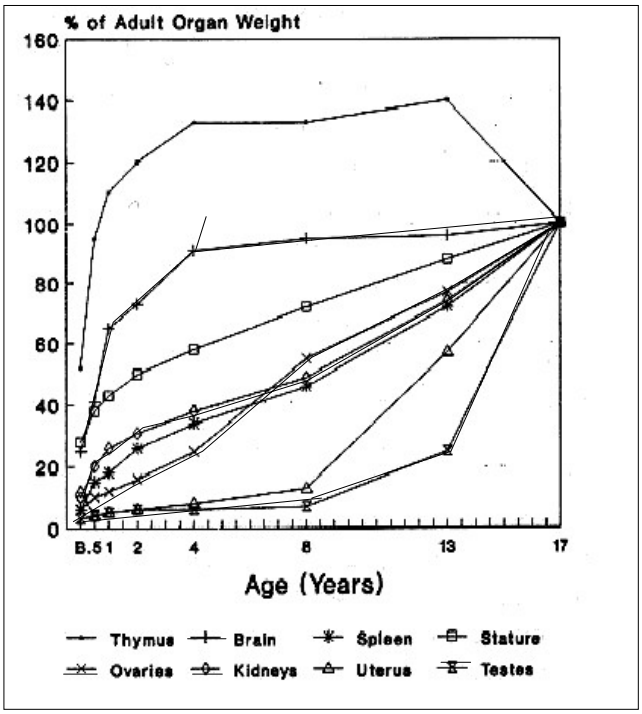


Fig 3 Dynamic developmental physiology– Oxygen Demand (Miller, Differences Between Children and Adults: Implications for Risk Assessment at California EPA, Int J Toxicol. (2002)21(5):403. Review)



I will end this section of the lecture by examining the effect of environmental factors on selected systems of the body. As shown in Fig. 4 various organ systems are affected to varying degrees of severity, depending on the stage of development and the velocity of growth of the particular organ. And we know that growth does not stop at birth, but continues through adolescence. It is not just physical growth, but the maturation and continued differentiation of physiologic functions. The graph in the first of the series of slides shows rates of growth of major organs as well as their different trajectories. As shown, the brain grows most rapidly in the first four years of life and is therefore most vulnerable to insults during this period of rapid growth. Exposures occurring very early in pregnancy could result in fetal loss, while those occurring later in pregnancy could affect different organs to varying degrees.

Fig 4: *Growth Velocity and Trajectory of Major Organs*



- **Vital Organ Growth**
  - Brain
  - Lungs
  - Kidneys
  - Reproductive Organs
- **Physiologic Function**
  - Central Nervous System
  - Immune System
  - Endocrine System

Altman eds, Growth-Including reproduction and morphological development, FASEB, 1962

2.3.1 The Central Nervous System

Children are mostly affected in terms of continuous exposure to environmental assaults. This is because the neurodevelopment continues through the second decade with significant changes in myelinization, synaptogenesis and neurotransmitter distribution throughout the maturation phase. Vulnerable periods during the development of the nervous system are sensitive to environmental insults because they are dependent on emergence of critical developmental processes (i.e., proliferation, migration, differentiation, synaptogenesis, etc). Evidence from numerous sources demonstrates that neural development extends from the embryonic period through adolescence. Exposure to numerous agents (e.g., X-ray irradiation, heat, heavy metals, chemicals, etc) demonstrates that interference with one or more of these developmental processes can lead to developmental neurotoxicity.

2.3.2 The Respiratory System

Like the nervous system, the respiratory system continues to grow and develop through linear growth. At birth a baby has only about 10 million alveoli, but at age 8, he/she has 300 million. Exposures during these growth periods are known to have adverse consequences on both structure and function of the respiratory system. Since toxic particles have the potential of being carried over considerably long distances I will like to examine the issue of air pollution in a little more detail. The major environmental pollutants are particulate matter, sulfur dioxide, ozone, carbon monoxide and nitrogen oxides. The particulate matters are complex heterogeneous mixture of solid and liquid components from power plants and industries, gas flaring, motor vehicles and natural sources (dust storms). The coarse particles (2.5 – 10 microns) are deposited in the upper respiratory tract and large airways whereas the fine particles (<2.5 microns) may reach terminal bronchioles and alveoli. The adverse effects of fine particle deposits include acute respiratory morbidity (pneumonia, asthma), increased mortality (from all causes) and decrease in lung function in children.

2.3.3 Water and Sanitation

Globally only about 2.5% of water surrounding the earth is fresh and most of that lies frozen and inaccessible. As a result, less than 1% of fresh water is accessible in lakes, river channels and underground. Forty percent of the world

population have no access to sanitation facilities. In Asia and Africa the situation is critical. Environmental pollution from human activities reduces this by a further two-thirds, and what remains is unequally distributed around the world. We are aware that access to safe water, provision of sufficient supplies of water, and access to sanitation are three factors that together contribute to the health and safety of the world's population. A lack of adequate water supplies of good quality, together with poor sanitation, exacts a high health toll, particularly in rural areas, hindering both social and economic development. This makes the promotion of hygienic behaviour a high priority.

The situation in Nigeria with other countries regarding availability of water and environmental sanitation situation is compared as shown in Table 1. As shown the Nigerian situation is worse compared to the other countries. Diarrhoea is the major public health problem caused by unsafe water and lack of sanitation. To give an indication of the scale of health problems caused by lack of safe water, there are approximately 4 billion cases of diarrhea each year, causing 1.8 million deaths. These deaths occur mostly among children under the age of five and represent 15% of all deaths in this age group in developing countries.

Table 1: Some aspects of health/social services indicators in selected countries

% of population using improved drinking water sources – 2000				**% of population using adequate sanitation facilities – 2000**			
Country	***Total***	***urban***	***rural***	***Country***	***Total***	***urban***	***rural***
Nigeria	60	72	49	Nigeria	38	48	30
Kingdom of Saudi Arabia	95	100	64	Kingdom of Saudi Arabia	100	100	100
Cuba	91	95	78	Cuba	98	99	95
Sweden	100	100	100	Sweden	100	100	100

source: UNICEF – State of the World's Children 2005

Contamination of water can be conveniently divided into two categories – biological and chemical. The primary public health concern regarding water contamination is microbiological contamination of drinking-water. The effects of water-contamination on humans are summarized in Table 2. Water-related infections can be classified in four categories namely waterborne diseases (directly acquired from drinking water), water-washed (indirectly acquired) diseases, water-based diseases, and diseases transmitted by water-related insect vectors

Table 2: Water-related infections, Inorganic chemical: arsenic, inorganic chemical: fluoride

Water-based diseases	**Inorganic chemical: Arsenic (As)**
Schistosomiasis	•From natural erosion, pesticide run-off, coal burning, smelting, glass and electronic production waste
Dracunculiasis (guinea worm disease)	•Skin lesions and cancer, vascular and neurological disease, increased risk of cancer
Diseases transmitted by water-related insect vectors	WHO guideline: 0.01 mg/L (ppm)
Malaria	**Inorganic chemical: Fluoride (Fl)**
Onchocerciasis	•From natural erosion, discharge from fertilizer and aluminum factories, added to drinking water
African trypanosomiasis	• Bone disease, mottled teeth
Yellow fever	WHO guideline: 1.5 mg/L (ppm)
Dengue	
Filiariasis	

Microbial contamination usually results from the contamination of water with human or animal faeces. If drinking-water is contaminated with faeces, pathogens are likely to be widely and rapidly dispersed. If the contamination is recent, and if the faeces are from carriers of communicable enteric diseases, the microorganisms (bacteria, viruses, or protozoa) that cause these diseases may be present in the water. The diseases range from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, cholera, or typhoid. Helminths and amoebae may also be transmitted in water and are common in poor quality water supplies

Arsenic is a naturally occurring element, which can be introduced into water through the dissolution of minerals, from industrial effluent and from atmospheric deposition (burning of fossil fuels and wastes). These sources make significant contributions to arsenic concentrations in drinking-water and may be harmful to health. The body rapidly excretes organic forms of arsenic, and it is the inorganic trivalent form that is of most concern. While concentrations in natural water are generally less than 0.005 mg/litre, some countries have reported very high concentrations particularly in groundwater supplies. I was not able to obtain figures for Nigeria. Arsenic compounds are readily absorbed by the gastrointestinal tract, and then bind to hemoglobin and are deposited in the liver, kidneys, lungs, spleen, and skin. Inorganic arsenic does not appear to cross the blood-brain barrier, but can cross the placenta. The major health effects are caused by low-level chronic exposure from the consumption of arsenic-contaminated water. Consumption over periods of 5 to 25 years has been reported to produce skin lesions, skin cancer, vascular disease, effects on the nervous system, and possibly cancer of other organs. The only available treatment for chronic arsenic poisoning is to remove the patient from the source of exposure and provide supportive care.

Fluoride occurs naturally in soil and water, and is a by-product of industrial activities such as the aluminium and fertilizer industries. It is also added to drinking water to help prevent dental caries. Concentrations in surface water are usually relatively low (< 0.5 mg/litre) while deeper groundwater wells in areas high in fluoride minerals may have concentrations as high as 10 mg/litre. Again I was not able to obtain figures for Nigeria. Fluoride is absorbed quickly following ingestion, but is not metabolized, and diffuses throughout the body. About 40% is excreted in urine within 9 hours, and 50% over 24 hours.

Fluoride has an affinity for mineralizing tissues of the body – in young people the bones and teeth, and in older people the bones. As the excretion rate is greater in adults, mineralization is proportionally less than in children. The most readily identifiable health effects of consuming water with elevated levels of fluoride are a mottling of the teeth, known as fluorosis, and sclerosis of the bones. Children are particularly affected by fluorosis, because teeth take up fluoride during their formation. Fluoride has been shown to be effective in preventing dental caries, from the observed association of low dental caries with naturally occurring fluoride in drinking-water (at about 1 mg/litre). As a result, many health authorities around the world, including the World Health Organization, recommend fluoridation of public water supplies as an important public health measure. However, at concentrations above 1.5 mg/litre fluoride may affect tooth mineralization in children leading to a mottling of the teeth, which can in some cases be unsightly. The regular consumption of water with fluoride concentrations above 4 mg/litre, however, can cause progressively increasing skeletal fluorosis.

3.0 THE NIGERIAN SCENE

Having generally looked at possible effects of some adverse environmental situations on organ development and function, I will now focus on the state of the environment in relation to health in the country. I will examine the following questions:

Are there situations or activities that can bring about air pollution in the country?

Are there situations or activities that can bring about pollution of water in the country?

Are there situations or activities that can bring about pollution of the soil in the country?

The major sources of environmental pollution in the country are; large-scale industries, particularly the oil industry, gas flaring, emissions from motor cars and electricity-generating plants, poor environmental sanitation, etc. A typical traffic scene in the country and another very familiar object in most parts of Nigeria – the electricity generating plant are major sources of carbon monoxide emission in the country.

Oil was discovered in Nigeria in the 1950s. Since then, the growth of the oil industry, combined with a population explosion and a lack of environmental regulations, led to substantial damage to Nigeria's environment, especially in the Niger Delta region, the centre of the country's oil industry. The country also faces environmental challenges from air pollution and desertification, with the encroachment of the Sahara Desert in the north and severe air pollution in overcrowded cities such as Lagos and Port Harcourt.

There have been over 4,000 oil spills in the Niger Delta since 1960, and gas flaring from oil extraction has resulted in serious air pollution problems in the area. One of the most visible consequences of the numerous oil spills has been the loss of mangrove trees. The mangrove was once

a source of both fuelwood for the indigenous people and a habitat for the area's biodiversity, but is now unable to survive the oil toxicity of its habitat. The oil spills also had an adverse effect on marine life, which has become contaminated, in turn having negative consequences for human health from consuming contaminated seafood.

Nevertheless, even with the end of gas flaring, air pollution is likely to remain a problem in Nigeria, as other sources such as automobiles and diesel-fired electricity generators contribute to the choking air in cities such as Port Harcourt and Lagos. Studies carried out by the Federal Environmental Protection Agency (FEPA) show a moderate-to-high concentration of pollutants such as carbon monoxide, sulfur dioxide, nitrogen oxides, organic acids and hydrocarbons in the atmosphere, the majority of which come from car engines, electricity generating plants and industries.

Gas flares cause atmospheric pollution by releasing particulate carbon and hydrocarbons into the air, which the inhabitants breathe. The inhalation of these particles results in coughing, difficulty with breathing and watery eyes. Disturbed sleep rhythm occurs in some because of the bright light and heat from the flares. Gas flaring has been shown to result in low white and red blood cell counts in host communities with the possibility of impaired resistance to infection, [*Nwafor et al 1991]*. Vanadium products from gas flaring have been implicated in some diseases of the respiratory system [*Obianime, Hirst and Dale 1985]*. In towns like Bonny and Okrika wastes discharged into open pits sieve into the underlying water tables. Increased concentration of trace elements in water above tolerance limits results in ingestion by humans both directly and indirectly through contaminated water and aquatic flora and farms. The net effect is poor harvest and low yield in the fishing industry.

Still in association with the oil industry, some questions are being raised as to a possible relation between some form of cancers and congenital malformations and oil exploration activities. In this respect I looked up some published work from the Amazon Basin of Ecuador (*Int J Occup Environ Health 2004;10:245–250*). The study was conducted in order to determine whether there was any difference in childhood leukaemia incidence rates between populations living in the proximity to oil fields and those living in areas free from oil exploitation in the Amazon basin of Ecuador. 91 cancer cases among children (0–14 years) from the provinces of Sucumbios, Orellana, Napo, and Pastaza during the period 1985–2000 were studied. The relative risks for all leukaemias indicated significantly elevated levels in the youngest age group (0–4 years), both genders combined (RR 3.48, 95% CI 1.25–9.67), and in all age groups (0–14 years) combined for females (RR 2.60, 95% CI 1.11–6.08) and both genders combined (RR 2.56, 95% CI 1.35–4.86).Study results are compatible with a relationship between childhood leukemia incidence and living in the proximity of oil fields in the Ecuadorian Amazon.

In the University of Port Harcourt Teaching Hospital, the Oncology Unit of the Department of Paediatrics examined records of cases of cancer from January 2001 to May 2005. Twenty cases of acute lymphoblastic leukaemia were admitted; 2 were resident in Yenagoa, while 18 were resident around the Port Harcourt Metropolis. There is an apparent increase in the proportion leukaemia cases being seen now compared to 25 years ago, but the situation has not been systematically studied. Similarly, there is an apparent increase in the incidence of some congenital malformations; particularly neural tube defects and cleft lip/palate. Again the situation has not been systematically studied.

3.1 REMEDIAL MEASURES

These will be examined in two broad sections – actions being taken by the Federal Government of Nigeria and challenges to health and environmental professionals.

3.1.1 Intervention measures by the Federal Government of Nigeria

In July 2002, the Federal Government ordered oil companies operating in the country to comply with the Environmental Guidelines and Standards for the Oil Industry, published by the Department of Petroleum Resources (DPR), the monitoring arm of the Nigeria National Petroleum Corporation (NNPC), or risk paying a fine. The guidelines provide rules to reduce pollution and procedures for environmental monitoring. The DPR also has been tasked with conducting regular health, safety and environment audits of the oil companies. The Government has taken action to show it is serious about enforcing environmental regulations. In addition, the Government has now committed to ending the process of gas flaring from oil production by 2008.

3.1.2 Role of health professionals

Health and environment professionals have a critical role to play in maintaining and stimulating changes that will restore and protect environmental health generally. At the one on one patient level we can include environmental etiologies in our differential diagnoses and in our preventive advice. We should look hard for environmental causes of disease and disability. We can publish sentinel cases and develop and write up community based interventions. We can educate our patients, families, colleagues and students didactically. Finally, we must all become vigorous advocates for the environmental health of our

patients and particularly the children. We should use our research and other findings as tools for advocacy. And, we must all recognize that as professionals with understanding of both health and the environment, we are powerful role models.

4.0 CONCLUDING REMARKS

Mr. Chairman, Distinguished Ladies and Gentlemen, I have examined environmental health hazards by focusing on effects on children principally because they are the most vulnerable. Focusing on the most vulnerable section of society is one way of ensuring that no one is missed out.

As we have seen the air we breathe, the water we drink and the food we eat are all potential sources of danger. The solution lies not only with Government, but indeed with all of us. We should all learn to be conscious of maintaining a healthy environment.

I thank you all for your time.