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PO Box 72135, Lynnwood Ridge, Pretoria, South Africa, 0040
Tel: +27 12 349 6600 Fax: +27 86 576 9520
E-mail: admin@assaf.org.za



The Academy of Science of South Africa (ASSAf) was inaugurated in May 1996. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: activist in its mission of using science and scholarship for the benefit of society, with a mandate encompassing all scholarly disciplines that use an open-minded and evidence-based approach to build knowledge. ASSAf thus adopted in its name the term 'science' in the singular as reflecting a common way of enquiring rather than an aggregation of different disciplines. Its Members are elected on the basis of a combination of two principal criteria, academic excellence and significant contributions to society.

The Parliament of South Africa passed the Academy of Science of South Africa Act (*Act 67 of 2001*), which came into force on 15 May 2002. This made ASSAf the only academy of science in South Africa officially recognised by government and representing the country in the international community of science academies and elsewhere.

This report reflects the proceedings of the Environment and Health Symposium jointly hosted by the Academy of Science of South Africa (ASSAf), the Ethiopian Academy of Sciences (EAS), the Ghana Academy of Arts and Sciences (GAAS) and the German National Academy of Sciences Leopoldina from 1 – 3 June 2015 at the CSIR Convention Centre, Pretoria, South Africa. Views expressed are those of the individuals and not necessarily those of the Academy nor a consensus view of the Academy based on an in-depth evidence-based study.

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Partnership between Ethiopian Academy of Sciences, the Ghana Academy of Arts and Sciences, the German National Academy of Sciences Leopoldina and ASSAf.

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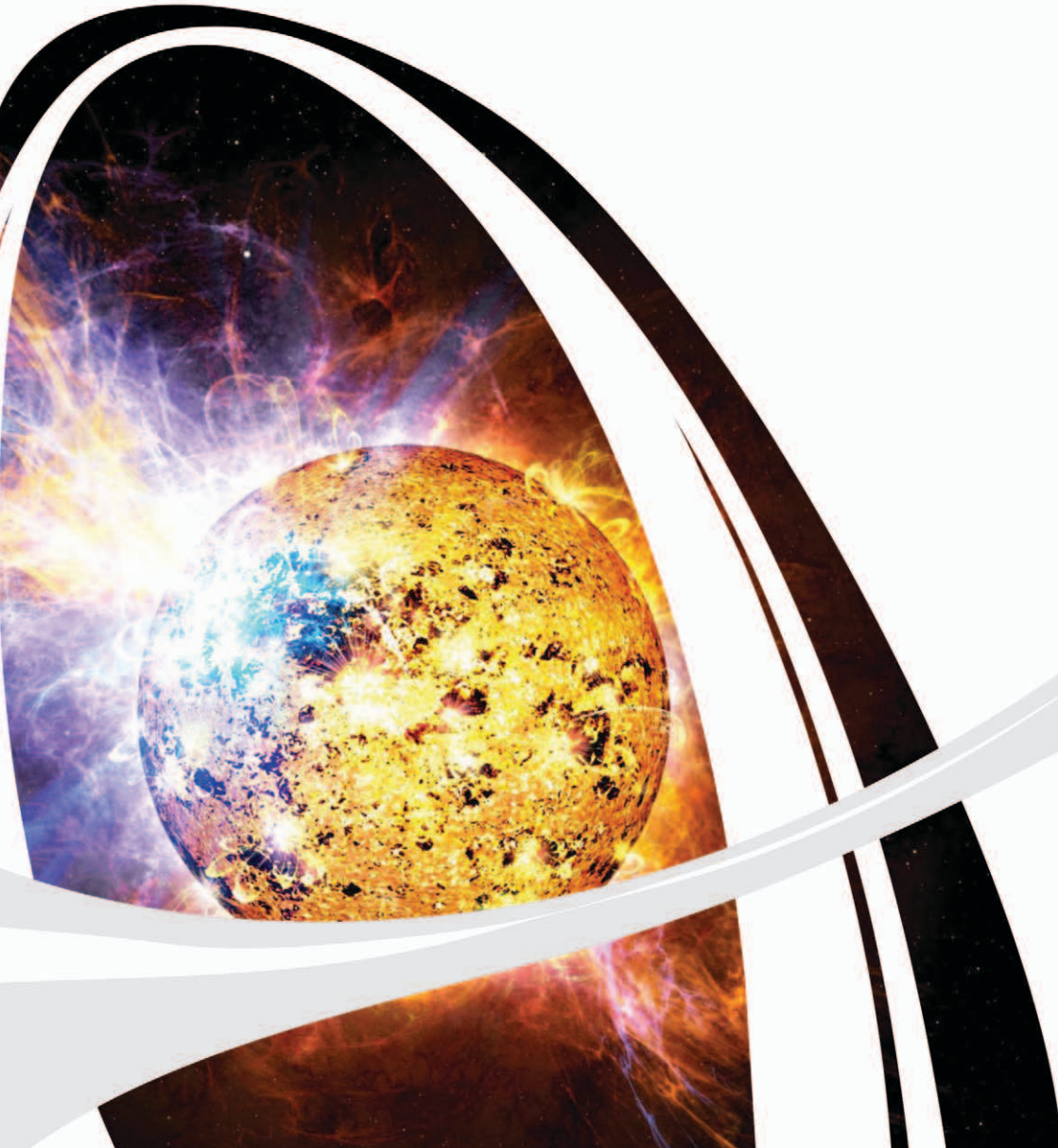

# List of Acronyms

| | |
|---|---|
| AIDS | Acquired immune deficiency syndrome |
| AOP | Advanced oxidation processes |
| ASGM | Artisanal and small-scale gold mining |
| ASSAf | Academy of Science of South Africa |
| CBO | Community-based organisation |
| CFCs | Chlorofluorocarbons |
| COPD | Chronic obstructive pulmonary disease |
| CSIR | Council for Scientific and Industrial Research |
| DNA | Deoxyribonucleic acid |
| EAS | Ethiopian Academy of Sciences |
| EPA | Environmental Protection Agency |
| EQS | Environmental Quality Standards |
| ERY | Erythemal |
| EU | European Union |
| GAAS | Ghana Academy of Arts and Sciences |
| GAMA | Greater Accra Metropolitan Area |
| HEP | Health Extension Programme |
| HEISS | Health and Environment Integrated Surveillance Systems |
| HIV | Human immunodeficiency virus |
| HSDP | Health Sector Development Programme |
| ICSU | International Council for Science |
| IQ | Intelligence quotient |
| IR | Infrared |
| IRP | Integrated Resource Plan |
| ITA | Individual typology angle |
| IUF | Leibniz Research Institute for Environmental Medicine |
| MMP | Matrix metalloproteinase |
| MRC | Medical Research Council |
| NGO | Non-governmental Organisation |
| NRW | North Rhine-Westphalia |
| OCA | Oculocutaneous albinism |
| PAHs | Polycyclic aromatic hydrocarbons |
| PM | Particulate matter |
| PPP | Public-private partnerships |
| REACH | Registration, Evaluation, Authorisation and Restriction of Chemicals |

| | |
|---|---|
| **RNA** | Ribonucleic acid |
| **SA** | South Africa |
| **SADC** | Southern African Development Community |
| **SHIA** | Strategic Health Impact Assessment |
| **TLV** | Threshold limit value |
| **UN** | United Nations |
| **UNICEF** | United Nations Children's Fund |
| **UV** | Ultraviolet |
| **UVI** | UV index |
| **UVR** | Ultraviolet radiation |
| **WASH** | Water, sanitation and hygiene |
| **WFD** | Water Framework Directive |
| **WHO** | World Health Organisation |
| **WMO** | World Meteorological Organisation |
| **WWTP** | Waste Water Treatment Plant |
| **ZWU** | Centre for Water and Environmental Research, University of Duisburg-Essen, Germany |

## 1 Welcome Address (Prof Roseanne Diab, Executive Officer, ASSAf)

Prof Diab welcomed delegates to the symposium on behalf of the President of the Academy of Science of South Africa (ASSAf), Prof Daya Reddy. A special word of thanks was offered to the symposium scientific collaborators from the Ethiopian Academy of Sciences (EAS), the Ghana Academy of Arts and Sciences (GAAS), the German National Academy of Sciences Leopoldina, and ASSAf. The Volkswagen Foundation was thanked for sponsorship of the event. Attendance by representatives of the various academies and young scientists from around Africa was acknowledged.

The event demonstrated the powerful convening ability of academies by bringing together top scientists from across the globe to address a particular challenge and was a good example of a collaborative effort among academies. The theme, Environment and Health, was of utmost importance and although recognised by the World Health Organisation (WHO) and the International Council for Science (ICSU), remained relatively under-emphasised in the scientific arena in many countries. This symposium brought together a multi-disciplinary audience and was an opportunity to place this important topic on the agenda of policymakers and ensure good health outcomes.

Prof Diab thanked the speakers, panel members, moderators and delegates in anticipation of stimulating presentations, discussions and interactions during the symposium.

## 2 State of Environment and Health in Ethiopia (Prof Tenalem Ayenew, Addis Ababa University)

The large majority of Ethiopia's population of over 90 million reside in rural areas where infrastructure is poor, adult literacy is 36% and up to 80% of mortality is due to preventable diseases. Current life expectancy in Ethiopia is 56 years of age.

Although drinking water is available to 75% of households in urban areas, it is only accessible to 49% of rural households. Nearly 48 million people lack access to basic sanitation services and about 46% of the population use open defecation. Figures provided by the World Health organisation (WHO)/United Nations Children's Fund (UNICEF) Joint Monitoring Programme in respect of trends in water supply and sanitation coverage in rural and urban areas of Ethiopia, indicate a remarkable improvement in the provision of drinking water and sanitation facilities since 1990. Consequently, this has enhanced the environmental health status of its population, particularly in the three main cities of the country.

More than 90% of child deaths are due to pneumonia, diarrhoea, malaria, neonatal complications, malnutrition, HIV/AIDS, or a combination of these diseases.

Environmental health and nutritional interventions could prevent the spread of communicable diseases, a major cause of morbidity, mortality and disability in Ethiopia. Maternal deaths are mainly due to the shortage of skilled midwives, inadequate infrastructure, equipment and financing, as well as weak referral systems at health centre levels.

Several ministries of government, non-government organisations (NGOs) as well as the WHO and UNICEF play a strong role in the health sector in Ethiopia. The government's strategy focuses on water, sanitation and hygiene (WASH) and capacity building in the health sector, and aims to dramatically improve the environmental health conditions of the country. A number of policies and regulations instituted between 1990 and 2004, including the decentralisation of health services in rural districts and the Health Sector Development Programme (HSDP), form the backbone of the progress made to date. The HSDP has ensured growth in the number of health facilities and health professionals and workers. The government's Growth and Transformation Plan provides a 15 to 20-year plan for the country's development in terms of the Millennium Development Goals, addressing different development sectors and improving the status of environmental health initiatives.

The strategic framework for sanitation and hygiene in Ethiopia takes into account social, economic, cultural, institutional, environmental, behavioural and educational factors. It also focuses on the eradication of poverty and the prevention of communicable diseases by building an enabling environment, promoting sanitation and hygiene, and providing access to infrastructure. The Health Extension Programme (HEP) provided health extension workers and voluntary community health workers who address sanitation, hygiene and other health-related issues at community level.

Although WASH and environmental health programmes in Ethiopia have produced limited improvements to date, government's effective use of resources, in particular through the HSDP and HEP, integrated with rural development and poverty alleviation efforts at a national level, provide opportunities for far-reaching improvements.

Recommendations for improving the state of environment and health in Ethiopia focus on:

- Optimal enforcement of constitutional rights and policies.
- Development of a framework addressing the following areas in particular and avoiding duplication of efforts of the various institutions and ministries:
    - Scientific research for the evaluation of drinking water and sanitation coverage and descriptions of determinants for the success and failures need to be encouraged.
    - Improvement of organisational behaviour of institutions involved in the enforcement of environmental health regulations.

- Popularisation, reinforcement and sustainment of a modest approach to encourage demand-driven, community involvement and hygiene education in order to bring rapid improvement in water and sanitation services

## 3 State of Environment and Health in Germany (Prof Jean Krutmann, Leibniz Research Institute for Environmental Medicine, Düsseldorf)

The Environmental Protection Agency (EPA) classified pollutants into six distinct categories. In Europe, the major focus is on particulate matter (PM).

The global burden of disease study (2010) showed that pollution resulting from burning solid fuels, or indoor air pollution, and ambient PM pollution are the major causes of health problems such as cancer and cardiovascular, circulatory and pulmonary diseases. European countries are becoming more concerned about $PM_{2.5}$ and $PM_{10,}$ but also about ultrafine particles, which are nano-sized particles. The lungs are the primary target of chronic exposure to PM, which contributes to the pathogenesis of some of the common lung diseases, such as asthma, chronic obstructive pulmonary disease (COPD) and lung cancer.

A study done by the Leibniz Research Institute for Environmental Medicine (IUF) in Germany, found an association between COPD and ambient $PM_{10}$ among a cohort of 4 757 elderly, rural women living in a previously heavily polluted industrialised area. The International Agency for Research on Cancer states that outdoor air pollution was a leading environmental cause of cancer deaths and classifies outdoor air pollution as carcinogenic to humans. More recent studies have shown that PM contributed significantly to the pathogenesis of coronary atherosclerosis and myocardial infarction. In addition, a close correlation has been identified between exposure to traffic-related air pollution and the incidence of Type 2 diabetes. Exposure to PM seriously affects the skin and leads to pigmentation and wrinkle formation, and contributes to the aggravation of pre-existing skin diseases. In addition, there is growing evidence that the brain may be affected by exposure to ambient PM as living near to a major road was associated with reduced cognitive function.

In terms of prevention, the concentration of PM in ambient air pollution can be reduced to the defined limit values. This was demonstrated when a number of simple measures were put in place to address severe air pollution in industrialised areas of Germany in the 1980s. These measures ensured the decreased usage of fossil fuels for heating, the closure of coal mines and the introduction of filters on high chimney stacks. As a result, a significant reduction in PM concentrations in ambient air became evident within a few years. It was shown that a reduction in levels of exposure to $PM_{10}$ can lead to an attenuation of age-related decline in lung function. However, a very recent analysis of 22 European cohorts showed

that hazard risks for $PM_{2.5}$ remained significantly raised even when levels of exposure to PM concentrations are lower than the European annual mean limit value. This shows that some individuals have a higher susceptibility to PM-induced health effects.

A further prevention strategy involves the protection of high-risk groups from PM-induced health problems. The approach taken by the IUF was to understand the underlying mechanisms (for example, how PM can induce lung inflammation) and then do target driven screenings to identify molecules of interest for drug development and medical interventions in order to protect the general population from the adverse effects of PM inhalation. One such molecule, ectoine, was found to be effective in preventing, for example, signalling induced by environmental stress, environmentally-induced lung inflammation, pro-inflammatory signalling *in vivo*, and restoring apoptosis rates in neutrophils from COPD patients.

Exposure to a large number of chemicals in the environment and in consumer products is a growing problem throughout the world. A European Union (EU) regulation known as Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) requires intensive safety testing of any new chemical. This places pressure on the chemical industry with regards to toxicology, particularly environmental toxicology. The regular approach to human risk assessments is to undertake a combination of animal studies to identify the hazard and then do exposure measurements and calculate the risk. However, assessing the risk of chemicals to humans is logistically impossible because of the high cost and the excessive number of chemicals and would be scientifically unsound because of the differences between animal and human physiology. However, it has been shown that early life exposure to neurotoxic chemicals can cause neurological diseases and degenerative changes in the brain. Six chemicals known to cause developmental neurotoxicity in human beings were identified in 2006 and a further six by 2013. In testing developmental neurotoxicity, cells from the human and rodent foetal brains were taken, cultured as neurospheres and used in a 'neurosphere assay' process to identify species differences as part of ongoing studies.

## 4 State of Environment and Health in Ghana (Dr Emmanuel Kyerematen-Amoah, Occupational and Environmental Health Unit, The Health Service, Accra, Ghana)

A direct relationship exists between the biophysical environment and human health in Ghana. For instance, damming of streams and rivers in certain areas of the country results in an increased incidence of diseases such as bilharzia, malaria and onchocerchiasis. Contaminated water and food sources and poor waste management have adverse effects on the health of the population. Sources of air pollution include emissions from vehicles, certain industries, burning of waste and dust.

The current ambient air parameters being monitored in Ghana are: PM, ozone, sulphur dioxide, nitrogen dioxide, carbon monoxide, lead and manganese. Results of air quality monitoring at roadside, commercial and industrial locations from two metropolitan areas in the Greater Accra region indicated high concentrations of $PM_{10}$ and $PM_{2.5}$, with the highest concentrations occurring between January and March during the dry season. During this period, the north-east trade winds (Harmattan) bring dust from the Sahara desert through the northern part of the country. An increased incidence of cerebrospinal meningitis was also found in the northern sector of the country during this period. Monthly mean $PM_{2.5}$ concentrations were higher than the EPA guideline limit of 30µg/$m^3$.

In Ghana, acute respiratory infections ranked second among the top five diseases and were associated with poor air quality. In most rural parts of the country, biomass fuel was used for cooking, which often took place indoors and in poorly ventilated areas. A current study is examining the health effects of utilising clean stoves as opposed to biomass fuel on foetal development among pregnant women. A study of children under five years of age living in Accra found that those who live along main roads had higher levels of respiratory problems than those who live at a distance from these roads.

A further challenge to environment and health in Ghana relates to waste management and the lack of implementation of regulations in this regard. Contaminated food and water account for most of the food-borne diseases, including cholera, salmonellosis and hepatitis A. In 2014, the country experienced its worst cholera epidemic, when a total of 28 922 cases including 243 deaths (case fatality rate of 0.8%) had been reported from 130 out of the 216 districts (60%) in all the ten regions of the country. Further cases and deaths were reported in the first quarter of 2015, mainly in the capital city, Accra. Most of the causes of the cholera were attributed to the intake of contaminated water and food sources, mostly sold by vendors along the roadside.

Artisanal and small-scale (illegal) mining operations pollute the rivers and streams used by communities and also affect the health of the miners. This matter is a priority on the government's agenda. A task force has been set up by the government to stop the operations of the illegal artisanal and small-scale gold miners.

The United Nations Development Programme Project on Health Adaptation to Climate Change has completed a pilot study in three districts of Ghana to assess climate health sensitive indicators, establish baseline levels, and develop tools to communicate climate change-related health issues at the community level. The Health National Action Plan (2015 – 2019) for climate change adaptation, incorporating climate change issues into the planning of the health sector, is being developed by the Ministry of Health, through the Ghana Health Service.

Ghana has set up the Health and Environment Strategic Alliance, a platform which serves as a linkage between health and environmental indicators to address environment and health challenges in the country. Environmental impact assessments are mandated by law and are carried out for projects with potential impacts on health and the environment. The Environmental Protection Agency has completed a strategic environmental assessment of the oil and gas industry in the country. In a similar manner, the Ministry of Health through the Ghana Health Service is currently undertaking a Strategic Health Impact Assessment (SHIA) of the oil and gas industry. The country discovered major oil deposits recently and has begun producing crude oil in commercial quantities.

The total health of a country is a function of their environmental health. Ghana has taken measures to promote healthy environments, however further commitment is required from government to ensure proper waste management and the provision of resources needed to embark on rigorous research and detailed exposure assessments that link sources and exposures to adverse health outcomes. In addition, national institutions with the mandate need to be equipped to manage the environment and health of the country. Public-private partnerships (PPPs) should be encouraged to ensure the sustainability of environment and health initiatives in Ghana. Inter-sectoral action is required to develop a coherent and coordinated strategy to address the environment and health challenges in the country.

## 5 State of Environment and Health in South Africa (Prof Angela Mathee, Environment and Health Research Unit, Medical Research Council (MRC), Johannesburg, South Africa)

South Africa has two oceanic neighbours. The warm Indian Ocean brings rainfall to the east of the country, while the cold Atlantic Ocean brings dry weather to the west, resulting in desert-like conditions. The country is water scarce, yet enjoys a rich diversity of flora and fauna. Amongst the key forces driving the South African environmental health status are urbanisation, industry, mining, poor economic growth, poverty and inequality.

South Africa has a population of about 53 million and an unemployment rate of around 24%. Poverty is widespread and in terms of the Gini coefficient, South Africa is the most unequal society in the world. A wave of urbanisation followed the abolition of influx control in the 1980s, and ongoing urbanisation, together with natural population increase has resulted in a current urbanisation city level of over 60%, with predictions of 80% urbanisation by 2030. Rapid urbanisation, unmatched with settlement development, has resulted in inner city degradation, and the formation of sprawling informal settlements, where overcrowding, and inadequate access to basic environmental health services such as water, sanitation and waste removal services, are widespread. Numerous social problems, such as violence and substance abuse, also abound. Although the government's efforts in hous-

ing delivery are commendable, many people remain homeless or live in informal settlements.

Statistics produced by the WHO in 2013 show an increase in the proportion of the population with access to drinking water and sanitation, which is considerably higher than the continental average, but lags behind the average for Europe. The use of solid fuels for domestic purposes has decreased substantially, mainly due to electricity provision, but recent rises in the cost of electricity and the sporadic nature of supply may cause households to revert to burning solid or liquid fuels for cooking and heating purposes. Life expectancy at birth has shown an increase, particularly after the earlier vulnerability due to the AIDS epidemic.

Emissions from major industries in the country, including mining, automobile, metal works, chemical, machinery and textiles, contribute to the contamination of the land, air and water resources. Energy production is mostly coal-driven and many housing developments are located close to power stations and mine dumps.

Studies undertaken by the MRC indicate that many communities are at risk of exposure to toxic substances, including lead, mercury and particular matter. There is a need for greater public environmental health activism in the country and many of the environment and health challenges in South Africa could be tackled more effectively through sharing experiences with other countries.

## 6 Plenary Session: Solar Ultraviolet Radiation (Moderator: Prof Angela Mathee, Environment and Health Research Unit, MRC, Johannesburg, South Africa)

### 6.1 Skin Damage by Solar Radiation Beyond Ultraviolet (Prof Jean Krutmann, Leibniz Research Institute for Environmental Medicine, Düsseldorf, Germany)

More than 50% of the total energy emitted by the sun and transferred to the earth's surface is in the infrared (IR) range. The near-IR range, known as IRA radiation, accounts for 30% of the total energy and penetrates deeply into human skin, much more so than ultraviolet A (UV-A) or ultraviolet B (UV-B) radiation. A number of independent studies on IRA-induced matrix metalloproteinase-1 (MMP1) expression in human skin have shown that IRA radiation, similarly to UV radiation, can cause photoaging of human skin and that varying responses have no correlation with sex, age or site of biopsy.

The analysis of the skin fibroblast transcriptome showed that damage takes place beyond MMP-1 and revealed 599 IRA-regulated transcripts. When grouping the genes functionally, it was found that many were involved in the homeostasis of extracellular matrix, which matched the clinical perception that IRA contributed to wrinkle formation. Other genes were involved in calcium signalling, stress signalling and apoptosis, raising the question of whether IRA contributed to photocarcinogenesis.

UV, as well as IRA, causes damage to the human skin. This damage includes skin ageing, but might contribute in one or other way to the development of skin cancer implying that photo-protection of skin should address UV-A, UV-B as well as IRA radiation. Photo-protection is provided by chemical or physical filters, but currently there is no known chemical filter capable of absorbing IRA for use in sunscreens. Although physical filters could work, they would be visible and therefore not likely to be cosmetically acceptable to consumers. An alternative photo-protection option therefore has to be found.

IRA-induced MMP1 expression or gene expression in general, in human skin fibroblasts in a process within the mitochondrion resulted in increased oxidative stress and affected calcium signalling, leading to increased transcription of IRA responsive genes and the production of MMP1. It was found that this process could be halted from the onset by application of mitochondria-targeted (mt-targeted) antioxidants (known as MitoQ). *In vitro* studies have shown that this approach was successful.

As MitoQ could not be used in testing (because it is being developed as a drug and could not be used in a cosmetic product, and it is too expensive to use in sunscreen products) the topical application of mt-targeted antioxidants to human skin before radiation, a cocktail of antioxidants was developed and used to pretreat human skin. The skin was radiated, biopsies were taken and MMP1 expression analysed. The study showed that IRA radiation-induced upregulation of MMP1 was reduced but not fully inhibited through topical application of antioxidants. However, topical application of the right combination of antioxidants to human skin was found to prevent IRA radiation-induced damage to human skin.

A subsequent intervention and comparative study showed that pre-treating skin using a regular sunscreen product containing the antioxidant cocktail produced a significant reduction in IRA-induced upregulation of MMP1 expression, proving the efficacy of antioxidants and implying that special sunscreens were required in order to protect human skin. Thus far, the antioxidant, carnosine, provides the best photo-protection for human skin. It could therefore be concluded that IRA protection was necessary and possible and should be taken into account in the development of products for daily photo-protection.

In addition, there is evidence that visible light causes skin pigmentation in human skin, although only in darker pigmented individuals, and is linked to melasma. The need for protection against visible light is an area that requires more research.

### 6.2 Solar Ultraviolet Radiation over Africa in a Changing Climate: Implications for Health (Dr Gizaw Mengistu, Addis Ababa University/Botswana International University of Technology and Science)

Climate change is the result of an energy imbalance between incoming and out-

going solar radiation. The imbalance is attributed to anthropogenic factors (e.g., increase in greenhouse gases namely carbon-dioxide, methane, chlorofluorocarbons (CFCs) etc.). Some of these greenhouse gases (e.g., CFCs) can stay in the atmosphere longer and release radicals such as chlorine which destroys the ozone layer, the layer that protects humans from UV radiation from the sun, in catalytic reaction cycles. The depletion of the ozone is evident in all regions of the globe, which ranges from a 12% decrease over mid-latitude to a 1% decrease over the equator on average in the last 34 years with respect to the 1979 values. The changes led to enhanced exposure to UV radiation. Unfortunately, the impact of increased UV radiation on human health as a result of global climate change has not been studied sufficiently.

Monitoring UV radiation over Africa over a 34-year period produced several interesting results. Southern and northern Africa experience increased levels of UV irradiation in January, while West Africa experiences increased UV irradiation in July. Changes in UV radiation levels are due to changes in the ozone, an increased aerosol burden over West Africa and part of the Arabian Peninsula (caused mainly by Sahara dust), thereby, strengthening UV irradiation at the earth's surface. Laboratory studies on UV exposure have shown a decrease in vitamin D, DNA, plant growth and erythemal (ERY) UV action spectra in response to UV exposure with increasing UV wavelengths.

The changes in UV radiation have shown an upward trend over southern and northern Africa as a result of downward ozone trends. The action spectrum weighted UV irradiation has also exhibited an overall upward trend peaking in spring and summer in both hemispheres. Southern and northern African regions experience an increase in DNA damaging UV irradiation in spring and summer. There was less than 8% change in ERY UV irradiation over Africa over the 34-year period. The depletion of ozone has resulted in hemispheric asymmetry, affecting the southern hemisphere more than the northern hemisphere.

### 6.3 Impact of UV Radiation on the Immune System (Prof Thomas Schwarz, Department of Dermatology and Allergology, University of Kiel, Kiel, Germany)

UVB radiation is a unique immune-suppressor with surprising features and there is a close link between UV radiation (UVR)-induced immunosuppression and photocarcinogenesis, a major issue in Europe and the United States of America. The link is best illustrated by the first photoimmunology experiment by Prof Margaret L Kripke where mice were exposed to UVR and developed skin cancer tumours. The tumours were transplanted onto healthy mice but were immunologically rejected, yet grew when the recipients were immunosuppressed (using drugs) or when they were exposed to low doses of UVR.

Patients that are immunosuppressed, such as transplantation patients, have a dramatically increased risk of skin cancer. This risk correlates strongly with the cumulative UV load. One-third of deaths of renal transplant patients is due to metastasising skin cancer and not renal failure.

Photocarcinogenesis involves multiple cancers (field cancerisation), which may disappear upon application of immunomodulators i.e. topical substances that activate the immune system. This illustrates the link between the immune system and skin cancer.

UV-induced immunosuppression requires low (physiologic) doses, is antigen specific, suppresses primarily T-cell responses and because of the antigen specificity may have possible therapeutic potential. UV-induced immunosuppression plays a role in UV-induced carcinogenesis (suppression of tumour immune response). UVR has a therapeutic effect in a variety of inflammatory dermatoses and in some cases could exacerbate infections including herpes simplex. However, sunburn patients do not tend to develop problems with bacterial super-infections and exposure to UVR improves a disease heavily colonised with bacteria, such as atopic dermatitis.

The innate immune response is human's oldest and most effective defence mechanism and has ensured the survival of the species over millions of years. The innate immune system is effective, rapid, involves complement, granulocytes, natural killer cells and is responsible for the antibacterial defence. One major component of this defence are antimicrobial peptides. A study at the University of Kiel discovered that the epidermis produced antimicrobial peptides, called defensins, which are more important in the antibacterial defence than the classical adaptive immune response. In contrast to the suppression of the adaptive immune response, UV radiation induces antimicrobial peptides. This could explain why bacterial superinfections do not occur after UVR exposure.

Volunteers were exposed to UVR (at low doses that suppress the specific immune response) and biopsies were taken and tested for antimicrobial peptides. A strong upregulation of antimicrobial peptides was found in the most outer layer. It was concluded that UVR exposure (at low doses not causing sunburn) suppressed the classical adaptive immune response but the innate immune response induced antimicrobial peptides. It is probable that the T cells in the skin are more harmful than beneficial and that UVR is effective as a therapeutic agent because it has an effect on the T cells. A hypothesis is that a constant level of suppression of the adaptive and of induction of the innate immune response through physiologic (daily) UVB doses might make sense from nature's perspective.

In conclusion, UV-induced immunosuppression in acute low doses provides protection from bacterial infection, maybe from allergic and auto-immune reactions.

In acute high doses it could induce melanoma and exacerbate viral infections, and chronic low doses (daily cumulative loads over many years) is crucial to the induction of non-melanoma skin cancer. The skin cancer epidemic in Europe cannot be blamed on the depletion of the ozone, but on excessive exposure to UVR.

### 6.4 Harmful Health Consequences of Solar Ultraviolet Radiation and Photo-protection in Africa: A Systematic Review (Dr Caradee Wright, Environment and Health Research Unit, MRC, Johannesburg, South Africa)

There is broadening interest in the changing climate. Ozone depletion is stabilising to some extent and temperatures are likely to become warmer. This means that lifestyles could change in various ways. Regardless of the future climate, cognisance needs to be taken of how people relate to the weather.

UVR levels around the equator are high for most of the year, whereas in South Africa they vary according to the season. Research done by the WHO presenting the burden of disease in relation to personal exposure to UVR relative to skin type explains the complicated health effects of UVR exposure on the range of skin types. The full range of skin colours and types, based on the different melanin content of the skin, exists in South Africa. Low UVR exposure can be associated with the risk of skeletal diseases and vitamin D deficiency, for example.

In Africa particularly, optimal UVR exposure levels differ from individual to individual based on skin type and colour, and are therefore, almost impossible to define. In addition, health risks such as skin cancer and eye diseases result from high UVR exposure, particularly occupational exposure, yet occupational legislation in many African countries fails to address solar UVR exposure.

Skin cancer is the most commonly known adverse human health effect of excess exposure to the sun. In South Africa, the mean age-standardised annual incidence of non-melanoma and malignant melanoma per 100 000 persons varies by population group, as well as by gender. Although unconfirmed, skin cancer incidence among the South Africa population groups could be changing. There is some evidence to suggest that with the high prevalence of HIV in South Africa there are more cases of squamous cell carcinoma (of the skin and of the cornea) amongst immunocompromised individuals, specifically in the black population group. Population-based evidence on UV-induced skin cancers in Africa was extremely limited, but from the few reports available, it appears that these cancers do still occur in people with pigmented skin. More evidence is required to be able to address the matter from a public health perspective.

In the 1970s, Prof Thomas B Fitzpatrick developed a classification of skin types based on phenotypic characteristics and effects of the sun. This classification cannot be

readily applied in the South African and possibly the African context because not many people relate to the terms 'burn' and 'tan'. Skin colour and melanin content are particularly important to consider in relation to sun exposure. Skin colour varies from light to very dark and can be described by using an individual typology angle (ITA) when skin colour is visually assessed or physically measured.

An assessment of 550 South Africans using self-reported skin colour and erythemal sensitivity measured against ITA values found an overall strong positive monotonic relationship between self-reported and measured skin colour, but a very weak correlation between self-reported erythemal sensitivity and measured skin colour.

One of the most important issues, not only from a psychological perspective but from the health consequences of sun exposure, relates to sun exposure of individuals with oculocutaneous albinism (OCA) as they are extremely susceptible to harmful effects of solar UVR. OCA is a grave public health issue in sub-Saharan Africa, with a prevalence of up to 1/1000 in some groups. Commitment to prevention of excess sun exposure, and sun protection awareness and treatment regimes, is essential in order to curb the problem of harmful sun exposure effects in people with OCA.

Photo-protection is of utmost importance, even in the African context. The WHO recommendations in this regard are not contextualised within an African environment and alternative approaches are required for appropriate sun protection in an African context. In addition, the acceptability of different photo-protective methods needs to be tested in Africa.

The WHO and the World Meteorological Organisation (WMO) recommend the UV Index (UVI) as a communication tool to explain predicted levels of solar UVR exposure linked to behavioural responses. However, in the African context, in summer the UVR levels far exceed the maximum level of the UVI scale, raising the question of the relevance of the UVI to Africa. There is a scarcity of data on levels of awareness and knowledge of UVR exposure in Africa.

In summary:

- Although there is a lack of data, the potential disease burden associated with exposure to solar UVR in Africa is considered high, particularly for skin cancer and cataracts.
- Action is needed to provide advice to African communities at particular risk of solar UVR-related diseases.
- Support for the monitoring of these diseases is required to assess changes in incidence rates and the impact of awareness campaigns.

## 6.5 Solar Ultraviolet Radiation in the Context of Climate Change (Dr Leonard Amekudzi, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana)

Solar radiation is the driver of all natural activities and processes on the earth. Africa has an abundance of solar radiation and tropical areas of the continent receive a larger proportion of UVR. UVR contributes to about 1% of the total irradiance and is highly variable. Protection from UVR is crucial as it can be harmful to living organisms. Changes in solar irradiance produce both direct and indirect effects on the climate system, as is evident in climate-related data.

Factors that influence atmospheric radiation include aerosols, water vapour, clouds and vegetation. Clouds modify the global energy balance by altering absorption and scattering properties of the atmosphere. Convection also contributes to large transfers of heat from the earth's surface, which is another important heat source for the atmosphere.

The density of the ozone layer varies across the earth's latitude. Although ozone is mainly produced in the tropics, it is denser over the pole and thinner over the tropics. Even a very thin ozone layer is crucial in ensuring absorption of UVR. The ozone layer is responsible for absorption of the harmful UV-radiation (UV-C) and part of UV-B. Depletion of the ozone layer is therefore a threat to life on earth.

There is a close link between climate change, human health and the environment, and all of these are influenced by socio-economic factors, such as population and literacy levels, cultural practices, hygiene and standard of living.

## 6.6 Wrap-up and Trans-disciplinary Discussion

Q: Have the findings of studies relating to the addition of antioxidants to sunscreen products described by Prof Krutmann been taken up by industry or policymakers?
R: Sunscreen products on the market contain antioxidants for purposes of UV photo-protection. The first product for IRA protection was launched in Germany some years ago and now there are five or six brands available on the market. The next challenge will be to standardise these products.

Q: Prof Krutmann mentioned the link between air pollution and Type 2 diabetes. Has this link been investigated further?
R: A paper from the IUF showed the association between PM exposure and the incidence of Type 2 diabetes was controlled for by some of the obvious compounders such as body weight, education level, and does not tell us anything about the mechanisms, which are still very poorly understood.

Q: Prof Schwarz indicated that some skin cancers are related to UVR. Arsenic levels in groundwater in Bangladesh have produced similar manifestations. Is there a way to tell the difference between the effects of UVR and the effects of polluted groundwater?
R: It is widely known that arsenic induces multiple skin cancers, which look similar to UVR-induced skin cancer. There have been instances of this in Europe.

Q: Mineral exploration and exploitation has been part of Africa's drive towards development but many of our people are being exposed to health hazards from mining. Has work been done to identify the health-related impacts of different mining activities?
R: South Africa has a long history of mining activity and the health-related problems are huge. Water levels in the decommissioned mines in Gauteng are rising, leading to acid mine drainage and affecting the surface and groundwater systems. The National Institute for Occupational Health has done studies showing the environmental impacts of past mining practices. A programme on mining and health has started recently at the MRC, and will look at exposure to radon, uranium and toxic metals in communities close to and far away from mine dumps in the Gauteng region. Very little is known at this stage.

Q: How do we know when the level of UVR exposure is too high?
R: This issue was addressed in Dr Wright's presentation. We do not know how much UVR exposure is too much. Tolerance levels differ from individual to individual. It is better to educate people on photo-protection rather than suggest that they avoid the sun completely.

Q: We know that negative effects of UVR are caused by anthropogenic factors, such as excess exposure, which are not driven by people in the southern hemisphere, and yet climate change and UVR and other problems will affect us all. Knowledge on these matters is generated in the northern hemisphere. How can the knowledge be shared across regions?
R: Published research that is disseminated using open source mechanisms means that information is becoming more accessible and is free of charge. Findings in one ethnic group should not be transferred to another ethnic group elsewhere in the world. Studies need to be done in the different populations and compared with one another. Collaborative research presents an opportunity to ensure that knowledge is shared across regions. There is a need for multi-country partnerships and collaboration, and for countries and regions to tackle their own problems and find solutions.

Q: How can those who are occupationally exposed be protected from the sun?
R: Local acceptance of sun protection options will vary across the country and the continent. Plenty of research needs to be done to respond to this question.

Germany, for example, has recognised skin cancer resulting from working outdoors as an occupational disease. This step has had a dramatic effect on preventative strategies. There are lessons from the private sector in South Africa, where creative solutions have been found to protect farm labourers and road workers, for example workers start early in the morning and stop work before midday when UVR is at its highest.

Q: Is there a history of open defecation in Ethiopia or is this just due to the lack of toilets? Is there not a simple intervention to overcome this huge problem?
R: In Africa, particularly sub-Saharan Africa, water-borne diseases create the most problems, and not skin cancer. In a country such as Ethiopia where the majority of the population lives in rural areas, providing sanitation would change the lives of many people and some work has already been done in this regard. Sanitation and hygiene interventions, as well as water supply systems in rural Africa are essential if environment and health in Africa are to be addressed.

Crime, particularly in informal settlements, impacts on society and has implications for health and environment.

The theme of the symposium (environment and health) excluded the social processes and driving forces, such as urbanisation, population growth, and community health. Most of Africa's environment and health issues are rooted in social problems.

## 7 Plenary Session: Water Pollution (Moderator: Dr Caradee Wright, Specialist Scientist, MRC, Johannesburg, South Africa)

### 7.1 Public Health Challenges of Anthropogenic and Geogenic Water Quality Problems in Ethiopia (Prof Tenalem Ayenew, Addis Ababa University, Ethiopia)

Although Ethiopia has substantial water resources, the country is water scarce due to infrastructural limitations and an increasing demand for water from a growing population. Urban water supply is made up of 70% surface water and 30% groundwater, whereas rural areas depend on groundwater. In Addis Ababa, 35% of the water supply is lost to leakage.

Water pollution by municipalities, industry and agriculture, and common contaminants such as solid waste, sewage, chemicals and fuels, is a threat to water quality. The rate of pollution of groundwater is dependent on the vulnerability of the aquifer and the type of pollutants.

Common aspects relating to water pollution in Africa are:
- Rapid urban development, resulting in many informal settlements.

- Groundwater extraction from shallow wells, often contaminated by pit latrines.
- The lack of formal domestic waste disposal and sanitation services.

Over-extraction of water from groundwater systems close to the sea disturbs the natural balance between salt and fresh water and results in high salinity affecting water quality.

Geogenic water quality problems are also widespread, particularly the prevalence of high levels of fluoride, which affects the health of over 40 million people.

In 1997, a project by UNICEF to identify the most common pollutants of Addis Ababa's surface and groundwater found the main threats to be leaking pit latrines and sewerage systems, industrial effluent, agrochemicals, as well as biological pollutants, such as nitrates and heavy metals. Industries were found to be responsible for polluting the Akaki River and only two of the 53 industries investigated had waste treatment plants.

Water pollution remains a major problem and a serious public health challenge in Ethiopia. No national research institution has been tasked to address the country's water quality problems and enforcement of legislation is limited. Integrated water resource management systems and strategic plans focusing on the protection of the environment and sustainable water resource utilisation are a necessity. Current interventions to improve water quality must be strengthened, research and training capacity developed, and community participation enhanced in order to bring about tangible improvements to water quality in Ethiopia.

### 7.2 From Indoor Water Contamination to City Level Water Pollution: The Accumulation of Water-related Risks in Greater Accra Metropolitan Area, Ghana (Prof Jacob Songsore, University of Ghana, Legon, Ghana)

An adequate supply of easily accessible, potable water is a necessary condition for households to attain a good quality of life. Improvements in hygiene and sanitation are reliant on the availability of water, yet most cities and human settlements in sub-Saharan Africa lack clean water supply and infrastructure. Water and sanitation issues have remained high on the policy agenda since the United Nations (UN) declared the International Decade on Drinking Water Supply and Sanitation in the 1980s.

According to the environmental transition model, two general categories of environmental risks affect human well-being: the everyday risks that directly affect human health and risks that have negative impacts on the ecosystems on which humanity depends. Everyday risks are the dominant risk factors that confront most cities in sub-Saharan Africa.

The current population of the Greater Accra Metropolitan Area (GAMA) is about 4 million, and the majority of inhabitants lack adequate environmental and housing services, employment, secure livelihoods and personal security. While most wealthy households in GAMA have in-house piping connected to overhead storage containers, the poorest and most deprived households rely mostly on informal water vendors, communal stand pipes and other less-efficient water supply sources. Water supply interruptions necessitate water storage, compromising water quality and leading to higher diarrhoeal prevalence, particularly in young children. Poor households in GAMA have access to small quantities of water and pay the highest price, and the water is likely to be contaminated. What therefore takes place 'between the tap and the mouth' is crucial in determining health outcomes.

In this study, samples were collected from the households' water sources and their storage containers and tests were conducted to determine the levels of both faecal coliform and faecal streptococci contamination of potable water in domestic households. The water was found to be contaminated prior to the point of consumption because of poor hygiene behaviour and broken water pipes resulting in cross-contamination of water supply at the local level even when water was initially treated to WHO standards. Overall, 10% of the tap water samples in GAMA exceeded the WHO faecal coliform guideline and 71% exceeded the guidelines on faecal streptococci.

Landfills are the principal anthropogenic sources of groundwater pollution, while salinity also results from geogenic factors. One looming threat is the widespread pollution of streams, rivers and lagoons within GAMA as a result of anthropogenic activities. Causes of pollution include the release of industrial effluents, untreated sewage, domestic and municipal wastes including e-waste into the rivers, streams and lakes. Inappropriate and ineffective urban management systems found in GAMA have resulted in widespread pollution of the cityscape including its principal water bodies. The study revealed that most of the defined water quality parameters of the various locations at the city level were above the limits recommended by the WHO. Rain-water harvesting is common, but the water collected is rarely treated.

A crude reminder of the environmental, behavioural and especially the poor water, sanitation and food hygiene conditions in GAMA is the 2014 cholera pandemic. As stated by the WHO Country Office in Ghana, "The potential for spread of cholera is high considering the continuous existence of the following risk factors: inadequate supply of safe water, poor food and personal hygiene, street vending of water and food, poor liquid and solid waste disposal, and urban slums".

The solutions of the myriad problems require an inter-sectoral approach with both hardware and software components. These include the provision of better water

and sanitation infrastructure and also behaviour change through public health interventions in addition to better housing provision and better overall urban planning.

### 7.3 Elimination of Micropollutants from Waste Water Treatment Plants using Advanced Oxidation Procedures (Dr Jochen Türk, Institute of Energy and Environmental Technology and Centre for Water and Environmental Research (ZWU), Duisburg/Essen, Germany)

The EU addressed the occurrence of micropollutants in its Water Framework Directive (WFD) to ensure a good biological and chemical status of surface waters.

North Rhine-Westphalia (NRW) in Germany has a high population density and most of the drinking water came from surface water. However, the environmental quality standards do not meet WFD requirements for 90% of the water bodies and new micropollutants like hormones are under discussion. Therefore, the occurrence of micopollutants requires more technical effort during the production of drinking water.

Increasing concentrations of micropollutants (pharmaceuticals, personal care products, endocrine disrupting compounds, industrial chemicals, pesticides and biocides) in effluents of waste water treatment plants (WWTP) and surface water bodies affected the aquatic environment. Although the WFD watch list excludes Environmental Quality Standards (EQS) for pharmaceuticals, European water bodies are at risk of high concentrations of pharmaceuticals, particularly diclofenac.

WWTPs are the main source of micropollutants being discharged into water bodies in European countries, raising the need to find advanced technologies for waste water treatment. Advanced oxidation processes (AOP) using ozone, hydrogen peroxide, and UV, was tested to establish suitability to address the problem of micropollutants in drinking water.

Large-scale projects to upscale AOP operations were implemented in three WWTPs in NRW, with the aim of eliminating pharmaceutical residues, studying metabolite formation during the use of ozone and assessing the economic benefits of retrofitting municipal WWTPs to eliminate organic micropollutants, pharmaceuticals, industrial chemicals, pathogenic germs and viruses. The experiments showed that not all the compounds could be removed completely, but the compounds that remained were in low concentrations and had no toxic effect. The AOP decreases genotoxicity and estrogen effects to a very low level.

In conclusion, a combination of chemical and biological tools is useful for the investigation of new processes and full-scale ozonation at WWTPs can be operated robustly and safely for micropollutant removal, leaving no formation of bromate

or acute toxicity. Some of the slight negative effects require further investigation. The average cost of waste water treatment in Germany is around 2.50 €/$m^3$ and the additional cost for micropollutant removal would be about 0.15 to 0.20 €/$m^3$.

### 7.4 Sanitation Failures in Low-cost Housing Schemes: A Disaster in the Making (Dr Jo Barnes, Stellenbosch University, South Africa)

The South African government has embarked on an ambitious rehousing programme (known as 'Breaking New Ground') focusing on the urban poor (people with no income or an income below R1 500) with the aim of improving living conditions, health and well-being of the rehoused families. This was done to upgrade the living conditions of inhabitants of informal housing areas which are traditionally regarded as a significant source of health problems and environmental pollution.

A recent study assessed the structural living conditions of low-cost housing settlements in the City of Cape Town and the associated health conditions of the inhabitants. Four sites were carefully chosen and household surveys involved a systematic random sample of 1 080 persons living in 173 main houses and 163 shacks in the backyards of the same premises.

Some of the findings of the study were:

- Toilets in 58% of the houses were non-operational and many were not cleaned regularly.
- Dirty water and kitchen waste were disposed of by flushing these down the toilets.
- All the houses had visible serious structural damage, but the inhabitants did not know how to or could not afford to maintain them.
- Most houses had blocked drains and the yards were strewn with rubbish.
- Water leaks were common: only 2% of owners paid for water and most were unconcerned about the water wastage.
- The addition of shacks alongside the houses increased the roof area by 23%, resulting in substantial flooding during storms, and damp walls.
- 32% of the dwellings reported one or more cases of diarrhoea in the preceding two weeks, mostly in children under the age of five years.
- None of those who self-reported tuberculosis and HIV/AIDS were on treatment or had visited the local clinic in the preceding two months.
- 6% of respondents indicated that they ate only one meal a day.
- Most dwellings had one or more smokers and reported alcohol consumption and illegal drug use.
- *E. coli* counts of water in streets and sidewalks in the four sites were found to be excessively high.

Poor hygiene, damp walls, obscured windows, hazardous electrical connections, blocked sewage systems and storm water drains, informal access to sewer lines,

overuse of facilities inevitably lead to diseases from exposure to microbiological pathogenic pollution.

Government's rehousing programme has been undermined by the "shack in the backyard" phenomenon, as the slum conditions followed the newly rehoused. Densification caused by backyard dwellings had huge implications for the provision of municipal services and the Breaking New Ground communities showed considerable health vulnerabilities and poor utilisation of primary care facilities. There was high infection pressure due to failing sanitation in the new houses and the poor conditions of dwellings and poor sanitation behaviour subverted the aims of rehousing impoverished people.

Improvements were suggested in terms of repairs and maintenance to the formal sewerage system and broken or blocked infrastructure inside the houses. New homeowners need to be educated and trained in basic home maintenance, home hygiene and safe disposal of waste prior to taking possession of a subsidised house. Some jurisdiction ought to be maintained over the structure for some time (with inspections and training in home maintenance) before the occupant can take full ownership. A system of home-based visits by community workers to address sustained education of inhabitants would assist in reducing cases of diseases such as diarrhoea, and should be maintained for a long period of time in order to prevent relapse.

### 7.5 Wrap-up and Trans-disciplinary Discussion

Q: Prof Ayenew mentioned iron as a form of geogenic pollution of water. There is an iron deficiency, particularly in pregnant women, and a threat of fluoride exposure in Ghana. Could wars be the source of radioactive pollution?
R: Most of the Great Rift Valley groundwater systems have a very low iron content, but water in certain areas of Ethiopia where there are volcanic aquifer systems, has very high levels of iron, more than the WHO drinking water quality standards. A concise mapping of the levels of iron is required. Fluoride is one of the widely spread public health concerns, especially in countries centred on the Great Rift Valley. Ethiopia is one of the seriously affected countries, after India. The fluoride content of water is entirely geogenic and associated with two types of sources: acidic volcanic rock and geothermal fields. Radioactive waste is apparently being dumped in coastal areas of Africa, particularly along the coast of war-torn countries. In some countries where there is mining activity, radioactive pollution is a real concern, but in Ethiopia, it is not a serious problem.

Q: Many of the studies that have been done in South Africa show that the scoop used to decant water from the container is put to the mouth. Has Prof Songsore found possible ways that the pathway between container and mouth is being contaminated?

R: The water utility in Ghana is very sensitive to water quality standards. Conditions can be monitored at the point source but monitoring along the value chain is difficult. Water storage is a common phenomenon, particularly in lower-income groups. The containers are open, communal scoops are used to drink water and hands are not washed making it conducive to contamination. In some cases the water containers have been used to store chemicals or fuel and are used for a variety of purposes in households. The hygiene behaviour aspect is central to the problem.

Q: Dr Türk, is the cost of cleaning water to remove micropollutants more affordable than not having the pollutants in the water in the first place? What about microplastic?
R: Microplastic from products like toothpaste or cosmetics can be removed by the industry. Phasing out industrial chemicals and pesticides would be also possible, but pharmaceuticals remain a problem because human health is a priority. There is a huge concern about drinking water production from surface water. Switzerland has instituted a new regulation to extend their major WWTP with a tertiary clarification step. Africa needs to resolve its hygiene and sanitation challenges before looking at micropollutants.

Q: Dr Barnes, it appears that in the housing settlements where the study was done, behaviour is constrained by a lack of choice. Is government intervention appropriate where there is a lack of choice?
R: The study was done in a group of people who already have formal houses, piped water and toilets inside their homes. Waste removal services are provided to the houses. They do have choices but choose to increase the number of people sharing facilities that are suitable for five or six people. They have the opportunities to practise basic hygiene but lack the knowledge and/or motivation. They can take a number of actions within their budget and such skills can be taught. Programmes need to be designed and rolled out to inspire them to realise that they have choices that will improve their sanitation situation. Government intervention is essential to ensure that those who are given houses understand that ownership is about taking responsibility. This is difficult to inculcate in people, particularly in those who have spent much of their lives in informal settlements.

Q: Dr Barnes, have you considered directing the change communication and education through young children?
R: It is important to educate the children. Although children are taught to wash hands at school, the lessons learnt are not necessarily taken home. When there is no tap, soap or towel available at home, it is easy not to wash hands. The challenges are huge and there is no single answer. More than one approach will be needed to reach both children and adults. Skills and goodwill are lost if there is no infrastructure to support safe hygiene behaviour.

## 8 Plenary Session: Air Pollution (Moderator: Prof Jean Krutmann, Leibniz Research Institute for Environmental Medicine, Düsseldorf, Germany)

### 8.1 Adverse Childhood Health Outcomes and Air Pollution: Antenatal, Neonatal and Early Infancy Exposures (Prof Rajen Naidoo, University of KwaZulu-Natal, Durban, South Africa)

There is substantial evidence to support the hypothesis that prenatal air pollution impacts foetal health and neonatal health, which may influence infant and early childhood outcomes, and ultimately may influence the subsequent stage of development into adulthood. However, there are substantial challenges in proving causal relationships and addressing appropriate interventions.

Fundamental impacts of PM exposure affecting the nervous system, cardiovascular system and lungs were seen during the critical period of foetal development, between two to eight weeks. Prenatal exposure may influence conception, but if the foetus survives, foetal growth will be impacted in the period from 16 weeks onwards resulting in intrauterine growth retardation and organogenesis. There are well established mechanisms as to why this could occur, particularly with regard to the impact on the placenta and the foetal cardiovascular system, and subsequent impacts on the respiratory and cardiovascular organ development and specific birth outcomes.

PM exposure induces changes in multiple placental compartments, including maternal vascular space, foetal capillaries and surface exchange areas and direct or indirect hits on several cell types to influence cell differentiation, proliferation and/or maturation. These can result in the alteration of the normal developmental pattern range of metabolic, immune and neurological functions *in utero* and postnatal growth. There is evidence that polycyclic aromatic hydrocarbons (PAHs) induce DNA adducts causing tissue and organ damage.

Other processes that impact childhood health outcomes of pollution have recently come to the fore and include the influence of oxidative stress on the inflammatory processes within the foetus, and more importantly, epigenetic changes. Effects that the foetus may experience *in utero* may be multiplied in childhood through the ongoing exposure to pollutants. There is evidence that children who are born well and then exposed in the neonatal or early infancy period will develop chronic disease, particularly respiratory and cardiovascular outcomes, but also neurological and other outcomes. A number of different pollutants, especially $PM_{2.5}$ and black carbon, are associated with increasing risk of subsequent asthma and lung development generally in childhood. New studies show an improvement in lung function among children in those communities with reduced air pollution.

In terms of childhood neurological outcomes, there is historical evidence that lead exposure affects cognitive development. The reduction of environmental lead

has a corresponding improvement in cognitive function. There is further emerging evidence concerning other pollutants and neurologic outcomes. In terms of childhood cardiovascular outcomes, an association of early signs of impaired vascular health, with residential exposure to highly trafficked roads was found among 600 children in southern Italy.

The birth outcome itself contributes to an increased risk of disease such as asthma. Health impacts on the foetus resulting in chronic disease independent of what the child experiences after birth were investigated, and a theory of the foetal origins of disease put forward in the late 1980s has been replicated in a number of other studies. More recently, the concept of the developmental origins of health and disease has been put forward. The hypothesis is that what happened in foetal development would influence health in adult life.

In summary, there is sufficient evidence for the adverse impacts of air pollution on the health of the growing child, from *in utero* through to early childhood. Apart from the acute effects, these impacts influence long-term chronic outcomes and disease in adulthood. Improving health of the next generation requires intervention and protection during the prenatal/antenatal period.

### 8.2 A Review of Urban Air Pollution in Africa (Prof Samuel Agyei-Mensah, University of Ghana, Legon, Ghana)

Urban air pollution is responsible for an estimated two to three million deaths annually worldwide. Even though there are similarities in terms of the sources and spatial patterns of air pollution in cities in developing countries and those in developed countries, there are also significant differences. A sustained body of evidence from both developed and developing countries has established that PM causes a wide range of short and long-term adverse health effects. PM is also the most health-relevant indicator of urban air quality and is widely used in setting air quality guidelines worldwide.

As Africa undergoes major economic, demographic and epidemiologic transition, it is essential that air quality monitoring programmes, the setting of standards, cleaner cooking fuels, land use and living environment planning and health impact assessments become the focus of African scholars and governments.

Data in respect of long-term systematic monitoring of PM in African cities are not comprehensive and monitoring is being done in only some countries. Available data show that most of the PM levels exceed WHO guidelines.

One of the most comprehensive air pollution studies in Ghana started in 2006 and was a collaborative project between the University of Ghana, Harvard University and Imperial College, University of London. PM pollution was monitored in four

areas of Accra and the roles of the different sources of pollution were quantified based on the spatial patterns. Household questionnaires and PM measurements, together with data from the Ghana 2000 Population and Housing Census, were used to quantify the impact of household and community biomass usage and traffic on household PM pollution. Some of the findings of the study were:

- The use of biomass fuels and living in a community with high biomass usage were both associated with high PM levels in cooking areas.
- The lowest $PM_{2.5}$ and $PM_{2.5-10}$ were measured in the higher class residential areas of the city where clean fuels were used for cooking.
- PM concentrations were found to be highest in late-December and January, due to dust blown from the Sahara.
- The low income and densely populated neighbourhoods have the single highest residential PM concentration.

A more recent study looked at personal PM exposures and locations of students in four neighbourhoods in Accra and showed that females have a higher exposure than males and that exposure is inversely associated with the distance of the home or school to main roads and the use of biomass fuels.

Monitoring of long-term trends in PM levels is insufficient. Studies on personal exposures to air pollution on the continent, especially in urban areas, as well as studies on the links between air pollution and pregnancy outcomes are required.

### 8.3 Air Pollution Effects on the Lung and Brain (Dr Tamara Schikowski, Leibniz Research Institute for Environmental Medicine, Düsseldorf, Germany)

Air pollution is of anthropogenic origin or comes from natural sources, such as volcanic ash, wildfires and Saharan dust. Sources of indoor air pollutants include cook stoves, heater smoke, asbestos, household chemicals and cigarette smoke. $PM_{10}$ (dust, pollen, mould) and $PM_{2.5}$ (combustion particles, organic compounds, metals) are measured in Europe. $PM_{10}$ is known to enter the lungs and causes inflammation, and $PM_{2.5}$ can go beyond the lungs and enter the circulation system causing cardiovascular diseases, or enter the brain and cause cognitive defects. Monitoring pollutants is central to exposure assessments, but hardly any routine monitoring is taking place across Africa.

In recent years the focus has shifted to ultrafine and nanoparticles (<100 nm size), especially in urban areas. As it is very difficult to measure these particles, the distance to the nearest major road is used as a proxy.

Two studies on the global burden of disease (1992 and 2010) looked at the effects of outdoor air pollution on lung health. The 2010 study ranked household air pollution from solid fuels as the third and ambient air pollution as the eighth cause of morbidity and mortality worldwide. Exposure to outdoor air pollution can affect the

unborn child through the pregnant mother and lung function during childhood. A study of 4 757, elderly, rural women in Germany showed an association between COPD and ambient $PM_{10}$. Women from heavily polluted areas developed COPD at a very early age. A study of the burden of COPD worldwide showed the highest prevalence of COPD was in South Africa, particularly in women, and that most of the people with COPD in South Africa developed the disease at a much earlier age than those in other countries.

Central and western Africa and India have the biggest burden of disease due to indoor air pollution. The WHO estimated that about three billion people worldwide use fossil fuels for heating or cooking. Approximately 5% of the total burden of disease is caused by indoor air pollution, which is also responsible for more than 1.5 million pulmonary and cardiovascular deaths yearly. The WHO estimates that there are 4.3 million deaths per year from illness (mainly respiratory diseases that cause cardiovascular diseases) attributable to household air pollution caused by the inefficient use of solid fuels.

A research question about the brain being a target for inhaled particles originated from animal studies that showed a translocation and accumulation of inhaled carbon nanoparticles in rat brains through nasal deposition (the olfactory route) and through the lung alveoli (circulation route). A study in Mexico found an association between PM exposure and neuropathology.

Assessments of long-term exposure to traffic-related PM, including cognitive function tests, showed that people living less than 50 meters from major roads developed cognitive impairment at an earlier age than those who lived at a distance from major roads.

In the 1980s, air pollution in certain areas of Europe was severe. In 1987, the German government introduced its Clean Air Plans with very strict measures to abolish the use of fossil fuels for heating. Coal mines were closed and filters were placed on high chimney stacks. Since then, air pollution levels ($PM_{10}$) have reduced substantially and there has been a consistent reduction over time.

Strategies to reduce the burden of air pollution worldwide involve the use of improved fuels, the control of emissions at point source and the introduction of cleaner cook stoves with ventilation.

In 2009, the German government offered owners of cars older than ten years an incentive to buy new, clean cars. The old cars, which contribute to air pollution, were shipped to Africa. Although Germany's air pollution levels have dropped as a result of this initiative, the pollution problem has been transferred to Africa.

### 8.4 Wrap-up and Trans-disciplinary Discussion

Q: Prof Naidoo, what is known about the mechanisms in relation to the effects of exposure of the foetus to PM?
R: Inflammatory changes that take place in the mother are transferred to the foetus via the placenta. Epigenetic changes are seen both in the mother and the foetus. It is therefore important that interventions focus on both mother and the foetus.

Q: Dr Schikowski, what advice could be given to governments about the practice of exporting old vehicles to Africa and the resultant transfer of air pollution to African countries?
R: People who buy the cars should be provided with the knowledge to make the cars cleaner, by adding filters for example. The German government ought to be made aware of the impacts of their actions on air pollution in Africa.

Q: Are there any education programmes in Africa that address the issue of air pollution?
R: In Ghana, there have been education campaigns and practical efforts, especially with regard to the use of clean fuels, using modified cook stoves. Most of this work is done by NGOs. There is a need for further education about the link between air pollution and respiratory diseases.

In Durban, South Africa, there have been important developments in terms of monitoring and controlling air pollution. There used to be an extremely good monitoring programme in the city. Activism through NGOs has forced government to start paying attention to these matters. The key source of pollution is largely industrial and there are programmes in place in some of the most polluted parts of South Africa, such as Durban and the Vaal Triangle.

The export of old German cars to Africa is related to the global political economy, and could have a ripple effect in terms of the impact on the entire ecosystem and is not sustainable. It is therefore important to set global standards and do more to ensure intra-regional equity. Air pollutants add to climate change and cause the thinning of the ozone layer. If air pollution is reduced, climate change could be slowed down.

It is difficult for an African farmer to export produce to the EU market because of the need to comply with numerous and complex standards. Similarly, standards should be put in place that control Germany's export of old cars to Africa.

## 9 Roundtable Discussion: Strengthening Environmental Health Services to Support A Healthy Society (Moderator: Prof Petro Terblanche, Pelchem Pty Ltd, South Africa)

**Panel: Dr Tamara Schikowski (Leibniz Research Institute for Environmental Medicine, Germany), Prof Harold Annegarn (Cape Peninsula University of Technology, South Africa), Mr Desmond D'Sa (South Durban Community Environmental Alliance, South Africa)**

Prof Terblanche introduced the panellists and invited contributions to the discussion in the context of the global initiative, Healthy People 2020 and the services that support a healthy society, a critical component of the initiative.

Environmental health factors contribute to between 30% and 35% of the burden of disease in Ghana, South Africa and Ethiopia, but these factors only contribute 10% to the burden of disease in Germany. This interesting divide requires further consideration. What is needed collectively from across the sectors, tiers of government, institutes and custodians of environmental health to ensure the prevention, treatment and minimisation of the burden of disease?

Prof Annegarn's response reflected on the broad nature of partnerships and intellectual sustainability. Africa would not prosper unless a sustainable intellectual community was created on the continent. This was the importance of this symposium and the partnership with Germany. Many of the European institutes were obliging scientists to form multi-national, multi-institutional partnerships across Europe, as recognition that intellectual community underpinned the long-term sustainability of the economic viability of the EU. Germany had embraced this notion and formed partnerships, such as those reflected in this symposium that provided the resource and experience to assist with the creation of sustainable intellectual partnerships within Africa. The German National Academy of Sciences Leopoldina and the Volkswagen Foundation were particularly generous in supporting these multi-national African endeavours. The custodians of knowledge and the different tiers of government needed to create and nurture the intellectual community across borders of Africa in order to prevent, treat and minimise the burden of disease resulting from environmental factors.

Dr Schikowski confirmed the EU's support of multi-national, multi-institutional partnerships and commented on the importance of involvement from industry partners and community groups in collaborative work.

Mr D'Sa, an activist from an environmental NGO, initiated a campaign in 1995 against the chemical refineries and factories that he believed were the cause of the high levels of asthma, cancer and leukaemia in large communities located

close to the industries south of Durban. This action was the beginning of government's realisation of the impact of the high levels of toxins and pollutants on the people. Information was developed by a group of activists together with the communities, networks of scientific and civil society and partnerships with occupational scientists were established. In 2001, the government adopted a multi-point plan that was implemented in Durban. Over 50 air pollution officers were trained and appointed by the city's health department. The NGO started the first air quality monitoring programme, and together with scientists, gathered credible information and interpreted the data. Indigenous knowledge from the community was incorporated into the scientific information. These actions led to increased awareness of the problems. Communities lodged formal complaints with the city authorities, articles appeared in the mainstream media, books were published and workshops held about the problems of air pollution in Durban. The knowledge developed about the threats to environmental health was incorporated in the high school curriculum and was presented to the authorities as evidence for pressure placed on industry and government to take mitigating steps. These actions led to the development of legislation, i.e. National Environmental Management: Air Quality Act of 2004, which was centred on the human right to a clean and healthy environment in South Africa. Continued pressure on government resulted in a collaborative environmental health study, which was undertaken by a team of scientists, including Prof Rajen Naidoo.

Where a community's health is at stake, the industry can lose a lot of money; the notion of a public-private partnership (PPP) is often a pipedream. How have PPPs failed or succeeded in the Durban industrial basin or other areas of the country?

Prof Annegarn observed the absence of community representation at occasions when knowledge was shared and commented on the importance of communities being given the opportunity to share their stories and experiences without mediation through academics, consultants and government agencies.

Mr D'Sa shared his experiences in trying to manage dissent and negotiations with industry, and of some of the divisive and obstructive methods used by industry. Efforts to ensure the enforcement of legislation and constitutional requirements led to a change of heart by the Durban authorities. Since 2010, the monitoring data have no longer been accessible, all officials who were skilled, qualified and knowledgeable in pollution and environmental health issues have left the employ of the municipality, there has been no enforcement and budgets for monitoring equipment have been cut. The NGO had recourse through the Promotion to Access of Information Act and continued its work analysing and collecting data and recently lodged a case against the city health authorities and against the big oil refineries in Durban, demanding access to information. Similar efforts to demand

access to information from industry by NGOs in the Vaal Triangle have been successful.

Dr Schikowski pointed out the importance of distinguishing between scientists employed by government to do research funded by government agencies and scientists at universities and other research institutions.

South African gold mining companies in Ghana have retrenched 4 000 workers but the Ghanaian government has no legal recourse in this regard. This is an example of a PPP that is an alliance between foreign capital and the state, which does not serve the interests of the people. It takes civil society movements to break the monopoly of such PPPs and bring corrupt, complicit practices to the fore and make the PPPs more horizontal.

Dr Schikowski indicated that in Switzerland, law required that the findings of studies must be disseminated to the entire population and made available on government websites. In Germany, some efforts were made to communicate findings and subsequent information with all study participants. It was helpful to have a good partnership with the media and produce press releases that tell the truth.

Mr D'Sa commented that in terms of science and credible information, government tended to appoint people who produced reports that did not reflect negatively on the government sector. Independent scientists are more likely to produce credible data. Government does not act on credible data. The CSIR did a study on water quality, which showed that the water sources (and the ocean) around Durban were highly polluted, but government had not acted on the findings of the study. There should be a link between civil society and scientists so that lobby groups can put pressure on government.

Within the medical tradition, the curative sector has more power than the public sector. Budgets are skewed towards curative medicine and pharmaceuticals even though public health can address over 40% of the burden of disease with very little financial outlay. Public health should be more emphasised and given more funding to address hygiene, sanitation and water problems. The balance between public health and curative medicine needs to be realigned, particularly if there is intention to address the concerns of the poor. Environmental health is the stepchild of the budgets for healthcare. Is this because the cause-effect relationships are not well understood, because curative medicine provides a clear treatment line or because funding drives the behaviour?

Mr D'Sa agreed that environmental health was the stepchild of healthcare budgets. Big corporations did not allow the government to acknowledge the direct correlation between air pollution and health problems. The less monitoring was

done, the less information was made known and the less would be known about the health impacts of pollution.

Prof Annegarn pointed out that the worst air pollution problem in South Africa was the generation of smoke (nanoparticles) from domestic combustion of coal (the major fuel for heating in indigent households), regularly exposing the entire population to concentrations of $PM_{2.5,}$ that were three to four times higher than the new international limits. Government had done very little to alleviate the problem of domestic pollution. In areas that were widely electrified, people were still using coal because it was a lot cheaper than electricity. Government was in a predicament as it promised a better life for all, which meant that there would have to be clean electricity for the poor. There was no national policy relating to energy for the poor to address the problem of domestic combustion of biofuels and coal, one of the top air pollution problems on the continent.

Government has made some very unhealthy decisions, particularly in terms of planning and development. New, big housing settlements were still being built on the doorstep of mine dumps and of industry. Industry's profit motive allowed for scant attention to be paid to community health. This explained the powerful statement by the WHO Commission on the Social Determinant of Health about the continued focus on curative treatment instead of on public health. This problem will not be resolved in the foreseeable future, but there was hope in what could be achieved by public pressure groups. Consideration should be given to how these groups can be built, supported and funded to play this very important role and ensure a much more powerful citizenry.

There was a gender aspect to the displacement of the burden of disease. Women, particularly poor women, were the most exposed to air pollution from the domestic environment.

Efforts should be focused on poverty eradication using environment and health programmes. This would reduce the need to subsidise energy for the poor. It would be more effective to address the root cause of the problem (poverty, the lack of alternative options, focus on survival) and the predicament Africa was in because of its dependence on development aid.

Interventions that would ensure a cleaner environment and provide alternative options towards improving the current situation in terms of air pollution included:

- Adaptations in the built environment (more efficient structure and the use of clean materials), which can play a role in decreasing air pollution levels.
- Effective public transport systems and the promotion of environmentally friendly modes of transport.
- Cleaner energy production using abundant resources, such as sunshine.
- The use of other sources of energy (such as plant-based fuels, biogas and waste) to power households and industries.

The stagnation in addressing the environment health issues was the result of the barrier between reliable and useful research data that could have a direct impact on society and policymakers in many African countries. In most cases, policies were based on political interests and not on scientific evidence.

Africa should follow best practices and implement quality systems in respect of the environment.

In Mauritius, scientists had an obligation to take their study findings to communities. This was done with the help of NGOs and students, who were also used to educate communities.

Population growth was a serious matter that affected government's efforts to provide low-cost housing, social grants, electricity and water. South Africa was becoming a welfare state.

### What are the next steps that should be taken?

Mr D'Sa was of the view that the climate change crisis should drive the world to urgency. The fossil fuel industry was responsible for much of the problem relating to environmental health. In South Africa, 77% of the energy was used by the ten biggest companies and 23% was used by people, mostly the richest people. He was involved in a campaign for the disinvestment of fossil fuel and against coal-fired power stations (particularly those being constructed in water scarce areas of the country). South Africa should learn lessons from Germany, which had done away with fossil fuels and nuclear and was now producing 40% of its energy from renewable sources. Africa had sufficient resources to provide adequate renewable energy. The mines had only brought ill health to the people of this country. Foreign mining companies exploited the natural resources of this country and the continent, leaving Africa in poverty. The land used for mining should rather be used to grow crops, thereby ensuring food security. Scientists were aware of the threat of climate change and pollution and should be the voice of the people, arguing on behalf of the people who did not benefit from fossil fuel mining. People's health needed to be put above profits.

Prof Annegarn commented that the current cost of electricity was three times more expensive than using domestic coal for space heating. There were many good reasons to move to a low carbon economy, and climate change was not the biggest problem. The concept of climate change had little resonance with the everyday circumstances of poor people. A community that did not have food or work as a result of closing the mines would not be sustainable. The focus should be on community engagement and empowering communities to assist themselves rather than thinking that the problem was with big business and government.

Dr Schikowski disagreed that closing the mines would resolve the problems because it would result in increased poverty. This was what happened in Germany where cities were dying as a result of closing the mines and there was a high level of unemployment. Sustainable energy, particularly solar energy, was the solution to the problem. There were very good examples of renewable energy being produced successfully and sold across Germany. South Africa had sufficient sunshine and solar panels were becoming more affordable. Natural resources should be used optimally and this would resolve many of the environmental health problems. Population growth and the influx of refugees cannot be stopped but would have to be addressed and resolved.

Prof Terblanche concluded the discussions by stating that finding solutions to environmental health issues was not only the problem of governments, but also that of scientists. A culture of accountability and responsibility needed to be fostered. The world called for a balanced view and a deep understanding of the roles and contributions of the different partners. Fostering partnerships was what would make the difference. A systems approach had to be taken in order to bring about progress in the environmental health sector. Renewable energy was attractive and appeared very clean, but questions needed to be asked about the life-cycle analysis of the chemicals used in the manufacturing process. There had to be a change of mind set or the problems would not be resolved. The call was for the environmental health community and its knowledge base to stop, rethink and look more innovatively at what was being done to change the *status quo*.

Some of the points highlighted in the discussion to put forward to the organisers of the symposium and brought to the attention of key stakeholders of environmental health in the different countries were:

- Air pollution was the most important environmental burden of disease issue and PM was a key contributor to this.
- Information that became knowledge brought sustainability.
- Empowerment of communities to build partnerships led to successful interventions.
- There was a very important value system in having a common goal, but different players in delivering health services needed to work together.
- PPPs and community-based organisations (CBOs) have a strong role to play in fostering environmental health.
- Credible scientific data and transparency of information were essential in ensuring that policy decisions were based on fact.
- There were unintended consequences of policy and policy enforcement or the lack thereof.
- Education played an important role in changing attitudes.
- Multi-facets of environment health required interventions with a multi-disciplinary, multi-player approach involving not only enforcement and government,

but also the education system, behavioural aspects and value systems in society.
- The energy issue probably posed the biggest challenge to environmental health, from the perspective of air pollution, as well as many other development issues.
- Recommendations should be made concerning the policy in respect of the energy mix, particularly in terms of domestic energy requirements and their impact on environmental health.
- The different role players were ineffective in preventing industry (and government) from ignoring environmental health consequences of pollution. Public lobby groups and scientists had grappled with the same issues for decades and have had little success. Instead of recycling the same problems, the environmental health community needed to be innovative, provide implementable and sustainable solutions, and educate people about environmental health issues.
- Poverty eradication was the only way to address problems relating to domestic air pollution.
- Funding for CBOs and NGOs with an environmental agenda needed to be addressed.
- Population growth and the influx of immigrants into the country posed a variety of threats to environmental health, which have to be addressed.

## 10 Plenary Session: Metal Exposure (Moderator: Prof Tenalem Ayenew, Addis Ababa University, Ethiopia)

### 10.1 Assessing Effects of Metal Toxicities on Health from Mine Wastes in the Southern African Development Community (SADC) Region and some Plant-based Remediation Measures for Contaminated Soils (Prof Fisseha Itanna, Addis Ababa University, Ethiopia and University of Namibia, Namibia)

Mining wastes are waste products originating, accumulating and present in mine sites, which are unwanted, have no current economic value and include metals. Mineral deposits in Namibia include diamonds, gold and uranium and the country has diverse soil types.

Archaeological evidence indicates that mining in Namibia began over 500 years ago. Most exploration began in the 1880s, when the mineral deposits known today were discovered. Early exploration and mining activities were conducted with little regard for the environment and rehabilitation measures were not in place. Environmental awareness began in the 1990s, but the problem of abandoned and un-rehabilitated mine sites is only recently beginning to be addressed. Today there are about 157 abandoned mine sites in Namibia, where no rehabilitation has been done, leaving behind a trail of safety hazards including contaminated soil and ground water, and windblown dust.

Exposure to chemicals in the environment can be through the skin, inhalation, oral ingestion or injection. The route of exposure may be important if there are tissue-specific toxic responses. Multiple exposures to chemicals lead to chronic effects in humans. Soil can be contaminated by heavy metals.

Blood and urine samples taken from inhabitants of Tsumeb in Namibia, where there are several abandoned mines, showed lead concentrations exceeding WHO guideline values (max. 55 mg/dl) in more than a fifth of the samples. Arsenic levels in urine of every sixth person exceeded the WHO guideline value. The anomalous values could be attributed to the industrial zone of the city which caused inhalation of contaminated dust as well as contact with contaminated soil and the consumption of contaminated crops by inhabitants.

Another study was done in Limpopo, South Africa, and looked at the epidemiology risk assessment for rehabilitated asbestos mines, which tend to have a significant amount of exposed asbestos fibres that contaminate water, soil and air making the areas more prone to risk. Breathing air containing an asbestos fibre concentration of 10 f/ml will cause asbestos-related illnesses in most people over a period of 50 years. The study indicated the presence of asbestos minerals on the rehabilitated sites.

One of the remediation measures to address contamination of abandoned mines is phyto-remediation, which involves a series of processes. Phyto-extraction involves the uptake and concentration of substances from the environment into the plant biomass. These processes have demonstrated efficient extraction of excess heavy metals.

In conclusion, abandoned mine sites in Namibia and South Africa pose major health risks from heavy metals and other sources. Adapted grasses and vegetation in and around mine sites could be used for phyto-remediation purposes.

### 10.2 Human Bio-monitoring of Metal Exposures: Bridging Exposure and Risk Assessment (Dr Heiko Udo Käfferlein, Institute for Prevention and Occupational Medicine, Bochum, Germany)

Chromium is a major component of stainless steel that is used for welding. Where there is exposure to welding fumes, there is also exposure to chromium, nickel and many other metals.

A cross-sectional study was done on welders in the German industrial sector and the health effects from exposure to welding fumes or welding-induced oxidative damage. Welding fumes are rich in metal oxides, which once taken up can form reactive oxygen species, which in turn interact with DNA and protein and contribute to the inflammatory and carcinogenic risks in the human body. Parameters of ambient and biological monitoring involved measuring an external dose, internal dose and effective dose.

Some of the areas of the study that could contribute to development of prevention measures were:

- The good association between the respirable and inhalable fraction in welding fumes. This means that a large part of the respirable fraction reaches the alveoli where it may cause damage. About 15% of the workers were above the current threshold limit values (TLV).
- The implementation of helmets with independent air supplies during welding, reduced exposures considerably. Biological monitoring was able to prove the success of this protective measure.
- The strong linear association between the chromium levels in air and those in urine. Such an association was also observed for nickel. However, metals in welding fumes that are also essential minerals and thus tightly regulated such as iron and manganese do not show such strong associations.
- Increased levels of manganese in the blood only resulted from extremely high exposures to manganese in the air.
- Increasing oxidative damage was observed in urine with increasing exposure to iron.
- Increasing exposure to chromium was associated with increased oxidative damage.

The exposure assessment study showed that biomonitoring offers an advantage when studying dose-response as it measures the dose taken up by humans, takes into account homeostatic control of metals with dual function and allows for controlling the effectiveness of protective measures. The assessment of the effects of welding exposure showed increasing oxidative DNA/RNA damage in terms of increasing 8-oxo-dGuo levels in urine with increasing levels of iron and chromium. However, welders did not show increasing oxidative DNA damage in terms of 8-oxo-dGuo in blood lymphocytes with increasing exposure to metal oxides. Therefore, the observed increase in oxidative damage in urine appeared to be more an inflammatory risk than a carcinogenic risk (lung cancer).

In a second study the role of environmental exposure to metals/metalloids and their effects on the homeostasis of essential minerals was studied. The primary endpoint of concern in the environment is developmental neurotoxicity rather than inflammatory or carcinogenic risk. The study analysed the uptake of environmental metals (lead, mercury, cadmium) and essential metals (manganese, iron, copper, zinc) and their trans-placental passage in 50 mother/child pairs, looking at the distribution of the metals in the maternal/foetal unit and the interactions between the metals.

As anticipated, it was found that the foetus has a higher level of essential metals (iron, manganese) than the maternal blood due to its increased energy and oxygen consumption. The latter requires high amounts of iron. However, a side effect of increased levels of iron is oxidative stress. Therefore, manganese levels in the foetus were also increased because manganese counteracts the iron-induced

oxidative stress. A strong association between maternal and foetal levels of lead and mercury were also found. Decreasing foetal levels of iron and manganese were found with increasing maternal levels of lead, even at very low doses. The benefits of the increased foetal iron and manganese are therefore counteracted by the presence of lead.

In summary, most of the metals go through the placenta barrier, with the exception of cadmium. The increase in iron and manganese and the decrease in copper and zinc in the foetus are supposed to be beneficial to the foetus. However, lead and mercury also go through the placenta. In particular, lead is capable to interact with essential minerals such as iron and manganese thus altering foetal oxygen and energy supply.

This study contributes to our understanding of how lead acts at the molecular level. The results may also provide an explanation for the observed lead-associated decreases of intelligence quotient (IQ) in children in previous studies. It would be interesting to follow this up in a future study.

### 10.3 Research Developments in South Africa: Toxic Lead Exposure and Impact on Health (Dr Nisha Naicker, Environment and Health Research Unit, MRC, Johannesburg, South Africa)

Lead, arsenic, mercury and cadmium are ranked among the top ten substances that pose the most significant threat to human health due to their known or suspected toxicity and their potential for human exposure.

Lead has been known to be a human toxicant for centuries, but exposure has not decreased, especially in low-income countries. Routes of exposure include prenatal, as it is mobilised during pregnancy and crosses the placenta, and postnatal by ingestion, inhalation or dermal exposure. Lead is very versatile and is used in a variety of industries and products. Regulations in South Africa have banned the use of lead in petrol and in commercial paint products, but exposure remains a threat because lead does not degrade in the environment and is strongly absorbed in the soil. Recently the WHO and other health authorities have taken steps to limit exposure to children by decreasing the levels of exposure to >5µg/dl. However, health effects continue to be observed, even at low levels of exposure.

Lead has no role in the human body and the effects of exposure to lead vary in terms of the dose, timing and duration of exposures, and the health and nutritional status of individuals. Children are particularly vulnerable between the foetal stage and two years of age, and those exposed to even low doses of lead have shown neurological effects and development of toxicity, which persist and increase in the long term. Once lead has entered the body very little is excreted. The stored lead provides a continuous supply in the body during high metabolic states. The

symptoms and signs of lead exposure are non-specific and cover a wide spectrum affecting almost every organ in the body.

The Environment and Health Research Unit of the MRC has done a variety of studies on the health effects of lead. Some of these are:

- A cross-section of surveys that started in 2002 across two cities and one smaller town soon after the total banning of lead in petrol. The insignificant decreases in blood lead levels indicated continued exposure to lead in certain pockets of the community and toxic exposure of children living in fishing communities, where melting of lead products is common practice.
- A study on lead exposure post-ingestion of Ayurvedic medicine in slightly higher-income communities found acute levels of lead exposures.
- A study on the distribution of blood lead in a lead mining community, which commenced in 1991 and followed two mining communities until 2008, showed an initial significant drop in lead exposure between 1991 and 2002 (possibly due to the banning of leaded petrol), but little change thereafter. Not enough was being done to educate the mining community about the dangers of lead exposure. In similar mining communities elsewhere in the world, education and enforcement measures taken to mitigate lead exposure had brought substantial decreases in levels and instances of lead exposure.
- A study on prenatal and adolescent blood levels in South Africa, maternal and household risk factors in the birth to twenty cohort in Soweto, Johannesburg, showed that people living in poorer socio-economic environments are much more vulnerable to high blood-lead levels.
- A study on environmental lead exposure and socio-behavioural adjustment in the early teens found a significant association between socio-behavioural problems and lead exposure, particularly in boys. This is important for the social and economic development of communities and the country. Multiple studies have been done internationally showing the associations between lead exposure in early childhood and cognitive and behavioural changes.

The MRC intended to undertake further studies addressing lead exposure in adults, which has already been found to be responsible for IQ changes into adulthood, poor performance in abstract reasoning, cognitive flexibility, verbal memory, verbal fluency and fine motor speed. Associations with dementia, loss of visual acuity, peripheral neuropathy, psychosis, depression, anxiety, aggression, as well as Alzheimer's and Parkinson's disease have also been shown.

The severity of adverse health effects of metal exposure is related to the type of heavy metal and its chemical form, and is also time and dose-dependent. Although the acute and chronic effects are known for some metals, little is known about the health impact of mixtures and combinations of toxic metals. Simultaneous exposure to multiple heavy metals may produce a toxic effect that is additive, antagonistic or synergistic. More research into genotoxic effects and carcinogenic effects of metals is necessary.

## 10.4 The Health Impacts of Mercury Use in Artisanal and Small-scale Gold Mining (ASGM) in Ghana (Dr Emmanuel Kyerematen-Amoah, Occupational and Environmental Health Unit, The Health Service, Accra, Ghana)

Mercury is recycled in the environment through natural sources and processes, and as a result of anthropogenic activities. Once it has entered the environment, mercury rotates in the air, on land and in water until it becomes entrapped in mineral compounds. Artisanal and small-scale gold mining (ASGM) is responsible for the bulk of the total anthropogenic mercury emissions into the environment.

Mercury exists in three main forms:

- Elementary mercury (the metallic form of mercury).
- Inorganic mercury (salts used in detergents and pesticides).
- Organic mercury or methylmercury (the most toxic bio-accumulative form of mercury, usually found in fish and aquatic living organisms).

In ASGM, rocks or sediments containing gold ore are extracted manually and elemental mercury is used in the processes for the purpose of separating the gold from the ore through amalgamation and smelting, which releases mercury vapour into the air. Washing of the amalgamated ore releases mercury into the soil and water, which reaches the food chain, contaminating fish in local streams. Miners are also exposed to mercury through inhalation of fumes produced by smelting the metallic ore, and through handling mercury with no protective equipment.

Exposure assessments that have been done in Ghana and some of the findings of the assessments include:

- Occupational and environmental mercury exposure among small-scale gold miners in the Talensi–Nabdam District of Ghana's Upper East region (Parachuri *et al.*, 2010)

  Occupational exposures to elemental mercury (via urine sampling) and dietary exposures to methylmercury (via hair sampling) were assessed among 120 participants recruited from the mining community. More than one-fifth of the participants had moderately high levels of urinary mercury (>10 µg/L) and 5% had urine mercury levels that exceeded the WHO guideline value of 50 µg/L. Those active in the mining industry had the highest mercury levels, specifically individuals that burned the amalgam. There was a significant positive Spearman correlation between fish consumption and hair mercury levels, although further studies are needed to document which types of fish are consumed as well as portion sizes. Given that 200 000 people in Ghana are involved in the small-scale gold mining industry and that the numbers are expected to grow in Ghana and many other regions of the world, clarifying mercury exposure pathways in such communities is important to help shape policies and behaviours and minimise health risks.

- Environmental and occupational exposures to mercury among indigenous people in Dunkwa on Offin, a small-scale gold mining area on the south-west of Ghana (Kwaansa-Ansah *et al*., 2010).

  Total mercury concentrations in human hair and urine samples were determined to ascertain the extent of environmental and occupational mercury exposure. Hair and urine samples collected from 40 miners and 54 farmers were analysed. The comparison showed that the total mercury concentrations in urine of the miners were higher than those of the farmers and that there was no significant correlation between the total mercury concentration and the average weekly fish diet. Although the results indicate elevated internal dose of mercury, the current levels of exposures do not appear to pose a significant health threat.

- An assessment of mercury pollution in rivers and streams around ASGM areas of the Birim North District of Ghana (Nartey *et al*., 2011).

  The mercury levels in the water during both rain and dry seasons exceeded the WHO guidelines level for drinking water. Samples from sediments also exceeded EPA guidelines. Water from boreholes in this area was found to have excessively high levels of mercury.

Health effects of mercury exposure are broad and exposure occurs via the central nervous system, lungs, cardiovascular system, liver, kidneys, placenta and the skin. Some of the symptoms are non-specific and may be difficult to target. Currently there are no available data on the actual effects of mercury on human health in Ghana. In February 2015, the WHO set up a pilot study in the country to train health workers on the environmental and occupational health effects of mercury among ASGM miners. The project aimed to develop a training manual for use by health workers in managing the health of ASGM miners and their communities. As a signatory to the Minamata Convention, Ghana intends to roll out several activities, including undertaking a situational analysis of the mercury burden in the country and scaling up the training of health workers on the environmental and occupational health effects of mercury use among ASGM miners.

### 10.5 Wrap-up and Closing Discussion

Q: Prof Itanna, concerning plant-based phyto-remediation of heavy metals to address contaminated soil, is there any experience of using forestry for this purpose?
R: Usually smaller plants are used for phyto-remediation for quick results. Larger plants, such as certain shrubs like willow (*Salix spp.*) are effective in the extraction of metals. Although forestry could be effective, it would not be practical for use in phyto-remediation over a short period.

Q: The speakers have mentioned that metal exposure can lead to anti-social behaviour. Would this warrant a study to be conducted to assess terrorist tendencies in individuals?
R: Dr Naicker indicated that studies done on juvenile and violent prisoners have shown that they have higher blood-lead levels. However, the association can be mitigated depending on other factors.

Q: Prof Itanna, once the metals are extracted into a biomass material, what is the subsequent fate of the plants?
R: There is awareness of avoiding recycling the metals into the ecosystem. Some suggestions to avoid the human exposure route include burning the biomass in wastelands or making chip board products from grasses used for phyto-remediation.

Q: Are there any steps being taken to prevent the mobilisation of lead during pregnancy to avoid the lead passing through to the foetus?
R: This is not being studied. This process is a natural phenomenon that occurs during pregnancy and even in early childhood. The use of substances to remove lead from the body is not recommended. Prevention from any form of exposure is the key.

Q: The discussions and presentations have focused on the environment and human health. Is there any plan to integrate the other pathways (such as agriculture) that affect human health?
R: The aspect of agriculture can be addressed in a future forum.

Q: Would increased levels of lead in pregnant women be able to be mitigated by giving the women iron and manganese supplements that reach the foetus?
R: Dr Käfferlein indicated that the women analysed in the study were not anaemic and the foetuses were healthy. Lead certainly has been shown in this study to affect manganese and iron in the foetus, but this is not necessarily an adverse effect. If the lead exposure was the only reason for the IQ deficits then it would be necessary to interfere. However, there are clearly other factors that contribute to IQ deficits. Nevertheless, prevention of lead exposure is an important factor that needs to be addressed.

Q: Are the ASGM miners made aware of the dangers of using mercury?
R: Illegal mining is one of the biggest challenges in Ghana. It is very difficult to control and regulate the use of mercury and to manage or even interact with the miners. Recently, associations have been formed and they are beginning to engage with government and the miners have been receiving training about the effects of mercury exposure. However, implementation remains a challenge.

## 11 Closure (Dr Jan Nissen, Senior Officer, International Relations, German National Academy of Sciences Leopoldina)

Dr Nissen thanked the participants for their contributions to the discussions and for sharing valuable insights into the four different topics on environment and health: UV radiation, water pollution, air pollution and metal exposure. Although there had been progress in terms of research on these topics, there was also a great need for further research to understand the challenges that were discussed.

He thanked the speakers, moderators, members of the discussion panel and the young scientists who presented their research and inspired discussions. He added that everyone who had attended the symposium had helped make it an active platform for discussion, interaction and networking.

Additionally, he thanked the scientific coordinators of the symposium, Prof Angela Mathee and Dr Caradee Wright from South Africa, Prof Tenalem Ayenew from Ethiopia, Prof Jean Krutmann from Germany and Prof Chris Gordon from Ghana (who was unable to attend the symposium) for their enthusiasm and input to the planning of the event.

Dr Nissen thanked his co-organisers from ASSAf, EAS, GAAS and the German National Academy of Sciences Leopoldina and concluded by acknowledging the financial contribution made by the Volkswagen Foundation, which had made the symposium possible.

## Appendix A: List of Symposium Participants

| Full Name | Title | Affiliation |
|---|---|---|
| Fufa Abunna Kurra | Dr | Addis Ababa University, Ethiopia |
| Tenalem Ayenew | Prof | Addis Ababa University, Ethiopia |
| Gizaw Mengistu | Dr | Addis Ababa University, Ethiopia |
| Fisseha Itanna | Prof | Addis Ababa University, Ethiopia |
| Mpho Baisitse | Mr | Africabio, South Africa |
| Llywelyn Ngongoma Ndumiso | Mr | AfricaBio, South Africa |
| Awoke Guadie Alemu | Dr | Arba Minch University, Ethiopia |
| Pamela Semiono | Ms | Ardhi University, Tanzania |
| Harold Annegarn | Prof | Cape Peninsula University of Technology, South Africa |
| Christian Selbach | Mr | Centre for Water and Environmental Research (ZWU), Germany |
| Dwayne Koot | Dr | Chemetrix/University of Pretoria, South Africa |
| Abebe Mekuriaw | Mr | Ethiopian Academy of Sciences |
| Jan Nissen | Dr | German National Academy of Sciences Leopoldina |
| Francesca Azara | Ms | German National Academy of Sciences Leopoldina |
| Emmanuel Kyerematen-Amoah | Dr | Ghana Health Service |
| Hlamulo Makelane | Dr | Human Sciences Research Council, South Africa |
| Heiko Udo Käfferlein | Dr | Institute for Prevention and Occupational Medicine, Germany |
| Jochen Türk | Dr | Institute of Energy and Environmental Technology and ZWU, Germany |
| Wilson Yetoh Fantong | Dr | Institute of Geology and Mining, Cameroon |
| Vincent Mgiba | Mr | JHP, South Africa |
| Leonard Amekudzi | Dr | Kwame Nkrumah University of Science & Technology, Ghana |
| Anke Hüls | Dr | Leibniz Research Institute for Environmental Medicine, Germany |
| Tamara Schikowski | Dr | Leibniz Research Institute for Environmental Medicine, Germany |

| | | |
|---|---|---|
| Jean Krutmann | Prof | Leibniz Research Institute for Environmental Medicine, Germany |
| Celia Nalwadda | Ms | Makerere University, Uganda |
| Caradee Wright | Dr | Medical Research Council, South Africa |
| Nisha Naicker | Dr | Medical Research Council, South Africa |
| Angela Mathee | Prof | Medical Research Council, South Africa |
| Pascoal Micolo Diogo de Campos | Mr | National Technology Centre, Angola |
| Jayne de Vos | Ms | National Metrology Institute of South Africa |
| Ozayr Patel | Mr | South Africa |
| Lourens Erasmus | Mr | North-West University, South Africa |
| Anja Franken | Dr | North-West University, South Africa |
| Solomon Olaoye Balogun | Dr | Obafemi Awolowo University, Nigeria |
| Naoual Oukkache | Dr | Pasteur Institute of Morocco |
| Petro Terblanche | Prof | Pelchem (Pty) Ltd, South Africa |
| Elkhatim Ahmed Efatih Saad | Mr | Petrodar Operating Company, Sudan |
| Najya Muhammed | Dr | Pwani University, Kenya |
| Desmond D'Sa | Mr | South Durban Community Environmental Alliance, South Africa |
| Jo Barnes | Dr | Stellenbosch University, South Africa |
| Candice Bailey | Ms | The Conversation, South Africa |
| Jacqueline McGlade | Prof | United Nations Environment Programme, Kenya |
| Célia Marília Martins | Dr | Universidade Eduardo Mondlane, Mozambique |
| Toundou Outéndé | Mr | Université de Lomé, Togo |
| Yadouleton Tadagbe Anges | Dr | Universite de Parakou, Benin |
| Thomas Schwarz | Prof | University Clinic for Dermatology, Allergology and Venereology, Germany |
| Isoken Henrietta Igbinosa | Dr | University of Benin, Nigeria |
| David Dodoo-Arhin | Dr | University of Ghana |
| Jacob Songsore | Prof | University of Ghana |
| Samuel Agyei-Mensah | Prof | University of Ghana |
| David Kimemia | Dr | University of Johannesburg, South Africa |
| Rajen Naidoo | Prof | University of KwaZulu-Natal, South Africa |

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| Susheela Devi Biranjia-Hurdoyal | Mrs | University of Mauritius |
| Anne Wairimu Muohi | Dr | University of Nairobi, Kenya |
| Okgantsheng Pule | Ms | University of Pretoria, South Africa |
| Patricia Forbes | Dr | University of Pretoria, South Africa |
| Amanda Maswanganye | Ms | University of Pretoria, South Africa |
| Priyen Pillay | Mr | University of Pretoria, South Africa |
| Dan Molefe | Mr | University of Pretoria, South Africa |
| Eyob Tesfamariam | Dr | University of Pretoria, South Africa |
| Ikenna Mbakwe | Dr | University of Pretoria, South Africa |
| Sibongiseni Mgolozeli | Mr | University of Pretoria, South Africa |
| Tafadzwa Taderera | Mrs | University of Zimbabwe |
| Roseanne Diab | Prof | Academy of Science of South Africa |
| Stanley Maphosa | Mr | Academy of Science of South Africa |
| Dorothy Ngila | Ms | Academy of Science of South Africa |
| Siyavuya Bulani | Dr | Academy of Science of South Africa |
| Phyllis Kalele | Ms | Academy of Science of South Africa |
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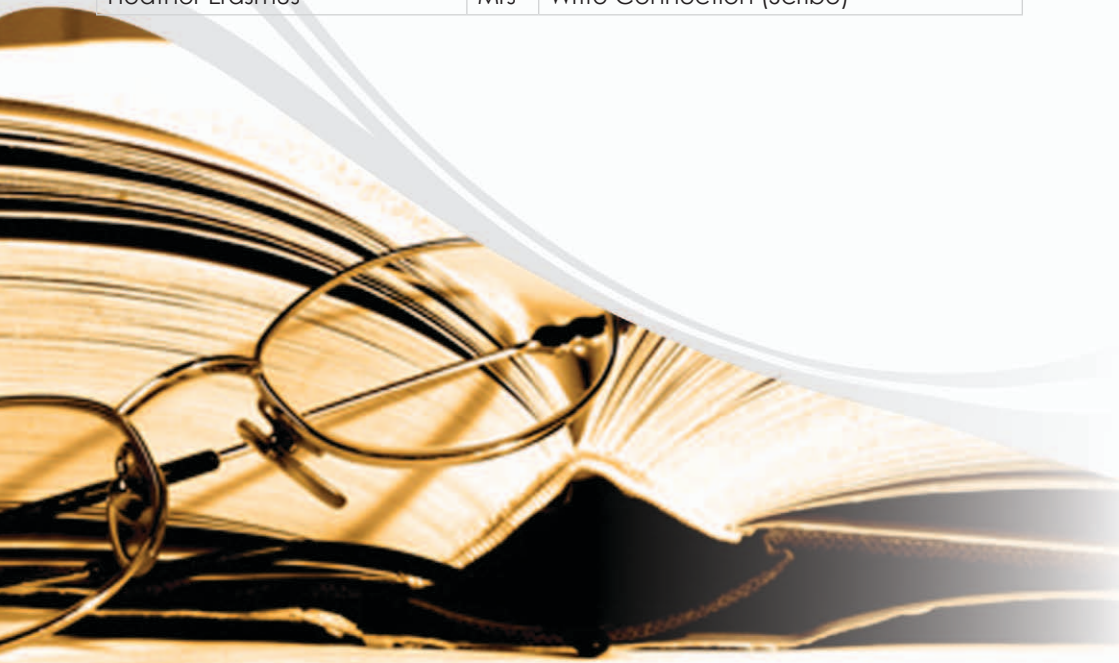

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