United Nations Environment Programme (UNEP)

African Regional Implementation Review for the 14th Session of the Commission on Sustainable Development (CSD-14)

Report on Atmosphere and Air Pollution

Prepared by United Nations Environment Programme (UNEP) on behalf of the Joint Secretariat UNECA, UNEP, UNIDO, UNDP, ADB and NEPAD Secretariat

Contents

Abbreviations

APPA	Atmospheric Pollution Prevention Act
APINA	Air Pollution Information Network for Africa
ARSCP	African Roundtable on Sustainable Consumption and Production
ARI	Acute Respiratory Infection
ALRI	Acute Lower Respiratory Infection
CFCs	Chlorofluorocarbons
CP	Cleaner Production
CSD	Commission for Sustainable Development
ESALIA	Eastern and Southern African Leather Industry Association
EST	Environmentally Sound Technology
GAW	Global Atmospheric Watch
GCOS	Global Climate Observing System
GEF	Global Environment Facility
IGBP	International Geosphere Biosphere Programme
IPCC	Intergovernmental Panel on Climate Change
JPoI	Johannesburg Plan of Implementation
LPG	Liquefied Petroleum Gas
NACA	National Association for Clean Air
NEPAD	New Partnership for African Development
NCPC	National Cleaner Production Centre
START	System for Analysis, Research and Training
SADC	Southern African Development Community
SAFARI	Southern African Fire Atmosphere Research Initiative
SME	Small and Medium Enterprises
SAPIA	South African Petroleum Industry Association
UNIDO	United Nations Industrial Development Organisation
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation
WSSD	World Summit for Sustainable Development

1. Introduction

Since UNCED, governments and other stakeholders have pursued a wide range of strategies aimed at surmounting the rapidly deteriorating environmental quality in the region. Air pollution has particularly risen high up in many countries' and sub-regional political agenda. Although the key air pollutant sources vary among countries, certain source types are predominant in certain economies and sub-regions. Generally, key sources include the industrial sector (thermal power stations, smelters, cement factories, chemical industries), transport sector, forest/savanna fires, domestic fuel use and waste burning. Resultant emissions from these sources have impacts on human health, ecosystems on which livelihoods depend, materials and infrastructure, climate change and biodiversity.

To intervene against these impacts in Africa, various interested stakeholders have pursued many activities aimed at reducing or eliminating atmospheric emission all together. No proper assessment has been carried out yet to establish the nature, scope and success of these activities. At a time when the world is preparing to mark the 14th session of the UN CSD—which will focus on, *inter alia*, the status of the atmosphere and air pollution—there is urgent need to evaluate progress achieved at all levels in implementing relevant commitments, goals and targets agreed upon in Agenda 21, the Programme for the further implementation of Agenda 21 and the Johannesburg Plan of Implementation with regard to air pollution. This is necessary to gauge the success of existing strategies and map out the way forward towards a cleaner atmosphere.

This report reviews the status of the atmosphere and air pollution in Africa since Rio as well as the impacts such pollution has had on man and the environment. It goes further to examine the range of activities implemented in response to the air pollution challenge while assessing the challenges and constraints in meeting the goals and targets. Further to that, the report synthesizes key lessons learnt and proposes the way ahead towards cleaner air in Africa.

In developing this report, attempts were made to access data from as many countries as possible. However, data on air pollution as well as activities aimed at reducing it are scanty if not missing for most countries. Where available, a lot of data is not recent or available for just a few countries. These limitations notwithstanding, the reports conclusion provide the impetus for new strategies for achieving clean air in Africa.

2. The Status of the Atmosphere and Air Pollution in Africa

2.1 Overview of Key Pollutants and their Sources

Increased activity in key social and economic sectors are contributing significantly to air pollution—which has gradually grown into a major environmental concern for African policy makers and gained prominence on the region's political agenda.[1] Unsustainable patterns of consumption and production of energy resources by industry, transport and household sectors have, in particular, been the leading sources of key indoor and outdoor air pollutants. Air

[1] See various AMCEN reports and NEPAD Action Plan for the Environment.

emissions are a growing nuisance from Africa's growing **industry**[2]. Moroccan industry, for instance, burns 1 million tons of fossil fuels each year, generating 2 millions tons of CO_2. South Africa emitted 306.3 million metric tons of carbon dioxide from coal consumption, amounting to 90.6% of Africa's energy-related carbon emissions and 3.4% of world energy-related carbon dioxide emissions (Fig. 1). Reliance on coal-based energy sources explains South Africa's proportionally larger carbon dioxide emissions in comparison with many other industrializing countries.[3] Mining and cement production in countries including Morocco, Zimbabwe, Zambia and South Africa among others are also contributing significantly to the region's air pollution mainly through dust and CO_2 from coal combustion.

Another 1.8 million tonnes of SO_2 are also emitted from electricity generation alone each year. Similarly, NO_2 and SO_2 emission levels in many African countries have also increased significantly over the past few years also attributed to the region's industrial activity.[4] In fact the average annual ambient SO_2 concentration is now approaching 20 ppb (WHO guideline) in many places in South Africa.[5]

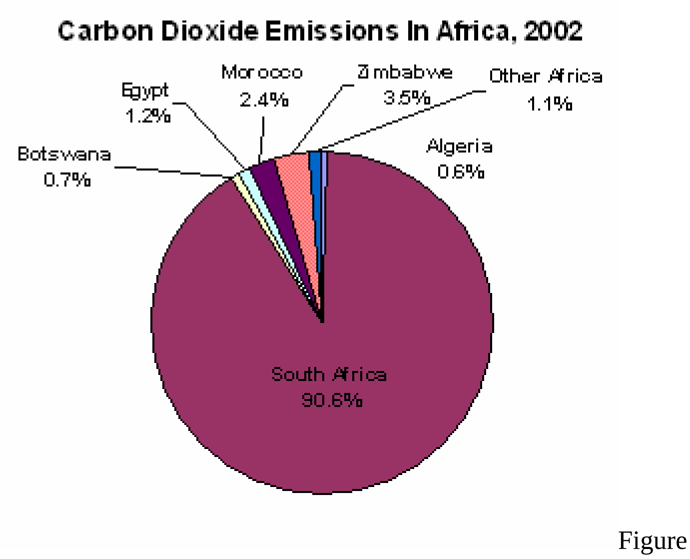

Figure 1: Key emitters of CO_2 in Africa in 2002.

Although the manufacturing sector is responsible for part of the air pollution, the **transportation** sector is increasingly being recognized as the highest polluter in key African cities such as Cairo, Nairobi, Johannesburg, Cape Town and Dakar. In 2000, Africa had 2.5% of the total world vehicle population, then 700 million.[6] There has been a doubling of motor vehicle fleets in the past 10 years in Zimbabwe and Botswana.[7] Transport systems are emitting tonnes of reactive atmospheric gases (mainly NO_x and SO_2 and volatile organic compounds) and other toxic particulate species. These pollutants are products of combustion of diesel and gasoline—the key fuels used. Although the past three years have witnessed some countries make a total transition to the use of unleaded gasoline in the transportation sectors, many other countries in the region still use leaded gasoline, which is no longer in use in over 90% of countries in the world. In East Africa, leaded gasoline contains lead in the range 0.4 – 0.8 g/l. The composition and concentration levels of any pollutant species depends on the distance traveled, fuel type, age of the vehicle, and also the composition of the fleet. The rapidly growing number of second-hand cars and poor road networks have lead to traffic congestion in most African cities with impacts on fuel wastage and air pollution. For

2 UNEP (2004) Sustainable Consumption and Production Activities in Africa: Regional Status Report (2002 – 2004)
3 http://www.eia.doe.gov/emeu/cabs/safrenv.html#AIRPOLL
4 UNEP (2004) Op Cit note 1.
5 Eskom 2004 Annual Report

7 APINA (2003) *APINA and Status of Air Pollution in Southern Africa*: Policy Dialogue Theme Paper. Maputo, Mozambique, 22 – 24 September 2003.

instance, about 50 million vehicle hours were lost in 2002 in Nairobi owing to such congestion at peak hours, which translates to about 63 million litres of fuel worth US$ 25 million.[8]

It is now clear that fires from the household energy (mainly firewood, charcoal and kerosene use) and land use sectors (including savannah, forest clearing, and agro wastes) are the most important greenhouse gas emission sources in Africa, contributing about 4% to the global overall CO_2 budget.[9] Southern African savannas and grasslands are the most important sources, constituting 86% of the total biomass burned annually, which is in the range 562 – 1736 Tg.[10] The fires occur at a frequency of 1 – 6 years and are a combination of surface fires in grass layers, and ground fires. They also involve canopies of trees which are scorched but not usually contribute to combustion.[11]

About 50% of all large biomass fires on earth occur in Africa[12] (Hao et al, 1991) where burning emissions are strongest in the dry season south of the equator between July and October.[13] Of these fires, 50% is attributed to savanna burning, 24% to shifting cultivation, 10% deforestation, 11% domestic burning and 5% agricultural waste burning.[14] The significance of these biomass sources is however, exemplified in their role in global photochemical ozone formation, to which they contribute as much as 35%.[15] The seasonal persistence of ozone on the equatorial West African coast is attributed both to the intensity and duration of biomass burning on the African continent.[16]

Miombo clearing fire in Zambia. SAFARI 2000 http://www.umt.edu/chemistry/

It is also clear that emissions from traditional cooking in Africa are significant enough to influence the tropical and subtropical atmosphere. Compared to CO_2, CO and NO_x emissions

[8] Republic of Kenya (2004) National Energy Policy, Sessional Paper No 4 of 2004.

[9] Kituyi E, Wandiga SO, Andreae MO and Helas G (2005) Biomass burning in Africa: Role in atmospheric change and opportunities for emission mitigation. In *Climate Change and Africa* (ed. Pak Sum Low) pp 79 – 89. Cambridge University Press.

[10] Van Wilgen BW and Scholes RJ (1997) The vegetation and fire regimes of southern Hemisphere Africa. In *Fire in Southern African Savannas: Ecological and Atmospheric Perspectives* (eds. Van Wilgen et al.) pp 27 – 46. Witwatersrand University Press.

[11] Ibid.

[12] Hao et al. (1991) Estimates of annual and regional releases of CO2 and other Trace gases to the atmosphere from fires in the tropics based on the FAO statistics for the period 1975 – 1980. In *Fire in the tropical Biota* (ed. JG Goldammer) Springer-Verlag, Berlin, pp440 – 462.

[13] Justice et al. (1996) Satellite remote sensing of fires during SAFARI campaign using NOAA-AVHRR data. *Journal of Geophysical Research* **101**, 23851 – 23863.

[14] Hao WM and Liu MH (1994) Spatial and temporal distribution of tropical biomass burning. *Global Biogeochemical Cycles* **8**, 495 – 503.

[15] Marufu TM (1999) Photochemistry of the African Troposphere: The influence of Biomass Burning. *PhD Thesis*, University of Utrecht.

[16] Ibid.

from wildfires, of Africa, the source strengths from cooking are approximately 30 – 40% of the extensive savanna and tropical forest fires.[17]

Over 70% of energy needs in most sub-Saharan African countries are met by biofuels, mainly in the household sector. Currently, 161,430,000 tons of oil equivalents (*toe)* of residential biomass, 575,000 ton of LPG, 1,607,000 ton of coal, 54,265 GWh of electricity and 3,784,000 ton of kerosene are consumed in Africa each year.[18] All the fuel combustion processes emit a wide range of pollutant gases and particulate matter. In addition to emitting significant levels of CH_4, CO and other products of incomplete combustion, charcoal production—to meet the ever growing charcoal demand—is a key source of particulate matter (PM). Figure 2 shows the variation of PM and CO levels along the conventional energy ladder. According to this Figure, the pollutant concentration reduces as one goes up the ladder. With the rapidly growing urban-poor populations in sub-Saharan African countries (urbanization rates of 4–8%) the demand for charcoal is also growing with similar implications for local and regional air pollution. Trace gas and particulate pollutants from charcoal production[19] and consumption[20] processes in African settings have been documented.

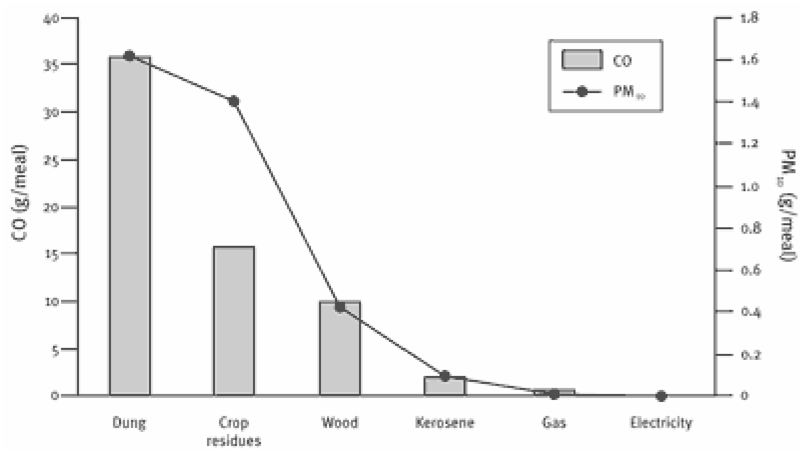

Figure 2. Fuel emissions along the energy ladder

Other recently recognized air pollutants in most urban areas of Africa are the Unintentional Persistent Organic Pollutants (U-POPs). They are chemical toxins defined by the Stockholm Convention as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). They resist photolytic, chemical and biological degradation and pose significant risks for human and animal health as well as ecosystems. Basically, they are unintentionally formed and released as byproducts from thermal processes involving organic matter and chlorine reactions (mainly medical waste incineration and municipal waste burning). Recent inventory studies in Kenya[21] have revealed significant levels of these substances with potentially high

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17 Ibid.

18 International Energy Agency (2003) Energy Statistics of Non-OECD countries2000 – 2001. Paris, OECD.

19 Lacaux JP, Brocard D, Lacaux C, Delmas R, Brou A, Yobue V, and Koffi M (1994) Traditional charcoal making: an important source of atmospheric pollution in the African tropics. *Atmospheric Environment* **35**, 71-76.

20 Kituyi E. N. (2000) Trace Gas Emission Budgets from Domestic Biomass Burning in Kenya. *PhD Thesis*, University of Nairobi.

21 MENR/UNEP (2005) Kenya National Inventory of Persistent Organic Pollutants under the Stockholm Convention. Final Report, March. Ministry of Environment and Natural Resources/UNEP. 148p.

toxicities to man. Waste **incineration** and uncontrolled combustion processes (such as grassland fires) are by far the most important sources, releasing over 9600g toxic equivalents per annum into the air. This represents 85% of the total national inventory.

Other numerous but small contributors of important trace gas emissions to the atmosphere abound on the continent. For instance, dust has been reported recently as an important pollutant in Sahelian countries. Wind-blown dusts from mine dumps are also a significant pollutant in Soweto, Johannesburg and other places near the mining industry in southern African countries. Other sources include biogenic processes and lightning. Overall, a total of 1724 Tg of CO_2 was emitted annually in 1999 from all major sources on the African continent. Emissions of other trace gas species included 414 Tg/yr of CO, 67 Tg/yr of CH4, 455 Tg/yr of non-methane hydrocarbons and 15 Tg/yr of NO_x. Table 1 gives the breakdown of the contributions by source to each of these totals.

Table 1. African trace gas emissions by source (Tg/yr)

	CO_2	CO	CH_4	NMHC	NO_x
Biofuel	670	60	3	5	1
Bushfires[1]	577	295	20	44	6
Industry[2]	477	15[22]	9	17	2
Biogenic[3]		44	36	389	4
Lightning					3
TOTAL	1724	414	67	455	15

[1]Includes savanna fires, agricultural waste burning, and deforestation fires
[2]Includes fossil fuel burning and industrial process emissions
[3]Includes soil and vegetation emissions.
Source: Marufu TM (1999)[23]

2.2 Impact of Air Pollution on Human Health and Physical Environment

Respiratory Infections

According to WHO,[24] smoke from burning solid fuels is estimated to be responsible for 1.6 million deaths each year in the world's poorest countries. Acute respiratory infections (ARI) ranked fourth in the share of the burden of diseases in sub-Saharan Africa (accounting for 7% of the total).[25] Lack of reliable data in most African countries makes it impossible to quantify the impact of indoor air pollution on the continent as a whole. However, some recent country studies lend credence to just how serious the situation is in sub-Saharan Africa. Respirable suspended particles in a house measured over 24 hours have been found to range between 1000μg/m^3 and

[22] Recent studies suggest that this figure, documented for 1999, may be much lower than the actual figure. It is estimated that Eskom alone emits 30Tg of carbon dioxide annually in 2004.
[23] Marufu TM (1999) Photochemistry of the African Troposphere: The influence of Biomass Burning. *PhD Thesis*, University of Utrecht.
[24] ARI http://www.who.int/fch/depts/cah/resp_infections/en/print.html
[25] World Health Report 1999, World Health Organisation.

9000 μg/m^3 with peaks reaching 21,000 μg/m^3.[26] This range is far higher than the 100 μg/m^3 to 150 μg/m^3 range recommended by the WHO, and the 260 μg/m^3 limit recommended by the US Environmental Protection Agency.

Moreover, prevalence of ARI and conjunctivitis among children aged below five years and women aged between 15 to 60 years in households with traditional 3-stone stove is significantly higher than that in households with improved stoves.[27] However, Evidence on the ability of improved stoves to reduce indoor air pollution is contentious. It has been reported that such stoves can actually increase indoor emissions. Smoke is a result of incomplete combustion which occurs due to insufficient oxygen. Improved stoves save fuel by controlling the burning rate and hence the air flow. The effectiveness of improved stoves depends on maintenance, and therefore on age or hours of usage. ARI and Acute Lower Respiratory Infection (ALRI) are also increasing concave functions of average daily exposure to PM_{10} with the rate of increase declining for exposures above the 1000–2000 μg/m^3 range[28]. Carbon monoxide, for example, can cause acute and chronic effect on humans at various concentrations which may be manifested as headache, dizziness, vision and hearing impairment, asphyxia, cerebral congestion, edema and death. The particulates in wood smoke are of considerable concern. They are small, mostly less than 5 microns in diameter, which means they are in the respirable size range and readily penetrate into the lungs.

Well over one hundred chemical compounds have also been identified in wood smoke, many of which are priority pollutants, carcinogens or respiratory irritants.[29] SO_2 levels exceeding 1000 ug/m^3 affects people 15 km downwind of a major smelter in *Selebi Phikwe,* a residential area in Botswana, this being well above the WHO guideline of 350 ug/m^3. Some of the effects of exposure to SO_2 include irritation, reduced lung function, impaired vision and increased respiratory diseases.[30]

Radiative Forcing of Climate Change

Increasing concentrations of a number of trace gases in the atmosphere (mainly CO_2, CH_4, N_2O, O_3 and CFCs) have been known to cause an increase in global temperature through the greenhouse gas (see IPCC reports). The contributions by CO_2 to overall warming effect would ultimately depend on whether the region is a net sink or emitter of the gas. To establish this remains a key policy challenge since requisite reliable GHG emission data for most countries and sectors are not readily available. It is worth noting, however, that the total impact on global warming by African households, industry, agriculture and other land use activities have been found to be less than 3% of the global total.

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[26] Wafula, EM, et al. (2000) Effect of Improved Stoves on Prevalence of Acute Respiratory Infection and Conjuctivitis Among Women and children in a Rural community in Kenya. *East African Medical Journal*, **77,** 37-41.
[27] Ibid
[28] Kammen, D.M. and Ezzati, M. (2001) Acute respiratory infection and indoor air pollution from biomass combustion in Kenya: an exposure-response study. *The Lancet* **358**, 619–624 (August 25 issue).
[29] Todd, JJ (1990) Particulates and Carbon Monoxide Emissions for Small Scale Fuelwood Combustion. In: *Energy and Environment in the 1990s*. Vol.3 England: Pergamon Press.
[30] APINA (2003) Op Cit note 5.

The contribution of household energy use to the regional and global climate change has been elucidated.[31,32] Figure 3 shows the global warming impact for different household energy technologies. The figure stands to demonstrate the critical contribution charcoal production and consumption makes to the global warming effect whether all biomass burning-related CO_2 is sequestered by regenerating plants or not. Consumption of 2.5 million tons of charcoal in 2000 in Kenya may have contributed to a net Global Warming Impact of 2.4 million tons of carbon in 20 year CO_2 equivalent units with 100% regeneration of trees or 5.1 million with out any regeneration.[33]

Dust and other aerosols have been known to cause local and regional cooling effects. Recent studies in the Sahel and southern Sahara indicate that the presence of atmospheric dust over these regions is generally associated with cooling in the first 1.5 km of the atmosphere. Cooling at these levels is likely to be caused by the presence of a dust layer above 1.5 km, reducing incoming solar radiation and causing surface cooling and reduced outgoing longwave radiation.[34].

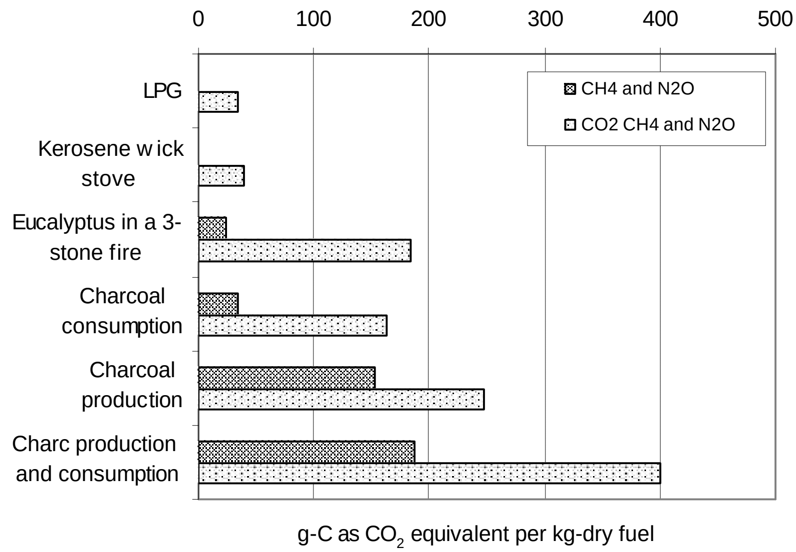

Figure 3: Global warming impact for different household energy options

Acidification

Sulphur dioxide (SO_2) and Nitrogen Oxides (NO_x) are the primary causes of acid rain. It occurs when these gases react in the atmosphere with water, oxygen and other chemicals to form various acidic compounds. Sunlight increases the rate of most of these reactions. The result is a mild solution of sulphuric and nitric acids. These acids fall out of the atmosphere by wet (acidic rain or fog) or dry (acidic gases or particles) deposition. Prevailing winds may blow the compounds causing both wet and dry deposition over hundreds of kilometres.

When sulphurous, sulphuric and nitric acid in polluted air react with the calcite in marble and limestone, the calcite dissolves. Many exposed buildings and states in African cities suffer

[31] Bailis, R, Ezzati, M and Kammen DM (2005) The role of technology management in the dynamics of greenhouse gas emissions from household energy use in sub-Saharan Africa. *Journal of Environment and Development* **14**, 149 – 174.
[32] Bond T, Venkataraman C and Masera O (2004) Global atmospheric impacts of residential fuels. **Energy for Sustainable Development**, Vol.3 No.3, September.
[33] Bailis et al. (2005) Op cit note 7.
[34] Brooks N (1999) Dust-climate interactions in the Sahel-Sahara zone of northern Africa, with particular reference to late twentieth century Sahelian drought. *PhD Thesis*, University of East Anglia. http://www.cru.uea.ac.uk/~e118/thesis/chap7.pdf

roughened surfaces, removal of material and loss of curved detail. Automotive coatings are damaged by all forms of acid rain including dry deposition, especially when dry deposition is mixed with dew or rain. The damage caused is permanent, the only solution being to repaint.

Within 40 km of the *Mufulira* Smelter in Zambia, vegetation sensitive to SO_2 aren't common, whereas the same are abundant far away from the plume.[35] Acid rain does not usually kill trees directly. Instead, it is more likely to weaken trees by damaging their leaves, limiting the nutrients available to them, or exposing them to toxic substances slowly released from the soil. Quite often, injury or death of vegetation are the key effects of acid rain in combination with other additional threats. Trees can be damaged by acid rain even if the soil is well buffered. Forests in high mountain regions e.g. Kilimanjaro often are exposed to greater amounts of acid than other forests because they tend to be surrounded by acidic clouds and fog that are more acidic than rainfall.

SO_2 and NO_x interact in the atmosphere to form fine sulphate and nitrate particles that can be transported long distances by winds and inhaled deep into people's lungs. Many scientific studies link elevated levels of these fine particles to increased illnesses and premature death from heart and lung disorders such as asthma and bronchitis.

Tropospheric Ozone Formation (photochemical Smog)

A model estimate of tropospheric ozone over Africa (in the region below 100 hPa) in 1999 gave 26.3 Tg of which 15.5% was attributed to biomass burning.[36] There is a sharp increase of O_3 with altitude in the tropics, hence the high risk of vegetation damage in high mountainous regions. Available data shows that ambient concentrations of ozone are causing both visible injury and economic damage to crops, forests and natural ecosystems.[37] It is also clear that injurious effects of ozone on vegetation frequently occur as a result of cumulative exposures over many days, weeks and months rather than during a few hours of peak ozone days.[38] Ozone concentrations in the Southern Africa Development Community (SADC) region are currently comparable to levels that caused crop yield reductions in Europe.[39] Ozone actually kills plants by inhibiting their ability to open the microscopic pores on their leaves and breathe.[40] Ozone actually inhibits stomatal opening by directly affecting the 'guard cells' that control the opening process.

Ozone pollution originating in urban areas can extend into surrounding rural and forested areas that are hundreds of kilometers downwind. Episodes of elevated ozone concentrations are associated with warm, slow moving high pressure systems and contain between 30 and 50 parts per billion by volume. When it is close to the planet's surface, in the air we breathe, ozone is a harmful pollutant that causes damage to lung tissue and plants, and is considered to be "bad ozone." It is a powerful photochemical oxidant that damages rubber, plastic, and all plant and animal life. It also reacts with hydrocarbons from automobile exhaust and evaporated gasoline to

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[35] APINA (2003) Op Cit note 5.
[36] Marufu (1999) Op Cit note X
[37] Heck WW, Furiness CS, Cowling EB and Sims CK (1998) Effects of ozone on crops, forest and natural ecosystem: assessment of research needs. In *EM: Magazine for Environmental Managers*, pp 11 – 22. Pittsburg, PA. AWMA.
[38] Ibid.
[39] APINA (2003) Op Cit note 5.
[40] Roach J (1999) Ozone Inhibits Plants' Ability to Breathe http://healthandenergy.com/ozone_damages_plants.htm

form secondary organic pollutants such as aldehydes and ketones. The peroxyacyl nitrates are especially damaging photochemical oxidants that are very irritating to the eyes and throat.[41]

Ozone impacts on human health include a number of morbidity and mortality risks associated with lung inflammation. Other respiratory ailments including asthma, emphysema, and bronchitis represent the primary health problems associated with human exposure to ground level ozone. Children are especially susceptible to ozone related illnesses because on average they spend more time outdoors than adults and their airways are narrower than adults.

Impacts of Lead Intake

It is has previously been established that leaded gasoline combustion contributes significantly to pollution in urban areas more so areas that have high traffic densities.[42] As a result, the vegetables that are farmed in urban and peri-urban sites are exposed to fine particulate lead matter that are transported by wind to their surfaces. While lead can be taken up by some crops, roots usually contain more lead than stems, leaves and fruits. However, surface contamination by lead in air and soil is considered a greater problem. Again, since lead does not dissipate, biodegrade or decay, lead pollution deposited into soil and dust remains a potential source of lead exposure.[43] Crops grown close to heavily trafficked roads or industrial sources can therefore accumulate atmospheric lead deposits on stems and foliage.

Table 2. Traffic-related lead concentration levels

Country	Air (µg/m³)	Soil (µg/g)	Food (µg/g	Water (µg/l)	Blood (µg/dl)
South Africa	0.36-2.1 (0.76)	76.7-80			3.8-12 (9.7)
Nigeria	0.5-45		0.01-1.6 (0.1)	0.9-9.8 (4.05)	8.7-60 (30.1)
Kenya	0.4-1.3	26.73-4000 (105)	0.45-85.5 (10.15)	0.11-19.1 (5.65)	
Egypt	0.6-4.9 (1.9)				11-36 (19)
Uganda		2.5-703 (25.5)			
Senegal					6.1-10.67 (8.4)
Zambia	0.15	16-10000[44] (1830)	0.4-66		

[a]Figures in the parentheses are median concentrations.
[b]The reported values are from available literature published in the period 1982-2005.

Since most of these vegetables are consumed by the urban dwellers, there exists a great risk of exposure to lead via their consumption. Studies of gastrointestinal absorption indicate 10-15% of dietary lead is absorbed though this can rise up to 63% in fasting conditions[45] or in poor diet patterns as exhibited by the lower economic class population. There is therefore cause for concern on the levels of lead exposure through dietary patterns in the various socioeconomic as well as age classes. Children below age 6 are more susceptible to health deficiencies caused by elevated levels of lead exposure. Some of the reported health deficiencies include, *inter alia*,

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41 http://greennature.com/article35.html
42 *Sources of lead in the environment* from http://www.epa.nsw.gov.au/leadsafe
43 *Pathways of exposure to lead* from http://www.epa.nsw.gov.au/leadsafe
44 In Zambia, values of soil lead as high as 240 near a mining have been reported
45 *How lead gets into people* from http://www.epa.nsw.gov.au/leadsafe

delayed puberty in girls, abnormal deliveries in women, low sperm count in men, lowered IQ, reading and learning disabilities in children, impaired hearing, reduced attention span and hyperactivity in children[46], all of which are effects of exposure to lead.

3.0 Progress in Implementing Sustainability Goals and Targets

3.1 Challenge of Protecting the Atmosphere

As recognized by Chapter 9 of Agenda 21 and various sections of the JPoI, protection of the atmosphere is a broad and multi-dimensional endeavour involving various sectors of economic activity. The main programme areas proposed to intervene are predicated on the fact that (a) there is need for better understanding and prediction of the various properties of the atmosphere and of the affected ecosystems as well as health impacts and their interactions with socio-economic factors (b) the need to control atmospheric emissions should increasingly be based on efficiency in energy production, transmission, distribution and consumption and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy. This would also include the removal of barriers to accessing environmentally sound energy systems (c) pursuing sustainable production and consumption practices in industry and transportation sectors (d) appropriate land-use and resource policies (e) compliance with control measures identified within the Montreal Protocol, and (f) the need for cooperative programmes for systematic observation of air pollution, assessment and exchange of information. The Air Pollution Information Network for Africa (APINA) identifies gaps in knowledge as: lack of reliable emissions inventory; lack of experience in the use of atmospheric transfer models; and lack of data on measured impacts.[47] The African Fire Management Network was founded under the auspices of the Global Fire Monitoring Centre to help contain fires and hence contribute to reduction of air pollution[48].

3.2 Activities and Means of Implementation

Since UNCED in 1992, governments, civil society groups and industry have been engaged in the search and implementation of activities aimed at minimizing air pollution. Table 2 shows the means of implementation[49] for some of the successful activities in Africa versus the major groups[50] involved. Concern about climate change and climate variability, air pollution and ozone depletion has created new demands for scientific, economic and social information to reduce uncertainties in these fields. A number of research activities have been implemented since Rio aimed at improving the understanding of processes that influence or are influenced by the Earth's atmosphere on a global, regional or even local scale. For instance, high-level atmosphere-terrestrial ecosystem campaigns have been carried out in Africa since 1992 by international teams of scientists hosted by African institutions.

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[46] *Pure Poison* by *Parselelo Kantai* pg 27 in Ecoforum, Volume 26 Number 4
[47] APINA (2003) Op Cit note 5.
[48] http://www.fire.uni-freburg.de/globalnetworks/africa/afrifirenet.html
[49] As outlined in Section 4 of Agenda 21.
[50] Defined in Section 3 of Agenda 21.

Research: Atmosphere-Terrestrial Ecosystem

The project Southern African Fire Atmosphere Research Initiative, which commenced in 1992 (SAFARI-92) was a preliminary study with a large impetus from outside Africa to study biomass burning in Africa and its effects on tropospheric ozone levels.[51] After SAFARI-92, the scientists involved were left with a lot of unanswered questions such as "*How might changes in atmospheric aerosols and trace gas concentrations affect the regional climate, biogeochemistry and land use of southern Africa?"* This motivated the SAFARI 2000 whose targets included smoke and gases released into the atmosphere by industry, biological sources and the burning of African forests and savannas. The international body of scientists elucidated how these emissions affected phenomena ranging from regional crop productivity to global climate change.

[51] http://safari.gecp.virginia.edu/

Table 3. Some activities and means of implementation

	Financial resources & mechanisms	EST Capacity building and Cooperation	Science for sustainable development	Education, public awareness & training	International Cooperation for capacity building	International institutional arrangements	Information for decision making
NGOs	GEF-SGP	HERITAGE ITDG RETAP					
	GTZ/GoK	KENGO					
	Dutch Govt			UNEP PCFV ELCI, NEMA			
	DFID	ITDG-Smoke					
	World Bank			AFRICACLEAN			
	Sida/World Bank				APINA		APINA
Industry	GEF	KAM Industrial energy efficiency					
	Oil companies	Retailing unleaded and low sulphur fuels					
	World Bank						Clean Air Initiative
	Power and fuel companies					GRI	Monitoring and reporting
	Multi & bilateral, UNDP	NCPCs		NCPCs			NCPCs UNIDO
Scientific institutions	Various multi and bilateral donors		IGBP Projects SAVANA 92 SAVANA 2000		START NASA, NCAR, MPI		Pb studies Biomass emission Dust in Sahel
Intergovernmental institutions	Multi/bilateral					AMCEN initiative NEPAD EAP	
UN Bodies	WMO						GAW Mt Kenya station

The study region for SAFARI 2000 includes Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe. An accessible data repository has been created at the University of the Witwatersrand for use by regional scientists studying global climate change and natural resource management, as well as governments of the countries of southern Africa as they make policies to manage natural resources. Related studies in West Africa in the mid 90s were those under FOS/DECAFE. The International Geosphere Biosphere Programme (IGBP) also supported many other regional and global scale studies focusing on emissions from Africa, through its International Global Atmospheric Chemistry (IGAC) core project. At least eight African scientists received their doctorate degrees through working on these projects.

International Cooperation for Capacity Building

Another important international project that has benefited Africa is the System for Analysis, Research and Training (START), which establishes and fosters regional networks of collaborating scientists and institutions in developing countries. These networks conduct research on regional aspects of environmental change, assess impacts and vulnerabilities to such changes, and provide information to policy-makers. START activities implemented to build capacity and enhance international cooperation have include several visiting scientist and postdoctoral fellowships by African scientists in leading atmospheric research institutions in the West such as NASA, National Centre for Atmospheric Research, Colorado, US, and various Max Planck Institutes in Germany.

Similarly, START, through funding from the United States Climate Change Science Project (Global Change Research Program), runs a programs that supports global change research in Africa. Proposals are solicited on an annual basis from scientists based at African institutions for research projects related to: climate variability and climate change in Africa; impacts, adaptation and vulnerability to global change; land use and ecosystem change; bio-geochemical fluxes, and biodiversity. Proposals are usually required to fall within the research frameworks of START's sponsoring programs which also encourages international collaboration. Several projects are being implemented through this programme.

Tool Development and Assessments

In October 1999 a Global Atmosphere Watch (GAW)[52] station for the sub-Saharan Africa region was inaugurated near Mt Kenya as one of the six WMO GAW stations supported by the Global Environment Facility (GEF). GAW provides measurements for long-term accounting of greenhouse gases and aerosols and the complex atmospheric chemical reactions which determine the depletion, transformation, lifetimes and transport of these gases and particles that contribute to climate change. Observations provided by GAW have served as scientific basis for the assessment of environmental degradation, which contributed to stimulating the convening of the UN Conference on Environment and Development UNCED in Brazil in 1992 and the adoption of a number of international conventions. These include the UN Framework Convention on Climate Change (UNFCCC) and subsequent Kyoto Protocol, the UN Convention to Combat Desertification (UNCCD) and the UN Convention on Biological Diversity (UNCBD). GAW is

[52] http://www.wmo.ch/web/arep/gaw/gaw_home.html

considered the atmospheric chemistry component of the Global Climate Observing System (GCOS).

GAW will contribute to the detection and interpretation of future changes in the chemical composition of the tropical area within and outside the continent of Africa. As one of the GAW stations closest to the equator straddling the two hemispheres, the Mount Kenya station is expected to make a significant contribution to GAW's system, which also determines global and regional levels and long-term trends of natural and man-made atmospheric constituents and forecasts future state of, and stresses on, the environment. APINA is developing air pollutant, atmospheric transfer, monitoring and abatement strategies. It is also building a regional emission inventory. Some of the tools developed so far for information dissemination include newsletters and website for APINA.

There have been some concerted efforts to develop methodologies and generate baseline data for various atmospheric pollutants and greenhouse gases. Some of these include the quantification of biomass activity (production consumption rates and patterns). Emission factors for atmospheric pollutants and GHGs for key household fuels have also been determined in some countries including Zimbabwe,[53] Kenya,[54] Cote d'Ivoire.[55] As a result of these, trace gas inventories have been developed for use in determining national and regional emission budgets. Countries have also benefited from such inventories in the development of National Communications to the UNFCCC. These Communications comprise, *inter alia*, a national greenhouse gas inventory and have largely been made possible through climate change enabling activities—GEF-funded grants that assist non-Annex I Parties in preparing these National Communications in order to meet their commitments to the UNFCCC.

Promotion of Environmentally Sound Energy Technologies

In the household energy sector, efforts since the late 1980s promoted the dissemination of improved cookstoves, mainly Kenya Ceramic Jiko (KCJ) for charcoal and Maendeleo for fuelwood in Kenya. The KCJ dissemination is a major success story today as over 60% of urban charcoal users in Kenya use this stove. Improved charcoal kilns such as the *Casamance* in Senegal and *Kakuzi* in Kenya have higher efficiency—over 35%--but have been disseminated much less in their respective countries. Sudan and Namibia are other countries where efficient charcoal production takes place for commercial purposes. A number of other activities have been implemented mainly by NGOs aimed at reducing exposure to indoor air pollution in many parts of Africa.

In addition to adopting improved woodfuel stoves, there has been increased diversification of fuels/cooker combinations to include more modern fuels e.g. kerosene and LPG and renewable energy technologies in household fuel mixes. Others have involved improving household ventilation by introducing more windows and installing smoke hoods above fire places. Other simpler approaches have involved training households on good fireplace management practices e.g. use of pot lids and drying of fuelwood, and putting off with water any unburned pieces of

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[53] Marufu et al
[54] Kituyi et al
[55] Brocard et al

wood.[56] The Sunstove Organisation in South Africa has since 1992 manufactured and promoted the Sunstove—a unique solar cooker. It is a thermally efficient solar cooker. The solar cooker has proved be to be acceptable to the most important target group of users—the rural and peri-urban poor. Of the latest 2 models, about 8 000 had been sold by mid 2004. Current sales among the target South African communities average about 200 per month.[57]

A hood over a fireplace

Launched in October 2001, the GEF-funded Industrial Energy Efficiency project implemented by the Kenya Association of Manufacturers (KAM) focused on the removal of barriers to energy efficiency and conservation in industry, mainly SMEs. The project accomplished this through working with industry to develop and implement widespread energy efficiency measures and energy conservation practices through training, awareness raising, capacity building, energy audits, demonstration projects and development of new financial mechanisms. After two years of implementing the project, a local textile enterprise has its annual electricity bill reduced by 14% and that of fuel oil lowered by 30%. Similarly in the SME sector, HERITAGE, a local Zimbabwean NGO with funding from GEF and in collaboration with other stakeholders, trained SMEs and informal sector enterprises to utilise energy in an efficient and environment friendly manner. Implemented between 2001 – 2003, the project reduced energy usage per unit of service ranging from 10 – 30% of current consumption patterns, and at least one person trained in energy efficiency management per enterprise. They leant that energy consumption can be controlled, benefiting production processes and profits, and reducing occupational pollution levels.[58] A similar energy efficiency initiative had also been implemented in Cote de Ívoire though it is currently difficult to identify the status and impacts.

In the institutional sector, another GEF-funded initiative in Kenya implemented by a local NGO, RETAP, aimed at eliminating barriers to accessing energy efficient institutional stoves and promote sustainable fuelwood production through woodlot establishment. The financial barrier was eliminated through establishment of a revolving micro-finance scheme through which boarding schools in Kenya are being assisted to purchase improved institutional woodstoves. This project is being upgraded

The petroleum industry in some countries in Africa has played a major role in fighting automobile-based air pollution, mainly by introducing unleaded gasoline to fully or partially eliminate leaded gasoline from the local markets. Low sulphur diesel was also introduced on the market. The leaded gasoline phase-out process received a major boost in 2001 when African governments signed to the Dakar Declaration committing to the total phase-out of the leaded fuel from their respective countries by December 2005. The WSSD also emphasized the need to urgently phase-out leaded gasoline from developing countries, a recommendation that led UNEP

56 ITDG Smoke and Health Programme www.itdg.org/?id=smoke_report_3
57 http://www.up.ac.za/academic/phys/sunstove/
58 GEF (2003) Responding to Climate Change, Generating Community Benefits. A Review of Community Initiatives Supported by the Global Environment Facility's Small Grants Project 1992 – 2003.

to establish the Partnership for Clean Fuels and Vehicles[59] to promote the process through information dissemination and awareness raising through lobbying governments and business. African Ministers of Environment also fully endorse the need for mechanisms to phase out leaded gasoline.[60] Significant progress has been made so far, towards implementing commitments to the Dakar Declaration. Many countries such as Rwanda, Ghana and Ethiopia have totally switched to unleaded gasoline while others such as Kenya have only made partial transition.[61] South Africa will also switch from 3000 ppm sulphur in diesel to 500 ppm in 2006.[62] This initiative is government driven, in addition to pressure from the automobile industry. South Africa's power utility, Eskom, retrofitted modern particulate removal technology to many of its power stations between 1998 and 2003—which, though not clean technology, have significantly reduced pollution levels with significant attendant health benefits.[63] Other important initiatives in Africa that have contributed through information for policymakers and public awareness raising include AFRICACLEAN,[64] a regional network of African urban air pollution experts, and the World Bank's Clean Air Initiative.[65]

Box 1. The Clean Air Initiative Sub-Saharan Africa

The Clean Air Initiative in Sub-Saharan Africa was launched in 1998 as a response to an increase in air quality problems in the region. Urban air pollution tends to increase with the rate of urbanization. This type of pollution is largely due to vehicle emissions. By providing access to business and public facilities, urban transport plays a critical role in the development of urban areas and overall economic growth but it also generates a number of externalities in terms of accidents, noise, traffic congestion, and air pollution. The latter is becoming a major environmental and health concern in Sub-Saharan Africa.

The five specific objectives of the Clean Air Initiative are to:

- Raise awareness of the dangers of urban air pollution, and its relation to vehicle and fuel choices, on the part of stakeholders involved in the urban transport sector, including those segments of the population at highest risk (children and their mothers, street vendors, and pedestrian commuters);
- Measure baseline vehicle emissions, air quality, pollution exposure, and pollution effects;
- Identify the most cost-effective measures targeting changes in vehicles, fuels, and traffic management;
- Design, implement, and monitor the impacts of Air Quality Action Plans to reduce pollution, including clear, measurable, and enforceable goals for reducing pollutants; and
- Strengthen local expertise on air pollution and vehicle and fuel performance.

http://www.cleanairnet.org/ssa

59 http://www.unep.org/pcfv/main/main.htm
60 The AMCEN Initiative http://www.unep.org/pcfv/Documents/AMCEN-Decision6.pdf
61 http://www.unep.org/PCFV/documents/MatrixAfricaLead.pdf
62 South African Petroleum Industry Association (http://www.sapia.co.za)
63 Eskom 2004 Annual Report
64 AFRICACLEAN information may be found at www.africaclean.sn/
65 Clean Air Initiative of the World Bank http://www.cleanairnet.org/ssa/1414/article-33950.html

In 1997, the APC—the Moroccan cement industry association bringing together 9 factories—and the Moroccan environment Ministry signed a voluntary convention regulating the cement sector's environmental and quality upgrading. A comparative study (for the years 1997 and 2003) has been performed to assess the environmental performance of the sector before and after the upgrading. The environmental degradation caused by cement production has considerably been reduced thanks to technical and managerial improvements undertaken since 1997. In 1997, costs of damages and inefficiencies were estimated at 12.7% of the sector's Value Added (VA) and 4.7% in 2003.[66]

Sustainable Consumption and Production in Industry

Promotion of sustainable production and consumption activities in African SMEs over the past decade has led to improvements in air quality, although in small magnitude. Much of the success is attributed to the application of Cleaner Production (CP) concept in manufacturing processes in SMEs in various countries where National Cleaner Production Centres (NCPCs) exist. These centres are a project of UNEP and UNIDO and are supported by UNDP or bilateral donors in some cases. Despite the many barriers, NCPCs achieved a reasonable level of success in implementing their mandates in their respective countries between 2002 – 2004. Their efforts concentrated on CP and manufacturing processes with little focus on products and services. The leather industry has particularly benefited from CP. In 1995, UNIDO established the Eastern and Southern Africa Leather Industries Association (ESALIA), located in Nairobi, Kenya, which was designed to channel assistance and feedback and to coordinate all field activities.[67] A sharply focused regional project financed by the Government of Switzerland was launched in 1997 and was aimed primarily at reducing the amounts of major tannery pollutants such as chromium salts, sulphides, and nitrogen compounds. It undertook the introduction of five cleaner technologies at 11 tanneries in Ethiopia, Kenya, Malawi, Namibia, the Sudan, Uganda, Zambia and Zimbabwe with significant success in air pollution reduction.

Future efforts should cover more sectors, include more stakeholders and focus on context relevance, and should aim at scaling up the documented success stories as well as expanding scope to cover sustainable consumption (SC). Numerous opportunities exist to enable the various stakeholders achieve this, while concurrently contributing towards the implementation of country obligations to regional and international agreements and development processes.

Similarly, the first African Expert Meeting on the 10 Year Framework of Programmes on Sustainable Consumption and Production was held in Casablanca, Morocco, in May 2004 with a view to launching the continent's formal contribution to the Marrakech Process. This process is response to Johannesburg's call for more holistic approaches to addressing production and consumption systems and challenges simultaneously. The Casablanca forum also institutionalized the African Roundtable on Sustainable Consumption and Production (ARSCP)[68] whose overall objective is to facilitate the development of national and regional capacities for sustainable consumption and production and promote the effective implementation of the concepts and tools of sustainable consumption and production in African countries. The second

[66] Morocco Cleaner Production Centre.
[67] http://www.unido.org/doc/4580
[68] See http://www.arscp.org

African Expert Meeting on the 10 Year Framework of Programmes on Sustainable Consumption and Production was held in Nairobi, Kenya in February 2005. This special forum served to propose the African 10 Year Framework Programme[69] on Sustainable Consumption and Production and to lay the strategy for its implementation.

Review of National Policies and Legislation

Though most cities and townships have high levels of air pollution, most countries in Africa have long lacked legally binding air pollution regulations on a national level. Yet others have only non-binding guidelines and no enforcement authority. However, significant progress has been made by some governments in response. For instance in April 2003, the South African government proposed draft legislation for new ambient air quality standards for industries. The National Air Quality Management Bill, which replaced the outdated 1965 Atmospheric Pollution Prevention Act (APPA), aims to control air pollution, emission of greenhouse gases, and ozone-depleting pollutants by setting permissible concentrations of several polluting substances as well as total emissions levels.

Towards implementation of regional agreements (such as the Dakar Declaration on the phase out of leaded gasoline and the Maputo Declaration on the prevention and control of regional air pollution in southern Africa and its likely Transboundary effects), countries are currently amending existing or making new laws and implementation mechanism to lessen environmental damage and pollution. The use of leaded gasoline will end in 2006, and all motor fuels (diesel and gasoline) will be required to contain less than 500 parts per million (ppm) of sulfur by that time. Motor fuel sulfur content will further be reduced to 50 ppm by 2010. The South African Petroleum Industry Association (SAPIA) estimates that the refining industry will need to invest $950 million to reach these new fuel specifications. Many petroleum retailers in South Africa switched from lead to MMT (a manganese-based additive) to boost octane. Because manganese is also a toxic metal, the petroleum firm BP introduced South Africa ’s first unleaded fuel that is free of heavy metals in September 2003. In June 2004, British Petroleum (BP) opened the first lead-free station in South Africa. Adoption of unleaded-gasoline is still curtailed by inavailability of this fuel in most areas outside the major urban centres and limited awareness among consumers.

Regional Networks for Data/Information Collection for Decision-Making

The Air Pollution Information Network for Africa (APINA) was formed to address issues related to Air pollution in southern Africa. It is a network of Scientists, Policy-makers, Industry and Non-Governmental Organisations (NGOs). The APINA network aims to form a strong link between the air pollution scientific community and policy makers at national and regional levels. It acts to transfer knowledge and data derived in the scientific programmes and existing research to influence policy and decision-makers in matters related to air pollution. Currently, APINA links different networks and programmes on air pollution in southern Africa and in the future aims to cover the whole of Africa. AFRICACLEAN is also a network of African experts in urban air pollution which has concentrated on information collection on transport-based

[69] This Programme has since been endorsed by AMCEN.

pollution. The National Association for Clean Air (NACA)[70] of South Africa also brings together a broad spectrum of experts in air pollution from South Africa. All these organisations have played a major role in collecting and collating information that is useful for decision-making.

4.0 Challenges and Constraints in Meeting the Goals and Targets

Challenges that have slowed the progress towards meeting air pollution goals and targets include socio-economic and political impacts of closing down outdated refineries, lack of information and understanding of gasoline engine performance, weak national energy policies, lack of local lead-exposure data for policymaking and standard setting, as well as inadequate retail infra-structure for unleaded gasoline. Barriers in mitigating indoor air pollution associated with energy use, on the other hand, include limited access to cleaner technology financing, lack of awareness, weak public health policy and regulation, and cultural diversity. Lack of appropriate early warning systems and prediction of atmospheric changes and fluctuations resulting from local air pollution is another serious challenge to intervention. This is particularly so for desert dust storms, savanna and grassland/forest burning and related emissions. Institutions in the regions are also weak in data collection and transformation for policymaking. . Overall, most countries lack relevant, strong and autonomous regulatory bodies It is critical that these barriers be lifted urgently to meet the air pollution targets for the region.

5.0 Key Lessons learnt and Way forward

Although some exceptions exist, such as in South Africa, where government and industry played a major role, most activities implemented towards air pollution reduction in Africa were by NGOs. The activities mainly involved the application of new environmentally sound technologies (ESTs) or the scale-up of previously proven pollution reduction technologies with a view to widening the scope of impact. For their implementation, most of the activities were funded by bilateral and multilateral arrangements in addition to other donor organisations. There is need to identify means to access finance to enable industry to access state of the art technologies and hence shift from using second-hand technologies. the transport sector will remain a challenge as majority can only afford second-hand vehicles. While some countries limit the year of manufacture of imported vehicles, this measure may not always be sufficient in addressing the problem. Involving micro-finance institutions in accessing efficient energy technologies by households and small businesses is on the increase. However as long as such technologies are not used to generate income, the ability to service the loans will remain low. Therefore, although air pollution reduction was achieved by the projects implemented, the magnitude of the reduction is expected to be small owing to the small number of points of intervention. There's therefore need to scale-up significantly, the tested air pollution options in all sectors.

Another key lesson is that although a lot of air pollution data has been generated by recent scientific campaigns in Africa, there is little evidence of its use in planning and decision-making for resource management or technology deployment. It will be difficult for the role of scientific

[70] http://www.asosh.org/Societies/NACA.htm

information in sustainable development to be actualized if those responsible for the information dissemination process neglect this duty. A proper integrated system is necessary to link the scientific processes of air pollution observation to those of decision-making.

An important lesson learnt over the past decade is that significant capacity has indeed been built among Africans through participation in international global change research initiatives, many receiving their PhDs. However, almost none of these scientists can be traced within African institutions, since almost all have relocated to better-paying western research institutes. It is imperative that Africa motivates its upcoming young scientists through better remuneration or identify innovative ways of harnessing the potential in its scientists in the Diaspora from their present institutions, hence turning brain-drain to brain-gain.

Localized air pollution projects are not always comprehensive and may sometimes transfer the pollution from one site to another. This is the case in congested residential urban areas where chimneys are used to eject smoke from the house only to create outdoor air pollution due to poor airflow rates and low heights of the chimneys. As such an integrated approach should be adopted when addressing air pollution.