DEPARTMENT OF ENVIRONMENTAL AFFAIRS

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WHY WE NEED TO MANAGE AIR QUALITY

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ACRONYMS

CH_4	Methane
CO	Carbon monoxide
DALYs	Disability adjusted life years
DEAT	Department of Environmental Affairs and Tourism
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
O_3	Ozone
PCBs	Polychlorinated biphenyls
PCDDs	Polychlorinated dibenzo-p-dioxins
Pb	Lead
PM	Particulate matter
POPs	Persistent organic pollutants
RHA	Respiratory hospital admissions
SCP	Sustainable Cities Programme
SO_2	Sulphur dioxide
SVOCs	Semivolatile organic compounds
TOC	Total organic compounds
TSP	Total suspended particles
US EPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WHO	World Health Organization

GLOSSARY

Absorption	The penetration of one substance into or through another. Specifically, the penetration of a substance into the body from the skin, lungs, or digestive tract
Acute	Diseases or responses with short and generally severe course (often due to high pollutant concentrations).
Carcinogenic	Cancer causing.
Carcinogenesis	Development of carcinoma; or, in more recent usage, producing any kind of malignancy.
Chronic	Having a persistent, recurring or long-term nature.
Exposure Concentration	The concentration of a chemical or other pollutant representing a health threat in a given environment.
Fine particles	Particulate matter less than 2.5 µm aerodynamic diameter. In contrast to coarse particles.
Health effect	A deviation in the normal function of the human body.
NO_x	Total oxides of nitrogen. Conventionally the sum of nitrogen monoxide (NO) and nitrogen dioxide (NO_2).
PM_{10}	Particulate matter less than 10 µm aerodynamic diameter (or, more strictly, particles which pass through a size selective inlet with a 50 efficiency cut-off at 10 µm aerodynamic diameter). PM_{10} is the thoracic fraction (particles that pass the larynx) of the particulate matter in the atmosphere.
Precursor pollutants	Gaseous pollutants that form secondary pollutants in the atmosphere by chemical transformation. The most important precursor pollutants to form secondary particles are sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3) and volatile organic components (VOCs).
Toxicity	The degree of danger posed by a substance to animal or plant life.
TSP	Total suspended particulate matter.
$\mu g/m^3$	Microgram per cubic meter (unit measure the mass content of particles in the atmosphere)

CONTENTS

1 INTRODUCTION

This book provides a motivation of why air quality needs to be managed. It looks at the history of air pollution, environmental links between air pollution and health, exposure to air pollution and air pollution associated health, environmental and economic effects is provided.

1.1 Why we need to manage air quality

Air is an environmental resource available to support human health, environmental, and development processes. However, the quality of air is often not found in a state conducive to the healthy existence of these parameters, particularly in urban areas or cities characterised by high industrial development, heavy traffic and densely populated areas (SCP, 1999). Such a state of air is known as air pollution, which is defined as the presence of contaminants in air in sufficient quantities to impair human and animal health and welfare, vegetation and materials (Murray and McGranahan, 2003). Cities plagued by air pollution are characterised by poorly controlled emission sources, high emissions, high ambient concentrations of pollutants, high exposure and associated morbidity and mortality, and inadequate environmental management policies and strategies targeted at addressing air pollution issues. Morbidity and mortality associated with air pollution in such cities have secondary effects, which are often measured in economic terms such as lost productivity due to absenteeism or sick days, and high health costs, which impact negatively on economic growth (SCP, 1999). Poor air quality effects extend beyond local sources, due to the transboundary nature of air pollution, which leads to both regional and global impacts. For example, pollutants such as persistent organic pollutants (POPs) have been detected in areas where they have never been used before such as the Artic (WHO, 2003). In addition, poor air quality leads to global warming, depletion of the ozone layer and climate change (IPCC, 2001).

The above suggest that air pollution need to be effectively managed to control its effects. The goal of air pollution control or air quality management is to protect public health and the environment from harmful effects of air pollution. The control or management of air quality requires both the technical, social and economic inputs, a combination which often leads to difficult and complex processes which require careful management. This is therefore suggestive of air quality management programmes, with clearly formulated strategies and plans, and their effective implementation to address both the short- and long-term effects of air pollution.

1.2 Historical perspective

Air pollution is not a new phenomenon. The remains of early humans clearly indicate a possibility of death as a result of exposure to smoke (Brimblecombe, 1987). The industrial revolution which began in England in the 1700s resulted in, along with economic development, localised air pollution problems including health effects and mortality, visibility degradation, vegetation impacts and corrosion of materials (Elsom, 1992). In the 1800s London experienced smog episodes which resulted in respiratory and other health problems with reported 270-700 excess deaths in 1873 (Elsom, 1992).

In 1880 approximately 2000 excess deaths were reported to have resulted from a smog episode which lasted 3 days. Twelve years later in 1892, another 3-day smog episode claimed approximately 1000 lives (Elsom, 1992). Despite the evident effects of air pollution on human health in London at the time, there were no concerted efforts on the part of the government to address the problem. Almost 60 years later, another smog episode which lasted 5 days, popularly known as the great London smog claimed more than 4000 lives (DEFRA, 2002). This became a wake-up call not only to the British government, but for industrialised nations to deal with air pollution issues. In 1956, the Clean Air Act was passed by the British parliament. Since this landmark milestone, the London smog episode of 1991 resulted in reduced excess deaths (188) (POSC, 2002).

In the United States the government promulgated the Air Pollution Control Act of 1955, which was later replaced in 1963 by the Clean Air Act (Vandenberg, 2005). This came after the Donoroa, Pennsylvania fluoride fog disaster of 1948, in which 20 people died and 7000 hospitalised for difficulty in breathing (Schwartz, 1994; McCabe, 1998). There were other air pollution disasters in other parts of the world. Belgium experienced one of its worst air pollution disasters in the Meuse Valley in 1930, in which 63 excess deaths were reported (Elsom, 1992; Neremy et al., 2001).

2 AIR POLLUTION IMPACTS: CURRENT SITUATION

2.1 Health significance of air pollution

The historical perspective provided above indicates that air pollution is a major health hazard, and as a result health impacts have been used as a measure of the degree of impact of air pollution (WHO, 2005). Air pollution is responsible for a myriad of health effects including different types of cancer and various systemic conditions. Approximately 800 000 deaths are estimated to result from exposure to air pollution on a yearly basis (Valent *et al.*, 2004). Different groups of individuals are affected by air pollution in different ways depending on their level of sensitivity. Young children and elderly people often suffer most from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more than healthy people when exposed to polluted air. The extent to which an individual is harmed by air pollution usually depends on the total exposure to the damaging chemicals. In some cases, even healthy individuals may be susceptible to health effects.

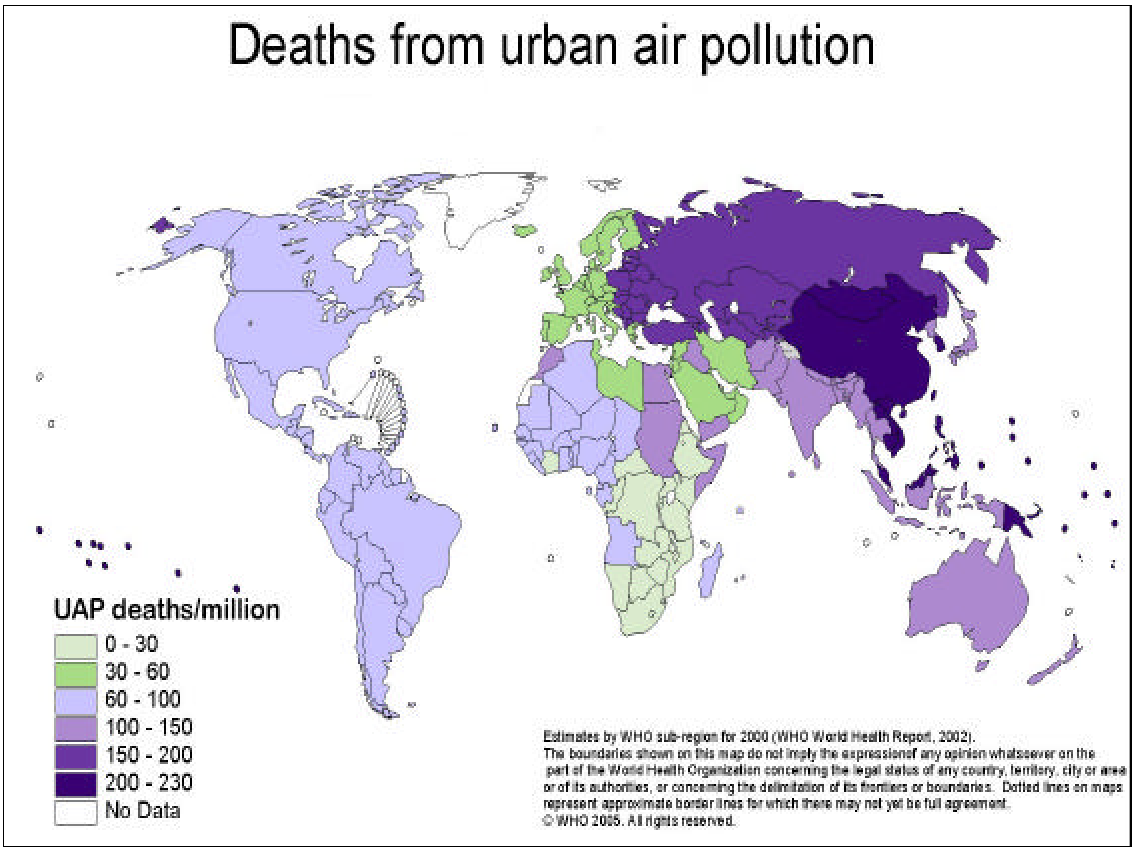
Ambient air pollution

Recent estimates of global burden of disease measured in disability-adjusted-life-years (DALYs) (number of healthy life years lost due to premature morality and morbidity) indicates that ambient air pollution is responsible for 1.4% mortality, 0.5% DALYs and 2% of cardiopulmonary morbidity based on particulate matter (PM) exposure studies of adults and children (WHO, 2002, Cohen *et al*., 2004). Table 1 below indicates that outdoor air pollution accounts for 81% deaths and 49% of DALYS in the elderly (60+years) (WHO, 2002). Figure 1 on the next page depicts the number of deaths which could be averted if air pollution was managed effectively (WHO, 2002).

Ambient air pollution associated morbidity and mortality is largely attributed to PM particularly $PM_{2.5}$ because of its potential to penetrate the respiratory system to reach the distal airways, and ozone, although its degree of impact is less than that of PM (Valent *et al.*, 2004).

Indoor air pollution

Historically the focus on air pollution has been on ambient air pollution (Desai *et al.,* 2004). However, research has shown that indoor air pollution is a significant risk factor for health because air pollution exposures occur mainly indoors where people are reported to spend approximately 90% of their time (Klepeis *et al.*, 2001).



Deaths from urban air pollution

Estimates by WHO sub-region for 2000 (WHO World Health Report, 2002).
The boundaries shown on this map do not imply the expressionof any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.
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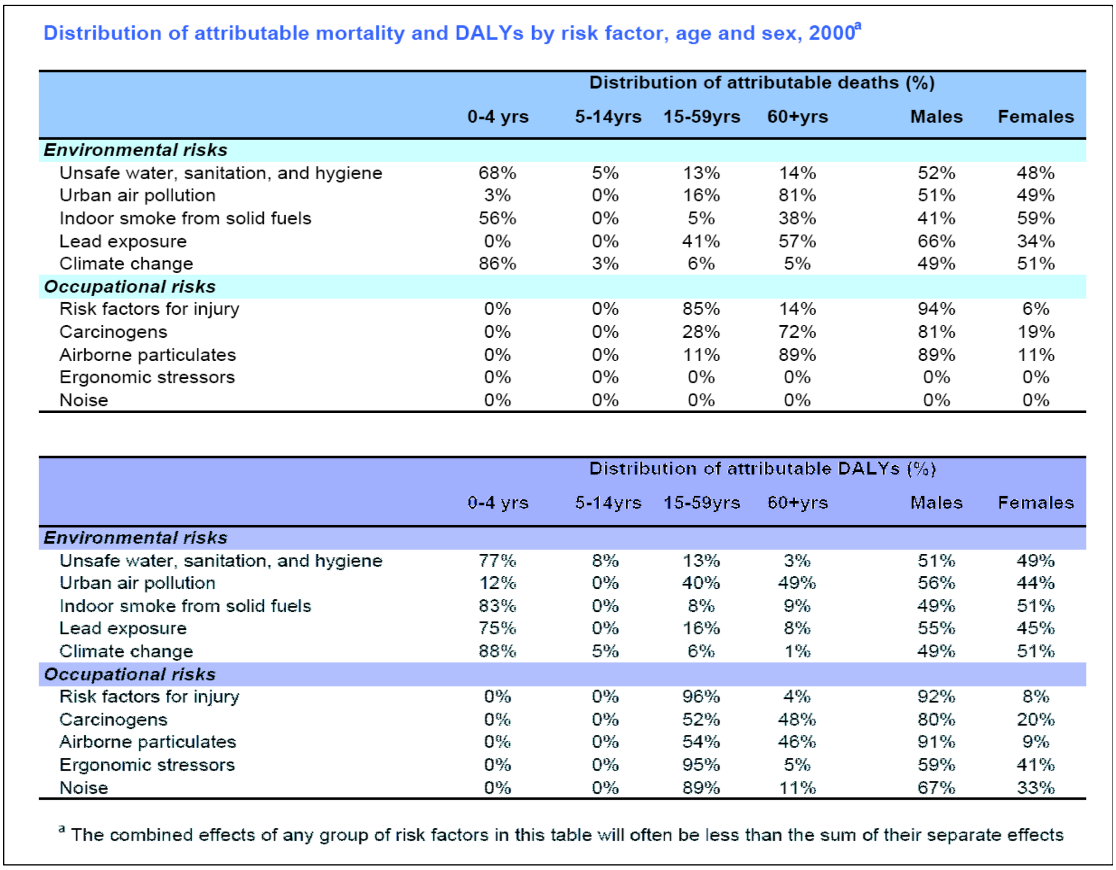
Figure 1: Deaths from urban air pollution (After WHO, 2002)

According to the World Health Organization (WHO) (2002) estimates of indoor air pollution resulting from burning of fuels (solid) low on the energy ladder, is the 8th largest risk factor responsible for 2.7% of the global burden of disease and 1.6 million deaths due to pneumonia, chronic respiratory disease and lung cancer. The DALYs are five fold higher than DALYs resulting from ambient air pollution (WHO, 2002). Acute respiratory infections (ARI) alone were responsible for 7% of the global burden of disease (WHO, 2001). Table 1 below indicates that indoor air pollution mainly affects children under five years of age and the elderly (60+years). It accounts for 83% DALYS and 56% mortality in children below five years of age. In the elderly, it accounts for 9% DALYS and 38% mortality (WHO, 2002). In the year 2000, ARI was responsible for the deaths of 2 million children under the age of five with 98% of these attributable to acute lower respiratory infections (ALRI) (WHO, 2001).

The above indicates that air pollution is a major risk factor for human health and appropriate control and management measures are required in order to protect public health from adverse effects of air pollution.

Table 1: Distribution of attributable mortality and DALYs by risk factor, age and sex, 2000



Distribution of attributable mortality and DALYs by risk factor, age and sex, 2000[a]

	Distribution of attributable deaths (%)					
	0-4 yrs	5-14yrs	15-59yrs	60+yrs	Males	Females
Environmental risks						
Unsafe water, sanitation, and hygiene	68%	5%	13%	14%	52%	48%
Urban air pollution	3%	0%	16%	81%	51%	49%
Indoor smoke from solid fuels	56%	0%	5%	38%	41%	59%
Lead exposure	0%	0%	41%	57%	66%	34%
Climate change	86%	3%	6%	5%	49%	51%
Occupational risks						
Risk factors for injury	0%	0%	85%	14%	94%	6%
Carcinogens	0%	0%	28%	72%	81%	19%
Airborne particulates	0%	0%	11%	89%	89%	11%
Ergonomic stressors	0%	0%	0%	0%	0%	0%
Noise	0%	0%	0%	0%	0%	0%

	Distribution of attributable DALYs (%)					
	0-4 yrs	5-14yrs	15-59yrs	60+yrs	Males	Females
Environmental risks						
Unsafe water, sanitation, and hygiene	77%	8%	13%	3%	51%	49%
Urban air pollution	12%	0%	40%	49%	56%	44%
Indoor smoke from solid fuels	83%	0%	8%	9%	49%	51%
Lead exposure	75%	0%	16%	8%	55%	45%
Climate change	88%	5%	6%	1%	49%	51%
Occupational risks						
Risk factors for injury	0%	0%	96%	4%	92%	8%
Carcinogens	0%	0%	52%	48%	80%	20%
Airborne particulates	0%	0%	54%	46%	91%	9%
Ergonomic stressors	0%	0%	95%	5%	59%	41%
Noise	0%	0%	89%	11%	67%	33%

[a] The combined effects of any group of risk factors in this table will often be less than the sum of their separate effects

(After WHO, 2002)

2.2 Links between air pollution and health

Health effects can only occur following exposure. Exposure to air pollution is therefore an important link between pollutants or chemicals in the environment and the receptor. Through exposure assessment, the interactions between the pollutant and the receptor can be determined. It is therefore important to understand exposure and exposure concepts to contextualise health impacts as detailed in Figure 2. Figure 2 depicts the environmental pathway model which contextualises exposure. Therefore, in order to understand and develop appropriate mitigation measures for health impacts of air pollution, there needs to be an understanding of the source to health effects pathway.

Briefly, sources of air pollution need to be identified and characterised. It is through such a process that what is emitted into the environment and quantities thereof can be known. The behaviour of those emissions once in the environment also requires some form of understanding. It is therefore important that transformation processes that take place in ambient air, water, soil and food are understood as these have a bearing on what the receptors become exposed to in the environment. Once this has been established, concentrations of pollutants of concern can be determined which provide an indication of the magnitude of concentrations of environmental chemicals receptors are likely to come into contact with. The interactions between the chemicals and the receptors determine the magnitude of exposure, upon which health effects can be determined. The concept of exposure is discussed further below.

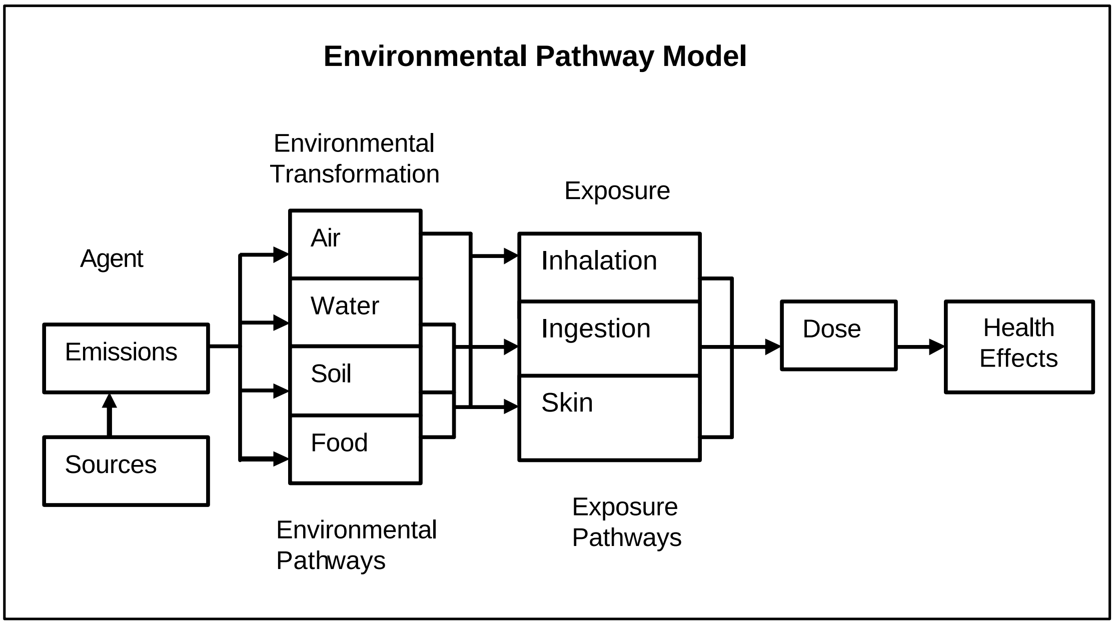


Figure 2: Environmental pathway model

2.3 Exposure to air pollution

Exposure refers to *contact* between the chemical and the outer boundary layer such as the skin, linings of the gastrointestinal tract and respiratory tract of the receptor (US EPA, 1992; IPCS, 2000). The amount of chemical present in the environmental medium (air, water, soil, food) through which contact occurs, is termed exposure concentration. Contact is followed by the actual movement of the chemical from the point of contact into the human body through exposure pathways such as inhalation, ingestion and dermal contact.

This occurs through two processes known as *intake* and *uptake* as shown in Figure 3. Intake refers to the physical movement of the chemical from the point of contact into the human body through openings such as the nose, mouth, and open-skin (US EPA, 1992). Uptake occurs in situations where the chemical is directly absorbed through the skin or other exposed tissues such as the eye (US EPA, 1992).

Once the chemical is inside the human body it joins the circulatory system which provides a vehicle for delivering the chemical to various tissues and organs. The amount of the chemical that enters the body is termed dose (IPCS, 2000). Potential dose refers to the amount of chemical inhaled, ingested or applied to the skin. It is often equated to administered dose in experimental settings. The amount of chemical that reaches the boundary layer and is available for absorption is termed applied dose (US EPA, 1992). Applied dose may sometimes be less than potential dose depending on the bioavailability profile of the chemical in question. Internal dose refers to the amount of absorbed chemical available to undergo transformation through processes such as metabolism, or storage in bodily tissues, excretion or transport (US EPA, 1992). Delivered dose refers to the amount that is transported and delivered to various tissues and organs. The amount of the delivered dose that reaches the sites of action is referred to as the biologically effective dose (US EPA, 1992). This is the important dose as it represents the amount that causes adverse effects. However, it is difficult to establish biologically effective dose particularly in studies with human subjects for ethical reasons. Potential dose is often used as a proxy for biologically effective dose, although models are available which can be used to determine biologically effective dose. However, data (pharmacokinetics) is often a limiting factor in their applications (US EPA, 1992).

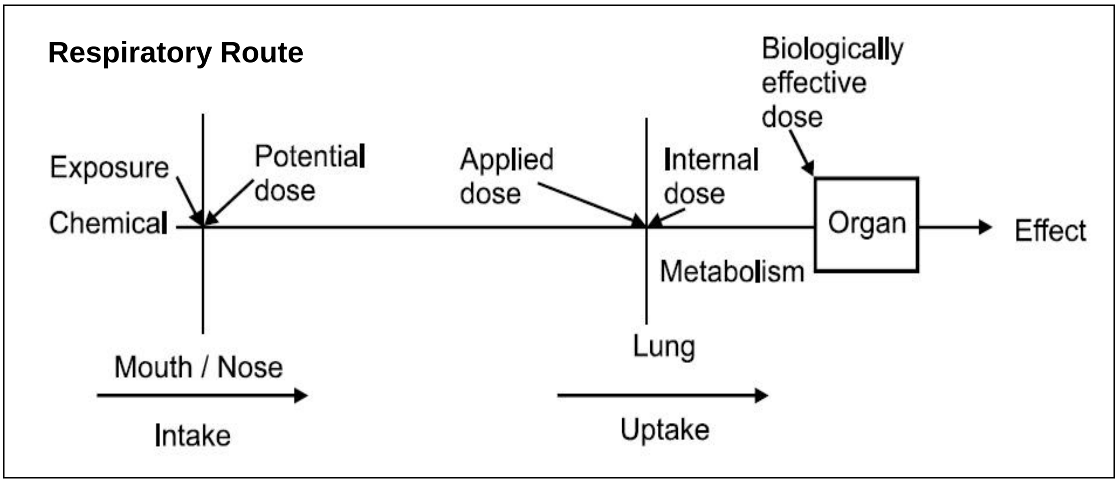


Figure 3: Exposure pathway: Respiratory (After US EPA, 1992)

3 SPECIFIC POLLUTANTS AND THEIR HEALTH AND ENVIRONMENT IMPACTS

3.1 Effects of air pollution on human health

Sulphur Dioxide (SO_2)

SO_2 is inhaled through the nose and most SO_2 only penetrates as far as the nose and throat. Here it is absorbed in the moist upper respiratory tract and converted to sulphuric acid (H_2SO_4), which can irritate respiratory tissue because of its acidity. Very little reaches the lungs, unless the person is breathing heavily, breathing only through the mouth, or if the concentration of SO_2 is high.

Acute health effects from SO_2 exposure set in very rapidly and include a reduction in lung function, an increase in airway resistance, wheezing and shortness of breath (WHO, 2000).

Particulate Matter

Particulate matter is regarded as one of the most critical of all pollutants as it can have serious effects on human health. The extent to which particulates are considered harmful depends on their composition and their size. Anthropogenic sources of particulates such as emissions from diesel vehicle exhausts mainly contain unburned fuel oil and hydrocarbons that are known to be carcinogenic (cancer producing). Very fine particulates ($PM_{2.5}$) (less than 2.5 µm or 2.5×10^{-6} cm in diameter) pose the greatest health effects as they can penetrate deep into the lung and cause more damage, as opposed to larger particles that may be filtered out in the upper respiratory tract (WHO, 2000).

Ozone (O_3)

Ozone mainly affects the respiratory system. Short-term exposure causes a decrease in lung function and is accompanied by wheezing and coughing and breathing difficulties during exercise or outdoor activities. Exposure over a longer period can lead to permanent lung damage and increased susceptibility to respiratory illnesses such as pneumonia and bronchitis (WHO, 2000).

Lead (Pb)

Lead occurs in particulate form in the environment. Upon inhalation, the particles are deposited in the respiratory system where they become absorbed into the bloodstream. The absorbed lead is transported to various body organs and tissues through the blood. In the blood, lead is found attached to the red blood cells where it binds with haemoglobin.

Children are more vulnerable to lead poisoning than adults. Expectant mothers with high blood lead contents can pass lead onto their unborn children. Infants can also be exposed to lead through breast feeding. Lead can enter the body through ingestion, i.e. eating foods and/or drinking water contaminated with lead. Children can also ingest lead from playing in soils contaminated with dust containing lead particles.

The main health effect of lead is damage to the central nervous system. In children it causes developmental problems and a reduction in the Intelligent Quotient (IQ). Lead can cause high blood pressure and anaemia and is also associated with decreased fertility, miscarriages and stillbirths in pregnant women. At high concentrations, lead may result in brain and kidney damage (WHO, 2000).

Carbon Monoxide (CO)

Once inhaled, carbon monoxide enters the blood stream through the lungs. In the blood stream CO combines readily with haemoglobin in the blood to form carboxyhaemoglobin. The haemoglobin affinity for CO is approximately 200-250 times higher than that of oxygen. Carboxyhaemoglobin reduces the oxygen carrying capacity of the blood, starving tissues of oxygen. Effects may include impaired coordination, vision problems, concentration difficulties and difficulty in performing complex tasks. At high concentrations death may occur (WHO, 2000).

Nitrogen Dioxide (NO_2)

The effects of NO_2 exposure are related more to its concentration than the length of exposure. NO_2 affects mainly the respiratory system. Asthmatics are the most sensitive subjects to NO_2 exposure. Symptoms include nose, eye and throat irritation, coughing, a feeling of inability to breathe, headache and nausea. At high concentrations irreversible damage to the lungs may occur. Although effects of NO_2 have been reported in several studies, the current literature is controversial (WHO, 2000).

Volatile Organic Compounds (VOCs)

There are many VOCs that impact on human health. Benzene is one of the most serious. It has been linked to a number of neurological effects, changes to the immune system, and excessive bleeding, but the most serious health impact is that it is carcinogenic and causes cancer of the blood (leukemia) (WHO, 2000).

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds comprising two or more fused aromatic rings made up of carbon and hydrogen atoms (ICPS, 1998; WHO, 2003). As PAHs occur in mixtures in the environment, it is difficult to characterise one specific PAH's health effects. Based on human data the most important health endpoint for PAHs exposure is cancer of the lung, which has been reported in workers exposed to coke ovens, foundries and aluminium smelters, as well as diesel exhaust emissions (WHO, 2003).

Pesticides

Pesticides refer to chlorinated semi-volatile organic compounds and include a variety of toxic chemicals in various forms such as insecticides, herbicides, fungicides, rodenticides, germicides, algaecides, and slimicides (UNEP, 2001). Pesticides exposure is associated with neurotoxicity, hepatoxicity, carcinogenesis, endocrine disruption and reproductive effects (ATSDR, 2002; WHO, 2003).

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are man made organic aromatic compounds that have the biphenyl structure with two linked benzene rings (WHO, 2003).

Their health effects include neurodevelopment effects in infants, immunotoxic effects and cancer (WHO, 2003).

Polyhalogenated Dibenzo-p-Dioxins and Dibenzofurans

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) collectively referred to as dioxins are a group of organic pollutants that consists of two groups of tricyclic aromatic compounds, the most toxic being 2,3,7,8-tetrachlorodibenzodioxin (TCDD) (WHO, 2003). Cancer is the main health effect associated with dioxins. Other health effects include delayed neurodevelopmental and behavioural effects in children (WHO, 2003).

3.2 Effects of air pollution on ecological systems

Air pollutants are known to cause damage to vegetation, water bodies and even certain animals in ecosystems. Air pollutants that are currently considered to be the most important in terms of their ecological effects are sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter and fluoride (F). Certain metals are also known to be toxic to ecological systems. However, some of the most serious ecological effects are caused by acid rain, which is formed by the reaction of primary pollutants such as SO_2 and NO_2 with water vapour to form sulphuric acid (H_2SO_4) and nitric acid (HNO_3). Acid rain damages forests and crops, changes the chemistry of the soil, and causes streams and lakes to become acidic and unsuitable for fish.

Damage to vegetation can be a visible or invisible injury. Visible injury usually consists of discolorations on the leaf surface caused by internal damage to cells. The appearance of the leaf is affected and this can lead to reduced market value. Invisible injury results from pollutant impacts on plant physiology and this can lead to a reduction in growth, reduced crop yields and changes in the quality of agricultural crops.

Sulphur Dioxide (SO_2)

SO_2 damage is characterised by chlorosis of leaf tissue (whitened areas of dying tissue) and also a reduction in growth and yield. The most important effect however, is as a precursor of acid rain.

Nitrogen Oxides (NO_x)

NO_x enters the leaves of plants through the small openings known as the stomata. At high concentrations, NO_x can reduce plant growth through inhibiting photosynthesis. However, in situations where the nitrogen content of soil is low, it can actually stimulate growth.

NO_x also contributes to the formation of acid rain and photochemical smog (of which ozone is a constituent) and thus has a wide variety of environmental impacts. Increased nitrogen loading in water bodies, particularly coastal estuaries, upsets the chemical balance of nutrients used by aquatic plants and animals. Additional nitrogen accelerates eutrophication of water bodies, which leads to oxygen depletion and reduces fish and shellfish populations.

Ozone (O_3)

Ozone causes damage to broad leaf plants giving rise to chlorosis, bleaching, bronzing, flecking, stippling and necrosis. It can also cause reductions in crop yields.

Particulate Matter (PM)

The effect of particulate matter on vegetation depends on the chemical composition of the particles. Some particles, for example heavy metals, may be toxic to plants. The deposition of particulate matter on leaves can also reduce the transmission of light and affect plant growth.

Fluoride (F)

Fluoride causes a wide range of damage to vegetation such as chlorosis and necrosis. Exposure to fluoride can also result in a reduction in photosynthesis.

Lead (Pb)

Animals and fish are mainly exposed to lead by breathing and ingesting it in food, water, soil, or dust. Lead accumulates in the blood, bones, muscles, and fat and it has the same kind of neurological effects on animals as on people.

Mercury (Hg)

Mercury can be deposited on to the ground from the atmosphere and will eventually be washed into water bodies by rain. Bacteria that are present in soils and sediments convert mercury to methylmercury, which can be taken up by tiny aquatic plants and animals and then pass down the food chain. The effects are very serious, including reduced fertility and reduced growth, and it can even lead to death.

3.3 Effects of air pollution on buildings and materials

Certain air pollutants may damage buildings. For example, particulate pollution may accumulate on the exterior of buildings, changing their appearance, staining the building material and increasing cleaning costs. Acid rain can accelerate the decay of building materials and paints, and it is known to cause irreparable damage to many historical monuments, statues, and sculptures.

3.4 Effects of air pollution on climate

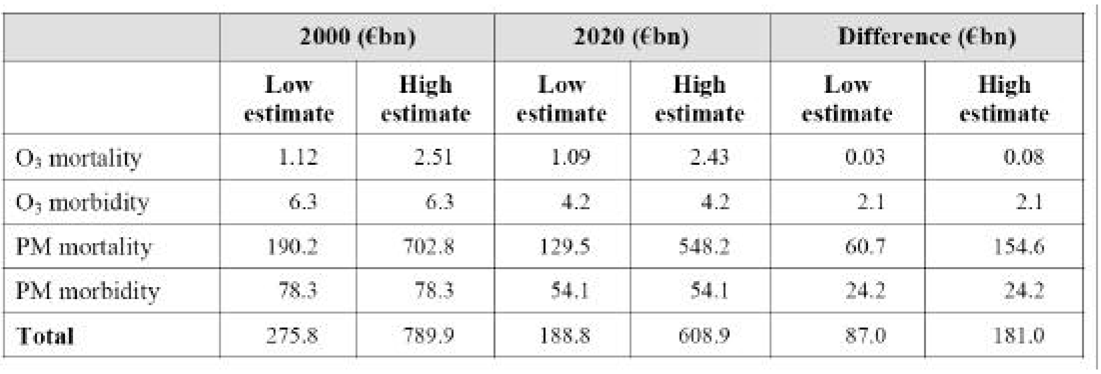
There are some air pollutants that are referred to as greenhouse a gas because of their ability to absorb infrared radiation emitted by the earth and in so doing prevents heat from escaping to space. They thus contribute to global warming. The most common greenhouse gas is carbon dioxide (CO_2), which occurs naturally in the atmosphere and is often not referred to as a pollutant. However, concentrations of CO_2 are increasing dramatically as a result of the burning of carbon-containing fossil fuels such as oil, natural gas and coal, and deforestation. Other greenhouse gases contributing to global warming are chloroflurocarbons, ozone and nitrous oxide (N_2O).

Air pollutants such as chloroflurocarbons can also cause damage to the ozone layer, which is responsible for absorbing most of the sun's ultraviolet radiation and thus protecting life on earth from the harmful effects of ultraviolet radiation. In addition to the serious human health effects, destruction of the ozone layer can cause damage to plants and the reduction of plankton populations in the ocean.

4 ECONOMIC IMPACTS OF POOR AIR QUALITY

Impacts of air pollution are not confined to health impacts, materials or vegetation. It also has economic impacts which are often assessed through a cost benefit analysis and willingness to pay techniques. According to Watkiss et al. (2005) (Table 2) the implementation of the current European Union (EU) policies from 2000 through 2020 are projected to yield benefits in the region of €87 (low estimate) to €181 (high estimate) billion per year. Projections of benefits to be accrued from the prevention of non-health impacts (materials and vegetation) by implementing the current EU policies are estimated at €1.7 billion per year. These estimates exclude non monetary benefits.

Table 2: Implementing the current EU legislation: Core estimates of annual health damage due to air pollution in 2000 and 2020 in EU 25, plus the difference between 2000 and 2020.



	2000 (€bn)		2020 (€bn)		Difference (€bn)	
	Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
O_3 mortality	1.12	2.51	1.09	2.43	0.03	0.08
O_3 morbidity	6.3	6.3	4.2	4.2	2.1	2.1
PM mortality	190.2	702.8	129.5	548.2	60.7	154.6
PM morbidity	78.3	78.3	54.1	54.1	24.2	24.2
Total	275.8	789.9	188.8	608.9	87.0	181.0

After Watkiss et al. 2005

Using the willingness to pay approach, the total cost of health impacts of poor air quality (PM_{10}) were estimated to be in the region of 49,700 million EUR, in Austria (6,690 million EUR), Switzerland (4,170 million EUR) and France (38, 860 million EUR) in 1996 (Filliger et al., 1999). Road traffic related PM_{10} associated health impacts were estimated to account for 26,700 million EUR (54%) of total (Filliger et al., 1999).

5 SOUTH AFRICAN PERSPECTIVE

South African as a developing country requires economic growth to meet the needs of its people. To achieve this South Africa plans to have grown its economy by 6% by 2010 (SAGI, 2006). This is seen as a move that will allow South Africa to half unemployment which is currently in the region of 26% and poverty by 2014 (SAGI, 2006). With the envisaged economic growth, loom environmental problems amongst others air pollution, which is already a problem in highly industrialised areas such as South Durban, Vaal Triangle and Milnerton in Cape Town (EIA, 2004), as the South African energy sector which provides the basis for economic growth is largely coal driven (EIA, 2004). Air pollution is a common feature of urban areas where large industrial developments are located. In addition, air pollution resulting from crude petroleum refining to produce petroleum products such as petrol, diesel and paraffin, and vehicular emissions and emissions from other miscellaneous sources exacerbates the problem. This suggests that South Africa needs to manage its air resource effectively to avoid air pollution and its associated impacts as detailed below.

5.1 Sources, pollutants and health effects

Domestic sector

The domestic sector uses approximately 4% of annual coal consumption in South Africa (Annergarn and Scourgie, 2004). Other sources include wood burning, kerosene, and candles which are common in places with no or limited access to electricity. Emissions from these sources include sulphur dioxide (SO_2), and fine particulates, total organic compounds (TOC), benzene and greenhouse gases including carbon monoxide (CO) and methane (CH_4) (APP & BWMC, 2004). Domestic fuel-burning was estimated to account for ~70% of respiratory hospital admissions (RHA) and ~75% of premature mortality, with an associated cost of R1 100 million per annum (APP & BWMC, 2004). However, this is estimated to decline to 64% by 2011 (APP & BWMC, 2004).

Power plants

South Africa's power generation activities are coal based. These activities contribute SO_2, oxides of nitrogen (NO_x), CO and TOCs, emissions into the atmosphere. In addition, the power generation sector contributes greenhouse gas emissions (CO_2, N_2O) into the atmosphere. Mpumalanga Highveld and the Vaal Triangle are the high impact areas of these emissions. Electricity generation was estimated to account for 6% RHA and 5% premature mortality (APP & BWMC, 2004). Coal-fired boilers were estimated to account for 4% RHA and premature mortality in 2003 and an associated cost of approximately R 150 million per annum. Projections indicated that by 2011 the situation would not have changed (APP & BWMC, 2004).

Vehicles (diesel and petrol)

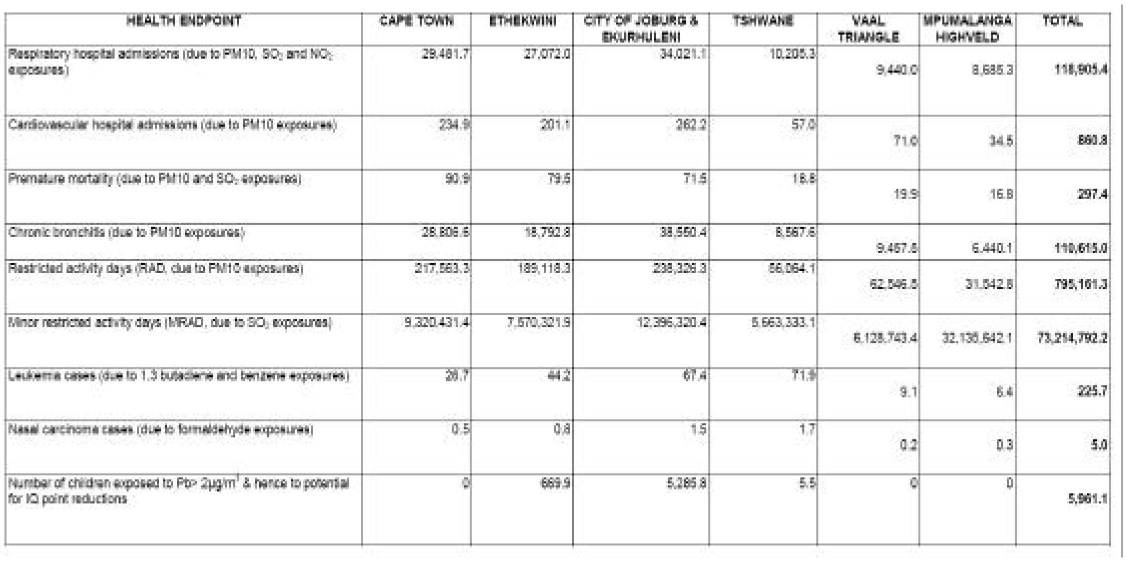
Both petrol and diesel powered vehicles are significant sources of conventional, air toxics and greenhouse gases. According to APP & BWMC (2004), vehicles were responsible for emissions of volatile organic compounds (TOC, NMTOC, benzene, formaldehyde, 1.3-butadiene, acetaldehyde), lead, CO, NO_x, ~30% of total fine particulates and SO_2 emissions. However, SO_2, NO_x and CO emissions from vehicles were reported low in highly industrialised areas such as the Mpumalanga Highveld and the Vaal Triangle (APP & BWMC, 2004). It is also a significant source of greenhouse gas emissions (CO, N$_2$0, and CH$_4$). Vehicle emissions was estimated to account for 12% RHA and 6% of daily mortality cases in 2003 with an associated cost of approximately R 150 million per annum. This is anticipated to grow to 15% by 2011 (APP & BWMC, 2004). Vehicles were also reported to be responsible for ~95% of leukemia cases (APP & BWMC, 2004).

Industrial, commercial and institutional sector

Industrial, commercial and institutional fuel-burning sectors are a significant source of particulates (TSP = 81 807 tpa) and SO$_2$ (571 860 tpa) in all areas but particularly Cape Town, Ethekwini, the Vaal Triangle, Ekurhuleni and the Mpumalanga Highveld. These sectors were also noted to contribute to NO$_x$ (288 238 tpa) emissions and various greenhouse gas emissions (CO$_2$, N$_2$O) (APP & BWMC, 2004).

Table 3 below provides a summary of health impacts of air pollution for South Africa as predicted by APP & BWMC in 2004.

Table 3: Health impacts associated with fuel-burning predicted for the base year 2002



HEALTH ENDPOINT	CAPE TOWN	ETHEKWINI	CITY OF JOBURG & EKURHULENI	TSHWANE	VAAL TRIANGLE	MPUMALANGA HIGHVELD	TOTAL
Respiratory hospital admissions (due to PM10, SO$_2$ and NO$_2$ exposures)	29,481.7	27,072.0	34,021.1	10,205.3	9,440.0	8,685.3	**118,905.4**
Cardiovascular hospital admissions (due to PM10 exposures)	234.9	201.1	262.2	57.0	71.0	34.5	**860.8**
Premature mortality (due to PM10 and SO$_2$ exposures)	90.9	79.5	71.5	18.8	19.9	16.8	**297.4**
Chronic bronchitis (due to PM10 exposures)	28,806.6	18,792.8	38,550.4	8,567.6	9,457.6	6,440.1	**110,615.0**
Restricted activity days (RAD, due to PM10 exposures)	217,563.3	189,118.3	238,326.3	56,064.1	62,546.5	31,542.8	**795,161.3**
Minor restricted activity days (MRAD, due to SO$_2$ exposures)	9,320,431.4	7,570,321.9	12,396,320.4	5,663,333.1	6,128,743.4	32,135,642.1	**73,214,792.2**
Leukemia cases (due to 1.3 butadiene and benzene exposures)	26.7	44.2	67.4	71.9	9.1	6.4	**225.7**
Nasal carcinoma cases (due to formaldehyde exposures)	0.5	0.8	1.5	1.7	0.2	0.3	**5.0**
Number of children exposed to Pb> $2\mu g/m^3$ & hence to potential for IQ point reductions	0	669.9	5,285.8	5.5	0	0	**5,961.1**

After APP & BWMC, 2004

6 CONCLUSIONS

Good air quality is a prerequisite for health and environmental well being, which are the cornerstone of sustainable development. Therefore, advancing economic development at the expense of health and environmental well being has grave consequences for humankind. Ineffective management of air quality may lead to health, economic and environmental effects, suggesting that the need to achieve economic growth should be balanced with improvements in health and environmental well being.

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