# ATMOSPHERIC POLLUTION AND CLIMATE CHANGE IMPACTS IN SOUTH AFRICA

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## INTRODUCTION

Although a developing country, South Africa has one of the largest industrialised economies in the Southern Hemisphere and is the only industrialised regional power. A large proportion of the industrial infrastructure, much of which is coal based, is concentrated in the Gauteng conurbation and on the extensive Witbank coal fields in the adjacent Eastern Transvaal Highveld (ETH) region. The co-existence of heavy industry, alongside underdeveloped communities creates a very real potential for serious air quality degradation to take place. Further, there are about 5 million licensed vehicles in South Africa, many of which are used for relatively short urban driving cycles. In per capita terms, the number of vehicles is approaching that of many countries which are generally considered as being developed. In addition, a large proportion of the fuel for these vehicles is manufactured from coal, adding to the pollution burden from the road transport sector (Turner and Snyman, 1994).

Since the introduction of The Atmospheric Pollution Prevention Act (Clean Air Act) in 1965, atmospheric pollution control with respect to scheduled industrial processes has been effected by the principle of Best Practicable Means. This has led to ever tightening control measures being required on each successive generation of plant. Each scheduled process must operate within the limits defined in a Registration Certificate issued by the Department of Environmental Affairs and Tourism (DEA&T) for the specific process and plant concerned. In addition, smoke control in urban areas has been carried out by municipalities through the promulgation of smoke control zones for certain residential and commercial districts. Unfortunately, this principle has not been applied evenly and in most low income, high density residential areas, domestic smoke emissions are not controlled. Apart from certain constraints on the emission of smoke from diesel engined vehicles, motor vehicle exhaust emissions are not subject to controls. In addition to negotiating and setting emission limits for the various scheduled processes, the DEA&T issues Guideline Values for ambient air quality. Although these Guideline Values do not carry legal status, they nonetheless are often used as standards by which ambient air quality may be assessed or as compliance values for the design of new plant (IUAPPA, 1991).

In many urban area, ambient smoke and sulphur dioxide ($SO_2$) concentrations have been measured since the early 1960's as a continuing process (Department of National Health and Population Development, 1991). Large scale continuous monitoring of ambient $SO_2$ in rural areas was initiated by Eskom in the late 1970's. Since then, oxides of nitrogen ($NO_x$), ozone ($O_3$) and fine particulate matter (FPM) have been added to the monitoring inventory (Turner et al, 1991). During the early 1980's, the Council for Scientific and Industrial Research (CSIR), under government contract, operated an extensive rural network to measure the concentrations of anion species in the atmosphere (Snyman, 1989(. This has since been discontinued. During 1985, Eskom initiated an extensive rain quality monitoring network (Turner, 1993). This has provided the foundation for a national wet deposition monitoring network (Held et al, 1991). In addition many scientific studies have been carried out with respect to pollution dispersion and climatology in South Africa (Tosen and Jury, 1987, Tosen and Pearse, 1986, Tosen and Turner, 1990). Other studies have looked at specific air quality impacts such as health issues among residents of low income, high density residential areas (Terblanche et al, 1992).

Thus there is an extensive knowledge of air quality degradation and, to some extent, its impacts in South Africa. Further, the scientific understanding of pollution transport and dispersion mechanisms in South Africa has been scientifically established. This should give some confidence to predicting the potential impacts of global warming on air and rain quality degradation, assuming that it is possible to predict the expected climate changes with some confidence.

## METEOROLOGY AND CLIMATOLOGY

The rate at which air pollutants disperse in the atmosphere depends on the state of the atmosphere, particularly within the earth's boundary layer where thermal (convective) and mechanical processes dominate. Thus, to assess atmospheric dispersion it is necessary to have information relating to the general climate of a region and the characteristics of the diurnal and seasonal variations within the boundary layer. There, atmospheric dispersion climatology deals with the average of factors such as the overall degree of disturbances of the atmosphere throughout the year, synoptic scale processes and the seoscale effects such as surface inversions, micro-ventilation and local wind regimes. These characteristics are discussed in this section with particular reference to the situation in South Africa.

### Macroscale Circulations

Above the 700hPa level (about 3000m above sea level), Southern Africa is dominated by anticyclonic circulations throughout the year. In summer, a trough develops nearer the surface over the central areas of the country at about the 850hPa level. Over the remainder of the northern and eastern regions, mean airflows remain anticyclonic (Figure 1). In

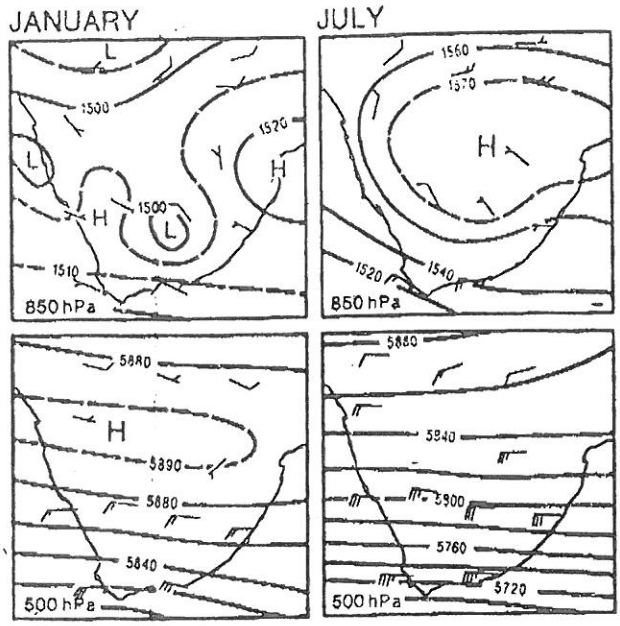


Figure 1. **Monthly mean winds and contours of the 850 and 500hPa surfaces (gpm) in January and July (after Taljaard, 1981).**

winter, the north-eastern parts are strongly dominated by anticyclonic systems throughout the troposphere in which airflows are associated with frequent subsidence within the atmosphere. Subsidence produces increased stability which, in turn, suppresses the amount of precipitation received, increasing the frequency of dry spells. This is most important with regard to atmospheric dispersion as it results in conditions that are highly favourable for the formation of both surface and elevated inversions (Tyson, 1974).

Taken over the year, the frequency of nocturnal surface inversions increases towards the drier north-western parts of South Africa (Figure 2). During the midday period, surface inversions are seldom observed anywhere, except over the extreme western parts of the country. In winter, surface inversion depths vary from 300-500m over the plateau to 500-600m over the coastal regions. The maximum depth occurs at around sunrise, when average strengths are typically 6oC. During summer, surface inversions are less frequent and, on average, their strengths are considerably weaker, being typically of the order of 2oC.

Anticyclonic circulations cause the subsidence of air which, in turn, generates elevated inversions. Figure 3 indicates the height and strength of elevated inversions during both summer and winter over Southern Africa. In summer, base heights are of the order of 2000-3000m above ground over the plateau and 1000m over the coastal regions (Tyson et al, 1976). In winter, with stronger subsidence, the base height over the plateau lowers to 1000-1500m (Tosen and Pearse, 1986) with inversion strengths varying from 4-5oC in the west to 1-2oC over the central regions.

SURFACE INVERSION

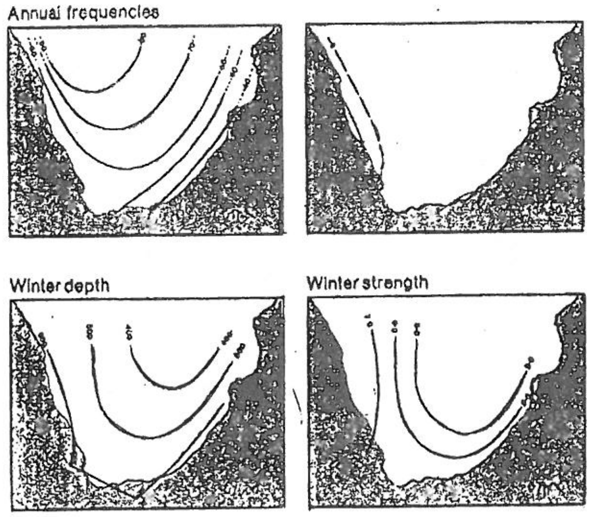


Figure 2. **Annual surface inversion frequencies at midnight and midday and generalised winter early morning inversion depths and strengths (after Tyson et al, 1976).**

SUBSIDENCE INVERSION

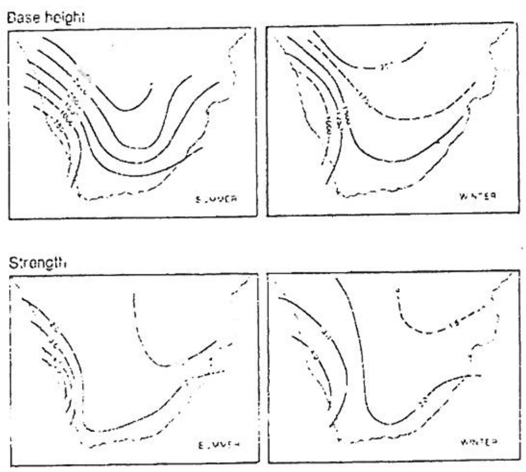


Figure 3. **Base height and strength of subsidence inversions over Southern Africa in summer and winter (after Tyson et al, 1976).**

**Mesoscale Circulations**

The development of local topographically induced circulations are complex and depends on the geography of the area and the time of day. Topographically induced local winds have been studies extensively in South Africa (Preston-Whyte and Tyson, 1988). In sloping terrain during the night, in the absence of strong synoptically induced winds, early morning circulations occur in the form of drainage winds. However, during the daytime wind flows reverse and up slope winds dominate. As a rule of thumb, valley and mountain winds systems extend to the ridge lines of the valleys in which they occur. Such circulations have a major impact on the low-level winds of the region and, to a large extent, control the transport of low-level emissions of pollutants.

Another phenomenon associated with the boundary layer that has an impact on the dispersion of atmospheric pollution is the urban heat island effect. Urban boundary layers are influenced by many processes, including change in the energy balance of the atmosphere above cities and the emission of anthropogenic heat into the air. This heat island effect reduces the frequency of occurrence of surface inversions as well as increasing the frequency of low-level elevated inversions occurring at the top of the boundary layer (Tyson and Von Gogh, 1976). Consequently, conditions for the fumigation of pollution in these areas are enhanced. These conditions can be observed in all major cities in South Africa, particularly in the interior.

General wind fields pertinent to air pollution transport have been studied extensively (Tosen and Jury, 1987a, Tosen and Jury, 1987b). By day, convective mixing dominates within the boundary layer and results in a more uniform velocity field than during night-time periods. During the night the situation is very different as the lower atmosphere is decoupled from the upper layers at the top of the surface inversion. Under such conditions the surface wind field may bear little relationship to the overall synoptic airflows. The 800hPa pressure surface occurs about 350m above ground level over the central plateau and is thus a useful level from which to infer the circulation likely to be relevant to the transport of industrial emissions from high stacks in this region. There are seasonal changes in the circulation over the central and western regions of Southern Africa. However, airflows are predominantly northerly to north-westerly throughout the year.

As the stable layer and the atmosphere decouple, turbulence is rapidly damped in the stable layer. Thus surface wind speeds decrease and a low-level wind maximum develops immediately above the top of the surface inversion, irrespective of wind direction. Studies have shown that this mesoscale jet-like wind is a common feature over the Eastern Transvaal Highveld (Tosen and Jury, 1987a, Tosen and Jury, 1987b). An example of such a low-level jet occurring at the top of the surface inversion is shown in Figure 4. Under these conditions, pollutants emitted from tall stacks are rapidly dispersed and transported out of the region at the top of the inversion layer, thus minimising the impact at ground level.

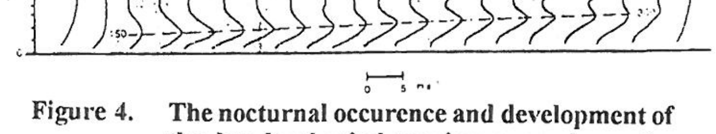

**Figure 4. The nocturnal occurence and development of the low-level wind maximum as shown by mean hourly wind profiles for June 1985 at Phoenix, Transvaal (after Tosen and Jury, 1987b).**

## AIR QUALITY

### The Eastern Transvaal Highveld

### Primary air quality

The potential sources of air quality degradation in the rural ETH region include agricultural activities, small domestic settlements, mining operations including burning coal discard dumps, industries including synthetic fuel manufacture and power generation. Urban plumes from the adjacent metropolitan areas can also play a significant role.

The local air quality impact of any particular source group is not so much dependent on source strength but more on the height of emission above ground level. In general, plumes emitted from tall stacks, such as those employed on power stations, can only reach ground level during daytime convective boundary layer (CBL) conditions. The dispersive mixing under these conditions is very effective. Thus the ground level concentrations associated with such plumes are low. At night, under stable boundary layer (SBL) conditions, high stack plumes penetrate the inversion and have virtually no direct ground level impacts. On the other hand, under SBL conditions, low level sources can give rise to high local ground level concentrations.

It has been widely reported that, in general, ambient air quality in the rural ETH remains satisfactory in respect of all the major measured primary pollutants when compared to the DEA&T Guideline Values. For instances, Turner et al (1991) reported long term $SO_2$ and $NO_x$ concentrations of about 10 parts per billion (ppb) and FPM concentrations of $16\mu gm^3$ for the central ETH region. Further, a recent analysis of the long term data set from Elandsfontein, Eskom's air quality monitoring site in the central ETH region, has revealed a trend of long term improvement.

SO2 has been measured on a continuous basis at this site since January 1984. The site is in an exposed position and is frequently intercepted by plumes from many of the power stations and industries, as well as smoke emissions from burn colliery discard dumps. The concentration data were analyzed for long term trends using moving annual mean values calculated on a month by month basis for the decade spanning 1984 to 1993. The results are shown in Figure 5. Although there is a large degree of variation on a year to year basis, which results in only a moderate value for the correlation coefficient, there is an overall downward trend of 4,7% per annum. The trend is highly significant. The annual variations probably largely result from such factors as fluctuations in the mean mixing heights that are experienced from one year to the next.

Whereas it is not possible to specifically identify the exact reasons for the downward trend, it is worth noting that the decade saw a moderate growth in electricity production in the region. This increase in electricity production is all associated with the large modern power stations which are equipped with tall stacks. Thus is can be deduced that a major proportion of the improvement must have come from a decrease in low-level emissions in the region.

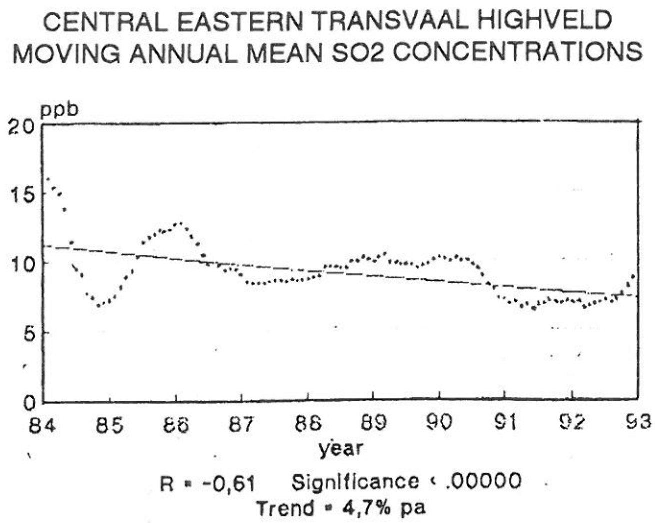


**Figure 5.**

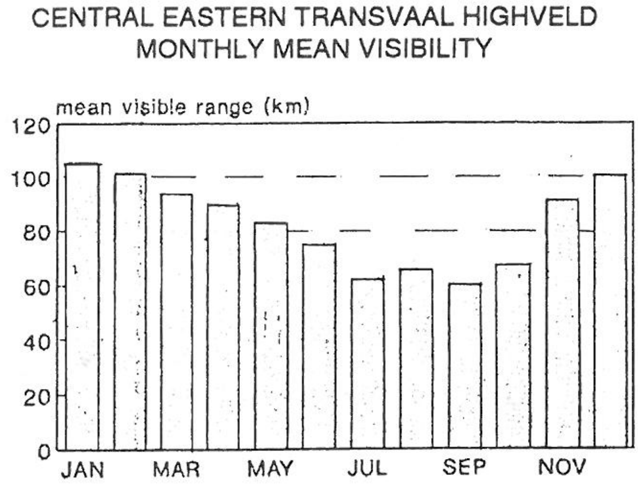


**Figure 6.**

### Aerosols and secondary pollutants

Aerosols, in the form of fine particulates and droplets suspended in the atmosphere, can be attributed to a variety of natural and anthropogenic processes. These processes include the entrainment of soil particles in the atmosphere due to convective action or windy conditions, smoke emissions from biomass sources, industrial and domestic smoke emissions and the chemical conversion of gaseous emissions such as SO2 and NOx into oxidised forms such as sulphates (SO42) and nitrates (NO3). These latter are normally referred to as secondary pollutants.

It has been shown that, under certain conditions, these species re-circulate over the sub-continent giving rise to a reservoir of pollutants trapped in a layer of air beneath the subsidence inversion (Held and Snyman, 1994). However, this does not generally translate into high ground level concentrations of these pollutants, presumably because of the dispersion characteristics associated with the large scale air movements involved. Further, studies of the composition of aerosols in the region have shown that main identifiable source groups, are in decreasing concentration order, crustal, marine, anthropogenic, sulphur, biomass combustion products and heavy metal (Annegarn et al, 1993). Thus the bulk of the aerosol does not consists of anthropogenically derived species.

### Visibility degradation

Aerosols in the atmosphere are a primary cause of visibility degradation. Regional visibility has been monitored on a continuous basis in the central ETH since mid 1985, using nephelometry. The mean visible range from 1985 to 1993 was 76,3km. Figure 6 shows the seasonal variation in mean visibility. In summer, mean visibility exceeds 100km. This is similar to that found during summer months in the most unpolluted regions of the United States, that is, in the arid mid south-west of that country (Pitchford et al, 1989). In winter, mean visible range reduces to about 60km. However, this can still be considered generally acceptable. On over half the days, visible range does not fall below 40kms and on more that 10% of days, it betters 100km. However, it should be noted that on about 2,4% of days, that is about 9 days per year, visible ranges of 16,1km (10 miles) or less occur. This is the value adopted in many of the American States as the criterion for acceptability.

Maximum visibility occurs in the late afternoon period. This can be attributed to the effects of atmospheric mixing under the action of convective turbulence. This pattern is essentially the opposite of that observed for ground level $SO_2$ concentrations originating from tall power plant stacks on the Highveld (Turner, 1990; Turner, 1993b).

The season mean visible range, as shown in Figure 6, shows a distinct skew towards minimum mean visible range occurring during the late winter to early spring months. This corresponds to the time when biomass burning in the sub-continent can be expected to have maximum impact on visibility impairment (Annegarn et al, 1993), and thus this source group if probably of some significance.

Figure 7 shows the trend in mean visible range between 1985 and 1993. The situation has improved at a mean rate of about 5% per annum. Whereas it is not possible to attribute this improvement to any particular source group, it nonetheless could be due to the prevention of spontaneous combustion in local coal discard dumps through improved management practices and the closing down of some older power stations with relatively short stacks. The impact of protracted regional drought on biomass and crustal sources may also have had a significant effect.

### Urban Areas

Air quality degradation can be a major problem in South Africa inland cities due to the poor ventilation characteristics with respect to low level sources under SBL conditions. Urban areas are generally characterised by a number of low

CENTRAL EASTERN TRANSVAAL HIGHVELD
MOVING ANNUAL MEAN VISIBILITY

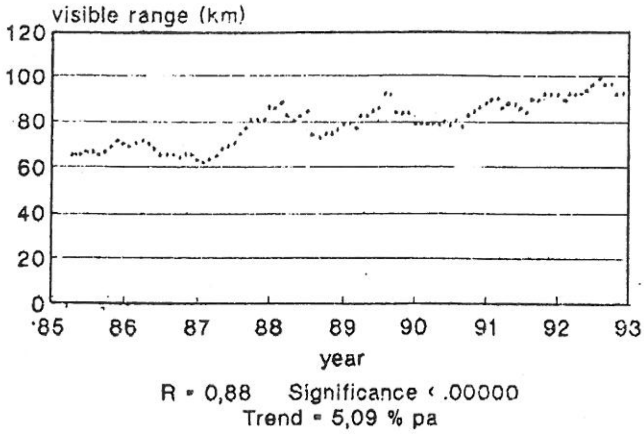


**Figure 7.**

SMOKE TRENDS IN MAJOR CITIES

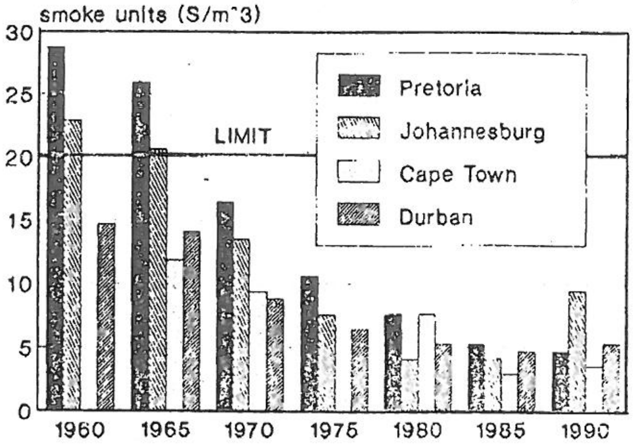


**Figure 8.**

level source groups including domestic coal burning and motor vehicles. Although not as sever, coastal cities may also experience problems when air re-circulation episodes occur (Linde 1993; De Villiers and Dutkiewicz, 1993).

Since the inception of the Clean Air Act, it has been reported that there has been a general downward trend in certain primary ambient air pollutants in city centres. This is illustrated in Figures 8 and 9 which show that smoke and SO2 concentrations can generally by considered satisfactory at the respective monitoring sites (Department of National Health and Population Development, 1992). However, this is not reflected in the ambient concentrations measured in low income, high density residential areas. For instance, measurements from Soweto show that $SO_2$ concentrations approach the DEA&T Guideline Values and FPM concentrations well in excess of accepted limits are frequently experiences (Turner et al, 1991; Turner and Lynch, 1992: Tosen and Rorich, 1992). Similarly, total suspended particulates also frequently exceed DEA&T guidelines. This is illustrated in Figure 10 (Annegarn and Sithole, 1994). Certain other urban areas, often containing industrial sources, also give cause for concern. For instance, unhealthy FPM concentrations and frequent odour complaints have been reported in the East Rand area (Terblanche et al, 1993).

Further, smoke and $SO_2$ concentrations do no reflect the full range of pollutants emitted from motor vehicle exhausts. Motor vehicles, with exhaust pipe outlets at typically 330mm above ground level, inject large quantities of $NO_x$ and hydrocarbons (HCs) into the zone where respiration takes place. Recent measurements from Cape Town have shown that, during the winter, the DEA&T Guideline Values are frequently exceeded (City of Cape Town, 1993). The Guideline Values are also exceeded in Johannesburg, although not as frequently (Johannesburg City Council, 1993). Although both cities contain many sources other than motor vehicles, it has been reported that, in Johannesburg, the diurnal variation in the concentrations of pollutants associated with vehicle exhaust emissions follow the established patterns associated

SULPHUR DIOXIDE TRENDS IN MAJOR CITIES

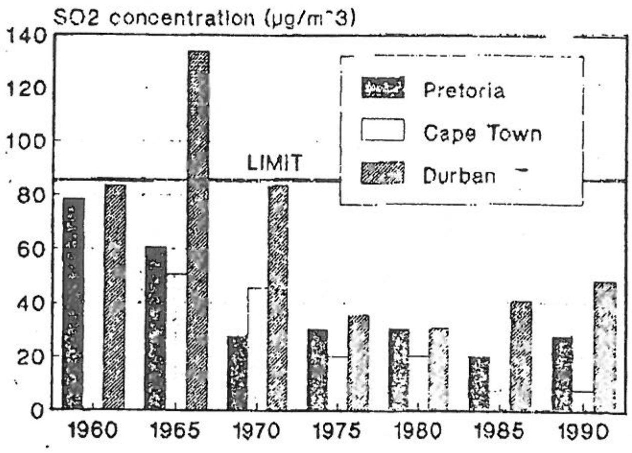


**Figure 9.**

SOWETO PARTICULATE MONITORING NETWORK
MAXIMUM 24 hr CONCENTRATIONS FOR 1993

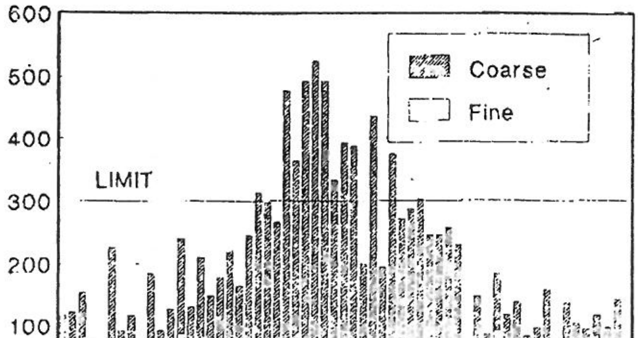


**Figure 10.**

with this source (Krohm, 1992). This diurnal pattern is also evident in the Cape Town data.

In addition to primary pollutants, motor vehicle emissions give rise to secondary species which are also toxic. The most notorious of these is due to the reactions of $NO_x$, HCs and ozone under the action of sunlight to form photochemical smog. Whereas conditions in Johannesburg are not particularly conducive to the formation of photochemical smog, photochemical reactions do take place, as evidenced by measurements of ozone and peroxyacetyl nitrate (PAN) (Krohm, 1992). In Cape Town, however, under certain meteorological conditions, there is a distinctive build up of brown haze (Linde 1993: De Villiers and Dutkiewicz, 1993). Although this phenomenon is still under investigation, it appears superficially similar to that observed in other cities around the world, such as Los Angeles, which are known to be chronically affected by photochemical smog formation.

## DEPOSITION CHEMISTRY IN SOUTH AFRICA

### Wet Deposition

The overall chemistry of rainfall is determined by the presence of many chemical species in the atmosphere, both from natural and anthropogenic sources. Many anthropogenic emissions, such as $SO_2$ from fossil fuel combustion, alter the ionic composition of the rain towards greater acidity. Hence the common usage of the term 'acid rain' to describe rain that contains chemical species derived from such pollutants.

The overall rain pH value is dependent on the balance between acidifying species such as sulphuric, nitric and organic acids and the availability of neutralizing basic cations such as calcium ($Ca_2$) and ammonium ($NH_4^+$) ions (Vong, 1990). The presence of strong mineral acids is dependent on the oxidation rates of the emitted acid pre-cursors in addition to the relative source strengths. These oxidation rates are thought to be relatively slow in South Africa (Turner and Snyman, 1991). Biomass combustion products, originating from grassland and forest fires, can also be a significant source of acid anions, particularly in Africa and Amazonia where such fires occur very frequently (Andreae et al, 1990; Crutzen and Andreae, 1990; Helas et al, 1992; Lacaux et al, 1993). For instance, mean pH values of 4,74 have been found in Central Africa (Lacaux et al, 1992).

The availability of neutralizing species differs widely from region to region, depending on meteorology and transport mechanism, climate, crustal composition, flora and maritime influences, amongst other factors. Terraceous material, a major source of $Ca^{2+}$, can be transported very long distances when entrained in the atmosphere (Losno et al, 1991: Scorer, 1992). Further, atmospheric ammonia ($NH_3$) is often freely available over land masses from vegetative, animal and agricultural sources. It has been reported that neutralization can be virtually complete in rain originating from air masses that traverse land (Pio, 1991). Thus rains exhibit a wide range of acidities, even in remote unpolluted areas. Mean pH values between 4 and 7 have been reported for such regions (Galloway et al, 1982).

The only long term consistent deposition measurements in South Africa have been made by Eskom, who have operated an event type wet-only deposition network since 1985. Full chemical analyses, including the determination of formate and acetate concentrations, are carried out by ion chromatography. The following deductions are based on the data from the Eskom network (Turner, 1993a, Turner, 1993b).

Figures 11 and 12 show long term mean anion and cation concentrations measured in rainfall at Amersfoort, typical of the Eastern Transvaal Highveld (ETH) region, together with values for Louis Trichardt in the far Northern Transvaal. $SO_4^{2-}$ is the most abundant anion species in both regions. However, the concentrations are much higher in the ETH and show a distinct inverse relation to distance from the Highveld source region.

SEVEN YEAR MEAN ANION CONCENTRATIONS

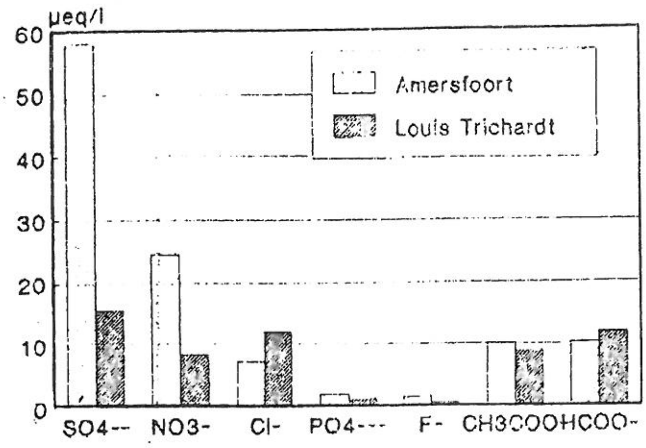


**Figure 11.**

SEVEN YEAR MEAN CATION CONCENTRATIONS

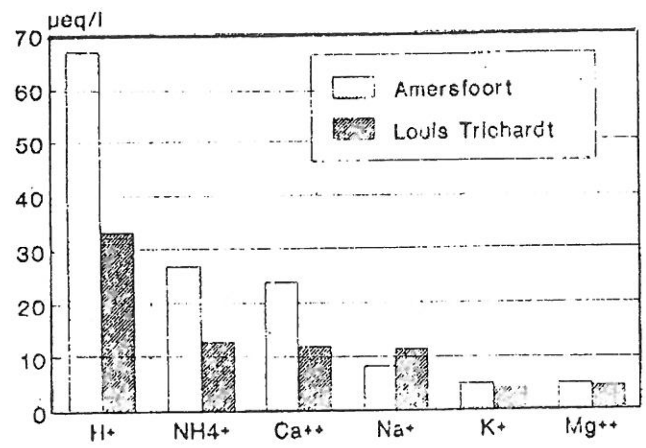


**Figure 12.**

At Louis Trichardt, however, the sum of the organic anion concentrations exceeds that of $SO_4^{2-}$. This implies that, at this site, biomass combustion products exert a greater influence than fossil fuel emissions. Further, the organic anion concentrations show relatively little variation over the entire network region, suggesting that biomass combustion influences extend over the entire sub-continent, rather than being local to South Africa.

As expected, hydrogen ion ($H^+$) concentration in the ETH are somewhat higher than at Louis Trichardt. The measured $H^+$ concentrations translate to mean pH values of about 4,2 and 4,5 respectively, the lower value for the ETH reflecting, to some extent the presence of fossil fuel combustion products.

It was found from the results of multivariate correlation and factor analysis techniques that regional rainfall chemistry is influenced by four main source groups (Turner, 1993a). These are maritime, fossil fuel, biomass combustion products and soil/agricultural sources.

The linkage of source groups to acidity can be estimated by examining the correlative balance between $H^+$, the cations associated with neutralising substances, principally $NH_4^+$ and $Ca^{2+}$ ions, and the acid anion species (Kwajha and Husain, 1990; Saylor et al, 1992; Casado et al, 1992). The summation of $H^+$, $NH_4^+$ and $Ca^{2+}$ concentrations can be termed potential acidity and represents the acidity that could be expected in the absence of the principal neutralizing species.

Using these techniques, it was confirmed that, in the ETH, fossil fuel sources are the biggest contributor to potential acidity. At Louis Trichardt biomass combustion products predominate. This is illustrated in Figure 13. Maritime components, although present in significant quantities, do not affect the acidity balance substantially.

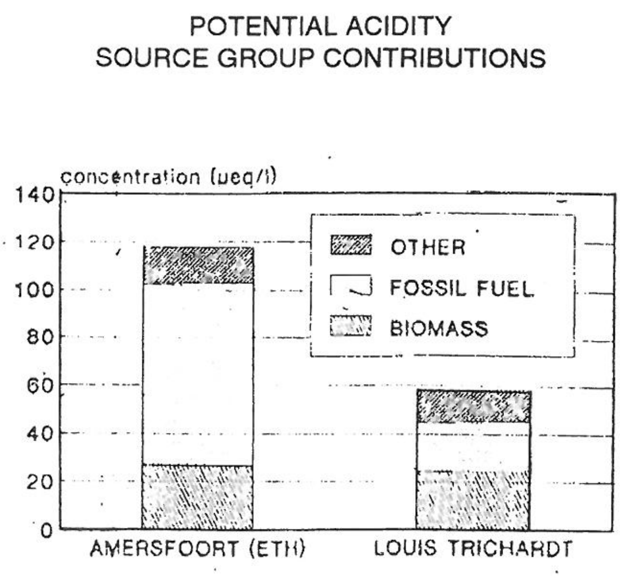


**Figure 13.**

The period between 1985 and 1992 was characterised by a deepening drought throughout the region. At Louis Trichardt, for instance, rainfall decreased by more than 16% per year. This was accompanied by a significant decrease in potential acidity throughout the region. However, there was not significant change in $SO_4^{2+}$ concentrations. Rather, a significant decrease occurred in the organic anion concentrations. This strongly suggests that overall rainfall acidity in the region, in the absence of anthropogenic pollutant species, is controlled by the availability of biomass for combustion. Biomass growth can be expected to be severely limited under drought conditions.

With respect to fossil fuel components, $H^+$, $SO_4^{2-}$ and $NO_3^-$ concentrations in ETH rains are similar to those reported for industrialised regions in the United States, (Kwajha and Husain, 1990; Saylor et al, 1992; Sisterton and Shanon, 1990). However, it must be emphasised that this is not a certain indication that impacts can be expected. The annual rainfall over the ETH is normally between 600 to 700 mm. This relatively low rainfall results in typical annual $SO_4^{2+}$ wet-deposition loads of about 17kg/ha in the ETH which is about one half the maximum reported for the American studies.

### Dry Deposition

Dry deposition of air pollutants involved the removal from the atmosphere of gaseous and particulate matter by all processes other than those involving rainfall and other precipitation processes. In regions where wet climates prevail, particularly those situated at high latitudes and remote from major source areas, wet deposition processes predominate. Thus the measurement of wet-only deposition can provide a reasonable surrogate for total deposition measurement. In addition, even the so called bulk deposition monitoring methods, which are relatively cheap to implement, will not give rise to serious errors with respect to the abundant inorganic anions such as sulphates and chlorides.

In arid regions, such as most of the South African interior, wet-only deposition monitoring will not provide a reliable surrogate for total deposition as dry deposition processes can predominate. Dry deposition processes take many forms, none of which are easy to measure with any degree of certainty and reliability. Nonetheless, the fact remains that a reliable methodology for estimating dry deposition is essential if total deposition is to be realistically quantified.

Near to major source areas, dry deposition is likely to be dominated by gaseous components. Near source dry deposition rates are likely to be large compared to far-field rates. Thus the majority of impacts are most likely to be localised in their extent. Far from major source areas, dry deposition is dominated by aerosols, both particulate and droplet. This is due to atmospheric conversion processes. Although the far-field deposition rates are much lower, impacts can still result in the long term, if the receiving environment is sensitive. This is important as it implies that both these types of dry deposition must be adequately characterised.

The consequences of surface-control on dry deposition are now well recognised. Deposition at particular sites can be preferred, regardless of the averaging period, unlike wet deposition. As a result, representing dry deposition as interpolated isopleth contours, as is the common practice for wet deposition, is unlikely to give realistic values. This has sever implications regarding the critical loads approach as applied to dry deposition (Hicks, 1993).

The subject of dry deposition in South Africa has been recently reviewed (Wells, 1993). It was concluded that, in South Africa, the flux of acidic pollutants to soil and vegetation due to dry deposition could be equal to or exceed that due to wet deposition.

## POSSIBLE IMPACTS OF GLOBAL CLIMATE CHANGE ON AIR QUALITY

In this discussion, potential climate change scenarios which could have an impact on air quality with respect to both pollutant concentrations and visibility are evaluated.

Apart from obvious and non-quantifiable changes in energy usage, social habits, populations growth and socio-economic impacts, it can be concluded that rainfall and temperature would have the most meaningful impacts on air quality. Thus the potential air quality impacts of two scenarios, namely increased and decreased rainfall, are evaluated. Increasing atmospheric concentrations of greenhouse gases, due to the low concentrations involved, are considered to have a minimal direct impact on macroscopic air quality.

### Effects of Higher Average Rainfall in the Region

It is assumed that, under this scenario, more cloud cover will be experienced and the number and duration of rain episodes will increase. Such situations lead to atmospheric conditions which would assist in the dispersion and dilution of pollutants. Conditions for the formation of surface and elevated temperature inversions would be less favourable and their depth and strength would decrease. The washout of pollutants would be more efficient. Increased cloud cover would reduce loss of heat due to radiation during the night, resulting in higher average nocturnal temperatures. These conditions would all, in general, contribute to an improved air quality situation at ground level. The more favourable atmospheric conditions would prevent build up of pollution and higher nocturnal temperatures should reduce the need to use coal for domestic heating purposes. Higher rainfall would encourage plant growth and increase ground coverage, reducing the contribution of wind blown dust. However, higher ambient humidities could create conditions more favourable for the formation of photochemical smog with an attendant reduction in visibility. This could, to some extent, offset the gain in visibility due to the decrease in wind blown dust.

Historically, favourable climatic conditions have served as an economic stimulus. This could lead to increased emissions from industrial sources. However, this could be offset by increased expenditure on control measures.

Economic welfare would cause a growth in the motor vehicle population and higher atmospheric moisture content would enhance the formation of photochemical smog caused by motor vehicle exhaust emissions. This could, however, be countered by stricter control measures, improved mass transit systems and the introduction of electric vehicles.

Stimulated plant growth would act as a temporary sink for carbon dioxide ($CO_2$) but would tend to increase methane ($CH_4$) emissions. The effect of veld fires, due to an increase in available biomass, could however, have a detrimental impact on air and rain quality and visibility.

### Effects of Lower Average Rainfall in the Region

This is the opposite of the previous scenario with significant adverse air quality impacts being realised. In particular, more stable atmospheric conditions would increase the formation of both surface and elevated temperature inversions and they would be both stronger and deeper. This would result in a more frequent build up of high ground level pollutant concentrations with an attendant decrease in air quality and an increase in adverse health impacts. This would be further exaggerated by the fact that less cloud cover would increase the frequency of cold nights, resulting in higher domestic coal consumption and a further deterioration in urban air quality.

Drier conditions and less ground cover would enhance the contribution of wind blown dust and visibility could be degraded over large areas.

A poorer economic situation may lead to less industrial activity. However, less funds would be available for investment in control equipment and maintenance. Poor economic conditions could also cause more people to be dependent on coal or wood for domestic energy purposes.

Decreased rainfall would lead to a decrease in available biomass with a parallel decrease in regional emissions from veld fires. This should result in an improvement in rain quality. However, the relative contribution of anthropogenic sources to rain contaminants would increase. Seasonal improvements in visibility could be realised due to fewer veld fires.

## CONCLUSION

The pollution climatology of South Africa is fairly well understood with respect to air circulations, inversions, seasonal characteristics and urban heat island effects. In particular, the inland plateau displays a distinct bi-modal pattern with SBL conditions occurring at night and CBL conditions occurring during the day. The SBL conditions are responsible for very poor dispersion of pollutants emitted at low level. However, under such conditions, plumes emitted from tall stacks are buoyed above the ground based inversion and swept away and dispersed in the low level jet. Plumes from tall stacks are mixed down to ground during the daytime CBL conditions. However, under such conditions, they are well dispersed resulting in low concentrations at ground level. In coastal regions, SBL conditions also occur for a substantial part of the time. Thus low level sources can give rise to high concentrations in these areas as well.

Air quality and regional visibility in the ETH region is generally acceptable and has been improving over the last decade. Further, secondary pollutants do not, per se, present a problem in terms of concentrations. However, although the overall cycle of rain acidity appears to be connected to the rainfall cycle and biomass combustion in the sub-continent, rain quality in South Africa is influenced by anthropogenic emissions. On the other hand, there have been no substantial reports of rain acidity impacts in Southern Africa to date.

In urban areas, although city centres have shown a marked improvement since the introduction of the Clean Air Act, air quality in low income, high density, residential areas is unacceptable. Further, motor vehicle emissions appear to be presenting potential air quality problems.

Thus, given the relatively good understanding of the driving factors and the amounts of available air quality data for South Africa, it should be possible to predict, with some degree of confidence, the likely impacts of climate change on air quality in this country. Given the current state of knowledge, it is predicted that, under a scenario of increased rainfall, positive air quality impacts would be realised, with negative impacts being obtained under a lower rainfall scenario. The confidence of such predictions, however, will depend on the confidence of the climate change predictions. This is an area that needs substantially more clarification.

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