5 Air quality and health

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Introduction

Exposure to polluted air causes millions of premature deaths each year and can lead to health risks such as reduced lung growth and function, respiratory infections and aggravated asthma. Many deaths related to air pollution occur in Asia and Africa and poor air quality places an additional burden on the health.

This chapter considers the linkages between air quality and health in the South African context and highlights the benefits for future iterations of the District Health Barometer to include an analysis of the impact of air quality on health.

Background to air quality and health in South Africa

In South Africa, air quality is generally perceived as good. However, this is misleading because global models consistently underestimate air pollution in the region. Air pollution has multiple impacts on human health, ecosystems, agriculture, water, materials, visibility and climate. Indoor air pollution associated with domestic fuel use also has the potential for a significant impact on health. Air pollution in South Africa is the result of complex processes and drivers.

In the Highveld, for example, air pollution often exceeds health-based ambient air quality standards; particulate matter (PM) and ozone (O3) levels are regularly out of compliance with National Ambient Air Quality Standards (NAAQS), especially in low-income areas. Emissions vary in time and space as do ambient concentrations and their impact. There are many gaps in understanding the processes and chemistry involved in these reactions.

Ambient air quality guidelines and standards

In 2021, the World Health Organization (WHO) released updated air quality guidelines to address the continued threat of air pollution to public health.[1] The current guidelines, which are all lower than the previous ones set in 2005, are based on global scientific evidence.[2] Although these guidelines are not standards and are thus not legally binding, they offer expert guidance on how to reduce the impact of air pollution on health, even at low exposure levels. A commentary published in the Clean Air Journal in response to the guidelines stated that, while the guidelines motivate for swifter actions to improve air quality, it should be acknowledged that these levels are not attainable in many parts of South Africa. This is because of the many natural sources of pollution, including dust, biomass burning, biogenic and marine sources, are areas that require further research.[3]

The National Environment Management: Air Quality Act 39 of 2004[4] (NEMAQA) aims to protect the environment by regulating air quality and taking reasonable steps to prevent pollution, ecological damage and unsustainable development, while also promoting justifiable economic and social growth. National Ambient Air Quality Standards (NAAQS) have been stipulated to regulate air quality monitoring, management and control of all criteria pollutants. In Table 1 below, regulatory concentrations or limit values are quoted in relation to their averaging periods, the allowable frequency of exceedance (FOE) and the compliance date. The averaging period refers to the length of time over which an average is calculated. The FOE refers to the number of times that the limit value can be exceeded within one calendar year. If the limit value is exceeded on more occasions than specified by the FOE value, then there is no longer compliance with that standard. The compliance date refers to the date that the standard was promulgated and the period over which compliance of the standard is required. Air quality standards are essential for effective air quality management as they provide the indicators to safe exposure levels with respect to human health. Should the need arise, the NEMAQA allows local authorities to develop their own standards that are stricter or that address additional pollutants.

[1]World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide; 2021. URL: https://www.who.int/publications/i/item/9789240034228

[2]World Health Organization. What are the WHO air quality guidelines? 2021. URL: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines Accessed: [20 November 2023]

[3]Garland R, Wernecke B, Feig G, Langerman K. The new WHO Global Air Quality Guidelines: What do they mean for South Africa? Clean Air J. 2021; 31(2). URL: https://cleanairjournal.org.za/article/view/12915

[4]National Environment Management: Air Quality Act 39 of 2004. URL: https://www.gov.za/documents/national-environment-management-air-quality-act#

Table 1: South African National Ambient Air Quality Standards (NAAQS) per pollutant, averaging period and allowed frequency of exceedance (FOE)[5]

Pollutant	Averaging Period	10 minutes	1 hour	8h (running)	24 hours	1 year
Sulphur dioxide (SO_2)	Limit Value	500 µg/m³	350 µg/m³		125 µg/m³	50 µg/m³
	FOE	526	88		4	0
	Compliance Date	Immediate	Immediate		Immediate	Immediate
Nitrogen dioxide (NO_2)	Limit Value		200 µg/m³			40 µg/m³
	FOE		88			0
	Compliance Date		Immediate			Immediate
Particulate Matter (PM_{10}) Original	Limit Value				120 µg/m³	50 µg/m³
	FOE				4	0
	Compliance Date				Immediate – 31-12-2014	Immediate– 31-12-2014
Particulate Matter (PM_{10}) Revised	Limit Value				75 µg/m³	40 µg/m³
	FOE				4	0
	Compliance Date				01-01-2015	01-01-2015
Particulate Matter ($PM_{2.5}$) Original	Limit Value				65 µg/m³	25 µg/m³
	FOE				4	0
	Compliance Date				Immediate – 31-12-2015	Immediate– 31-12-2015
Particulate Matter ($PM_{2.5}$) Revised	Limit Value				40 µg/m³	20 µg/m³
	FOE				4	0
	Compliance Date				01-01-2016-31-12-2029	01-01-2016 31-12-2029

[5]Department of Forestry, Fisheries and the Environment. National Environmental Management: Air Quality Act 2004. National Ambient Air Quality Standards; 2019.

Pollutant	Averaging Period	10 minutes	1 hour	8h (running)	24 hours	1 year
Particulate Matter ($PM_{2.5}$) Revised	Limit Value				25 µg/m³	15 µg/m³
	FOE				4	0
	Compliance Date				01-01-2030	01-01-2030
Ozone (O_3)	Limit Value			120 µg/m³		
	FOE			11		
	Compliance Date			Immediate		
Benzene (C_6H_6)	Limit Value					10 µg/m³
	FOE					0
	Compliance Date					Immediate 31-12-2014
Benzene (C_6H_6) Revised	Limit Value					5 µg/m³
	FOE					0
	Compliance Date					01-01-2015
Lead (Pb)	Limit Value					0.5 µg/m³
	FOE					0
	Compliance Date					Immediate
Carbon monoxide (CO)	Limit Value		30 mg/m³	10 mg/m³		
	FOE		88	11		
	Compliance Date		Immediate	Immediate		

Note: *Grey text indicates earlier limit values that are no longer current.*

The application of SAAQIS data for public health purposes

Air quality monitoring is an essential tool to ensure compliance with the ambient air quality guidelines.[6] The South African Air Quality Information System (SAAQIS) is a central repository for managing and sharing air quality information with all stakeholders, including the public.[7] It aims to provide all South Africans with accurate and up-to-date information on the state of their air quality and the progress of efforts to ensure their right to clean and healthy air. In 2017, the South African Air Quality Information System (SAAQIS) mobile information tool was launched, providing stakeholders with real-time air quality information.[8] Data from air quality monitoring networks are also used in research projects, such as burden of disease estimations and environmental impact assessments.[6] The design of air quality monitoring approaches varies, depending on whether the objectives are to protect people's health or map the general impact of industrial sources.

There are several locations in South Africa where the South African National Ambient Air Quality Standard (NAAQS) for O_3 is exceeded [an 8-h running average of 61 parts per billion (ppb)]. Two areas, identified by the South African government as areas with consistently poor air quality, have been declared as national air pollution priority areas (Vaal Triangle Air Pollution Priority Area and the Highveld Air Pollution Priority Area). The O_3 exceedances in these areas occurred from August to September 2014 and were most likely attributed to the increase in biomass burning during this time. This poses a risk to the health of residents in the priority areas and requires ambient air quality management interventions. In rural areas, O_3 is often higher than in industrial areas. This has been observed in Hendrina where a monitoring station measured 234 exceedances in one year.[9] High levels of O_3 were attributed to the absence of nitrogen monoxide (NO) from urban emission sources, which is required to remove O_3 from the air. O_3 has a negative impact on the respiratory system and can reduce lung function, cause lung irritation. Furthermore, it can increase the risk of mortality in the long term.[10]

Determinants of disease burden associated with air pollution exposure

When assessing the health impacts of air quality exposure, it is important to consider all the relevant information, including the type and concentration of pollutants, the duration of exposure and the characteristics of the exposed population. Different tools can be used to assess the impact of air quality exposure on health.

Exposure-response functions (which relate the pollution concentration to which the population is exposed to the increase in health risk) are used to estimate the risk of developing cancer or other chronic health conditions from exposure to a single air pollutant or a mixture of pollutants. They are based on data from epidemiological studies that have measured the health effects of people exposed to different levels of air pollution. The outcomes may be used to inform public health policy and decision-making. It is, however, important to consider whether a particular exposure-response function is relevant to the South African context.[11] Factors that may contribute to under- or over-estimation of health risks include whether multiple or individual sources are considered, and whether the exposure-response functions are linear or exponential.

The WHO's Ambient air pollution: Global assessment of exposure and burden of disease has used integrated exposure-response (IER) functions to model disease risks from different sources of air pollution.[11] These functions show that the relative risk of mortality for an incremental increase in exposure may vary between lower and higher concentrations for some pollutants.

To get a more accurate estimate of health effects from air pollution, different sources of pollution, such as vehicles, households and industry, should be considered as well as how much they contribute to the total amount of pollution people are exposed to.[11] The health costs of the emissions should be weighed against the health benefits of alternatives. For example, whether or not reducing emissions from cars will improve air quality and reduce the risk of death from air pollution. However, the benefits of cars, such as transportation and economic activity, should also be considered.

[6] Wright CY, Benyon M, Mahlangeni N, Kapwata T, Laban T, Garland RM. Data gaps will leave scientists 'in the dark: How load shedding is obscuring our understanding of air quality. South Afr J Sci. 2023; 119(9/10). URL: https://sajs.co.za/article/view/16009

[7] South African Air Quality Information System (SAAQIS). URL: https://saaqis.environment.gov.za/

[8] Gwaze P, Mashele SH. South African Air Quality Information System (SAAQIS) mobile application tool: bringing real time state of air quality to South Africans. Clean Air Journal. 2018. URL: https://www.scielo.org.za/pdf/caj/v28n1/01.pdf

[9] Beukes JP, Van Zyl PG and Laban TL. Measurement of surface ozone in South Africa with reference to impacts on human health: commentary. Clean air journal 7461; Tydskrif vir Skoon Lug. 2015; 25(1):9-12.

[10] Vicedo-Cabrera AM, Sera F, Liu C et al. Short Term Association Between Ozone and Mortality: Global Two Stage Time Series Study In 406 Locations In 20 Countries. BMJ; 2020.

[11] Langerman KE, Pauw CJ. A critical review of health risk assessments of exposure to emissions from coal-fired power stations in South Africa Clean Air J. [Internet]. 2018. [cited: 2023 Nov 30]; 28(2): 68-79. Available from: https://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2410-972X2018000200019

A Health Risk Assessment (HRA) may be used to assess the potential for health effects from exposure to a single air pollutant, to compare the potential health risks of different air pollutants and to screen for potential health risks in a population. For single-pollutant exposure, hazard quotients (HQ) and estimates of cancer risk are calculated to assess the potential for non-cancer and cancer health effects respectively. An HQ is calculated by dividing the exposure dose by a reference dose, which is the maximum dose that a person can be exposed to without experiencing adverse health effects.[12] A health risk due to exposure to multiple pollutants that affect the same target organ or organ system can be determined by calculating a Hazard Index (HI), which is the sum of the HQs of the pollutants in the mixture.

Health impacts

Different studies have reported a wide range of health effects from air pollution, which can be confusing.[11] These health effects are typically divided into categories based on the length of exposure, the type of health effect and the age of the population. Effects are often measured in terms of premature mortality, morbidity, such as hospital admissions or incidences of illness, and disability-adjusted life years (DALYs). DALYs are a measure of the total health impact of air pollution, including both the years of life lost and the years of life lived with disability. It is important to note that health impacts are estimated at population level rather than for individuals, so it is not possible to identify which individuals died because of air pollution.

National burden of disease studies contribute to evidence of the association between air pollution and health impacts in the South African context. One specific assessment found, for example, that outdoor air pollution causes 3.7% of mortality from cardiopulmonary disease and 5.1% of mortality is attributable to cancers of the trachea, bronchus and lungs.[13] Local epidemiological studies confirm these findings, including the Vaal Triangle Air Pollution and Health Survey, which assessed whether air pollution in this highly polluted area was detrimental to the health of school children.[14] Sixty-five percent of participants suffered from upper respiratory diseases and 29% from 234 lower respiratory diseases. School children in the Vaal Triangle had a 134% higher risk of developing upper respiratory illnesses and a 203% higher risk of developing lower respiratory illnesses than the children in a control area.[14]

A comparative risk assessment investigated short-term association between O_3 and mortality in 20 countries, including South Africa.[10] A 10 μg/m^3 increase in ozone during the day of assessment and the previous day was found to be associated with an overall relative risk of mortality of 1.0018 (95% confidence interval 1.0012 to 1.0024). The study suggested that stricter air quality standards might reduce ozone-related mortality. South Africa does, however, not consider O_3 as a key pollutant of concern.[9]

Particulate matter (PM) is widely studied. One such study investigated the association between ambient air pollution (PM10, NO2, and SO2) and cause-specific mortality in three South African cities – Cape Town, Durban and Johannesburg.[15] The study found independent associations between air pollution, susceptible groups and environmental conditions. The highest number of deaths from cardiovascular and respiratory diseases occurred in winter, which the authors attributed to colder temperatures.[15] Another study, using the BenMap model,[16] found that reducing exposure to $PM_{2.5}$ would avoid 28 000 premature deaths in South Africa.[17]

[12]Goumenou M, Tsatsakis A. Proposing new approaches for the risk characterisation of single chemicals and chemical mixtures: The source related Hazard Quotient (HQS) and Hazard Index (HIS) and the adversity specific Hazard Index (HIA). Toxicol Rep. 2019 Jun 21;6:632-636. doi: 10.1016/j.toxrep.2019.06.010. PMID: 31334033; PMCID: PMC6616343.
[13]Norman R, Cairncross E, Witi J, Bradshaw D. Collaboration, South African Comparative Risk Assessment. Estimating the burden of disease attributable to urban outdoor air pollution in South Africa in 2000. SA Med Jour. 2007: 97(8):782-790.
[14]Gerblanche AP. Vaal Triangle Air Pollution Health Study: Summary of Key Findings, Recommendations and Bibliography. National Urbanisation & Health Research Programme, Medical Research Council; 1998.
[15]Thabethe NDL, Voyi K, Wichmann J. Association between ambient air pollution and cause-specific mortality in Cape Town, Durban, and Johannesburg, South Africa: any susceptible groups? Environ Sci Pollut Res Int. 2021 Aug;28(31):42868-42876. doi: 10.1007/s11356-021-13778-w. Epub 2021 Apr 7. PMID: 33825108; PMCID: PMC8354869.
[16]BenMap. Environmental Benefits Mapping and Analysis Program - Community Edition (BenMAP-CE); 2023. URL: https://www.epa.gov/benmap
[17]Altieri KE, Keen SL. Public health benefits of reducing exposure to ambient fine particulate matter in South Africa. Science of het Total Environment 684; 2019. URL: https://www.sciencedirect.com/science/article/abs/pii/S0048969719324088

The lack of access to clean energy is a key driver of the impact on health of air pollution in Southern Africa, as is the case with the rest of Africa. A narrative review of household air pollution (HAP) exposure and respiratory health outcomes found that many South Africans burn coal, charcoal, wood, agricultural residues and kerosene for heating and cooking.[18] They often use open fires or cookstoves with limited ventilation and are exposed to high concentrations of air pollutants, specifically particulate matter. This renders women, often tasked with cooking, particularly vulnerable to PM exposure. Although the review indicated the possible association of HAP with negative health outcomes, none of the studies provided local estimates of relative risks and concentration-response functions for criteria pollutants that may be applied in burden of disease studies.[19]

Air quality and the District Health Barometer

Many of the leading causes of death listed in previous versions of the District Health Barometer (DHB), including respiratory diseases, preterm birth complications, cerebrovascular disease, hypertensive heart disease and diabetes, have been linked to air pollution in other studies, both locally and internationally.[19]

Information on the impact of ambient air pollution on health in South Africa is sparse. However, there is growing evidence that air quality in the region is deteriorating, and that human health is being affected. In addition to ambient or outdoor air pollution, people are also exposed to indoor air pollution from inefficient cookstoves in poorly ventilated spaces, which poses a considerable threat to health. Epidemiological studies point to O_3 and $PM_{2.5}$ as significant hazards for human health.[8]

Conclusion

A key challenge to assessing health effects of air pollution in South Africa is the lack of relevant data at appropriate scale and distribution[17], which includes ambient monitoring data and population statistics, such as concentration-response functions for the South African population.[9] This will enable researchers to pursue studies such as cohort, time series and randomised intervention trials.[19]

[18]Shezi B, Wright CY. Household air pollution exposure and respiratory health outcomes: a narrative review update of the South African epidemiological evidence. Clean Air J. [Internet]. 2018 May 31 [cited 2023 Nov. 30];28(1). Available from: https://cleanairjournal.org.za/article/view/6962

[19]Wernecke B, Pillay Naidoo N, Wright CY. Establishing a baseline of published air pollution and health research studies in the Waterberg-Bojanala Priority Area. Clean Air J [Internet]. 2023 Jun 26 [cited 2023 Oct 18];33(1). Available from: https://cleanairjournal.org.za/article/view/14887