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GUIDELINE FOR THE MANAGEMENT OF DOMESTIC INDOOR AIR QUALITY

A GUIDE FOR ENVIRONMENTAL HEALTH PRACTITIONERS IN SOUTH AFRICA

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PREFACE

It is with pleasure that the national Department of Health presents these guidelines for the management of domestic indoor air quality in South Africa. The guidelines serve as a uniform basis to assist Environmental Health Practitioners (EHPs) in protecting communities and eliminating exposure to poor domestic indoor air quality (IAQ), through monitoring IAQ, advising communities, raising awareness and advocating for sound local environmental practices. Domestic indoor air pollution is a challenge in South Africa, as many South African households still depend on biomass fuels, coal and paraffin for cooking and heating. According to the *Burden of Disease from Household Pollution* document for 2012 by WHO, 4.3 million deaths globally were attributable to indoor pollution, with 580 000 of those in Africa, primarily as a result of domestic use of solid fuel for heating, lighting and cooking.

According to the *2013 Country Situational Analysis and Needs Assessment,* conducted on the implementation of the Libreville Declaration on Health and Environment in Africa, respiratory diseases and lung cancer are amongst the main health conditions of concern influenced by environmental pollution in South Africa. There are other non-energy generation sources of domestic indoor air pollution that the guidelines will unpack. The implementation of these guidelines will contribute in addressing the Sustainable Development Goals (SDGs) Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

It is a fact that acute lower respiratory infections (ALRI) are a major cause of death world-wide amongst children under the age of five years, hence the WHO has sought to complement the clinical management of ALRI by developing a range of primary preventive initiatives, which include prevention of exposure to domestic indoor air pollution, an important and yet neglected factor. In many cases, simple preventive measures exist to reduce the burden of disease from domestic indoor air quality-related risks, although systematic incorporation of such measures into policy guidelines has been a challenge.

The national Department of Health has developed these guidelines to align with several of the *WHO Guidelines for Indoor Air Quality*, the *WHO Regional Strategy for the Management of Environmental Determinants of Human Health in the African Region 2017–2021* and the proposed country's *Strategy to Address Air Pollution in Dense Low-Income Settlements* that calls for the promotion and protection of public health from exposure to domestic indoor air pollutants, in which EHPs have a major role to play. The implementation of this guideline will serve as a stepping stone on which IAQ management programmes should be casted for the benefit of particularly poor and vulnerable communities and for the achievement of SDGs.

We would like to thank everyone who has participated in the development of this guideline, especially Zanokuhle Environmental Health Services that developed the original draft guideline.

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1. INTRODUCTION

1.1 Background

In South Africa, exposure to domestic indoor air pollution (IAP) is a major contributor of respiratory diseases, especially in poor communities, and yet no guiding measures are in place to ensure affected communities are protected. Indoor air is also important because people spend a substantial amount of time indoors. A large number of communities still rely on poor combustion fuels and appliances for cooking, which largely contribute to IAP and the burden of respiratory diseases. The use of dirty fuels does not only cause respiratory diseases but also injuries, burns and poisoning.

The Development of World Health Organization guidelines for Indoor Air Quality (2006) notes that "indoor air quality management is made difficult not only by the large number and variation of indoor spaces but also the complex relations of indoor air quality and the building design, materials, operation and maintenance, ventilation and behaviour of the building users". The impacts of climate change such as floods from storms and heavy rainfall and the subsequent rise in sea level, that are experienced in the country, contribute to dampness problems in houses and buildings.

The Sustainable Development Goals' (SDGs) Goal 13 emphasises taking action to combat climate change and its impacts. Flood-prone areas such as river valleys and coastal areas are particularly vulnerable. The national Department of Health, in consultation with stakeholders, identified the need for developing a guideline for the management of domestic indoor air quality (IAQ) in South Africa, as there were no established guidelines applicable in this field. Public health awareness on domestic indoor air pollution has lagged behind in comparison to outdoor air pollution.

The development of the guideline was informed by:

- sources of indoor pollution and their relationship with outdoor pollution
- indoor levels exceeding the levels of health concern
- scientific evidence of health effects of indoor pollution
- identified critical indoor pollutants
- outcome of questionnaire that was developed for the guideline development project
- inputs from consulted stakeholders
- WHO and national policy provisions

The purpose of this guideline is to:

- provide guidance in undertaking indoor air pollutants assessments in a domestic environment
- provide guidance on mitigation measures or actions that can be implemented to ensure exposure to safe indoor pollutant levels
- support IAQ monitoring as part of air quality management programmes
- support air quality health research studies
- give the ability to respond to IAQ complaints

The guideline is not presented as a regulatory document but acts as a means to assist environmental health practitioners (EHPs) in undertaking domestic indoor air quality assessments and in providing appropriate mitigation guidance in order to manage domestic indoor air quality. The document does not seek to be prescriptive in its application but rather offers the user a framework for an approach to developing a management strategy and a guide to different pollutant measurement options and mitigation measures available for domestic IAQ.

The scope of application of this guideline:

This guideline applies to air quality in the domestic, private and public environment that is used for temporary or permanent habitable purposes; special environments that accommodate vulnerable population groups due to their health status or age; and includes **private and public homes/households, household boats, tents or caravans, accommodation establishments used for habitable purposes (hotels, lodges, chalets, guest houses), retirement/old age homes, healthcare facilities and places of child care, learning and tutoring**.

Because this guideline was adopted from WHO guidelines, it is not intended to address indoor air quality in workplace environments. WHO guidelines are not a basis for occupational exposure standards and this area is managed by the Occupational Health and Safety Act, 1993 (Act 85 of 1993).

The **guideline does not cover tobacco smoke** as the WHO has not found scientific evidence to use to set the guideline limit value. The available tobacco legislative prescripts in the country can be applied where appropriate, however discouraging the use of tobacco and promoting quitting tobacco smoking should be promoted as tobacco contains a number of pollutants, some of which are covered in this guideline.

The guideline is presented for monitoring air quality in the indoor environments as prescribed above, however the techniques presented could be applied in other indoor environments where no indoor maximum permissible emission exposure limits or levels are prescribed by any relevant legislation.

The indoor pollutants considered in this guideline include (**benzene, carbon monoxide, formaldehyde, particulate matter, sulphur dioxide, mould and allergens, relative humidity, naphthalene, nitrogen dioxide, polycyclic aromatic hydrocarbons (especially benzo[*a*]pyrene), radon, trichloroethylene and tetrachloroethylene)** because of the availability of WHO guidelines, existence of indoor pollution sources, the availability of toxicological and epidemiological data and on exposure levels causing health concerns.

The guidelines for relative humidity are not applicable in settings with particular production processes and hospitals with high-risk patients or sources of exposure to pathogens.

1.2 Legislative context

There are various legislative frameworks that govern and empower an EHP to protect communities from exposure to domestic IAQ through conduction of various environmental health activities. The legislations referred to are as follows:

- The Constitution of the Republic of South Africa, 1996 (Act 108 of 1996)
- National Health Act, 2003 (Act 61 of 2003), as amended.
- Municipal Structures Act, 1998 (Act 117 of 1998)
- Municipal Systems Act , 2000 (Act 32 of 2000)
- Health Professions Act, 1974 (Act 56 of 1974), as amended.
- National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004)
- National Building Regulations and Building Standards, 1977 (Act 103 of 1977)
- Regulations defining the Scope of the Profession of Environmental Health (Government Gazette No. 32334, Notice No. R. 698, dated 26 June 2009)

The environmental health profession is one of the listed health professions required to register for independent practice after qualifying and meeting prescribed requirements in terms of Section 24 of the Health Professions Act.

The functions of an EHP can be performed at national, provincial and municipality level since Schedule 4, Part A of the Constitution include health services and pollution control as functional areas of concurrent national and provincial legislative competency while Schedule 4, Part B include municipal health services as a functional area that is a municipal competency. Section 156 of the Constitution further outlines municipal administration provisions that must be followed in municipalities rendering the allocated or assigned functions.

The powers and functions of municipalities outlined in the Constitution are further highlighted in Section 83 of the Municipal Structures Act and Section 8 of the Municipal Systems Act. Section 32 of the National Health Act, provides for the rendering of municipal health services as the responsibility of metropolitan and district municipalities.
In terms of Section 2(c)(ii), the objectives of the National Health Act are to regulate national health and to provide uniformity in respect of health services across the country by protecting, respecting, promoting and fulfilling the Section 24 Constitutional right of the people of South Africa to an environment that is not harmful to their health and well-being.

The definition of health services, in terms of Section 1 of the National Health Act include, amongst others, municipal health services, which is defined in the Act as including health surveillance of premises and environmental pollution control.

In addition, the Regulations Defining the Scope of Profession of Environmental Health sets out the scope of practice of EHPs, for each of the defined municipal health services. These regulations were promulgated in terms of the Health Professions Act.

In terms of these Regulations, **health surveillance of premises** by EHPs includes the following:
(a) conducting environmental health impact assessments of, amongst others, housing projects
(b) assessing aspects such as ventilation and indoor air quality, lighting, moisture-proofing, thermal quality, structural safety and floor space
(c) assessing overcrowded, dirty or unsatisfactory health conditions on any residential, commercial, industrial or other occupied premises
(d) monitoring all buildings and all other permanent or temporary physical structures used for residential, public or institutional purposes (including healthcare and other care, detainment, work and recreation, tourism, holidaying and camping) and the facilities in connection therewith and the immediate precincts
(e) ensuring urban and rural land-use planning and practices that are conducive to sustainable development by conducting sound environmental health impact and other assessments
(f) ensuring the prevention and abatement of any condition on any premises, which is likely to constitute a health hazard
(g) ensuring the health and safety of public transport facilities such as buses, trains, taxis, boats and aeroplanes as well as all other facilities in connection therewith
(h) ensuring compliance with the principles of Local Agenda 21 and the Healthy Cities approach to integrated service rendering and the practical minimising of any environmental health risk

Environmental pollution control, in terms of this regulation includes the following:
(a) ensuring hygienic working, living and recreational environments
(b) identifying the polluting agents and sources of water, air and soil pollution
(c) conducting environmental health impact assessments of development projects and policies, including assessments of major hazard installations;
(d) identifying environmental health hazards and conducting risk assessment and mapping thereof
(e) preventing accidents, e.g. owing to paraffin usage
(f) approving environmental health impact assessment reports and commenting on environmental impact assessment applications
(g) ensuring clean and safe air externally (ambient and point sources) through emission inventory monitoring, modelling and toxicological reports, reviews and complaint investigations
(h) controlling and preventing vibration and noise pollution
(i) preventing and controlling soil pollution that is detrimental to human, animal or plant life
(j) ensuring compliance with the provisions of the Occupational Health and Safety Act and its regulations, including anticipating, identifying, evaluating and controlling occupational hazards
(k) taking the required preventative measures to ensure that the general environment is free from health risks
(l) ensuring the registration, permitting, monitoring and auditing of all industries, activities, trade, etc., which

involves controlling the internal effects of pollution on the worker and the external effects of pollution on the community and the environment

(m) monitoring management of infrastructure integrity, including management of the infrastructure integrity of pipelines and tanks

(n) ensuring, jointly with other role players, a readiness for abnormal operating conditions and disasters

(o) developing sustainable indicators appropriate for monitoring the effectiveness of environmental management systems of industries

It is important to take into consideration outdoor air pollution that can be a source of indoor air pollution. The objective of the National Environmental Management: Air Quality Act is to prevent air pollution to ensure the public constitutional right to a healthy environment.

1.3 Structure of the guideline

The guideline includes the following chapters:

Chapter 1: Introduction	Provides background on the development of the guideline, including the purpose, scope of application and the legislative context.
Chapter 2: Exposure to domestic indoor air pollution	Gives a general introduction to domestic indoor air pollution exposure and highlights different indoor air pollutants, their sources, exposure pathways, related health effects and recommended guideline limit values.
Chapter 3: Domestic indoor air quality monitoring and exposure assessment	Define the role of assessment and describe different exposure assessment objectives and methodologies for IAQ.
Chapter 4: Domestic indoor air pollution interventions	Provides some recommendations to mitigate domestic indoor air pollution exposure problems, including outdoor pollution in order to protect public health.

In summary, **Chapter 1** provides the background to the document while **Chapters 2** offers a general overview of domestic indoor air pollutants and recommended guideline limit values. **Chapter 3** provides an introduction and explanation of the measurement and monitoring techniques and steps required to undertake an IAQ assessment while **Chapter 4** explains measures that can be recommended and implemented to eliminate exposure to domestic indoor air pollutants.

2. DOMESTIC INDOOR AIR POLLUTION EXPOSURE

2.1 South African situation

Domestic indoor air quality is not an easily defined concept as it is a constantly changing interaction of factors that determines the type and levels of pollutants in an indoor environment. It may be broadly defined as the characteristics of air that affects the health and comfort of building occupants. Domestic indoor air pollution (IAP) involves exposures to particulates, carbon oxides and other pollutants carried by indoor air or dust.

It is caused by an accumulation of contaminants that come from inside the building and to some extent from outside the building. According to the WHO, domestic indoor air quality has been recognised as an important risk factor for human health in both low-income, middle and high-income communities. In South Africa, the disparities that exist between these communities in terms of human settlements are vast. The low-income dwellings are usually poorly constructed, overcrowded and have insufficient living space and inadequate ventilation. Some of the old houses in these disadvantaged areas were built with asbestos roof sheeting. Most of these households have no access to electricity and use biomass fuels, coal and paraffin for cooking and space heating which contributes significantly to exposure to IAP.

The different types of housing found in South Africa within the different income communities pose a challenge in the assessment of IAQ in that the different housing structures and associated activities within the different households offers a diverse range of IAQ aspects that should be taken into account when undertaking an IAQ assessment. Dwelling types in South Africa can be broadly classified into the following groups:

- formal (houses, flats, townhouses, rooms and flatlets)
- informal (shacks, shanties)
- traditional (huts or other structures made out of traditional materials such as mud and grass)
- other (houseboats, tents, caravans)

The low-income settlements usually comprise a myriad of all the housing types while the middle and high-income settlements usually encompass the formal housing type. In terms of the formal housing types available in the low-income settlements, these are further categorised as the traditional township four roomed house and the reconstruction and development programme (RDP) (one room and up) type dwelling or the newer low cost house type dwelling. The former consists of one large room with a separate ablution facility while the latter comprises a small two-bedroom dwelling that includes a kitchen, living area and outside ablution facility.

Household energy needs in the country are met by a variety of fuels: electricity (grid, solar, dry cells, and lead acid batteries), paraffin, wood, coal, liquid petroleum gas (LPG), cow dung and other biomass fuels such as crop residues. Across much of South Africa, in particular the low-income settlements, exposure to indoor air pollution is particularly influenced by indoor fuel combustion, because many households still depend on biomass fuels, coal and paraffin for cooking and space heating. However, in South Africa, paraffin (kerosene) is nearly as popular as wood for cooking with around 50 per cent of low-income households using kerosene as compared to approximately 41 per cent using wood. Geographical locations, as well as income, are strong determinants of fuel use: low-income households in densely populated rural areas use wood, while near the coal fields coal is popular.

According to the *March 2018 Final Draft Strategy to Address Air Pollution in Dense Low-Income Settlements*, various country State of Air Reports indicate instances of exceeding ambient air quality standards in areas where domestic fuel burning is commonly used and thus impacting on residential fuel burning on ambient air quality.

The majority of households in South Africa (ca. 57 per cent) have been classified as low-income, with most in rural areas where the living conditions are still considered poor.[1.] Typically, these low-income households in South Africa cook at least twice a day. The most common method of cooking is boiling and often involves staple foods that take a long time to cook.

Although the use of dirty combustion fuels is a major contributor to indoor pollution in poor South African households, it should be noted that there are various other pollutants that are found in indoor environments covered in this guideline. Examples of such pollutants include building materials, damp environment, consumer products, cleaning and personal care products, contaminated foods and water.
There are various types and sources of hazardous indoor air pollutants that have been proven to be found indoors at concentrations that are of health concern. People spend a lot of time indoors and therefore exposure to the quality of indoor air is a major determinant of human health. Some of the domestic indoor air pollutants from the outdoor environment go through dispersion and enter through doors and windows.

2.2 Domestic indoor air pollutants human exposure pathways

There are various pathways through which domestic indoor air pollutants can enter the human body, including inhalation, skin absorption and accidental ingestion of contaminated soil/dust, water and food. **Table 1** outlines various routes of human exposure to some of the common domestic indoor air pollutants.

Table 1: Pathways/routes of human exposure to domestic indoor air pollutants

Pollutant	Routes of human exposure
Carbon monoxide	Inhalation
Nitrogen dioxide	Inhalation
Particulate	Inhalation
Benzene	Inhalation
Mould and microbes	Inhalation and skin contact
Sulphur dioxide	Inhalation
Napthalene	Inhalation is the primary route of exposure, skin absorption is a possibility and should not be ignored
Radon	Inhalation Ingestion of contaminated water
Relative humidity	Inhalation
Formaldehyde	Inhalation, ingestion and skin absorption
Polycyclic Aromatic Hydrocarbons (PAHs)	Air, soil, dust inhalation; consumption of contaminated food and water and dermal contact with soil and dust

Trichloroethylene (TCE)	Inhalation of soil gas that enters homes through cracks and foundations, ingestion of contaminated water and food and skin contact with consumer products (see details in Table 4).
Tetrachloroethylene (PCE)	Inhalation, ingestion of contaminated water and food

2.3 Sources of domestic indoor air pollutants

Domestic indoor air pollutants can be classified into three categories: particles, gases and biological.

Table 2 lists the typical **sources of indoor contaminants** that can be found in the domestic indoor environment, while **Table 3** list sources of molds in an indoor environment.

Table 2: Sources of pollutants in the domestic household environment

Bathroom	**Home office**
• Excess humidity causing mould spores • Personal care products such as air freshener aerosol sprays, medicines and cosmetics (perfume, nail polish remover, jewellery cleaner) • Detergents	Volatile organic compounds (VOC) from printers, photocopiers VOC and formaldehyde from melamine furniture
Bedroom	**Laundry**
• Dust and dust mites • Pet hair • Carpet • Carbon dioxide • Allergens • Cosmetics (perfume, nail polish remover, jewellery cleaner)	• Mould spores from leaking pipes • Detergents, disinfectants and softeners
Kitchen	**Living room**
• Lingering odours • Cooking appliances using biomass fuels, coal and paraffin • Detergents, disinfectants and softeners	• Fireplace smoke • Dust and dust mites • Second-hand cigarette smoke • Humidifiers and air conditioners • Pet hair • Carpet • Houseplants
Basement	**Garage**
• Excess humidity causing mould spores • Unpleasant odours • Carbon monoxide • Radon	• Carbon monoxide • Stored gasoline and paraffin • Stored paints, chemicals, pesticides and household cleaners • Stored firewood

• Paints, chemicals, pesticides, household cleaners, gasoline and paraffin • Stored firewood	

Table 3: Sources of moulds in an indoor environment

Moulds	Species	Origin	Indication
Water damage moulds			
Chaetomium	Globosum	Soil, air, and decaying plant material.	A sign of serious water problem.
Stachybotrys	Chartarum	Very wet gypsum boards, pipe insulation, wallpaper, asbestos building substitute.	Common in buildings with mechanical or structural defects that result to moisture damage or dampness.
Ulocladium	Chartarum and atrum	Wood, wallpaper, gypsum boards, floor and mattress dust.	Indication of water damage.
Trichoderma	Harzianum, citrinoviride, Atroviride and longibrachiatum	Mostly on wood, wallpaper, carpet and mattress dust, paint, and air-conditioning filters.	Water-damaged indoor environments.
Alternaria	Tenuissima	Wallpaper, gypsum.	Indicative of wet conditions, not just high humidity or condensation on indoor surfaces.
Aureobasidium	Pullulans	Paint especially in bathrooms and window frames.	Wet buildings.
Rhodulotorula	Rubra	Paints, wood.	Indicators of severe moisture damage in a building.
Phoma	*Aspergillus*	Paints, wood, wall paper, caulk, especially in bathrooms.	Indicators of severe moisture damage in a building
High relative humidity moulds			
Aspergillus	Versicolor	Most materials, primary coloniser, grows in dust.	Indicators of moderate damp and of relatively dry building environment.
The Penicillium Species	Chrysogenum, brevicompactum, corylophilum, palitans, expansum, Polonicum	All materials.	Indicators of relatively dry building environment.

Aspergillus	Sydowii	Most materials, primary coloniser.	Indicators of moderate damp building environment.
Aspergillus	Ustus	Food, soil and indoor environments.	Indicators of moderate damp building environment.
Cladosporium	Sphaerospermum	Paints, wood, wall papers, caulk, especially in bathrooms.	Indicators of moisture damage building environment.
Cladosporium	Herbarum	Paints, wood, wall paper, caulk, especially in bathrooms.	Indicators of moisture damage building environment.
High relative humidity moulds			
Eurotium	Repens	Carpet dust.	Indicators of moisture damage building environment.
Wallemia	Sebi	Wall cavity or on the underside of a carpet.	Indicators of moisture damage building environment.
Paecilomyces	Variotii	Air, damp walls, wet plaster work, carpet dust and HVAC fans.	Indicators of moisture damage building environment.
Aspergillus	Niger	Floor, carpet and mattress dust, acrylic paint, leather, HVAC filters and fans, and potted plant soil.	Indicators of moisture damage building.

2.4 Health effects of domestic indoor air pollutants

Indoor exposure to air pollutants causes very significant damage to health globally especially in developing countries, South Africa included. According to the WHO document, 4.3 million deaths globally were attributable to indoor pollution, with 580 000 of those in Africa, primarily as a result of domestic use of solid fuel for heating, lighting and cooking. According to the *2013 Situational Analysis and Needs Assessment* completed in fulfilment of the Libreville Declaration on Health and Environment in Africa, respiratory diseases and lung cancer are amongst the main health diseases/conditions of concern influenced by environmental pollution in South Africa. Women, children and people with pre-existing heart and respiratory health conditions are more vulnerable.

Table 4 summarises the health effects of some of the general commonly found indoor pollutants and their indoor and outdoor sources.

Table 4: Health effects of general common domestic indoor pollutants

Pollutant	Origin		Health effects
	Outdoor sources	Indoor sources	
Carbon monoxide	• Petrol and diesel powered motor vehicles exhaust emissions from traffic. • Burning of wood, petrol, coal and natural gas, wildfire smoke.	• Biomass combustion (burning of wood, petrol, coal, charcoal, crop waste, natural gas and kerosene). • Tobacco smoking. • Incense burning.	When inhaled, carbon monoxide enters the blood stream to produce carboxyhemoglobin, which reduces the ability of blood to carry oxygen to vital body organs such as the heart and brain. Acute exposure causes related reduction of exercise tolerance and increase in symptoms of ischaemic heart disease (e.g. ST-segment changes).
Nitrogen dioxide	• Petrol and diesel powered motor vehicles exhaust emissions from traffic, fuel combustion. • Off-road sources such as construction, lawn and gardening equipment. • Industrial emissions.	• Combustion appliances fuel-burning heating systems (wood, oil, natural gas, fireplaces etc.). • Fuel-burning stoves - (wood, kerosene, natural gas, propane, etc.). • Tobacco smoking	Nitrogen dioxide irritates the lungs. It can decrease lung function and increase susceptibility to allergens for people with decreased immune defense, leading to increased susceptibility to respiratory infection with asthma. Prolonged exposure to low levels of nitrogen dioxide has been found to increase the risk of respiratory symptoms such as coughing and wheezing, bronchoconstriction, increased bronchial reactivity and airway inflammation.
Particulates	Natural processes, ammonia operation from agricultural processes, petrol and diesel powered motor vehicles exhaust emissions from traffic, fuel combustion (wood, dung, crop wastes, charcoal, coal), wildfire smoke.	Cooking, smoking, combustion appliances (wood, dung, crop wastes, charcoal, coal, kerosene lamps and stoves).	The size of particles is directly linked to respiratory symptoms such as wheezing and coughing, especially in children.
Benzene	Petrol stations and certain industries (e.g. coal, oil, natural gas, chemicals and steel).	Building materials and furniture, attached garages, heating and cooking systems, smoking tobacco and stored solvents	It is a genotoxic carcinogen and hence studies have not recommended any safe level of exposure.
Mould and microbes	• Natural sources such as rain, ground moisture/water melting snow and	• Mould growth usually occurs when building material becomes exposed to a moisture source or when	• Moulds are recognised by its musty smell and airways diseases and rhinitis.

Pollutant	Origin		Health effects
	Outdoor sources	Indoor sources	
	flooding of surface water. • Outdoor air from breathing and perspiration from humans, plants and animals.	inadequate ventilation promotes relative humidity build up. • Dampness caused by poor building location or plumbing leakages from water supply, sewage, air conditioning systems and fire extinguisher systems. • Breathing and perspiration from humans, plants and animals. • Damp indoor environments attract termites, fungi, viruses, bacterial growth and house dust mites. Dust mites are common in mattresses and carpets or rugs.	• Moulds produce allergens, irritants and in some cases mycotoxins (toxic substances). • Exposure to moulds can induce respiratory illness in adults and cause early onset of asthma and allergies in children. Inhaling or touching mould or mould spores can cause allergic reactions such as irritation of the skin, eyes, nose, throat and lungs.
Sulphur dioxide	Combustion of fuels (coal and oil) containing sulfur, metal smelting involving roasting metal sulfide ores, use of automobile diesel.	Combustion of fuels (coal and oil) containing sulfur, kerosene stove and lamp.	Damage to the epithelium of the airways; epithelial hyperplasia; bronchoconstriction and respiratory symptoms.
Napthalene	• Production of plasticisers, paints, and synthetic resins. • Ingredients for plasterboards. • Fugitive emissions (from petrol stations and oil refineries) and petrol and diesel powered motor vehicles exhaust emissions from traffic.	• Consumer products such as multipurpose solvents, lubricants, herbicides, charcoal lighters and hair sprays, naphthalene insect repellents (mothballs). • Unvented kerosene heaters and tobacco smoke.	Respiratory tract lesions leading to inflammation and malignancy.
Radon	• Naturally occurring radioactive gas emitted from bedrock.	• Diffuses through soil into cracked walls and foundations of residences.	Associated with lung cancer, in particular leukemia and cancers of extra thoracic airways.

Pollutant	Origin		Health effects
	Outdoor sources	Indoor sources	
	• Very little radon is contained in river and surface reservoir water supplies while high concentrations are found in groundwater that may enter the water supplies.	• Contaminated indoor water supplies.	
Relative humidity	Natural rain water flooding and ground water intrusion.	• Originate from plumbing (water supply, sewage, and air conditioning, heating systems leakages, water emissions from cooking, cleaning, shower / bath, dishwashing, washing and drying laundry. • Occupants breathing and perspiration. • Allowing surfaces to become cooler than the surrounding air that may result in unwanted condensation or the ground.	Too low humidity causes eye irritation, dry skin, dry nose and rashes, while high humidity promotes the growth of moulds and microbes. *See health effects of moulds and microbes earlier in* ***Table 4****.*
Formaldehyde	• Biomass combustion (forest and bush fires) or decomposition. • Through volcanoes. • Combustion processes (power plants, incineration, etc.) • Industrial emissions and fuel combustion from traffic.	• Tobacco smoking, heating, cooking or candle or incense burning. • Kerosene stove and lamp. • Building materials, consumer products, furniture and wooden products emitting formaldehyde. • Paints, wallpapers, glues, adhesives, varnishes and lacquers.	High concentrations of formaldehyde can cause irritation of the eyes, nose and throat and can worsen asthma symptoms in children and infants.

Pollutant	Origin		Health effects
	Outdoor sources	**Indoor sources**	
	• Secondary formation of formaldehyde occurs in air through the oxidation of volatile organic compounds (VOCs) and reactions between ozone (mainly from outdoors) and alkenes.	• Household cleaning products (e.g. detergents, disinfectants, softeners, carpet cleaners and shoe products). • Cosmetics (e.g. liquid soaps, shampoos, nail varnishes and nail hardeners). • Electronic equipment (computers and photocopiers).	
Polycyclic aromatic hhydrocarbons (PAHs)	Petrol and diesel powered motor vehicles exhaust emissions from traffic, industrial plants, power generation plants, waste incinerators and open burning.	Combustion appliances (fuel stoves, open fireplaces, kerosene stoves and lamps), incense and candle emissions.	PAH compounds can lead to cancer if high exposures occur.
Trichloroethylene (TCE)	Contaminated soil.	• Contaminated drinking water. • Use of wood stains, varnishes, finishes, lubricants, adhesives, typewriter correction fluid, paint removers and certain cleaners. • In foodstuffs where TCE is used e.g. butter and margarine, though banned in some countries.	Carcinogenicity (liver, kidney, bile duct and non-Hodgkin's lymphoma), with the assumption of genotoxicity.
Tetrachloroethylene (PCE)	• Dry clean facilities. • Polluted soil.	• Contaminated drinking water. • Dry cleaned clothes.	Effects in the kidney indicative of early renal disease and impaired performance.

2.5 Domestic indoor air quality guideline limit values

The air quality guideline limit values for the list of pollutants covered in this guideline are presented in **Table 5** and have been adopted from the *WHO 2006, 2009 and 2010 Indoor Air Quality Guidelines*. **Table 6** outlines fuel emission rate targets guideline values for particulate matter ($PM_{2.5}$) and carbon monoxide (CO) in clean household fuels and technologies that have been adopted from the 2014 WHO IAQ: Household energy combustion, and have been proven to cause minimal health hazards. The fuel emission rate targets have been set for $PM_{2.5}$ and CO, because these are the two most important products of incomplete combustion for health, though it is acknowledged that there are other pollutants of health concern.

The listed substances are identified critical pollutants that are common in the indoor environment and have been proven to have concerning high indoor exposure levels and scientific evidence exists that they cause health effects. The decision on identified pollutants is based on professional expert judgment on studies of the health effects of indoor and outdoor exposure to these pollutants, where the strength, quality, diversity and number of studies were taken into consideration.

Across South Africa, exposure to domestic indoor air pollution is particularly influenced by indoor fuel combustion. In many situations, indoor air quality problems may be attributable to the lack of technology necessary to mitigate indoor air pollution (e.g. chimneys, hoods or use of clean fuels). There is, however, a realisation that practical measures to improve general domestic indoor air quality need not always focus on specific pollutants or target specific concentration levels. In some cases, introducing effective measures to improve domestic indoor air quality may be more cost effective than identifying the key pollutants and measuring their concentrations.

It is considered that the guideline limit values will be most effective when used in conjunction with other strategies, for example, the use of appropriate fuels and exposure reduction. This guideline takes the view that the guideline limit values set in **Table 4** are health guidelines that act as an indicator of pollutants concentration level and exposure period at which reduced health effects can occur, however if exceeded, mitigation actions should be initiated to protect public health. Particulate matter ($PM_{2.5}$) and carbon monoxide (CO) are the two primary pollutants from household combustion fuels and technologies that have been identified to be of major public health concern, hence fuel emission rate targets guideline values as prescribed in **Table 5** have been set. The targets were set to determine if fuel emission rates from used clean household fuels and technologies are within the acceptable emission levels in order to meet the WHO air quality guideline values.

These guideline limit values are used to determine acceptable indoor pollution levels to which people can be exposed and to guide any intervention action that should be taken where necessary. Furthermore, the guideline limit value is not to be regarded as a regulatory limit or standard that is to be legally enforced. To have such in the country, a number of socio-economic factors such as poverty alleviation with access to affordable clean energy (electricity, LPG gas, solar energy) should first be addressed. People can be provided with clean fuels but if it is unaffordable, reliance on the use of dirty fuels for cooking and heating will continue. This is a major challenge that needs to be addressed by various stakeholders in the country. Routine monitoring of homes during weekdays to ensure compliance will be a challenge in terms of access.

Nevertheless, the WHO is aware of some of these challenges in developing countries, and will continue to provide technical guidelines to ensure the goal of elimination exposure to IAP is achieved.

Table 5: Domestic indoor air quality guideline limit values

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
Carbon monoxide	mg/m^3	15 minutes	100	WHO IAQ Guideline, 2010	Exposure to this level should not occur more than once per day. Light exercise can be done.
		1 hour	35		Exposure to this level should not occur more than once per day. Light exercise can be done.
		8 hours	10		Arithmetic mean concentration. Light to moderate exercise.
		24 hours	7		Arithmetic mean concentration. Awake and alert but not exercising.
Particulate matter (PM) Guidelines for PM do not offer complete protection against adverse health effects of PM, as thresholds have not been identified. Guideline values given provide guidance on the concentration at which increasing and specified mortality	$\mu g/m^3$	24 hours	25	WHO AQ Guideline, 2006	For the 24-hour guideline a maximum of three days exposure per year. Guideline value is based on the relation between 24-hour and annual PM levels.
		IT-1	75		NB. Interim Targets (IT) - In areas where it is a challenge to meet the guideline value, IT should be used to measure progress towards achievement of the guideline value. Based on published risk coefficients from multicentre studies and meta-analyses (about five per cent increase in short-term mortality over AQG).
		IT-2	50		Based on published risk coefficients from multicentre studies and meta-analyses (about 2.5 per cent increase in short-term mortality over AQG).
		IT-3	37.5		About 1.2 per cent increase in short-term mortality over AQG.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
responses due to PM are expected.		Annual mean/ average	10		These are the preferred guidelines in comparison to 25µg/m³, 24-hour guideline value for $PM_{2.5}$.
		IT-1	35		These levels are estimated to be associated with about 15 per cent higher long-term mortality than at AQG levels.
		IT-2	25		In addition to other health benefits, these levels lower risk of premature mortality by approximately six per cent (two to eleven per cent) compared to IT-1.
		IT-3	15		In addition to other health benefits, these levels reduce mortality risk by approximately another six per cent (two to eleven per cent) compared to IT-2 levels.
	PM_{10} µg/m³	24 hours	50	WHO AQ Guideline, 2006	Based on relation between 24-hour and annual PM levels
			IT- 1 =150		Refer to notes under $PM_{2.5}$ µg/m³, IT-1, under 24-hour average time.
			IT-2 = 100		Refer to notes under $PM_{2.5}$ µg/m³, IT-2, under 24-hour average time.
			IT- 3 = 75		Refer to notes under $PM_{2.5}$ µg/m³, IT-3, under 24-hour average time.
		Annual mean/ average	20		These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95 per cent confidence in response to PM2.5. The use of the PM2.5 guideline (10) is preferred.
			IT – 1 = 70		Refer to notes under $PM_{2.5}$ µg/m³, IT-1, under annual mean average time.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
			IT – 2 = 50		Refer to notes under $PM_{2.5}$ µg/m³ , IT-2, under annual mean average time.
			IT – 3 = 30		Refer to notes under $PM_{2.5}$ µg/m³ , IT-3, under annual mean average time.
Nitrogen dioxide	µg/m³	1-hour mean/ average	200	WHO IAQ Guideline, 2010	No evidence from epidemiological studies for an exposure threshold. Studies of the indoor environment provide no evidence for an indoor guideline different to the ambient guideline.
		annual mean/ average	40		
Formaldehyde	mg/m³	30 minutes average	0.1		The guideline is valid for any 30 minutes period and will also prevent effects on lung function, including long-term health effects, such as nasopharyngeal cancer and myeloid leukaemia.
Benzene	µg/m³	Refer to guideline limit	• No safe level of exposure is recommended. • The individual possibility of lifetime (over 70-year lifetime) risk of leukemia when exposed to an air concentration of 1 µg/m3 is 6 × 10^{-6}(or 60 chances per million). • Excess individual possibility of lifetime (over 70 year lifetime) risk of leukemia when exposed to an air concentration of : ○ 17 µg/m3 is 1 chance per 10 000)		No safe level of exposure can be recommended. It should be kept as low as possible. Cancer unit risk factor for different compounds are already determined.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
			○ 1.7 µg/m3 is 1 chance per 100 000) ○ 0.17 µg/m3 is 1 chance per 1 000 000)		
Mould and allergens		n/a	High (aw, > (water activity) 0.90; ERH (equilibrium relative humidity), > 90%)	WHO IAQ Guideline for Dampness and Mould, 2009	Inadequate ventilation, dampness and excess moisture is the cause of growth of microbial organisms and allergens
Microorganism - Tertiary colonizers (hydrophilic) Alternaria alternata Aspergillus fumigatus Epicoccum spp. Exophiala spp. Fusarium moniliforme Mucor plumbeus Phoma herbarum Phialophora spp. Rhizopus spp. Stachybotrys chartarum (S. atra) Trichoderma spp. Ulocladium consortiale Rhodotorula spp. Sporobolomyces spp.					Moisture levels required for growth of selected microorganisms in construction, finishing and furnishing materials.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
Actinobacteria (or Actinomycetes)					
Microorganism-Secondary colonizers Aspergillus flavus Aspergillus versicolora Cladosporium cladosporioides Cladosporium herbarum Cladosporium sphaerospermum Mucor circinelloides Rhizopus oryzae	%	n/a	Intermediate (aw, 0.80–0.90; ERH, 80–90%)		Moisture levels required for growth of selected microorganisms in construction, finishing and furnishing materials.
Microorganism - Primary colonizers (xerophilic) Alternaria citri Aspergillus (Eurotium) amstelodami Aspergillus candidus Aspergillus (Eurotium) glaucus	%	n/a	Low (aw, < 0.80; ERH, < 80%)		Moisture levels required for growth of selected microorganisms in construction, finishing and furnishing materials.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
Aspergillus niger Aspergillus penicillioides Aspergillus (Eurotium) repens Aspergillus restrictus Aspergillus versicolorb Paecilomyces variotii Penicillium aurantiogriseum Penicillium brevicompactum Penicillium chrysogenum Penicillium commune Penicillium expansum Penicillium griseofulvum Wallemia sebi Note. aw,					
Sulphur dioxide	µg/m3	10 minutes	500	WHO AQ Guideline, 2006	Sharp peaks exposure depends on the nature of local sources and meteorological conditions.
		24 hours	20		As the 24-hour guideline might be difficult to achieve, IT for it have then been set.
			IT – 1= 125		None.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
			IT – 2 = 50		Intermediate goal based on controlling either (*a*) motor vehicle (*b*) industrial emissions and/or (*c*) power production
Napthalene	mg/m^3	annual mean/ average	0.01	WHO IAQ Guideline, 2010	The long-term guideline is assumed to prevent potential malignant effects in the airways. No reliable human data for long-term inhalation toxicity are available
Relative humidity	%	n/a		WHO IAQ Guideline for Dampness and Mould, 2009	NB: Ideally relative humidity should be kept below the guideline limits.
			<45		The guideline limit prevents mould and dust mites.
	%	n/a	<75		The guideline limit prevents mould fungal growth in buildings.
	%	n/a	75–90		Critical relative humidity (maximum long-term relative humidity) allowed for non-growth in clean building materials.
	%	n/a	75–80		Critical relative humidity (maximum long-term relative humidity) allowed for non-growth in contaminated or soiled building materials.
	%	n/a	75-80		Critical relative humidity allowed for non-growth in wood and wood-based materials.
	%	n/a	80-85		Critical relative humidity allowed for non-growth in paper on plasterboard.
	%	n/a	90-95		Critical relative humidity allowed for non-growth in mineral insulation materials.
	%	n/a	90-95		Critical relative humidity allowed for non-growth in extruded and expanded polystyrene.
	%	n/a	90-95		Critical relative humidity allowed for non-growth in concrete.

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
Polycyclic Aromatic Hydrocarbons (PAH)	B[a]P ng/m³	Refer to guideline limit	• No safe level of exposure is recommended. • The individual possibility of excess lifetime (over 70 year lifetime) risk of leukaemia when exposed to an air concentration of 1 ng/m³ B[a]P is 8.7×10^{-5} (or 87 chances per 100 000).	WHO IAQ Guideline, 2010	B[*a*]P is taken as a marker of the PAH mixture.
Radon	Bq/m³	Refer to guideline limit	100	WHO IAQ Guideline, 2010	Among ex-smokers, the risk is intermediate, depending on the time since smoking cessation.
Trichloroethyl ene	µg/ m³.	Refer to guideline limit	• 4.3×10^{-7} per µg/m3. • The concentrations of airborne TCE associated with an excess lifetime cancer risk of 1:10 000 is 2.3 µg/m³ , 1:100 000 is 23 µg/m³and 1:1 000 000 is 230 µg/m³	WHO IAQ Guideline, 2010	
Tetrachloroeth ylene	mg/m³	Annual average	0.25 mg/m³	WHO IAQ Guideline, 2010	Carcinogenicity is not used as an endpoint as there are no indications that tetrachloroethylene is genotoxic. There is uncertainty about the

Pollutant	Units	Averaging time	Concentration guideline limit	Reference	Notes
					epidemiological evidence and the relevance to humans of the animal carci nogenicity data.

An explanation of the various acronyms is provided in the Glossary

Table 6: Fuel emission rate targets guideline values for particulate matter ($PM_{2.5}$) and carbon monoxide (CO) in clean household fuels and technologies

Pollutant	Emission rate guideline value	Intermediate Emission Rate Target	Notes
Particulate matter	PM2.5 (unvented) - 0.23 (mg/min)	1.74 mg/min	**Fuel emission rates** For PM2.5, these are the fuel emission rates required to meet WHO (annual average) air quality guidelines and interim target-1 (IT-1). For CO, these are the fuel emission rates required to meet WHO (24-hour average) air quality guideline for CO. The fuel emission rates indicate the rate at which 90 per cent of the homes will reach the WHO IAQ guideline values. **Interim target (IT)** This is the target set for areas where it is a challenge to meet the guideline value. The IT can be used to measure progress towards achievement of the guideline value. **Intermediate emission rate target** This I The target rate that will result in 60 per cent of homes meeting IT-1 for PM2.5and the 24-hour AQG for CO. Intermediate emission rate target should be used to monitor progress towards achievement of the emission rate guideline values.
	Interim Targets (IT) – 1 = 35		
	PM2.5 (vented)- 0.80 (mg/min)	7.15 mg/min	
Carbon Monoxide	CO (unvented) - 0.16 (g/min)	0.35 g/min	
	CO (vented)- 0.59 (g/min)	1.45 g/min	

3. DOMESTIC INDOOR AIR QUALITY MONITORING AND EXPOSURE ASSESSMENT

A domestic indoor air quality monitoring and exposure assessment is used to determine household and community exposure to a potentially hazardous indoor air pollutant, the concentration level, duration, route and media of exposure. People are exposed to indoor air pollutants depending on the activities of individuals.

In this guideline, the approach recommended by the WHO has been embraced and the term "monitoring" within this guideline is defined so as to include a more holistic approach to improving indoor air quality than that based on "measurements" alone.

For the purpose of this guideline, **monitoring** – refers to an assessment of indoor air quality conditions within a building, based on a survey of different parameters, for example, potential pollution sources, building condition, ventilation and air quality measurements.
Measurement – refers to the characterisation of indoor air quality by quantifying specific pollutant concentrations or other parameters (e.g. humidity levels).

3.1 Objective and principles of domestic indoor air quality monitoring and exposure assessment

It is important that the principles and objectives for domestic indoor air quality monitoring and exposure assessments be outlined in order to determine the assessment approach, define the assessment protocol**,** methodology to be applied and ethical issues to be considered.

The objectives of a domestic indoor air quality monitoring and exposure assessment is to:

- determine the source of the problem to poor domestic indoor air quality
- determine whether a guideline limit has been exceeded
- quantify pollution trends to identify future problems or progress in achieving the domestic indoor air quality guideline limits
- support "ad hoc" air quality and health studies
- inform the affected households and community about the status of air quality they are exposed to and advise or educate on intervention measures to be exercised to eliminate exposure
- assist in investigation and management of complaints related to exposure to poor domestic indoor air quality
- support monitoring of IAQ as part of existing ambient air quality monitoring in the country
- determine the effectiveness of any adopted indoor pollution reduction interventions
- provide the information required by non-governmental organisations, industries, policy-makers and planners and make informed decisions to contribute towards improving the quality of air in the environment and to protect human health

The following principles should be considered during a domestic indoor air quality monitoring and exposure assessment**:**

- **designing and planning a monitoring system**
  A monitoring system should be planned and designed, taking into consideration pollutants in question and objective to achieve.
- **cost-effectiveness**
  Monitoring programmes need to be cost-effective, have stable financial, material and personnel resources and be adjusted to local needs and conditions.
- **simple technologies**
  Simple technologies and procedures that are consistent with fulfilling the overall objectives of monitoring should be used.
- **quality assurance**

Quality assurance should be exercised to ensure measurements are accurate, reliable and are suitable for the intended purpose.

- **communication**
  Information from monitoring programmes should be managed and communicated to researchers, health policy makers and the public, since they have the right to know about the quality of air they breathe and to raise awareness and educate communities.

3.2 Techniques for monitoring and assessing domestic indoor air pollution exposure

There are various ways to monitor and assess domestic indoor air pollution exposure, which include qualitative and quantitative methods. Qualitative methods include the use of in-depth, open-ended interviews and direct observations of behaviours. Direct observations of behaviours can be done using the walk-through survey technique. Quantitative methods include the use of domestic indoor air pollution monitoring techniques and questionnaires. Quantitative methods can be used to compare one intervention with another. One method may be deemed to be sufficient or a combination of both can be used to draw conclusions on the quality of the indoor air relating to the effects on health, however best practice is choosing the simplest technique that will do the job.

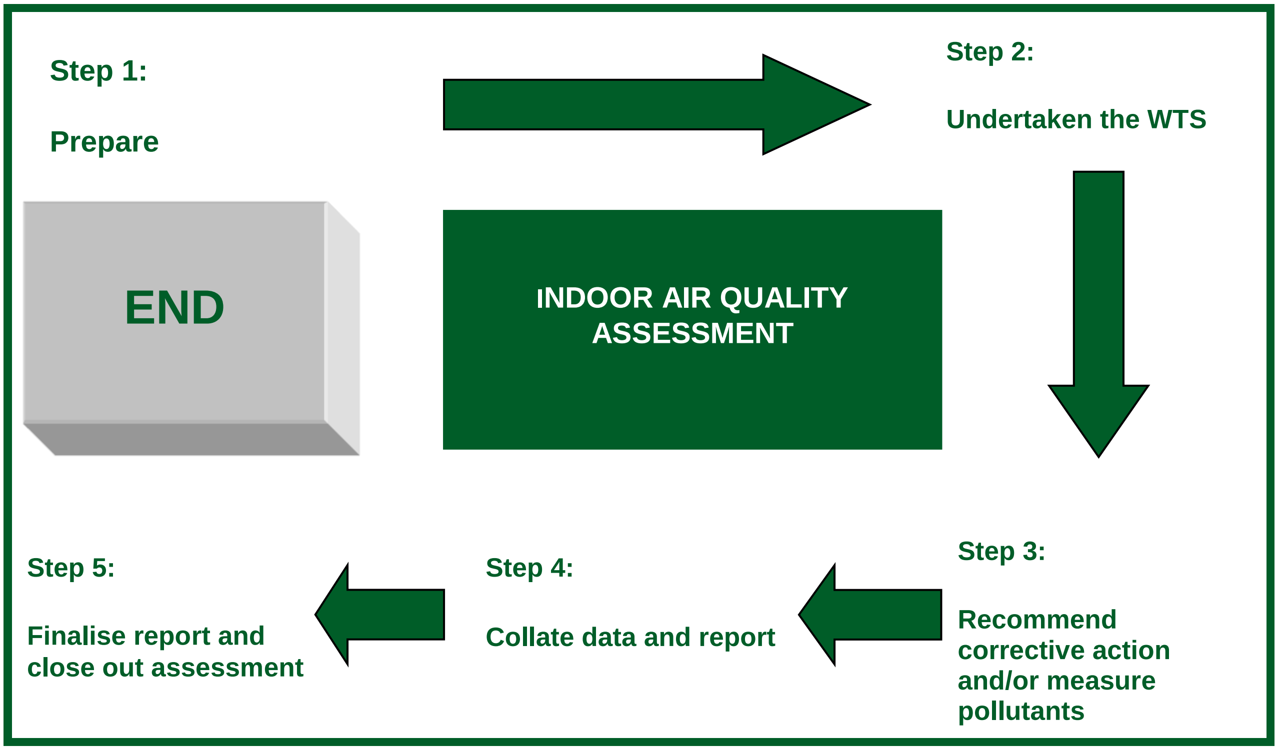
Taking into consideration that the WHO recognises that the management of indoor air quality requires different approaches to those applicable to outdoor exposures, this guideline focus on feasible approaches to reduce the health risks from indoor air pollutants. Based on the epidemiological evidence that links exposure to PM and CO to various health outcomes, the WHO regards PM and CO as primary pollutants of interest for both health effects and IAP monitoring. Considering financial challenges that may be encountered by municipalities and other interested organisations in procuring available technologies, due to the relative associated cost, the WHO recommends that organisations focus on measuring levels of PM 2.5 and CO as a start.

Taking into consideration various IAP sources, which includes outdoor air, the characteristics that can be measured for IAP exposure that are recommended by WHO include personal exposure, indoor pollution concentrations and outdoor pollution emissions, which determines population exposure. These characteristics can be measured using qualitative and quantitative methods recommended by WHO for IAQ monitoring and assessment.

3.3 Domestic indoor air quality monitoring and assessment steps

The following steps to monitor and assess indoor air pollution are useful in assessing personal exposure and indoor pollution concentrations, as they incorporate WHO-recommended qualitative and quantitative methods such as direct observation of behaviours by using walk-through surveys (WTS) and taking measurements of levels of indoor pollutants in line with relevant ethical considerations.

Figure 1: Five-step IAQ assessment process



An IAQ assessment pack has been designed to support the five-step process.

3.3.1 Step 1 – Prepare

a. Why prepare in advance when undertaking an IAQ assessment?

In preparing for an IAQ assessment, one puts into perspective the assessment objectives and protocol to be applied. Part 1 **(Assessment protocol)** of the IAQ assessment pack (**Appendix 1**) provides a template on which the protocol can be documented.

The following should be considered in preparation for the assessment:

- clarify the reason and define the objectives and methodology of the IAQ assessment
- identify and understand the potential pollutants of concern
- understand the pollutant guideline limit values to be used
- specify the types of equipment likely to be used in the event that measurement of pollutants is required

b. Ethical considerations during preparation:

- legal requirements (e.g. National Building Regulations or local by-laws)
- in the event of a complaint:
  - contact dwelling or institution representative in advance to sensitise about the visit and to access the dwelling or institution
  - ensure that the time of the visit is suitable for the representative
  - consider that this may be after working hours to accommodate their schedule
  - prepare the consent form in Section 3 of the IAQ assessment pack

- in the event of a survey or as a result of a study
  - meet the community leader in the area to inform them of the proposed sampling and explain the sampling objectives and strategy
  - allocate time for pre-site visits to sensitise dwelling representatives of the survey or study and ensure that they are informed of the intention to undertake the monitoring
  - during this pre-visit ensure that suitable time for the WTS and measurement survey to be undertaken is requested if the representative agrees to the monitoring
  - discuss the reason that a consent form needs to be signed
  - thank the community leader representative

- in the event of sampling:
  - pollutants that will be measured
  - general sampling point locations
  - duration and frequency of sampling
  - identification of all equipment and sampling methodology to be used
  - protocol for handling sample transportation
  - identification of the laboratory that will undertake analysis of the samples collected
  - all field and laboratory QA/QC (quality assurance/quality control) checks to be employed
  - identification of the personnel that will be undertaking the sampling

Remember to document the assessment protocol derived from the preparation undertaken in Part 1 of the IAQ assessment pack.

3.3.2 Step 2 - Walk-through survey (WTS)

The walk-through survey (WTS) is considered to be the first essential component of any IAQ assessment.

It should be undertaken as an initial step in an IAQ assessment and used to gather pertinent information on the dwelling being assessed and the behaviour and practices of the occupants. A WTS is essential for an IAQ assessment as it provides information based on observation of the following aspects:

- building characteristics
- occupant behaviour
- condition of wall, roof and floor surfaces
- pollutant sources

a. Ethical considerations during the WTS

- Ensure that you arrive at the specified time of your appointment with the household.
- Ensure that the consent form is understood by the dwelling representative when requesting a signature.
- Explain how the WTS will be undertaken and the reasons for the questions that may be raised.
- Ask permission before entering each of the rooms in the dwelling.
- Respect the customs and practices of the household. (Eg. If shoes have to be removed prior to entering the dwelling or a certain room in the house).
- Thank the dwelling representative for their time and allowing access to the property.

Appendix 1: **Comprises of checklists and templates listed in the below box to assist in undertaking an IAQ assessment.**

Part 1:	Part 2:	Part 3:	Part 4:	Part 5:
Assessment protocol	*WTS checklist*	*Floor plans*	*Pollutant measurement results*	Additional comments for reporting

A WTS should be performed as follows:

- To access the property in order to undertake a WTS, the ethical considerations should be complied with before entering the household or institution and the consent form in **Appendix 2** must be signed by the dwelling or institution representative. The signed consent form should be attached to the completed WTS checklist.

- The WTS checklist is provided in **Appendix 1** IAQ assessment pack to guide personnel through conducting the survey. It is also used to prompt the household or institution representative to answer pertinent questions and to note observations of activities and practices in an attempt to diagnose the IAQ problem.

The WTS checklist provides for observations in different rooms in the dwelling and sufficient copies of these sections should be made to ensure that observations from all rooms are noted.

NB. When undertaking the WTS, the checklist may need to be adapted to suit the type of housing as noted in the introduction. For example, in a one-room house, not all sections of the checklist would need to be completed. Similarly, in a large house, more copies of Part 2a of the checklist may be required.

- A floor plan sketch of the dwelling should be drawn in Part 3 of the **Appendix 1** IAQ assessment pack to give an indication of the pollutant sources.

- **Tables 2 and 3** can be used as a reference to identify the possible location of various pollutants.

  Table 3 focus specifically on different mould species. Conducting further literature research is encouraged.

NB. Evidence of the following issues should be assessed during the WTS:

- ventilation problems – such as high levels of odour, high temperatures, stuffiness, excess dust and humidity
- water intrusion problems – such as cracks/ bulging/ discolouration of walls, ceilings and carpeting – evidence of mould
- structural failures – roof leaks and moulds growing on outside walls
- overall cleanliness of the dwelling – such as dustiness and food or drink spills
- fuel(s) used for cooking and space heating – evidence of adequate ventilation
- personal behaviour e.g. tobacco smoking, use of household products

- When carrying out the WTS, it is imperative to take account of the temporal and spatial variability of indoor air quality problems.

  Domestic indoor air pollution levels may vary significantly depending on activity levels e.g. space heating may only be used at certain times of the year; cooking will only be carried out for parts of the day.

  Doors and windows to buildings will normally only be opened during periods of warm weather. Thus, pollution levels arising from indoor combustion may be many times greater during the cold months and in the early evening; at such times both space heating and cooking is likely to be used and doors and windows are likely to be closed. Care should therefore be taken in the timing of the WTS and the conclusions that are drawn from it. Where appropriate, it could be necessary to delay the WTS or to include a second visit in the assessment.

- Once the WTS is complete, an overview of the findings of the WTS and other information gathered previously needs to be undertaken to determine if corrective actions could be applied or if further pollutant measurements need to be done. Details of how to undertake pollutant measurements is outlined in **Step 3**.

3.3.3 Step 3 - Recommend corrective action and/or measure pollutants

3.3.3.1 Recommend corrective action

If corrective actions are recommended, the following activities should be undertaken:

a. If there is a domestic indoor air quality problem that can be resolved by applying different practices or implementing recommended corrective actions, the EHP should document this on the WTS checklist for discussion with the dwelling representative. Depending on the source of the IAQ problem, a number of corrective actions to manage IAQ can be recommended by the EHP.

   Details of how to undertake the discussion with the property representative are as follows:
   - once the WTS is complete, the EHP should conclude by explaining the findings, recommendations and potential for further pollutant measurements to the dwelling representative
   - the EHP should remember the following in this communication:
   - keep the explanation easy and simple to understand
   - explain the observations noted during the WTS and their significance

b. Describe possible corrective measures that the representative could put in place to mitigate the IAP. Examples of such corrective actions which are non-exhaustive are provided in **Chapter 4.**
   (It must be noted that these corrective measures can either be recommended by the EHP after the WTS or as part of a coordinated response to the household based on the communication protocol applied at each institution. It may be that the EHP would have to report back to a manager before feedback to the household).

3.3.3.2 Recommended measurement of pollutants

Measurements of pollutants can be undertaken to serve as an indicator as to whether a potential IAQ problem exists, the possible indoor location and the level of exposure to a pollutant. Measurements of pollutants during the WTS act as a "snapshot" of the indoor air conditions that change from hour to hour and day to day. Direct reading instruments for the measurement of pollutants can be used during the WTS for short period of sampling with repeated measurements at the same location to confirm the indoor pollution high concentration levels. However, it should be noted that longer term sampling would be far more indicative of the indoor air environment.

Measurements of indoor air quality when applied correctly, can:

- provide unequivocal information on public exposures to indoor air pollutants
- provide information for comparison with indoor air quality guidelines limit values
- identify the magnitude of the problem and provide an evidence base for interventions
- assist in determining the effectiveness of interventions

It should be noted that methods to measure fuel emission rates for particulate matter (PM 2.5) and carbon monoxide (CO) in clean household fuels and technologies to compare with the guideline values targets as outlined **Table 6** are not yet available, but according to the WHO it is in the process of being developed. Although methods to assess clean stove emissions is not yet in place, the measurement of PM 2.5 and CO levels using the methods prescribed in this guideline can also determine the extent of domestic indoor air pollution and thus impact on health.

If measurement of pollutants is recommended, ethical considerations are to be considered before and during sampling.

a. Ethical considerations during sampling

- Obtain consent before, ensure the consent form in **Appendix 2** is completed.
- Be diplomatic when explaining the various recommendations.
- Ensure that the agreed times for sampling and site visits are adhered to.
- Ask permission before entering each of the rooms in the dwelling.
- Respect the customs and practices of the household. (E.g. If shoes have to be removed prior to entering the dwelling or a certain room in the house).
- Ask permission if it is necessary to move any asset indoors.
- Thank the dwelling representative for their time and allowing access to the property.

b. Quality assurance/quality control (QA/QC) ethical considerations for Step 3

When indoor air quality monitoring is carried out, it is important to ensure that the data are “fit for purpose” in all cases i.e. that the results of the monitoring campaign provide information that is sufficiently robust to meet the overall objectives and to allow the appropriate conclusions to be drawn. All monitoring campaigns, be they short-term “spot” measurements, or long-term measurements carried out over several days, weeks, or longer, should be subject to an appropriate level of QA/QC.

The overall aim of the QA/QC procedure is to ensure that the monitoring data fulfil the objectives of the assessment. In this context, quality assurance and quality control play two fundamentally different roles.

Figure 2: Difference between quality assurance and quality control outlined

i. Quality assurance procedures for IAQ monitoring

The quality assurance procedures associated with indoor air quality monitoring should include the following elements:

- monitoring strategy
- instrument selection
- instrument calibration and field blanks (where appropriate)
- instrument service and repair
- sample handling and analysis
- operator training

Monitoring strategy: It is important that the purpose and objectives of any assessment are always fully documented, and that the requirements with regard to the accuracy and precision of measurements and the duration of the monitoring campaign are consistent with fulfilling these objectives.

Instrument selection: The outcome of the monitoring protocol will determine what type of sampling method is required to meet the objectives of the assessment. For example, can the monitoring be time-integrated, or does it need to provide real-time data? What detection limit is required for comparison with the guideline limit values? In some cases, a combination of methods may be appropriate. As a general guideline, the detection limit of the method should be less than 10 per cent of the guideline limit value.

Instrument calibration and field blanks: Instruments should be calibrated according to manufacturers' specifications, using certified blanks and standards. These calibrations should normally be carried out before the instruments are taken onto site; where practicable, additional calibration checks should be performed on site. Where long-term monitoring is carried out, e.g. over several weeks or months, then a post-sampling calibration should be conducted. Records of these calibrations should be retained.
Where appropriate, field blanks should be included in the study; these should be treated in the same manner as all other samples, apart from active sampling.

Instrument service and repair: All instruments should be regularly serviced according to manufacturers' specifications, and records of findings and any actions taken should be kept. Performance checks should be carried out in the laboratory on a regular basis, or prior to each site visit. These pre-site checks should include (as appropriate):

- operation of battery packs
- inspection of tubing and flow lines for crimps and kinks
- checks on flow rates

Sample handling and analysis: Where samples are collected on site for subsequent laboratory analysis, care needs to be taken to how these samples are labelled, handled, transported and stored. Transportation of samples to laboratory and download data needs to be arranged where necessary.

A clear chain-of-custody system should be operated. All samples should be clearly labelled with unique reference numbers. In addition, care needs to be taken in the handling and storage of samples, e.g.:

- filters should always be handled with tweezers and care should be taken to avoid contamination or damage
- filters should not be stored or transported at high temperatures (>20 deg C) to avoid loss of semi-volatile components
- diffusive samplers should be stored in refrigerated containers prior to analysis

Operator training: All site monitoring should be undertaken by suitably trained personnel, relevant for the instruments and samplers that are being deployed. Records should be maintained of all personnel training.

ii. Quality control procedures for IAQ monitoring

Quality control involves the checking of collected monitoring data, including calibration values, which may result in the data being subsequently accepted, rejected or adjusted. All data should be thoroughly scrutinised in this manner before the results are used.

Quality control checks should be carried out by experienced personnel and it is difficult to be prescriptive about methodologies. It is often useful to plot data as time series to identify any usual “spikes” or “step changes”.

iii. Measurement protocol

Characterising the domestic indoor air quality environment by measurement of pollutants is a difficult task, as financial and practical constraints will frequently limit the number of samples that can be taken and the period over which sampling can be carried out. Concentrations of pollutants within buildings are not constant, and vary according the local activities, location within the building and time.

The principal questions that need to be resolved are:

- When should monitoring be carried out?
- Is more than one sampling period required?
- How long should monitoring be carried out for?
- Where should monitoring be carried out, and at how many locations?

To answer these questions, **Tables 7 and 8** and guidance notes on short and long term monitoring, sampling duration, sampling frequency and sampling locations should be referred to.

Additional notes on measurement protocols

- All sampling equipment should be properly decontaminated, calibrated and leak checked (as appropriate) prior to use. Periodical site visits to be conducted to ensure integrity of the equipment and sample collection.
- When undertaking “spot sampling” during the WTS, at least two sampling events should be conducted per sampling location. Each event should be conducted to take into account the temporal considerations.
- Any anticipated laboratory checks for precision, accuracy or bias (e.g. method blank) should be addressed in the protocol.
- Each sampling event (where appropriate) should have at least one field blank and one duplicate sample taken, analysed, and reported.
- Laboratory results reported in volumetric concentrations (e.g., parts per billion by volume, or ppbv) must also be reported in units of mg/m3.
- Try to have an accredited laboratory analyse samples. If this is not possible or affordable, ensure that the laboratory has documented QA/QC protocols for the specific method.
- Ensure that the detection limits of the laboratory method are within that required by the guideline limit value of the pollutant.

iv. Choice of the sampling method

The choice of sampling method is dependent on:

Required performance – the selected method needs to be able to measure concentrations that can be directly comparable to the guideline limits and must have appropriate limits of detection, measurement range, and response time e.g. for carbon monoxide, the sampling system(s) should be capable of recording ten-minute to eight-hour mean concentrations and have a detection limit of approximately 1 mg/m3.

Definitions related to instrument performance:

Detection limit: This is the lowest pollutant concentration that can be reliably determined by the instrument or method. The detection limit of the method should normally be less than about 10 per cent of the guideline limit value.

Measurement range: This is the range over which the instrument or method can reliably determine pollutant concentrations (i.e. 0 to 1000 µg/m3). Some instruments can operate over more than one measurement range.

Response time: This defines how quickly an instrument can respond to a change in pollutant concentration from the current state to a new state, and give a stable output. It is often stated as the response time between five per cent and 95 per cent of the measurement range. Short response times are important where pollutant concentrations are rapidly fluctuating.

Cost – capital costs of sampling systems can range considerably. Some methods collect samples that require subsequent laboratory analysis (which can be expensive) whilst other methods carry out continuous measurements e.g. by electrochemical or optical sensors. Both capital and running costs should be borne in mind;

Practicality – placing monitoring equipment within indoor environments can be challenging, and issues such as portability, size, noise of operation, power provision need to be taken into account.

General considerations in the selection of measurement methods are summarised in **Box 1**.

Box 1: Considerations in selecting measurement methods

Considerations in selecting measurement methods

- Ease of use:
  - portability
  - size and noise
  - direct reading vs subsequent analysis
  - power requirements
- Quality assurance/quality control
  - experience and training
  - calibration and maintenance
- Output
  - time-averaged vs instantaneous output
  - accuracy and precision
  - sensitivity and response
  - interferences
- Cost
  - capital vs running costs

General information on some of the commonly available monitoring methods for the parameters that are covered in this guideline are described using a flow chart and an accompanying table, with each method assigned a rating ranging from one star (unlikely to be useful for monitoring indoor air quality in South Africa) to four stars (highly likely to be useful for monitoring indoor air quality in South Africa). These scores take account of points set out in **Box 1** (including the training that has already been undertaken by a number of EHPs).

It is intended that these ratings will assist EHPs in the selection of the most appropriate measurement techniques, but it is important to note that they should not be treated as prescriptive recommendations as to which specific technique or instrument should (or should not) be used.

However, for the purpose of ensuring best practice, it is suggested that the method rated four star be applied for each pollutant.

It should be noted that there are a number of commercially available instruments that combine one or more monitoring techniques for different pollutants e.g. measuring parameters such as carbon monoxide, particulate matter, nitrogen dioxide, temperature and humidity using techniques such as non-dispersive infra red (NDIR) , gas specific semiconductors (GSS), photo ionisation detectors (PID) and optical light scattering.

Examples of commercially available measurement instruments are given in **Appendix 5**. The equipment included in the appendix is not intended to be prescriptive nor exhaustive, but provides some examples of commercially available instruments.

c. Activities for measurement of pollutants

If measurement of pollutants is recommended, the following activities should be undertaken:

i. explain to the household or institution why it is necessary to conduct sampling
ii. highlight the procedure that will be followed if further sampling is required (ensure that the impact on the dwelling or building are fully explained – e.g. use of noisy equipment)

iii. the following administration needs to be done if further pollutant measurements are undertaken:

- Undertake sampling of the identified pollutants using sampling method as identified in **Step 1** (preparation). There are two types of sampling methods namely active sampling and passive sampling. Active sampling, entails pump to sample and flow rate/volume used to quantify. Passive sampling entails diffusion sampling, with timing used to quantify (volume of sample not know).
- Refer to the sections on quality assurance, quality control, sampling methods and ethical considerations and measurement protocols that can be followed. **Appendix 6** should be referred for sampling methods and protocols.
- Refer to the sampling guidelines notes provided in **Table 7** and **Table 8** for recommended sampling periods and notes on sampling frequency.

iv. Follow these steps to measure pollutants:

Figure 3: Steps to measure pollutants

Confirm dates and times of sampling with dwelling representative

↓

Set up sampling equipment and reiterate the operational aspects of the equipment to the dwelling representative

↓

Visit site to collect data and change sample filters and check equipment integrity periodically in accordance with each method applied

↓

Arrange for transport of samples to laboratory if necessary. Confirm transport procedures with laboratory and check method applied

↓

De-commission equipment on site. Ensure that all equipment is removed from dwelling and any household items returned to original

↓

Document all sampling activity and results in Part 4 of the IAQ assessment pack – pollutant measurement results

Table 7: Sampling guidelines

Pollutant	Units	Averaging time	Guideline limit value	Sampling guidelines notes
Carbon monoxide	mg/m^3	15 minutes	100	Sources of indoor CO emissions should be active during the entire period of sampling (e.g. cooking and space heating). Doors and windows should be closed. Sampling period to be from morning to evening. For longer sampling period that goes to months, sampling during different seasons must be considered.
		30 minutes	60	
		1 hour	30	
		8 hours	10	
Airborne particles	PM_{10} µg/m^3	24 hours	75	Sources of indoor PM emissions should be active during the entire period of sampling (e.g. cooking and space heating). Doors and windows should be closed
		Annual mean	40	Sources of indoor PM emissions should be used as normal throughout the sampling period, but during a time of year when space heating is used.
Nitrogen dioxide	µg/m^3	1-hour mean	200	Sources of indoor NOx emissions should be active during the entire period of sampling (e.g. cooking and space heating). Doors and windows should be closed
		Annual mean	40	Sources of indoor NOx emissions should be used as normal throughout the sampling period, but during a time of year when space heating is used.
Formaldehyde	µg/m^3	30 minutes	100	Doors and windows should be closed.
Benzene	µg/m^3	Annual mean	5	Sampling should be carried out during a time of year when doors and windows are normally closed.
Napthalene	µg/m^3	Annual mean	10	Sampling should be carried out during a time of year when doors and windows are normally closed.
Relative humidity	%RH	Ideally to be kept below	60	Doors and windows should be closed.

Pollutant	Units	Averaging time	Guideline limit value	Sampling guidelines notes
PAH	B[a]P ng/m^3	Annual mean	5	Sources of indoor PAH emissions should be used as normal throughout the sampling period, but during a time of year when space heating is used.
Radon	Bq/m^3	Annual mean	148	Sampling should be carried out during a time of year when doors and windows are normally closed.
Sulphur dioxide	µg/m3	Refer to **Table 5**	Refer to **Table 5**	Refer to notes to **Table 7.**
Trichloroethylene	µg/ m^3.	Refer to guideline limit	• 4.3 X 10^{-7} per µg/m3 • The concentrations of airborne TCE associated with an excess lifetime cancer risk of 1:10 000 is 2.3 µg/m^3 , 1:100 000 is 23 µg/m^{3}and 1:1 000 000 is 230 µg/m^3.	Refer to notes to **Table 7.**
Tetrachloroethylene	mg/m^3	Annual average	0.25 mg/m^3	Refer to notes to **Table 7**

Notes to Table 7:

- Where possible, both short and long-term monitoring would be carried out.
- The duration of a particular sampling study should depend in part on the nature of the contaminant source. Some sources are more constant whereas others may be more variable.

Short-term monitoring

- Short-term monitoring needs to reflect "worst case" conditions e.g. if combustion sources are of concern, collect samples with all doors and windows closed and during periods when combustion sources are in use.
- Short-term monitoring can determine acute exposures.
- An acute exposure is generally defined as occurring with a time period of less than or equal to 24 hours with an observation period not to exceed two weeks.
- Grab samples are often used to represent acute exposures but in addition, any exposure period less than or equal to 24 hours would also be appropriate as long as the sampling duration does not exceed the actual exposure time.
- 24-hour sampling may be difficult because of the expense, the lack of control over the situation for e.g. tampering by unsupervised building occupants and the technical limitations of the available sampling methods. The use of shorter sampling intervals (two or four hours) offers flexibility and availability of resources to resample in the future when conditions are presumed to have changed.

Longer-term monitoring

- Longer-term monitoring should reflect "normal" periods of occupancy.
- Longer-term monitoring can determine chronic and sub-chronic exposures.

- Sub-chronic exposure for a human is generally defined as a period of time of about two weeks to seven years in duration. Toxicologically, sub-chronic exposures are of interest based on the potential non-cancer risks associated with such mid-range exposures.
- To better estimate a sub-chronic exposure, the sample should consider longer-term as well as seasonal considerations. Grab samples are therefore not appropriate for representing sub-chronic durations.
- Chronic exposure durations are essentially of the same type as sub-chronic except that the number of years exposed is greater, defined to be seven or more years.
- Toxicologically, chronic exposures are based on the potential for chronic non-cancer and cancer risks associated with such long-term exposure. A similar sampling approach can be used as that used to assess sub-chronic exposures.
- There is no practical way to take a long-term (i.e. over a period of years) real-time sample other than to use a continuous monitor to do real-time sampling.

Sampling location

- The location selected should be the most appropriate and representative for obtaining samples. This requires knowledge of the building being studied:
  - its orientation relative to the sun
  - the number of hours it receives direct sunlight
  - the number of floors, the type of compartmentalisation
  - if ventilation is natural or forced air, if its windows can be opened, and so on
- Knowing the source of the complaints and the problems is necessary, for example, whether they occur in the upper or the lower floors, or in the areas close to or far from the windows, or in the areas that have poor ventilation or illumination, among other locations.
- Selecting the best sites to draw the samples will be based on all of the available information regarding this criteria.

Sampling duration

- Whatever the duration of an indoor air-sampling event (from several hours to several weeks), the results are usually used to represent exposures that occur over much longer periods of time (from several months to a lifetime). In planning the duration of a sampling event, a balance must be struck between the need to collect samples that are reasonably representative of the desired exposure and the financial and technical constraints of available technologies.

- In general, the longer the sampling time, the greater the confidence in representativeness of the sample to determine the real contamination situation. This rule of thumb is especially important when a contaminant enters the indoor air on a more sporadic basis and the source is non-constant.

Table 8 prescribes recommended sampling durations or acute, sub-chronic and chronic exposures

Table 8: Recommended sampling durations

Type of exposure	Grab	2 to 24-hour	~3 weeks	Seasonal repeated
Acute	Only for quantitative screening	√		
Sub-chronic		√	√	√
Chronic		√	√	√

Sampling frequency

- The number of times sampling should be conducted is based on the objectives of the study or sampling and the nature of the contamination. In a situation in which the nature of the contaminant source is expected to change fairly quickly, more frequent sampling would be more appropriate than in a more static contaminant situation.
- If the intent is to characterise domestic indoor air quality over a long term (i.e. chronic) exposure, then a single sampling event will not yield data that are representative of exposure concentrations over a chronic period of time.
- Seasonal factors may seriously influence the concentrations of contaminants in indoor air. Winter conditions usually involve a minimal air exchange rate operation of mechanical heating systems where contaminated air is pulled inside the building to create a stack effect. Summer conditions often involve open windows and use of mechanical ventilation systems. Because of the increased ventilation and air exchange rate, sampling during these conditions may often yield less concentrated indoor air contaminant concentrations. In order to characterise exposure over the long term, multiple sampling studies should be conducted during the actual exposure conditions. Therefore, sampling should occur over at least three seasons (winter and spring included) to get a representative of a range of conditions, including the “worst-case” time of year.
- If immediate indoor air exposure information is needed, then the worst-case exposure situations seal in the building should be simulated for a period of between 24 and 48 hours, during periods when both space heating and cooking activities are underway, by closing all doors and windows and shutting down mechanical air ventilation, conditioning and filtration units in order to minimise air exchange in the building.
- This approach may maximise indoor air concentrations detected in this one study, which may still not be representative of conditions during “worst-case” seasonal conditions. Therefore, it is recommended in such a case that the study be followed up with periodic sampling studies over various seasons.

Figure 4: Measurement systems for carbon monoxide

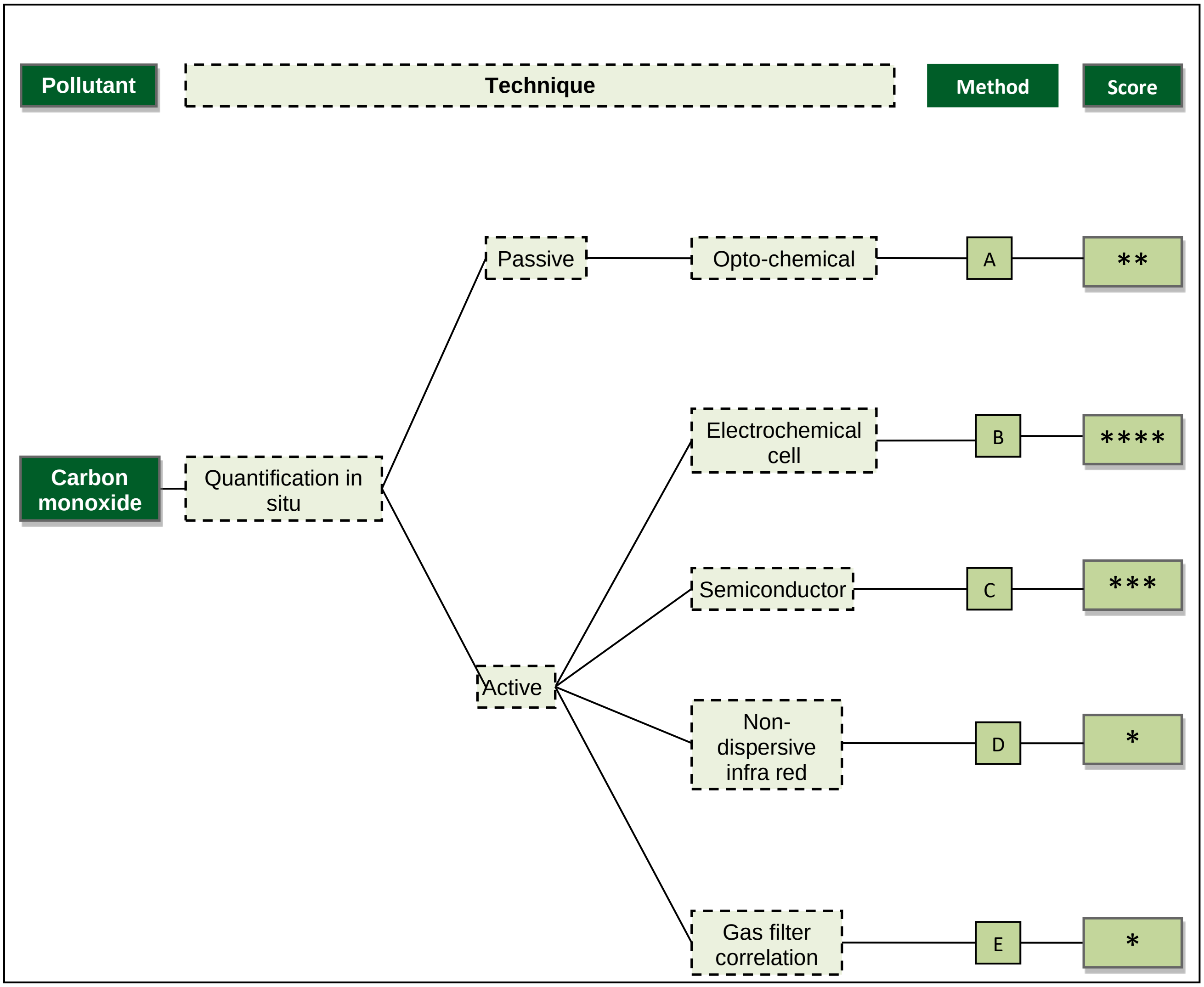


Table 9: Summary of selected measurement systems for carbon monoxide

Method	Principle	Key advantages	Key disadvantages
A Opto-chemical (e.g. dosimetry tubes) **	Pads or tubes containing compounds that change colour on exposure to carbon monoxide. Time-weighted average concentrations can be read by matching the colour change with a key.	Low capital and operating costs. Require no power supply; small, and simple to use; direct reading. Calibrations are not required.	Sensitivity may be unsuited to indoor monitoring.
B Electrochemical cell (e.g. HOBO logger) ****	Sample air passes into an electrochemical cell where oxidation of carbon monoxide to carbon dioxide produces a signal related to the carbon monoxide concentration. Measurement of the current gives a measure of the concentration of carbon monoxide.	Small hand-held instruments with internal batteries. Direct reading and low resolution. Currently in use/training received in South Africa. Can be combined with other sensors to record a number of parameters.	Higher capital costs. Requires training. Requires zero and span calibrations.
C Semiconductor **	Carbon monoxide reduces the electrical resistance of a tin dioxide sensing element. Measurement of the current gives a measure of the concentration of carbon monoxide.	Direct reading and low resolution. Can be combined with other sensors to record a number of parameters.	Higher capital costs. Requires training. Requires zero and span calibrations. Often requires power supply or external battery.
D Non-dispersive infrared *	Infrared radiation passes through parallel optical cells, one containing sample air, and the other containing reference carbon monoxide-free air. The difference in absorbance relates to the carbon monoxide concentration.	Direct reading. Greater sensitivity and precision than electrochemical cells.	Higher capital cost. Requires training. Requires zero and span calibrations. Potential interference with CO_2.
E Gas filter correlation *	Infrared radiation passes through a spinning filter wheel that contains a sealed carbon monoxide reference cell and a nitrogen reference cell. The infrared beam then passes through a chamber containing sample air and is detected. The signal difference observed between the nitrogen cell and the carbon monoxide cell relates to the carbon monoxide concentration.	Direct reading. Reference method analysers used in ambient networks. Low detection limit with short time resolution (less than one hour).	Large instrument; may be noisy in operation. High capital cost. Requires training. Requires on site zero and span calibrations.

Figure 5: Measurement systems for airborne particulates

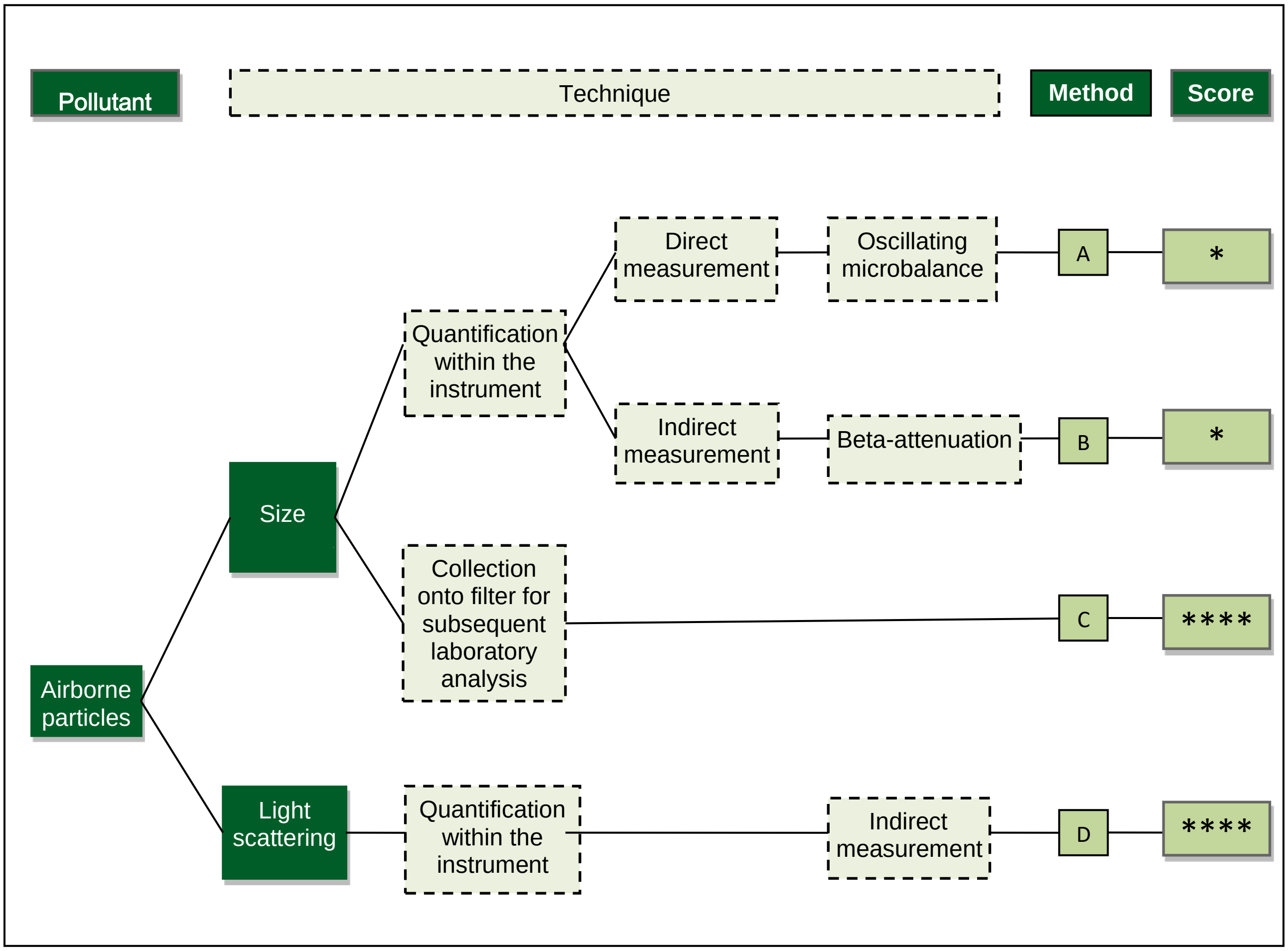


Table 10: Summary of selected measurement systems for airborne particles

Method	Principle	Key advantages	Key disadvantages
A (Oscillating microbalance) e.g. TEOM *	Sample air passes through a size-selective inlet and particles collected onto a filter. Particle mass determined by the change in frequency of oscillation of a glass, tapered tube (on which the filter sits).	Direct reading. Capable of providing real-time data with short time resolution (less than one hour).	Large instrument; may be noisy in operation. Requires mains power. High capital cost. Requires training. Requires checking of flow rates. Heated inlet results in loss of semi-volatile particles.
B (Beta-attenuation) e.g. BAM *	Sample air passes through a size-selective inlet, and particles collected onto a filter gr tape. The mass of the particles is determined from the reduction in intensity of beta particles passing through the dust-laden filter.	Direct reading*. Capable of providing real-time data with short time resolution (less than one hour).	Large instrument; may be noisy in operation. Requires mains power. High capital cost. Requires training. Requires checking of flow rates. If heated inlet is used, some semi-volatile material may be lost. Unheated samples may suffer from interference due to the presence of water. Analyzer contains radioactive source.
C (Filter-based gravimetric) e.g. MiniVol, Partisol ***	Sample air passes through a size-selective inlet. Particles are retained on filters for mass determination in that laboratory by weighing.	Small, semi-portable samplers' are available. Battery operation possible for short periods. Relatively low capital cost. Currently in use/training received in South Africa.	Relatively high operating costs. Time resolution is limited to 24-hour periods. Labour intensive. Requires laboratory facilities.
D (Light scattering) ****	Utilises the interaction between airborne particles and visible, infrared or laser light.	Direct reading. Small, portable (hand-held) analysers available (relatively low capital cost). Can monitor a range of size fractions. No site calibration required. Battery operation possible for short periods.	Particle mass calculated from a range of assumptions (calibration from in-line filters may be required).

Important considerations for monitoring airborne particles.
Monitoring airborne particles presents a number of challenges, due to the complex nature and composition of the particles. For monitoring of domestic indoor air quality, the use of filter-based gravimetric or light scattering instruments is most practical.

- Filter-based gravimetric samplers consist of a PM_{10} sampling inlet that is directly connected to a filter substrate and a regulated flow controller. A filter is pre-weighed, and then fitted to the sampling device. Air is drawn through the inlet by a sampling pump and deposited in the filter for subsequent determination of the particle mass by weighing. Whilst the method is simple to use, great care needs to be taken in the preparation, handling and weighing of the filters.

- There are several different filter types that can be used, including quartz, glass fibre and Teflon. There are also "hybrid" filters such as Teflon-coated quartz. Each of these filter types displays unique characteristics which are very important:
  Quartz and glass fibre filters: Both filter types are friable, and care must be taken to ensure that filter material is not lost during transport and handling. Both filter types are also hygroscopic and must be conditioned at a reference temperature and humidity prior to each weighing. Quartz filters, in particular, are prone to significant hysteresis effects, and extended periods of conditioning might be required. Various reference conditions for conditioning are used, ranging from 30 to 50 per cent RH and 20 degrees Celsius.

  Teflon (and Teflon-coated) filters: Filters still need to be conditioned, but this is less critical than for quartz and glass fibre. Teflon filters are however prone to static problems, and the filters should be discharged before weighing.
  For all sampling campaigns it is also important to include "field blanks" (i.e. filters that are exposed at the sampling site, but do not have air drawn through them. Like the exposed filters, the field blanks are conditioned and weighed before and after going to site. The field blank mass (which should be close to zero) is subtracted from the exposed filter masses.

  Balances used for weighing should have a resolution of 10 µg, and should be calibrated on a regular (e.g. annual) basis.

  Light scattering instruments do not provide a direct measure of particle mass concentrations. These instruments are often small, lightweight and battery powered and very useful for defining particle concentration distributions in both space and time. Where measured concentrations are close to the guideline limit values, it is recommended that the instruments are "calibrated" – some instruments allow simultaneous gravimetric determinations to be carried out for this purpose.

Figure 6: Measurement systems for nitrogen dioxide

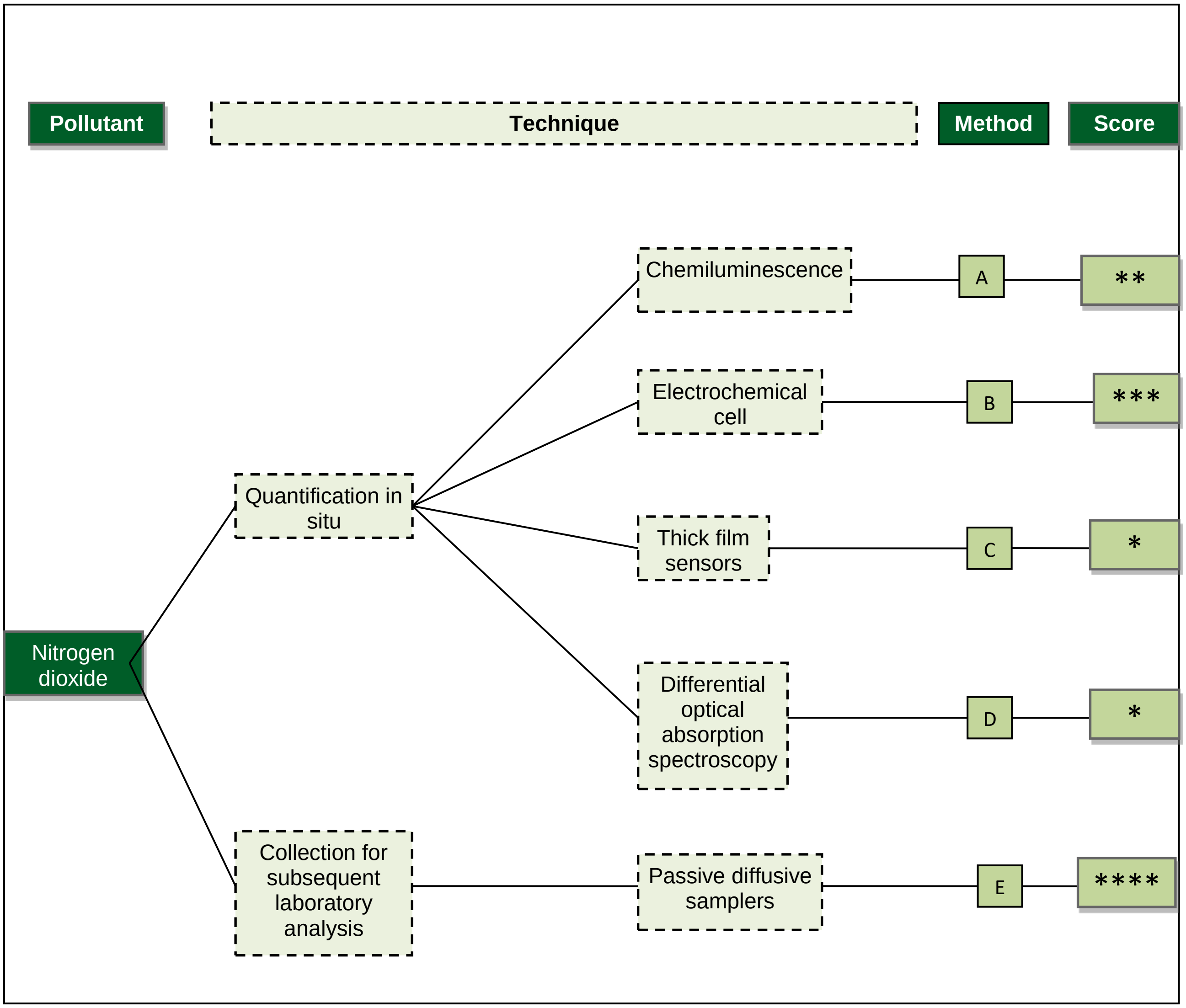

Pollutant
Technique
Method
Score
Chemiluminescence
A
**
Electrochemical cell
B
***
Quantification in situ
Thick film sensors
C
*
Nitrogen dioxide
Differential optical absorption spectroscopy
D
*
Collection for subsequent laboratory analysis
Passive diffusive samplers
E
****

Table 11: Summary of selected measurement systems for nitrogen dioxide

Method	Principle	Key advantages	Key disadvantages
A (Chemiluminescence) **	Based on the reaction of NO with ozone to form an "excited" form of NO_2 that emits fluorescent radiation as it returns to its ground state.	Direct reading. Reference method analysers used in ambient networks. Low detection limit with short time resolution (less than one hour).	Large instruments; may be noisy in operation. High capital cost. Requires training. Requires on site zero and span calibrations.
B (Electrochemical cell) ***	In its simplest form, the principal of operation depends on the electrochemical reduction of NO_2 between two electrodes immersed in an electrolyte reservoir. NO_2 present in the sample air passes through a capillary diffusion barrier into the reaction cell, where it is reduced at the electrode. The migration of electrons produced by the reaction results in a net current flow, which is proportional to the NO2 concentration.	A variety of portable samplers are available; direct reading and battery powered.	Sensitivity of many instruments are unsuited to indoor monitoring. Requires regular calibration.
C (Thick film sensors) *	Solid-state thick film gas sensors based on semi-conducting oxides. sensors are constructed from nano-structured semi-conducting metal oxides, which are maintained at an operating temperature of between 250 and 400°C. As current is passed through the sensor, an electrical response is produced in proportion to a specific gas concentration.	Potential to measure a number of pollutants simultaneously; small and potentially portable.	Limited availability. Requires regular calibration.
D (DOAS) *	Concentration integrated over the length of the light path. In the usual configuration, light (visible, non-laser light) from a light source passes through a fixed path in the atmosphere, typically 100 – 1 000m in length.	Potential to measure a number of pollutants simultaneously. No inlet manifold required.	High capital cost. Light path unsuited for indoor environments.

Method	Principle	Key advantages	Key disadvantages
E (Passive diffusion samplers) e.g. Ogawa and Palmes tubes ****	Nitrogen dioxide is adsorbed onto a treated substrate (in pad or tube) with subsequent quantification in the laboratory.	Small, cheap, and simple to deploy. Requires no power supply. Site calibrations not required. Currently in use/training received in South Africa.	Accuracy of the method may be defendant on the method of preparation and laboratory analysis – "calibration" with reference sampler required. Only provides concentrations averaged over one week to one month. Requires analysis in a laboratory.

Important considerations for monitoring nitrogen dioxide.

- Monitoring nitrogen dioxide concentrations in indoor environments is best suited to the use of passive diffusion samplers (although it is recognised that this approach does not measure one-hour concentrations). These are cheap, simple to use, and require no power supply. However, some studies have shown that these types of diffusive samplers may systematically under or over-read nitrogen dioxide concentrations when compared with a reference sampler (such as a chemiluminescence analyser), and that systematic differences can arise between laboratories.
- It is recommended that where possible inter comparison tests are carried out between collocated passive devices and a chemiluminescence analyser to determine whether such a bias exists in an indoor setting. If necessary, the results from passive monitoring should then be adjusted to take account of this bias.
- Travel blanks should be included in all monitoring campaigns. These are taken to site but not exposed. It is not usual practice to subtract the travel blank from the exposed samples, but rather to highlight any potential contamination issues.

Figure 7: Measurement systems for formaldehyde

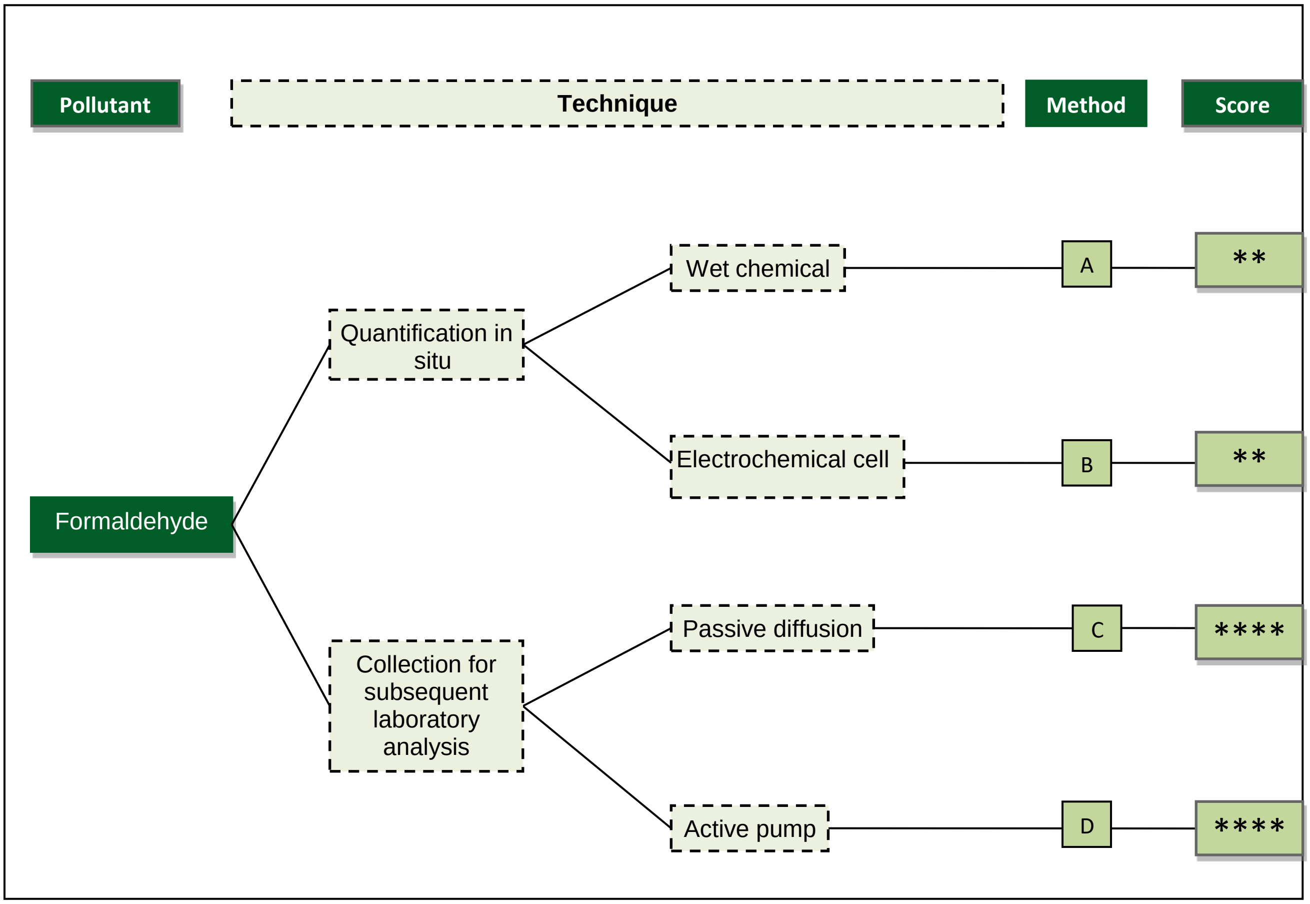


Table 12: Summary of selected measurement systems for formaldehyde

Method	Principle	Key advantages	Key disadvantages
A (Wet chemical) **	Formaldehyde is scrubbed from a pumped airstream by a standard reagent solution. Addition of a second reagent forms a distinctive colour whose intensity is related to the formaldehyde concentration	Low capital cost.	System unsuited to domestic environments.
B (Electrochemical cell) **	Formaldehyde is determined by electrochemical oxidation of formaldehyde at an iridium electrode while maintaining the electrode at a fixed potential and measuring the current flowing through the electrode. The sensor response is linear with the concentration of formaldehyde in air.	Small hand-held instruments with internal batteries. Direct reading and low resolution. Currently in use/training received in South Africa. Can be combined with other sensors to record a number of parameters.	Higher capital costs. Requires training. Requires zero and span calibrations.
C (Passive diffusion) ****	Formaldehyde is passively adsorbed onto treated substrate and subsequently desorbed and quantified in the laboratory	Small, cheap, and simple to deploy. Requires no power supply. Site calibrations not required.	Only provides concentrations averaged over e.g. one week. Requires analysis in a laboratory.
D (Pumped sampler) ****	Formaldehyde is pumped and adsorbed onto treated substrate and subsequently desorbed and quantified in the laboratory.	Typically higher precision than passive sampling.	Requires pump and power supply.

Figure 8: Measurement systems for benzene

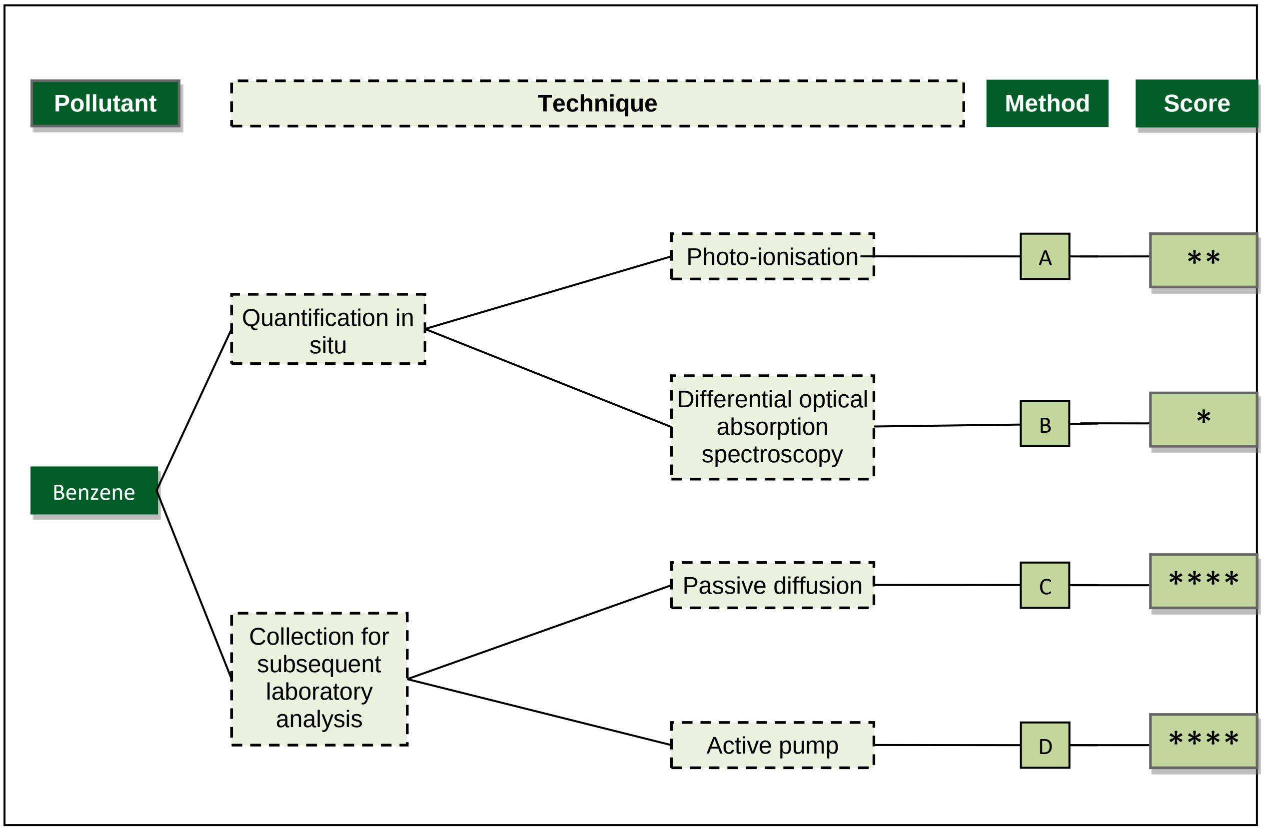


Table 13: Summary of selected measurement systems for benzene

Method	Principle	Key advantages	Key disadvantages
A (Photo-ionisation) **	Benzene-specific low energy lamp used to detect the low ionisation potential of benzene.	Detectors can be built into multi-parameter instruments. Small and portable, with battery power.	Require calibration.
B (DOAS) *	See discussion under nitrogen dioxide.	Potential to measure a number of pollutants simultaneously. No inlet manifold required.	High capital cost. Light path unsuited for indoor environments.
C (Passive diffusion) ****	Benzene is passively absorbed onto a treated substrate for quantification in the laboratory.	Small, cheap, and simple to deploy. Requires no power supply. Site calibrations not required.	Only provides concentrations averaged over e.g. one week. Requires analysis in a laboratory.
D (Active pump) ****	Benzene is pumped and absorbed onto a treated substrate for quantification in the laboratory.	Typically higher precision than passive sampling.	Requires pump and power supply.

Figure 9: Measurement systems for microbes and allergens

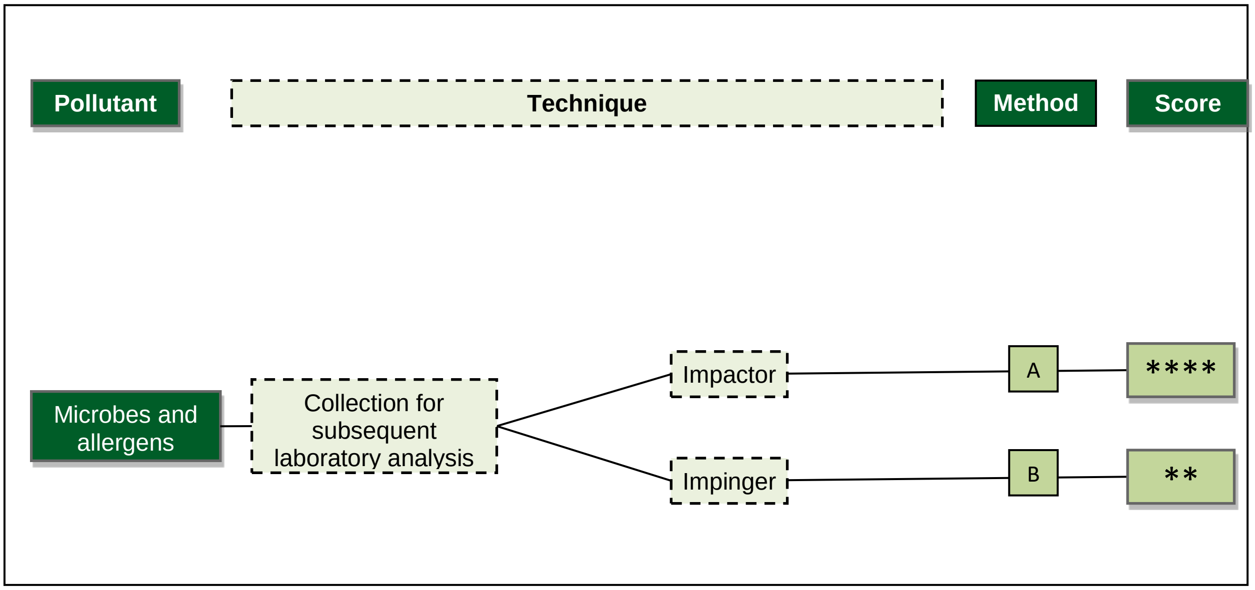


Table 14: Summary of selected measurement systems for mould and allergens

Method	Principle	Key advantages	Key disadvantages
A (Impactor) e.g. Andersen Sampler ****	Sample air passes through a series of selective stages (petri dish containing agar). Inertial effects cause particles in size ranges of interest to collide with collector surface. Microbial colonies are incubated and counted manually.	Ease of operation. Collection media are relatively cheap and so multiple samples can be collected. Already in use/training received.	Can underestimate the number of viable bacteria or fungal spores.
B (Impinger e.g. AG-30 Glass Impinger **	Glass bubble tubes collect into a liquid medium. A known volume of air is pumped through the glass tube that contains a liquid specified in the method. The liquid is then analysed to determine airborne concentrations.	Improved accuracy over impactor method.	Collection vessels are relatively expensive if multiple samples are required.

Further to the above:

- The identification of moulds is critical in understanding the subsequent health effects. It is recommended that if moulds are present, a swab sample is collected and submitted to a suitable laboratory for identification.
  See Appendix 3 for the fungal swab sampling protocol for sampling moulds for subsequent identification in the laboratory. (Source: Indoor Air Sampling Methods Guide, UKZN, Centre for Occupational and Environmental Health)
- For the identification of allergen and fungal spores, dust can be collected from surfaces for subsequent analysis
  See Appendix 3 for the dust sampling protocol for subsequent identification in the laboratory. (Source: Indoor Air Sampling Methods Guide, UKZN, Centre for Occupational and Environmental Health)

Figure 10: Measurement systems for napthalene

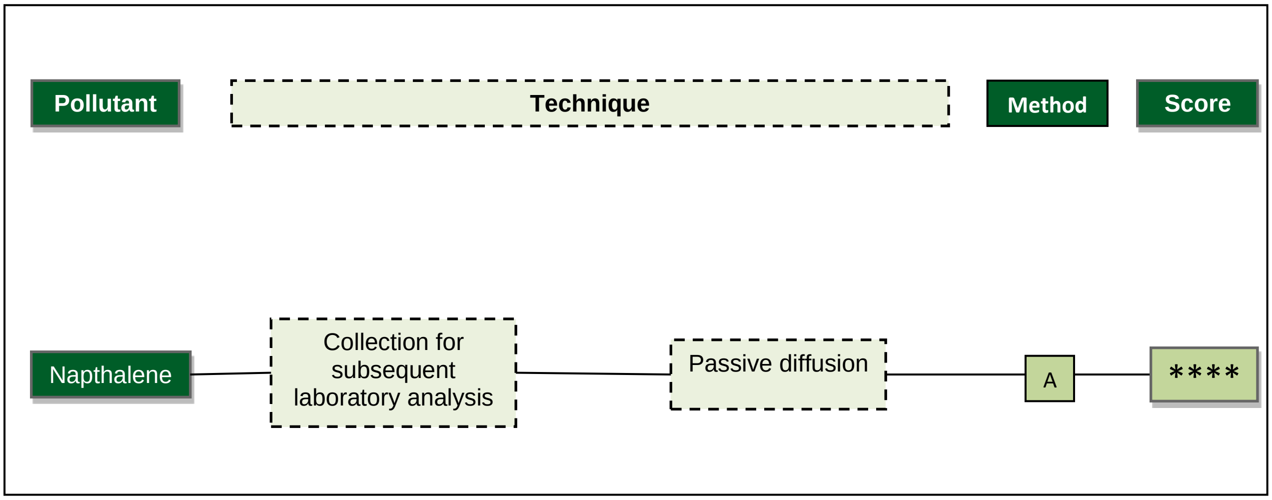


Table 15: Summary of selected measurement system for napthalene

Method	Principle	Key advantages	Key disadvantages
A (Passive diffusion) ****	Napthalene is passively absorbed onto a treated substrate (e.g. Carbograph) for quantification in the laboratory.	Small, cheap, and simple to deploy. Requires no power supply. Site calibrations not required.	Only provides concentrations averaged over e.g. one week. Requires analysis in a laboratory.

Figure 11: Measurement systems for relative humidity

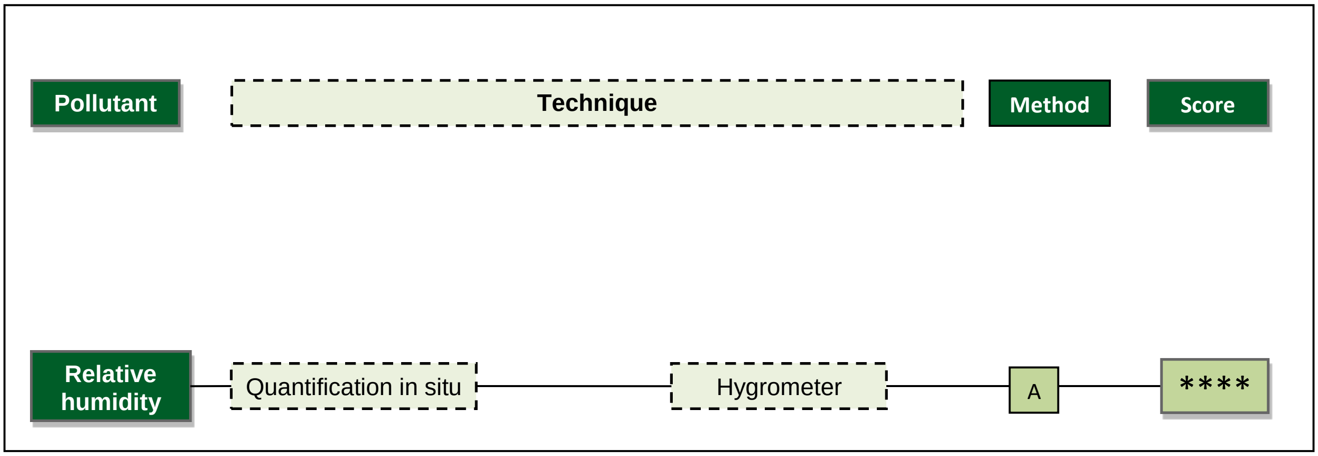


Table 16: Summary of selected measurement system for relative humidity

Method	Principle	Key advantages	Key disadvantages
A (Hygrometer e.g. HOBO logger) ****	Measure change in temperature, electrical resistance or capacitance in the air.	Small hand-held instruments with internal batteries. The same instrument can be used to record a number of different parameters. Already in use/training received.	N/A

Figure 12: Measurement systems for PAH

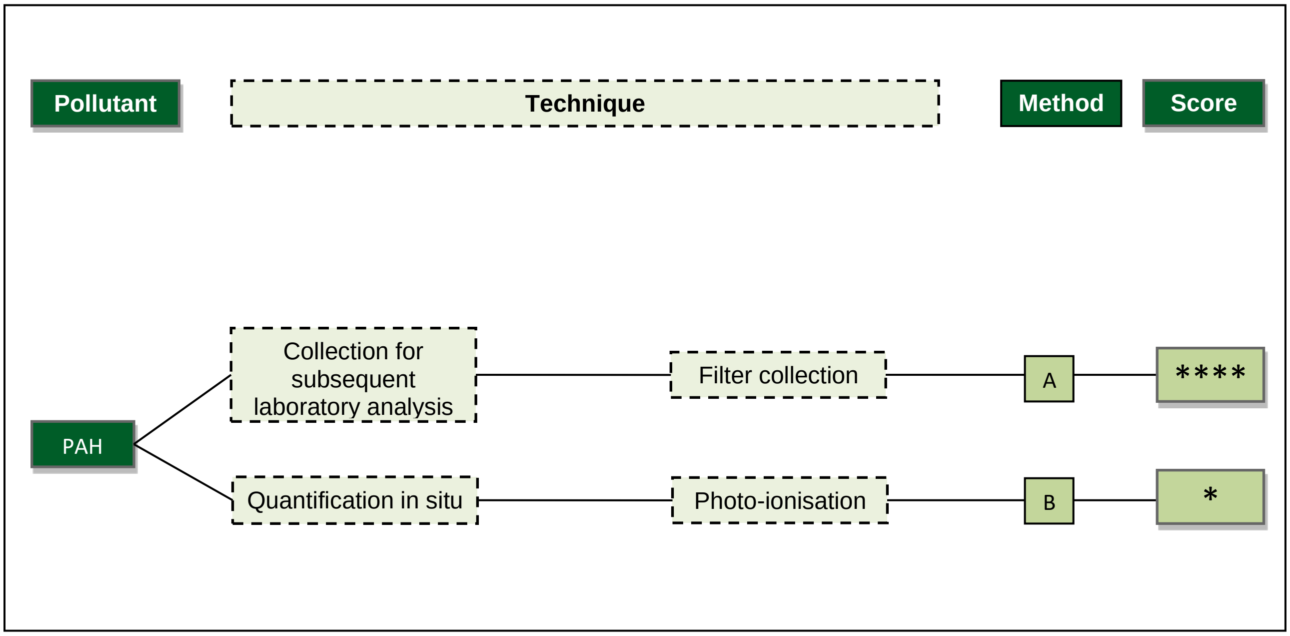


Table 17: Summary of selected measurement systems for PAH

Method	Principle	Key advantages	Key disadvantages
A (Filter collection) ****	Particulate matter collected onto a filter which is then subjected to laboratory analysis for PAH (using benzo[a]pyrene as an indicator compound, for which there is a guideline limit).	Samples can be collected using instruments for filter-based gravimetric determination of particle mass.	Requires specialised laboratory analysis. Only provides 24-hour samples.
B (Photo-ionisation e.g. EcoChem Analytics) *	PAH coated aerosols are excited by UV radiation – the positively charged particles are collected and measured.	Direct reading of total particle-bound PAH.	Poor sensitivity. Requires power supply and calibration. High capital cost. There is no guideline limit for total particle-bound PAH.

Figure 13: Measurement systems for radon

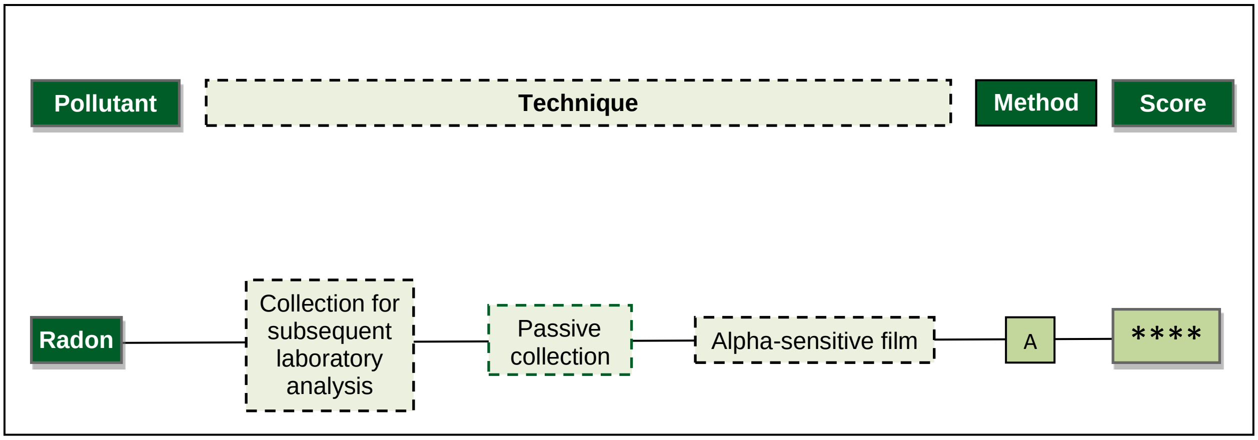


Table 18: Summary of selected measurement system for radon

Method	Principle	Key advantages	Key disadvantages
A (Alpha-sensitive film) ****	Alpha-sensitive film registers damage tracks when chemically etched; average radon concentration is related to the number of damage tracks per unit area.	Simple and cheap. Requires no mains power or calibration.	N/A

Table 19: Summary of selected measurement system for sulphur dioxide

Method	Principle	Key advantages	Key disadvantages
A Bag collection, lab analysis ***	Involves direct capture of air in a bag, and sending of the sample to the laboratory for analysis.	Is useful as an exploratory measure when the type of pollutant is unknown.	Without concentrating the sample there may be insufficient sensitivity and further laboratory processing may be necessary to increase the concentration. Response on measurement outcomes may delay from the laboratory.
B Color-change diffusion tubes ***	Involves the capture pollutants by diffusion or permeation onto a base that may be a solid adsorbent, either alone or impregnated with a specific reactant. The most commonly used are tubes that contain a solid reactant and air is drawn through them using a manual pump.	More convenient and easy to use than active systems. They do not require pumps to capture the sample nor highly trained personnel.	Sampling may take a long time and the results tend to furnish only medium concentration levels, therefore this method cannot be used to measure peak concentrations.
C Electro-chemical monitors ****	Involves taking the sample and measuring the concentration of pollutant simultaneously.	Are becoming increasingly precise and their sensitivity more refined. Have built-in memory to store the readings, which can then be downloaded to computers for the creation of databases and the easy retrieval of the results. Are fast and the measurement is instantaneous, allowing for precise data at a relatively low cost. Can be used to make measurements of short or long duration	

3.3.4 Step 4 – Collate data and report

This step is the culmination of the assessment where the qualitative and quantitative data are pieced together like a puzzle and the quality of the indoor air validated based on the findings of the assessment.

3.3.4.1 Desktop collation data activities

The desktop collation of data should include the following activities:

a. Check that all the relevant quality assurance (QA) measures had been applied during the measurement campaign. Issues such as maintenance, field blanks and calibration of instruments can be checked by reviewing the record sheets of the sampling undertaken.
b. Ensure that all results of sampling are recorded in the pollutant measurements results sheet in Part 4 of the IAQ assessment pack or that a copy of the results is available in this section.
c. Once all data is on hand, the results of the WTS and the pollutant sampling should be reviewed. This review would encompass:
    - an evaluation of the results of the WTS to understand the dynamics of the dwelling and pollution sources (Ensure that the temporal considerations are made in evaluating the information)
    - conduct data quality control checks (data validation and adjustment if necessary) and analysis. Data validation should be conducted as per following phases.
    - A comparison measured pollutant results to the guideline limit value**s**.
    - The development of a written report in line with guidance.
d. A comparison of the measured pollutant results to the guideline limit values.
e. Conclude the findings and recommendations of the assessment and develop a written report in line with the guidance set out in Section 3.3.4.2.

3.3.4.2 The assessment report content guideline

A written report on the assessment should include but not be limited to the following sections:

- **Title page:** To indicate the subject of the report, the author's name(s), date and organisation.

- **Introduction**: This section should provide a brief description of what prompted the assessment and what the writer understands the problem to be.

- **Background:** The following should be presented here:
    - what prompted the assessment
    - review of the literature available (what is known about the indoor environment being assessed and what are the typical IAQ problems)
    - the objectives of the assessment
    - what ethical considerations were taken into account during the assessment

- **Methodology:** This section puts the chosen methodology into perspective based on the objectives of the assessment. The section should encompass details of:
    - the rationale for deciding on the assessment protocol
    - the equipment used for pollutant measurements (if undertaken)
    - any other assessment tools that were used (e.g. WTS)
    - an indication of what was recommended (if any) to the dwelling owner during the WTS
    - how the monitoring/ pollutant measurements were undertaken
    - what guideline limits/standards were used in determining the measurement options

- **Results:** This section should present the results in a step by step format in as much detail as possible.

- General characteristics – For example, location of dwelling, general area description and description of household including type of dwelling.
- Monitoring data –
  - observations from the WTS that are considered of significance and contribute to the findings of the assessment
  - measurement data in a descriptive format and from the data analysis

- **Conclusion and recommendations:** This section should provide the following:
  - an analysis of the data and a meaningful interpretation of what the data means
  - a discussion on relevant legislation that may impact the outcome of the assessment
  - a comparison of the pollutant measurements with guideline limits/ international standards
  - a comparison with other data if part of a larger study or survey
  - recommendations to improve the IAQ problem based on the information gathered during the assessment

- **References:** This section should provide a list of references used in the development of the report. The report writer must ensure that these references are reliable especially if downloaded from the internet.

- **Appendices:** These may include the raw data collected during the assessment. For example:
  - WTS checklist
  - results of analysis received from a laboratory
  - pollutant sampling activity sheets

It is acknowledged that each institution has it standardised procedure and format of a report, however it is essential that an assessment report framework outlines key issues as indicated above.

3.3.5 Step 5 – Finalise report and close out assessment

The step to close out the assessment may involve the activities listed below. These steps are a guide in terms of closing out an assessment and the actual activities will depend on the relevant institutional procedures in each organisation.
Ethical considerations need to be met during closing and finalisation of the assessment report.

a. Ethical considerations during the close out of the assessment (Step 5)

- Call in advance if possible to make an appointment to discuss the outcomes of the assessment.
- Ensure that you arrive on time for the appointment.
- Be diplomatic when explaining the various recommendations to the dwelling representative.
- Be sympathetic to the needs of the dwelling when making such recommendations.
- Ensure that the household or institution representative understands why the assessment was carried out if not initially a complaint. This explanation should highlight how the assessment could assist in improving the IAQ conditions.
- Respect the customs and practices of the household or institution. (E.g. If shoes have to be removed prior to entering the household or a certain room in the house).
- Thank the household or institution representative.

b. Close out procedure

These procedures should be followed for each of the reasons an IAQ assessment that may be undertaken:
As part of a larger study:

- liaise with colleagues on the outcome of the assessment to solicit comments on the report
- forward report to the study coordinator ensuring that important points are highlighted

As a result of a complaint:

- liaise with colleagues on the outcome of the assessment to solicit comments on the report
- set up a meeting with the dwelling representative and explain the outcome of the assessment and provide advice on measures that can be put in place by the occupants to mitigate the effects of the source of the pollution
- provide contact details to the dwelling representative in the event that further assistance is required

3.4 Outdoor air pollution exposure monitoring and assessment

Outdoor pollution can contribute to indoor air pollution as the polluted outside air can make its way indoors through household doors and windows. To determine the actual indoor pollution exposure, both indoor and outdoor air quality should be monitored and assessed. The use of indoor sources and concentrations alone would underestimate actual personal exposure. The monitoring of ambient air quality focuses on the concentrations of outdoor pollutants. The ambient air quality can be considered to be an indicator of population exposure. The concentrations people experience in their living environments, determines exposure.

To assess population exposure correctly, the following factors and activities should be known, considered and undertaken:

3.4.1 Population outdoor air pollution exposure assessment factors

- Knowledge of population distribution. The location of the population varies according to the time of day, day of the week and the season. Most of the population is located in homes at night.
- Knowledge of location of air monitoring stations to identify the pollution concentrations to which the population is exposed.
- Monitoring stations should measure the concentrations in representative community sites where most of the population lives and in areas with high concentrations.

3.4.2 Population outdoor air pollution exposure assessment activities

Activities to assess population exposure include the following:

- use one monitoring station only or use some selected or all monitoring stations in a city and to take an arithmetic mean of selected concentrations. This average value, such as daily or yearly, is then used to indicate the exposure of the whole population

- the use of data from one monitoring station is considered the simplest way to determine the area or population exposure however can be inaccurate in case of pollutants that can have different concentrations levels when measured at different locations. Therefore, more measurement stations, when available, can be added and the exposed population can be assigned to the concentrations obtained at different monitoring stations

  N.B. Analysed data from different monitoring stations/networks across the country can be requested and obtained from Department of Environmental Affairs, South African Air Quality Information System website link (http://www.saaqis.org.za/RequestData.aspx).

4. DOMESTIC INDOOR AIR POLLUTION INTERVENTION STRATEGIES

While monitoring and measurement of IAQ provides an important indicator for environmental health, the ultimate objective for monitoring IAQ is for the protection of health.

Once an assessment is complete and the findings noted and acknowledged, intervention strategies to mitigate the IAP may need to be undertaken and this may not only involve the EHP and the household or person in charge of the institution, but may be a wider concern and include an integrated approach by various government departments and/ or spheres of government.
Understanding the extent to which air quality influences population health helps in selecting the most effective intervention strategy to prevent risk and contributes to improvement of population health.

This guideline serve as a “first line of defense process” that informs the development of intervention strategies since it provides the tools for developing a scientific basis on which decisions can be made.

While the identified interventions can be administered at local level, there are instances where interventions are required on a more national scale and this may involve an integrated governmental approach to managing the problem.

There are various interventions that can be recommended, which may include, but are not limited to the following:

4.1 Acting on source of pollution

a. Encouraging communities to use alternative clean and safe fuels such as alcohol fuels (ethanol, methanol) LPG gas, biogas for homes with no farm animals), piped natural gas in rural areas, solar cookers, geyser and heater or electricity.
b. Considering the fact that the use of new, clean fuel technologies may be unaffordable to poor communities, who may revert to the use of dirty fuels, replacing an open fire for cooking with a ventilated, enclosed and well-insulated solid fuel and biomass stove should be promoted. E.g. initiating the *basa-njengo-magogo* programme, that should be monitored for effectiveness and sustainability.
c. Discouraging the use of kerosene.
d. Advocating for production industries to produce improved, clean and safe, cost effective, time efficient and reliable household fuels and appliances.
e. Promoting improvement in increasing cleanliness of combustion in unvented and vented household energy devices.
f. Advocating for industries to:
    - implement changes in industrial processes or exhaust filtering
    - change the demand for certain highly polluting activities. Increasing energy efficiency is an example of reducing emissions by controlling the demand for the product
    - use better designed equipment and clean and smokeless combustion equipment and fuels
    - install tall chimneys
    - use the other different techniques to control outdoor air pollution caused by gaseous and particulate pollutants, which can include the following:

Methods of controlling gaseous pollutants:

- Combustion: This technique is applied when the pollutants are organic gases or vapours. The organic air pollutants are subjected to "flame combustion" or "catalytic combustion" when they are converted to less harmful product carbon dioxide and a harmless product water.
- Absorption: In this method, the polluted air with gaseous pollutants is passed through a scrubber containing a suitable liquid absorbent. The liquid absorbs the harmful gaseous pollutants present in air.
- Adsorption: In this method, the polluted air is passed through porous solid adsorbents kept in suitable containers. The gaseous pollutants are adsorbed at the surface of the porous solid and clean air passes through.

Methods of controlling particulate emissions:

- Fabric filters: The particulate matter is passed through a porous medium made of woven or filled fabrics. The particulate present in the polluted air are filtered and gets collected in the fabric filters, while the gases are discharged. The process of controlling air pollution by using fabric filters is called 'bag filtration".
- Wet scrubbers: They are used to trap SO2, NH3 and metal fumes by passing the fumes through water.
- Electrostatic precipitators: When the polluted air containing particulate pollutants is passed through an electrostatic precipitator, it induces an electric charge on the particles and then the aerosol particles get precipitated on the electrodes.

- Mechanical devices: Works in two ways, firstly on the basis of gravity, where the particles settle down by the action of gravitational force and get removed; and secondly where there is a sudden change in the direction of air flow that brings about the separation of particles due to greater momentum.

4.2 Town and building development applications assessment

a. An environmental health impact assessment of town development planning and National Environmental Management Act environmental authorisation applications of development projects involving release of outdoor air pollutants, in order to ensure communities are protected from exposure to released outdoor pollutants that have the potential to enter indoors.

b. An environmental health impact assessment of house/ building development plans to ensure provision of adequate cross ventilation to eliminate the concentration of indoor pollutants and provision of a waterproofed foundation to eliminate growth of mould.

N.B. Inlets for fresh air should be located at the least polluted side of the building.

4.3 Ventilation improvement

a. Promoting provision of hoods and chimneys over cooking stove.

b. Promote improvement of adequate natural cross ventilation by providing air bricks or doors and window openings, turbulent. Natural ventilation needs careful design and construction in order to supply adequate ventilation rates, where necessary the building owner will have to adjust or alter natural ventilation openings. Natural ventilation is best suited for buildings located in mild-to-moderate climates away from inner city locations.

c. Single-sided ventilation in a building does not provide adequate means to remove indoor air pollutants and is not recommended.

d. Promote improvement of adequate artificial ventilation by providing properly maintained artificial ventilation systems e.g. fans, domestic or business air conditioning/mechanical exhaust ventilation systems. Air conditioning/mechanical exhaust ventilation systems can be used in any type of building.

e. Individual control of ventilation should be encouraged, as it improves user satisfaction.

f. Mechanical ventilation systems should be provided in an energy-efficient way, e.g. heat recovery system. The use of electricity should be limited.
g. An effective mechanical ventilation system should meet the following criteria:
   - ventilation air should be distributed and used effectively in the building
   - ventilation air should be distributed to the rooms of the building according to their design and use
   - in practice, therefore, the system should be designed and constructed so that airflow can be measured and balanced.
   - ventilation air should reach the breathing zone of the rooms as soon as possible after entering the room
   - ventilation air should remove pollutants from the room effectively
   - minimum ventilation rates should be increased when pollution loads are higher and can be lowered when pollution loads are low
   - air-handling systems should not degrade the quality of the air supply
   - ventilation systems should be regularly inspected and maintained

4.4 Change of behaviour

a. Reduce exposure through:
   - using pot lids to conserve heat
   - properly maintaining appliances (e.g. stoves and chimneys)
   - reducing time of exposure by advising to leave and return to the cooking stove area after a few minutes, which depends on the type of food in preparation
b. Reducing or eliminating human activities that release pollutants or results in exposure to pollutants e.g. smoking tobacco, using solvents, building materials, household detergents and personal care products. Refer to **Table 2** for different sources of pollutants and **Table 1** for routes of exposure as a guide.
c. Promote avoiding the use of naphthalene-containing mothballs.
d. Promote separating the kitchen from the living area to reduce exposure of the family.

NB This is an activity that is normally found in an informal living settlement. e.g. human settlement or rented out household garage or outside room.

4.5 Public awareness

a. Conducting public awareness campaigns on types of indoor pollutants, sources, routes of exposure, health effects and methods to prevent exposure.
b. Conducting public awareness campaigns on available alternative clean fuels and technologies, with practical projects.
c. Running pre-season public service announcements or news releases to advise the public on fire smoke season preparation and prevention of exposure from smoke inhalation.
d. Using a wide range of communication media such as leaflets, storytelling, dramas, practical demonstrations, local radio stations and newspapers when conducting awareness.
e. Using various methods of education to target various wide groups e.g. one on one or house per house education, group education targeting schools, crèches, NGOs, community interest groups, public transport terminals, shopping centres, businesses, etc.
f. Promote planting of trees along roadsides, in residential, places of education, places of care and business premises.
g. Promote energy conservation programmes.
h. Promote the use public transportation and pool cars.
i. Educate the public on the importance of maintaining cars, boats and other engines and using clean energy fuelled and green cars.
j. Discourage open burning of refuse and human induced wildfire activities.

k. Promote and educate the public on recycling.
l. Educate the public on the links between wildfires, indoor air pollution and health effects and on preventive measures against exposure to wildfire smoke.

4.6 Preventing exposure to mould

Moisture control is the main method for controlling mould and allergens.

Methods for controlling moisture in buildings include:

a. *Building construction*
- Improve thermal properties of windows.
- Design structures to resist the moisture loads of local climate and typical use of buildings (e.g. use vapour barriers).
- Ventilate walls and other building components to prevent condensation.
- Improve thermal insulation of building envelope to increase indoor surface temperatures to prevent condensation in cold and moderate climates.
- Prevent moisture migration from ground by draining surface waters.
- Improve protection against rain throughh roofing, walls and windows.
- Design and install material for minimum leakage of plumbing.

b. *Ventilation*
- Provide operable (can open) windows in all living rooms and kitchen.
- Provide adequate, controllable average ventilation.
- Ventilate all rooms where needed.
- Provide effective kitchen range hood.
- Provide possibility for controlling ventilation on demand.
- Use mechanical exhaust ventilation in warm and moderate climates; tighten building envelope to prevent excess ventilation.
- Use mechanical supply and exhaust ventilation with heat recovery to reduce relative humidity indoors.

c. *Heating*
- Use central heating in cold and moderate climates.
- Do not use unvented open-flame heaters.
- Control indoor temperature with thermostats.
- Encourage use of district heating.
- Require chimneys for all heating boilers and furnaces.
- Improve thermal efficiency of fireplaces with e.g. dampers or shutters.

d. *Consumer behaviour and operation*
- Limit use of humidifiers.
- Do not dry laundry in living area.
- Use kitchen range hoods and ventilation during cooking.
- Use ventilation and airing to prevent high indoor humidity and condensation.
- Increase indoor temperature to decrease relative humidity.
- Clean and dry any damp or wet building materials and furnishings within 24 to 48 hours to prevent mould growth.

e. *Refurbishment*
- Improve performance of ventilation (natural or mechanical).
- Install mechanical ventilation system to improve ventilation (with or without heat recovery).
- Install double glazing to prevent condensation.

- Improve roofing to prevent water leakages, where necessary.
- Ventilate crawl spaces to prevent moisture migration from ground, when applicable.
- Install range hoods in kitchen.
- Replace unvented open-flame heaters and appliances with vented ones.
- Fix the source of the water problem or leak to prevent mould growth.
- In areas where there is a perpetual moisture problem, do not install carpeting (i.e., by drinking fountains, by classroom sinks or on concrete floors with leaks or frequent condensation).

4.7 Prevention of exposure to outdoor air

4.7.1 Prevention of exposure to industrial emissions

a. Filtration of ambient pollution by building envelopes and cleaning of mechanical ventilation systems provides protection from outdoor pollutants.
b. Emitters of outdoor pollutants should ensure that the outdoor air quality meets the prescribed National Ambient Air Quality Standards.
c. Promote outdoor emissions preventive measures' activities for industries as outlined under Section 4.1 (d).
c. Promote provision of adequate indoor ventilation systems to eliminate the concentration of outdoor particles. If the outdoor concentration levels exceed the indoor, the use of natural ventilation should be avoided and mechanical ventilation as prescribed in Section 4.3 should be provided.

4.7.2 Preventing dust exposure

a. Promoting and ensuring that street sweeping equipment (e.g. vacuum trucks) are equipped with an effective bag house or other filtering devices.
b. Discouraging the use of sweeping equipment with air pollution control devices that are in disrepair.
c. Allowing mechanical devices without filtering equipment to be used only when wet sweeping methods are effectively employed.
d. Discouraging the use of leaf blowers and other similar equipment for sweeping.
e. Promoting manual broom sweeping.

4.7.3 Preventing wildfire smoke exposure

a. Staying indoors provides some protection, especially with doors and windows closed tightly, in an air-conditioned home in which air conditioner re-circulates indoor air.
b. People who wish to clean their residences after or between wildfire smoke events should use cleaning practices that reduce re-suspension of particles that have settled such as damp mopping or dusting and using a high efficiency particulate air filter-equipped vacuum.
c. The use of ozone generators as air cleaners should be avoided as the ozone contained therein is harmful to human health.
d. Reducing physical activity e.g. exercising, as breathing increase air intake and health risk during a smoke event.
e. Smoke levels from wildfires often change substantially over the course of the day, so plan crucial outdoor activities to avoid the worst periods of smoke.
f. Keeping the windows and vents closed when inside a car, and, if available, operating the air conditioning in "re-circulate" mode.
g. Promoting the use of National Institute for Occupational Safety and Health (NIOSH) of South African Bureau of Standards (SABS) certified filtering face-piece respirators or respiratory protection devices masks or protectors to prevent inhalation of smoke particles. Covering the mouth with a (damp or dry) bandana, handkerchief or tissue and use of surgical masks will not prevent the wearer from breathing in airborne particles contained in wildfire smoke.
h. Advising on consideration to close or curtail business activities and public events depending on the level of outdoor smoke, depending on whether the level of smoke emissions in schools

and businesses is similar to or lower than in households. Children's physical activity may be better controlled in schools than in homes. Schools in smoky areas may make travel to school hazardous.

i. When an evacuation to a common center is considered by the municipality's disaster management unit, an evacuation plan should be in place considering the expected duration, intensity, and direction of smoke and possible health risks associated with evacuation. Sensitive population groups should be identified for priority protection. The evacuation center should be assessed for possible fire smoke exposure and be equipped with adequate mechanical ventilation that re-circulates air. The evacuees should be provided with effective certified respiratory protective devices to protect against smoke inhalation.
j. Advising people with asthma and heart disease to check with their healthcare providers about precautions to take during smoke events.
k. Advising the public to contact a healthcare provider if one's health condition worsens when exposed to smoke.
m. Advising the public to be alert to public service announcements or weather forecasts early warnings.

4.8 Monitoring and research

Conducting research studies assist in providing an understanding on the extent of indoor air quality problems and the effectiveness of interventions. There are various research needs that have been identified by the WHO, which needs to be conducted by researchers and include the following:

a. Field evaluation of the impact of the everyday use of alternative safe technologies on health.
b. The impact of new clean technologies on indoor air quality.
c. Policies to achieve rapid and sustainable transitions to low emission, efficient and safe options suitable for different population groups.
d. Assessment of health programmes designed to address indoor air pollution exposure adverse health effects.

It is recommended that research in these topics, including any other related relevant topics be conducted to strengthen and improve public health protection against indoor air pollution exposure.

5. GLOSSARY OF TERMS

Airborne particles	Particles less than three microns can stay airborne for much larger distances (hundreds of miles) before they settle out or are removed by rain.
AQG	Air Quality Guidelines
Assessment protocol	A full description of the objectives of the assessment including the methodology to be applied and the approach to measurement of IAP and other issues such as the ethical considerations.
Bq/m^3	Becquerel per cubic meter
Calibration	A comparison between measurements - one of known magnitude or correctness made or set with one device and another measurement made in as similar a way as possible with a second device
CO	Carbon monoxide
CO_2	Carbon dioxide
EHP	Environmental Health Practitioner
Emissions	The introduction of chemicals, particulate matter or biological materials that cause harm or discomfort to humans or other living organisms or damages the natural environment into the atmosphere
EPA	United States Environmental Protection Agency
IAP	Indoor air pollution
IAQ	Indoor air quality
LPG	Liquid petroleum gas
GSS	Gas specific semiconductors
Measurement	Refers to the characterisation of indoor air quality by quantifying specific pollutant concentrations or other parameters (e.g. humidity levels)
mg/m^3	Milligram per cubic meter
$\mu g/m^3$	Micrograms per cubic meter
Monitoring	Refers to an assessment of indoor air quality conditions within a building, based on a survey of different parameters, for example, potential pollution sources, building condition, ventilation and air quality measurements
ng/m^3	Nanogram per cubic meter
NDIR	Non-dispersive infra-red
NDoH	National Department of Health
NOx	Nitrogen oxides
PAH PID	Polycyclic aromatic hydrocarbons Photo ionization detectors
PM_{10}	Small airborne particles, more specifically particulate matter less than 10 micrometers in aerodynamic diameter

$PM_{2.5}$	Small airborne particles less than 2.5 micrometers in aerodynamic diameter
Pollutants	A waste material that pollutes air, water or soil
QA/QC	Quality assurance/quality control
Qualitative	Descriptions or distinctions based on some quality rather than on some quantity; featuring a high degree of subjectivity; data that is not quantified
Quality assurance	Refers to the overall management of the process that is undertaken in the collection of the data
Quality control	Refers to the activities that are undertaken to check and optimise data accuracy and precision
Quantitative	Expressed or expressible as a quantity or relating to susceptible of measurement or relating to number or quantity
RDP	Reconstruction and Development Programme
Relative humidity	Used to describe the amount of water vapour that exists in a gaseous mixture of air and water vapour, compared to the upper limit of what it could be at the same temperature and bulk pressure.
Sampling	That part of statistical practice concerned with the selection of an unbiased or random subset of individual observations within a population of individuals intended to yield some knowledge about the population of concern, especially for the purposes of making predictions based on statistical inference. Sampling is an important aspect of data collection
SO_2	Sulphur dioxide
Spatial variability	Occurs when a quantity that is measured at different spatial locations exhibits values that differ across the locations.
Stakeholders	A person, group, organisation or system that affects or can be affected by an organisation's actions
Temporal variability	Temporal variability speaks to the variability of time. Time is not a constant
Ventilation	The process of "changing" or replacing air in any space to provide high indoor air quality i.e. to control temperature or remove moisture, odours, smoke, heat, dust, airborne bacteria, carbon dioxide, and to replenish oxygen. Ventilation is used to remove unpleasant smells and excessive moisture, introduce outside air, to keep interior building air circulating and to prevent stagnation of the interior air
VOC	Volatile organic compounds
WHO	World Health Organization
WTS	Walk through surveys

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