



DEVELOPMENT OF AN EMISSIONS COMPLIANCE MONITORING SYSTEM FOR SOUTH AFRICA

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Declaration

I hereby declare that the dissertation that I hereby submit for the degree of MSc Applied Science (Environmental Technology) at the University of Pretoria is my work, and that it has not been previously submitted by me for the degree purpose at any other university. I also declare that all sources I have quoted have been indicated and acknowledged by complete references.

Dedication

To my grandmother Tshegofatso Matshediso,

I am grateful for all you are to me.

Acknowledgements

I will like to thank God, my creator and sustainer for my life, and for the fulfilling career that impacts positively in the lives of ordinary South Africans. To my family, friends and colleagues, especially my sister, Kelemogile Matshediso, thank you for continued support and words of encouragement. Yvonne Scorgie, I appreciate the assistance you provided on Australian legislation, and for your work that inspired this study. Gerrit, I appreciate your supervision, patience and your guidance. Thank you for your kindness.

DEVELOPMENT OF AN EMISSIONS COMPLIANCE MONITORING SYSTEM FOR SOUTH AFRICA

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Synopsis

The promulgation of the minimum emission standards for the list of activities resulting in significant air pollution under the National Environmental Management: Air Quality Act, 2004 (Act No.39 of 2004) introduces a command – and – control regulation, in which the listed activities are required to obtain atmospheric emission licenses prior to operation. Under this regime, the licensed activities are required to demonstrate compliance with the minimum emission standards incorporated into their license on an annual basis, in accordance with the norms and standards for emission monitoring. In the absence of these norms and standards, monitoring of compliance with the emission standards, and related enforcement activities cannot be carried out effectively.

The aim of this study is therefore to develop a compliance monitoring system for atmospheric emissions to support effective implementation of the National Environmental Management: Air Quality Act, 2004. The objectives of the study are to:

- Identify critical elements of compliance monitoring system for emissions;
- Review best practices on selection of emission measurement methods, quality assurance and quality control, data handling, reporting and compliance assessment procedures; and

- Make recommendations on compliance monitoring system for South Africa, based on identified local needs and international best practice.

A desktop study on the elements of emissions compliance monitoring system was conducted and subsequently an appraisal on how these are implemented in countries that have comprehensive emissions control programmes was done. This study concludes that, while environmental regulations are triggered by the needs and policy decisions of the country, the emission compliance monitoring is largely dependent on the systematic implementation of the various scientific processes and procedures that result in the acquisition of credible and reliable emission data, to be used in compliance assessments and other air quality management programmes. The study recommends a model of emissions compliance monitoring system for South Africa, comprising of processes and procedures required for the acquisition of good quality, credible data to be used in compliance assessments. .

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Abbreviations and Acronyms

AEL	Atmospheric Emission License
AELA	Atmospheric Emission Licensing Authority
AETBs	Air Emissions Testing Bodies
AMSAAP	Approved Methods for Sampling and Analysis of Air Pollutants
APPA	Atmospheric Pollution Prevention Act
AQA	Air Quality Act
ASTM	American Society for Testing and Materials
BAT	Best Available Techniques
BREF	Best Available Techniques Reference Documents
BSI	British Standards Institution
CAA	Clean Air Act
CAPCO	Chief Air Pollution Control Officer
CAR	Clean Air Regulation
CEM	Continuous Emission Monitoring
CEMS	Continuous Emission Monitoring System
CEN	Committee for European Norms
CFR	Code of Federal Regulations
COM	Continuous Opacity Monitoring
DEA	Department of Environmental Affairs
EC	European Commission
ELV	Emission Limit Value
EPBCA	Environment Protection and Biodiversity Conservation Act
EPL	Environmental Protection License

EU	European Union
FTIR	Fourier Transform Infrared (FTIR) Spectroscopy
HAPs	Hazardous Air Pollutants
HSE	Health and Safety Executive
IMPEL	European Union Network for the Implementation and Enforcement of Environmental Law
IPPC	Integrated Pollution Prevention and Control
ISO	International Standardization Organization
LDAR	Leak Detection and Repair
MACT	Maximum Achievable Control Technology
MCERTS	Monitoring Certification Scheme
NATA	National Association of Testing Authorities
NEFAP	National Environmental Field Activities Program
NELAC	National Environmental Laboratory Accreditation Conference
NEPC	National Environment Protection Council
NEPMs	National Environment Protection Measures
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health
NMISA	National Metrology Institute of South Africa
NSPS	New Source Performance Standards
NSW	New South Wales
NSWEPA	New South Wales Environmental Protection Agency
PAEL	Provisional Atmospheric Emission License
PEM	Periodic Emission Measurements

POEOA	Protection of the Environment Operations Act
QA/QC	Quality Assurance/ Quality Control
SANAS	South African National Accreditation System
SRM	Standard Reference Method
STAC	Source Testing Accreditation Council
TNG	Technical Guidance Notes
TNI	The NELAC Institute
TÜVs	Technischer Überwachungs-Vereine
UKAS	United Kingdom Accreditation System
UKEA	United Kingdom Environmental Agency
USA	United States of America
VDI	Verein Deustcher Ingenieure
VHAPS	Volatile Hazardous Air Pollutants
VOC	Volatile Organic Compounds
USEPA	United States Environmental Protection Agency

1 INTRODUCTION

The National Environmental Management: Air Quality Act, 2004 (Act No.39 of 2004) (the “AQA”) defines air pollution as “any change in the composition of the air caused by smoke, soot, dust (including fly ash), cinder, solid particles of any kind, gases, fumes, aerosols and odorous substances” (South Africa, 2005). These pollutants, at various levels of concentration results in undesired impacts on human health, wellbeing and the environment. As such, air quality management programmes are established to minimize and prevent pollution and environmental degradation. These programmes encompass elements on the identification of pollutants, control of their emission sources, monitoring of both ambient air and emissions and others.

In South Africa, air pollution has been the subject of legislation since the early 1960s through the Atmospheric Pollution Prevention Act, 1965 (Act no 45 of 1965) (the “APPA”). This Act provided for the appointment of the Chief Air Pollution Control Officer (the “CAPCO”) and inspectors to carry out the functions of the Act, mainly the control of noxious or offensive gases in controlled areas, as well as other pollution control functions triggered by regulations. Furthermore, APPA provided for establishment of various tools such as the smoke control zones, dust control areas as well as control of pollution from vehicles (South Africa, 1965). With regard to industrial emissions, APPA adopted a “command-and-control” approach, under which appliances and processes identified to release noxious or offensive odours were to be listed as Schedule 2 processes. These scheduled processes were required to obtain a valid APPA Registration Certificate (operating permit) prior to operation. Conditions of the permits were determined based on “best practicable means” principle, determined by the operator of the Scheduled Process and the CAPCO (Fuggle & Rabie, 1992). One of the limitations of this approach was that permits issued in terms of the APPA only dealt with specific major activities, while other atmospheric emission such as fugitive emissions were often overlooked. Furthermore the conditions of the permits were negotiated between the operator and the CAPCO, which resulted in inconsistencies in the permits of similar sources. This was

exacerbated by the absence of mandatory emission limits that could form the basis of such negotiations. Also, this tool was implemented without consideration of the receiving environment, with the exception of instances where complaints were made. Hence, processes or problem areas that attracted the most complaints were included in the schedules so that the department could put controls in place to reduce emissions (Scorgie & Kornelius, 2007). There were also issues of capacity constraints as licensing; compliance monitoring; and enforcement functions were centralized at national level, with only six air pollution control officers responsible for administration of these functions for the whole country.

In April 2010, the AQA came into effect, repealing the APPA, a dated legislation that had been in operation since 1965. In contrast to the APPA, the AQA adopted a new objective-based approach, in which air quality objectives defining acceptable levels of air pollutants in the ambient air are established, and air quality management planning is implemented to achieve these objectives. The focus moved from managing the sources at site to management of impacts on the receiving environment (DEAT, 2006). Under this approach, there is a need for correlation between the ambient air quality and management of the emission sources. Furthermore the AQA introduces identification of pollution hotspots, which provides an opportunity for government and stakeholders, mainly polluters, to invest efforts in the most problematic areas, at the same time ensuring that the air quality in compliant areas remains within the standards. Of specific interest to this study is the provision in the AQA for identification and listing of significant emission sources and establishment of minimum emission standards for such sources. Once listed, each emission source must obtain a valid atmospheric emission license (AEL) before it operates. This command-and-control tool was implemented under the APPA, but has now been adopted with modification to incorporate elements of mandatory emission standards, monitoring and reporting. To give effect to the provisions of the AQA, the Minister of the Department of Environmental Affairs has published a list of activities that results in significant emissions in terms of section 21 of this Act (commonly known as AQA S.21 Notice) (DEA, 2013a). This Notice establishes minimum emission standards for each listed activity, including emission limits, measurement methods and reporting requirements.

Although stipulation of measurement requirements plays an important role in demonstration of compliance with the emission standards, effective compliance monitoring requires more than the prescription of measurement methods. Emissions measurements planning and siting procedures; data quality control procedures; quality assurance (accreditation and certification) protocols, as well as the standardization of emission reporting are critical aspects of compliance monitoring that should be implemented to ensure the production of the quality data that can be used to the benefit of the license holder as well as the regulator. In addition to these aspects, the establishment of the criteria for compliance assessment, forming the basis for interpretation of the results is critical for enforcement purposes.

The aim of the study is therefore to develop a compliance monitoring system for atmospheric emissions to support effective implementation of the National Environmental Management: Air Quality Act, 2004. The objectives of the study are to:

- Identify critical elements of compliance monitoring system for emissions;
- Review best practices on selection of emission measurement methods, quality assurance and quality control, data handling, reporting and compliance assessment procedures; and
- Make recommendations on compliance monitoring system for South Africa, based on identified local needs and international best practice.

Adoption of the best practice in development of emissions compliance assessment system requires an in depth understanding of air quality management practices employed internationally, with specific focus on how industrial emissions are controlled; thus Chapter 2 (Literature survey) will describe and critically evaluate selected air quality management systems. Chapter 3 will describe in details elements of compliance monitoring; accreditation; and certification systems while Chapter 4 will focus on an appraisal of how these elements are implemented in various compliance monitoring systems across the world. Lastly, Chapter 5 will provide a synthesis on the experiences and lessons learned from study countries in order to make recommendations for the emission monitoring system for South Africa.

2 LITERATURE SURVEY

2.1 BACKGROUND

Industrial emission sources remain significant contributors to air pollution in South Africa. According to the State of Air Report 2005, about 1 500 operational industrial processes were issued with valid registration certificates in terms of the APPA. This number excluded all small-scale and other non-scheduled processes that did not require a permit to operate. Of these registered processes, major pollution sources were found to be those related to fuel combustion for process heating and electricity generation. The report records total annual emissions estimates for major industrial areas in the country for year 2002, citing industry and power generation's contribution of approximately eighty percent of the total particulates emissions, ninety seven percent of sulphur dioxide (SO₂) and eighty percent of oxides of nitrogen (NO_x) (DEA, 2009).

Although the permitting system was implemented for most of these industrial sources since 1965 through the APPA, this has not lead to a commensurate improvement in ambient air quality. There are various possible reasons for this. Firstly, air quality has been managed without ambient air quality objectives or targets, which define the quality of air acceptable to society and are normally used as a yardstick to measure effectiveness of air pollution control interventions in the country (DEAT, 2007a). Although there were ambient air quality guidelines, "these guidelines appear to have been internal guidelines that were never published, but were well known throughout the air quality management fraternity" (DEAT, 2007b). Secondly, identification of the significant emission sources for control was not necessarily objective. Schedule of controlled industrial processes was primarily based on the historical replication of processes in the older British Alkali Works Regulations and the British Clean Air Act applicable at the time of the development of APPA in the 1960s and 1970s (Fuggle & Rabie, 1992). Other processes were listed in the schedule as a response to complaints received by the department and those that operated in problematic areas. This meant that industrial processes or problem-areas that attracted the most complaints were

included in the schedule, while some significant emission sources that did not attract complaints were left out (DEAT, 2006). Lastly, where processes were required to have operating permits (called registration certificates under the APPA), the conditions of these permits were based on non-mandatory guidelines, and were further negotiated between the regulator and the applicant or registration certificate holder. This led to inconsistent permit conditions between scheduled activities of the same class, and also rendered enforcement ineffective as highlighted by the 2008/9 National Environmental Enforcement Report. The report highlights the following specific challenges encountered by inspection officers while conducting inspections for atmospheric emissions requirements (DEAT, 2009):

- “Vague and lenient permits issued to facilities;
- The lack of enforceable emission standards and monitoring obligations in the permits; and
- Outdated technologies used on sites presenting difficulties in the implementation of effective pollution abatement measures”.

With respect to emission compliance monitoring and reporting, self-monitoring approach was adopted, probably due to the capacity constraints. A variety of self-monitoring tools, mainly mass balances and periodic measurements were used. Some industries conducted continuous emission monitoring as industry standard work practice and for other non-air quality compliance reasons. This however applied mainly to larger industries and the scale of adoption was marginal. In the absence of a mandatory emission monitoring and reporting requirements, industries did not fully disclose their environmental impact information, thus the extent to which facilities have implemented emission monitoring remains unclear.

As highlighted in Chapter 1, the new air quality regime introduced by the promulgation of the AQA brings a significant change to how air quality is managed in South Africa. With the introduction of the AQA, a paradigm shift from limited, source-based emission control to ambient air quality management is established (DEAT, 2006). The constitutional right to an environment that is not harmful to health and wellbeing is given effect to by adopting an objective-based approach, in which air quality standards defining the acceptable levels (i.e.

the air that is not harmful to health and wellbeing) of air pollutants in the ambient air are promulgated. Air quality management planning, comprised of strategies aimed at attainment of these standard, is integrated with other development planning processes by all spheres of government and businesses to promote sustainable development. Furthermore the AQA introduces identification of pollution hotspots, which provides an opportunity for government and affected stakeholders to invest efforts in the most problematic areas, at the same time ensuring that the air quality in compliant areas remain within the prescribed standards. There are also significant noticeable differences in the authorizations system. While permitting was previously the function of the national government, this power is decentralized under AQA, making it a function of local government, with provincial and national governments licensing only under certain instances. Furthermore, licensing administration has been improved by replacing the system of permit-per-process with a site license incorporating all listed activities on site, and taking into account the impact of non-listed activities when making decisions on the license. Also, mandatory emission standards are now established, including compliance monitoring and reporting requirements. High penalties for offenses are incorporated (South Africa, 2005).

Notwithstanding these improvements, there are elements of the air quality management system that still need to be developed to ensure that the authorization system results in meaningful emission reductions to support attainment of the ambient air quality standards. The air quality governance cycle Figure 2-1 adopted by the National Framework for Air Quality demonstrate that air quality governance is comprised of a number of elements that are interdependent, thus the absence of one of the tools has a potential to affect effective implementation of the system (DEA, 2013b).

Of specific interest to this study is compliance monitoring. Almost all air quality tools are dependent on monitoring of the effectiveness of implementation, which translates to confirmation of whether the tools result into desired outcomes or not. With respect to emissions licensing, monitoring is undertaken by assessing compliance of the licensed processes with the conditions imposed in the licenses, as informed by the minimum emission

standards. Where there is non-compliance, enforcement activities are triggered. Therefore, in the absence of monitoring, the implementation of the licensing system, including enforcement function, cannot be fully effective.

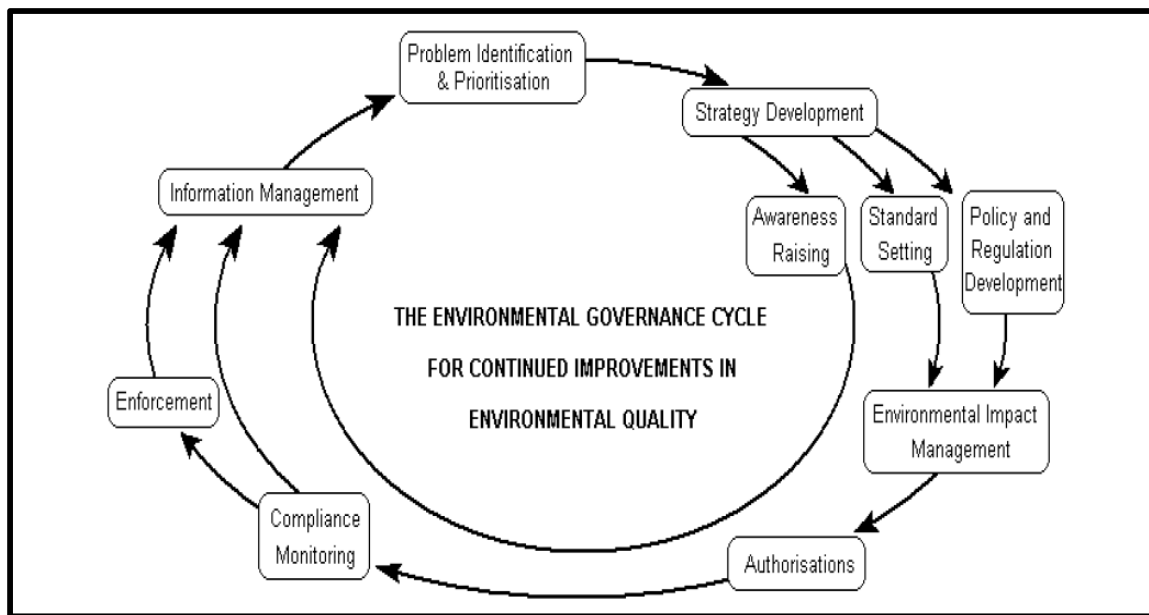


Figure 2-1: Air Quality Governance Cycle (DEA, 2013b)

Compliance monitoring can range from less intensive self monitoring exercises to highly intensive mandatory reporting, regulatory inspections and audits as well as enforcement activities by relevant agencies. All these forms of monitoring have some benefits to overall emission reductions, depending on how they are implemented and the frequency thereof. For instance, emission reductions can be achieved by frequently conducting random inspections. In their study on the impact of inspections on the self-reported emission levels of plants in the pulp and paper industry in Quebec, Canada, (Laplante & Rilstone, 1999) found that both inspection and a threat of inspection have an impact on emissions. As frequent randomly conducted inspections occur, or a threat of such inspection exists, industries tend to move towards reducing their emissions. Where inspections do not occur or are not threatened, less effort is made by industries to reduce their emission levels.

Another study with similar conclusions was conducted by (Macho-Stadler & Pérez-Castrillo, 2006) on the optimal audit policy in situations where firms may evade environmental taxes. In this study, authors demonstrate that the audit policy has a deterrent effect on the actual emission level and the sources' reported emission. Where the inspection is not likely to happen, the emission source pollutes freely and reports no pollution. Only when faced with intensified audit pressure do they start decreasing their emission levels, but continue to report no pollution. A more radical audit pressure triggers the truthful and consistent reporting by the emission source on its actual level of emission compliance.

The same notion applies to enforcement activities. Increased enforcement actions significantly increase the level of compliance with emission standards. When studying the relationship between regulators' enforcement of air pollution regulations and firms' compliance decisions in the U.S steel industry, (Gray & Deily, 1996) have provided evidence that compliance decisions of integrated steel firms were affected by the enforcement decisions of regulators. Inspections and enforcement actions by the regulators increased compliance at steel plants. In addition to this, the plant's future viability and the cost of bringing it into compliance influenced firms' compliance decisions as expected. (Foulon, Lanoie & Laplante, 2002) drew conclusion that the presence of clear and strong standards accompanied with a significant and credible penalty system does send appropriate signals to the regulated community, which then responds by lowering emissions. Furthermore, the public disclosure of environmental performance creates additional and strong incentives for pollution control.

All these studies support the need for a coherent compliance monitoring system for realization of emission reductions targets. Over and above the emission reduction benefits of compliance monitoring and enforcement, additional benefits on acquisition of information that can be used for general air quality management decisions are realized. For instance, a wealth of information about the emission source characteristics and environmental performance is generated when the frequency of reporting is increased (Laplante & Rilstone, 1999), and through compliance inspections. Resource management is one aspect of environmental

management that benefits from this. The observation of the characteristics of plants and industries, and the use of the information generated from this for prediction of potential non-compliance may influence how monitoring resources are allocated and assists in reduction of the demand on these scarce resources. This increases the effectiveness of the monitoring programme, as supported by (Macho-Stadler & Pérez-Castrillo, 2006). These authors contend that when firms differ in their effectiveness of the audit, it is optimal to target facilities that are easy to audit. As more financial resources are allocated for this function, more facilities are monitored and the audit intensity on inspected facilities increases.

The need to have an emission compliance monitoring system as part of the overall air quality management system can therefore not be overemphasized. The effective implementation of the licensing regime under the AQA requires investment of resources in development and implementation of emission monitoring, reporting and assessment system aimed at ensuring that all listed activities meet the emission standards. Since emission standards promulgated under S.21 Notice are mainly concentration-based; the associated compliance monitoring approach will therefore be biased towards utilization of various emission estimation techniques and measurement methods. Although the AQA provides for the Minister to prescribe how measurements must be carried out as part of minimum emission standards, only a list of measurement methods is currently included in the standards (DEA, 2013a). The standards lack details on criteria for the application of these methods, assessment protocols, and QA/QC procedures.

An emission compliance monitoring system providing these details is therefore required. This system has to provide clear guidance on how measurements for regulated pollutants should be conducted, and on how emission data should be reported and interpreted. Furthermore, QA/QC procedures, accreditation protocols for laboratories and certification requirements for staff competence must also be prescribed. Section 7 of the AQA describes this system as the norms and standards for emission monitoring (South Africa, 2005).

The use of the international best practice to inform the development of the system for South Africa will require detailed understanding of air quality governance systems implemented by countries that are chosen as case studies for this purpose. Ideally, selection of countries should focus on countries that have similar governance structures and legislative approaches as South Africa, especially with respect to industrial emissions control. This approach is beneficial to draw lessons from the successes and failures of these countries, as well as to put South Africa's legislative requirements in par with the best international regulatory systems. This may also benefit multinational companies as compliance strategies become easily shared and knowledge base used to improve compliance in non-compliant countries. The rest of this chapter is therefore dedicated to understanding air quality management systems of countries selected on the basis of their advanced emission control legislation, and similarity in governance systems.

2.2 AIR QUALITY MANAGEMENT IN AUSTRALIA

2.2.1 Air quality legislative framework

Australia is governed by a federal system, under which powers are divided between a central government and individual states. The Environment Protection and Biodiversity Conservation Act 1999 (EPBCA) is Australia's main legislation, providing a framework for the protection and management of matters of national environmental significance (Australia, 2014a). "It streamlines national environmental assessment and approvals process, protects Australian biodiversity and integrates management of important natural and cultural places" (Scorgie & Kornelius, 2007). The EPBCA came into force on 17 July 2000 and was recently amended in 2014.

With regard to coordination of environmental protection measures between the central government, the states, territories and local governments, the National Environment Protection Council Act, 1994 (Act No.126 of 1994) (the NEPCA) has been enacted to establish the National Environment Protection Council (NEPC). This council is established to ensure that Australians enjoy the benefit of equivalent protection from air, water or soil

pollution and from noise wherever they live in the country, and that “decisions of the business community are not distorted, and markets are not fragmented, by variations between participating jurisdictions in relation to the adoption or implementation of major environment protection measures” (Australia, 2014b). NEPC has powers to make National Environment Protection Measures (NEPMs) on various environmental issues, including ambient air quality. NEPMs outline national objectives for protecting or managing particular aspects of the environment and may include a combination of goals, guidelines, standards or protocols. Once NEPMs are developed, states and territories are expected to implement them by incorporation in their own legislation (Scorgie & Kornelius, 2007). Industrial emission standards are however not covered by NEPMs.

2.2.2 Ambient air quality standards

The Ambient Air Quality NEPM, established in terms of Section 14 (1) (a) of the NEPCA, was initially published in June 1998, sets ambient air quality standards to protect human health and wellbeing. This NEPM includes air quality standards for carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO₂), particulate matter with an equivalent aerodynamic diameter of 10 micrometers or less (PM₁₀), ozone (O₃), and sulphur dioxide (SO₂). These standards, documented in Table 2-1 below, are applicable to all states and territories of Australia.

The Ambient Air Quality NEPM was varied in May 2003 to introduce Advisory Reporting Standards for particulate matter with an equivalent aerodynamic diameter of 2.5 micrometres or less (PM_{2.5}) (See Table 2-2). All eight states and territories are required to monitor and report on these standards annually, and may set their own standards, which are to be stricter than the national standards.

Table 2-1: National Ambient Air Quality Standards and Goals (Australia, 2003)

Pollutant	Averaging Period	Maximum Concentration	Maximum Allowable Exceedences
Carbon monoxide	8 hours	9.0 ppm	1 day a year
Nitrogen dioxide	1 hour 1 year	0.12 ppm 0.03 ppm	1 day a year None
Photochemical oxidants (as ozone)	1 hour 4 hours	0.10 ppm 0.08 ppm	1 day a year 1 day a year
Sulphur dioxide	1 hour 1 day 1 year	0.20 ppm 0.08 ppm 0.02 ppm	1 day a year 1 day a year None
Lead	1 year	0.5 µg/m ³	None
Particles as PM ₁₀	1 day	50 µg/m ³	5 days a year

Table 2-2: Advisory Reporting Standards and Goals for PM_{2.5} (Australia, 2003)

Pollutant	Averaging Period	Maximum Concentration	Goal
Particles as PM _{2.5}	1 day 1 year	25 µg/m ³ 8 µg/m ³	Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of the review of this Measure scheduled to commence in 2005

Over and above these standards, the NEPC has also published the NEPM for five toxic pollutants. The aim of the Air Toxics NEPM is to provide a framework for monitoring, assessing and reporting on ambient levels of these toxics to improve the information base regarding ambient air toxics with the Australian environment in order to facilitate the development of standards (Australia, 2011). Monitoring investigation levels published for these air toxics is documented in Table 2-3.

Table 2-3: Monitoring Investigation Levels for Air Toxics (Australia, 2011)

Pollutant	Averaging Period	Maximum Concentration	Goal
Benzene	Annual average	0.003 ppm	8-year goal is to gather sufficient data nationally to facilitate development of a standard
Benzo(a)pyrene as a marker for Polycyclic Aromatic Hydrocarbons	Annual average	0.3 ng/m ³	
Formaldehyde	24 hours	0.04 ppm	
Toluene	24 hours	1 ppm	
	Annual average	0.1 ppm	
Xylenes (at total of ortho -, meta and para isomers)	24 hours	0.25 ppm	
	Annual average	0.2 ppm	

2.2.3 Industrial emissions control

With respect to industrial emissions control, each state and territory is responsible to set up its own protection of environmental measures. The industrial emissions control measures of the New South Wales (the “NSW”) territory are the most comprehensive ones thus chosen here as a model to understand Australian industrial emissions control approach. The Protection of the Environment Operations Act 1997 (the POEOA) (NSW, 1997) provides statutory framework for environment protection legislation in the NSW. Under this Act, the Protection of Environmental Operations (Clean Air Regulation) (the “CAR”) has been promulgated, providing regulatory measures to control emissions from wood heaters, open burning, motor vehicles and fuels and industry. The CAR identifies schedule of activities that have to be regulated according to the specific class, and sets maximum limits on emissions for those activities for various pollutants. Furthermore, the CAR address emissions from transport and storage of volatile organic liquids; restricts the use of high sulphur liquid fuel; and make requirements for certain afterburners, flares, vapour recovery units and other treatment plant (NSW, 2010). Scheduled activities have to be granted valid Environmental Protection Licenses (EPL) issued in terms of the POEOA, prior to operation. The POEOA makes it an offence to carry any scheduled activity without a valid EPL.

With respect to emissions standards, the CAR categorizes activities into six groups, based on the age of the activity. The activities belonging to the old plants group categories are phased out over time. Three types of emission standards are set for scheduled premises as follows:

- Afterburners, flares and vapour recovery units – These emission standards are set for pollution abatement equipment as specified. It is observed that these are abatement equipment that has the potential to generate other emissions through destruction of primary pollutants.
- Activities and plant used for specific purposes – the standards are set for specific industrial sectors.
- General activities and plant – these standards are general standards applicable to activities not requiring site – specific controls.

2.2.4 Compliance monitoring requirements

Emission monitoring requirements for demonstration of compliance with the standards are also included under the CAR. Reference is made to periodic emissions measurement (PEM) and continuous emission monitoring (CEM) methods. Detailed compliance requirements such as measurement frequency are not provided in the regulations. Such requirements are typically included in facility specific EPLs. The Approved Methods for the Sampling and Analysis of Air Pollutants (the “AMSAAP”) in NSW (NSWEPA, 2006) lists the statutory methods that are to be used to sample and analyze air pollutant emissions from stationary sources, in addition to pollutants in ambient air.

2.3 AIR QUALITY MANAGEMENT IN THE UNITED STATES OF AMERICA

2.3.1 Air quality legislative framework

The Clean Air Act (the “CAA”) provides the legal framework concerning management of air quality in the United States of America (the “USA”), with the objective of protecting and promoting public health and public welfare. The Act pursues five major goals, namely (NRC, 2004):

- “Mitigate potentially harmful ambient concentrations of six “criteria” pollutants by establishment of the national ambient air quality standards for criteria pollutants;
- Limit the sources of exposure to hazardous air pollutants (the “HAPs”);
- Protect and improve visibility in wilderness areas and national parks;
- Reduce emissions of substances that cause acid deposition, specifically sulphur dioxide and nitrogen oxides (NO_x); and
- Curb use of chemicals that have the potential to deplete the stratospheric ozone layer”.

The CAA is “intended in part to provide a degree of national uniformity in air quality standards and approaches to pollution mitigation so that all individuals in America are assured a basic level of environmental protection” (NRC, 2004). The Environmental Protection Agency (the “USEPA”) coordinates the implementation of the CAA. States and local governments are responsible for implementation and enforcement of the federally mandated rules and regulations within their jurisdictions, including the implementation of strategies and control measures to meet national air quality standards and goals.

2.3.2 Ambient air quality standards

The ambient air quality objectives and standards, aimed at the protection of public health and welfare across the nation, are established by the USEPA. Currently, primary and in some cases, secondary national ambient air quality standards have been set for six common criteria pollutants which are CO, NO₂, SO₂, O₃, PM, and Pb (See Table 2-4). Primary standards provide public health protection, including protecting the health of sensitive populations such

as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

Table 2-4: National Ambient Air Quality Standards for Criteria Pollutants in the USA (USEPA, 2014c)				
Pollutant	Primary/ Secondary	Averaging time	Level	Form
Carbon Monoxide	Primary	8 - hour	9 ppm	Not to be exceeded more than once per year
		1 - hour	35 ppm	
Lead	Primary and secondary	Rolling 3 month average	0.5 µg/m ³	Not to be exceeded
Nitrogen dioxide	Primary	1 -hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Primary and secondary	Annual	53 ppb	Annual Mean
Ozone	Primary and secondary	8 - hour	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
Particulate Matter (PM _{2.5})	Primary	Annual	12 µg/Nm ³	annual mean, averaged over 3 years
	Secondary	Annual	15 µg/m ³	annual mean, averaged over 3 years
	Primary and secondary	24 - hour	35 µg/m ³	98th percentile, averaged over 3 years
Particulate Matter (PM ₁₀)	Primary and secondary	24 - hour	150 µg/m ³	Not to be exceeded more than once per year on average over 3 years
Sulphur dioxide	Primary	1 - hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Secondary	3 -hour	0.5 ppm	Not to be exceeded more than once per year

In addition to the control of criteria pollutants, the CAA also regulates the release of the HAPs. To date, the CAA has listed 187 HAPs such as dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds. This list is made up of pollutants that have potential to cause serious health effects and cancer (USEPA, 1989).

The CAA criteria and HAP standards are implemented by development and implementation of control strategies. These strategies include source control technology standards, emission trading programs, pollution prevention and compliance assurance programs. Information is collected as these control strategies are being implemented, and it is then used for assessment of status of air quality, effectiveness of the strategies to inform continual improvements.

2.3.3 Industrial emissions control

The CAA divides stationary emission sources into two categories. These are major stationary or point sources and area sources. The criterion for categorization of sources is defined by either the CAA or by the state regulatory agency, and is based on the exceedence or non-exceedence of established nominal emission rates. These emission sources are controlled through the imposition of a technology based standards applied to individual facilities or through the imposition of the overall cap on a specific industry or segment of sources (NRC, 2004).

(a) New Source Performance Standards for criteria pollutants

The CAA requires the development of technology-based standards known as the New Source Performance Standards (the “NSPS”). The NSPS are promulgated for specific source categories that the USEPA judges to cause or contribute to air pollution that may be reasonably anticipated to endanger public health or welfare. They are applicable to new, modified and reconstructed affected facilities in specific source categories (Erbes, 1994). Table 2-5 lists pollutants that are regulated in the NSPS programme in the state of Nebraska.

Table 2-5: List of pollutants regulated under NSPS permit programme (Nebraska, 2014)

Pollutant	Pollutant
Particulate Matter	Cadmium
Sulphur Dioxide	Lead
Nitrogen Oxides	Mercury
Carbon Monoxide	Total Reduced Sulphur
Volatile Organic Compounds	Municipal Solid Waste Landfill Emissions
Opacity	Municipal Waste Combustor Metals
Dioxins/Furans	Municipal Waste Combustor Acid Gases (SO ₂ and HCl)
Fluorides	Sulphuric Acid Mist

NSPS emission limits are expressed in terms of emission rates, concentrations and opacity, depending on the type of source category and pollutant as shown in the example on Table 2-6. Test methods and procedures for all emission limit requirements are stipulated in the standards to facilitate monitoring and reporting, which forms part of a detailed compliance testing process.

(b) National Emission Standards for Hazardous Air Pollutants for toxics

National Emission Standards for Hazardous Air Pollutants (NESHAPs) are established for HAPs emissions from both existing and new stationary sources. These standards are set in line with the Maximum Achievable Control Technology (MACT) requirements, which requires that technology – based standards requiring maximum degree of reduction in emissions of the HAPs be established for these HAPs. Different criteria for implementation of the MACT apply for new and existing sources (USEPA, 2013).

Table 2-6: Example of New Source Performance Standard with different expressions adopted for each pollutant (USEPA, 1976)

CAA Provision	Standard for particulate matter	Standard for sulphur dioxide.	Standard for visible emissions.
Subpart P—Standards of Performance for Primary Copper Smelters	On and after the date on which the performance test required to be conducted by § 60.8 (of the CAA) is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any dryer any gases which contain particulate matter in excess of 50 mg/dscm (0.022 gr/dscf).	(a) On and after the date on which the performance test required to be conducted by § 60.8 (of the CAA) is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any roaster, smelting furnace, or copper converter any gases which contain sulphur dioxide in excess of 0.065 percent by volume, except as provided in paragraphs (b) and (c) of this section.	(a) On and after the date on which the performance test required to be conducted by § 60.8 (of the CAA) is completed, no owner or operator subject to the provisions of this subpart shall cause to be discharged into the atmosphere from any dryer any visible emissions which exhibit greater than 20 percent opacity.

(c) Title V Operating Permits

Emission standards are implemented by the states using various operating permitting programs, under EPA's overseeing role. Operating permits, commonly referred to as Title V permits, are issued for major stationary sources and a limited number of smaller sources (called "area" sources, "minor" sources, or "non-major" sources) (USEPA, 2014d). The Title V permit lists all the control requirements for a particular source to provide the necessary information for inspectors to verify compliance. These include emission limits to be attained, performance of abatement equipment, monitoring, recordkeeping and reporting procedures.

Demonstration of compliance with permit conditions is conducted annually and evaluates and certifies to each term and condition of the permit, and not just emission amounts (Erbes, 1994). This is undertaken through government inspections and through acceptable self-monitoring. In terms of inspections, EPA and state inspectors typically conduct both routine and for-cause inspections, depending on whether there is suspicion for violation or not. These inspections involve observation of visible emissions; examination of data on control devices and operating conditions for comparison with those specified in the facility's permit; and review of the records and log books on the facility's operations (NRC, 2004).

2.3.4 Compliance monitoring requirements

The CAA requires the inclusion of applicable monitoring and analysis procedures or test methods in the permits. These requirements are stated under NSPS and NESHAP rules, as well as under Compliance Assurance Monitoring rules for individual source categories. Where the applicable requirement under NSPS or NESHAP rules does not require CEM or any monitoring at all, the CAA requires that "periodic monitoring sufficient to yield reliable data from the relevant time period that are representative of the source's compliance with the permit", must be instituted (USEPA, 1992b). The types of monitoring approaches adopted by the CAA range from performance tests for sources that have add-on abatement equipment to emission tests using test methods promulgated by the USEPA.

Quality of emission data is a critical factor in the demonstration of compliance and for the use of this data in other applications. There is high interest in QA/QC for emissions measurements in the USA. This is made evident by the number of accreditation institutions for emissions testing, as well as the variety of accreditation requirements. Accreditation frameworks for emission-testing bodies have been established by the USEPA – linked National Environmental Laboratory Accreditation Conference (the "NELAC") Institute and the American Society for Testing and Materials (the "ASTM"). Furthermore, the use of the International Standardization Organization (ISO) framework is also acceptable in the USA.

2.4 AIR QUALITY MANAGEMENT IN THE UNITED KINGDOM

2.4.1 Air quality legislative framework

The United Kingdom (the “UK”) is a member state of the European Union (the “EU”), a union comprised of twenty-eight European countries. This union has established an institution called the European Commission (the “EC”), which is responsible for, amongst others, drafting and management of implementation of European laws or directives (European Union, 2014). With regard to environmental legislation, the European Directives place a duty on each EU member state to institute policies to protect and improve its environment and the health of its citizens. The EC action is designed to protect the environment, reduce exposure to air pollution, ensure sustainable development; and promote better regulation. The air quality policy adopted by the EC has involved two complementary approaches – (i) controlling emissions at source, and (ii) the setting of long-term ambient air quality objectives. This is done through promulgation of the EU Directives that all member states of the EU must incorporate or transpose into their own national law by a specified date (Scorgie & Kornelius, 2007).

The United Kingdom is made up of England, Wales, Scotland and Northern Ireland. Although it has a central parliament, this nation has since the late 1990s decentralized some of the powers this parliament held to the Scottish Parliament, the National Assembly for Wales as well as the National Assembly for the Northern Ireland, the process known as devolution. Amongst the devolved powers are policy and legislative decisions affecting the environment, which includes air quality management. However, due to the transboundary nature of air pollutants, the UK government and devolved administrations are making joint decisions on air quality management, as evident in strategies for air quality that have been published to date.

Air quality management in the UK is legislated by the Environment Act 1995 for England, Wales and Scotland. This Act which requires the Secretary of State to prepare and publish a strategy containing policies with respect to the assessment and management of air quality (United Kingdom, 1995). Similarly, in Northern Ireland, the Environment (Northern Ireland)

Order 2002 requires the department to do the same (Northern Ireland, 2002). The first National Air Quality Strategy was published in 1997 with commitments to achieve new air quality objectives throughout the UK by 2005. A review of the strategy led to the publication of Air Quality Strategy for England, Scotland, Wales and Northern Ireland in January 2000 as well as in July 2007. The overall objectives of this strategy are “to map out future ambient air quality policy in the UK in the medium term; to provide best practicable protection to human health by setting health-based objectives for air pollutants; to contribute to the protection of the natural environment through objectives for the protection of vegetation and ecosystems; to describe current and future levels of air pollution; as well as to establish a framework to help identify what we all can do to improve air quality” (DEFRA, 2007).

2.4.2 Ambient air quality standards

Ambient air quality objectives for nine air pollutants are established as shown in Table 2-7.

Table 2-7: Air Quality Objectives for the purposes of air quality management in the UK (DEFRA, 2007)				
Pollutant	Applicable	Air Quality Objective		Date to be achieved by
		Concentration	Measured as	
Polycyclic aromatic hydrocarbons	UK	0.25 ng/m ³ B[a]P	annual average	31.12.2010
Benzene	UK	16.25 µg/m ³	running annual mean	31.12.2003
	England and Wales	5 µg/m ³	annual mean	31.12.2010
	Scotland and Northern Ireland	3.25 µg/m ³	running annual mean	31.12.2010
1,3 Butadiene	UK	2.25 µg/m ³	running annual mean	31.12.2003
Carbon monoxide	UK	10.0 mg/m ³	running 8-hour mean	31.12.2003
Lead	UK	0.5 µg/m ³	annual mean	31.12.2004
		0.25 µg/m ³	annual mean	31.12.2008

Table 2-7: Air Quality Objectives for the purposes of air quality management in the UK (DEFRA, 2007)

Pollutant	Applicable	Air Quality Objective		Date to be achieved by
		Concentration	Measured as	
Nitrogen dioxide	UK	200 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 18 times a year	1 hour mean	31.12.2005
		40 $\mu\text{g}/\text{m}^3$	annual mean	
Particles (PM_{10})	UK	50 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 35 times a year	24 hour mean	31.12.2004
		40 $\mu\text{g}/\text{m}^3$	annual mean	
	Scotland	50 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 7 times a year	24 hour mean	31.12.2010
		18 $\mu\text{g}/\text{m}^3$	annual mean	31.12.2010
Particles ($\text{PM}_{2.5}$) Exposure reduction	UK (Except Scotland)	25 $\mu\text{g}/\text{m}^3$	Annual mean	2020
	Scotland	12 $\mu\text{g}/\text{m}^3$		Between 2010 and 2020
	UK (Urban areas)	Target of 15% reduction in concentrations at urban background		
Ozone	UK	100 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 10 times a year	8 hour mean	31.12.2005
Sulphur dioxide	UK	350 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 24 times a year	1 hour mean	31.12.2004
		125 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 3	24 hour mean	

Table 2-7: Air Quality Objectives for the purposes of air quality management in the UK (DEFRA, 2007)

Pollutant	Applicable	Air Quality Objective		Date to be achieved by
		Concentration	Measured as	
		times a year		
		266 $\mu\text{g}/\text{m}^3$ not to be exceeded more than 35 times a year	15 minute mean	31.12.2005
National air quality objectives for the protection of vegetation and ecosystems				
Nitrogen oxides	UK	30 $\mu\text{g}/\text{m}^3$	annual mean	19.7.2001
Sulphur dioxide	UK	20 $\mu\text{g}/\text{m}^3$	annual mean	31.12.2000
		20 $\mu\text{g}/\text{m}^3$	winter average	
Ozone: protection of vegetation & ecosystems	UK	Target value of 18,000 $\mu\text{g}/\text{m}^3$ based on AOT40 to be calculated from 1 hour values from May to July, and to be achieved, so far as possible, by 2010.	Average over 5 years	1.1.2010

2.4.3 Industrial emissions control

With regard to emissions control at the source, the EC has put in place a specific directive (Directive 2008/1/EC) on integrated pollution prevention and control (IPPC). The IPPC regime applies an integrated environmental approach to the regulation of certain large industrial activities. It requires each installation to apply for a permit in order to operate (European Union, 2008). The current permitting framework has within its foundations the concept of “best available techniques” (BAT), which is the principle requiring that environmental conditions of the permits be based on available techniques that achieve the best control in minimization or prevention of pollution from the applicable source. These techniques are detailed in specific sector reference documents describing best available techniques, commonly known as BREF documents, which are published by the EC to support implementation of the IPPC directives.

Permit conditions also have to address energy efficiency, waste minimization, and prevention of accidental emissions and site restoration. The IPPC directive and associated directives have been revised into a newly integrated directive known as the Industrial Emissions Directive 2010/75/EC. This directive, brought into effect in 2011, consolidates the 2008 IPPC and other directives into one integrated directive (European Union, 2010).

The Environmental Permitting (England and Wales) (Amendment) Regulations of 2013 (the “EPR”) provide a framework for implementation of the above industrial emissions directive(s), for England and Wales. These regulations stem from the Pollution Prevention and Control Act, 1999 that provides for establishment of an environmental permitting system for some industrial activities (United Kingdom, 1999). The aim of the permitting regime is “to protect the environment and human health, deliver permitting and compliance effectively and efficiently in a way that provides increased clarity and minimizes the administrative burden on both the regulator and the operators of facilities, encourage regulators to promote best practice in the operation of regulated facilities, and continue to fully implement European legislation” (DEFRA, 2010). The EPR gives effect to the EU directives by incorporating requirements of these directives by reference in the permits. Emission limits prescribed in these directives are mostly concentration-based limits, as shown in the example in Table 2-8 below.

Table 2-8: Emission limit values (mg/Nm ³) for SO ₂ for combustion plants using solid or liquid fuels with the exception of gas turbines and gas engines (European Union, 2010)				
Total rated thermal input (MW)	Coal and lignite and other solid fuels	Biomass	Peat	Liquid fuels
50 -100	400	200	300	350
100-300	200	200	300 250 in case of fluidized bed combustion	200
> 300	150 200 in case of circulating or pressurized fluidized bed combustion.	150	150 200 in case of fluidized bed combustion	150

2.4.4 Compliance monitoring requirements

In the EC compliance monitoring is to be conducted using relevant standards published by the Committee for European Norms (CEN), where they are specified under the respective requirements of the directives. Where CEN standards are not available, methods published by ISO, national or other international standards, which ensure the provision of data of an equivalent scientific quality, are to be used (European Commission, 2003).

The Environmental Agency (the “EA”) for England and Wales has published technical guidance notes on stack emission monitoring, giving effect to EC monitoring requirements. Under these notes, standard reference methods for pollutants regulated are specified. Furthermore, the EA has set up a monitoring certification scheme (MCERTS), which is responsible to ensure compliance with European Directives regulating industrial emissions, monitoring data, equipment and personnel.

3 ELEMENTS OF AN EMISSIONS COMPLIANCE MONITORING SYSTEM

3.1 INTRODUCTION

Over the years, a variety of emission monitoring tools have been developed to prove compliance with emissions standards and for other reasons such as data collection for emissions inventories, environmental impact assessments, process control and evaluation of performance of emissions abatement systems.

Due to the variety and complexity of industrial emissions control requirements stipulated in the standards, as well as the technical complexity of the stack emissions monitoring process, a compliance monitoring system is normally developed to support the implementation of these standards. This chapter is intended to understand various elements required for effective implementation of emissions monitoring, and to provide a picture of how they are interlinked according to their interdependence. This overview is informed by published literature and standards on the aspects of emissions measurements, reporting, interpretation and quality management.

Figure 3-1 provides a framework of procedures and processes comprising an emissions compliance monitoring system. Emissions monitoring focuses mainly on point source emissions, measured at the stack, either periodically or continuously, with emissions estimations used as additional measures for validation or estimation techniques in instances where measurements cannot be done. QC activities are implemented to ensure that emissions data produced meets basic scientific principles that define credibility and ensure repeatability of measurements. Once data quality has been ascertained, it is reported in the format required by regulations and interpreted by authorities to determine compliance or non-compliance. All these processes are carried out within the quality management system.

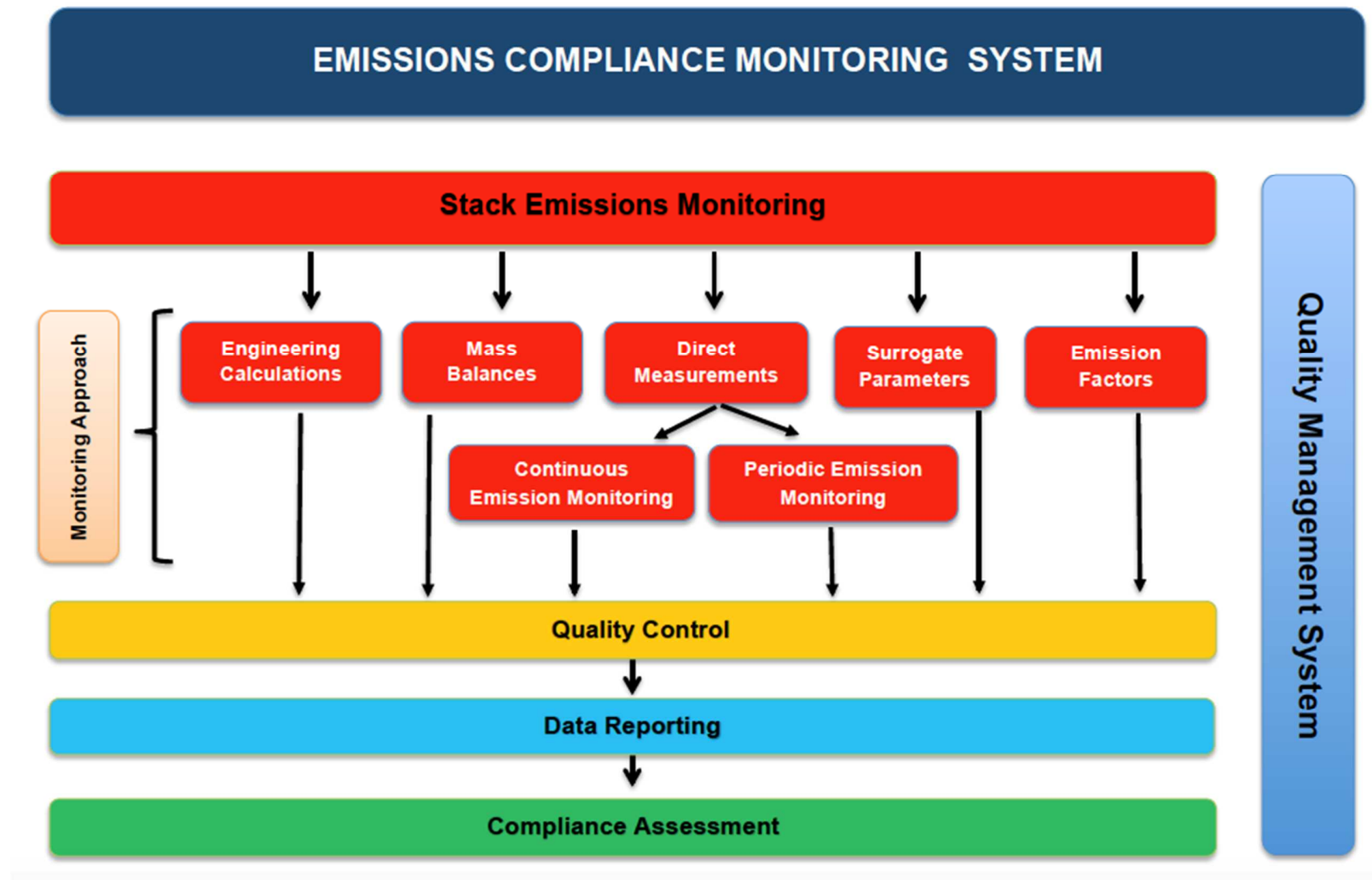


Figure 3-1: Schematic diagram illustrating the elements of compliance assessment system.

3.2 EMISSIONS MONITORING APPROACHES

Emissions limits set out in the standards may be expressed in absolute terms or relative terms. In the case of gaseous pollutants, limits may be stated in volumetric rather than gravimetric terms (Vallero, 2007). As a result, several approaches to monitoring of emission parameters have been developed; including direct measurements, mass balances, emission factors; as well parametric surrogate measures (European Commission, 2003). Several factors influence the choice of the approach adopted to measure pollutant emissions, including the likelihood of exceeding the emission limit value, the consequences of exceeding the emission limit value, the required accuracy, costs, simplicity, rapidity, reliability, suitability etc. (InfoMil, 2012).

3.2.1 Direct measurements

Direct measurement is defined as “specific quantitative determination of the emitted compounds at the source” (European Commission, 2003). This can be divided into two techniques, PEM and CEM.

3.2.2 Periodic emission monitoring

PEM ascertains the extent and nature of emission through taking spot samples over a limited period of time (Umweltbundesamt, 2008). Samples may be obtained over a period specified in the standards, ranging from minutes (grab samples) to hours. Depending on the type of instrument used, analysis of the compound measured can be directly performed in the flue gas (i.e. in-situ) or later in a laboratory, away from the site (extractive or manual sampling) (EA, 2007).

In-situ measurement (See **Figure 3-2**) is advantageous in that values of parameters and components are known immediately after the measurement exercise is complete, reducing transportation errors and laboratory costs. This method is used, inter alia in the determination of physical flue gas parameters, such as temperature, pressure and velocity. The

disadvantage is that both the flue gas conditions and the available measurement principles, however, often prevent a direct analysis in the flue gas. For example, optical methods are disturbed by high concentrations of dust in the flue gas and infrared methods due to the presence of water vapour. An extractive measurement with an external method of analysis is then the alternative.

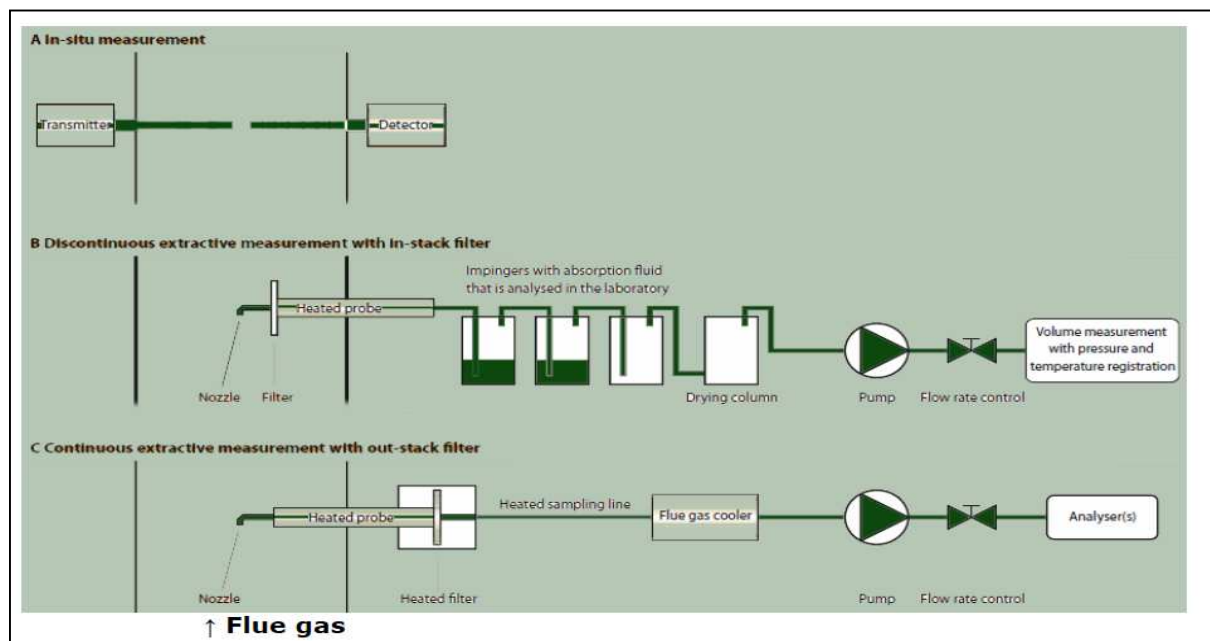


Figure 3-2: In-situ and extractive measurement techniques (InfoMil, 2012)

With a probe partial flow of the flue gas is extracted, transported and analyzed outside the flue gas duct **Figure 3-2**. In general, extractive sampling is only applied in determining the chemical composition of the flue gas. Inherent in extractive measurements is the transport of the sample. Here errors can occur in the concentration determination due to dilution of the flue gas as a result of leakage, due to chemical reactions or due to adsorption of the component onto surfaces within the transport system. It is therefore important that the leak-tightness of the sampling system is monitored and that it is inert with respect to the components to be determined. Materials such as quartz, teflon and stainless steel are

therefore often used. In addition, the conditioning of the sample with respect to particulates and water vapour is important (InfoMil, 2012).

3.2.3 Continuous emission monitoring

Continuous emission monitoring systems (CEMS) are systems that are capable to carry out emission measurements continuously, producing comprehensive data, with very few gaps. These systems range from portable emission testing equipment to big equipment that is permanently installed in-stack. Measurement may be carried out in situ in the stack or extractive using with an instrument permanently located at or near the stack (EA, 2007).

A CEMS is actually comprised of several subsystems as shown in **Figure 3-3**. These are the sampling interface made up of sampling probes and flow meters, the gas analyzers, and the data acquisition systems.

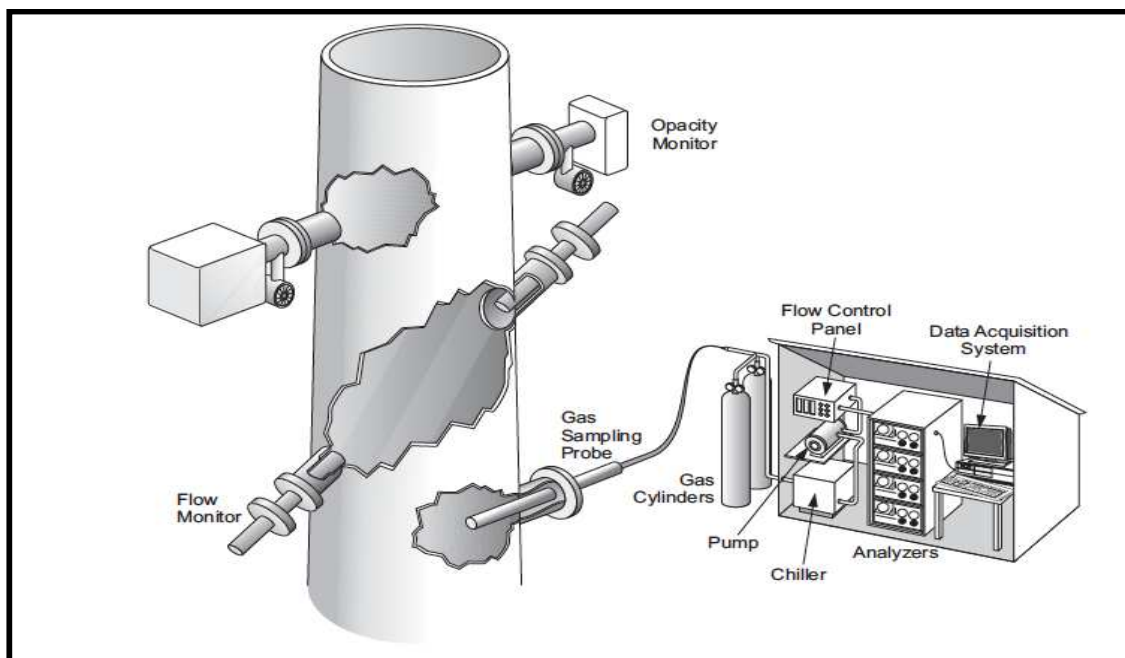


Figure 3-3: A continuous emission monitoring system (Jahnke J.A, 2000)

3.2.4 Surrogate parameters

Surrogate parameters are measurable or calculable quantities, which can be closely related, directly or indirectly, to conventional direct measurements of pollutants, and which may therefore be monitored and used instead of the direct pollutant values for some practical purposes. Where they are used, surrogate parameters provide complementary information about the plants' emission behavior. The surrogate may provide an indication of whether the emission limit value can be satisfied if the surrogate parameter is maintained within a certain range (European Commission, 2003).

Whenever a surrogate parameter is proposed to determine the value of another parameter of interest, the relationship between the surrogate and the parameter of interest must be demonstrated, clearly identified and documented. In addition, traceability of the parameter's evaluation on the basis of the surrogate is needed (InfoMil, 2012).

3.2.5 Mass balances

Mass balances, or material balances can be used for an estimation of the emissions to the environment from a site, process, or piece of equipment. The procedure normally accounts for inputs, accumulations, outputs and generation or destruction of the substance of interest, and the difference is accounted for as a release to the environment (European Commission, 2003)

Mass balances are based on the application of the law of conservation of mass to the process. Essentially, if there is no accumulation within the system, then all the materials that go into the system must come out. Fuel analysis data is a good example of the mass balance approach in predicting emissions. For example, if the concentration of a contaminant or contaminant precursor in a fuel is known, emissions of that contaminant can be calculated by assuming that all of the contaminant is emitted prior to the application of an emission control (Ontario MOE, 2007).

3.2.6 Engineering calculations

This method uses physical/chemical properties, for example, vapour pressure of the substance and mathematical relationships (such as ideal gas law). Theoretical models for specific processes can also be used, although these can be complex.

3.2.7 Emission Factors

Emission factors are numbers that can be multiplied by an activity rate or by throughput data, such as the production output, fuel consumption, etc. in order to estimate the emissions from the facility. They are applied under the assumption that all industrial units of the same product line have similar emission patterns. These factors are widely used for determination of charges at small installations (European Commission, 2003).

These factors are developed from separate facilities within an industry category, so they represent typical values for an industry, but do not necessarily represent a specific source. These factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e. a population average) (USEPA, 2003).

3.3 DATA QUALITY CONTROL

For data obtained from emission monitoring to be credible for use in decision-making, it has to meet certain requirements confirming reliability and comparability. It is therefore a norm to put in place a system for data quality control as part of the overall QA/QC programme. (Konieczka & Namieśnik, 2009) defines quality control as a complex system of actions to obtain measurements (determination results) with the required quality level. QA concerns the data measurement process itself, whilst quality control refers to post-collection activities for optimization of data accuracy and precision (Heard, 2006). QC activities would include the calibrations, linearity checks, leak test, and comparison to the standard reference methods.

3.4 DATA REPORTING

Once quality control measures have been conducted to confirm the reliability and comparability of the emission results, the results have to be documented and reported to authorities for compliance assessment and other decision-making processes. Regulations usually provide specifications on how this needs to be done. Elements of emission reporting such as normalization, units of expressions, averaging periods are typical examples of these specifications. Also, data recording and logging requirements that meet the regulator's legal and system requirements have to be observed. This is critical in ensuring that data recorders used are compatible with the regulators' reporting systems. Where manual reporting is required, emission report templates provided by the regulators are to be used.

3.5 COMPLIANCE ASSESSMENT

Compliance assessment generally involves a statistical comparison between the measurements, or a summary statistic estimated from the measurements; the uncertainty of the measurements; and the relevant emission limit value or equivalent parameter (European Commission, 2003). It is common practice to consider any exceedence of emission limits as non-compliance, irrespective of the extent of exceedence. Alternatively, additional criteria may be included, which determine compliance on risk band approach. Under this approach, a level of statistical probability or confidence above which measurements are deemed to be not compliance is applied by comparing the differences between measurements and the limit with the certainty in the measurements. Three compliance bands are then established to represent compliance, borderline and non-compliance status (IMPEL, 2001).

3.6 QUALITY ASSURANCE

Because of the legal implications of non-compliance to emission standards, as well as the cost associated with measurements, specific attention to the quality of data produced must be exercised. This applies to both the sampling and analytical processes, as they are closely related and dependent on each other. If sampling has not been properly collected, the results produced will not be representative of the expected performance. Similarly, if the analyst is unable to define an inherent level of analytical error (precision, accuracy, recovery, and so forth), such data are also useless (Zhang, 2007).

In order to acquire scientifically reliable and repeatable data, Quality Assurance (QA) programme is implemented from sampling processes up to the final stages of analysis and reporting. QA is defined as “an integrated management system to ensure that QC system is in place and working as intended” (Zhang, 2007). The main purpose of the quality control is to reduce uncertainties in measurements to a minimum (Clarke, 1998). This QC system includes, amongst others (Konieczka & Namieśnik, 2009):

- Assuring a suitable level of staff qualifications (certification);
- Assuring the proper calibration of instruments and laboratory equipment; mainly by the use of certified reference materials; participation in various inter-laboratory comparisons; and validation of the applied analytical procedures;
- The assurance of measuring traceability of the obtained results;
- Evaluation of uncertainty in obtained results of measurement; and
- Implementation of good laboratory practice (GLP) and standard procedures.

In emission measurement and monitoring field, the QA management system is usually implemented in the following high – level processes:

- Accreditation of testing and calibration laboratories
- Certification of personnel involved in emission testing
- Certification of equipment used for emission measurements.

3.6.1 Accreditation of testing and calibration laboratories

Although various acceptable quality systems exist, the most commonly used for emission measurements is accreditation of a laboratory according to ISO 17025 -General requirements for the competence of testing and calibration laboratories. Under this system, testing bodies are accredited for competency in provision of analytical services for specific testing fields and analytical methods. Because of its general application, ISO 17025 provides a platform for explanation or interpretation of certain requirements, specifically in the field of application to ensure that the requirements are applied consistently (ISO, 2005). This is also the case in the emission-testing field, where national accreditation bodies and regulators normally provide additional requirements. Currently, the following standards are widely adopted as supplementary requirements applied in accreditation of emission testing:

- CEN/TS 15675: 2007 Measurement of Stationary Source Emissions. Application of EN ISO/IEC 17025:2005 to periodic measurements (BSI, 2007c)
- ASTM D7036 - Standard Practice for Competence of Air Emission Testing Bodies
- Manual Stack Emission Monitoring Performance Standard for Organization

3.6.2 Certification of personnel involved in emission testing

For a laboratory to be found competent to carry out sampling and analysis functions for emission standards, it needs competent staff that is experienced to conduct test for specific pollutants, employing credible methods. Laboratory personnel are therefore trained to implement specific standard reference methods. Some accreditation bodies and regulators prepare a standard training programme for this purpose.

3.6.3 Certification of the equipment used in emission measurements and monitoring

Automated monitoring equipment is validated for performance using the standard reference methods adopted for specific pollutants. Both portable and continuous automated instrument undergo certification prior to use.

4 INTERNATIONAL BENCHMARKING OF EMISSIONS COMPLIANCE MONITORING SYSTEMS

4.1 METHODOLOGY

Since emission monitoring involves implementation of measurement methods of measurements (sampling to analysis of chemical species) in a systematic and integrated manner that achieves international norms of sampling and analysis of chemical species, a desktop appraisal of the norms and standard practices in collation of emissions data has been used as the methodology for this study. The appraisal has followed this structure:

- Establishment of critical components of emission monitoring system through synthesis of documented measurement procedures; and
- Review of monitoring systems adopted by countries that have similar industrial emissions control approach as South Africa with a view to inform a South African approach to emission monitoring.

4.2 SCOPE OF THE STUDY

This study is an extension of a project that was conducted by the Department of Environmental Affairs on the development of emission standards for South Africa. A comprehensive review of international legislation on industrial emission control was undertaken with a view to inform the approaches for identification and classification of activities to be listed, prioritization of pollutants and emission standards options (Scorgie & Kornelius, 2007). While this study focused on various elements of emission standards, it did not adequately address issues pertaining to emission measurements, monitoring and reporting. As emphasized by (Jahnke, 2000), these details are important to make use of the data, and when they are not incorporated in the regulatory system; the system may be too ambiguous to fulfill its regulatory intent.

Chapter 3 of this study provides a summary of elements of compliance monitoring that are critical for realization of emission data that meets scientific norms, thus credible for use in decision making. Based on this chapter, and on the information gathered by the standards setting project, the following processes and procedures have been identified as components of the emission compliance monitoring system that are to ensure that the system developed for South Africa is credible with respect to production of good quality and reliable emission data to be used in compliance and enforcement activities:

- Criteria informing the choice of the monitoring approach adopted to demonstrate compliance with the standards or emission limits in the license.
- Procedures on how measurement methods are selected for qualitative and quantitative determination pollutants.
- Procedures on how emission data should be handled, and reported.
- The requirements and protocols for accreditation of organizations conducting emission measurement tests and related certifications.
- Procedures for compliance determination (data interpretation) by air quality officers and compliance inspectors.

The scope of this study focus primarily on countries that were considered in the standards setting project referred to above, which are the United States of America (USA), Australia, and the United Kingdom. With respect to Australia, the state of New South Wales has been chosen the best model due to its comprehensive air quality management system as compared to other Australian states and territories. For the United Kingdom, England and Wales is the focus of this review due to the interest in the monitoring certification scheme implemented by their Environment Agency. Where necessary, information from other countries such as Germany and Denmark is considered to support or supplement areas where no adequate information was found from study countries. The choice of these countries is largely influenced by how environmental regulations, especially emission standard, are developed and implemented in South Africa. The best practice is determined and chosen as

the ultimate target of the standard, and a phased approach to implementation of this best practice is established under compliance timeframes. This is believed, mainly by industry, to be providing regulatory certainty, and at the same time, promoting efficient environmental management practices. Over and above this motivation, study countries have also been selected based on similarities of the air quality management systems when compared with South Africa (as detailed in Chapter 2. Furthermore, similar to South Africa, the selected countries have various statutory scientific bodies that play a major role in the quality and standardization infrastructure. Appraisal on the effectiveness of cooperative functioning of these bodies with the regulators will provide lessons on the effective cooperative governance.

This chapter provides critical analysis of the elements of compliance assessment system in the case studies, with the objective to guide recommendations on areas that have been identified above.

4.3 ELEMENTS OF SUCCESSFUL EMISSION MONITORING

Emission monitoring is a complex exercise involving implementation of various procedures, processes and activities aimed at producing credible, reliable and accurate emission data for use in various air quality management functions. To acquire data of the said characteristics, it is important that measurement activities are conducted within the prescripts of the acceptable processes and procedures.

Due to various uses of emission monitoring, it is necessary that whenever monitoring is planned, objective of monitoring be determined to ensure that monitoring conducted is fit-for-purpose. When making regulatory decisions on emission monitoring, consideration has to be placed on important aspects such as selection of the correct choice of method, technique and equipment; access to and suitability of the sampling plane, location and number of sampling ports and others in order to meet requirements for representative sampling (EA, 2007). Also requirements for isokinetic sampling for inhomogeneous flue gas, sample conditioning and reporting of results are important factors that regulators have to consider in decision-making.

4.4 CRITERIA ON THE CHOICE OF THE MONITORING APPROACHES

As described in Chapter 3, there are different monitoring approaches that may be adopted for implementation of industrial emission standards. These approaches are usually adopted either within the emission standards, regulations or are prescribed as conditions in the emission licenses or permits. Approaches are usually ranked according to reliability (i.e. due to the quality and usability of data they produce) and cost. The least cost ones tend to take short period in estimating emissions, resulting in less credible and less reliable data. The most reliable ones are those that are capable of producing good quality data at almost real-time. These are usually expensive to install and maintain. Due to this wide variety of factors that have potential to influence the monitoring outcome, it is critical for regulators to set out criteria to determine which approach to adopt for different emission sources, pollutants and situations. Appraisal of the criteria adopted by study countries is provided below:

4.4.1 The Australian (NSW) criteria for determination of the monitoring approach

Section 66 of the POEO Act 1997 makes provision for the conditions of a license to require monitoring by the holder of the license of the activity or work authorized. This may include monitoring of the operation or maintenance of premises or plant; discharges from premises, relevant ambient conditions prevailing on or outside premises, and any other conditions made in the license. Furthermore, the license can require provision and maintenance of appropriate measuring and recording devices for monitoring, and the analysis; reporting and retention of monitoring data (NSW, 1997). Part 5 of the Protection of the Environment Operations (Clean Air) Regulation 2010 largely focuses on industrial, agricultural and commercial scheduled activities but also specifies some requirements for non-scheduled activities. This regulation prescribes emission standards for activities, including generic requirements on measurements methods that should be used in monitoring compliance with these standards (NSW, 2010). Although the emission standards do not provide specifications on what monitoring approach should be adopted for individual scheduled activities, the standards provide instruction for the inclusion of these details in the emission licenses (DEC, 2006).

4.4.2 The USA criteria for determination of the monitoring approach

The CAA requires the inclusion of applicable monitoring and analysis procedures or test methods in the permits, and further requires that periodic monitoring sufficient to yield reliable data from the relevant time period that are representative of the source's compliance with the permit be instituted for source categories that does not require any monitoring under applicable requirements under NSPS or NESHAP rules instituted (USEPA, 1992b). The USEPA Emissions Measurement Centre has developed test methods and performance specifications that are promulgated and incorporated under NSPS and NESHAP rules. The following are the monitoring approaches adopted by the CAA:

(a) Continuous Emission and Opacity Monitoring

Although the CAA recognizes several emission-monitoring approaches, continuous monitoring for emissions and opacity is preferred due to its reliability in producing quality data. **Figure 4-1** provides a list of rules requiring continuous emission monitoring. Once CEMS and continuous opacity monitoring systems (COMS) have been installed, they undergo performance evaluation tests to confirm that the system meet performance specifications. These specifications, include requirements for the installation, design, performance, and testing of the systems. If a CEMS or COMS meets the specifications, it is considered capable of providing quality data for the purpose of the implementing rule (USEPA, 1992a).

Where CEM is required, the CAA requires that performance tests be conducted within 60 days post achievement of maximum production capacity to determine the performance of continuous monitoring equipment. These evaluations are conducted using USEPA performance specifications and QA procedures. Where CEMS are required to be used for continual compliance determination, they undergo evaluation for accuracy and precision using reference methods specified under subparts of the standards rules.

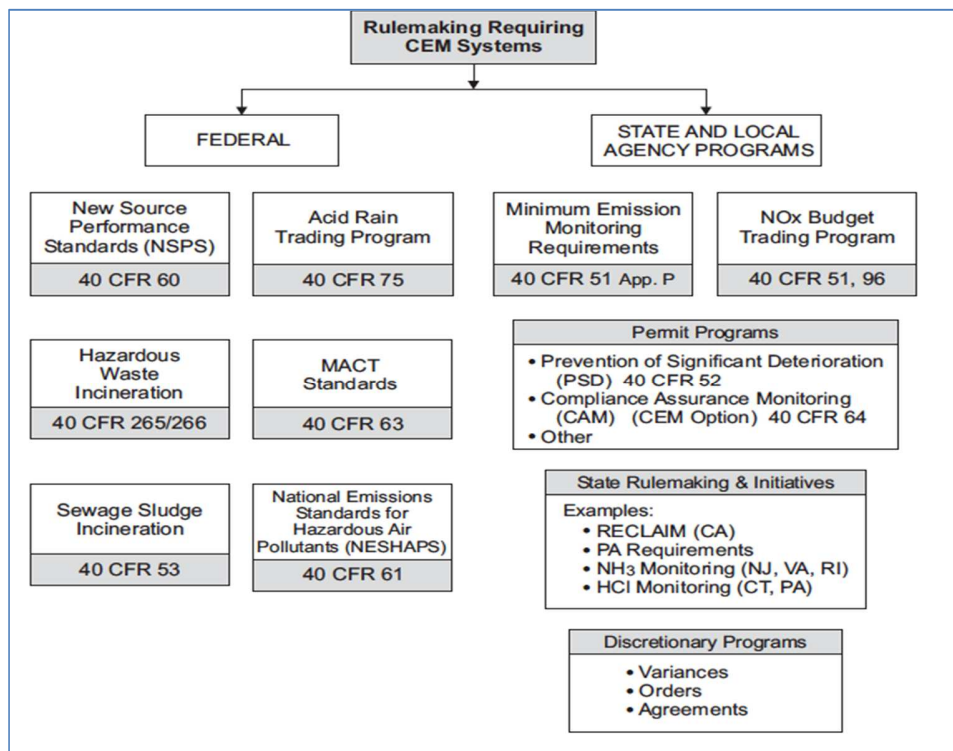


Figure 4-1: Rulemaking requiring CEMS in the USA (Jahnke, 2000)

(b) Periodic emission measurements

PEM is used to demonstrate compliance with emission standards specified under NSPS, NESHAP, MACT, and other rules, specifically where CEM is not required on continual basis, where emission monitoring requirements are not specified or are inadequate for compliance determinations, as well as for relative accuracy test audits or correlation tests conducted to evaluate the accuracy and precision of CEMS.

Factors influencing determination of the need for PEM include size of emission unit; the time elapsed since last stack test; results of that test and margin of compliance; condition of control equipment; and availability and results of associated monitoring data (USEPA, 2014a).

Detailed evaluation criteria for PEM have been established by the USEPA as tabled under Table 4-1.

(c) Parameter monitoring (surrogate measures)

Parameter monitoring (See Figure 4-2) may be required instead of CEM where pollutant monitoring is impractical or infeasible to meet the regulatory goals; and where it is requirement to monitor process parameters such as pressure drop, temperature, water injection or flow rate (USEPA, 1997b). Other uses of parameter monitoring include:

- using parameters as indicators of proper operation and maintenance practices,
- using parameter values directly as surrogates for emissions determinations,
- using parameters in models that calculate emissions,
- performing mass balance calculations, or
- employing a CEMS to monitor a more easily analyzed gas as a surrogate for one that is more difficult to analyze.

The NESHAP also require continuous monitoring for a limited number of sources covered under Part 61 of Title 40. Although most MACT standards require parametric monitoring rather than the installation of CEMS, they do also incorporate monitoring requirements to determine, on a continuous basis, whether emission limits are being met.

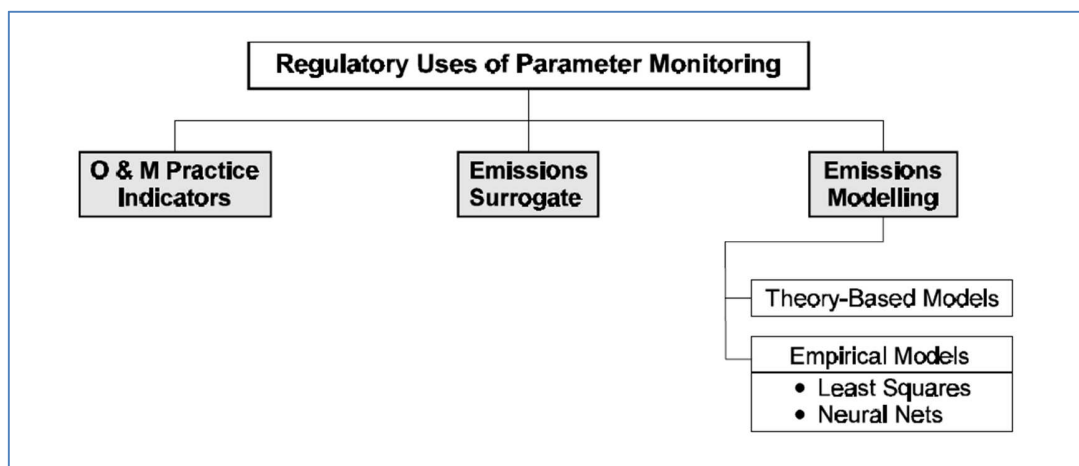


Figure 4-2: Uses of parameter monitoring in regulatory programs (USEPA, 1997b)

Table 4-1: Factors Helpful to Consider in Evaluating Periodic Monitoring (USEPA, 2014b)	
Factor	Considerations
The likelihood of violating the applicable requirement (i.e., margin of compliance with the applicable requirement);	Consider how close a unit's emissions are to the emission limits during normal and likely upset operations.
Whether add-on controls are necessary for the unit to meet the emission limit;	If controls are required, consider whether the controls will assure compliance with the emission limit. If so, the best option may be to monitor the control equipment for proper operation instead of or in addition to the process.
The variability of emissions from the unit over time;	Consider how emissions may vary: <ul style="list-style-type: none"> • Emissions may vary day to day under normal operation, • Emissions may vary slowly over time, • Emissions may vary quickly due to malfunction.
The type of monitoring, process, maintenance, or control equipment data already available for the emission unit;	Sources often conduct monitoring and/or maintenance of emission units' even if not required under an applicable requirement. Consider whether these activities would assure compliance; if so, they may be the best fit/lowest cost monitoring option for that source.
The technical and economic considerations associated with the range of possible monitoring methods; and	When developing monitoring options, consider what is technically feasible for the emission unit in question. Cost information will help in selection between two or more monitoring options that assure compliance.
The kind of monitoring found on similar emission units.	When evaluating whether an example could be applied in another case, it is important to compare the emission limit in the example to the emission limit in the case in question, to determine if the monitoring would be assuring of compliance in the new case. Sources for this information: <ul style="list-style-type: none"> • Existing title V and construction permits • Federal, State and Local rules • CAM Guidelines Document • California monitoring recommendations • Monitoring guidance developed by States

4.4.3 The UK (England and Wales) criteria on the monitoring approach

Article 16 of the industrial emissions directive (Directive/2010/75/EU) requires that monitoring be based on conclusions of the best available techniques, with frequency of the periodic monitoring be determined by the competent authority in a permit for each individual installation or in general binding rules (European Union, 2010). The directive specifies emission-monitoring requirements for large combustion plants, waste incineration, solvent emissions and titanium dioxide production activities. In some instances, a criterion for choosing one approach over the other is specified, as reflected in Table 4-2. Both CEM and PEM approaches are imposed, with parametric or surrogate measures specified as exceptions.

4.4.4 Other internationally accepted criteria on the monitoring approach

The international best practice is biased towards adoption of CEM and PEM as the main approaches to proving compliance with concentration-based emission limits. Parametric or surrogate measures are mostly used where there are technological limitations to use direct emission measurements, and as a supplementary measure where infrequent PEM is the primary approach. Mass flow thresholds of pollutants appears to be the main criteria used by many countries in making decisions about adoption of either CEM or PEM for activities that need to measure their pollutants. Some additional examples are German TA Luft (See Table 4-3) and Danish Guidelines for Air Emission Regulation (See Table 4-4).

In the case of Germany, CEM is imposed on a permitted source if its emissions constitute over 20 per cent of the entire mass flow of the facility, and if mass flow rates of the individual pollutants exceed those specified in the table. Also, if it is to be expected that a facility will repeatedly exceed the emission standards established in the licensing notice, e.g. when changing its mode of operation, or due to the fault-liability of an emission reduction facility, continuous emission measuring may also be requested for lower mass flows than those established (Germany, 2002).

Sources are exempted from CEM requirement under the following circumstances (Germany, 2002):

- If it emits for less than 500 hours in any one year or is less than 10% of the annual emission of the facility.
- Insofar as air-polluting substances in waste gas are in constant relation to each other, continuous measuring may be restricted to a lead component.
- If applying other tests, composition of fuels or raw materials, or processing conditions may adequately prove attainment of emission standards.

The Danish regulations establish three different types of emission inspection procedures, and the criteria for adoption of each. These procedures are performance inspection, automatic measuring system (AMS) inspection, as well as random inspection as described here (DEPA, 2002):

- Performance inspection is an inspection type that is carried out in a minimum period of three hours, with three individual measurements, each lasting for an hour carried out.
- Automatic measuring system inspection involves continuous measurements carried out in a period of a month, during operating periods.
- Random tests is a type of inspection carried out on six randomly chosen days a year, in which the installation is operating. A minimum of two samples is taken, each lasting for at least an hour.

AMS inspection limits are set out for different pollutants (see Table 4-4) and are the trigger for the type of monitoring approach adopted for a source.

Installations with a pollutant mass flow less than the mass flow limit (prior to purification or abatement) are insignificant sources that does not require emission measurements, where an inspection can be limited to an effective inspection of operation. Installations with significant air pollution are those with mass flow exceeding the mass flow limit, but remains below the AMS inspection limit. These installations require performance inspections. Installations with the mass flow exceeding the AMS inspection limits are very significant and AMS inspection is compulsory for them (DEPA, 2002).

Table 4-2: Criteria for specific sources in the EU directive (European Union, 2010)

Pollutant	CEM Criteria	Periodic Emission Measurements (The competent authority may decide not to require the continuous measurements in the following cases):	PEM condition	Surrogate measures
Dust	Combustion plant with a total rated thermal input of 100 MW or more.	Combustion plants with a life span of less than 10 000 operational hours. Combustion plants firing natural gas.	Measurements shall be required at least once every 6 months.	
Sulphur dioxide	Combustion plant with a total rated thermal input of 100 MW or more.	Combustion plants with a life span of less than 10 000 operational hours. Combustion plants firing natural gas. Combustion plants firing oil with known sulphur content in cases where there is no waste gas desulphurisation equipment.	Measurements shall be required at least once every 6 months.	As an alternative to the PEM of SO ₂ and NO _x other procedures, verified and approved by the competent authority, may be used to determine the SO ₂ and NO _x emissions. Such procedures shall use relevant CEN standards or, if CEN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality.
Oxides of nitrogen	Combustion plant with a total rated thermal input of 100 MW or more.	Combustion plants with a life span of less than 10 000 operational hours.	Measurements shall be required at least once every 6 months.	
Carbon Monoxide	Combustion plant firing gaseous fuels with a total rated thermal input of 100 MW or more.	Combustion plants with a life span of less than 10 000 operational hours.	Measurements shall be required at least once every 6 months.	
Mercury		Combustion plants firing coal or lignite.	Total mercury shall be measured at least once per year.	

Table 4-3: Mass flow rates triggering continuous emission monitoring requirements in Germany (Germany, 2002)

Pollutant or parameter measured	Mass flow rate
Continuously monitoring of the functioning of the waste gas purification facility and the established emission limits.	1 to 3 kg/h particles mass flow
Dust emission mass concentrations.	3 kg/h particle mass flow
Total particles concentrations (if the emission mass flow is more than five times greater than one of the relevant mass flows).	Facilities with dust emissions of substances under 5.2.2 ^a or 5.2.5 Class I ^b or 5.2.7 ^c of TA Luft
Sulphur dioxide.	30 kg/h
Nitrogen monoxide and nitrogen dioxide, to be indicated as nitrogen dioxide.	30 kg/h
Carbon monoxide as lead substance for evaluating the efficiency of combustion processes.	5 kg/h
Carbon monoxide, all other cases.	100 kg/h
Fluorine and gaseous inorganic fluorine compounds, to be indicated as hydrogen fluoride.	0.3 kg/h
Gaseous inorganic chlorine compounds, to be indicated as hydrogen chloride.	1.5 kg/h
Continuously determine the mass concentrations chlorine.	0.3 kg/h
Hydrogen sulphide.	0.3 kg/h
^a Inorganic Particulate matter as classified according to species and associated mass concentrations and or mass flow rates. ^b Organic substances contained in waste gas, except organic particle matter, and associated mass concentrations and or mass flow rates. ^c Carcinogenic, mutagenic or reproduction toxic substances or emissions of slowly degradable, accumulative and highly toxic organic substances as classified under TA Luft	

Table 4-4: Mass flow rates triggering continuous emission monitoring requirements in Denmark (DEPA, 2002)

Pollutant	Mass flow rate triggering continuous emission measurements (substance quantity prior to purification or abatement).
Sulphur dioxide	200 kg/hr SO ₂
Organic substances	25 kg/hr organic substances, measured as TOC
Oxides of Nitrogen	200 kg/hr NO _x , measured as NO ₂
Group 1 substances* (gaseous)	2 kg/hr group 1 substance
Particulate matter (substances not specified elsewhere)	200 kg particles/hr
Particulate matter (substances specified below): Group 1 substances; Lead and lead compounds, measured as lead; Copper and copper compounds, measured as copper; Mercury and mercury compounds, measured as mercury; Tellurium and tellurium compounds, measured as tellurium; Thallium and thallium compounds, measured as thallium; and or Vanadium and vanadium, measured as vanadium.	2 kg/hr of the substances (both gaseous or particulate form) specified
*Very potent biologically active substances are regarded as Group 1 substances. The Danish EPA on the basis of a specific assessment of the toxicological and eco-toxicological documentation available carries out the final classification of these substances, and their C-values.	

4.5 METHOD SELECTION PROTOCOLS

Differing measurement methods used to investigate the same object of measurement do not always produce comparable results due to the variation in the degree of validation work carried out as part of their development. A validated method refers to the method that has been laboratory and field tested to determine optimum operating parameters and identify interferences. In addition method bias and precision under actual testing conditions is established as part of method validation.

Due to this validation issues, standardization of measurement and analysis methods is important in order to make measurement results comparable when differing methods have been used at different sites. It is normal practice for regulations and standards to make reference to specific methods to be used for compliance assessment purposes. Different regulators will have different criteria on method selection. Appraisal is thus made here to study various method selection criteria adopted worldwide.

4.5.1 Method selection criteria adopted in Australia (NSW)

In the NSW, monitoring of air impurities to show compliance must be done in one either in accordance with the AMSAAP; the methods specified in the relevant statutory instrument; or if no method is specified in either AMSAAP or the statutory instrument, in a manner approved by the EPA in writing before any tests are conducted (NSWEPA, 2006). The AMSAAP is a legal instrument providing guidance on how air quality measurements should be done to prove compliance with the requirements of the CAR (NSW, 2010), as well as with the conditions of the environment licenses issued to give effect to these regulations. Where no method is specified in either this methods document or the statutory instrument, monitoring should be done in a manner approved by the EPA in writing before any tests are conducted (NSWEPA, 2006). As such, there is no flexibility in choosing any other method except those meeting the above highlighted requirements. It is important to note that most of the methods listed in the AMSAAP are the USEPA methods, followed by Australian Standards and ISO methods.

4.5.2 Method selection criteria adopted in the USA

The USEPA Emission Measurement Center develops test methods, which are promulgated as an appendix to the emission standards under NSPS, NESHAP and other rules. For each source category, specific uses of these methods and specifications are described under respective subparts of the standards. Due to the incorporation of test methods under specific subparts of the standard, it appears that no specific criteria for method selection have been established, except for the requirement to undertake periodic monitoring that is sufficient to yield reliable data from the relevant time period that are representative of the source's compliance with the permit.

4.5.3 Method selection criteria adopted in the UK (England and Wales)

In the UK, the Environment Agency EPA has published the Technical Guidance Notes (TGN) on stack-emission monitoring, as guided by the European Commission's General Principles of Monitoring (European Commission, 2003). Method selection is determined primarily by the EC directives, with detailed implementation guidance documented in the TGN for stack emission monitoring. The EC directives make it mandatory requirement to use relevant CEN standards. A prioritization criteria table under Table 4-5 is used where mandatory standard has not been specified under the directive.

Although the final choice of technique will also depend on the averaging period specified in the license or standards, some practical considerations, such as the instrument performance, portability of the equipment and its ease of operation as described under **Figure 4-3** are also critical elements determining the choice of method.

Table 4-5: Ranking of standard reference methods required by EU (European Commission, 2003)	
Prioritization criteria	Standardization Body
Priority Methods	Comité Européen de Normalisation (CEN)
	International Standardisation Organisation (ISO)
If the substance cannot be monitored using standards covered by the above, a method can be selected from any of the following:	American Society for Testing and Materials (ASTM)
	Association Française de Normalisation (AFNOR)
	British Standards Institution (BSI)**;
	Deutsches Institut für Normung (DIN);
	United States Environmental Protection Agency (US EPA);
	Verein Deutscher Ingenieure (VDI)
If the substance cannot be monitored using standards covered by the above, then following occupational methods may be adapted, following the requirements of ISO 17025 for stack-emission monitoring:	Method for the Determination of Hazardous Substances (MDHS) series published by the Health and Safety Executive (HSE)
	National Institute of Occupational Safety and Health (NIOSH);
	Occupational Safety and Health Administration (OSHA).

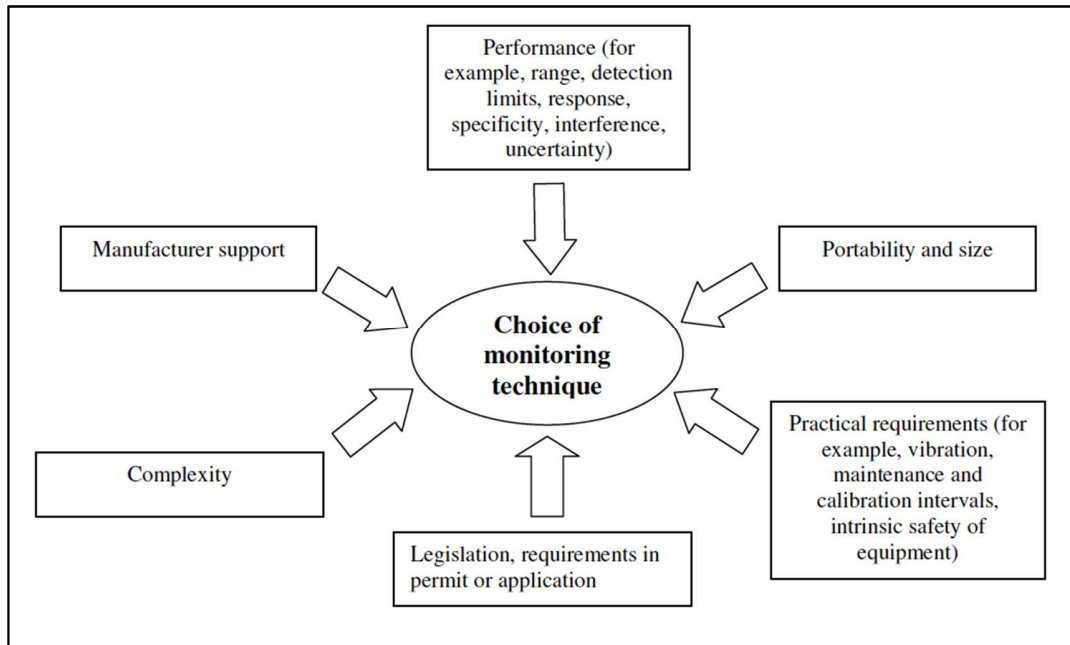


Figure 4-3: Factors influencing the choice of monitoring technique (EA, 2007)

4.5.4 Other internationally accepted method selection criteria

Queensland Territory, Australia, requires the use of validated emission measurement method published by Standards Australia, BSI, ASTM, ISO, USEPA and a number of Australian State regulatory authorities. The territory, in recognizing that more than one method might be available for the same pollutant at in many circumstances, has provided the following guidance for selection of appropriate method based on an assessment of the test conditions for a particular source. These are (Queensland, 1997):

- Sampling platform access;
- Sampling plane diameter;
- Exhaust gas temperature, moisture content and velocity;
- Anticipated atmospheric contaminant concentration;
- Limit of detection required; and
- Specific regulatory authority requirements”.

4.6 PROCEDURES ON DATA HANDLING (DATA QUALITY CONTROL)

The primary objective of emission measurements and monitoring is to produce consistent emission data that is reliable and credible to be used in decision-making. Data quality objectives are therefore established as part of the quality management plan, and implemented throughout the measurements and monitoring processes. These objectives are data completeness, representativeness, known accuracy and precision.

A number of data quality control activities are conducted to ensure a high degree of excellence. Quality control (QC) activities refer to those activities carried out during routine internal operations to ensure that the data produced are within known limits of accuracy and precision. Examples of QC activities include periodic calibrations, routine zero and span checks, routine leak checks, routine check of optical alignment, etc. (Oregon State, 1992). Although regulations and standards do not often elaborate on the technical details of how quality objectives are accomplished, they usually provide high-level guidance on these aspects. Guidance on measurement siting selection criteria, measurement techniques and methods are usually provided. Procedure for the calculation of uncertainty, procedures on corrections required by the standards and examples or templates for computation of results are also provided.

4.6.1 Data quality control in Australia (NSW)

QC procedures are not specifically prescribed under AMSAAP. It is assumed that the control procedures or activities required under individual methods are the main activities used to ensure that data produced is complete and representative, as well as that it is of known accuracy and precision.

4.6.2 Data quality control in the USA

USEPA methods incorporate QC procedures required for implementation of the methods. Furthermore, the federal rules make requirements for QA to be implemented for CEM required for NSPS (Title V Operating permits) and Acid Rain Programs. Under NSPS rules (USEPA, 2012), data QC activities required are detailed under specific QA procedures for gaseous, particulate matter and for vapor phase mercury (Hg) CEMS. These activities are:

- Calibration of CEMS.
- CD determination and adjustment of CEMS.
- Preventive maintenance of CEM (including spare parts inventory).
- Data recording, calculations, and reporting.
- Accuracy audit procedures including sampling and analysis methods.
- Program of corrective action for malfunctioning CEMS.

Where PEM is conducted, data quality objectives are established by standard reference methods.

4.6.3 Data quality control in the UK (England and Wales)

Although QC procedures are outlined under specific standard methods, supplementary requirements named Method Implementation Documents are published to ensure consistent application of the methods. Stack monitoring TGN requires that the operator should ensure that, wherever possible, the equipment is MCERTS certified at an appropriate range for their application during installation. The CEMS is checked for functionality and its performance verified.

4.7 REPORTING REQUIREMENTS

Once the emission data has been collected and validated, it has to be reported to authorities and other relevant end-users in a format that is usually stipulated by the standards and in accordance with any method instructions. In addition to a presentation of the measurement results, the report should also contain relevant background information on the installation that is being measured, on the method used and measuring equipment and on the QA aspects. Factors influencing the results such the operating conditions must be detailed and any deviations from the standards used must be motivated in the measurement report and an explanation given of their possible influence on the results.

Due to multiple uses of the emission data, it is international best practice for the standards, regulations and permits to provide requirements on how this data must be reported. Where emission data is used for compliance assessment purposes, these requirements covers point of compliance, that is, the point where measurements must be taken for single stacks as well as for common or shared stack, which account for emissions from a number of individual sources. Other requirements include information on what averaging periods are applicable, how to express the units of measurements including a format for emission data reporting systems or even specific templates to be used in reporting.

Guidance on the contents of the emission report is included in the AMSAAP guidance document for Australia (NSWEPA, 2006) and in the *Manual stack emission monitoring - Performance standard for organizations* for the UK (EA, 2011). A number of different emission reports are required under the CAA in the USA. The contents of the intermittent emission test reports are established by the states, taking into account the National Stack Testing Guidelines.

Due to the close similarities of the contents of the emission reports in the study countries, these requirements are hereby summarized:

Aspect	Details of the report content
Report details	<ul style="list-style-type: none"> • Title of the report, permit number, operator and installation name, including contact details. • Name, address and accreditation status (indicating all measurement methods accredited for) of the monitoring organization. • Certification level and technical endorsements held of the person approving the report for the monitoring organization and the signature of the person approving the report. • Dates of the monitoring visit and reporting.
Operating Information	<ul style="list-style-type: none"> • Process information, with emissions points clearly marked or identified. • Whether process was a continuous or batch process, (if batch, whether the whole of the batch was sampled or the details of the part of the batch sampled). • Fuel and feedstock types used during monitoring. • The normal load, throughput or continuous rating of the plant. • Abatement systems information (efficiency, availability).
Monitoring objectives	<ul style="list-style-type: none"> • The overall aim of the monitoring campaign, legal and any other requirements.
Monitoring results	<ul style="list-style-type: none"> • Emission points, substances measured and associated emission limit values expressed in the terms and units defined in the permit. • Start and end times for the monitoring. • Name and reference number of the measurement method used. • Periodic measurement results, normalized according to standards. • Uncertainty associated with the result at a 95% confidence level.
Monitoring deviations	<ul style="list-style-type: none"> • An explanation why any substance(s) in the monitoring objectives was not monitored, or why any substance(s) were not monitored in accordance with the monitoring method and any other issues relevant to the monitoring results.
Additional information	<ul style="list-style-type: none"> • Required attachments such as process flow diagrams identifying the point sources, non-point and area sources and calibration and accreditation certificates.

4.8 PROCEDURES FOR COMPLIANCE DETERMINATION

After emission report is submitted, the regulators evaluate the reports to assess compliance with emission standards. Compliance assessments “generally involve numerical and statistical comparisons between monitoring results, taking into account the associated uncertainties in the results, and limit values” (IMPEL, 2001). Prior to compliance assessment, it is best practice to ensure that the available monitoring results provide evidence that is adequate before using it to determine compliance with emission limits and environmental quality standards. This is essential because if the evidence is inadequate then any determination of compliance based on it will be invalid (IMPEL, 2001). This process, termed evidential compliance, assess whether:

- appropriate methods for sampling and analysis were followed;
- the number of samples taken, and data capture efficiency were adequate to give representative performance; and
- that the factors that contribute to measurement uncertainties have been considered and uncertainty measured.

This exercise actually confirms whether approved monitoring plan was implemented with respect to method selection and data quality objectives (detailed under section 4.5 and 4.6 of this report, respectively). Once these requirements are satisfied, compliance assessment may then be conducted to determine the facilities’ compliance status. Compliance determination is criteria vary from country to country, based on how the emission limits are interpreted in the standards regulations.

4.8.1 The Australian (NSW) procedures for compliance determination

Licensees are required to submit an annual return form to the EPA. The annual return is a statement of compliance with the license conditions and reports the pollutant loads generated by the premises. Although the licensees are required to interpret their own reports to determine whether they achieved compliance during reporting period, the EPA makes the final determination on this matter. The EPA analyses the non-compliances reported by

licensees to determine what action it should take (NSWEPA, 2013). It appears that non-compliance with the emission limits is attained when emission results exceed the emission limit. No additional interpretation information is provided.

4.8.2 The USA procedures for compliance determination

In the USA, there is a requirement for Title V permit holders to submit deviation reports every six months, as part of the monitoring report. A deviation from the permit terms occur when any permit term is not met, including emission control requirements and compliance assurance methods (monitoring, recordkeeping, and reporting). Deviations are not necessarily considered violations (i.e. they are potential violations) as these are determined by the USEPA or the states as delegated. The following are examples of deviations:

- Emissions that exceed an emission limit;
- Parameter value that indicates that an emission limit has not been met;
- Observations or data that show noncompliance with a limitation or other requirement;
- Required monitoring that is not performed; and failure to submit a report.

Although exceedence of the emission limit is highlighted under deviations, it is not clear on how the states determine it as a violation.

4.8.3 The UK (England and Wales) procedures for compliance determination

The following criteria for determination of compliance with limit values have been established for Europe (IMPEL, 2001). Comparison is made between the emission limit value for the relevant operating condition and the relevant measured pollutant or parameter value, taking into account estimated uncertainty value. Furthermore, a level of statistical probability or confidence above which measurements are deemed to be not compliance is applied by comparing the differences between measurements and the limit with the certainty in the measurements. This exercise results in the three compliance zones as described in **Figure 4-4**.

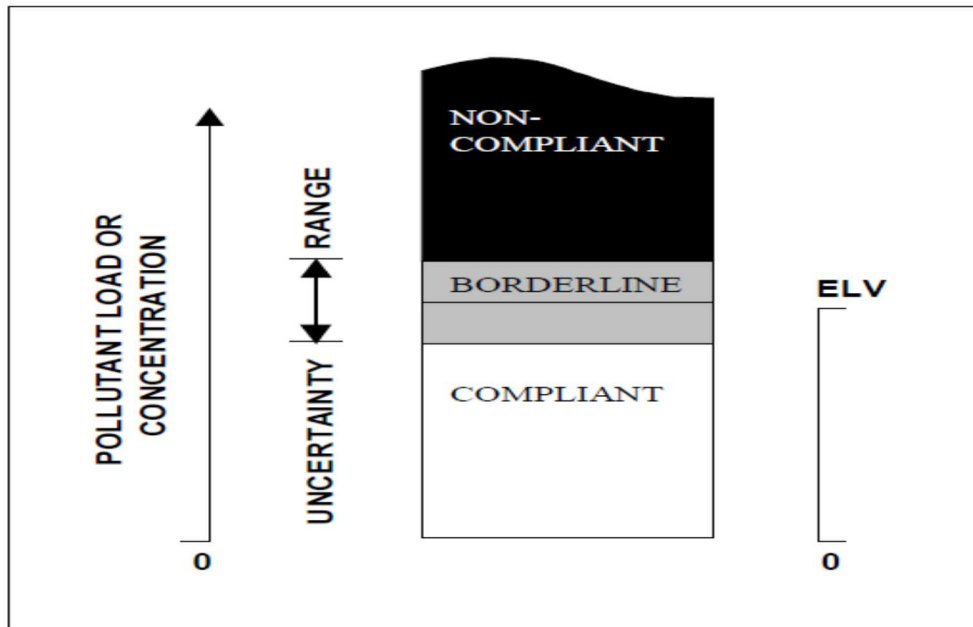


Figure 4-4: Schematic diagram of the three possible compliance assessment scenarios (European Commission, 2003)

- Compliant zone: is achieved when the measured value is less than the limit, even if the value is increased by uncertainty.
- Borderline zone: occurs the magnitude of difference between the measured value and the limit is less than uncertainty.
- Non-compliant zone: when the measured value is more than the limit, even if the value is decreased by the magnitude of the uncertainty.

4.9 ACCREDITATION REQUIREMENTS (DATA QUALITY ASSURANCE)

To be confident that measurements meet the specified requirement, QA is necessary. Elements that play an important role in air emission measurements are the use of standardized and validated measurement methods, the QA of measuring bodies (through accreditation and certification) and the QA of automated measurement systems (through periodic calibration and control). Quality Assurance is defined as “all the planned and

systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirements for quality” (Konieczka & Namieśnik, 2009). QA of analytical measurement results is a system comprising five interdependent elements (Konieczka & Namieśnik, 2009):

- Assurance of measuring traceability of the obtained results
- Evaluation of uncertainty in obtained results of measurement
- Use of certified reference materials
- Participation in various inter-laboratory comparisons
- Validation of the applied analytical procedures

These elements are interdependent. To assure measuring traceability, it is indispensable to use both the certified reference materials and the analytical procedures subject to prior validation (Konieczka & Namieśnik, 2009).

Although various quality systems focused on the above-mentioned elements exist, the most commonly used systems in emission measurements is accreditation of a laboratory according to ISO 17025 - “General requirements for the competence of testing and calibration laboratories”. Under this system, testing bodies are accredited for being competent to provide analytical service for specific testing fields and analytical methods. Accreditation is the procedure used to recognize whether an organization or person is competent to perform specific tasks. Major subjects are: independence, impartiality, objectivity, transparency, consistency, continuity and competence (InfoMil, 2012).

4.9.1 Accreditation requirements in the Australia (NSW)

The National Association of Testing Authorities is the authority responsible for the accreditation of laboratories, inspection bodies, calibration services, producers of certified reference materials and proficiency testing scheme providers throughout Australia. In Australia, accreditation of the stack emission testing falls under the chemical analysis field. Laboratories or testing facilities are accredited to ISO 17025, taking into consideration

additional interpretative criteria and recommendations for the application of ISO 17025 in the chemical testing field for different testing activities.

4.9.2 Accreditation requirements in the USA

In contrast to the Australian and the UK systems, there are three accreditation programmes in the USA. Air emission testing bodies (AETBs) may seek accreditation to *ASTM D7036 - Standard Practice of Competence of Air Emission Testing Bodies*; *ISO 17025*; or *both*. *ASTM D7036* is however, a mandatory requirement for AETBs involved in Protocol Gas Verification Program and Relative Accuracy Test Audit. This standard follows the same requirements as ISO 17025. Currently Source Testing Accreditation Council (STAC) administers accreditation programme for AETBs seeking accreditation to ASTM D7039 and the National Institute for Standards and Technology and American Association for Laboratory Accreditation run the assessment programme for this standard and for the ISO 17025.

Lastly, The NELAC Institute, established by the US EPA, has recognized the need for a standard specifically written for environmental organizations that perform sampling or measurement in the field on any type of matrix, including air and has therefore established the National Environmental Field Activities Program (NEFAP) with the function to establish and implement an accreditation program for field sampling and measurement organizations (FSMOs) (TNI, 2008). The TNI has also put in place the standard for FSMOs, which is modeled after ISO 17025. Some states as well as the American Association for Laboratory Accreditation administer this programme (AALA, 2015).

Table 4-6: Accreditation programmes for emission testing in the USA	
Accreditation Body	Accreditation Standards
NIST	ASTM D7036
American Association for Laboratory Accreditation (A2LA)	ISO 17025 ASTM D7036 TNI Standards
States	TNI Standards

4.9.3 Accreditation requirements in the UK (England and Wales)

UK has a single accreditation system administered by the United Kingdom Accreditation System (UKAS). Laboratories are assessed for competence to ISO 17025 standard. In England and Wales, the Environment Agency (the “EA”) has established the Monitoring and Certification Scheme, which provides assurance to the agency that monitoring equipment, personnel and services are fit for purpose and capable of delivering results of the required quality and reliability. With regard to manual stack testing, the agency requires monitoring be carried out by accredited laboratories and certified personnel. Supplementary requirements for the application of EN ISO/IEC 17025 in the field of monitoring of emissions from stationary sources have are documented under the MCERTS in the *Manual Stack Emission Monitoring - Performance Standard For Organizations* (EA, 2011). Furthermore, the scheme provides for the examination and assessment of personnel seeking competence certification at 3 levels (Trainee, Technician and Team Leader) (EA, 2015). With respect to automated measuring equipment, the EA has published Performance Standard for Portable Emission Monitoring Systems (EA, 2010) as well as Performance Standards and Test Procedures for Continuous Emission Monitoring Systems (EA, 2012).

5 CONCLUSIONS AND RECOMMENDATIONS

As outlined in Chapter 1, the aim of the study is to develop a compliance monitoring system for atmospheric emissions to support effective implementation of the National Environmental Management: Air Quality Act, 2004 by:

- Identification of critical elements of emission compliance monitoring system for emissions;
- Review of the best practices on selection of emission measurement methods, quality assurance systems and data handling and reporting; and
- Make recommendations on compliance assessment system for South Africa, based on identified local needs and international best practice.

Chapter 3 followed the practice of science in the qualitative and quantitative determinations of pollutants from the industrial emissions. While the primary driver of emissions tracking is regulations, this chapter appreciates that for emissions data acquisition is dependent on adherence to the basic scientific principles and practices aimed at ensuring reliability, repeatability of data. Furthermore, it is clear from this chapter that effective compliance monitoring can be achieved if the interdependency of these principles and standard practices is taken into account when developing a compliance monitoring system.

In chapter 4, an appraisal was made on how various elements of the emissions compliance monitoring system has been implemented in some developed countries that has advanced in industrial emissions control. This appraisal confirms that, although the regulatory intent is the same, countries implement control measures differently, based on what is more important and elevated in the emissions control policy of the country.

With respect to emissions monitoring approaches, a number of approaches each having different advantages and disadvantages, are used interchangeably, based on the situation.

Direct measurements, an approach involving periodic emissions testing and continuous emission monitoring is however preferred by many countries. This is because direct measurements produce rigorous, high quality emissions data, which can stand the test of litigation and science. Therefore, where there is high risk to non-compliance, and subsequently enforcement actions, it is preferred that an approach that can adequately meet the objectives of the monitoring is adopted.

Furthermore, limitations such as the cost of monitoring can be a limitation to adopt a full programme on direct measurements, especially continuous emissions monitoring. In that cases, it has been found that many countries reduce the frequency of reporting for emissions using direct measurements, and complement this with the use of surrogate parameter monitoring in between of direct measurements reporting periods. This gives the regulator confidence that continual compliance will be attained, thus sustainable environmental protection.

The use of validated standard reference methods is preferred to ensure acquisition of good quality data. Emission reporting is usually standardized by either putting pointers in the standards on what the reports submitted for compliance should contain, or by providing standard templates for use in reporting. For consistent assessment of compliance, compliance monitoring systems should provide clear criteria for interpretation of emission reports.

Due to the nature of the emission measurements activities, regulators are dependent on scientific bodies for infrastructure to support quality emissions data acquisition. These are standardization bodies, which provides standard reference methods; metrology bodies, providing calibration gases and related infrastructure, as well as accreditation bodies who certifies competence of testing institutions.

The system of compliance recommended for South Africa should therefore should integrate various elements required for production of credible data, and should enhance cooperation of statutory scientific bodies responsible for various scientific infrastructure. This will result in effective emission monitoring required for full implementation of the emissions control aspects of the National Environmental Management: Air Quality Act, 2004 (Act No.39 of 2004).

6 RECOMMENDED COMPLIANCE ASSESSMENT SYSTEM FOR EMISSION IN SOUTH AFRICA

This chapter recommends a system for emission monitoring compliance in South Africa, attached as Appendix A of this report. The system provides guidance on how emissions measurements and monitoring should be done to support emissions standards published in terms of the Act.

APPENDIX A : EMISSION COMPLIANCE MONITORING IN SOUTH AFRICA

1 INTRODUCTION

1.1 LEGAL MANDATE/REQUIREMENTS

Section 21 of the National Environmental Management: Air Quality Act, 2004 (Act No.39 of 2004) requires the Minister to publish a list of activities which result in atmospheric emissions and which she reasonably believes have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage.

Section 21 of the AQA also requires the establishment of minimum emission standards for specified pollutants or mixtures of substances emitted by the identified activities. In this regard, the permissible amount, volume, emission rate or concentration of the pollutant or mixture of pollutants must be specified as well as the manner in which measurements of such emissions must be carried out.

Furthermore, Part 3 of the Act requires that the Minister prescribe the manner in which measurements of emissions from point, non-point or mobile sources, including the form in which such measurements must be reported. These requirements are commonly referred to as the norms and standards for emission monitoring.

1.2 PURPOSE AND SCOPE

This document provides the norms and standard for emission monitoring in South Africa. This document is intended to provide all required processes, procedures and methods with the view to ensure consistent and efficient emission measurements, reporting and assessment in the South Africa.

The document is divided into chapters as summarized below:

Chapter 1: Introduction – provides an introductory background to this document, legal requirements and scope of the document.

Chapter 2: Emission measurement planning – provides requirements for emission measurement planning and structure of emission measurement plans.

Chapter 3: Emission measurement siting – outlines requirements for sampling platforms locations, number of ports and other critical requirements for the achievement of representative sampling and safety.

Chapter 4: Measurement of pollutants – this chapter elaborates on available techniques and standard reference methods for all pollutants listed in the minimum emission standards.

Chapter 5: Other emission requirements – provides guidance on regulatory intent and clarity on additional requirements incorporated as transitional and other special arrangement in the minimum emission standards.

Chapter 6: Data handling - this chapter establishes requirements for data collection, manipulation, and calibration.

Chapter 7: Emission reporting – Guidance on conversion of emission data to standard conditions and reporting template are provided here.

Chapter 8: Compliance assessment procedures – provides instructions on how emission reports should be interpreted.

Chapter 9: Quality Assurance Programme – establishes procedures for quality assurance including accreditation requirements, quality management systems and personnel training requirements.

1.3 How to use this document

This document is intended to provide guidance to the Atmospheric Emission Licensing Authorities (AELA) on emission measurements and reporting requirements to be included in the AELs, to assess the validity of emission reports received and subsequently to assess whether the listed activity is compliant with the conditions of the AEL.

The second intended audience of this document are the AEL holders who are by law required to measure, monitor and report on the performance of their listed activities, and the independent service providers who might be appointed to support the AELA or AEL holders.

2 EMISSION MEASUREMENT PLANNING

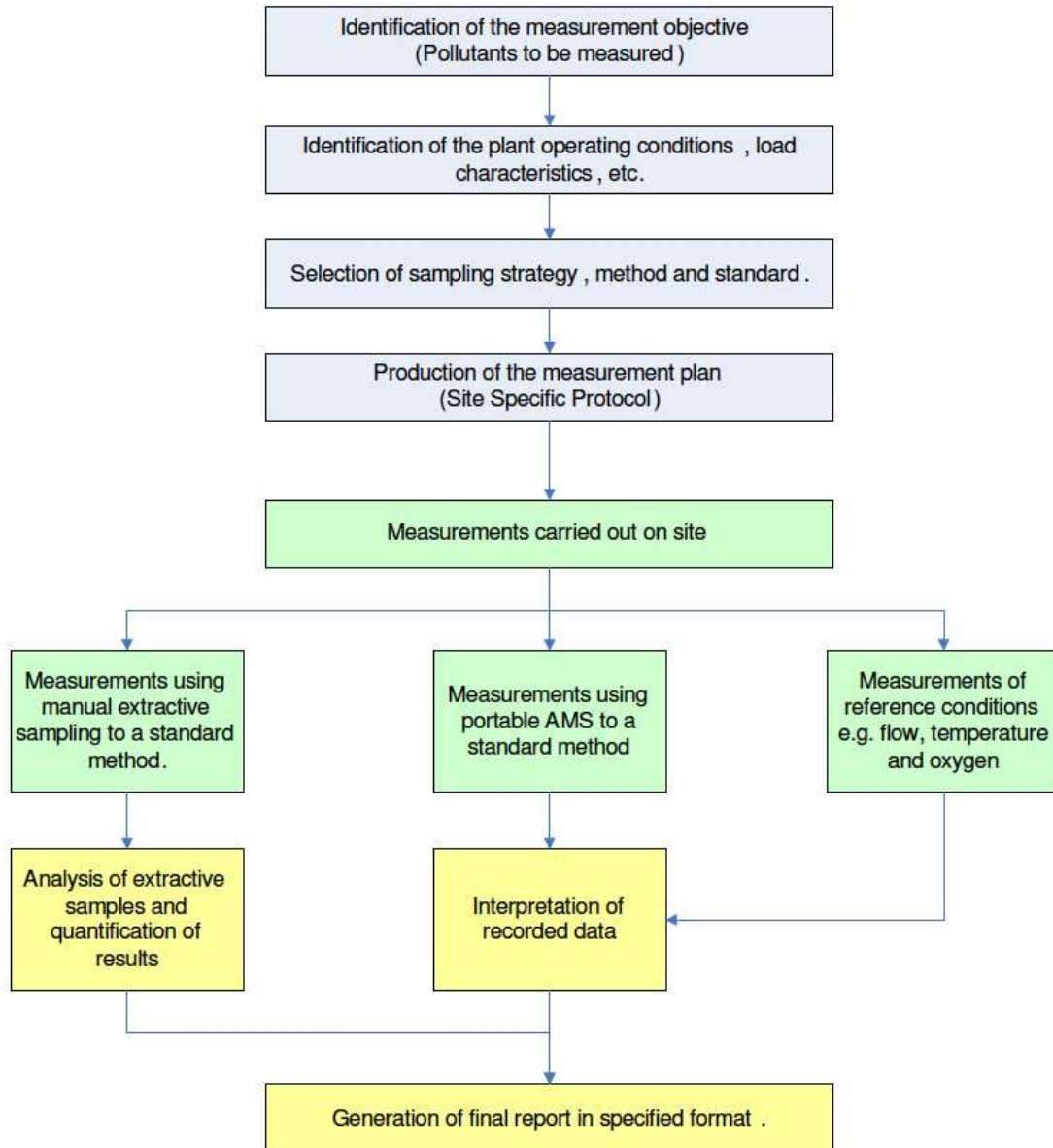
Although emission requirements are prescribed under the S.21 Notice, compliance to these requirements is given effect by transposing them into the conditions of the Atmospheric Emission License. It is therefore important that the AELA ensure that all relevant requirements are incorporated into the AEL. The operator of the listed activity is responsible for carrying out the measurements, reporting, records keeping and demonstrating compliance with the emission conditions of the AEL.

Before the measurements are carried out, a measurement plan must be drawn up to clarify the objectives of measurements campaign as well as to confirm applicable regulatory requirements. The following standard provides guidance on how planning for emission measurements should be carried out:

BS EN15259 Air Quality - Measurement of Stationary Source Emissions. Requirements for measurement sections and sites and for the measurement objective, plan and report”.

This standard is prescribed under the S.21 Notice thus is mandatory for use as minimum requirement.

Figure A-1 provides the process flow for a typical emission measurement process that guides the preparation of the measurement plan.



Appendix A-1: Typical periodic emission measurement/monitoring process (IEPA, 2014)

3 MEASUREMENT SITE REQUIREMENTS

Measurement siting is an important element of emission measurements aimed at addressing representativeness of the sample and safety concerns. For measurements to be carried safely and efficiently by the measurement personnel, it is necessary to have free access to the sampling plane and appropriate measuring ports and working platforms for typical sampling equipment. This part outlines the requirements pertaining to measurement siting.

3.1 Sampling requirements

The fundamental sampling principle, requiring that a small amount of collected material be a representative sample of the overall character of the material, must always be adhered to when sampling for emissions, irrespective of the monitoring technique or method chosen, or equipment used for this purpose.

For the purpose of compliance determination, sampling for emissions must be undertaken on the stack. Where individual listed activity units share a common stack, sampling must be carried out in the suitable listed activity duct, prior to the point release or stack. When determining the point of compliance under common stack activities, interference of the duct bends, duct branching and any other obstructions that might affect the representativeness of the emissions must, where possible be prevented. These factors must be accounted for in the emission report.

Where sampling for particulate matter emissions is required, care should be given to the homogeneity of the flue gas. In this case, a number of samples that need to be taken and the number of locations to be considered to make up a representative sample depend on how homogeneous the flue gas is. If the flue gas is homogeneous, only a few samples may be required as opposed to the non-homogeneous flue gas, which may require more samples and sampling points.

Homogeneity of the flue gas can be affected by various factors such as differences in chemical composition (e.g. where the gas is also carrying particulates along the duct, there is likely to be even less homogeneity); differences in temperature (e.g. temperature differences are causing the flue gas to mix poorly) and velocity (e.g. high flue gas velocity results in short residence time in the installation, which may lead to stratification and swirling). Percentage isokineticity must therefore be determined and reported in the emission report.

The following standard methods are used for the determination of measurements site, the location and nature of measurement sections and planes for various phases or pollutant conditions. Supplementary guidance or elaboration documents for these methods (such as the UK Technical Guidance Note on sampling requirements for stack emission monitoring (EA, 2007)) may be used as additional or interpretation guides:

- (a) BS EN 14181 Stationary Source Emissions – Quality assurance of automated measuring systems (BSI, 2004a).**
- (b) BS EN 15259 Air Quality - Measurement of stationary source emissions. Requirements for measurement sections and sites and for the measurement objective, plan and report (BSI, 2007a).**
- (c) USEPA Method 1 - Sample and velocity traverses for stationary sources (USEPA, 1991a)**

Another relevant method that is not in the S.21 Notice but relevant for this purpose is:

- (d) VDI 3950 Stationary Source Emissions – Quality assurance of automated measuring and electronic evaluation systems (VDI, 2006).**

These methods must be used to determine the following specific aspects of the sampling requirements:

- The position and form of the measurement section in the flue gas duct.
- The position of measurement plane in the measurement section.
- The number, location and nature of the sampling points.
- The nature of the measurement platform (e. g. minimum dimensions, weather protection).

3.2 Access and safety

The sampling approach, techniques, methods and equipment implemented for emission testing can have different effects on the plant access requirements. The following requirements must be considered in measurements planning:

- Compliance with the requirements of Occupational Health and Safety Act, 1993 (Act No.85 of 1993) as amended, and other relevant safety standards and work practice.
- There must be sufficient space for measuring equipment and for the personnel to operate the equipment.
- Where the nature of the operation provide limited access to the measurement platform, or prevents the installation of a permanent platform, temporary structures may be used.
- If sampling traverses are being carried out, sufficient traverse space must be available to move the probes.
- Care should be taken to make sure that protective grids or railings do not interfere with the moving of the probes.
- The operational height from the floor of the measurement platform up to the measurement axes should be 1.2 to 1.5 m.

3.3 Determination of gas velocity and flow rate

The gas volumetric flow rate must be measured where flue gas is non-homogenous and where emission rates are required. Determination of the flow rate requires that velocity be measured at several points across the sampling plane. The volumetric flow rate expressed in terms such as cubic meters per second (m^3/s) can be obtained by measuring the weighted-average gas velocity multiplied by the inside diameter of the duct. The average of velocities measured at the traverse points provides an acceptable weighted-average velocity for the system, provided that the sampling points represent equal cross-sectional areas. Gas velocities may be obtained by measuring either the gas kinetic or the velocity pressure.

The applicable standards for measuring velocity and volumetric flow rate are listed below:

(a) ISO 10780 Stationary Source Emissions - Measurement of velocity and volume flow rate of gas streams in ducts

“This standard specifies manual methods for determining the velocity and volume flow rate of gas streams in ducts, stacks and chimneys vented to the atmosphere. The standard specifies the use of two types of Pitot tubes, type L and type S, for determining the velocity and the volume flow rate for each type of Pitot tube. The standard applies to gas streams with essentially constant density, temperature, flow rate and pressure at the sampling point” (ISO, 1994).

(b) ISO 14164 Stationary Source Emissions - Determination of the volume flow rate of gas streams in ducts - Automated method

“This International Standard describes the operating principles and the most important performance characteristics of automated flow-measuring systems for determining the volume flow rate in the ducts of stationary sources. Procedures to determine the performance characteristics of automated volume flow-measuring systems are also contained in this standard. The performance characteristics are general and not limited to specific measurement principles or instrument systems” (ISO, 1999).

(c) USEPA Method 2 - Determination of stack gas velocity and volumetric flow rate (Type S Pitot Tube)

“This method is applicable for the determination of the average velocity and the volumetric flow rate of a gas stream. The method is not applicable at measurement sites that fail to meet the criteria of USEPA Method 1, section 11.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams (section 11.4 of Method 1 shows how to determine cyclonic or swirling flow conditions)” (USEPA, 1991e).

3.4 Moisture content

The determination of water vapour is required where emission concentrations are to be expressed at standard conditions (i.e on dry gas), and for use in adjustment of the flow rate for isokinetic sampling, when a dry gas flow rate-metering device is used (IEPA, 2014). The following standard methods shall be used for the determination of the humidity or moisture content of the flue gas:

(a) BS EN 14790 Stationary Source Emissions - Determination of the water vapour in ducts

“This European Standard specifies the standard reference method (SRM) based on a sampling system with a condensation/adsorption technique to determine the water vapour concentration in the flue gases emitted to atmosphere from ducts and stacks. The standard specifies the performance characteristics to be determined and performance criteria to be fulfilled by measuring systems based on the measurement method. It applies to periodic monitoring and to the calibration or control of automated measuring systems (AMS) permanently installed on a stack, for regulatory or other purposes. This European Standard specifies criteria for demonstration of equivalence of an alternative method to the SRM by application of prEN 14793” (prEn is a code for draft standard) (BSI, 2006a).

(b) USEPA Method 4 Determination of moisture content in stack gases

“This method is applicable for the determination of the moisture content of stack gas. The reference method is used for accurate determinations of moisture content (such as are needed to calculate emission data). The approximation method provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein the method is only a suggested approach; alternative means for approximating the moisture content (e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc.) are also acceptable. The reference method is often conducted simultaneously with a pollutant emission measurement run. When it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent. These calculations shall not be based upon the results of the approximation

method, unless the approximation method is shown to be capable of yielding results within one percent H₂O of the reference method” (USEPA, 1991k)

4 MEASUREMENT OF POLLUTANTS

4.1 Emission measurement approaches

Periodic emission measurement (PEM) or continuous emission monitoring (CEM) are prescribed as minimum requirements for demonstration of compliance with emission limits specified under the S.21 Notice. However, there are other monitoring approaches that the AELE may use as alternative measures where the prescribed approaches are not feasible, or as additional measures (e.g. the use of mass balances between reporting periods). These approaches will be discussed under chapter 7 below.

Furthermore, the S.21 Notice has provided a list of internationally accepted methods for use in determination of compliance with the emission limits of the Notice. It should however be noted that, methods for determination of most of the regulated pollutants are not specified, thus the purpose of this section is to consider and identify relevant methods for each regulated pollutant. This document is anticipated for use as the basis of the revision of the list of measurement methods attached to S.21 Notice.

Currently, there are no nationally developed emission measurement methods. Methods developed and or adopted by the following international bodies are accepted for the purpose of compliance determination with the S.21 Notice:

- International Standardization Organization (ISO)
- United States Environmental Protection Agency (USEPA)
- British Standards Institution (BSI)
- European Committee for Standardization (CEN)
- The Association of German Engineers (VDI)
- American Society for Testing and Materials (ASTM)

Where no methods for sampling and or analysis of certain pollutants are not yet established for stationary sources, acceptable occupational health methods may be used, taking into account all relevant measures.

Occupational health methods from the following bodies are accepted:

- National Institute for Safety and Health (NIOSH)
- Health and Safety Executive (HSE)

While S.21 Notice does not establish criteria for prioritization of measurement methods, the following factors (related to fit-for-purpose method selection) must always be taken into consideration when choosing the monitoring technique, standard method and associated equipment/instruments:

- Instrument certified ranges;
- Analytical limit of detection;
- Linearity;
- Instrument response speed; and
- Measurement uncertainty.

The following factors must be considered by an AELA when making decisions about the emission-monitoring approaches to include as a condition in the AEL for various listed activities:

- Emission standards requirements – the S.21 Notice might prescribe CEM for some activities under special arrangements of a subcategory. Where this is the case, it is mandatory to prescribe CEM.
- Measurements that guarantee the reliability of the measuring results - These aspects relate to the implementation of the measurements, for example requirements on the

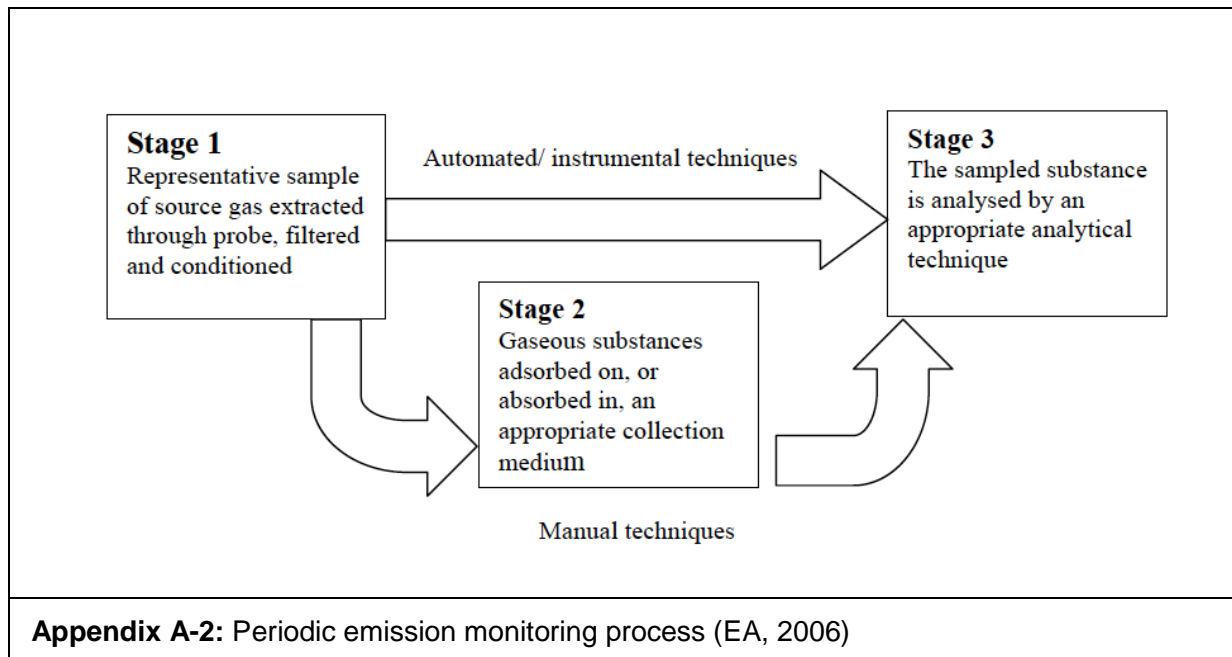
measurement location, the use of measurement standards, QA of the measurement bodies and of automated measuring systems.

- The type of installation, capacity and/or fuel, in addition to the size and harmfulness of the emission.
- Harmfulness of an emission and the increase of an emission if an abatement technique or a process-integrated measure fails.
- Complaints history, previous non-compliance and potential effects of the listed activity emissions.

4.1.1 Periodic emission measurement

Under PEM, emission measurements can either be directly performed in the flue gas channel (in situ) by using automated techniques or by extracting a partial stream with a sampling system (extractive) and analyzing it in a laboratory (See Appendix A-2).

Where PEM is conducted, established criteria for representative sampling must be followed, and verification that the monitoring techniques is relevant for the pollutant, and that the results shall be traceable to the standard reference method must be carried out. Furthermore, the material and condition (e.g. temperature) of the sample/measurement systems should be maintained such that there is neither loss of pollutant nor addition of interfering contaminant. Any supporting measurements that are required such as volumetric flowrate, oxygen and moisture must be run simultaneously with the sampling/measurement process, using suitable techniques.



Automated or instrumental techniques (commonly referred to as portable analyzers) are widely used by local industry in PEM. These involve sampling and determination of a parameter in real-time (or almost real time). Under this technique, no sample is extracted from the flue gas, but the parameter is to be determined as measured in the flue gas. Automated instruments are mostly used for determination of physical flue gas parameters, such as temperature, pressure and velocity, but can also be used to measure pollutants. Where these are used, the following factors should be observed:

- “The range of the analyzer is appropriate to the purpose of the measurement. In general, the lower the range, the more accurate the measurement. This is because accuracy is usually expressed as a percentage of range. So, for example, it would not be appropriate to use an analyzer whose range is 1 to 100 mg/Nm³ to measure pollutant levels in and around an emission limit value of 5 mg/Nm³.
- Calibration before and after measurement using standards that are traceable to certified reference materials. In general, the standards used should be in line with the expected measurement concentration [or at the very least the emission limit value (ELV)].

- The analyzer is free from any bias that can be caused by substances in the waste gas other than the determinant.
- The analyzer is suited to the environment in which it is being operated.
- A non-specific detection system cannot be used to measure the levels of a specific chemical substance in an emission unless that substance is the sole component of the emission to which the detection system is sensitive and the instrument response factor for the substance is known, (e.g. the use of a portable FID to measure levels of toluene in an emission)” (IEPA, 2014).

It is recommended that only the portable analyzers that have been certified to meet performance characteristics and QA requirements of relevant methods be used. Where no certification is provided, the manufacturer shall provide evidence that the instrument has undergone and passed performance tests.

Certification and performance tests from the following organizations shall be accepted:

- 1) UK MCERTS
- 2) German Technischer Überwachungs-Vereine (TÜVs)
- 3) National Metrology Institute of South Africa (NMISA)

The S.21 Notice requires that SANAS accredited laboratories should be used for PEM, correlation tests and audits. As such, the personnel responsible for equipment calibration activities, sampling, analysis of emissions, including those operating portable analyzers, must have necessary specialist skills for these functions. The competence requirements are discussed under Chapter 9 of this document.

4.1.2 Continuous emission monitoring

CEM entails the use of automated measurement systems to take measurements of pollutants in real –time, “with few - if any - gaps in the data produced. Measurement may be carried out in situ in the stack (often called cross-stack or cross-duct monitoring), or extractive sampling may be used with an instrument permanently located at or near the stack “(EA, 2007).

Where CEM is required, only certified CEMS must be installed for compliance purposes. The three-part standard that has been adopted under S.21 Notice for certification of CEMS is BS EN 15267. This standard is detailed as:

- (a) BS EN 15267-1 Air Quality - Certification of automated measuring systems. General principles (BSI, 2009a)**
- (b) BS EN 15267-2 Air Quality - Certification of automated measuring systems. Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process(BSI, 2009b)**
- (c) BS EN 15267-3 Air Quality - Certification of automated measuring systems. Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources (BSI, 2007b)**

Over and above certification, the S.21 notice requires that CEMS be calibrated and audited (i.e. correlation tests using standards reference methods) every two years as a minimum, or per manufacturer’s specifications where it is required more frequently. Auditing and correlation tests of CEMS shall be done using;

BS EN 14181- Stationary Source Emissions. Quality assurance of automated measuring systems (BSI, 2004a).

4.2 Emission measurement methods

This section identifies measurement methods for every pollutant that is regulated under S.21 Notice. Some methods are not specified under S.21 Notice. These methods are listed here as guidance and will be used as the basis to update the list of methods provided in S.21 Notice.

4.2.1 Particulate Matter: Extractive Sampling

When sampling particulate matter in a flue gas stream it is imperative to sample isokinetically in order to ensure that data produced is representative. Isokinetic sampling is achieved by drawing the sample into the sample probe at a velocity equal to the gas velocity in the duct where the sample's tip is located. Gas samples are withdrawn proportionally, which means that as the gas flow in the duct changes, the sample rate is changed proportionally to provide properly weighted results. This means that duct velocities must be taken simultaneously with the samples and at the same locations. It is important to be able to relate sample meter flow rates to probe-tip flow rates by accounting for pressure, temperature, and moisture changes,

Requirements on siting of the location of suitable sampling points for this purpose and on isokinetic sampling in general are detailed in the standard methods listed below.

(a) ISO 9096 Stationary Source Emissions - Manual determination of mass concentration of particulate matter

"ISO 9096 describes a reference method for the measurement of particulate matter (dust) concentration in waste gases of concentrations from 20 mg/m³ to 1000 mg/m³ under standard conditions. This standard is applicable to the calibration of automated monitoring systems (AMS). If the emission gas contains unstable, reactive or semi-volatile substances, the measurement will depend on the filtration temperature. In-stack methods may be more applicable than out-stack methods for the calibration of automated monitoring systems" (ISO, 2003c)

(b) ISO 12141 Stationary Source Emissions - Determination of mass concentration of particulate matter (dust) at low concentrations - Manual gravimetric method

"ISO 12141 describes a reference method for the measurement of low dust content in ducted gaseous streams at concentrations below 50 mg/m³ under standard conditions. This method has been validated with special emphasis on the region around 5 mg/m³. ISO 12141 has been developed and validated for gaseous streams emitted by waste incinerators. More

generally, it may be applied to emissions from other stationary sources, and to higher concentrations. If the gases contain unstable, reactive or semi-volatile substances, the measurement will depend on the sampling and filter treatment conditions” (ISO, 2002a)

(c) ISO 10155 Stationary Source Emissions - Automated monitoring of mass concentrations of particles. Performance characteristics, test methods and specifications.

“This standard specifies conditions and criteria for the automated monitoring of the mass concentration of particulate matter in stationary source gas streams, including performance characteristics and test procedures. It provides the field evaluation test program and its application to automated monitoring systems. This standard is applicable only on a site-specific basis by direct correlation with the manual testing method in ISO 9096” (ISO, 1995).

(d) USEPA Method 5 - Determination of particulate matter emissions from stationary sources.

“This method is applicable for the determination of PM emissions from stationary sources” (USEPA, 1991)

(e) BS EN 13284-1 Stationary Source Emissions - Determination of low range mass concentration of dust: manual gravimetric method

“BS EN 13284-1 specifies a reference method for the measurement of low dust concentration in ducted gaseous streams in concentrations below 50 mg/m³ standard conditions. This method has been validated with special emphasis around 5 mg/m³ on an average half hour sampling time. This standard has primarily been developed and validated for gaseous streams emitted by waste incinerators. It may be applied to gases emitted from stationary sources, and to higher concentrations. If the gases contain unstable, reactive or semi-volatile substances, the measurement depends on the sampling and filter treatment conditions” (BSI, 2002a).

4.2.2 Particulate Matter: Opacity Measurements

Visible emissions are expressed either in terms of their appearance of the plume, i.e. smoke density, or in terms of the mass concentration of the particulate matter.

(a) USEPA Method 9 - Visual Opacity

“This method allows for the visual measurement of smoke densities from stationary sources. The method requires that observers be trained to recognize plume opacities. Once this has been done, a trained observer will read the smoke plume over a test period and report the results” (USEPA, 1991n).

Due to the subjective nature of this method, and considerations of seriousness of any non-compliance to emission standards, it is not recommended for use in South Africa. The department is therefore not planning to train smoker observers in this regard.

(b) Opacity measurements using opacity meters

Optical devices for continuous opacity measurement are commonly used and recommended for use in determining opacity requirements in South Africa. These monitors use the same principles as extractive methods for particulate matter and methods for QA of automated measuring systems and are calibrated using these methods.

4.2.3 Sulphur Dioxide, Sulphur Trioxide and Total Sulphur

(a) ISO 7935 Stationary Source Emissions - Determination of the mass concentration of sulphur dioxide. Performance characteristics of automated measuring methods

“This international standard specifies a complete set of values of performance characteristics for automated measuring systems for the continuous measurement of the mass concentrations of sulfur dioxide in stationary source emissions. This standard is applicable to extractive and non-extractive automated sulfur dioxide measuring methods” (ISO, 1992).

(b) BS EN 14791 Stationary Source Emissions - Determination of mass concentration of sulphur dioxide. Reference method

“This European standard describes a manual method for sampling and determining SO₂ content in ducts and stacks emitting to the atmosphere by two analytical methods: Ion chromatography and the Thorin method. It is the Standard Reference Method (SRM) for periodic monitoring and for calibration or control of automatic measuring systems permanently installed on a stack, for regulatory purposes or other purposes. To be used as the SRM, the user shall demonstrate that the performance characteristics of the method are better than the performance criteria defined in this European standard and that the overall uncertainty of the method is less than +20,0 % relative at the daily Emission Limit Value (ELV)” (BSI, 2005a)

(c) USEPA Method 8 Determination of sulfuric acid and sulfur dioxide emissions from stationary sources

“This method is applicable for the determination of H₂SO₄ (including H₂SO₄ mist and SO₃) and gaseous SO₂ emissions from stationary sources” (USEPA, 1991m).

4.2.4 Oxides of Nitrogen

(a) ISO 10849 Stationary Source Emissions - Determination of the mass concentration of nitrogen oxides. Performance characteristics of automated measuring systems

“This standard specifies the fundamental structure and the most important performance characteristics of automated measuring systems for oxides of nitrogen to be used on stationary source emissions, for example combustion plants. The procedures to determine the performance characteristics are also specified” (ISO, 1996).

(b) BS EN 14792 Stationary Source Emissions - Determination of mass concentration of nitrogen oxides (NO_x). Reference Method: Chemiluminescence

“This European Standard describes the chemiluminescence method, including the sampling and the gas conditioning system, to determine the NO/NO₂/NO_x concentrations in flue gases

emitted from ducts and stacks at atmosphere. It is the Standard Reference Method (SRM) for periodic monitoring and for calibration or control of automatic measuring systems permanently installed on a stack, for regulatory or other purposes such as calibration. To be used as the SRM, the user shall demonstrate that the performance characteristics of the method are better than the performance criteria defined in this European standard and that the overall uncertainty of the method is less than + 10 % relative at the daily Emission Limit Value” (BSI, 2005b).

(c) ASTM D6348 - Standard test method for determination of gaseous compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy

“This field test method employs an extractive sampling system to direct stationary source effluent to an FTIR spectrometer for the identification and quantification of gaseous compounds. Concentration results are provided. This test method is potentially applicable for the determination of compounds that (1) have sufficient vapor pressure to be transported to the FTIR spectrometer and (2) absorb a sufficient amount of infrared radiation to be detected. This field test method provides near real time analysis of extracted gas samples from stationary sources. Gas streams with high moisture content may require conditioning to minimize the excessive spectral absorption features imposed by water vapor. This field test method requires the preparation of a source specific field test plan” (ASTM, 2003).

4.2.5 Carbon Monoxide

(a) ISO 12039 Stationary Source Emissions - Determination of carbon monoxide, carbon dioxide and oxygen. Performance characteristics and calibration of automated measuring systems

“This international standard specifies the principles, the essential performance characteristics and the calibration of automated systems for measuring carbon dioxide, carbon monoxide and oxygen in the flues of stationary sources. The standard specifies extractive and non-extractive systems in connection with several types of instrumental analyzer.

The following techniques have provided the basis for practical instrumentation:

- (a) paramagnetism (O_2);

- (b) magnetic wind (O_2);
- (c) differential pressure (O_2);
- (d) magnetodynamics;
- (e) zirconium oxide (O_2);
- (f) electrochemical cell (O_2 and CO);
- (g) infrared absorption (CO and CO_2).

Other equivalent instrumental methods may be used provided they meet the minimum requirements proposed in this international standard. The measuring system may be calibrated with certified gases, in accordance with this international standard, or comparable method" (ISO, 2001).

(b) BS EN 15058 Stationary Source Emissions - Determination of the mass concentration of carbon monoxide (CO). Reference Method: Non-Dispersive Infrared Spectrometry

"This European Standard specifies the standard reference method based on the infra - red (IR) absorption principle. It includes the sampling and the gas conditioning system, and allows the determination of the carbon monoxide CO in flue gases emitted to the atmosphere from ducts and stacks. This standard specifies the characteristics to be determined and the performance criteria to be fulfilled by measuring systems using the IR measurement method. It applies for periodic monitoring and for the calibration or control of automatic measuring systems permanently installed on a stack, for regulatory or other purposes. This European Standard specifies criteria for demonstration of equivalence of an alternative method to the SRM by application of prEN 14793 (BSI, 2014) "(BSI, 2006b).

(c) ASTM D6348 - Standard test method for determination of gaseous compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy

"This field test method employs an extractive sampling system to direct stationary source effluent to an FTIR spectrometer for the identification and quantification of gaseous

compounds. Concentration results are provided. This test method is potentially applicable for the determination of compounds that (1) have sufficient vapor pressure to be transported to the FTIR spectrometer and (2) absorb a sufficient amount of infrared radiation to be detected. This field test method provides near real time analysis of extracted gas samples from stationary sources. Gas streams with high moisture content may require conditioning to minimize the excessive spectral absorption features imposed by water vapor. This field test method requires the preparation of a source specific field test plan” (ASTM, 2003).

(d) USEPA Method 3A Determination of oxygen and carbon dioxide concentrations in emissions from stationary sources - (Instrumental Analyzer Procedure).

“USEPA Method 3A is a procedure for measuring oxygen (O₂) and carbon dioxide (CO₂) in stationary source emissions using a continuous instrumental analyzer” (USEPA, 1991h).

(e) USEPA Method 3B - Gas analysis for the determination of emission rate correction factor or excess air

“This method is applicable for the determination of O₂, CO₂, and CO concentrations in the effluent from fossil-fuel combustion processes for use in excess air or emission rate correction factor calculations. Where compounds other than CO₂, O₂, CO, and nitrogen (N₂) are present in concentrations sufficient to affect the results, the calculation procedures presented in this method must be modified” (USEPA, 1991i).

(f) USEPA Method 3C - Determination of carbon dioxide, methane, nitrogen, and oxygen from stationary sources

“This method applies to the analysis of carbon dioxide (CO₂), methane (CH₄), nitrogen (N₂), and oxygen (O₂) in samples from municipal solid waste landfills and other sources” (USEPA, 1991j)

4.2.6 Heavy Metals

(a) BS EN 14385 Stationary Source Emissions - Determination of the total emission of As, Cd, Cr, Co, Cu, Mn, Ni, Pb, Sb, Tl and V

“The method is applicable to each of the specific elements in the concentration range of 0,005 mg/m³ to 0,5 mg/m³. Unless otherwise stated, concentrations are expressed at volumes under dry conditions, normalized to 273 K, 101,3 kPa, and oxygen content with a volume fraction of 11 %. Specific elements according to this standard are antimony (Sb), arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), nickel (Ni), thallium (Tl), and vanadium (V). This European standard is also applicable for exhaust gases from other sources with a flue gas composition, similar to that given tabled in the standard” (BSI, 2004b).

(b) BS EN 13211 Stationary Source Emissions - Manual method of determination of the concentration of total mercury

“This European standard specifies a manual reference method for the determination of the mass concentration of mercury in exhaust gases from ducts or chimneys. It is validated for the determination of the mass concentration of total mercury in exhaust gases from the incineration of waste for the concentration range of total mercury from 0,001 mg/m³ to 0,5 mg/m³. The method may be applicable for exhaust gases from other sources with the typical composition tabled in the method” (BSI, 2001).

(c) BS EN 14884 Stationary Source Emissions - Determination of total mercury: automated measuring systems

“This European Standard specifies specific requirements on automated measuring systems (AMS) for monitoring of total mercury. It is derived from EN 14181, which is the general document on the quality assurance of AMS. It is only applicable in conjunction with EN 14181. This standard sets specific requirements for the quality assurance levels and annual surveillance test as specified in EN 14181, for mercury AMS used for proving that the mercury emissions from a source are compliant with emission limits below 0,5 mg/m³ (standard conditions) in ducted gaseous streams. It is applicable by direct correlation with the standard

reference method (SRM) described in EN 13211, and was primarily developed for emissions from waste incinerators. From a technical point of view, it may be applied to other processes, for which measurement at an emission limit is required with defined uncertainty” (BSI, 2005c).

4.2.7 Dioxins and Furans

(a) BS EN 1948 Stationery Source Emissions – Determination of the mass concentration of PCBBS/PCDFS and Dioxin-like PCBS

“This European standard specifies the sampling of PCDDs/PCDFs in part 1. It is an integral part of the complete measurement procedure. The use of the other two parts EN 1948-2 and EN 1948-3 describing extraction and cleanup and identification and quantification, respectively, is necessary for the determination of the PCDDs/PCDFs. The standard has been developed to measure PCDD/PCDF concentrations at about 0,1 ng I-TEQ/m³ in stationary source emissions. It specifies both method validation and a framework of quality control requirements, which shall be fulfilled by any PCDD/PCDF sampling. The user has the possibility to choose between three different methods:

- "filter/condenser method"
- "dilution method"
- "cooled probe method"

Although this European Standard is primarily developed and validated for gaseous streams emitted by waste incinerators, the practical experience shows that it can be applied for wide concentration ranges and various emission sources. The procedure described in the three parts of EN 1948 specifies requirements, which shall be met in order to measure the 17 congeners necessary to calculate the total I-TEQ. Besides the determination of PCDDs/PCDFs the described measurement methods are suitable for determination of other low-volatile substances, e.g. of dioxin-like PCBs (details for sampling and analyses see CENTS 1948-4 (CEN, 2007)), although no validated performance characteristics are available yet” (BSI, 2006c).

(b) USEPA Method 23 Determination of Polychlorinated Dibenzo-P-Dioxins and Polychlorinated Dibenzofurans from stationary sources

“This method is applicable to the determination of polychlorinated dibenzo-p-dioxins (PCDD's) and polychlorinated dibenzofurans (PCDF's) from stationary sources” (USEPA, c)

4.2.8 Volatile Organic Compounds

(a) BS EN 12619 Stationary Source Emissions - Determination of the mass concentration of total gaseous organic carbon. Continuous Flame Ionisation Detector Method

“This European Standard specifies a set of minimum performance requirements for an instrument using flame ionization detection, together with procedures for its calibration and operation, for the measurement of the mass concentration of total gaseous organic carbon (TOC) in stationary source combustion emissions. It is suitable for the measurement of low level gaseous or vapour phase TOC emissions such as those from municipal waste incinerators and hazardous waste incinerators, but is not recommended for performing measurements on solvent using processes. Minimum operational requirements for long-term emissions monitoring are suggested in annex A of this standard. The results obtained using this standard are expressed in milligrams per cubic metre as total carbon (mg/m³). This standard is suitable for use in the range 0 mg/m³ to 20 mg/m³. The method can be used as a reference method or, with suitable minimum operational requirements, for continuous monitoring. It can also be used for the calibration of automated measuring systems” (BSI, 2013).

(b) BS EN 13526 Stationary Source Emissions - Determination of the mass concentration of total gaseous organic carbon in flue gases from solvent using processes. Continuous Flame Ionisation Detector Method

“This European Standard specifies a set of minimum performance requirements for an instrument using flame ionization detection, together with procedures for its calibration and operation, for the measurement of the mass concentration of total gaseous organic carbon (TOC) in flue gases. It is suitable for the measurement of gaseous or vapour phase TOC

emissions from solvent using processes. The results obtained using this standard are expressed in milligrams per cubic metre as total carbon (mg/m^3) and is most suitable for the measurement of concentrations from $20 \text{ mg}/\text{m}^3$ to $500 \text{ mg}/\text{m}^3$ but can be used at lower concentrations. The method can be used as a reference method or, with suitable minimum operational requirements, for continuous monitoring. It can also be used for the calibration of automated measuring systems. An indication of the uncertainty of the measurement is shown in an annex to the standard” (BSI, 2002b).

(c) BS EN 13649 Stationary Source Emissions - Determination of the mass concentration of individual gaseous organic compounds. Activated Carbon and Solvent Desorption Method

“This European standard specifies procedures for the sampling onto activated carbon, the preparation and the analysis of samples of volatile organic components such as those arising from solvent using processes. It can be used as a reference method. The results obtained using this standard are expressed as the mass concentration (mg/m^3) of the individual gaseous organic components. This standard is suitable for use in the range of approximately $0.5 \text{ mg}/\text{m}^3$ to $2\,000 \text{ mg}/\text{m}^3$. For the measurement of the mass concentration of total organic carbon arising from solvent using processes EN 13526 should be used” (BSI, 2002c).

(d) USEPA Method 18 - Measurement of gaseous organic compound emissions by gas chromatography

“This method is designed to measure gaseous organics emitted from an industrial source. While designed for ppm level sources, some detectors are quite capable of detecting compounds at ambient levels, e.g. ECD, ELCD, and helium ionization detectors. Some other types of detectors are evolving such that the sensitivity and applicability may well be in the ppb range in only a few years. This method will not determine compounds that (1) are polymeric (high molecular weight), (2) can polymerize before analysis, or (3) have very low vapor pressures at stack or instrument conditions” (USEPA, b).

4.2.9 Polycyclic Aromatic Compounds

(a) ISO 11338-1 Stationary Source Emissions - Determination of gas and particle-phase polycyclic aromatic hydrocarbons. Part 1: Sampling

ISO 11338-1 describes methods for the determination of the mass concentration of polycyclic aromatic hydrocarbons (PAHs) in flue gas emissions from stationary sources such as aluminium smelters, coke works, waste incinerators, power stations, and industrial and domestic combustion appliances.

The standard describes three sampling methods, which are here regarded as of equivalent value, and specifies the minimum requirements for effective PAH sampling. The three sampling methods are the dilution method (A), the heated filter/condenser/adsorber method (B) and the cooled probe/adsorber method (C). All three methods are based on representative isokinetic sampling, as the PAHs are commonly associated with particles in flue gas. ISO 11338-1 is not applicable to the sampling of fugitive releases of PAHs” (ISO, 2003a).

(b) ISO 11338-2 Stationary Source Emissions - Determination of gas and particle-phase polycyclic aromatic hydrocarbons. Part 2: Sample preparation, clean-up and determination

ISO 11338-2 specifies procedures for sample preparation, cleanup and analysis for the determination of gas and particle phase polycyclic aromatic hydrocarbons (PAH) in stack and waste gases. The analytical methods are capable of detecting sub-microgram concentrations of PAH per cubic metre of sample, depending on the type of PAH and the flue gas volume sampled. The methods described in ISO 11338-2 are based on either high performance liquid chromatography (HPLC) or gas chromatography-mass spectrometry (GC-MS)” (ISO, 2003b).

4.2.10 Hydrogen Sulphide and Total Reduced Sulphur Compounds

(a) USEPA Method 11 - Determination of hydrogen sulfide content of fuel gas streams in petroleum refineries

“This method is applicable for the determination of the H₂S content of fuel gas streams at petroleum refineries” (USEPA, 1991b)

(b) USEPA Method 15 - Determination of hydrogen sulfide, carbonyl sulfide, and carbon disulfide emissions from stationary sources

“This method applies to the determination of emissions of reduced sulfur compounds from tail gas control units of sulfur recovery plants, H₂S in fuel gas for fuel gas combustion devices, and where specified in other applicable subparts of the regulations” (USEPA, 1991c).

(c) Method 16B - Determination of Total Reduced Sulfur Emissions from Stationary Sources

“This method is applicable for determining TRS emissions from recovery furnaces (boilers), lime kilns, and smelt dissolving tanks at kraft pulp mills, and from other sources. The flue gas must contain at least 1 percent oxygen for complete oxidation of all TRS to SO₂ (USEPA, 1991d).

(d) BS EN 13649 Stationary Source Emissions - Determination of the mass concentration of individual gaseous organic compounds. Activated Carbon and Solvent Desorption Method (Use NIOSH 1600 (NIOSH, 1994a) for analysis) (BSI, 2002c)

4.2.11 Ammonia

(a) EPA CTM 027 - Ammonia Analysis

“This method is applicable for the determination of ammonia emissions from stationary sources” (USEPA, 1997a).

(b) ASTM D6348 - Standard test method for determination of gaseous compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy

“This field test method employs an extractive sampling system to direct stationary source effluent to an FTIR spectrometer for the identification and quantification of gaseous compounds. Concentration results are provided. This test method is potentially applicable for

the determination of compounds that (1) have sufficient vapor pressure to be transported to the FTIR spectrometer and (2) absorb a sufficient amount of infrared radiation to be detected. This field test method provides near real time analysis of extracted gas samples from stationary sources. Gas streams with high moisture content may require conditioning to minimize the excessive spectral absorption features imposed by water vapor. This field test method requires the preparation of a source specific field test plan” (ASTM, 2003).

4.2.12 Hydrogen Cyanide and Total Cyanide

No standard method for stationary source emissions is published. The use of occupational health standards MDHS 56/2 or NIOSH 7904 for analysis is an accepted practice.

(a) MDHS 56/2 – Methods for the determination of hazardous substances – Hydrogen Cyanide in air (HSE, 1990)

This method is suitable for the determination of time weighted average concentrations of hydrogen cyanide in workplace atmospheres, and may be used, for example, in assessing compliance with statutory requirements. The method is suitable for air sample volumes within range 10 litres to 40 litres, and may be used to measure both short-term and long-term exposure.

(b) NIOSH 7904 - CYANIDES, aerosol and gas (NIOSH, 1994e)

4.2.13 Hydrogen Chloride

(a) USEPA Method 26 Determination of hydrogen halide and halogen emissions from stationary sources non-isokinetic method

This method is applicable for determining emissions of hydrogen halides (H_x) (HCl, HBr, and HF) and halogens (X_2) (Cl_2 and Br_2) from stationary sources. Sources, such as those controlled by wet scrubbers, that emit acid particulate matter must be sampled using USEPA Method 26A (USEPA, 1991f).

4.2.14 Hydrogen Fluoride

(a) USEPA Method 26A —Determination of hydrogen halide and halogen emissions from stationary sources non-isokinetic method

“This method is applicable for determining emissions of hydrogen halides (H_X) (HCl , HBr , and HF) and halogens (X_2) (Cl_2 and Br_2) from stationary sources. Sources, such as those controlled by wet scrubbers, that emit acid particulate matter must be sampled using USEPA Method 26A” (USEPA, 1991g)

(b) ISO 15713 Stationary Source Emissions - Sampling and determination of gaseous fluoride content

“This International Standard is applicable to the measurement of the gaseous fluorides that are entrained in gases carried in stacks or ducts. The gaseous fluoride content is expressed as a mass of hydrogen fluoride in the stack gas. The standard is applicable to all stacks emitting gases with fluoride concentrations of below 200 mg/m^3 . It can be used for higher concentrations, but then the absorption efficiency of the bubblers should be checked before the results can be regarded as valid. The detection limit of the method is estimated as $0,1\text{ mg/m}^3$, based on a sample volume of $0,1\text{ m}^3$. All compounds that are volatile at the filtration temperature and produce soluble fluoride compounds upon reaction with water are measured by this method. The method does not measure fluorocarbons. The concentration of fluoride in the adsorbent solution is then measured using an ion selective electrode and is then expressed as hydrogen fluoride by convention, though this may not reflect the chemical nature of the compounds being measured” (ISO, 2006).

4.2.15 Phosphorous and its inorganic compounds

No emission method is published. The use of occupational health standards NIOSH 6402 for analysis is accepted practice.

(a) NIOSH 6402 - Phosphorus Trichloride (NIOSH, 1994d)

4.2.16 Methylamines

Sampling is done using BS EN 13649, and analysis using NIOSH 2002 and NIOSH 2010.

(a) BS EN 13649 Stationary Source Emissions - Determination of the mass concentration of individual gaseous organic compounds. Activated carbon and solvent desorption method

“This European standard specifies procedures for the sampling onto activated carbon, the preparation and the analysis of samples of volatile organic components such as those arising from solvent using processes. It can be used as a reference method.

The results obtained using this standard are expressed as the mass concentration (mg/m^3) of the individual gaseous organic components. This standard is suitable for use in the range of approximately $0.5 \text{ mg}/\text{m}^3$ to $2\,000 \text{ mg}/\text{m}^3$. For the measurement of the mass concentration of total organic carbon arising from solvent using processes EN 13526 should be used (BSI, 2002c).

(b) NIOSH 2002 – Amines, Aromatic (NIOSH, 1994b)

(c) NIOSH 2002 – Amines, Aliphatic (NIOSH, 1994c)

4.2.17 Acrylonitrile

(d) USEPA Method 0031 Sampling method for volatile organic compounds (SMVOC) (USEPA, a)

USEPA Method 0031 is used to determine volatile organic compounds in gaseous emissions from a wide variety of stationary sources including hazardous waste incinerators. The method can determine various organic compounds including acrylonitrile.

5 OTHER EMISSION REQUIREMENTS

5.1 Leak detection and repair (LDAR) programme

The S.21 Notice requires that LDAR programmes be prepared and implemented for listed activities that are known to have a significant risk to emit volatile hydrocarbons. This section provides details of what a LDAR programme is considered to be in South Africa, as adopted from the USEPA, which promulgated the method for detection of the hydrocarbons leaks which is prescribed for use under S.21 Notice.

5.1.1 What the LDAR programmes is

The LDAR programmes are designed to limit the amount of hydrocarbon emissions that can escape into the atmosphere from various operating equipment including valves, flanges, pumps, and other components. The programme also sets forth the criteria for leak repair and record keeping.

5.1.2 LDAR techniques

LDAR programme employ the use of Flame Ionized Detectors (FID) or Photo Ionized Detectors (PID) to identify leaks that range from near ambient air readings to as much as 100,000 parts per million (ppm). USEPA Method 21 is the method widely used for determination of VOC leaks and is adopted under the SA S.21 Notice.

5.1.3 USEPA Method 21 - Determination of Volatile Organic Compound Leaks

This method is applicable for the determination of VOC leaks from process equipment. These sources include, but are not limited to, valves, flanges and other connections, pumps and compressors, pressure relief devices, process drains, open-ended valves, pump and compressor seal system degassing vents, accumulator vessel vents, agitator seals, and access door seals. This method involves moving a gas sampling instrument probe around all leak interfaces (seals) and determining the highest VOC/HAP concentration. After determining the location of the highest concentration, the probe must remain at that location

for two times the response time. The instrument readings are compared with levels established by the USEPA and/or the state air pollution regulatory agency to determine if the component leaks. If the measured VOC concentration at a component exceeds the leak definition (which typically varies from 500 parts per million by volume (ppmv) to 10,000 ppmv, depending on the type of component, the component must be repaired or replaced within a specified period of time. The repeated Method 21 measurement of emissions following such maintenance must be below the leak concentration level for the component to be considered repaired.

5.1.4 Smart LDAR – Use of Optical Gas Imaging with USEPA Method 21

Smart LDAR involves the use of optical imaging techniques to identify and locate leaking points on the piping network in real-time, without having to check each pipe in the plant using USEPA Method 21. These remote sensing techniques provides for scanning of a complex process comprising hundreds of pipes and other potential VOC sources in real-time, thereby increasing monitoring efficiency and reducing costs incurred in using USEPA Method 21 alone. The benefit of real-time monitoring is that significant leaks can be identified immediately, allowing for quicker repair thus saving product loss and environmental and safety risks.

Currently, two types of optical gas imaging cameras are available for use as under Smart LDAR:

- 1) “**Active Optical Gas Imaging**” - utilizes a laser beam reflected (backscattered) by the background to detect the chemical present. The optical image is produced by the reflected light, with a light wavelength strongly absorbed by the gas cloud. The image is displayed real-time on the screen of the gas imaging camera.
- 2) **Passive Optical Gas Imaging** - a passive technology that records the difference in absorption of specific infrared (IR) wavelengths in the field of vision and produces the appearance of a cloud where the chemical is present. The technology uses different combinations of lenses, detectors and filters for detecting different pollutants. The optical

lens of a passive gas imaging camera can be tuned to illuminate target compounds (a principle similar to that used in “night-vision” equipment) to detect leaks” (Meister, 2014).

5.1.5 Documentation of LDAR Programme

The following represent contents of the documented LDAR programme:

- “An overall, facility-wide leak rate goal that will be a target on a process unit-by-process-unit basis.
- A list of all equipment in light liquid and/or in gas/vapor service that has the potential to leak VOCs within process units that are owned and maintained by each facility.
- Procedures for identifying leaking equipment within process units.
- Procedures for repairing and keeping track of leaking equipment.
- A process for evaluating new and replacement equipment to promote the consideration of installing equipment that will minimize leaks or eliminate chronic leakers.
- A list of “LDAR Personnel” and a description of their roles and responsibilities, including the person or position for each facility that has the authority to implement improvements to the LDAR programme.
- Procedures (e.g., a Management of Change program) to ensure that components added to each facility during maintenance and construction are evaluated to determine if they are subject to LDAR requirements, and that affected components are integrated into the LDAR program” (USEPA, 2007).

Internationally published guidance documents on documentation, implementation and adoption of the latest leak detection techniques must be used to inform the programme.

5.2 Dust fallout monitoring

Where dust fallout monitoring is required, the procedures outlined in the National Norms and Standards for Ambient Air Quality Monitoring must be followed.

5.3 Odour measurements

S.21 Notice makes requirements for implementation of the best practice measures intended to minimize or avoid offensive odours for specific activities. Where this is required, measures must be agreed to with the AELA and incorporated in the AEL. Compliance will therefore be measured against this plan.

5.4 Ambient air quality monitoring

Where ambient air quality monitoring is required, the procedures outlined in the National Norms and Standards for Ambient Air Quality Monitoring must be followed.

6 DATA HANDLING

6.1 Equipment calibration

Calibration is a process that either makes a physical adjustment to a device that affects its response to the measurand or it determines a calibration factor that is used in the calculation of the measurement result. The following calibration requirements must be adhered to:

- Calibration programmes should be established for each piece of equipment that can have a significant effect on the results.
- Intermediate checks must be carried out to maintain confidence in the calibration status of the equipment.
- Before being placed into service, equipment should be calibrated or checked to establish that it meets the specification requirements and complies with the relevant standard specifications.
- Procedures should ensure that equipment transported to site remains in valid calibration or is otherwise subject to checks or calibration on-site.
- Zero and span gas checks should be conducted on the entire sampling system to verify its integrity.

- Equipment calibration must be traceable. The organization should hold traceable calibration materials (where available) for all aspects of the monitoring process.
- Where calibrations give rise to a set of correction factors, e.g. Pitot tubes for measuring flow, the laboratory should have procedures to ensure that copies (e.g. in computer software) are correctly updated and used.
- Calibration gases must be obtained from the National Metrology Institute of South Africa, or service providers meeting NMISA certification requirements.
- Valid calibration certificates for all pertinent equipment used in the emission testing campaign must be included in the emission report.
- The calibration certificate must include all pertinent data, the date of calibration, and the name of the technician who performed the calibrations.

Note:

The National Metrology Institute of South Africa (NMISA) was established under the Measurement Units and Measurement Standards Act, 2006 (Act No.18 of 2006). *NMISA is responsible for maintaining the SI units and to maintain and develop primary scientific standards of physical quantities for SA and compare those standards with other national standards to ensure global measurement equivalence. It must also provide reference analysis in the case of a measurement dispute and maintain and develop primary methods for chemical analysis to certify reference materials for SA and the region.*

6.2 Process data collection

The S.21 Notice requires that emission measurements be carried out under normal operating conditions. A site review must be undertaken to confirm that the plant is operating under these conditions. This information should be collated to form part of the site-specific protocol, which details the process conditions under which sampling should occur. The process conditions during the sampling exercise must be recorded to ensure that they are the same as those specified in the site-specific protocol.

6.3 Measurement uncertainty

There are a number of sources of measurement uncertainty associated with any particular measurement, and the goal in calculating the uncertainty is to account for and quantify the effect of all significant sources. The measurement uncertainty is composed of sources of uncertainty in sampling, sample handling and analysis.

Procedures for calculating the measurement uncertainty must be followed. The basic statistic data may be found in the measurement standards and the specifications of the measuring instruments.

(a) ISO 14956 Air Quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty

“This international standard specifies, for the field of air quality measurement procedures, the estimation of measurement uncertainty from actual or claimed values of all important performance characteristics of a method under stationary conditions; assessment of whether or not specified values for these performance characteristics comply with the required quality of a measured value at a stated measurand value; evaluation of the applicability of the measurement method based on laboratory performance and confirmatory field test; establishment of requirements on dynamic behaviour of instruments. This international standard is applicable to measurement procedures whose output is a defined time average” (ISO, 2002b).

A generic approach to uncertainty calculation is described in:

(b) ISO/IEC Guide 98 - Guide to the Expression of Uncertainty in Measurement (GUM).

“This document describes a procedure in which individual uncertainty sources are identified, quantified and combined to provide the measurement uncertainty.

The GUM approach should be used as the most general method. The steps that should be taken are:

- Review the measurement method and identify potential sources of uncertainty

- Quantify the significant sources of uncertainty
- Combine the uncertainty components and expand to give required level of confidence
- Report the measurement uncertainty with measurement result” (ISO, 2008)

6.4 Emissions Estimations Instruments and Techniques

In addition to the minimum requirements of PEM and CEM required under S.21 Notice, the AELA may also prescribe mass balances, engineering calculations, and emission factors as supplementary emissions estimation requirements.

7 EMISSIONS REPORTING

7.1 Emission monitoring requirements

In preparation of data for reporting and subsequent compliance assessment, emission requirements such as how the emission limit is expressed (mass emission rate (g/s) versus mass concentrations (mg/m³), the prescribed averages (hourly, daily, rolling, etc.) must be considered, and the results computed in line with these requirements. This is important in comparison exercises and compliance determination.

7.1.1 Normalization

The emission limits specified in the minimum emission standards are mainly expressed as mass concentrations, under normalized conditions. Before a measurement can be assessed against the prescribed emission limit value, it must therefore be converted to the same standard or normal conditions and unit as the emission limit value.

7.1.2 Averaging

Pollutant emission levels are almost always stated over a particular averaging time called rolling averages. Averaging periods should be as determined in the permits, taking into account the minimum requirements stipulated under S.21 Notice.

7.1.3 Common stack

Minimum emission standards are specified for each listed activity, and the point of compliance is at the stack. However, there are instances whereby activities share a common stack. Where this occurs, point of compliance shall be at the duct between the activity and the stack. Measures must be taken to ensure stable flow and velocity with any interference prevented.

7.2 Data storage

Data must be stored for a minimum period of 5 years and produced when required.

7.3 Templates for emission reports

S.21 Notice has provided minimum requirements of the contents of the emission report to be submitted by AEL holders in demonstration of compliance with emission limits. A recommended template for emission report is hereby provided.

ATMOSPHERIC EMISSION LICENCE NUMBER:		REPORTING PERIOD:	
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**EMISSIONS REPORT SUBMITTED BY THE HOLDER OF ATMOSPHERIC EMISSION LICENSE
OR PROVISIONAL ATMOSPHERIC EMISSION LICENSE ISSUED IN TERMS OF CHAPTER 5 OF
THE NATIONAL ENVIRONMENTAL MANAGEMENT: AIR QUALITY ACT, 2004 (ACT NO. 39 OF
2004)**

Name of Facility/ Plant: _____

Declaration of accuracy of information provided:

Submission of atmospheric emission report to demonstrate compliance with conditions of an atmospheric emissions license / provisional atmospheric emission license issued in terms of chapter 5 of the National Environmental Management: Air Quality Act, 2004 (Act No. 39 of 2004).

I, _____ [*delegated by the Accounting Officer*], declare that the information provided in this report or attached to this report is, to the best of my knowledge, in all respects factually true and correct and that normal operating conditions were maintained during emission tests. I am aware that the supply of false or misleading information in the emission report is a criminal offence in terms of section 51(1) (g) of the Act.

Signed at _____ on this _____ day of _____

SIGNATURE

CAPACITY OF SIGNATORY

SECTION A: FACILITY INFORMATION

Facility Name			
Trading as			
Physical address of the facility			
Description of the site (Where there is no street address)			
Postal address of the facility			
Metropolitan/ District Municipality		Local Municipality	
Province		Designated Priority Area	
Emission Control Officer			
Telephone Number (Direct)		Telephone Number	
Mobile Number			
Fax Number		E-mail Address	

SECTION B: ACCREDITATION STATUS OF THE LABORATORY

Name of the Service Provider			
Accreditation Status*			
Last Audit Conducted (Date)		Audit status	
Address			
Telephone Number		Mobile Number	

*Schedule of accreditation indicating the methods accredited for must be attached.

\$Where sampling and/or analysis of the pollutants are done by more than one laboratory, the table should be duplicated to provide accreditation status of each laboratory.

SECTION C: PERSONELL INVOLVED IN MEASUREMENT TESTS

NAME OF PERSONELL	AFFILIATION/ACCREDITATION

SECTION D: PROCESS DESCRIPTION* (Process diagram with a clear description of emission points should be attached)

* Clean description of the process, including information about emission control equipment (e.g. efficiency, availability); Attachment of process flow sheet or diagram; and Information about raw materials used, and production rates (of products and by-products as well as emission rates) at the time of test.

SECTION E: LISTED ACTIVITIES AS REFLECTED IN THE LICENSE

Category	Subcategory	Description of the activity	Associated Unique Stack ID

SECTION F: UNIT PROCESSES AND ASSOCIATED HOURS OF OPERATION

Unit Processes	Unit Process Function	Batch/ Continuous Process	Hours of Operation

SECTION G: PROCESS OPERATING CONDITIONS DURING COMPLIANCE TESTING. (Where any upset conditions have been observed during measurement tests, detailed information regarding their impact on test results must be provided).

SECTION H: SAMPLING AND ANALYTICAL PROCEDURES* (this table should be duplicated for each unit activity)

UNIQUE STACK ID:

ASSOCIATED UNIT ACTIVITY:

Parameter measured	Sampling/ Analysis method	Sample Run #1	Sample Run #2	Sample Run #3	Average of Runs

- (a) The sketch illustrating the sampling locations must be attached to this report. These sketch must indicate the following:
 - (i) The stack cross-section dimensions at the sampling location.
 - (ii) Distances to the nearest upstream and downstream flow disturbances
 - (iii) The number of traverse points and the distance along a traverse to each.
- (b) Where the sampling location does not meet international best practice, discussion on the available sampling options and their potential effect on the measurement test results.
- (c) Copies of all sampling data sheets, process operating logs, pretest and post-test calibrations must be attached

SECTION I: RECORD OF DEVIATION FROM METHODS SPECIFIED UNDER SCHEDULE A OF THE LISTED ACTIVITIES AND MINIMUM EMISSION STANDARDS NOTICE (approval by the national air quality officer to be attached).

Pollutant measured	Method specified in the license	Alternative method used	Reasons for deviation from the specified method

SECTION J: POINT SOURCE PARAMETERS

Unique Stack ID	Stack location coordinates (Latitude & Longitude)	Altitude above mean sea level of the base of the stack	Height of release above ground (m)	Height above nearby building (m)	Diameter at stack tip/ exit point (m)	Actual gas exit temperature (K/ °C)	Actual gas volumetric flow rate (Nm ³)	Actual Exit velocity (m/s)	Actual mass flow (g/s)	Average pressure (Pa)	Moisture content (% v/v)	Oxygen Content (% v/v)

SECTION K: EMISSION MEASUREMENT RESULTS PER ACTIVITY (This table should be duplicated for each unit activity)

UNIQUE STACK ID:

ASSOCIATED UNIT ACTIVITY:

Measured Pollutant	Pollutant Concentration (mg/m ³ , at 273 K, 101,3 kPa, dry gas), at specified reference conditions	Estimated uncertainty of results	Comparison with AEL emission limits	Percent isokineticity	Comments on the results

* Copies of all analytical laboratory reports and data sheets must be attached

SECTION L: AMBIENT AIR QUALITY MONITORING (Where ambient air quality monitoring requirements are specified in the license)

Monitoring Location	Pollutant to be Measured	Monitoring / Sampling Method	Monitoring Frequency	Monitoring Duration	Target	Reporting Frequency

SECTION M: DUSTFALL EMISSIONS

Where dustfall emission requirements have been specified in the Atmospheric Emission License, the dust fallout report must be attached.

SECTION N: Any other conditions as specified in the license

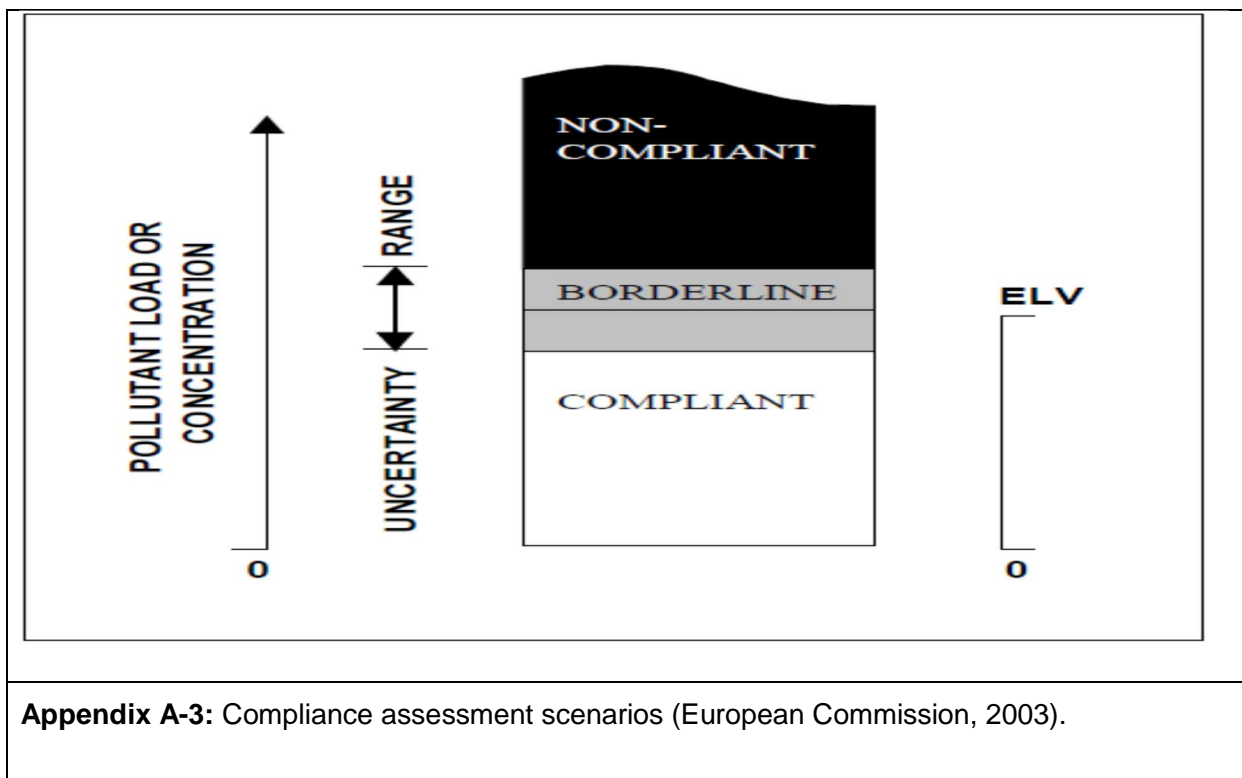
AEL Condition	Compliance Status	Notes

SECTION O: GENERAL COMMENTS

8 COMPLIANCE ASSESSMENT

8.1 Assessment of compliance periodic emission measurements

When reporting results from PEM, the S.21 Notice stipulates an average of at least 3 samples, each measured for a period not less than 60 minutes. This average is therefore considered the result of the PEM. The average should be reported after consideration of uncertainty. Compliance is attained when the result of the PEM after the measurement uncertainty has been subtracted are lower than the emission limit value. Different compliance bands are established as follows:



- Compliant zone: is attained when measured value is less than the ELV, even when this value is increased by the uncertainty.
- Borderline: is attained when the measured value is between (ELV - uncertainty) and (ELV + uncertainty).
- Non-compliant: is when measured value is more than the limit, even when the value is decreased by the uncertainty.

8.2 Assessment of compliance continuous emission monitoring

For continuous measurements, the results of measurements are also assessed after the measurement uncertainty has been subtracted from the emission limit value. In addition to the monthly averages being reported, the daily emissions concentrations may not exceed the emission limit/ standard by 20 percent.

9 QUALITY ASSURANCE FOR EMISSION MEASUREMENTS

9.1 Introduction

In order for the emission data produced to be used in ascertaining compliance or non-compliance with emission standards established under the S.21 notice, it has to meet minimum quality requirements. These requirements are that the emission data produced must be credible and traceable to standard reference methods. In order to achieve this objective, the QA programme must pay detailed attention to the quality of results, quality of the process, quality of the instruments, and quality of the work and organization. This programme results in a system comprising five interdependent elements:

- Assurance of measuring traceability of the obtained results
- Evaluation of uncertainty in obtained results of measurement
- Use of certified reference materials
- Participation in various interlaboratory comparisons
- Validation of the applied analytical procedures.

This section therefore, provides guidance on minimum requirements for QA required specifically for atmospheric emissions data produced for the purpose of the implementation of the National Environmental Management: Air Quality Act, 2004 (Act No.39 of 2004) as amended. The section provides requirements for accreditation, the use of validated method (and criteria to be met when alternative methods are used) and certification of personnel.

9.2 Accreditation of laboratories by SANAS

To this end, the S.21 Notice requires that laboratories performing emission tests, calibration and analysis must be accredited by the South African National Accreditation System (SANAS) or any accepted equivalent body.

Note:

SANAS is recognized by the South African Government as the single National Accreditation Body that gives formal recognition that Laboratories, Certification Bodies, Inspection Bodies, Proficiency Testing Scheme Providers and Good Laboratory Practice (GLP) test facilities are competent to carry out specific tasks in terms of the Accreditation for Conformity Assessment, Calibration and Good Laboratory Practice Act (Act 19 of 2006).

9.2.1 Accreditation requirements

For any laboratory to be accredited by SANAS, it has to demonstrate its competence to carry out general testing, calibration and analysis activities in line with the requirements stipulated under ISO/IEC 17025 (ISO, 2005). Without repetition of this standard, this section summarizes these requirements as follows:

(a) The requirement of personnel or staff competence

Job descriptions and responsibilities of the emission testing team have to be formalized and documented, with clear identification of individual experiences and training requirements. Appointment of a team leader with the responsibility of quality management and system maintenance must be done.

(b) The requirement to have the quality management system documented

- The laboratory shall establish, implement and maintain a management system appropriate to the scope of its activities. Documentation of the laboratory's policies, systems, programmes, procedures and instructions must be undertaken to the extent necessary to assure the quality of the test and/or calibration results. The system's documentation shall be communicated and be accessible to appropriate personnel.

- The laboratory's management system policies related to quality shall be defined in a quality manual. It should contain, amongst others:
 - ✓ A quality policy statement of the laboratory,
 - ✓ A statement of the overall objectives,
 - ✓ Organizational charts to define responsibilities, and
 - ✓ Description of procedures used to control laboratory activities and preventative measures for deviations.

(c) The requirements to use proper equipment intended for the purpose

- Appropriate equipment to be used and maintained.
- Proper identification and labeling of malfunctioned or inaccurate equipment to avoid accidental use.
- Regular maintenance and calibration of equipment, and recordkeeping of such activities.

(d) The requirements of have calibration and measurement systems traceable to accepted national and international standards

- Calibration of the equipment
- Assurance of measuring traceability of the obtained results
- Evaluation of uncertainty in obtained results of measurement
- Use of certified reference materials
- Validation of the applied analytical procedures.

(e) The requirements to have the laboratories' activities periodically audited, and to participate in interlaboratory comparisons

- Implementation of acceptable audit programmes and exercises (spot checks, system audit, vertical and horizontal audits).

9.2.2 Air quality specific requirements

ISO/IEC 17025 recognizes that it might be necessary to explain or interpret certain requirements in the standard to ensure that the requirements are applied in a consistent manner. This is done through adoption of supplementary requirements made by the accreditation body, taking into account the objective of the accreditation required. Within SANAS, supplementary requirements are prepared by the Technical Committee, and adopted for use, guided by the regulatory intent for accreditation of the field. With respect to emission requirements, the Department of Environmental Affairs has made the following requirements under S.21 Notice as supplementary requirements for accreditation. These have also been presented to SANAS for adoption for this purpose. It should be noted that the S.21 notice provides minimum requirements, and that additional requirements can be put in place or used where the minimum requirements are not sufficient.

9.2.2.1 Additional requirements for periodic measurements

(a) DD CEN/TS 15675 Measurement of stationary source emissions. Application of EN ISO/IEC 17025 to periodic measurements

“This Technical Specification supplements the requirements of ISO/IEC 17025, and is suitable for the demonstration of competence of laboratories that undertake periodic measurement of emissions from stationary sources including:

- the taking of representative samples of emissions and subsequent laboratory analysis for gases and for particulate species,
- the determination of reference quantities such as temperature, pressure, water vapour and oxygen content in the field, and
- the use of portable instruments (such as hand held instruments and transportable instruments used in mobile laboratories) in the field.

This Technical Specification is applicable to all laboratories undertaking periodic measurements of emissions from stationary sources, the calibration of installed automated measuring systems in accordance with EN 14181 and/or the field testing of automated measuring systems for conformity assessment purposes” (BSI, 2007c).

9.2.2.2 Quality Assurance of automated measuring systems

(a) BS EN 14181 Stationary Source Emissions - Quality assurance of automated measuring systems

“BS EN 14181 specifies procedures for establishing quality assurance levels (QAL) for automated measuring systems (AMS) installed on industrial plants for the determination of the flue gas components and other flue gas parameters. This standard specifies:

- A procedure (QAL2) to calibrate the AMS and determine the variability of the measured values obtained by it, so as to demonstrate the suitability of the AMS for its application, following its installation.
- A procedure (QAL3) to maintain and demonstrate the required quality of the measurement results during the normal operation of an AMS, by checking that the zero and span characteristics are consistent with those determined during QAL1.
- A procedure for the annual surveillance tests (AST) of the AMS in order to evaluate (i) that it functions correctly and its performance remains valid and (ii) that its calibration function and variability remain as previously determined.

BS EN 14181 is for use after the AMS has been accepted according to the procedures specified in ISO 14956 (QAL1). It is restricted to quality assurance of the AMS, and does not include the quality assurance of the data collection and recording system of the plant” (BSI, 2004a).

9.2.2.3 Certification of automated measuring systems

Certification of measurement systems from the following organizations shall be accepted:

- (a) UK MCERTS**
- (b) German Technischer Überwachungs-Vereine (TÜVs)**
- (c) National Metrology Institute of South Africa (NMISA)**

Certification of the measurement systems shall follow criteria set out under these methods:

(a) BS EN 15267-1 Air Quality - Certification of automated measuring systems. General principles

“BS EN 15267-1 specifies the general principles, including common procedures and requirements, for the product certification of automated measuring systems (AMS) for monitoring ambient air quality and emissions from stationary sources. This standard 15267-1 consists of the following sequential stages:

- (a) Performance testing of an automated measuring system
- (b) Initial assessment of the AMS manufacturer's quality management system
- (c) Certification
- (d) Surveillance” (BSI, 2009a).

(b) BS EN 15267-2:2009 Air quality. Certification of automated measuring systems. Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process

“This standard specifies the requirements for the manufacturer's quality management system, the initial assessment of the manufacturer's production control and the continuing surveillance of the effect of subsequent design changes on the performance of certified automated measuring systems. BS EN 15267-2 also serves as a reference document for auditing the manufacturer's quality management system” (BSI, 2009b).

(c) EN 15267-3 - Air quality - Certification of automated measuring systems - Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources

“This European Standard specifies the performance criteria and test procedures for automated measuring systems that measure gases and particulate matter in, and flow of, the waste gas from stationary sources. This European Standard supports the requirements of particular EU Directives. It provides the detailed procedures covering the QAL1 requirements of EN 14181 and, where required, input data used in QAL3” (BSI, 2007b).

9.3 The use of validated methods

Another important element of quality management is the utilization of validated methods for sampling, testing, calibration and analysis. For the purpose of implementation of S.21 Notice, acceptable national and international methods are as listed under the Notice. These methods however, are minimum requirements and are thus not exhaustive. For some pollutants and other parameters, relevant methods have not been listed. The methods listed under Chapter 4 of this document should therefore be used.

The laboratory should always use the latest valid standards unless it is not appropriate or possible to do so. Where supplementary requirements are published to ensure consistent application of the standard are available, they must also be used.

9.4 Procedures to prove equivalence of the alternative method to the standard reference method

The S.21 notice provides for the use of equivalent methods where necessary. This pertains to methods developed in-house by the laboratory, or by other recognized organizations. The laboratory shall validate non-standards methods, laboratory – designed or developed methods and any other alternative methods as required by ISO/IEC17025. The following standards for validation of alternative methods must be used where applicable:

(a) Draft BS EN 14793 Stationary source emissions - Demonstration of equivalence of an alternative method with the reference method

“This European standard specifies a procedure to demonstrate the equivalence of an alternative method (AM) with the reference method (RM) or the standard reference method (SRM), both implemented to determine the same measurand. In particular, this European Standard provides the statistical tools and different criteria to evaluate the alternative method. This does not release the body performing the equivalence testing from bearing technical and analytical judgment on the evaluation of the different criteria.

Three steps are required for demonstration of equivalence:

- description of the alternative method and setting of the field of application (measurement range and type of gas matrix);
- determination of the performance characteristics of the alternative method and calculation of the expanded uncertainty where appropriate and check of compliance with the maximum expanded uncertainty allowed for the reference method;
- check of repeatability and lack of systematic deviation of the alternative method in the field or on a recognized test bench in comparison with the reference method for the type of matrix defined in the field of equivalence. This European standard requires that a reference method has been defined and validated and only considers the case of linear quantitative methods.

(b) USEPA METHOD 301 - Field Validation of Pollutant Measurement Methods from Various Waste Media.

As specified under S.21 Notice, the National Air Quality Officer should approve the use of alternative method. Where a request to use an alternative method is made, it should be accompanied by proof of equivalence of this method with a prescribed standard reference method.

9.5 Certification Programme: Training

One critical element of quality management is to have qualified personnel to conduct all measurements, calibration and analysis activities. It is international best practice that the

regulator, in collaboration with emission testing service providers (in a form of associations), and statutory bodies such as accreditation, standards and metrology bodies and academic institutions develop programmes and certification requirements for this purpose.

In South Africa, no specific training has been designed yet. Notwithstanding, there is a pool of various skills that are used for this purpose, mostly:

- Service providers that were primarily interested in occupational health and safety related monitoring;
- Service providers from the chemical laboratories background
- Service providers from the chemical/ process engineering who were primarily interested in process optimization.

As a result, there is some level of inconsistency in skills currently used for this purpose. It is therefore imperative that the certification programme be established urgently. In the meantime, it is recommended that in order to bridge the skills gap between the current skills and stack emission testing for compliance (required skills), the personnel conducting stack testing for the purpose of compliance with the air quality act be trained on general air quality management processes, including legislative aspects of the emission measurements. Also, internationally accepted training and certification such as the UK MCERTS programme should be considered where possible.

Intentionally left blank.

7 REFERENCES

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- ASTM (2003) *ASTM D6348 Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy*, American Society for Testing and Materials, West Conshohocken, Pennsylvania. United States.
- Australia (2014a) *Environment Protection and Biodiversity Conservation Act 1999 (Act No.91 of 1999) as in force on 1 July 2014 (ComLaw Authoritative Act C2014C00506)*, Australian (Commonwealth) Government, Canberra, Australia.
- Australia (2014b) *National Environment Protection Council Act 1994 (Act No.126 of 1994) Amendment Act as into force on 1 July 2014 (Act C2014C00452)*, Australian Commonwealth Government, Canberra, Australia.
- Australia (2011) *National Environment Protection (Air Toxics) Measure. Measure published in terms of Section 14 (1)(a) of the National Environmental Protection Council Act, 1994 (Act No.126 of 1994). (Federal Register of Legislative Instruments F2011C00855)*, Australian Commonwealth Government, Canberra, Australia.
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Post Certification Surveillance for the Manufacturing Process, British Standards Institution.

BSI (2007a) *BS EN 15259:2007 Air Quality - Measurement of Stationary Source Emissions. Requirements for Measurement Sections and Sites and for the Measurement Objective, Plan and Report*, British Standards Institution.

BSI (2007b) *BS EN 15267-3:2007 Air Quality - Certification of Automated Measuring Systems. Performance Criteria and Test Procedures for Automated Measuring Systems for Monitoring Emissions from Stationary Sources*, British Standards Institution.

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BSI (2006b) *BS EN 15058: 2006 Stationary Source Emissions - Determination of the Mass Concentration of Carbon Monoxide (CO). Reference Method: Non-Dispersive Infrared Spectrometry*, British Standards Institution.

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