Chapter 1
Introduction

In this chapter, the relevance of the current investigation in terms of air pollution, atmospheric processes, climate change, environmental impacts and human health is briefly discussed (Par. 1.1). Chapter 1 also presents the scientific gap that was identified (Par. 1.2) and the objectives set for this study (Par. 1.3).

1.1. Background

Both anthropogenic- as well as biogenically produced species released into the troposphere affect the natural balance of the atmosphere, with the effects of the former usually more significant than that of the latter. This balance is imperative to our well-being and is easily disturbed by the introduction of foreign contaminants or overloading of natural occurring species. These species may interact with each other (Dentener *et al.*, 1996) forming secondary pollutants. Some of these secondary pollutants may have long life spans and may therefore be transported over vast distances (Wenig *et al.*, 2003), causing aged air masses to have a detrimental effect on remote, rural sites.

The climate and atmospheric chemical composition of a region directly influences the health and stability of an ecosystem and it is therefore crucial to keep exposure from pollutants to a minimum (Pöscle, 2005). The air quality of a region is determined by the emissions of pollutants, transportation processes that remove and disperse pollutants, as well as the transformation process of gases and aerosols (particles or condensed droplets suspended in air). Developing economies dependent on the production of commodities, such as South Africa, emit large quantities of pollutants. It is therefore becoming increasingly important to study these emissions, as well as the transportation and transformation processes (e.g. atmospheric chemistry) in order to quantify the impacts on the surrounding ecosystems and human health. Atmospheric pollutants can broadly be divided into two categories, i.e. gaseous and aerosols.

In this study, the criteria pollutant gaseous species nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and carbon monoxide (CO) were investigated. NO_2 is a key species in photochemical O_3 production, since it is an O_3 precursor. When NO_2 is oxidised it forms NO_3^-. SO_2 is mainly produced by the combustion of fossil fuels (coal and oils) and by domestic heating. It can also react photochemically or catalytically with other pollutants to form sulphur trioxide, sulphuric acid and sulphates (Elsom, 1987). The oxidation products of both SO_2 and NO_2 are the main contributors to acid rain. NO_x and SO_2 have long-term health effects, such as pulmonary asthma and chronic bronchitis, respectively (Kampa & Castanas, 2008). O_3, which is highly phytotoxic, causes damage to crops and native vegetation (Parra *et al.*, 2006). It is also regarded as a significant greenhouse gas (IPCC, 2007b). Greenhouse gases absorb terrestrial long-wave radiation that causes positive radiative forcing (RF) which, in turn, leads to warming of the atmosphere (IPCC, 2007b).

Particulate matter (PM) with a diameter smaller than 10 µm, another criteria pollutant, was also investigated in this study. The impact of aerosols (or PM) on air quality and climate is determined by their physical (size, mass and optical density) and chemical properties (IPCC, 2007b). Atmospheric aerosol particles originate from natural and anthropogenic sources. Particulate matter can be emitted directly into the atmosphere or is formed in the atmosphere by secondary (physical and chemical) processes. Primary particles are emitted directly from sources such as biomass burning, incomplete combustion of fossil fuels, mineral dust and volcanic eruptions. Secondary aerosols are formed by atmospheric chemical reactions and gas-to-particle conversions (Pöscle, 2005). Wet deposition is the main sink of atmospheric aerosols, while dry deposition – through convective transport, diffusion and adhesion to the earth's surface – also occurs (Pöscle, 2005). The health effects of aerosols are related to the specific surface area and the presence of chemical species such as transition metals and organic compounds (Bernstein *et al.*, 2004). According to the World Health Organization (WHO), thoracic coarse particles may affect the airways and lungs, while fine particles affect the cardiovascular system. Ultra fine particles can also migrate through the lungs to other locations in the human body, such as the liver, brain, spleen and placenta (WHO, 2007).

Various studies have also revealed that an increase in aerosol pollution is associated with an increase in mortality and hospital admissions (Brunekreef & Holgate:, 2002; Suwa *et al.*, 2002).

The physical and chemical properties of aerosols also determine their influence on RF and the subsequent impact on climate, i.e. cooling or warming (Mcfiggans *et al.*, 2006). Atmospheric aerosols found in urban and industrialised areas consist primarily of black (elemental) carbon, organic compounds, nitrates, ammonium and trace metal species (Lack, 2003). These chemical species determine whether airborne aerosols have a cooling or a warming effect on the atmosphere. Black carbon, for instance, absorbs radiative energy that leads to heating of the atmosphere. White or grey particles, such as sulphates and several organic compounds, on the other hand, scatter sunlight and have a cooling effect on the earth's atmosphere (IPCC, 2007b).

Considering the above-mentioned negative effects of the criteria pollutants considered, it is evident that long-term studies of concentration, composition, transformation and deposition of atmospheric species are necessary. This will enable the tracking of temporal and spatial evolution of atmospheric chemistry and is a pertinent indicator of natural and anthropogenic influences on atmospheric conditions. This information is needed to improve our understanding of the behaviour of the atmosphere and its interactions with the biosphere (Held *et al.*, 1996), as well as the impacts on the environment and human health.

1.2. Problem statement

The Bushveld Igneous Complex (BIC) stretches over an area of approximately 66 000km^2 and holds significant resources of several minerals. This includes >70% and >80% of the world's viable chromium and platinum group minerals resources, respectively, as well as smaller deposits of vanadium, cobalt, nickel, tin and copper. The mining and metallurgical operations in the BIC are also surrounded by formal and informal settlements and a wide variety of agricultural activities. Due to current and possible future air quality considerations, the western BIC area is being considered as a possible third national priority area by the SA government (Scott, 2010).

Notwithstanding the importance of the western BIC in terms of air quality and the important role it plays in the SA economy, limited air quality data is currently available for this area. To at least partially address this knowledge gap, a comprehensive air quality study was undertaken in the heart of the western BIC at Marikana. The monitoring station was fitted with online gas- and aerosol analysers.

By comparing the results with the South African and international air quality standards, valuable information will be obtained with regard to the current state of air quality that will also serve as a future reference considering the current economic growth and development of South Africa and the western BIC in particular.

1.3. Objectives

The specific objectives of this study are to:

I. Measure atmospheric gaseous species, i.e. SO_2, NO_2, O_3, CO and PM_{10} at a monitoring station in the western BIC for at least a full seasonal cycle.

II. Process high resolution data obtained from atmospheric measurements for the entire sampling period.

III. Compare the ambient concentrations of the measured species to current national and European air quality standards and assess the status quo of air quality in the western BIC.

IV. Determine the seasonal and diurnal trends for the atmospheric gaseous species and PM_{10} measured.

V. Correlate the atmospheric concentrations of the species measured to possible sources in the region.