AN ASSESSMENT OF THE MANAGEMENT OF ODOUR AT THE ATHLONE WASTEWATER TREATMENT WORKS, CAPE TOWN

BY

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DECLARATION

I, **Colette Nchong Takwi**, hereby declare that; “An assessment of the management of odour at the Athlone Waste Water Treatment Works, Cape Town", is my own work and that it has never been previously submitted for any degree in any other university. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

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Signed Date

ABSTRACT

[1]Odour nuisance is increasingly becoming one of the major environmental problems in various countries across the world, especially odour associated with wastewater (Alfonsin *et al.*, 2015; Schlegelmilch *et al.*, 2005; Gostelow *et al.*, 2001). As a result, the management of odour from Wastewater Treatment Works (WWTW) has become one of the environmental challenges besetting these facilities in recent times. The dispersion of odour across the physical boundary of wastewater treatment facilities presents not only negative environmental impacts to the natural environment, but also constitute a nuisance to surrounding populations. The Athlone (WWTW) located in the urban City of Cape Town with high demographics and adjacent to sensitive communities is thus not immune to poor air quality associated with WWTW activities (Walton, 2005). The population growth due to rural-urban migration has further put severe pressure on the facility and thus worsening the odour problem in the area. As a result, complaints have been received by the City Council from the surrounding communities over the last 20 years. In response to these complaints, the management of the WWTW introduced an odour management system with a particular focus on the use of a biotrickling filter coupled with the use of odour masking sprays. This management intervention was adopted in order to control the odour emitted to the atmosphere from the facility (WWTW). While these measures are said to reduce the prevalence of odour to the surrounding environment, it was, however, not clear whether or not such management interventions have reduced odour emitted from the treatment plant.

This research was premised on two postulations as an approach to analyse the effect of the odour management plan adopted by the Athlone WWTW's management and these are: 1) the perceived experience of odour by the adjacent neighbouring communities and, 2) the understanding of the inherent atmospheric dynamics (such as wind velocity, atmospheric stability, inversion layer and ventilation) which influence odour dispersal in the area. The research project argues that these two factors should be taken into account to ensure that the

[1] Odour is a sensation that is perceived when a compound(s) (called odourants) stimulate sensory receptors in the nasal cavity.

management of odour is sustainable. It is within this background that the research aimed at assessing the management of odour at the Athlone WWTW and to find out, if at all, the inherent local atmospheric conditions in the area and views of the surrounding communities are incorporated into the management of odour from the plant. The methodological design adopted in the study was case study approach. However, the atmospheric data (wind speed and direction) was obtained from the South African Weather Service (SAWS). These variables were analysed qualitatively and experimentally by the use of wind diagrams to provide insight on [2]atmospheric stability conditions, surface inversion and topographical properties, and how these phenomenon influences odour dispersion. The study also reviewed previous odour management reports produced by the Althone WWTW management. This type of data was finally supported by data collected from the community by means of a community survey, face-to-face in-depth interviews and qualitative observation. Some major findings from the study revealed that the local weather of Athlone influences the dispersion of odour – facilitating dispersion in the summer through high wind velocities, while impeding dispersion during winter due to the presence of atmospheric stability conditions. Prevailing odours in this community has led to a general feeling of displeasure amongst community members especially since the management of the treatment plan does not include the local community in the decision-making process. In spite of these, the facility's management approach was found to be more of a response driven nature even though it is ranked as a high-risk facility.

The study was crucial as such findings add to the existing knowledge in the field of Environmental Management, Air Quality Management, Health and Safety Management and Risk Assessment/Management. At a broader level, the study is interdisciplinary in nature as it merges natural scientific approach with social science philosophical construct as an approach to understand the effects of the WWTW odour management in Athlone.

Keywords: Odour, Atmospheric Stability, Air Pollution.

[2] According to Tyson & Preston-Whyte (2002) stable atmospheric conditions are associated with poor air quality due to the lack of ventilation in the atmosphere following the development of the inversion layer leading to slow vertical movement of winds.

ACKNOWLEDGEMENTS

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Special appreciation goes to my husband, Mr. Joseph Atemkuh whose support, encouragement and love is second to none in the world; my adorable daughter Chloe-Azariah Akumbom Atemkuh, who was growing inside of me while I went about collecting data and who even after birth understood that mummy sometimes needed to lock herself up in her room to work uninterrupted.

Finally, profound gratitude goes to my supervisors Dr. Zungu Vincent and Dr. Malaza Ntokozo whose insistence for high quality and attention to detail were the reasons for the quality of this thesis.

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LIST OF ACRONYMS

ASP	Activated Sludge Process
CoCT	City of Cape Town
COD	Conductivity, oxygen- demanding
DALR	Dry Adiabatic Lapse Rate
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs & Tourism
DMS	Development Management Scheme
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWAS	Department of Water Affairs and Sanitation
EIA	Environmental Impact Assessment
ELR	Environmental Lapse Rate
NEMA	National Environmental Management Act
NEMAQA	National Environmental Management Air Quality Act
NIMBY	Not In My Back Yard
NO_x	Nitrogen oxides
OCS	Odour Control Solutions
OCS	Odour Control Solutions
PM_{10}	Suspended Particulate Matter with aerodynamic diameters less than 10µm
PST	Primary Settling Tank
RTO	Regenerative thermal oxidation
SALR	Saturated Adiabatic Lapse Rate
SAWS	South African Weather Service
SO_2	Sulphur dioxide
SST	Secondary Settling Tank
UKWIR	United Kingdom Water Industry Research
VOC	Volatile Organic Compounds
WHO	World Health Organisation
WRC	Water Research Commission
WWTW	Wastewater Treatment Works

CHAPTER ONE

INTRODUCTION

1.1. Background to the study

Recent research in the field of Environmental Management shows that there is constant altercation on the notion of the effects of odour management from significant emissions such as Oil Refineries and Wastewater Treatment Works (hereafter referred to as WWTW) on the environment and neighbouring communities (Brooks *et al.*, 2010, Lejano & Stokols, 2010; Leonard & Pelling, 2010; Lebrero *et al.*, 2011; Southern Wastewater Treatment Works, 2014; Ground Work, 2014). This thesis reports on research aimed to assess the odour management system adopted by the Athlone Wastewater Treatment Works to reduce the level of odour emissions to the surrounding areas. The focus here is to understand whether or not the odour management system takes into account the inherent local atmospheric conditions and views of the surrounding communities as an approach to address air quality (odour) associated with the day-to-day operation of the wastewater treatment plant. Such a consideration is crucial when planning the management of odour because as Walton (2005) points out, the characteristic of inherent local weather will either promote or inhibit atmospheric dispersion. In this case, the extent of dispersion will influence impact thereof on the surrounding environment; the people element.

While South Africa has, over the last 20 years, promulgated policies[3] and legislative frameworks to curb poor air quality, experiences on the ground indicate that economically challenged, vulnerable and previously marginalised communities continue to raise concerns regarding their persistent exposure to the continuous odour emissions (Brooks *et al.*, 2010). This is a worrying concern, as Schiffman (1998:1343) argues that "odour could affect human health through the toxicological effects of Volatile Organic Compounds (VOCs); or irritation of the eyes, throat and nose; by neurochemical changes via stimulation of the sensory nerves". The critical question is how does the odour management systems adopted by these plants address the issue of odour in the Athlone area? Owing to the continued escalation of WWTW's and similar facilities, there is a need to critically examine the extent to which odour is managed to minimise its effects on the ambient environment. For instance, the findings from a study in

[3]National Environmental Management Act (NEMA) 107 of 1998 which outlines principles that govern the protection of the environment
The National Environmental Management: Air Quality Act of 2004 which ensures the protection of human health and the environment
The National Ambient Air Quality Standards: Published in 2009 ensures that atmospheric emissions of particular criteria pollutants are within limits set out in this legislation

Northern Germany on the relationship between livestock odours and neighbouring communities (4,537 sample population) revealed that the level of odour annoyance was inversely proportional to the quality of life of respondents. In these cases, the socio-economic status of neighbouring residents was predominantly associated with high unemployment, low educational status and inadequate access to essential amenities. Consequently, it was also discovered that these communities have a high psychological prevalence of anger, tension, depression, fatigue and confusion as well as reduced vitality as a result of annoyance from livestock odour (Radon *et al.*, 2004).

It is thus from this context that the study assessed the effects of the odour management on the surrounding environment (people inclusive), with specific reference to the Athlone WWTW. Given the history of the area and the fact that the adjacent communities were located in the area as part of the Apartheid Spatial Planning[4], it was crucial to understand how the current WWTW's managers deal with environmental injustices of the past. The research sheds light on how the management of the facility internalises the externalities concerning odour management.

1.2. The study area

The study was conducted in the Athlone WWTW which is located on the Cape Flats on the east of the City of Cape Town with GPS coordinates Latitude: -33°57'14.76" Longitude: 18°30'54". The extent of the treatment facility stretches 3.35km in length and is bound to the north by the N2 Highway and the Vygekraal River where the "treated" effluent from the plant is discharged (CoCT, 2009). On the western side, it is bound by the Cape Peninsula Mountain range while the Bottelary Hills dominate the east side with the treatment plant situated in a riverine valley (Taylor, 1972; Cowling, 1996). The plant is surrounded by the residential community of Athlone, which has a predominantly Coloured population and also considered as a previously disadvantaged low-income population (see Figure 1.1 below).

The facility was commissioned in 1923 to provide services to the Langa pump station, Epping, Ruyterwatcht, Thornton, Northern Elsies River, Beaconvale, Parrow East and Northern Athlone (CoCT, 2012). The primary function of the Athlone WWTW is to collect sewage water from these areas, treat and then discharge the treated wastewater into the Vygekraal River in accordance with the stipulated standards set by the Department of Water Affairs and Sanitation (DWAS) formerly known as the Department of Water Affairs and Forestry (DWAF).

[4] Apartheid Spatial Planning was based on the philosophy of separate development to create fragmented spatial planning along racial lines where poor black communities were located in areas exposed to extreme environmental risk (see Di Scott, 1999).

The plant has a capacity of 105 [5]Ml/d and the treatment method employed is the activated sludge method with primary sedimentation and anaerobic digestion of sludge (CoCT, 2012).

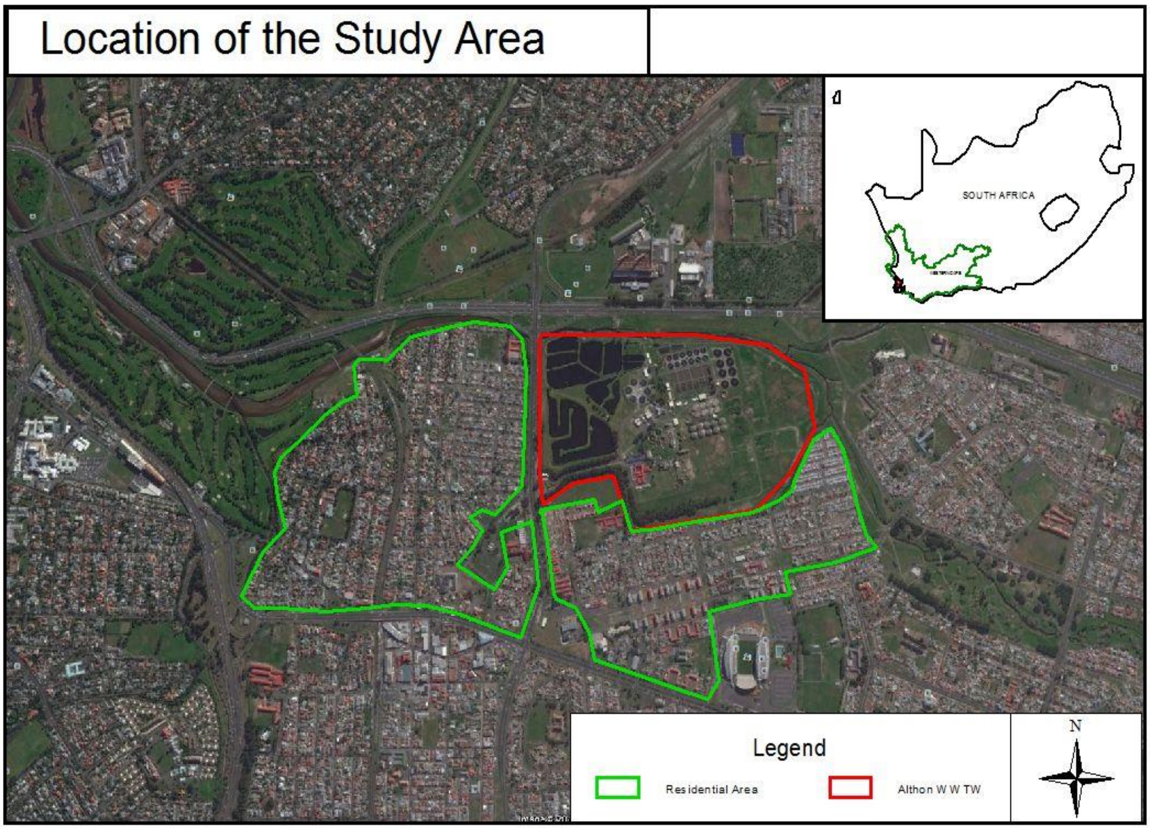

Figure 1.1: Location of Study area (modified from Google Earth, 2016)

1.2.1 The Athlone WWTW operation and odour emission

The plant has been designed to remove excess biological phosphorus and nitrogen from sludge. Sludge is dried on drying beds and shallow lagoons with no effective disinfection of effluent (CoCT, 2012). The primary sludge is thickened by gravity, then anaerobically digested and after that, transported through pipework to another site where it is treated and used for agricultural purposes as fertilizers (CoCT, 2012). Odours can emanate from the thickening sludge process or the anaerobic degradation of organic matter due to microbial action (especially during unfavourable weather conditions- where wet conditions characterised by low temperatures and low wind speed prevail). These processes release chemical substances such as Hydrogen Sulphide, Ammonia and Toluene (Lebrero *et al.*, 2011). These substances

[5] Ml/day= Million litres per day

can be vertically and horizontally transported via air movements to sensitive communities (residential community) adjacent to the plant thus posing odour nuisance in these communities (DEAT, 2004; Southern Waste Water Treatment Works, 2014).

1.2.2. Climate and topography

The Athlone area, which is part of the greater Cape Town area, has a Mediterranean climate characterised by warm, dry summers and damp cold winters with winds dominated by northwesterly winds in winter and southeasterly winds during summer. Rainfall averages to between 82 and 93 mm. Average daily temperatures in the summer (December - February) reach up to about 26^{o}C while in winter (June - August) daily temperatures average between 7-18^{o}C (CoCT, 2014).

During the summer, southeasterly winds caused by a ridging anticyclone over the Atlantic Ocean flow through the city. This has a diluting effect on pollution as a result of its high velocity and atmospheric turbulence. In the winter, cold northwesterly winds flow over Cape Town making conditions favourable for temperature inversion hence accumulation of pollution (odour) (Walton, 2005; Jury *et al.*, 1990).

Athlone has a complex topography, dominated by the Cape Peninsula Mountain range. Its most spectacular feature is the Table Mountain which is bordered on the West by Signal Hill and on the East side by Devil's Peak. These mountains drop, nesting the city in a flat low-lying terrain (CoCT, 2011).

During the daytime, differential heating and cooling occur on slopes forming distinctive air circulation patterns. The slopes absorb incoming solar radiation and warm the air above the surface causing anabatic air flow upwards, while at night winds blow downslope. This air flowing downwards warms adiabatically forming regional subsidence inversion preventing the movement of air hence the dispersion of pollutants or odour at night. The mountain walls together with the inversion layer trap pollutants (or odour) within the valley location through the night, but as morning sets in with solar radiation, the condition starts reversing with anabatic upward air flow (DEAT, 2004).

1.3. Motivation for the study

The scientific debates on the effects of the technical interventionist approach to odour management have resurfaced over the last few years (Brooks et al., 2010). The issue of odour management, especially at wastewater treatment facilities, has become crucial over the past two decades due to heightened environmental awareness and expectation (McGinley, 1995; Luginaah *et al.*, 2002; Lebrero *et al.*, 2011). Nevertheless, odour management is a complex task. It is complicated because odour perception is subjective in its right as well as the fact that the processes of odour measurement, characterisation and impact assessment are fastidious (Gostelow *et al.*, 2001a; Van Herreveld, 2004; Schlegelmilch *et al.*, 2005; Estrada *et al.*, 2011). Further, the disparity between the scientific construct of odour management and the 'layman' understanding of the process does not make the situation any less complicated (Oelofse, 2003). Nonetheless, the role of science and technological innovation is to provide insight to the state and society for more sustainable management (Barnett & Scott, 2007; Brooks *et al.*, 2010). Under these premises, the study was crucial to integrate both scientific and social dimensions hence contribute to the body of knowledge on this subject. The study is also crucial in the field of Environmental Management as it creates a debate on the contestation between the scientific and social dimension of odour management. Furthermore, Environmental Management is an interdisciplinary field of enquiry that fosters the triple helix of sustainability based on an ecological, social and economic aspect of the environment. These three aspects are addressed in chapter five of the National Environmental Management Act (NEMA) 107 of 1998 under the principles of Integrated Environmental Management (DEA, 1998).

The realisation of this study may contribute to the understanding of odour management at WWTW as an Environmental Management issue that needs to be addressed in an integrated and holistic manner.

1.4. Statement of the research problem

The management system of odour associated with wastewater treatment has not received sufficient attention from scholars. This is despite the fact that odour nuisance emitted from Wastewater Treatment Works (WWTW) is increasingly becoming one of the significant environmental problems experienced from the recent past, especially in rapidly growing cities (Canovai *et al.*, 2004; Sarkar & Hobbs, 2003). Increasing populations in urban cities mean an increase in the amount of sewage to be treated and thus exerting enormous pressure on existing wastewater treatment infrastructure. Owing to the complex nature of odour, recent studies state that the management of odour and erratic air quality resulting from odour from WWTW is becoming one of the challenging tasks besetting managers and technical experts of these facilities (Jiang *et al.*, 2015; Molinos-Senante *et al.*, 2014; CoCT, 2011; Lebrero *et al.*, 2011; Nicell, 2009; Schlegelmilch *et al.*, 2005; Gostelow *et al.*, 2001a). Albeit, the management of odour has predominantly been driven by a scientific, if not a technocratic engineering focus over the years especially with the complexity of odour perception given that it is subjective by nature. In the case of the Athlone WWTW, a specific odour management plan was devised to curb odour emitted from the wastewater treatment activities. The odour management plan constitutes the treatment of odour using a biotrickling filter and the use of odour masking sprays that go off periodically during wastewater treatment. Considering the location of the plant at the foot of Table Mountain, cold northwesterly winds sweep over this region in the winter thus bringing rains. After the rains, then comes cold anticyclones ridging eastward thus creating stable atmospheric conditions which trap pollutants (odour) released near the surface increasing the intensity of odour in the area (Jury *et al.*, 1990). It is, therefore, critical that the odour management plan adopted by the Athlone WWTW holistically manage odour. The question is whether the plan takes into consideration the inherent atmospheric conditions that influence dispersal of air pollutants (odour).

Recently, the Athlone WWTW has undertaken to upgrade the treatment facility to increase its capacity and improve its efficiency. This upgrade was commissioned in 2009 after a malfunction in the sludge handling mechanism occurred in November of 2008 (CoCT, 2012[6]; CoCT 2009). However, it was not clear whether or not the communities adjacent to the treatment plant view odour as a significant environmental problem in the area. It is for these reasons that the study set out to further investigate whether or not the odour management system adopted by Athlone WWTW takes into account the current natural local atmospheric conditions of the area as well as the impact on the surrounding communities for effective odour management.

1.5. Hypothesis and research questions

- Odour management at the Athlone WWTW is not holistic. It does not take into account the relationship between prevailing atmospheric conditions and odour dispersion;
- There is a high prevalence of discontent within the neighbouring community about odour levels.

The research questions are;

- How is odour from the Athlone WWTW managed?

[6] CoCT 2012 documents the details of the Athlone WWTW. It specifically mentions the upgrade that was commissioned after malfunctioning of the sludge handling mechanism which was addressed in media release NO. 10/2009.

- How do the prevailing atmospheric conditions influence the dispersion of odour in the area?
- What is the view of the communities towards the management of odour in the area?

1.6. Aims

This study aimed to investigate the extent to which odour is managed at the Athlone WWTW and how this affects the neighbouring community.

1.7. Objectives

- To investigate how odour emitted from the Athlone WWTW is managed;
- To find out, if at all, if the local atmospheric conditions influence odour dispersion in the area;
- To investigate whether or not the management of odour takes into account the atmospheric conditions in an attempt to deal with odour and poor air quality in the area;
- To explore the opinion of Athlone community members about odour management at the Athlone WWTW.

1.8. Structure of this report

This thesis is divided into seven chapters.

Chapter one introduces the study beginning with a brief background. The chapter also presents the background to the study area by showing the location and the spatial footprint of the Athlone WWTW that generates odour. The climate and topography aspect of the study area in relation to the odour dispersal is presented. The motivation for the study, the statement of the research problem, research hypothesis and research questions, as well as the aim and objectives of the study, are presented in this chapter.

Chapter two locates the study within existing literature and delves into different thematic areas which inform the study. This chapter discusses the meteorological factors that influence the dispersion of odour and looks at the different ways in which odour management has been conducted in WWTW over the years. Debates surrounding the 'layman' in the face of emerging odour management at odour producing facilities are explored while looking at the dynamics of land use compatibility amidst contrasting land uses in an urban setting.

In **Chapter three**, the research methodology is outlined with a detailed description of data collection methods, sources and how collected data were analysed for the study. The motivation for selection of research design and study approach about the nature of data that was collected is presented. A description of ethical procedures mandatory for the study is presented as well as the challenges encountered with data collection is detailed in this chapter. The most challenging aspect of the data collection was the bureaucratic bottlenecks that had to be overcome through the data acquisition process.

Chapter four deals specifically with the role of the weather in odour dispersion using surface wind data from collected data from the Cape Town International Airport weather station by the South African Weather Service (hereafter referred to as SAWS). This station is near the study area hence is representative of the study area. Surface wind speed and direction in the study area during winter and summer months were analysed by the use of wind rose diagrams looking at diurnal, seasonal and interannual variability of surface wind characteristics from 2005 to 2016. The purpose of this analysis was to understand how surface winds in relation to the topography influences odour dispersion in the study area. A notable highlight in this chapter is that it shows a correlation of surface wind data with results of a community survey in this study.

Chapter five presents results of collected data from all stakeholders who participated in the research (public officials, Odour Control Solutions staff, Athlone WWTW staff and Athlone community members). Results presented are a summary of key findings from the study and are presented under thematic areas addressing those aspects that informed the study while answering research questions.

Chapter six reports on the analysis of surface wind data and its influence on odour dispersion, as well as the results of a community survey and interview with key stakeholders in this research. The analysis also identifies linkages of research findings with previous studies while answering research questions. Data analysis is also presented along themes which informed the study, the final results show a complete synthesis of research questions and objectives.

Chapter seven shows that the objectives of the study were met while concluding the study with significant findings. This chapter also makes a recommendation for future research

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

It is crucial to state first and foremost that the literature and conceptual framework informing the research is located within the broader aim of the study which is to: evaluate the odour management approach adopted by the Athlone WWTW. As indicated earlier in this thesis there is limited academic analysis on the aspect of odour management with regard to meteorological factors with specific reference to wastewater treatment plants in South Africa (Lebrero *et al.*, 2011). The sparse work done in South Durban Industrial Basin by Brooks *et al.* (2010) and Barnett and Scott (2007) provide a basis to further interrogate the notion of odour management and its effects on the surrounding environment (including people). The point of departure of the literature review and a particular focus for the study broadly draws from the following thematic areas to locate the study and these are;

- odour,
- sources of odour,
- climate and atmospheric dispersion potential over Southern Africa,
- elevated inversions,
- thermo-topographical influences of odour dispersion,
- odour and the local environment,
- nature of odour management in WWTW, and
- odour management and neighbouring communities and land use compatibility and urban environmental quality.

Managing odours from wastewater treatment plants has become one of the critical environmental challenges besetting these facilities for many past decades. In the past, odour emissions associated with industrial processes were perceived as part of the process and hence acceptable. However, in more recent times, following industrialisation coupled with urbanisation, there is a significant increase of wastewater treatment facilities, and hence odour has become an issue of environmental concern. As Canovia *et al.* (2004) and Sarkar and Hobbs (2003) argue that people have become more resentful of odour, in particular, that which is emitted from waste disposal facilities or treatment plants. Invariably, these facilities have an odour management plan to manage odour emissions from the wastewater treatment processes.

2.2. Odour

Odour, as defined by Schiffman and Williams (2005), is a sensation that is perceived when a compound(s) (called odorants) stimulate sensory receptors in the nasal cavity. Gostelow *et al.* (2001) concur with Schiffman & Williams (2005) that odour is the perceived effect of an odourant by the olfactory system. Gostelow *et al.* (2001) further distinguish between odour and the odourants by stating that an odourant is the substance(s) responsible for causing odour while Schlegelmilch *et al.* (2005) articulates odours as a complex mixture of hundreds of single odorous compounds that vary from industry to industry or facility. These odourants will not constitute an odour nuisance except when they are transported from the liquid medium (odour source) to the atmosphere where they are then carried via convection currents to surrounding neighbourhoods (Lebrero *et al.*, 2011; Gostelow *et al.*, 2001). The transport of odour from formation to its final receptors to where it constitutes a nuisance is summarised in Figure 2.1. As can be seen in the diagram, the dispersion component is the link that exposes the environment (people) to odour. However, what determines dispersion characteristics is a function of the local conditions that obtain in the area. This will be dealt with in detail in subsequent sections.

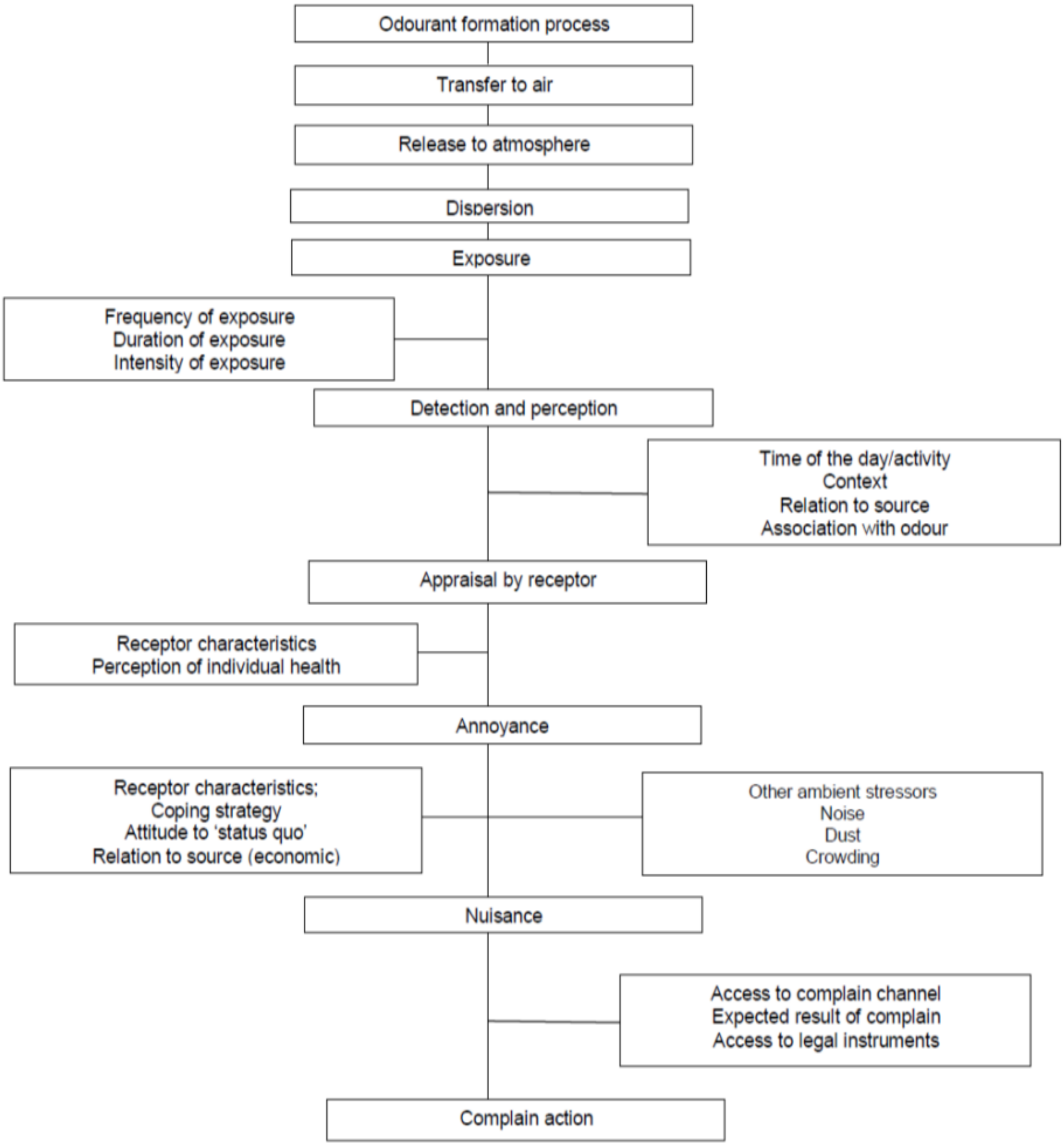

Figure 2.1: Pathway of odour from production to receptors where it triggers complain and action (UKWIR, 2014)

The common underlying factor that seems to run through all the definitions of odour is that odours are caused by chemical compounds in a liquid medium that when released into the atmosphere, is detected by the nostrils as a smell. In the case of a WWTW, the liquid medium is the wastewater. As wastewater treatment takes place, chemical compounds (odorants) escape into the atmosphere via evaporation into the air from where they can be perceived as odour. Table 1 illustrates the significant odourants associated with WWTW.

Table 2.1: Chemical constituents of odour and description adapted from; Bonnin *et al.* (1990); Brennan (1993); Burlingame *et al.* (2004), Suffet & Rosenfeld (2007)

Chemical compound	**Odour description**
Hydrogen sulphide	Rotten eggs
Dimethylsulfide	Decaying vegetation
Ammonia	Decaying fish
Toluene	Tar
Sulphur dioxide	Pungent
Indole	Faecal
Formaldehyde	suffocating
Benzyl mercaptan	Unpleasant
Diamines	Decaying meat

2.2.1. Sources of odour (internal and external)

Internal sources of odours from WWTW include first settlers, sludge-digestion tanks, and sludge thickening and dewatering units (Gostelow *et al.*, 2001; Cele, N, 2015, Personal communication, 30 March 2015). Figure 2.2 illustrates the wastewater treatment process, showing which units are ideally targeted for odour control. It is essential to consider all potential sources of odour emission when assessing odour management. It is important because sources of escaping odours such as

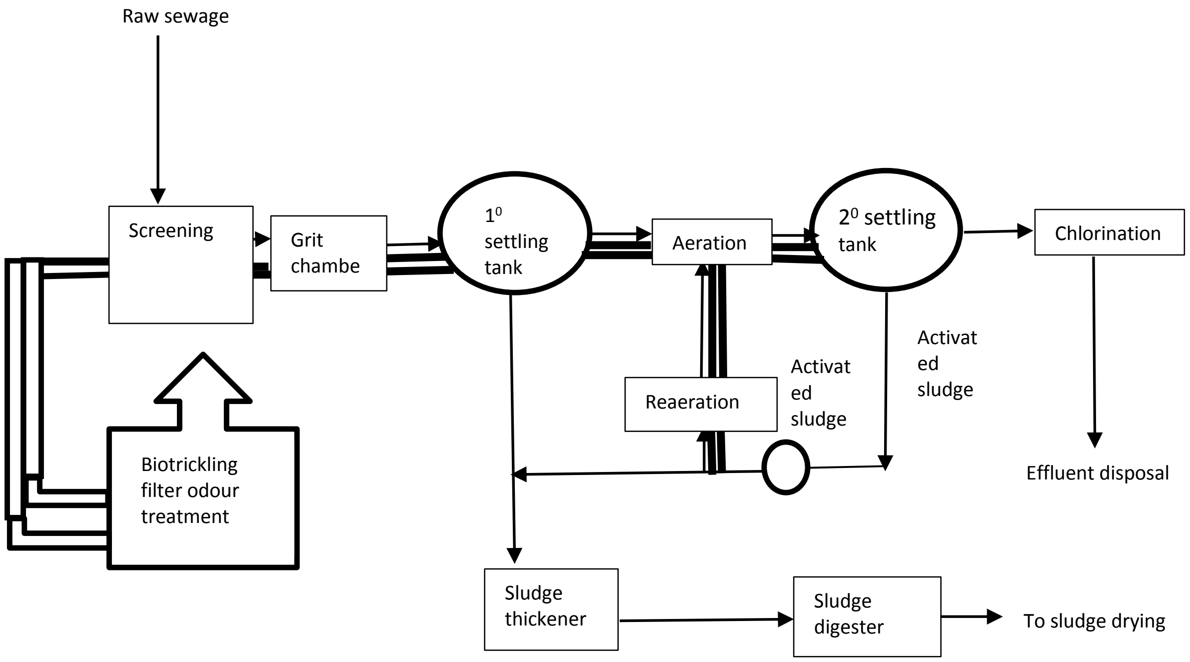

Figure 2.2: Illustration of activated sludge method coupled with biotrickling filter odour treatment technology (Adapted from Civil digital, 2016)

windows, open doors, open delivery or system malfunction (Schlegelmilch et al., 2005) are often overlooked, hence failing to ascertain the actual sources of odour. This results in mediocre or less than adequate odour management.

External odour sources may comprise adjacent landfill sites, waste dump, animal feedlot which together with the WWTW activities may form cumulative effects overtime and produce an odour nuisance in that vicinity (Southern Wastewater Treatment Works, 2014). Determining the odour source is therefore imperative for managing odour and averting odour nuisance in sensitive communities.

2.3. Climate and atmospheric dispersion potential over Southern Africa

The fate of an air pollutant once released into the atmosphere is influenced by meteorological characteristics of that area. These characteristics influence vertical movement (which is a function of atmospheric stability and mixing depth) of air hence air pollutants as well as horizontal movement (which is a function of the wind field) (Tyson & Preston-Whyte, 2000; DEAT, 2004). Therefore, it is essential to examine the macroscale and mesoscale processes to accurately determine the dispersion potential of the atmosphere at a particular place and time. Macroscale processes include the general circulation over a region such as synoptic systems while mesoscale processes include thermo-topographic influences over particular areas (Preston-Whyte *et al.*, 1977; Thomas, 2008).

2.3.1. General synoptic circulation and weather over Southern Africa

The weather over Southern Africa is influenced by circulation systems in the tropics (northward) and the temperate latitudes. It is also influenced by high-pressure systems which constitute semi-permanent, sub-tropical high-pressure cells (Garstang *et al.*, 1996; Tyson & Preston-Whyte, 2000) (Figure 2.3). However, the central control of daily weather over Southern Africa stems from subtropical, tropical and temperate controls (Tyson & Preston Whyte, 2000).

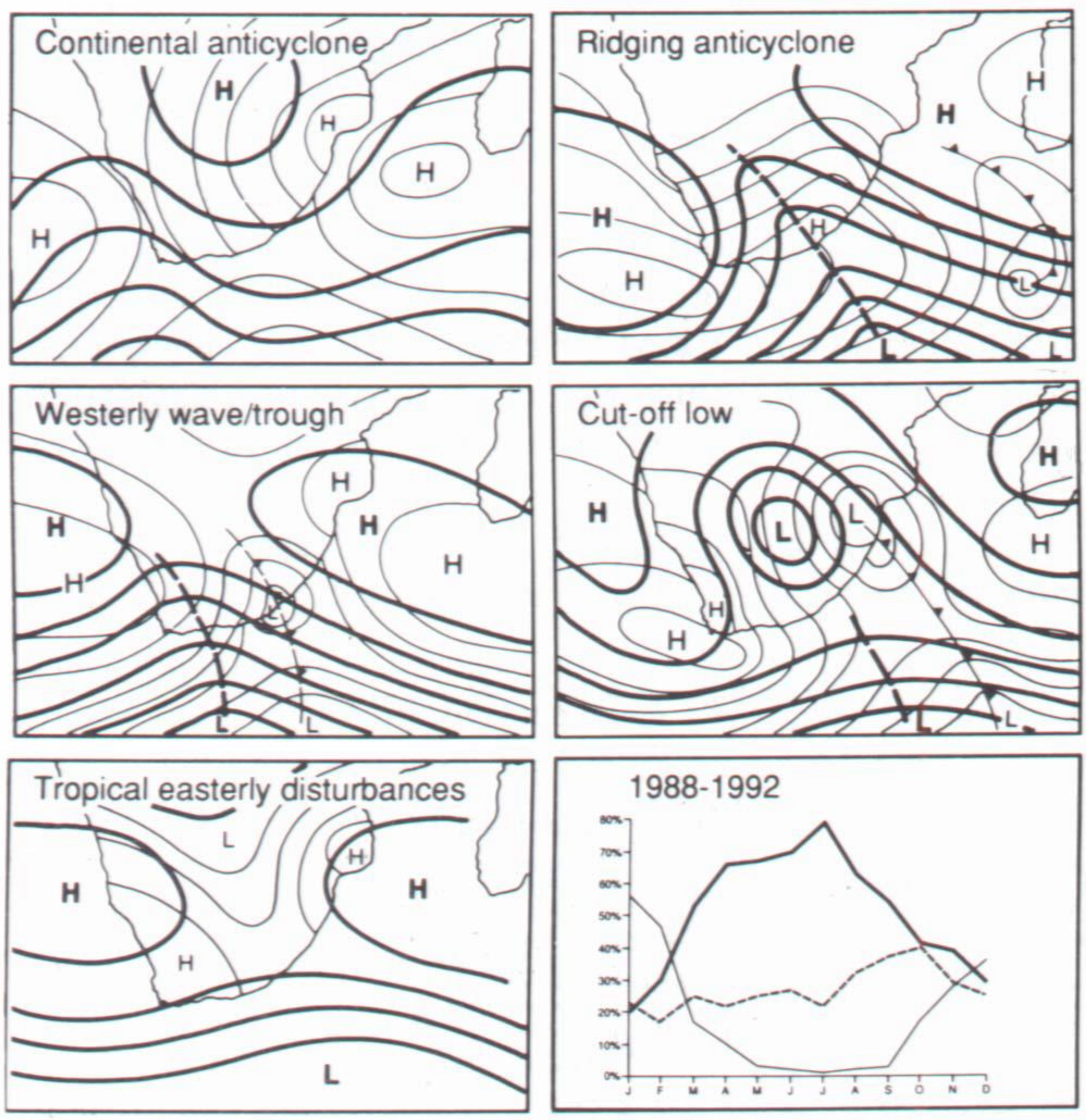

Figure 2.3: Major circulation systems affecting Southern Africa from 1988-1992 (Tyson *et al.*, 1996)

The subtropical control is powered by the semi-permanent South Indian Anticyclone, the Continental High and the South Atlantic Anticyclone (Figure 2.4). The occurrence of these pressure cells creates very stable conditions and fine clear skies over Sothern Africa with the highest frequency of occurrence (79%) in the winter months of June and July (Preston-Whyte

& Diab, 1980; Tyson *et al.*, 1996c; Tyson & Preston-Whyte, 2000). Under these conditions, pollution (and odour) dispersion is inhibited.

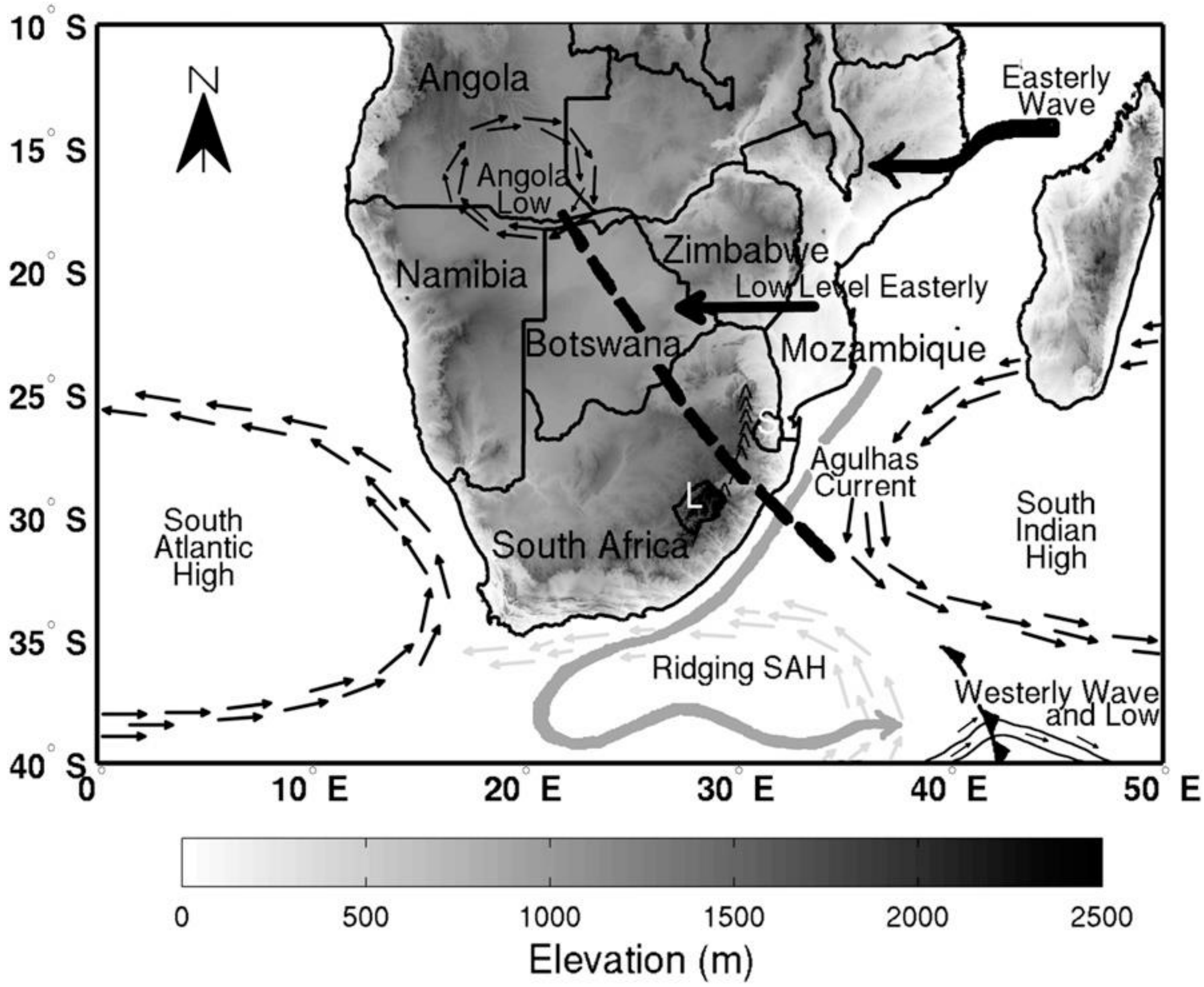

Figure 2.4: Some important features of surface atmospheric circulation over Southern Africa (Blamey & Reason, 2013)

Tropical controls, however, originate deep within easterly currents adjacent to an easterly jet and may occur as easterly waves or lows. When occurring as an easterly wave, it may bring instability conditions wherewith there will be a substantial uplift which may cause rainfall over vast areas for a couple of days to the east of the trough coupled with northerly winds (Jury, 2013). The implication on pollution (and odour) dispersion is that instability conditions produced by this system will enhance dispersion. With easterly lows, it tends to bring rainfall with a northerly flow of air. Rainfall tends to clear the atmosphere of pollution (DEAT, 2004; Guo *et al.*, 2006)

Temperate control has been classified into six different classes. These classes do not occur distinctively but may sometimes overlap one another to influence the prevailing weather conditions. These classes are westerly waves, cut-off lows, southerly meridional flow, ridging anticyclones, west coast troughs and cold fronts (Tyson & Preston-Whyte, 2000).

The peculiarity about westerly waves is that they converge behind the trough in the southwesterly airflow direction while at 500hPa and above, they diverge to the east and ahead of the trough line producing persistent but gentle uplift of air. As such, cloud formation, rainfall and unstable conditions will prevail behind the surface trough while clear skies with stable conditions develop ahead of the trough (Tyson & Preston-Whyte, 2000).

The temperate control in the cut-off lows class is an intense version of westerly waves. They tilt to the west with height and are associated with strong convergence and vertical motion. Moreover, as such, cut-off lows bring about unstable conditions that favour the dispersion of pollutants (Tyson & Preston-Whyte, 2000).

As for the southerly meridional flow, they occur in a westerly wave at 500hPa resulting in upward movement of air which sustains rainy conditions along the coastal and low-veld regions of South Africa; while ridging anticyclones are formed when sharp pressure gradients over the Indian Ocean and adjacent inland areas exist. As the pressure gradient reduces, the change in curvature of flow, mesoscale orographic forcing and upper-level divergence in the westerly wave combine to produce widespread uplift and sometimes rainfall or thunderstorms over the eastern region while producing hot weather and clear skies in the western regions of South Africa (Tyson & Preston-Whyte, 2000). This type of condition will prevent the dispersion of pollutants hence accumulation at the source.

On the other hand, west coast troughs occur due to surface troughs of low pressure over the west coast and an upper westerly wave to the west of the continent producing widespread rain over the western region of South Africa. They converge at the surface and diverge at upper levels ahead of the trough making the upward vertical motion of air pollutants possible (Tyson & Preston-Whyte, 2000).

Finally, cold fronts are a significant determinant of weather in Southern Africa. They occur together with westerly waves, depressions or cut-off lows hence an attempt to understand the influence of cold front on weather in isolation may not be helpful. Cold fronts usually usher in cold air from the south to south-west with characteristic episodes that last for a few days. They occur in winter when the westerly is strongest (Tyson & Preston-Whyte, 2000). Coastal lows allow for air from the interior to descend over the escarpment, and as it descends, it warms up adiabatically and arrives as dry, warm air at the coast. Upon arrival of a cold front, the warm, dry air is pushed upwards with low-level convergence in airflow behind the front promoting convection in the southerly direction and rainfall conditions over the coast. As the cold air circulates over land, continental warm air surges beneath it, forming an inversion layer with clear skies thus trapping pollutants and preventing dispersion below the inversion layer. However, strong wind speeds associated with this system will enhance dispersion potential of the atmosphere (Preston-Whyte & Tyson, 1989)

2.4. Elevated inversions

The dominant type of elevated inversions over Southern Africa is persistent absoluely stable layers that are formed by dominant anticyclonic activities in the subcontinent (Tyson *et al.*, 1996a; Tyson *et al.*, 1996b). As cold air sinks, it warms adiabatically, and its resultant temperature becomes higher than that of the surrounding mixed boundary layer. This temperature difference between the subsiding air and that of the mixed boundary layer depicts an elevated subsidence inversion or absolutely stable layer(s) (Tyson *et al.*, 1996c; Tyson & Preston-Whyte, 2000). An illustration of absolutely stable layers with corresponding circulation types and the time of the year are presented in Figure 2.5. This is a common phenomenon in the weather over Southern Africa (Sangeetha *et al*., 2018). Its implication collectively with synoptic systems and weather disturbances on the pollution dispersion potential of the atmosphere is discussed hereunder.

Elevated inversions prevent the vertical dilution of pollutants in the atmosphere while restricting transport horizontally within the layers (Tyson *et al.*, 1996a; Tyson *et al.*, 1996c; Tyson & Preston-Whyte, 2000; Freiman & Tyson, 2000; Tyson & Gatebe, 2001). They may stretch continuously over long distances even across regions or subcontinents thus increasing the pollution potential of the atmosphere (Tyson & Preston-Whyte, 2000; Freiman & Tyson, 2000).

Generally, over Southern Africa, four high inversion layers exist and are especially frequent and persistent in the winter months. Over the escarpment, three of these layers are visible. The first layer occurs at ~700 hPa (~3km in altitude) and persists for 6-7 days after which it is broken by oncoming westerlies (Preston-Whyte & Tyson, 1973). The second layer occurs at ~500 hPa (~6km in altitude) and is even more persistent and can persist for periods of up to 53 days as was observed during the Southern Africa Fire-Atmosphere Research Initiative (SAFARI) (Garstang *et al.*, 1996). This layer is produced and sustained when subsidence occurs on a large scale. The third layer occurs at ~ 300 hPa (~9km in altitude). At the coast, the fourth inversion layer can be seen at ~800hPa (~ 1km in altitude) (Cosijn &Tyson, 1996; Tyson *et al.*, 1996c; Freiman & Tyson, 2000; Tyson & Gatebe, 2001). This layer increases with height from the coast towards the hinterland. On the western region of the subcontinent, this layer rises and merges with the ~700 layer over the escarpment around Springbok while on the west side, it ends against and below the escarpment (Cosijn &Tyson, 1996). The elevated inversion layers are shallow with depths varying between 51hPa and 68hPa (Cosijn &Tyson, 1996).

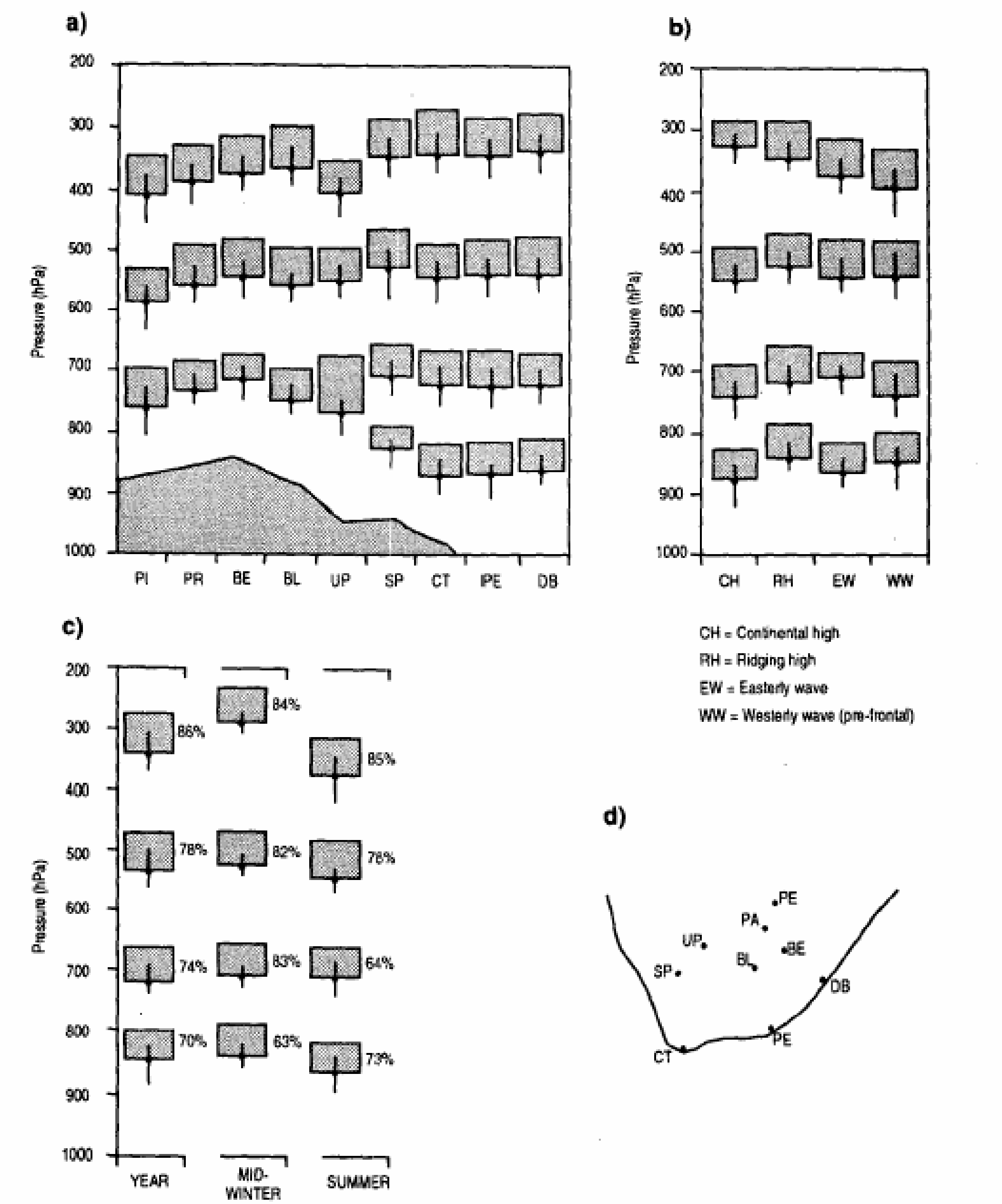

Figure 2.5: stable layers over South Africa grouped into circulation type and time of year. Gray shaded boxes represent absolutely stable layers with base heights (95% confidence limits) and depths (a) for spatial distribution across South Africa, (b) by circulation type, and (c) by the time of year. (d) Locations of stations. The results are based on the analysis of a total of 2925 radiosonde ascents taken over the period 1986-92 (Tyson *et al.*, 1996c)

It has been shown that circulation changes do not affect the formation of elevated stable layers as a result of the anticyclonic nature of circulation that dominates the area (Cosijn &Tyson, 1996; Freiman & Tyson, 2000). Even with the passage of a cold front or westerly waves, elevated stable layers persist while prefrontal conditions lower the base of the elevated layers hence reducing mixing height (Cosijn &Tyson, 1996). As the cold front passes, the mixing height begins to increase slowly in the interior of the escarpment (Preston-Whyte & Tyson, 1989). The only system that disrupts or dissipates the formation of absolutely stable layers is the occurrence of a rapid moving and deeply unstable system (Cosijn &Tyson, 1996; Freiman & Tyson, 2000). Such conditions occur ~18% of the year producing ~86% annual rainfall over the interior escarpment. Even though this condition ensures local dissipation of absolutely stable layers, temporal and spatial dissipation may not be as significant (Cosijn &Tyson, 1996; Freiman & Tyson, 2000).

2.5. Thermo-Topographic influences

These include influences driven by temperature and topographic variations in the wind field. South Africa is situated in the high-pressure anticyclonic belt hence it is characterised (to a great extent) by high subsidence, inversion, low winds and clear skies (cloudlessness). As such, it experiences high temperatures during the day with differential heating on different topography and shallow temperatures at night. As a result, a pressure gradient develops with local and mesoscale thermo-topographic influences (Held *et al.*, 1994; Piketh, 1995; DEAT, 2004)

2.5.1. Topographically induced winds

In areas where the topography is not plain or smooth, a wind type may develop that is referred to as topographically induced winds. They can be divided into the following three categories; slope winds, valley winds, regional mountain-plain winds (DEAT, 2004).

Slope winds come about as the air circulates through the walls of a slope. During the day, the sides of a slope receive more insolation and heat up faster than the floor of the valley. As such, a pressure gradient develops which creates a circulation within the valley cross-section resulting in an anabatic (upward) flow of air. At night, the walls of the slope cool faster than the valley floor again generating a pressure gradient which creates a circulation within the valley cross section, but this time, air flow is katabatic or downward (Figure 2.6) (DEAT, 2004).

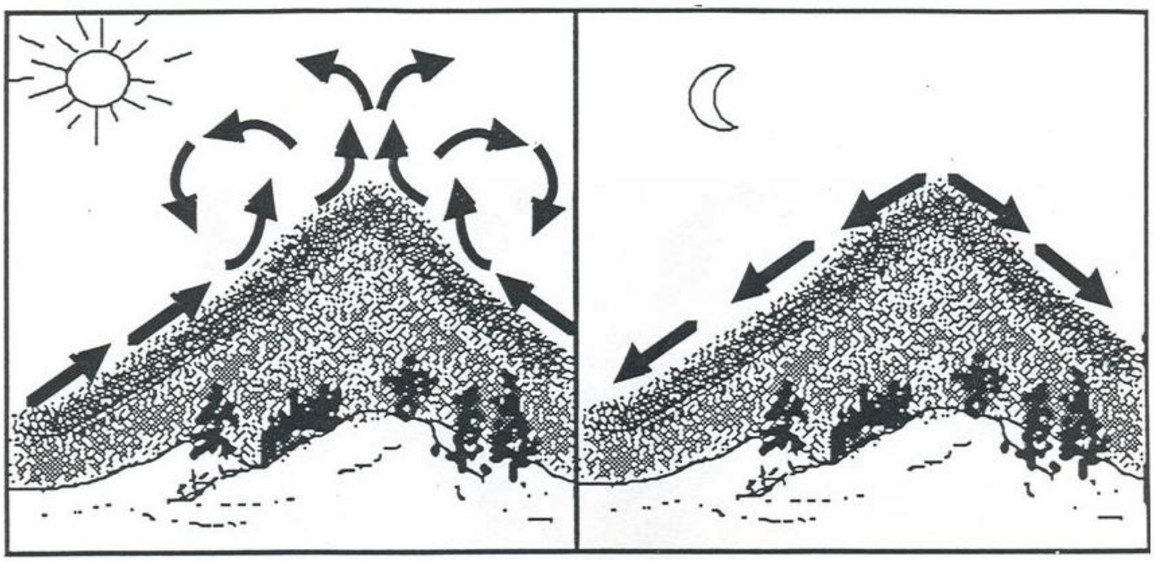

Figure 2.6: Diagrammatic representation of anabatic and katabatic flow associated with slope winds (Fire Weather, 2016)

Valley winds blow to and fro along the length of the valley (Figure 2.7). During the day, these winds blow up the valley and are thus called valley winds, and at night they blow down the valley (mountain winds) (DEAT, 2004).

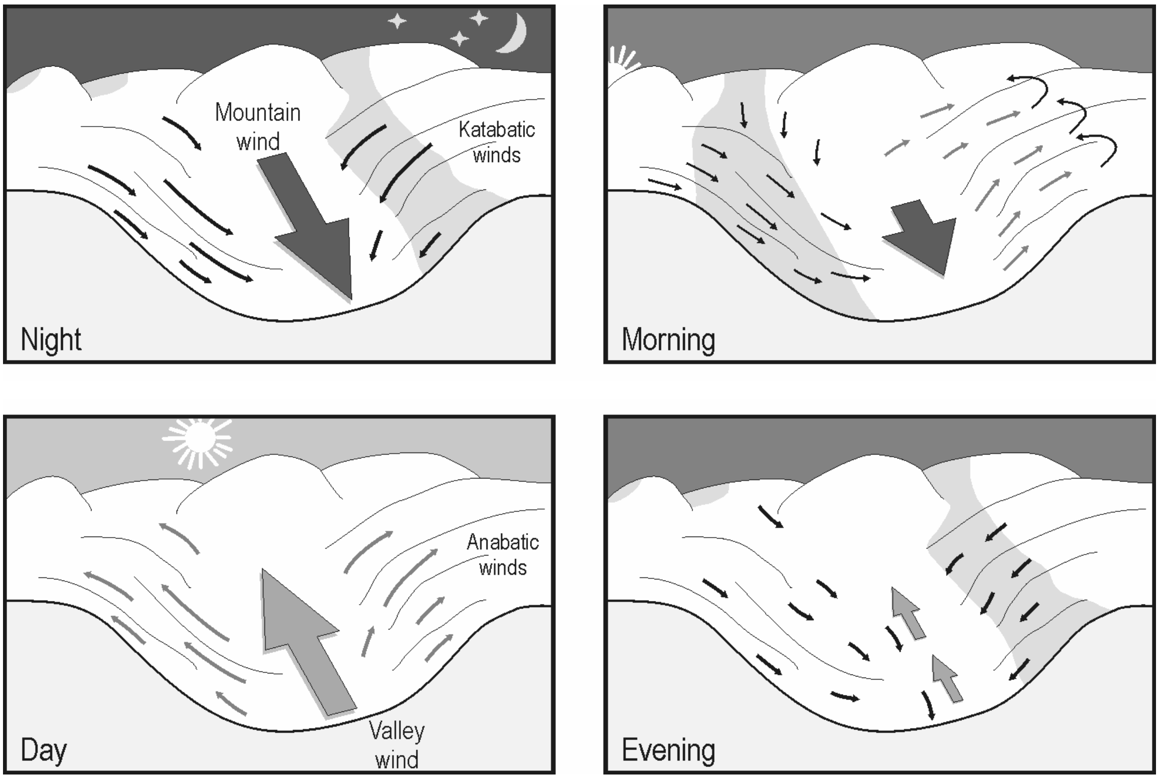

Figure 2.7: Schematic representation of valley winds coupled with slope winds (DEAT, 2004)

At night, cold dense air sinks towards the floor of the valley while lighter warm air remains above the cold air creating a valley inversion. Warm air continues to rise with descending cold air pushing it up until the cold air fills the valley. As a result, the valley inversion occurs from the valley floor to the slope, replacing mixing layer as it causes low-level stability (Preston-Whyte & Tyson, 1989; Stull, 1997). Surface stability in combination with elevated inversion traps pollutants (odour) within the valley atmosphere (Figure 2.8). As a mixing layer begins to develop slowly, fumigation conditions develop with the valley inversion acting as a blanket, trapping pollutants beneath the inversion layer. With incoming solar radiation in the morning, inversion layer begins to dissipate as surface temperatures increase. Hence the highest ground level pollution (and odour) concentrations are experienced at night and early mornings (Rautenbach, 2006).

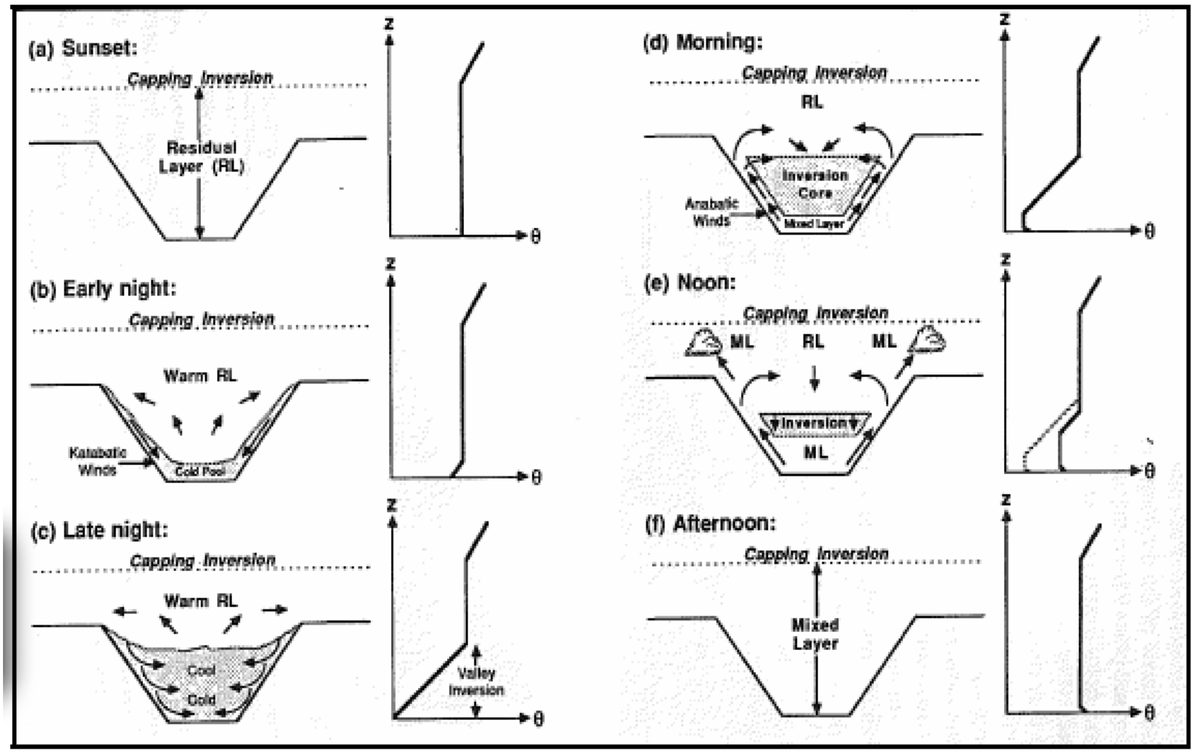

Figure 2.8: Idealized evolution of the cross-valley circulations during a diurnal cycle (Stull, 1997)

Regional mountain plain-winds develop when mountain (valley) winds in an area with highly contorted topography or juxtaposed with mountains and valleys deepen and overflow to the surrounding terrain across regions. Such wind on a regional scale during the day is called plain-mountain winds, and at night, it is called mountain-plain winds (DEAT, 2004). These winds significantly contribute to the long-distance transport of pollutants whereby pollutants originating far inland are transported to the coast only to be recirculated back to land by sea breezes (DEAT, 2004).

2.6. Odour and the local environment

The local atmospheric conditions play a crucial role in determining the dispersal of air pollutants (including odour) released into the atmosphere from any emission source (Walton, 2005). According to Tyson and Preston-Whyte (2000), the vertical and horizontal motion of air pollutants from emission sources is mostly influenced by the atmospheric stability inherent in a particular locality. This includes the variations in mixing depth as well as atmospheric circulation patterns and transport of air pollutants once released into the atmosphere. Atmospheric stability under normal atmospheric conditions (i.e. without massive lateral wind motion) is best determined by comparing the temperature of the ambient air molecule- Environmental Lapse Rate (ELR) with the temperature of a rising or sinking parcel of air molecule- Dry Adiabatic Lapse Rate (DALR) or the Saturated Adiabatic Lapse Rate (SALR) if this air has risen above condensation level or dew point temperature (Tyson & Preston-Whyte, 2000).

In this case, the ELR is the rate at which the temperature of ambient air changes with respect to height while the DALR is the rate of change of the temperature of a parcel of rising or sinking dry air within the air environment and the SALR is the rate of change of temperature of a rising or sinking parcel of saturated air (DEAT, 2004).

If the ELR is higher than the DALR, the air is therefore dense, and thus sinks with the pull-down force of gravity. This atmospheric phenomenon will lead to stable atmospheric conditions and slow wind movement (wind speed) (DEAT, 2004). Concerning air pollutant dispersion under stable atmospheric conditions, air pollutant dispersion is restrained and thus leads to poor air quality in the area. As Tyson and Preston-Whyte (2000) describe, stable atmospheric conditions are acuter in riverine valley areas during late afternoons or evenings to the early morning before incoming solar energy from the sun. This is due to the katabatic flow (downwards movement) of cold winds from the mountain displacing warm air which eventually sits on top of the cold air in the surface of the tropospheric layer of the atmosphere (as previously discussed under slope winds). This layer is sometimes referred to as the “mixing layer” as it is responsible for the transportation of air molecules during the daylight. Figure 2.9 illustrates how a parcel of dry air behaves with height. At a particular altitude (Z_1) the temperature of a parcel of dry air (T_p) is less than the temperature of ambient air (T_e). This means the parcel of air molecules is denser than the surrounding air molecules and will, therefore, sink due to the pull-down effect of gravity. This atmospheric phenomenon will lead to stable atmospheric conditions. Concerning the behaviour of air pollutants (odour) under stable atmospheric conditions, dispersion of pollutants is restrained and thus leads to poor air quality in the area.

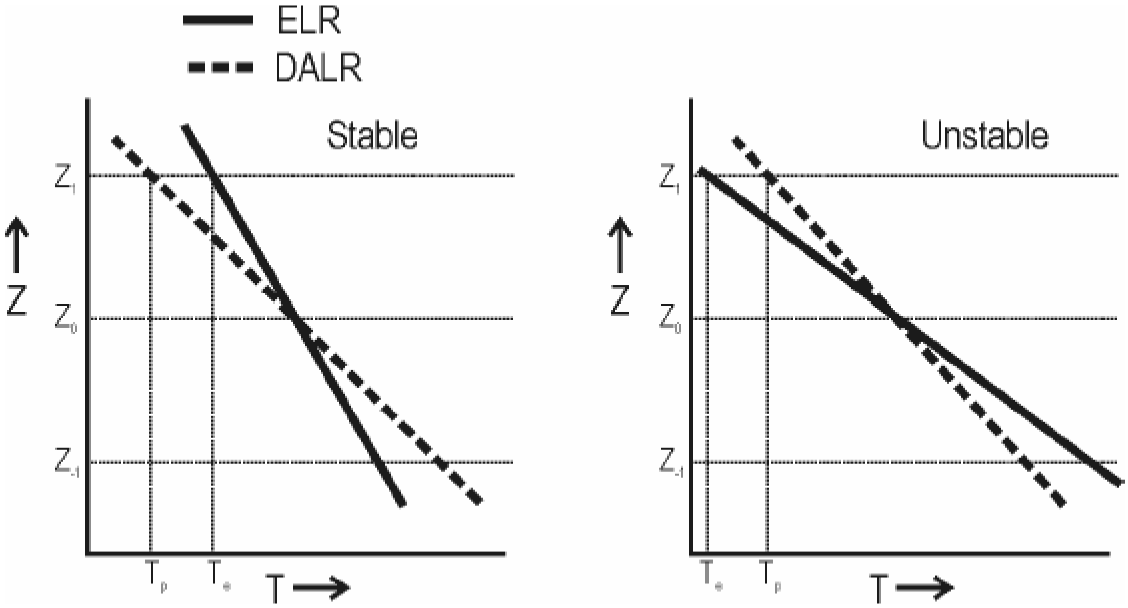

Figure 2.9: Stable and Unstable atmospheric conditions in tropospheric layer of the atmosphere (Source: Tyson & Preston-Whyte, 2000)

Conversely, if T_p is greater than T_e, the air will be less dense and thus rise (Figure 2.9 right). This phenomenon will lead to unstable conditions where movement of air molecules is unrestrained leading to dispersal of pollutants and odour during the emission episode (DEAT, 2004). These atmospheric conditions are summarised as follows:

ELR > DALR = dry unstable conditions

ELR = DALR = dry neutral conditions

ELR < DALR = dry stable conditions (DEAT, 2004).

Conversely, in a saturated environment if the ELR is less than the SALR it will lead to wet, unstable conditions, and when the ELR is greater than the SALR, this leads to stable wet conditions. When the ELR is equal to SALR, this leads to wet neutral conditions. That is

ELR>SALR= wet unstable

ELR=SALR= wet neutral

ELR< SALR= wet stable (DEAT, 2004).

As shown in Figure 2.10, at a particular altitude Z the temperature of a parcel of saturated air (Ts) is higher than the temperature of ambient air Te hence less dense and thus will rise. This phenomenon will lead to unstable conditions characterised by vertical and horizontal air movement. During this atmospheric condition, air rises and disperses removing pollutants from the source of emission leading to improved air quality in the area. In the same way, during unstable atmospheric conditions, air will rise and disperse, removing odour from emission source thus improving air quality in the area (DEAT, 2004).

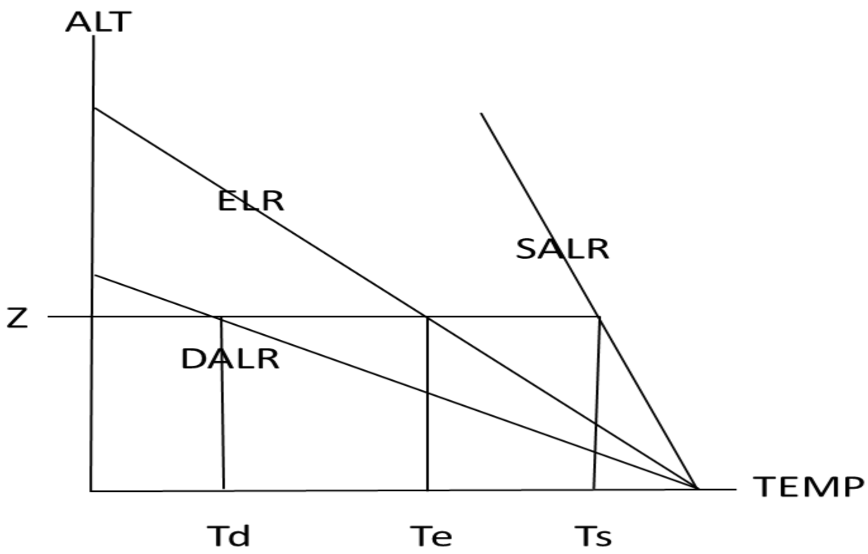

Figure 2.10: Atmospheric Stability in a Saturated Environment (source: Tyson & Preston-Whyte, 2000)

When the atmosphere is entirely unstable, the air is unstable whether it is dry or saturated and when the atmosphere is absolutely stable, the air is stable whether it is dry or saturated. However, when the ELR lies between the DALR and SALR, and this leads to conditional stability. That means that stability will depend on whether the air is saturated or not (DEAT, 2004).

Conditions for atmospheric stability include; type of inversion, stable layer, mixing height and daily temperature range (DEAT, 2004). Incoming solar radiation heats up the earth surface and the air above the earth surface causing thermal turbulence leading to unstable conditions, which causes air pollutants to disperse. The depth of mixing (which depends on the intensity of solar radiation) is crucial in determining the extent and magnitude of air pollution and odour in a particular episode (DEAT, 2004). Atmospheric circulation patterns are a combination of atmospheric forces, which govern wind speed and direction. These include the wind-force relations, which occur when there is differential solar heating of the Equatorial and the Polar Regions causing warm light air to rise while cold dense air sinks hence causing air movement from the cooler to the warmer region at the surface and an upward movement of air from the warmer to the cooler region (Tyson & Preston-Whyte, 2000). At mesoscale, the Coriolis force is another force which influences atmospheric circulation patterns and occurs as a result of the rotating action of the earth on its axis (Barry & Chorley, 2009). Other forces which influence atmospheric circulation include friction force, Hadley cell, momentum, resonance and Cellular flow (Barry & Chorley, 2009).

It is, thus, for this reason that atmospheric conditions influence pollutants or odour dispersion. Such atmospheric elements as wind speed, wind direction, temperature, relative humidity, solar radiation, cloud cover and precipitation play a critical role in determining pollutant dispersal (DEAT, 2004; Walton, 2005; Guo *et al.*, 2006;). In this context, strong wind velocity (speed and associated wind direction), as opposed to weak wind velocity, is invariably associated with the high dispersal of pollutants. However, on the other hand, the presence of the inversion layer (i.e. increase in atmospheric temperature with height) on top of the cold layer usually prevents upward movement of air hence trapping pollutants (odour) close to the surface of the earth. This usually happens during still weather conditions in winter and is most robust during early mornings and late evenings. As solar radiation peaks by noonday, inversion conditions become reversed because high temperatures during the day promote convective mixing which leads to dispersion of pollutants (Tyson & Preston-Whyte, 2000). In this case, the solar radiation is responsible for temperature increases as well as a catalyst for photochemical reactions. Cloud cover reduces the amount of incoming solar radiation during the day and prevents the escape of infra-red radiation at night causing a surface inversion, which is a condition that inhibits the dispersion of pollutants in the atmosphere. Precipitation is the process through which pollutants can be washed out of the atmosphere as rain (DEAT, 2004; Guo *et al.*, 2006).

Therefore, the atmosphere may promote or inhibit pollutant (odour) dispersion depending on the prevailing local meteorological conditions (Tyson & Preston-Whyte, 2002; DEAT, 2004). In other words, given the best odour treatment technologies without taking into consideration when the atmospheric dispersion is optimum, the odour management effort will be unsustainable. As mentioned earlier, these concepts are well established theoretically. A comprehensive knowledge of how these factors influence pollutant (odour) dispersion is necessary for the holistic management of odour in the Athlone WWTW and a sustainable effort at odour management and treatment.

2.6.1. Linking atmospheric stability and air pollutant dispersion

Pollution from a stack is dispersed in a variety of patterns (as displayed by characteristic plume) depending on the nature of the atmosphere (see Figure 2.11).

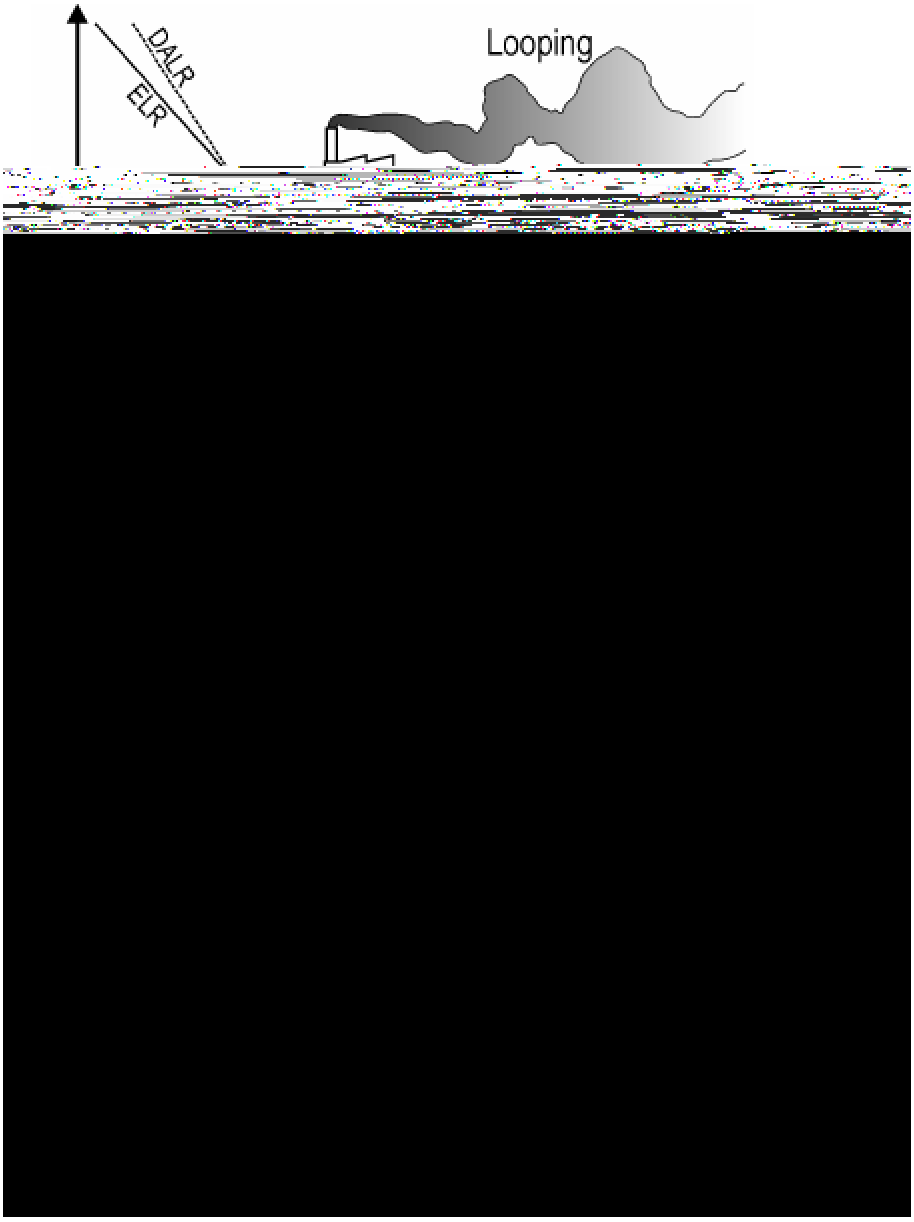

Figure 2.11: Different stability states and corresponding dispersion patterns (DEAT, 2004)

When unstable conditions prevail with turbulent eddies, pollution from a stack is dispersed in a looping plume, moving up and down away from the source. With this plume type, there is a high probability of it being intercepted at the surface leading to brief periods of high concentration near ground level (DEAT, 2004).

Under a neutral atmosphere, pollutants from a stack will be dispersed in a coning plume. Coning plumes are stable with small-scale turbulence. Pollutants travelling through such a plume tend to travel long distances before reaching ground levels at an insignificant amount. For example, effects of pollution originating far inland may be experienced at the coast through coning plumes (DEAT, 2004).

CHAPTER SIX

DISCUSSION OF RESULTS

6.1. Introduction

The emerging findings from chapter five in this study are that the Athlone WWTW fails to internalise the externalities of its wastewater treatment activities. This means that the plant management 1) fails to adequately take into consideration atmospheric dynamics which influence the dispersion and resultant perception of odour from its activities and 2) does not factor in the impact of odour resulting from their activities on the surrounding community. The chapter argues that management of odour is inherently myopic, focusing more on an engineered expert-oriented approach instead of a holistic, participatory and community-oriented management approach. This chapter aims at consolidating scientific atmospheric data and empirical social data in an attempt to understand how odour management at the Athlone WWTW influences the broader environment which includes the social or people element, as an approach to sustainable Environmental Management. In doing this, the chapter focuses firstly on the policies under which such a management approach is premised and how these policies act as an enabling mechanism to compromise sustainable Environmental Management. Secondly, the relationship between the plant odour management and the surrounding community will be brought to view to show the dynamics and missing links that debilitate this odour management strategy. Finally, it is shown that in as much as odour is an issue that plagues the physical environment and is influenced by physical parameters such as wind speed and direction, its perception is socially constructed. This was done by collating the scientific atmospheric data and social data from the community survey to draw linkages between the two datasets.

6.2. Policy consideration- the international versus the local perspective

Emerging findings from this study suggest that odour is not considered as a severe environmental problem. This stance is reflected in many aspects including the fact that odour management only started recently (2010) meanwhile the plant was commissioned in the first quarter of the twentieth century (1923). The reason behind this take can be associated with the legal framework guiding practices of gaseous emitting facilities to define air quality, the risk to the environment and public health internationally. This framework is the World Health Organisation (WHO) Air Quality Guidelines. This document does not provide guidelines for H_2S which is one of the leading gases resulting from wastewater treatment. As a result, one could interpret such an omission to mean that there is no direct relationship between exposure to this gas and health effects. Therefore, processes associated with its release (such as WWTW) are not given enough attention in policy considerations. This omission has been translated to the national legislation guiding the activities of wastewater processes where there are no clearly defined enforceable laws mandating such facilities to ensure minimum odour concentrations in the atmosphere. Reason being that, as stated in the NEMA Air Quality Act, the odour is a nuisance or in other words, not a major environmental issue or at least not severe enough to necessitate a policy regulation with specific minimum exposure measurements such as the other defined parameters. To make matters worse is the fact that there are no national minimum standards for H_2S making enforcing or even monitoring of Section 35 of the NEMAQA 39 of 2004 impossible. What then happens when community members insist that they experience high levels of odour concentration in their community (as was the finding from this study) yet the plant management argue that this is not possible since they have "*taken all reasonable steps to prevent the emission of any offensive odour*" as stipulated in Section 35 of the NEMAQA 39 of 2004? This is a deterrent to the execution of a sustainable Environmental Management approach which the Act is supposedly propagating and therefore a contradiction. How so? Odour is socially constructed by the individual perceiving it, and as Brookes *et al.* (2010) put it, the degree of tolerance is determined by the receptor's unique socio-economic situation, historical background and social expectation. In the case of the Athlone community, this backdrop was evident in their responses to odour management -typical responses such as ³«P\ JUDQGSDUHQWV *were born here and even me, since I was growing up the smell is always there. We do not like it but what can we do*?" A majority of the population is unemployed, so the option of relocating to another neighbourhood is a bit farfetched.

Despite all these, from the viewpoint of the community members, odour in their environment is indeed a major environmental problem and this to them (in part) is because of their spatial proximity to the source of emission. It is also because of the fear of the unknown - they do not know the details of the process that is responsible for the odour, and they, therefore, fear that odorous emissions may have dire consequences on their health especially for children and older people. This finding is consistent with findings from previous studies where the perceived risk was fortified by the uncertainty of negative health implications associated with odour emissions from the plant on children and the elderly (Wilson, 1996; Taylor *et al.*, 1997; Luginaah *et al.*, 2002). The views of these communities, their anxieties, fears and uncertainties are excluded entirely in the broader management of odour, and this starts from the policy itself which fails to incorporate these issues to facilitate management. This is unacceptable especially at a time like this when there are increasing levels of environmental awareness and therefore high expectations on the government (local and national) to ensure environmental justice. This inherently calls for concerted efforts on the part of the government and policymakers to set standards that define what exactly an acceptable odour concentration is and what degree of tolerance is permissible (Lebrero *et al.*, 2011).

6.3. The relationship between odour management by Athlone WWTW and the neighbouring community

Odour management is tantamount to the management of the environment. Odour is an issue that affects the way we interact with the environment so when managing odour, it is, in fact, managing the environment and therefore, all interested and affected persons need to be involved especially as it affects their livelihood. Speaking of livelihood, we refer to their wellbeing which is the way the people perceive their environment concerning the odour being emitted from the WWTW. Looking at the management approach adopted by the Athlone WWTW, it is evident that so much effort is focused on the capability of the biotrickling filter technology and the odour masking spray. However, no performance tests or monitoring in the form of a survey has ever been done where community members are involved in finding out the strength of performance of this technology from the perspective of the community. In fact, recent studies have shown that 85% of the commercially available masking sprays do not deliver the acclaimed odour masking potential even at maximum doses and under supplier specifications (Decottignies *et al.*, 2007; Bruchet *et al.*, 2008). Even the efficiency of the treatment technology on a day-to-day basis is yet to be proven since no performance tests have been done to prove that it is indeed removing 99.8% of H_2S. In this light, one can say without fear of contradiction that the confidence in the technocratic, expert-driven approach is misplaced. A representation of the stakeholders involved in odour management at the Athlone WWTW as shown in Figure 6.1 is one where the community takes the role of an invisible stakeholder.

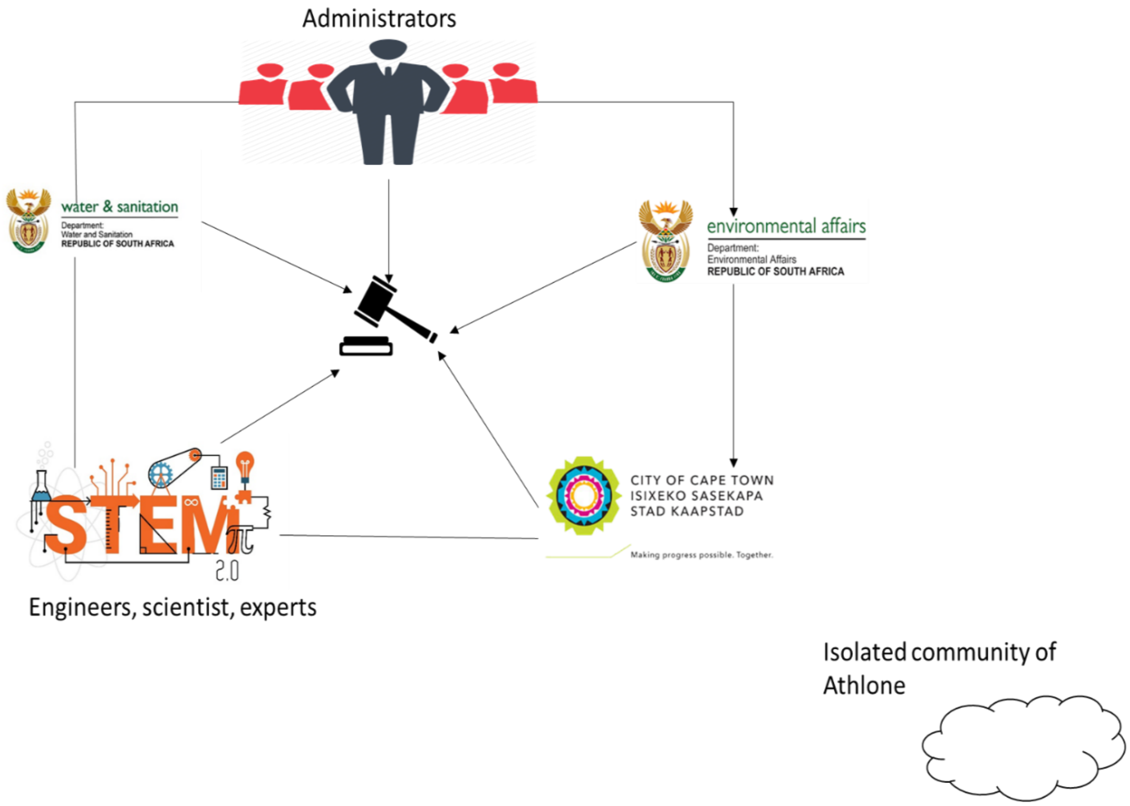

Figure 6.1: Relationship between odour management by Athlone WWTW represented by the City of Cape Town and its stakeholders

As shown in the diagram above, all the other stakeholders (including the law and regulatory bodies, the administrators, the City of Cape Town which owns the facility, the Department of Water and Sanitation which is the mother body of the City of Cape Town, the Provincial Department of Environmental Affairs and the engineers and scientific experts who built the odour treatment technology); work together and are each actively involved in the decision making process. However, there is yet another group of stakeholders who are there in principle as stakeholders but are not actively involved in any decision-making process. These are the community members of the Athlone community. This is ironic because the issue that brings these stakeholders together is odour management and it directly impacts the lives of these neighbouring communities- the very ones who have taken the back seat in this entire dynamic. Evidently, the only time there is an engagement of any sort between the plant management and the community, it is initiated by the community in the form of a complaint. Therefore, it is paramount that the community members actively take part in the process that manages odour in their environment. Unfortunately, this is not the case. Nonetheless, if there was indeed active participation on the part of the community whereby they are given the opportunity to be part of the decision-making process of an issue that affects their lives, then and only then would the management approach be described as inclusive or participatory.

In this case, community members would be able to see for themselves that something is being done rather than just being told that the plant is managing odour emissions. Indeed, the spray dispensers are visible to the community as they are planted along the entire perimeter of the plant, but an inclusive, participatory approach will make a difference in the way the community relates to odour management by the plant. Yes, it is true that the nature of wastewater treatment will always produce odour of some sort, but if the community were brought into the management process, their response to resultant odour would be more agreeable. It should be noted here that participation is not only to influence decision making regarding how odour should be managed by the WWTW, but it also has to do with changing the community's perception of the plant and the attempts that the management is making so they can appreciate the difference for themselves. This, therefore, raises the question why are communities not involved in the odour management process? Perhaps the answer to that question stems from the public deficit model paradigm that Wayne (2005) refers to that lay people are unable to arrive at a textured understanding of technical details and as such need only be given scientific facts by scientific experts. Hence the plant management does not see the need to involve the community in the odour management strategy.

However, emerging scholastic literature argues that it is paramount to take into consideration the layman's concerns, even if these concerns do not have strong ties with scientific facts, they still constitute social facts and it is, therefore, important to consider them in order to properly understand risks as per the layman (Renn, 2008; Brooks *et al.*, 2010). However, sadly, the majority of the people do not even complain. Those who want to do not even know where to complain, or whom to complain to. Others who have formally complained do not see any difference that their complaints make. So, it is clear that there is a sense of powerlessness on the part of the community as they are out of options concerning how to deal with the odour that plagues their environment. However, they believe that the management of the facility can find a better way of managing their odours to reduce odour levels in the community. In other words, they relinquish power to the plant management and trust in technological advancement. On the one hand, they are disgruntled that nobody ever involves them to find out their opinions about odour levels or how they are coping. On the other hand, they expressed faith in the plant management and science to find a solution especially a solution that integrates their input or participation. This is integrating participatory Environmental Management- an approach that is recommended by NEMA Act 107 of 1998 to encourage the use of all forms of knowledge including traditional and ordinary knowledge and heralded in the sustainable Environmental Management discourse. That is why in Irwin's (1995) opinion, knowledge is not simply constructed by expert analysis but also through the values of a collection of communities including scientific, local and administrative. Elsewhere, it has been shown that decision making processes that included public participation have produced better, fairer and balanced decisions (Wester-Herber, 2004). Therefore, involving these people in the odour management process will go a long way in changing their perceptions on the way odour is being managed while re-establishing a proper sense of place of their community which has been affected by odour from the WWTW and achieving a sustainable odour management effort.

6.4. Social construction of odour as a physical environmental problem

It is important to reiterate here that two types of data sets were used for the current study to understand how odour is managed at the Athlone WWTW and how this management impacts the surrounding environment. Firstly, as outlined in the methodology (chapter three) and as presented in chapter four, atmospheric data was used which provided measurements of wind speed and direction and was analysed using wind diagrams to show their influence on odour dispersion in that community. This data was supplemented by empirical social data to show how the community perceives odour. The aim of integrating both data sets was to try and demonstrate how these data are integrated or congruent with what is being perceived by the community or to show the various points of intersection between both data sets. Such integrations are apparent when results from the community survey show that, a portion of the community agree that odours are high at early in the mornings and at night, a time when low nocturnal temperatures act as a break in wind speed. This resultant low wind speed prevents atmospheric ventilation causing increased odour intensities. Respondents of the community survey also agreed that odour was influenced by particular local weather conditions such as still conditions (that is still weather with no lateral winds). According to these respondents, highest odour intensities were experienced during calm weather conditions. This fact is corroborated by scientific data which demonstrates that when no lateral winds prevail, there exists no effective mixing and hence no dilution of odours in the atmosphere. The result is odour build-up and high odour intensities; what was being reported by respondents who felt odour intensities were high when no winds prevailed. Such results are coherent with results from others studies on the influence of weather in the dispersion of pollutants in Cape Town (Jury *et al.*, 1990; Wicking-Baird *et al.*, 1997; Piketh *et al.*, 2004; Weber, 2004; Walton, 2005; Gwaze *et al.*, 2007; Jenner, 2013; Abiodun *et al.*, 2014).

Albeit these linkages, results from the community survey suggest some contradictions. For instance, the majority of respondents reported that they experienced more odour occurrences in the summer. While results from atmospheric data of wind speed and direction showed that wind speed is significantly reduced in the winter; a period when temperatures are very low meaning reduced chances of atmospheric ventilation and increased chances of odour occurrence. This supposed contradiction can be associated with the fact that winters in Cape Town are cold and rainy (wet). In this case, the apparent response to such weather conditions would be that residents remain indoors with closed doors and windows making it difficult for odours to creep into the house or for residents to even notice odours. Secondly, rainfall has been described as a cleansing mechanism through which air pollutants are purged out of the atmosphere (Jury *et al.*, 1990). Therefore, it is probable that the rain episodes wash out odorous gases from the atmosphere in the winter months hence respondents do not notice odours in the winter. Conversely, in the summer, temperatures are usually high, with high wind speeds allowing for adequate dispersion of odour and air pollutants. Under such conditions, it is difficult to experience odours, but survey results show that respondents reported that they experienced odour in the summer especially about midday when temperatures are high. This seemingly inconsistent finding can be associated with one or more of the following reasons. Firstly, because summers in Cape Town are usually dry, hot and windy, there tend to be more outdoor activities (gardening, ‘braaiing’, outdoor exercise, or just sitting out in the yard) hence chances of noticing odours is increased. Also, it is important to note that even though wind speed and atmospheric stability are the significant determinants of odour dispersion, they are not the only determinants of odour dispersion. Other factors such as emission rate also determine the degree of dispersion. Odour emission rates increase with an increase in temperature (a common phenomenon in the summer). With such high emission rates, it is possible for odours to travel long distances even under atmospheric turbulence (Guo *et al.*, 2006). Hence this would explain why respondents reported odour occurrence in the summer despite high temperatures and wind speed.

Another reason for such results could be associated with bias from being frustrated with odour nuisance, so respondents tend to exaggerate in their report in a bid to get attention and a solution to their plight. This is probably because results also revealed that there exists a high level of dissent among community members against odour in the atmosphere.

It is equally important to note that some respondents (though a smaller percentage) reported high odour occurrence in the winter. This is consistent with scientific data and with other studies conducted in Cape Town concerning the influence of meteorology on pollutant dispersion (Wicking-Baird *et al.*, 1997; Piketh *et al.*, 2004; Jenner, 2013; Abiodun *et al.*, 2014).

Notwithstanding, this does not dispel the fact that the prevailing atmospheric conditions influence odour dispersion and its resultant perception. Compelling evidence of this has repeatedly been shown in academia. The location of the Athlone WWTW and its surrounding community in a valley, trapped by the Cape Peninsula Mountain range and the Bottelary Hills further enhances the stability phenomenon which prevents the vertical transport and dispersion of odour. Surface inversions which are responsible for stability conditions are very common in the winter period in Cape Town. Therefore, even though odour is socially constructed and resultant response towards it is underpinned by the individual socio-economic situation and historical background, it is also a physical environmental problem that needs sufficient attention and consideration in equal weighting like any other “pressing” issue that plagues humanity.

6.5. Conclusion

This chapter dissected the main findings of the current study and the discussion was mainly centred on two core elements that were missing in the management approach adopted by Athlone WWTW. These were the failure to adequately integrate the influence of the atmosphere on odour dispersion and the failure to integrate the impact of odour on surrounding communities. The chapter went on to show the different elements that have made such oversight possible such as weak policy framework guiding odour management and the relationship (or lack thereof) that the plant management has with its surrounding community who are the receptors of its resultant odour. Finally, the chapter integrated empirical social data from a community survey and atmospheric scientific data to show synergies and dichotomies in both data sets as a unique approach towards a more participatory, community centred management that understands risk from the layman's perspective.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

The primary focus of this study was to investigate the odour management approach of the Athlone WWTW, to understand its scope and how this approach impacts the broader environment which is the people element. The following objectives steered the study towards achieving this aim;

- Investigating what the odour management strategy at the Athlone WWTW currently entails;
- Exploring the local atmospheric conditions to find out whether or not they influence odour dispersion in the area;
- Investigating if at all the odour management strategies take into account the influence of local weather on odour dispersion; and
- Investigating the perceptions of the community concerning odour management at the Athlone WWTW.

The following section presents a summary of the previous chapters to show how each of them systematically built on the overall attainment of the aim of the study. Then a discussion of the critical findings of the study and concluding remarks ensues, while the chapter concludes with limitations encountered during the study and recommendations for future research.

7.2. Key findings

Based on data emerging from a community survey and atmospheric data, the significant finding of this research indicates that the local weather of Athlone has a bearing on the dispersion of odour, especially in the winter months. The dispersion thereof is enhanced during summer through high temperatures and high wind velocities creating turbulence in the atmospheric boundary layer. Turbulent winds are ushered in when anticyclones ridge in from the South Atlantic Ocean, bringing with them high winds blowing in the southeasterly direction. These high and turbulent winds efficiently disperse odour in the atmosphere of Cape Town during summer. In contrast, the dispersion is impeded during winter not only because of normal low wind speed but also due to the combined effects of atmospheric stability brought on by weak high-pressure systems, surface inversion and the shielding effects of mountainous topography. Average wind speed is lower during the night and reaches its peak between midday and 3 pm. Time series showed that most years have two distinctive peaks in wind speed, indicative of summer months (around January and October) when wind speed reaches its maximum. However, some years experienced more than two wind speed peaks indicating the passage of cold fronts which bring about increased wind speed in the winter and hence reduced odour concentrations. Mechanisms responsible for these winds originate at the level of regional atmosphere.

Community survey data revealed that there is a general feeling of discontent among Athlone community members associated with high odour levels in their community. This feeling of annoyance has been fuelled by the presence of odour in that community which, in the opinion of the community members, the odour has been in their community all their lives. While community members unanimously agreed that odour is a problem in their community, there is a debate with regard to the odour source. Athlone WWTW was indicated as the most likely source of odour in that community. Respondents based their choice of selection on the direction the odour seems to always come from, indicating the location of the plant. This also affirms the influence of wind on the transportation or dispersion of odour. An additional justification of the source of odour in the community is the duration of stay and familiarity with ambient odours. A majority of respondents were above thirty (30) years old and therefore have a good idea of the ambient nature of their surroundings.

A majority of the members of the Athlone community believe that odour is worst during summer and not during winter. Such misconception was attributed to the fact that most people stay indoors during winter with locked doors and windows, making it almost impossible to perceive odours from outdoors. Unlike winter, summer is a time in Cape Town when most outdoor activities take place due to the hot, dry and windy conditions. This being the case, people would be more likely inclined to believe that odours are worst in summer because of the amount of time spent outdoors near the odour source. Further, although atmospheric stability and wind speed are significant odour determinants, they are not the only determinants. Other factors such as odour emission rates have been shown to increase with an increase in temperature and this could account for the reason why some people felt that odours are worst in the summer. Further, the high level of discontent expressed by community members towards odour levels in the atmosphere of their community can indicate that perhaps, there was some element of bias in their report to call attention to their plight and underscore the intensity of their displeasure. Hence, it is logical to conclude that their response to the frequency of odour occurrence (even during times when it is expected to be less) was somewhat exaggerated.

Though in the minority, a portion of the community agreed that odour intensity is worst in winter when temperatures and wind speed is low. This is consistent with works done by others proving that indeed, winter weather-characteristic of low wind speed and temperature inversion and atmospheric stability prevent the dispersion of odour.

The study also found that odour management at the Athlone WWTW is a responsive approach instead of a proactive approach. In other words, plant staff only goes out to find if systems are functioning correctly only after a complaint is logged. Indeed, the only time the plant management has some form of interaction with the community is when a community member registers an odour complaint. There have been times when the plant management disregarded or wholly ignored complaints, labelling the management approach even less than reactive. Therefore, the management approach adopted by the plant is neither integrative nor inclusive of the public.

Considering that the facility was commissioned for wastewater treatment since 1923 notwithstanding, odour management resulting from the process only started recently (2010) after the biotrickling filter was installed. Ever since its installation, no odour testing, as a monitoring procedure, has been done. Atmospheric dynamics do not influence the odour management strategy in any way. That means the plant does not internalise the externalities of its activities. This can be interpreted in some ways; for instance, it could mean that the management has little or no regard of the external environment; or that there is a lack of understanding and appreciation of sustainable Environmental Management. Such conclusions are worrisome in the wake of increased levels of environmental awareness and expectations.

Results also revealed that the Athlone WWTW is operating beyond its designed capacity making it a high-risk facility to the receiving environment. This was justified by budgetary constraints. However, on a critical note, this further underscores the low regard for environmental considerations. Things get done by prioritising essential needs and allocating budgets appropriately. That being the case, if the expansion of the facility has not been given due consideration especially after it has been flagged as a high-risk facility, then it, unfortunately, affirms that the management has low regard for environmental issues.

Despite high levels of displeasure towards odour levels in the community, community members strongly believe public participation and integration in the odour management process would improve odour levels within that community. This is a confirmation of the principles of sustainable Environmental Management whereby the opinions of the common man need to have its place in development, especially development that impacts his wellbeing. Decision making processes that have included the common man have been shown to produce better and fairer decisions. In like manner, if community members of Athlone are integrated into the odour management process, it will result in a more sustainable management intervention.

7.3. Concluding remarks

This study was premised on two main hypotheses; the first hypothesis was that the current odour management strategy adopted by the Athlone WWTW is not holistic- that it fails to take due consideration of the prevailing atmospheric conditions and its influence on odour dispersion. It further hypothesised that community members of the Athlone community are not happy about odour levels in their environment. In satisfying the objectives to answer the research questions, the results of the thesis are an affirmation of the hypotheses. The failure of consideration of meteorological factors in the odour management approach speaks of a lack of understanding of the relationship between atmospheric conditions and odour dispersion and a general lack of appreciation of the resultant impact of odour on the broader environment (the people element). This approach, therefore, defies the principles of sustainable Environmental Management- a management approach that is all inclusive of social, economic and ecological elements of the environment. Indeed, the Athlone WWTW is making a genuine effort to reduce resultant odour to its surrounding environment. Unfortunately, an intervention that does not integrate both science (technology and atmospheric dynamics) and society (opinion of the common man) will yield less than sustainable results in the struggle to maintain minimum odour levels in neighbouring communities, especially in winter.

The study has contributed to the understanding of odour emanating from facilities such as WWTW as not only an aesthetic nuisance but rather an environmental problem that needs to be given its due place of consideration. It is the first of its kind to aggregate scientific and social data as an approach towards understanding odour management specifically at WWTW in South Africa. The salient nature of laws and regulations guiding odour management, have been the dominant deterrent to proper odour management at such facilities.

7.4. Limitations and recommendation for future research

During data collection, the researcher realised that there might be some degree of exaggeration in the responses of some respondents, for instance, reports that odours were a daily continual (24/7) experience irrespective of the season of the day. Such responses were associated with heightened levels of frustration of odour and a disregard for their complaints. So, in a bid to bring attention to their plight, some respondents may have exaggerated in their responses.

The researcher proposes that to establish a better link between meteorological conditions and odour dispersion in future research, detailed weather conditions for days with odour should be sampled as a step towards better odour management. Parameters such as temperature, wind speed and direction, humidity and atmospheric stability are the meteorological parameters of interest concerning odour dispersion.

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APPENDIX A

QUESTIONNAIRE FOR ATHLONE COMMUNITY

An assessment of the management of odour at the Athlone waste water treatment works, Cape Town

Date of Administration: ______________________________

Time Administered: ______________________________

NOTE

- ✓ This interview is purely for academic purposes and hence your name is not required to ensure information is confidential and anonymous
- ✓ Your participation in this study is entirely your choice and you can withdraw at any time
- ✓ There are no incentives whatsoever given for participation in this research
- ✓ The information provided may assist the Athlone Waste Water Treatment Works to better understand the extent and impact of odour impact in your community.
- ✓ Researcher details- Name: Colette Nchong Takwi; Masters student in the Department of Environmental & Occupational Studies @ CPUT. 0714004616; email colettent@gmail.com/212042173@mycput.ac.za
- ✓ Supervisor details- Name: Zungu Vincent, Senior Lecturer. Department of Environmental & Occupational Studies @ CPUT. 0214609064. Email ZunguV@cput.ac.za

1. Gender (tick applicable answer)

☐ Male

☐

Female

2. Race (tick applicable answer)

☐ African

☐ Indian

☐ White

☐ Coloured

3. Age

……………………………………………………………………………………………………

………………………………………………

4. Employment status

☐ Own business

☐ Employed

☐ Unemployed

5. a. Do you experience odour from external sources?

☐ Yes

☐ No

6. b. If yes is the odour experience regular?

☐ Yes

☐ No

7. c. If yes how regular is this experience?

☐ Once a day

☐ Once a week

☐ Once a month

☐ More Often

8. d. Around which areas is the odour most offensive?

☐ Inside the house

☐ Out in the yard

☐ Next to the highway (N1) or on the streets

☐ All of the above

9. e. How long have you been experiencing this odour event?

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10. f. How long does the odour event usually last?

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………………………..

11. g. Is there a specific time during the day when the odour is experienced?

☐ Early morning

☐ About mid-day

☐ Early evening

☐ At night

11. h. Is the odour associated with particular weather conditions?

☐

Yes

☐ No

h_1. If yes which weather condition best describes when odour is experienced?

☐ Still

☐ Windy

☐ Fog

☐ Rainy

☐ Any/All

H_2. What season of the year is it worst?

☐ Winter

☐ Summer

☐ Autumn

☐ Spring

11. i. Describe the odour

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11. j. How do you feel about this odour?

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11. k. What do you think is responsible for the odour?

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11. l. Is it always the same type of odour all the time?

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11. m. Would you describe it as

- ☐ Rotten eggs
- ☐ Rotten fish

☐ Rotten meat

☐ Suffocating

☐ Urine/Faeces

11. n. Does it always seem to come from the same source?

☐ Yes

☐ No

11. o. Has the odour intensity changed over the years?

☐ Yes

☐ No

11. oi. If yes how has it changed and in what time scale?

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11. p. Have you complained?

☐ Yes

☐ No

11. q. If no why not?

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11. r. If yes, who did you complain to?

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11. s. Did they respond adequately to your complain?

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11. t. How did they respond to your complain?

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11. u. What would you have preferred them to do?

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11. v. Do you have any other concerns of odour?

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11. w. Do you have any recommendations?

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…………………………

APPENDIX B

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

Making progress possible. Together.

Athlone WWTW
Off Jan Smuts Rd
Athlone 7764
Tel: **+27 21 444 9198**
Fax: **+27 21 638 5860**

Athlone WWTW
Off Jan Smuts Rd
Athlone 7764
Umnxeba: **+27 21 444 9198**
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Athlone WWTW
Off Jan Smuts Rd
Athlone 7764
Tel: **+27 21 444 9198**
Faks: **+27 21 638 5860**

E-mail: nonhlanhla.cele@capetown.gov.za

To Whom It May Concern

Please be advised that permission to conduct a study has been granted to the student details appearing below:

Name of student: Colette Nchong Takwi
Level: Masters
Institution: Cape Peninsula University of Technology Cape Town
Name of Supervisor: Zungu Vincent.

Summary of area of study:

The research will be carried out by reviewing the current odour management plan the facility uses to see if it is a holistic plan or not and also to find out whether it takes into consideration meteorology conditions of the local environment. It will also entail the review of atmospheric data and how it influences dispersion of odour. Finally, it will also constitute a community survey of the neighbouring community to find out their personal experience of odour nuisance.

Both parties City of Cape Town Athlone WWTW & her agree (see student commitment attached) that the contents of the study are confidential & therefore are limited for usage for academic purpose only.

Yours Faithfully,
Fred Cupido

16/02/2016.

To whom it may concern

Dear Sir/madam,

I the undersigned Colette Nchong Takwi, a master's student at Cape Peninsula University of Technology (student number 212042173) declares that:

- The finding of my research will be used strictly for academic purposes
- That materials used will not harm or put the City of Cape Town in a bad light.

Regards,

Colette N. TAKWI.

APPENDIX C

Consent statement: Community Survey

With reference to the above title, you are kindly requested to participate in the study in a form of answering interview questions designed to address aim of the research study. The research study's aim is to assess the odour management system adopted and used by the Athlone Waste Water Treatment Works (WWTW). It also intends to find out how do you feel about the management of odour emitted from the waste water treatment plant (WWTW).

Should you be willing to participate in this research, you could please indicate by signing in the space provided below. Please note that your participation in the interview is not compulsory which mean that you can withdraw your participation at any time you so choose to. In addition, any forms of material gains (such gifts) will be not be given as an incentive to participate in the research.

Information for this research is purely for academic purposes hence your name and identification is NOT required. That means whatever you say to me, no one will link your utterances with your identity.
Information collected will be stored in a password protected computer. Only the research supervisor in addition to the researcher will have access to this information. The findings of the researching will be shared with you.

Accept: Yes/ No

Signature……………………..Date…../…../2016

APPENDIX D

Cape Peninsula
University of Technology

HEALTH AND WELLNESS SCIENCES RESEARCH ETHICS COMMITTEE (HW-REC)
Registration Number NHREC: REC- 230408-014

P.O. Box 1906 • Bellville 7535 South Africa
Symphony Road Bellville 7535
Tel: +27 21 959 6917
Email: sethn@cput.ac.za

4 October 2016
REC Approval Reference No:
CPUT/HW-REC 2016/H37

Faculty of Applied Science

Dear Ms Colette Nchong Takwi

Re: APPLICATION TO THE HW-REC FOR ETHICS CLEARANCE

Approval was granted by the Health and Wellness Sciences-REC on 15 September 2016 to Ms Takwi for ethical clearance. This approval is for research activities related to student research in the Department of Applied Science at this Institution.

TITLE: An assessment of the management of odour at the Athlone waste water treatement works, Cape Town

Supervisor: Mr V Zungu
Co-Supervisor: Dr M Ntokozo

Comment:

Approval will not extend beyond 5 October 2017. An extension should be applied for 6 weeks before this expiry date should data collection and use/analysis of data, information and/or samples for this study continue beyond this date.

The investigator(s) should understand the ethical conditions under which they are authorized to carry out this study and they should be compliant to these conditions. It is required that the investigator(s) complete an **annual progress report** that should be submitted to the HWS-REC in December of that particular year, for the HWS-REC to be kept informed of the progress and of any problems you may have encountered.

Kind Regards

Mr. Navindhra Naidoo
Chairperson – Research Ethics Committee
Faculty of Health and Wellness Sciences

APPENDIX E

South African Weather Service

ISO 9001 Certified Organisation

DISCLOSURE STATEMENT

The provision of the data is subject to the User providing the South African Weather Service (SAWS) with a detailed and complete disclosure, in writing and in line with the requirements of clauses 1.1 to 2.4 (below), of the purpose for which the specified data is to be used. The statement is to be attached to this document as Schedule 1.

1 **Should the User intend using the specified data for commercial gain then the disclosure should include the following**:

1.1 the commercial nature of the project/funded research project in connection with which the User intends to use the specified data;

1.2 the names and fields of expertise of any participants in the project/funded research project for which the specified data is intended; and

1.3 the projected commercial gains to the User as a result of the intended use of the specified data for the project/funded research project.

2 **Should the User intend using the specified data for the purposes of conducting research, then the disclosure should include the following**:

2.1 the title of the research paper or project for which the specified data is to be used;

2.2 the details of the institution and supervisory body or person(s) under the auspices of which the research is to be undertaken;

2.3 an undertaking to supply SAWS with a copy of the final results of the research in printed and/or electronic format; and

2.4 the assurance that no commercial gain will be received from the outcome from the research.

If the specified data is used in research with disclosure being provided in accordance with paragraph 2 and the User is given the opportunity to receive financial benefit from the research following the publication of the results, then additional disclosure in terms of paragraph 1 is required.

The condition of this disclosure statement is applicable to the purpose and data requirements of the transaction recorded in Schedule 1 on page 2. This statement is effective from December 2015.

Bolepi House, 442 Rigel Avenue South, Erasmusrand, 0181 Private Bag X097, Pretoria, 0001 Tel: + 27 (0) 12 367 6000

www.weathersa.co.za Weatherlines 083 123 0500 USSD: *120*7297#

COR-LETT.EXT.009.1

South African Weather Service
ISO 9001 Certified Organisation

Disclosure Statement

SCHEDULE 1

Please note: The South African Weather Service will only act upon customer requirements noted on this disclosure statement and not from any other correspondence.

FULL PERSONAL DETAILS OF USER

Full Names	Colette Nchong Takwi
University/school/organisation	Cape Peninsula University of Technology
Student Number (if applicable)	212042173
Email address	colettent@gmail.com
Cellphone	0714004616
Supervisor	Zungu, V
Project/Thesis Title	Assessing the management of odour at the Athlone Waste Water Treatment Works
Current registered degree (e.g. BSc)	MTech
Expected finalization date (MMYYYY)	December 2016

The South African Weather Service reserves the right to request, at any time, from the student proof of registration for the Degree at the University.

THE PURPOSE *(Please indicate a detailed description of the purpose for which the data will be used)*

The data will be used to establish the climate of the study area. This will help illustrate why weather and climate need to be considered when managing odour since odour dispersion is influenced by meteorological conditions. Having established the climate of the study area, it will be clear why odour is prevalent at particular times of the day and particular seasons of the year.

DATA REQUIRED *(Please include the weather elements (e.g. rain, temperature), place/s and time period)*

Surface and upper air data for (2005-2016);

Atmospheric stability, variations in mixing depth, atmospheric circulation patterns, wind speed, wind direction, temperature, relative humidity, solar radiation, cloud cover and precipitation

I hereby accept that:

- SAWS will be acknowledged in the resulting thesis/project or when published, for the data it provided.
- SAWS will be provided with a copy of the final results in printed or electronic format.
- The data received shall not be provided to any third party.

Signature of the User: [signature] Date: 23/08/2016

Disclosure Statement

(Please sign the document and do not type your name in as this is a legal document and requires a signature.)