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Assessing the PM10 footprint of an iron and steel plant on ambient air quality : modelling PM10 emissions from the ArcelorMittal Vanderbijlpark Works iron and steel plant.

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ASSESSING THE PM_{10} FOOTPRINT OF AN IRON AND STEEL PLANT ON AMBIENT AIR QUALITY:

MODELLING PM_{10} EMISSIONS FROM THE ARCELORMITTAL VANDERBIJLPARK WORKS IRON AND STEEL PLANT.

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A Research Report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Master of Science

Johannesburg, Dec 2012

Declaration

I declare that this research report is my own unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Science in the School of Geography, Archaeology and Environmental Studies at the University of Witwatersrand, Johannesburg. It has not been submitted previously for any degree or examination in any other university.

(Sham Jagathlal)

----------Day of----------2012

Dedicated to my two adorable children Nikhil and Neha and loving wife Omitha and in memory of my late Dad, Jagathlal Jack Jalim

ABSTRACT

Iron and steel plants in general are significant sources of PM_{10} pollution. Many studies have concluded that PM_{10} is harmful to human health and well being. ArcelorMittal Vanderbijlpark Works falls within the jurisdiction of the Vaal Triangle Airshed Priority Area (VTAPA) and has been given PM_{10} reduction targets in the Air Quality Management Plan. The aim of this study is to use dispersion modelling to determine the impact of the Vanderbijlpark Works steel plant on ambient PM_{10} and to assess the effectiveness of the reduction strategies with respect to PM_{10}

The AERMOD dispersion model was chosen for the exercise because of its reliability when modelling near field dispersions on relatively flat terrain. Meteorological data was obtained from on-site stations. Emissions data was obtained from an already existing emissions inventory on site. The study modelled the PM_{10} baseline for 2010 and then modelled the predicted concentrations after implementation of the strategies as outlined in the VTAPA. The modeling scenarios were compared to the measured PM_{10} data from the fence line monitors.

The following findings were made: Point sources were not significant contributors to PM_{10} emission. Modeling of area sources and other fugitive dust sources were found to be high and when compared to measured concentrations were found to be over predicted. It is concluded that the fugitive sources have been found to be the major source of PM_{10} emissions and that reduction of fugitives should feature prominently in emission reduction plans going forward. In addition, the fugitive emissions inventory needs to be refined to enhance the accuracy of the predictions.

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NOMENCLATURE

ADMS	**Atmospheric Dispersion Modelling System**
AERMOD	**AERMIC Regulatory Model Improvement Committee Model**
AMSA	**ArcelorMittal South Africa**
AQA	**National Environmental Management: Air Quality Act (No 39 of 2004)**
AQMP	**Air Quality Management Plan**
APPA	**Air Pollution Prevention Act**
BOF	**Basic Oxygen Furnace**
CALPUFF	**Californian Puff Model**
CO	**Carbon Monoxide**
DEAT	**Department of Environmental Affairs and Tourism**
DRI	**Direct Reduced Iron**
EAF	**Electric Arc Furnace**
H_2S	**Hydrogen Sulphide**
ISCST3	**Industrial Source Complex short term 3 model**
MM5	**Mesoscale Model 5**
NO/NO_2	**Nitrogen oxide/Nitrogen dioxide**
0_3	**Ozone**
PCDD/F	**Polychlorinated dibenzodioxins/furans**
PM_{10}	**Particulate matter smaller than**
$PM_{2.5}$	**Particulate matter smaller than 2.5 microns**
SO_2	**Sulphur Dioxide**
TSP	**Total suspended particles**
UF	**Ultra Fine Particles**
USEPA	**United States Environmental Protection Agency.**
VOC	**Volatile Organic Carbon**
VTAPA	**Vaal Triangle Airshed Priority Area**

CHAPTER ONE: OVERVIEW

Chapter one provides a brief overview of the iron and steel industry and its impact on air quality. It also looks at the health impacts of PM_{10} and briefly examines developments with regard to air quality legislation. Both the dispersion potential of pollutants and dispersion modelling in general is discussed. An outline of the research goals is also presented.

1.1 Introduction

The iron and steel industry has a long history. The modern iron and steel industry can truly claim to be the leading protagonist in ushering in the Industrial Revolution in the mid 1800's. For better or worse, this industry contributed largely to the shaping of the modern era, producing the steel that made the modern railroads and the huge skyscrapers in our cities possible. It also enabled mass production of motor vehicles which has had a profound effect on not only the morphology of modern settlements but also on the lifestyles of humans on Earth. The other modern conveniences which are much taken for granted also owe their very existence to the modern iron and steel industry.

Today, these heavy industries normally form the backbone of the economy of a region. They create a demand and hence stimulate development not only for the raw materials like coal and iron ore that it consumes, but it also stimulates infrastructure development like rail, road, and power, not forgetting the numerous other downstream and off shoot industries that it gives rise to. The fact that these industries are significant employers within a region also enhances their economic importance.

1.2 The iron and steel plant

In as much as there may be positive aspects of the iron and steel industry, it does also have its downside. It is energy intensive, resource consuming and of course a significant polluter as well. The industry is noted for emitting various pollutants, like SO_2, NO_2, and VOCs, but its main source of pollution is its particulate emissions. (The World Bank 1998; European Commission 2001)

Particulates are generated at nearly all phases but most heavily during the coke-making and blast furnace stages. (http://ecm.ncms.org/ERI/new/index.html, USEPA, 1995, Integrated Pollution Prevention and Control, 2001, Prati, P. *et al*., 2000, Yong-Hua Xue. *et al*., 2010). Particulates are emitted through stacks and also fugitively, via roof emissions, from exposed stockpiles etc. In a study in Panzhihua, China that looked at source characterization and apportionment of particulate matter smaller than 10 microns (PM_{10}), the PM_{10} concentration related to iron and steel manufacturing was 19.5% and had little periodic variation (Yong-hua Xue. *et al.*, 2010). A very brief description of the iron and steel industrial process follows.

In any integrated steel works, the basic process followed is, firstly, the production of iron, which is then converted to steel, which in turn is processed into steel products like flat, coiled or tubular steel.

Before liquid iron can be made in the blast furnace, coke is needed together with sinter, fluxes, like limestone, and manganese and iron ore as input materials. Coke and sinter needs to be manufactured, usually on site and in close proximity to the blast furnace. Coke is produced by baking coking coal in an oxygen free environment in what are called coke ovens. This process generates significant quantities of PM_{10}. For every ton of coke produced, approximately 0.7 to 7.4kg of PM_{10} is generated. Coal handling operations could account for as much as 10% of the particulate load. Coal charging, coal pushing and quenching are also significant sources of dust emissions. The sintering process is also a significant contributor to the PM_{10} load. These operations can emit dust quantities of up to 20kg per metric ton of steel. Sinter is required in the blast furnace for the production of iron. Sinter is produced on what is called a sinter strand where fine sized

iron ore, fluxes, like limestone and dolomite and other metallurgical by-products are heated and fused together. In the blast furnace where the liquid iron is produced, particulate emissions can range from 10kg/t of steel produced to 40kg/t. (World Bank 1998).

The particulates are released both fugitively and through stacks. In an air quality investigation conducted at Vanderbijlpark Works, it was found that the Sinter Plant is one of the main contributing sources of particulates (PM_{10} and $PM_{2.5}$) contributing 37% to all PM_{10} emissions (including all point sources and non-point releases) and 59% to all point source releases (Zantow, 2010).

Steel making can be done via two processes. Firstly, via the Basic Oxygen furnace (BOF) where the liquid iron is converted into steel through the use of pure oxygen to remove carbon, silicon and other elements and the addition of fluxes and alloying agents, including the use of Directly Reduced Iron (DRI) which are produced in DRI kilns. The DRI unit is also a source of PM10 emissions. Secondly, steel could also be made by using the electric arc furnace (EAF) that uses steel scrap as input material. Both the BOF and EAF are sources of PM_{10} emissions.

Lastly, the steel slabs are semi-processed further by being fed through rolling mills that produces coiled or rolled steel or flat steel as per customer requirements. These processes do produce PM_{10} emissions but are not significant when compared to the other sources.

1.3 PM 10 emissions from an iron and steel plant

In a study carried out for the Vaal Triangle area, a total of 34 907 tons of PM 10 or 77.4% of PM_{10} were identified as emanating from industry, commerce and mining (Scorgie, *et al*., 2003).

Mestl and Fang (2003) used the AMS/EPA Regulatory Model Improvement Committee Model known as AERMOD to estimate the air quality of the city of Taiyuan in China. This model is basically a Gaussian plume air dispersion model. They found that the highest concentrations of PM_{10} were found around the iron and steel industry. They also found that large emissions reductions from tall stacks only gave limited air quality

improvement as compared to smaller reductions close to the ground. Onofrio *et al*., (2011), in their attempt to assess the role of a steel plant in determining the concentrations of polychlorinated dibenzodioxins/furans (PCDD/F's) to the local air found AERMOD useful. They found that the model was able to locate maximum concentrations within the study area once meteorological and terrain data were known and available.

1.4 Air Quality Legislation in South Africa

Since 1994, there have been widespread legislative changes consequent to the creation of a democratic and more transparent state. The prime driver of these legislative changes was the inclusion of the Bill of Rights which forms the core of the South African constitution. The responsibility of ensuring that these rights are respected and fulfilled rests with the government of the day.

1.4.1 Constitution – Section 24

Within the South African context itself, various obligations are placed on the state to provide a cleaner environment to its people. The *Constitution* (Act No.108 of 1996) provides the overarching framework, which directs Governments' efforts in terms of environmental protection. The *Bill of Rights* enshrined within the constitution provides that:

> "*Everyone has the right*
>
> *(a) to an environment that is not harmful to their health or well-being; and*
> *(b) to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that –*
> *(1) prevent pollution and ecological degradation,*
> *(2) promote conservation; and*
> *(3) Secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development.*

With respect to the above, South Africa underwent a paradigm shift with regard to Air Pollution legislation. The then existing Atmospheric Pollution Prevention Act (Act 45 of 1965), more commonly known as APPA was outdated and even unconstitutional (Republic of SA, 2003, DEAT, 2007) Amongst other things, this act only had limited powers and means to protect the environmental right; the act did not take sustainable development principles into account which basically required the integration of social, economic and environmental factors in development planning. APPA's "best practicable means" approach did not prevent pollution effectively, the Act itself was difficult to enforce and penalties for non compliance were impractical or vey low. It did not encourage the move towards cleaner production or energy efficiency. APPA had no ambient limits for pollutants. APPA was basically non-participatory, non-transparent and open to unfair administrative practices. APPA allowed for the development of air pollution "hotspots" (DEAT, 2006; Thambiran and Diab, 2010).

In view of this, a new approach to air quality management was deemed necessary (Republic of SA, 2003) This new approach would see a shift from a source based, end of pipe solution type of approach to protecting the receiving environment or receptors with the identification of priority pollutants, the establishing of limit values for the ambient air based on human health standards and the monitoring and management of these limits (DEAT, 2006; 2007; Strydom and King, 2009).

This new approach is embodied in the National Environmental Management: Air Quality Act (Act No.39 of 2004), (AQA) which has replaced the now repealed APPA. In terms of this new Act, the Minister or MEC is empowered to declare any substance contributing to air pollution as a priority air pollutant. So far, Particulate Matter, Sulphur Dioxide, Nitrogen Oxides, Ozone, Lead, Benzene and Carbon Monoxide have been identified as priority pollutants. The national ambient air quality standards were promulgated in December 2009. Air quality standards for 10 minutes, 1 hour, 24 hours and 1 year averaging periods, together with compliance dates were stipulated for sulphur dioxide, nitrogen dioxide, PM_{10}, Ozone, Benzene, lead and carbon monoxide (DEA, 2009). The national ambient air quality standard for PM_{10} for the 24 hour averaging period is

120ug/Nm^3 which drops to 75ug/Nm^3 by January 2015, while the annual average is set at 50ug/Nm^3 which drops to 40ug/Nm^3 by January 2015.

The AQA also recognizes that there exist areas within the republic that encounter very poor air quality that could be impacting negatively on human health and well being due to ineffective management in the past. The Act empowers the Minister to identify these areas of poor air quality, also called pollution "hot-spots" and declare them as "Priority Areas" (DEAT 2009)

1.4.2 Declaration of priority areas

The declaration of priority areas had three strategic purposes. Firstly, it allows for the concentration of limited human, technical and financial capacity to focus on identified problem areas in order to obtain measurable air quality improvements in the short, medium and long term, secondly it prescribes a co-operative governance regime between the three spheres of government in managing these areas, and lastly, it allows for the adoption of air quality management methodologies that take into account all contributors to the air pollution problem. (DEAT 2006, 2009)

The first priority area to be declared by the Minister was the Vaal Triangle Airshed Priority Area (VTAPA) on 21 April 2006. In terms of the process, an air quality management plan (AQMP) was to be drawn up for the area with the cooperation and involvement of all the relevant stakeholders. After the finalization of the AQMP, an implementation task team comprising of the relevant stakeholders involved in the drafting of the AQMP would be created to drive the implementation of the recommendations of the AQMP.

1.5 Research goals

The main objective of this research is to evaluate the impact of the Vanderbijlpark Works steel plant on ambient PM_{10} levels in the Vaal Triangle. This will be conducted via atmospheric dispersion modelling of PM_{10} emissions emanating from the Iron and Steel plant, the ArcelorMittal South Africa (AMSA) Vanderbijlpark Works in particular, using a steady-state Gaussian atmospheric dispersion model called AERMOD

An attempt will be made to undertake the following:

- Evaluate the impact of the Vanderbijlpark Works steel plant on ambient PM_{10} levels in the Vaal Triangle.
- Assess the impact of the proposed emissions reduction strategy on the ambient PM_{10} levels.

1.6 Literature Review

1.6.1 Air pollution

A report by the Global Environmental Facility (Anon, 2002) points out that the drive for global sustainability should be rooted in the growing recognition of the strong links between the environment and development. A clean environment is essential for both development and poverty eradication. Sickness and poor health mean lost production for the people and countries that can least afford it. Apart from the health impacts on humans, air pollution damages the crops, forests, rivers and lakes that countries need for their economic development.

Fuggle and Rabie (1983) provide a comprehensive definition of air pollution. They state that the problem of a polluted atmosphere arises when the, "emissions of contaminants into a volume of air exceeds the ability of that air to disperse and change the contaminants into harmless substances. Under such circumstances waste products accumulate in the atmosphere in such quantities and for such durations as may be, or may tend to be injurious to human, plant or animal life, or property, or which impair the efficient performance of normal activities, or unduly interfere with the comfortable enjoyment of life, property and the natural environment." Man has impacted on the atmosphere in various ways through the ages but not as excessively as in recent decades, which is unprecedented in human history.

The 1970's brought into focus the general realization that the different physical components of the environment have limited assimilative and carrying capacities and that pollution control measures must be instituted to safeguard the environment and the quality of human life (Holdgate *et al.*, 1982)

The concentration levels of particulate matter (PM) are considered one of the most potent indicators to diagnose the extent of air pollution (Lu, 2002; Wilson *et al*., 2002, cited from Ki-Hyun *et al.*, 2005).

1.6.2 Definition of PM_{10} and $PM_{2.5}$

The ambient air that we breathe is laden with particulate matter of various sizes and compositions, including mineral dust, metals, metalloids, sea salts, nitrate and sulphate of ammonium, organic compounds, elemental carbon as well as organic and inorganic pollutants residing almost exclusively in the gas phase. The concentration and mixture of particulate matter is both temporally and spatially highly variable. Some of them are directly emitted into the atmosphere either by natural and anthropogenic sources (primary particles), while others are the result of homogeneous or heterogeneous nucleation and condensation of gaseous precursors (secondary particles) (Seinfeld and Pandis, 1998, Pöschl, 2005, cited from Dongarra *et al.*, 2010).

PM_{10} is defined as particulate matter with an aerodynamic diameter smaller than 10um, while $PM_{2.5}$ refers to particulate matter with an aerodynamic diameter smaller than 2.5um (Ariola *et al*., 2006). PM however is a complex mixture of ultrafine, fine and coarse particles from a variety of sources (Boogard *et al*., 2010). PM can be characterized by origin, e.g., anthropogenic or geogenic, primary or secondary particles; by source, e.g., combustion products and traffic, or by physicochemical properties such as solubility. In terms of practicality and for the purposes of emission measurements, PM is characterized by particle size (aerodynamic diameter) (Ariola *et al*., 2006, Boogard *et al*., 2010.) Several metrics have been or are still used. Total suspended particles (TSP) are the most comprehensive term including particles of any size suspended in air. However, particles larger than 30–70um only remain suspended for a very short period before deposition. PM_{10} and $PM_{2.5}$ is PM with an aerodynamic diameter of less than 10 and 2.5 um, respectively. Ultrafine particles (UF) are those with a thermodynamic diameter of less than 0.1 um, also called $PM_{0.1}$. The $PM_{2.5}$ fraction is also called “fine particles”, and those particles between 10 and 2.5um are currently named “coarse particles”. PM_{10} is also called “inhalable particles”. The larger fractions comprise the smaller ones, i.e., $PM_{2.5}$ is part of PM_{10}, UF are part of $PM_{2.5}$ and PM_{10}. (Englert, 2004)

1.6.3.1 Health Impacts of PM_{10} and $PM_{2.5}$

In a study looking at emissions from industrial plants undertaken by Ehrlich *et al*. (2007), it was found that from the individual emission measurements carried out at the industrial plants and domestic stoves, in 70% of these measurements, the PM_{10} portion amounted to more than 90% and the $PM_{2.5}$ portion between 50% and 90% of the total PM emission.

Many studies have already documented the impact of particulate matter both directly and indirectly on human health expressed as increased mortality and morbidity especially for fine particles (Almeida *et al*., 2005; Almeida *et al*., 2006; Hwang and Hopke, 2007; Minguillon *et al*., 2008; Querol *et al*., 2001; Tsai and Chen, 2006, cited from Kong *et al* 2010; Ostro *et al*., 1996; Schwartz, 2000, cited from Gulliver and Briggs, *2007*, Alfaro-Moreno *et al*., 2007a; Delfino *et al*., 2005, cited from Davalos, 2010, Pope *et al*, 2002; Brunekreef and Holgate, 2002; Pope and Dockery,2006) PM10 increases and induces the production of inflammatory cytokines and induce apoptosis in epithelial lung cells (Hetland *et al*., 2004).

Long term exposure to high concentrations of urban particulate matter increases the risk of lung cancer, respiratory diseases and arteriosclerosis, while short term exposure to sudden peaks causes the worsening of several forms of respiratory diseases, including bronchitis and asthma, as well as changes in heart rate variability (de Kok, *et al*.,2006). De Kok *et al*, (2006) further postulate that particulate matter deposited in the lung could stimulate the formation of reactive oxygen species which could lead to the damage of membrane lipids, proteins and DNA which could result in cell death.

However, it would seem that causative components actually responsible for these health impacts are currently unknown, although it is suspected that components like metals, organics, acids, biogenic materials and ultrafine diesel soot could be the instigators (Monn and Becker, 1999). This suspicion is derived from results of experiments with rodents which have shown that particle acidity and metal content cause inflammation and interfere with host defence functions of lung macrophages (Chen *et al*., 1992, Dreher *et al*., 1996, Kodavanti *et al*., 1997, cited from Monn and Becker, 1999)

It has also been found that both PM_{10} and $PM_{2.5}$ are associated with respiratory allergic diseases and asthma and could also act as a carrier of allergens, (D'Amato, 2000, Knox *et.al*., 1997; Ormstad *et.al*., 1998, cited from Adhikari, *et.al*., 2006).

1.6.3.2. Other Impacts of PM_{10} and $PM_{2.5}$

Particulate matter emissions also impact on global climate by primarily cooling temperatures, due to increased scattering to space by the atmospheric aerosol burden that has increased and continues to increase. (Chen *et al*., 2003; Gerasopoulos *et al*., 2006; Nair *et al*., 2006) Fine particulate matter with trace metal constituents deposited on vegetation could induce toxic effects to phyllosphere fungi and flowering plants (Adhikari *et al*., 2006).

High concentrations of particulate matter also impacts negatively on visibility (Hwang and Hopke, 2007; Tsai and Chen, 2006), which in turn can pose a danger to human health by increasing the risk of accidents etc. due to poor visibility.

1.6.4 Air Pollution in the Highveld

The city of Vanderbijlpark lies near the southern border of Gauteng province. The longitudinal profile of the country from the west coast to the east coast is unique in that there is a coastal plain which rises sharply forming a string of mountains which more or less follows the coastline called the escarpment. The height of the escarpment ranges from around 1500m along the east to about 500m along the west. The area above the escarpment is relatively flat with a slight dip towards the west. This area is called the plateau. The Gauteng province lies on the higher elevated section of the plateau which is called the Highveld as shown in Figure 1. The cities of Johannesburg, Pretoria, Soweto and Vanderbijlpark fall within this region and actually are part of the first declared air pollution priority area. This unique geography as well as South Africa's location at around 30 degrees south latitude also combine together to create a unique type of climate on the Highveld which has peculiar implications for pollution.

The city of Vanderbijlpark falls within a highly developed region that is referred to as the Vaal Triangle. Within this region there are many residential suburbs, many of them informal settlements that use coal as a source of fuel. This is a highly industrialized

region with large ferro alloy industries like Samancor and ArcelorMittal South Africa, as well as Sasol and a coal fired power station. Together with emissions from agricultural activities, biomass burning and mining, amongst other activities, the region has over the years developed very poor air quality, hence earning the honour of being declared the first pollution priority area in the country by the Minister of Environmental Affairs and Tourism on 21 April 2006. As depicted in Figure 1, PM_{10} has been identified as the major pollutant in the region. (DEAT, 2009)

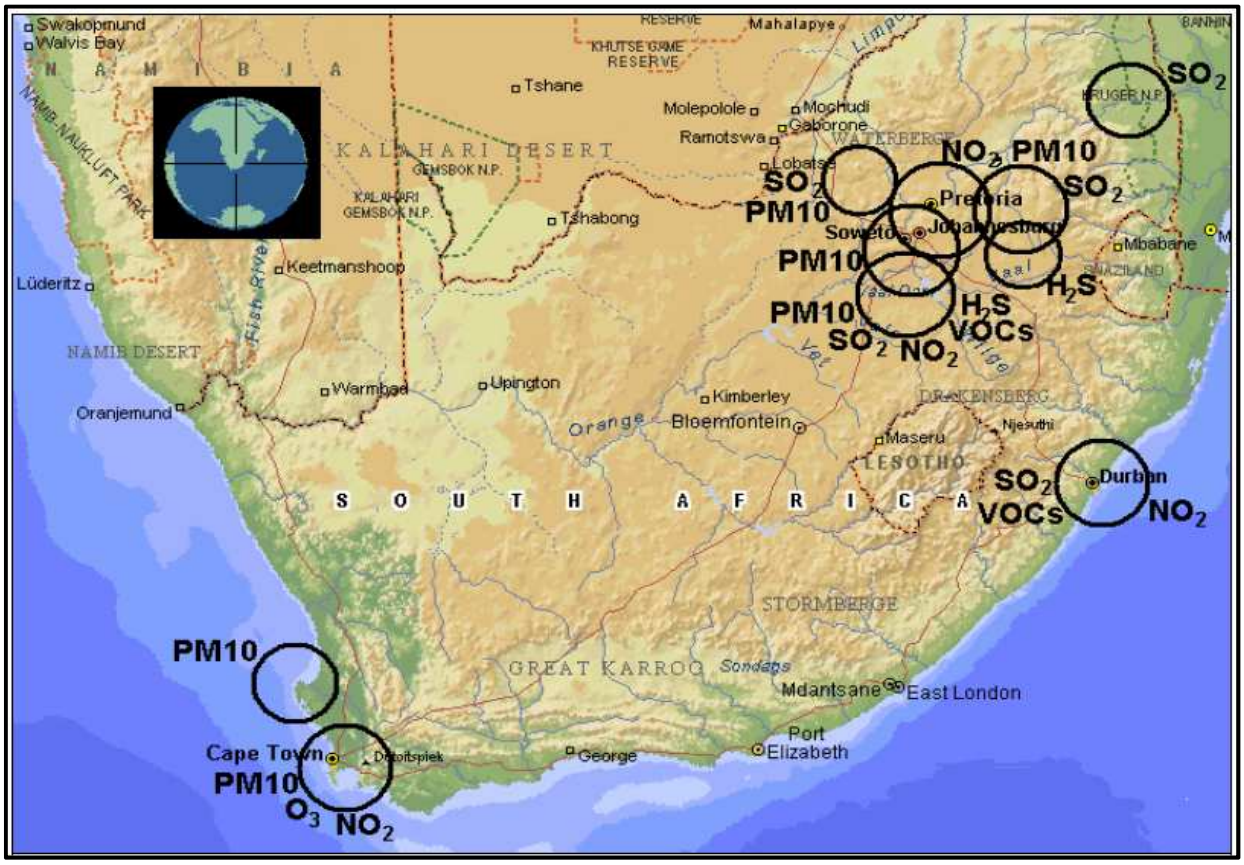


Figure 1.1: Areas in South Africa where elevated air pollutant concentrations exceeding health thresholds have been recorded. The Highveld region is located in the north eastern interior within which is the Vaal Triangle Airshed Priority Area (DEAT, 2005)

1.6.5 Dispersion potential of pollutants in the atmosphere

Meteorological and topographical conditions largely determine the transportation, dispersion and deposition of air pollutants (Sharan *et. al*., 1996,). The ability of the

atmosphere to remove and/or dilute pollution is referred to as the dispersion potential, hence, the extent of pollution in any given area and hence the risk to health and well being will be dependent not only on the emissions from the various sources but also on the dispersion potential of the atmosphere. According to Wark and Warner (1981, cited from Sharan et al, 1996), there are basically two mechanisms that govern the dispersion of pollutants in the atmosphere, viz. the mean air flow that transports the pollutants downwind, and, the turbulent velocity fluctuations that disperse the pollutants in all directions. The level of turbulence in the atmosphere, especially in the layer closest to the surface (boundary layer) will determine the extent to which pollution will accumulate or disperse in the atmosphere. This movement of air or turbulence occurs both horizontally and vertically. Vertically, thermal circulation generated by surface heating during the day occurs only to a certain height thereby setting a limit to the upward mixing of pollutants (Myrick *et al*, 1994). Mixing heights therefore become significant parameters in a dispersion model. The stability of the atmosphere and the depth of the surface boundary layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field and atmospheric stability. (Liebenberg-Enslin and Venter, 2005). The wind speed will determine how far downwind pollutants will be transported as well as the rate it will dilute in the atmosphere, as well as, together with surface roughness, determine the degree of mechanical turbulence. The general direction that pollutants will follow and the extent of cross wind spreading will be determined by the wind direction and the variability in wind direction. (Tyson and Preston-Whyte, 2000). Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field (Goldreich and Tyson, 1988, cited from Liebenberg-Enslin, 2006, Freiman and Tyson, 2000). The dispersion potential and eventual removal of pollutants from the atmosphere is therefore governed by the meteorological characteristics of a site. Information on wind speed, wind direction, temperature, humidity etc. is required in order to determine the dispersion potential of a site.

1.6.6 The horizontal transport of pollutants and air circulation over the Highveld

The dynamics of local climate which involves both the vertical and horizontal movement of air will determine what will happen to pollution when it is released into the atmosphere. Pollution levels will fluctuate daily and hourly, in response to changes in atmospheric stability and variations in mixing depth (vertical movement), while, atmospheric circulation will have an effect on the rate of transport and dispersion of pollution (horizontal movement). (Tyson and Preston –Whyte, 2000)

Horizontal transport which occurs on a meso and local scale also has a direct bearing on removal of pollutants and in the case of the Highveld; recirculation can maintain high concentrations of pollution within a region.

The southern African subcontinent has a unique set of meteorological and physical characteristics which significantly affect the transport, emission and climate forcing of aerosols (Garstang *et al*., 1996; Ichoku *et al*., 2003). Stable layers, anticyclonic circulation and inversions increase the pollution problem over southern Africa by preventing vertical mixing (Piketh and Walton, 2004; Tyson and Von Gogh, 1976; Tyson *et al.,* 1996a).

The regional circulation over Southern Africa is dominated by the sinking Hadley high pressure cell while the semi-permanent subtropical anticyclones dominate lower tropospheric circulation (Tyson *et al*.,1996b) at a geopotential height of 800 hPa (Piketh *et al.,* 1999). As descending air is the dominant motion, the air warms and dries up due to adiabatic processes, creating a highly stable thermodynamic structure of the atmosphere (Tyson *et al*., 1996b).

Multiple persistent stable layers are able to control transport over the sub-continent as air masses may become trapped between stable layers after convection has occurred from the lower troposphere (Garstang *et al*., 1996). Four stable layers are present over southern Africa, three of which lie over the interior plateau. The first is situated at the top of the midday mixing layer at 700 hPa. The second occurs at 500 hPa, and is produced and sustained by large-scale subsidence. The third layer exists at 300 hPa but carries greater significance for the transport of ozone, rather than aerosols. A fourth stable layer lies

between the plateau and ocean, over the coastline at 850 hPa (Tyson *et al*., 1996b). Stable layers inhibit vertical diffusion and transport of aerosols and trace gases and restrict horizontal transport between layers, increasing pollution concentrations (Cosjin, and Tyson 1996, Tyson *et al*., 1996b, Zunckel *et al*, 2000).

Specifically over the Highveld itself, the stable anticyclonic conditions are ideal for the formation of surface based inversions (Held *et al*, 1996,). Frequent nocturnal surface inversions up to about 300m above ground level, create a very stable boundary layer with extremely unfavourable dispersion conditions for low level emissions, especially during the winter months. Mesoscale factors such as regionally induced topographic winds, urban heat island effects and atmospheric stability are important control factors in atmospheric pollution dispersion. These mesoscale circulations and atmospheric conditions control to a large extent the transport and dispersion of low level emissions of pollutants, especially during the night and in winter (Held, *et al*, 1996).

Accumulation of pollutants on the Highveld is influenced by sub-continental and regional scale recirculation and down mixing of pollutants that were trapped at higher elevated inversion layers. Scheifinger and Held (1997) concluded that synoptic scale transport mechanisms have a large controlling influence on aerosol concentrations at the escarpment. Rapid large scale increases in concentrations of pollutants can usually be ascribed to effective down-mixing. Sub-continental scale recirculation could be responsible for the importation of pollutants arising from biomass burning in regions far north of South Africa (Held, *et.al.*, 1996). Almost 75% of pollutants are recirculated around the South Atlantic high along the east coast (Tyson, P.D. and Preston-Whyte, 2000, Tyson and Gatebe, 2001).

The Highveld lies on a plateau some 1600m above sea level. The regional scale topography slopes gradually downwards towards the west and south. To the east lies the escarpment of the Drakensberg. The southern area of the Highveld is dominated by the Vaal Basin some 1400m above sea level, which tends to drain cold air from the surrounding high-lying plateau of the Gauteng region.

According to Held *et.al* (1996), over the Vaal Triangle, surface air flows are dominated in summer by northerly to north westerly winds and in winter by westerly to south westerly winds. The topography of the area has a significant local impact on the diurnal cycle of surface winds. During the night drainage flows dominate from north and south under stable conditions, resulting in increased north- easterly and south-easterly winds. However, as the ground heats up during the day, the surface inversion weakens and drainage flows stop. The daytime convective boundary layer develops. Convective dispersion in the vertical however is limited because this convective layer usually does not develop sufficiently to break through the elevated inversion layer. Synoptic forced surface winds dominate during the daytime. This has the impact of causing local recirculation to occur on a diurnal basis over the Vaal Triangle region.

It is not yet clear for the Vaal Triangle Area itself, to what extent recirculation of pollution over the Highveld may influence ambient PM_{10} concentrations. While this study will only be focussing on the impact of PM_{10} that is created directly from the plant itself, the presence of recirculated pollution, if any, may contribute towards elevated concentrations of PM_{10}.

1.6.7 Dispersion Modelling

A simple definition of dispersion is the spread of pollution as it moves through the atmosphere both vertically and horizontally. A dispersion model is a tool that is used to predict the impact of one or more sources of air pollutants on the ambient air. Dispersion models make the use of mathematical equations which describes the atmosphere, dispersion and chemical and physical processes within the plume, to calculate concentrations at various locations (Holmes and Morawska, 2006). Vannucci et al., (2008), expands further by stating that the equations are based on, firstly meteorological conditions (wind speed and direction, stability class of the particular atmosphere, air temperature profile); emissions parameters such as source location and height, stack diameter and exit velocity, exit temperature and mass flow rate, terrain morphology, and, the presence, positions and dimensions of buildings or other structures which can affect the path of emission. The New Zealand Ministry of the Environment (2004) further adds that the models are useful in predicting downwind concentrations provided we input the

required information about the pollutant emissions and the necessary meteorological data. Dispersion models also assists in the development of an understanding of the mechanisms that give rise to observed concentration characteristics (Turner, 1996). No model will ever replicate reality exactly and at most, will present a reasonable approximation of the real situation. Good models, based on a sound understanding of the physical principles involved, can provide very meaningful results, provided that good input data are used and that the modeller is fully aware of the limitations of the result. The use of real measured data like on-site meteorological data as well as measured concentrations of pollutants further enhance the viability of the results produced.

According to Seinfeld (1975); Zannetti (1993); New Zealand Ministry for the Environment (2004) and Annegarn *et.al*, (2006); cited from Buthelezi, (2009), the application of air dispersion models, amongst others, include:

- Establishing emission control legislation;
- Evaluating proposed emission control techniques and strategies, i.e. evaluating the impact of future abatement and mitigation control options;
- Selecting locations of future sources of air pollutants, in order to minimize their environmental impacts.

Of course, modelling is essential for establishing baseline conditions which helps in planning future mitigation measures required.

Modes can be classified into three types, viz. Gaussian, Lagrangian and Eulerian. The Gaussian type is widely used in atmospheric dispersion modelling, (Holmes and Morawska, 2006; Zannetti *et al*., 2003, Seangkiatiyuth, *et.al*., 2011), and is widely used for estimating the ground level concentration of non-reactive pollutants (Vannucci, *et al*., 2008).

The Gaussian model is based on the Gaussian plume formula which is derived by assuming steady state conditions i.e. the formula is not time dependent and the meteorological conditions are assumed to remain constant during the dispersion from source to receptor (New Zealand Ministry for the Environment, 2004). According to Tyson and Preston Whyte (2000), the Gaussian model can be easily applied and has

modest data requirements and can be adapted to a variety of different uses and circumstances.

The Eulerian and Lagrangian models are also numerical models and are used for modeling reactive pollutants. They require much more extensive input data and resources. The Eulerian model employs advection and diffusion processes and has a reference system that is fixed in relation to the Earth (Byun, *et al*., 2003). In Lagrangian models, the motion of air masses or particles passively following the flow is studied, including the simulation of the presence of turbulent eddies by subjecting particle velocities to a random forcing (Anfossi and Physick, 2003). The Lagrangian puff type model attempts to incorporate the effects of varying wind conditions, where it considers pollutants to be emitted in a series of puffs with each puff being transported in a simulated wind field. The puffs are considered to take on the Gaussian form that expands as the transit time progresses. (Turner, 1996)

Receptor models are based on statistical analyses of ambient pollutant measurements and relevant emissions information and are valuable where detailed knowledge of actual emission rates is uncertain. Statistical models, alternatively, utilize variables of space, time, meteorological, emissions and other relevant variables to provide estimates of concentration levels by using regression, statistical and analysis techniques. These models however have limited applicability (Roth and Reynolds, 2003).

1.6.8 Modelling low-level emissions

In the Vaal Triangle region, and especially in winter when the inversion layer is strongly developed, pollutants emitted at low level during the night are poorly dispersed in the stable boundary layer resulting in high concentrations being experienced at ground level near the source, whereas during the day, the onset of convective mixing leads to lower concentrations. According to Turner (1996), this day and night time occurrences are basically simple single layer plume dispersion, and almost any of the published or commercially available models can give satisfactory predictions, provided that the input data is reasonably good.

He goes on to add that there are two broad types of dispersion models that can be used in this context. These are either the Gaussian plume or the Lagrangian puff-type model. He believes that the Gaussian plume model is useful under Highveld conditions; however, their accuracy diminishes further for very low wind speeds which occur frequently on the Highveld often at night.

1.6.9 Comparison between the various commercially available dispersion models.

The brief comparison between the ISCST3, AERMOD, Calpuff and the ADMS has been adapted from Buthelezi (2009). Of the four models, three are steady state Gaussian based while one is Lagrangian puff based.

ISCST3

Advantages:

- It is very simple to use. Does not require sophisticated data
- Can be used as a screening model to determine whether more advanced modelling is required.

Disadvantages:

- Is useful for point, area and volume sources only to a distance of 50km,
- Can only be used in simple terrain,
- Cannot incorporate the improved knowledge of the structure of the atmospheric boundary layer and the resulting estimations of turbulent dispersion processes.

AERMOD

Advantages:

- Can be used in simple and complex terrains,
- It is an improvement over ISCT in the sense that: (i) it has a continuous rather than discreet parameterization of atmospheric stability and (ii) makes provision for vertically asymmetric plumes.

Disadvantages:

- Limited in terms of treating atmospheric chemical processes,
- Cannot deal with odours and there are no specific processes for dealing with ammonia and hydrogen sulphide, i.e. except by approximation, it is unable to deal with atmospheric chemistry.
- May under-predict for sources less than 100m and not reliable for modelling at distances greater than 50km.

CALPUFF

Advantages

- Can model complex terrain and can account for the effect of elevated terrain on ground level concentrations,
- It has the algorithms to handle the land water temperature differences along coastal areas.

Disadvantage:

- Requires sophisticated meteorological inputs,
- Is data intensive,
- Requires more expertise and resources than other models.

ADMS

Advantages:

- Can simulate both continuous plumes and short duration puff releases,
- Can be used for point, area, volume sources and can be used to model motor vehicle emissions.

Disadvantages:

- High costs of both the software and training will limit the accessibility of this model.

The AERMOD model, based on the Gaussian Plume model, which is widely used world wide, will be used for the dispersion modelling in this study. The model has been applied to evaluate the dispersion of a number of pollutants, including PM_{10}, hydrogen cyanide, $SO_{2,}$ Sulphur hexafluoride and VOCs (Venkatram *et al*., 2001, 2004, 2009; Bhardwaj *et al*., 2005; Orloff *et.al*.,2006; Zou *et.al*., 2009, 2010, cited from Seangkiatiyuth, *et.al*., 2011). The model does produce reliable results if the modelling domain has a relatively flat terrain and the atmospheric processes are not too complex e.g. the modelling domain is not traversed frequently tropical or mid-latitude cyclones and if one is modelling near field concentrations, i.e. within 10km from the source. (New Zealand Ministry of Environment, 2004; EPA, 2004). These conditions prevail at the study site. Further information on the model will be provided in chapter two.

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The impacts of the iron and steel industry on air quality were discussed, together with an explanation of the health impacts of PM_{10} on humans. The vertical and horizontal dispersion of pollutants in the study area was examined, including a brief overview of dispersion modelling in general. The research goals of the study were also outlined.

CHAPTER TWO: DATA AND METHODOLOGY

Chapter two contextualizes the study by identifying the Vaal Triangle Airshed Priority Area, as well as detailing the emission reduction plan of Vanderbijlpark Works. It provides a detailed description of the site and surrounds. The data sources, data acquisition, methods, analysis and model input data are discussed.

2.1 The Vaal Triangle Airshed Priority Area: Context of study

The Vaal Triangle Airshed Priority Area comprises of various metropolitan areas from both the Gauteng and the Free State provinces. To the north is the City of Johannesburg, followed by the Emfuleni, Midvaal and Metsimaholo Metropolitan areas (see figure 2.1). The city of Vanderbijlpark falls within the Emfuleni Metropolitan area. The ArcelorMittal Vanderbijlpark Works is located on the north western outskirts of Vanderbijlpark City.

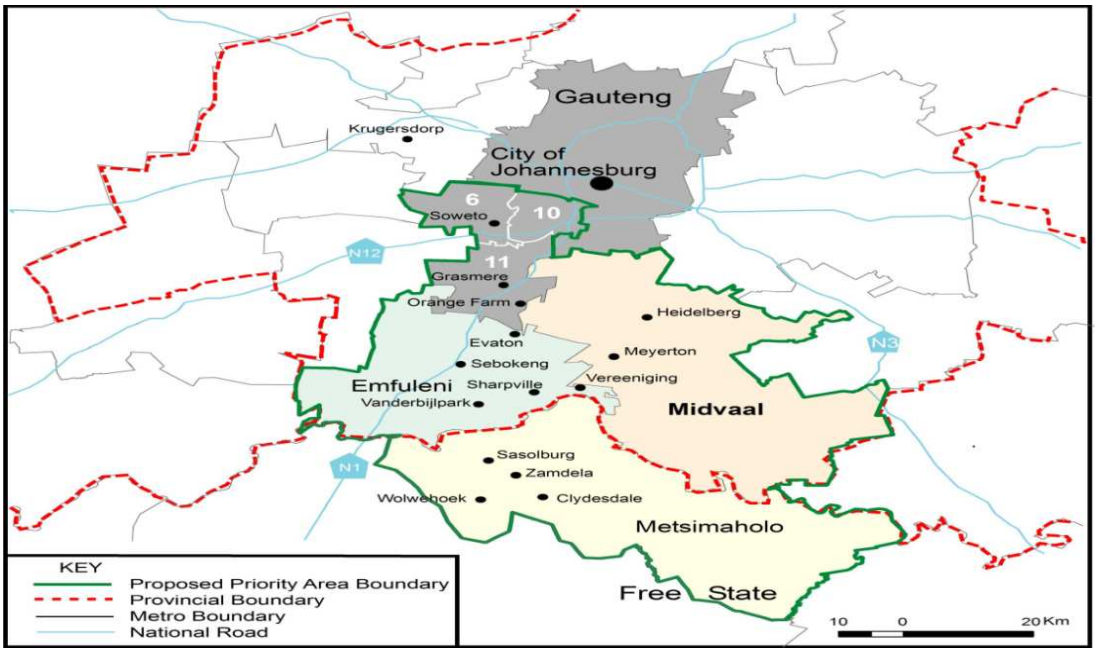


Figure 2.1: Map outlining boundary of VTAPA (R.G.Thomas, 2008)

The VTAPA Air quality management plan was eventually published in 2009 and basically outlined the emission reduction strategies for the various significant polluters in the region.

The emission reduction strategies, including targets for AMSA were set out in this document. It is recognized and acknowledged that particulates are the main problem in the area. The following ambient air quality limits were adopted for Particulate Matter for the VTAPA, a 24 hour maximum of 75ug/nm3 and an annual average of 40ug/Nm3. ArcelorMittal and Samancor Metalloys were identified as the main contributing sources to PM_{10}. ArcelorMittal needs to reduce ambient PM_{10} air quality concentrations resulting from the Vanderbijlpark Works by between 1 % and 21 % (DEAT 2009). It is not clearly understood why this range was selected and why such a large range. It is assumed that within this target, as long as 1% decrease can be demonstrated, compliance to the AQMP is proven. This should be reviewed and revised at the next review of the AQMP and a more realistic, achievable and meaningful target should be chosen.

2.2 ArcelorMittal South Africa Vanderbijlpark Works Emissions reduction strategy

It must be noted that the reduction strategy was submitted in 2007; hence the short term interventions had a start timeline from 2008. Some of these interventions have therefore already been implemented and these reductions are actually reflected in the 2010 baseline that was modelled. ArcelorMittal Vanderbijlpark has committed towards the minimization of impacts from their operations in the receiving environment. Information on the Emissions Reduction Strategy was sourced from the AMSA internal Emissions Reduction Strategy document compiled by K. Zantow (June 2010, version 6). Calculations of expected reduced tonnages were derived using the information gathered during the development of a detailed emissions inventory in 2004 and which was peer reviewed the following year.

Specific interventions that were expected to impact on PM10 emissions in the ***short term (2008/9)*** included:

The stoppage of dosing with spent pickling liquor at the Sinter plant: Past practices required Spent Pickling Liquor to be sprayed into the mixing drum forming potassium chloride (KCI) which form part of the gas released to atmosphere. The removal of KCI particulates downstream proved ineffective and the practice was stopped. This project was completed in May 2006 resulting in a fugitive particulate emission reduction of 5 107 tpa.

Reducing roof emissions from Blast Furnace D (BF-D): During the last reline of BF-D, the effectiveness of the primary extraction system was improved to capture a significant portion of the roof emissions from the cast house. It is expected that this intervention will reduce the fugitive dust emissions by 300 tpa.

Dust suppression at the waste disposal site: A dust suppression system using high pressure to create a fine water mist will be constructed at the waste disposal site to prevent dust transportation. The expected reduction in fugitive dust emissions is 70 tpa.

Secondary Dust Extraction System at EAF: Installation of a secondary dust/fume extraction system with its own bagfilter system with an average capacity of -5,000,000 m3/hr is proposed. This will capture fumes and dust currently escaping through the openings in the roof reducing dust emissions by 500 tpa.

Direct Reduction (kilns) Electrostatic Precipitator (ESP) rebuild: This involves the replacement of the refractory linings that will improve the performance of the ESPs at the Direct Reduction kilns. The fugitive particulate emission reduction is expected to be 50 tpa.

Proposed ***Short -Medium term (2012)*** interventions for ArcelorMittal Vanderbijlpark are as follows:

Replacement of old Coke Batteries: Replace Batteries 1, 3, 6 and 7 with two larger batteries (10 & 11). These batteries will be informed by "best available techniques" (BAT) and reduce emissions from the combustion stacks. Batteries V4, V8 and V9 will continue to operate until 2020. Particulate emissions will reduce by 318 tpa and $S0_2$ by 1 712 tpa. The project was expected to be completed by December 2013.

2.3 Site Description



Figure 2.2: Map showing location of ArcelorMittal South Africa Vanderbijlpark Works (Liebenberg Enslin, 2005)

Vanderbijlpark Steel is situated directly north to northwest of the town of Vanderbijlpark in Gauteng (see Figure 2.2). The current land uses in the region include farming, small residential communities and business trade. Besides Vanderbijlpark which is situated directly southeast of the plant, the residential areas of Sharpville and Bophelong are to the southeast and southwest, respectively. Boipatong is immediately to the east, with Sebokeng to the north (see also Figure 2.3). Evaton and Orange Farm are located north of Sebokeng. The town of Vereeniging is approximately 6 km to the east northeast and Sasolburg is approximately 20km further to the south. A smaller residential area is located to the east, directly north of Boipatong.

The general topography is characterised by gently rolling terrain with no hills within the surroundings. In the immediate vicinity of the plant the average elevation is 1500 m above mean sea level (mamsl) decreasing to 1480 mamsl in the centre of town and to the east and west. (Libenberg-Enslin and Venter, 2005)



Figure 2.3: Location of sensitive receptors (residential areas) in relation to the plant (AMSA, Vanderbijlpark)

2.4 Meteorological monitoring at Vanderbijlpark Works

Figure 2.4 displays the positions of the four ambient stations situated at the 4 sides of the plant. They are called 600, 350 and 300 (due to the length of the Opsis light beam) and the one located in the farm outside the fenceline (Yellow in Fig 2.4) on the western side is referred to as the caravan station. The 350 station is situated along the south eastern fence line (Blue - Fig 2.4), the 620 is along the southern fence line (Red – Fig. 2.4), and the 300 is along the northern fence line (Green – Fig 2.4).



Figure 2.4: Position of the fenceline monitoring stations at Vanderbijlpark Works

All the stations monitor meteorological parameters. The meteorological parameters measured on a continuous basis include: Wind speed, wind direction, temperature, humidity, and, rainfall. We also measure the noise levels at all the stations. These parameters are measured approximately 2m from the ground and the period of measurement is from 1 January 2010 to 31 December 2010.

2.5 Pollutants measured per station

The Opsis light beam from the 620 station measures the following: Ozone, Sulphur Dioxide, Nitrogen Dioxide, benzene, toluene and xylene. The station also houses 3 analysers, viz. H_2S, CO and PM10 analysers.

The Opsis light beam from the 350 station measures the same parameters as 620. There are however two PM 10 monitors: Verewa and Opsis SM 200. The station also houses a H_2S and a CO analyser.

The Opsis light beam from the 300 station also measures the same parameters as the 620. It also contains a SM 200 PM_{10} monitor and a CO monitor.

The western station is referred to as the Caravan station which houses the SO_2/H_2S analyser, NO/NO_2 analyser, CO/O_3 analyser and a PM_{10} analyser

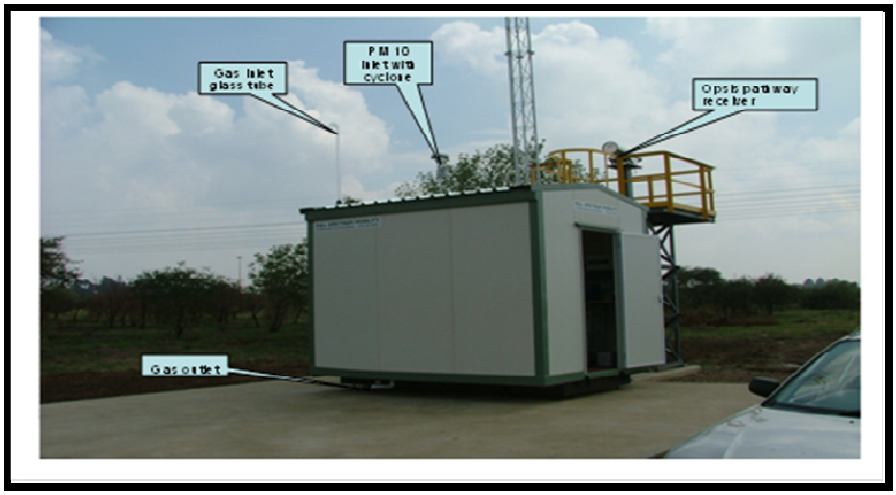


Figure 2.5: Position of PM_{10} inlet with cyclone for the 350 station

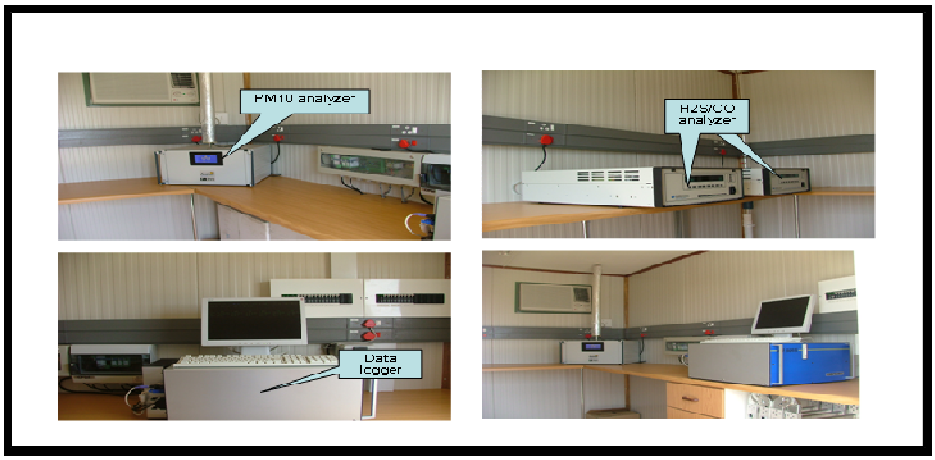


Figure 2.6: Position of PM_{10} analyser and data logger at ambient stations in Vanderbijlpark Works

2.6 PM_{10} emissions from Vanderbijlpark Works

The Vanderbijlpark steel works is an integrated steel works and its PM_{10} emissions are typical of this. Significant sources of PM_{10} emanate from the sinter plant, the blast furnace and the steel making plant amongst others. These emissions are released through stacks located at the various plants. It has been determined that significant PM_{10} emissions are released fugitively from various sources like roof emissions, stockpiles etc.

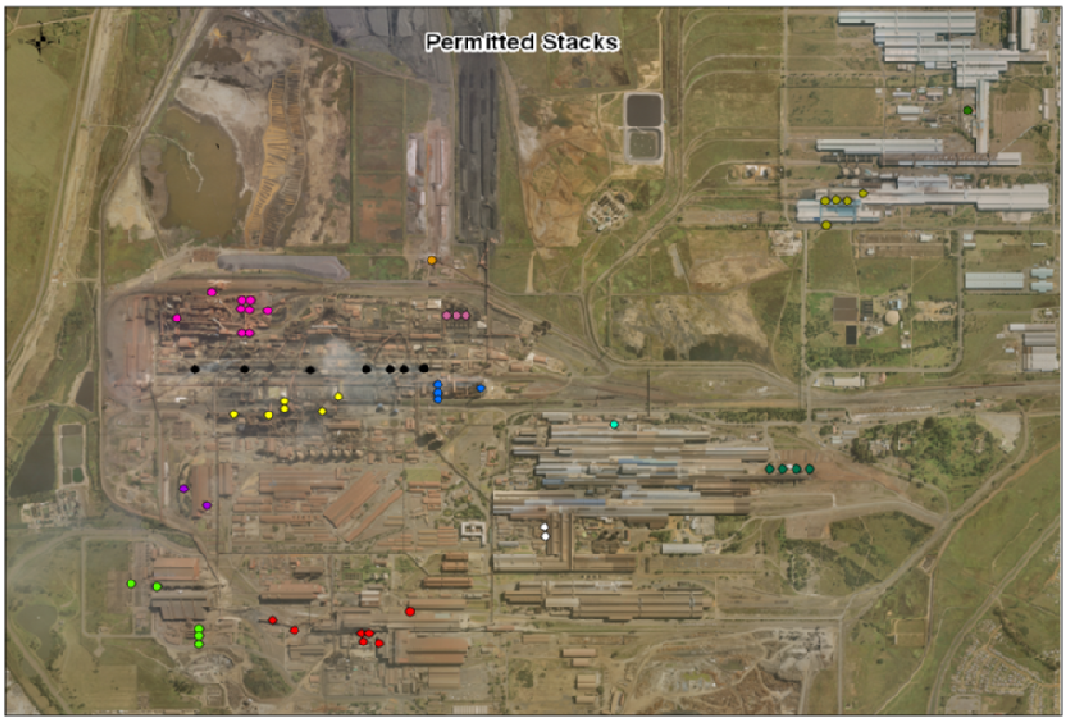


Figure 2.7 Photo showing all the point source emissions from the plant: Pink-Direct Reduction Stacks; Black- Coke Oven Stacks; Yellow-Blast Furnace stacks; Blue-Sinter stacks; Green-Electric Steel making stacks; Red-Oxygen steel making stacks (AMSA, Vanderbijlpark)

2.6.1 Emission data from stacks (Point Sources)

Figure 2.7 illustrates the main point source stacks that emit PM_{10} from the plant. Measured PM_{10} data has been sourced from the different plants emitting point source PM_{10}. Almost all the point sources have continuous dust monitors installed on the stacks.

For the few that do not have, periodic isokinetic samples are taken. The data is gathered at source which is then transmitted via radio signal to software where it is converted to data that could be manipulated and converted into 10 minute, 24 hour, monthly or annual averages. This data is then validated on a monthly basis before being recorded as the monthly stack emissions.

An emissions inventory for the point and fugitive sources was developed by consultants in association with Vanderbijlpark Work's environmental professionals. This inventory is updated on a bi-annual basis. The emission rates from the final 2010 inventory were used to input into the model for the point sources.

The updated emissions inventory for Vanderbijlpark Works for 2010 was used to access the emission rates for the different sources for 2010. It was mainly the point sources that were updated. The inventories for the fugitives were not updated for 2010. An emissions inventory for fugitives was done in 2005 when an air quality survey was conducted as part of an EIA for the installation of an additional baghouse on the Blast Furnace D Stockhouse at Vanderbijlpark Steel. This information was used for the fugitive emissions data in this study as this was comprehensively done and not any significant changes are expected from then till now with respect to fugitive emissions.

The key point sources emitting PM_{10} from the plant as illustrated in Figure 2.7 above were provided with source codes which were then inputted into the model. Table 2.1 in the next page provides the source codes with the source descriptions and the emissions rates for 2010 which was inputted into AERMOD. Altogether 66 point sources were identified and they have been grouped according to the plants, i.e., the Sinter plant, Coke Ovens, Blast furnace, Direct Reduction, Electric and Oxygen Steelmaking. All the other stacks from the smaller plants were grouped as "others". With regard to the emission rates for the Lurgi stacks, the rates for 2005 were used as this was the last time it was measured. The stacks are now only monitored for HCL as this is the only legal requirement currently. This plant is stable and there is not much variation in emissions, further, it is not a significant emitter of PM_{10} so the 2005 rates are considered adequate.

From all the stacks the sinter main stack had the highest emission rate of 0.0201 kg/s. It was one of the stacks that was targeted for intervention but was not included in the VTAPA AQMP as an intervention. The installation of a baghouse at the main sinter stack is expected to reduce PM_{10} emissions by 85% (Liebenberg-Enslin and Krause, 2008). By 2012, the baghouse has been installed and the plant is currently busy with its commissioning. The expected reduction in PM_{10} emissions would therefore also be included in modelling the interventions.

The emission rate for the Direct Reduction Kilns emergency stacks is showing nil because these stacks only emit during emergencies which occur at irregular intervals and for short periods of time in any case. The amount emitted is not expected to be significant and hence an emission rate of 0 was given for these stacks. During 2010, there were no readings taken at the Cooling Carousels at the Sinter plant and hence these stacks also reflect a 0 emission rate.

Table 2.2 displays all the source characteristics that are required by AERMOD. These are the stack heights, the stack diameters, the exit velocities and the stack temperatures.

TABLE 2.1: POINT SOURCES AT VANDERBIJLPARK WORKS

(AMSA, Vanderbijlpark)

SINTER

Source code	Source Description	Emission rate g/s
SPSBSRN	Sinter bed screen	0.1
STP	Sinter tippler	0.4
SPSTND12	main sinter stack	20.1
SPAG	Sinter stack AG	0.8
SPBG	Sinter stack BG	0.8
SPCG	Sinter stack CG	1.1
SPCC1	Cooling Carousel 1	0
SPCC2	Cooling Carousel 2	0

OTHER POINT SOURCES

Source code	Source Description	Emission rate g/s
HMREHF1	hot strip re heating furnace 1	0.4
HMREHF2	hot strip re heating furnace 2	0.4
HMREHF3	hot strip re heating furnace 3	0.4
HMREHF4	hot strip re heating furnace 4	0.4
LURGAP1	Lurgi stack 1	0.42
LURGAP2	Lurgi stack 2	0.35
LURGAP3	Lurgi stack 3	0.39
SMREHF1	Plate mill re heat furnace1	0.01
SMREHF2	Plate mill re heat furnace2	0.01
HPBOIL1	HP boiler 1	0.02
HPBOIL2	HP boiler 2	0.02
HPBOIL3	HP boiler 3	0.02
MFCYCL	Foundry cyclone	0.63
STLCAR	steel serv stack	0.1

COKE OVENS

Source code	Source Description	Emission rate g/s
COQNTWR1	Quench Tower 1	1.23
COQNTWR2	Quench Tower 2	1.23
COQNTWR3	Quench Tower 3	1.23
COQNTWR4	Quench Tower 4	1.23
COOVN1	Battery stack 1	0.34
COOVN3	Battery stack 3	0.32
COOVN4	Battery stack 4	0.37
COOVN6	Battery stack 6	0.32
COOVN7	Battery stack 7	0.33
COOVN8	Battery stack 8	0.29
COOVN9	Battery stack 9	0.41

DIRECT REDUCTION

Source code	Source Description	Emission rate g/s
DRSEPESP	Separation ESP	3.21
DRKLN1E	Emergency stack 1	0
DRKLN2E	Emergency stack 2	0
DRKLN3E	Emergency stack 3	0
DRKLN4E	Emergency stack 4	0
DRRMESP	Raw materials ESP	0.55
DRKLN1	Kiln 1 stack	0.43
DRKLN2	Kiln 2 stack	0.52
DRKLN3	Kiln 3 stack	0.63
DRKLN4	Kiln 4 stack	0.27

BLAST FURNACES C AND D

Source code	Source Description	Emission rate g/s
BFDSTKH	D Stockhouse	0.05
BFDSTV	D Stove	0.02
BFCSTKHS	C Stockhouse	0.05
BFCCSTH	C Casthouse	0.02
BFCSTV	C Stove	0.01
BFPCI1	Pulverized coal injector 1	0.002
BFPCI2	Pulverized coal injector 2	0.03
FLARE 1		0.03
FLARE 2		0.03
FLARE 3		0.03
FLARE 4		0.03

ELECTRIC AND OXYGEN STEELMAKING

Source code	Source Description	Emission rate g/s
ESMLDLF1	Ladle furnace 1	0.01
ESMLDLF2	Ladle furnace 2	0.1
ESMFNC1	Furnace 1 stack	0.09
ESMFNC2	Furnace 2 stack	0.09
ESMFNC3	Furnace 3 stack	0.13
OSMPOST1	Primary outlet 1	0.13
OSMPOST2	Primary outlet 2	0.13
OSMLDL1	Ladle furnace 1	0.06
OSMLDL2	Ladle furnace2	0.16
OSMBLT3	Bagfilter 3	0.23
OSMBFLT4	Bagfilter 4	0.25
OSMSOBH1	secondary outlet baghouse 1	0.31

TABLE 2.2: SOURCE CHARACTERISTICS FOR THE POINT SOURCE STACKS (AMSA, Vanderbijlpark)

SINTER PLANT STACKS				
Source characteristics	Height (M)	Diameter (M)	Exit Velocity	Stack Temperature
screen	6	0.9	4.5	298
Sinter tippler	8	1.4	13.7	298
main sinter stack	99	6.7	9.5	373
Sinter stack AG	37	2.8	9.6	323
Sinter stack BG	37	2.8	10.7	304
Sinter stack CG	33	2.8	7.5	312
Cooling Carousel	5	2	6.7	373
2	5	2	6.7	373

COKE OVENS				
Source characteristics	Height (M)	Diameter(M)	Exit Velocity	Stack Temperature
1	15	8.9	7.3	373
Quench Tower	15	8.9	7.3	373
Quench Tower	18	8.9	7.3	373
Quench Tower	18	8.9	7.3	373
Battery stack 1	110	3	1.7	403
Battery stack 3	110	3	1.7	403
Battery stack 4	110	3	1.7	403
Battery stack 6	110	3	1.7	403
Battery stack 7	110	3	1.7	403
Battery stack 8	110	3	1.7	403
Battery stack 9	110	3	1.7	403

BLAST FURNACES C AND D				
Source characteristics	Height (M)	Diameter (M)	Velocity (M/S)	Temperature (K)
D Stockhouse	20	2.5	12	298
C Stockhouse	18	1.8	14.4	298
C Casthouse	25	2.8	12.3	325
C Stove	61	3.8	2.1	373
Pulverized coal injector 1	45	1	10.4	368
Pulverized coal injector 2	45	1	10.4	368
FLARE 1	45	2.6	3.2	1273
FLARE 2	45	2.6	3.2	1273
FLARE 3	45	2.6	3.2	1273
FLARE 4	45	2.6	3.2	1273

ELECTRIC AND OXYGEN STEELMAKING				
Source characteristics	Height (M)	Diameter(M)	Velocity (M/S)	Temperature (K)
Ladle furnace 1	18	1	16.8	341
Furnace 1 stack	25	2.5	6.2	341
Furnace 2 stack	25	2.5	6.2	341
Furnace 3 stack	25	2.5	6.2	341
Primary outlet 1	75	1.8	16.3	1273
Primary outlet 2	75	1.8	16.3	1273
Ladle furnace 1	11	2.1	5.4	363
Ladle furnace2	15	2.1	9.9	318
Bagfilter 3	20	3.4	15.8	320
Bagfilter 4	60	1.4	13.8	297
secondary outlet	20	3.3	16.4	316

DIRECT REDUCTION				
Source characteristics	Height (M)	Diameter (M)	Exit Velocity	Stack Temperature
Separation ESP	30	3.1	12.4	298
Emergency stack 1	31	2.1	5.5	1253
Emergency stack 2	31	2.1	5.5	1253
Emergency stack 3	31	2.1	5.5	1253
4	31	2.1	5.5	1253
ESP	25	2.5	18.7	298
Kiln 1 stack	100	2.1	7.6	443
Kiln 2 stack	100	2.1	7.6	443
Kiln 3 stack	100	2.1	7.6	443
Kiln 4 stack	100	2.1	7.6	443

OTHER POINT SOURCES				
Source characteristics	Height (M)	Diameter(M)	Exit Velocity	Stack Temperature
hot strip re heating	40	2.3	5.7	477
hot strip re heating	40	2.3	5.7	477
hot strip re heating	40	2.3	5.7	477
hot strip re heating	40	2.3	5.7	477
Lurgi stack 1	38	0.75	4.2	368
Lurgi stack 2	38	0.75	4.2	368
Lurgi stack 3	38	0.75	4.2	368
Plate mill re heat furnace1	32	1	2.2	364.6
Plate mill re heat furnace2	32	1	2.2	364.6
HP boiler 1	15	3.9	4.2	463
HP boiler 2	15	3.9	4.2	463
HP boiler 3	15	3.9	4.2	463
Foundry	14	1.7	5.1	296
steel serv stack	4	1.7	8.5	312

2.6.2 Fugitive dust emission data

It has been noted that fugitive dust emissions emitted from various area sources within the plant footprint are also very significant. Investigations carried out on site indicate that fugitives can represent almost half the PM_{10} emissions from the site. These sources range from dust, both from paved and unpaved roads, from raw material stockpiles, from the waste disposal site and from roof emissions, amongst others. These fugitive emissions will have to be considered. The emissions factors from the various fugitive sources will be obtained from the USEPA (1995) Compilation of Air Pollutant Emission Factors, Stationary Point and Area Sources, AP42, Volume 1, 5th Edition.

The fugitive emissions were divided into volume and area sources and USEPA emission factors were used to calculate the emission rates. A comprehensive fugitive inventory was done in 2007 by consultants as part of an Environmental Impact Study for the installation of an additional baghouse on the blast furnace D stockhouse (See Watson and Landman, 2007). This inventory has not been reviewed since. There have not been any major changes that would have impacted on the fugitive emissions from then until now and so the fugitive inventory was used as is. It should be noted, however, that the fugitive inventory needs to be reviewed in order to capture any reductions in emissions from 2007 until now.

2.6.2.1 Building Fugitives

Watson and Landman (2007) identified five processes as resulting in the release of significant quantities of building fugitives. These include the Stockhouse, the Blast Furnace buildings C and D as well as the oxygen steel making process (BOF). The particulate emission rates and source characteristics as identified in this study for these five processes are used as input into the model. This is outlined in the table in the following page.

TABLE 2.3: EMISSION RATES AND SOURCE CHARACTERISTICS FOR BUILDING FUGITIVES (Watson and Landman, 2007)

SOURCE DESCRIPTION	PM10 (G/S)	RELEASE HEIGHT (M)	INITIAL SIGMA Z (m/s)	INITIAL SIGMA Y(m/s)
STOCK HOUSE BUILDING[1]	3.06 [2]	20	37	1.2
ELECTRIC ARC FURNACE BUILDING VENTS [1]	142.7	40	96	1.2
BLAST FURNACE C BUILDING VENTS [1]	10.9	20	37	1.2
BLAST FURNACE D BUILDING VENTS [1]	13.8	20	37	1.2
OXYGEN STEEL MAKING (BOF) BUILDING VENTS [1]	19.5	55	90	1.2

Note: [1] Treated as a buoyant line source, with the average line buoyancy parameter calculated to be 702.45 (m/s^2), the average length of the buildings were calculated as 121.6 m, the average width of the buildings as 17.2 m and the average height was set at 31.3 m respectively.

[2] Emissions estimated from samples taken outside the Stockhouse building. A median value of 191mg/m³ was used in the calculations

2.6.2.2 Materials Handling Operations

As with any heavy industry, materials handling does play a significant part in the operations. Materials handling basically refer to the moving of the different raw materials and waste and/or by-products from one point to another which involves tipping, loading and off loading of trucks.

The emission rates for the materials handling operations were calculated using the USEPA emission factors for these source types. Required information is the material moisture content and the wind speed at the time. Variable emission rates were calculated for the source types identified in Table 2.4 using wind speeds obtained for the Vereeniging Weather Service station for the period January to December 2004 (the ambient stations at Vanderbijlpark Works were not operational at this time). These emission rates were averaged out for the year so they could be inputted into the model.

The total suspended particulate loads were estimated at 165.0 tonnes per annum with the PM10 fraction estimated at 57.8 tonnes per annum respectively (Watson and Landman, 2007).

TABLE 2.4: MATERIAL TRANSFER AT EACH OPERATION
(Watson and Landman, 2007)

OPERATION	LOCATION	THROUGHPUT (tpm)	MOISTURE CONTENT(%)[1]
Off loading of coal	Coal preparation area	174 000	3.2
Off-loading of coal fines	Coal preparation area	15 841	3.2
Loading of coal	Coal preparation area	174 000	3.2
Loading of coal fines	Coal preparation area	15 841	3.2
Tipping of coal	Coke plant	140 980	3.2
Tipping of coal	Direct reduction kilns	33 020	3.2
Tipping of coal fines	Direct reduction kilns	15 841	3.2
Off-loading of sinter bed material	Sinter mixing beds tippler	243 200	2.4
Tipping at sinter bed material	Sinter bed screen	243 200	2.4
Tipping from tippler/conveyor	Sinter mixing Bed 1	200 000	2.4
Tipping from tippler/conveyor	Sinter mixing Bed 2	200 000	2.4
Sinter bed material off-load	Sinter plant storage pile 1	200 000	2.4
Sinter bed material transfer	Sinter plant storage pile 2	200 000	2.4
Loading of coke	Coke ovens	8 581	3.2
Off-loading of coke	Coke storage piles at coal preparation area	8 581	3.2
Loading slag	Behind electric arc furnace	80 000	0.6
Dumping of slag	At back of waste dump	10 000	5.1
Loading of furnace dust	Direct reduction furnaces	12 307	6.5
Loading of separation plant dust	Direct reduction furnaces	3 582	9.5
Loading of raw material dust	Direct reduction furnaces	157	5.4
Loading of dolochar (0-1mm)	Direct reduction furnaces	2 472	9
Loading of dolochar (>1mm)	Direct reduction furnaces	9 967	9
Tipping of furnace dust	Rail tippler at waste site	12 307	6.5
Tipping of separation plant dust	Rail tippler at waste site	3 582	9.5
Tipping of raw material dust	Rail tippler at waste site	157	5.4
Tipping of dolochar (0-1mm)	Rail tippler at waste site	2 472	9
Tipping of dolochar (>1mm)	Rail tippler at waste site	9 967	9
Loading of furnace & tap floor dust	Blast furnace C	568	5.1

TABLE 2.4: CONT.

OPERATION	LOCATION	THROUGHPUT (tpm)	MOISTURE CONTENT(%)[1]
Loading of stock house dust	Blast furnace C	598	5.1
Loading of furnace dust	Blast furnace D	682	5.1
Loading of stock house dust	Blast furnace D	235	5.1
Tipping of furnace & tap floor dust	Rail tippler at waste site	568	5.1
Tipping of stock house dust	Rail tippler at waste site	598	5.1
Tipping of furnace dust	Rail tippler at waste site	682	5.1
Tipping of stock house dust	Rail tippler at waste site	235	5.1
Loading of dust	Electric arc furnace 1,2 & 3	2 083	0.4
Tipping of dust	Rail tippler at waste site	2 083	0.4
Loading of BOF furnace slag	BOF furnace	41 667	1.5
Off-loading of BOF furnace slag	Rail tippler at waste site	41 667	5.1
Loading of BF furnace slag	BF furnace	6 667	5.1
Off-loading of BF furnace slag	Rail tippler at waste site	6 667	5.1
Off-loading of OSM dust	FIDA bin site	206	0.4
Off-loading of ladle furnace dust	FIDA bin site	90	1.5
Loading of furnace dust	BOF furnace 1 & 2	250	1.5
Off-loading of furnace dust	FIDA bin site	250	1.5
Loading of furnace dust	BOF furnace 3, ladle furnace 1 & 2	42	1.5
Off-loading of furnace dust	FIDA bin site	42	1.5
Loading of foundry dust	Foundry area	4	1.5
Off-loading of foundry dust	FIDA bin site	4	1.5
Loading of silica sand	Foundry area	42	1.5
Off-loading of silica sand	FIDA bin site	42	1.5
Loading of dust [(2)]	Rail tippler at waste site	80 985	4
Off-loading of dust [(2)]	On-top of waste dump	80 985	4

Notes for Table 4:

(1) Used site-specific information except for coal where typical moisture content was used.

(2) Including all Direct Furnace, Blast Furnace, and Electric Arc Furnace dust.

2.6.2.3 Wind erosion from exposed areas

A large industrial site is usually associated with stockpiles and in the case of Vanderbijlpark Works, there is also a waste dump on site. Exposed storage piles facilitate the easy entrainment of dust particles during windy episodes and can be a significant contributor to elevated PM_{10} levels.

Table 2.5 details the source characteristics of the storage piles and waste dump on-site, which were included in the assessment of particulate impacts. Table 2.6 outlines the particle size distribution of the material stored at each site. The combined particulate emissions estimated using the US-EPA emission Factors (See below) from these piles were 785 tonnes per annum for total suspended particulates and 121 tonnes per annum for inhalable particulates respectively.

TABLE 2.5: PARAMETERS PERTAINING TO THE STORAGE PILES AND WASTE DUMP (Watson and Landman, 2007)

Source	Volume (m^3)	Height (m	Area (m^2)	Moisture (%)	Clay content (%)	CE (%)	Bulk density (kg/m^3)
Coal	438,619	5	146,206	3.2	0.62	0	770(1)
Fines	145,824	5	48,608	3.2	0.62	0	770(1)
Coke	133,725	5	44,575	3.2	0.62	0	770(1)
Sinter mix beds	62,853	15	12,571	4.3	5.16	0	1,630
Waste dump	6,769,132	40	1,483,702	4	16	0	1,630

Notes: Information supplied by Mittal Steel personnel; CE = control efficiency.

(1) Typical values taken from literature for Coal and Coke piled (Perry, 1997, cited from Watson and Landman, 2007)

TABLE 2.6: PARTICLE SIZE DISTRIBUTIONS OF FUGITIVE DUST MATERIAL [(1)]
(Watson and Landman, 2007)

Source	Cumulative Particle Size Fractions (%)							
	300µm	75µm	45µm	30µm	10µm	4 m	2.5µm	1µm
Coal/Fines/ Coke	-	100	-	-	36	-	-	-
Sinter Mixing Beds	100	30.57	26.49	23.4	15.34	9.96	7.19	3.68
Waste Material	100	36.87	28.35	22.33	11.66	6.02	3.49	1.01

[(1)] No source specific information was available therefore use was made of information from similar operations.

2.6.2.4 Dust from Vehicle entrainment

The perimeter of the industrial footprint is about 20km; hence the plant does have a substantial number of paved and unpaved roads with a relatively high traffic volume especially during daylight hours. Moving vehicles on road surfaces create turbulence which lifts and entrains particulates that have settled on their surfaces.

Table 2.7 outlines the source characteristics required for the calculation of vehicle entrained dust from the unpaved road surfaces investigated as required by the USEPA emission factor for unpaved roads. Table 2.8 contains the parameters required for the calculation of vehicle entrainment on paved road surfaces.

The total suspended particulate loads and inhalable particulate fraction estimated on the paved roads was established as 10.1 tonnes per annum and 1.9 tonnes per annum respectively. Similarly emission rates of 15.1 tonnes per annum and 4.6 tonnes per annum were estimated for the TSP and PM_{10} fractions on the unpaved road networks respectively. (Watson and Landman, 2007)

TABLE 2.7: PARAMETERS USED TO CALCULATE EMISSIONS FROM VEHICLE ENTRAINED DUST ON UNPAVED ROADS (Watson and Landman, 2007)

Road	Type of Vehicles	Ave Weight (ton)	Length of road (m)	Width of road (m)	Ave Speed (km/hr)	Silt (%)[(1)]	VKT/day
Road around EAF slag handling area	2 trucks 4 slag carriers	120	845	10	30	9.41	6.27
Road to coal storage area	Trucks	32	55	10	30	10.87	39.35
Road to fines storage area	Trucks	32	115	10	30	10.87	7.49
Road to sinter mixing beds	Trucks	32	2010	10	30	10.87	5.24
Road from paved road to Steelserve plant 85	6 trucks 2 FELs	120	1020	10	30	23.8	12.24
Road from rail tippler to current waste dump	Trucks	32	770	10	30	10.87	256.41
Road from paved road to FIDA area	4 Trucks	32	2010	10	30	10.87	5.24
Road to BF slag crushing and storage	Trucks	60	3100	10	30	10.87	67.98

Notes: VKT/day is vehicle kilometres travelled per day for all the trucks on the roads

(1) Derived from particle size analysis for paved road sample (<75µm).

TABLE 2.8: PARAMETERS USED TO CALCULATE EMISSIONS FROM VEHICLE ENTRAINED DUST ON PAVED ROADS AT THE SITE
(Watson and Landman, 2007)

Road	Truck Type	Length (m)	Ave Speed (km/hr)	Width (m)	Silt (%)[1]	Average Vehicle Weight (ton)	VKT/ day
Road from Plant to coke storage area	Coal trucks	230	30	10	7.03	32	165
	Coal fines trucks					32	15
ESM road (south of plant)	3 slag trucks to furnace	1 475	30	10	54.17	120	9
	6 slag trucks to Plant 85	1075	30	10	54.17	120	13

Notes: VKT/day is vehicle kilometres travelled per day for all the trucks on the roads

[1] Derived from particle size analysis for paved road sample (<75µm).

2.6.3 Emission factors used for the calculation of Fugitives from USEPA

An emission factor can be defined as a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are used for estimating emissions when measured data does not reflect the variability of actual emissions over time. In most cases, these factors are mere averages of all acceptable available data, and are generally assumed to be representative of long term averages for all facilities in the source category (USEPA, 1995)

2.6.3.1 Wind erosion of storage piles

The emission factor for wind-generated particulate emissions from mixtures of erodible and non-erodible surface material subject to disturbance may be expressed in units of grams per square meter (g/m^3) per year as follows (Cowherd, C. *et al* 1974):

$$(i) EmissionFactor = K\sum_{i=1}^{N} p_i$$

Where

K = particle size multiplier

N = number of disturbances per year

P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m²

The particle size multiplier (k) varies with aerodynamic particle size, as follows:

Aerodynamic Particle Size Multiplier			
30µm	**<15µm**	**<10µm**	**<2.5µm**
1.0	0.6	0.5	0.2

The erosion potential function of a dry, exposed surface is: (Muleski, 1985):

$$(ii) P = 58(u^* - u_t)^2 + 25(u^* - u_t^*)$$

$P = 0$ for $u^* \leq u_t^*$

Where

u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

The value of the threshold friction velocity is 1.02. The following formula was used to calculate u, where u´, v´ and w ´are measured. (Jacobson, M.Z. 1999)

$$u_* = [(\overline{w'u'})_s^2 + (\overline{w'v'})_s^2]^{\frac{1}{4}} = (|\tau_z|/\rho_a)_s^{\frac{1}{2}}$$

2.6.3.2 Vehicle entrainment on unpaved roads

The following empirical expression is used to estimate the quantity in kilograms (kg) of size-specific particulate emissions from an unpaved road, per vehicle kilometer travelled (VKT) (Cowherd, et al, 1974):

$$(iii) E = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$

Where

k, a and b are constants given below:

Constant	**PM-10**	**TSP**
K	1.5	4.9
A	0.9	0.7
B	0.45	0.45

and

E = size-specific emission factor (lb/VMT)

S = surface material silt content (%)

W = mean vehicle weight (tons)

The following range of source conditions were used by the USEPA in developing the equation above:

Surface Silt Content (%)	**Mean Vehicle Weight (Mg)**	**Mean Vehicle Speed (km/hr)**	**Mean No. of Wheels**	**Surface Moisture Content**
1.8 – 25.2	1.8 – 260	8 – 69	4 – 17	0.03 – 13

2.6.3.3 Vehicle entrainment on paved roads

The following equation was used to calculate the emission factor for paved roads (Dunbar, 1976)

$$(iv)E = k\left(\frac{s}{12}\right)^{0.65}\left(\frac{W}{3}\right)^{1.5} - C$$

Where:

E = particulate emission factor (having units matching the units of k),

k = particle size multiplier for particle size range and units of interest,

sL = road surface silt loading (grams per square meter) (g/m2),

W = average weight (tons) of the vehicles travelling the road, and

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear.

Constant	**PM_{10}**	**TSP**
k (g/VKT)	4.6	24
C	0.1317	0.1317

2.6.3.4 Material transfer

Either adding material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation.

The quantity of particulate emissions generated by either type of drop operation, per kilogram (kg) (ton) of material transferred may be estimated using the following empirical expression (Cowherd et al, 1974):

$$(v)Ek(0.0016) = \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}\left(\frac{kg}{megagram[Mg]}\right)$$

Where

E = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed, meters per second (m/s)

M = material moisture content (%)

The particle size multiplier in the equation, k, varies with aerodynamic particle size range, as follows:

Aerodynamic Particle Size Multiplier (k)	
PM_{10}	**TSP**
0.35	0.74

2.7 AERMOD Dispersion Model

2.7.1 Model overview

AERMOD, the dispersion model of choice for this study, is a 'near-field' steady-state Gaussian model designed for short range (< 50km) dispersion of air pollutant emissions from stationary industrial sources. This model was regarded as being the most suitable; especially given the relatively flat terrain of the modeling area. (Vannucci *et.al.*, 2008). This USEPA approved model was developed in 1995, and fully replaced the ISC Short Term Model version 3 in December 2006.

In AERMOD, rather than look at turbulence and dispersion coefficients as a discrete set of stability classes, boundary-layer similarity theory is used to define these as a

continuum providing better predictability. This allows the model to vary turbulence with height providing a better dispersion scenario from different release heights. Also, the dispersion coefficients for unstable conditions are non-Gaussian, to represent the high concentrations that can be observed close to a stack under convective conditions (New Zealand Ministry for the Environment, 2004; USEPA, 2004).

The AERMOD modeling system used in this work was run with a commercial interface, ISC-AERMOD View (Version 7.1.0) (Lakes Environmental Software, Waterloo, Ontario, Canada). The data flow through the AERMOD model is depicted in figure 2.3 below. AERMOD requires the pre-processing of data. For this, two pre-processors have been inputted into the model viz. the meteorological data pre processor referred to as AERMET and the terrain pre processor, referred to as AERMAP. AERMET makes meteorological data compatible for characterizing the planetary boundary layer (PBL). It makes use of both surface meteorological data as well as upper air data which is then used to calculate the atmospheric parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukhov length and surface heat flux. (USEPA, 2004). The diagrammatic representation of the physical model on which AERMOD is based is depicted in Figure 2.10.

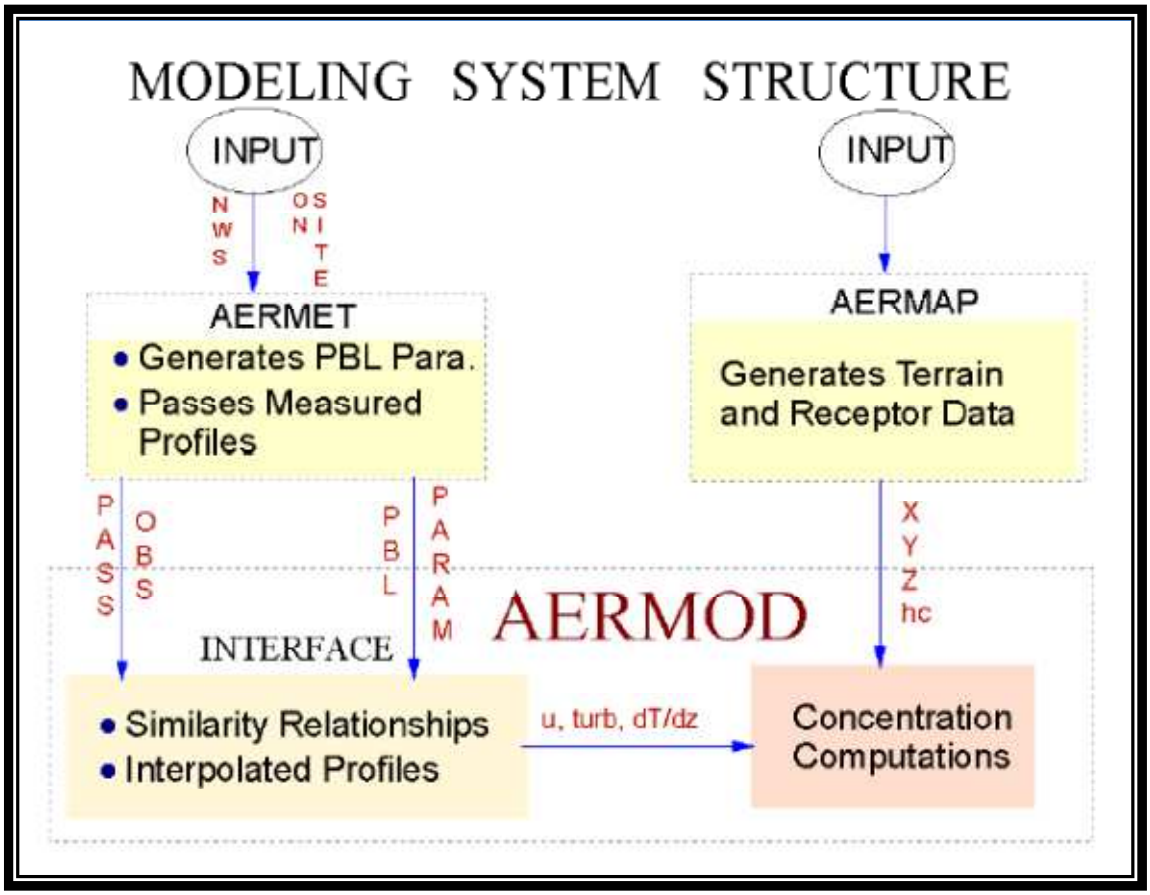


Figure 2.8: Flow of data processing in AERMOD (USEPA, 2004)

AERMAP shows the relationship betwen terrain features and the behaviour of air pollution plumes. It generates location and height data for each receptor location and provides information that allows the dispersion model to simulate the effects of air flowing over hills or splitting to flow around hills (USEPA, 2004).

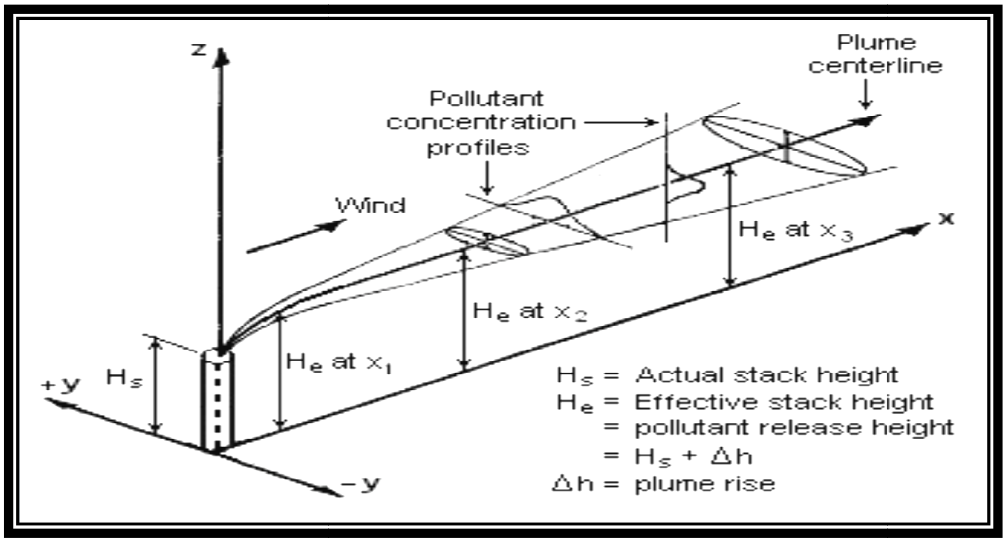


Figure 2.9: Diagrammatic representation of the physical model on which AERMOD is based (Vannucci *et.al.*, 2008)

2.7.2 Model input data

2.7.2.1 Modelling domain and grid resolution

Total modelling domain coverage of 20km by 20km, with a grid resolution of 1km was used in the simulations. The exercise was an attempt to determine impacts at receptors at close proximity to the fenceline. Sensitive receptors located around the fenceline of the plant was identified, especially the residential areas that border the plant. Uniform Cartesian grid receptor type was selected in AERMOD to specify receptor location for this modeling exercise.

2.7.2.2 Geophysical data

The Highveld region is highly characterized by a relatively flat terrain. There are no major topographical features located in or near the vicinity of the plant, hence a flat terrain option was used and no additional terrain or landuse data was inputted into the model.

2.7.2.3 Meteorology

Having realistic planetary boundary layer similarity profiles and ensuring that the dispersive capacity of the atmosphere is properly characterized is crucial for dispersion

modeling. A crucial discovery was made by Mr Roelof Burger during supervision of a post graduate student where it was discovered that AERMET, the meteorology pre-processor of AERMOD was hard coded to calculate boundary layer parameters using the western hemisphere sounding just before sunrise. The AERMET code was corrected to convert the sounding times to local time and then look for the morning sounding. This improved the accuracy of calculating the mixing height. The corrected convective planetary boundary layer (CPBL) similarity profiles were found to be more realistic and representative of typical daytime meteorological conditions and enabled adequate characterization of the dispersive capacity of the atmosphere (Buthelezi, 2009). This upper air data that was used for the Buthelezi study was also used in this study

Surface and profile meteorological data was processed using Mesoscale Model 5 (MM5) due to the lack of upper air data for the region. This data was found in a previous study to depict meteorological conditions that was similar to what was recorded at a local ambient station (Buthelezi 2009).

2.7.3 The calculation of emission rates for the fugitive dust sources

Emission rates for fugitive dust sources were generated based on the United States AP42. (Chapter 13.2.5 Industrial Wind Sources). Hourly meteorological data was used to calculate an hourly emission rate for individual sources based on wind speed, particle size and density. The hourly emission values calculated were then averaged out to a single annual average emission rate, which was entered into the AERMOD dispersion model, as the emission rate for the source.

2.8 The modeling Scenarios

2.8.1 Baseline 2010

Point sources were grouped together and scenarios for I hour and 24 hour periods were modeled. The same was done for fugitive sources. Lastly, all the sources were combined together to give the PM_{10} concentrations for 2010 for both 1 hour and 24 hour periods.

2.8.2 Modeling the interventions

The expected reduction for each intervention was estimated. This was then subtracted from the 2010 baseline emission rate. This is expanded further below:

Intervention 1: The stoppage of dosing at the Sinter plant with spent liquor was already in operation by 2010. The emission reductions achieved by this intervention is therefore already incorporated into the 2010 baseline.

Intervention 2: Reducing the roof emissions from blast furnace D. The improvement of the effectiveness of the primary extraction system is expected to reduce the fugitive dust emissions by 300tpa, converted to g/s is 9.5g/s. The building fugitives from blast furnace D is reflected in Source ID BE in the model, which had a baseline reading for 2010 of 13.8g/s. The difference of 4.3 g/s was inputted for the intervention scenario for this specific intervention.

Intervention 3: Dust suppression at the waste disposal site. This intervention was also completed by 2010 and hence the reduced emissions were included in the 2010 baseline.

Intervention 4: The installation of a secondary dust extraction system with its own bagfilter was expected to capture roof emissions, approximately 500 tpa. Converted to g/s, this equates to 15.8g/s. The roof emission fugitives from the Electric Arc Furnace is reflected in source ID BG in the model, which had a 2010 baseline reading of 15.8g/s. This source therefore reflected an emission rate of 0 for the intervention scenario.

Intervention 5: The rebuilding of the Direct Reduction Electrostatic Precipitator is expected to reduce the fugitive emissions from the Separation plant by 50tpa. This translates to 1.6g/s. The fugitive emissions from the Direct Reduction separation plant is reflected in the source ID DRSEPESP in the model, which had a 2010 baseline of 3.21g/s. The difference of 1.61g/s was inputted for this intervention.

The medium term intervention of replacing the old coke batteries with two new batteries will not occur due to economic constraints. This scenario was therefore not modeled.

A new intervention that was not included in the VTAPA action plan was the installation of the baghouse at the sinter. The sinter plant was identified as a significant point source emitter of PM_{10}, which became a priority project after the emission reduction plan, was submitted to the authorities. In terms of the EIA study conducted for this installation, it was estimated that this installation would reduce PM_{10} emissions by 87%. With a pre installation measurement of 2117tpa, an 87% reduction would be 1842tpa. This means that the emissions would be reduced to 275tpa which equates to 8.7g/s. The source ID for the main sinter stack in the model is SPSTND12. The emission rate for this source was dropped from 20.1g/s to 8.7g/s.

The modeling scenarios for the interventions were similar to the baseline. Point sources were modeled separately from the fugitives for both 1 hour and 24 hour periods and then all interventions were modeled together for both 1 hour and 24 hour periods.

The modeling scenarios are presented in the next chapter.

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Chapter two provided an outline of air quality monitoring at the plant. It clarified how data for input into the model was derived, as well as provided an overview of AERMOD. It provided a detailed description of how point and fugitive source PM_{10} data was derived. The meteorological conditions in the study area were also discussed. Dispersion modeling results will be discussed in chapter three.

CHAPTER THREE: RESULTS AND DISCUSSION

- Chapter three outlines the AERMOD modelling results for both stack and fugitive emissions from Vanderbijlpark Works. Ambient data is used to verify modelling results and shortcomings of the modeling exercise is discussed

3.1 Modelling results

In order to assess the impact on air quality in and around the Vanderbijlpark Steel Plant, one-hour, and 24-hour PM_{10} concentrations are presented in the form of concentration contours. Both the one hour and 24 hour concentrations will be compared with the one hour and 24 hour ambient data for that period, and to compare this with the national ambient air quality standards. The actual PM_{10} measurements for 2010 were obtained from the four ambient stations located around the plant. This was compared with the dispersion scenario presented by the model.

Two scenarios are presented. The first is showing the dispersion at the 2010 baseline level for both one hour and 24 hours, and the second scenario is showing the dispersion for both one hour and 24 hours after most of the interventions as outlined in the VTAPA air quality management plan have been implemented. Due to financial constraints, the medium term intervention of replacing the old coke batteries with new ones will not be going ahead and so the expected reductions from this intervention has been excluded in the intervention scenario. The intervention scenario is therefore presented as a composite and since some have not been implemented as yet, these will still remain as future projected reductions.

Contour plotlines reflecting hourly and daily averaging periods contain the modeled ground level concentrations for that averaging period, over the entire period for which

simulations were undertaken. It is therefore possible that even though a high daily concentration is predicted to occur at certain locations, that this may only be true for one day during the entire period. The ambient PM_{10} standard for Vaal Triangle was set at 75ug/m^3 for the 24 hour average and 40ug/m^3 for the annual average. The modeled concentrations will be compared against these standards.

3.1.1 2010 Baseline modelled concentrations of PM_{10}

3.1.1.1 Modelled concentrations for one hour for point, area and volume sources

The one hour average is showing high concentrations as depicted in Figure 3.1. On the far north eastern boundary of the plant the one hour average varies from 582ug/Nm^3 to 37ug/$Nm^{3.}$ As expected the highest concentrations are within the boundary fence of the Vanderbijlpark plant. The average for PM_{10} for 2010 as recorded by the ambient station referred to as 620 is 43.88ug/Nm^3, with the highest one hour average reading for the year recorded at 472 ug/Nm^3 and the lowest at 6.41 ug/Nm^3. The 620 station is located close to the southern fenceline and the model is showing a reading of between 1128ug/Nm^3 and 582ug/Nm^3 along this fenceline. The discrepancy between the recorded PM_{10} measurements and the modelled concentrations is attributable to fixed emission rates that were used for the variable emissions. A more accurate way of estimating these emissions will provide a better scenario. There are no one hour concentration limits for the Vaal Triangle Priority Area, but high concentrations occur across the western and southern boundaries of the plant. For now there are no sensitive receptors to the west of the plant. However, the residential suburb of Bophelong to the south and the suburb of Boipatong to the south east could be impacted by these predicted high concentrations.

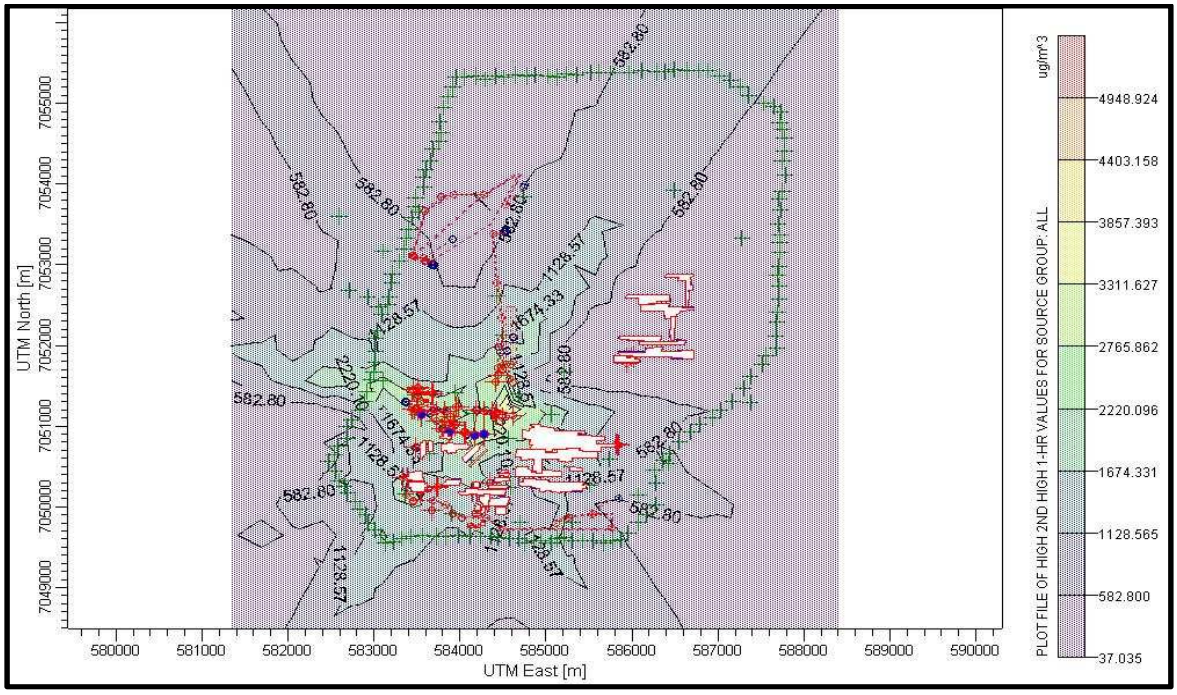


Figure 3.1: 2010 Baseline modelled concentrations for one hour for point, area and volume sources

3.1.1.2 Modelled concentrations for 24 hour average for point, area and volume sources

A similar pattern of high concentrations along the western fenceline and across the southern boundary is illustrated in Figure 3.2. The 24 hour average as recorded at the 620 station is 73.12ug/Nm^3, with the highest recorded reading for the year being 178.37ug/Nm^3 and the lowest being 19.78ug/Nm^3. The 24 hour average concentration limit for the Vaal Triangle Priority Area is 75 ug/Nm^3. In terms of the model predictions, high concentrations are predicted along the western and southern fenceline. The high concentrations of 143 ug/Nm^3 along the south western fenceline do pose a problem. The suburbs of Bophelong and Boipatong will be impacted by the higher concentrations averaging at 143ug/Nm^3. It should be however noted that these higher concentrations are due to the use of fixed emission rates for each variable source which has consequently resulted in the overestimation of fugitive PM_{10} concentrations.

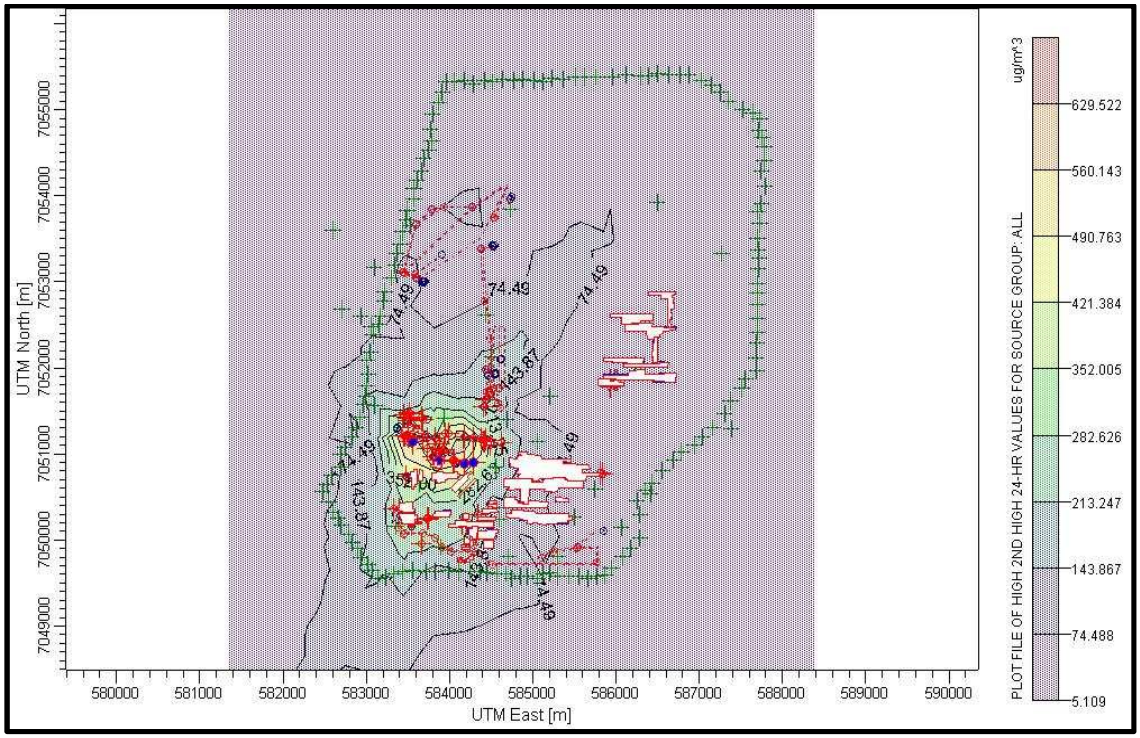


Figure 3.2: Baseline modelled concentrations for 24 hours for point area and volume sources

3.1.1.3 Modelled concentrations for one hour average for point sources

The point sources alone, as illustrated by Figure 3.3, presents a more favourable picture, suggesting perhaps that the point sources may not be the problem on the plant. The highest concentrations, as illustrated by Figure 3.3, outside the fenceline are shown at 70ug/Nm^3 which is relatively low although there are no limits stipulated for one hour averages. The measured average for one hour concentrations is 43.88ug/Nm^3. What probably assists in tempering the concentrations is the fact that point sources are released at an average height of 70m which assists greatly in the dispersion of pollutants at height before impacting on ground level concentrations.

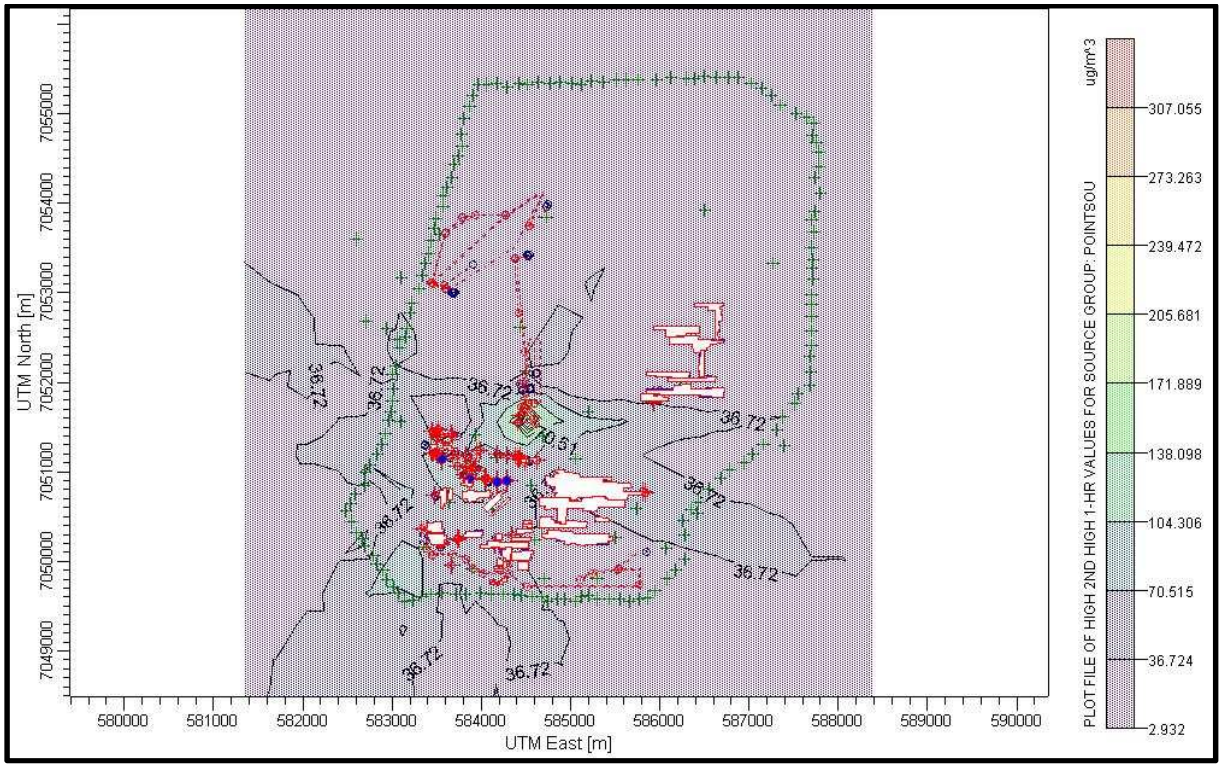


Figure 3.3: Baseline modelled concentrations for point sources for one hour

3.1.1.4 Modelled concentrations for 24 hour average for point sources

The 24 hour average for the point sources is depicted by Figure 3.4 which is once again demonstrating that point sources may not be the main emitters of PM_{10} at Vanderbijlpark Steel as the highest concentrations outside the fenceline is only 13ug/Nm^3. This is very low when compared to the 24 hour average of 75ug/Nm^3 that is stipulated in the VTAPA AQMP or with the measured 24 hour ambient average of 73.12ug/Nm^3. This also further demonstrates that it is the fugitive dust sources that are responsible for the high concentrations.

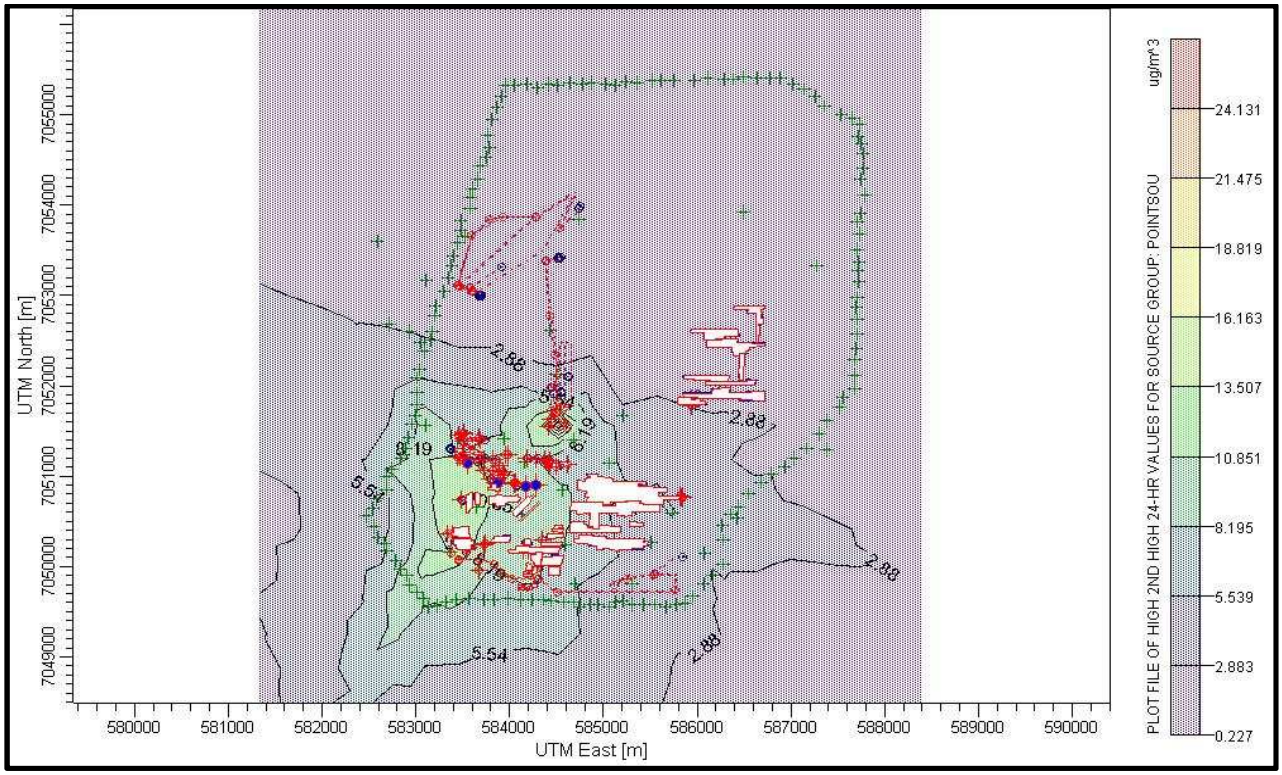


Figure 3.4: Baseline modelled concentrations for point sources – 24 hours

3.1.1.5 Modelled concentrations for one hour average for fugitive emissions

The modelled concentrations for fugitives present a totally different scenario when compared to the point sources, as illustrated by Figure 3.5. The one hour average fugitive emissions scenario indicates that PM_{10} concentrations as high as 1122ug/Nm^3 prevails to the south, while concentrations as high as 2207 ug/Nm^3 exist along the western fenceline. Once again, given that the measured average, which does include the fugitives, is recorded as 43.88ug/Nm^3, with the highest at 472 ug/Nm^3, this would suggest that the use of fixed emission rates for the variable emissions is resulting in the overestimation of fugitive concentrations. It is clear from these results that the challenge for PM_{10} lays to the south and west. As there are no sensitive receptors at close proximity to the western boundary, focus should be concentrated on decreasing the PM_{10} levels over the southern side of the plant.

The high concentrations in the south will definitely impact on the two suburbs of Bophelong and Boipotong as identified previously. This scenario is confirming that it is the fugitive dust sources

on the plant that is contributing most to the exceedences and hence should be targeted for action in any PM_{10} reduction program. Although it is acknowledged that the model is overpredicting, it is expected that the fugitive dust levels will in any case be relatively high given the comparison with already measured PM_{10} levels from the ambient stations located around the plant.

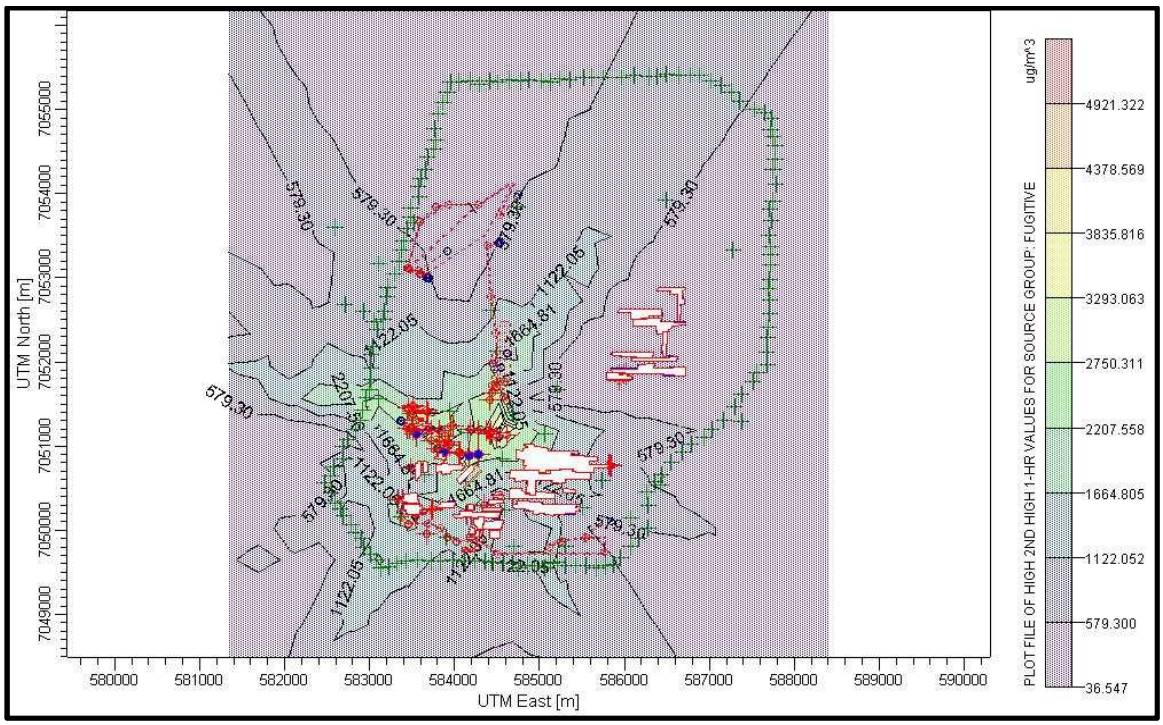


Figure 3.5: Baseline modelled concentrations for fugitive emissions one hour

3.1.1.6 Modelled concentrations for 24 hour average for fugitive emissions

The 24 hour fugitive concentration contours depicted by Figure 3.6 once again indicates that the problems of exceedences exist to the south with concentrations as high as 142ug/Nm^3. This is almost double the 24 hour average limit of 75ug/Nm^3. The scenario painted seems to indicate that it is the suburbs of Bophelong and Boipotong which may be impacted by these exceedences.

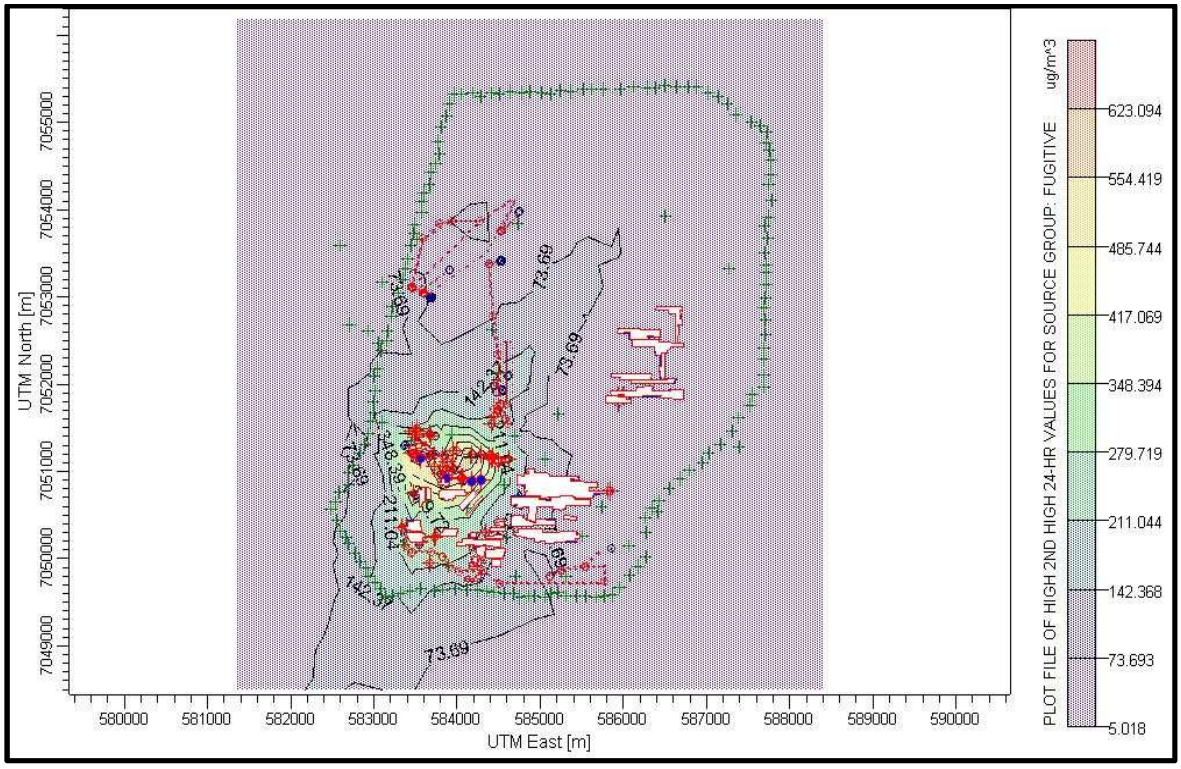


Figure 3.6: Baseline modelled concentrations for fugitives – 24hours

3.1.2 PM_{10} modelled concentrations after implementation of Reduction Strategy.

ArcelorMittal South Africa Vanderbijlpark Works have developed and reviewed over the years an Emissions Reduction Strategy in preparation for environmental compliance. This strategy is detailed in a document entitled the Emissions Reduction Strategy which was compiled by K Zantow, environmental manager at Vanderbijlpark Works in 2010. In the process of compiling this strategy, an emission inventory was developed and peer reviewed. The tonnages that were expected to be reduced by each intervention were calculated with the use of the newly developed inventory which, is updated annually. The emission rates were changed to take into account the reduced emissions after the interventions were implemented. The expected reductions in tons per annum were also included with each intervention (Zantow 2010). These were converted to grams per second and then deducted from the emission rate from that source as per the 2010 baseline. In terms of the VTAPA the following reduction interventions were identified:

a) From a PM_{10} point of view, the production of sinter is one of the chief contributors to these emissions. Prior to 2006, spent pickling liquor (iron chloride and hydrogen chloride mixture) was used to reduce the levels of Potassium in the sinter product. This activity resulted in very high potassium chloride emissions which are released as particulates. A decision was taken to stop dosing from February 2006. This activity was expected to reduce PM_{10} emissions by 5 107 tpa (Zantow, 2010). Since this activity was implemented in 2006 already, this reduction would have been accounted for in the 2010 baseline scenario. This action was included in this discussion because it is a part of the actions required in terms of the VTAPA action plan. It must be noted that discussions and commitments were made to the action plan many years before it was gazetted, so we have a few actions in the plan that were completed by 2010.

b) Fugitive emissions were early recognized as the biggest contributors to the PM_{10} emissions with the blast furnace being identified as a significant contributor. Significant quantities of PM_{10} escape via the roof during tapping of the blast furnace. A dust extraction system aimed at curtailing roof emissions from the blast furnace D was identified as an intervention. This intervention is expected to reduce emissions by 300tpa (Zantow 2010). Source ID for this volume source in the model was BE which had an emission rate of 13.8 for 2010. 300tpa converted to 9.5g/s which were deducted giving an emission rate of 4.3g/s.

c) The waste disposal site was also regarded as a significant contributor to PM_{10}, where, apart from the movement of heavy trucks, dust disposed there from baghouses etc., were easily entrained back into the atmosphere during windy episodes. Dust suppression at the waste disposal site is expected to reduce fugitive emissions by 70tpa (Zantow 2010). This action also was completed before 2010 but is included in the VTAPA action plan so the reduced emissions would be accounted for in the 2010 baseline scenario.

d) The Electric Arc Furnace (EAF) uses scrap metal as input to make hot metal. In the process a lot of dust is emitted which cannot be ducted. The installation of a dust extraction system at the Electric Arc Furnace has been calculated as

expecting to reduce emissions by 500tpa (Zantow, 2010). The source ID for this volume source was BG which had an emission rate of 15.8g/s. (2010 inventory). 500tpa converted to g/s also amounted to 15.8g/s. The emission rate for this source was reduced to 0.

e) The Direct Reduction Plant produces directly reduced iron (DRI) which is used as an input material in the steel-making process. The process of making DRI results in the generation of large volumes of dust which is trapped either in a baghouse or in an electrostatic precipitator (ESP). The current ESP is not functioning optimally and part of the strategy includes the rebuild of this ESP. The Direct Reduction electrostatic precipitator rebuild is expected to reduce emissions by 50tpa. The source ID for this source was DRSEPESP which had a 2010 emission rate of 3.21. 50tpa converted to g/s amounted to 1.6g/s. So the reduced emission rate is 1.61g/s.

An additional reduction was modelled which was not identified as an intervention strategy in the VTAPA. This is the installation of the baghouse at the main sinter stack, which according to the EIA conducted will reduce PM_{10} emissions by 87%. The baseline emissions were measured at 2117 tpa. An 87% reduction amounted to 1842 tpa which leaves us with 275tpa converted to g/s is 8.7g/s. The source ID for the main sinter stack is SPSTND12 which had a 2010 emission rate of 20.1, which in turn was reduced to 8.7g/s. The modelled scenarios after intervention are depicted below.

3.1.2.1 Modelled concentrations after implementation of improvements – all interventions one hour average.

The scenario for one hour concentrations after all proposed interventions are implemented is illustrated in Figure 3.7. The one hour concentration levels are high still showing exceedences as high as 1562ug/Nm^3 along the western fenceline and as high as 542ug/Nm^3 along the southern fenceline. The 2010 baseline exceedences along the southern and western fenceline are 1128ug/Nm^3 and 582ug/Nm^3. This suggests that for the one hour averages, the interventions did not make much of an impact. However, given that the average for the measured one hour concentrations is around 43.88ug/Nm^3,

with the highest being 472ug/Nm^3, the accuracy of the projections is brought into question. It does seem that the model is overpredicting for reasons already discussed.

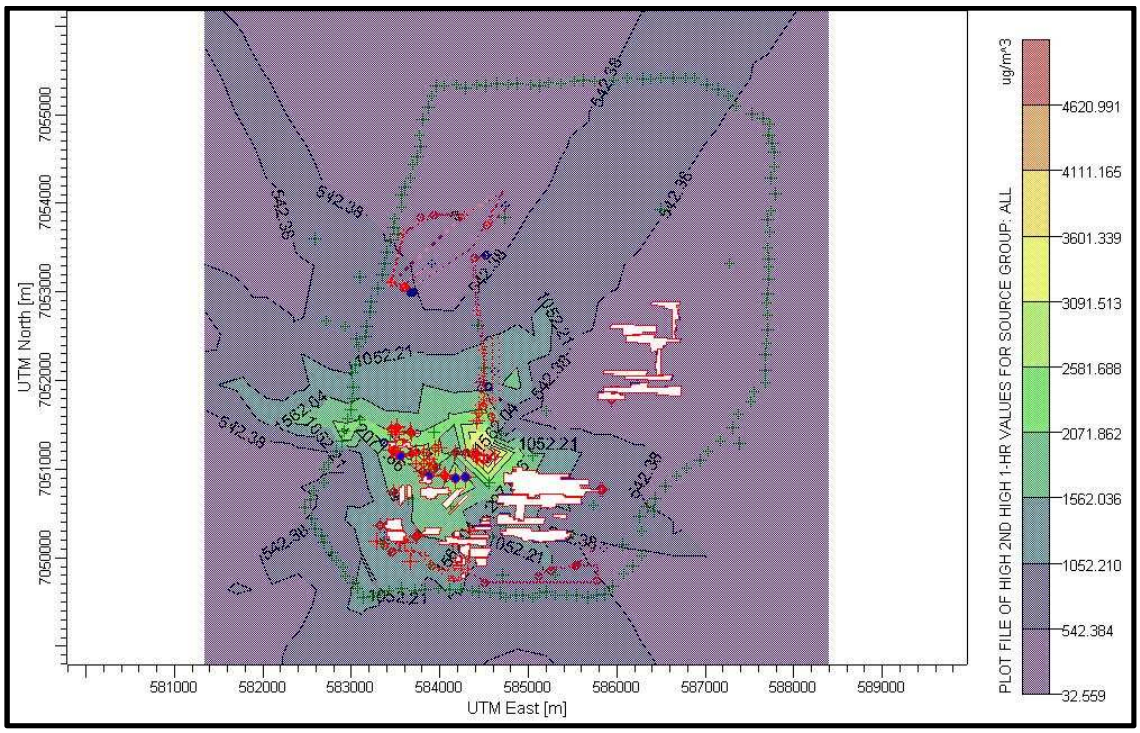


Figure 3.7: Model scenarios after implementation of improvements – all interventions one hour average

3.1.2.2 Modelled concentrations after implementation of improvements – all interventions 24 hour average.

The 24 hour concentrations after all interventions are implemented are illustrated in Figure 3.8. The 2010 baseline scenario showed an exceedence over the south western boundary as 143ug/Nm^3; while the proposed interventions show that the exceedences actually increase to 145ug/Nm^3 over the same boundary. This is attributable to the constant refining of the emission inventory which is updated twice a year, and does not necessarily mean that these intervention measures are not effective. Before any decisions can be made regarding the effectiveness of the current strategy or the implementation of any other strategy, the calculation of the emission rates for the fugitive emissions and adapting it to the requirements of the updated version of the Lakes Environmental

AERMOD needs to be undertaken which will result in a more realistic scenario being presented.

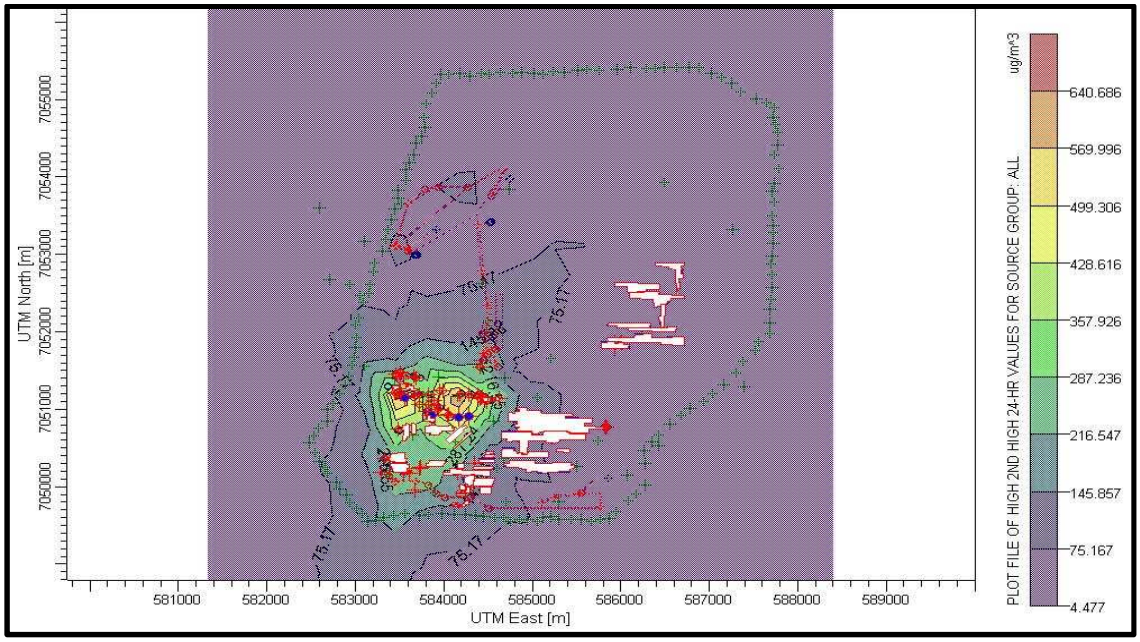


Figure 3.8: Model scenario after implementation of improvements – all interventions 24 hour average

3.1.2.3 Modelled concentrations after implementation of improvements for point sources only

As expected, the point sources, as illustrated in figures 3.9 and 3 10 for the one hour and 24 hour averages respectively, shows very low emission concentrations, similar to what was depicted in the 2010 baseline. This suggests that the point sources are not the major challenge for PM_{10} emissions at the Vanderbijlpark Steel plant. Although it is acknowledged that the use of fixed emission rates for the variable emissions has resulted in overestimation of PM_{10} concentrations, it can still be deduced from the dispersion modelling that point source dust emissions is not the challenge at the plant.

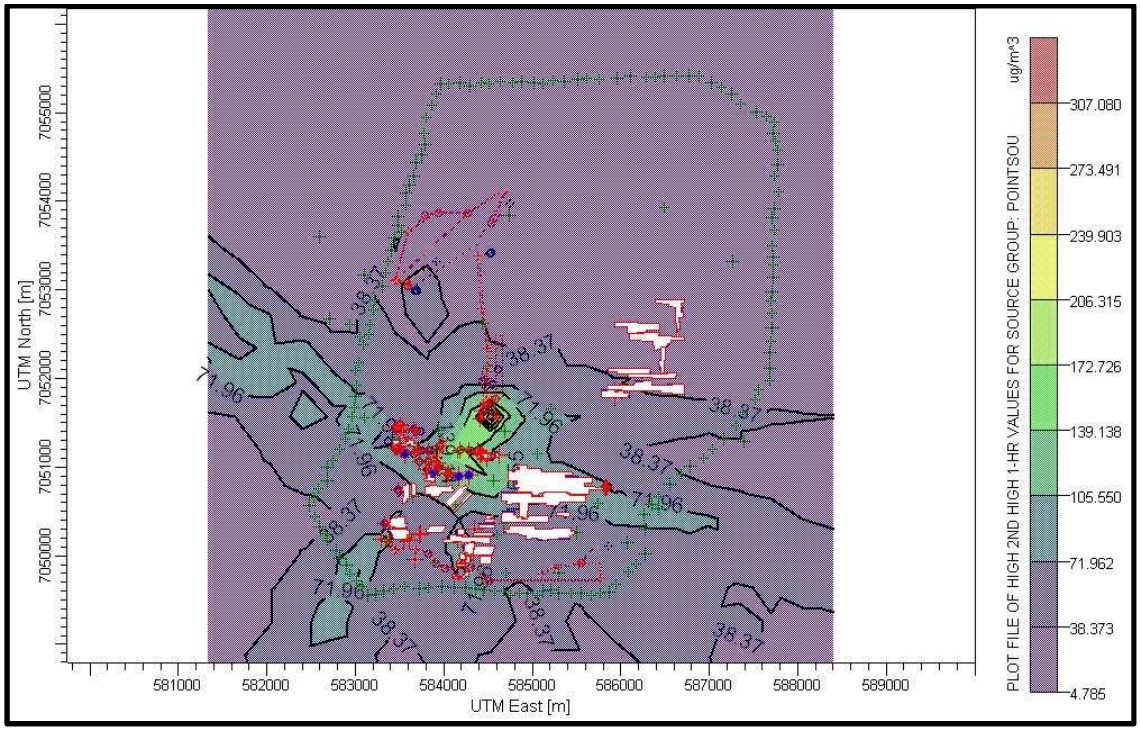


Figure 3.9: Model scenario after implementation of improvements – point source one hour

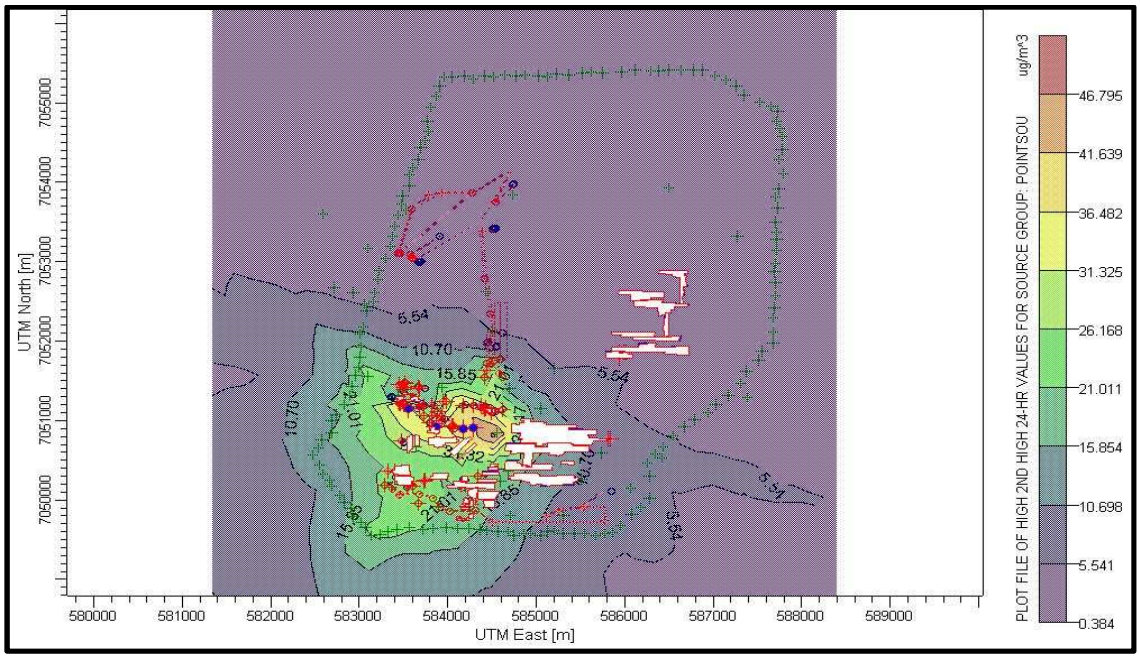


Figure 3.10: Model scenario after implementation of improvements – point source 24 hour

3.1.2.4 Modelled concentrations after implementation of improvements for fugitive sources –one hour average

The one hour concentrations of fugitive emissions after implementing the interventions are illustrated in Figure 3.11. The fugitives, even after implementation of the interventions, are showing exceedences. There are no limit values for one hour concentrations, but exceedences could reach as high as 2019ug/Nm^3.

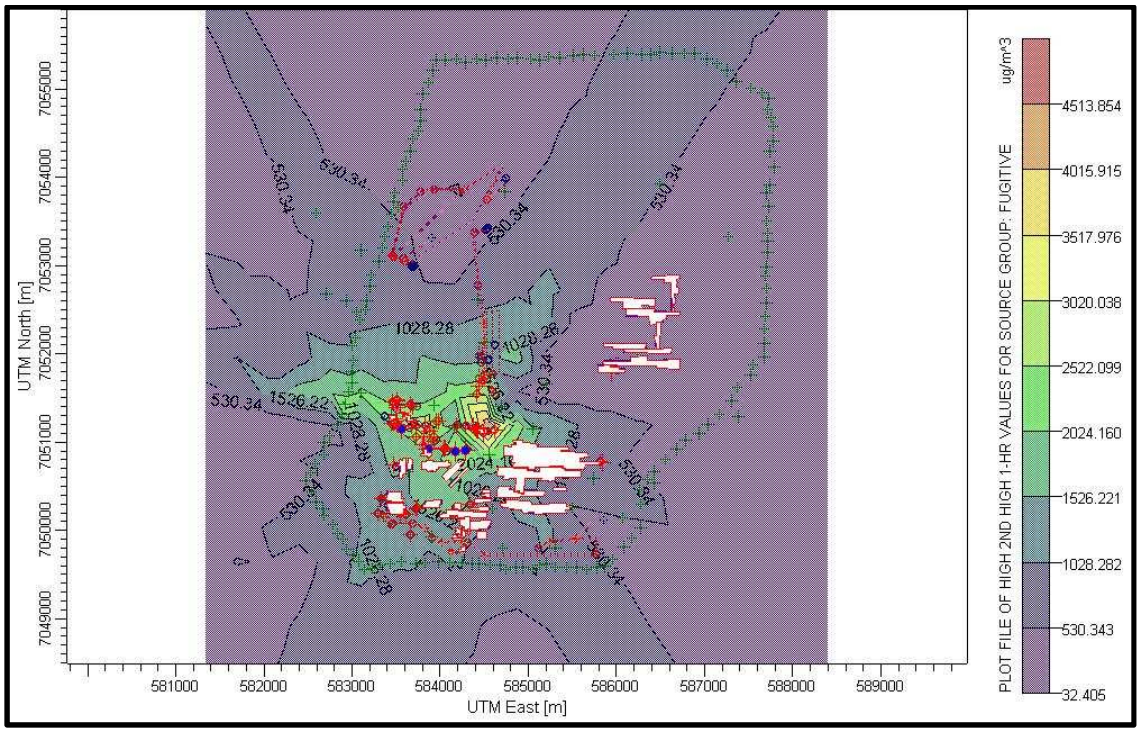


Figure 3.11: Model scenario after implementation of improvements – fugitives one hour

3.1.2.5 Modelled concentrations after implementation of improvements for fugitive sources –24 hour average

The 24 hour concentrations of fugitives after implementation of improvements are illustrated by Figure 3.12. The modelled concentration plotlines for the 24 averages show that exceedences range from as high as 140ug/Nm^3 to about 71ug/m^3 across the modelling domain. The 24 hour average for the VTAPA is 75ug/Nm^3 and while the limit is still being exceeded along the southern boundary, it is not excessively higher than the

average. This scenario clearly demonstrates that the exceedences are mainly confined to the southern boundary fenceline, and that it is the volume and area sources, that is, the fugitive sources of dust which is responsible for exceedences from the plant area.

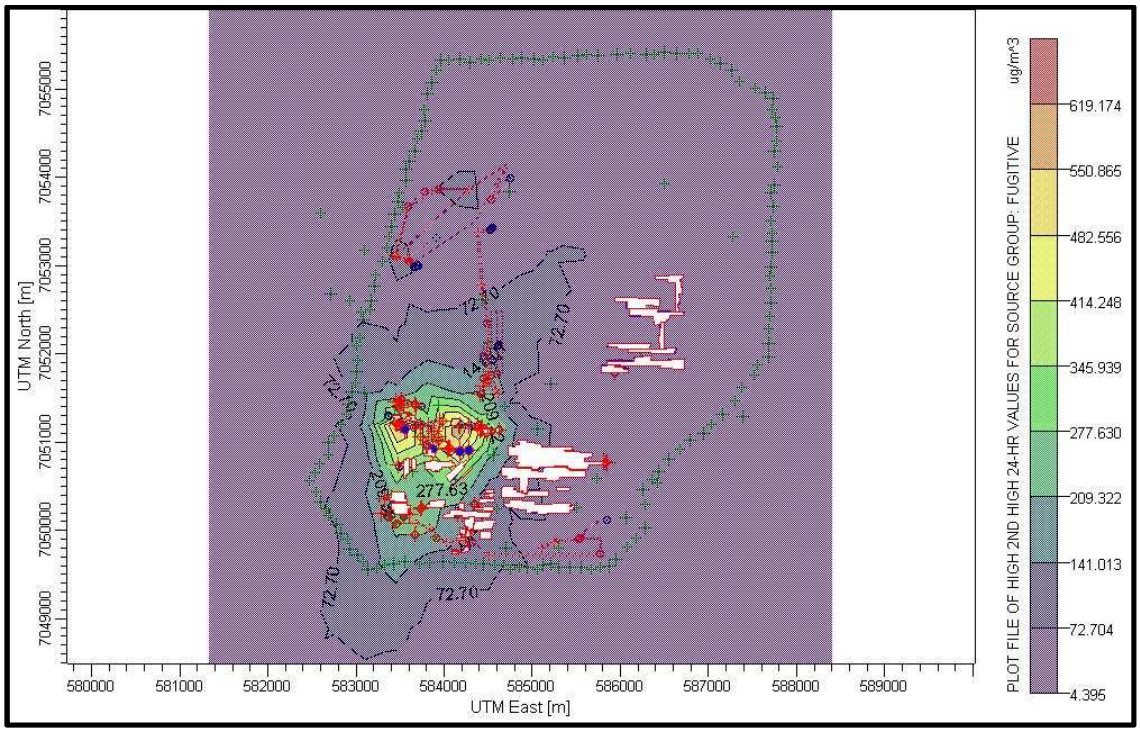


Figure 3.12: Model scenario after implementation of improvements – fugitives 24 hour

3.1.3 Comparison of the modelled results with the measured ambient data

The spread of the 24 hour averages for the whole of 2010 as measured by the ambient stations on the plant is illustrated by Figure 3.13. The measured data shows that ambient PM_{10} could be as high as 200ug/Nm^3 especially during winter months when the lack of rain facilitates the easy entrainment of dust into the atmosphere.

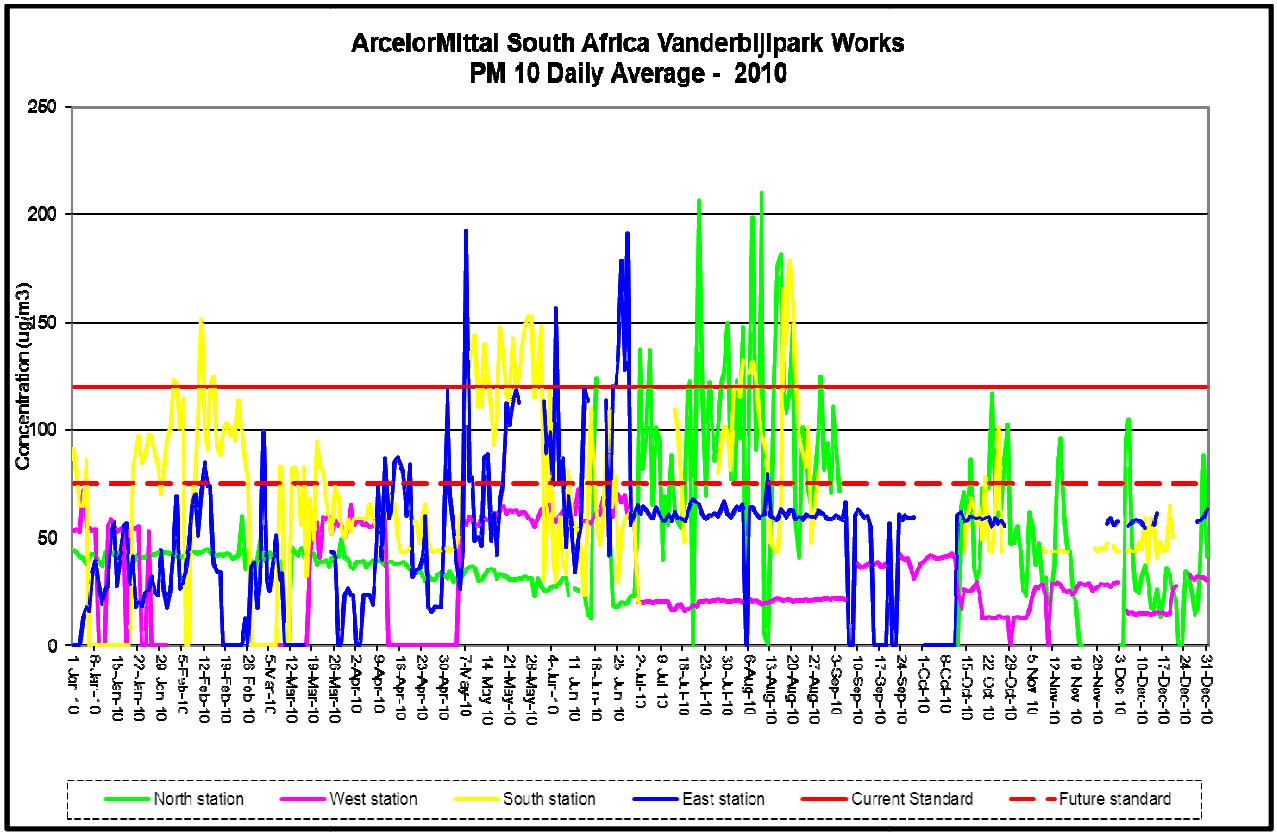


Figure 3.13: Graph showing measured 24 hour average concentrations for 2010 on site.

The modeled scenario after interventions shows that the 24 average concentrations, especially along the southern and western fenceline average at 110ug/Nm^3 (highest concentration 145 ug/Nm^3 and lowest 75ug/Nm^3). The measured 24 hour average for the south station was calculated with a data availability of 64% from the recorded daily average. The calculated average worked out as 77 ug/Nm^3. The difference between the modeled and measured average along the southern fenceline worked out as 33ug/Nm^3. This indicates that the model is overpredicting by 30%.

The overprediction is occurring in the fugitives as the point source modeling has already indicated very low concentrations (see Figure 3.10) with a maximum concentration of 21ug/Nm^3 along the southern boundary, which is far below the average of 77ug/Nm^3. On the other hand, the modeled scenario for fugitives is showing a maximum concentration of 141ug/Nm^3 (see Figure 3.12) compared to a measured average of 77ug/Nm^3.

The over prediction is thus occurring with the fugitives and could be due to the following reasons:

- The use of fixed emission rates:

  Emission rates for fugitive dust sources were generated based on the United States AP42. (Chapter 13.2.5 Industrial Wind Sources). Hourly meteorological data was used to calculate an hourly emission rate for individual sources based on wind speed, particle size and density. The hourly emission values calculated were then averaged out to a single annual average emission rate, which was entered into the AERMOD dispersion model, as the emission rate for the source. Due to the conservative nature of this approach an over-estimation in the model for fugitive sources is identified and noted. A more comprehensive way of deriving the hourly emission rate therefore needs to be developed.

  Currently, with the update of the Lakes Environmental version of the AERMOD dispersion model, the existing methodology of calculating the hourly emissions file which is referred to as the HRY (hourly emission) file, is no longer useable in its current format, as the new version has additional data and parameters required for which information is not available at present (Thé et. al., 2011).

  Each record of line of the HRY file must include the following parameters in the order given below:

  - SO HOUREMIS
  - Year
  - Month
  - Day
  - Hour
  - Source ID
  - Emission Rate (in grams per second)

  For Area and Volume sources the following additional parameters are required, which at this point have not been included in the HRY file generator:

  - Variable Release Height (m)

- Initial Vertical Dimension of the Plume (m) – area Sources
- Initial Lateral Dimension (m) – Volume Sources
- Initial Vertical Dimension (m) – volume sources

- The equation that is used to calculate the emission rate from the wind speed is based on the relationship between wind speed and erosion that is not linear but an exponential log which means that even a slight overestimation of wind speed can have an impact on the emission rates.

- The possibility of errors in the source data for fugitive sources is acknowledged as the data was taken from a previous study without any modifications. Fugitive dust sources are difficult to measure and are extremely variable, but the model requires a constant gas exit velocity from a fugitive source and all particles have been assumed to be in the size fraction of PM_{10} or less than 10 micron in size.

Although the model has been found to be over predicting for reasons already explained, the following positives can be taken form this research report:

- The PM_{10} impacts (exceedences) are largely confined to the areas across the southern fenceline, impacting mainly on the townships of Bophelong and Boipotong.

- The modeling scenarios both before and after the interventions clearly points out that the main source or challenge of PM_{10} emissions is fugitive and hence future planned interventions should focus in this area rather than stack emissions.

Having stated all of the above, it must be noted that the emission rates for fugitives still needs to be more refined and it will be easy to calibrate the modeling as there are on site data available to do this.

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Chapter three described the AERMOD output of predicted concentrations from the stack only, and stack, area and volume sources combined. It also modelled the area and volume sources alone. Comparisons between modelled and monitored concentrations were discussed. The summary and conclusions are provided in chapter four.

CHAPTER FOUR: SUMMARY AND CONCLUSIONS

This chapter concludes the main findings of this study, indicating the reliability of AERMOD to model PM_{10} concentrations from the Vanderbijlpark Works steel plant

The main objective of this study was to determine the impact of an iron and steel plant, the ArcelorMittal Vanderbijlpark Steel Works, in particular, on the ambient PM_{10} levels beyond its fenceline through dispersion modelling using specifically a steady-state Gaussian atmospheric dispersion model called AERMOD.

A second objective was also to assess the impact of the proposed reduction strategy as detailed in the VTAPA AQMP on the ambient PM10 levels. PM_{10} has been identified as a significant pollutant in the VTAPA and The Vanderbijlpark steel plant was identified as a significant emitter of PM10. The ambient air quality limit for PM_{10} for a 24 hour average was set at 75ug/Nm^3.

The Emission Reduction Strategy was submitted in late 2007 to the Department of Environmental Affairs and Tourism as part of the requirement for the implementation of the VTAPA AQMP, and contained short and medium term interventions. Some short term interventions were already implemented by 2010 and hence these reductions became part of the 2010 baseline.

AERMOD was chosen for the dispersion exercise because it is widely accepted as a very reliable tool for short distance modelling especially from industrial or stationary sources.

The sources of PM_{10} at Vanderbijlpark Steel stem from point sources and fugitive emissions. Emission rates for the point sources were obtained from an updated (for 2010) comprehensively compiled emissions inventory. The fugitive sources were more challenging and this basically comprised of dust from the waste dumps and other

stockpiles, fugitive dusts escaping through roofs and other orifices and dust from paved and unpaved roads. An air quality impact assessment was undertaken in 2007 as part of the EIA for the installation of an additional baghouse on the blast furnace D stockhouse. This study used the emission factors from the USEPA AP 42 to compile an inventory for the fugitives which were grouped into volume and area sources, including the paved and unpaved roads. The same information was used for the dispersion scenario presented in this study.

Surface and profile meteorological data was processed using Mesoscale Model 5 (MM5). Onsite meteorological data were gathered from the on-site stations.

The Highveld region is typified by flat terrain and in particular, the study area has no major topographical features located within the immediate vicinity. A flat terrain option was used and no terrain or land use data was used due to the lack of complex terrain.

The modeling scenarios were compared to the measured PM_{10} data from the fence line monitors and it was found that the model generally over predicted concentrations along and over the fence line. What also was quite distinctive was that the fugitive emissions were shown to be the largest contributors to the high concentrations along the fence line.

One hour and 24 hour concentration contours were illustrated and compared to measured data on site. The baseline scenario for 2010 showed very high fenceline concentrations of 143 ug/Nm^3 when compared to the measured average (stations are also situated along the fenceline) of 73.12ug/Nm^3. When the baseline scenario was split between point and fugitive (volume and area) sources, it became evident, despite the overprediction, that point sources are not responsible for high ambient PM_{10} levels. From the modeling results, given the limitations already discussed, the point sources only accounted for about 19% of the ambient concentrations.

It also became evident that the fugitive emissions for the baseline 2010 were being seriously overpredicted due to the large difference between the measured average along the fenceline (43.88ug/Nm^3, highest measured 472ug/Nm^3) and the modeled fenceline concentration of 1122ug/Nm^3. This serious overprediction would also impact the post

intervention scenario as well, as the same fugitive emissions inventory was used to model all interventions.

As a result of the above it was not possible to derive any credible dispersion conclusions from the post intervention scenario as the modeling exercise has shown that there was no improvement in the ambient PM_{10} concentrations after intervention. What further compounded the evaluation of the intervention measures was the fact that a few of the intervention measures were already implemented by 2010 and hence these improvements actually became part of the baseline for 2010. Furthermore, the medium term strategy has been abandoned due to economic reasons and these projected reductions were also left out. A proper evaluation of the intervention measures will only be possible once the issue of the variable emission rates as discussed on pages 69 and 70 has been resolved.

The over prediction can be rectified by refining the method of determining the hourly emission rates which was simply averaged over the year for all volume and area sources. A more comprehensive way of deriving the hourly emission rate therefore needs to be developed. Currently, with the update of the Lakes Environmental version of the AERMOD dispersion model, the existing methodology of calculating the hourly emissions file which is referred to as the HRY (hourly emission) file, is no longer useable in its current format, as the new version has additional data and parameters required for which information is not available at present (Thé et. al., 2011).

Each record of line of the HRY file must include the following parameters in the order given below:

- SO HOUREMIS
- Year
- Month
- Day
- Hour
- Source ID
- Emission Rate (in grams per second)

For Area and Volume sources the following additional parameters are required, which at this point have not been included in the HRY file generator:

- Variable Release Height (m)
- Initial Vertical Dimension of the Plume (m) – area Sources
- Initial Lateral Dimension (m) – Volume Sources
- Initial Vertical Dimension (m) – volume sources

As soon as the HRY has been updated and adapted, the modeling scenarios need to be re-run which should then present a more realistic outcome which should correlate with the measured ambient PM_{10} levels.

The following positives can be taken away from this study. We can say with a high degree of confidence that:

- Point sources is not a significant contributor to the PM_{10} ambient levels at Vanderbijlpark Works;
- The main area of impact is along the southern boundary and more specifically the southern townships that lie on that boundary;
- The HRY files must be adapted for the updated version of the Lakes Environmental AERMOD for any meaningful dispersion modeling in the future for this specific site, and,
- Reduction of fugitive PM_{10} should feature prominently in any future emission reduction plan.

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