*Project done for*

*Zitholele Consulting (Pty) Ltd*

# Duvha Power Station FFP Retrofit Project:

# Air Quality Opinion

**Report No.: APP/11/ZIC-03 Rev 0**

***DATE: July 2011***

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## REPORT DETAILS

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# List of Acronyms and Symbols

| | |
|---|---|
| **AEL** | Atmospheric Emissions License |
| **Airshed** | Airshed Planning Professionals (Pty) Ltd |
| **AWMA** | Air & Waste Management Association |
| **AQA** | Air Quality Act of 2004 |
| **BAT** | Best Available Techniques |
| **ESP** | Electrostatic Precipitator |
| **FFP** | Fabric Filter Plants |
| **IFC** | International Finance Corporation |
| **IPPC** | Integrated Pollution Prevention and Control |
| **NAAQS** | National Ambient Air Quality Standards |
| **$PM_{10}$** | Particulate Matter with an aerodynamic diameter of less than 10$\mu$ |
| **SANS** | South African National Standards |
| **SAWS** | South African Weather Services |
| **tpa** | Tonnes per annum |
| **US** | United States |
| **US.EPA** | United States Environmental Protection Agency |

# 1 Introduction

Duvha Power Station, located near eMalahleni in Mpumalanga (Figure 1), plans to retrofit Unit 4 with a fabric filter plant (FFP) utilizing pulse jet technology. The power station currently operates six units emitting through two 300 m high stacks. Units 1, 2 and 3 have already been retrofitted with FFPs but Units 4, 5 and 6 still have Electrostatic Precipitators (ESPs).

Airshed Planning Professionals (Pty) Ltd was appointed by Zitholele Consulting to determine the improvement in particulate emissions and resulting ground level concentrations from retrofitting Unit 4 at the Duvha Power Station. The scope of work is for an air quality impact opinion, including the following tasks:

- Review the two technologies under discussion;
- Indicate the relation of the chosen technology to world-wide best practise;
- Comment on the effectiveness of $PM_{10}$ emission reduction using the chosen technology; and
- Rate the potential reduction in $PM_{10}$ using the impact methodology provided by Zitholele.

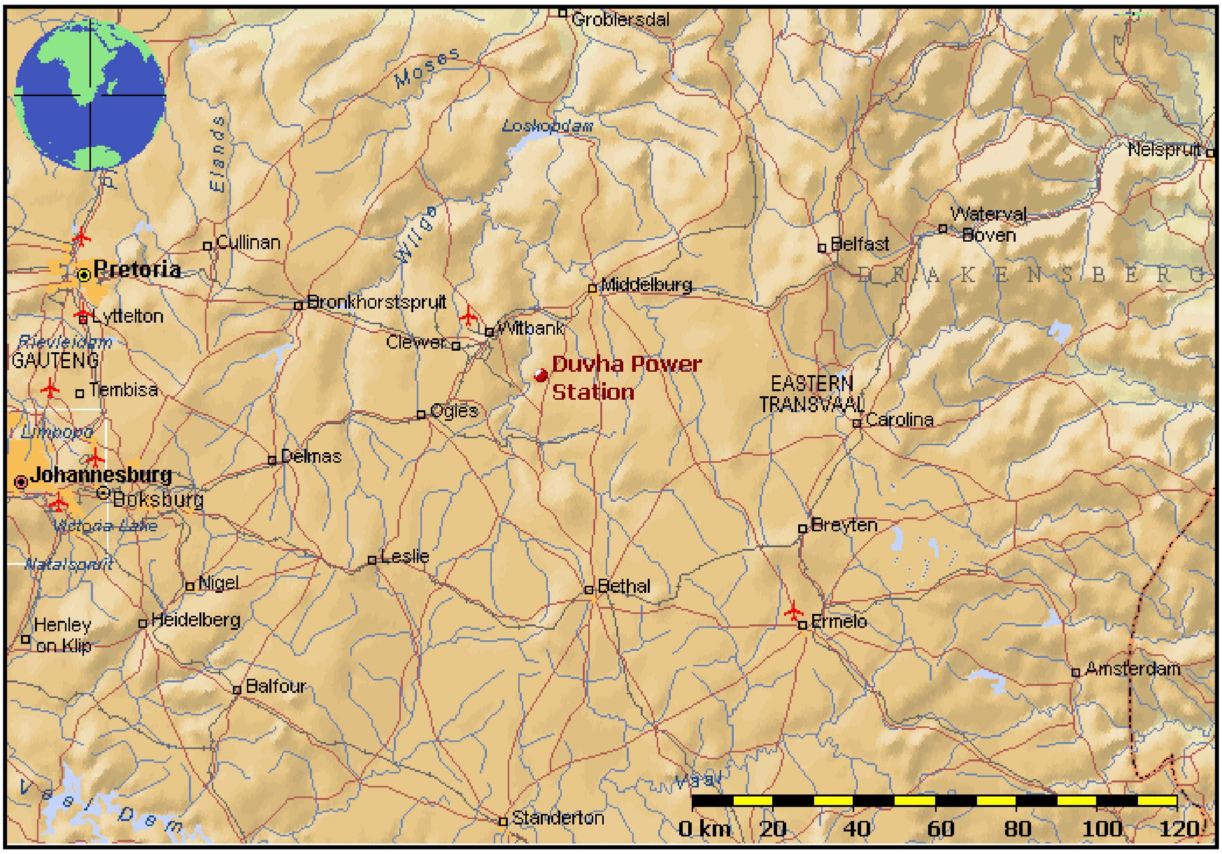


**Figure 1. Location of Duvha Power Station, Mpumalanga.**

With the new technology applicable to particulate emissions only, no other pollutants associated with coal fired power generation are investigated.

## 1.1 Methodology

The study followed a semi-quantitative approach, using available meteorological data and typical pollutants associated with the proposed activities to evaluate the potential for off-site impacts.

The technology review includes the evaluation of the two technology options as provided by Eskom. The design specifications are compared to the required emission limits as per the National Listed Activities and Minimum Emission Standards. Based on the scope of work, no detailed review could be conducted and the findings are based on a literature review only.

The effectiveness of the proposed technology is evaluated through a dispersion modelling screening exercise. The US Environmental Protection Agency's (US EPA) approved regulatory model (AERMOD) is used to quantify ambient air concentrations from the power station operations. This is done for both the baseline situation (i.e. current operating conditions) and future scenario (i.e. with Unit 4 retrofitted with FFP). Since this is not a comprehensive air quality impact assessment, only Duvha Power Station Stacks are included for evaluation with no background sources considered. The sources parameters (i.e. stack heights, stack diameters, exit velocity, temperature and emission rates) were provided by Eskom personnel.

Whereas source strengths determine the amount of pollution emitted to atmosphere, local meteorological conditions determine the dispersion and eventual removal of pollutants from the atmosphere. The influence of the local meteorology is assessed based on available data as obtained from the South African Weather Services station at eMalahleni airfield for the period 2008 to 2010. The most important parameters include wind direction, wind speed, ambient temperature, atmospheric stability and mixing depth. Although the wind field and temperature regime are routinely measured, mixing depths and atmospheric stabilities are not and need to be calculated based on measured parameters, e.g. solar radiation and temperature. Daytime and night-time mixing heights are calculated using prognostic equations and various diagnostic approaches, respectively. The hourly standard deviation of wind direction, wind speed and solar radiation are used to determine hourly-average stability classes.

Finally, the results are used to evaluate the significance, spatial scale, temporal scale, probability and degree of certainty of the proposed project. The methodology as provided by Zitholele is used.

## 1.2 Report Outline

Section 2 of the report provides an overview of the current Air Quality legislation with the wind field and regional meteorology around eMalahleni described in Section 3. Section 4 includes the basic technology review, emission and impact evaluation and assessment rating with the conclusions summarised in Section 5. The references are provided in Section 6.

# 2 Legal Overview

The National Environmental Management Air Quality Act (NEMAQA) has shifted the approach of air quality management from source-based control to the control of the receiving environment. The act has also placed the responsibility of air quality management on the shoulders of local authorities that will be tasked with baseline characterisation, management and operation of ambient monitoring networks, licensing of listed activities, and emissions reduction strategies. The main objective of the act is to ensure the protection of the environment and human health through reasonable measures of air pollution control within the sustainable (economic, social and ecological) development framework.

NEMAQA commenced on the 11th of September 2005[1] with the exclusion of the sections pertaining to the listing of activities and the issuing of atmospheric emissions licences. Listed Activities and associated Minimum Emission Standards were published in the Government Gazette on the 31st of March 2010 (No. 33064) as Section 21 of the AQA. The Atmospheric Pollution Prevention Act (APPA) of 1965 was repealed on the 1st of April 2010 bringing NEMAQA into full force.

According the to the Air Quality Act, air quality management control and enforcement is in the hands of local government with District and Metropolitan Municipalities as the licensing authorities. Provincial government is primarily responsible for ambient monitoring and ensuring municipalities fulfil their legal obligations, with national government primarily a policy maker and co-ordinator. Each sphere of government must appoint an Air Quality Officer responsible for co-ordinating matters pertaining to air quality management. Given that air quality management under the old Act was the sole responsibility of national government, local authorities have in the past only been responsible for smoke and vehicle tailpipe emission control.

## 2.1 Listed Activities and Minimum Emissions Standards

Power Generation was a Scheduled Process under the Atmospheric Pollution Prevention Act of 1965 (Process 29) and a Listed Activity under the NEM Air Quality Act of 2004 (AQA). Thus minimum national emission limits have been developed for Combustion Installations with a design capacity of more than or equal to 50 MW heat input. All existing and new applications are subject to a new Atmospheric Emissions License (AEL). This license requires provision of all sources of pollution from a Listed Activity facility, including point and non-point emissions. The Listed Activities and Associated Minimum Emission Standards were published in terms of Section 21 of the NEM Air Quality Act on the 31st of March 2010 (Government Gazette No. 33064).

[1] The National Environmental Management: Air Quality Act (Act no.39 of 2004) commenced with on the 11th of September 2005 as published in the Government Gazette on the 9th of September 2005. Sections omitted from the implementation are Sections 21, 22, 36 to 49, 51(1)(e),51(1)(f), 51(3),60 and 61.

Table 1 provides the requirements as set out in the published Listed Activities and Associated Minimum Emission Standards for Combustion Installations (31 March 2010). Note that "New plant" relates per definition to all installations applying for authorisation after the final publication of these regulations. "Existing plant" include operations legally authorised to commence before the publication of the Listed Activities and Associated Minimum Emission Standards. "New Plants" must comply with the minimum emissions standards on the date of publication of the Listed Activities and Minimum Emission Standards. "Existing plants" are granted five years to comply with the existing plant standards and another five to comply with "new plant" standards.

The minimum emission standards apply to normal operating conditions. Should normal start-up, maintenance, upset and shut-down conditions exceed a period of 48 hours, Section 30 of NEMA (as amended) shall apply unless otherwise stipulated by the Licensing Authority.

Additional requirements, as set out in the published Section 21 include specific requirements for continuous monitoring, include:

- The averaging period for the purposes of compliance monitoring is one calendar month.
- The emissions monitoring system must be maintained to yield a minimum of 80% valid hourly average values during the reporting period.
- No more than five half-hourly average values in any day, and ten daily average values per year, may be disregarded due to malfunction or maintenance.
- Continuous monitoring systems must be audited by a SANAS accredited laboratory at least once every two years.

**Table 1: Section 1 on Combustion Installations, Subcategory 1.1. Solid Fuel Combustion Installations**

| **Description:** | Solid fuels (excluding biomass) combustion installations used primarily for steam raising or electricity generation | | |
|---|---|---|---|
| **Application:** | All installations with design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used | | |
| **Substance or mixture of substances** | | **Plant status** | **Mg/Nm³ under normal condition of 10% $O_3$, 273 K and 101.3 kPa** |
| **Common name** | **Chemical symbol** | | |
| Particulate matter | N.A. | New | 50 |
| | | Existing | 100 |
| Sulphur dioxide | $SO_2$ | New | 500 |
| | | Existing | 3 500 |
| Oxides of nitrogen | NOx expressed as $NO_2$ | New | 750 |
| | | Existing | 1 100 |
| (a) The following special agreement shall apply:<br>a. Continuous monitoring of PM, $SO_2$ and NOx is required | | | |

Specific requirements for reporting include:

- The Atmospheric Emissions License holder must submit an emission report annually.

- The report must be in the format as stipulated under 8.2 of the Section 21 notice.
- Reporting on continuous emission monitoring must include:
    - Results of the spot measurements or correlation tests carried out to verify the accuracy of continuous emissions measurements;.
    - The most recent correlation tests; and,
    - The availability of the system must be maintained to yield a minimum of 80% valid hourly average values during the reporting period.
- Report on all instances where minimum emission standards were exceeded, why this happened and how it was rectified.

## 2.2 Ambient Air Quality Standards

The National Framework provided a stepped approach in setting ambient air quality standards. Based on this the standard for a specific pollutant must include limit values for specific exposures, the number of allowed exceedances and a timetable for compliance. The limit values (concentrations) are based on scientific evidence. National Ambient Air Quality Standards (NAAQS) were determined based on international best practice for particulate matter less than 10 µm in aerodynamic diameter ($PM_{10}$), dustfall, sulphur dioxide, nitrogen dioxide, ozone, carbon monoxide, lead and benzene. These standards were published for comment in the Government Gazette on 9 June 2007 with the new standards, which include frequency of exceedance and implementation timeframes, published on the 24th of December 2009 (*Government Gazette 32816*).

With the focus of the current study being on particulates, only the standards for $PM_{10}$ are listed in Table 2.

**Table 2: National ambient air quality standards for $PM_{10}$**

| Pollutant | Averaging Period | Limit Value (µg/m³) | Frequency of Exceedance | Compliance Date |
|---|---|---|---|---|
| **$PM_{10}$** | 24 hour | 120 | 4 | Immediate – 31 Dec 2014 |
| | 24 hour | 75 | 4 | 1 Jan 2015 |
| | 1 year | 50 | 0 | Immediate – 31 Dec 2014 |
| | 1 year | 40 | 0 | 1 Jan 2015 |

# 3 Regional Climate and Atmospheric Dispersion Potential

The meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction and the variability in wind direction, determine the general path pollutants will follow, and the extent of cross-wind spreading (Shaw and Munn, 1971; Pasquill and Smith, 1983; Oke, 1990).

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. Spatial variations, and diurnal and seasonal changes in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales (Goldreich and Tyson, 1988). Atmospheric processes at macro- and meso-scales must be accounted for to accurately parameterise the atmospheric dispersion potential of a particular area. A qualitative description of the synoptic climatology of the study region is provided based on a review of the pertinent literature. The analysis of meteorological data observed for the proposed site, where available, and data for neighbouring sites will provide the basis for the parameterisation of the meso-scale ventilation potential of the site.

The analysis of at least one year of hourly average meteorological data for the study site is required to facilitate a reasonable understanding of the ventilation potential of the site. The most important meteorological parameters to be considered are: wind speed, wind direction, ambient temperature, atmospheric stability and mixing depth. Atmospheric stability and mixing depths are not routinely recorded and frequently need to be calculated from diagnostic approaches and prognostic equations, using as a basis routinely measured data, e.g. temperature, predicted solar radiation and wind speed.

With the Duvha Power Station located approximately 16 km southeast of eMalahleni, the SAWS data for this site are considered suitable for the air quality evaluation. Data for the period 1 January 2008 to 31 December 2010 were available for use in the study.

## 3.1 Local wind field

Figure 2 provides period wind roses for eMalahleni, with Figure 3 including the seasonal wind roses for the same site.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflected the different categories of wind speeds; the blue area for example, representing winds of 1 m/s to 2 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The figure given for calm conditions represents the frequency with which the calms occurred, i.e. periods during which the wind speed was below 1 m/s.

The eMalahleni period wind roses (Figure 2) depict the predominance of the northerly, easterly and east-southeasterly winds with wind speeds of greater than 5 m/s, especially during the day. The night-time wind rose shows a decrease in the northerly and the north-westerly winds and an increase in the easterly and east-southeasterly winds. The night time is also characterised by an increase in the frequency of calm conditions.

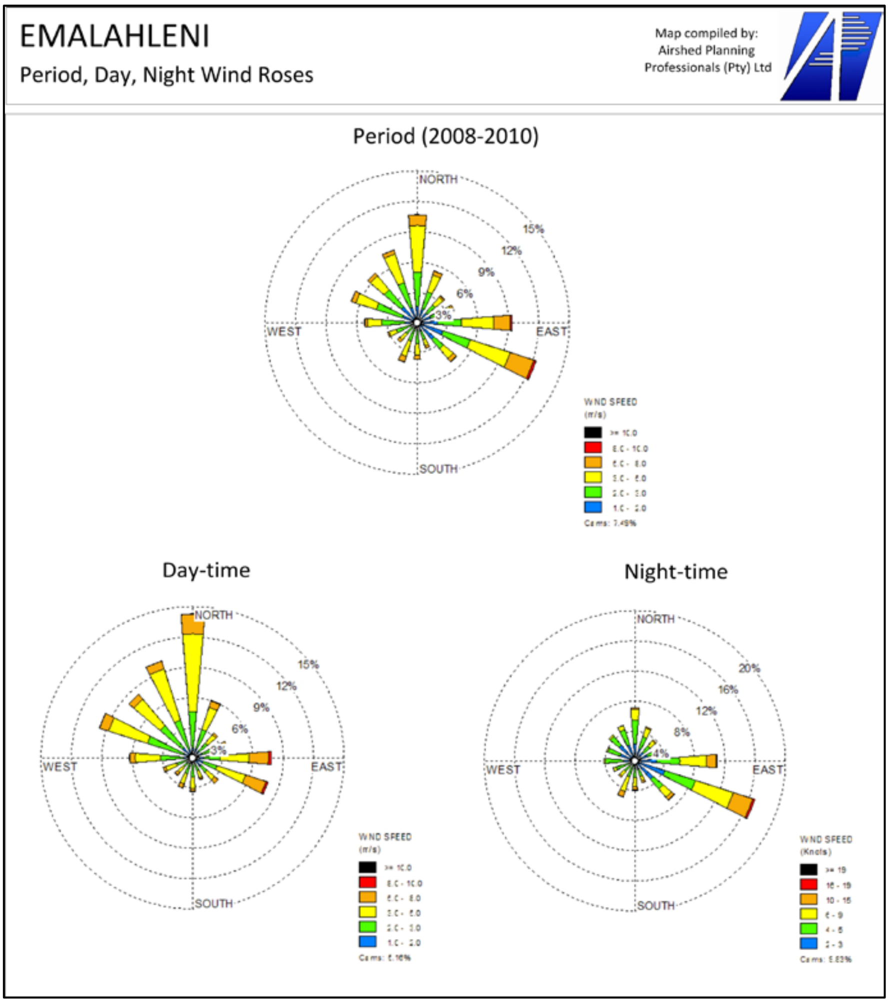


**Figure 2: Period, day-time and night-time wind roses for eMalahleni (2008 - 2010).**

An increase in the frequency of northerly winds during summer months (December to February) reflects the influence of the predominant high pressure system over the Highveld (Figure 3). Autumn and winter months are associated with a greater frequency of calm wind conditions, with the smallest number of calms occurring during spring.

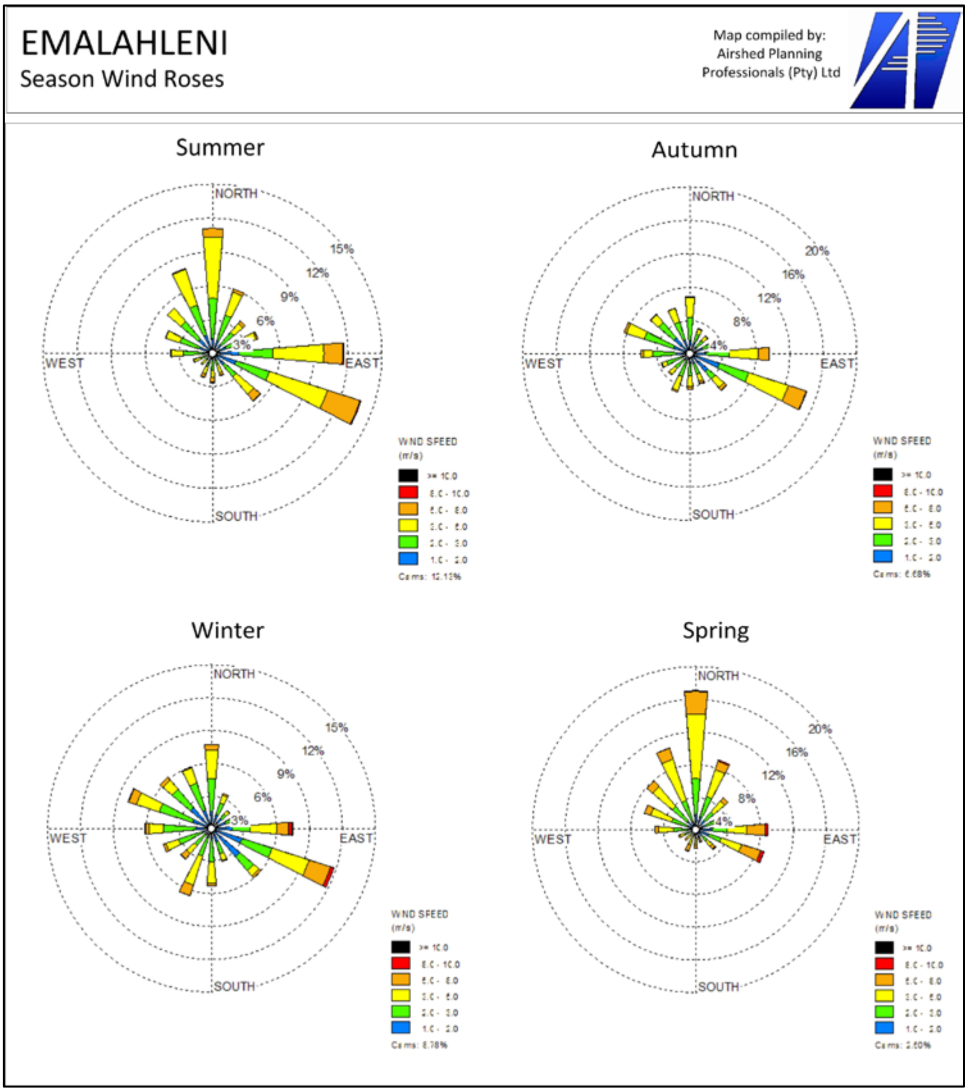


**Figure 3: Seasonal wind roses for eMalahleni (2008 - 2010).**

## 3.2 Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere. This layer is directly affected by the earth's surface, either through the retardation of flow due to the frictional drag of the earth's surface, or as result of the heat and moisture exchanges that take place at the surface. During the daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface and the extension of the mixing layer to the lowest elevated inversion. Radiative flux divergence during the night usually results in the establishment of ground-based inversions and the erosion of the mixing layer. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer ranges in depth from a few metres (i.e. stable or neutral layers) during nighttimes to the base of the lowest-level elevated inversion during unstable, daytime conditions. Elevated inversions may occur for a variety of reasons and on some occasions as many as five may occur in the first 1 000 m above the surface. The lowest-level elevated inversion is located at a mean height above ground of 1 550 m during winter months with a 78 % frequency of occurrence. By contrast, the mean summer subsidence inversion occurs at 2 600 m with a 40% frequency.

Atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 3.

**Table 3: Atmospheric stability classes**

| | | |
|---|---|---|
| **A** | very unstable | calm wind, clear skies, hot daytime conditions |
| **B** | moderately unstable | clear skies, daytime conditions |
| **C** | unstable | moderate wind, slightly overcast daytime conditions |
| **D** | neutral | high winds or cloudy days and nights |
| **E** | stable | moderate wind, slightly overcast night-time conditions |
| **F** | very stable | low winds, clear skies, cold night-time conditions |

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. During the night, a stable layer with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

For elevated releases such as stack emissions, the highest ground level concentrations will occur during unstable, daytime conditions. Ground level concentrations depend on a combination of wind speed and plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to the increased ventilation, it will be more diluted. A wind speed between these extremes will therefore be responsible for the highest ground level concentrations.

# 4 Technology Review and Evaluation

## 4.1 Proposed FFP Technology

Primary kinds of particulate control used for coal combustion, according to the Air Pollution Engineering Manual (AWMA, 2000), include multiple cyclones, ESPs, fabric filters and venture scrubbers. The type of technology is guided by the type of furnace, coal properties and operating conditions. In the USA, ESPs were the preferred technology for emissions control in the 1970's. Due to significant progress in the recent years in the design and operation of fabric filter collectors, specifically for the collection of coal fly ash, these have become more popular for use in coal fire power stations (AWMA, 2000).

Whereas ESPs remove particles from the gas stream through electrical forces, fabric filters remove dust by passing the gas stream through porous fabric. The affectivity of dust removal by bag filters is dependent on the design parameters. Bag filter designs are usually either reverse-air or pulse-jet types. The latter, as the option considered by Eskom, removes the particles by sending a pulsed jet of compressed air into the bag, resulting in an effective way of cleaning (AWMA, 2000).

Bag filters in general, have a higher removal efficiency for fine, submicrometer particles than ESPs (AWMA, 2000).

According to the information provided by Eskom, the coal used at Duvha Power Station has high ash content and lower sulphur content. The design of the ESPs at the power station is such that it cannot limit the particulate matter emissions to less than 100 – 150 mg/Nm³ on a constant basis The FFP is given to limit emissions to 40 mg/Nm³.

## 4.2 Relation of FFP to World-Wide Best Practice

Best Available Techniques (BAT) according to the Integrated Pollution Prevention and Control (IPPC, 2004) on Large Combustion Plants includes either ESPs of FFPs. It states that particulate emission control of less than 20 mg/Nm³ can be achieved for coal and lignite plants of more than 300 $MW_{th}$ through ESPs and/ or FFPs.

The IPPC confirms that FFPs achieve higher control efficiencies on the removal of small particles (i.e. 99.6% on particles <1 µm) than ESPs (i.e. 96.5% on particles <1 µm). Both technology options can achieve 99.95% removal of particles larger than 10 µm (IPPC, 2004).

The World Bank emission limits for Boilers (Solid Fuels Plant >/=600 MWth) in degraded areas is 30 mg/Nm³ (IFC, 2008). The South African Minimum Emission Limits are however based on international best practice and applied. The FFP should therefore achieved as a minimum, 50 mg/Nm³.

## 4.3 Effectiveness of FFP to reduce $PM_{10}$

### *4.3.1 $PM_{10}$ Emissions*

The emission information as supplied by Eskom is listed in Table 3. The emission concentration for the ESPs are based on particulate emission monitoring and control conducted on Units 4, 5 and 6. The FFP Retrofit Works Information Specification informed the emission limit for the FFPs.

**Table 4: Stack parameters and emissions concentrations for the six units at Duvha Power Station**

<table>
<tr><th>Stack Height (m)</th><th>No. of stacks</th><th>Stack diameter (m)</th><th>Average Stack Temperature (°C)</th><th>Volumetric Flow Rate ($Am^3/hr$)</th><th>Stack Exit Velocity (m/s</th></tr>
<tr><td>300</td><td>2</td><td>6.15 [a]<br>20.5 [b]</td><td>147.7</td><td>5 644 080</td><td>17.59 [c]</td></tr>
<tr><th colspan="2">$PM_{10}$ Emission Concentration with ESP ($mg/Nm^3$)</th><th colspan="2">$PM_{10}$ Emission Concentration with FFP ($mg/Nm^3$)</th><th>$PM_{10}$ Emission Rate with ESP (g/s)</th><th>$PM_{10}$ Emission Rate with FFP (g/s)</th></tr>
<tr><td colspan="2">75</td><td colspan="2">40</td><td>76.32</td><td>40.70</td></tr>
</table>

**Notes:**

[a] Inside diameter of flue.
[b] Outer diameter of chimney windshield.
[c] Calculated.

At present Units 1, 2 and 3 are fitted with FFP whereas Units 4, 5 and 6 still have ESPs. The total tonnes of $PM_{10}$ per annum emitted from the current operations at Duvha Power Station is 3 690.36. With the retrofitting of Unit 4 with FFP, the total $PM_{10}$ emission will be 3 315.98 tpa, thus resulting in a 10% reduction in the overall $PM_{10}$ emissions.

When compared to the national minimum emission limits for $PM_{10}$ from Combustion Installations, the ESP emission concentration of 75 $mg/Nm^3$ coal fired power stations complies with the limit of 100 $mg/Nm^3$ for existing plants but not with the limit of 50 $mg/Nm^3$ applicable to new plant (Emission Limits are provided in Table 1). The FFP emission concentration of 40 $mg/Nm^3$ does however comply with both limits.

### *4.3.2 Predicted $PM_{10}$ Impacts*

Predicted $PM_{10}$ ground level concentrations from the operations at Duvha is reflected in Figure 4. The plots shows the same ground level concentration of 0.5 $\mu g/m^3$ for highest daily averages, for the current situation (i.e. Units 1-3 with FFP and Units 4-6 with ESP) and the future scenario (i.e. Units 1-

4 with FFP and Units 5-6 with ESP). From this these predicted impacts the following can be concluded:

- Predicted $PM_{10}$ ground level concentrations for highest daily averages are very low for both the current situation and the future scenario, falling well within the NAAQS of 75 µg/m³ (Table 2).
- By retrofitting Unit 4 with a FFP, the spatial impact on the surrounding environment will decrease.

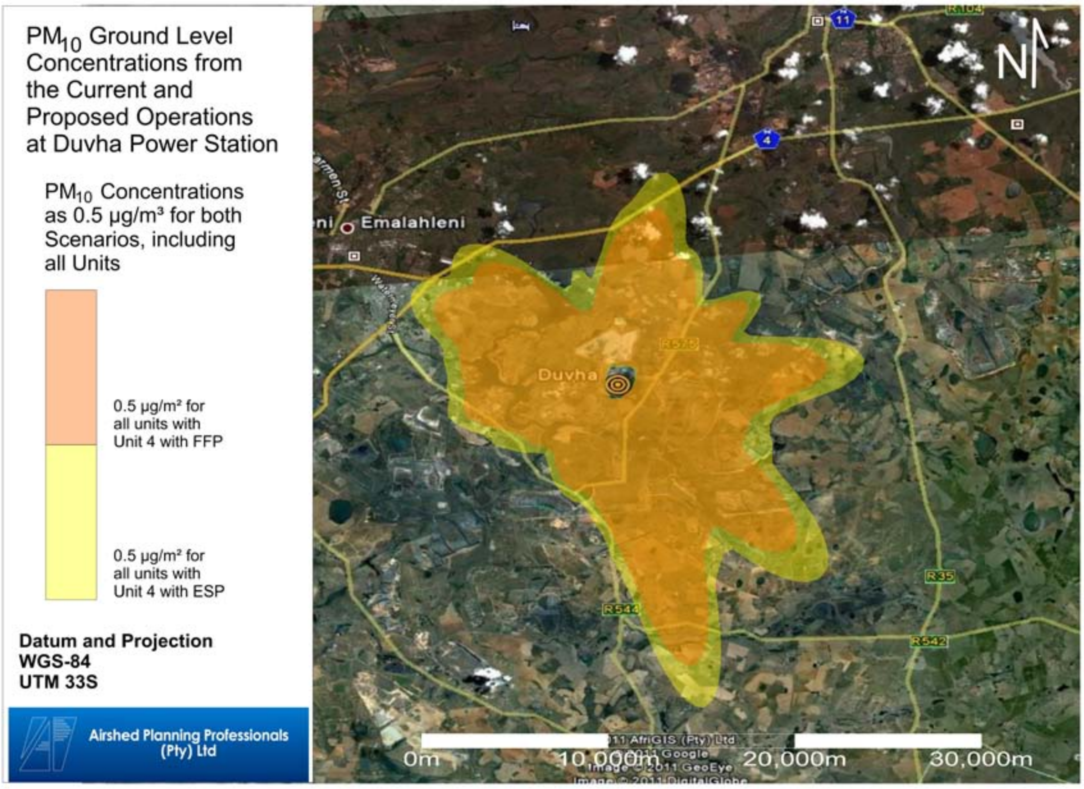


**Figure 4: Predicted highest daily ground level $PM_{10}$ concentrations from Duvha Power Station for both the current situation and the future scenario.**

## 4.4 Impact Assessment

Based on the quantitative evaluation of the effectiveness of $PM_{10}$ emission reduction of the proposed technology, the significance of the potential reduction in $PM_{10}$ is summarised in Table 5.

Based on the impact ratings, the overall risk can be regarded as VERY LOW for both the current situation and the future scenario.

**Table 5: Air Quality Impact Assessment.**

| Scenario | Impact Class | Significance | Spatial Scale | Duration Scale | Degree of Probability | Degree of Certainty |
|---|---|---|---|---|---|---|
| *Current Situation* (Units 1-3 with FFP and Units 4-6 with ESP) | 1 | Very Low | Study Area | Medium term | Unlikely[(a)] | Probable |
| *Future Scenario* (Units 1-4 with FFP and Units 5-6 with ESP) | 1 | Very Low | Study Area | Medium term | Unlikely[(a)] | Probable |

**Notes:**

[(a)] Based on the efficiency of the control equipment and not accounting for upset conditions or accidental releases.

# 5 Conclusion

In conclusion, the proposed FFP technology option will result in an overall 10% reduction in particulate emissions from the Duvha Power Station. It will also reduce the already low $PM_{10}$ ground level concentrations further. The overall assessment ranking for the proposed technology option is VERY LOW.

It is indicated that the FFP design that will be installed at Unit 4 will achieve 40 mg/Nm³ particulate emission concentration. This is well below the National Minimum Emission Limit for new plants of 50 mg/Nm³.

## 5.1 Recommendation

Based on the design specifications provided for the FFP of 40 mg/Nm³ particulate emission concentration. It is recommended that Unit 4 at Duvha Power Station be retrofitted with this technology.

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