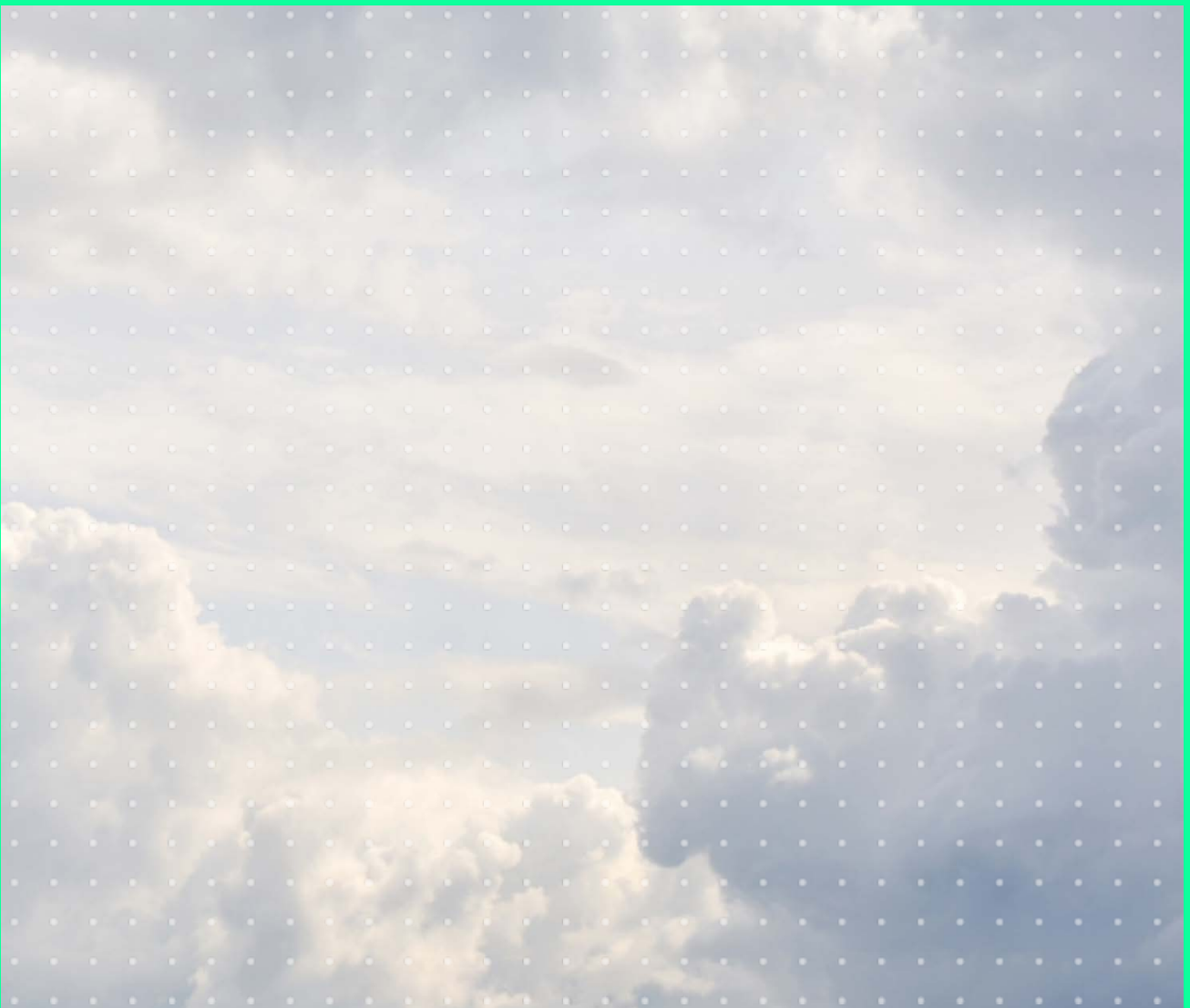Environment Protection Authority

# Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales

# Contents

# List of tables

# 1. Introduction

## 1.1. Objective

This document, the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (Approved Methods), lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources in the State. It is referred to in Part 5: Air Impurities Emitted from Activities and Plant in the *Protection of the Environment Operations (Clean Air) Regulation 2021* (the Regulation). Industry has an obligation to ensure compliance with the requirements specified in the Regulation.

This document may also be referred to in conditions attached to statutory instruments, such as:

- licences or notices issued under the *Protection of the Environment Operations Act 1997*
- environmental assessment requirements under Part 4 of the *Environmental Planning and Assessment Act 1979*.

The procedures and methodologies contained in this document will undergo regular review, coinciding with the five-yearly review of the Regulation required by the *Subordinate Legislation Act 1989*.

## 1.2. Overview

This document covers:

- preparation of emissions inventory data
- preparation of meteorological data
- methods for accounting for background concentrations and dealing with elevated background concentrations
- dispersion modelling methodology
- interpretation of dispersion modelling results
- impact assessment criteria for
  - sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), lead (Pb), $PM_{2.5}$, $PM_{10}$, total suspended particulates (TSP), deposited dust, carbon monoxide (CO) and hydrogen fluoride (HF)
  - individual and complex mixtures of toxic air pollutants
  - individual and complex mixtures of odorous air pollutants
- modelling of chemical transformation
- procedures for developing site-specific emission limits, including hydrogen sulfide as specified in clause 43 of the Regulation as amended
- worked examples.

# 2. Methodology overview

## 2.1. Different levels of assessment

The two levels of impact assessment are:

- Level 1 – screening-level dispersion modelling technique using worst-case input data
- Level 2 – refined dispersion modelling technique using site-specific input data.

The impact assessment levels are designed so that the impact estimates from the second level should be more accurate than the first. This means that, for a given facility, the result of a Level 1 impact assessment would be more conservative and less specific than the result of a Level 2 assessment. It is not intended that an assessment should routinely progress through the two levels. If air quality impact is considered to be a significant issue, there is no impediment to immediately conducting a Level 2 assessment. Equally, if a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2.

## 2.2. Impact assessment methodology

There are five main stages in an air quality impact assessment:

1. input data collection
2. dispersion modelling
3. processing dispersion model output data
4. interpretation of dispersion modelling results
5. preparation of an impact assessment report.

### 2.2.1. Input data collection

The first stage in the impact assessment is the collection of all the information required to complete the dispersion modelling. This includes development of an air emissions inventory and compilation of meteorological data, background air quality data and terrain data. Sections 3, 4 and 5 of these Approved Methods detail the EPA's requirements regarding the air quality impact assessment input data.

The development of the emissions inventory is one of the most important components of the impact assessment process. The inventory provides detailed information about all sources of air pollution at a premises. Emissions from the premises must be demonstrated to comply with the requirements of the Regulation before progressing through the other stages of the air quality impact assessment.

### 2.2.2. Dispersion modelling

AUSPLUME v. 6.0 is the approved dispersion model for use in most applications in NSW. However, it is not approved in some applications where other more advanced dispersion models, such as CALPUFF and TAPM, may be more appropriate. The dispersion model input file should be prepared in accordance with the requirements of Section 6 of these Approved Methods and using the data collected in stage 1 of the impact assessment.

### 2.2.3. Processing dispersion model output data

Stage 3 of the assessment process is the prediction of ground-level concentrations (glcs) of pollutants in the region surrounding the premises. The predicted glcs of all pollutants must be in the same units and for the same averaging period as the relevant impact assessment criteria. The

EPA's impact assessment criteria, together with the requirements regarding the presentation of the predicted glcs, are specified in Section 7.6.

## 2.2.4. Interpretation of dispersion modelling results

Stage 4 of the impact assessment is the interpretation of the dispersion modelling results. The predicted glcs are compared with the EPA's impact assessment criteria and compliance indicates the proposal is unlikely to result in adverse air quality impacts.

If a premises does not comply with the impact assessment criteria, the assessment must be revised to incorporate additional control or mitigation measures. To determine incremental increases in the cost of air pollution abatement, a sensitivity analysis can be carried out by varying:

- source release parameters
- separation distance
- efficiency of pollution control equipment
- level of management practice.

The results can be used to select the most cost-effective and environmentally effective control strategy.

## 2.2.5. Preparation of an impact assessment report

Stage 5 of the impact assessment is the preparation of a report. The air quality impact assessment report must be prepared in accordance with the requirements specified in Section 9 of these Approved Methods.

## 2.3. Bibliography

Earth Tech 2000, *A User's Guide for the CALPUFF Dispersion Model (Version 5)*, Earth Tech Incorporated, Long Beach CA, USA.

Earth Tech 2000, *A User's Guide for the CALMET Meteorological Model (Version 5)*, Earth Tech Incorporated, Long Beach CA, USA.

EPA Victoria 1985, *Plume Calculation Procedure: An Approved Procedure under Schedule E of State Environment Protection Policy (The Air Environment)*, Publication 210, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1986, *The AUSPLUME Gaussian Plume Dispersion Model*, First Edition, Publication 264, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1999, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Publication 671, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 2000, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Environment Protection Authority of Victoria, Melbourne.

Hurley, P. 2005, *The Air Pollution Model (TAPM) Version 3: User Manual*, CSIRO Atmospheric Research Technical Paper No. 31, CSIRO Division of Atmospheric Research, Melbourne.

USEPA 1999, *Guideline on Air Quality Models*, 40 CFR, Chapter I, Part 51, Appendix W, United States Environmental Protection Agency, Washington DC, USA.

# 3. Emissions inventory

The emissions inventory is the foundation of the air quality impact assessment. Developing a sound emissions inventory should be a priority task and requires the collation of a significant amount of data. A thorough air emissions inventory for a premises identifies all sources of air pollution, the air pollutants emitted from each source, and estimates the emission concentration and rate of all air pollutants emitted. The following section provides guidance on each step of the development of an emissions inventory.

## 3.1. Identify all sources of air pollution and potential emissions

A thorough understanding of the premises is essential in developing an emissions inventory. Undertaking a site visit of the existing premises or a detailed review of the engineering drawings for the proposed premises is necessary to identify all sources of air pollution and gain an understanding of the process and industry. This knowledge can be supplemented with a literature review on the industry and its most prevalent air pollution issues.

For all sources of air pollution at a premises, identify the following:

- release type
- location (in metres relative to fixed origin, elevation and discharge geometry)
- potential air pollutants emitted.

### 3.1.1. Release type

Source configuration may be one of the following types.

#### Point sources

For a point source, emissions emanate from a very small opening such as a stack or vent. Stacks usually emit hot gases forcefully into the atmosphere at a fixed height above ground level.

**Tall point sources**: The term 'tall' point source usually refers to sources that protrude out of the surface boundary layer (e.g. over 30–50 m tall).

**Wake-affected point sources**: Where nearby buildings interfere with the trajectory and growth of the plume, the source is called a wake-affected point source. A point source is wake-affected if stack height is less than or equal to 2.5 times the height of buildings located within a distance of 5L (where L is the lesser of the height or width of the building) from each release point.

**Wake-free point sources**: Wake-free point sources are more than 2.5 times the height of the largest nearby building, so that surrounding buildings do not influence the stack top airflow.

#### Area sources

An area source has a more realistic two-dimensional structure but only a limited vertical extent. It is a source with a large surface area such as a liquid surface (pond, lagoon) or a landfill surface.

#### Line sources

A line source is a special case of a long, thin area source. In practice, these sources are taken to be at ground level and thin. A line source becomes an area source if the breadth exceeds 20% of the length.

### Volume sources

A volume source is an essentially three-dimensional structure. Usually there are a sufficient number of emission points to consider a uniform emission rate over the full source structure. They are diffuse sources, such as emissions from within a building.

## 3.2. Determine source release parameters

For proposed premises this information is obtained from the engineering drawings and plans. For existing premises, this information can be obtained from site-specific sampling and analysis. The release parameters for each source type are:

**Point**: stack height, stack diameter, temperature, discharge velocity, moisture, pressure, carbon dioxide and oxygen concentration

**Diffuse area**: surface area, side length and release height

**Diffuse volume**: side length, release height, and initial horizontal and vertical plume spread ($\sigma_y$ and $\sigma_z$).

## 3.3. Estimate emission rates

There are a number of methods that can be used to estimate the emission rate from each source. The EPA's preferred methods are direct measurement for existing sources and manufacturers' design specifications for proposed sources. Emission factors are generally used when there is no other information available or when emissions can reasonably be demonstrated to be negligible.

### 3.3.1. Manufacturers' design specifications or performance guarantees

Manufacturers' design specifications or performance guarantees can be used to estimate the emission rate of air pollutants from proposed sources. Such specifications provide a reliable means of determining the upper limit to the emission rate or concentration of air pollutants for sources that are maintained and operated in a proper and efficient manner.

Post-commissioning testing may be required to establish that sources comply with the manufacturers' design specifications and/or performance guarantees.

### 3.3.2. Direct measurement

For sources where manufacturers' design specifications or performance guarantees are unknown, emission rates and source release parameters should normally be established from the results of source emission sampling and analysis. All sampling of source emissions and analysis of air pollutants must be in accordance with the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales* (EPA 2022).

### 3.3.3. Emission factors

An emission factor is usually an equation that relates the quantity of a pollutant released to process throughput. These factors are generally averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category. As stated above, emission factors are generally used when there is no other information available or when emissions can reasonably be demonstrated to be negligible.

Some databases of emission factors include:

- US EPA's AP-42 Emission Factors[1]
- National Pollutant Inventory Emissions Estimation Technique Manuals[2].

### 3.3.4. Accounting for variability in emission rates

If the source is large, the frequency distribution of emission rates should be compiled and used in conjunction with the frequency distribution of meteorological conditions to predict the overall frequency distribution of predicted glcs. Manufacturers' design specifications or performance guarantees can be useful for establishing the upper bounds of likely operational variability.

If the source is smaller and data is available to describe the distribution of emission rates, use the **99.9th percentile**.

If no data is available to describe the distribution of emission rates, use the maximum measured or calculated emission rate.

Where practicable, emission rate data should be constructed using an averaging period that is the lesser of one hour or the sampling time used in the concentration calculations.

## 3.4. Calculate emission concentration for point sources

The concentration of a pollutant emitted from a source is calculated using equation 3.1:

**Equation 3.1**

$$C_i = \frac{ER_i}{FR}$$

*where*:

$C_i$ = the concentration of pollutant *i* emitted from a source in mg/m$^3$

$ER_i$ = the rate pollutant *i* is emitted from the source in mg/s

$FR$ = the gaseous volumetric flow rate in m$^3$/s

The inventory should contain two emission concentrations:

1. actual concentration of a pollutant emitted from a source (mg/Am$^3$) calculated using the actual gaseous volumetric flow rate (Am$^3$/s) and measured emission rate in Equation 3.1
2. concentration of a pollutant emitted from a source corrected to the reference conditions as specified in the Regulation (mg/Nm$^3$ @ O$_2$%). This is calculated using the gaseous volumetric flow rate corrected to normal conditions (dry, 273K, 101.3 kPa) and the measured emission rate in Equation 3.1. The emission concentration (in mg/Nm$^3$) is then corrected to the appropriate oxygen reference condition. Further guidance on correcting to reference and equivalent values is provided in EPA (2022).

## 3.5. Assess compliance with the Regulation

The inventory must be used to demonstrate compliance with the Regulation. All sources of air emissions must comply with the requirements of the Regulation. If a source does not comply, the

---

[1] www.epa.gov/ttn/chief

[2] www.npi.gov.au/handbooks/approved_handbooks/sector-manuals.html

emissions inventory must be revised to reflect the implementation of new technology and/or pollution control equipment that will comply with the Regulation.

## 3.6. Presentation of emissions inventory

The results of the emissions inventory must be presented to include:

- all release parameters of stack and fugitive sources (e.g. temperature, exit velocity, stack dimensions, flow rate, moisture content, pressure, carbon dioxide and oxygen concentration)
- pollutant emission concentrations and a comparison against the relevant requirements of the Regulation.

Tables 1 and 2 show a suggested format for summarising and presenting the results of the emissions inventory in the impact assessment report. Table 3 shows the additional data that should be included in the impact assessment report for complex mixtures of odour and hydrogen sulfide.

**Table 1        Stack source release parameters**

| Source | Release type | Stack height (m) | Exit temp. (°C) | Exit diameter (m) | Exit velocity (m/s) | Oxygen conc. (%) | Moisture content (%) | Flow rate (Am$^3$/s) | Flow rate (Nm$^3$/s) |
|---|---|---|---|---|---|---|---|---|---|
| Boiler No. 1 | Wake-affected | 20 | 150 | 4 | 15 | 10 | 15 | 188.5 | 103.4 |

**Table 2        Stack emission concentrations and regulation limits**

| Pollutant | Emission rate (g/s) | Emission concentration (mg/Am$^3$) | Corrected emission concentration (mg/Nm$^3$ at stack reference conditions) | Regulation emission concentration limit (mg/Nm$^3$ at stack reference conditions) |
|---|---|---|---|---|
| Sulfur dioxide | 40 | 212.2 | N/A | N/A |
| Solid particles | 2 | 10.6 | 31.6 | 100 |
| Oxides of nitrogen | 15 | 79.6 | 237.4 | 350 |

**Table 3        Peak odour emission rates**

| Source | Source type | Odour emission rate (OUm$^3$/s) | Stability class | Peak odour emission rate (OUm$^3$/s) – Near-field | Peak odour emission rate (OUm$^3$/s) – Far-field |
|---|---|---|---|---|---|
| Lagoon No. 1 | Area | 20,000 | A, B, C, D | 50,000 | 46,000 |
| " | " | " | E, F | 46,000 | 38,000 |

## 3.7. Bibliography

EPA 2001, *Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*, NSW Environment Protection Authority, Sydney.

EPA 2001, *Technical Notes – Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*, NSW Environment Protection Authority, Sydney.

EPA 2022, *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wale*s, NSW Environment Protection Authority (https://www.epa.nsw.gov.au/your-environment/air/industrial-emissions/sampling-analysing-air-emissions/approved-methods-sampling-analysing-air-pollutants)

EPA Victoria 1985, *Plume Calculation Procedure: An Approved Procedure under Schedule E of State Environment Protection Policy (The Air Environment)*, Publication 210, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1990, *The AUSPLUME Gaussian Plume Dispersion Model,* First Edition, Publication 264, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1999, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Publication 671, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 2000, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Environment Protection Authority of Victoria, Melbourne.

Department of Environment and Heritage, *National Pollutant Inventory Emissions Estimation Technique Manuals* (www.npi.gov.au/handbooks/approved_handbooks/sector-manuals.html)

USEPA 1995, AP 42, *Fifth Edition Compilation of Air Pollutant Emission Factors,* Volume 1: Stationary Point and Area Sources (www.epa.gov/ttn/chief/ap42/index.html)

# 4. Meteorological data

The meteorological data used in the dispersion model is of fundamental importance as it drives the transport and dispersion of the air pollutants in the atmosphere. The most critical parameters are wind direction, which determines the initial direction of transport of pollutants from their sources; wind speed, which dilutes the plume in the direction of transport and determines the travel time from source to receptor; and atmospheric turbulence, which indicates the dispersive ability of the atmosphere.

## 4.1. Minimum data requirements

The meteorological data used in the dispersion modelling is one factor that determines the level of assessment.

**Level 1** impact assessments are conducted using 'synthetic' worst-case meteorological data. Table 4 lists the wind speed and stability class combinations that need to be included in the synthetic worst-case meteorological data file.

**Level 2** impact assessments are conducted using at least one year of site-specific meteorological data. The meteorological data must be 90% complete in order to be acceptable for use in Level 2 impact assessments (i.e. for one year, there can be no more than 876 hours of data missing). If site-specific meteorological data are not available for a Level 2 impact assessment, at least one year of site-representative meteorological data must be used. The site-representative data should be:

- preferably collected at a meteorological monitoring station. Where measured data is unavailable or of insufficient quality for dispersion modelling purposes, a meteorological data file may be generated using a prognostic meteorological model such as TAPM (Section 4.5)
- correlated against a longer-duration site-representative meteorological database of at least five years (preferably five consecutive years) to be deemed acceptable. It must be clearly established that the data adequately describes the expected meteorological patterns at the site under investigation (e.g. wind speed, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift).

## 4.2. Siting and operating meteorological monitoring equipment

The following methods specified in EPA (2021) must be used for establishing, siting, operating and maintaining meteorological monitoring equipment:

- AM-1
- AM-2
- AM-4

All meteorological stations used to collect data for dispersion modelling purposes must use an anemometer that has a stall speed of 0.5 m/s or less.

For the AUSPLUME dispersion model, the meteorological parameters required are:

- wind speed (m/s)
- wind direction (°)
- ambient temperature (°C)
- atmospheric stability class
- mixed layer height (m).

For deposited dust, the data file should include hourly average values for the following additional parameters:

- Monin–Obukhov length (m)
- surface friction velocity (m/s)
- surface roughness height (m).

Wind speed, wind direction and ambient temperature can be directly measured, but atmospheric stability class and mixed layer height need to be determined indirectly using other meteorological parameters with empirical formulas.

A meteorological station needs to measure and electronically log wind speed, wind direction and ambient temperature. In addition, for determining atmospheric stability class, one of the following is required:

- cloud cover and cloud ceiling height by visual observations obtained from the Bureau of Meteorology
- total solar radiation measured in conjunction with temperature at two levels and electronically logged
- sigma theta (the standard deviation of the horizontal wind direction fluctuation) electronically logged.

All parameters must be logged as 1-hour average values as a minimum requirement. In some circumstances these variables may need to be averaged and logged at intervals of 10 minutes or less.

## 4.3. Preparation of Level 1 meteorological data

The EPA's preferred methods for the preparation of synthetic meteorological data are specified below. The use of methods other than these should be discussed with the air technical team of the EPA.

### 4.3.1. Wind speed and stability class

Gaussian plume dispersion models use stability categories as indicators of atmospheric turbulence and the dispersive properties of the atmosphere. Based on the work of Pasquill and Gifford, seven stability categories have been defined:

A – very unstable

B – unstable

C – slightly unstable

D – neutral

E – slightly stable

F – stable

G – very stable conditions.

In most dispersion models, stability classes F and G are combined into one class, F.

The stability class at any given time depends on:

- static stability (vertical temperature profile of the atmosphere, i.e. migrating high and low air-pressure masses)
- convective or thermal turbulence (caused by the rising of air heated at ground level)
- mechanical turbulence (a function of wind speed and surface roughness, i.e. wind flow over rough terrain, trees or buildings).

Table 4 lists the minimum wind speed and stability class combinations that must be included in a Level 1 meteorological data file.

**Table 4    Wind speed (m/s) and stability class combinations for a Level 1 meteorological data file**

| Stability class | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | * | * | * | * | * | * | | | | | | | | | | | | | |
| B | * | * | * | * | * | * | * | * | * | * | | | | | | | | | |
| C | * | * | * | * | * | * | * | * | * | * | * | * | * | * | | | | | |
| D | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| E | * | * | * | * | * | * | * | * | * | * | | | | | | | | | |
| F | * | * | * | * | * | * | | | | | | | | | | | | | |

### 4.3.2. Ambient temperature

For Level 1 impact assessments, the maximum and minimum ambient temperatures that are representative of the site must be included in the Level 1 meteorological data file to account for the range in possible plume rise. Higher ambient temperatures will result in the lowest plume rise and hence the largest impacts.

### 4.3.3. Mixing height

For Level 1 impact assessments, the mixing height for neutral and unstable conditions (classes A–D) can be calculated using an estimate of the mechanically driven mixing height. The mechanical mixing height, h, can be calculated as follows:

**Equation 4.1: Mechanical mixing height for stability classes A–D**

$h = 0.3 \times u^* / f$

*where:*

*h = mixing height (m)*

*u\* = friction velocity (m/s)*

*f = Coriolis parameter*

For Level 1 impact assessments, the mixing height, h, for stable conditions (classes E and F) can either be set at an unlimited value (e.g. 5000 m) or calculated as follows:

**Equation 4.2: Mechanical mixing height for stability classes E and F**

$h = 0.4 \times (u^* L / f)^{0.5}$

*where:*

h = mixing height (m)

u\* = friction velocity (m/s)

L = Monin–Obukhov length (m)

F = Coriolis parameter

### 4.3.4. Monin–Obukhov length

The Monin–Obukhov length, L, characterises the stability of the surface layer. The surface layer is defined as the layer above the ground in which the vertical variation of heat and momentum flux is

negligible. The surface layer is typically 10% the height of the mixed layer. The parameter, L, can be calculated using the linear approximation to Golder's plot (Golder 1972) as follows:

### Equation 4.3: Monin–Obukhov length

$1/L = X + Y \times \log_{10}(Z_o)$

*where:*

L = Monin–Obukhov length (m)

X & Y = parameters dependent on the Pasquill–Gifford stability class (see Table 5)

$Z_o$ = surface roughness height (m) (see Table 6)

**Table 5    Parameterisation of Golder's plot, by Pasquill–Gifford stability class**

| Parameter | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| X | −0.096 | −0.037 | −0.002 | 0.000 | 0.004 | 0.035 |
| Y | 0.029 | 0.025 | 0.018 | 0.000 | −0.018 | −0.0365 |

In Equation 4.3:

- the value of $Z_o$ is the surface roughness height, unless the surface roughness height is outside the range $Z_{o\ min}$ to $Z_{o\ max}$ presented in Table 6
- if the surface roughness height < $Z_{o\ min}$ use the value of $Z_{o\ min}$ for $Z_o$
- if the surface roughness > $Z_{o\ max}$ use the value of $Z_{o\ max}$ for $Z_o$.

**Table 6    Upper and lower limits for surface roughness heights for each Pasquill–Gifford stability class**

| Parameter | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| $Z_{o\ min}$ | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| $Z_{o\ max}$ | 18.0 | 30.0 | 1.25 | 50.0 | 1.6 | 9.0 |

Table 7 presents typical values of surface roughness height for various land uses.

**Table 7    Typical values of surface roughness height for various land-use categories (AUSPLUME version 6.0)**

| Land-use category | Roughness height $Z_o$ (m) |
|---|---|
| Hill | 2.0 |
| Industrial area | 0.8 |
| Forest | 0.8 |
| Rolling rural | 0.4 |
| Flat desert | 0.01 |
| High-rise | 1.0 |
| Commercial | 0.8 |
| Residential | 0.4 |
| Flat rural | 0.1 |
| Water | 0.0001 |

## 4.3.5. Surface friction velocity

The surface friction velocity, u\*, is a measure of mechanical turbulence and is directly related to the surface roughness. The parameter, u\*, can be calculated using the procedure presented below (Businger and Fleagle 1980; McRae 1981).

**Condition 1: Wind speed = 0**

$u* = 0.001$ m/s

**Condition 2: Unstable conditions (Pasquill–Gifford stability classes A, B or C, or 1/L < 0)**

$u* = VK \times W_{sp} / \phi$

*where:*

$u*$ = surface friction velocity (m/s)

$VK$ = von Karman constant; use a value of 0.4

$W_{sp}$ = absolute value of the wind speed at height $Z_r$ (m/s)

$\phi$ = calculated according to the following equation:

$\phi = \ln (Z_r / Z_o) + \ln ((PZ_o{}^2 + 1.0) \times (PZ_o + 1.0)^2 / ((PZ_r{}^2 + 1.0) \times (PZ_r + 1.0)^2)) + 2 \times (\tan^{-1}(PZ_r) - \tan^{-1}(PZ_o))$

*where:*

$Z_r$ = reference height for the wind measurements (m)

$Z_o$ = surface roughness height (m)

$PZ_o$ and $PZ_r$ = calculated according to the following equations:

$PZ_r = (1.0 - 15.0 \times Z_r / L)^{0.25}$

$PZ_o = (1.0 - 15.0 \times Z_o / L)^{0.25}$

$Z_r$ = reference height for the wind measurements (m)

$Z_o$ = surface roughness height (m)

$L$ = Monin–Obukhov length (m)

**Condition 3: Neutral conditions (Pasquill–Gifford stability class D, or 1/L = 0)**

$u* = VK \times W_{sp} / \ln (Z_r/Z_o)$

*where:*

$u*$ = surface friction velocity (m/s)

$VK$ = von Karman constant; use a value of 0.4

$W_{sp}$ = absolute value of the wind speed at height $Z_r$ (m/s)

$Z_r$. = reference height for the wind measurements (m)

$Z_o$ = surface roughness height (m)

**Condition 4: Stable conditions (Pasquill–Gifford stability class E or F, or 1/L > 0)**

$u^* = VK \times W_{sp} / (\ln (Z_r / Z_o) + 4.7 / L \times (Z_r - Z_o))$

*where:*

$u^*$ = surface friction velocity (m/s)

VK = von Karman constant; use a value of 0.4

$W_{sp}$ = absolute value of the wind speed at height $Z_r$ (m/s)

$Z_r$ = reference height for the wind measurements (m)

$Z_o$ = surface roughness height (m)

## 4.3.6. Coriolis parameter

The Coriolis parameter accounts for variation in wind direction with height (wind shear) at different latitudes and can be calculated in accordance with well-established techniques. The Coriolis parameter, f, can be calculated as follows:

$f = 2\Omega\sin(\phi)$

*where:*

$\Omega$ = Earth's rotation rate ($2\pi/86400$ or $7.29 \times 10^{-5}$ rad·s$^{-1}$)

$\pi$ = pi or 3.1416 radians (rad)

86,400 = number of seconds in the day (s/day)

$\phi$ = latitude in radians (rad)

Table 8 lists an example of typical mixing heights for a location with a similar latitude to Sydney (34°) and in a rural location (surface roughness height of 0.3 m) to be included in the Level 1 meteorological data file.

**Table 8**    **Typical mixing heights for a rural location (km), for different values of wind speed (m/s) and stability class (A–F)**

| Wind speed (m/s) | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 0.5 | 0.2 | 0.2 | 0.2 | 0.2 | 5.0 | 5.0 |
| 1.0 | 0.4 | 0.4 | 0.3 | 0.3 | 5.0 | 5.0 |
| 1.5 | 0.6 | 0.5 | 0.5 | 0.4 | 5.0 | 5.0 |
| 2.0 | 0.8 | 0.7 | 0.6 | 0.6 | 5.0 | 5.0 |
| 2.5 | 1.0 | 0.9 | 0.8 | 0.7 | 5.0 | 5.0 |
| 3.0 | 1.2 | 1.0 | 0.9 | 0.8 | 5.0 | 5.0 |
| 3.5 | - | 1.2 | 1.1 | 1.0 | 5.0 | 5.0 |
| 4.0 | - | 1.4 | 1.2 | 1.1 | 5.0 | - |
| 4.5 | - | 1.6 | 1.4 | 1.3 | 5.0 | - |
| 5.0 | - | 1.8 | 1.5 | 1.4 | 5.0 | - |
| 6 | - | - | 1.8 | 1.7 | - | - |
| 7 | - | - | 2.1 | 2.0 | - | - |
| 8 | - | - | 2.4 | 2.2 | - | - |
| 10 | - | - | 3.1 | 2.8 | - | - |

| Wind speed (m/s) | A | B | C | D | E | F |
| --- | --- | --- | --- | --- | --- | --- |
| 12 | - | - | - | 3.3 | - | - |
| 14 | - | - | - | 3.9 | - | - |
| 16 | - | - | - | 4.5 | - | - |
| 18 | - | - | - | 5.0 | - | - |
| 20 | - | - | - | 5.0 | - | - |

Table 9 lists an example of typical mixing heights for a location with a similar latitude to Sydney (34°) and in an urban location (surface roughness height of 1.0 m) to be included in the Level 1 meteorological data file.

**Table 9** **Typical mixing heights for an urban location (km), for different values of wind speed (m/s) and stability class (A–F)**

| Wind speed (m/s) | A | B | C | D | E | F |
| --- | --- | --- | --- | --- | --- | --- |
| 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | 5.0 | 5.0 |
| 1.0 | 0.6 | 0.5 | 0.4 | 0.4 | 5.0 | 5.0 |
| 1.5 | 1 | 0.8 | 0.7 | 0.6 | 5.0 | 5.0 |
| 2.0 | 1.3 | 1.1 | 0.9 | 0.8 | 5.0 | 5.0 |
| 2.5 | 1.6 | 1.4 | 1.1 | 1.1 | 5.0 | 5.0 |
| 3.0 | 2 | 1.7 | 1.3 | 1.3 | 5.0 | 5.0 |
| 3.5 | - | 1.9 | 1.5 | 1.5 | 5.0 | 5.0 |
| 4.0 | - | 2.2 | 1.8 | 1.7 | 5.0 | - |
| 4.5 | - | 2.5 | 2 | 1.9 | 5.0 | - |
| 5.0 | - | 2.7 | 2.2 | 2.1 | 5.0 | - |
| 6 | - | - | 2.6 | 2.6 | - | - |
| 7 | - | - | 3.1 | 2.9 | - | - |
| 8 | - | - | 3.5 | 3.4 | - | - |
| 10 | - | - | 4.4 | 4.3 | - | - |
| 12 | - | - | - | 5.0 | - | - |
| 14 | - | - | - | 5.0 | - | - |
| 16 | - | - | - | 5.0 | - | - |
| 18 | - | - | - | 5.0 | - | - |
| 20 | - | - | - | 5.0 | - | - |

## 4.4. Preparation of Level 2 meteorological data

For guidance on processing meteorological data for dispersion modelling purposes, the USEPA guide (USEPA 2000) and USEPA processor (USEPA 1996) should be used.

### 4.4.1. Stability class

In order of preference, the following methods outlined in USEPA (2000) should be used to determine stability class:

**Turner's 1964 method:** This requires information on solar altitude or zenith angle, cloud cover, cloud ceiling height and wind speed. Solar altitude can easily be calculated, but cloud cover and ceiling height are generally determined through visual observations.

**Solar radiation–delta temperature method:** This retains the basic structure and rationale of Turner's 1964 method but eliminates the need for observations of cloud cover and ceiling height. The method uses the surface-layer wind speed (measured at 10 m) in combination with measurements of total solar radiation during the day and a low-level vertical temperature difference (i.e. at 2 m and 10 m) at night.

**Sigma theta method** (the standard deviation of the horizontal wind direction fluctuation): All modern meteorological data loggers include software to determine sigma theta.

For Level 2 impact assessments, hourly stability class should be estimated using the USEPA meteorological pre-processor for regulatory models (USEPA 1996) or a processor that includes similar techniques.

### 4.4.2. Mixing height

Mixing height is the depth through which pollutants released to the atmosphere are typically mixed by dispersive processes. Dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place. Mixing height determines the vertical extent of dispersion for releases occurring below that height. Releases occurring above that height are assumed to have no ground-level impact (with the exception of fumigation episodes). Therefore, the greater the vertical extent of the mixed layer, the larger the volume available to dilute pollutant emissions.

Morning and afternoon mixing heights are estimated using vertical temperature profiles (otherwise known as 'upper air data') and surface temperature measurements. For Level 2 impact assessments, hourly mixing heights should be estimated from the twice-daily mixing height values, sunrise and sunset times, and hourly stability categories by using the USEPA meteorological pre-processor for regulatory models (USEPA 1996) or a processor which includes similar techniques.

## 4.5. Developing site-representative meteorological data using prognostic meteorological models

In some areas of NSW neither site-specific nor site-representative meteorological data are available that are suitable for use in regulatory dispersion modelling applications. Where this is the case, prognostic meteorological models may be used.

CSIRO's TAPM (Hurley 2005a and 2005b; Hurley et al. 2005) is a three-dimensional prognostic meteorological and dispersion modelling system. TAPM is the prognostic meteorological model most frequently used in NSW. TAPM uses databases of terrain, vegetation, soil type, sea surface temperature and synoptic-scale meteorological analyses for Australia. TAPM is driven by 6-hourly synoptic analyses at approximately 75-kilometre resolution – a database derived from Local Area Prediction System analysis data from the Bureau of Meteorology.

The following model set-up is the minimum specification that must be used to generate a meteorological data file for regulatory dispersion modelling applications:

- TAPM version 2.0 or later
- GEODATA 9-second (~250 m) terrain height database
- TAPM default databases for land use, synoptic analyses and sea surface temperature
- 25 by 25 horizontal grid points
- 25 vertical levels
- outer grid of 30 kilometres, with nesting grids of 10 km, 3 km and 1 km
- TAPM defaults for advanced meteorological inputs.

## 4.6. Availability of meteorological processing software, guidance documents and prognostic meteorological models

Meteorological processing software and guidance documents can be electronically downloaded, free of charge, from the USEPA website.[3]

TAPM can be purchased from CSIRO and includes a terrain and land-use database CD and synoptic analysis databases for two calendar years for Australia. Data for other geographical regions can be purchased together with extra synoptic analyses for other calendar years and a finer-resolution terrain (9-second digital elevation model) dataset for Australia.

## 4.7. Bibliography

Businger, J. and Fleagle, R. 1980, *An Introduction to Atmospheric Physics*, Academic Press, New York.

EPA 2021 *Table of AM-coded methods for ambient air monitoring* (https://www.epa.nsw.gov.au/your-environment/air/industrial-emissions/sampling-analysing-air-emissions/approved-methods-sampling-analysing-air-pollutants)

Golder, D. 1972, 'Relations among stability parameters in the surface layer', *Boundary Layer Meteorology* 3, 47–58.

Hurley, P. 2005a, *The Air Pollution Model (TAPM) Version 3, Part 1: Technical Description*, CSIRO Atmospheric Research Technical Paper No. 71, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P. 2005b, *The Air Pollution Model (TAPM) Version 3: User Manual*, CSIRO Atmospheric Research Technical Paper No. 31, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P., Physick, W., Luhar, A. and Edwards, M. 2005, *The Air Pollution Model (TAPM) Version 3, Part 2: Summary of Some Verification Studies*, CSIRO Atmospheric Research Technical Paper No. 72, CSIRO Division of Atmospheric Research, Melbourne.

McRae, G.J. 1981, Mathematical Modelling of Photochemical Air Pollution, Chapter 4, 'Turbulent Diffusion Coefficients', PhD Thesis, California Institute of Technology, Los Angeles.

Standards Australia 1987a, AS 2922–1987, *Ambient Air – Guide for the Siting of Sampling Units*, Standards Australia, Sydney.

Standards Australia 1987b, AS 2923–1987, *Ambient Air – Guide for the Measurement of Horizontal Wind for Air Quality Applications*, Standards Australia, Sydney.

USEPA 1996, *Meteorological Processor for Regulatory Model (MPRM), User's Guide*, EPA-454/B-96-002, United States Environmental Protection Agency, Washington DC, USA.

USEPA 2000, *Meteorological Monitoring Guidance for Regulatory Modelling Applications*, EPA-454/R-99-005, United States Environmental Protection Agency, Washington DC, USA.

Zanetti, P. 1990, *Air Pollution Modelling: Theories, Computational Methods and Available Software*, Van Nostrand Reinhold, New York.

---

[3] www.epa.gov/ttn/scram/

# 5. Background air quality, terrain, sensitive receptors and building wake effects

## 5.1. Background air quality data

Including background concentrations of pollutants in the assessment enables the total impact of the proposal (i.e. impact of emissions on existing air quality) to be assessed. The background concentrations of air pollutants are ideally obtained from ambient monitoring data collected at the proposed site. As this is extremely rare, data is typically obtained from a monitoring site as close as possible to the proposed location where the sources of air pollution resemble the existing sources at the proposal site.

### 5.1.1. Accounting for background concentrations

For impact assessments of sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), $PM_{2.5}$, $PM_{10}$, total suspended particulates (TSP), deposited dust, lead (Pb), carbon monoxide (CO) and hydrogen fluoride (HF), the existing background concentrations of the pollutants in the vicinity of the proposal should be included in the assessment as follows.

#### Level 1 assessments

- Obtain ambient monitoring data that includes at least one year of continuous measurements.
- Determine the maximum background concentration of the pollutant being assessed for each relevant averaging period.
- At the maximum exposed off-site receptor, add the maximum background concentration and the **100th percentile** dispersion model prediction to obtain the total impact for each averaging period.

#### Level 2 assessments

- Obtain ambient monitoring data that includes at least one year of continuous measurements and is contemporaneous with the meteorological data used in the dispersion modelling.
- At each receptor, add each individual dispersion model prediction to the corresponding measured background concentration (e.g. add the first hourly average dispersion model prediction to the first hourly average background concentration) to obtain hourly predictions of total impact.
- At each receptor, determine the **100th percentile** total impact for the relevant averaging.

The use of an approach other than those above should be discussed with the air technical team of the EPA.

### 5.1.2. Sourcing ambient monitoring data

Ambient monitoring data from a variety of locations in NSW is available online[4] and may be of assistance in characterising the existing ambient air quality. Data may also be obtained from various industry monitoring programs.

---

[4] https://www.environment.nsw.gov.au/topics/air

All monitoring to establish background concentrations must be conducted in accordance with the appropriate methods specified in EPA (2021).

### 5.1.3. Dealing with elevated background concentrations

In some locations, existing ambient air pollutant concentrations may exceed the impact assessment criteria from time to time. In such circumstances, a licensee must demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity and that best management practices will be implemented to minimise emissions of air pollutants as far as is practical. Refer to the worked example included in Section 11.2.

## 5.2. Terrain and sensitive receptors

The dispersion modelling input file requires information regarding the surrounding terrain and sensitive receptors. Terrain and receptor files are developed which include the location and height in metres relative to a fixed origin. The location of any particularly sensitive receptors (and likely future sensitive receptors) such as residences, schools and hospitals can also be specifically included in the receptor file.

## 5.3. Building wake affects

PRIME is EPA's preferred building wake algorithm. AUSPLUME v. 6.0 includes the PRIME building wake algorithm and the Building Profile Input Program (BPIP) for entering the location and dimension of buildings. The location and dimensions of buildings located within a distance of 5L (where L is the lesser of the height or width of the building) from each release point for buildings with a height greater than 0.4 times the stack height should be entered in BPIP.

## 5.4. Bibliography

DEC 4th Quarter 2003–present, *Quarterly Air Quality Monitoring Report Part A: DEC Data*, Department of Environment and Conservation NSW, Sydney.

DEC 4th Quarter 2003–present, *Quarterly Air Quality Monitoring Report Part B: Industry Data*, Department of Environment and Conservation NSW, Sydney.

EPA 1992–3rd Quarter 2003, *Quarterly Air Quality Monitoring Report Part A: EPA Data*, NSW Environment Protection Authority, Sydney.

EPA 1992–3rd Quarter 2003, *Quarterly Air Quality Monitoring Report Part B: Industry Data*, NSW Environment Protection Authority, Sydney.

EPA Victoria 2000, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Environment Protection Authority of Victoria, Melbourne.

EPA 2021 *Table of AM-coded methods for ambient air monitoring* (https://www.epa.nsw.gov.au/your-environment/air/industrial-emissions/sampling-analysing-air-emissions/approved-methods-sampling-analysing-air-pollutants)

Schulman, L.L., Strimaitis, D.G. and Scire, J.S.1998, *Development and Evaluation of the PRIME Plume Rise and Building Downwash Model,* Preprint Volume for the Tenth Joint Conference on Applications of Air Pollution Meteorology with A&WMA, American Meteorological Society, Phoenix, Arizona.

SPCC 1975–1991, *Quarterly Air Quality Monitoring Reports*, State Pollution Control Commission, Sydney.

USEPA 1995, *User's Guide to the Building Profile Input Program*, Revised February 1995, PA-454/R-93-038, United States Environmental Protection Agency, Washington DC, USA.

# 6. Dispersion modelling

## 6.1. Dispersion models

Dispersion models provide the ability to mathematically simulate atmospheric conditions and behaviour. They are used to calculate spatial and temporal sets of concentrations and particle deposition due to emissions from various sources. Dispersion models can be used to determine the affected zone around an emitter by producing results that can be compared against impact assessment criteria.

Dispersion models can provide concentration or deposition estimates over an almost unlimited grid of user-specified locations, and can be used to evaluate both existing and forecast emission scenarios. In this capacity, air dispersion modelling is a useful tool in assessing the air quality impacts associated with existing and proposed emission sources. The results of the dispersion modelling analysis can be used to develop control strategies that should ensure compliance with the assessment criteria. Dispersion models can also be used to estimate the cumulative impacts of various industries that are located close to one another.

Dispersion models are widely used by environmental regulators in Australia, New Zealand, the United States, the United Kingdom and Europe, and industry well understands their limitations. The results have been shown, through numerous model evaluation studies, to be sufficiently robust to be relied on to calculate concentration limits for point-source stack emissions.

## 6.2. Approved dispersion models

AUSPLUME v. 6.0 or later is the approved dispersion model for use in most simple, near-field applications in NSW, where coastal effects and complex terrain are of no concern.

AUSPLUME is a Gaussian plume model, based on the assumption that cross-sections through elevated plumes from point sources of pollution have a Gaussian (or normal) distribution of concentration. AUSPLUME is also a steady-state model, which assumes the atmosphere is in a state of uniform flow, and wind velocity is a function of height alone and does not vary with direction. The mathematical basis of AUSPLUME is the Victorian EPA's Plume Calculation Procedure (EPA Victoria 1985), which itself is an extension of the ISC model (USEPA 1995).

AUSPLUME v. 6.0 or later is specifically **not** approved for use in the following applications:

- **complex terrain, non-steady-state conditions**
  AUSPLUME is a steady-state model and is unable to adjust the winds to reflect the effects of terrain. The straight-line trajectory assumption of the plume model is unable to handle the curved flow associated with terrain-induced deflection of channelling. AUSPLUME should not be used for terrain where the height of any receptor exceeds the lowest release height.
- **buoyant line plumes**
  (e.g. discharges from the roof vents of aluminium smelters)
- **coastal effects such as fumigation**
  AUSPLUME is unable to consider large changes in meteorological conditions which can occur over short distances across a coastline.
- **high frequency of stable calm night-time conditions**
  Pollutants can accumulate under such conditions or will flow downwind with the drainage flow. AUSPLUME has no memory of the previous hour's weather conditions as each hour is treated independently of the next and material is carried away instantaneously, to the edge of the grid, even if only light winds are prevailing.
- **high frequency of calm conditions**
  AUSPLUME cannot handle calm conditions because of the inverse wind-speed dependence

plume equation. AUSPLUME assumes a minimum wind speed, which shoots the plume out to the edge of the grid even though the plume may not have moved at all.

- **inversion break-up fumigation conditions**.

There are also other situations where another dispersion model may be more scientifically sound than AUSPLUME. In these instances, CALPUFF or TAPM (Section 6.3) may be appropriate. The two key factors that should be considered in evaluating whether to use a conventional plume model, such as AUSPLUME, or a more sophisticated approach are:

1. Is the steady-state assumption in the plume model valid?
2. Do the technical parameterisations in the plume model adequately treat the situation to be modelled?

For other applications, the choice of a dispersion model other than AUSPLUME, CALPUFF or TAPM should be discussed with the air technical team of the EPA. For the calculation of site-specific emission limits for hydrogen sulfide and sulfur dioxide, written approval must be obtained from the EPA for the use of a dispersion model other than AUSPLUME, CALPUFF or TAPM. The application must show that the alternative dispersion model is scientifically sound for the proposed application.

## 6.3. Advanced dispersion models for specialist application

In circumstances where the AUSPLUME dispersion model is not approved or suitable for use, other dispersion models may be appropriate. Guidance on choosing appropriate alternative dispersion models can be found in the USEPA publication *Guideline on Air Quality Models* (USEPA 1999). CALPUFF and TAPM are the most commonly used alternative dispersion models for regulatory dispersion modelling applications in NSW. However, only experienced, appropriately trained professionals should use them.

### 6.3.1. CALPUFF

CALPUFF is a multi-layer, multi-species, non-steady-state Gaussian puff dispersion model that is able to simulate the effects of time- and space-varying meteorological conditions on pollutant transport. This enables the model to account for a variety of effects such as spatial variability of meteorological conditions, causality effects, dry deposition and dispersion over a variety of spatially varying land surfaces, plume fumigation, low wind-speed dispersion, pollutant transformation and wet removal. CALPUFF has various algorithms for parameterising dispersion processes, including the use of turbulence-based dispersion coefficients derived from similarity theory or observations.

CALPUFF has been accepted by the USEPA as a guideline model to be used in regulatory applications involving the long-range transport of pollutants (> 50 km). It can also be used on a case-by-case basis in situations involving complex flow and non-steady-state cases up to 50 kilometres form the source.

CALPUFF v. 5.7, CALMET v. 5.5 and CALPOST v. 5.4 or later should be used.

### 6.3.2. TAPM

The Air Pollution Model (TAPM) was developed by the CSIRO to simulate three-dimensional meteorology and pollution dispersion in areas where meteorological data are sparse or non-existent. The modelling system contains a number of dispersion modules. These include a particle/puff dispersion model for dispersion from point, line, area and volume sources, and a three-dimensional grid-point model for urban air pollution studies. The dispersion models allow for plume rise and building wake effects, wet and dry deposition and photochemistry for urban airshed applications. TAPM v. 2.0 or later should be used.

## 6.4. Dispersion modelling methodology using AUSPLUME

Unless otherwise stated, the default options specified in the *Technical Users Manual* (EPA Victoria 2000) must be used with AUSPLUME. These options are the most appropriate for most impact assessment applications.

### Terrain effects

- Use the Egan half-height approach to account for terrain effects.

### Building wake effects

- All building dimensions must be entered in 10-degree increments. Use the USEPA utility program BPIP (USEPA 1995) within AUSPLUME to calculate the 36 wind-direction-dependent building dimensions.
- Use the PRIME method to account for building wake effects.
- The USEPA's guidance document on good engineering practice (USEPA 1985) must be taken into account when designing new stacks to avoid building wake effects.

### Horizontal dispersion curves

- For stacks < 100 m high, use sigma theta values or Pasquill–Gifford curves.
- For stacks > 100 m high, use Briggs rural curves.

### Vertical dispersion curves

- For stacks < 100 m high, use Pasquill–Gifford curves.
- For stacks > 100 m high, use Briggs rural curves.

### 'Enhance plume spreads for buoyancy'

- Enable this option for both the horizontal and vertical dimensions.

### 'Adjust Pasquill–Gifford formulas for roughness height'

- Use this option.

### Plume-rise parameters

- Use the AUSPLUME defaults.

### Wind speed categories

- Use the AUSPLUME defaults.

### Wind profile exponents

- Use Irwin rural wind profile exponents for rural areas.
- Use Irwin urban wind profile exponents for urban areas.

## 6.5. Dispersion modelling methodology using CALPUFF

CALPUFF includes an option to automatically set all the options to the USEPA default values. These include:

- wind speed profile: ISC Rural
- transitional plume rise modelled
- stacktip downwash

- partial plume penetration
- dispersion curves: Pasquill–Gifford or dispersion coefficients using turbulence-based micro-meteorology
- no adjustment of dispersion curves for roughness
- terrain: partial plume adjustment method.

## 6.6. Calculate peak concentrations

The evaluation of odour impacts requires the estimation of short or peak concentrations on the time scale of less than one second. Dispersion model predictions are typically valid for averaging periods of one hour and longer. Dispersion models, such as AUSPLUME, therefore need to be supplemented to accurately simulate atmospheric dispersion of odours and the instantaneous perception of odours by the human nose.

The prediction of peak concentrations from estimates of ensemble means can be obtained from a ratio between extreme short-term concentration and longer-term averages. Properly defined peak-to-mean ratios depend upon the type of source, atmospheric stability and distance downwind. Table 10 shows the EPA-recommended factors for estimating peak concentrations for different source types, stabilities and distances as developed by Katestone Scientific (1995 and 1998).

The P/M60 ratios in Table 10 are for an idealised situation for one source in flat terrain where the receptor is located along the centreline of the single plume. The ratios do not consider fluctuations away from the centre line, terrain influences or plume interaction from multiple sources.

The EPA requires peak ground-level concentrations to be calculated for the following pollutants:

- hydrogen sulfide
- complex mixtures of odour.

A screening-level assessment of peak glcs can be undertaken by applying the ratios in Table 10 to multiple sources at a premises. These ratios can be applied to the emission rates entered into the dispersion model as follows:

1. Determine the source type, stability class and if the receptors are near-field or far-field or both.
2. Select the appropriate P/M60 ratios from Table 10.
3. For wake-affected point sources, determine the meteorological conditions (i.e. wind speed and stability class) under which the source is wake-affected and wake-free.
4. Apply P/M60 ratios to odour and hydrogen sulfide emission rates so they vary with wind speed and stability class.

More detailed procedures for estimating peak glcs from multiple sources are discussed in Katestone Scientific (1995 and1998).

**Table 10    Factors for estimating peak concentrations in flat terrain (Katestone Scientific 1995 and 1998)**

| Source type | Pasquill–Gifford stability class | Near-field P/M60* | Far-field P/M60* |
|---|---|---|---|
| Area | A, B, C, D | 2.5 | 2.3 |
| | E, F | 2.3 | 1.9 |
| Line | A–F | 6 | 6 |
| Surface wake-free point | A, B, C | 12 | 4 |
| | D, E, F | 25 | 7 |
| Tall wake-free point | A, B, C | 17 | 3 |
| | D, E, F | 35 | 6 |

| Source type | Pasquill–Gifford stability class | Near-field P/M60* | Far-field P/M60* |
|---|---|---|---|
| Wake-affected point | A–F | 2.3 | 2.3 |
| Volume | A–F | 2.3 | 2.3 |

* Ratio of peak 1-second average concentrations to mean 1-hour average concentrations

## 6.7. Availability of dispersion modelling software and guidance documents

Windows-based **AUSPLUME** v. 6.0 can be purchased by writing to:

Environment Protection Authority of Victoria
27 Francis Street
Melbourne Victoria 3000.

The **BPIP PRIME** (BPIPPRM) user's manual and software can be electronically downloaded, free of charge, from the USEPA website.[5]

The **CALPUFF** dispersion modelling package and guidance documents can be electronically downloaded, free of charge, from the Earth Tech Incorporated website at earthtec.vwh.net/download/download.htm

The **TAPM** software can be purchased by writing to:

Dr Peter Hurley
CSIRO Atmospheric Research
PMB 1
Aspendale Victoria 3195.

Guidance documents and information about TAPM can be obtained from the CSIRO.

Other dispersion modelling software and guidance documents can be electronically downloaded free of charge from the USEPA website.[6]

## 6.8. Bibliography

Earth Tech 2000, *A User's Guide for the CALPUFF Dispersion Model (Version 5)*, Earth Tech Incorporated, Long Beach CA, USA.

Earth Tech 2000, *A User's Guide for the CALMET Meteorological Model (Version 5)*, Earth Tech Incorporated, Long Beach CA, USA.

EPA Victoria 1985, *Plume Calculation Procedure*, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1986, *The AUSPLUME Gaussian Plume Dispersion Model*, First Edition, Publication 264, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 1999, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Publication 671, Environment Protection Authority of Victoria, Melbourne.

EPA Victoria 2000, *AUSPLUME Gaussian Plume Dispersion Model: Technical User Manual*, Environment Protection Authority of Victoria, Melbourne.

---

[5] www.epa.gov/scram001/tt22.htm#bpipprm

[6] www.epa.gov/ttn/scram/

Hurley, P. 2005, *The Air Pollution Model (TAPM) Version 3, Part 1: Technical Description*, CSIRO Atmospheric Research Technical Paper No. 71, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P. 2005, *The Air Pollution Model (TAPM) Version 3: User Manual*, CSIRO Atmospheric Research Technical Paper No. 31, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P., Physick, W., Luhar, A. and Edwards, M. 2005, *The Air Pollution Model (TAPM) Version 3, Part 2: Summary of Some Verification Studies*, CSIRO Atmospheric Research Technical Paper No. 72, CSIRO Division of Atmospheric Research, Melbourne.

Katestone Scientific 1995, *The Evaluation of Peak-to-Mean Ratios for Odour Assessments*, volumes I and II, Katestone Scientific Pty Ltd, Brisbane.

Katestone Scientific 1998, *Peak-to-Mean Concentration Ratios for Odour Assessments*, Katestone Scientific Pty Ltd, Brisbane.

Schulman, L.L., Strimaitis, D.G. and Scire, J.S., *Development and Evaluation of the PRIME Plume Rise and Building Downwash Model*, Preprint Volume for the Tenth Joint Conference on Applications of Air Pollution Meteorology with A&WMA, American Meteorological Society, Phoenix, Arizona, 1998.

USEPA 1985, *Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations)*, Revised, EPA-450/4-80-023R, United States Environmental Protection Agency, Washington DC, USA.

USEPA 1995, *User's Guide to the Building Profile Input Program*, Revised February 1995, EPA-454/R-93-038, United States Environmental Protection Agency, Washington DC, USA.

USEPA 1995, *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume 1 and Volume 2*, US EPA Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division Research Triangle Park, North Carolina.

USEPA 1997, *Addendum to ISC3 User's Guide, The PRIME Plume Rise and Building Downwash Model*, United States Environmental Protection Agency, Washington DC, USA.

USEPA 1999, *Guideline on Air Quality Models*, 40 CFR, Chapter I, Part 51, Appendix W, United States Environmental Protection Agency, Washington DC, USA.

# 7. Interpretation of dispersion modelling results

The primary purpose of an air quality impact assessment is to determine whether emissions from a premises will comply with the appropriate environmental outcomes. The assessment criteria outlined below reflect the environmental outcomes adopted by the EPA.

To ensure the environmental outcomes are achieved, emissions from a premises must be assessed against the assessment criteria. The cumulative impact of emissions from several facilities also needs to be considered. Impacts of sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), ozone ($O_3$), Lead (Pb), particles ($PM_{2.5}$ and $PM_{10}$), total suspended particulates (TSP), deposited dust, carbon monoxide (CO) and hydrogen fluoride (HF) must be combined with existing background levels before comparison with the relevant impact assessment criteria.

Assessment criteria must not be used as limit conditions in environment protection licences. Compliance with assessment criteria (i.e. in the ambient air at the boundary of the premises or nearest sensitive receptor) cannot be readily determined for regulatory purposes. For point sources, a site-specific stack emission limit can be calculated (see Sections 10 and 11.1) so that the assessment criteria will not be exceeded at and beyond the boundary of a premises because of emissions from those sources.

# 7.1. SO$_2$, NO$_2$, O$_3$, Pb, PM$_{2.5}$, PM$_{10}$, TSP, deposited dust, CO and HF

## 7.1.1. Impact assessment criteria

**Table 11**      Impact assessment criteria for SO$_2$, NO$_2$, O$_3$, Pb, PM$_{2.5}$, PM$_{10}$, TSP, deposited dust, CO and HF

| Pollutant | Averaging period | Concentration | | Source |
|---|---|---|---|---|
| Sulfur dioxide (SO$_2$) | 1 hour | 10 pphm [a] | 286 µg/m$^3$ | NEPC (2021) |
| | 1 hour | 7.5 pphm [b] | 215 µg/m$^3$ | NEPC (2021) |
| | 24 hours | 2 pphm | 57 µg/m$^3$ | NEPC (2021) |
| Nitrogen dioxide (NO$_2$) | 1 hour | 8 pphm | 164 µg/m$^3$ | NEPC (2021) |
| | Annual | 1.5 pphm | 31 µg/m$^3$ | NEPC (2021) |
| Photochemical oxidants (as ozone) | 8 hours | 6.5 pphm | 139 µg/m$^3$ | NEPC (2021) |
| Lead | Annual | – | 0.5 µg/m$^3$ | NEPC (1998) |
| PM$_{2.5}$ | 24 hours | – | 25 µg/m$^3$ | NEPC (2021) |
| | Annual | – | 8 µg/m$^3$ | NEPC (2021) |
| PM$_{10}$ | 24 hours | – | 50 µg/m$^3$ | NEPC (2021) |
| | Annual | – | 25 µg/m$^3$ | NEPC (2021) |
| Total suspended particulates (TSP) | Annual | – | 90 µg/m$^3$ | NHMRC (1996) |
| Deposited dust[e] | Annual | 2 g/m$^2$/month[c] | 4 g/m$^2$/month[d] | NERDDC (1988) |
| Carbon monoxide (CO) | 15 minutes | 87 ppm | 100 mg/m$^3$ | WHO (2000) |
| | 1 hour | 25 ppm | 30 mg/m$^3$ | WHO (2000) |
| | 8 hours | 9 ppm | 10 mg/m$^3$ | NEPC (2021) |
| Hydrogen fluoride | 90 days | 0.5 µg/m$^3$ [f] | 0.25 µg/m$^3$ [g] | ANZECC (1990) |
| | 30 days | 0.84 µg/m$^3$ [f] | 0.4 µg/m$^3$ [g] | ANZECC (1990) |
| | 7 days | 1.7 µg/m$^3$ [f] | 0.8 µg/m$^3$ [g] | ANZECC (1990) |
| | 24 hours | 2.9 µg/m$^3$ [f] | 1.5 µg/m$^3$ [g] | ANZECC (1990) |

**Notes**

a.   This impact assessment criterion applies to assessments prepared before 1 January 2025
b.   This impact assessment criterion applies to assessments prepared after 1 January 2025
c.   Maximum increase in deposited dust level
d.   Maximum total deposited dust level
e.   Dust is assessed as insoluble solids as defined by AS 3580.10.1–1991 (AM-19)
f.   General land use, which includes all areas other than specialised land use
g.   Specialised land use, which includes all areas with vegetation sensitive to fluoride, such as grapevines and stone fruits

### 7.1.2. Application of impact assessment criteria

The assessment criteria in Table 11 must be applied as follows:

1. At the **nearest existing or likely future off-site sensitive receptor**.
2. The **incremental impact** (predicted impacts due to the pollutant source alone) for each pollutant must be reported in units and averaging periods consistent with the impact assessment criteria.
3. **Background concentrations** must be included using the procedures specified in Section 5.
4. **Total impact (incremental impact plus background)** must be reported as the **100th percentile** in concentration or deposition units consistent with the impact assessment criteria and compared with the relevant impact assessment criteria.

## 7.2. Individual toxic air pollutants

### 7.2.1. Impact assessment criteria

Tables 12 and 13 list the impact assessment criteria for individual toxic air pollutants. The principal toxic air pollutants in Table 12 are defined on the basis that they are carcinogenic, mutagenic, teratogenic, highly toxic or highly persistent in the environment. Criteria for other individual toxic air pollutants are shown in Table 13.

Principal toxic air pollutants must be minimised to the maximum extent achievable through the application of best-practice process design and/or emission controls. Decisions with respect to achievability will have regard to technical, logistical and financial considerations. Technical and logistical considerations include a wide range of issues that will influence the feasibility of an option: for example, whether a particular technology is compatible with an enterprise's production processes.

Financial considerations relate to the financial viability of an option. It is not expected that reductions in emissions should be pursued 'at any cost'. Nor does it mean that the preferred option will always be the lowest-cost option. However, it is important that the preferred option is cost-effective. The costs need to be affordable in the context of the relevant industry sector within which the enterprise operates. This will need to be considered on a case-by-case basis through discussions with the EPA.

**Table 12    Impact assessment criteria (mg/m³ and ppm) for principal toxic air pollutants (Victorian Government Gazette 2001)**

| Substance | Averaging period | Code | mg/m³ ª | ppm |
|---|---|---|---|---|
| Acrolein | 1 hour | 1 | 0.00042 | 0.00018 |
| Acrylonitrile | 1 hour | 2 | 0.008 | 0.0037 |
| Alpha chlorinated toluenes and benzoyl chloride | 1 hour | 3 | 0.009 | 0.0018 |
| Arsenic and compounds | 1 hour | 4 | 0.00009 | N/A |
| Asbestos | 1 hour | 4 | 0.18 | N/A |
| Benzene | 1 hour | 4 | 0.029 | 0.009 |
| Beryllium and beryllium compounds | 1 hour | 4 | 0.000004 | N/A |
| 1,3-butadiene | 1 hour | 3 | 0.04 | 0.018 |
| Cadmium and cadmium compounds | 1 hour | 4 | 0.000018 | N/A |
| Chromium VI compounds | 1 hour | 4 | 0.00009 | N/A |
| 1,2-dichloroethane (ethylene dichloride) | 1 hour | 5 | 0.07 | 0.018 |
| Dioxins and furans[b] | 1 hour | 4 | 2.0E–09 | N/A |
| Epichlorohydrin | 1 hour | 3 | 0.014 | 0.0037 |
| Ethylene oxide | 1 hour | 4 | 0.0033 | 0.0018 |
| Formaldehyde | 1 hour | 6 | 0.02 | 0.018 |
| Hydrogen cyanide | 1 hour | 1 | 0.20 | 0.18 |
| MDI (diphenylmethane diisocyanate) | 1 hour | 1 | 0.00004 | N/A |
| Nickel and nickel compounds | 1 hour | 4 | 0.00018 | 0.00009 |
| Polycyclic aromatic hydrocarbon (as benzo[a]pyrene)[c] | 1 hour | 3 | 0.0004 | N/A |
| Pentachlorophenol | 1 hour | 1 | 0.0009 | N/A |
| Phosgene | 1 hour | 1 | 0.007 | 0.0018 |
| Propylene oxide | 1 hour | 2 | 0.09 | 0.037 |
| TDI (toluene-2,4-diisocyanate; toluene-2,6-diisocyanate) | 1 hour | 1 | 0.00004 | N/A |
| Trichloroethylene | 1 hour | 3 | 0.5 | 0.09 |
| Vinyl chloride | 1 hour | 4 | 0.024 | 0.009 |

**Notes**

a.  Gas volumes are expressed at 25°C and at an absolute pressure of 1 atmosphere (101.325 kPa).

b.  Toxic equivalent as defined in clause 41 of the Regulation

c.  Refer to Table 14

**Codes**

1.  USEPA extremely toxic

2.  USEPA Group B1 carcinogen (probable human carcinogen)

3.  IARC Group 2A carcinogen (probable human carcinogen)

4.  IARC Group 1 carcinogen (known human carcinogen)

5.  Mutagen (USEPA)

6.  IARC Group 2B carcinogen (possible human carcinogen)

**Table 13    Impact assessment criteria (mg/m$^3$ and ppm) for individual toxic air pollutants (Victorian Government Gazette 2001)**

| Substance | Averaging period | mg/m$^{3\,a}$ | ppm |
|---|---|---|---|
| Acetone | 1 hour | 22 | 9.2 |
| Acrylic acid | 1 hour | 0.11 | 0.037 |
| Ammonia | 1 hour | 0.33 | 0.46 |
| Aniline | 1 hour | 0.14 | 0.037 |
| Antimony and compounds | 1 hour | 0.009 | N/A |
| Asphalt (petroleum) fumes | 1 hour | 0.09 | N/A |
| Barium (soluble compound) | 1 hour | 0.009 | N/A |
| Biphenyl | 1 hour | 0.024 | 0.0037 |
| Bromochloromethane | 1 hour | 19 | 3.7 |
| Bromoform (tribromomethane) | 1 hour | 0.09 | 0.009 |
| Bromotrifluoromethane | 1 hour | 112 | 18 |
| Carbon black | 1 hour | 0.05 | N/A |
| Carbon tetrachloride (tetrachloromethane) | 1 hour | 0.012 | 0.0018 |
| Chlorine | 1 hour | 0.05 | 0.018 |
| Chlorine dioxide | 1 hour | 0.0051 | 0.0018 |
| Chloroform (trichloromethane) | 1 hour | 0.9 | 0.18 |
| Chloromethane (methyl chloride) | 1 hour | 1.9 | 0.9 |
| Chromium (III) compounds | 1 hour | 0.009 | N/A |
| Copper fumes | 1 hour | 0.0037 | N/A |
| Copper dusts and mists | 1 hour | 0.018 | N/A |
| Cotton dust (raw) | 1 hour | 0.0037 | N/A |
| Crotonaldehyde | 1 hour | 0.1 | 0.037 |
| Cyanide (as CN) | 1 hour | 0.09 | N/A |
| Cyclohexane | 1 hour | 19 | 5 |
| Cyclohexanol | 1 hour | 3.8 | 0.9 |
| *o*-dichlorobenzene | 1 hour | 5.5 | 0.9 |
| 1,2-dichloroethylene | 1 hour | 14.4 | 3.7 |
| Dichlorvos | 1 hour | 0.018 | 0.0018 |
| Dinitrobenzene (all isomers) | 1 hour | 0.018 | 0.003 |
| Dinitrotoluene | 1 hour | 0.027 | N/A |
| Ethanolamine | 1 hour | 0.14 | 0.05 |
| Ethylbenzene | 1 hour | 8.0 | 1.8 |
| Ethyl butyl ketone | 1 hour | 4.2 | 0.9 |
| Ethyl chloride (chloroethane) | 1 hour | 48 | 18 |
| Ethylene glycol (vapour) | 1 hour | 1 | N/A |

| Substance | Averaging period | mg/m³ ᵃ | ppm |
|---|---|---|---|
| n-hexane | 1 hour | 3.2 | 0.9 |
| 2-hexanone | 1 hour | 1.8 | 0.46 |
| Hydrogen chloride | 1 hour | 0.14 | 0.09 |
| Iron oxide fumes | 1 hour | 0.09 | N/A |
| Magnesium oxide fumes | 1 hour | 0.18 | N/A |
| Maleic anhydride | 1 hour | 0.018 | 0.0046 |
| Manganese and compounds | 1 hour | 0.018 | N/A |
| Mercury organic | 1 hour | 0.00018 | N/A |
| Mercury inorganic | 1 hour | 0.0018 | N/A |
| Methyl acrylate | 1 hour | 0.66 | 0.18 |
| Methyl bromide (bromomethane) | 1 hour | 0.35 | 0.09 |
| Methylene chloride (dichloromethane) | 1 hour | 3.19 | 0.9 |
| Nitric acid | 1 hour | 0.09 | 0.037 |
| n-pentane | 1 hour | 33 | 11 |
| 2-pentanone | 1 hour | 12.8 | 3.7 |
| Phthalic anhydride | 1 hour | 0.1 | 0.018 |
| Propylene glycol monomethyl ether | 1 hour | 6.6 | 1.8 |
| Silver metal | 1 hour | 0.0018 | N/A |
| Silver, soluble compounds (as Ag) | 1 hour | 0.00018 | N/A |
| Sulfuric acid | 1 hour | 0.018 | N/A |
| 1,1,1-trichloroethane (methyl chloroform) | 1 hour | 12.5 | 2.3 |
| 1,1,2-trichloroethane | 1 hour | 1.0 | 0.18 |
| Trichlorofluoromethane | 1 hour | 103 | 18.3 |
| Trimethylbenzene (mixed isomers) | 1 hour | 2.2 | 0.46 |
| Vinyl toluene | 1 hour | 4.4 | 0.9 |
| Welding fumes (total particulate) | 1 hour | 0.09 | N/A |
| Wood dust hardwoods | 1 hour | 0.0018 | N/A |
| Wood dust softwoods | 1 hour | 0.009 | N/A |
| Zinc chloride fumes | 1 hour | 0.018 | N/A |
| Zinc oxide fumes | 1 hour | 0.09 | N/A |

**Note**

a.  Gas volumes are expressed at 25°C and at an absolute pressure of 1 atmosphere (101.325 kPa).

**Table 14    Potency equivalency factors (PEFs) for PAHs (OEHHA 1994)**

| PAH or derivative | CAS number | PEF |
| --- | --- | --- |
| Benzo[a]pyrene | 50-32-8 | 1 |
| Benzo[a]anthracene | 56-55-3 | 0.1 |
| Benzo[b]fluoranthene | 205-99-2 | 0.1 |
| Benzo[j]fluoranthene | 205-82-3 | 0.1 |
| Benzo[k]fluoranthene | 207-08-9 | 0.1 |
| Bibenz[a,j]acridine | 224-42-0 | 0.1 |
| Bibenz[a,h]acridine | 226-36-8 | 0.1 |
| 7h-dibenzo[c,g]carbazole | 194-59-2 | 1 |
| Dibenzo[a,e]pyrene | 192-65-4 | 1 |
| Dibenzo[a,h]pyrene | 189-64-0 | 10 |
| Dibenzo[a,i]pyrene | 189-55-9 | 10 |
| Dibenzo[a,l]pyrene | 191-30-0 | 10 |
| 5-nitroacenaphthene | 602-87-9 | 0.01 |
| Indeno[1,2,3-cd]pyrene | 193-39-5 | 0.1 |
| 5-methylchrysene | 3697-24-3 | 1 |
| 1-nitropyrene | 5522-43-0 | 0.1 |
| 4-nitropyrene | 57835-92-4 | 0.1 |
| 1,6-dinitropyrene | 42397-64-8 | 10 |
| 1,8-dinitropyrene | 42397-65-9 | 1 |
| 6-nitrocrysene | 7496-02-8 | 10 |
| 2-nitrofluorene | 607-57-8 | 0.01 |
| Chrysene | 218-01-9 | 0.01 |
| Dibenz[a,h]anthracene | 53-70-3 | 0.4 |
| 7,12-dimethylbenzanthracene | 57-97-6 | 21.8 |
| 3-methylcholanthrene | 56-49-5 | 1.9 |

### 7.2.2. Application of impact assessment criteria

The impact assessment criteria for individual toxic air pollutants in Tables 12 and 13 must be applied as follows:

1. **At and beyond the boundary of the facility**.
2. The **incremental impact** (predicted impacts due to the pollutant source alone) for each pollutant must be reported in concentration units consistent with the criteria (mg/m$^3$ or ppm), for an **averaging period of 1 hour** and as the:
   a. **100th percentile** of dispersion model predictions for Level 1 impact assessments
      or
   b. **99.9th percentile** of dispersion model predictions for Level 2 impact assessments.
3. Polycyclic aromatic hydrocarbons (PAH) as benzo[a]pyrene (BaP) must be calculated using the potency equivalency factors for PAHs in Table 14.
4. Dioxins and furans as toxic equivalent must be calculated according to the requirements of clause 41 of the Regulation.

## 7.3. Complex mixtures of toxic air pollutants

### 7.3.1. Risk assessment criteria

Where a number of toxic and carcinogenic air pollutants are emitted in significant amounts, demonstrating compliance with impact assessment criteria may not adequately demonstrate the protection of human health. A risk assessment can be used to assess the potential risk arising from exposure to emissions of toxic air pollutants after emissions of principal toxic air pollutants have been reduced to the maximum extent achievable, and compliance with the impact assessment criteria has been demonstrated. Health risk assessment is particularly useful for the assessment of multiple chemicals and exposure through multiple pathways (e.g. inhalation, ingestion or dermal adsorption).

Take care when interpreting the results of a risk assessment. A risk assessment does not demonstrate that a particular impact will happen. Often the information available to risk assessors is imperfect, and consequently assumptions are made that tend to overestimate a risk. It is legitimate for a risk assessor to go through a process of refining assumptions to obtain a more realistic assessment of risk.

Guidelines for undertaking risk assessment in Australia have been prepared by the enHealth Council (enHealth 2002). These guidelines provide a broad framework for risk assessment that aims to enhance its use in environmental impact assessment.

The risk assessment process includes the following aspects:

- hazard identification
- assessment of exposure
- dose response assessment
- risk characterisation.

Assessment of exposure should be based on enHealth's published information on the assessment of exposure in Australia (enHealth 2001 and 2003).

Dose response assessment and risk characterisation can be undertaken in accordance with the following:

- *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments* (OEHHA 2003)
- *Hot Spots Analysis and Reporting Program* (HARP) (CARB 2003a)

- *Hot Spots Analysis and Reporting Program – User Guide Version 1.0* (CARB 2003b).

The results of the risk assessment should be compared with the criteria specified in Table 15 for carcinogenic risk and the acute and chronic non-carcinogenic hazard index.

**Table 15**      **Acceptance criteria for risk and hazard index**

| Evaluation | Carcinogenic risk (CR) | Acute and chronic non-carcinogenic hazard index (HI) |
|---|---|---|
| Acceptable | Less than 1 in 1 million ($1 \times 10^{-6}$) | Less than 0.2 |
| Require best practice for air toxics and CR < 1 in 1 million and HI < 0.2 | 1 in 1 million to 1 in 10 thousand ($1 \times 10^{-6}$ to $1 \times 10^{-4}$) | 0.2 to 10 |
| Not acceptable | Greater than 1 in 10 thousand ($1 \times 10^{-4}$) | Greater than 10 |

## 7.4. Individual odorous air pollutants

### 7.4.1. Impact assessment criteria

Table 16 lists the impact assessment criteria for individual odorous air pollutants. Equation 7.1 must be used to select the appropriate impact assessment criterion for hydrogen sulfide as a function of population density:

**Equation 7.1**

Impact assessment criterion ($\mu g/m^3$) = ($\log_{10}$ (population) – 4.5) / –0.87

**Table 16**     Impact assessment criteria (mg/m³ and ppm) for individual odorous air pollutants (Victorian Government Gazette 2001)

| Substance | Averaging period | mg/m³ a | ppm |
|---|---|---|---|
| Acetaldehyde | 1 hour | 0.042 | 0.023 |
| Acetic acid | 1 hour | 0.27 | 0.11 |
| n-butanol | 1 hour | 0.5 | 0.16 |
| n-butyl acetate | 1 hour | 1.02 | 0.21 |
| Butyl acrylate | 1 hour | 0.10 | 0.019 |
| Butyl mercaptan | 1 hour | 0.007 | 0.002 |
| Carbon disulfide | 1 hour | 0.07 | 0.023 |
| Chlorobenzene | 1 hour | 0.1 | 0.023 |
| Cumene (isopropyl benzene) | 1 hour | 0.021 | 0.004 |
| Cyclohexanone | 1 hour | 0.26 | 0.07 |
| Diacetone alcohol | 1 hour | 0.7 | 0.15 |
| Diethylamine | 1 hour | 0.03 | 0.01 |
| Dimethylamine | 1 hour | 0.009 | 0.0052 |
| Diphenyl ether | 1 hour | 0.08 | 0.01 |
| Ethanol | 1 hour | 2.1 | 1.1 |
| Ethyl acetate | 1 hour | 12.1 | 3.5 |
| Ethyl acrylate | 1 hour | 0.0004 | 0.0001 |
| Methanol | 1 hour | 3.0 | 2.4 |
| Methylamine | 1 hour | 0.0027 | 0.0023 |
| Methyl ethyl ketone | 1 hour | 3.2 | 1.1 |
| Methyl isobutyl ketone | 1 hour | 0.23 | 0.05 |
| Methyl mercaptan | 1 hour | 0.00046 | 0.00023 |
| Methyl methacrylate | 1 hour | 0.12 | 0.027 |
| Methyl styrene | 1 hour | 0.14 | 0.028563 |
| Nitrobenzene | 1 hour | 0.0026 | 0.00052 |
| Perchlorethylene (tetrachloroethylene) | 1 hour | 3.5 | 0.52 |
| Phenol | 1 hour | 0.020 | 0.0052 |
| Phosphine | 1 hour | 0.0031 | 0.0023 |
| n-propanol | 1 hour | 0.041 | 0.016 |
| Pyridine | 1 hour | 0.007 | 0.0023 |
| Styrene (monomer) | 1 hour | 0.12 | 0.027 |
| Toluene | 1 hour | 0.36 | 0.09 |
| Triethylamine | 1 hour | 0.20 | 0.05 |
| Xylenes | 1 hour | 0.19 | 0.04 |

**Note** a.    Gas volumes are expressed at 25°C and at an absolute pressure of 1 atmosphere (101.325 kPa)

Table 17 provides a summary of appropriate impact assessment criteria for hydrogen sulfide as a function of population density.

**Table 17**    **Impact assessment criteria for hydrogen sulfide (nose-response-time average, 99th percentile) (AWT, 2001)**

| Population of affected community | Impact assessment criteria ($\mu g/m^3$) |
|---|---|
| Urban ($\geq \sim 2000$) | 1.38 |
| ~500 | 2.07 |
| ~125 | 2.76 |
| ~30 | 3.45 |
| ~10 | 4.14 |
| Single residence ($\leq \sim 2$) | 4.83 |

### 7.4.2. Application of impact assessment criteria

The impact assessment criteria for individual odorous air pollutants in Tables 16 and 17 must be applied as follows:

1. **At the nearest existing or likely future off-site sensitive receptor**.
2. The **incremental impact** must be reported in concentration units consistent with the impact assessment criteria ($\mu g/m^3$) for an **averaging period of 1 hour, except for hydrogen sulfide, which must be reported as peak concentrations** (i.e. approximately one second average) in accordance with the requirements of Section 6, and as the:
   a. **100th percentile** of dispersion model predictions for Level 1 impact assessments
      or
   b. **99.9th percentile** of dispersion model predictions for Level 2 impact assessments, **except for hydrogen sulfide**, which must be reported as the **99th percentile** of dispersion model predictions.

## 7.5. Complex mixtures of odorous air pollutants

### 7.5.1. Impact assessment criteria

The impact assessment criteria for complex mixtures of odours have been designed to take into account the range of sensitivity to odours within the community and to provide additional protection for individuals with a heightened response to odours. This is achieved by using a statistical approach dependent upon population size. As the population density increases, the proportion of sensitive individuals is also likely to increase, indicating that more stringent criteria are necessary in these situations.

Equation 7.2 should be used to determine the appropriate impact assessment criteria for complex mixtures of odorous air pollutants:

**Equation 7.2**

Impact assessment criterion (OU) = ($\log_{10}$ (population) – 4.5) / –0.6

Table 18 provides a summary of appropriate impact assessment criteria for various population densities.

**Table 18    Impact assessment criteria for complex mixtures of odorous air pollutants (nose-response-time average, 99th percentile) (EPA 2001)**

| Population of affected community | Impact assessment criteria for complex mixtures of odorous air pollutants (OU) |
|---|---|
| Urban (≥~2000) and/or schools and hospitals | 2.0 |
| ~500 | 3.0 |
| ~125 | 4.0 |
| ~30 | 5.0 |
| ~10 | 6.0 |
| Single rural residence (≤~2) | 7.0 |

## 7.5.2. Application of impact assessment criteria

The impact assessment criteria for complex mixtures of odorous air pollutants must be applied as follows:

1. **At the nearest existing or likely future off-site sensitive receptor**.
2. The **incremental impact** (predicted impact due to the pollutant source alone) must be reported in units consistent with the impact assessment criteria (OU), as **peak concentrations** (i.e. approximately 1 second average) in accordance with the requirements of Section 6 and as the:
   a. **100th percentile** of dispersion model predictions for Level 1 impact assessments
      or
   b. **99th percentile** of dispersion model predictions for Level 2 impact assessments.

## 7.6. Presentation of assessment results

The results of an impact assessment should be presented as follows:

1. concentration, hazard index and/or risk contours (isopleths) to define potential affected zones
2. concentration, hazard index and/or risk predictions in tabular form for
   a. existing and likely future sensitive receptors
   b. maximum exposed off-site receptor
   c. maximum outside the boundary of the premises.

## 7.7. What if impact assessment criteria are exceeded?

If the EPA's impact assessment criteria are exceeded, the dispersion modelling must be revised to include various pollution control strategies until compliance is achieved. To determine incremental increases in the cost of air pollution abatement, a sensitivity analysis can be carried out by varying:

* source release parameters
* separation distance
* efficiency of pollution control equipment
* level of management practice.

The results can be used to select the most cost-effective and environmentally effective control strategy.

## 7.8. Bibliography

ANZECC 1990, *National Goals for Fluoride in Ambient Air and Forage*, Australian and New Zealand Environment and Conservation Council, Canberra.

AWT 2001, *Literature Review – Australian and Overseas Odour Threshold Data and Ambient Air Quality Criteria for Hydrogen Sulphide, A Report to the NSW EPA*, Australian Water Technologies, Sydney.

Carson, P. and Round, J. 1989, *Feedlot Odours*, Department of Primary Industry, Brisbane.

CARB 2003a, *Hot Spots Analysis and Reporting Program (HARP)*, California Environmental Protection Agency, Air Resources Board, www.arb.ca.gov/toxics/harp/harp.htm

CARB 2003b, *Hot Spots Analysis and Reporting Program, User Guide Version 1.0*, California Environmental Protection Agency, Air Resources Board, Sacramento.

enHealth 2001, *Exposure Scenarios and Exposure Settings, March 2001*, Department of Health and Ageing and enHealth Council, Canberra.

enHealth 2002, *Environmental Health Risk Assessment: Guidelines for Assessing Human Health Risks from Environmental Hazards, June 2002*, Department of Health and Ageing and enHealth Council, Canberra.

enHealth 2003, *Australian Exposure Assessment Handbook, Consultation Draft, December 2003*, Department of Health and Ageing and enHealth Council, Canberra.

EPA 1998, *Action for Air: The NSW Government's 25-Year Air Quality Management Plan*, NSW Environment Protection Authority, Sydney.

EPA 2001, *Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*, NSW Environment Protection Authority, Sydney.

EPA 2001, *Technical Notes – Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*, NSW Environment Protection Authority, Sydney.

EPA Victoria 1985, *Plume Calculation Procedure: An Approved Procedure under Schedule E of State Environment Protection Policy (The Air Environment)*, Publication 210, Environment Protection Authority of Victoria, Melbourne.

NEPC 2021, *National Environment Protection (Ambient Air Quality) Measure*, National Environment Protection Council, Canberra.

NERDDC 1988, *Air Pollution from Surface Coal Mining: Measurement, Modelling and Community Perception*, Project No. 921, National Energy Research Development and Demonstration Council, Canberra.

NHMRC 1996, *Ambient Air Quality Goals Recommended by the National Health and Medical Research Council*, National Health and Medical Research Council, Canberra.

OEHHA 1994, *Benzo[a]pyrene as a Toxic Air Contaminant, Executive Summary*, California Air Resources Board and the Office of Environmental Health Hazard Assessment, Sacramento.

OEHHA 2003, *The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments*, Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento.

Streeton, J.A. 1990, *Air Pollution, Health Effects and Air Quality Objectives in Victoria*, Environment Protection Authority of Victoria, Melbourne.

SPCC 1983, *Air Pollution from Coal Mining and Related Developments*, State Pollution Control Commission, Sydney.

*Victorian Government Gazette*, Friday 21 December 2001, 'State Environment Protection Policy (Air Quality Management)', No. S 240, Government of Victoria, Melbourne.

WHO 2000, *WHO Air Quality Guidelines for Europe*, 2nd Edition, World Health Organization, Geneva.

# 8. Modelling pollutant transformations

Photochemical smog is a complex mixture of chemicals and is sometimes visible as a white haze during the warmer months. In the Greater Metropolitan Region of NSW (Sydney, the Lower Hunter and Illawarra), its most significant components are ground-level ozone ($O_3$) and nitrogen dioxide ($NO_2$). These pollutants are formed in the atmosphere when volatile organic compounds (VOCs) and oxides of nitrogen ($NO_x$) react under the influence of sunlight.

Oxides of nitrogen are formed during high-temperature combustion processes from the oxidation of nitrogen in the air or fuel. $NO_x$ from combustion consists largely of nitrogen oxide (NO) and partly of $NO_2$. After emission from the stack, NO is transformed to $NO_2$ through oxidation with atmospheric ozone.

The formation of $O_3$ and $NO_2$ in the atmosphere can be assessed by various methods. Minor sources of $NO_x$ and VOCs may need only a simple assessment to demonstrate compliance with impact assessment criteria, while larger sources may need a more detailed scientific assessment. An assessment of impacts of a new source of $NO_x$ and/or VOCs on $NO_2$ and/or $O_3$ formation is unlikely to be necessary outside the Greater Metropolitan Region.

Various methods of assessment are described below.

## 8.1. Nitrogen dioxide assessment

The oxidation of NO to $NO_2$ in the atmosphere can be assessed by various methods. The methods below range from the simple (Method 1) to more detailed (Method 3).

### 8.1.1. Method 1: 100% conversion of NO to $NO_2$

#### Level 1 assessment: Maximum prediction and maximum background concentrations

1. Use a dispersion model to predict 1-hour and annual average ground-level concentrations of $NO_x$ (as $NO_2$).
2. Assume that 100% of the $NO_x$ emitted is converted to $NO_2$.
3. Determine the total ground-level concentration of $NO_2$ by adding the maximum predicted 1-hour and annual average ground-level concentrations with the maximum 1-hour and annual average background concentrations respectively.
4. If the impact assessment criteria are exceeded, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

#### Level 2 assessment: Contemporaneous prediction and background concentrations – 1-hour average

1. Use a dispersion model to predict 1-hour average ground-level concentrations of $NO_x$ (as $NO_2$).
2. Assume that 100% of the $NO_x$ emitted is converted to $NO_2$.
3. Determine the total ground-level concentration of $NO_2$ by adding the predicted 1-hour average ground-level concentration with the contemporaneous 1-hour average background concentration.
4. Determine the frequency at which the 1-hour average impact assessment criteria are exceeded at each sensitive receptor with and without the subject source.
5. If additional exceedances of the impact assessment criteria are caused by the addition of the subject source, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

### 8.1.2. Method 2: NO to NO₂ conversion limited by ambient ozone concentration (OLM)

The USEPA's Ozone Limiting Method (OLM) (Cole and Summerhays 1979; Tikvart 1996) may be used to predict ground-level concentrations of $NO_2$. This method assumes that all the available ozone in the atmosphere will react with NO in the plume until either all the $O_3$ or all the NO is used up. This approach assumes that the atmospheric reaction is instant. In reality, the reaction takes place over a number of hours. A detailed methodology can be downloaded from the USEPA website.[7]

Using Equation 8.1, various levels of refinement can be adopted, depending on the scale of emissions and impact.

**Equation 8.1**

$[NO_2]_{total}$ = {0.1 × $[NO_x]_{pred}$} + MIN{(0.9) × $[NO_x]_{pred}$ or (46/48) × $[O_3]_{bkgd}$} + $[NO_2]_{bkgd}$

*where:*

$[NO_2]_{total}$ = the predicted concentration of $NO_2$ in $\mu g/m^3$

$[NO_x]_{pred}$ = the dispersion model prediction of the ground-level concentration of $NO_x$ in $\mu g/m^3$

MIN = the minimum of the two quantities within the braces

$[O_3]_{bkgd}$ = the background ambient $O_3$ concentration in $\mu g/m^3$

(46/48) = the molecular weight of $NO_2$ divided by the molecular weight of $O_3$ in $\mu g/m^3$

$[NO_2]_{bkgd}$ = the background ambient $NO_2$ concentration in $\mu g/m^3$

#### Level 1 assessment: Maximum prediction and maximum background concentrations

1. Use a dispersion model to predict 1-hour average and annual ground-level concentrations of $NO_x$ (as $NO_2$).
2. Assume 100% of the $NO_x$ emitted is converted to $NO_2$ ($[NO_x]_{pred}$ in Equation 8.1).
3. Determine the maximum 1-hour and annual average background concentrations of $NO_2$ and $O_3$ ($[NO_2]_{bkgd}$ and $[O_3]_{bkgd}$ respectively in Equation 8.1).
4. Determine the maximum total 1-hour and annual average ground-level concentrations of $NO_2$ ($[NO_2]_{total}$ in Equation 8.1) by substituting $[NO_x]_{pred}$, $[NO_2]_{bkgd}$ and $[O_3]_{bkgd}$ into Equation 8.1.
5. If the impact assessment criteria are exceeded, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

#### Level 2 assessment: Contemporaneous prediction and background concentrations – 1-hour average

1. Use a dispersion model to predict 1-hour average ground-level concentrations of $NO_x$ (as $NO_2$).
2. Assume 100% of the $NO_x$ emitted is converted to $NO_2$ ($[NO_x]_{pred}$ in Equation 8.1).
3. Obtain continuous 1-hour average ambient measurements of $NO_2$ and $O_3$ for the same period as the dispersion modelling predictions ($[NO_2]_{bkgd}$ and $[O_3]_{bkgd}$ respectively in Equation 8.1).
4. Determine the total ground-level concentration of $NO_2$ ($[NO_2]_{total}$ in Equation 8.1) by substituting $[NO_x]_{pred}$, $[NO_2]_{bkgd}$ and $[O_3]_{bkgd}$ into Equation 8.1 for each hour of the dispersion model simulation.

---

[7] www.epa.gov/scram001/tt25.htm#review

5. Determine the frequency at which the 1-hour average impact assessment criteria are exceeded at each sensitive receptor with and without the subject source.

6. If additional exceedances of the impact assessment criteria are caused by the addition of the subject source, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

### 8.1.3. Method 3: NO to NO₂ conversion using empirical relationship

Janssen et al. (1988) developed an empirical equation for estimating the oxidation rate of NO in power plant plumes. The equation is dependent on distance downwind from the source and the parameters A and $\alpha$ and has the following form:

**Equation 8.2**

$$NO_2 / NO_x = A(1 - \exp(-\alpha x))$$

*where*:

$x$ = the distance from the source

A and $\alpha$ are classified according to $O_3$ concentration, wind speed and season (Janssen et al. (1988) provides values for A and $\alpha$)

Equation 8.2 can be used with various levels of refinement to calculate ground-level concentrations of $NO_2$.

### Level 1 assessment: Maximum prediction and maximum background concentrations

1. Use a dispersion model to predict 1-hour average and annual ground-level concentrations of $NO_x$ (as $NO_2$).

2. Assume 100% of the $NO_x$ emitted is converted to $NO_2$.

3. Determine the distance of the maximum predicted 1-hour and annual average $NO_2$ ground-level concentrations from the source ($x$ in Equation 8.2).

4. Determine the maximum 1-hour and annual average background concentrations of $NO_2$.

5. Calculate the ratio of $NO_2$ to $NO_x$ by substituting $x$ in Equation 8.2 and assuming worst-case values for A and $\alpha$.

6. Determine the total ground-level concentration of $NO_2$ by applying the ratio of $NO_2$ to $NO_x$ to the maximum predicted 1-hour and annual average $NO_2$ ground-level concentrations and adding the result to the maximum 1-hour and annual average background concentrations respectively.

7. If the impact assessment criteria are exceeded, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

### Level 2 assessment: Contemporaneous prediction and background concentrations – 1-hour average

1. Use a dispersion model to predict 1-hour average and annual ground-level concentrations of $NO_x$ (as $NO_2$).

2. Assume 100% of the $NO_x$ emitted is converted to $NO_2$.

3. For each hour of the dispersion model simulation, determine the distance of the maximum predicted 1-hour average $NO_2$ ground-level concentration from the source (x in Equation 8.2).

4. Obtain continuous 1-hour average ambient measurements of $NO_2$ for the same period as the dispersion modelling predictions.

5. For each hour of the dispersion model simulation, calculate the ratio of $NO_2$ to $NO_x$ by substituting $x$ and appropriate values for A and $\alpha$ in Equation 8.2.

6.  Determine the total ground-level concentration of $NO_2$ for each hour of the dispersion model simulation by applying the ratio of $NO_2$ to $NO_x$ to the predicted 1-hour average $NO_2$ ground-level concentration and adding the result to the 1-hour average background concentration.

7.  Determine the frequency at which the 1-hour average impact assessment criteria are exceeded at each sensitive receptor with and without the subject source.

8.  If additional exceedances of the impact assessment criteria are caused by the addition of the subject source, a more refined assessment should be undertaken and/or additional management practices or emission controls applied.

## 8.2. Detailed assessment of ozone and nitrogen dioxide

Before undertaking a quantitative assessment of photochemical smog, seek advice from the EPA's air technical team. Some models that can provide a more detailed assessment of changes in ambient $O_3$ and $NO_2$ are outlined below.

### 8.2.1. Integrated Empirical Rate (IER) Reactive Plume Model

The CSIRO's IER-Reactive Plume Model (Johnson 1983; Johnson et al. 1990; Azzi et al. 1993; Azzi and Johnson 1994) can be used to provide a more refined assessment of the changes in ambient $NO_2$ concentrations than the methods specified above. The IER-Reactive Plume Model can also predict changes in ambient $O_3$ concentrations.

### 8.2.2. TAPM

CSIRO TAPM includes gas-phase photochemistry based on the semi-empirical mechanism, called the Generic Reaction Set (GRS). In chemistry mode, TAPM includes 10 reactions for the following 13 species: smog reactivity, radical pool, hydrogen peroxide ($H_2O_2$), NO, $NO_2$, $O_3$, $SO_2$, stable non-gaseous organic carbon, stable gaseous nitrogen products, stable non-gaseous nitrogen products, stable non-gaseous sulfur products, airborne particulate matter and fine particulate matter.

## 8.3. Bibliography

Azzi, M. and Johnson, G.M. 1994, 'Photochemical smog assessment for $NO_x$ emissions using an IER-Reactive Plume technique', *Proceedings of the 12th International Clean Air Conference*, Clean Air Society of Australia and New Zealand, Perth, Australia, vol. 2, pp. 219–30, November 1994.

Azzi, M., Johnson, G.M., Hyde, R. and Young, M. 1993, 'Predicting the chemistry of $NO_x$ plumes for urban regions, *Proceedings of the International Congress on Modelling and Simulation*, eds M. McAleer and A. Jakeman, vol. 1, pp. 287–92, Perth, 6–10 December 1993.

Cole, H.S. and Summerhays, J.E. 1979, 'A review of the techniques available for estimating short term $NO_2$ concentrations', *Journal of the Air Pollution Control Association*, 29(8),

812–17.

Hurley, P. 2005a, *The Air Pollution Model (TAPM) Version 3, Part 1: Technical Description*, CSIRO Atmospheric Research Technical Paper No. 71, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P. 2005b, *The Air Pollution Model (TAPM) Version 3: User Manual*, CSIRO Atmospheric Research Technical Paper No. 31, CSIRO Division of Atmospheric Research, Melbourne.

Hurley, P., Physick, W., Luhar, A. and Edwards, M. 2005b, *The Air Pollution Model (TAPM) Version 3, Part 2: Summary of Some Verification Studies*, CSIRO Atmospheric Research Technical Paper No. 72, CSIRO Division of Atmospheric Research, Melbourne.

Janssen, L.H.J.M., van Wakeren, J.H.A., van Duuran, H. and Elshout, A.J. 1988, 'A classification of NO oxidation rates in power plant plumes based on atmospheric conditions', *Atmospheric Environment*, 22(1), 43–53.

Johnson, G.M. 1983, 'An empirical model of photochemical smog formation', *Proceedings of the 7th World Congress on Air Quality*, 16–20 May, Paris, 1, 25–32.

Johnson, G.M., Quigley, S.M. and Smith, J.G. 1990, 'Management of photochemical smog using Airtrak approach', *Proceedings of the 10th International Conference of the Clean Air Society of Australia and New Zealand*, Auckland, NZ, pp. 209–14.

Tikvart, J.A. 1996, *Application of Ozone Limiting Method*, Model Clearinghouse Memorandum No. 107, US Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, USA.

# 9. Impact assessment report

An air quality impact assessment report must clearly document the methodology and result of the assessment. The EPA's minimum requirements regarding the information contained within an impact assessment report are specified below.

## 9.1. Site plan

- Layout of the site clearly showing all unit operations
- All emission sources clearly identified
- Plant boundary
- Sensitive receptors (e.g. nearest residences)
- Topography

## 9.2. Description of the activities carried out on the site

- A process flow diagram clearly showing all unit operations carried out on the premises
- A detailed discussion of all unit operations carried out on the site, including all possible operational variability
- A detailed list of all process inputs and outputs
- Plans, process flow diagrams and descriptions that clearly identify and explain all pollution control equipment and techniques for all processes on the premises
- A description of all aspects of the air emission control system, with particular regard to any fugitive emission capture systems (e.g. hooding, ducting), treatment systems (e.g. scrubbers, bag filters) and discharge systems (e.g. stacks)
- The operational parameters of all emission sources, including all operational variability, i.e. location, release type (stack, volume or area) and release parameters (e.g. stack height, stack diameter, exhaust velocity, temperature, emission concentration and rate)

## 9.3. Emissions inventory

- A detailed discussion of the methodology used to calculate the expected pollutant emission rates for each source
- All supporting reports of source emission tests. All analytical reports must contain all the information specified in EPA (2022).
- Methodologies used to sample and analyse for each of the pollutants considered
- Detailed calculations of pollutant emission rates for each source
- Tables showing all release parameters of stack and fugitive sources (e.g. temperature, exit velocity, stack dimensions, and emission concentrations and rates), and all pollutant emission concentrations with a comparison of the emission concentrations against the relevant requirements of the Regulation. A suggested format for the tables is given in Tables 1, 2 and 3.

## 9.4. Meteorological data

### 9.4.1. Level 1 meteorological data

- A description of the techniques used to prepare the meteorological data in a format for use in the dispersion modelling

- The meteorological data used in the dispersion modelling supplied in a *Microsoft* Windows-compatible format

### 9.4.2. Level 2 meteorological data

- A detailed discussion of the prevailing dispersion meteorology at the proposed site. The report should typically include wind rose diagrams; an analysis of wind speed, wind direction, stability class, ambient temperature and mixing height; and joint frequency distributions of wind speed and wind direction as a function of stability class.
- Demonstration that the site-representative data adequately describes the expected meteorological patterns at the site under investigation (e.g. wind speed, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift)
- A description of the techniques used to prepare the meteorological data into a format for use in the dispersion modelling
- A quality assurance and quality control analysis of the meteorological data used in the dispersion modelling. Provide and discuss any relevant results of this analysis.
- The meteorological data used in the dispersion modelling supplied in a *Microsoft* Windows-compatible format

## 9.5. Background air quality data

- Methods used to sample and analyse for each of the pollutants considered
- A detailed discussion of the methodology used to calculate the background concentrations for each pollutant
- Tables summarising the ambient monitoring data

## 9.6. Dispersion modelling

- A detailed discussion and justification of all parameters used in the dispersion modelling and the manner in which topography, building wake effects and other site-specific peculiarities that may affect plume dispersion have been treated
- A detailed discussion of the methodology used to account for any atmospheric pollutant formation and chemistry
- A detailed discussion of air quality impacts for all relevant pollutants, based on predicted ground-level concentrations at the plant boundary and beyond, and at all sensitive receptors
- Ground-level concentrations, hazard index and risk isopleths (contours) and tables summarising the predicted concentrations of all relevant pollutants at sensitive receptors
- All input, output and meteorological files used in the dispersion modelling supplied in a *Microsoft* Windows-compatible format

## 9.7. Bibliography

EPA 2022, *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*, NSW Environment Protection Authority.

# 10. Emission limits

## 10.1. Legislation

The *Protection of the Environment Operations Act 1997* (POEO Act) is the major legislation governing environment protection in NSW. The Act is administered by the EPA.

Section 128 of the POEO Act makes it an offence for emissions of air impurities to exceed 'standards of concentration' as prescribed by the POEO Regulation. These standards are in-stack emission limits and are the maximum emissions permissible for an industrial source anywhere in NSW. These limits are based on levels that are achievable through the application of reasonably available technology and good environmental practices.

The emission limits in the POEO Regulation do not take into account site-specific features such as meteorology and background air quality, and therefore do not necessarily protect against adverse air quality impacts in the areas surrounding the premises. An objective shared by the EPA and the POEO Act is to reduce the risks to human health and the environment by reducing to harmless levels the discharge of substances into the air (section 6 of the *Protection of the Environment Administration Act 1991* and section 3 of the POEO Act). The impact of emissions on local air quality from premises is determined through an air quality impact assessment. The methods required by statute to be used to model and assess emissions of air pollutants from stationary sources in NSW are outlined in this document.

## 10.2. How does the EPA set emission limits in environment protection licences?

In an environment protection licence for a new or expanded industrial source:

1. **Emission limits reflect reasonably available technology and good environmental practice.** The POEO Regulation sets the maximum emissions permissible for an industrial source located anywhere in NSW. The Regulation limits are based on levels that are achievable through the application of reasonably available technology and good environmental practices.

2. **Emission limits reflect proper and efficient operation.** Consistent with the requirement of the POEO Act (section 124), it is EPA policy to prescribe emission limits that are consistent with the proper and efficient operation of plant and equipment. Depending on the plant and equipment, these levels can be lower than those prescribed by the POEO Regulation.

3. **Emission limits protect the health and amenity of the surrounding community.** This document sets out:
   a. health- and amenity-based impact assessment criteria for the protection of ambient air quality
   b. the process for assessing the impacts of air pollutant emissions on ambient air quality and the surrounding community.

Proponents of new or expanding developments must use these principles to demonstrate that a proposed development will not adversely affect human health and amenity or the surrounding air quality.

By using the above three criteria, emission limits in a licence can be even more stringent than the requirements of the Regulation.

## 10.3. What information does the EPA use to set emission limits?

The information submitted by the proponent or licensee in the impact assessment is used to set the emission limits in an environment protection licence. This includes the emission concentration and rates used in the dispersion modelling.

# 11. Worked examples

## 11.1. Developing site-specific emission limits

This section shows how a site-specific emission limit may be developed.

The example is for hydrogen sulfide, but the principles are equally applicable to other air pollutants that are regulated in NSW.

### 11.1.1. Scenario

A major industry is proposed to be located near Deniliquin (latitude 35.53°S, longitude 144.95°E).

Hydrogen sulfide will be emitted through a stack 40 metres high. The stack is more than 2.5 times as high as the nearest buildings located within 200 m. The distance of 200 m is five times the stack height, meaning building wake effects are not likely to occur. The topography of the proposed site is dominated by flat terrain.

It is not practicable for this industry type to meet the Regulation emission limit for hydrogen sulfide of 5 mg/m$^3$.

What would be an appropriate site-specific emission limit calculated using a Level 2 assessment?

### 11.1.2. Source characteristics

Source characteristics are summarised in Table 19.

**Table 19**     **Worked example 1 – source characteristics**

| Source characteristic | Value |
|---|---|
| Stack height (m) | 40 |
| Stack diameter (m) | 1 |
| Exhaust temperature (°C) | 180 |
| Exhaust velocity (m/s) | 20 |
| Building wake effects | No |
| Exhaust flow rate – Am$^3$/s | 15.71 |
| Exhaust flow rate – Nm$^3$/s | 9.47 |
| Hydrogen sulfide emission concentration – mg/Am$^3$ | 21.0 |
| Hydrogen sulfide emission concentration – mg/Nm$^3$ | 34.8 |
| Hydrogen sulfide emission rate (g/s) | 0.33 |
| Location | Rural |
| Terrain | Flat |
| Roughness height (m) | 0.3 |
| Location of nearest sensitive receptor (m) | 2,950 |

### 11.1.3. Methodology

Dispersion modelling was conducted using AUSPLUME v. 5.4. A Level 2 meteorological data file, prepared according to the requirements of Section 4.4, was used for the assessment.

Since the nearest sensitive receptor is located at a distance that is greater than 10 times the largest source dimension (i.e. 2,950 m > 400 m or 10 times the stack height), far-field peak-to-mean ratios for a tall wake-free point from Table 10 are appropriate.

### 11.1.4. Results

A hydrogen sulfide emission concentration of 34.8 mg/Nm$^3$ gave a maximum 100th percentile ground-level concentration of 4.22 µg/m$^3$ at a distance of 2,950 m from the stack. This is less than the impact assessment criterion for hydrogen sulfide of 4.83 µg/m$^3$ at a single residence (see Table 17).

Hence, an appropriate site-specific emission limit for hydrogen sulfide would be approximately 35 mg/Nm$^3$.

## 11.2. Dealing with elevated background concentrations

### 11.2.1. Scenario

A mine is proposed to be located in a sparsely populated area. The nearest sensitive receptors are rural residential dwellings located to the north and west at distances of 1,000 and 1,500 m respectively.

Background PM$_{10}$ levels are elevated. Accounting for background concentrations using the Level 1 assessment methodology results in exceedances of the PM$_{10}$ impact assessment criteria.

How are background concentrations taken into account using a level 2 impact assessment?

### 11.2.2. Background ambient monitoring results

Ambient monitoring data for PM$_{10}$ are available from a nearby mine in a similar rural environment and have been shown to be representative of the site.

This data can be summarised as:

- maximum 24-hour average: 41 µg/m$^3$
- annual average: 22 µg/m$^3$.

### 11.2.3. Results of modelling

#### a. Level 1 assessment – Maximum impact

Dispersion modelling has been undertaken and 24-hour average and annual increments of PM$_{10}$ have been predicted at each sensitive receptor.

Table 20 presents the maximum impact (Section 5.1.1, Level 1 assessment).

**Table 20     Worked example 2 – maximum impact**

| Particulates (PM$_{10}$) | Predicted concentration (µg/m³) Maximum impact (increment) | | Impact assessment criterion (µg/m³) |
|---|---|---|---|
| | A: 1000 m north | B: 1500 m west | |
| 24-hour average | **63 (22)** | 49 (8) | 50 |
| Annual average | 24 (2) | 23 (1) | 25 |

The dispersion modelling results indicate that:

- The maximum impact at receptor A (shown in bold) is likely to exceed the 24-hour average impact assessment criterion. Further assessment is required.
- The 24-hour and annual average impact assessment criteria are not likely to be exceeded at receptor B. No additional assessment is required.

### b. Level 2 assessment – contemporaneous impact and background

To refine the assessment at receptor A, each individual dispersion model prediction is added to the corresponding measured background concentration (Section 5.1.1, Level 2 assessment).

From this refined analysis, no additional exceedances of the 24-hour average impact assessment criterion (50 µg/m³) are likely.

The results of this analysis are summarised in Tables 21 and 22. Table 21 shows the total predicted concentration on days with the highest background, while Table 22 shows the total predicted concentration on days with the highest predicted incremental glcs.

No additional assessment is required.

**Table 21     Worked example 2 – summary of contemporaneous impact and background – days with highest background**

| Date | Background – PM$_{10}$ 24-hour average (µg/m³) | Predicted increment ) – PM$_{10}$ 24-hour average (µg/m³) | Total |
|---|---|---|---|
| 27/01/01 | 41 | 5 | 46 |
| 26/01/01 | 40 | 3 | 43 |
| 08/10/01 | 40 | 5 | 45 |
| 04/03/01 | 38 | 8 | 46 |
| 02/02/01 | 37 | 10 | 47 |
| 31/05/01 | 36 | 12 | 48 |
| 06/08/01 | 34 | 10 | 44 |
| 09/10/01 | 34 | 8 | 42 |

**Table 22     Worked example 2 – summary of contemporaneous impact and background – days with highest predicted increment**

| Date | Background – PM$_{10}$ 24-hour average (µg/m$^3$) | Highest predicted increment – PM$_{10}$ 24-hour average (µg/m$^3$) | Total |
|---|---|---|---|
| 23/05/01 | 20 | 22 | 42 |
| 15/09/01 | 21 | 18 | 39 |
| 25/09/01 | 15 | 17 | 32 |
| 24/02/01 | 30 | 17 | 47 |
| 04/01/01 | 34 | 15 | 49 |
| 12/04/01 | 29 | 14 | 43 |
| 14/11/01 | 34 | 13 | 47 |
| 13/02/01 | 30 | 11 | 41 |

In cases where additional exceedances might be predicted at a receptor, the applicant should either:

1. review site selection and/or apply more effective mitigation measures or emission controls that reduce emissions to a greater extent, and revise the impact assessment

    or

2. if emissions and impacts have been reduced as far as they can, consider whether there are opportunities to mitigate impacts through other measures such as negotiated agreements and/or acquisition of sensitive receptors.

# 12. Conversion factors

The physical state of gaseous air pollutants at atmospheric concentrations may be described by the ideal gas law:

**Equation 12.1: Ideal gas law**

pv = nRT

*where:*

p = absolute pressure of gas (atm)

v = volume of gas (L)

n = number of moles of gas (mol)

R = universal gas constant (L.atm/mol.K)

T = absolute temperature (K)

The number of moles (n) may be calculated from the weight of a pollutant (W) and its molecular weight (m) by:

**Equation 12.2**

n = W / m

Substituting Equation 12.2 into Equation 12.1 and rearranging terms yields:

**Equation 12.3**

v = WRT / pm

Parts per million (ppm) refers to the volume of pollutant (v) per million volumes of air (V):

**Equation 12.4**

ppm = v/V $\times$ 10$^6$

Substituting Equation 12.3 into Equation 12.4 yields:

**Equation 12.5: Conversion from volume to mass units of concentration**

ppm = (W / V) $\times$ RT / pm $\times$ 10$^6$

Using the appropriate values for the variables in Equation 12.5, a conversion from volume to mass units of concentration for carbon monoxide may be derived as shown below:

T = 298.15 K (25°C)

P = 1 atm

M = 28 g/mol

R = 0.08205 L.atm/mol.K

$$ppm = \frac{W(g) \times 10^3 (mg/g)}{V(l)} \times \frac{0.08205(L.atm/mol.K) \times 298.15(K)}{1(atm) \times 28(g/mol) \times 10^6}$$

1 ppm = 1.15 mg/m$^3$

1 mg/m$^3$ = 0.873 ppm

Table 23 contains some common conversion factors for the criteria air pollutants.

**Table 23      Common conversion factors for criteria air pollutants**

| Pollutant | Units | To convert to: | Multiply by: |
|---|---|---|---|
| Ozone ($O_3$) | pphm | $\mu g/m^3$ (0°C) | 21.4 |
|  |  | $\mu g/m^3$ (25°C) | 19.6 |
| Nitric oxide (NO) | pphm | $\mu g/m^3$ (0°C) | 13.4 |
|  |  | $\mu g/m^3$ (25°C) | 12.3 |
| Nitrogen dioxide ($NO_2$) | pphm | $\mu g/m^3$ (0°C) | 20.5 |
|  |  | $\mu g/m^3$ (25°C) | 18.8 |
| Sulfur dioxide ($SO_2$) | pphm | $\mu g/m^3$ (0°C) | 28.6 |
|  |  | $\mu g/m^3$ (25°C) | 26.2 |
| Lead (Pb) | $\mu g/m^3$ (0°C) | $\mu g/m^3$ (25°C) | 0.92 |
| Carbon monoxide (CO) | ppm | $mg/m^3$ (0°C) | 1.25 |
|  |  | $mg/m^3$ (25°C) | 1.15 |

# Glossary

| | |
|---|---|
| **Affected zone** | The area within which the impact assessment criteria are likely to be exceeded, and unacceptable air quality impacts may result |
| **Am$^3$** | Actual cubic metre; the volume of gas that occupies a volume of 1 m$^3$ at stack discharge conditions |
| **AUSPLUME** | EPA Victoria's Gaussian dispersion model |
| **Background levels** | Existing concentrations of pollutants in the ambient air |
| **BPIP** | Building Profile Input Program (USEPA software used to generate data for AUSPLUME to account for building wake effects) |
| **Building wake effects** | The effect on plume dispersion caused by the presence of buildings near a stack, usually resulting in increased ground-level concentrations of pollutants |
| **C** | Convective atmospheric conditions |
| **°C** | Temperature in degrees Celsius |
| **C$_p$** | Peak concentration |
| **CALPUFF** | A multi-layer, multi-species, non-steady-state Gaussian puff dispersion model that is able to simulate the effects of time- and space-varying meteorological conditions on pollutant transport |
| **Criteria air pollutants** | The pollutants sulfur dioxide, nitrogen dioxide, ozone, PM$_{2.5}$, PM$_{10}$, lead and carbon monoxide |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **Deposition velocity** | The ratio of deposition at the surface (g/m$^2$/s) to its concentration in the atmosphere (g/m$^3$) for a particular substance |
| **Diffuse source** | Activities that are generally dominated by fugitive area or volume-source emissions of odour, which can be relatively difficult to control, such as wastewater treatment plants |
| **Dispersion modelling** | Modelling by computer to mathematically simulate the effect on plume dispersion under varying atmospheric conditions; used to calculate spatial and temporal fields of concentrations and particle deposition due to emissions from various source types |
| **DEC** | Department of Environment and Conservation NSW |
| **Ensemble mean** | The average of a predicted variable over an ensemble of forecasts. |
| **EPA** | NSW Environment Protection Authority |

| | |
|---|---|
| **Far-field** | The far-field region is the zone where plume rise and meandering have fully occurred and the plume is well mixed in the vertical plane from ground level to the base of the first temperature inversion |
| **g** | Mass in grams |
| **glc** | Ground-level concentration |
| **glc criteria** | Criteria for individual odorous or toxic air pollutants; specified in $mg/m^3$ or ppm as a 3-minute average |
| **IARC** | International Agency for Research on Cancer |
| **IER** | CSIRO's Integrated Empirical Rate model |
| **Incremental impact** | The impact due to an emission source (or group of sources) in isolation, i.e. without including background levels |
| **K** | Temperature in kelvins |
| **kPa** | Pressure in kilopascals |
| **L** | Monin–Obukhov length, which characterises the stability of the surface layer |
| **Level 1** | A screening dispersion modelling procedure |
| **Level 2** | A refined dispersion modelling procedure |
| **m** | Length in metres |
| **$m^3$** | Volume in cubic metres |
| **µg** | Mass in micrograms |
| **Mid-field** | The mid-field region is the zone where source characteristics are important but not dominant |
| **mg** | Mass in milligrams |
| **Near-field** | The near field is the zone where source structure directly affects plume dispersion. The near field is typically 10 times the largest source dimension, either height or width. |
| **$Nm^3$** | Normal cubic metre; the volume of dry gas that occupies a volume of $1\ m^3$ at a temperature of 273.15 K (0°C) and an absolute pressure of 101.3 kPa |
| **$NO_x$** | Oxides of nitrogen, including NO and $NO_2$ |
| **OLM** | USEPA's Ozone Limiting Method |
| **OU** | Odour units; indicates concentration of odorous mixtures. The number of odour units is the concentration of a sample divided by the odour threshold or the number of dilutions required for the sample to reach the threshold. This threshold is the numerical value equivalent to when 50% of a testing panel correctly detect an odour. For complex mixtures of odours, odour is specified in $OU/m^3$ (odour units per cubic metre) as a nose-response-time average. |
| **$OU/m^3$** | Odour units per cubic metre |
| **PAH** | Polycyclic aromatic hydrocarbon |

| | |
|---|---|
| **Peak-to-mean ratio** | A conversion factor that adjusts mean dispersion model predictions to the peak concentrations perceived by the human nose |
| **PEF** | Potency equivalency factor |
| **pphm** | Concentration in parts per hundred million |
| **ppm** | Concentration in parts per million |
| **PM$_{10}$** | Particulate matter less than 10 μm in aerodynamic equivalent diameter |
| **PM$_{2.5}$** | Particulate matter less than 2.5 μm in aerodynamic equivalent diameter |
| **Point source** | Source of emissions of odour, generally a stack. Emissions can generally be relatively easily controlled by using waste reduction, waste minimisation and cleaner production principles or conventional emission control equipment. |
| **Sensitive receptor** | A location where people are likely to work or reside; this may include a dwelling, school, hospital, office or public recreational area. An air quality impact assessment should also consider the location of known or likely future sensitive receptors. For hydrogen fluoride, a sensitive receptor includes land-use areas with vegetation sensitive to hydrogen fluoride, such as grapevines and stone fruit. |
| **Separation distance** | The distance between a source and sensitive receptors (or likely future sensitive receptors) |
| **Source separation** | The distance between two emission sources |
| **σ** | Standard deviation |
| **σ$_y$** | Initial horizontal plume spread for volume sources |
| **σ$_z$** | Initial vertical plume spread for volume sources |
| **Stack** | A vertical pipe used to vent pollutants from a process |
| **Stationary source** | Any premises-based activity; does not include motor vehicles |
| **TAPM** | CSIRO's PC-based, 3-D prognostic model for air pollution studies |
| **Total impact** | The total impact of an emission source (or group of sources) and existing ambient levels of a pollutant; i.e. total impact = background levels + incremental impact |
| **TSP** | Total suspended particulate [matter] |
| **USEPA** | United States Environmental Protection Agency |
| **VOC** | Volatile organic compound |