Emissions Estimation Technique Manual

for

Aggregated Emissions from Cutback Bitumen

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Environment Australia

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EMISSIONS ESTIMATION TECHNIQUE MANUAL: AGGREGATED EMISSIONS FROM CUTBACK BITUMEN

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1.0 Introduction

1.1 The NPI

The National Pollutant Inventory (NPI) was established under a National Environment Protection Measure (NEPM) made by the National Environment Protection Council (NEPC) under Commonwealth, State and Territory legislation on 27 February 1998. This Measure is to be implemented progressively through the laws and administrative arrangements of each of these participating jurisdictions (i.e. State and Territory Governments).

The NEPM and an associated Memorandum of Understanding for the NPI, which have been published as a single document by the NEPC, provide more details on the purpose and structure of the NPI, and the arrangements for implementation of the NEPM that have been agreed by the jurisdictions. Users of this Manual should read this publication if they are unfamiliar with the NEPM or the NPI.

1.2 Purpose and Scope of the Manual

The NPI will be developed as an internet database designed to provide information on the types and amounts of certain chemical substances being emitted to the air, land and water environments. If the NPI is to achieve its aim of communicating useful and reliable information to the community, industry and governments on pollutants present in our environment, the emissions estimation techniques (EETs) used to generate inputs to the NPI need to be consistent, and the process for developing these techniques needs to be transparent. This Manual has been developed, reviewed and finalised in this context.

The NEPM contains a list of substances for which emissions will be reported on an annual basis to the Commonwealth Government, which will then compile and publish the NPI. The aggregated emissions manuals, of which this is one, have been prepared to assist State and Territory Governments in preparing these submissions, and to facilitate consistent reporting between these jurisdictions.

State and Territory Governments will also be compiling and submitting emissions data based on annual inputs from reporting facilities. These facilities are primarily industrial enterprises which use (or handle, manufacture or process) more than specified amounts of certain polluting substances, burn more than specified amounts of fuel, or consume more than certain amounts of energy. These amounts or “thresholds” (which are clearly defined in the NEPM) govern whether an industrial facility is required to report and what substances it is required to report on, and industry handbooks are being developed to help industries to prepare the information for these reports.

The aggregated emissions manuals complement these handbooks, and are intended to enable Governments to estimate emissions from non-industrial activities (e.g. transportation, domestic and commercial activities) and emissions from industry which are not reported because the relevant thresholds are not exceeded or are exempt from reporting.

Annual submissions are also to be prepared and submitted in conformance with the NPI Data Model and Data Transfer Protocol. For emissions to the air environment, this Protocol only requires jurisdictions to submit data on emissions into the particular airsheds that are listed in the Protocol, and not to the rest of each jurisdictional area. For example, under the 1998 to 2000 Memorandum of Understanding, in Victoria, emissions data are only required for the Port Phillip and Latrobe Valley Regions. In addition, emissions data are required to be submitted on a gridded basis, with each jurisdiction determining a grid domain and grid cell size necessary to meet its obligations under Section 7 of the NEPM.

Therefore, in addition to recommending and providing details and examples of appropriate emissions estimation techniques (EETs) for the relevant NPI substances, this Manual provides guidance on the spatial allocation of emissions and the use of area-based surrogates for accurately distributing the activities or sources in question.

1.3 Application of the Manual

Each of the aggregated emissions manuals provides details of:

- the NPI substances that are expected to be emitted from the relevant aggregated source type;
- the origins or sources of the emissions, and the processes that may generate them;
- the impacts of any control equipment or procedures on those emissions;
- the broad approaches that may be employed in the estimation and spatial allocation of emissions;
- details of emission factors to be used in the estimation of emissions; and
- a series of illustrative sample calculations for each estimation technique.

Each of the manuals also contains a section on “Uncertainty Analysis”, which provides information and guidance to users on the reliability of the various estimation techniques, problems and issues associated with their development and application, and recommendations for their improvement. In preparing the aggregated emissions manuals it has been recognised that some jurisdictions already undertake detailed emissions inventories on a regular basis, based on relatively sophisticated methodologies. For these jurisdictions the manuals offer techniques which represent commonly available best practice for emissions estimation in Australia (i.e. techniques of high quality which can be employed by larger or more experienced jurisdictions with an acceptable expenditure of time and effort). The most recent developments in inventory methodology in Australia and overseas have been considered in selecting and documenting these techniques.

Where a more simplified methodology for emissions estimation of acceptable quality is available, it is recommended in the manual for the use of those jurisdictions which may, for the time being at least, lack the data, resources or expertise to employ a more sophisticated approach, or not see the need for highly reliable estimates in that particular part of the inventory.

2.0 Emissions Covered by the Manual

2.1 NPI Substances

Bituminous materials used in road construction and maintenance work give off volatile organic compounds (VOCs). VOCs is a general term that refers to a large and diverse group of chemicals including hydrocarbons, oxygenates and halocarbons.

The road construction and maintenance industry is not required to report its emissions under the NEPM for the NPI. However, States and Territories (jurisdictions) are required to estimate and report aggregated emissions from these sources under the agreed arrangements (EA 1998). NPI substances that may be emitted from road construction and maintenance are listed in Table 1.

Table 1: NPI Substances Typically Emitted by Road Construction and Maintenance Activities [a]

Benzene	Polycyclic aromatic hydrocarbons
Biphenyl	Styrene
Cumene	Toluene
Cyclohexane	Total volatile organic compounds (VOCs)
Ethylbenzene	Xylenes
n-Hexane	

[a] The substances listed are based on a default speciation profile, and will vary according to the composition of the diluent used.

2.2 Emission Sources and Related Processes

Roads are constructed from naturally occurring gravels, sandstones, limestone, granitic sands and other crushed rocks. To protect these surfaces from excessive wear, a bituminous seal is applied. Depending on the materials and solvents used, various amounts of VOCs are emitted during road construction and maintenance operations. These operations include surface treatment, pavement treatment and the application of seal coats.

Surface treatment refers to the application of slow curing oil to reduce dust and the priming of newly constructed or reconstructed pavement in order to hold the pavement and assist bonding with the seal coat. Surface treatment may also refer to the application of a primer binder or tack coating to a primed or existing bituminous surface prior to other surfacing work.

Cutback bitumen primer and primer binder are commonly used in spray sealing operations. The bitumen is ‘cut back’ by blending with petroleum solvents such as kerosene or aviation turbine fuels (the ‘cutter’) to reduce the viscosity of the bitumen to enable it to be used for spray-sealing operations. Cutback bitumen primers and primer binders may also be produced in the field by adding cutter or flux oil.

Flux oils reduce the viscosity of the bitumen for a longer period and increase the storage life of the bitumen mixture. Commonly used flux oils are diesel oils or proprietary oil-based products.

Cutback bitumen is the major source of VOC. Other types of bitumen and bitumen paving emit only minor amounts of VOC.

The quantity of diluent (cutter or flux oils) added to bitumen varies from zero to about 100 parts of diluent per 100 parts of bitumen by volume, depending on the method of road construction, ambient conditions and expected traffic load. Methods of road surfacing and associated VOC emissions may vary significantly between regions due primarily to variations in ambient temperature.

VOC emissions from cutback bitumen result from the evaporation of the cutter oil used to reduce the viscosity of the bitumen. Emissions occur both at the job site and the mixing plant. However, the largest source of emissions is from the road surface itself.

For any given amount of cutback bitumen the total emissions are believed to be the same regardless of stockpiling, mixing and application times. The two major variables affecting the quantity of VOCs emitted are the type and quantity of the diluent used.

2.3 Emission Controls

Cutback bitumen is the most commonly used form of primer. No control devices are employed to reduce evaporative emissions from cutback bitumen. Although bitumen emulsions (water-based) can be used in place of cutback bitumen to eliminate VOCs, their use is not widespread in Australia.

3.0 Emissions Estimation Techniques

This section describes techniques for estimating VOC emissions from road construction and repair activities using cutback bitumen.

3.1 Approaches Employed

3.1.1 Best Practice EET

The best practice technique for estimating emissions is based on the consumption of cutter and flux oils. The amount of VOCs emitted is dependent on the type and quantity of the diluent used.

The information that is required for this EET is as follows:

- the consumption of cutter and flux oils in an airshed;
- the density and composition of the cutter and flux oils used; and
- gridded vehicle kilometres travelled (VKT) data (or population data) by collection district (CD), and the co-ordinates of the CDs in the airshed.

Data on cutter and flux oils can be obtained from the relevant Government departments or bitumen manufacturers. For smaller regions municipal councils may also be able to supply these data. Material safety data sheets (MSDSs) should be acquired to obtain the density and composition of cutter and flux oils. Default density and composition data are provided in Tables 2 and 3 respectively.

Gridded VKT data are used for spatial allocation of emissions. This approach assumes that roads with more traffic require proportionally more maintenance. Gridded VKT data are also used in estimating and distributing motor vehicle emissions. Details of techniques for deriving gridded VKT data can be found in the AE manual for Motor Vehicles.

Data on population distribution should only be used if gridded VKT data are not available. Population data can be obtained from the Australian Bureau of Statistics (ABS).

3.1.2 Default EET

The alternative or default EET is based on bitumen consumption. This technique requires the following information:

- the amount of bitumen used in an airshed; and
- gridded VKT (or population) data by CD, and the co-ordinates of the CDs in the airshed.

Bitumen consumption data are available from ABARE (1999) at jurisdiction level. These data need to be scaled to airshed level using VKT or population data.

3.1.3 Estimating VOC Emissions

Equation 1: Estimating VOC emissions using a mass balance approach

$$E_{VOC,cutter} = T_c * (d_c * 10^{-2}) * \rho_c$$

where

$E_{VOC,cutter}$ = Total VOC emissions from use of cutter oils in an airshed, kg yr^{-1}
T_c = Total cutter oil consumption in the airshed, L yr^{-1}
d_c = Fraction of cutter oil evaporated, % by weight
ρ_c = Density of cutter oil, kg L^{-1}

and

$$E_{VOC,fluxoil} = T_f * (d_f * 10^{-2}) * \rho_f$$

where

$E_{VOC,fluxoil}$ = Total VOC emissions from use of flux oils in an airshed, kg yr^{-1}
T_f = Total flux oil consumption in the airshed, L yr^{-1}
d_f = Fraction of flux oil evaporated, % by weight
ρ_f = Density of flux oil, kg L^{-1}

For the default EET, the calculation of VOC emissions involves application of a volume-based emission factor to total bitumen consumption in the airshed.

Equation 2: Estimating VOC emissions using a volume-based emission factors

$$E_{VOC} = EF_v * V$$

where

E_{VOC} = Total VOC emissions from use of cutback bitumen in an airshed, kg yr^{-1}
EF_v = Volume-based emission factor, kg L^{-1}
V = Volume of bitumen used in the airshed, L yr^{-1}

Per capita emission factors based on national average bitumen use are not recommended for cutback bitumen, because population is not a reliable indicator of local activity when scaling down from the national level. Usage can also vary from year to year, so that a factor developed from a particular year’s data may be inappropriate for another year.

3.1.4 Speciating VOC Emissions

The percentage by weight of individual VOC species should be taken from a MSDS and then multiplied by the estimated total VOC emissions to determine the emissions of NPI substances in an airshed. As a default speciation technique, the speciation data for cutter oil provided in Table 3 may be used.

Equation 3: Speciating VOC emissions

Speciated VOC emissions can be calculated using the following equation

$$E_{i,diluent} = E_{VOC,diluent} * C_{i,diluent} * 10^{-2}$$

where

$E_{i,diluent}$ = Total emissions of substance i from use of diluent (cutter or flux oil) in an airshed, kg yr^{-1}
$E_{VOC,diluent}$ = Total VOC emissions from use of diluent in the airshed, kg yr^{-1}
$C_{i,diluent}$ = Concentration of substance i in diluent, % weight

If total VOC emissions have been estimated using the default technique (Equation 2), and composition data for both cutter and flux oils are available, it will be necessary to estimate the proportions of VOC emissions from the use of cutter and flux oils respectively. In the absence of relevant data, it can be assumed that 50% of total VOC emissions arise from use of cutter oil. Since cutter oils are more volatile and more commonly used (EPAV 1996a), this assumption may underestimate the emissions of some VOC species.

3.2 Spatial Surrogates and Spatial Allocation

Equation 4: Estimating emissions of an NPI substance in a grid cell

$$E_{in} = E_i * K_n / K$$

where

E_{in} = Emissions of substance i in grid cell n, kg yr^{-1}
E_i = Total emissions of substance i from use of cutback bitumen in the airshed, kg yr^{-1}
K_n = Total VKT in grid cell n, km yr^{-1}
K = Total VKT in the airshed, km yr^{-1}

The spatial allocation of emissions may be performed on the basis of either VKT (preferred) or population distribution. VKT data can usually be provided in gridded format, whereas population data are provided by CD and must be converted to gridded population data using a specific program or GIS.

3.3 Emission Factors and Speciation

Table 2 lists values of weight fraction evaporated for cutter and flux oils to be used Equation 1.

Also, where information on the densities of cutter and flux oils cannot be obtained, the values in the Table 2 may be used.

Table 2: Default Properties of Cutter and Flux Oils for Estimating VOC Emissions from Cutback Bitumen

Diluent	**Fraction Evaporated[a] (% by weight)**	**Density (kg L^{-1})[b]**
Cutter oil (kerosene)	65	0.813
Flux oil (diesel oil)	40	0.846

[a] EPAV (1996b).
[b] ABARE (1999)

The volume-based emission factor for use in Equation 2 is 0.251 kg VOCs per litre of bitumen (USEPA 1991).

Information on the speciation of cutter and flux oils should be obtained from the manufacturers where possible. If this information is not available then the data in Table 3 can be used.

Table 3: VOC Speciation Profile for Cutter Oil

NPI Substance	**Weight % [a]**
Benzene	0.00575
Biphenyl	0.017
Cumene	4.05
Cyclohexane	0.00025
Ethylbenzene	0.278
n-Hexane	0.00025
Polycyclic aromatic hydrocarbons	0.32
Styrene	0.0008
Toluene	0.171
Xylenes	1.42

[a] Quilligan, J., Shell October 1999, pers. comm. This data should only be used if no MSDS is available.

3.4 Sample Calculations

Example 1: Estimating VOC emissions using a mass balance approach

Assuming that 600,000 L of cutter oil and 200,000 L of flux oil are used in an airshed during the year, and using Equation 1 and the default properties in Table 2, total VOC emissions in the airshed are estimated as follows

$$\begin{aligned} E_{VOC} &= T_c * (d_c * 10^{-2}) * \rho_c + T_f * (d_f * 10^{-2}) * \rho_f \\ &= 6 * 10^5 * (65 * 10^{-2}) * 0.813 + 2 * 10^5 * (40 * 10^{-2}) * 0.846 \\ &= 3.17 * 10^5 + 6.77 * 10^4 \\ &= 3.85 * 10^5 \text{ kg yr}^{-1} \end{aligned}$$

Example 2: Estimating VOC emissions using a volume-based emission factors

If 20 million litres of bitumen are used in a jurisdiction during the year, and the VKTs in the airshed and jurisdiction are 80 and 120 million kilometres per day respectively, total VOC emissions in the airshed can be estimated using Equation 2 and the volume-based emission factor from Section 3.3 as follows

$$\begin{aligned} E_{VOC} &= EF_v * V \\ &= 0.251 * 20 * 10^6 * (80 * 10^6) / (120 * 10^6) \\ &= 3.35 * 10^6 \text{ kg yr}^{-1} \end{aligned}$$

Example 3: Speciating VOC emissions

Toluene emissions from the use of cutter oils in an airshed can be estimated using Equation 3, the default speciation profile in Table 3, and the estimated total VOC emissions from use of cutter oils from Example 1, as follows

$$\begin{aligned} E_{i,cutter} &= E_{VOC,cutter} * C_{toluene,cutter} * 10^{-2} \\ &= 3.17 * 10^5 * 0.171 * 10^{-2} \\ &= 5.42 * 10^2 \text{ kg yr}^{-1} \text{ of toluene} \end{aligned}$$

4.0 Uncertainty Analysis

4.1 Data Reliability

Data on the evaporated fraction are derived from USEPA and Australian sources, and are considered moderately reliable. However, these fractions do not allow for loss of solvents during the mixing or stockpiling phases.

If accurate data on cutter and flux oils use, density and composition can be obtained from suppliers or users, the overall emissions estimates should be moderately reliable. Estimates will be of comparatively low reliability if they are based on ABARE data on bitumen consumption and the volume-based emission factor.

4.2 Reliability of Emission Factors

Use of emission factors will give a less reliable result than using a mass balance approach and accurate speciation profiles.

Emission factors that make use of the actual consumption of cutback bitumen in a region are considered more reliable than per capita factors.

Also, since the composition of diluents may vary from region to region, use of the default speciation profile is considered to be of low reliability.

4.3 Recommendations for Further Work

A comprehensive database on the properties and composition of different types of diluents and cutback bitumen formulations used in various regions of Australia should be developed.

Testing of solvent retention in cutback bitumen would enable more accurate calculation of emissions.

5.0 Glossary of Terms and Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AE	Aggregated emissions
CARB	California Air Resources Board
CD	Collection District
EA	Environment Australia
EET	Emissions estimation technique
EF	Emission factor
EPAV	Environment Protection Authority of Victoria
GIS	Geographic information system
MSDS	Material safety data sheet
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NPI	National Pollutant Inventory
USEPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled
VOC	Volatile organic compound

6.0 References

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