TODOROSKI AIR SCIENCES

AIR QUALITY REVIEW

DISPERSION MODELLING ASSESSMENT OF METHYL BROMIDE

New Zealand Environmental Protection Agency

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Air Quality Review
Dispersion Modelling Assessment of Methyl Bromide

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 EXECUTIVE SUMMARY

The review found a fundamental technical error in how the modelling results were processed. The error appears to stem from the FORTRAN code used to extract data from the modelling files. The FORTRAN extracted data (that is processed to generate the presented results), shows levels significantly lower than the actual results in the modelling files. This arises in all scenarios and averaging periods examined by the reviewer where the FORTRAN code was used.

As a consequence of the error, none of the results in the Assessment Report are valid, and the assessment needs to be re-done.

This and other issues are detailed further in this report. Another key issue is that the modelling has not been carried out as per the Experts' recommendations, or does not conduct the various analyses recommended by the Experts for specific scenarios. This affects the ability to interpret and use the modelling for decision making.

Other comments are set out in the report and generally seek clarification or make suggestions on lesser points. For example, the modelling results contain values at all points in the domain and are not curtailed to only the plotted area of the domain shown in the figures. This would appear to unnecessarily prolong the model run times and has generated large approximately 3GB files (that may complicate data processing).

2 INTRODUCTION

Todoroski Air Sciences (TAS) has been engaged by the New Zealand (NZ) Environmental Protection Authority (EPA) to review and provide independent advice in relation to air dispersion modelling for the modified reassessment of methyl bromide as a fumigant used for quarantine and pre-shipment purposes.

In this report, The Stakeholders in Methyl Bromide Reduction Inc (STIMBR) are also referred to as the Proponent.

This report provides an outline of the findings of our peer review of the proponents modelling assessment report titled; *Modelling Report for Methyl Bromide Exposures for Timber Fumigation at the Port of Tauranga, New Zealand* (the Assessment Report) (**Sullivan Environmental Consulting, 2020**) conducted by Sullivan Environmental Consulting (SEC).

This report is limited to reviewing the information in the SEC Assessment Report.

3 OVERVIEW OF THE SITUATION

The NZ EPA is conducting a modified reassessment for the continued use of methyl bromide as a quarantine and pre-shipment fumigant subject to controls.

The EPA decision-making committee have directed an Expert conference to provide advice regarding air dispersion modelling. In light of the Expert conference, air dispersion modelling has been conducted by Sullivan Environmental Consulting for STIMBR.

This report is focussed on providing an evaluation of the air dispersion modelling in relation to the decisions reached by the Expert conference.

3.1 Applicable assessment criteria

Suitable ambient air quality criteria need to be considered in order to determine whether the predicted levels of methyl bromide are acceptable.

The Assessment Report provides modelled predictions and makes an assessment of compliance with the relevant worker and public exposure levels outlined below.

Whilst **the Assessment Report** explicitly sets out the relevant exposure levels for an 8-hour and annual average period, it **does not enumerate the applicable 1-hour and 24-hour TEL standards**.

Similarly, **the report makes no statement about compliance (or the lack of compliance) with the relevant standards**.

3.1.1 Worker exposure standards

The NZ Government Workplace Exposure Standards and Biological Exposure Indices (**NZ Government, 2018**) identifies workplace exposure standards for methyl bromide, as set out in **Table 3-1**. The Workplace Exposure Standard Time Weighted Average (TWA) standard is for an 8-hour average exposure level based on a 40-hour week.

Table 3-1: Workplace Exposure Standards for methyl bromide

Averaging Period	Parts per million (ppm)	Milligrams per cubic meter (mg/m^3)
TWA (8 hours)	5	19

The workplace standard does not afford protection for people off-site, please refer to the following section in this regard.

3.1.2 Public exposure limits

The Tolerable Exposure Limits (TELs) are designed to protect the most sensitive members of the population from adverse effects from exposure to methyl bromide. These TELs cannot be exceeded outside the minimum buffer zone established around the fumigation activity. The TELs for methyl bromide are set out in **Table 3-2**.

Table 3-2: NZ Tolerable Exposure Levels (TELs)

Averaging Period	Parts per million (ppm)	Milligrams per cubic meter (mg/m3)
TEL air (annual)	0.0013	0.005
TEL air (24-hour)	0.333	1.3
TEL air (1-hour)	1	3.9

4 REVIEW OF THE ASSESSMENT REPORT

The key components of the Assessment Report have been examined and any potential issues which arise from our review are outlined below.

4.1 Modelling approach

4.1.1 Model choice

The Assessment Report has used CALPUFF 7.2.1 to simulate methyl bromide fumigation activities at The Port of Tauranga. This is **consistent with the recommendations of the Expert conference** that it is a suitable model to represent regular sea breeze and other coastal weather influences generally arising at the Port of Tauranga. **The model used can suitably predict the potential impacts** under various likely air dispersion conditions.

The Lakes Environmental CALPUFF VIEW graphical user interface (GUI) was used to set up and run the model. The commercial package used appears to restrict a modeller's ability to develop the most optimal approach for the modelling needed in this case. It is noted that more complex or bespoke modelling approaches, not supported by the GUI used would be the most effective means to model the sporadic nature of the timber fumigation practices.

4.1.2 Modelling scenarios

Six scenarios were recommended from the Expert conference, as follows;

- Scenario 1: Worst case one hour result for no control in every hour with possible ventilation (sets worst case outer bound of possible effect);
- Scenario 2: Base case scenario based on based on current testing recovery & Genera 2019 data (a realistic status quo scenario);
- Scenario 3a: Effect of removal efficiency (30% control for 70% of logs);
- Scenario 3b: Effect of removal efficiency (45% control for 70% of logs);
- Scenario 3c: Effect of removal efficiency (60% control for 70% of logs);
- Scenario 3d: Effect of removal efficiency (80% control for 70% of logs);
- Scenario 4: General Target (80% control for 80% of log stacks);
- Scenario 5: Best Case Target (80% control for 100% of log stacks); and,
- Scenario 6: Validation Scenario, pairing up contemporaneous weather, operating and monitoring data to test the veracity of modelling predictions.

Selected scenarios were to be modelled for the far field and near field. The near field was to use closely spaced ring receptors (i.e. several concentric rings of closely spaced receptors for the purpose of determining suitable buffers e.g. for workers or nearby bystanders with or without PPE).

A range of percentiles, hours with and without ventilation, and varying log sizes and dose rates were to be modelled also.

However, Scenarios 1, 4 and 5 were not modelled as SEC considered them to be unrealistic in the proposed recapture efficiency rates. SEC considered that Scenarios 4 and 5 could be represented conservatively by scenario 3c. Scenario 3b was considered to be approximately the same as Scenario 2 and for this reason **Scenario 3b was also not modelled in the Assessment Report**.

The Base (Validation) Scenario is used for comparison of actual measured data and aims to provide an indication of concentration decrease as percentiles drop below the 100th percentile.

The model scenarios in the Assessment Report also considered the following scenarios:

- Scenario 7: Low Rate; and,
- Scenario 8: Low Rate based on only first hour of venting.

Additional modelling was also conducted on periods associated with the first hour of venting (maximum emissions).

All scenarios used Monte Carlo sampling to simulate actual Port operations as closely as possible. The size of venting operations, locations (zones), seasonal variability, and hour of the day, was based on probabilities computed using the General 2019 Port of Tauranga log fumigation data records.

Due to the limited time available to write this review after receiving the modelling files, it is unclear from the modelling files if all the stated modelling scenarios were modelled, or modelled correctly.

4.2 Monitoring

The Experts made recommendations regarding monitoring methyl bromide. The aim of the recommended monitoring was to obtain valid data with which to evaluate model performance. **Nothing provided to the reviewer indicates that that this was done or attempted by the proponent.**

It appears that some monitoring has been provided in Appendix A of the report, but the Appendix is not mentioned in the report, the data are cryptic, unitless and are not decipherable. A clarification of the headings/ data in the Appendix was not available at the time of preparing this report.

4.3 Meteorological modelling

The Assessment Report has used hourly, pre-processed monthly CALMET data files for the Port of Tauranga, New Zealand area for the period January 2014 through December 2016 produced by Atmospheric Science Global (ASG). The use of this meteorological dataset is consistent with the CALMET dataset decided upon in the Expert conference.

Scenarios were modelled eight times for the three year data set, generating a total of 24 years of hourly emission files (i.e. processing the three-year meteorological data set eight times for each scenario).

Whilst only a brief examination was able to be made in the available time, no issues were identified with the meteorological modelling files.

4.4 Modelling sources and emissions

4.4.1 Sources modelled

The ships were modelled as a square volume source per cargo hold, with 5 cargo holds per ship. The volume sources have a length and width of 22 metres and a depth of 20.1 metres. The Assessment Report states alternative modelling was also conducted using volume sources with a depth of 8 metres. However, all of the emission files provided only show sources with a depth of 8 metres. Clarification of the source parameters actually used in the modelling of the presented results in Assessment Report should be provided.

The dimensions of a single timber stack are 50m x 5m per timber stack with a 6m height. Timber stacks were modelled however as a square volume source with dimensions of 25m x 25m with a 6m height per source, or 15m x 15m with a 6m height when modelling sources that had volumes that were significantly less than 25m x 25m. **This has the potential to lead to underestimated and overestimated results in various parts of the near-field**, and possibly the mid-field depending on the actual row alignment relative to the prevailing wind, but is unlikely to make any significant difference in the far-field. Instead of using a single 25m x 25m source to represent a 50m x 5m timber pile, it would be better to have modelled several say ten 5m x 5m or five 10m x 5m sources, noting that this will increase model run times.

Five timber stack groups' sizes were modelled including:

- Group 1: Five volumes sources (volume of 18,750m^3), with a 5% probability of occurrence;
- Group 2: Four volumes sources (volume of 15,000m^3), with a 20% probability of occurrence;
- Group 3: Four volumes sources (volume of 15,000m^3), with a 25% probability of occurrence;
- Group 4: Two volumes sources (volume of 7,500m^3), with a 25% probability of occurrence; and,
- Group 5: One volume source (volume of 3,750m^3), with a 25% probability of occurrence.

Both ships and log ventilation have been modelled concurrently. As the ships are a far larger source than any log stack, the consequence of doing this is that due to the very periods modelled with ships present the ship data are in essence removed for the lower percentiles, and only the ship data will dominate the higher percentiles.

The choice to not provide separate modelling results for the ships and logs makes it impossible to determine whether or not the operations for log ventilation are safe, or what the actual risks for ventilating ships are. It is not possible to use the modelling provided for any reasonable decision making either for log or ship ventilation.

4.4.2 Emissions modelled

Treatment rates of methyl bromide ventilation have been modelled representing the regulatory requirements of China. The application rates were modelled as a function of temperature. The maximum application rate was 120 g/m^3 (during cooler temperatures) and more typically were in the range of 72 to 80 g/m^3. The Low Rate scenarios (scenario 7 and 8) modelled an application rate of 40g/m^3.

Recapture efficiency rates of methyl bromide listed in the Expert conference range from 30% to 80%. The Base (Validation) scenario and the Low Rate scenarios adopted the minimum recapture rates of 30% as a conservative measure, assuming 70% of the stacks have recapture technology applied.

4.4.3 Ventilation

Emissions during the ventilation phase (when the tarpaulin is lifted or ship hold opened) were modelled over a 12-hour ventilation period.

For the multiple timber stack scenarios the fumigation cycle start times were determined using Monte Carlo methods between 7:00am and 8:00pm. However, in the emissions files provided this scenario appears to have been modelled between 6:00am and 7:00pm, and in some cases 6 am to 6pm or 7 am to 5 pm. **The modelling files do not always reflect the stated modelling periods.**

For the ship ventilation, which in actual practice occurred six times in 2019, the start times were set in each scenario to 10:00pm except for the Base (Validation) Scenario. For the Base (Validation) Scenario start times were variable and modelled using similar Monte Carlo methods to represent actual start times used from the 2019 Port of Tauranga methyl bromide data which included 6:00am, 12:00pm, 10:00pm, 10:00am, 1:00pm and 7:00am. **However, the start times for ship ventilation in the emissions files provided do not appear to reflect this.**

For the ventilation of ship cargo holds it was assumed one hatch was opened each hour releasing constant emissions over two hours for the Base (Validation) Scenario. For the other scenarios it was assumed that one hatch was opened every two hours. However, in Table 2-1 of the Assessment Report it is stated that for the Base (Validation) Scenario five holds are opened within the same hour. This may be a typographical error and is inconsistent with their previous statement that only one hatch is opened each hour and warrants clarification.

The Assessment Report has assumed 50% of methyl bromide at the start of fumigation remains at the time of ventilation. Of the 50% it has been assumed that during the first hour, 47% of the applied amount is being released from the headspace and 3% is released from log desorption. For each of the remaining 11 hours, it is assumed that 1% of the original applied amount was released through desorption from the treated timber stacks. The desorption of logs in cargo holds was modelled so that a 17.5% headspace loss and 3% log desorption is assumed to be lost in the first hour of venting, followed by 17.5% headspace loss and 1% log desorption lost in the second hour of venting, followed by 1% of the initial dose during each of the remaining 10 hours.

For the near-field (deterministic) modelling, emissions for the first hour of ventilation have been applied for every hour between 7:00am and 7:00pm. **However, in the emissions files provided this appears to have been modelled between 6:00am and 5:00pm.**

4.5 Project area and modelled receptors

The dispersion modelling was setup using nested grids to predict potential methyl bromide concentrations up to 3km. The grid format is per that recommended in the Expert conference statement.

4.6 Assessment of predicted impacts

The Assessment Report presents 1-hour, 8-hour, 24-hour and annual average modelling predictions. These have been modelled at the 100th, 99.99th, 99.5th, 99th, 98th, 95th, 90th percentiles and include results for 'all hours', 'only on hours with active venting at the port', and 'only on periods associated with the first hour of venting (maximum emissions)'. However the Assessment Report only presents results for the 98th to the 100th percentiles, and notes that results at a lower percentile would be less than those presented. This limits the scope to evaluate the risks.

The Assessment Report says that due to a relatively high probability for model artifacts/outliers to occur the use of the highest percentiles may be unreliable and suggests that the 98th percentile results are most suitable. The results however to not support this statement (e.g. the modelling is incorrect due to errors in the data processing, not model outliers), and the NZ criteria do not apply at a 98th percentile, which makes the approach of focusing the assessment on 98th percentile results fundamentally incorrect for use in NZ.

New Zealand legislation does not specify any tolerance or allowance for exceedances at any time above the criteria. For the purpose of modelling, the NZ modelling guidelines specify that when the emissions are modelled in every hour of the year (i.e. 8,760 hours) then the 99.9th percentile may be reported as the likely maximum for comparison with evaluation criteria.

In our opinion, the NZ legislation and modelling guidelines generally reflect the established modelling practice in Australia, and a 100th percentile result should be used for evaluating the compliance when doing a probabilistic approach (for sources that emit significant emissions and are modelled for commensurately limited periods and times). In such cases any suspected outliers in the results may need to be analysed, and a clear and convincing justification provided if these data are to be excluded. In our experience, when a high quality metrological file is used, there are few if any genuine outliers in the results of a well configured CALPUFF model.

In this case the reported and commented-on outliers are likely to be caused by incorrect processing of the results, and no evaluation as to whether any actual modelling artefacts occur has been provided.

The Assessment Report reaches the following conclusions:

- The Base (Validation) Scenario indicates that the 1-hour and 24-hour TELs are met at the Port boundary using the 99.5th percentile (which SEC considers is comparable to the 98th percentile equivalent concentrations). **However, per NZ legislation and guidelines this would be an exceedance**;
- The Base (Validation) Scenario indicates that the 8-hour WES is met using the 99th percentile (which SEC considers is comparable to the 98th percentile equivalent concentrations) in all scenarios. **However, per NZ legislation and guidelines this would be an exceedance**;
- The Base (Validation) Scenario presents exceedances of the annual TEL at the Port boundary. If the volume of log stacks vented at one time in southern fumigation areas was reduced, it is expected that the annual TEL could be met at the Port boundary;
- Concentrations in residential areas are well below the annual TEL;

- Scenarios based on recapture efficiency rates greater than 30% indicate only a minor reduction in predicted concentrations for the upper percentiles associated with the short-term average impacts; and,
- Predicted results suggest a significant reduction in impacts associated with an application rate of 40g/m^3.

No assessment was made in regard to compliance with the relevant 1-hr TEL. **The plotted results in Figure 1-7 indicate that if unfavourably dispersing winds blowing towards receptors had been modelled to coincide with emissions, there would be extensive impacts in residential areas of the Base (Validation) Scenario.**

4.7 Verification of the SEC modelling

TAS conducted modelling of a single log ventilation source using the same modelling parameters as in the Assessment Report per the provided emission files with the same three-year meteorological data. Emissions were modelled using the average of the applied emissions for the first hour of ventilation assuming every hour as a possible starting hour.

Figure 4-1 below presents the maximum 100th percentile results from the Assessment Report's deterministic modelling (MB-5), and the modelling results conducted by TAS for all hours and between 7:00am and 7:00pm.

The deterministic modelling (MB-5) was selected to evaluate a single source for the purpose of determining if there are any major differences in the extent of the predicted impacts.

The results indicate that the deterministic modelling conducted by SEC is comparable with the equivalent maximum emissions modelling conducted by TAS between 7am and 7pm. However, the results presented in the Assessment Report are significantly lower than in the modelling.

Figure 4-1: Modelling comparison

4.8 SEC model verification

SEC provides a plot comparing its modelling results with the measured values. Scant information is provided regarding the measured data in the report however, some clarification was provided by SEC subsequently. The discussion does not provide a convincing explanation for the significant discrepancy between the modelled and measured data. For example,

- the claimed "outliers" in the modelling correspond reasonably with BOPRC monitoring data;
- the claim that the 98th percentile modelled values are reliable indicators of actual performance is not supported by the comparison where the measured data appear to be approximately 10 times lower than the modelled results at the 98th percentile;
- the comment that the measured data contain 17% methyl bromide is not supported with any actual data.

Information regarding the measured data was provided by SEC to TAS (and EPA) on the 15 July 2020. Upon review of these data it is noted there was only approximately three to six minutes of elapsed time between the opening of each ship hold being ventilated, whereas it is understood that this is intended to be controlled to two hours of time between the opening of each ship hold. i.e. intended ventilation is at a slower rate over approximately 10 hours instead of 15 to 20 minutes as occurred in 2019.

5 RESULTS PROCESSING

The modelled data need to be collated and processed to identify the various percentiles at each location, and to thus allow the modelled result to be presented in the Assessment Report. The presented results were compared with the modelled results in the modelling files provided. There is an immediately obvious discrepancy in that the presented results are lower than those in the corresponding modelled values.

There is an error in the way the FORTRAN results percentile program (PERCENTILE-1HR-NZERO-2I.FOR) works. For example:

- The very first result for the 1-hour average 100th percentile of discrete receptor 1 (427.681, 5830.631) in Run2 (RUN2\PERCENTILE-PROGRAMS-MATRIX\PERCENTILE-1HR.DAT) is stated as being 0.1948476ppm. However, review of the files used to create PERCENTILE-1HR.DAT shows that discrete receptor 1 recorded a higher result of 0.3594ppm in the first CALPOST timeseries result file (RUN2\CALPOST-TIME-SERIES-FILES\TSERIES_MB_1HR_CONC_1.DAT, Year: 2014, Julian Day: 195, Hour: 13).

- The 1-hour average 100th percentile of discrete receptor 844 (427.850, 5831.825) in Run2 (RUN2\PERCENTILE-PROGRAMS-MATRIX\PERCENTILE-1HR.DAT) is stated as being 129.1469ppm. However, review of the files used to create PERCENTILE-1HR.DAT shows that discrete receptor 844 recorded a higher result of 163.1920ppm in the first CALPOST timeseries result file (RUN2\CALPOST-TIME-SERIES-FILES\TSERIES_MB_1HR_CONC_1.DAT, Year: 2016, Julian Day: 244, Hour: 18). This result of 163.1920ppm is higher than all of the results stated in the PERCENTILE-1HR.DAT file (shown as 131.5176ppm recorded by discrete receptor 965 427.875, 5832.025)

- The 8-hour average 100th percentile of discrete receptor 4 (427.899, 5831.917) in Run2I (RUN2I\PERCENTILE-PROGRAMS-MATRIX\PERCENTILE-8HR.DAT) is stated as being 6.059181ppm. However, review of the files used to create PERCENTILE-8HR.DAT shows that discrete receptor 4 recorded a higher result of 9.9704579ppm in the first CALPOST timeseries result file (RUN2I\CALPOST-TIME-SERIES-FILES\TSERIES_MB_8HR_CONC_7.DAT, Year: 2016, Julian Day: 169, Hour: 8).

These three examples are provided to illustrate that the error affects all the results and is not just limited to a certain scenario or averaging period. We have only had sufficient time to consider the maximum value; as this value is absolute it is the simplest to check with certainty. As the maximum result for the whole model run set is not extracted from the modelling data by the FORTRAN code (or some other related computing fault has occurred) and a significantly lower value is being extracted in many cases (e.g. second example dot point) this will have a flow-on effect causing underestimation of the other percentiles (e.g. 99.9th percentile) determined using the FORTRAN program.

As a consequence of the error, none of the modelling results presented are correct or valid, and the assessment must be re-done.

6 SUMMARY

The following is a brief summary of the issues identified in the Assessment Report. The key issues are presented in categories according to the estimated significance of the issue in regard to it affecting the outcomes of the assessment.

6.1.1 Fundamental errors

- The modelling results were not correctly processed, the assessment is based on incorrect data and is invalid. The assessment must be re-done.

It would be prudent to correct other issues when re-doing the work.

6.1.2 Significant or potentially significant issues

- Inconsistencies between the emission files provided and the stated modelled ventilation hours in the Assessment Report.
- The modelling is not per the Experts recommendations in key aspects, in particular there is insufficient modelling and analysis per the deterministic approach, or in other words per the NZ guidelines for modelling.
- There is no valid analysis of compliance with the applicable criteria, per NZ legislation or modelling guidelines.
- There is no convincing model validation

6.1.3 Moderately significant issues

- Clarification of the source parameters used for the ship holds.
- Clarification of the number of cargo holds opened within an hour during ventilation of ship holds for the Base (Validation) Scenario should be provided.

6.1.4 Minor issues

- 1-hour and 24-hour average TELs not explicitly stated.

7 CONCLUSIONS

The review found fundamental errors that make the assessment invalid, hence the assessment must be re-done.

The review found that the approach taken in the modelling would underestimate the likely concentrations of methyl bromide both on and off-site, and does not follow key aspects of the Experts' recommendations. The various issues with the modelling approach and analysis should be corrected when the work is re-done.

8 REFERENCES

NZ Government (2018)

"Workplace Exposure Standards and Biological Exposure Indices – 10th Edition", New Zealand Government, November 2018.

Sullivan Environmental Consulting (2020)

"*Modelling Report for Methyl Bromide Exposures for Timber Fumigation at the Port of Tauranga, New Zealand*", prepared for Stakeholders in Methyl Bromide Reduction by Sullivan Environmental Consulting, June 2020.