Review of TAS Air Sciences Air Modelling Assessment of Methyl Bromide at Port of Tauranga

Attention:

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Executive Summary

ASG has been engaged by Bay of Plenty Regional Council to conduct a review of a dispersion modelling study of Methyl Bromide at the Port of Tauranga conducted by Todoroski Air Sciences (TAS) on behalf of New Zealand Environmental Protection Authority (EPA). TAS was engaged by the EPA to simulate the expected airborne Methyl Bromide concentrations from the Port of Tauranga during ventilation events. The purpose of the modelling assessment was to determine the 1-hour maximum, 24-hour and annual airborne concentrations of Methyl Bromide fumigant at both the India and China application rates. TAS used CALPUFF to simulate ship and 3 log piles at a central location in the Port.

ASG has conducted this review based on the information in the October 2019 TAS report. Some of the methods used in the modelling were not included in the report and, no model control files or hourly emission files were supplied. Therefore, ASG has not been able to provide a complete review of the methods and decisions made by TAS, and how these may affect the ground level concentrations of Methyl Bromide.

In summary, TAS has potentially underestimated the emission rates since the modelling only considered ventilations from 3 log piles of medium size at one location, and did not consider log pile fumigation\ventilation events happening at other areas of the Port. TAS assumed a 450 m^3 air headspace containing MB at the end of fumigation, available for release to the atmosphere from a nominal log pile size of 60m x 5m x 4m. TAS used the Sullivan ventilation flux equations to estimate the release of MB to the air, and TAS assumed log pile ventilation occurred every single hour of the day. TAS did this to capture worst case dispersion hours, but in reality the log pile fumigations is mostly carried out in the day. There may only be a couple of hours a day at a single location emitting at a higher rate whilst the other hours will have much lower emissions due to desorption from the logs. Because emissions were largely constant the 99.9th and 98th percentile concentrations were very similar to the 1-hour maximum results.

For ship holds TAS assumed a headspace size of 3,800m^3, consistent with the ASG review of the Sullivan report. This allowed for an average MB usage of ~600 kg. The results for ship holds assuming no recapture, and an application rate of 40 g/m^3 looks reasonable, and generally conservative where the 1 ppm TEL extends beyond the Port boundary. The 0% recapture and 120 g/m^3 application looks too conservative. TAS was able to show that the preferred time for log fumigations was during the day time, which is expected as the atmosphere is generally unstable, and dispersion is better than at night. Similarly for ship hold ventilations daytime ventilations produced significantly lower concentrations than during the night time. It is understood Genera would prefer to ventilate ship holds at night when workers and bystanders are not around. The new proposed slow release rate of the ship holds is sensible as exposure is reduced. Further it is recommended that ship hold ventilations do not occur at the same time as log pile ventilations.

The results in this study are significantly higher than those in the Sullivan study and for certain application types and recapture are quite similar to those results from Golders which assumed 80% recapture on 80% of all log piles. The TAS 1-hour maximum results for lower application rates and higher recapture rates are more in alignment with the monitoring, and show that three log piles or a ship on their own can cause exceedances of the 1-hour 1ppm TEL.

The real benefit of the TAS results is that this is the first Air Assessment where the Consultant has considered the effects of different application rates, with, and without the effects of recapture technology. The difference in their results is significant. At the 1-hour maximum with no recapture and an application rate of 120 g/m^3 the 1 ppm TEL at the Port boundary is exceeded. However, for the same application rate and 80% recapture the 1-hour maximum result shows no exceedance of the TEL beyond the Port boundary. Genera and Golder need to break down the monthly usage of MB at each location into individual piles with and without recapture and at different application rates. A single location of ventilating log piles at a low application rate of say 40 g/m^3 and 80% recapture is unlikely to cause any exceedance either to workers or extend beyond the Port boundary, but the same log piles at a higher application rate with no recapture is much more likely to cause exceedances beyond the Port boundary. This is important as recapture is not yet that efficient, is currently only happening on average 70% of the time, and often is not applied at all due to operational restrictions on a day to day basis. Therefore it is anticipated that no recapture events will continue to occur for the next few years.

The TAS modelling did not consider on-Port modelling and only referred to the 8-hour NZ WES TWA as an assessment criteria for worker safety. With the high predicted ground level concentrations predicted on-Port in their modelling scenarios from just three log piles, this should have raised a red flag. There were other minor concerns such as modelling the ship holds as a point source rather than a volume source, allowing log pile ventilations to occur at night-time rather than during work hours which is what typically occurs.

1. Introduction and Review

This is a brief review. So far there have been 4 modelling exercises conducted by 4 different consultants in chronological order from oldest to latest;

1. Sullivan Environmental Consulting, Inc. *Air Concentration Dispersion Modeling Assessment of Ethanedinitrile (EDN) Concentrations in Tauranga Port, New Zealand, 19 September 2018*.

2. Golders Associates Limited (Golders). Of which there were three critical documents made up of a technical memo and two reports. The first, a technical memo was submitted to Genera limited in July 2019 and was titled;
   Technical Memorandum. Project no. 1898728-7403-009-TM-rev0. Dated 10 July 2019.
   The second document was the main modelling report called;
   'Report. Technical Air Quality Assessment, Genera Limited 1898728_7403_008_R_RevA'
   The third document which forms part of the main report is the Appendices which are enclosed in a document titled;
   'Combined appendices.pdf. Document 19A, Version 2.0. August 2019.

3. Beca Limited (Beca). *Genera Limited - Air discharge Consent Application. October 2019.* This report includes the latest Golder (October 2019) modelling in Appendix D and Appendix G as well as the ESR report in Appendix F.

4. Todoroski Air Sciences (TAS). *Air Dispersion Modelling Methyl Bromide. NZEPA. November 2019*.

Each of these modelling assessments have produced different results due to; different emission rates, different models, and different meteorology. The Sullivan model used the AERMOD model and numerical weather forecast data (WRF) to generate surface and upper meteorology. They derived their emissions from ventilation flux equations. All other Air Assessments used CALPUFF. The Sullivan results were generally thought to under predict the MB concentrations. The July 2019 Golder modelling used the BOPRC 3D meteorological data set and used real MB usage at the Port to derive the emission rates. Although the 1-hour modelling results that were presented in the report may be conservative in that all locations were assumed to emit at maximum usage at the same time, the results are not overly conservative at any location. Further there were some concerns that the emission rates had been under predicted. The concerns are related to; the capping effect of a maximum MB dosage of 450kg/hr at a single location, the amount of MB released from ship holds, and rate of that release at ventilation. There were also concerns that log piles with no recapture had not been adequately assessed. In October 2019, Beca produced an Air Assessment report that included the new latest modelling by Golders and a review of the health risks by ESR. This report showed some major changes for modelling which including a lower annual MB emission rate from 200,000 kg to 150,000 kg, and a change in the way ship holds are opened, with each ship hold opening 2 hours apart. In November 2019, on behalf of the EPA, TAS Air Sciences conducted a modelling assessment of ship holds and log piles based on the Sullivan ventilation equations. TAS used the Australian CSIRO TAPM model to develop the upper air data, and biased the model to the Tauranga Airport meteorological station at the surface. The meteorology in this sense was not too different at the surface than the BOPRC data set. Specifically TAS looked at the effects of different application rates and recapture, and is the only work to date to have done so.

The reason why these modelling exercises are all different is because the model is highly sensitive to the meteorology, and in this application, especially the emissions data. Assuming the meteorology is mostly similar at the Port which is the case for the Golders and TAS assessments, the model inputs (listed below in points 1 to 10) which affect the emission rates in the model, are different, and will have an effect on the model output concentrations. Further since no model files are available for any of the modelling jobs done to date, it is possible there could be multiple other differences (model switches, human error etc) that are unlikely to ever be picked up.

Neither the TAS model nor the Golder modelling are overly conservative. They have both potentially underestimated the emission rates, i.e. TAS through the assumption of just three log piles and one location, and, Golder through the capping of MB usage, assumptions behind the ventilation rates and amount of MB in the headspace. Equally, there are also some over estimations of the emission rate, i.e., TAS through assuming every single hour of the day is a ventilating hour, and Golder modelling for all high ventilation hours. TAS modelling assumed every hour was a ventilation hour, hence the plots reflect worst case dispersion conditions at night time in stable atmospheric conditions. Most log pile fumigation/ventilations will occur during daytime hours. The Golder modelling is more representative at each location as actual MB usage per location is used representing actual high MB usage days. But, they are not representative of reality since different meteorology than what actually occurred, was used. TAS in comparison used fictitious emissions representative of 3 log piles at different application rates with and without recapture for five years of modelling. Both models have generated their emissions in this way in order to show potentially worst case dispersion, which is acceptable and is one way modelling could be conducted for MB at the Port. Both TAS and Golder models are useful in that their results are not too dissimilar despite different emission assumptions.

TAS modelling shows very high 99.9th percentile concentrations compared to that from Golders modelling. This is because they considered every hour to be a ventilation hour. In reality a fumigation\ventilation event will likely happen once a day at a location, so it makes sense that the 99.9th percentile level should be significantly lower than the maximum. The Golders October 2019 modelling who have considered actual events show that the 99.9th percentile is much lower. This is more representative of actual conditions and is expected.

It is important to point out after the 4 different modelling exercise that the model is sensitive to all of the following:

1) **Time of day of ventilation**. TAS and Golder (July 2019) looked at ventilations each hour of the day. In the case of Golder it only modelled ventilations for those hours that ventilations actually occurred. TAS on the other hand assumed every hour was a ventilation hour, both day and night. Both Air Assessments considered a diurnal profile of emissions with a peak ventilation hour, followed by desorption emissions from the logs over multiple additional hours. Assuming that every hour is a high ventilation hour 24 hours per day, or, even several hours in a row as in the case of Golders does not happen in reality. There may be one large job of 17 log piles fumigated in an hour or two, and then no more for the rest of the day at that

location. Both models have generated their emissions in this way in order to show potentially worst case ground level concentrations, which is generally acceptable, and is one way that modelling should be conducted for MB at the Port. Both TAS and Golder models are in agreement in that they show that the 1-hour maximum from ships and log piles alone can cause exceedances beyond the Port boundary.

2) **The size of a single log pile**. The bigger the log pile the bigger the headspace and the more the MB emission rate. TAS assumed a nominal 60m x 5m x 4m pile size, but, in reality they can be much bigger. Log pile size does not come into Golder modelling as they used a mass monthly usage of MB. It is important that the monthly usage of MB used in the Golder modelling be evaluated for a single log pile. In reality three log piles used by TAS appears to be an under estimate of the number of log piles typically ventilated at any one time.

3) **The number of log stacks being ventilated in the hour**. Golders assumed a mass emission rate of 450 kg/hr which is 4-6 log piles; TAS assumed 3 log piles at a single location. In reality multiple log piles at any one location are routinely fumigated together. MB from log piles is additive, so 17 log piles is 17 times as much MB into the air as one log pile. Neither Air Assessment has considered REAL events.

4) **The emission profile of the release, i.e., how much in first hour and how much in second hour and what does remaining 24 hour emissions look like**. Both models allowed for the release of emissions to occur in the first hour for log piles. Both models included a 24-hour emission profile of ventilation followed by desorption. Golder capped the ventilation in the first hour at a single location to a maximum of 450 kg/hr of MB used, which amounts to approximately 76.5 kg in the headspace available for release to the air. This is approximately equivalent to 3 TAS log piles at an application rate of 80 g/m^3 and 75% recapture. Golder capped any excess and forced it to ventilate in the next hour. For three log piles where the application rates were greater than $72g/m^3$ and recapture less than 50%, TAS emissions appear to be higher than Golders. It is necessary that Genera take the dosage rate of MB per hour and relate this to a single log pile at the same time considering the ventilation flux equations used by TAS and Sullivan which rely heavily on the assumptions around the head space volume.

5) **The location of the log piles**. TAS only assumed one log pile location of three log piles at a central location at the Port. Golder assumed three log pile locations. Effectively both models capped the emission rates at a single location for an hour, thereby limiting the maximum potential concentration and emission rate. Further, the larger the area the emission rate is spread over at time of the release the larger the area of initial dilution and the better the dispersion. Therefore the concentration downwind and at the source will be lower.

6) **The initial dose**. TAS looked at several dose application rates for several recapture scenarios. This is good and is exactly what needs to be reported. You can see how the results vary (Figure 4-1, 4-2, 4-3) according to application rate and recapture percentage. Golders only considered actual mass of MB used, regardless of application rate, so Golders results are a confusing mix of all application rates with and without recapture. It is impossible for any

reviewer to understand what an application rate of 450 kg/hr means in so far as number of log piles, application rate, recapture, log pile size, etc. Below is TAS Table 3-4 adjusted to reflect kg/10 minutes for a single ventilation from a single log pile, using the ventilation equations and assuming a 450m^3 headspace. The amount of MB available for release differs significantly as expected depending on recapture and application rate.

MB emission rate in kg/10 minutes for a single log pile of size (60m x 4m x 4m) for varying application rates and recapture, from TAS Table 3-4

Recapture (%)	Dose application (g/m^3)			
	40	72	80	120
0	9	16.2	18	27
50	4.5	8.1	9	13.5
75	2.25	4.05	4.5	6.75
80	1.8	3.24	3.78	5.4
90	0.9	1.62	1.8	2.7

7) **The amount of MB left in the head space (logs)**. Golders assumed 47% left in the head space. Sullivan and TAS assumed 50% for logs. Fifty percent is more consistent with the literature. Depending on the percent will make a difference to the first hour's emission rate, and therefore the MB concentrations downwind.

8) **The amount of MB left in the head space (ships)**. Golders assumed 37% of MB was left in the head space, and TAS assumed 50%. The resulting emission rates from these head space assumptions could be significantly different as Golders used a mass MB usage of >5,000 kg for 5 holds at a single location whereas TAS computed the amount of MB needed (~600kg per hold), depending on application rate and assumptions around head space size of 3,800m^3.

9) **The release rate of ship holds**. Golders (July 2019) assumed 37% of MB used for ship holds was released in the first two hours, 17% in the first hour, and 17% in second hour. TAS assumed 50% of MB used for ship holds was released over 6 hours. This difference between the Consultant's approaches will have a significant effect on the amount of MB released and the emission rate per hour. The Golder approach releases less MB to the atmosphere (lower glc), but does this over two hours (higher glc), whereas TAS releases more MB to the atmosphere (higher glc) but spreads the emission over 6 hours (lower glc).   In reality two recent ship fumigation/ventilation events for ships showed that the ship ventilated at night time (not considered by Golder, (poor dispersion)), and, that all ship holds were opened within one hour of the first hold opening. So Golders model may have underestimated the mass of MB released to the air, but then the TAS model may have dispersed its MB mass too slowly.

10) **Recapture or no recapture**. TAS has shown what 3 log piles looks like with no recapture. This produces exceedances. Golder has not shown MB concentrations from zero recapture for log piles and only loosely accounts for zero recapture in their mass emission rate.

Hence it is critical to understand a single log pile with and without recapture for a range of application rates. TAS modelling comes the closest to this.

Other points ASG noticed in TAS Modelling;

1) TAS used TAPM for upper air instead of BOPRC meteorological data set. TAPM evaluated very poorly (see statistics, Appendix A) especially for wind direction and wind speed. Calmet fortunately could correct this to some degree with the use of Tauranga airport data. It is a shame TAS could not use the BOPRC meteorological data set used by other Consultants in MB modelling. This would have removed quite a lot of additional uncertainty and made model results between various Consultants more comparable.

2) TAS accounted for ventilation from ships and logs for all hours of the day.

   '*The fumigation and emission for either three log stacks or a ship was modelled for any hour by separately modelling a ship or three log piles for each hour of the day. This is necessary as for example, a ship would not be ventilated every hour, but could be ventilated in any hour. The period with the highest impacts is considered in the assessment*'.

   This means that any hour's glc could be the sum of a ventilation hour plus any residual concentrations from previous hour's ventilations. The result of modelling like this is good in that it identifies worst case dispersion, i.e., at night time with low winds and stable atmosphere, but it means that the 99.9th, 99th and 98th percentiles will be high due to all the residual concentration in the air. Therefore, the TAS 99.9th percentile MB concentrations are not representative because ventilation does not happen at a single location every single hour of the day. But the Golders (October 2019), 99.9th percentile glcs are more representative as their modelling used real mass emission rates at multiple locations over a whole year, and so did not assume ventilation happened at every hour of the day, even though they assumed worst case emission rates.

   The 1-hour maximum results are important especially since there is no 15-minute STEL.

3) TAS assumed 50% of ship hold fumigation was available for ventilation. Golder only assumed 37%. According to Golder this value was measured at a single monitoring incident. The literature seems to support 50%. This difference in how much fumigant was available for ventilation is significant. The difference for a 120 g/m^3 application for a single ship hold is 98 g/s or 352 kg/hr of additional MB released to the atmosphere. For modelling purposes a conservative value should always be chosen.

4) TAS allowed the ship holds to ventilate slowly over 6 hours. At the time of writing this report, the latest Golder October 2019 modelling assumed ship holds opening 2-hours apart. But, in August 2019 all 5 ship holds were open within the hour, potentially emitting all 1903 g/s of MB into the atmosphere. To spread the emission (380 g/s x 5 ship holds) over 6 hours is too drastically reduce the ground level concentration (glc). What is real?

Should forcing ship emissions over multiple hours be a new consent condition for ship holds, rather than rely on ambient measures of TVOCs? This is a sensible approach as monitoring is mostly a hit and miss process for these variable releases and this slow approach to opening holds one at a time is more protective or workers on-Port.

5) TAS assumed 3,800m^3 of head space in ship hold contains MB. This is consistent with ASG 2019. A single hold is approximately 9,000 m^3 and according to Sullivan will contain approximately 5,194 m^3 logs, which leaves a residual head space of 3,800 m^3. At 120 g/m^3 application rate a single ship hold would use 623 kg of MB and 5 ship holds would use approximately 3,116 kg. The emission rate from one ship hold would be 380.7 g/s which TAS has split up over 6 hours.

6) TAS treated ship hold as a point source. It is not a point source. Each ship hold should be treated as a square volume source. Downwash effects are likely to be negligible.

7) TAS assumed a single log pile of volume 1200m^3 (60m x 5m x 4m). This is an average size log pile. No modelling was done on larger log piles with larger head spaces. TAS assumed head space size of 450m^3 (same as Sullivan) for a single log pile. ASG review pointed out that the model is very sensitive to head space size, so for a 600m^3 head space which can occur for larger log piles then the emission rate would be significantly higher. This is no fault of TAS, measurements need to be conducted to find out what typical head space sizes are.

8) Log pile source characteristic is treated as having initial dilution of 14.2 (sigma y (m)). ASG assumes this is the ratio of 4.2 to the length of the volume source. However, leakage of emissions can occur for long sources. It is recommended for more accurate near field modelling that each log pile should be broken into 4 small square 1:1 ratio volume sources which would allow for representative very near field modelling. The initial sigma z of dilution has been set at 1 m by TAS. However, within a few minutes the vertical distribution of MB will be more like 5m or more. The effect of reducing sigma z is to cap the dilution which can cause higher concentrations close to the source and lower concentration downwind.

9) Figure 4-1 shows the 1-hour maximum extent of MB as isopleth concentration contours for one ship, where 50% of the applied MB for different application rates is available for release to the atmosphere. The model results show that even for a low application rate of 40 g/m^3 the 1-hour TEL is exceeded beyond the plant boundary. These results are high because the plot represents the 1-hour maximum glc (as opposed to 99.9th percentile), and because TAS assumed 50% of the applied MB was available for release to the atmosphere (recommended in literature). These results are conservative, but they are also important as there is no short term (15-minute) STEL in place. Further it is perfectly reasonable given the right meteorological conditions that 50% of the MB applied may actually be available at ventilation. If TAS had not spread the total emission over 6 hours, and instead allowed the emission to occur after 1 or even two hours the results would be significantly higher.

10) Figure 4-2 shows the 1-hour maximum extent of MB as isopleth concentration contours for 3 log piles, where 50% of the applied MB for different application rates was available for ventilation. Note Golder assumed 47%.
    a. For 3 log piles with no recapture at an application rate of 120 g/m^3 the 1-hour maximum results are significant and extend well beyond the plant boundary.
    b. For 3 log piles with 80% recapture at an application rate of 120 g/m^3 the 1-hour maximum results are much smaller, but still extend beyond the plant boundary.

    These results are important as they show the large difference between application rates and recapture rates. This is not something one can deduct from the Golder modelling in any way. For real events with multiple log piles it may be plausible to have 6 log piles being fumigated at once at multiple application rates where 3 of the 6 log piles experience recapture, and 3 of the log piles have zero recapture. The resulting worst case MB isopleth contour may look worse than any contour in Figure 4-2.
11) ASG agrees findings from Tauranga port is extendable to other ports, wind direction will change the MB footprint, but all other assumptions will be much the same. Representative meteorology from other ports needs to be evaluated.
12) There are other multiple minor questions, concerns, but none of them are considered to make a hug difference.

In summary, there are still a couple of concerns that the TAS modelling has under estimated the emission rates for the following situations.

- Only 3 log piles were considered to be ventilated at the same time. In reality we know that many more log piles can be fumigated within an hour at a single location
- TAS assumed a mean log pile volume of 1200 m^3 for a log pile size of (60m long x 5m wide x 4m long). There are log piles that are bigger than this. Bigger log piles means more MB and greater emission rate
- TAS allowed the ship holds to ventilate over 6 hours. The effect of this is to greatly reduce the downwind and near field MB concentrations. The ship hold ventilation on August 2019 showed that all holds were fully opened within the hour. (However, Golder latest modelling also allowed a slow release, so perhaps this is something recommended by Genera).

Other than these emission and downwind concentration underestimation concerns TAS has considered various application rates (40 g/m^3, 72 g/m^3, 80 g/m^3 and 120 g/m^3) as well as different recapture rates. The results are varied as expected and the contour plots represent conservative 1-hour maximum contours. The modelling is meant to be conservative and it is imperative to show the 1-hour maximum as well as the 99.9th percentile. The 1-hour maximum results are significant because there is no current 15 minute STEL in place, and the 99.9th percentile concentrations are important as they show how quickly the concentrations decrease. The 99.9th and 98th, 95th percentile results from TAS modelling are too conservative because the modelling assumed ventilation happened every hour of the day, which it doesn't. However, how TAS has conducted the modelling is considered 'normal practice' as the model results are used to show the potential highest concentration coinciding with poor dispersion days over a long period of time. However, as well as present the model results as TAS has done, real events where multiple log piles (more than 3) at a single location also needs to be considered.