# Global Analysis of International Studies on the Use of Ethanedinitrile (EDN)[1]

A Report Prepared for Stakeholders in Methyl Bromide Reduction

Jack Armstrong, Ph.D., Quarantine Treatments and Market Access Specialist
Quarantine Scientific Limited, Kerikeri, New Zealand

Terms of Reference: STIMBR requested that I undertake a review of global EDN research to identify data sets that supported the results from EDN research in New Zealand, and to compare, where possible, the data sets that support New Zealand research results. I was asked to undertake the review based on my professional experience, including a 40-year career as a research scientist with the US Department of Agriculture and over ten years working as a biosecurity consultant, during which I was closely associated with fumigants and fumigation technologies and methods, and authored or coauthored numerous scientific reviews of international research.

## BACKGROUND

In a 2010 ruling, New Zealand Environmental Authority (EPA, then Environmental Risk Management Authority, ERMA) required the recapture or destruction of all methyl bromide (MB) remaining in the headspace of all completed fumigations after October 2020 (ERMA 2011). Stakeholders in Methyl Bromide Reduction, Inc. (STIMBR, www.stimbr.org.nz), embarked on a research program to find both recapture or destruction technologies and alternatives to MB for the phytosanitary treatment of export pine, *Pinus radiata*, logs.

To identify potential MB alternatives, STIMBR and the Crown Research Institutes for Forestry (Scion) and Plant & Food Research conducted a comprehensive literature review of all known quarantine treatment methods and technologies, including all available fumigants, heat and cold treatments using a wide range of technologies, irradiation, systems approach, and others. The review (Armstrong et al. 2014) found that fumigation with EDN was the only treatment and fumigant option that had any potential for success as a phytosanitary treatment for the log export industry.

In the five-year period since 2014, a comprehensive efficacy data set was developed in the laboratory that resulted in (1) the identification of the most EDN-tolerant forest insect species and life stage of the three phytosanitary-related species in New Zealand, and (2) the EDN concentrations and fumigation times (treatment schedules) that would be needed to control the most EDN-tolerant species in export logs.

Commercial-scale confirmatory tests of selected treatment schedules based on the results of the laboratory efficacy data sets are nearing completion (anticipated by end of May 2019). The confirmatory tests completed to date have confirmed that EDN is efficacious against the three forest insects most commonly found in association with forest products. Two tests will be conducted in the week commencing 20 May 2019 which the data gathered to date indicates will confirm that efficacy will be achieved when fumigated with 100 g/m$^3$ EDN for 20 h (the results of those tests will be forwarded as soon as they are known).

Globally, numerous studies were done to assess the efficacy of EDN against a range of insect pests, pathogens and nematodes. Some of the studies informed the registration of EDN for use on wood products (including logs) in Australia, Korea and Malaysia. However, because the tests were conducted in different countries and by different researchers, the ranges of forest products and wood species treated, the target organisms, the

[1] Ethanedinitrile is an internationally recognized fumigant that is owned and produced by Lučební Závody Draslovka a.s. Kolín, Czech Republic, herein referred to as Draslovka.

experimental designs and the parameters that were tested are widely varied. This report collates the results for these studies to enable comparison, if possible, with the results from EDN efficacy research that has been undertaken in New Zealand.

## DISCUSSION

Because EDN is a relatively new fumigant that has not been used for commercial fumigations (until recently), the overseas studies discussed here are of an exploratory nature and record a range of measurements associated with single units of product (e.g., a single stack of logs) and/or were not systematically replicated. In contrast, the EDN research in New Zealand has been very systematic and has produced the most robust data of any country worldwide. Results from laboratory-scale trials have been confirmed in commercial-scale log stacks of, initially, approximately 700 $m^3$ (total volume) and latterly approximately 170 $m^3$ as lower treatment rates and shorter durations were explored. In all instances efficacy has been demonstrated with nearly 100,000 target insects killed[2]. There have been no survivors. Probit 9, a statistical measure often required of phytosanitary treatments has been achieved.

**Comment: International phytosanitary standards**

The EDN Advisory sub-committee of the International Forest Quarantine Research Group convened (international teleconference) on 8 May 2019 to discuss the status or EDN research, the worldwide registration of EDN, and to consider the data required by the *International Plant Protection Convention* Technical Panel on Phytosanitary Treatments (TPPT). The meeting considered, and confirmed its support of the application for the inclusion of EDN in the relevant International phytosanitary standards (ISPM 15 and ISPM 28).

Dr Adnan Uzunovic[3] commented, in his role as chair of the sub-committee, that the quantity and quality of the EDN research data now available that supports its efficacy is far greater than that previously submitted by any National Plant Protection Organisation to the TPPT for any other treatment. Further, he noted the importance of the New Zealand generated data (citing the depth, thoroughness and robustness of the research) and the weight it will lend to the case for including EDN in the international standards.

Dr Mike Ormsby[4] confirmed that MPI will take the submission seeking inclusion of EDN in the treatment standards to TPPT at its next meeting.

The reports appended to this paper were conducted in various parts of the world and used different tree species and target pest species. In each instance, the researchers have designed their experiments to provide data for a country specific concern. The tests were conducted using a wide range of EDN concentrations, temperatures, load factors and approaches to fumigation. Consequently, it is not possible to use this data to derive scientifically justifiable statements about the behavior of EDN by comparing the results among the globally produced studies or with the results of EDN research in New Zealand.

As stated researchers in New Zealand have produced the most comprehensive and robust EDN efficacy data in the laboratory, then confirmed the laboratory data using commercial scale tests. I have carefully considered the papers and the New Zealand data. Direct comparisons cannot be made between the research results from the studies worldwide either among those studies or directly with the results from research in New Zealand.

[2] The results from both laboratory - and commercial-scale studies in New Zealand will be presented to the Australian Pesticide and Veterinary Medicine Authority for modification of the EDN label for fumigating wood products, including logs, in Australia.
[3] Dr Uzunovic is employed at a Mycologist-Research Scientist at FPInnovations, Vancouver.
[4] Dr Ormsby is the Manager for Plant and Pathways Biosecurity Science and Risk Analysis, NZ Ministry for Primary Industries.

However, there are trends that are apparent in the appended studies that allow several high-level conclusions to be drawn from those studies confirming the results reported from New Zealand.

Specifically, these trends include:

1. EDN is efficacious against all the forest pest(s) tested. In all of the research, the results found fumigation concentrations and times that provided complete mortality of the target pest(s).
2. The various types of cover (sheets/tarpaulins) can reduce emissions during fumigation to very low levels. Sheet/tarpaulin is the determining factor in preventing EDN emissions during fumigation, to protect both the workers and the environment.
3. The concentration of EDN under the sheet/tarpaulin declines to low levels rapidly over the fumigation times used. Unlike other fumigants, all of the research results show that EDN under the sheet/tarpaulin quickly vaporizes and sorbs within the treated product, then degrades to low concentrations by the end of fumigation.
4. When venting occurs very little EDN is released to the atmosphere. The rapid decline in EDN concentration over time directly results in less EDN available at the end of fumigation to be released into the atmosphere.
5. EDN released during venting diffuses rapidly over short distances resulting in a rapid decrease in the EDN concentration in the environment. All the studies found that EDN does not “pool” or linger in the fumigation area during the venting process but decreases rapidly over a short period of time by diffusion into the environment

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The New Zealand Ministry for Primary Industries will present the results of the New Zealand trials to trading partners during bi-lateral meetings seeking approval for the recommended treatment schedules for the use of EDN as a phytosanitary treatment against forest insects found in association with pine logs exported from New Zealand. Once approved by our trading partners, EDN will become a tool for the New Zealand log export industry as it is a viable alternative for methyl bromide.

**List of appended research papers:**

1. “Commercial Fumigations of Wood in Czech Forests – First Experiences” November 2018, 1496-$m^3$ stack study.
2. “Commercial Fumigations of Wood in Czech Forests – First Experiences” November 2018 86-$m^3$ stack study.
3. New Technology of Wood Fumigation Against Bark Beetle – First Trial Results EDN Product Used for Forest Protection in the Czech Republic”, Lesnicka Prace, 19-21, 11, 2017.
4. Russian study 2018 to inform registration in Russia Executive Summary
5. Preliminary trials of the ethanedinitrile fumigation of logs for eradication of *Bursaphelenchus xylophilus* and its vector insect *Monochamus alternatus.* Byung-Ho Lee, Jeong-Oh Yang, Stephen Beckett and Yonglin Ren. Paper referring to three different fumigation with different parameters.
6. Presentation reporting the results of paper 5 above with photographs and some additional data

**Czech studies: Two Draslovka reports presented at the Methyl Bromide Alternatives Outreach forum, November 2018, Orlando, Florida (https://mbao.org/static/docs/confs/2018-orlando/papers/hnatek.pdf),**

## Context

The purpose of the research was to:

1. verify EDN efficacy in a log stack fumigation greater than 1,000 stacked $m^3$
2. verify EDN distribution in a log stack fumigation above 1,000 stacked $m^3$
3. monitor EDN concentrations during ventilation and determine safety distances
4. other measurements.

The two separate trials *Abies picea* (Norway spruce) logs were treated under a critical use exemption (CUE)[5] approved by the government of the Czech Republic. The treatments were done using log stacks covered with tarpaulin sheets. The CUE was provided to allow Draslovka to determine the efficacy of EDN against the European spruce bark beetle, *Ips typographus*, that is currently devastating Norway spruce in Czech forests. A total 200,000 $m^3$ of logs were treated under the CUE in the Czech Republic during the 2018 summer. A second approval was granted by the Czech government to treat up to 1 million $m^3$ over the 2019 summer.

The two presentations included:

1. A fumigation of a 1,496-$m^3$ log stack and a 86-$m^3$ log stack (the original presentation mis-stated the log stack volume as 150 $m^3$). The purpose of the 1,496-$m^3$ log stack trial was to measure EDN concentrations within the stack and the surrounding area during fumigation.

2. The purpose of the 86-$m^3$ log stack fumigation was to determine the efficacy of EDN for the control of *I. typographus*, six toothed spruce bark beetle or Spruce wood engraver, *Pityogenes chalcographus*, hairy spruce bark beetle, *Dryocoetes autographus* and Brown spruce longhorn beetle, *Tetropium fuscum.*

Data from these trials are summarised below.

[5] EDN is not yet registered for use with-in the EU. The Czech government has made application to the EU seeking registration of EDN for use in the EU.

***Data summary***

| Document | Draslovka report – Study 1 |
|---|---|
| Date | 5th September 2018 |
| Location | Vápenná (Jeseník District) Czech Republic |
| Set up details | |
| Type of logs | *Picea abies (L)* Norway spruce |
| Log size | 2m length |
| Replication | 1 stack 1 application |
| Stack cover | The stack was covered with plastic tarpaulin which was joined by folding and sealing the joint with spring clamps (30cm apart |
| Stack volume | 1,496$m^3$ |
| Stack dimensions | 68.0 x 4.4 x 5.0 m |
| Load factor | 64% |
| Fumigation | |
| Dose rate | 50gm/$m^3$ |
| total EDN used | 75 kg |
| Length of fumigation | 10 hours |
| Measurement device in stack - fumigation | GC Shimadzu GC-17A |
| Maximum start concentration | 27 and 28 gm/$m^3$ *measured in 2 places in the stack* |
| End concentration | 3.8 and 4.1 g/$m^3$ – *measured in 2 places in the stack* |
| Temperature $^0$C - under tarp | 11 to 23 $^0$C |
| Temperature $^0$C – Ambient air | 10 to 30 $^0$C |
| Air movement | 0 to 3.5 m/s |
| Measurements | |
| Measure device outside stack -fumigation | MSA (6 EDN monitors placed at 20m from the tarp all directions)<br>Lumasense (10 m downwind centre of the tarp) |
| EDN in environment during fumigation | 0 ppm at both 10 and 20 m |
| Measure device outside stack - ventilation | Gasmet (20 m downwind direction from the tarp)<br>Lumasense (10 m downwind centre of the tarp) |
| Environmental EDN – Fumigation | 0ppm at 10 and 20 m |
| Environmental EDN – ventilation – lumaSence at 10m | 0-20min 12 ppm average 88 ppm maximum<br>20-40 min 2 ppm average 16 ppm maximum<br>40-60 min 1 ppm average 3 ppm maximum |
| Environmental EDN – ventilation – Gasmet at 20m | 0 ppm average and maximum throughout ventilation |
| Environmental EDN – ventilation – MSA at 20 m N,S.E,W | 0 ppm average and maximum throughout ventilation |
| Concentration in stack 1.5 hours post ventilation | 0 ppm |

***Data summary***

| Document | Draslovka report – Study 2 |
|---|---|
| Date | September 2018 |
| Location | Vápenná (Jeseník District) Czech Republic |
| Set up details | |
| Type of logs | *Picea abies* |
| Log size | *4.1 x 1.9m* |
| Replication | 1 stack 1 application |
| Stack cover | Single tarpaulin secured with sand snake |
| Stack volume | 86$m^3$ |
| Stack dimensions | No data |
| Load factor | 62% |
| Fumigation | |
| Dose rate | 50gm/$m^3$ |
| total EDN used | 4.3 kg |
| Length of fumigation | 10 hours |
| Measurement device in stack - fumigation | GC Shimadzu GC-17A |
| Maximum start concentration | 61.21 to 67.8 gm/$m^3$– *measured in three different places in the stack* |
| End concentration | 1.97 to 2.5 g/$m^3$ – *measured in three different places in the stack* |
| CT product | 169 g h/ $m^3$ |
| Temperature $^0$C - under tarp | no data |
| Temperature $^0$C – Ambient air | no data |

## Czech Study : Efficacy study 2017

### *Context*

A report for the Czech Forestry Protection Service (Ochrana lesa) reporting on trials conducted by Draslovka and the Czech University of Life Sciences.

The work tested efficacy against several species of bark beetles (*Ips sp., Pityogenes sp., Hylurgops sp.).*

| Document | Paper produced by Draslovka and the Czech University of Life Sciences. |
|---|---|
| Date | 18th May 2017 |
| Location | Near Libef Village, Czech Republic |
| Set up details | |
| Type of logs | *Picea abies and Pinus sylvestris(L)* Scots pine |
| Log size | 4m long 15 to 40 cm diameter |
| Replication | 1 stack 1 application |
| Stack cover | A tarpaulin was placed on the ground before the pile was made. The stack was covered with a plastic tarpaulin weighed down by sand bags. |
| Stack volume | 130 $m^3$ |
| Stack dimensions | 12.5 x 4 x 2.5m |
| Load factor | 62% |
| Fumigation | |
| Dose rate | 50gm/$m^3$ |
| total EDN used | 6.5 kg |
| Length of fumigation | 7 hours 45 minutes |
| Measurement device in stack - fumigation | Lumasense |
| Maximum start concentration | Highest 49.2 gm/$m^3$ measured in 2 places in the stack |
| End concentration | 3.8 and 4.1 g/$m^3$ – measured in 2 places in the stack |
| CT product | 119.5 and 158.5 g hr/$m^3$ i.e. 2 places in the stack |
| Temperature $^0$C - under tarp | No data |
| Temperature $^0$C – Ambient air | No data |
| Efficacy | 100% of insects |

## Russian study: Report to the Russian authorities

### *Context*

To inform the EDN registration process in Russia, a fumigation study was conducted for the Russian government on December 2018 by Novorossiysk branch of the Russian fumigation group, Moscow at Apcharovsk, Krasodar Krai[6]. The purpose of the trial was to measure levels of EDN in the environment during fumigation and ventilation of a log stack.

The Russian Authorities have agreed to provide the Executive study from that study. They conclude in their report that EDN can be used as a fumigant without scrubbing and propose a buffer zone of 15 m.

### *Data summary*

<table>
<tr><th>Document</th><th>Russian fumigation group report</th></tr>
<tr><td>Date</td><td>5$^{th}$ September 2018</td></tr>
<tr><td>Location</td><td>Apcharovsk, Krasodar Krai. Russia</td></tr>
<tr><td>Set up</td><td></td></tr>
<tr><td>Type of logs</td><td>Oak and pine (species not known)</td></tr>
<tr><td>Log size</td><td>No data</td></tr>
<tr><td>Replication</td><td>1 stack 1 application</td></tr>
<tr><td>Stack cover</td><td>The stack covered in plastic tarpaulin and logs stacked on concrete. A sand snake was used to secure the tarpaulin.</td></tr>
<tr><td>Stack volume</td><td>No data</td></tr>
<tr><td>Stack dimensions</td><td>No data</td></tr>
<tr><td>Load factor</td><td>No data</td></tr>
<tr><td>Fumigation</td><td></td></tr>
<tr><td>Dose rate</td><td>50$gm/m^3$</td></tr>
<tr><td>total EDN used</td><td>2.5 kg</td></tr>
<tr><td>Length of fumigation</td><td>8 hours</td></tr>
<tr><td>Measurement device in stack - fumigation</td><td>Rikken FI-8000 instrument</td></tr>
<tr><td>Maximum start concentration</td><td>50$gm/m^3$</td></tr>
<tr><td>End concentration</td><td>8 $gm/ m^3$</td></tr>
<tr><td>Temperature $^0$C - under tarp</td><td>not provided</td></tr>
<tr><td>Temperature $^0$C – Ambient air</td><td>Measured – data not supplied</td></tr>
<tr><td>Measurements</td><td></td></tr>
<tr><td>Measure device outside stack - fumigation</td><td>MSA Ultima XA safety detector</td></tr>
<tr><td>EDN in environment during fumigation</td><td>0 ppm at 5, 15, 100 and 200 m</td></tr>
<tr><td>Measure device outside stack - ventilation</td><td><table>
<tr><td></td><td>0 to 15 min</td><td>30 minutes</td><td>1 hour</td></tr>
<tr><td>3 metres from stack</td><td>> 10 ppm</td><td>4 ppm</td><td>0 ppm</td></tr>
<tr><td colspan="4">At 5, 15 , 100 and 200 m 0 ppm</td></tr>
</table></td></tr>
</table>

[6] Located in the North Caucasus region in Southern Russia

**Korean studies:**

***Context***

Lee et al in 2016 published a paper in Pest Management Science Journal and supporting presentation on work undertaken in South Korea primarily to measure the efficacy of EDN for the control of *Bursaphelenchus xylophilus* Pine wood nematode, and its vector *Monochamus alternatus* Japanese pine sawyer, a long horn beetle. Environmental levels of EDN were also measured.

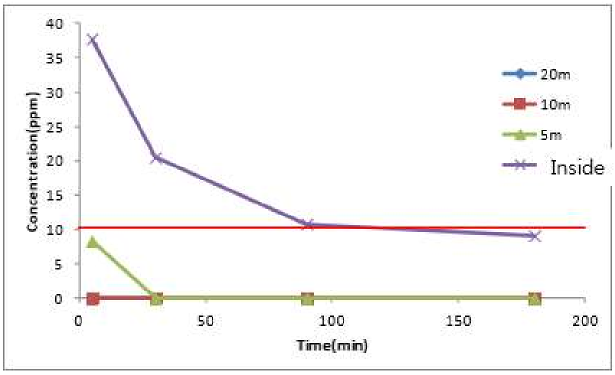
The paper describes the treatment of three different sized stacks at different treatment rates over several months. Environmental data was reported in the paper for the first and last of these three treatments. Graphs are provided in the presentation summarizing environmental data for all three treatments. All treatments were efficacious against the target pests.

Note:

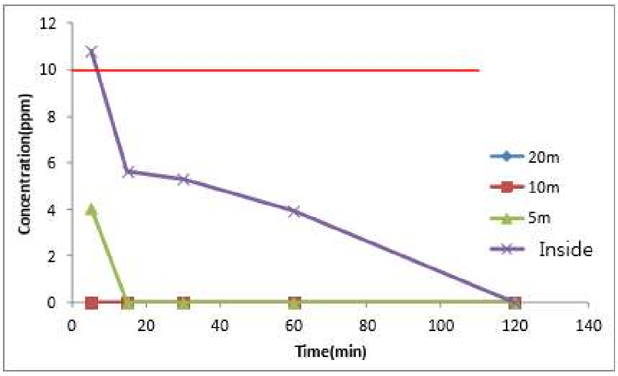
- There are some small inconsistencies between the figures quoted in the presentation and the paper.
- Ventilation was undertaken by first lifting the edge of the tarpaulin and removing the tarpaulin completely after a period of time.

**Data summary**

| Document | Lee paper: Study 1 |
|---|---|
| Date | 23-24 / 9/2014 |
| Location | Gunsan Port, Jeonbuk Province |
| Set up | |
| Type of logs | *Pinus radiata* |
| Log size | No data |
| Replication | 1 stack 1 application |
| Stack cover | PVC tarpaulin |
| Stack volume | 107m$^3$ |
| Stack dimensions | No data |
| Load factor | 46% |
| Fumigation | |
| Dose rate | 100gm/m$^3$ |
| total EDN used | No data |
| Length of fumigation | 24 hours |
| Measurement device in stack - fumigation | Did not |
| Maximum start concentration | No data available |
| End concentration | 60 ppm |
| CT | 398 g h / m$^3$ |
| Temperature $^0$C - under tarp | 21 to 33 $^0$C |
| Temperature $^0$C – Ambient air | 21 to 33 $^0$C |
| wind speed | 3 to 5 m/s |
| Measurements | |
| Measure device outside stack - fumigation | GC and tedlar bags |
| EDN in environment during fumigation | <0.05 ppm at 5, 10 and 20 m from 0 to 18 hours |
| Measure device outside stack - ventilation | GC and tedlar bags |
| Environmental EDN – ventilation | Measurements given for 5, 10 and 20 m see below |

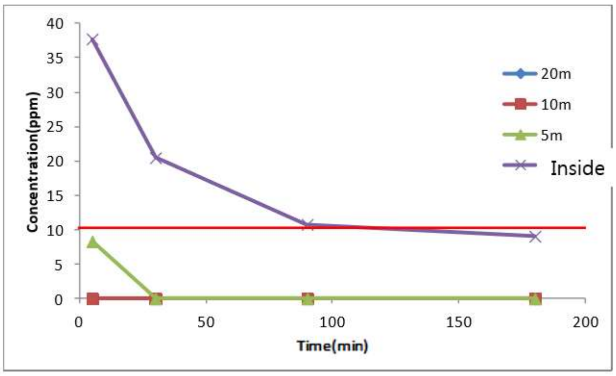



**Side open ventilation**
**(under TLV: 2hr after vent)**

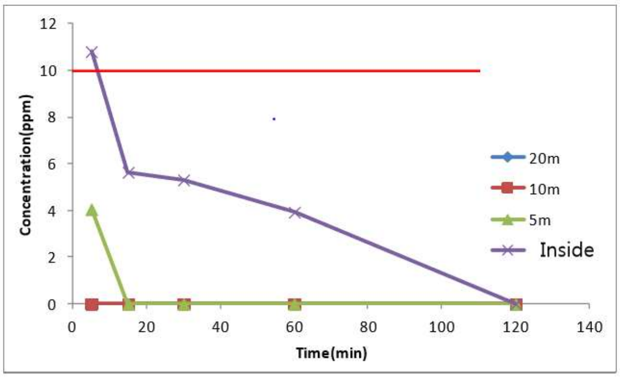



**Full open ventilation**
**(under TLV: 1hr after vent)**

| | |
|---|---|
| Document | Lee paper: Study 2 |
| Date | 17 – 18/11/2014 |
| Location | Gunsan Port, Jeonbuk Province |
| Set up | |
| Type of logs | *Pinus radiata* |
| Log size | No data |
| Replication | 1 stack 1 application |
| Stack cover | PVC tarpaulin |
| Stack volume | 50 $m^3$ |
| Stack dimensions | not given |
| Load factor | 46 % |
| Dose rate | 120 $gm/m^3$ |
| total EDN used | not given |
| Length of fumigation | 24 hours |
| Measurement device in stack - fumigation | Agilent GC Shimadzu GC-17A with samples collected in a Tedlar bag |
| Maximum start concentration | not given |
| End concentration | 38 ppm |
| CT | 547.22 g h / $m^3$ |
| Temperature Celsius - under tarp | 6 to 12 $^0C$ |
| Temperature Celsius – Ambient air | 6 to 12 $^0C$ |
| Measurement | |
| Measure device outside stack -fumigation | |
| EDN in environment during fumigation | |
| Measure device outside stack - ventilation | GC and tedlar bags |
| Environmental EDN – ventilation | Measurements given for 5, 10 and 20 m see below |

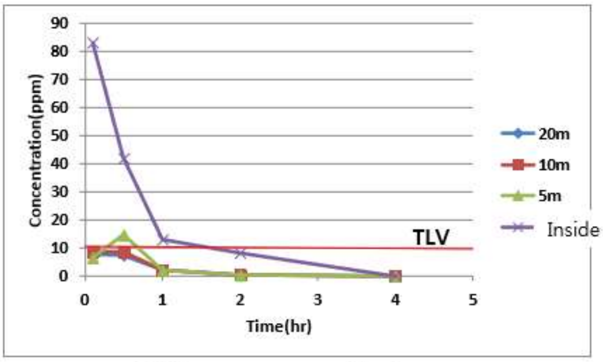



**Side open ventilation (under TLV: 2hr after vent)**

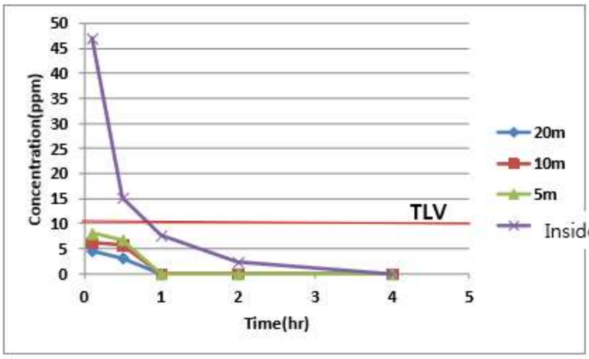



**Full open ventilation (under TLV: 1hr after vent)**

| Document | Lee paper: Study 3 |
|---|---|
| Date | 20-21/1/2015 |
| Location | Gunsan Port, Jeonbuk Province |
| Set up | |
| Type of logs | *Pinus radiata* |
| Log size | 2m length |
| Replication | 1 stack 1 application |
| Stack cover | PVC tarpaulin |
| Stack volume | 108m$^3$ |
| Stack dimensions | No data |
| Load factor | 30 % |
| Dose rate | 150 gm/m$^3$ |
| total EDN used | No data |
| Length of fumigation | 24 hours |
| Measurement device in stack - fumigation | Agilent GC Shimadzu GC-17A with samples collected in a Tedlar bag |
| Maximum start concentration | No data available |
| End concentration | 82 ppm |
| CT | 595.95 g h / m$^3$ |
| Temperature Celsius - under tarp | -1 to 3 $^0$C |
| Temperature Celsius - Ambient air | -1 to 3 $^0$C |
| Measurements | |
| Measure device outside stack -fumigation | GC and tedlar bags |
| EDN in environment during fumigation | <0.05 ppm at 5, 10 and 20 m from 0 to 18 hours |
| Measure device outside stack - ventilation | GC and tedlar bags |
| Environmental EDN – ventilation | Measurements given for 5, 10 and 20 m see below |




**Side open ventilation (under TLV: 2hr after vent)**




**Full open ventilation (under TLV: 1hr after vent)**