FORMALDEHYDE EMISSION FROM SOLID WOOD – WILL IT BECOME AN ISSUE ?

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SUMMARY

The formaldehyde emission from wood of seven tree species was compared with *Pinus radiata* (radiata). It was found that there was little difference between wood from radiata trees grown in different areas of New Zealand nor was there much difference between trees within an area.

Air-dried and oven dried radiata released similar levels of formaldehyde to wood from seven other tree species tested. Emissions after air-drying from all species tested were less than a third of the Japanese low emission limit for wood products. Sixteen days after high temperature drying the emissions were close to the Japanese low emission limit. However after 30 days the emission had reduced to about one third of the Japanese low formaldehyde limit.

Formaldehyde emission from solid radiata wood products will not prevent green labeling of products made from the wood nor will there be problems with sale into the low emission markets like Japan.

INTRODUCTION

There is an increasing public focus on the health and safety implications of both natural and man-made materials in workplaces and homes. In particular there is an increasing awareness of possible short and long term health effects of various substances in the air we breathe. The effect of these substances on sensitive individuals is often referred to by the emotive description "toxic (or sick) house syndrome". Formaldehyde is often implicated in this syndrome and therefore the World Health Organisation (WHO) has made recommendations on the maximum levels of formaldehyde permitted in indoor air. Based on these values and driven by public concern, the emission of formaldehyde and other volatile components from products used within buildings is being increasingly regulated by some government bodies. Additionally, in some countries like Japan there are now premiums paid for very low emission furniture components and building materials.

There have been recent reports from the marketplace that the emissions of formaldehyde from some wood and furniture made from wood may exceed the tight specifications already set or about to be introduced in countries like Japan. Unconfirmed rumours suggest that this could be a concern for New Zealand exporters. This study reports the levels of formaldehyde released from air- and oven-dried radiata. Prior to the studies presented in this report there was no information available on the level of formaldehyde emitted from New Zealand grown wood.

Additionally, these studies have helped to develop an understanding of the effects of drying and time after drying on emission values.

METHODS

Experiment 1: Develop Test Method.

A method based on EN717-3 was developed for the following studies. The new method used small samples of wood, 30 × 30 mm and the testing was conducted for 24 hours at 20 °C rather than 3 hours at 40 °C as specified by EN717-3. Figure 1 shows the apparatus used to perform the test. Emission testing was conducted at room temperature because the effect of pre-treatment temperature was to be examined in subsequent trials and measurement at 40 °C according to EN717-3 may have influenced the interpretation of the results.

The new method was correlated against the Japanese Agricultural Standard - JAS 235 2003: Structural Glued Laminated Timber. Using this regression equation shown in Figure 2, all the results were converted to values which correspond to the Japanese standard methods. According to JAS 235, the result of the analysis in mg/L are divided by 3.75 to provide results which are then catagorised according the F-star rating. The low emission limit in the F-star system is a value of 0.3mg/L/3.75 and is catagorised as F****.

Figure 1: Testing flask and cube of wood used as the test-piece

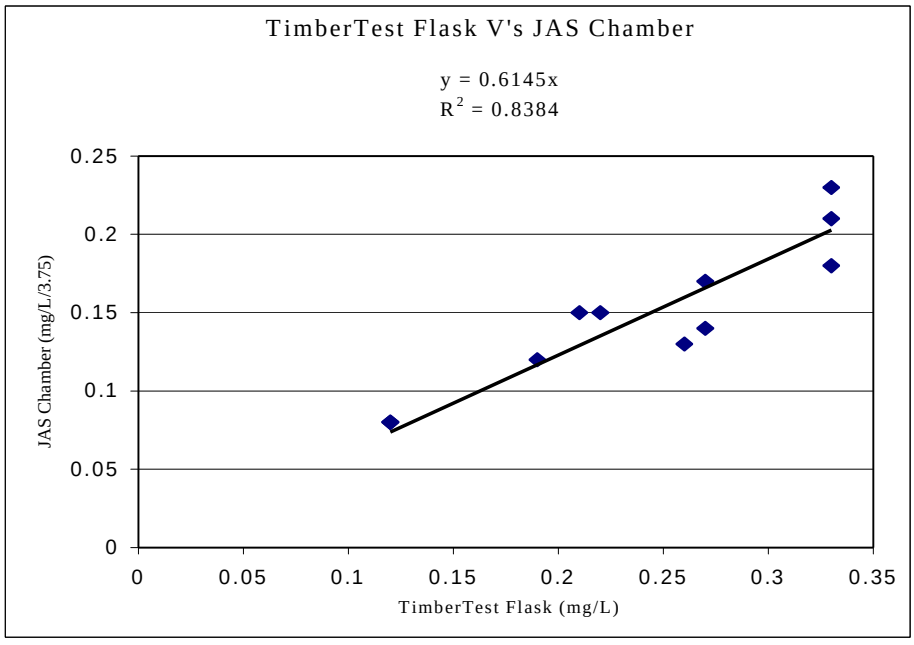

Figure 2: Regression TimberTest flask method against Japanese chamber method

Experiment 2: Differences between sites and within and between trees.

Background

There is some data available for formaldehyde emission from wood species (Meyer and Boehme 1997), however there is no data published for New Zealand grown radiata. This project examined formaldehyde emission from radiata from a range of sites, for a number of trees within each site, and from a number of sampling positions within each tree.

Method

Four sites around New Zealand were sampled (Figure 3), these sites included high wood density regions in the North Island and one low wood density region in the South Island. At each site either five or ten trees were sampled at each of four sample positions - sapwood and heartwood at both 1.4 metres and 15 metres .

The emission testing was conducted 20 days after laboratory oven drying at 103 ºC for 24 hours. The amount of formaldehyde formation is related to the drying conditions (Roffael 2002) and therefore while this study examines the relative differences within and between trees, the absolute values will vary with drying temperature.

Figure 3: Map of New Zealand showing sample plots

Results and Discussion

Samples obtained from one site (Athenree) showed lower formaldehyde emissions than the other sites, however all the results were very low and the absolute difference small so it was not possible to draw conclusions on the significance of the differences All results were less than half the Japanese low emission (F****) value of 0.3mg/L/3.75. There was little difference in formaldehyde emissions between either sapwood or heartwood or between the two sample heights.

Table 1: Average values (and standard deviations in brackets) for each site

Site	Number of Trees Tested	1.4 Meter Sap (mg/L/3.75)	1.4 Meter Heart (mg/L/3.75)	15 Meter Sap (mg/L/3.75)	15 Meter Heart (mg/L/3.75)
Athenree	10	0.06 (0.024)	0.04 (0.013)	0.08 (0.027)	0.06 (0.022)
Ruatoria	10	0.11 (0.036)	0.11 (0.043)	0.13 (0.030)	0.12 (0.034)
Aupouri	10	0.13 (0.007)	0.11 (0.017)	0.14 (0.015)	0.13 (0.013)
Southland	5	0.14 (0.013)	0.17 (0.051)	0.14 (0.013)	0.14 (0.014)

Experiment 3: Effect of Drying Temperature.

Background

The effect of drying temperature on formaldehyde emission from radiata was examined.

In studies by the WKI in Germany (Meyer and Boehme 1997) very low emissions were measured from a range of solid wood species. However this work was on air dried samples and did not examine the effect of elevated heat on the wood, much of the wood used in New Zealand has been dried at high temperature.

Roffael reported that press temperature during particleboard production effected the emission of formaldehyde from the presses (Roffael 1993). Roffael theorised that thermolysis of wood led to formaldehyde formation from lignin and polysaccarides. However this work was concerned with emission from the press section of a particleboard plant where formaldehyde was also present in the glues and did not report results for wood alone and therefore the result may not relate to solid wood samples. Roffael has also carried out some fundamental work examining the formation of formaldehyde from various wood components when they are heated (Roffael 2002). He found wood contains a number of molecules, which under heating break down to produce formaldehyde. It was also found that these emissions increased with temperature from 40 ºC to 150 ºC. Roffael also measured emission from pulp and particles of pine and spruce as they were heated for three hours at temperatures or 40 ºC, 100 ºC and 150 ºC. He found that emission increased substantially from 40 ºC to 150 ºC. Interestingly, he also found that some wood extractives act as formaldehyde scavengers.

While these previous studies indicate that heating wood within certain temperature ranges increases formaldehyde emission, they did not measure formaldehyde emission after the wood returned to ambient temperatures. Also these studies examined wood particles, not whole-wood, the material was not radiata pine and the methods used in the studies did not produce values which can be directly compared with the new Japanese limits.

Method

Samples were taken from one stem of 18 year old radiata. Wood disks were taken from two positions within the tree: 1.5 metres and 15 metres and at each level the disks were sub-sampled to separate the material into heartwood and sapwood. Two trials were carried out, in the first trial sapwood samples taken from 1.5 metres were heated at 60 ºC to 190 ºC for 24

hours in a laboratory oven. In the second trial, samples from the four sample positions were dried for 48 hours at 60 ºC decreasing to 8 hours at 160 ºC. Control samples were retained at 20 ºC. After drying the samples were retained in conditions of 20 ºC and 65%RH for 20 days and then tested in duplicate.

Results and Discussion

Values of 0.26 were measured on some samples - this is close to the Japanese F**** limit of 0.3.

It was also found that the elevated drying temperatures increased formaldehyde emission by up to 500%. The sample position within the tree influenced emissions at higher drying temperatures, the 15 metre sapwood samples giving the highest results.

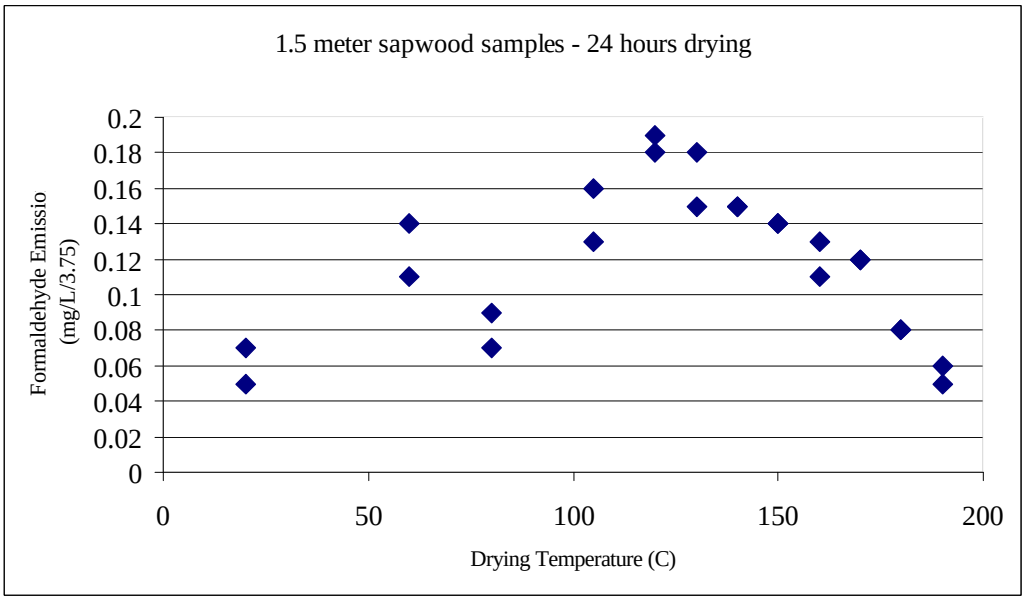

Figure 4: Emission after drying – all samples dried for 24 hours

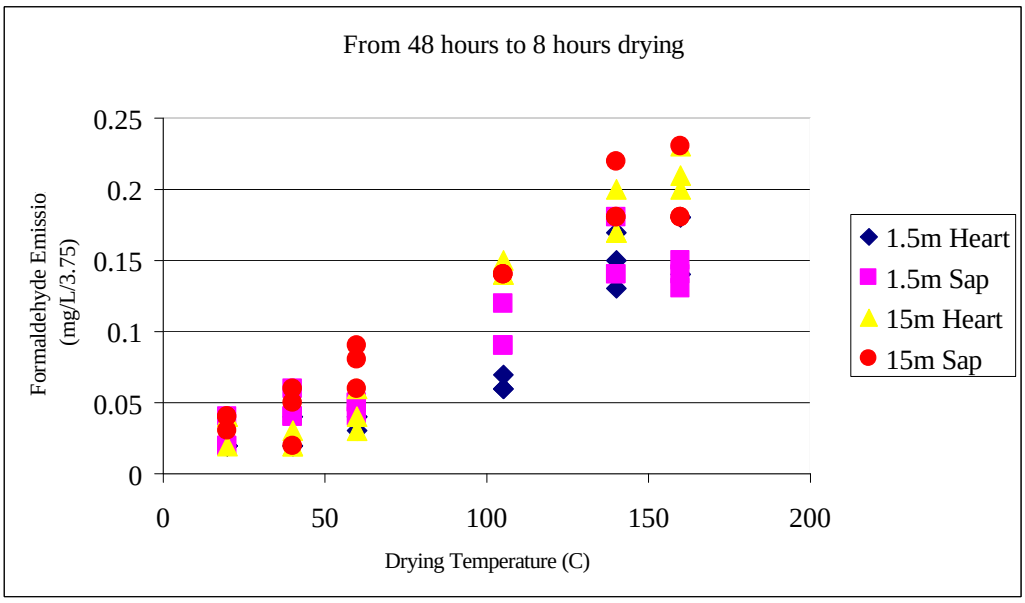

Figure 5: Emission after drying – decreasing time of drying

Experiment 4: Reduction in formaldehyde with time after drying.

Background

This study was conducted to examine the reduction over time after heat drying wood. This was considered an important relationship to enable interpretation of the emission test results obtained from solid wood and engineered wood products.

Method

Samples from three different trees *Pinus radiata* (radiata), *Pseudotsuga menziesii* (Douglas Fir) *Picea abies* (Spruce) were heated to 60 ºC and 140 ºC for 24 hours in a laboratory oven. Control samples were retained at 20 ºC. After drying, the samples were retained in conditions of 20 ºC and 65%RH and tested in triplicate, at intervals from 16 to 51 days. The mean values of each triplicate are presented in the following graphs (Figures 6,7,8). Background formaldehyde levels were measured in the conditioning room and quality control samples of MDF were measured in parallel with the wood samples (Figure 9).

Results and Discussion

Sixteen days after drying at 140 ºC, the emission from all three types of wood was close to or exceeding the Japanese low emission limit. The samples heated to 60 ºC were slightly higher than those of the controls samples kept at 20 ºC. The 20 ºC controls for all three types of wood gave emissions of about one third the Japanese F****. However, after one month, formaldehyde emissions from the heat dried samples had fallen and were producing results only about 10% higher than the 20 ºC control samples.

All the samples increased in emission at day 45. This increase is thought to be due to higher levels of background formaldehyde in the conditioning environment over that period (Figure 9). Interestingly, the solid wood samples appear to be effected to a greater degree than the MDF quality control samples. This has implications for future testing of solid wood samples and for engineered wood products such as laminated veneer lumber and glued lumber. It may be necessary to have very low formaldehyde environments for conditioning of samples prior to testing. This type of conditioning environment is not available in most production laboratories.

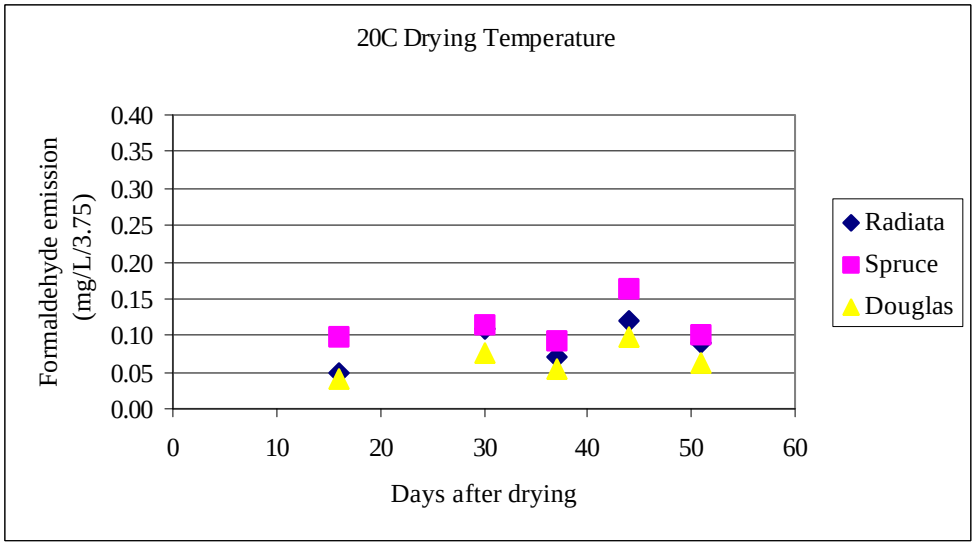

Figure 6: Emission from sample retained at 20^{o}C

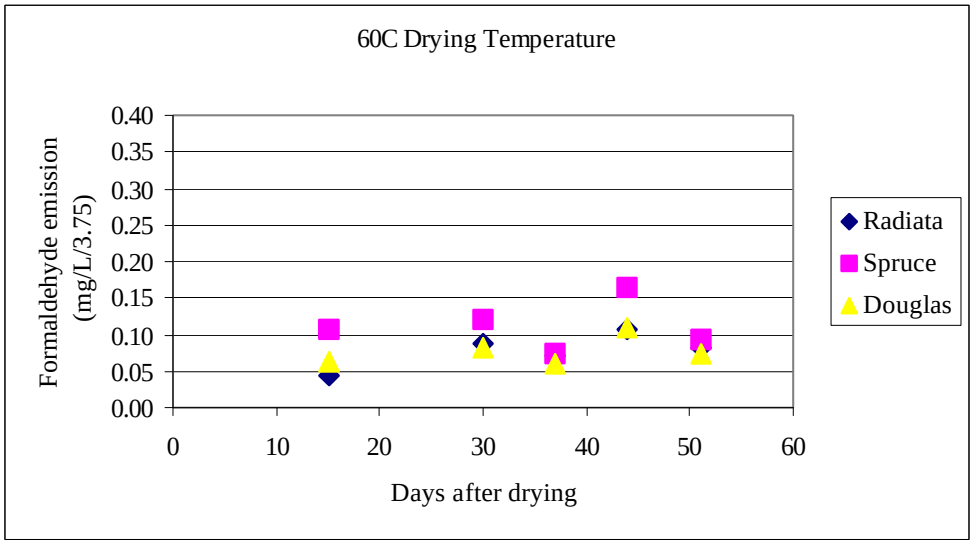

Figure 7: Emission from sample dried at 60°C

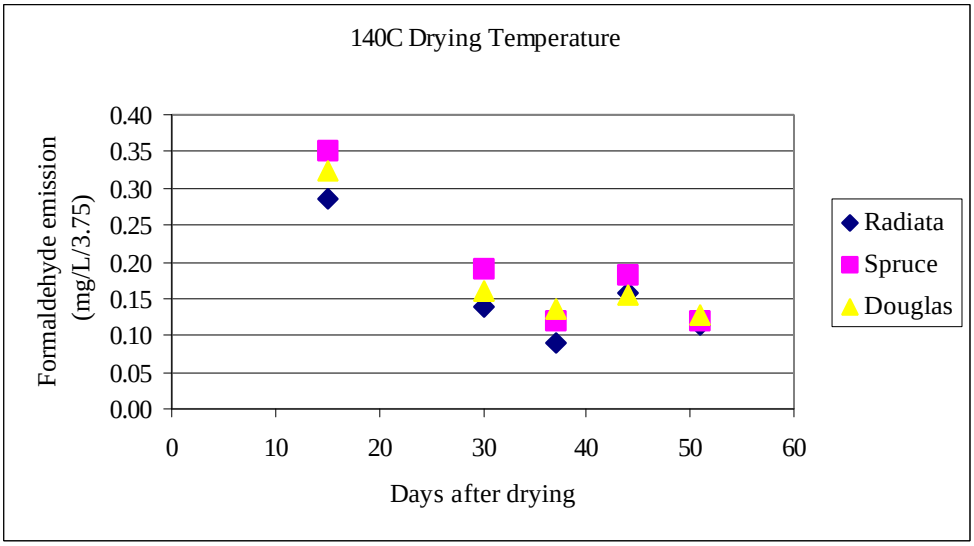

Figure 8: Emission from sample dried at 140 °C

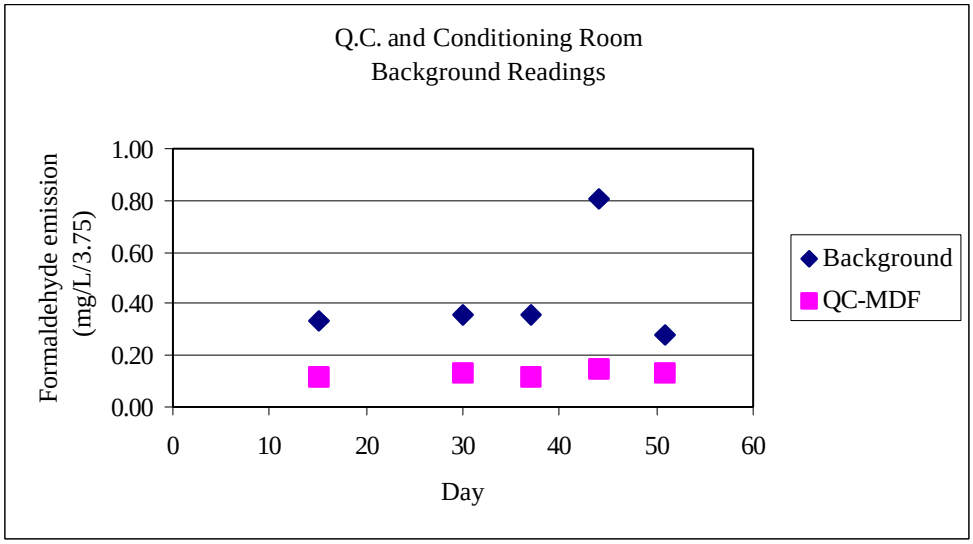

Figure 9: Quality control and background formaldehyde in the conditioning room

Experiment 5: Emissions From Wood of Different Tree Species.

Background

The New Zealand Forest Research Laboratories have conducted a number of studies examining emissions during kiln drying of radiata (Sargent, Dare and Hague, 2004). These studies indicated significant formaldehyde emissions during kiln drying, however this work did not examine different species or the emission from the wood after drying.

Method

The emission from the wood of eight different tree species treated at three temperatures was tested. All the wood except for the spruce was fresh material. The emission testing was conducted 16 days after heat treatment (not 20 days as in the previous trials). The testing was carried out in triplicate.

Table 2: Species, age and sample position within the tree.

Species	**Age (Years)**	**Sample Position**	**Condition**
Pinus radiata (Radiata)	26	2.6 meters	Green disk
Larix europaea (Larch)	98	3.8 meters	Green disk
Pseudotsuga menziesii (Douglas Fir)	46	4.8 meters	Green disk
Eucalyptus ovata (Swamp-gum)	99	2.0 meters	Green disk
Sequoiadendron giganteum (Redwood)	30	7.4 meters	Green disk
Castanea sativa (Chestnut)	90	6.0 meters	Green disk
Cupressus macrocarpa (Macrocarpa)	?	?	Green Lumber
Picea abies (Spruce)	?	?	Dry Lumber

Results and Discussion

The emission measured from radiata after treatment at 140 ºC was higher than in previous trials and the result of 0.29 is close to the F**** limit of 0.30. This difference is due to the shorter period from heat treatment to testing (16 compared to 20 days). Formaldehyde emission from radiata pine was found to be similar to the seven other wood types dried under identical conditions.

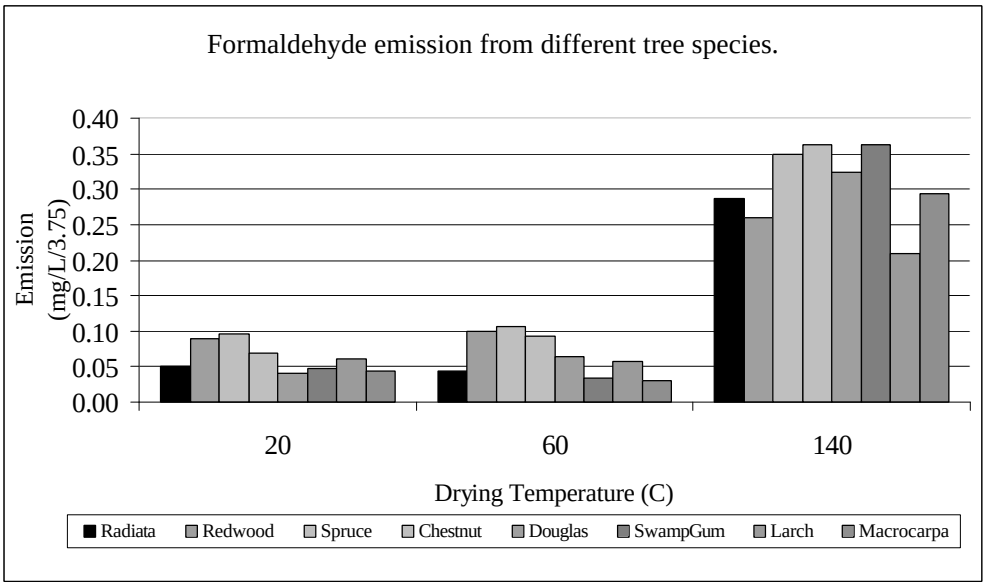

Figure 10: Formaldehyde emission from different tree species.

CONCLUSIONS

There were only small differences between radiata wood grown in different areas of New Zealand and there was little or no difference between trees within an area.

Air dried radiata pine wood gave similar formaldehyde emission to wood from seven other tree species and results after air-drying for all samples were less than a third of the Japanese low emission (F****) limit.

After high temperature treatment at 140 ºC, the formaldehyde emission from all wood species tested was again similar. Sixteen days after high temperature drying the emissions were close to the F**** limit, but within one month of drying the levels had reduced to about one third of this limit.

Formaldehyde emission from solid radiata pine should not prevent application of green labeling or sale into the low emission markets like Japan.

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