In-Home Testing of Particulate Emissions from NES-Authorised Woodburners: Compressed Wood Products versus Firewood

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A preliminary assessment of particulate emissions from National Emission Standard (NES)-authorised woodburners burning compressed wood products (firelogs) and operated under real-life operating conditions was carried out by Landcare Research, Lincoln, for the Foundation for Research, Science and Technology (contract CO1X0405 – Protecting New Zealand's Clean Air) over August 2007 to September 2008.

Objective

- Determine if further testing of particulate emissions from NES-authorised woodburners using compressed wood products is warranted to validate emissions reduction potential and determine an emission factor.

Methods

- Emissions from NES-authorised woodburners in two houses (TAU2 and TAU6) were monitored using an in-home sampling apparatus. Sampling was undertaken for up to 7 days when householders were using wood, and subsequently for a further 7 days when the householders used a compressed-wood product, 'Solid Energy Hotlogs'.

Results

- The results for the two houses were compared separately as, due to sampler malfunction, all but one of the sample runs from house TAU6 had a run time less than 80 min.
- The emissions from house TAU2, where no sampling issues occurred, were 1.35 g/kg (dry wt) and 1.23 g/kg (wet wt), representing a 56% and 47% reduction in emissions compared to that from wood. Emissions rates from this house were also lower when Hotlogs were burned (1.74 g/h Hotlogs vs 4.6 g/h wood; 62% reduction).
- The emissions from house TAU6 for Hotlog combustion for runs with run times less than 80 min were 6.9 g/kg (dry weight). This compares with emissions of 33.2 g/kg (dry weight) for wood combustion for runs of a similar duration from other houses involved in a larger testing programme, and represents a 79% reduction in emissions.

Conclusions and recommendations

- The use of alternative fuels such as Hotlogs may assist regional councils to meet the NES requirement of 50 $\mu g/m^3$ (24-h average). Based on an initial sample of two houses, further emission testing to determine an emission factor for compressed wood products in NES-compliant woodburners is warranted.

1. Introduction

A preliminary assessment of particulate emissions from NES-authorised woodburners burning compressed wood products (firelogs[1]) and operated under real-life operating conditions was carried out by Landcare Research, Lincoln, for the Foundation for Research, Science and Technology (contract CO1X0405 – Protecting New Zealand's Clean Air) in August 2007 to September 2008.

2. Background

In New Zealand, the National Environmental Standard (NES) for ambient concentrations of particulate matter less than 10 microns in diameter (PM_{10}) is 50 µg/m^3 when averaged over 24 h. This standard is regularly exceeded in many of New Zealand's urban areas during the winter months (Aberkane & Wilton 2002), with woodburners the primary contributors to high particulate concentrations (Scott & Gunatilaka 2004; Wilton 2005; Smith & Wilton 2007).

The NES contains a design standard for new woodburner installations in urban areas. From September 2005, all woodburners installed on properties less than 2 ha in size have been required to have a thermal efficiency greater than 65% and emission rate less than 1.5 g/kg, when tested to AS/NZS4012 and AS/NZS4013 respectively. Further, by September 2013 only one exceedance of the PM_{10} standard per year is allowable. Replacement of older woodburners with NES-authorised woodburners is anticipated to lower emissions, although additional emission-reduction strategies are required in many areas to meet the NES.

There are various compressed wood products currently available in New Zealand including 'Solid Energy Hotlogs', 'Duncan Wattie Firelogs', 'Beehive Firelogs', 'Solid Energy Ecobricks', 'Green Lucifer Logs', and 'Lighthouse' compressed-wood logs. These products are made from woodwaste, typically sawdust, under high temperature and pressure to activate the natural resins of the wood, which binds the sawdust together. Such products have been promoted as alternative energy sources to electricity for space heating (Blakely 2006; Mellhuish 2005a,b, 2006; Green Party 2007) and meet government objectives for renewable energy use and waste minimisation. However, there is limited information on emissions from compressed wood products to indicate the potential impact (positive or negative) on air quality as a result of wider usage of these products in New Zealand.

A number of councils have developed management strategies designed to reduce woodburner use. In Christchurch, once a household has converted to non-solid-fuel heating, regulations

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[1] 'Firelog' is both a generic term for manufactured wood log products and a trade name of products available in New Zealand and internationally. In this report 'firelog' is used as a general terms for compressed wood log products while 'Firelog' is used when appropriate to indicate a trade name.

prevent the future use of solid fuel heating. In Nelson woodburners (excluding pellet burners meeting a specified emission criterion) cannot be installed into new homes or into homes that did not have solid fuel heaters before the Nelson Air Plan was notified. The introduction of a low emission fuel may mean that councils could allow a greater proportion of households to retain solid fuel heating while ensuring the NES is met by 2013.

Smokeless fuels, including compressed wood products, were considered as an option for reducing PM_{10} concentrations in Christchurch and Nelson (Foster 1998; Wilton 2002). The two main limitations identified in those reports were that the high costs of smokeless fuels meant that they were not economically viable for householders and that there was a lack of data quantifying the benefits of smokeless fuels compared with other fuels used to heat homes. Since the preparation of those reports several factors have changed that may warrant reconsideration of the viability of smokeless fuels, and in particular, compressed wood products. These factors include an increased emphasis on renewable resources and increased electricity prices. Further, pellet burners, which also use a fuel derived from wood waste and previously had debateable economic viability for householders, are increasingly gaining acceptance as low emission alternatives to traditional solid fuel burners. The increased use of pellet-fired burners means that pellet production has increased to a level that is economically viable for householders.

Compressed wood products have the advantage of being able to be used in existing woodburners. It may be the case that a simple switch in fuel type from wood to firelogs may reduce more emissions than other, more expensive, methods. Similarly, the use of firelogs may be advantageous as a temporary measure for situations where replacement of older woodburners through natural attrition is sufficient to meet the NES but where older burners are unlikely to be replaced by 2013. In this case it may be more economically and environmentally viable to utilise the full life of a burner by using firelogs for the remaining years. Adoption of these measures would require further testing and validation of the effectiveness of firelogs in existing burners.

Laboratory studies have typically indicated that compressed wood products have lower emissions than firewood, although in some cases they may be higher (see below). However, testing is limited and no testing has been undertaken during real-life operation of woodburners, which may often produce higher emissions compared with laboratory testing. Before adopting an expensive testing programme, a preliminary project feasibility investigation was undertaken. Specifically, this report evaluates whether further investigations into emissions reductions associated with the use of compressed wood products is warranted.

3. Literature Review

In the United States firelogs have been reported to have lower particulate and air pollutant emissions than firewood (e.g. Barnett & Bighouse 1992; Bighouse & Houck 1993; Houck et al. 2000, 2008; Houck & Tiegs 2001). There are two types of manufactured firelogs: wax/sawdust logs and compressed wood logs. Wax/sawdust logs are most widely used in the US and are composed of 40–50% of petroleum, or more recently plant wax, and sawdust.

These products have twice the heat content (on a per weight basis) and lower moisture (~2%) content than firewood (Houck & Tiegs 2001; Houck & Eagle 2006).

Because of the difference in weight-based heat content, comparison of emissions from wax/sawdust firelogs with those from firewood is most appropriately undertaken on a grams per hour (g/h) basis (Houck et al. 2000). Wax/sawdust logs have lower emissions than firewood, with an average reduction of 73% for particulate g/h emissions, and a 91% reduction of the US-EPA 16–polycyclic aromatic hydrocarbon (PAHs) g/h emissions observed when burning these products in open fireplaces (Houck et al. 2000). More recently biowax-fibre firelogs were demonstrated to have global warming reduction benefits by having lower CO_2 emissions than cordwood and petroleum based wax-sawdust firelogs (Houck 2007). These products are designed for one at a time use in open fireplaces and the convenience of individually wrapped, easily started widespread usage for the occasional use of fireplaces for aesthetic purposes is suggested to be an important factor for consumers (Houck & Tiegs 2001). As these products are designed for use in open fireplaces, they are not relevant for consideration for emissions reduction in New Zealand.

Compressed wood logs are more commonly used in woodburners, and thus are more relevant for New Zealand. These products are made from woodwaste, typically sawdust, under high temperature and pressure to activate the natural resins of the wood, which binds the sawdust together. As compressed wood products are made up of wood alone, they have the same heat content per kilogram as firewood (on a dry weight basis) and it is valid to compare both emission factors and rates with that from firewood. However, they are considered to be a superior fuel as they contain less moisture (Houck & Tiegs 2001) and in many situations where wood burned is not dry, less compressed wood product (by wet weight) would be required to be burned to achieve the same level of comfort. The calorific value of compressed wood products made from pine is around 19–20 MJ/kg (dry weight basis), which is the same for pine and compares with around 10–16 MJ/kg for wood with moisture content ranging from 12 to 40 % moisture, with lower values for wetter wood (MED 2008).

In the United States studies have shown reductions of between 45 and 95% for particulate g/kg emissions and between 24 and 94% for particulate emissions (g/h) when compressed wood products were burned in older and newer design woodburners under laboratory conditions (Barnett & Bighouse 1992; Bighouse & Houck 1993; Houck & Tiegs 1998). More modest reductions in carbon monoxide and volatile organic compounds were also observed (Barnett & Bighouse 1992). Emission reductions are suggested to be due in part to their higher density, lower moisture, and uniform shape and in part because they are made with clean sawdust or wood shavings without bark or debris (Houck & Tiegs 2001). However, some products showed an increase in emissions when burned in newer design woodburners, which is suggested to be due in part to the optimisation of these stoves for burning firewood cleanly (Bighouse & Houck 1993).

Limited testing of compressed wood products outside the US has been undertaken and Environment Australia (2002) and Whitely (2007a) were the only two studies found. Environment Australia (2002) reported that emissions from a woodburner operated under laboratory conditions using a compressed wood product manufactured from a mix of hardwood and softwood sawdust ranged from 3 to 5.5 g/kg. These emissions were lower than those from pine (*Pinus radiata*) (>7 g/kg), the dominant fuel burned in New Zealand, and the average emissions from eucalypt when a low burn setting was used (average ~7 g/kg), but higher than that from eucalypt when a high burn setting was used (<2.8 g/kg).

The New Zealand Consumer Magazine report by Whitley (2007a) provides the most extensive information available and compares additional factors such as fuel price, running cost, efficiency, and average heat output. While not a peer-reviewed report, it nonetheless provides relevant indicative results particularly as, in contrast to the US studies, Whitley (2007a) found higher emissions from the combustion of four compressed wood products compared with that produced from the combustion of seasoned pine under laboratory conditions (Table 1)[2]. Compressed wood products had lower power output, but longer burn times and higher efficiency than the seasoned radiata.

Table 1 Comparison of various parameters from compressed wood products and seasoned pine (Source: Whitely 2007a).

Fuel	Running cost (c/kWh)	Fuel price (c/kg)	Emissions (g/kg)	Burn time (min)	Average output (kW)	Efficiency
Clear seasoned *Pinus radiata*	6	19	1.3	100	6.8	65
Duncan Wattie Firelogs	15	54	3.3	165	5.2	75
Solid Energy Firelogs	15	55	2.7	164	5.2	73
Solid Energy Ecoheat Bricks	19	65	2.7	115	7.0	70
Lighthouse firelogs	27	105	5.8	167	5.1	71

Optimisation of woodburners to produce the lowest emissions and highest efficiency during burning of a test-fuel (kiln-dried pine in New Zealand) under laboratory conditions is suggested to be one factor that may result in higher emissions when woodburners are operated with different fuel types, including compressed wood products (Bighouse & Houck 1993; ARS 2008b). However, there remains a dearth of information on woodburner emissions from compressed wood products under real-life operating conditions.

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[2] Testing was carried by Applied Research Services (ARS) using the equipment specified in ASNZ-4013, but testing differed from ASNZ-4013 in that once a bed of embers was established using pine the same fuel weight (3.8 kg) for each fuel was added to the firebox, air controls set at medium and then the fuel load allowed to burn out with emissions, heat output and burn time determined. (Bill Whitley, Consumer Organisation, pers. comm.).

4. Objective

- Determine if further testing of particulate emissions from NES-authorised woodburners using compressed wood products is warranted to validate emissions reduction potential and determine an emission factor.

5. Methods

Sampling was undertaken as part of a larger programme to test the emissions from NES-authorised woodburners under real-life operation. Details of this testing programme and sampling apparatus are provided in Smith et al. (2008). Briefly, 18 households with NES-authorised burners from Rotorua, Taumaranui and Nelson were selected for testing. Two samplers were operated contemporaneously at separate households and monitoring was conducted daily for at least 7 d. The 7-d monitoring period was required to give a reasonable amount of data per burner to account for daily variations in operation and, consequently, emissions. Testing was carried out using firewood belonging to the homeowners and burners were operated by the householders as they would in real life, on each day of the testing period.

Emissions were monitored using an in-home testing system developed by Applied Research Services (ARS) that comprises a particulate sampling head that attaches to the flue of the woodburner, and a gas analyser (ARS 2008a). The flue gas is drawn into two probes inserted into the flue. For particulate sampling the flue gas is drawn into a manifold along with ambient air, and following mixing, the diluted gases are drawn through two 47-mm glass fibre filters (Gelman Type A/E Cat No. 61631) that collect the particulate emissions. This dilution simulates the dilution and cooling that occurs when woodburner emissions exit chimney flues. The dilution gas is passed through a desiccant prior to a gas anlayser to determine CO_2 concentrations. Filters were changed daily. Flue gas for gas analyses (CO_2 and O_2) are scrubbed and filtered prior to being passed through an electrochemical oxygen analyser.

The flue gas composition is used to calculate the total volume of gas that has passed up the flue per kilogram of fuel burned. The total emissions are then calculated using the dilution ratio and the particulate mass on the filter, and provided as an emission factor (g/kg dry weight of wood burned) and as an emission rate (g/h). The emission factor is independent of any information provided by the householder. In addition, a wet weight emissions factor was determined using the moisture content from an on-site moisture meter (wood) or laboratory determination of moisture content (Hotlogs). The wet weight emission factors are provided for comparison with those determined in Smith et al. (2008).

The emission rate is calculated from the burn rate (kg dry wt/h), which in turn is calculated from householder records of the weight of fuel burned, the moisture content of the wood determined using an on-site moisture meter, and the sampler run time. The accuracy of the emissions rate is thus dependent on the accuracy of the householder records and wood moisture measurements.

Subsequent to the conduct of the in-home emissions testing programme, two houses from Taumaranui voluntarily undertook additional testing and were provided with Solid Energy Hotlogs, and emissions monitored for up to 7 d. The woodburner, type of wood burned, wood and Hotlog moisture content for each household is shown in Table 2. Sampling was conducted from 20 to 26 August 2007 for wood combustion and from 27 August to 4 September 2007 for Hotlog combustion, using the same emissions testing method as described above.

Table 2 Summary of woodburner type, wood typically burned, and moisture content for the households used in the current study.

Household[1]	Woodburner	Wood type	Wood moisture content (%)[2]	Hotlog moisture content(%)[3]
TAU2	Woodsman Matai ECR Mark 2	Redwood, pine, kanuka	26.3 (9.2)	8.9
TAU6	Metro Eco Series Wee Rad	Blue gum, kaikatio	27.7 (6.4)	8.9

[1] Household identifications are those used in Smith et al. (2008)

[2] On-site moisture meter, mean (s.d.)

[3] Laboratory determination

In addition, the temperature of the room in which the woodburner was located was monitored continuously over the sampling period. The daily external maximum and minimum temperatures in Taumaranui over this period were obtained from the NIWA Climate Database (http://cliflo.niwa.co.nz/) for weather station 2250.

6. Results

A summary of the results are shown in Table 3, with the raw data shown in Appendix 1. For household TAU2, burning Hotlogs resulted in significantly lower emission factors ($P < 0.05$, one-sided t-test, $t = 2.7$) and lower emissions rates compared with burning wood, representing a 56% and 47% reduction in the dry and wet weight emissions respectively and a reduction of 65% in emission rate.

For household TAU6 Hotlog emissions were compared with woodburner emissions for run times less than 80 min (from all houses tested in the Smith et al. (2008) study) because all but one sample run for the Hotlogs was for a period of less than 80 min. The results showed that emissions during Hotlog combustion (6.9 mg/kg dry wt) were markedly lower than the emissions from wood combustion for runs of a similar duration (33.2 mg/kg dry wt) (Table 3, Fig. 1) and represent a 79% reduction in emissions. For the one run that was longer than 80 min, emissions were also markedly lower than emissions from wood combustion (Table 3). However, even for this run, sampling issues were experienced and the sampler stopped and was restarted during the sample run; thus emissions measurements may not be representative.

Table 3 Emissions from the two households during wood combustion and combustion of Hotlogs

Household	**Wood**				**Hotlogs**			
	Emissions		Emission rate	Run time	Emissions		Emission rate	Run time
	Dry weight (g/kg)	Wet weight (g/kg)	(g/hr)	(min)	Dry weight (g/kg)	Wet weight (g/kg)	(g/hr)	Min
TAU2	1.5	1.14	2.60	414	1.39	1.27	2.03	571
TAU2	4.4	3.28	9.26	709	0.92	0.83	1.0	844
TAU2	2.7	1.99	4.87	845	1.73	1.58	1.34	1261
TAU2	3.8	2.84	3.46	1434	1.65	1.51	3.14	614
TAU2					1.04	0.94	1.32	528
Mean (SD)	**3.1 (1.3)**	**2.3 (0.9)**	**5.0 (3.0)**	**850**	**1.35* (0.36)**	**1.23* (0.33)**	**1.77 (0.85)**	**763**
TAU6	6.4	4.66	26.96	321	5.4	4.91	23.19	79
TAU6	5.8	4.20	18.36	93	6.3	5.72	44.11	42
TAU6	3.3	2.38	5.94	635	8.9	8.13	56.50	38
TAU6					7.8	7.13	43.60	53
TAU6					1.9[1]	1.72	4.87	456
TAU6					7.0	6.34	37.85	71
TAU6					6.0	5.49	26.21	66
Mean (SD)	**4.0 (1.7)**	**2.9 (1.2)**	**11.9 (10.6)**	**475**	**6.2 (2.2)**	**5.6 (3.2)**	**33.8 (24.9)**	**115**
Run time <80 min	**33.2 (8.3)[2]**	**NA**	**NA**	**56**	**6.9 (1.3)**	**6.3 (1.18)**	**38.6 (28.4)**	**58**
Run time <100 min	**25.5 (13.2)[3]**	**NA**	**NA**	**71**	**6.9 (1.3)**	**6.3 (1.18)**	**NA**	**58**

*Significantly different from emissions during wood combustion (*P* < 0.05, one-sided t-test, t_3=2.7, t_3=2.4 respectively)

[1] Sampler stopped was restarted during the run, and thus emissions measurements may not be accurate.

[2] From all households involved in the in-home testing programme (Smith et al. 2008), *n* = 3.

[3] From all households involved in the in-home testing programme (Smith et al. 2008), *n* = 5.

NA-data not available

The short run time is a result of sampler malfunction shortly after the fire was started. Specifically, the householder noted that the filter status was shown as ‘clogged’ on the sampling apparatus. However, the particulate mass on these filters was much lower than that from other houses involved in the wider testing programme (1–5 mg compared with 30–50 mg, and even up to 90 mg) so it is unclear as to why the sampler stopped. A disproportional amount of particulate emissions occurs during start-up and before efficient combustion is underway (Hueglin et al. 1997), thus ‘short’ runs that predominantly capture fire start-up are likely to have higher emissions. This is also demonstrated in Wilton et al. (2006) where particulate emissions from real-life testing of older woodburners in New Zealand were higher when the quantity of wood burned was less (indicating a shorter duration of sampling). The markedly lower emissions from the ‘short’ runs during the Hotlog combustion compared with that from wood combustion indicates that hotlogs may perform better during start-up than wood. Further, emissions generally reduce as the run time increases (Fig. 1) and after about 80 min it appears that emissions drop significantly. The subsequent difference in emissions at the longer run times may be more attributable to differences in the woodburner type, wood used, or other operational variables.

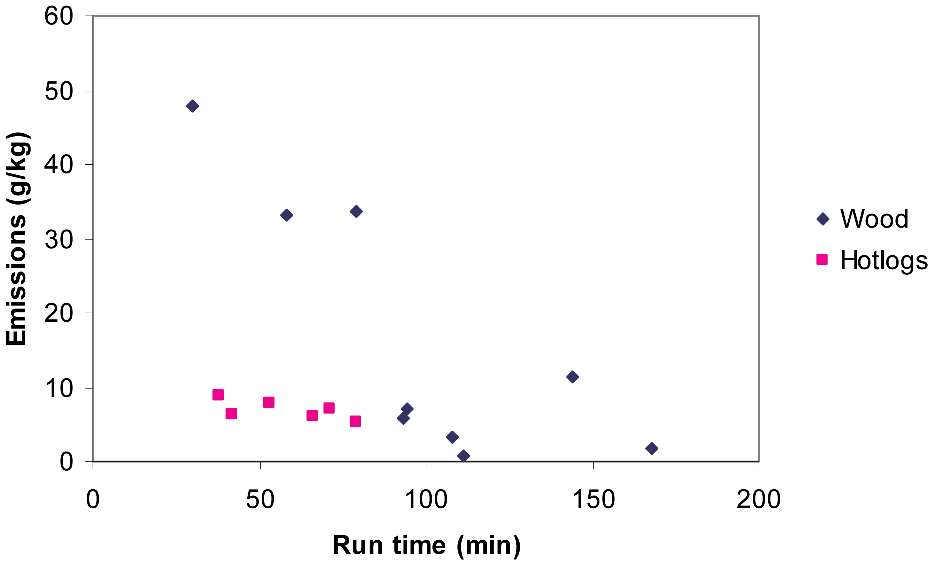

Fig. 1 Emissions (g/kg) from various woodburners using wood and from one woodburner using Hotlogs at various ‘short’ run times.

The lounge room temperature in the two households for the duration of the study period, and external temperature are shown in Figure 2. A sharp increase in temperature is observed shortly after the fire is started, subsequently there is a gradual cooling after the last load has been placed on the fire. In most cases, elevated temperatures were maintained for the duration of the night and the lowest temperatures were generally observed between 7-11 am.

A difference in heat output from different fuels may influence emissions from those fuels, which in turn will influence air quality. While compressed wood products have the same calorific value as the wood from which they are made (on a dry weight basis) a difference in moisture content will influence the actual heat output. Room temperature is one measure of heat output from a fire. However, under real-life conditions a householder’s perception of room temperature is likely to be a key factor influencing woodburner operation. Thus room temperature is an unsatisfactory measure of any differences in heat output. Further it will be influenced by other factors such as external temperatures and the degree of insulation in a house. As such, a more accurate measure of how any difference in heat output of different fuels influences emissions is likely to be comparison of emission rates (g/hr), which takes into account the rate at which fuel is burned. From Table 2, the emission rate for the "long" sample runs (house TAU2) were lower during the burning of Hotlogs compared to firewood. No comparison can be made for the short runs due to incomplete data. To provide accurate comparisons of emissions rate, an accurate record of the amount of the fuel burned and time over which it is burned needs to be maintained.

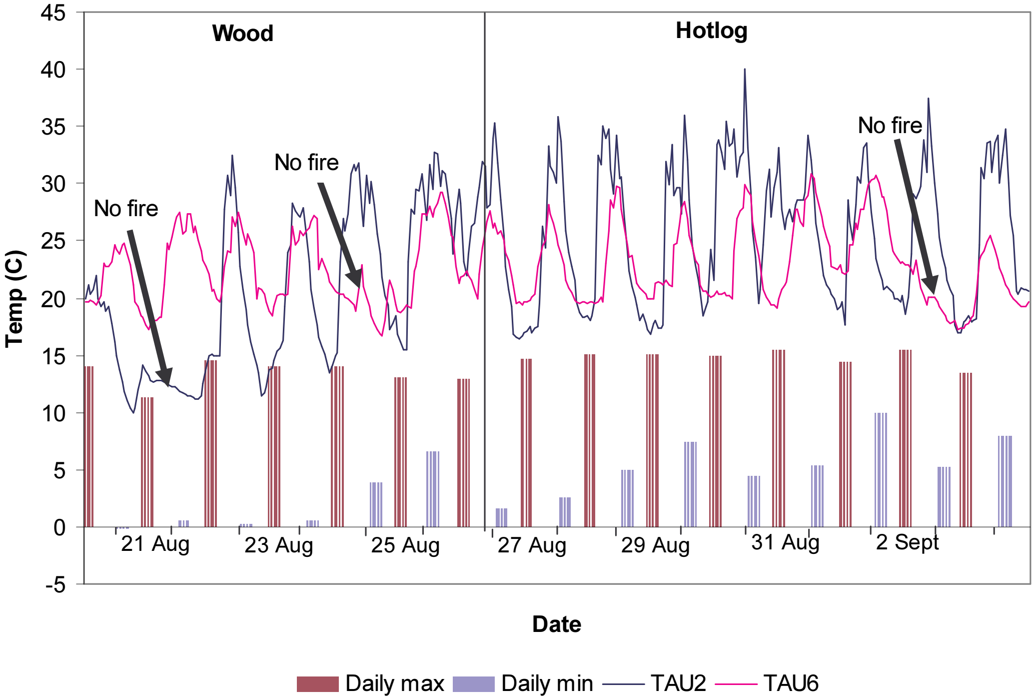

Fig 2. Room temperature in the two households, and daily maximum and minimum external temperatures over the duration of the study.

7. Discussion

7.1 Emissions

The average emissions from house TAU2, the long-run household for which no known sampling issues were encountered, were 1.35 g/kg dry weight. While the sample size is too small to draw conclusions regarding representative emission factors, initial findings indicate that average emissions from Hotlogs could be similar to those from pellet-burners when operated under real-life operation (1.4 g/kg dry wt; Kelly et al. 2007) and lower than the emissions from NES-authorised woodburners burning wood (4.6 g/kg dry wt, 3.3 g/kg wet wt) (Smith et al. 2008). Given the magnitude of this difference and the potential utility of this fuel for councils managing PM_{10}, further testing of compressed wood products appears warranted.

There are limited emissions data available for compressed wood products nationally or internationally with which to compare the current results. Most testing has been undertaken in the US and in these studies reductions of between 45 and 95% for particulate g/kg emissions and between 24 and 94% for particulate g/h emissions were observed for both older and newer design woodburners operated under laboratory conditions (Barnett & Bighouse 1992; Bighouse & Houck 1993; Houck & Tiegs 1998). In the current study, reductions of 44% for g/kg emissions and 38% for g/h emissions were observed. Direct comparison of the emission factors is less relevant given the older technology of the wood stoves used in the US studies.

Our results are in agreement with Environment Australia (2002), which found that emissions from a woodburner operated under laboratory conditions using a compressed wood product were lower than those from pine, although they contrast with Whitley (2007a) who found higher emissions from compressed wood products. This may reflect a difference between real-life and laboratory operating conditions and/or the fuel used in the two studies, although further testing is required.

Emissions from different fuel types appear to be variable. For example, Environment Australia (2002) found that emissions from pine (radiata) were consistently higher than those from eucalypt. Whitley (2007b)[1] found that seasoned radiata had higher emissions than the test material – kiln-dried radiata (2.6 g/kg vs 0.46 g/kg), and also seasoned blue gum (1.6 g/kg) and macropcarpa (1.9 g/kg) but lower than that from seasoned manuka (4.4 g/kg). Woodburners are considered to be optimised to produce the lowest emissions and highest efficiency for burning a test-fuel (kiln-dried pine in New Zealand) under laboratory conditions to meet regulatory requirements. This optimisation is considered to be one factor that may result in higher emissions when woodburners are operated with different fuel types, including compressed wood products (Bighouse & Houck 1993; ARS 2008b). While more rigorous testing of emissions from different wood types is required, the potential emission reduction of compressed wood products needs also to be considered alongside the variation in emissions arising from the use of different fuel types, ideally under real-life operating conditions, as well as other factors that influence emissions such as wood moisture and woodburner operation.

7.2 Other factors influencing compressed wood product use

While the emissions data indicate that compressed wood products may result in lower emissions compared with wood combustion, other factors such as ease of use, heat output and cost will also influence the extent of the usage of these products. Compressed wood products require minimal preparation prior to use in a woodburner once the fire has started, i.e. the products can generally be placed straight into a woodburner compared with wood, which typically requires splitting. While one household did not have any problems using the Hotlogs, the other household found the Hotlogs were difficult to use and burned poorly, had a tendency to roll out of the firebox, and the break-up of the Hotlogs resulted in a significant

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[1] Laboratory testing was undertaken with the fuelling method the same as that specified in AS/NZ4012/13, except for the type and size of fuel used. The woodburner was started from cold and enough fuel burned until an ember bed weighing 25% of the test fuel load was established. Fuel load weight was matched to that specified in the standard (5.4 kg), and each fuel load was run until it was fully consumed by weight (testing was performed at a medium setting). (Bill Whitely, pers.comm, NZ Consumer Organisation).

amount of unburned sawdust in the base of the firebox, particularly on low burn. However, as Hotlogs are a new product and are used differently to firewood, so it may take householders some time to become familiar with their use.

There is limited available information on heat output and efficiency of compressed wood products. A New Zealand consumer organisation report found that compressed wood products typically had a lower power output compared with seasoned radiata but they had a longer burn-time, which results in a higher efficiency (Table 1, Whitley 2007a) and total heat output (MJ) for a burn cycle. Finally, cost may be a significant factor influencing the use of compressed wood products and has previously been noted as a limitation in the use of such products (Foster 1998; Wilton 2002). The cost of various compressed wood products varies from \$6 to \$17 for a box (containing 6–12 logs), which may easily be burned in one sitting. Running costs (expressed as c/kWh) for compressed wood products (15–27 c/kWh) remain higher than firewood (6 c/kWh) (Whitley 2007a), and are also slightly higher than pellet burners (8–14 c/kwh) (Whitley 2007c). However, an increasing focus on renewable energy sources may result in an increased market for compressed wood products, thereby reducing costs to the householder.

8. Conclusions and Recommendations

The preliminary results obtained in the current study suggest that burning compressed wood products may result in lower emissions compared with burning firewood in NES-authorised woodburners, including during the early stages of fire establishment. These results differ from a previous study that undertook laboratory testing of emissions from various compressed wood products and seasoned pine (Whitley 2007a). This may reflect a difference between real-life and laboratory operating conditions and/or the wood used in the studies. However, further testing is required to enable a robust evaluation of potential emission reductions from compressed wood products. Specifically, emissions data from a wider range of woodburners and operating conditions are required. There is also a need to compare the influence of any difference in actual heat output from compressed wood products and firewood under real-life operating conditions; this may be best accomplished via comparison of emission rates.

While compressed wood products may result in lower emissions, the higher cost of these products compared with wood, particularly if free firewood is available, may limit the voluntary uptake of these products. However, in situations where regulatory measures are required to reduce PM_{10} emissions from solid fuel burners, uptake of compressed wood products may be preferable to restrictions on the number of households that can use NES-compliant burners or to early replacement of older solid fuel burners. In the case of the latter, further testing of emissions from compressed wood products in older woodburners would also be required.

9. Acknowledgements

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10. References

Aberkane T, Wilton E 2002. Christchurch – air pollution capital of New Zealand. Proceedings of the 16th International Clean Air Conference of Australia and New Zealand, Christchurch, New Zealand, 19–22 August 2002.

Applied Research Service 2008a. Technical Bulletin 72 NIW1. Nelson, Applied Research Services.

Applied Research Service 2008b. Firelog testing. Nelson, Applied Research Services.

Barnett SG, Bighouse RD 1992. In-home demonstration of the reduction of woodstove emissions from the use of densified wood logs. Report prepared for Oregon Department of Energy and the US Environmental Protection Agency, by Omni-Environmental Services Inc., Beaverton, OR.

Bighouse RD, Houck JE 1993. Evaluation of emissions and energy efficiencies of residential wood combustion devices using manufactured fuels. Report prepared for Oregon Department of Energy, by Omni-Environmental Services Inc., Beaverton, OR.

Blakely J 2006. Lignites or LNG? Energy Watch December. Pp.1–2. Available at: http://www.energywatch.org.nz/issues/EW42_12-2006.pdf

Environment Australia 2002. Emissions from domestic solid fuel burning appliances. Technical report no.5. Canberra, Environment Australia.

Foster E 1998. Reductions in suspended particulate concentrations in Christchurch. Environment Canterbury Report R98/1.

Green Party 2007. Energy Policy (administrative update 16 May 2007). http://www.greens.org.nz/node/17459 (accessed September 2008).

Houck JE 2007. Global warming reduction benefits of manufactured biowax-fibre fireplace logs. Report prepared for Duraflame Inc. by Omni Environmental Services Inc., Beaverton, OR.

Houck JE, Eagle BN 2006. Task 4. Technical Memorandum 2 (Emission Inventory). Control anlaysis and documentation for residential wood combustion in the MANE-VU region. Report prepared for: Mid-Atlantic Regional Air Management Association, OMNI Environmental Services, Beaverton, Oregon.

Houck J, Tiegs PE 1998. Residential wood combustion technology review Volume 1: Technical report. EPA-600/R-98-174a. Washington DC, US EPA.

Houck JE, Tiegs P 2001. Convenience Fuels. Hearth and Home December p.18-21.

Houck JE, Scott AT, Sorenson JT, Davis BS, Caron C. 2000. Comparison of air emissions between cordwood and wax-sawdust firelogs burned in residential fireplaces. In; Proceedings of AMWA and PNIS International Specialty Conference: Recent Advances in the Science of the Management of Air Toxics. April 2000.

Houck JE, Pitzman LY, Tiegs P 2008. Emission factors for new certified residential wood heaters. In: Proceedings of the 17th International Emission Inventory Conference, Inventory Evaluation – Portal to Improved Air Quality, 3–5 June 2008. Sponsored by Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency.

Hueglin C, Gaegauf C, Künzel S, Burtscher H 1997. Characterization of wood combustion particles: morphology, mobility and photoelectric activity. Environmental Science and Technology 31: 3439–3447.

Kelly C, Mues S, Webley W 2007. Warm homes technical report: real-life emissions testing of pellet-burners in Tokoroa. Ministry for the Environment Report no. ME813. Available at http://www.mfe.govt.nz.

MED (Ministry of Economic Development) 2008. Energy Datafile – June 2008. L. Fuel properties. Available at: http://www.med.govt.nz/templates/MultipageDocumentTOC_36571.aspx

Mellhuish M 2005a. Available at: http://ecan.govt.nz/NR/rdonlyres/9E1A4F20-DB39-474A-A38B-8AA3FC93A9F9/0/MollyMelhuishElectricityforCanterbury.pdf

Mellhuish M 2005b. Available at: http://www.electricitycommission.govt.nz/pdfs/submissions/pdfssecurity/pdfsresenergy2005/melhuish.pdf

Mellhuish M 2006. Available at: http://www.electricitycommission.govt.nz/pdfs/submissions/pdfstransmission/gpa-sep06/melhuish.pdf

Scott A, Gunatilaka M. 2002. Christchurch inventory of emissions to air. Report No. R04/03. Environment Canterbury, Christchurch, 2004, pp. 127.

Smith J, Wilton E 2007. Air emission inventory – Matamata, Putaruru and Waihi 2006. Hamilton, Environment Waikato.

Smith J, Bluett J, Wilton E, Mallet T 2008. In home testing of particulate emissions from low emission woodburners: Nelson, Rotorua and Taumaranui 2007. NIWA contract report CHC2008-092. National Institute of Water and Atmospheric Research.

Whitely B 2007a. Compressed firelogs. Consumer Organisation Report. Available at: http://www.consumer.org.nz/ (subscription only). Accessed August 2008.

Whitely B 2007b. Woodburner emissions. Consumer Organisation Report. Available at: http://www.consumer.org.nz/ (subscription only). Accessed August 2008.

Whitely B 2007c. Pellet burners. Consumer Organisation Report. Available at: http://www.consumer.org.nz/ (subscription only). Accessed August 2008.

Wilton E 2002. Improving air quality in Nelson, An assessment of the effectiveness of management options for reducing PM10 concentrations in Nelson – Stage One. Nelson City Council Technical Report.

Wilton E 2005. Air emission inventory – Hawke’s Bay Region – 2005. Report. Napier, Hawke’s Bay Regional Council.

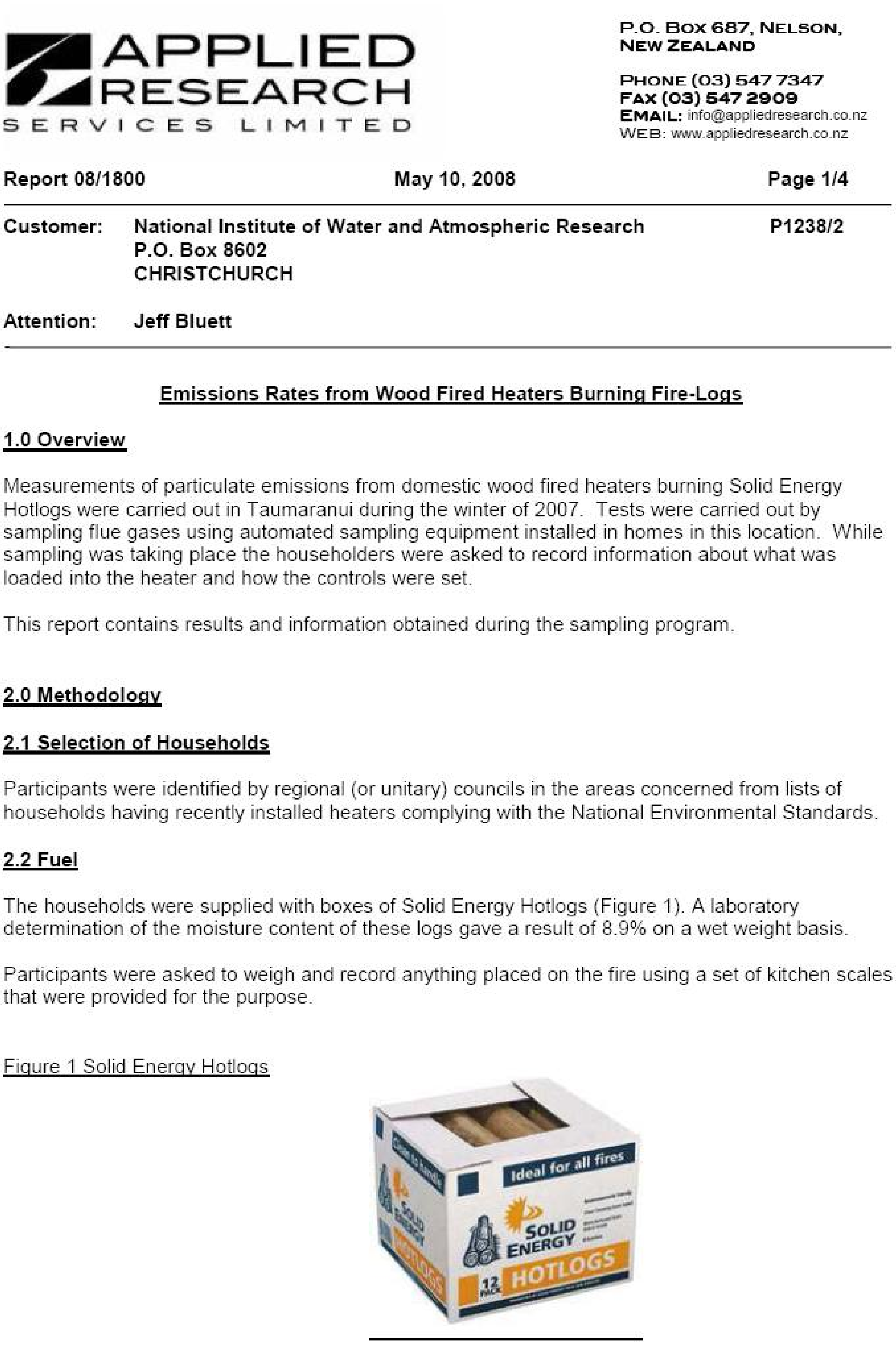
Wilton E, Smith J, Webley W, Dey K 2006. Real-life emissions testing. Clean Air 40(2): 43–47.

Appendix 1 Raw data collected during in-home testing

Household	Emissions Dry weight (g/kg)	Wet weight (g/kg)	Emission rate (g/h)	Duration (min)	Weight Electronic (kg)	Weight Worksheet (kg)	High %	Med %	Low %	Loadings (*N*)	Pieces (*N*)	Average flue temp (ºC)
Wood												
TAU2	1.5	1.1	2.56	414	25.9	15.5	15	0	85	6	17	269
TAU2	4.4	3.3	8.70	709	26.3	31.3	10	3	87	11	37	262
TAU2	2.7	2.0	3.73	845	13.4	26.3	2	0	98	8	17	259
TAU2	3.8	2.8	3.46	1434	36.4	29.2	0	0	100	9	21	244
TAU6	6.4	4.7	23.96	321	33.0	27.6	50	0	50	5	14	240
TAU6							48	15	37			112
TAU6	5.8	4.2	10.80	93	3.8	4.0	36	0	64	1	2	269
TAU6	3.3	2.4	5.11	635	28.8	22.8	18	5	77	3	10	222
TAU6												185
TAU6							16	0	84			
Hotlogs												
TAU2	1.4	1.4	2.03	571		15.3	3	0	97	9	17	270
TAU2	0.9	0.9	0.85	844		14.4	24	0	76	14	33	269
TAU2	1.7	1.7	1.34	1261		17.9	21	0	79	19	40	250
TAU2				200		6.2	8	0	92	4	7	272
TAU2	1.7	1.7	3.14	614		21.3	5	0	95	13	22	271
TAU2	1.0	1.0	1.32	528		12.3	5	0	95	8	16	118
TAU2				517		21.4	5	3	92	11	25	288
TAU6	5.4	5.4	13.42	79		3.6	75	0	25	2	4	283

TAU6	6.3	6.3	29.41	42		3.6	100	0	0	1	4	314
TAU6	8.9	8.9	25.68	38		2.0	100	0	0	1	2	319
TAU6	7.8	7.8	21.80	53		2.7	100	0	0	2	3	357
TAU6	1.9	1.9	4.77	456		21.1	83	17	0	12	24	240
TAU6	7.0	7.0	33.30	71		6.2	100	0	0	4	7	271
TAU6	6.0	6.0	21.97	66		4.4	100	0	0	3	5	223

Appendix 2 Original report from Applied Research Services



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Report 08/1800 **May 10, 2008** **Page 1/4**

Customer: **National Institute of Water and Atmospheric Research** **P1238/2**
P.O. Box 8602
CHRISTCHURCH

Attention: **Jeff Bluett**

Emissions Rates from Wood Fired Heaters Burning Fire-Logs

1.0 Overview

Measurements of particulate emissions from domestic wood fired heaters burning Solid Energy Hotlogs were carried out in Taumaranui during the winter of 2007. Tests were carried out by sampling flue gases using automated sampling equipment installed in homes in this location. While sampling was taking place the householders were asked to record information about what was loaded into the heater and how the controls were set.

This report contains results and information obtained during the sampling program.

2.0 Methodology

2.1 Selection of Households

Participants were identified by regional (or unitary) councils in the areas concerned from lists of households having recently installed heaters complying with the National Environmental Standards.

2.2 Fuel

The households were supplied with boxes of Solid Energy Hotlogs (Figure 1). A laboratory determination of the moisture content of these logs gave a result of 8.9% on a wet weight basis.

Participants were asked to weigh and record anything placed on the fire using a set of kitchen scales that were provided for the purpose.

Figure 1 Solid Energy Hotlogs

2.3 Emissions Sampling

A portable emissions sampler was installed in each household for the duration of the tests. Details of this sampler are given in our Technical Bulletin number 72 which is appended to our report 08/1776. Results from the sampler can be used to calculate an emissions rate in g/kg (dry wood basis) independently of any information recorded by the householder. Filters on the sampler were changed daily.

3.0 Results

Results are contained in the spreadsheet and personal document (pdf) files on the accompanying disc.

3.1 Master Table.

The worksheet contains the following data (where available) for each run:

column	ID	Description
1	Run	Run identification code
2	Wt worksheet	Weight of wood consumed (manual scales)
3	% high	% of time the appliance was operated with the control set to high
4	% medium	% of time the appliance was operated with the control set to medium
5	% low	% of time the appliance was operated with the control set to low
6	Loadings	Number of fuel loadings per run
7	Pieces	Number of fuel pieces added per run
8	Start g	Filter weight at start of run
9	Finish g	Filter weight at end of run
10	Diff mg	Weight of deposit (by difference)
11	Flue T	Average flue temperature
12	Sampler T	Average filter temperature
13	EF g/kg	Emissions rate g/kg
14	EF g/hr	Emissions rate g/hr
15	Flue Temp max	Maximum recorded flue temperature during run
16	Flue Temp min	Minimum recorded flue temperature during run
17	Flue Temp average	Average recorded flue temperature during run
18	Duration	Run duration
19	Sampler LPM	Gas flow rate through emissions sampling train
20	Gas Analyser LPM	Gas flow rate through gas analyser train
21	Comments	Comments recorded about sampler operation

3.2 Household Data Record Sheets

The householders completed a form while operating the heater on which they recorded information about the fuel and control settings. Copies of the completed worksheets can be found as pdf files on the accompanying disc.

4.0 Meta Data

This section provides information on problems we encountered during the test program and on areas where such programs could be improved in future.

4.1 General Issues

A number of general issues are addressed in the corresponding section of our report 08/1776 which relates to similar measurements made with firewood fuels. The present measurements were made at the conclusion of the firewood study.

4.2 Fire-log Specific Issues

While the heaters were fuelled with fire-logs the samplers were operated by volunteers located by Horizons Regional Council. Two sets of data were not recorded:

(1) Data from the electronic scales.
(2) Flue gas analysis data.

We are not clear as to why the data from the electronic scales was not recorded. The flue gas analysers were no longer functioning due to blocked scrubbers and collapsed tubing. When calculating results a typical value was used for the oxygen level in these runs and the Stack Dilution Multiplier (SDM) was calculated accordingly.

The sampler is designed to stop sampling when the filters become heavily loaded with particulates. This appears to have occurred on several runs in household TF as noted by the householder but not by the volunteer operating the sampler.

The weight of fuel consumed in each run was calculated from information recorded on the householder worksheets.

5.0 Discussion

5.1 Robustness of Data

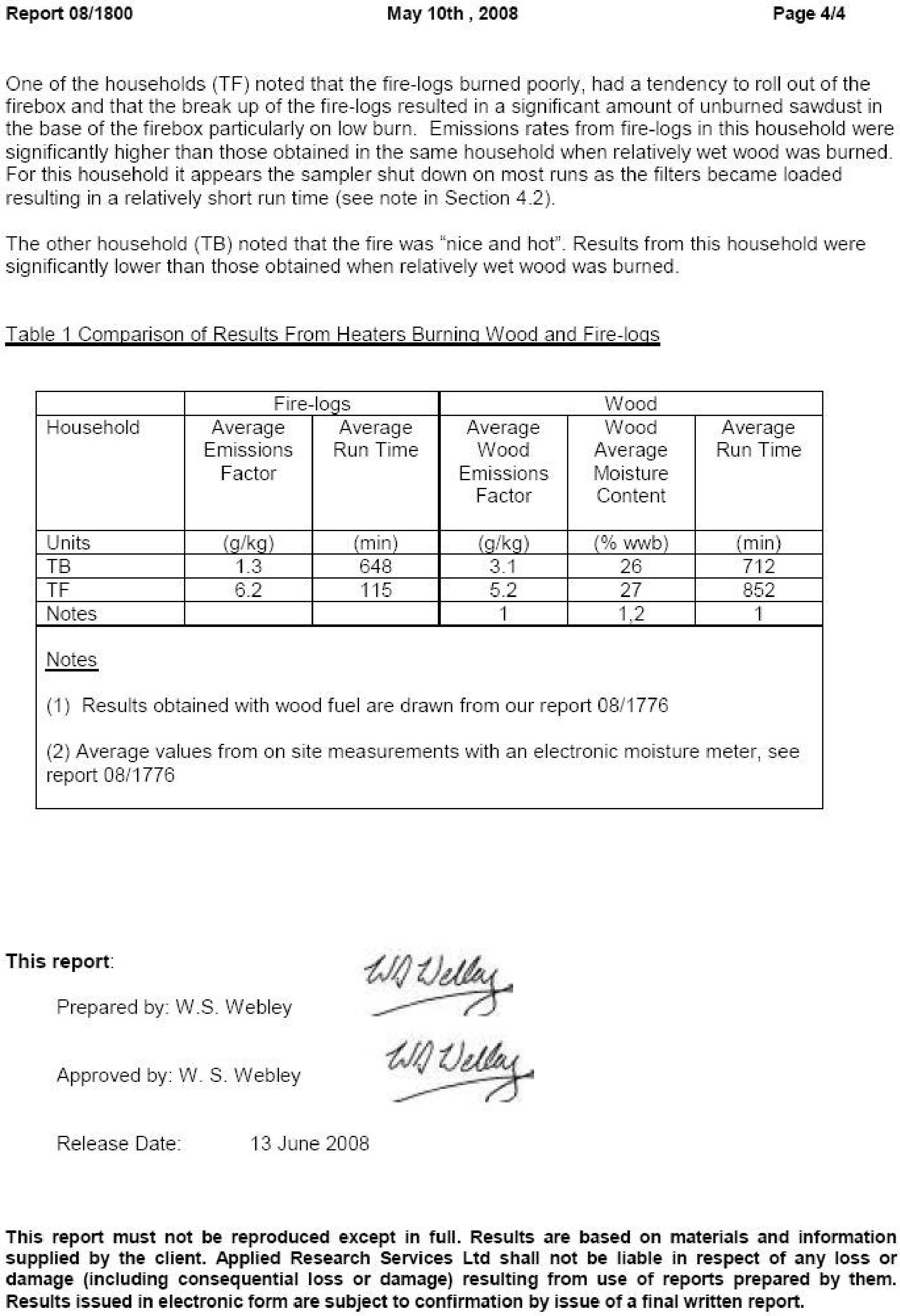
Our report 08/1776 contains a discussion on the robustness of data which is also applicable to these measurements. The run to run variability for the 13 valid fire-log runs was 41%.

5.2 General Comments on Emissions Data

Compressed wood fire-logs differ from typical wood fuel in a number of ways. They are denser, drier and tend to break apart as they burn.

Wood fired heaters in New Zealand are generally optimised to burn softwood with a moisture content in the range 16 to 20% on a wet weight basis. They are likely to perform differently with a different fuel.

Average results from the two households where fire-logs were burned are given in the table below.



One of the households (TF) noted that the fire-logs burned poorly, had a tendency to roll out of the firebox and that the break up of the fire-logs resulted in a significant amount of unburned sawdust in the base of the firebox particularly on low burn. Emissions rates from fire-logs in this household were significantly higher than those obtained in the same household when relatively wet wood was burned. For this household it appears the sampler shut down on most runs as the filters became loaded resulting in a relatively short run time (see note in Section 4.2).

The other household (TB) noted that the fire was "nice and hot". Results from this household were significantly lower than those obtained when relatively wet wood was burned.

Table 1 Comparison of Results From Heaters Burning Wood and Fire-logs

	Fire-logs		Wood		
Household	Average Emissions Factor	Average Run Time	Average Wood Emissions Factor	Wood Average Moisture Content	Average Run Time
Units	(g/kg)	(min)	(g/kg)	(% wwb)	(min)
TB	1.3	648	3.1	26	712
TF	6.2	115	5.2	27	852
Notes			1	1,2	1

Notes

(1) Results obtained with wood fuel are drawn from our report 08/1776

(2) Average values from on site measurements with an electronic moisture meter, see report 08/1776

This report:

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