Further Investigations of Low-frequency Noise Problem Generated by Freight Trains

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ABSTRACT

The Western Australia Department of Environment and Conservation (DEC) studied the rail noise and vibration at a residence in a Western Australian suburb in 2009. The study had identified very strong low frequency components in the range from 12-32 Hz inside that residence. In this follow-up investigation, four more residences in the same suburb and with similar distance to the rail track were studied. It has been confirmed that the low-frequency noise problem caused by the train movements does exist at all four residences, especially inside the houses. The sound transmission loss of the building of the residence was measured to be mostly above 20 dB at frequencies higher than 50 Hz, but dropped significantly at frequencies lower than 50 Hz and even enters the negative territory at lower frequencies, meaning the noise level at such low frequency range was amplified when transmitted from outdoor to indoor.

INTRODUCTION

The DEC Noise Regulation Branch initially conducted noise and vibration measurements in one residence in the Western Australian suburb of Canning Vale during March and April 2009, to investigate the complaint made by the residents who claimed that the whole house was vibrating when the freight train passed by. This residence is located at a distance of about 50 metres from the main freight railway to the Kwinana Industrial Area and is affected by the noise and vibration generated by the freight trains running on the rail day and night.

The 2009 study found that the vibration levels generated by freight trains did not exceed the base curve specified by AS2670.2: *Evaluation of human exposure to whole-body vibration – Continuous and shock-induced vibration in buildings (1-80 Hz)* at either the outside or inside locations. According to AS2670.2, a vibration level below the base curve is not likely to cause human annoyance. The 2009 report also found that the noise levels generated by the trains were in the range 36 to 46 dB(A) in the lounge area inside the house, and 56 to 69 dB(A) in the backyard of the residence. The night-time $L_{Aeq\ 8h}$ levels calculated from the measured train noise levels and the number of train movements were about 15 to 21 dB(A) inside the house and 42 to 50 dB(A) outside the house. Rail noise level in these ranges may sometimes cause community concerns, although it may not necessarily be considered unacceptable.

However, the spectral analysis of the 2009 measurement results identified a low-frequency problem with the rail noise, especially inside the house. The reason for this indoor noise amplification could be because the low-frequency acoustic modes were activated by the rail noise. As the acoustic modes depend on the shape and size of the rooms, the Noise Regulation Branch recommended a further study of the indoor rail noise at more residences to identify whether the indoor low-frequency problem was present in other dwellings.

When the 2009 report was released to the public, five residences in Canning Vale expressed their interest in participating in further studies, via their local Member of Parliament. The Noise Branch contacted the occupiers of all five residences in January 2011 and, of these, four indicated that they were still interested in the study.

This paper presents the results of the follow-up investigation into rail noise and vibration levels in these four houses, carried out in February 2011.

METHODOLOGY

The noise and vibration measurements were conducted between 16 February and 28 February 2011 at four residences in Canning Vale. The locations of the four residences participating in this study are shown in Fig. 1.

Figure 1. Locations of the four participating residences

It can be seen that all four residences are located very close to the train movements. The addresses of these four residences and their corresponding measuring periods are listed in Table 1.

Table 1. Description of the four residences

#	Address	Distance to track (m)	Measuring Period
1	11 Woodspring Trail	~50	16-18 Feb. 2011
2	7 Pinewood Walk	~50	18-21 Feb. 2011
3	23 Pinewood Walk	~120	21-23 Feb. 2011
4	18 McLean Road	~40	23-28 Feb. 2011

There were a total of two vibration monitoring locations and two noise monitoring locations gathering data during the measurement period at each of these four residences. One noise and vibration measurement system - a Rion DA-20 4-channel Data Recorder - was located in the lounge area inside the house, an example is shown in Fig. 2. The vibration transducer was a three channel Rion PV-83 accelerometer mounted as a single block to obtain X-Y-Z direction vibration levels, utilising a Rion VP-80 three-channel preamplifier. The noise was measured using the fourth channel of the recorder via a Rion UC-57 microphone and a Rion NH-22 preamplifier. This noise measurement system has a flat frequency response down to 10Hz. The microphone was mounted on a tripod approximately 1.2 metres above the floor, and at least 1.5 metres away from any walls.

Figure 2. Example Indoor Monitoring Locations

A second Rion DA-20 Data Recorder was used for the outdoor noise and vibration measurement. This recorder and its noise and vibration sensors were positioned in the under-cover open garage or pergola area, which is either on the side of the house or in the backyard, as shown in Fig. 3. The accelerometer was mounted on the floor of the open garage/pergola, to pick up the ground vibration level outside the house structure. The microphone for the noise channel was mounted on a tripod approximately 1.2 metres above the floor and located in the backyard side of the open garage/pergola.

Figure 3. Example Outdoor Monitoring Locations

Both the Rion DA-20 recorders were running in automatic triggering mode. In this mode, the recorder starts to continuously record 1-minute noise and vibration signals when a pre-set vibration trigger level of 0.02 m/s^2 is reached. Vibration measurement channels of the Rion DA-20 were calibrated by a Brüel and Kjær Type 4291 accelerometer calibrator before the measurement. A calibration signal of 10 mm/s^2 peak (7.07 mm/s^2 RMS) at 79.6 Hz generated by the calibrator was recorded into each vibration channel. The acoustic calibration signal of 94 dB at 1 kHz was recorded on the audio channel before the measurements. All subsequent analysis was made with reference to these recorded calibration signals.

Altogether 88 indoor and 77 outdoor valid train noise and vibration measurements were recorded during the monitoring period from 16th February to 28th February 2011. The events of valid recorded train movements at each of four residences are illustrated in Table 2. The reason why not all train events were recorded is that the recorder was triggered by activities other than the train movements, such as the residents' movements. As a result, the memory card of the recorder ran out of space faster than expected.

Table 2. Recorded Train Movement Events

Location	Dates	Indoor	Outdoor
11 Woodspring Trail	16^{th}-18^{th} Feb.	26	33
7 Pinewood Walk	18^{th}-21^{st} Feb.	20	36
23 Pinewood Walk	21^{st}-23^{rd} Feb.	12	5
18 McLean Road	23^{rd} -28^{th} Feb.	28	3

ANALYSIS AND RESULTS

The analysis of the data recorded by the Rion DA-20 was performed in the DEC Noise Regulation Branch laboratory using Rion DA-20 PA1 software. One-third octave spectral analysis was performed on the vibration channels over the 1 Hz to 80 Hz range, while the same analysis was conducted for the noise channel over the 10 Hz to 8,000 Hz range. The spectra were analysed as RMS values over the pass-by period for each train, which covered the time period that the peak train noise dropped by 6 dB and typically varied between 25 and 60 seconds. Overall A-weighted and C-weighted Leq noise levels were determined over the same averaging periods.

All recorded noise and vibration data have been analysed and the results and conclusions are based on these analyses. However, because of the volume of data, this report only presents the noise and vibration levels of a limited number of typical trains at each of the four participating residences.

Noise and vibration levels at 11 Woodspring Trail

The analysis of noise and vibration levels at this residence generated from the freight trains is focused on seven typical train movements. The measured outdoor and indoor noise levels are shown in Figs. 4 and 5. It can be seen from Fig. 4 that the Leq noise levels generated by these seven trains vary between 57 and 73 dB(A) in the pergola area. The train noise at the outdoor location contains quite strong low-frequency components, with the peak sound energy within the 50 to 160 Hz frequency range. Fig. 4 also shows that the train noise at this outdoor location also has significant energy at frequencies ranging from 160 Hz to 5,000 Hz. The differences between the A-weighted and C-weighted noise levels were generally around 15 dB, ranging up to 24 dB in the absence of high frequency wheel squeal.

Quite strong low-frequency components at frequency range between 10-160 Hz are also seen in the measured indoor noise levels, as shown in Fig 5. However, in comparison with the outdoor noise spectra, the peak noise energy is concentrated in the frequency range between 12.5 and 31.5 Hz. At frequencies above about 31.5 Hz the energy seems to be substantially reduced by the structure of the residence during transmission into the house. As a result, the differences between the A-weighted and C-weighted noise levels indoors increase to typically 18-19 dB and sometimes as high as 28 dB. It can also be seen in Fig. 5 that the indoor Leq noise levels generated by freight trains are mainly in the range between 50 and 60 dB(A), with the majority below 55 dB(A).

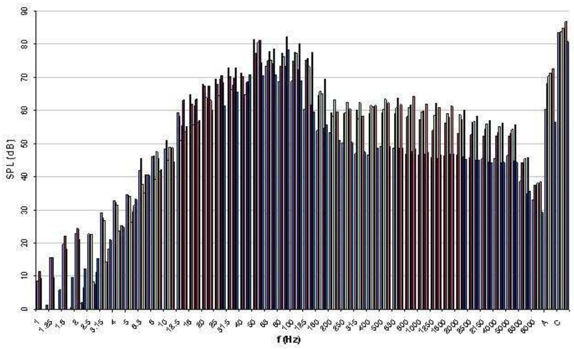

Figure 4. L_{eq} spectra of outdoor noise generated by trains

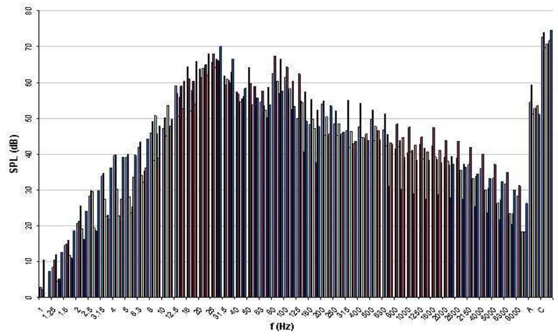

Figure 5. L_{eq} spectra of indoor noise generated by trains

The measured outdoor and indoor ground vibration levels are shown in Figs. 6 and 7, respectively. It can be seen from Fig. 6 that the highest ground vibration levels generated by trains are in the frequency range 8 to 31.5 Hz.

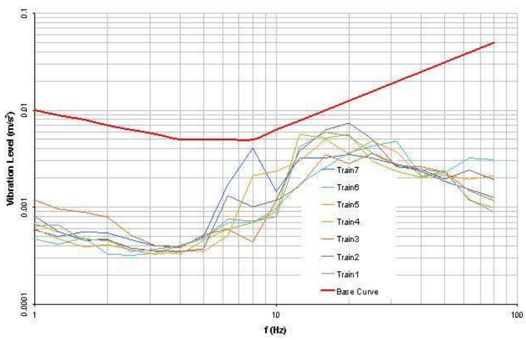

Figure 6. Spectra of outdoor vibration generated by trains

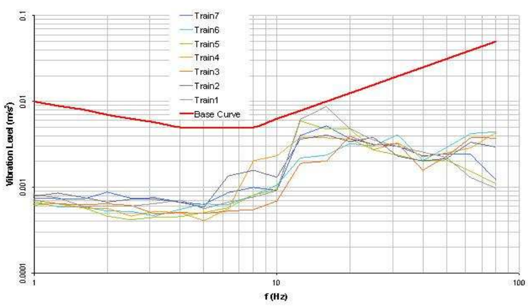

Figure 7. Spectra of indoor vibration generated by trains

Figure 7 indicates that high low-frequency floor vibration energy is seen in the range between 10 and 20 Hz. Compared to the indoor noise spectra, the peak vibration energy shifts more towards the lower frequency end.

Both the outdoor and indoor vibration recordings indicate that all the measured ground vibration levels generated by the freight trains were below the base curve given by AS2670.2. According to AS2670.2, vibration levels below the base curve are not likely to cause human annoyance.

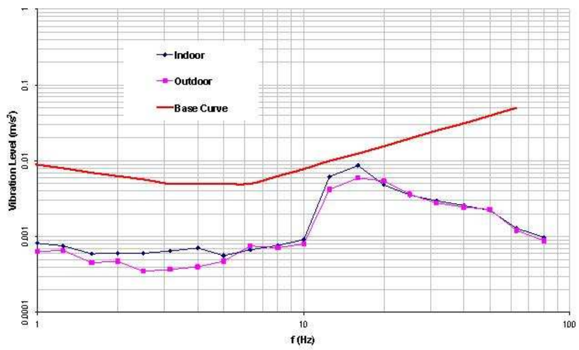

Figure 8. Comparison with the base curve

Figure 8 presents a comparison of indoor and outdoor vibration levels generated by a typical freight train (Train 1). It can be seen clearly in Fig. 8 that the indoor vibration level is even higher than the outdoor level, particularly at frequencies of 12.5 and 16 Hz. This demonstrates that the vibration level generated by freight trains is not attenuated when transmitted from outdoor to indoor. On the contrary, the vibration level seems to be amplified by the structure of the house in the low frequency range.

Noise and vibration levels at 7 Pinewood Walk

The analysis of noise and vibration levels at this residence generated by the freight trains is focused on 10 typical train movements. The measured outdoor and indoor noise levels are given in Figs. 9 and 10 respectively. Again quite strong low-frequency components are seen in the outdoor train noise measurements, which peak within the 10 to 125 Hz frequency range, as shown in Fig. 9. Fig. 9 also indicates that the Leq noise level generated by the trains varies between 65 and 75 dB(A) in the pergola area. Similar to the measured outdoor results at 11 Woodspring Trail, the differences between the A-weighted and C-weighted noise levels are also generally around 15 dB.

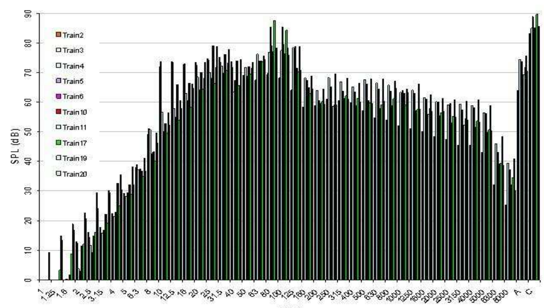

Figure 9. L_{eq} spectra of outdoor noise generated by trains

The strong low-frequency components in the measured indoor noise levels are again evident in the range 10 to 125 Hz, as shown in Fig 10, but with the peak noise energy now in the frequency range between 10 and 50 Hz. As with the measurements at 11 Woodspring Trail, comparison of the indoor and outdoor spectra shows that the train noise is more readily attenuated at the higher frequency range when transmitted into the house, as expected.

It can also be seen in Fig. 10 that the differences between the A-weighted and C-weighted noise levels inside the lounge area are substantially greater than 20 dB, a generally-accepted criterion for indicating the potential for significant low-frequency noise content. Fig. 10 also demonstrates that Leq noise levels generated by freight trains are around 50 dB(A) inside this residence, with the majority below 50 dB(A).

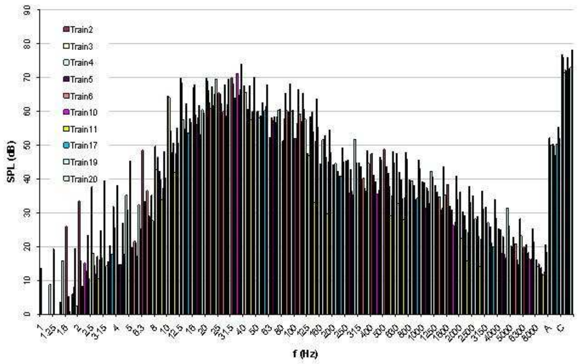

Figure 10. L_{eq} spectra of indoor noise generated by trains

To clearly show the differences between indoor and outdoor noise spectra, a comparison of noise spectra generated by a typical train (Train 20) is shown in Fig. 11. As can be seen in Fig. 11, the train noise at frequencies higher than 20 Hz was substantially attenuated during transmission into the house, while the noise levels at frequencies from 10 to 20 Hz were almost as high as the outdoor levels.

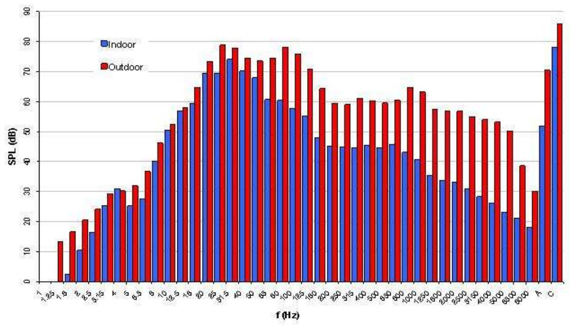

Figure 11. Comparison of indoor and outdoor L_{eq} spectra

The measured outdoor and indoor ground vibration levels are shown in Figs. 12 and 13, respectively. While there is a wide variation in the vibration levels between trains, the indoor and outdoor levels for each train are similar, with the indoor levels being lower at this site. Some correlation can be observed between the vibration levels in Fig. 12 and the sound levels in Fig. 9, especially in relation to Trains 2 and 3, which generate their highest vibration levels in the 10 to 16 Hz range.

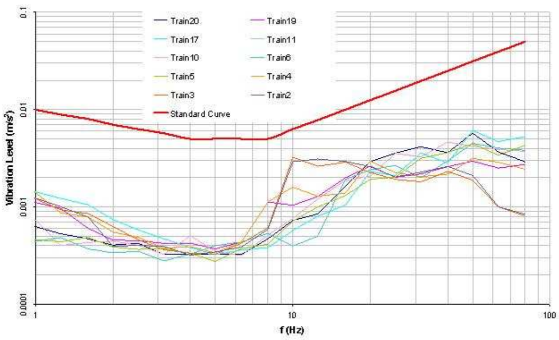

Figure 12. Spectra of outdoor vibration generated by trains

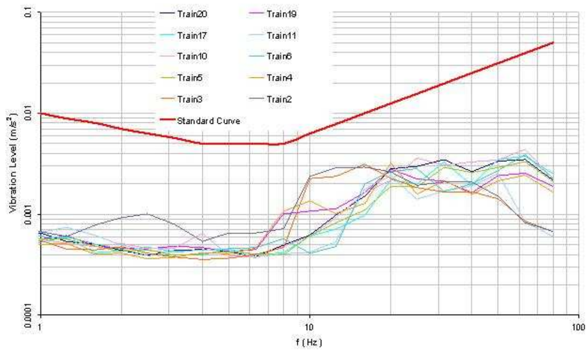

Figure 13. Spectra of indoor vibration generated by trains

It can be seen that both the outdoor and indoor ground vibration levels at 7 Pinewood Walk are slightly lower than those measured at 11 Woodspring Trail. Again, both the outdoor and indoor ground vibration levels generated by freight trains are below the base curve given by AS2670.2.

Noise and vibration levels at 23 Pinewood Walk

Of the four participating residences, this residence is the farthest from the railway, with the direct distance being about 120 metres from the rail track. The noise levels at this residence generated by the freight trains are illustrated with twelve indoor and five outdoor measurements. The five measured outdoor noise spectra are given in Fig. 14. Compared to the measured levels at the above two residences, the outdoor Leq noise levels are significantly lower, in the range between 50 and 55 dB(A). Figure 14 also demonstrates that the noise energy peaks in the frequency range between 10 and 100 Hz, which is also significantly lower than in the spectra measured at the above two residences. This result is understandable, as the noise energy at higher frequencies is attenuated to a greater extent when propagating over the extra distance to this residence.

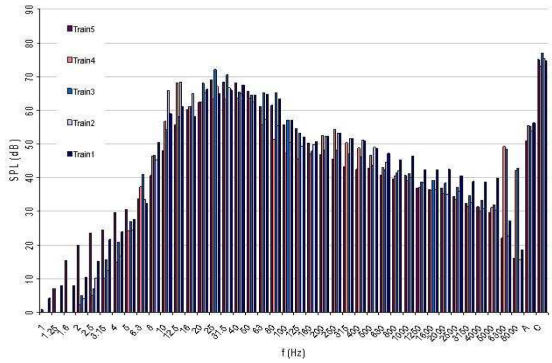

Figure 14. L_{eq} spectra of outdoor noise generated by trains

The indoor noise levels from twelve train movements recorded at this residence are shown in Fig 15. It can also be seen clearly that the indoor Leq noise levels generated by trains are significantly lower than those measured at the two above analysed residences, with the overall level ranging between 37 and 47 dB(A). It can however be seen in Fig. 15 that the differences between the A-weighted and C-weighted indoor noise levels are substantially greater than 20 dB, indicating significant low-frequency noise content.

The measured indoor ground vibration levels are shown in Fig. 16. The vibration levels have their main energy in the range 10 to 50 Hz, and the individual vibration spectra for each train correlate well with the corresponding indoor noise spectra in Fig. 15. It can be seen that the ground vibration levels measured indoors are below the base curve given by AS2670.2. As stated previously, these vibration levels are generally considered not likely to cause human annoyance.

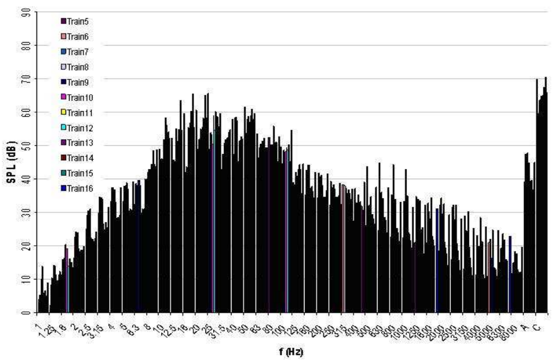

Figure 15. L_{eq} spectra of indoor noise generated by trains

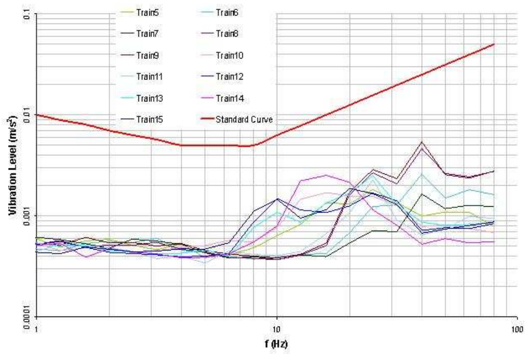

Figure 16. Spectra of indoor vibration generated by trains

Noise and vibration levels at 18 McLean Road

Of the four participating residences, this residence is the closest to the railway, with its entrance at a distance of about 40 metres from the rail. However, unlike the other two residences close to the rail (11 Woodspring Trail and 7 Pinewood Walk), where the rail is located behind the backyard fences, the rail is located in front of this residence. The outdoor noise and vibration measurements were conducted inside the pergola area in the backyard of this residence. The microphone would therefore have been shielded to some extent by the house itself, resulting in lower measured noise levels at the outdoor position when compared with the other two residences.

The three recorded outdoor noise levels generated by train movements are given in Fig. 17. These results confirm that the outdoor noise levels at this site were significantly lower than those measured at 11 Woodspring Trail and 7 Pinewood Walk.

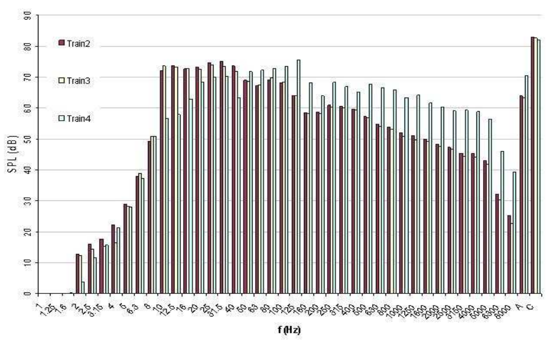

Figure 17. L_{eq} spectra of outdoor noise generated by trains

The indoor noise spectra of ten typical trains are given in Fig. 18. Again the peak low-frequency energy seen in the outdoor train noise measurements has shifted towards the lower frequency end and within the frequency range between 12 and 125Hz, as shown in Fig. 18. It is also indicated in Fig. 18 that the Leq noise level generated from each train movement varies significantly at this residence – from 45 to 63 dB(A) inside the lounge area. This demonstrates that train noise levels inside this residence can be quite high with certain trains, and are significantly higher than those measured at the other three residences. Fig. 18 also demonstrates that the differences between the A-weighted and C-weighted noise levels inside the house are not generally higher than 20 dB at this residence.

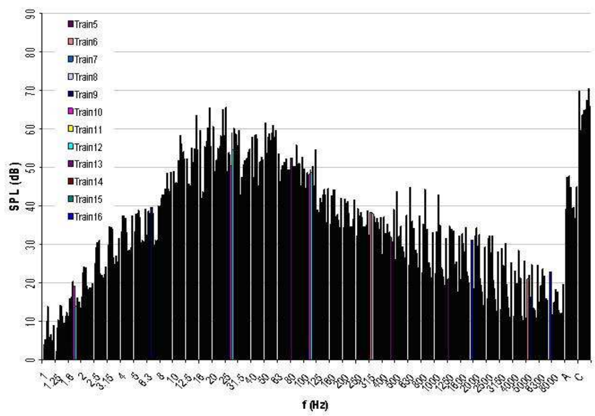

Figure 18. L_{eq} spectra of indoor noise generated by trains

The measured outdoor and indoor ground vibration levels are shown in Figs. 19 and 20, respectively. It can be seen that both the outdoor and indoor ground vibration levels generated by freight trains are below the base curve given by AS2670.2.

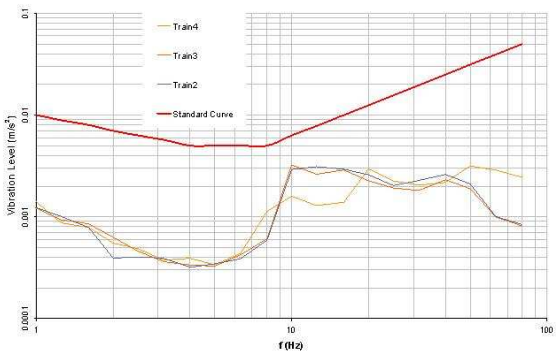

Figure 19. Spectra of outdoor vibration generated by trains

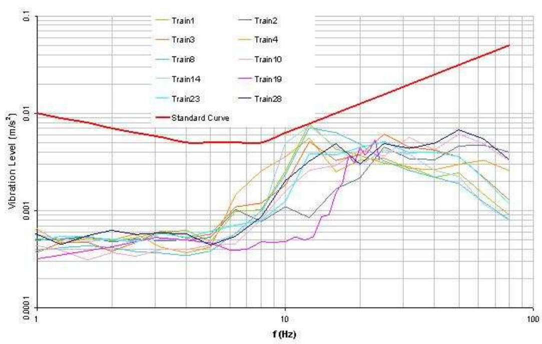

Figure 20. Spectra of indoor vibration generated by trains

However, the indoor vibration levels at this residence are significantly higher than those at the other three residences, and are quite close to the standard base curve with some freight train movements. It can also be seen in these two figures that the indoor vibration level is generally higher than that measured outside in the backyard of the residence.

Figure 21 clearly indicates, using a typical train as an example (Train 4), that the indoor vibration level generated by the train is significantly higher than that measured outside in the pergola area at almost all frequencies. This is also an expected result as the outdoor pergola area is behind the house structure – farther away from the rail track.

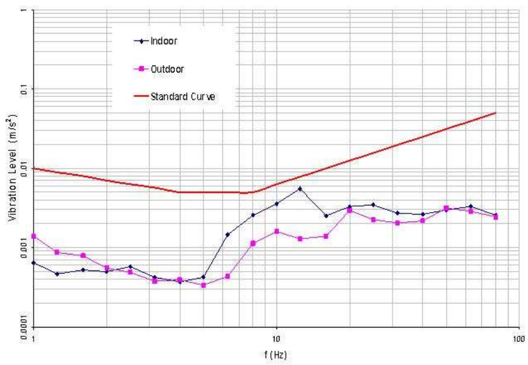

Figure 21. Comparison of indoor and outdoor vibration generated by Train 4 with the base curve

DISCUSSION AND CONCLUSIONS

As demonstrated above, the ground vibration levels generated by freight trains, when measured inside all four houses, were below the base curve specified by AS2670.2. Based on AS2670.2, a vibration level below the base curve is not likely to cause human annoyance. It can also be noted that, although the measured vibration levels are below the base curve, they are very close to the base curve at two participating residences (11 Woodspring Trail and 18 McLean Road). The ground vibration levels generated by freight trains are likely to be perceptible at these residences.

This study therefore concludes that ground vibration is not, of itself, an emission that is likely to cause significant loss of amenity for those living adjacent to the railway. This confirms the results of the 2009 study at a single house in Canning Vale.

The issue then is whether the indoor noise levels are sufficient to be causing significant impact.

It was observed during the study period that on average there were 16 train movements per day – four during night-time (10 pm – 6 am) and twelve in the daytime (6 am – 10 pm). It was also observed that most of the train pass-by movements lasted less than one minute. Shown in Fig. 22 is the waveform of a noise recording of a typical train pass-by inside a residence.

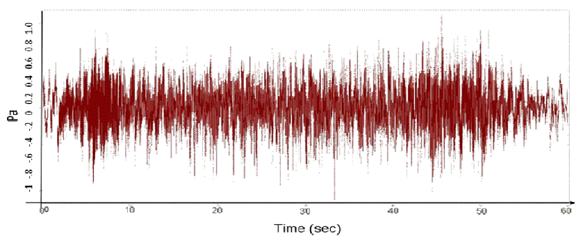

Figure 22. Noise recording of a typical train pass-by event

Table 3 shows the starting time and time period of each of the four night-time train pass-bys on a typical night at 18 McLean Road. The measured $L_{Aeq\ T}$ and $L_{Ceq\ T}$ levels during each train pass-by are also shown in Table 3. Leq T refers to the Leq noise level measured over a time period T, where T could be different for each train pass-by. The $L_{Aeq(Night)}$ level and $L_{Ceq(Night)}$ level inside this residence on that particular night can be calculated as 25 dB(A) and 52 dB(C), respectively.

Table 3. Typical indoor noise levels for night-time train pass-bys, 18 McLean Road

Date	Starting Time	T (s)	$L_{Aeq,\ T}$ (dB)	$L_{Ceq,\ T}$ (dB)
23 Feb	23:13:59	45	48	71
24 Feb	00:42:25	54	49	75
24 Feb	02:44:51	60	43	75
24 Feb	05:46:56	44	42	71

The typical ranges of the measured night-time indoor $L_{Aeq\ T}$ and $L_{Ceq\ T}$ levels, as well as the L_{Amax} level, at all four residences are given in Table 4. The analyses of measurements indicate that the daytime measured noise and vibration data, both indoors and outdoors, included contributions of noise and vibration generated other than by train movements, such as activities of the residents and road traffic noise, etc. In order to exclude the contributions from noise sources other than those from the train movements, night-time noise data were used for the following analyses. These ranges therefore exclude measured levels that were affected by noise sources other than train noise.

Table 4. Typical to worst indoor noise levels from train pass-bys at four residences

Residence	Time	$L_{A\ max}$ dB	$L_{Aeq\ T}$ dB	$L_{Ceq\ T}$ dB	L_{Aeq} dB	L_{Ceq} dB
11 Woodspring Trail	Day	47-58	43-51	70-71	28-32	52-53
	Night				26-30	49-50
7 Pinewood Walk	Day	44-57	43-50	71-76	27-31	54-57
	Night				25-29	52-55
23 Pinewood Walk	Day	≤47	≤40	≤67	≤21	≤48
	Night				≤19	≤46
18 McLean Road	Day	44-58	42-50	71-76	27-31	54-57
	Night				25-29	52-55

Assuming that, on average, each train movement lasted for 1 minute, the range between a typical day and a worst day $L_{Aeq(night)}$, $L_{Aeq(day)}$, $L_{Ceq(Night)}$ and $L_{Ceq\ (day)}$ levels inside the lounge area of each of four residences can be calculated, given twelve train movements during the day and four at night, as shown in Table 4. The $L_{eq(day)}$ levels are calculated over a 16-hour period and the $L_{eq\ (night)}$ levels are calculated over an eight-hour period. The worst-case scenario is based on the assumption that the noise from each of the train movements was at the highest measured level.

The Western Australian Planning Commission State Planning Policy 5.4: *Road and Rail Transport Noise and Freight Considerations in Land Use Planning* (SPP 5.4) recommends both indoor and outdoor $L_{Aeq(Day)}$ and $L_{Aeq(Night)}$ noise levels for residential buildings planned alongside rail or major roads. Although SPP 5.4 does not apply to existing residences, including those along the rail track in Canning Vale, these recommended acceptable noise levels provide one method with which to assess the noise impacts on these four residences.

The typical ranges of the measured night-time outdoor $L_{Aeq\ T}$ and $L_{Ceq\ T}$ levels at all four residences are given in Table 5. Based on the same assumptions made above, the outdoor $L_{Aeq(night)}$, $L_{Aeq(day)}$, $L_{Ceq(Night)}$ and $L_{Ceq\ (day)}$ levels of each of the four residences between a typical day and a worst day can be estimated, and these results are also presented in Table 5.

Table 5. Typical to worst outdoor noise levels from train pass-bys at four residences

Residence	Time	$L_{Aeq\,T}$ range dB	$L_{Ceq\,T}$ range dB	L_{Aeq} range dB	L_{Ceq} range dB
11 Woodspring Trail	Day	61-71	84-85	47-52	65-66
	Night			45-50	63-64
7 Pinewood Walk	Day	63-75	83-85	50-56	64-66
	Night			48-54	62-64
23 Pinewood Walk	Day	~55	~73	36	54
	Night			34	52
18 McLean Road	Day	~71	~82	52	63
	Night			50	61

Though most of the noise limits for indoor are based on the L_{Aeq} (logarithmic average) level, it is generally accepted that the maximum noise level inside the residences also has an impact on the residents, in particular in terms of sleep disturbance. Jansen etc. (2003) studied the impacts of aircraft noise on residents, in terms of disturbance of sleep. They proposed a set of criteria for indoor aircraft noise to protect residents. These criteria are not only based on the maximum levels (L_{Amax}), but also the frequency of occurrence of the noise events. For a comparison purpose, the measured maximum indoor train noise levels and the frequency of the night-time train pass-by events are assessed against these indoor noise criteria, as shown in Table 6.

It can be seen from Table 6 that the indoor L_{Aeq} night time noise levels at all four residences are all below the acceptable indoor noise criterion specified by SPP5.4 and the threshold proposed by Jansen etc. Considering both the frequency of the train movements and the measured maximum indoor noise levels, the indoor rail noise at all four residences is also below the threshold for maximum noise levels proposed by Jansen etc. It should be noted that although the measured train noise levels inside these four residences may not necessarily be considered unacceptable, noise levels in the range listed in Table 4 are easily noticeable, and may sometimes cause community concerns.

Table 6. Assessment of night-time indoor noise impacts

Residences				#1	#2	#3	#4
Measured level	L_{Aeq} dB			**≤30**	≤29	≤19	≤29
Reference	Metric	Criteria					
Jansen	L_{Aeq} dB	Threshold	30 dB(A)	✓	✓	✓	✓
		Protection	35 dB(A)	✓	✓	✓	✓
		Critical	40 dB(A)	✓	✓	✓	✓
	L_{Amax} dB	Threshold	23×40dB(A)	✓	✓	✓	✓
		Protection	13×53dB(A)	✓	✓	✓	✓
		Critical	6×60dB(A)	✓	✓	✓	✓
SPP5.4	L_{Aeq} dB	Acceptable	35 dB(A)	✓	✓	✓	✓

World Health Organisation (WHO) in the Night Noise Guidelines for Europe (2009) (NNG) recommends an $L_{Aeq\,(night)}$ of 40 dB as the lowest observable adverse effect level (LOAEL) for outdoors to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. A night outdoor L_{eq} level of 55 dB(A) is also recommended as an interim target for those European countries where the LOAEL cannot be achieved in the short term for various reasons, and where policy-makers choose to adopt a stepwise approach.

Outdoor low-frequency noise problems and the establishment of low-frequency noise criteria for assessment have been recently studied by Broner (2011). The desirable $L_{Ceq(Night)}$ of 60 dB and a maximum $L_{Ceq(Night)}$ of 65 dB are proposed in that study. Outdoor rail noise levels at the four residences are assessed against these two criteria as well as the outdoor criteria under SPP5.4, and are presented in Table 7.

Table 7. Assessment of night-time outdoor noise impacts

Residences				#1	#2	#3	#4
Measured level	L_{Aeq} dB			45-50	48-54	34	50
	L_{Ceq} dB			63-64	62-64	55	61
Reference	Metric	Criteria					
WHO (NNG)	L_{Aeq} dB	**LOAEL**	**40 dB(A)**	×	×	✓	×
		Interim target	**55 dB(A)**	✓	✓	✓	✓
Broner	L_{Ceq} dB	**Desirable**	**60 dB(C)**	×	×	✓	×
		Maximum	**65 dB(C)**	✓	✓	✓	✓
SPP5.4	L_{Aeq} dB	**Target**	**50 dB(A)**	✓	×	✓	✓
		Limit	**55 dB(A)**	✓	✓	✓	✓

It can be seen from Table 7 that the night-time rail noise levels are below the target level specified by SPP5.4 at all of the residences, except for 7 Pinewood Walk (#2). In the worst case scenario, the outdoor rail noise level will exceed the target noise level at 7 Pinewood Walk by approximately 4 dB(A).

Table 7 also indicates that although the rail noise levels at all four residences are below the interim target level specified by WHO, exceedances over the LOAEL for outdoors are seen at three residences (#1, #2 and #4). The outdoor noise levels at these three residences also exceed the desirable criterion for low-frequency noise as proposed by Broner.

The first conclusion that can be drawn from the above assessment is that, at the residence at 23 Pinewood Walk (#3), the vibration levels and the A-weighted and C-weighted noise levels, both indoors and outdoors, meet all of the criteria. As this residence is located some 120m from the track, it may be concluded that the main issues with noise and vibration are likely to be contained within a distance of (say) 100m from the track.

At the three closer residences, all of which are within about 50m of the track, it can be concluded that a 'worst case' analysis of the A-weighted noise levels indicates $L_{Aeq(Night)}$ noise levels in the range 40-55dB(A), that is described thus in the WHO Night Noise Guidelines for Europe: "Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected."

The spectral analyses of the train noise indicate the presence of significant levels of low-frequency rail noise, especially inside the houses. The building fabric of a residential house may provide quite significant noise attenuation in the high frequency range, but not much attenuation at frequencies lower than 50 Hz. It can be seen in Fig 23 that the sound transmission loss of the house at 11 Woodspring Trail is mostly above 20 dB at frequencies higher than 50 Hz, but drops significantly at frequencies lower than 50 Hz, and even becomes negative at frequencies lower than 5 Hz. This implies that the low-frequency noise might be amplified following transmission from outdoor to indoor, leading to higher indoor low-frequency components.

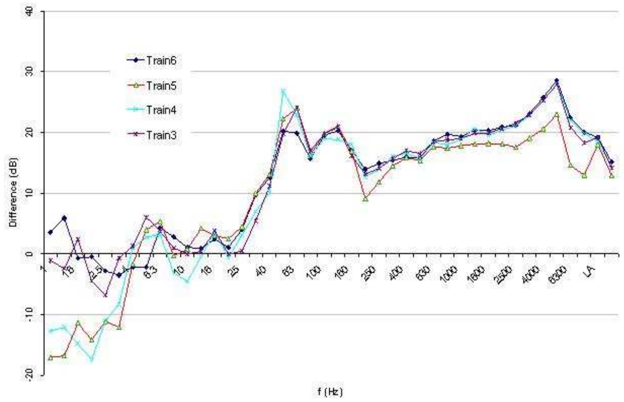

Figure 23. Differences between indoor and outdoor noise

The second stage study has confirmed that the findings obtained from the first stage investigation conducted at 11 Barraberry Retreat, Canning Vale between March and April 2009 are applicable to other residences, in that the low-frequency problem caused by the train movements does exist at all four residences participating in the second stage study.

The final issue is whether the results of this study can be used to identify appropriate ameliorative measures to reduce the indoor noise levels. The primary question here is whether the indoor low frequency noise is primarily ground-borne noise related to the vibration, or airborne noise entering through the building fabric.

Ground vibration may actuate lightweight building elements, causing noise to be re-radiated into the indoor spaces. This ‘regenerated noise’ can activate the low-frequency acoustic modes of the house, and thus contribute to the indoor low-frequency noise levels. Regenerated noise can be reduced by reducing the vibration energy transmitted into the house, through vibration isolation. The ground vibration results in this study indicate that the vibration level seems to be amplified when transmitted into the house, especially in the low-frequency range (10-20 Hz). This low-frequency vibration is well correlated with the indoor noise levels, that is, the spectral shape in the low frequencies is similar for both vibration and noise. Ground vibration cannot therefore be ruled out as a factor in the generation of internal low frequency levels.

The outdoor and indoor noise levels data in this study however indicate that, while the higher frequency noise is attenuated by the building, the lower frequency noise is present indoors at similar levels to those measured outdoors. While normal dwelling construction may be expected to provide some limited noise reduction at low frequencies, it can be seen from the measured data that there is a fairly good correlation between the indoor and outdoor noise levels at low frequencies (as there is between the indoor noise levels and the vibration levels), thus it is also difficult to rule out airborne noise.

From this study it is therefore not possible to conclude from the measured data whether the indoor low frequency noise levels are primarily the result of ground-borne or airborne noise, and hence to point to possible ameliorative measures.

RECOMMENDATIONS

Though the low-frequency noise, and by extension, infrasound, is currently not directly regulated in Western Australia, it has been reported that it can be a source of complaint. Because human hearing is relatively insensitive to low-frequency sound, the low-frequency noise may more readily be felt than heard, and hence easily be confused with vibration. Many countries, especially the European countries, have endeavoured to tackle the low-frequency problem and some have proposed regulatory criteria.

Based on the significant C-weighted indoor noise levels measured in this study, there is clearly a general low frequency problem in a number of houses in the Canning Vale area. The presence of complaints at these residences regarding train noise would suggest that the SPP5.4 criteria is incomplete and might also need to address low frequency noise from trains. It is recommended that this study be used to inform the two-year review of the SPP5.4 that is currently in progress.

Our studies found that higher ground vibration levels were generally measured inside the house than outside, especially at frequencies between 10 and 20 Hz. The vibration energy at this frequency range may contribute to the low-frequency noise problem inside the house. To tackle this low-frequency problem, it is important to understand how the noise and vibration are generated from the train movements and how they are transmitted from the rail track into the houses. For instance, it is important to know if the noise inside the house is airborne or structure-borne. This information will provide data to enable attenuation of low frequency noise, be it through attenuation of vibration via track isolation or the like or attenuation of airborne noise with barriers, insulation or possibly active noise control. It is recommended that a further study be undertaken to determine the contributions of the various noise pathways.

Another mechanism causing the low-frequency problem inside the house could be that the low-frequency acoustic modes of the rooms are activated by the rail noise or vibration. These acoustic modes depend on the shape and size of the rooms. A study of the train noise levels inside different rooms that have different size and shape may be able to verify this acoustic mode theory. A study of the effect of room modes may lead to attenuation of low frequency noise by specification of room sizes and shapes for residences in the vicinity of rail tracks. It is therefore recommended that a study be undertaken to investigate the effect of room modes.

It is anticipated that the next stage studies of the low-frequency problem caused by train movements will require substantial resources and effort, as well as the cooperation of the train operators. The DEC Noise Regulation Branch would be prepared to be involved or to coordinate a study group, if these further studies are conducted.

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