REPRESENTATIVE MONITORING OF ENVIRONMENTAL NOISE LEVELS FOR BS4142:2014

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1 ABSTRACT

The aim of this paper is to illustrate best practice in the monitoring of environmental noise levels from industrial sources as determined by the Environment Agency. BS4142:2014 makes regular mention of the requirement for 'representative monitoring'. This requirement is also mentioned in BS7445-1:2003 and BS7445-2:1991, and the IoA-IEMA "Guidelines for Noise Impact Assessment". Nevertheless, the requirement for representative monitoring is commonly overlooked by practitioners during environmental noise impact assessments. This paper will present noise monitoring examples from different industries. The data will be interpreted using modal analysis of discrete short periods and rolling hourly periods. The results of these different forms of analysis demonstrate whether a short or an hourly period can be considered representative of a longer monitoring period. It is concluded that for the industrial sources considered, monitoring periods exceeding an hour are required to sufficiently minimize the uncertainty to more than 50% of the data within ±1dBA.

2 INTRODUCTION

Previous work by the authors[1-5] has addressed best practice in the monitoring of environmental noise levels from industrial sources. The reason for this work is to provide practitioners with practical and technical advice and insight on environmental noise impact assessments as understood by the Environment Agency.

The aims of the Noise Policy Statement for England (NPSE) were discussed together with some less obvious and possibly surprising implications of the policy for industry regulated under an Environmental Permit administered by the Environment Agency[1,2]. Residential development near industrial noise emitters has been considered[3] and it was shown how the NPSE is consistent with consideration of Best Available Techniques (BAT) or appropriate measures under the EU's Industrial Emissions Directive (IED) and the UK's Environmental Permitting Regulations (EPR). Investigation and identification of noise sources where an environmental source has been found to be responsible for the low frequency noise complaint against regulated industries was considered[4].

More recently interest has developed in the notoriously contentious issues associated with the practical determination of representative background noise levels[5]. This paper continues this theme presenting noise monitoring examples from different industries. The data are interpreted and the results of the different forms of analysis used to examine the duration of monitoring required to perform a 'representative measurement' or various types of source. The work concludes with an international perspective on this approach and suggestions of areas for further study.

3 THE REQUIREMENTS OF BS4142

3.1 BS4142:1997

BS4142:1997 contained numerous requirements for environmental noise measurements to be representative. This included:

> *"6.3.8 Take the measurement of the specific noise level over a time interval, Tm, which reflects all significant temporal and level variations of the specific noise.*

NOTE. If the noise is steady, a short sample measurement will be sufficient. If it is cyclic or intermittent or varies randomly, a longer sample will be required to characterize it. It may be necessary to investigate the noise over relatively long periods to select an appropriate, representative measurement time interval."

"6.3.11 If the specific noise fluctuates at random, use the following procedure. Select the measurement time interval to give a reliable estimate of the equivalent continuous A-weighted sound pressure level over the reference time interval."

"7.1.2 Ensure that the measurement time interval is sufficient to obtain a representative value of the background noise level.

NOTE. The background noise level can often be significantly affected by meteorological conditions, particularly where the main background noise sources are remote from the assessment location. In such cases, it may be necessary to repeat the background noise measurements on a number of occasions to obtain a representative measurement sample. More than one assessment may be appropriate."

"7.1.3 Make measurements during periods when the background noise level is typical of the background noise when the specific noise source is or will be operating, but is not actually operating at the time of measurement."

3.2 BS4142:2014

The BS4142:2014 published draft follows the same pattern as BS4142:1997, and the requirement for monitoring to be representative is further developed:

"7.1 Ensure that all sample measurements are representative of the period of interest"

"7.3.5 The specific sound should as far as is practicable be representative of typical operating conditions"

"7.3.9: Ensure that the measurement time intervals are long enough to obtain representative values of the equivalent continuous A-weighted sound pressure level"

"7.3.10 Take the measurement of the specific sound level over a time interval, Tm, which reflects all significant temporal and level variations of the specific sound.

NOTE If the sound is steady, a short sample measurement is sufficient. If it is cyclic or intermittent or varies randomly, a longer sample is required to characterize it. It might be necessary to investigate the sound over relatively long periods to select an appropriate, representative measurement time interval."

"7.3.13 If the specific sound fluctuates at random, select the measurement time interval to give a reliable estimate of the equivalent continuous A-weighted sound pressure level over the reference time interval, measure the equivalent continuous A-weighted sound pressure level, LAeq,Tm, correct for the influence of residual sound and assign the result to the specific sound level."

"8.1 In using the background sound level in the method for rating and assessing industrial and commercial sound it is necessary to ensure that values are reliable and suitably represent both the particular circumstances and periods of interest. For this purpose, the objective is not to ascertain a lowest measurable background sound level, but rather to quantify what is typical during particular daytime, evening or night-time periods, or parts thereof."

"8.1.3 Ensure that the measurement time interval is sufficient to obtain a representative value of the background sound for the period of interest. This shall comprise continuous measurements of not less than 15 min intervals, which can be contiguous or disaggregated.

NOTE 1 To obtain a representative background sound level it is expected that a number of sequential or disaggregated measurements need to be carried out for the period(s) of interest, possibly on more than one occasion. A representative level should account for the range of background sound levels where there is variation of 1 dB or more and should not be assumed to be the lowest attainable value."

"8.1.4 The monitoring duration shall either reflect the full range of background sound levels or be able to target the most typical case. In practice, there is no "single" background sound level as the level varies throughout the day and throughout the year."

BS4142:2014 also includes a requirement to consider and minimize the uncertainty associated with the assessment.

4 PREVIOUS WORK

Craven and Kerry[6] present the following 'Estimation of Annual Indicators':

The table below compares sampling strategies for the estimation of annual indicators of road traffic noise (LAeq,24hr 10-year database). The figures clearly demonstrate:

• Increasing the length of the sample improves the quality of the estimate, however the improvement follows the rule of diminishing returns.
• A number of samples chosen at random will provide a more accurate estimate than one continuous sample of equal total length.

Sampling strategy	***Probability that sample is within 1 dB of the annual level***	***90% range***
1 day	*35%*	*10dB*
7 days continuous	*50%*	*6dB*
14 days continuous	*54%*	*5dB*
28 days continuous	*60%*	*4dB*
7 days random	*68%*	*3.6dB*
14 days random	*84%*	*2.2dB*
28 days random	*94%*	*<2dB*
2 weeks random	*64%*	*3.6dB*
3 weeks random	*74%*	*3.2dB*
4 weeks random	*76%*	*2.8dB*

This shows that for road traffic noise, a single 24 hour period has a 35% probability of being within ±1dB of the annual level. Industrial noise is generally more erratic than road traffic noise, and so may require a longer period in order to obtain a representative sample. It also shows that a random, discontinuous sampling strategy has a higher probability of being representative than the same duration of continuous monitoring.

Ng and Tang[7] assessed the accuracy of 'rolling' 30 minute periods at a progressive 1 second increments to estimate DEN, with a particular focus on traffic noise. This paper presented the table 'Statistics and estimation discrepancies for ∆NDs [difference in noise descriptors] using arbitrary chosen half-hour periods", a segment of which is replicated below in relation to LAeq:

	Mean	SD	Skew	Kurtosis	Median	Probability of discrepancy %				90% probability band (dB)
						1dB	2dB	3dB	5dB	
Day	3.1	3.0	2.3	7.1	2.1	22	50	66	83	7.0
Evening	1.9	1.6	1.6	3.0	1.6	32	69	82	93	4.4
Night	4.7	3.1	0.9	0.9	4.4	12	22	37	60	8.8

This indicates that a single 30-minute daytime LAeq has a 22% probability of being within 1dB, and that 90% of the data lay within 7.0dB.

5 METHODOLOGY

Two different methods of data analysis were employed. The first method was to analyze the modal distribution of discrete short period LAeq(t) during operating hours. Each short period, 5-15 minutes long, was rounded to the nearest integer and the distribution determined. This is not in strict accordance with BS4142 as each individual reference interval is not over a representative time interval. This method is the simplest, shows how erratic the noise source is over shorter periods, and shows the uncertainty associated with any short period measurement.

The second method was to analyze the same data using the modal distribution of rolling 1 hour LAeq periods (for example, 0800-0900, 0815-0915 etc). This method better represents noise perception than discrete hourly periods (0800-0900, 0900-1000 etc), is in strict accordance with BS4142, and has the added benefit of not significantly reducing the size of the data set. This is the same method presented by Ng and Tang[7]. This method is the most complex, and shows the uncertainty associated with any single one hour measurement period.

The case studies were chosen to demonstrate a range of industry size, and were all in locations where the industry was isolated from other industrial or commercial noise sources that might otherwise influence the measurements.

6 CASE STUDIES

6.1 Industrial wood chipper

The first case study is of an industrial wood chipper handling approximately 75,000 TPA of waste and clean wood. The full monitoring duration was 2 weeks, at a receptor that was 100m from the dominant source. When active, the overall long period LAeq was found to be 51.3dB(A)$_{(LAeq,\ 66hrs).}$ Figure 1 shows the modal analysis of discrete 5 minute LAeq, and Figure 2 shows the same data as rolling 1 hour LAeq. The figures show the stacked modal analysis from each working day.

Figure 1 shows a modal peak of 52dB(A), with 42% if the data within ±1dB(A). This indicates that a single 5 minute LAeq would have a 42% chance of being within ±1dB of the most common 5 minute LAeq. Figure 2 shows the same modal peak of 52dB(A) when considering the rolling hourly periods, but with a tighter (leptokurtic) distribution, with 50% of the data within ±1dB(A).

Figure 1: Modal distribution of discrete 5 minute LAeq

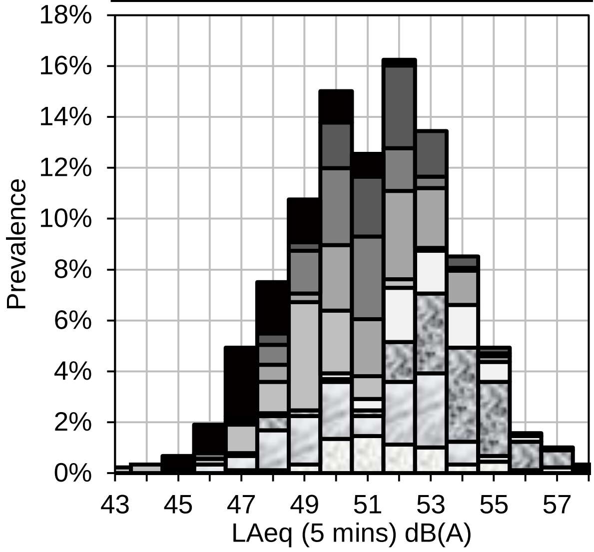
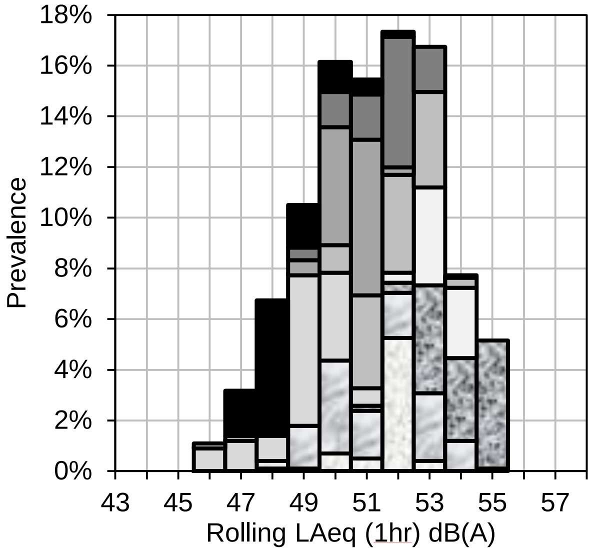


Figure 2: Modal distribution of rolling hourly LAeq



6.2 Landfill

The second case study is of an isolated landfill receiving 250,000TPA of mixed municipal waste. The monitoring period was 2 weeks long, at a residential location 20m from the site boundary. The overall long period LAeq was found to be 50.4dB(A)$_{(Leq,\ 108hrs).}$ Figure 3 shows the modal analysis of discrete 5 minute Leq, and Figure 4 shows the same data as rolling 1 hour Leq. The figures show the stacked modal analysis from each working day.

Figure 3: Modal distribution of discrete 5 minute LAeq

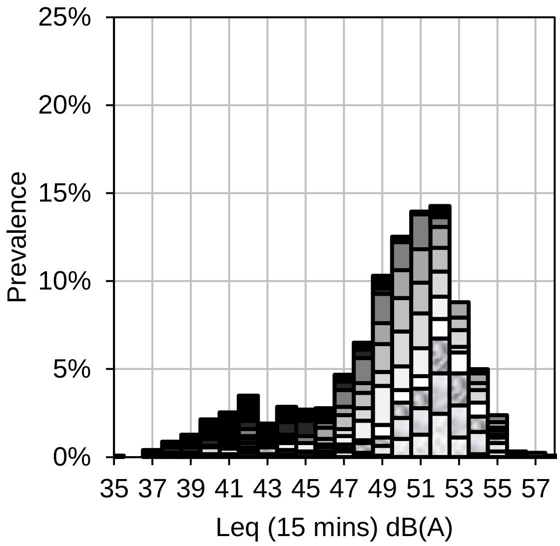


Figure 4: Modal distribution of rolling hourly LAeq

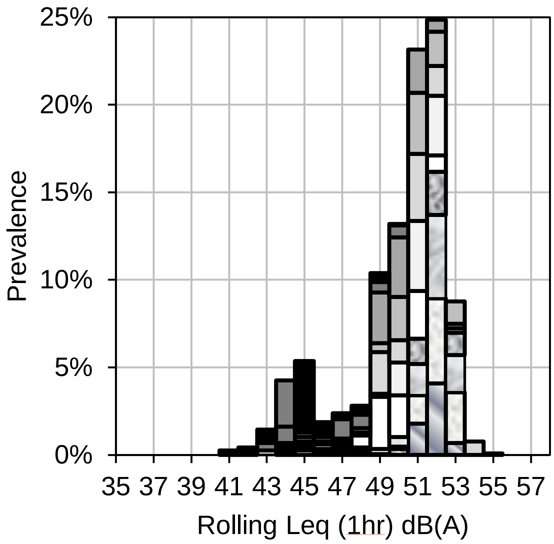


Figure 3 shows a modal peak of 52dB(A), with 37% if the data within ±1dB(A). Figure 4 shows the same modal peak of 52dB(A) when considering the rolling hourly periods, with 57% of the data within ±1dB(A).

6.3 Large Scrapyard

The third case study is of a large scrapyard receiving 40,000TPA of metal waste. The monitoring period was 2 weeks long at a non-sensitive location 20m from the dominant noise source. The overall long period LAeq was found to be 68.2dB(A)$_{(Leq,\ 63hrs).}$ Figure 5 shows the modal analysis of discrete 15 minute Leq, and Figure 6 shows the same data as rolling 1 hour Leq. The figures show the stacked modal analysis from each working day.

Figure 5: Modal distribution of discrete 5 minute LAeq

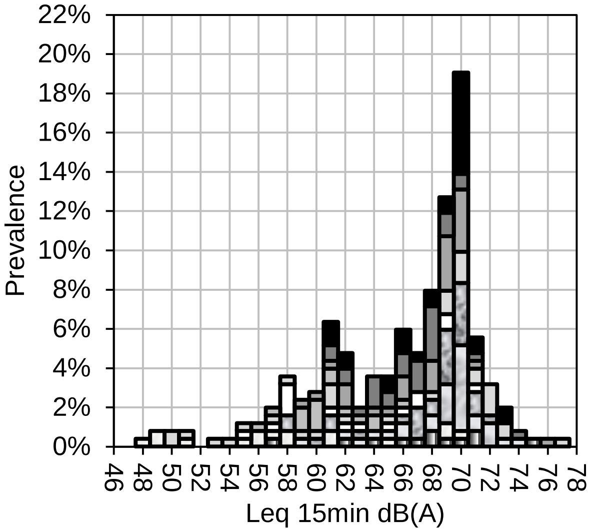


Figure 6: Modal distribution of rolling hourly LAeq

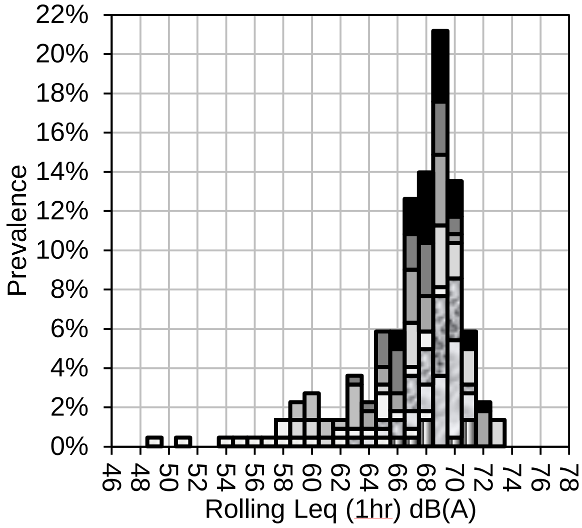


Figure 5 shows a modal peak of 70dB(A), with 37% if the data within ±1dB(A). Figure 6 shows a modal peak of 69dB(A) when considering the rolling hourly periods, with 49% of the data within ±1dB(A).

6.4 Small Scrapyard

The last case study is of a small scrapyard receiving 15,000TPA of metal waste. The monitoring period was 8 days long at a residential location 30m away. The overall long period LAeq was found to be 47.6dB(A)(Leq, 90hrs). Figure 7 shows the modal analysis of discrete 5 minute Leq, and Figure 8 shows the same data as rolling 1 hour Leq. The figures show the stacked modal analysis from each working day.

Figure 7 shows a modal peak of 45dB(A), with 25% if the data within ±1dB(A). Figure 8 shows a modal peak of 46dB(A) when considering the rolling hourly periods, with 44% of the data within ±1dB(A). Figure 8 shows a far tighter distribution than Figure 7, indicating a highly erratic noise source. Figure 8 also shows 2 days (in black and dark grey) clearly louder than the other days within the monitoring period.

Figure 7: Modal distribution of discrete 5 minute LAeq

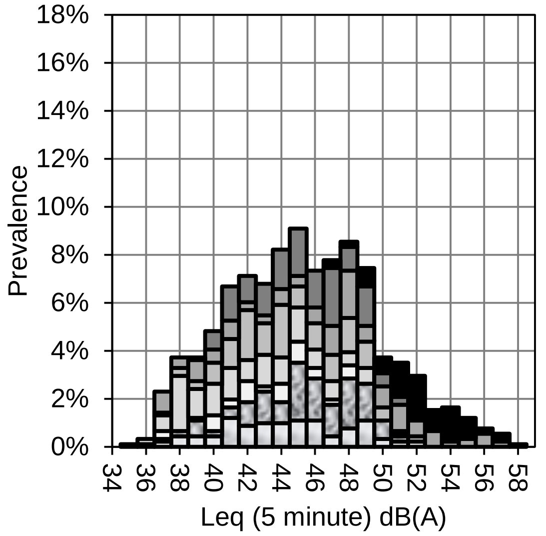
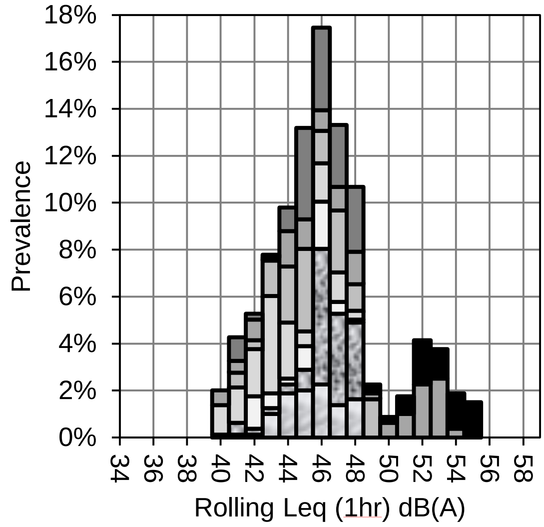


Figure 8: Modal distribution of rolling hourly LAeq



The data from all the case studies are summarized below:

Source	Ambient long period LAeq	Short LAeq (5-15mins)		Rolling LAeq(1hr)	
		±1dB%	Mode	±1dB%	Mode
Wood chipper	51.3dB(A)$_{(66\ hrs)}$	42%	52dB(A)	50%	52dB(A)
Landfill	50.4dB(A)$_{(108\ hrs)}$	37%	52dB(A)	57%	52dB(A)
Large scrapyard	68.2dB(A)$_{(63\ hrs)}$	37%	70dB(A)	49%	69dB(A)
Small scrapyard	47.6dB(A)$_{(90\ hrs)}$	25%	45dB(A)	44%	46dB(A)

7 DISCUSSION

When first encountering these results many practitioners are inclined to refute them. It is often argued that the time required to obtain a representative measurement is excessive and that the cost would not be borne by the client. However this view is not in line with current best practice, nor the current thinking behind the main European and International standards. It is considered best practice that any measurement should be accompanied by a quantitative indication of its quality, that is, the uncertainty of the measurement.

Alves[8] has examined methods for the estimation of the uncertainty associated with environmental acoustic noise measurements with respect to the working draft of the revision of ISO 1996-2:2007 “Acoustics - Description, measurement and assessment of environmental noise -Part 2: Determination of environmental noise levels”. The working draft ISO 1996-2:2011 (11-02-02 2nd working draft) follows the uncertainty calculation methodology recommended in the IMAGINE documents and specifically states that the estimation of measurement uncertainty should be reported. Alves performed the required calculations as two worked examples looking at road traffic noise and railway traffic noise. The worked examples are also analysed using the method detailed by Craven and Kerry[6] and the results according to both methods shown to be comparable. The results of this paper support the work of Alves in concluding that an estimate of the uncertainty of the measurement is essential, and that it is the role of the practitioner to understand their significance and the available methods for minimising the uncertainty associated with environmental noise level measurements.

8 CONCLUSIONS

The analysis showed that short period monitoring of between 5 minutes and 15 minutes had an average of only 35% of the data within ±1dB of the most common short period LAeq. The longer 1 hour periods averaged 50% of the data within ±1dB of the most common one hour period LAeq. In all cases the distribution spread (kurtosis) was narrower when considering rolling hourly LAeq. This demonstrates that the uncertainty associated with short period measurements is very high, particularly with erratic noise sources. The uncertainty associated with hourly periods is still substantial, and monitoring periods exceeding an hour would be required to sufficiently minimize the uncertainty to more than 50% of the data within ±1dBA. When comparing the data to previous work, this data spread exceeds that reported by both Craven & Kerry[6] and Ng & Tang[7]. This is likely to be because those studies used road traffic noise sources that were more stable than the industrial noise sources considered in this work.

9 REFERENCES

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