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Improving Environmental Noise Predictions

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ABSTRACT

In 2009 we embarked on a field study to ensure that the accuracy of our predictions of a future large scale industrial facility is improved on standard techniques. Noise propagation is significantly affected by prevailing meteorological conditions. Several standard modelling methods rely on measured meteorological data and estimation techniques. We decided to obtain realistic and actual noise level data including the effect of atmospheric conditions by conducting an experiment on sound propagation. Loud speakers were placed at a central location on a site, and used as an artificial sound source. A constant sound signal of a set of pure tones with varying sound intensity levels between each frequency is constantly producing sound at a fixed emission level for several hours at a time each night. The primary frequencies in the source signal were chosen to adequately simulate the main frequency range of machinery typical of the facility. The transmitter consists of a CD player with a CD containing the source noise, a power amplifier and four large loud speakers. The arrangement is powered by a petrol generator, all located in an open area. The sound was recorded by acoustic consultants at distant off-site locations, as well as at near-field positions to the speakers. There were three personnel conducting measurements simultaneously, each with a Type1 narrow band analyser. The operators collected random samples of at least 5-minute duration at various locations and times through each monitoring period. Meteorological data is continuously collected by three weather stations near by. Each narrow band sample was then analysed to filter the discrete pure tones from the ambient noise recorded. In the first instance the fluctuation of absolute source contribution at each monitoring site is quantified. The meteorological and noise data is correlated and analysed to quantify the effects of weather on noise propagation. These measurements are compared to predictive output from a detailed three-dimensional model. The comparison shows interesting divergence of results but with encouraging correlation in noise levels on average.

INTRODUCTION

The ability to accurately predict environmental noise for a new or expanding industrial facility is extremely important to the proponent, the community and regulators. This study is equally about this fact as it is about the science behind achieving this outcome.

From a proponent's perspective having the added assurance that predicted noise levels are as accurate as they can be means they are can make crucial financial decisions on the viability of a project with more confidence. For the community, the benefits are equally important providing them with the added assurance that noise levels predicted for their property and area are appropriately quantified. For example, overestimating noise impacts can unnecessarily sterilise an area for say residential development, and conversely underestimating noise impacts can result in serious conflict between adjoining land uses. Improving environmental noise predictions will also mean that the regulator can impose appropriate and achievable noise limits, which for sites in NSW, Australia, become legally binding once consent or licence is granted.

The influences on outdoor sound propagation are well documented, with the key factors being wind speed and direction, and temperature gradients. The noise impact assessment of industrial facilities in Australia is required to consider adverse weather conditions. Hence, accurately quantifying sound propagation for adverse weather conditions is critical. Noise modelling methods traditionally rely on measured meteorological data and estimation techniques. Given the uncertainty of modelling methods, it is extremely valuable to obtain realistic and site specific noise level propagation data, including the effects of atmospheric conditions. A case study presented herein does exactly that by conducting an experiment on sound propagation for a proposed expansion of a major industrial facility.

THE EXPERIMENTAL PROCEDURE

The procedure described below is one that is used to validate the tool (software in this case) that is used to model or predict noise, and not for correcting any inaccuracies with for example fluctuations in emission factors for various plant, how plant are operated or other such things at the control of operators. It is purely aimed at improving the predictions provided by a noise algorithm for situations of adverse weather conditions.

Noise Modelling

A commercially available modelling software was used that adopts the CONCAWE noise propagation algorithm. The following section relates to validation of the modelling software.

The software utilises weather parameters and intervening topography between the source and the receiver as part of its calculation procedure. Adverse source-to-receiver winds tend to create a substantial enhancement of noise at receivers. It is therefore prudent to investigate this phenomenon. The following are procedures that were used to validate the noise model and hence 'improve' the accuracy of the modelled results under adverse source-to-receiver wind conditions for this site.

Noise Source

An artificially generated noise source was set up at the location of a proposed industrial operation, which happened to be atop a relatively large ridge top. While the noise source is active, hand-held narrow band sound level analyser measurements were conducted to quantify the noise levels generated over various distances under varying weather conditions. The weather conditions were measured simultaneously with the noise measurements by three meteorological stations, one at the source position, another on a neighbouring ridge top and a third at the lower lying areas. A correlation of the data from all three weather stations confirmed that the use of data collected by the weather station near the source was suitable and representative of weather conditions more broadly across the area of interest. The weather stations sampled data continuously at 1-minute intervals.

The noise source consisted of four relatively large active speakers mounted 2m above the ground. The speakers were arranged in a semi-circular position facing westward. A CD player provided the input to the speakers and generated the signal containing pure tones comprising frequencies 100 Hz, 200 Hz, 400 Hz, 630 Hz, 800 Hz and 1000 Hz.

These pure tones enable measurements at distant locations possible and distinguishable from extraneous noise sources. Ambient noise in the area of the measurements was generally minimal, given that the monitoring was undertaken during the night time periods. This meant that the frequencies of interest, our pure tones, were readily identifiable. However, influence of background or ambient noise was subtracted on some occasions, dependent upon the strength of the received noise from the pure tones at the monitoring location.

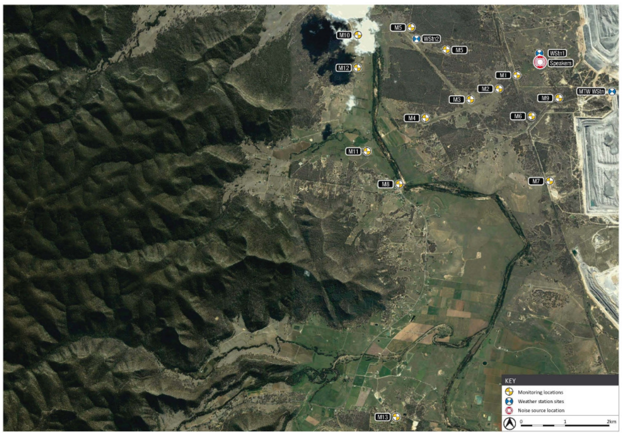
With the noise source active and stable, sound pressure level measurements were taken 15m from each speaker and at 360 degrees around the four speakers using narrow band sound level analysers (Type 1 as per Australian Standards). Data at these positions was used to establish the sound power level and directivity characteristics of the noise source. Refer to Figure 1 for the speaker arrangement.

Source: (Author, 2010)
Figure 1. Noise Source

Distant Measurements

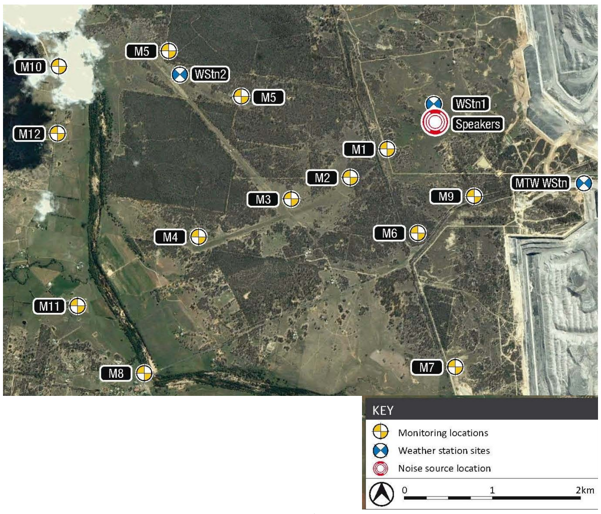
Noise measurements were conducted with hand held sound level analysers by three field operators throughout the quieter night time period between 9pm to 9am. All meters had their times synchronised with one another and with the meteorological station.

Typically, distant measurement locations ranged from less than 1km to just over 4km from the source, with lower frequencies audible and measurable at these distances, while noise at the higher frequencies was attenuated chiefly by air absorption. In the dead of night, the noise source tones were measurable and audible at a location as far away as approximately 8.5km from the sound source. Refer to Figure 2 (and Figure 2a, which is an enlargement of the main area of monitoring).



Source: (Author, 2010)

Figure 2. Noise Monitoring Locations



Source: (Author, 2010)

Figure 2a. Noise Monitoring Locations - Enlarged

The measurements were conducted over a period of 5 consecutive nights between 3 to 8 August (ie winter period) of 2009. The winter period was deliberately targeted for the experiment in order to maximise the potential for temperature inversions known to be prominent in the area of the site. Measurements were conducted generally between 9pm and 9am when winds are generally milder. A total of 13 different receiver locations were used for measurements over this period, with hundreds of samples collected and analysed.

Analysis of Results

Thousands of minute to minute meteorological weather conditions were modelled for the week of monitoring in order to correlate the hundreds of noise measurement samples against corresponding periods.

An example of the energy produced by the speakers at 15 m is demonstrated in Table 1.

Table 1. Typical 15m Source Noise Level, dB

Frequency, Hz	100	200	400	630	800	1000
Sound Level	102	91	86	81	86	84

Source: (Author, 2010)

The logic behind the analysis of the final sound data is as follows:

1. Determine the absolute total sound level for each pure tone. This was done by the log addition of three adjacent narrow band noise levels captured (eg adding noise levels at 99Hz, 100Hz and 101Hz), to account for 'leakage' of energy into adjacent bands. This was done for the close and distance field measurements, providing for a consistent approach.

2. Removing background noise. This was done by estimating the ambient background noise as the log addition of two narrow band values that are three values removed from centre frequency. For example, the 100Hz sound level from step 1 above is adjusted by subtracting the log addition of sound values at 98Hz and 102Hz.

3. The above steps are only possible on valid samples, which are defined by the subject tone sound level being at least 1dB higher than both narrow band values used in step 2 (ie the background level).

4. Synchronising of time on all measurement instruments was critical and was done at the beginning of the monitoring for all sound analysers and weather stations, and checked again at the end.

5. Modelling the conditions. Each 1 minute meteorological condition was modelled and a total received noise level at each measurement location was produced for each pure tone. The log average of a group of such predicted totals for a given location was used and compared against the corresponding log average of the measured values. The sound power level for each tone was obtained from the 15m measurements near the speakers and was checked at least once or twice each night and adjusted as appropriate.

6. Where measured noise samples were found to be contamination, the corresponding modelled value was discarded to ensure the analysis of modelled and measured data is comparable.

7. The field operator's measurement sheet was closely scrutinised for samples considered to be good or contaminated.

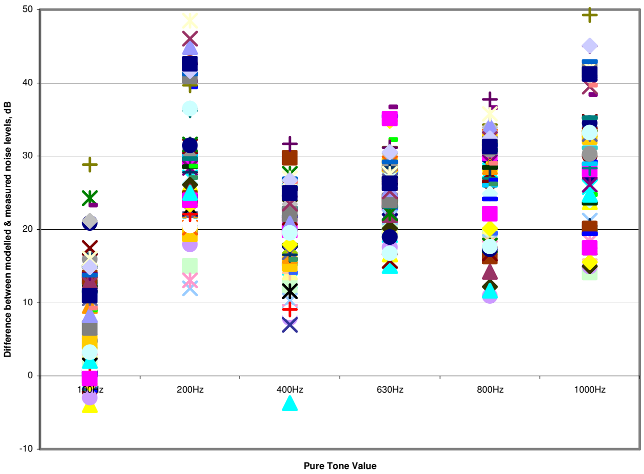
8. Typically 15 to 30 minute log averages of the noise measurements are used; but occasionally 3 to 4 minute averaging was used where measured data indicated strong correlation with the source tone.

9. The average measured result was subtracted from the average modelled noise level for each tone.

10. The numeric average of each tone's differential (modelled minus measured) is taken for each location individually and then altogether.

11. The end result is a correction at each tone. By applying this tone specific correction to the third-octave spectrum of a typical noise source (dump truck in this case), and only at the third-octave band centre frequency that corresponds to that tone alone, provides the resulting overall dBA correction factor. The correction factor is derived after log adding the third-octave spectrum before and after application of the individual tone corrections. A strong argument can be made to support applying the correction of each tone to neighbouring third-octave frequencies – resulting in an even larger overall dBA correction factor.

The resulting spread between modelled and measured noise levels for each individual tone is presented in Figure 3. This indicates an enormous disparity between the modelled and measured noise level for each tone in isolation. However, once this is applied as an average correction across a typical third-octave spectrum of say a dump truck as discussed earlier, the disparity is relatively modest as described later. The key finding from this data is the overwhelming trend shown in Figure 3 that indicates an overestimation of noise by the model at all tones tested.



Source: (Author, 2010)
Figure 3. Modelled vs Measured Noise by Tone

Result and Its Implications

The resulting validation factor for this experiment was an overestimation of 2 decibels overall by the model for adverse weather situations and for a source sound spectrum typical of a diesel engine. Whilst 2 decibels is a very modest and marginal value, and one that is equal to the human threshold of perceived change in noise levels, it can be very critical in certain situations. For the subject industrial operation an over estimation or change of 2 decibels corresponds to a substantial land take in areas that are typically 2km to 4km from the noise source. This means that the site's legally binding noise limits would apply and reach a much larger area that could include a significant quantity of private properties.

CONCLUSION

The importance of improving environmental noise predictions is paramount to our industry. The ramifications to both industry and to the community include economical and social impacts. Wherever possible and whenever the opportunity exists, diligent practitioners must embark on a form of field calibration or validation of their environmental predictive tools. This does not need to be an elaborate exercise as the one herein, but it could be as simple as taking one boundary noise reading for an industry and ensuring the predictive tool being used in the least can accurately calculate noise from site that is equal to that measured at the boundary. If we cannot calculate noise precisely at the boundary of a site, then we will have little hope for predicting beyond the site boundary and at more important noise sensitive receivers further away.

The experimental study herein indicates significant fluctuation of received sound level for a demonstrated relatively consistent sound source. This phenomenon is often simulated by weather conditions in modelling software. The results suggest the model marginally over predicts received noise during adverse weather. In the most, the results show that attempting to predict received noise using a single stable set of weather parameters is difficult due to complex atmospheric conditions between the source and receiver locations. It is much more sensible to look at average noise levels for weather averaged over an extended period in order to improve the reliability of predictions.

REFERENCES

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