Dearborn, Michigan
NOISE-CON 2008
2008 July 28-30

Assessing the prevalence of mining noise in a community using dichotomous correlation

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ABSTRACT

Correlation of surface mine noise with ambient sound in the community can be a difficult task due to the nonlinear nature of the relationship. That is, an increase in the sound generated at a mine does not necessarily result in one to one decibel increase in sound at a remote location. To overcome this problem, a dichotomous correlation technique was applied. In this technique, 1-second sound levels are recorded at the mine and in the neighborhood. Then, overall equivalent averages are calculated at each location. Each 1-second sample or 3 to 10-second moving average is compared to the equivalent average and assigned a +1 if it is above the average, 0 if it is equal to the average, and -1 if it is below. The unit +1/-1 binary data is then time matched and multiplied by the remote location binary data and summed. The result is divided by the total sample size to yield the percentage of time when the two stations are correlated. This method was applied to an operating crushed stone quarry and found to yield 0% to 25% correlation depending on the location and averaging time. Limitations and other nonparametric correlation techniques are also discussed

1. INTRODUCTION

The question of whether or how much noise from a source, such as a surface mine, is correlated to ambient noise monitored in an adjacent community is not straightforward.

First, sounds generated by the source change in frequency primarily due to diffraction and air absorption effects. Second, the delay in the sound as it travels from the source to receiver is dependent on the location of the source relative to the receiver. In a surface mine, this can be a large area of possible source locations. And thirdly, the level of sound measured at a receiver is not linearly proportional to the sound generated. For example, as the sound at the source increases, no change in sound level will be experienced at the receiver until the resulting source level is about 9 dB below the receiver background level. Afterwards, the increase in sound levels at the receiver is not linear, and depends on the relative difference between source and background sound levels. Finally, as the resulting source sound is above background levels, the increase will be more or less linear. That is, a 1 dB rise in source level results in a 1 dB rise in

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receiver levels. Even so, background sound levels constantly change, making an assessment even more difficult.

To address these problems, a so-called dichotomous correlation technique was developed to estimate the proportion of time sound levels from the source influence sound levels in the community. The advantage of this technique is that it is simple to use and eliminates the pitfalls mentioned above.

2. METHODOLOGY

A. Background

Figure 1 shows a scatter plot of a time-lagged (1 second) correlation between one-second sound pressure levels at the rim of a large crushed stone quarry and sound pressure levels at its southern property line. The lack of any distinguishable trend indicates that increased sound pressure levels from quarry activity in most cases are not associated with higher sound pressures at the property line monitoring station. This figure is a visual aid only and does not answer the question about statistical correlation alone.

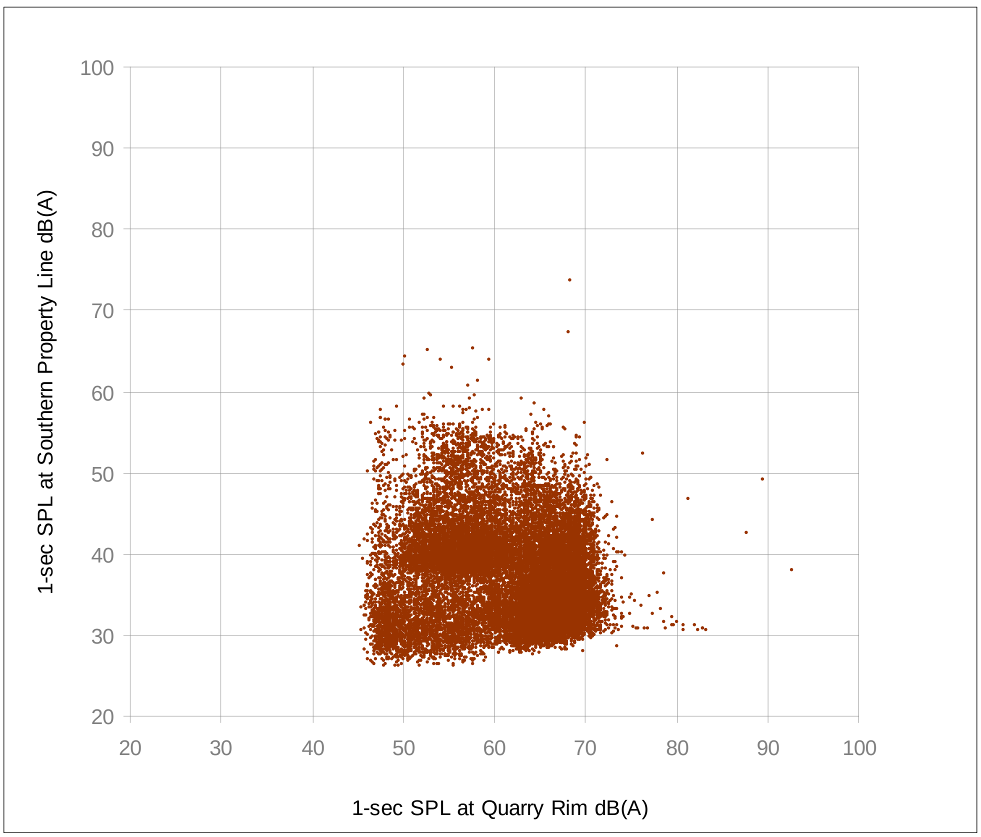

Figure 1: Plot of 1-second sound levels as measured at the Quarry Rim and at the Southern property line

While a simple regression could be used to "fit" a curve to this data, the results may not be meaningful due to the non-linear relationship between the level of the source noise and the level of the resulting ambient noise at a receiver. For example, say the quarry noise is 65 dBA and the boundary is registering 47 dBA. When the quarry noise drops to 60 dBA, the boundary monitor may stay at 47 dBA, since there are other sources of noise that control the dependent monitor (highway traffic, birds, etc). Because of this non-linear response, we developed an approach to understand correlation by evaluating the rises and falls of sound levels as they occur in both places.

B. Description of the method

To conduct a dichotomous correlation, 1-second sound levels must be conducted at the source and receiver. For a source such as a mine, the monitor should be located so as to be uninfluenced by any particular source. For example, a location on the quarry rim is ideal, so that it is capturing the overall sound generated by the quarry. The receiver sound level meter should be placed in a representative location. It can be near particular noise sources, if those sources are representative. For example, if homes are located near a roadway, then it would appropriate to place the sound level meter at a location that is as near to a roadway as are the homes.

After the monitoring period, which could range from a few hours to a few days, the average sound level (Leq) is calculated during the relevant periods when the source is in operation. Then each measured value is compared with the average. When a measured value is above its average, it is assigned a unit value of “+1”. When a value is below the average, it is assigned a “-1”, and when the value is equal to the average, a “0” is assigned. This is done for both the source monitor and the boundary monitor(s). Multiplying the source unit value with the boundary unit value yields the correlation product.

For example, if the quarry rim has an assigned value of 1 for some time s, and the property boundary has a value of -1 at time $s+t$, where t is the time it takes for sound to travel from the source to receiver, then the resulting value is -1 (+1 x -1 = -1). This means that the when the quarry monitor experienced an increase in sound levels over its Leq, the boundary monitor did not register a similar spike above its average and in fact registered a value below its average (negative correlation). If they were positively correlated, the product of the two values would be +1. This method is done over all seconds from time 0 to time t. The values are summed and divided by the sample size. This final value indicates the correlation ratio (or percentage). An example for a 20-second period is shown in Table 1.

The resulting ratio is a good indication of the proportion of time that the source influences sound levels at the receiver. If background noise levels at both source and receiver are randomly associated, then we would calculate a zero correlation. That is, the sound levels at the receiver are independent of source levels.

2. DEMONSTRATION

A. Experimental setup

To demonstrate this technique, we set up four sound level meters around a large crushed stone quarry. One sound level meter was located at the rim of the quarry. The other three were set up at the northern, southwestern, and southern property lines (Figure 2). Each meter was set to record 1-second Leq sound levels over a four hour period. A moving time average for each sound level meter was calculated to capture variations in the time for sound to travel from various parts of the quarry and slight timing errors in each sound level meter. A 3-second, 5-second, and 10-second moving average was used.

Table 2: Example of Dichotomous Correlation analysis for a 20-second sample

Source Monitor 1-sec Leq	Overall Leq at Source	Source Unit Coefficient	Property Line Monitor 1-sec Leq	Overall Leq at Property Line	Property Line Unit Coefficient	Multiplied Unit Coefficients
71.0	68.1	1	46.5	46.2	1	1
70.2	68.1	1	48.8	46.2	1	1
70.7	68.1	1	43.3	46.2	-1	-1
71.3	68.1	1	44.8	46.2	-1	-1
72.1	68.1	1	48.6	46.2	1	1
69.2	68.1	1	48.2	46.2	1	1
68.3	68.1	1	48.5	46.2	1	1
68.1	68.1	0	39.3	46.2	-1	0
67.2	68.1	-1	39.1	46.2	-1	1
66.2	68.1	-1	39.9	46.2	-1	1
77.8	68.1	1	43.1	46.2	-1	-1
72.0	68.1	1	40.1	46.2	-1	-1
67.0	68.1	-1	40.7	46.2	-1	1
65.0	68.1	-1	40.2	46.2	-1	1
65.0	68.1	-1	39.7	46.2	-1	1
66.2	68.1	-1	41.4	46.2	-1	1
70.4	68.1	1	42.9	46.2	-1	-1
69.9	68.1	1	42.9	46.2	-1	-1
72.0	68.1	1	43.7	46.2	-1	-1
73.1	68.1	1	43.0	46.2	-1	-1
					sum	3
					P	15%

B. Results

Results of the monitoring for the northern location are charted in Figures 3 and 4. Those graphs show a great deal of scatter and no obvious correlation. However, when the dichotomous correlation was calculated, as shown in Table 2, a 25% correlation was found. At the southwestern location a 7 to 8% correlation was found, and at the southern location, virtually no correlation was found.

The results were similar to our qualitative observations in the field. The northern monitor was located in an area near the project driveway that had much audible quarry activity, while the southwestern monitoring was only affected by crushing, and quarry activity was barely audible at the southern monitor.

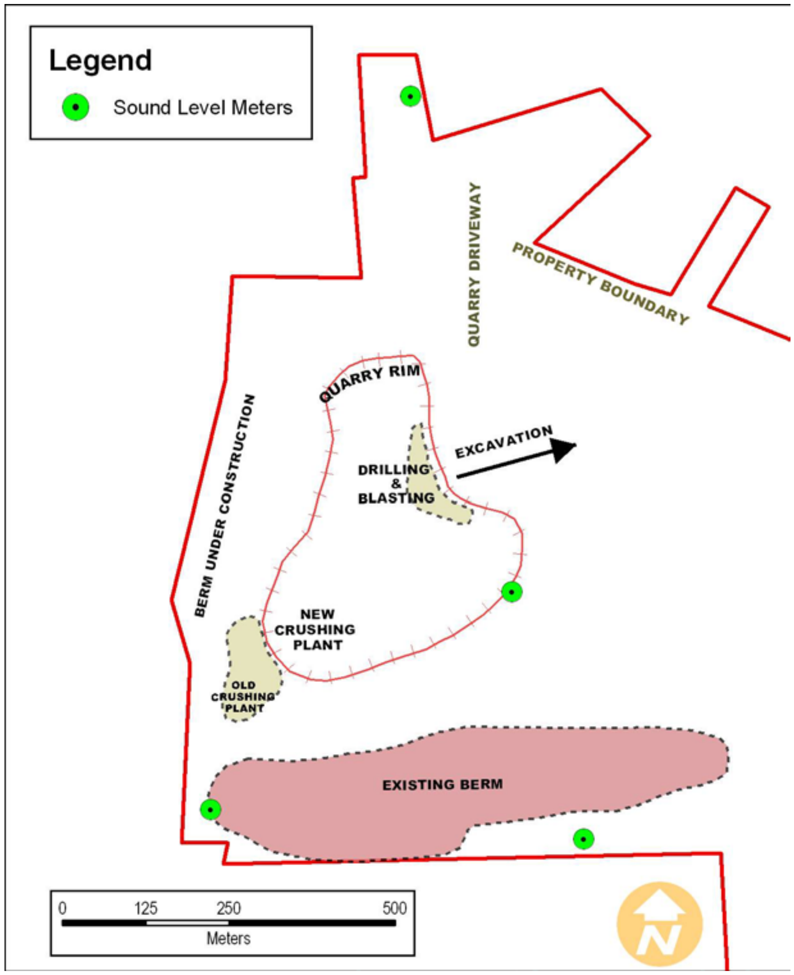

Figure 2: Site map showing the location of sound level monitors.

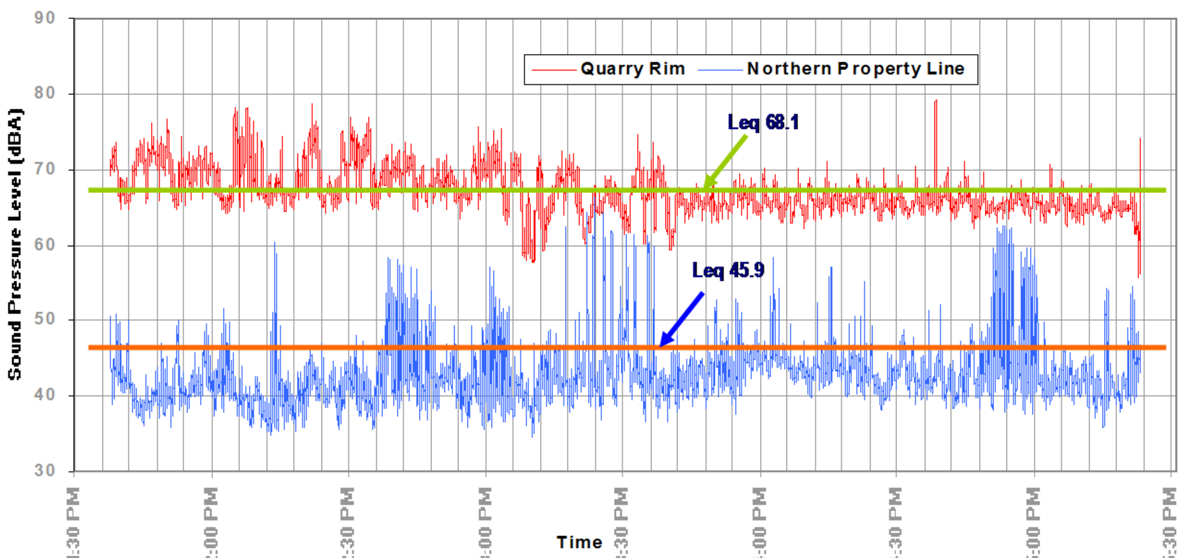

Figure 3: Chart of sound levels over time at the Northern monitor

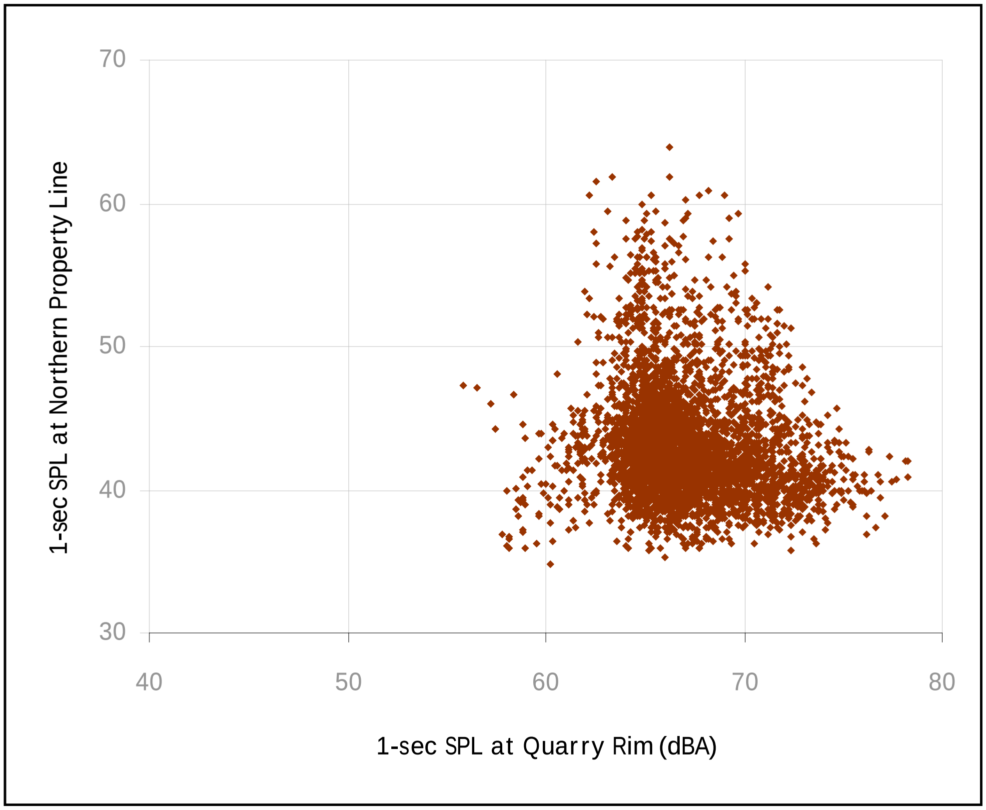

Figure 3: Scatterplot of 1-second sound levels at the Quarry Rim vs Northern monitor

Table 2: Results of dichotomous Correlation analysis for the monitoring stations

Monitoring Station	Averaging Period 3 second	5 second	10 second
Northern	25%	25%	24%
Southwestern	8%	7%	8%
Southern	0%	-3%	-5%

3. LIMITATIONS

Sound pressure levels can be distributed in a variety of ways. In instances when the receiver experiences abnormal sampling period or loud exogenous events are common, period-long Leqs could be problematic for correlation detection. For example, consider a receiver's Leq is elevated due to an abnormal number of exogenous loud events (e.g. residential hammering). Any real receiver SPL increase from surface mine noise may be detected but inappropriately assigned since its Leq was not exceeded. The choice of Leq (or other statistic, L50) to apply as the threshold can have important influence on the outcome. Shorter averaging periods (one-hour) need to be used if background sound levels change significantly during the study period. Our data presented adequate diagnostics to apply this technique but consideration is always advised. Depending on the averaging period available or nature of the underlying distribution, the long-term Leq may present a barrier to detecting important correlation events. If this is the case, other sampling-period statistics can be more appropriate.

Another challenge our approach presents is discerning actual causal source-receiver correlations from random correlation periods. For example, a loud period at the source could result in a corresponding SPL spike at the receiver (real correlation). Independently, source noise could rise but not initiate a rise at the receiver. By random chance, the receiver's background sound level could also be above its Leq at that instant (random correlation). Our method attempts to cancel this effect by assuming the probability of random positive-correlation events (1s) is equal to the probability of random negative-correlation events (-1s).

4. CONCLUSIONS

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The dichotomous correlation method can successfully be used to assess the prevalence of mining and other noise in surrounding communities. Our qualitative observations at the test site chosen for our analysis were confirmed by the correlation analysis. The methods used here can be adapted and adjusted for other sites, as appropriate.

Other statistical methods for estimating correlation and covariance can be applied to sound pressure data but are dependent on the question of interest and the influence of exogenous sources. Our purpose was to estimate the amount of time a property-line's SPL responded to changes in noise from an industrial site. We recommend other investigators develop a thorough understanding of the period's sampling distribution and influence that loud and quiet periods have on its Leq. Result sensitivity can be tested easily.

ACKNOWLEDGEMENTS

We thank SRM Aggregates for the use of their facilities, and Brian Fowler of Fowler Management Resources for his assistance.