SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING

UNIVERSITI SAINS MALAYSIA

ESTIMATING SOUND DISTRIBUTION WITH COMPARISON METEOROLOGICAL FACTOR USING STATISTICAL ANALYSIS AT QUARRY SITE

By

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Dissertation submitted in partial fulfillment
of the requirements for the degree of Bachelor of Engineering with Honours
(Mineral Resources Engineering)

Universiti Sains Malaysia

JUNE 2017

DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled "**Estimating Sound Distribution with Comparison Meteorological Factor using Statistical Analysis at Quarry Site**". I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or university.

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ACKNOWLEGDEMENTS

In the Name of Allah, Most Gracious, Most Merciful and Most Powerful

I would like to express my sincere appreciation to my supervisor, Dato Professor Dr Ir Eric K. H. Goh for the encouragement plus giving me the opportunity to conduct my thesis under his supervision, and having an utmost faith in me that I am capable to complete this thesis at my own pace in the required time. Not to forget, I and truly indebted to my Co-Supervisor, Dr Hj Izhar Abadi Bin Ibrahim Rais from Mineral Research Centre Ipoh, for his constant guidance and encouragement, which without them, this thesis could not have been possible. I am truly indebted for their unwavering support and grateful for their unconditional patience in guiding me.

I also would like to convey my gratefulness to all the staff in Mineral Research Centre, Ipoh and Mineral & Geoscience Department, Kelantan who has helped in many ways and give full cooperation towards successful completion of my thesis. There are so many challenges and knowledge learnt throughout the journey of this thesis.

A special thanks and heartfelt gratitude goes to my parents and family for their immensely unceasing support in term of financial, emotional and moral support. Their keen interest and encouragement were a great help throughout the course of this research work. Not to forget, I would like to express my utmost appreciation toward Saudari Nuramizah Bt Abd Rahim for willingly helped me out with her abilities throughout this research work and not forget to all my colleagues as well.

I humbly extend my thanks to all concerned person who co-operated with me, directly or indirectly toward the completion of this thesis.

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NIHL	Noise-Induced Hearing Loss
ANOVA	Analysis of Variance
PCA	Principal Component Analysis
MRA	Multiple Regression Analysis
SPSS	Statistical Package for the Social Sciences
dB	Decibel
SONAR	Sound Navigation and Ranging
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Act

ANGGARAN PENGEDARAN BUNYI BISING DENGAN PERBANDINGAN FAKTOR METEOROLOGI MENGGUNAKAN ANALISIS STATISTIK DI KAWASAN KUARI

ABSTRAK

Aras bunyi bising yang terhasil melalui mesin kejuruteraan meningkat seiring dengan peranan penting dalam penurunan pencemaran bunyi bising. Ia juga merupakan salah satu ikhtiar pihak kerajaan untuk menaik taraf kualiti kehidupan rakyat melalui kaedah mempertingkatkan kesedaran kepada masyarakat umum dengan penguatkuasaan undang-undang aras bunyi yang dibenarkan. Pertumbuhan perindustrian yang pantas terutama dalam bidang pengkuarian, yang juga merupakan salah satu faktor utama yang menyumbang pertumbuhan ekonomi negara. Oleh itu, langkah pelaksanaan harus diambil untuk mencapai tahap efektif kawalan penyebaran bunyi bising bagi memudahkan penyeliaan bunyi bising yang terhasil dari operasi aktiviti kuari ,terutamanya bunyi bising dari mesin penghancur. Terdapat beberapa kertas kerja berkaitan dengan hubungan bunyi bising dan meteorologi tetapi tidak banyak sumber atau informasi tentang model anggaran bunyi bising. Tesis ini bertujuan untuk menambahkan naratif dalam mengakses aras bunyi bising terhasil dari mesin penghancur dalam kawasan kuari dan sekaligus mengkaji kemungkinan faktor meteorologi yang mempengaruhi model anggaran bunyi bising. Sehubungan itu, untuk menciptakan formula empirikal dengan pendekatan kaedah statistik dan juga menentukan komponen utama untuk pembolehubah bebas. Justeru itu, model anggaran bunyi bising yang baru akan disahkan bertujuan untuk menjamin prestasi yang memberangsangkan, menyingkirkan input ketidakpastian dan sekaligus percanggahan model dalam erti kata untuk memeriksa perbezaan di antara model anggaran bunyi bising yang tercipta dan kajian kes sebenar.

ESTIMATING SOUND DISTRIBUTION OF WITH COMPARISON METEOROLOGICAL FACTOR USING STATISTICAL ANALYSIS AT QUARRY SITE

ABSTRACT

The noise level produced by engineering equipment is growing in importance with increasing emphasis on the reduction of noise pollution as parts of government effort to improve quality of life, by way of increasing public awareness and also through enforcement of noise level regulations. With the fast rate of industrialization especially for quarry industries which the major benefiting world economic contributor. Some implementation need to be taken in order to achieve an effective noise-control emission so that it can be used to supervise the daily noise exposure level yielding in the operating quarry conveniently especially noise generated by crusher. There are numbers of research work has been done on relationship between meteorological and sound level but there is not much information or resources on noise prediction model specifically. This study seeks to add growing narrative on accessing the sound level of crushing unit in quarry industries and simultaneously to study the possible meteorological factor influencing the noise prediction model. As well as to developed an empirical formula using the statistical approach and determine the principal component for the independent variables. The new prediction noise model is then verified for better performances, to eliminate any uncertainty input and model discrepancies which means to check the difference between the noise prediction model created and the real case study.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The quarrying sector is one of the key economics influential in any industrialized nation. Development of the country dependent strongly on the quarry industry as it plays vital role in fulfilling the demand and needs of the citizen or nation. The industry guarantees adequate and continuous supply of raw materials to the constructions, building and manufacturing sectors for the economic development of the country. Quarrying has been showing an enormous number of growth in Malaysia over the past recent years. According to the industrial mineral production statistics released by the Minerals and Geoscience Department Malaysia (JMG), aggregate production for 2014 stood up at 136,161,663 tonnes. The quarry count for the same year was 358 quarries, representing an 18.5% growth in the number of quarries in Malaysia as compared to 2011 (JMG, 2015). [Appendix A and Appendix B]

Beside than the remarkable role to the national development, there has always been division between the quarrying sector and the surrounding communities or simply public concerns due to the loud noises coming from the quarries itself. These concerns are often arises due to the noise pollution problems from quarry emission, giving rise to noise nuisance issues and health concerns. Noise pollution is greatly a serious global concern and there are few regulations standards established in order to tackle this problem.

According to the Department of Environment (DOE), placed under the jurisdiction of Ministry of Natural Resources and Environment Malaysia, has provide the noise acceptance criteria for quantitative assessment of noise to define disturbance or otherwise. (DOE,2007). This guidelines cover four certain objective which are : (1) specifying noise limits in the environment for the protection of the public from excessive noise ; (2) procedures on environmental noise measurement and impact assessment ; (3) noise parameters for the assessment of different noise sources ; and (4) noise abatement through planning and control. All the objectives in the guidelines standards are consistent with ISO 1996/1, BS 661 and BS 3015.

This study seeks to add growing theory knowledge on noise pollution due to quarry industry emission by coming up with a model to estimate the sound level yielded from quarry in Gua Musang, Kelantan. An innovative noise assessment approach via multivariate statistical analysis has been used to develop sound level estimation model to establish quantitatively the relationship between meteorological parameters and the sound level emitted from the quarry industries. The model on sound level prediction at quarry can be used for further upcoming quarry project or existing local quarry with the similar climatic and geological conditions.

1.2 Problem Statement

The noise issue has been a great concern for the people in the residential area that close to any blasting activities or processing plant as well as to the quarry industries. This project is focusing on noise issues happen in the main source of noise in quarry industries which is, from the crusher unit. Thus this thesis is aimed to access the sound level measurement and to the study the possible factor affecting the measurement. As there are question whether, the climate change, humidity and other possible factor could give an impact in the noise measurement.

Based on the papers and journal that has written, there could be a certain factor that would really influence the impact of noise measurement. For example, if the location of the dosimeter, the equipment used to measure the noise level, located at the crusher and during the measurement taken it was really hot or windy, would that kind of environment effecting the measurement. To test and conform which factor influences most is crucial in developing a formula for noise measurement calculation as the factor effecting would be the main key in the development formula. Beside that, to ensure the formula develop for the prediction sound level measurement calculation could be used by the quarry industries and to validate whether the formula that will be created is feasible to be used or not.

1.3 Research Objectives

This thesis aims to achieve several objectives:

1. To access the sound level of crushing unit in the quarry industries, study the possible factor effecting noise model measurement and analyze sound distribution of crushing activities using statistical analysis at quarry site.

2. To study and develop an empirical formula using the multivariate analyses for estimation prediction sound level measurement at quarry sites using principal component as the independent variables.

3. To externally validate the developed sound level prediction model formula for purpose of further usage.

1.4 Scope of Study

This research involved a detailed study carried out at Gua Musang, Kelantan. The data sampling location was taken at Kuari Dinar Sdn Bhd while the data for validation sound prediction model was taken at Kuari Damai Sdn Bhd which both located at Gua Musang, Kelantan. Multivariate statistical analysis was used to quantify empirically relationship of the effect meteorological factors on the sound level data set measurement around the quarry area and empirical equations were developed for the relationships. The statistical techniques applied were majorly principal component analysis (PCA) coupled with multiple regression analysis (MRA).

It is an unbiased method that shows the relations and associations between the samples and variables (Mencio and Mas-Pla, 2008). PCA is often used to identify the significant sources of air pollutant emissions which aims to: (1) extract the most important information from the data table; (2) compress the size of the data set by keeping only the important information extracted; (3) simplify the description of the data set; (4) analyze the structure of the observations and the variables (Abdi and Williams, 2010).

While on the other hand, Multiple Regression Analysis (MRA) utilizes the relationship between two or more quantitative variables to predict another variable that dependent on the rest. Both of the techniques were applied to build a prediction model for noise pollution emission in the quarry industry.

The data collected at Kuari Dinar Sdn Bhd on 1 April 2017 using the KIMO DB 200 Sound Level Meter, which is an acoustic measurement with main features of a conventional and integrating averaging sound level meter. The measurement of sound level dataset stores in DB 200 then transferred to a computer and processed through LBD200 software.

Multivariate analysis was used to undertake a detailed study of the data in order to achieve the research objectives. Meteorological data was used as independent variables to estimate sound levels, which was the dependent variables at the quarry site. The meteorological factors included in the final model were (1) wind speed; (2) wind speed; (3) pressure; (4) humidity; (5) solar radiation; (6) temperature; and (7) rain. Statistical analysis was conducted using IBM SPSS Statistics 13.0 software package. Validation of the model involved the use of a separate set of actual measured data of quarry site.

1.5 Thesis Outline

This research will cover five chapters which are introduction, literature review, methodology, results and discussion and lastly, conclusion and recommendation.

Chapter 1 which is introduction will explains on the research background of this thesis. Follow with Chapter 2, literature review on recent journal and information on the works regarding the topic discussed in this research project.

In Chapter 3, there will be a sequence of guidelines on how to engage this project from the early stages until the objective of this thesis is being achieved. Critically, the most crucial section is Chapter 4, which the content is explanation on results and discussion of this thesis. In this chapter will be the main key of this thesis, to prove whether the objective is achievable or the other way round.

Finally, the conclusion is being made regarding the result performance in this thesis and a few recommendations would be included for the future purposes in this Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Sound

2.1.1 Definition of Sound

Sound in the physiological sense, is result of pressure variations in the air which act on the surface of the eardrum. Sound is simply a vibration in an elastic medium with characteristic consist of definite frequency and intensity, longitudinal wave and require medium to travel. By bearing in mind that, sound cannot travel in vacuum. One of the senses of the human being is being able to hear sound within limited permissible frequency. In term of sequences movement, from the ear convert the pressure variations into electrical signal which interpreted by the brain as sound.

Main characteristic of sound are frequency and amplitude. Amplitude is a measure of heights of the sound wave from peak to valley which define the loudness or simply, intensity whilst frequency measure wave length to define the pitch of sound. Frequency is expressed in Hertz (Hz) and different frequency range yield belong to certain classification of sound which will be explained in the next point. Wavelength is the linear measurement of one full cycle of displacement where the motion of air molecules is first compressed and then rarefield or expanded (BRD,2014).

Decibel (dB) is a dimensionless unit calculated using the ratio of a measured value (p) to a reference value (BRD, 2014). There is confusion in the measurement of dB and dBA. It can be cleared off through available weighting scale which consists of A-Weighting scale, B-Weighting scale and C-Weighting scale.

These scale are used as a reference to different sensitivity scales for noise measurement and most commonly used is A-Weighting scale as it closely match with the limit loudness by the human ear. As for B-Weighting scale , for example like sound from loudspeaker, not feasible to use for industrial noise and C-Weighting scale is quite flat compared to other, it also perceive peak noise level and has high sensitivity of human ear at very high noise levels thus, commonly feasible for aircraft industries. As shown in the Figure 1.1 the standard weighting network according with frequency.

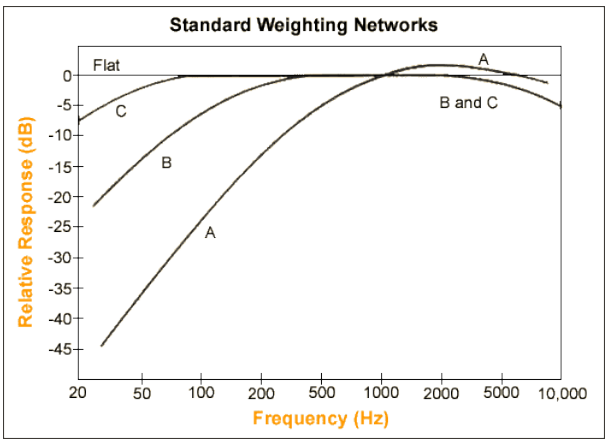

Figure 1.1 Standard weighting network in decibels according with frequency (By Courtesy USDL)

2.1.2 Classification of Sound

Sound can be categorized in frequency-based such as infrasound, audible sound and ultrasound. Each is separated by different range of frequency measured in unit of Hertz (Hz) according to the International System of Units as one cycle per second. Which, infrasound by $f < 20$ Hz, audible sound range by 20 Hz $< f <$ 20 kHZ and ultrasound by $f >$ 20kHz. Refer to Figure 1 that describe on the variation of the frequency in each type of sound yield.

Infrasound consist of frequencies below range human hearing and is sound that is not feasible for human beings and usually this only applies for animals such as whales communicate using infrasound over long distances, natural disasters for example, earthquakes generate infrasonic waves and through launching of nuclear or chemical explosions could install an infrasonic waves.

As for the audible sound which is sound that is transparent to human ear and the range frequency is within the human capabilities of hearing for example like sound from a bumble bee, mosquito ,alarm clock, vacuum cleaning, motorcycle and many others that range within the human hearing permissible frequencies. As for the ultrasound that have range of frequency above the human hearing capabilities for example sources like from medical ultrasonagraphy or simply an x-ray or sonograms of a human body, sound navigation and ranging (SONAR) that applies in fish finders and echo sounding.

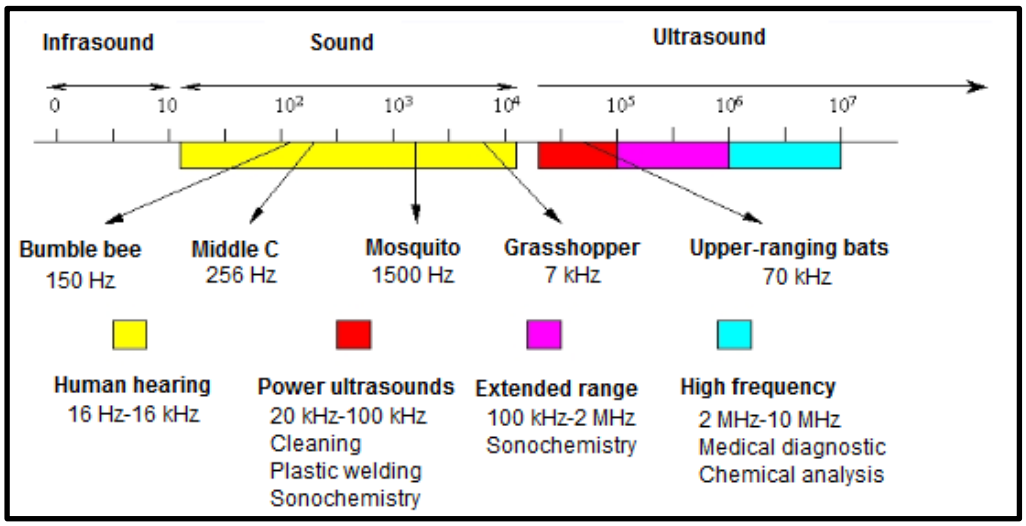

Figure 2.1 Sound classification based on the frequency (Boz.S,2005)

Properties of the sound fall into three important key which are pitch, loudness and timbre. Pitch is described as related to frequency of sound through vibrations. For example rapid vibration at sound source yield high pitch of sound, which unpleasant to hear. Next, loudness is related to intensity of sound as simple as, the increase in volume of sound, would increase the intensity of sound to the human ear receiver which is harmful if it is practices in continuous lifestyle or in working environment. Timbre is highly related to the quality of the sound which helps in distinguish between two sound having the same pitch and loudness.

2.2 Introduction to Noise

2.2.1 Definition of Noise

Sound and noise bring about the same definition but by considering the acoustic environment it could be differentiate. Noise is an unwanted or undesirable sound, or sound that happen at the wrong time and places that causes annoyance to human beings. It is only when the effects of sound are undesirable that it may be termed as noise (Singh,1989). By definition of noise from EPA (1972), stated that noise can also be defined as any sound that is undesirable because it interferes with speech and hearing, is intense enough to damage hearing or otherwise annoying.

2.2.2 Classification of Noise

Noise is a summation of unwanted or disturbing energy from natural and sometimes man-made sources (Kumar, 2012). Classification of noise could be divided into two type of noise which are external noises and internal noises. As for the external noise it could be categorized into atmospheric, extraterrestrial and man-made noise or simple an industrial noises.

An example of atmospheric noise is, caused by lighting through thunderstorms and releasing random electrical impulses in nature then, the energy is scattered in the frequency spectrum for communications purposes. While for extraterrestrial noise, for example solar noise that comes from the constant radiation of noise from the sun due to high temperature content it able to radiate electrical energy in the form of noise through wide frequency spectrum.

Man-made noise or simply industrial noise is yield by automobile, aircraft launching, heavy crushing machines, blasting activities, frequently heavy hauling transportation, air traffic, rail traffic, construction and other possible event that could create nuisance to the human ear. This thesis is aimed toward the industrial generated noises which fall into external noises.

2.3 Noise Occupational, Safety and Health Hazards

Environmental pollution issues has been the greatest concerns for this recent years as it lead to the negative impact on the natural world and the continuity of the health of the human beings Noise is an unwanted sound which may be hazardous to health, interfere with speech and verbal communications or is otherwise disturbing, irritating or annoying (BRD, 2017). The consequences of the over-exposure of noise is distinctively hazardous and should be avoided or spread more awareness on how critical noise effect toward human health. Figure 2.2 that show the structure of human ear.

Hearing depends on series of events that change sound waves in the air into electrical signals (NIH, 2014). Sound waves travel to the ear canal then eardrum, which send these vibrations to tiny bones in the middle ear called malleus, incus and

stapes. These bones then transfer the air to fluid vibrations in the cochlea then at the end of cochlea consist of basilar membrane where the key hearing structure placed.

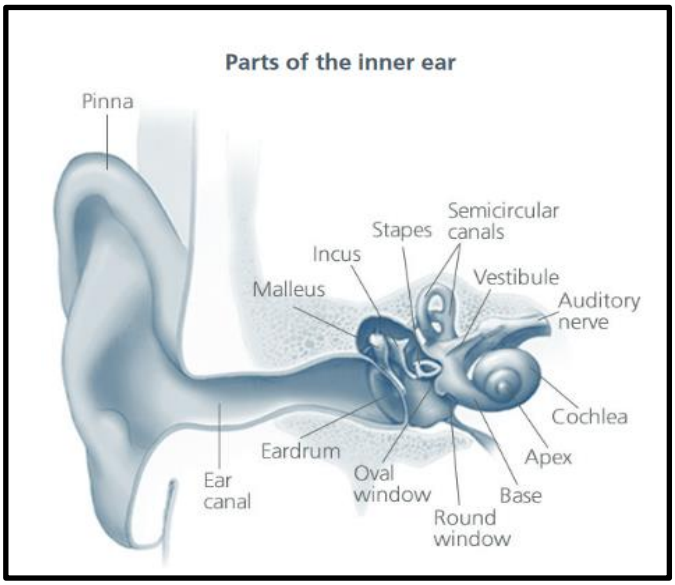

Figure 2.2 Structure of the human ear (NIH Arts, 2004

The hair cells inside the basilar membrane functions as sensory cells that convert to electric signal which then send to the brain for it to be recognize and understood. Noise-Induced Hearing Loss (NIHL) occurs when these hair cells is being damaged or rupture due to immense impulsive sound and most importantly, bearing in mind these hair cells do not have continuous growing characteristic. Once the hair cell is damaged, it is gone for good.

Noise could be into two type of noise exposure which are impulsive and continuous chronic noise. Both of them would give an adverse health affect to the human beings if it is beyond the limit control of human hearing capabilities. Impulsive noise is simply happen in the “one-time” impulse shorter duration, thus the sound appear as less loud but still physically damaging.

Beside that, the continuous chronic noise exposure would lead to a potential permanent hearing loss. Usually this scenario happen for a worker who works within the industrial activities especially those in the field of processing, field that needs to engage with electrical machines that involve vibration.

A daily routine with constant exposure of a loud sound, high vibration and high intensity is known as continuous chronic noise. A steady source of a loud sound would harm human ear severely if there is no prevention initiative taken.

Decibels are measured on a logarithmic scale which means that a small change in the number of decibels results in a huge chance in the amount of noise and the potential damage to a person's hearing (OSHA, 2013). NIHL can be immediate or it can take a long time to be noticeable and it can be either temporary or permanent (NIH, 2014).

Deafness is a preventable disease through a deep understanding of NIHL. Rather than a physical damage, noise pollution adversely has more psychological effect to the human being such as mental stress, anxiety, depression, speech interference, emotional instability, sexual impotence and neurosis. The World Health organization (WHO) estimates that 250 million people have hearing loss and two third of these people are living in developing countries (Babajide Charles Falemara, 2016).

Safety and health of the workers has been the main priorities for the every organization to be realistically aware, because it related to the efficiency of the manpower during the working hours. By ensuring a safe working area environment for the workers could benefit the organization positively.

Important factor that affects the working environment is noise which has directly or indirectly influence the worker health, safety and efficiency in workplace. Direct effects include hearing impairments and may also lead to complete hearing loss (Parsons,2000) either it could be a permanent or temporary effect.

The indirect effect are commonly annoyance, increased risk of accident (Ali,2011 ; Ekerbicer,2008) as it could be hard to hear within the quarry plant, emotionally instable and sleep disturbance. That noise could inflict potential damage on the ear was a claim that physicians had already made in the fifteenth century (Dembe , 1996).

2.4 Noise Standard and Legislations

Legislation enforcement is aimed to protect people from undue noise whilst enabling them to carry out business and social activities (EPA, 1997). Noise standard established under the act apply to any other noise generated within residential premises and noise levels measured in decibels (EPA 1997). Through law and legislation of Occupational Safety and Health Act, the workers must be provided with an adequate safety training, personal protection equipment (PPE) and awareness of possible incident and accident within the working hours.

The rationales behind the enactment of law and regulations are to protect the worker health and safety as well as it applies to public. It will eventually cause actual damage to hearing of workers due to over exposure at the workplace. Table 2.1 is the standard that has been set through law and legislation by the Department of Environment (DOE).

Table 2.1 Satisfactory Noise Level (DOE)

Area Category	Night Time	Day Time
Silent Zones (Hospital, Old Home, etc)	40 dB	50 dB
Residential Areas	45 dB	55 dB
Commercial Areas	60 dB	70 dB
Mixed Areas	50 dB	60 dB
Industrial Areas	70 dB	75 dB

There are few legislation aimed at setting acceptable standards in both areas which are National Institute Occupational Safety and Health (NIOSH) and Occupational Safety and Health (OSHA).

Both of the legislation is enacted to ensure that working men and women have safe and healthful working conditions. When the permissible noise exposure level has been exceeded, a feasible engineering control must be employed to decrease the sound level to within the permissible values.

Table 2.2 describe the permissible exposure time according to continuous sound level. Continuous exposure toward noise at working area need to have strict supervision from time to time so it could be really helpful if there is a noise prediction model created in order to access the noise level easily. As for Malaysia, every worker in the quarry industries is allowable to hear up to 85 dB per shift of 8hours/day.

Table 2.2 Decibel according to permissible exposure time (DOE)

Continuous dB	Permissible Exposure Time
85 dB	8 hours
88 dB	4 Hours
91 dB	2 Hours
94 dB	1 Hour
97 dB	30 minutes
100 dB	15 minutes
103 dB	7.5 minutes
106 dB	< 4 minutes
109 dB	< 2 minutes
112 dB	< 1 minutes
115 dB	< 30 second

2.5 Industrial Noise

Industrial noise sources are different from transport noise sources because of its constant presence at the same position. The environmental noise that will be discuss in this thesis in the broad of sense to encompass noise in the workplace specifically in the machinery in the quarry industries.

From the view of the quarry industrial prospect, the sources of noise that will be considered are surface transportation or traffic for hauling purposes, industrial equipment and the presence of the industry in the community or within the residence area.

This thesis aimed to create noise prediction model based on survey made on the crusher noise level yield daily. So it can be used by other quarry with the same meteorological factors in order to access the daily noise level yield from crusher processing.

2.5.1 Crusher

The mechanisms of noise generated depend on the particularly noisy operations and equipment including crushing, riveting, blasting in quarries and mines. (Samir N.Y Gerges.2002). Crusher is the main component of getting a raw product ready to be processed and send over to the processing plant. Crushing is known as the process operated by the crusher which also the first controlled size reduction stage in the aggregate production process plus preparation process for further size reduction. (Metso, 2015).

The main characteristic that should be taken account before crushing are size reduction and hardness. The harder the feeder input or raw material are, the higher the intensity sound produced from the crusher. It is also applies to the size of desired product, the smaller the size desired, the higher the tendency for continuous noise produced from the crusher. There are two type of crusher which are primary and secondary. Primary crusher are Jaw Crusher and Gyratory Crusher while secondary crusher is Cone Crusher.

There are two methods of crushing which are by compression and by impact. Both of them would give out the certain degree of intensity noise and vibrations. In general, vibrations that generate noise require control as it may resulting either one or mixed of these factors, pain or human discomfort and structure or mechanism failure. Based on the Figure 2.3 below, described the variety reading of

sound level, dB accordingly to the activities being done. For instance, normally for crusher control room would result approximately about within 70 to 80 dB.

The acoustic properties of any machine or piece of equipment producing sound defined in term four key parameters : type of sound source (Point, Line, Area), source height , total sound power produced by the source, spatial distribution of the sound radiation (directivity of the source).

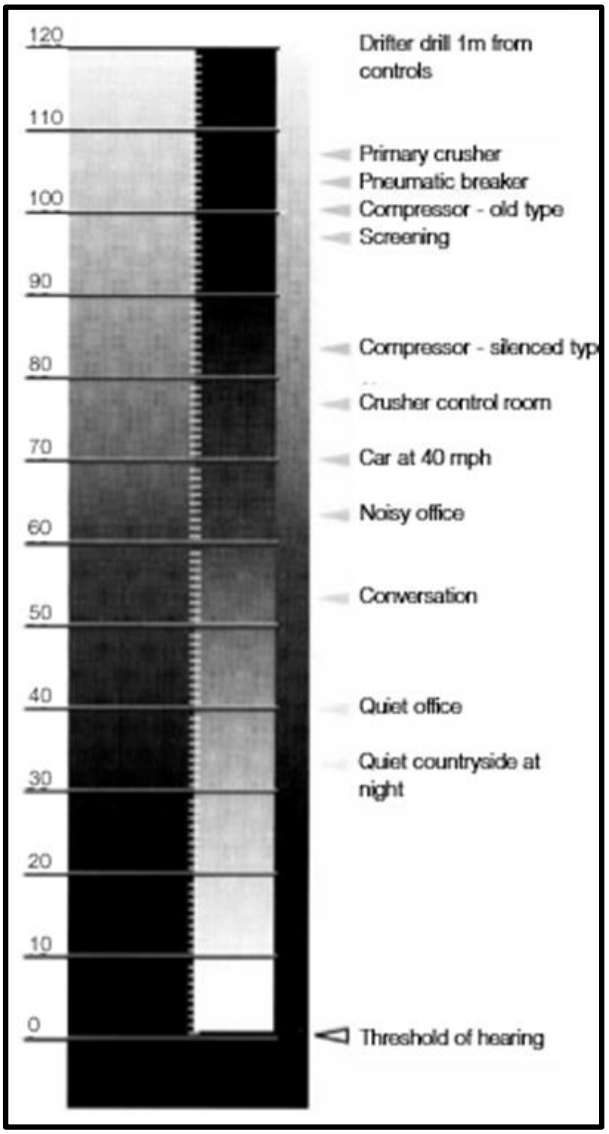

Figure 2.3 Decibel values accordingly in variety activities (Health and Safety Executive, 2015)

2.6 Noise Measurements

2.6.1 Basic Principle of Noise Measurements

Direct noise measurements, using establish techniques and specialized equipment and software are considered to be the most accurate option. (Gaetano Licitra, 2013). Basically in the first step, it is immensely important to figure out the type of sources environment measurement taken. Industrial sound sources are complex in terms of geometry, sound generating mechanism and radiation properties so it crucial to simplify the physical properties into a source model that realistically be handled in a calculation process (Licitra , 2013).

The environment condition is crucial and taken into account for development of noise prediction modeling, in order to ensure the accuracy and to eliminate any unpredictable error. Table 2.3 is the summary of conditions available for noise measurement. For this thesis it is, a semi reverberant conditions which a mixed of a free field conditions and reverberant field conditions.

Table 2.3 Summary condition environment for noise measurement

Conditions	Definition
Free Field	Completely open space where no sound reflections or other modifying factors present
Reverberant field	Sound energy at any point is the sum of that directly radiated from the source and sound levels reflected from the adjacent surfaces.
Full Reverberant	Sound energy striking the bounding surfaces is reflected without loss
Semi Reverberant	Prevailing conditions may be anywhere between free field and reverberant field conditions
Anechoic	All sound measured comes directly from the source , equivalent to taking measurements in an acoustically dead room where all in incident sound energy striking the walls fully absorbed
Semi-anechoic	The source is mounted above a hard reflective surface

2.7 Multivariate Data Analysis

The treatment of complex data sets using multivariate data analysis has been of high scientific interest over the last decade and is now commonly utilized in diverse fields of studies and application. The method is used for classification, modeling and interpretation of large data sets from environmental monitoring programs. Analysis via this method allows for the reduction of data dimensionality and information extraction (Dominick et al, 2012).

In order to identify the noise pollution sources, many sources apportionment models that apply multivariate analysis are often used, including : principal component analysis (PCA), multivariate linear regression (MLR), chemical mass balance (CMB), positive matrix factorization (PMF), multiple regression analysis (MRA), and cluster analysis (CA) (Izhar, 2012).

The function of multivariate analysis is to break down the data in order to detect and simplify into a model pattern for an easier approach to analyze. Multivariate data analysis can be divided into three main groups specifically (1) data description (explorative data structure modeling); (2) discrimination and classification; and (3) regression and prediction.

Data description deals with the determination of simple means and standard deviations., as well as correlations and functional regression models. Discrimination and classification refers to the separation of data groups, dividing a data matrix into two, or more groups of measurements. Regression and prediction on the other hand aims to relate two sets of variables to each other (Esbensen et al, 2002).

2.7.1 Principal Component Analysis (PCA)

Principal component analysis is a statistical approach that can be used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (Hair et al, 2006). Principal component analysis solves the problem of multicollinearity and transforms the original variables into new, uncorrelated variables called principal components.

Principal components are in essence linear combinations of the original variables which lie along the directions of the maximum variance. PCA provides information on the most meaningful and significant parameters while less significant parameters are excluded from the whole data set with a very minimal loss of the original information (Shrestha and Kazama, 2007).

The objectives of principal component analysis are to (Esbensen et al, 2002)

- extract the most important information from the data table;
- compress the size of the data set by keeping only the important information;
- simplify the description of the data set; and
- analyze the structure of the observations and the variables.

Pires et al (2008) further explained the role of PCA in creating new variables that are orthogonal and uncorrelated to each other. These principle components are linear combinations of the original variables. They are obtained in such a way that the first principal component explains the largest fraction of the original data variability.

Similarly, principal component two explains a smaller part of the variation of data compared to the first principal component. The same logic applies to the other principal components, with each subsequent component explaining lesser and lesser data variance.

In PCA, the factor loadings after rotation are used in the interpretation of the results as it is a reflection of how much a particular variable contributes to a particular principal component and also how similar two variables are to, one another. A higher factor loading means that the variable contributes to the explained variance more significantly in that particular principal component (Dominick et al, 2015).

2.7.2 Multiple Regression Analysis (MRA)

Multiple regression analysis is used to predict how the dependent variable will respond to change in the independent variables (Hair et al, 2006). MRA also provides information on how much a particular independent variable influences the dependent variable via a comparison of the coefficients of the independent variables (Dominick et al , 2005).

Before making any interpretation ,able to reason confidently ensure the multiple linear regression model yielded would provide a useful approximation to the actual relationship between dependent variable (Y) and independent variables (X_1, X_2, X_3 ...). There are three methods to evaluate how well a simple regression model fits the sample data namely regression standard error (s), coefficient of determination (R^2),and regression parameters (Pardoe,2012).

The R^2 value, or coefficient of determination is commonly utilized to evaluate model fit in MRA. For instance, if the value of R^2 is 0.75 ,it means that independent variables explained 75 percent of the possible variation in the dependent variable. Hence, the higher the value of R^2, the better the fit of the regression line to the observations (Izhar, 2012).

2.8 Multivariate Statistical Software Packages and Tools

Many multivariate statistical software packages are available in the market for research and data analysis. Some commonly used packages are SPSS, CRAN, SAS, R and S-Plus, Minitab and MATLAB. Each of these packages have their own strengths and weakness. These multivariate software packages and tools allow researchers to analyze, visualize and understand large and complex data sets swiftly and easily. The statistical package utilized for the treatment of data in this research is IBM SPSS Statistical Package.

2.8.1 IBM SPSS Statistics

SPSS is one of the most popular of the many statistical packages currently available for statistical analysis because of its easy-to-use graphical user interface. SPSS is being used in this thesis to build predictive models and conduct other analytic tasks. This software is able to leverage statistical and data algorithms without programming. Figure 2.4 below, shows the interface of the software. SPSS was initially an integrated system of computer programs designed for the analysis of social sciences data. Formerly known as “Statistical Package for the Social Sciences”, SPSS has moved beyond its initial market and is now widely used in many other fields. It is presently known as SPSS or IBM SPSS Statistics” in full. Table 2.4 shows the range of tools for analysis that are available in the base software.

Table 2.4 Statistical tools available in SPSS

Statistic	Tools for analysis
Descriptive	Cross tabulation, Frequencies, Descriptive, Explore, Descriptive Ratio Statistics
Bivariate	Means, t-test, ANOVA, Correlations (Bivariate, Partial Distances), Nonparametric tests
Predictive	Linear Regression, Factor Analysis, Cluster Analysis (Two-Step, K-Means, Hierarchical), Discriminant

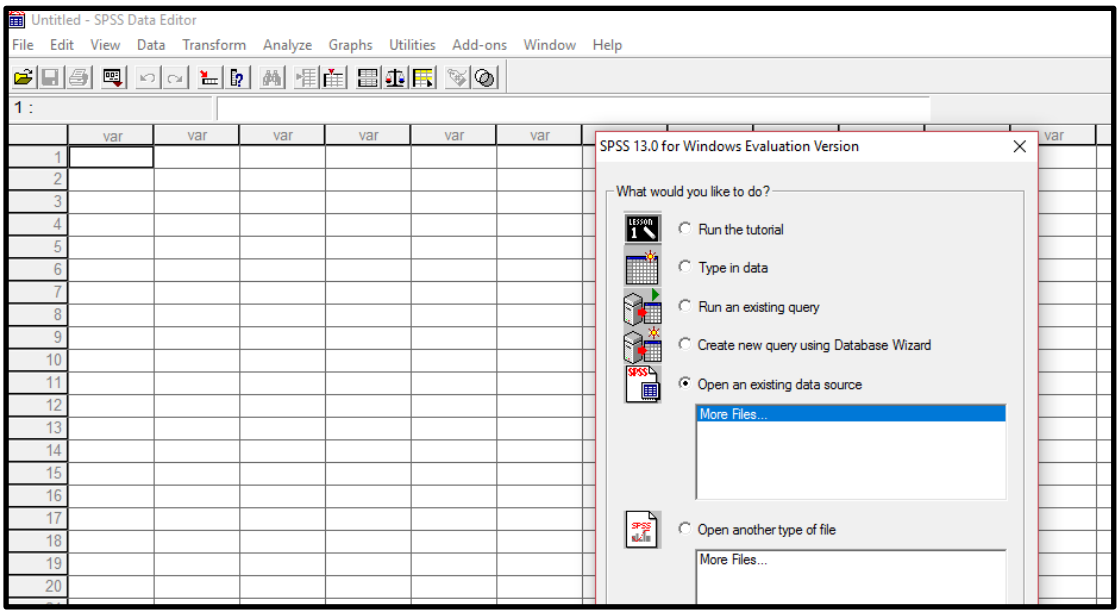

Figure 2.4 Interface SPSS Software Program