ALPHA FOUNDATION FOR THE IMPROVEMENT OF MINE SAFETY AND HEALTH

Final Technical Report

1.0 Cover Page

Project title: Assessing Noise Exposures, Hearing, and Risk of Injuries Among Miners

Grant number and title: AFC719-20

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Period of Performance: September 1, 2018 – May 31, 2020

Acknowledgement/Disclaimer: This study was sponsored by the Alpha Foundation for the Improvement of Mine Safety and Health, Inc. (ALPHA FOUNDATION). The views, opinions and recommendations express herein are solely those of the authors and do not imply any endorsement by the ALPHA FOUNDATION, its Directors and staff.

2.0 Executive Summary

According to the Bureau of Labor statistics in 2018, the injury rate across all private industries was 2.8 per 100 FTE and the fatality rate was 3.5 per 100,000 FTE. Compared to all private industries, the fatality rate in the mining, quarrying, and oil and gas extraction industry was almost 400% higher and the injury rate 50% lower (https://www.bls.gov/iif/oshcfoi1.htm#rates). Many factors may play a role in injury and fatality risk and they may vary substantially by industry. Mining has been labeled one of the noisiest industries, where 76% of miners are regularly exposed to hazardous noise [1]. Noise-induced hearing loss (NIHL) is highly prevalent in mining, with a prevalence of 27% in the industry [2,3]. Mining has one of the highest rates of usage of hearing protection devices (HPDs) with a rate of over 80% [1]. HPD use is necessary to protect hearing in high noise, but can hinder a worker's ability to communicate and hear directions and warning sounds and therefore may impact occupational nonfatal and fatal injury risk. NIHL may have a similar impact. Uniquely among industries, mining combines high noise exposure, high NIHL prevalence, high HPD use, and high fatality risk; therefore, it is important to understand how these characteristics interact and impact one another in mining in order to develop specific and contextually appropriate interventions.

To assess the role that noise exposure, NIHL, and HPD use have on nonfatal and fatal injury rates among miners we explored two specific aims. The first specific aim involved a retrospective analysis of injury and fatality rates among mines nation-wide and their association over time with noise exposure by Standard Industrial Classification (SIC) codes and Standard Occupational Classification (SOC) codes. Noise measurements from the research team's national quantitative Job Exposure Matrix (JEM) for noise (http://noisejem.sph.umich.edu/) were integrated with MSHA accident, injury, and fatality datasets (https://www.cdc.gov/niosh/mining/data/default.html) to test these relationships. The second specific aim was a prospective study that involved field visits to ten surface mines (e.g., lime, limestone, and sand/silica) in three Midwestern states to investigate the role of noise exposure, NIHL, and HPD use on reported and historical accidents, near-misses, and injuries in a current population.

The results of our national-level specific aim 1 activities indicated that occupational noise exposures were significantly associated with increased risk of nonfatal injuries in US mines, controlling for year, industry (via SIC code), and broad mine type (e.g., coal, metal, and nonmetal). Occupational noise exposures were also significantly associated with increased risk of fatal injury in US mines in a model controlling for year and mine type, as well as in a separate model controlling for year and occupation (via SOC code).

The results of our efforts related to specific aim 2 indicated that miners at the ten participating Midwest mining sites had high rates of hearing loss and HPD use, and high exposures to occupational noise. The vast majority of miners reported using earplugs, all workers achieved sufficient attenuation given their full-shift noise exposures, and most workers were overprotected (i.e., had personal attenuation ratings [PARs] in excess of what was required to reduce them below the relevant exposure limit). Reports of injuries and near-misses were rare within the past year, but nearly half of all workers had been injured during their career. While we developed a number of novel noise metrics, none were determined to be significantly associated with injury risk. We observed interactive effects of hearing loss and HPD use on achieved PAR, where workers with tinnitus and no hearing loss had significantly higher PARs, and workers with tinnitus and hearing loss had significantly lower PARs. We also found that age and speech reception threshold were significant factors for increased risk of hearing loss, and PAR was a significant protective factor for hearing loss. We identified a 3-way interaction of noise, hearing loss, and HPD use on near miss risk, where workers with no hearing loss, workshift noise >85 dBA, and reported use of HPDs had a significantly increased risk of reporting a work injury in the past year; Fatigue Severity Score, previous serious work injury, and safety perception were also associated with significantly higher risk of near miss in the past year. Finally, we identified an interactive effect between hearing loss and HPD use, wherein workers with no hearing loss and reported use of HPDs had a significantly increased risk of work injury in the past year; Fatigue Severity Score, previous serious injury at work, and safety perception were again associated with a significantly increased risk of work injury in the past year.

Together these results suggest that noise may be a significant independent risk factor for nonfatal and fatal occupational injuries when considered in conjunction with occupation, industry, and year, but that after controlling for use of HPDs, hearing status, fatigue, sleepiness, work experience, and perceived stress, the independent risk of noise on nonfatal injuries is no longer significant. The results also highlight the importance of ensuring that workers receive appropriate attenuation from their HPDs for their experienced noise exposure, and that this attenuation needs to be considered in light of their hearing status.

We have already begun dissemination of these results through conference presentations and manuscript preparation. We anticipate that our findings may have a large impact on hearing conservation and injury prevention programs in the mining industry, as they highlight the need to tailor HPD use to specific worker characteristics, including hearing ability and tinnitus, in order to reduce near-miss and injury risk.

2.1 Lay language summary

Workers in the mining industry face high rates of fatal injuries, high exposures to noise, and high rates of noise-induced hearing loss. They also have high rates of use of hearing protection devices (i.e., earplugs or earmuffs). Use of hearing protection is necessary to protect hearing in high noise, but can hinder a worker's ability to communicate and hear directions and warning sounds, and therefore may impact occupational nonfatal and fatal injury risk. Noise-induced hearing loss may have a similar impact. The aim of this study was to understand how noise exposure, noise-induced hearing loss, and use of hearing protection might influence the risk of workplace injuries among mining workers.

To achieve this goal, we used two different approaches. First, we used publicly-available information from the Mine Safety and Health Administration (MSHA), the National Institute for Occupational Safety and Health, the Bureau of Labor Statistics, and a national Job Exposure Matrix for noise to explore the effects of noise on fatal and nonfatal workplace injuries among all US miners between 1983 and 2018. Second, we completed field visits to ten surface mines in three Midwestern states in 2019 to investigate the role of noise exposure, noise-induced hearing loss, and hearing protector use on reported and historical accidents, near-misses, and injuries.

The results of our first research approach using publicly-available data showed that workplace noise was associated with increased risk of nonfatal injuries in US mines, accounting for calendar year, mining industry, and mine type (e.g., coal, metal, and nonmetal). Workplace noise was also associated with increased risk of fatal injury, accounting for year, mine type, and occupation. The results of our second research approach, using data collected from ten Midwestern mines, found that workers with tinnitus (ringing or buzzing in their ears) and no hearing loss received substantially more protection from their hearing protectors, and workers with tinnitus and hearing loss received substantially less protection. Workers with no hearing loss, noise exposures higher than the recommended 8-hour limit of 85 dBA, and who used hearing protectors had a substantially higher risk of reporting a work injury in the past year. Fatigue, having experienced an injury previously, and perceptions of safety on the job were also associated with substantially higher risk of almost experiencing an accident or injury in the past year.

The results of our study suggest that noise may be a significant risk factor for nonfatal and fatal occupational injuries, but that the risk of injury associated with noise is modified by use of hearing protection, hearing ability, fatigue, sleepiness, work experience, and perceived stress. The results also highlight the importance of ensuring that workers receive appropriate protection from their hearing protectors, and that the workers' hearing ability needs to be considered when assigning them hearing protection.

2.2 Glossary of terms

Abbreviation	Term	Definition
AI	Accident/illness/injury	Abbreviation for the accident, illness, and injury datasets compiled by NIOSH (https://www.cdc.gov/niosh/mining/data/default.html) and used for Specific Aim 1 to determine annual injury and fatality counts among mines
AIC	Akaike information criteria	Estimator of relative quality of statistical models for a given set of data. Lower numbers represent better model fit.
AL	Action level	Generally, an exposure level associated with a health or physical hazard. Specifically defined by MSHA and thus regulated as an 8-hour shift average of 85 dBA or greater that prompts the requirements for inclusion in a Hearing Conservation Program among regulated industries.
BLS	Bureau of Labor Statistics	A unit inside of the US Department of Labor and the primary agency to report on labor economics and statistics which was a resource for Specific Aim 1.
BMI	Body mass index	A measure of body fat based on height and weight (lbs/in^2).
CFOI	Census of Fatal Occupational Injuries	Annual reports developed by the BLS with data collected through the administration of the survey of Occupational Injuries and Illnesses (SOII). The report is generated by many different groupings and published on their website (https://www.bls.gov/iif/oshcfoi1.htm) and was used as a reference for Specific Aim 1.
CI	Confidence interval	The range of plausible values that applies to the associated effect estimate (OR, IR, IRR, etc.) and the confidence of 95% that the true effect lies within that range.
dB	decibels	The logarithmic presentation of measured sound pressure.

Abbreviation	Term	Definition
dBA	A-weighted decibels	The logarithmic presentation of measured sound pressure weighted to mimic how different frequencies are perceived by the human ear.
DI	Dispersion index	A measure of how varied the predicted probability is by different groupings (or within categorical variables) in a model.
ESS	Epworth Sleepiness Scale	A standardized scale to assess excessive daytime sleepiness.
FTE	Full time equivalent	The hours worked by one employee who is considered to be working full-time. For example, an annual FTE is considered to be 2,080 hours for 8 hours per day 5 days per week.
FSS	Fatigue Severity Scale	Standardized questionnaire used to evaluate fatigue differentially from clinical depression.
HL	Hearing loss	Generally, an increase in the hearing threshold level at any frequency compared to sometime prior. Mild hearing loss is generally recognized to be present when hearing threshold levels are ≥25 dB.
HPD	Hearing protection device	Personal protective equipment used to protect one's ears from noise exposure. They come in a variety of types but can be generally categorized as earplugs (e.g., foam or pre-molded) and earmuffs.
HTL	Hearing threshold level	The dB level at which one can hear a given frequency of noise. Typically determined by an Audiogram.
ID	Identifier	Specific number given to a mine to uniquely identify it.
IR	Incident rate	The rate at which an occurrence happens over a given unit, often time.
IRR	Incident rate ratio	The relative rate at which an occurrence happens over a given unit.
IQR	Interquartile range	A statistical measure of spread of a distribution. More specifically, the difference between the maximum and minimum values of the middle 50% of data.

Abbreviation	Term	Definition
JEM	Job Exposure Matrix	A collected set of data that estimates exposures for various job titles. Useful in research where measured noise is not obtainable.
JSS	Job Safety Score	The job safety section of the work safety scale used to evaluate various aspects of overall perceived work safety.
kHz	Kilohertz	A measure of the frequency of sound.
LL	Lower limit	The lower end of the confidence interval at 5%.
L_{AVG}	Average noise level	The average sound level measured over time using a 5 dB time-intensity exchange rate. For this study, LAVG was measured according to the MSHA Permissible Exposure Limit (PEL), with a 5 dB exchange rate, a threshold of 80 dBA, a criterion level of 90 dBA, slow response time, an upper limit of 140 dBA, and an allowable dose of 50%. This was used to determine the TWA_{MSHA}.
L_{EQ}	Equivalent noise level	The average sound level measured over time using a 3 dB time-intensity exchange rate. For this study, LAVG was measured according to the NIOSH Recommended Exposure Limit (REL), with a 3 dB exchange rate, a threshold of 80 dBA, a criterion level of 85 dBA, slow response time, an upper limit of 140 dBA, and an allowable dose of 100%. This was used to determine the TWA_{NIOSH}.
MDRS	MSHA Mine Data Retrieval System	Data system managed by MSHA that contains various items of mine related data, https://www.msha.gov/mine-data-retrieval-system.
MSHA	Mine Safety and Health Administration	Agency of the US Department of Labor that administers the Federal Mine Safety and Health Act of 1977 (Mine Act).
MV	Mines visited	This represents the historical data from the 10 Midwestern mines that were also visited for the prospective study in Specific Aim 2
N	Number	The number of observations used in each model.

Abbreviation	Term	Definition
NASA TLX	National Aeronautics and Space Administration task load index	A scale developed by NASA to quantify perceived workload.
NFDL	Nonfatal day lost	Nonfatal occupational injuries reported to MSHA that resulted in the loss of at least one day from the employee's scheduled work.
NIHL	Noise induced hearing loss	Generally, an increase in the hearing threshold level at any frequency of noise exposure compared to sometime prior. Specifically for this report, an average hearing threshold level ≥25 dB among the high frequency noise levels as measured by Fitcheck and/or an App based audiogram.
NIOSH	National Institute of Occupational Safety and Health	A non-regulatory agency within the US Centers for Disease Control and Prevention focused on research and recommendations for the prevention of work-related injuries and illnesses.
NM	Near miss	A self-reported incident in the last year that could have under slightly different circumstances resulted in injury ranging from mild to severe or even fatal.
NR	Not reported	A metric not reported by participants.
OR	Odds ratio	Measure of association between exposure and outcome in logistic regression.
PAR	Personal attenuation rating	The real-world individual measure of earplug attenuation (i.e., fit) using the Fitcheck Solo system.
PEL	Permissible Exposure Limit	Generally, a level exposure to a health or physical hazard that legally cannot be exceeded. Specifically defined by MSHA and thus regulated as an 8-hour shift average of 90 dBA or greater. Exposure must be reduced to at or below that level.
PSS	Perceived Stress Scale	A standardized scale used to quantify typical perceived stress over the past month.

Abbreviation	Term	Definition
REL	Recommended Exposure Limit	A non-regulatory recommendation of the level to health or physical hazard as defined by NIOSH. Specifically defined by NIOSH as an 8-hour shift average of 85 dBA or greater. Exposure should be reduced to at or below that level.
S&S	Significant and Substantial	Defined by MSHA as a violation that contributes a hazard that is reasonably likely to result in a serious injury or illness.
SD	Standard deviation	Statistical metric, often associated with a mean value that gives a measure of the deviation from the mean within a group.
SE	Standard error	A statistical measure of the accuracy of an estimate.
SIC	Standard Industrial Classification	A coding system used by federal agencies to classify industry areas in a consistent manner.
SNR	Signal to noise ratio	Generally, the ratio of the desired response to the stuff in the background. Specifically, this refers to the speech in noise test and represents the exact ratio of decibels of the spoken sentence to the decibels in the background noise.
SOC	Standard Occupational Classification	A coding system used by federal agencies to classify occupational areas in a consistent manner.
SRT	Speech recognition threshold	Metric quantified by the speech in noise test defined as the signal to noise ratio (SNR) where 50% of the words are correctly repeated by the participant.
TWA	Time weighted average	The average workplace exposure to a hazard normalized to 8 hours per day.
UL	Upper limit	The upper end of the confidence interval at 95%.
WI	Work injury	Self-reported injury in the last year. This is included minor cuts, scrapes, and bruises.

3.0 Problem Statement and Objective

Occupational Injuries

Fatal and non-fatal occupational injuries have a huge personal, medical, and economic burden in the US [4]. Even though fatal injuries are catastrophic, non-fatal injuries have an even greater impact when considered in terms of occurrence and cost [5]. Fatal and nonfatal occupational injuries were estimated to have an economic cost of $192 billion in 2007, greater than the economic cost of coronary heart disease ($151.6 billion), diabetes ($174 billion), or stroke ($62.7 billion) [5]. Across all private industries in 2018 the non-fatal injury rate was 2.8 per 100 FTE and the fatal injury rate was 3.5 per 100,000 FTE (https://www.bls.gov/web/osh/summ1_00.htm) and (https://www.bls.gov/news.release/pdf/cfoi.pdf). The mining, quarrying, and oil and gas extraction industry non-fatal injury rate was 1.4 per 100 FTE in 2018, lower than the all-industry rate (https://www.bls.gov/web/osh/summ1_00.htm), while the fatality rate was 14.1 per 100,000 FTE, significantly higher than the all-industry rate in 2018 (https://www.bls.gov/iif/oshcfoi1.htm#rates and https://www.bls.gov/web/osh/summ1_00.htm). The differences between non-fatal and fatal injuries in the mining industry compared to the overall private sector may indicate that unique factors impact occupational injury and/or fatality risk in the mining sector. Among miners, several injury risk factors have been identified by a handful of publications; gender, type of mine, work environment [6,7], smoking status [8], work activity [9,10], equipment used [11], and seniority [12]. Further research on occupational injury and fatality risk factors specific to the mining industry is necessary to develop targeted interventions aimed at reducing this risk.

Noise exposure is common in mining

Daily average noise exposures over 85 A-weighted decibels (dBA) has been shown to have auditory and non-auditory health effects, including noise induced hearing loss (NIHL) [13,14], sleep disturbance [15], hypertension [16–18], and heart disease [19–21]. In the US, mining is the industry with the highest prevalence of hazardous noise exposure, with one in four miners at risk [1]. Given the ubiquity of noise among miners and the range of negative health effects associated with this exposure, research is needed to guide future interventions in this industry.

Noise exposure may be a pathway to occupational injury

Studies in several industries have identified noise as a risk factor for occupational injuries [22–31] and a single study observed increased injuries among US coal miners with greater noise exposure [32]. The pathway(s) through which noise exposure effects injury risk are unclear. In other industrial settings, noise has been shown to increase stress [33], cause distraction or impede situational awareness [34,35], degrade performance [36], increase fatigue [37], and reduce the ability to hear critical sounds [38]. Two studies have associated long work hours and irregular/interrupted shifts with injury risk among miners [39,40]. Long, irregular hours likely increase fatigue, stress, and disruptions to performance and therefore may represent one pathway to injury. Much about this relationship remains understudied, particularly among miners.

Hearing loss may predispose to occupational injury

The mining industry has the highest prevalence of NIHL of any US industry (16.7% compared to 12.9% for all industries) [3]. A large proportion of miners have impaired communication and hearing due to both noise and NIHL or other types of hearing loss (HL) [38]. Associations between HL and injuries have been seen in various industries [22–30]. This association is unclear for the mining industry; one case-control study showed no effect of HL on injury risk [41]. Further research to understand how HL impacts injury risk in mining is needed given that HL is so prevalent in this industry.

Hearing protection devices (HPD) and occupational injuries

The rate of HPD use among miners is more than 80%, making it the US industry with the highest use proportion [1]. Although the use of HPDs in noisy environments is necessary to prevent NIHL, HPDs by design mimic or worsen high-frequency HL, and disrupt the user's ability to localize and understand speech [42]. This is particularly true when the noise exposure is high but not extreme and the HPD fit is good; this is referred to as "overprotection," wherein the wearer achieves more noise attenuation than is necessary or desirable. The hearing difficulty that results from overprotection may be a pathway for injuries [23,43]. Overprotected workers have reduced ability to hear or interpret speech and warning signals [44,45], especially during communication with other workers using HPDs [46]. Workers who wear HPDs and experience either temporary or permanent audiometric threshold shifts from noise (i.e., NIHL) may be further affected because of reduced signal detection ability [47]. Given the prevalence of noise and the propensity of miners to wear HPDs, it is important to better understand whether overprotection is common and if so, how it connects to injury risk.

Combined effects of noise exposure, HL, and HPD use on occupational injuries

A number of studies have demonstrated elevated risk of occupational injury in groups with high noise and HL [22,27,30,31,48], or found increased injury rates [31] among workers with HL who are using HPDs compared to those using HPDs with normal hearing. Hearing-impaired workers using HPDs may be at higher risk of injury in noise due to their doubly-reduced auditory abilities [45]. Unfortunately, none of the above studies were conducted among miners, and three-way interactions between noise, HL, and HPD use have yet to be explored in any industry. Given HL in the aging US mining workforce, the more than 16% of US miners who have NIHL [2,3], and the 76% of miners exposed to high noise [1] who utilize HPDs, research on these interactions in the mining industry is critical.

Therefore, the objective of our study is to evaluate the relationship between injuries and noise, HL, and HPD use among miners after adjusting for hazardous work as well as individual, organizational, and psychosocial factors known to be associated with injury and fatality risk. We have illustrated our conceptual framework of these relationships in **Figure 1**.

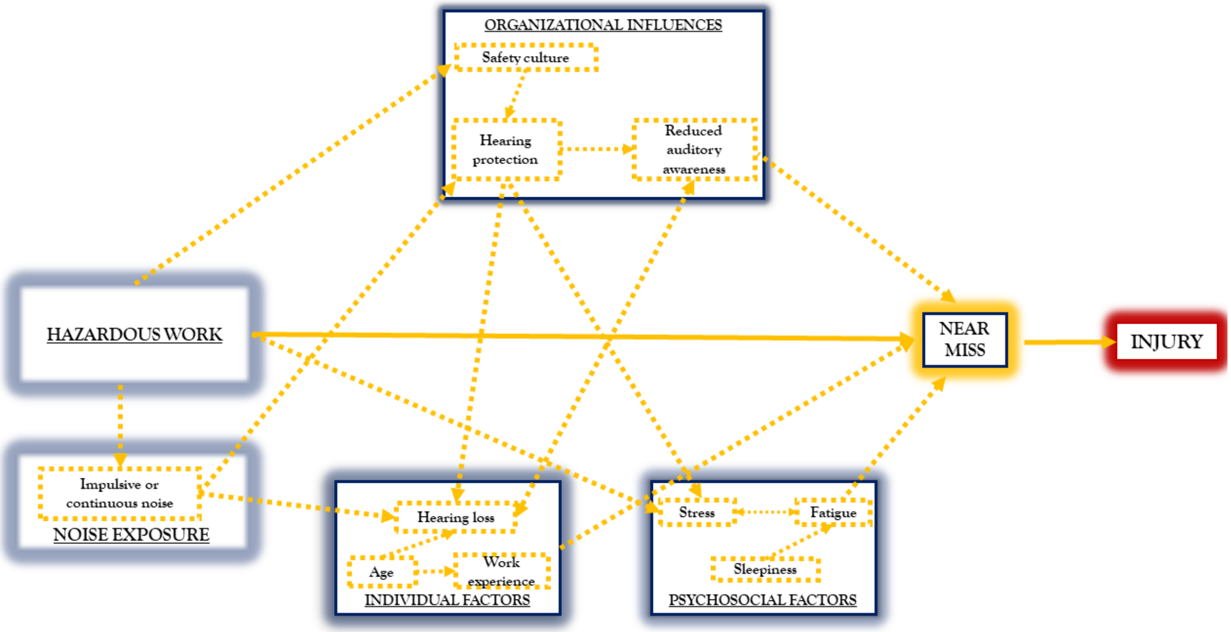

Figure 1. Conceptual framework of how hazardous work, noise exposure, organizational influences, individual factors, and psychosocial factors impact near-miss risk and ultimately injury risk among workers in general.

To achieve this objective, our study has two specific aims and two sub-aims:

Specific Aim 1: To retrospectively evaluate the risk of recordable injuries and fatalities associated with noise estimates made from a job-exposure matrix (JEM) by mine industry sector (as defined by the Standard Industrial Classification, SIC) and job title (as defined by the Standard Occupational Classification, SOC) from 1983 to current.

> **Sub-aim 1A:** To retrospectively evaluate the risk of recordable injuries, fatalities, and Significant and Substantial (S&S) violation rates per 100 inspection hour associated with noise measurements made by the Mine Safety and Health Administration (MSHA) for a subset of mines in Michigan, Illinois, and Ohio from 2000 to current.

Specific Aim 2: To prospectively evaluate the risk of nonfatal injuries, accidents, and near misses associated with measured noise, measured and self-reported NIHL, and robust and validated measures of HPD use.

> **Sub-aim 2A:** To explore novel noise metrics for application to injury risk assessment.

We proposed a number of activities to fulfill the objectives and specific aims. The methods and results of these activities are described below.

4.0 Research Approach

Due to challenges experienced early during the grant period the research approach changed substantially (as outlined in previous progress reports and approved by the Alpha Foundation) and subsequently some of the specific aims changed slightly as well.

4.1 Research Approach for Specific Aim 1

Data collection

Multiple resources were utilized to compile the most comprehensive datasets possible to address specific aim 1. We have illustrated our approaches to develop datasets focused on SIC data, SOC data, and data for the mines visited (MV) in this study. **Figure 2** shows how compilations were performed for each objective (i.e., each arrow in the flowchart), and the individual objectives and approaches used are described in **Table 1**. The detailed methods used to compile these comprehensive datasets are described below.

To assess national injuries and fatalities, we started with the publicly-available accident/illness/injury (AI) datasets among mines compiled by NIOSH (https://www.cdc.gov/niosh/mining/data/default.html). This resource yielded detailed information about each reported injury and/or fatalities for all mines, by mine ID number, in the US from 1983 to 2018. The data also included mine type (i.e., coal, metal, and nonmetal), mine industry (i.e., SIC), injury type and descriptive job titles. Five incident types were reported: NA (accident, no personal injury), NDL (injury with no days lost), NFDL (Non-fatal injuries with days lost), non-occupational fatality, and occupational fatality. We mirrored MSHA's own evaluation methods, and included only NFDL injuries and occupational fatalities reported among operators (i.e., excluding contractors) in our analyses. Job title was not standardized by any widely recognized method in this dataset; therefore, all unique job titles were manually assigned to the most specific 2010 SOC code possible. Given that the dataset was specific for the mining industry, any job title that was unclear or difficult to assign to a SOC code was assigned to miscellaneous extraction workers (i.e., SOC code 47-5090). From this dataset, annual NFDL injury and occupational fatality counts among operators were calculated by mine ID, mine type, SIC code, and minor SOC code group.

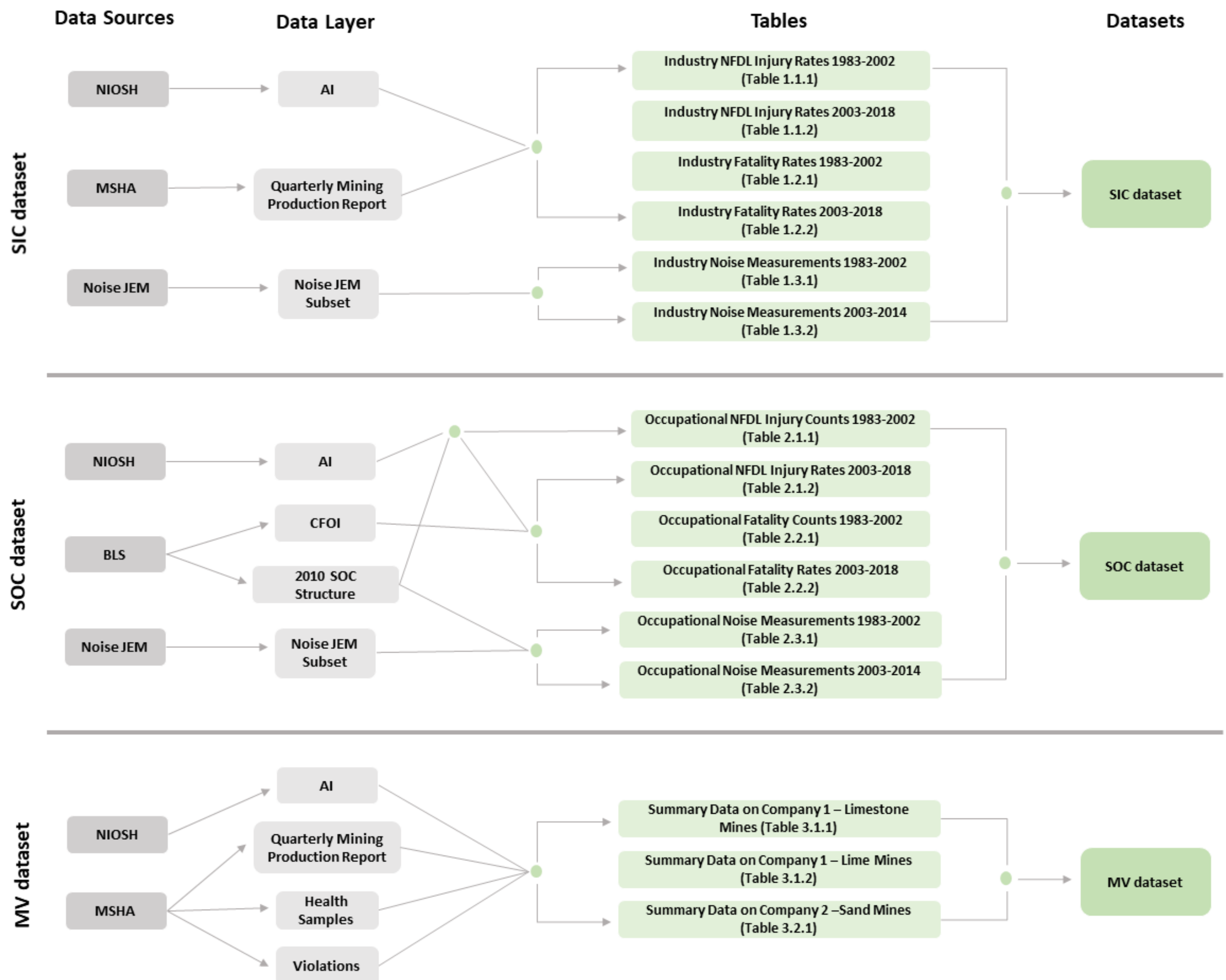

Figure 2. Flow-chart of data sources used to generate tables and datasets used for analysis of Aim 1. AI - accident/illness/injury; CFOI – Census of Fatal Occupational Injuries; NFDL – nonfatal injuries with days lost; JEM – Job Exposure Matrix; NIOSH – National Institute for Occupational Safety and Health; MSHA – Mine Safety and Health Administration; BLS – Bureau of Labor Statistics

In order to standardize NFDL injury and occupational fatality counts data (the only measures available for some years), a complementary dataset with total employees or employee hours was needed. We developed this using two separate datasets for the mine ID-level data and the job title category data, respectively.

Table 1. Objectives and approaches to data compilation in the development of the SIC, SOC, and MV datasets

	Objective	Approach
SIC dataset	Get annual NFDL injury and occupational fatality counts by SIC code from 1983-2018	Filtered NIOSH's AI dataset for NFDL injuries and occupational fatalities only. Generated annual counts by each mine ID. Annual counts per SIC code were also generated.
	Match annual total production hours by SIC code to calculate NFDL injury and occupational fatality rates from 1983-2018	Filtered the Quarterly Mining Production Report for mines contained within the AI dataset and generated annual total hours worked at each mine and annual total hours worked by SIC code. Matched the production hours with the NFDL injury and occupational fatality counts to calculate rates per 100 FTE. The absence of a reported NFDL injury or occupational fatality within a year was filled as 0 per 100 FTE by mine ID.
	Merge noise measurements with incident rate data from 1983-2014	Subset the Noise JEM annually by SIC code to match it with the merged AI dataset and Quarterly Mining Production Report.
SOC dataset	Get annual NFDL injury and occupational fatality counts per job title from 1983-2018	Filtered NIOSH's AI dataset for NFDL injuries and occupational fatalities only. Generated annual counts by unique job title.
	Assign a minor SOC code to each unique job title from within the AI dataset	Manually cross-matched each unique job title with minor SOC codes from the 2010 SOC Structure
	Merge annual total hours worked for each minor SOC code	Assigned minor SOC codes to job titles from 2003-2016 within the CFOI dataset using SOC codes from 2017 and 2018 already in the CFOI. Any job title matches which were not exact were then matched with the 2010 SOC Structure; the remaining were randomly assigned a minor SOC code. As a result, annual total employee populations (2003-2005) and annual total hours worked (in millions, 2006-2018) were summed by each unique minor SOC code.

	Objective	Approach
SOC dataset (cont.)	Calculate annual NFDL injury and occupational fatality rates from 2003-2018	From 1983-2002, annual NFDL injury and occupational fatality counts were used for each minor SOC code. From 2003-2005, annual NFDL injury and occupational fatality rates were calculated using the annual total employee population within a minor SOC code. From 2006-2018, annual NFDL injury and occupational fatality rates were calculated using annual total hours worked (in millions) by minor SOC code, normalized to 100,000 FTE. The absence of a reported NFDL injury or occupational fatality within a year was filled as 0 per 100,000 FTE by minor SOC code.
	Merge annual noise measurements from Noise JEM with each incident rate from 1983-2014 by minor SOC code	Subset the Noise JEM by each minor SOC code and year and matched with the incident rates calculated from the merged AI and CFOI datasets.
MV dataset	Get annual NFDL injury and occupational fatality counts for the 10 mines (visited for Aim 2) from 1983-2018	Filtered NIOSH's AI dataset for NFDL injuries and occupational fatalities only. Generated annual counts by unique mine ID.
	Match annual total production hours for each mine ID to calculate annual NFDL injury and occupational fatality rates from 1983-2018	Filtered the Quarterly Mining Production Report for the 10 mines (visited for Aim 2) and generated annual total hours worked at each mine. Merged the annual production hours with the annual NFDL injury and occupational fatality counts to calculate rates per 100 FTE. The absence of a reported NFDL injury or occupational fatality within a year was filled as 0 per 100 FTE by mine ID.
	Merge annual noise measurements of 80 and 90 dBA threshold dose for each mine ID from 2000-2018	Calculated the annual average dose at each noise level for each mine ID from MSHA's Health Samples dataset. These were then converted to annual TWA_{MSHA}, respectively, and matched to the annual incident rates by mine ID.
	Merge annual S&S rates of each mine ID from 2000-2018	Calculated annual S&S rates from MSHA's Violation dataset by summing S&S violation counts and dividing by total inspection hours by mine ID. This rate was then matched to the respective annual incident rates and noise measurements by mine ID.

Employee hours at the mine ID-level were based on data from the quarterly mining production reports from 1983 to 2018 which were downloaded from the MSHA Open Government Data site in January 2020 (https://arlweb.msha.gov/OpenGovernmentData/OGIMSHA.asp). These data are no longer available at that website as of May 2020, but can now be found at a Department of Labor developer website (https://developer.dol.gov/health-and-safety/) as .json files. This MSHA dataset lists the quarterly total hours worked by operators (i.e., excluding contractors) by mine ID. Total yearly hours for each mine ID were calculated and linked to the AI dataset by mine ID. Any mine ID that existed in the MSHA quarterly mining production reports was kept so as to include their hours worked in the overall calculations since the NIOSH AI dataset only included incident reports of injuries or fatalities. Annual NFDL injury and occupational fatality rates were then calculated by mine ID, SIC code, and mine type.

Total yearly hours by SOC code were difficult to determine for all included years because job classifications and reporting methods have changed substantially over time. For the years 1992 to 2018 we downloaded the Census of Fatal Occupational Injuries (CFOI) fatality rates created by the Bureau of Labor Statistics (https://www.bls.gov/iif/oshcfoi1.htm). For each year, total fatalities and fatality rates within each occupation were reported. Prior to 2006, these reports used total number of employees (in thousands) to create fatality rates. Beginning in 2006, rates were reported as counts per total hours worked in millions by occupation category. Only CFOI tables from 2017 and 2018 list occupation category with corresponding SOC codes; therefore, each occupation category from years prior to 2017 with identical string matches was linked to the SOC code presented in 2017 and 2018. For those that were not identically matched to the SOC code within the CFOI for 2017 and 2018, we applied the 2010 SOC code structure (https://www.bls.gov/soc/2010/#materials). Remaining unmatched occupation categories for CFOI post-2003 were manual assigned to 2010 SOC codes. Once the match was complete we used the reported total employee count or total employee hours worked to calculate NFDL injury and occupational fatality rates for each SOC code in the NIOSH AI dataset. However, these structured matching methods were not always feasible (i.e. multiple minor SOC codes were classified together) for CFOI data prior to 2003; therefore, only counts could be achieved for each SOC code in the NIOSH AI dataset prior to 2003.

To determine if there was an association between NFDL injuries and/or occupational fatalities and noise exposures by mine type, SIC code, and/or SOC code, we then connected the calculated rates with a Job Exposure Matrix (JEM) for occupational noise in the US (http://noisejem.sph.umich.edu/) [49,50]. The JEM is subset into mine data and other industry data and is structured such that each entry has a SIC code and a broad SOC code which allowed for a swift connection to the rate and count datasets created from combining the NIOSH AI and BLS CFOI datasets. Mine type was derived from the reported SIC codes. The most current version of the noise JEM contains noise measurements from 1979 to 2014.

When the NIOSH AI dataset was joined with the MSHA quarterly mining production reports, there were many mine IDs that existed in the MSHA quarterly mining production reports but not in the NIOSH AI dataset because the NIOSH AI dataset is based solely on *reported* incidents. Therefore, only mines which reported either a NFDL injury or an occupational fatality in the years 1983 to 2018 were kept for the subsequent analysis. This excluded 37,069 mine-years because they never reported (or have listed) a NFDL injury or an occupational fatality in the NIOSH AI dataset. An important caveat to note is that according to MSHA, only coal mines are legally required to report to this dataset and therefore all other mines reporting are doing so voluntarily (https://arlweb.msha.gov/OpenGovernmentData/OGIMSHA.asp). This resulted in a dataset for analysis that contains 23,004 mines and 353,042 mine-years. Unfortunately, the MSHA quarterly mining production report did not include SIC codes; however, we were able to fill in this information for mines that never changed SIC code over the years. There were 899 mines that changed their SIC code at least once between 1983 and 2018; therefore, 12,022 mine-years were not included in the analysis. Mine-years with a SIC code and without a reported NFDL injury or an occupational fatality were assumed to have a null report for that year and were filled in accordingly.

Data on occupational fatalities and NFDL injuries were collected in a similar fashion for the mines visited for our specific aim 2 prospective data collection in the summer of 2019. These mines had employee hours reported dating back to 1983 in the MSHA quarterly production hours report, as well as NFDL injuries and occupational fatalities in the NIOSH AI dataset, which were then merged. However, data on S&S rates and noise measurements at these mines were collected from the MSHA Mine Data Retrieval System (MDRS) (https://www.msha.gov/mine-data-retrieval-system) from the "Violations" and "Health Samples" datasets, respectively. The Violations dataset contains information on violations across mines in the US, with an "S&S" column signifying whether the violation was significant and substantial with a "yes"/"no". Any year which did not have an S&S rate at a mine was assumed to have no S&S violations occurred for that year and a rate of zero was assumed. The annual number of violations per mine ID was calculated by summing the S&S occurrences. Annual total inspection hours were summed by mine ID. Then a rate was calculated for each mine-year using **Equation 1**.

Equation 1. $$\left(\frac{Number\ of\ violations}{Inspection\ hours}\right) \times 100$$

The Health Samples dataset contains a "Contaminant Code" column as well as a "Concentration" column, which was filtered for contaminants "Noise dosimeter, 80dBA threshold dose" and "Noise dosimeter, 90dBA threshold dose", which correspond to percent of the allowable dose from noise measurements made according to the MSHA Action Level (AL, which uses an 80 dBA threshold) and Permissible Exposure Limit (PEL, which uses a 90 dBA threshold), respectively. Unfortunately, these two data sources only contained information from 2000 and on. The resulting filtered dataset contained noise measurements for 108 mine-years out of a possible 190 mine-years (i.e., 19 years across 10 mines). The final MV dataset was created by merging the filtered dataset with the NIOSH AI dataset for each mine visited from 1983 to 2018.

4.1.1 Data analysis

Overall, three main datasets were created from the data collection outlined above; a SIC dataset (industry-level), a SOC dataset (occupation-level), and an MV dataset (mines visited in the summer of 2019). Data preparation and analysis was completed using R version 3.6.1 (2019-07-05) in RStudio (Boston, MA, US), utilizing base R and the packages `tidyverse` and `MASS`. The SIC and MV datasets contained occupational fatality and NFDL injury rates from 1983 to 2018, while the SOC dataset contained occupational fatality and NFDL injury counts from 1983 to 2002 and rates from 2003 to 2018. NFDL injury and occupational fatality rates were calculated for the SIC and MV datasets per 100 FTE (full-time equivalent workers) using **Equation 2**, while the respective rates for the SOC dataset were calculated per 100,000 FTE using **Equation 3**, as the NIOSH CFOI dataset reported hours in millions.

Equation 2. $$\left(\frac{Current\ number\ of\ Fatal\ or\ Nonfatal\ Accidents\ for\ the\ Year}{Current\ Mine\ Hours}\right) \times 200{,}000\ hours$$

Equation 3. $$\left(\frac{Current\ number\ of\ Fatal\ or\ Nonfatal\ Accidents\ for\ the\ Year}{Current\ Mine\ Hours\ in\ millions}\right) \times 200\ hours$$

For the SIC and SOC datasets, arithmetic time-weighted averages (TWA) in dBA across each SIC code and minor SOC code, respectively, were calculated each year from the JEM. In the MV, mean percent dose for each noise measurement type (AL and PEL) by mine-year was calculated. Dose values by mine-year were then converted to TWA levels in dBA by mine-year to be consistent with the JEM dataset, using the following **Equation 4** in which D represents the dose.

Equation 4. $$TWA_{MSHA} = 16.61\ log_{10}\left(\frac{D}{100}\right) + 90$$

TW_{MSHA} levels converted from the 80 dBA threshold were used during statistical analysis for the MV dataset; TWA_{MSHA} levels from the 90 dBA threshold was highly correlated with it using Spearman's (r_s = 0.922). The SOC and MV datasets both contained years among each SOC code and mine ID in which no noise measurements were reported; therefore, imputation was completed by averaging the TWA_{MSHA} for SOC code and mine ID across all of the years included; this average value was then assigned to the years in which no TWA_{MSHA} was collected. The SIC dataset has noise information at the SIC code level, which is much broader than the SOC code and mine ID level, and resulted in no missing values; therefore, no imputation of TWA_{MSHA} was required during analysis of the SIC dataset.

A categorical variable for TWA_{MSHA} was created based on 5 dBA intervals. For the SIC and SOC datasets, classification began at <70 dBA and ended at ≥100 dBA. In the smaller MV dataset, TWA_{MSHA} classification began at <80 dBA and ended at ≥90 dBA.

Analysis to determine which model type would best fit the NFDL injury and occupational fatality rates initially began with visualization of the distributions of each respective rate. **Figure 3** demonstrates the shape of the NFDL injury and occupational fatality rate distributions within the SIC dataset.

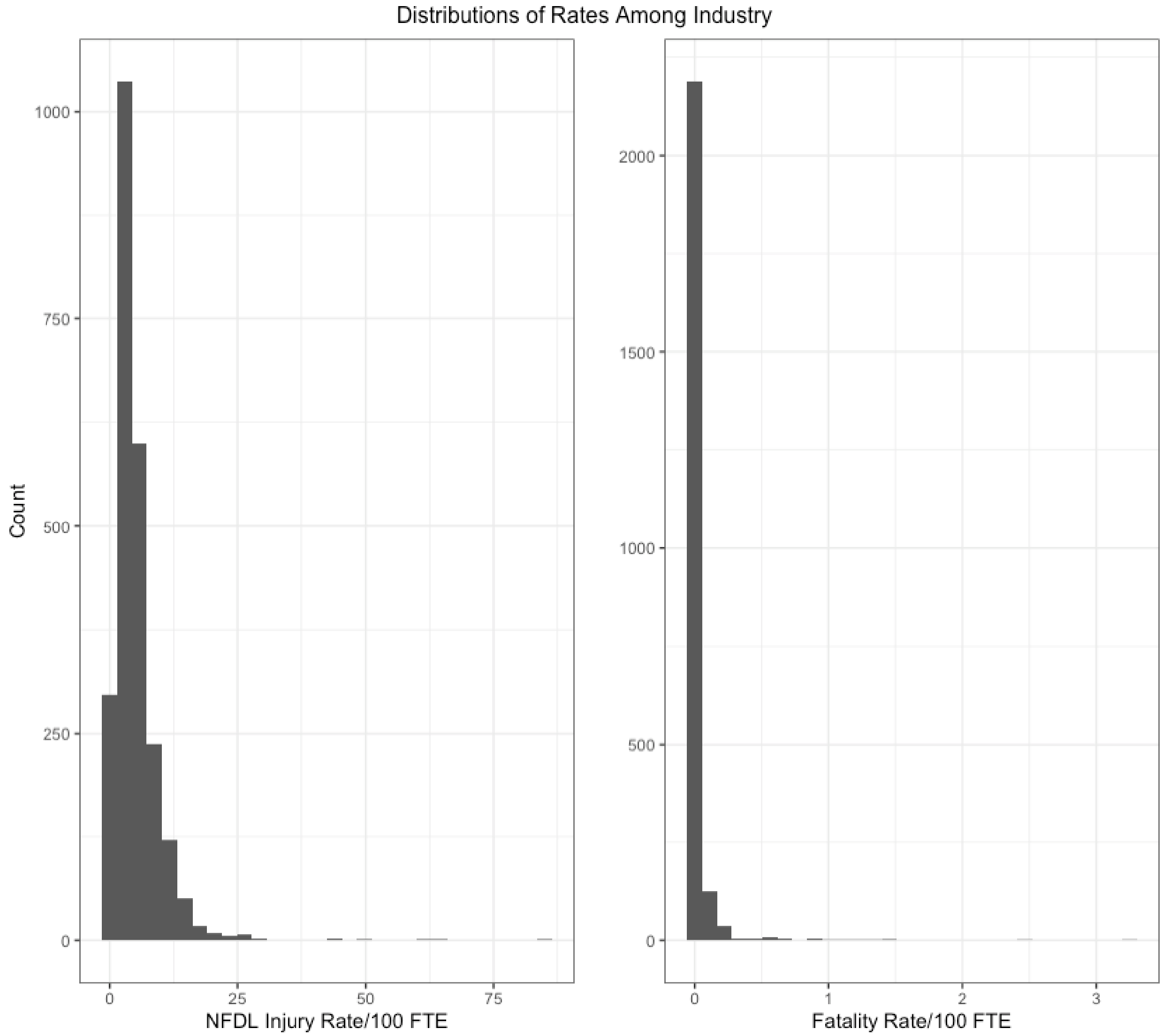

Figure 3. Distribution of NFDL injury rates and occupational fatality rates in the SIC dataset.

Among NFDL injury rates, 96 of 2,387 observations had a rate of zero (i.e. no injury), while the bulk of the observations occurred between rates zero and 10 per 100 FTE. The distribution of injury rates exponentially decayed towards zero. A similar exponential decay phenomenon was observed among fatality rates. However, 80% of the 2,387 data points occurred at a fatality rate of 0 per 100 FTE. For comparison, only 4 percent of the data from the NFDL injury rates had a rate of zero.

As a result, the NFDL injury rates were determined to follow a negative binomial distribution and negative binomial regressions were performed for NFDL injury rates in each of the three datasets gathered. Individual models were developed on the complete SIC dataset (1983-2014), the complete MV dataset (2000-2018), and subsets of the SOC dataset for counts and rates (i.e. 1983-2002 and 2003-2014, respectively). All NFDL injury counts or rates of zero were dropped from each dataset to better fit the negative binomial distribution and achieve more accurate modelling of the data. Therefore, the relationship between noise and injury risk was assessed only among reported NFDL injuries. All regressions were run in R using the function `glm()` with the argument `family = negative.binomial()`. The `negative.binomial()` function requires a theta input, which was calculated using a quasi-poisson regression on the same model to determine the dispersion index (DI) which was then put into the negative binomial for theta.

Due to the very large over-inflation of zeros in the occupational fatality rate data, fatality rates were categorized into a binary outcome of "no fatality occurred" and "fatality occurred"; logistic regression was performed to model this binary outcome. Use of logistic regression allowed all years of the SOC dataset to be included in a single model, as "no fatality occurring" is equivalent to both a rate of zero and a count of zero. Logistic regression for occupational fatalities was also applied to the SIC dataset for all the years available. Modelling could not be performed on the MV dataset because only one occupational fatality occurred between 2000 and 2018. Logistic regression was run in R using the function `glm()`, specifying `family = binomial()`.

Using the datasets created through the processes described above we sought to answer two main questions relevant to specific aim 1. First, among NFDL injuries, is noise exposure is associated with higher injury risk among reported injuries at mines? Second, is there is an association between noise exposure and the occurrence of occupational fatalities among miners?

4.2 Research Approach for Specific Aim 2

4.2.1 Sites

We originally proposed to visit a large mining facility located in Alpena, Michigan to perform repeated prospective measures on a cohort of miners in summer 2019. Unfortunately, this facility ultimately withdrew their agreement to participate due to business circumstances beyond our control. Therefore, we spent the majority of the late fall and early winter months of 2018-9 identifying contacts within the mining industry and reaching out to mines across the Midwest to identify an alternative site or sites for the research. We had success with two large mining conglomerates. Although these companies did not give us access to all of their mines in the Midwest region, they connected us with regional safety management teams, which in turn facilitated access to specific mine sites. These connections resulted in access to ten mine sites for the collection of data related to specific aim 2. Six sites were operated by one conglomerate and four by a second conglomerate. These sites were located in three different states; four sites were in Michigan, three in Ohio, and three in Illinois. All mines were surface mining operations. Two sites were limestone kiln operations, 4 were limestone aggregate operations, and 4 were sand/silica operations.

4.2.2 Participants

Participants were recruited from any aspect of the mining operation at each site; only contracted workers and non-mining workers were excluded. All aspects of the research were reviewed and approached by the University of Michigan Institutional Review Board – Health Sciences/Behavioral Sciences (approval number HUM00152393). Recruitment was primarily done during safety meetings and briefings at the start of a shift. However, some recruitment was done by word-of-mouth within the mine. Potential volunteers were clearly (and repeatedly) told that participation was completely voluntary and could be terminated at any time. Each interested individual signed a paper copy of the Informed Consent Form (see Appendix A). Participants were asked to participate for three consecutive workdays for the length of each of their shifts.

4.2.3 Data collection and analysis

Each site was visited at least once for a period of three days. During each visit our recruitment target was 15 miners per shift. **Table 2** provides an overview of the types of data that were collected, and at what cadence. Schedules were incredibly fluid and dynamic in this setting therefore, no standardized order or time of tests was possible. Through discussions with each participant about their availability over the sampled dates, times were determined for completion of all other tasks associated with the study (i.e., survey, audiometry, speech-in-noise, and Fitcheck). Research personnel and equipment limitations as well as available quiet space further necessitated this flexibility.

Table 2. Overview of data types collected during the study

Factor	Measurement
ONE-TIME EVALUATION	
1. Employment information, fitness, noise exposure history, hearing ability, injury history, and demographics	Survey – generic questions
2. Health	Survey - SF-12 [51]
3. Hearing protection device (HPD) use	Survey – part of the Hearing Protection Assessment-2 [52]
4. Safety perception	Survey – part of the Hearing Protection Assessment-2 [52]
5. Tinnitus history	Survey – 3-item questionnaire from the Epidemiology of Hearing Loss Study [53]
6. Stress	Survey – Perceived stress scale (PSS) [54]
7. Work safety culture	Survey – Job safety section of the Work Safety Scale (JSS) [55]
8. Sleepiness	Survey – Epworth Sleep Scale (ESS) [56]
9. Fatigue	Survey – Fatigue Severity Scale (FSS) [57]

Factor	Measurement
ONE-TIME EVALUATION	
10. Hearing ability - Hearing threshold level	Audiometry
11. Hearing ability in background noise	Speech in noise
12. HPD attenuation	FitCheck Solo and/or FitCheck Earmuff
DAILY EVALUATION FOR 3-DAY PERIOD	
13. Work activity/task, noise exposure, HPD use, injuries, near-misses, accidents, sleep, and stress	Daily survey – generic questions
14. Work demands/load	NASA TLX subjective tool [58]
15. Noise exposure	Personal noise dosimetry

4.2.3.1 Baseline Survey

Baseline surveys (see Appendix A) were administered via paper and took approximately 20 minutes to complete. Participants did so on their own. The baseline survey was developed to assess several key topical areas related to the research questions. They were: job information, health and fitness, noise exposure, hearing ability and tinnitus, hearing protection device (HPD) use, stress, injuries, safety perception and culture, sleepiness, fatigue, and personal demographics. Specific published and even in some cases licensed scales were used for consistency. Health was assessed with the SF-12 [51]. HPD use information and safety perception were collected using the Hearing Protection Assessment-2 [52]. A 3-item questionnaire from the Epidemiology of Hearing Loss Study was used to assess tinnitus [53]. Sleepiness was evaluated using the 8-item Epworth Sleepiness Scale [56]. Fatigue was assessed using the Fatigue Severity Scale [57] free for use to researchers. Permission to use of the 10-item Perceived Stress Scale was purchased from the American Sociological Association (permission number 707031) and was used to evaluate stress [54]. Finally, the 10-item Job Safety portion of the Workers Safety Scale was used to quantify job safety perception [55].

4.2.3.2 Daily Survey

Daily surveys (see Appendix A) were developed to ask specific questions about the shift sampled and were administered via paper at the end of each shift. Each daily survey took less than 5 minutes to complete and participants did so on their own. The daily survey asked about work activities and demands, noise exposure and use of HPDs, injuries, near-misses, and accidents, sleep, and stress. Work demands were assessed using five of six items from the NASA TLX [58].

4.2.3.3 Noise exposure measurement

DoseBadge dosimeters (Cirrus Research, North Yorkshire, UK) were used to make personal full-shift exposure measurements. Two channels were used on each doseBadge to collect exposure data according to two exposure standards simultaneously **(Table 3).** The first channel was set according to the MSHA Permissible Exposure Limit (PEL) of 90 dBA TWA, and the other channel was set according to the NIOSH Recommended Exposure Limit (REL) of 85 dBA. The two channel setting allowed the minute-by-minute collection of average levels (L_{AVG} for channel 1, L_{EQ} for channel 2) and L_{MAX} over the course of a shift as well as overall for the length of the shift. Following recruitment, the dosimeter was placed on the participants' chosen shoulder for the length of their shift (i.e., most often between 8 and 12 hours). Some participants needed to remove and replace the dosimeter themselves during their shifts as a result of donning and doffing safety gear. All participants were instructed for proper placement and advised that the dosimeter must remain on the outside layer of clothing.

Table 3. Dosimeter channel settings used for shift-level noise measurements

Channel and standard	Weight	Exchange Rate (dB)	Threshold (dBA)	Criterion Level (dBA)	Response time	Upper limit (dBA)	Calculated Metrics
1 MSHA PEL	A	5	80	85	Slow	140	Shift L_{AVG} TWA_{MSHA}
2 NIOSH REL	A	3	80	85	Disabled	140	Shift L_{EQ} TWA_{NIOSH}

Several calculations had to be performed to convert the minute-level noise measurements into shift-level L_{AVG} (**Equation 5**) and L_{EQ} (**Equation 6**) values and then into normalized 8-hour time-weighted averages, TWA_{MSHA} (**Equation 7**) and TWA_{NIOSH} (**Equation 8**), respectively. Person-level TWA_{MSHA} and TWA_{NIOSH} were calculated using **Equation 9 and 10**, respectively, to allow models at the person level to be run.

Equation 5. $$L_{AVG} = 16.61 \times \log_{10}\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\frac{1\min L_{AVG_i}}{16.61}}\right)$$

Equation 6. $$L_{EQ} = 10 \times \log_{10}\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\frac{1\min L_{EQ_i}}{10}}\right)$$

Equation 7. $$shift\ level\ TWA_{MSHA} = 16.61 \times \log_{10}\left(\frac{1}{480}\sum_{i=1}^{480} 10^{\frac{1\min L_{AVG_i}}{16.61}}\right)$$

Equation 8. $$shift\ level\ TWA_{NIOSH} = 10 \times \log_{10}\left(\frac{1}{480}\sum_{i=1}^{480} 10^{\frac{1\min L_{EQ_i}}{10}}\right)$$

Equation 9. $$person\ level\ TWA_{MSHA} = 10 \times \log_{10}\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\frac{TWA_{MSHA_i}}{10}}\right)$$

Equation 10. $$person\ level\ TWA_{NIOSH} = 10 \times \log_{10}\left(\frac{1}{N}\sum_{i=1}^{N} 10^{\frac{TWA_{NIOSH_i}}{10}}\right)$$

Novel noise metrics were calculated to investigate whether they had different relationships with accident, near-miss, or injury risk than average levels. The first metric was the crest factor for each channel measured as shown in **Equations 11 and 12** [59] or a measure of the average noise measured to the peak noise measure. Variability of L_{EQ} to L_{AVG} was also calculated following **Equation 13** to assess fluctuations in noise levels, as the L_{EQ} is more sensitive to fluctuations than the L_{AVG} [60]. Finally, statistical kurtosis across minutes measured in a shift were calculated to assess the weight of the tails of distribution of noise exposures experienced by an individual across a shift.

Equation 11. $$L_{EQ}\ crest\ factor = 10 \times \log_{10}\left(10^{\frac{L_{peak}}{10}} - 10^{\frac{L_{EQ}}{10}}\right)$$

Equation 12. $$L_{AVG}\ crest\ factor = 10 \times \log_{10}\left(10^{\frac{L_{peak}}{10}} - 10^{\frac{L_{AVG}}{10}}\right)$$

Equation 13. $$Variability = 10 \times \log_{10}\left(\frac{10^{\frac{L_{EQ}}{10}}}{10^{\frac{L_{AVG}}{10}}}\right)$$

4.2.3.4 Hearing ability evaluation

Due to logistic, monetary, and time restraints imposed by the last-minute withdrawal of the original research site, we used a smart-phone based application to perform hearing tests. App based hearing tests are relatively new but have been used in other resource constrained research settings [61]. Specifically, we used the Apple Research Kit (Apple Inc, Cupertino, CA) pure-tone audiometry and speech in noise tests. Using iPhone 6S with iOS 13.2 installed and Shure (Shure, Niles, IL) SE215 sound isolating earphones, these tests were self-performed by each participant under researcher supervision onsite. Many of the sites that were visited did not have extra space that could be used for our research activities. Often, small closets were used to perform hearing evaluations, and these spaces often had poor attenuation and audible ventilation systems. Therefore, to block as much background noise as possible, we adapted the test protocol for the hearing tests to require the participant to wear DD52 audiometric sound isolating headphones (Tungtech Industrial Limited, Xiamen, China) from our Fitcheck Solo system (described in section 4.2.3.5) over the Shure earphones.

Each hearing test took approximately 10 minutes. Hearing loss was quantified in a variety of ways. The pure-tone audiometry test in the Apple Research Kit App measured hearing threshold levels (HTLs) in dB HL at 0.25, 0.5, 1, 2, 4, 6, and 8 kHz, and was performed on each ear separately.

The speech in noise task in the Apple Research Kit App tested participants' ability to hear and understand spoken words with various levels of background noise. Specifically, the test generated a speech reception threshold (SRT), defined as the signal to noise ratio (SNR) where

50% of the words are correctly repeated by the subject. The SRT was calculated using the Tillman Olsen formula [62] as commonly used by the QuickSIN™ (Etymotic, Elk Grove Village, IL) and shown in **Equation 14:**

$$\textbf{Equation 14}.\ SRT = I + \frac{D}{2} - \frac{D \times R}{N}$$

Where *I* is the initial SNR, *D* is the SNR step size, *R* is the total number of correctly repeated words (from a total number of 35 words) and *N* is the number of keywords in each sentence. The speech in noise test used I = 18 dB, D = 3 dB, and N = 5 as parameters, simplifying Equation 14 to **Equation 15**.

$$\textbf{Equation 15}.\ SRT = 19.5 - (R \times 0.6)$$

Each worker completed two sets of 7-sentence wordlists. The first set (SRT_0) was used as a training set to familiarize participants with the test, while the results of second set (SRT_1) was used for analysis.

Extraction of the audiometry and the in noise data from the .json files output by the Apple Research Kit App on each iPhone was done by downloading them locally using iTunes and then developing code to extract relevant data from each file and generate summary spreadsheets. All code was written using Python 3 (Python Software Foundation, Beaverton, OR) in Jupyter Notebook (Project Jupyter, US).

A very small subset of audiometric HTL data was corrected to address a bug in the Apple Research kit App. Specifically, the application did not correctly detect threshold levels for certain frequencies if thresholds were variable. However, data for attempted threshold identification were stored, and allowed us to identify the lowest threshold that occurred at least twice on a down-step. This identified HTL was reassigned for each frequency.

4.2.3.5 Hearing protection device fit and use

Direct measurement of HPD attenuation (commonly referred to as "fit") for earplugs and earmuffs was performed in the field by research staff using FitCheck Solo and FitCheck Earmuff systems (both from Michael and Associates, Inc.), respectively. These systems allow for the measurement of a real-world individual Personal Attenuation Rating (PAR) [63]. The FitCheck Solo system measured attenuation at the frequencies 0.25, 0.5, 1, 2, 4, and 8 kHz. This test is considered robust even in the presence of moderate noise; nevertheless, fit testing was performed in the quietest available environments in the field. To allow the inclusion of data for the small subset of tests with missing values at higher frequencies (resulting from substantial high-frequency hearing loss in a few participants), PARs were calculated using **Equation 16**.

$$\textbf{Equation 16}.\ PAR_n = 10 \times \log_{10}\left(\sum_f^N 10^{\frac{L_{A_f}}{10}}\right) - 10 \times \log_{10}\left(\sum_f^N 10^{\frac{L_{A_f} - A_f}{10}}\right)$$

A three frequency calculation was used across frequencies (*f*) 500, 1000, and 2000 kHz. The reference value for each frequency was $L_{A_f} = 100\ dB$ and A_f was the attenuation measured at each frequency. This individual PAR was then compared to the PAR needed, defined as the average 3-day personal noise exposure (i.e., TWA_{MSHA} and TWA_{NIOSH}) minus the reference level of 85 dBA, below which HPD use is not mandated.

4.2.3.6 Relationship between noise exposure and injuries

Bivariate logistic regressions were run using Stata 16 SE (StataCorp, College Station, TX, command: logistic) to assess the relationship between odds of reporting an incident (accident, near-miss, or injury) and the various measured and calculated noise exposure metrics.

4.2.3.7 Relationship between hearing loss and injuries

Bivariate logistic regressions (Stata command: logistic) were run to assess the relationship between odds of reporting an incident (accident, near-miss, or injury) and various measures of hearing ability. These measures included self-reported hearing ability rating (3 levels), good hearing ability (Y/N), diagnosed hearing loss (Y/N), and tinnitus (Y/N). Only SRT_1 was used from the Apple Research Kit App speech in noise test for association testing because SRT_0 was a training set. From the Apple Research Kit App pure tone audiogram results, both best and worst ear thresholds were used to calculate average hearing threshold levels (average HTL) at 1, 2, and 4 kHz. Binary hearing loss variables were created, with hearing loss defined average HTL ≥25 dB. Binary variables were created for best ear HL at 1, 2, and 4 kHz (Y/N), and worst ear HL at 1, 2, and 4 kHz (Y/N). A categorical variable for each frequency average was made to indicate whether some suffered from binaural hearing loss, unilateral hearing loss, or no hearing loss. Additionally, unoccluded Fitcheck values were averaged across 1, 2, and 4 kHz for comparison with the best ear audiogram values from the Apple Research Kit App.

4.2.3.8 Relationship between hearing protection device fit and use and injuries

Hearing protection use and effectiveness was described by both self-reported and measured variables. Participants reported the percentage of time that they wore HPD while in high noise overall, as well as the frequency of time in which they wore HPDs in high noise during the measured shifts. The shift-level variable was converted to a person-level variable using the mode of the response reported across the measured shifts. To assess whether overprotection to noise due to HPDs was associated with incidents (accidents, near-misses, or injuries), an overprotected variables was created by comparing PAR to PAR_{needed} for each TWA_{MSHA} and TWA_{NIOSH} metric. When PAR exceeded PAR_{needed}, participants were considered to be overprotected. Bivariate logistic regressions (Stata command: logistic) were run to assess the relationship between odds of reporting an incident, near-miss, or injury and various metrics of HPD use and fit.

4.2.3.9 Combined effect of noise, HL, and HPD on injuries

Logistic regression models (Stata command: logistic) were developed to study the relationship between noise exposure, hearing ability, and HPD use and the risk of injury/near miss event. Important psychosocial (i.e., sleepiness, stress, fatigue, health) and work environment (i.e., work demands, safety culture and perception) factors were also considered to control for potential confounding.

Purposeful selection of potential risk factors and covariates for injury was conducted by bivariate analysis of each variable and the outcome independently. Potential candidates for a multivariable model were selected if their univariate test, a simple logistic regression, reported a significance of $p < 0.25$ [64]. The standard 0.05 significance was not used for screening potential covariates as it may not identify all important covariates required to develop the best fitting multivariable [65]. Variables related to age, work experience, hearing ability, and hearing protection use were kept for further analysis regardless of their significance level due to their established relationship with occupational injuries.

5.0 Summary of Accomplishments

5.1 Summary of Accomplishments for Aim 1

NFDL injury and occupational fatality rates were connected to noise estimates from 1983 to 2014 by SIC code to generate the SIC dataset. NFDL injury and occupational fatality counts were connected to noise estimates from 1983 to 2002 by SOC code while NFDL injury and occupational fatality rates were connected to noise estimates from 2003 to 2014 by SOC code to generate the SOC dataset. NFDL injury and occupational fatality rates for the mines visited during Aim 2 were compiled from 1983 to 2018 and connected to MSHA noise measures and S&S rates from 2000 to 2018 to generate the MV dataset.

5.1.1 Dataset

A total of 374,998 recorded non-fatal day lost (NFDL) injuries and 2,334 recorded occupational fatalities in the mining industry from 1983 to 2018 were included in the SIC and SOC datasets. These data included measurements from all three mine types (i.e., coal, metal, and nonmetal). For minor SOC code analysis, six NFDL injuries had to be dropped because they did not have any job title information. Five of these six removed observations occurred in 2016 among four different mines and the sixth removed observation occurred in 2017. After removing these observations, a total of 374,992 NFDL injuries were included in the SOC dataset analyses.

NFDL injury rates by year and by SIC code are included in the appendices in tables separated at year 2002 to accommodate their size (Appendix B. Table 1.1.1. and Appendix B. Table 1.1.2). Similarly, occupational fatality rates by year and by SIC code are also included in the appendices, again split at the year 2002 (Appendix B. Table 1.2.1 and Appendix B. Table 1.2.2).

NFDL injury and occupational fatality counts by year and by SOC code for 1983-2002 (Appendix B. Table 2.1.1 and Table 2.2.1, respectively) and NFDL injury and occupational fatality rates by year and by SOC code for 2003 to 2018 (Appendix B. Table 2.1.2 and Table 2.2.2, respectively) are included in Appendix B.

Noise measurements (TWA_{MSHA}) collected from the JEM are presented by year and by SIC code in Appendix B. (Table 1.3.1 and Table 1.3.2) divided at 2002 to accommodate their size. TWA_{MSHA} is similarly presented by year and by SOC code in Appendix B (Table 2.3.1 and Table 2.3.2).

Compiled data of NFDL injury and occupational fatality rates, MSHA noise measurements, and S&S rates by year from 1983 to 2018 is also presented in Appendix B for the mines visited in specific aim 2, but is separated first by company and industry (e.g., Company 1 – Limestone mines, Company 1 – Lime Mines, and Company 2 – Sand mines) in Tables 3.1.1, 3.1.2, and 3.2.1, respectively.

5.1.2 Noise and NFDL injury rates by SIC

Data among SIC codes shows a clear trend of decreasing NFDL injuries among mine types (**Figure 4**); however, the same clear trend for noise exposure over time is only evident among coal mines and is not as clear in metal and nonmetal mines (**Figure 5**).

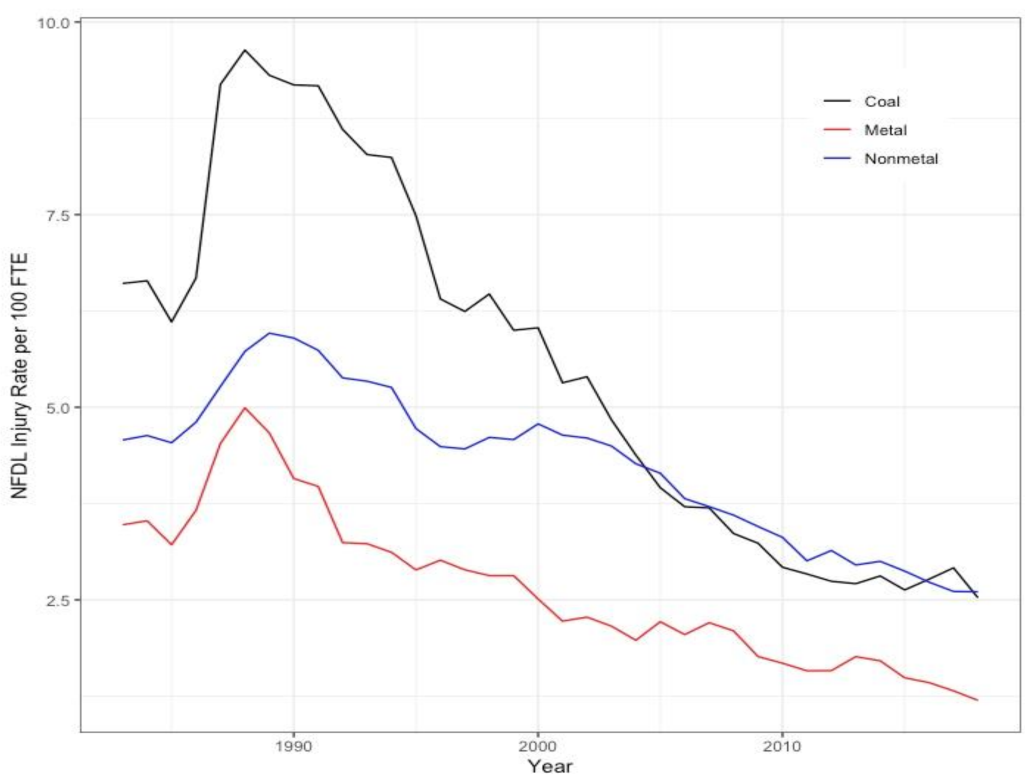

Figure 4. NFDL injury rates over time by mine type among the SIC dataset.

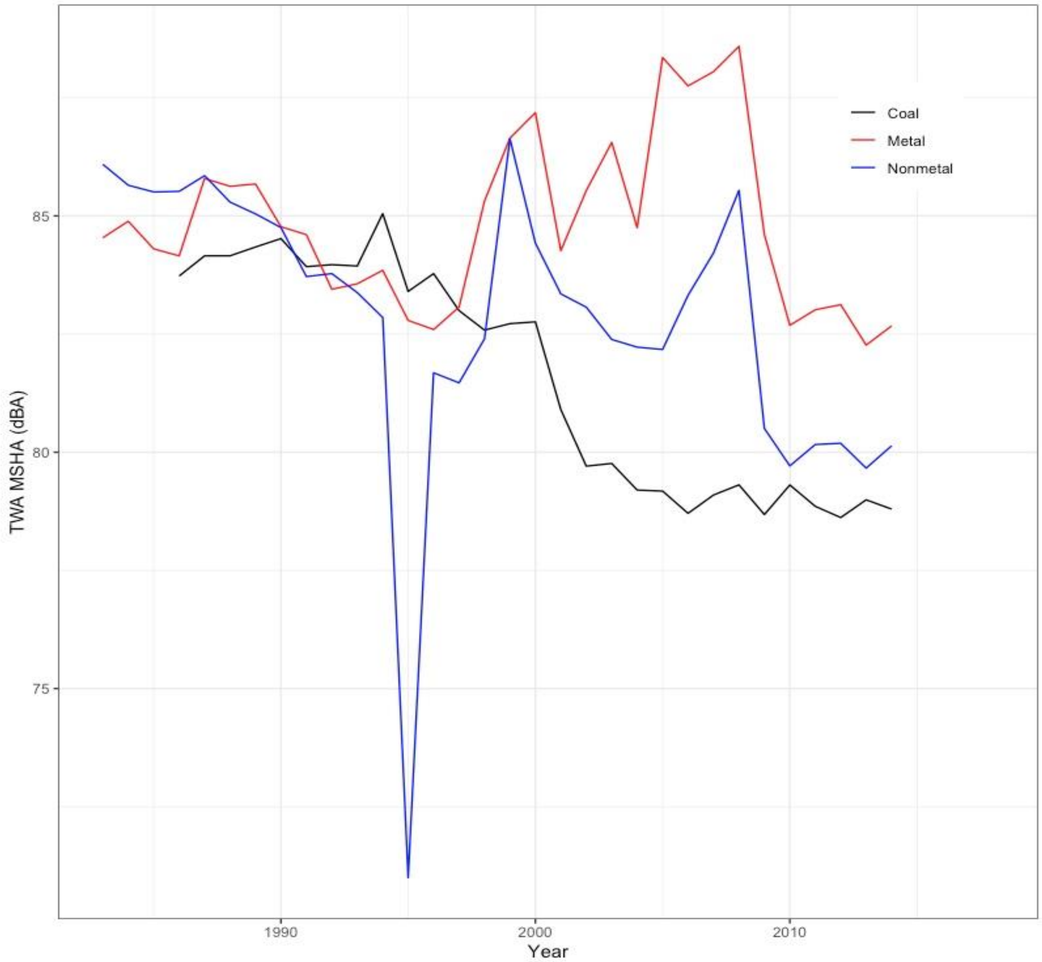

Figure 5. TWA_{MSHA} over time by mine type among the SIC dataset.

To assess the relationship between NFDL injury rates by SIC code and noise, four negative binomial SIC-NFDL models were created. These models sequentially added in predictors, starting with models with one predictor (i.e., TWA_{MSHA} (categorical)), then adding year, SIC code, and finally mine type. Table 4.1 (Appendix B) contains statistics on each of the unadjusted SIC-NFDL models (i.e. N, AIC, DI) along with the IRRs and 95% CI of each predictor. The SIC-NFDL-Unadjusted model in **Table 4** shows an association between TWA_{MSHA} (categorical) and NFDL injury rates where 70 to <75 dBA, 85 to <90 dBA, 90 to <95 dBA, and ≥100 dBA levels were all statistically significant and associated with higher IRRs of NFDL injuries. Although not always statistically significant, a general upward trend for noise exposure is evident in each of the models in Table 3, with the highest IRRs associated with the highest noise exposure category (≥100 dBA) after adjustment for year, SIC code, and mine type.

The fully adjusted model in **Table 4** (SIC-NFDL-Model 3) reported the lowest AIC (9030.65) and had the most randomly distributed residuals when plotted against fitted values. The SIC-NFDL-unadjusted model and model SIC-NFDL-1 both had lower AICs than SIC-NFDL model 2; however, the residuals for model SIC-NFDL-1 were not randomly distributed, while those for SIC-NFDL-

Models 2 and 3 were. Controlling for industry SIC code (n=83 categories) overfit the data (i.e., resulted in higher variance within the model measured by mean-square error); therefore, mine type was introduced into the model instead, which resulted in higher bias but minimized variance. A Kruskal-Wallis rank sum test run on TWA_{MSHA}(continuous) by each mine type found that the median noise level of each mine type was statistically significantly different ($\chi 2 = 131.7,\ df = 2,\ p < 0.001$). This further validated the improvement of the models in Table 3 with the addition of mine type.

Table 4. Negative binomial models for NFDL injury rates among the SIC dataset

Statistic	SIC-NFDL-Unadjusted			Model SIC-NFDL-1			Model SIC-NFDL-2			Model SIC-NFDL-3		
N	1779			1779			1779			1779		
DI*	3.64			3.48			1.27			3.49		
AIC	9200.52			9117.63			9291.64			9030.65		
Variable	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**
TWA_{MSHA}												
<70 dBA (ref)	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
70 to <75 dBA	2.10	1.06	4.21	2.03	1.04	4.00	1.51	1.02	2.23	1.83	0.92	3.66
75 to <80 dBA	1.88	0.99	3.57	1.95	1.05	3.65	1.51	1.05	2.15	1.59	0.84	3.03
80 to <85 dBA	1.82	0.97	3.45	1.79	0.97	3.35	1.58	1.10	2.24	1.51	0.81	2.87
85 to <90 dBA	1.99	1.06	3.79	1.90	1.03	3.55	1.53	1.07	2.17	1.68	0.90	3.20
90 to <95 dBA	2.00	1.05	3.89	1.91	1.04	3.64	1.34	0.92	1.93	1.82	0.95	3.53
95 to <100 dBA	1.97	0.96	4.11	1.89	0.93	3.88	1.42	0.94	2.14	1.89	0.23	3.94
≥100 dBA	2.56	1.10	6.09	2.46	1.08	5.73	1.53	0.93	2.52	2.54	1.09	6.02
Year				0.98	0.97	0.99	0.98	0.97	0.98	0.98	0.97	0.99
SIC code**							**	**	**			
Mine type												
Coal (ref)										1.00	-	-
Metal										0.46	0.37	0.57
Nonmetal										0.63	0.52	0.78

*The dispersion index (DI) was derived from each respective quasi-poisson model
**IRRs and 95% CIs for each SIC code (n=83) can be found in Appendix B Table 4.2

For TWA_{MSHA} noise levels ≥100 dBA, there was a 2.54 (95% CI: 1.09, 6.02) times higher IRR for NFDL injury rates when analyzed among the SIC dataset after adjusting for year and mine type. While the other categories of TWA_{MSHA} in the fully adjusted model were not statistically significant, there was a general upward trend in their association with NFDL injury rates, as illustrated also in **Figure 6**.

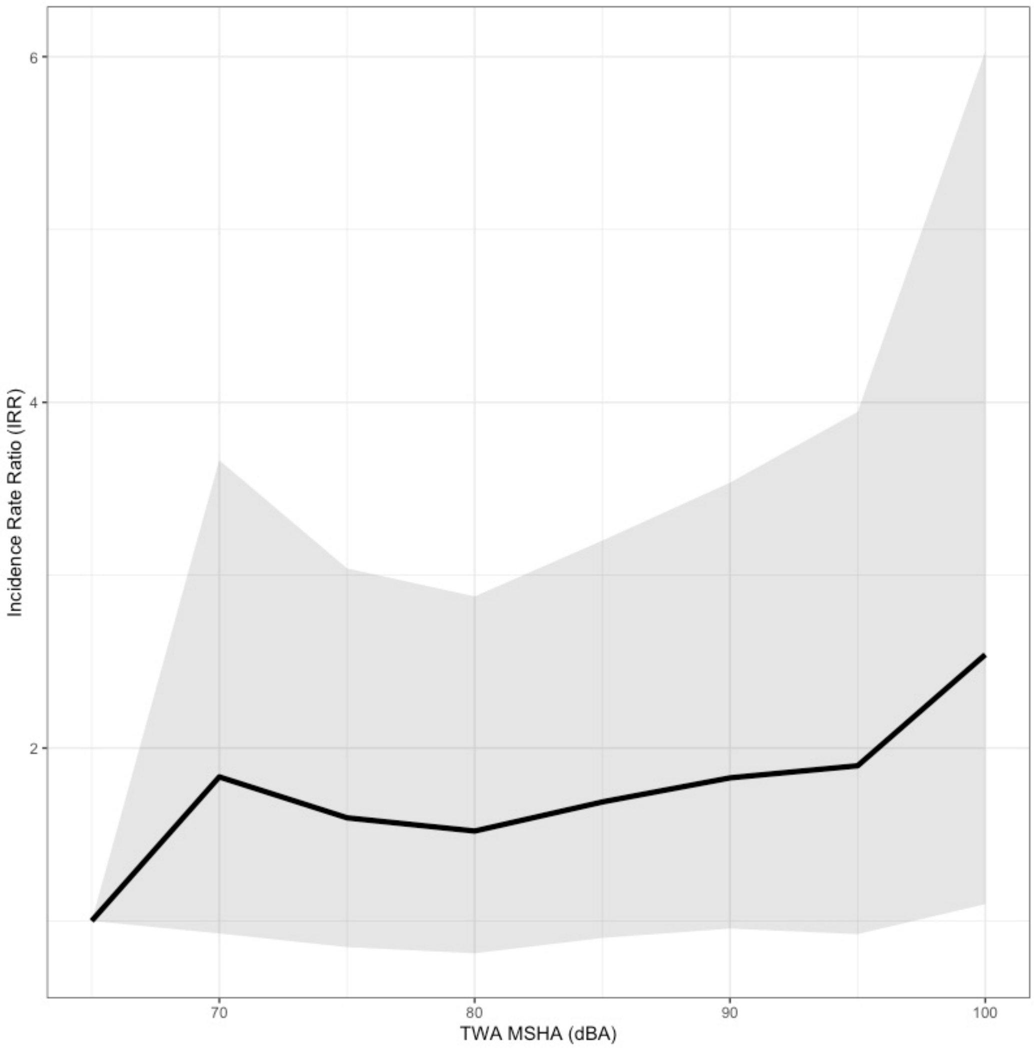

Figure 6: IRRs and 95% CIs by TWA_{MSHA} category from Model 3 in Table 3.

5.1.3 Noise and NFDL injury counts and rates among minor group SOC

When classified by SOC code, NFDL injury counts prior to 2002 (**Figure 7a**) declined over time, as did NFDL injury rates from 2003 (**Figure 7b**) on. However, as seen in **Figure 7c**, rates among workers in SOC code 47-5000 (i.e., extraction workers) remain significantly higher than the rest of the SOC codes in the data. As shown in **Figure 8**, noise among minor SOC codes has exhibited a general but very slight overall decrease over time.

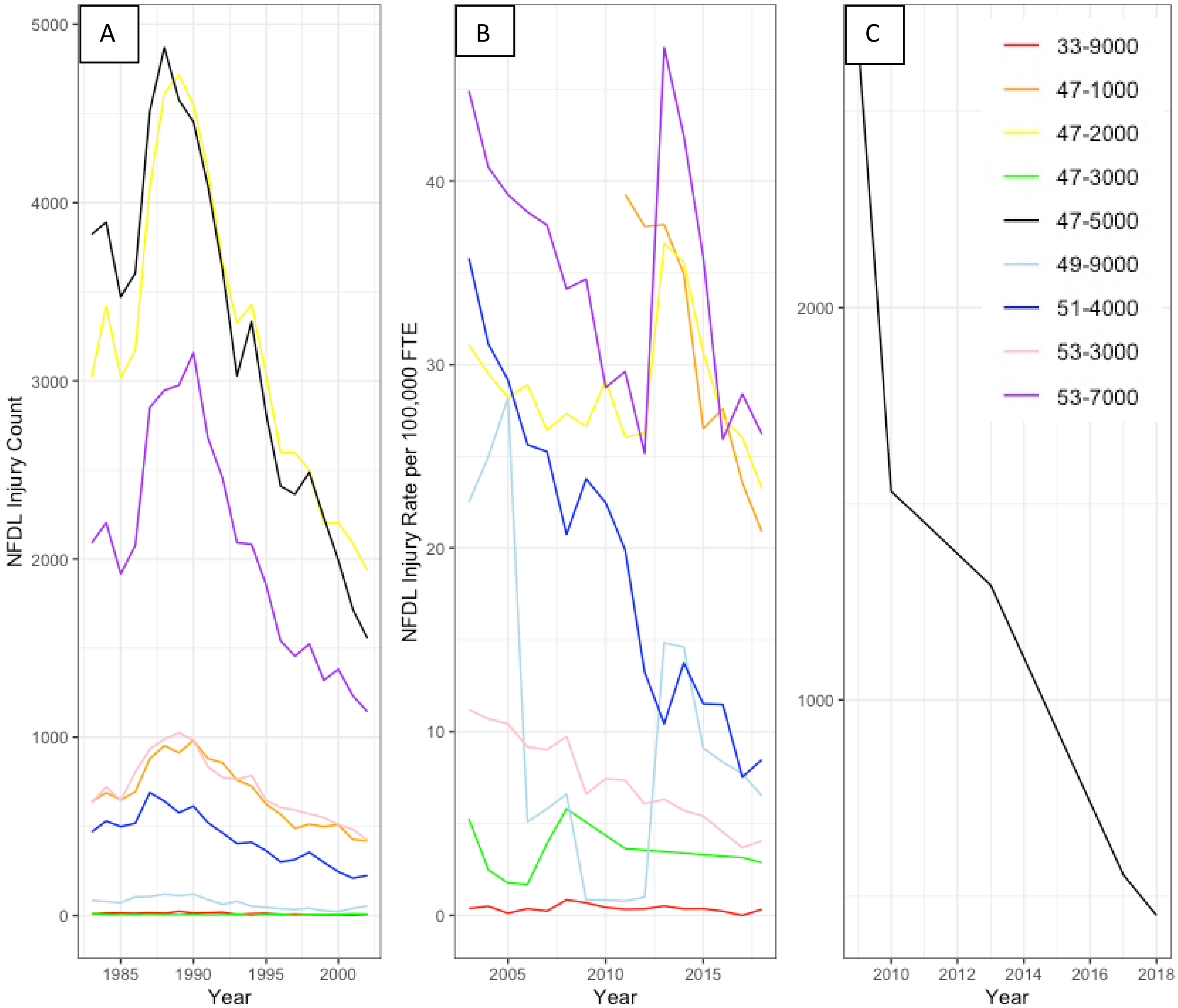

Figure 7. NFDL injury counts from 1983 to 2002 among SOC codes overtime (A). NFDL injury rates from 2003 to 2018 among SOC codes (B) except extraction workers which is presented in C because the scale was too different for presentation with the rest. SOC codes presented in the legend correspond to these job titles in order from top to bottom; Other protective service workers, Supervisors of construction and extraction workers, Construction trades workers, Helpers, construction trades, Extraction workers, Other installation, maintenance, and repair occupations, Metal workers and plastic workers, motor vehicle operators, and material moving workers from the 2010 SOC structure.

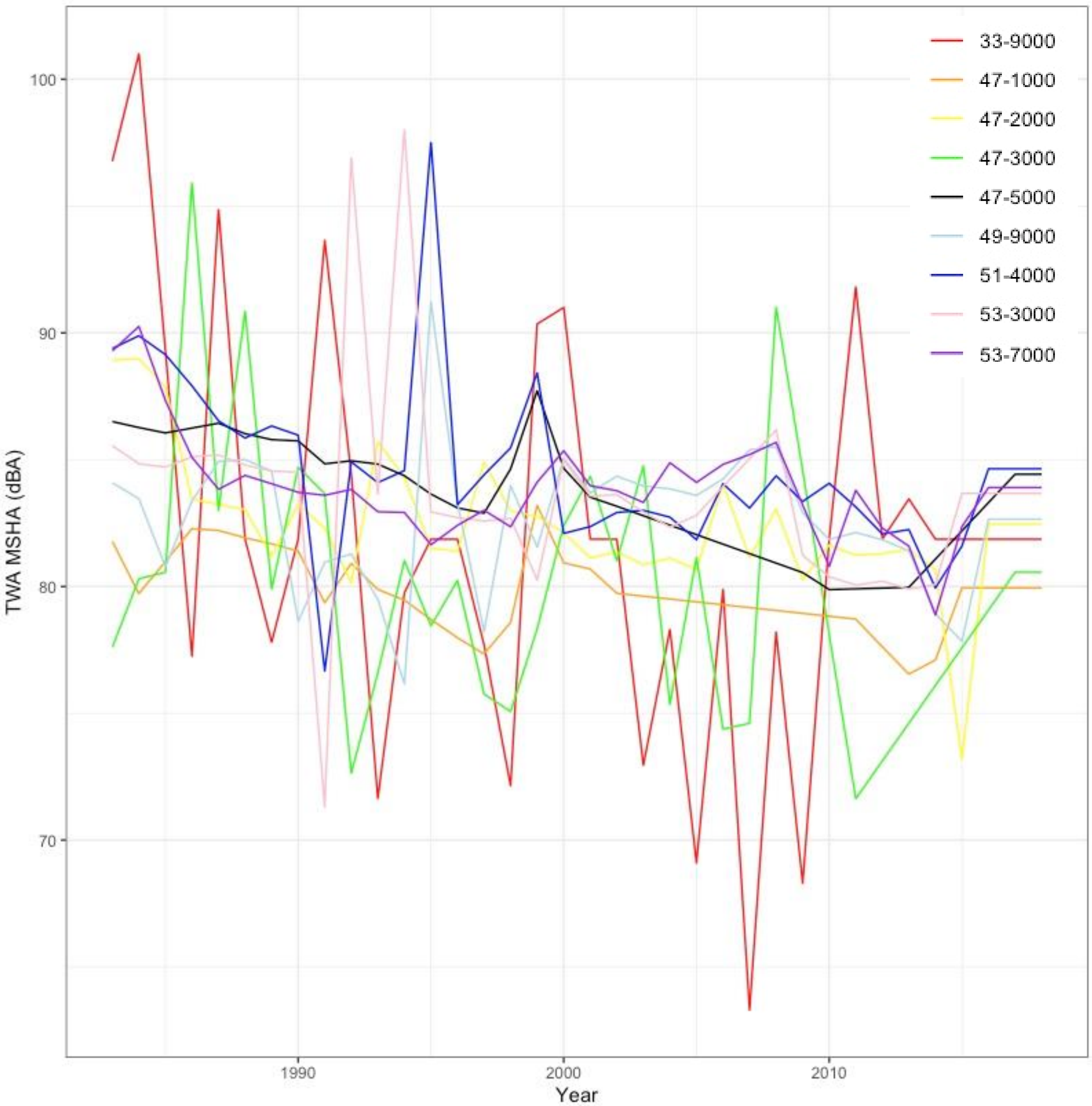

Figure 8. TWA$_{MSHA}$ from 1983 to 2018 among SOC codes overtime. SOC codes presented in the legend correspond to these job titles in order from top to bottom; Other protective service workers, Supervisors of construction and extraction workers, Construction trades workers, Helpers, construction trades, Extraction workers, Other installation, maintenance, and repair occupations, Metal workers and plastic workers, motor vehicle operators, and material moving workers from the 2010 SOC structure

To assess the relationship between NFDL injury counts by SOC code and noise, three sequential negative binomial SOC-NFDL models were built using TWA_{MSHA} (categorical or continuous), year, and minor SOC code. Table 4.1 (see Appendix B) contains all unadjusted models for counts from 1983 to 2002 and then for rates from 2003-2014. From 1983 to 2002 (**Table 5**), within the SOC-NFDL Unadjusted-83-02 model of TWA_{MSHA} (categorical) levels of from 80 to <85 and ≥85 to <90 dBA were statistically significant and associated with substantially higher IRs, 6.39 (95% CI: 1.41, 60.64) and 9.03 (95% CI: 1.95, 86.4), respectively. From 2003 to 2014, the SOC-NFDL-Unadjusted-03-14 model of TWA_{MSHA} (continuous) did not reach statistical significance.

Table 5. Negative binomial models for NFDL injury counts (1983-2002) among the SOC dataset

Statistic	Model SOC-NFDL-Unadjusted-83-02			Model SOC-NFDL-1-83-02			Model SOC-NFDL-2-83-02		
N	173			173			173		
DI	567.47			515.51			1.73		
AIC	105761.64			101503.84			2056.95		
Variable	**IR**	**LL**	**UL**	**IR**	**LL**	**UL**	**IR**	**LL**	**UL**
TWA_{MSHA}									
<75 dBA (ref)	1.00	-	-	1.00	-	-	1.00	-	-
75 to <80 dBA	1.23	0.23	12.46	1.24	0.25	10.09	1.14	0.80	1.59
80 to <85 dBA	6.39	1.41	60.64	6.49	1.51	54.03	1.07	0.77	1.47
85 to <90 dBA	9.03	1.95	86.42	7.63	1.72	64.35	0.97	0.69	1.35
90 to <95 dBA	1.53	0.22	17.58	1.39	0.21	14.01	0.84	0.55	1.27
95 to <100 dBA	1.82	0.23	21.72	1.69	0.23	17.72	1.06	0.72	1.54
≥100 dBA	0.07	-	17.29	5.32	-	11.09	0.96	0.38	2.19
Year				0.96	0.94	0.99	0.95	0.94	0.96
Occupation									
Construction Trade (ref)							1.00	-	-
Extraction							1.01	0.89	1.15
Helpers, Construction							<0.01	<0.01	<0.01
Material Moving							0.63	0.56	0.71
Metal and Plastic							0.13	0.11	0.15
Motor Vehicle							0.22	0.19	0.25
Other Installers, Maintenance, and Repair							0.02	0.01	0.02
Other Protective Service							<0.01	<0.01	<0.01
Supervisors of Construction and Extraction							0.20	0.17	0.23

*The dispersion index (DI) was derived from each respective quasi-poisson model

The fully adjusted SOC models (Model SOC-NFDL-2-83-0 and Model SOC-NFDL-2-03-14) performed best for NFDL injury counts or rates over the time period modelled, and had substantially lower AICs compared to the other models in their year groups (2056.95 and 739.13, respectively), highlighting the importance of controlling for occupation. However, none of the predictors in model SOC-NFDL-2-83-02 were statistically significant predictors of NFDL injury counts among the SOC dataset (**Table 5**). Analysis of the residual versus fitted values plot from the fully adjusted model SOC-NFDL-2-83-02 indicated that, while the residuals were randomly distributed about zero, there were clear gaps in the distribution, possibly due to the relatively low sample size (n = 173) in this model.

Similarly, none of the predictors in the fully adjusted SOC-NFDL-2-03-14 model (**Table 6**) for NFDL injury rates were associated with elevated injury risk, except for Extraction workers, which is highly statistically significant. Compared to Construction Trade workers, Extraction workers had an NFDL injury IRR 47.31 (95% CI: 35.03, 64.82) times higher after controlling for TWA_{MSHA} and Year. Analysis of the residual versus fitted values plot indicated that while the residuals were distributed about zero, the bulk of the predicted values lay between a NFDL injury rates of 2 to 4 per 100,000 FTE, with gaps on either side of this cluster. Once more, this poor model performance may simply be due to the small sample size (n=87).

Table 6. Negative binomial models for NFDL injury rates (2003-2014) among the SOC dataset

Statistic	**Model SOC-NFDL-Unadjusted-03-14**			**Model SOC-NFDL-1-03-14**			**Model SOC-NFDL-2-03-14**		
N	87			87			87		
DI	1248.91			1280.64			0.54		
AIC	30710.72			30742.07			739.13		
Variable	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**
TWA_{MSHA} (per 5 dBA)	0.89	0.35	2.29	0.88	0.33	2.33	0.92	0.79	1.07
Year	-	-	-	1.01	0.85	1.22	0.94	0.93	0.96
Minor SOC code	-	-	-	-	-	-			
Construction Trade (ref)							1.00	-	-
Extraction							47.31	35.03	64.82
Helpers, Construction							0.10	0.07	0.14
Material Moving							1.24	0.98	1.56
Metal and Plastic							0.64	0.50	0.82
Motor Vehicle							0.24	0.19	0.32
Other Installers, Maintenance, and Repair							0.33	0.25	0.42
Other Protective Service							0.01	<0.01	0.02
Supervisors of Construction and Extraction							1.24	0.93	1.66

*The dispersion index (DI) was derived from each respective quasi-poisson model

5.1.4 Noise and odds of fatality in the SIC dataset

Data among SIC codes showed a clear trend of decreasing occupational fatalities among mine types (**Figure 9**); however, the same clear trend for noise exposure over time was only evident among coal mines, and was not as clear in metal and nonmetal mines (**Figure 5**). Logistic regression was used to sequentially model odds of fatality in the SIC dataset using three predictors: TWA_{MSHA} (continuous), year, and mine type. ORs of TWA_{MSHA} are presented for every 5 dBA change in noise (**Table 7**). The industry variable is not presented for this outcome because the model with TWA_{MSHA}, year, and industry did not converge. For reference, unadjusted logistic models for each predictor independent of one another are presented in Table 4.2 (Appendix B).

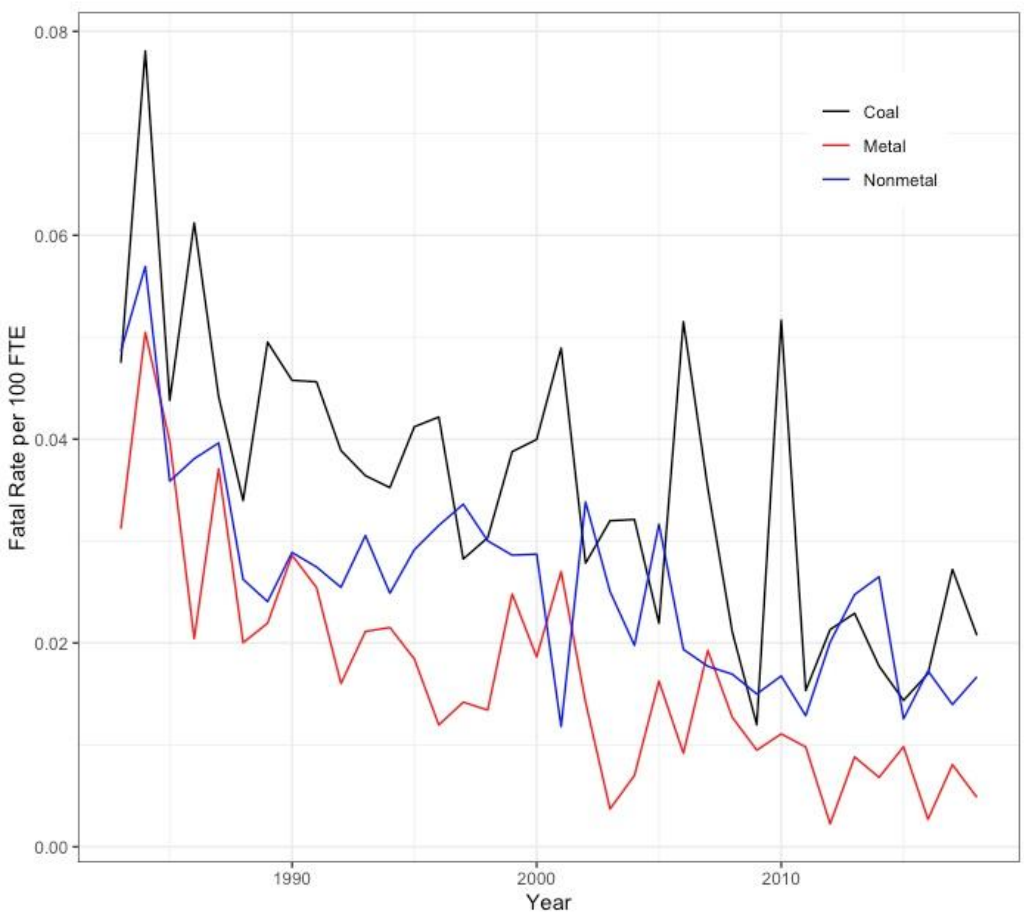

Figure 9. Occupational fatality rate over time by mine type among SIC data.

Table 7. Logistic model comparison for odds of fatality in the SIC dataset

Statistic	SIC-F-Unadjusted			Model SIC-Fatal-1			Model SIC-Fatal-2		
N	1826			1826			1826		
AIC	1990.11			1985.14			1915.54		
Variable	**OR**	**LL**	**UL**	**OR**	**LL**	**UL**	**OR**	**LL**	**UL**
TWA_{MSHA} (per 5 dBA)	1.14	1.01	1.30	1.12	0.98	1.26	1.16	1.01	1.32
Year	-	-	-	0.98	0.97	0.99	0.98	0.97	0.99
Mine Type	-	-	-	-	-	-			
Coal (ref)							1.00	-	-
Metal							0.11	0.05	0.20
Nonmetal							0.08	0.04	0.15

TWA_{MSHA} (continuous) was significantly positively associated with odds of fatality across all models, even after adjustments for year and mine type. Among the SIC dataset, every 5 dBA increase in TWA_{MSHA} was associated with 1.16 (95% CI: 1.01, 1.32) higher odds of an occupational fatality after adjustment for year and mine type, while year was negatively associated (OR = 0.98, 95% CI: 0.97, 0.99), as expected. Both metal and nonmetal mines had lower odds of an occupational fatality when compared to coal mines, controlling for TWA_{MSHA} and year, as demonstrated in **Table 7**.

Figure 10 demonstrates the positive relationship of TWA_{MSHA} (continuous) with the probability of an occupational fatality occurring among the SIC level in Model SIC-Fatal-2 (**Table 7**). Generally, as noise exposure increases across mines, the probability of an occupational fatality occurring also increases with varying degrees by mine type. The role that controlling for mine type plays in capturing the nuances of noise and fatality rate is evident, as each mine type shows differing probabilities of an occupational fatality occurring at the same noise level, with coal mines having the highest probability above metal and nonmetal mines.

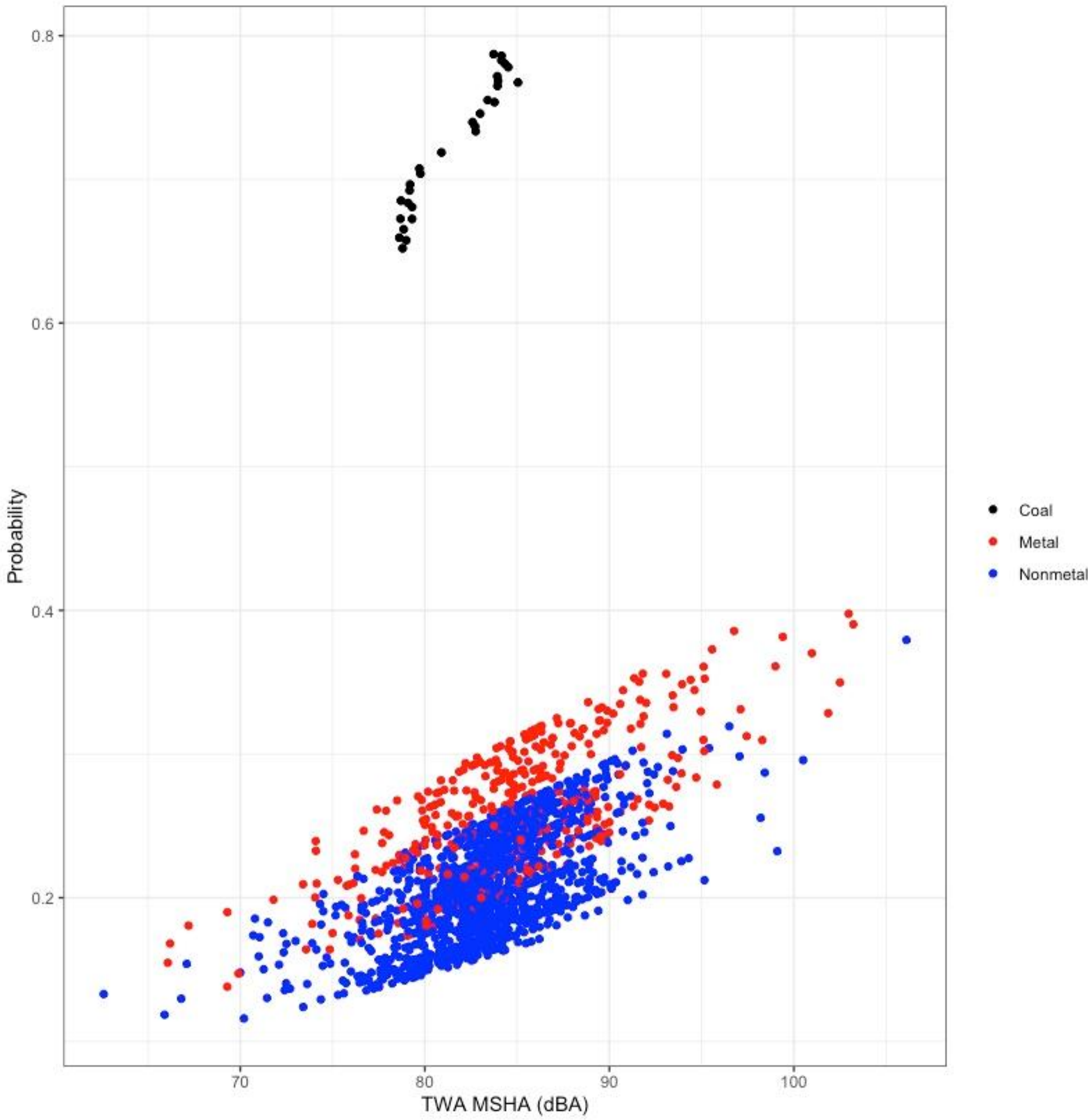

Figure 10: Scatterplot of TWA_{MSHA} levels (dBA) to predicted probability of an occupational fatality derived from Model SIC-Fatal-2 (Table 6), stratified by mine type.

5.1.5 Noise and odds of fatality in the SOC dataset

There was a clear decrease in occupational fatality counts over time by SOC code prior to 2002 (**Figure 11a**), and this trend continued from 2003 forward (**Figure 11b**). However, as seen in **Figure 11c**, rates among SOC code 47-5000 (i.e., extraction workers) remain significantly higher than the other SOC codes. As shown previously in **Figure 8,** noise among minor SOC codes exhibited a general but very slight decrease over time.

Odds of an occupational fatality in the SOC dataset were modelled using three predictors: TWA_{MSHA} (continuous), year, and major SOC groupings, as the inclusion of minor SOC groups prevented convergence in the fully adjusted model. ORs of TWA_{MSHA} are presented for every 5 dBA change in noise levels. Since a count of zero occupational fatalities in a year is equivalent to a fatality rate of zero, the entirety of the SOC dataset was utilized for the logistic regression, rather than sub-setting years after 2003. For reference, unadjusted logistic models for each predictor independent of one another are presented in Table 4.3 (Appendix B).

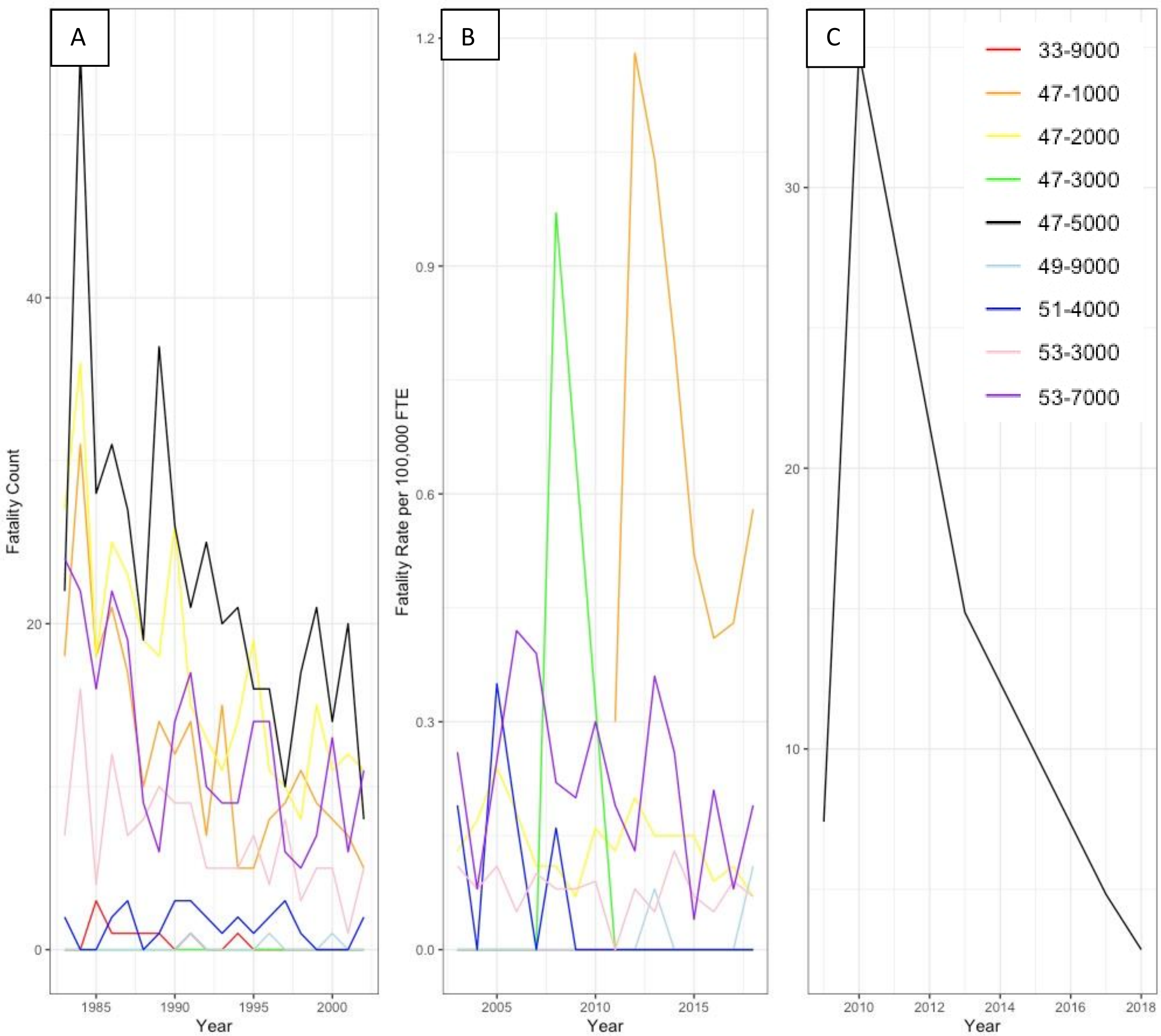

Figure 11. Occupational fatality counts from 1983 to 2002 among SOC codes overtime (A). Occupational fatality rates from 2003 to 2018 among SOC codes (B) except extraction workers which is presented in C due to significant scale differences from the rest. SOC codes presented in the legend correspond to these job titles in order from top to bottom; Other protective service workers, Supervisors of construction and extraction workers, Construction trades workers, Helpers, construction trades, Extraction workers, Other installation, maintenance, and repair occupations, Metal workers and plastic workers, motor vehicle operators, and material moving workers from the 2010 SOC structure.

Table 8. Logistic model comparison for odds of and occupational fatality among the SOC dataset (1983-2014)

Statistic	SOC-fatal-Unadjusted			Model SOC-Fatal-1			Model SOC-Fatal-2		
N	260			260			260		
AIC	328.45			329.51			228.14		
Variable	**OR**	**LL**	**UL**	**OR**	**LL**	**UL**	**OR**	**LL**	**UL**
TWA_{MSHA} (per 5 dBA)	1.47	1.09	1.99	1.41	1.02	1.93	1.49	1.00	2.23
Year	-	-	-	0.98	0.95	1.01	0.97	0.94	1.01
Major SOC code*	-	-	-	-	-	-			
Protective Service (ref)							1.00	-	-
Construction and Extraction							11.30	3.84	39.60
Installation, Maintenance, and Repair							0.43	0.09	1.87
Production							3.38	1.02	12.37
Transportation and Material Moving							200.39	31.72	4132.2

*Among occupational fatalities, the addition of minor SOC code in the fully adjusted model resulted in non-convergence; therefore, minor SOC codes were converted to major SOC codes. Major SOC codes: Protective Service (33-0000), Construction and Extraction (47-0000), Installation, Maintenance, and Repair (49-0000), Production (51-0000), and Transportation and Material Moving (53-0000)

TWA_{MSHA} (continuous) was significantly positively associated with odds of an occupational fatality across all models. In the SOC dataset, every 5 dBA increase in TWA_{MSHA} was associated with 1.49 (95% CI: 1.00, 2.23) higher odds of an occupational fatality after adjustment for year and major SOC code. After controlling for TWA_{MSHA} and year, both Construction and Extraction workers and Transportation and Material Moving occupations were statistically significant with higher odds of an occupational fatality compared to Protective Service workers (OR = 11.30, 200.39 respectively), as shown in **Table 8**.

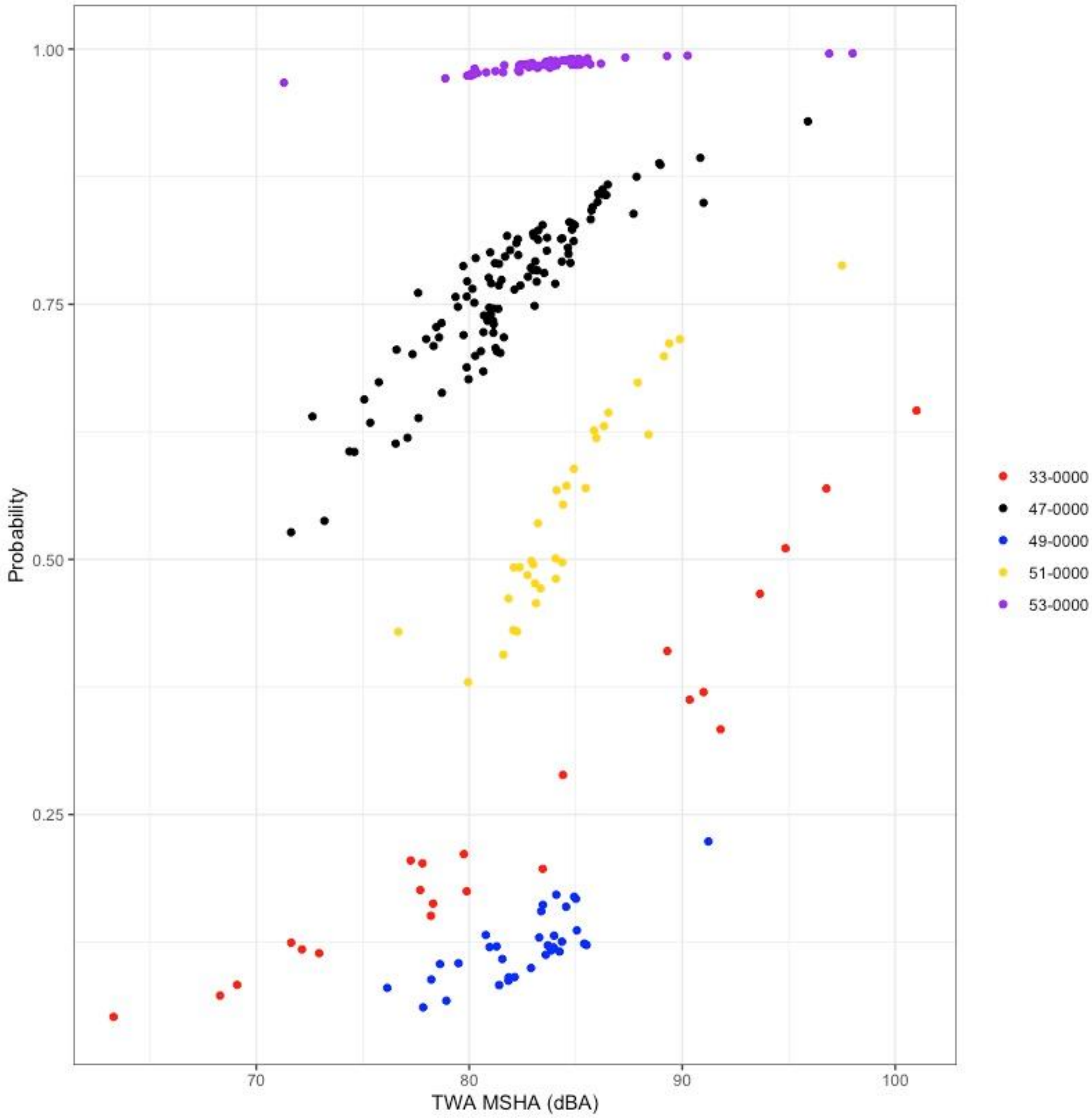

Figure 12. Scatterplot of predicted probability of an occupational fatality derived from Model SOC-Fatal-2 (Table 7) to TWA_{MSHA} levels (dBA), stratified by mine type. Major SOC codes presented in the legend are the following job title groups from top to bottom: Protective Service, Construction and Extraction, Installation, Maintenance, and Repair, Production, and Transportation and Material Moving.

Figure 12 illustrates the positive relationship between TWA_{MSHA} (continuous) and the probability of an occupational fatality occurring for the major SOC level from model SOC-Fatal-2. Consistent with the model in Table 7, Transportation and Material Moving workers (SOC: 53-0000) have the highest probability of an occupational fatality across all occupations. Overall, higher noise exposure for in the SOC dataset was associated with increased probability of an occupational fatality occurring for each of the major SOC codes.

5.1.6 Historic noise, injury, and fatality analysis at 10 Midwestern mines

Measured TWA_{MSHA} from 10 Midwestern mines (described in more detail under Specific Aim 2) are presented in **Table 9** as means with standard deviations. Noise measurements collected previously by MSHA at each of the mines visited are also presented as means from all years 1983 to 2018 by mine. All reported noise measurements from MSHA are presented by year by mine visited in separate tables by industry in Appendix B (Tables 3.1.1, 3.1.2 and 3.2.1). Mean differences and SE are reported from pairwise, two-sided t-tests between our measured TWA_{MSHA} and MSHA AL and PEL measurements are presented in **Table 9**. On average, noise measured across the ten mines visited during the summer of 2019 was lower than MSHA's 1983-2018 noise measurements using both the AL and PEL standards (by -3.4 and -0.5 dBA, respectively). These differences are consistent with the notion that MSHA measures worst-case scenario noise rather than typical noise exposures at a mine, as were captured in our study.

Table 9. Mean differences in TWA_{MSHA} noise levels (dBA) noise measured for 10 Midwestern mines and MSHA AL and PEL noise measurements collected between 1983 and 2018 by MSHA inspectors at the same mines

	TWA_{MSHA} (dBA) (measured 2019)			**MSHA AL (dBA, measured 1983-2018)**						**MSHA PEL (dBA, measured 1983-2018)**					
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	**Mean Diff**	**SE**	**p-value**	**N**	**Mean**	**SD**	**Mean Diff**	**SE**	**p-value**
Total	205	80.2	6.0	96	83.6	5.0	-3.4	0.5	<0.001	96	80.7	6.5	-0.5	0.7	0.279
Company 1	97	83.4	5.7	49	87.0	4.1	-3.6	0.8	<0.001	49	84.7	5.3	-1.3	1.0	0.196
Lime 1	9	81.9	5.4	14	85.8	3.4	-3.9	2.0	0.076	14	83.0	4.3	-1.1	2.1	0.609
Lime 2	16	80.9	4.1	8	85.0	2.5	-4.1	1.4	0.007	8	82.0	2.9	-1.1	1.4	0.461
Limestone 1	29	86.8	6.1	6	85.9	5.8	0.9	2.6	0.732	6	82.7	8.3	4.1	3.6	0.298
Limestone 2	9	84.2	5.9	6	89.4	2.6	-5.2	2.2	0.039	6	87.7	3.6	-3.5	2.5	0.172
Limestone 3	14	84.4	3.3	7	86.2	4	-1.8	1.8	0.335	7	84.8	3.7	-0.4	1.7	0.830
Limestone 4	20	80.1	5.1	8	90.9	3.5	-10.8	1.7	<0.001	8	89.2	5.8	-9.1	2.3	0.002
Company 2	108	77.4	4.6	47	80.8	3.8	-3.4	0.7	<0.001	47	77.3	5.4	0.1	0.9	0.976
Sand 1	24	79.5	4	13	82.2	3.1	-2.7	1.2	0.031	13	78.0	4.6	1.5	1.5	0.345
Sand 2	37	75.6	5.2	12	81.3	3.4	-5.7	1.3	<0.001	12	77.2	5.4	-1.6	1.8	0.384
Sand 3	44	77.9	3.9	13	79.5	4.6	-1.6	1.4	0.257	13	78.1	4.8	-0.2	1.5	0.910
Sand 4	3	76.2	1.8	9	78.9	3.9	-2.7	1.7	0.147	9	75.7	7.3	0.5	2.6	0.844

*Two-sided t-test

MSHA AL noise measurements were used as TWA_{MSHA} for all of the models run on the MV dataset. Once more, NFDL injury rates were modelled to see if there was an association between noise exposure and injury risk among miners at the mines visited. For NFDL injury rates among the mines visited, four predictors were used to build MV-NFDL negative binomial models: TWA_{MSHA} (categorical), year, S&S rate, and mine industry (i.e. Lime, Limestone, and Sand). Appendix B Table 4.1 contains statistics on each of the unadjusted models (i.e. N, AIC, DI) along with the IRRs and 95% CI of each predictor. Within the unadjusted model of TWA_{MSHA} (categorical) as the predictor of NFDL injury rates, no classes were statistically significantly associated with higher IRRs. **Table 10** below contains statistics of the model comparisons from the bivariate model TWA_{MSHA} (categorical) to the fully adjusted model, Model MV-NFDL-3.

Table 10. Negative binomial models for NFDL injury rates among 10 Midwestern mines (2000-2018)

Statistic	MV-NFDL-Unadjusted			Model MV-NFDL-1			Model MV-NFDL-2			Model MV-NFDL-3		
N	151			151			151			151		
Dispersion	4.23			3.63			3.68			3.72		
AIC	746.07			721.53			723.60			724.26		
Variable	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**	**IRR**	**LL**	**UL**
TWA_{MSHA}												
<80 dBA (ref)	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-
80 to <85 dBA	0.85	0.52	1.37	0.73	0.46	1.15	0.72	0.45	1.15	0.68	0.42	1.11
85 to <90 dBA	0.83	0.52	1.37	0.77	0.50	1.18	0.76	0.48	1.18	0.69	0.36	1.31
≥90 dBA	0.95	0.54	1.65	0.82	0.49	1.39	0.81	0.47	1.39	0.75	0.35	1.61
Year	-	-	-	0.95	0.92	0.97	0.95	0.92	0.97	0.95	0.92	0.98
S&S Rate	-	-	-	-	-	-	1.00	0.98	1.01	1.00	0.98	1.02
SIC code	-	-	-	-	-	-	-	-	-			
Lime (ref)										1.00	-	-
Limestone										0.73	0.44	1.21
Sand										0.70	0.39	1.24

*TWA_{MSHA} in the models is from the MSHA AL reported measurements summarized in Table 8.

Year was a statistically significant negative predictor of NFDL injury rates (IRR = 0.95; 95% CI: 0.92, 0.98). Although Model MV-NFDL-1 performed best with regards to AIC (721.53), the residual plots for Models MV-NFDL-2 and -3 looked slightly better. Unfortunately, the latter two models are not as powerful, likely due to lower sample size (n = 151) as well as a substantial portion of the noise data having to be imputed (approximately 50%).

It was not possible to do logistic regression on odds of occupational fatality due to the low count (n=1) of fatalities available among the mines visited from 2000 to 2018.

Summary of specific aim 1 *Collectively, the results of our analyses for Specific Aim 1 indicated that occupational noise exposures were significantly associated with increased risk of NFDL injuries in US mines, controlling for year, SIC code, and mining industry (Table 3). Occupational noise was also significantly associated with increased odds of occupational fatal injury in US mines, controlling for year and mine type (Table 6), as well as in a separate model controlling for year and SOC code (Table 7). Among the ten Midwestern mines (also assessed in Specific Aim 2), noise was not significantly associated with nonfatal injury risk even after controlling for year, S&S rate, and SIC code as hypothesized in Subaim 1a.*

5.2 Summary of Accomplishments for Aim 2

5.2.1 Sites

As described in section 4.2.1, we visited 10 separate mines in Michigan, Ohio, and Illinois in summer 2019 to fulfill the research objectives of Specific Aim 2. Six sites were operated by one conglomerate (Company 1) and four by a second conglomerate (Company 2). All mines were surface mining operations. Two sites were limestone kiln operations, 4 were limestone aggregate operations, and 4 were sand/silica operations.

5.2.2 Participants

We were not able to recruit from the entire population at each mine. Rather, we worked with the participating site management to target specific shifts and sections of each mine for recruitment. Each recruitment session occurred during a shift change, which normally included workers who were getting off of work. Due to these limitations, we are unable to report a participation rate from among the potential participants. The breakdown of subjects and days of measurements by Company and Site is shown in **Table 11.**

Table 11. Participants per company and mine

	N Subjects	%	N Days	%
Total	207	100	567	100
Company 1	97	46.9	271	47.8
Lime 1	9	4.3	25	4.4
Lime 2	16	7.7	45	7.9
Limestone 1	29	14.0	78	13.8
Limestone 2	9	4.3	27	4.8
Limestone 3	14	6.8	40	7.0
Limestone 4	20	9.7	56	9.9
Company 2	110	53.1	296	52.2
Sand 1	25	12.1	59	10.4
Sand 2	38	18.4	102	18.0
Sand 3	44	21.2	126	22.2
Sand 4	3	1.4	9	1.6

Data collection and analysis

5.2.2.1 Baseline demographics and work history

Our baseline survey was at least partially completed by 200 of the 207 participants. Five of the participants participated twice, contributing data for 3 shifts each time; these participants were not given the survey the second time that they participated.

On average participants in our prospective Specific Aim 2 data collection were 40.5 (±12.2) years old, worked 48.6 hours per week, were at least overweight (BMI ≥25), had been in their current job for 7.5 (±7.9) years, and in the industry for 11.6 (±9.7) years as reported in **Table 12**. Age, years in current job, and years in industry were significantly correlated (Spearman correlations >0.6, p<0.0001).

Table 12. Participant demographics from baseline survey (N = 202 participants)

Variable	N	Mean	SD	Median	IQR	Min - Max
Age (years)	197	40.5	12.2	39	18	18 - 66
Weight (lbs)	193	205.8	38.3	200	50	100 - 325
Height (inches)	195	70.4	2.6	70	3	62 - 78
BMI (lbs/in^2)	193	29.2	5.0	28.3	6.2	17.7- 46.6
Current job time (years)	200	7.5	7.9	4.4	8	0.04 - 43
Worked per week (hours)	198	48.6	9.6	48	13	20 - 84
Industry time (years)	199	11.6	9.7	8.2	13.2	0.08 - 43

5.2.2.2 Reported accidents, near-misses, and injuries

Among the 202 unique participants, 567 workshifts were measured for a total of 4,432 measured hours of noise exposure. Across these 567 shifts, five incidents on five shifts (0.88% of total shifts) occurred across the ten mines. These incidents consisted of one injury, two narrow misses, and two accidents. The injury occurred during a night shift, in which the participant's TWA_{MSHA} was measured above the PEL of 90 dBA. Unfortunately, none of the NASA TLX demands were reported for that particular shift, although a little stress and moderate sleep was reported. Across the other incidents, two TWA_{NIOSH} noise exposures were above the NIOSH REL of 85 dBA and one near miss was associated with a moderate level of frustration (9.6). Further description of the incidents along with noise measurements, HPD use, and other factors are reported **Table 13**.

Table 13. Self-reported injuries and near miss description of events (N=567 workshifts)

	Variable	Injury	Near miss		Accident	
		A	B	C	D	E
Incident description	**Company**	1	2	1	1	2
	Site	Limestone3	Sand 3	Limestone2	Limestone 4	Sand 3
	Shift	Night	Afternoon	Afternoon	Afternoon	Day
	Shift length (hours)	12	7.5	8	8	8
	Shift length (min)	690	497	464	431	427
	Task	Unloading metal	Replacing metal cover	Fixing conveyer	Fueling truck	Taking [off] housing [bolt]
	Outcome	Tweaked neck/back	NR*	NR*	Repairs required	Major damage
Noise variables	**MSHA noise**					
	TWA_{MSHA} (dBA)	92.2 (16.0)	74.4 (10.6)	89.4 (16.0)	68.4 (8.7)	81.5
	Kurtosis	1.9	2.2	1.9	1.3	5.0
	Crest factor	17.0 (12.7)	22.4 (11.6)	21.4 (13.5)	22.4 (11.1)	25.3 (9.5)
	% shift ≥85 dBA	28.3	3.6	24.8	0.0	8.0
	NIOSH noise					
	TWA_{NIOSH} (dBA)	96.4 (15.7)	81.6 (11.3)	94.5 (15.6)	73.1 (9.3)	93.1
	Kurtosis	1.9	2.0	1.03	1.3	3.9
	Crest factor	15.2 (12.7)	20.5 (11.9)	19.6 (13.5)	20.2 (11.3)	22.5 (10.2)
	% shift ≥85 dBA	31.2	5.2	26.5	0.7	9.6
	Kurtosis from peak	5.7	14.9	2.6	21.2	8.6
	L_{EQ}/L_{AVG}	1.03	1.0	1.02	1.03	1.04
HPDs	Hearing protection	No	Yes	No	No	NR
	$PAR_{needed, MSHA}$	7.2	-10.6	4.4	-16.6	-3.5
	$PAR_{needed,NIOSH}$	11.4	-3.4	9.5	-11.9	8.1
Other factors	Current sleepiness	6	7	5	2	3
	Sleep last night (hrs)	5.5	5	6	6.5	5.5
	Quality of sleep	6	6	5	7	4
	Stress	A little	A little	Some	Some	A little
	NASA TLX demands					
	Mental	NR*	9.7	7.6	4.5	11.5
	Physical	NR*	12.5	16.4	7.5	14.5
	Time	NR*	7.6	15.4	5.0	6.6
	Effort	NR*	8.7	15.5	8.3	14.4
	Frustration	NR*	9.6	0.7	3.7	3.8

*NR = not reported

Note: Shift length (hours) was self-reported by the participants while shift length (min) is the number of minutes of noise measured during that shift.

Participants were asked in the baseline survey whether any injuries, to varying degrees, occurred in the past month, past year, and in lifetime (**Table 14**). Overall, 12 injuries or conditions that affected work (5.8%) in the past month were reported. In the past year, 14 participants (6.8%) self-reported having been seriously injured at work, while nearly half of all participants (48.3%) reported having been seriously injured at work in their lifetime. Among the two companies sampled, no significant difference in self-reported historical injuries was seen.

Table 14. Self-reported accident, near-miss, injury and serious injury events (N=202 workers)

Time period/Variable	Overall		Company 1		Company 2	
	N	%	N	%	N	%
Past month						
Injuries or condition affect work						
No	183	88.4	91	93.8	92	83.6
Yes	12	5.8	3	3.1	9	8.2
NR	12	5.8	3	3.1	9	8.2
Past year						
Incident resulting in damage to tool						
No	147	71.0	63	64.9	84	76.4
Yes (span: 0.5 to 15)	60	21.3	34	29.9	26	13.6
NR	16	7.7	5	5.2	11	10.0
Near miss events frequency						
Never or almost never	171	82.6	81	83.5	90	81.8
Less than half of workdays	17	8.2	9	9.3	8	7.3
Every work day or almost every work day	1	0.5	--	--	1	0.9
NR	18	8.7	7	7.2	11	10.0
Almost seriously injured at work						
No	145	70.0	65	67.0	80	72.7
Yes (span: 1 to 30)	44	21.3	26	26.8	18	16.4
NR	18	8.7	6	6.2	12	10.9
Times injured at work						
0	140	67.6	65	67.0	75	68.2
1	27	13.0	13	13.4	14	12.7
2	11	5.3	7	7.2	4	3.6
≥3	20	9.8	12	12.4	8	7.3
NR	9	4.3	--	--	9	8.2
Times seriously injured at work						
0	180	87.0	91	93.8	89	80.9
1	12	5.8	3	3.1	9	8.2
2	1	0.5	--	--	1	0.9
≥3	1	0.5	--	--	1	0.9
NR	13	6.3	3	3.1	10	9.1
Worst injury, time missed from work						
Did not miss any work	41	61.2	25	78.1	16	45.7

Time period/Variable	Overall		Company 1		Company 2	
	N	%	N	%	N	%
Could not perform regular duties	1	1.5	--	--	1	2.9
Missed some work	5	7.5	--	--	5	14.3
NR	20	29.8	7	21.9	13	37.1
Lifetime						
Times seriously injured at work						
0	93	44.9	51	52.6	42	38.2
1	35	16.9	14	14.4	21	19.1
2	29	14.0	11	11.3	18	16.4
>3	36	17.4	17	17.5	19	17.3
NR	14	6.8	4	4.1	10	9.1

*NR = not reported

5.2.2.3 Self-reported and measured noise exposure metrics and their relationship with accidents, near-misses, and injuries

Due to equipment and software malfunctions as well as shifts terminating early the number of valid noise measurements is lower than the number of shift measurements attempted, hence the variable numbers in **Table 15**. Overexposures to noise were noted; based on $TWA_{MSHA,}$ 16.5% of measured shifts were ≥85 dBA, while 4.8% were ≥90 dBA. These percentages were higher using the TWA_{NIOSH} standard, with 44.4% of shifts ≥85 dBA and 18.3% ≥90 dBA. At the person level, 1 in 5 miners sampled experienced average TWA_{MSHA} noise levels ≥85 dBA and 1 in 20 experienced average noise levels ≥90 dBA on average when measured using MSHA criteria (data not shown). Using the NIOSH criteria, 1 in 2 participants experienced average TWA_{NIOSH} noise levels ≥85 dBA and more than 1 in 5 experienced them ≥90 dBA (data not shown). On average, minutes in a shift spent above ≥85 dBA and ≥90 dBA were higher among participants at Company 1 than at Company 2. Notably, Company 2 had no persons nor shifts that experienced a TWA_{MSHA} ≥90 dBA while Company 2 has 12 such measurements. These differences in noise exposure levels could be industry dependent, as all mines in Company 1 were either lime or limestone and all Company 2 mines were sand mines. However, these differences could be due to other structural differences.

Table 15. Personal noise exposure metrics (N=202 participants, 567 shifts, 265,918 minutes)

By shift	Overall			Company 1			Company 2		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
TWA $_{MSHA}$									
Crest factor	539	17.7	4.2	261	17.6	3.5	278	17.8	4.8
Kurtosis	539	2.5	1.4	261	2.3	0.9	278	2.6	1.7
L_{AVG} (dBA)	539	79.4	6.3	261	82.4	6.2	278	76.6	4.9
TWA (dBA)	539	79.4	6.3	261	82.2	6.3	278	76.7	5.1
TWA $_{NIOSH}$									
Crest factor	547	15.7	4.2	261	15.8	3.5	286	15.7	4.7
Kurtosis	547	2.6	1.3	261	2.4	1.0	286	2.7	1.6
L_{EQ} (dBA)	547	84.6	6.3	261	87.8	6.2	286	81.7	4.8
TWA (dBA)	547	84.6	6.3	261	87.7	6.2	286	81.7	4.8
Peak kurtosis	546	28.2	56.5	261	14.1	24.1	285	41.1	72.5
Variability (L_{EQ}/L_{AVG})	547	1.01	0.12	261	1.03	0.01	286	1.00	0.17

By person	N	Mean	SD	N	Mean	SD	N	Mean	SD
TWA $_{MSHA}$									
Crest factor	205	17.7	3.8	97	17.7	2.9	108	17.6	4.6
Kurtosis	205	2.5	1.1	97	2.3	0.6	108	2.7	1.4
L_{AVG} (dBA)	205	79.3	5.4	97	82.3	5.0	108	76.7	4.3
TWA (dBA)	205	80.2	5.9	97	83.4	5.7	108	77.4	4.6
% min $\geq$85 dBA	196	14.8	14.8	90	21.0	16.0	106	9.6	11.4
% min $\geq$90 dBA	196	6.8	10.1	90	11.7	12.7	106	2.6	3.6
TWA $_{NIOSH}$									
Crest factor	206	15.8	3.7	97	15.8	2.8	109	15.7	4.4
Kurtosis	206	2.6	1.1	97	2.4	0.7	109	2.7	1.3
L_{EQ} (dBA)	206	84.5	5.4	97	87.7	5.0	109	81.7	4.1
TWA (dBA)	206	85.5	6.0	97	89.9	5.7	109	82.4	4.3
% min $\geq$85 dBA	196	18.9	15.8	90	25.1	16.8	106	13.7	12.8
% min $\geq$90 dBA	196	8.9	10.8	90	14.2	13.4	106	4.4	4.7
Peak kurtosis	206	30.2	60.0	97	14.3	19.3	109	44.3	78.0
Variability (L_{EQ}/L_{AVG})	205	1.07	0.02	97	1.07	0.02	108	1.06	0.02

Bivariate logistic regression was performed to model self-reported accident, near-miss, and injury outcomes using two predictors: years worked in high noise and self-reported frequency of high noise exposure at work (**Table 16**). Participants who reported spending most of their time in high noise had 3.89 higher odds of a self-reported accident occurring in the past year compared to those who were exposed to high noise a little of the time, controlling for the years worked in high noise, and 4.27 higher odds of a self-reported near-miss occurring in the past year compared to those who spend a little of their time in high noise.

Table 16. Self-reported noise exposures by accident, near-miss, and injury outcomes

Variable	Accident in past year				Near-miss injury in past year				Work injury in past year				Serious work injury in past year			
	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p
Years working in high noise	181 (198.7)	0.98	0.02	0.25	179 (198.9)	0.98	0.02	0.13	185 (226.0)	1.02	0.01	0.23	183 (97.6)	1.01	0.02	0.65
Frequency of high noise exposure at work	190 (201.6)				188 (203.1)				195 (237.3)				193 (102.3)			
≤ A little of the time		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
Some of the time		1.46	0.81	0.50		2.52	1.48	0.12		0.71	0.30	0.42		0.24	0.18	0.06
≥ Most of the time		3.89	2.11	0.01		4.27	2.53	0.01		1.24	0.53	0.61		0.64	0.41	0.48

5.2.2.4 Self-reported and measured hearing ability and their relationship with accidents, near-misses, and injuries

We collected audiograms on 197 of the 202 unique participants. Due to a bug in the Apple Research Kit App related to pure tone audiometry test volume, we had to remove 6 participants from the analysis, leaving a sample of 191 audiograms. Similarly, after exploring the audiometric data from the App, it became evident that the testing algorithm was incorrectly assigning final values for some tests. However, the app saved the original threshold values, and we were able to develop code to recover these individual threshold measurements across the iterations and compute and assign the correct threshold.

Average left and right ear hearing threshold levels (HTL) across 1000, 2000, and 4000 Hz and stratified by company and site are presented in **Figure 13**. Only Sand 4 had an average HTL over 20 dB HL, and this was only the case for right ear results. However, as evidenced by the outliers, there were many participants at each company that may have more substantial hearing loss (i.e., HTLs > 40 dB HL). Limestone 3 and Sand 3 exhibited the widest range audiometric thresholds. No obvious trends in average HTLs were noted by mine type or company.

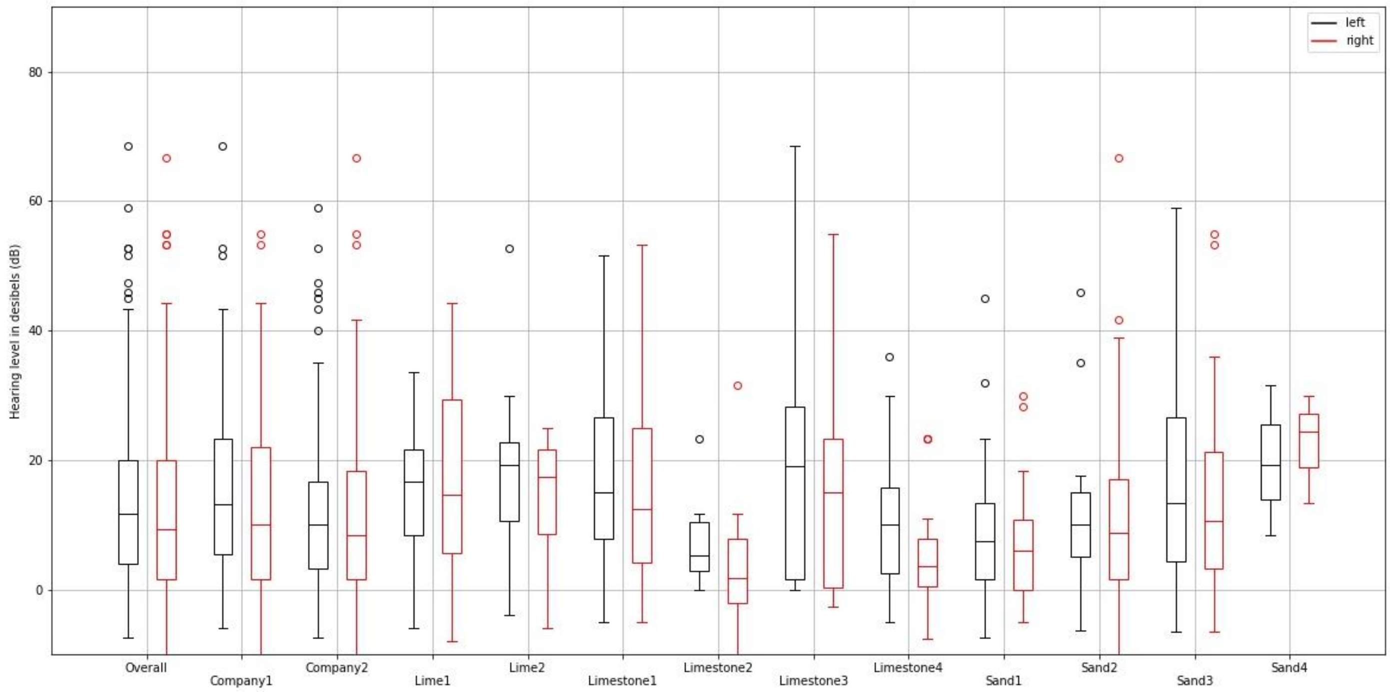

Figure 13. Box-plot of hearing threshold levels (HTLs) calculated as the both ear average at 1, 2, and 4 kHz from the Apple Research Kit App-based audiogram plotted by overall, company, and site.

Unoccluded values from the FitCheck Solo attenuation test were used as a comparison to the App based audiometric thresholds. Although the FitCheck Solo and its process is not identical to a conventional audiometric test, it nevertheless represents an independent measure of hearing thresholds. The spearman correlations between the HTL at each frequency measured in the Fitcheck and the best ear HTL in the audiogram are shown in **Table 17**. Correlations were generally moderate for frequencies below 2 kHz, and strong for the frequencies of 4 and 8 kHz, which are most sensitive to NIHL. Correlations were statistically significant across all matched frequencies.

Table 17. Spearman correlations between unoccluded thresholds from FitCheck and best ear thresholds from App based Audiogram (n = 119 - 189)

		Fitcheck Solo Unoccluded						Best ear - based on Audiogram						
	Variables	0.25 kHz	0.5 kHz	1 kHz	2 kHz	4 kHz	8 kHz	0.25 kHz	.5 kHz	1 kHz	2 kHz	3 kHz	4 kHz	8 kHz
FitcheckSolo Unoccluded	0.25 kHz	1.00												
	0.5kHz	0.77*	1.00											
	1 kHz	0.66*	0.83*	1.00										
	2 kHz	0.45*	0.61*	0.79*	1.00									
	4 kHz	0.37*	0.12	0.28*	0.41*	1.00								
	8 kHz	0.42*	0.37*	0.39*	0.40*	0.52*	1.00							
Best ear - based on Audiogram	0.25 kHz	0.38*	0.36*	0.21*	0.09	0.03	0.06	1.00						
	0.5 kHz	0.43*	0.54*	0.38*	0.23*	0.15	0.18*	0.76*	1.00					
	1 kHz	0.49*	0.45*	0.55*	0.42*	0.33*	0.35*	0.31*	0.63*	1.00				
	2 kHz	0.33*	0.27*	0.39*	0.63*	0.46*	0.35*	0.09*	0.32*	0.59*	1.00			
	3 kHz	0.37*	0.18	0.37*	0.51*	0.60*	0.37*	0.16*	0.29*	0.46*	0.73*	1.00		
	4 kHz	0.20*	0.08	0.27*	0.43*	0.75*	0.44*	0.12	0.18*	0.36*	0.59*	0.69*	1.00	
	8 kHz	0.39*	0.24*	0.34*	0.40*	0.57*	0.73*	0.26*	0.36*	0.50*	0.49*	0.57*	0.61*	1.00

*p≤0.05

Table 18 shows bivariate logistic regression models for four injury-related outcomes (accident in past year, near miss in past year, work injury in past year, and serious work injury in past year). In these unadjusted models, significantly elevated odds ratios were seen for at least one hearing measure within each of the four outcomes. The significant associations noted were between: worst ear HL ≥25 dB HL at 1-2-4 kHz and accident in past year (OR = 3.04, p=0.04); HL in both ears at 1-2-4 kHz and accident in past year (OR = 2.97, p=0.05); A lot of trouble hearing and near-miss in past year (OR=4.29, p=0.03); experienced tinnitus and work injury in past year (OR = 1.93, p=0.04); and A lot of trouble hearing and serious work injury in past year (OR = 6.52, p=0.02). These results suggest that certain measures of hearing ability may be associated with increased risk of accident, near-miss, or injury.

Table 18. Bivariate models of self-reported and measured hearing ability and occurrence of accident, near-miss, or injuries (n = 202 subjects)

Variable	Accident in past year				Near-miss in past year				Work injury in past year				Serious work injury in past year			
	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p
Hearing rating	191 (209.3)				189 (206.6)				196 (240.0)				194 (102.0)			
Good		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
A little trouble		0.96	0.35	0.92		1.41	0.51	0.35		1.13	0.37	0.71		1.23	0.77	0.74
A lot of trouble		2.96	1.94	0.10		4.29	2.95	0.03		1.55	1.04	0.51		6.52	5.34	0.02
Hearing difficulty (Y)	190 (209.6)	0.97	0.37	0.94	188 (207.4)	1.49	0.54	0.28	195 (234.9)	1.43	0.48	0.29	193 (101.9)	2.44	1.37	0.11
Diagnosed HL (Y)	191 (210.1)	1.11	0.44	0.80	189 (205.6)	2.07	0.79	0.06	196 (238.4)	0.88	0.34	0.75	194 (104.5)	0.87	0.59	0.83
Tinnitus (Y)	190 (209.1)	1.30	0.45	0.45	188 (207.5)	1.43	0.50	0.30	195 (233.6)	1.93	0.62	0.04	193 (104.4)	1.04	0.58	0.94
SRT_1	186 (201.5)	1.08	0.07	0.27	184 (200.8)	0.93	0.07	0.37	193 (237.8)	1.04	0.06	0.49	189 (101.7)	1.15	0.11	0.12
Fitcheck HTL at 1-2-4 kHz	174 (191.1)	1.01	0.01	0.48	172 (195.8)	0.98	0.02	0.22	180 (225.2)	1.01	0.01	0.56	177 (100.3)	1.03	0.02	0.19
Audiogram HTL Best ear at 1-2-4 kHz	178 (192.8)	1.01	0.01	0.34	176 (195.0)	0.99	0.01	0.75	185 (227.4)	1.00	0.01	0.81	181 (96.9)	1.02	0.02	0.43
Fitcheck HL ≥25 dB HL at 1-2-4 kHz	174 (190.8)	1.42	0.55	0.37	172 (196.4)	0.66	0.28	0.32	180 (225.5)	1.10	0.39	0.79	177 (100.1)	2.16	1.23	0.18
Audiogram worse ear HL ≥25 dB HL at 1-2-4 kHz	178 (189.7)	3.04	1.34	0.04	176 (194.9)	0.74	0.49	0.65	185 (226.8)	1.51	0.82	0.76	181 (94.9)	3.58	2.57	0.08
HL Category at 1-2-4 kHz	178 (191.2)				176 (195.6)				185 (228.6)				181 (96.8)			
No Loss		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
One Ear		0.87	0.47	0.79		0.53	0.31	0.28		0.81	0.36	0.64		1.18	0.97	0.84
Both Ears		2.97	1.62	0.05		0.68	0.45	0.56		1.45	0.80	0.49		3.69	2.72	0.08

5.2.2.5 Hearing protection device fit and use and their relationship with accidents, near-misses, and injuries

Bivariate logistic regression models were also run to explore potential associations between HPD use factors and the four injury-related outcomes (accident in past year, near miss in past year, work injury in past year, and serious work injury in past year). The results of these models (**Table 19**) identified significant odds ratios for at least one HPD use factor and three of the four outcomes. The significant associations were: a protective effect against accident in past year for workers overprotected using TWA_{MSHA} (OR = 0.96, p = 0.03); a protective effect against accident in past year for workers overprotected using TWA_{NIOSH} (OR = 0.96, p = 0.02); a significantly increased risk of near-miss in the past year associated with greater HPD use frequency (OR = 1.30, p=0.02); and a significantly increased risk of work injury in the past year associated with greater HPD use frequency (OR = 1.24, p=0.04). These results suggest that several measures of HPD use may be significantly associated with accident, near miss, or work injury, but the associations are variable and may be negative or positive depending on the predictor variable evaluated.

Table 19. Bivariate models of self-reported and measured HPD use for accident, near-miss, or injury (n = 202 subjects)

Variable	Accident in past year				Near-miss in past year				Work injury in past year				Serious work injury in past year			
	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p
HPD use time (%)	190 (209.0)	1.00	0.00	0.43	188 (208.4)	1.00	0.00	0.71	197 (240.3)	1.00	0.00	0.41	194 (104.5)	1.00	0.01	0.75
Fitcheck PAR	155 (167.1)	0.97	0.02	0.11	153 (181.8)	1.00	0.02	0.95	160 (202.4)	1.01	0.02	0.53	158 (91.3)	1.06	0.04	0.13
Overprotected using TWA_{MSHA}*	155 (164.5)	0.96	0.02	0.03	153 (181.9)	1.00	0.02	0.93	160 (202.7)	1.00	0.02	0.85	158 (91.8)	1.04	0.03	0.16
Overprotected using TWA_{NIOSH}*	155 (163.9)	0.96	0.02	0.02	153 (181.8)	1.00	0.02	0.95	160 (202.6)	1.01	0.02	0.66	158 (91.0)	1.05	0.03	0.10
HPD use frequency*	187 (202.8)	1.21	0.14	0.10	185 (199.3)	1.30	0.15	0.02	193 (233.9)	1.24	0.13	0.04	189 (103.6)	1.08	0.19	0.68

*indicates variable collected at the shift level and averaged to the person level

The majority of the HPD types used among 200 workers sampled was foam earplugs (79.4%), while 8.8 percent used earmuffs (**Table 20**). Only 5.2 percent use both earplugs and earmuffs (i.e., double protection) while at work. Of those who wore earplugs, the average PAR achieved from the Fitcheck Solo was 24.2 dB (±9.4 dB), while an average of 13.7 dB (±7.9 dB) was achieved among those who wore earmuffs. In other words, earplug users achieved nearly twice the attenuation of earmuff users on average. As shown in **Figure 14**, no workers were found to have inadequate PAR values (i.e., none were under-protected, or receiving insufficient attenuation from their HPDs).

Table 20. Hearing protection device usage and attenuation (n = 200 workers)

Variable	N	Mean	SD	Median	IQR	Span
PAR earplugs (dB)	176	24.2	9.4	24.9	12.7	0.0 – 43.1
PAR earmuffs (dB)	32	13.7	7.9	11.2	9.4	-5.6 – 28.0
HPD use time (%)	199	74.9	31.8	90.0	39	0.0 – 100.0

Variable	N	%
HPD type		
Foam	154	79.4
Muff	17	8.8
None	9	4.6
Pre-mold	4	2.1
Double Protection (Earplugs + Muffs)	10	5.2

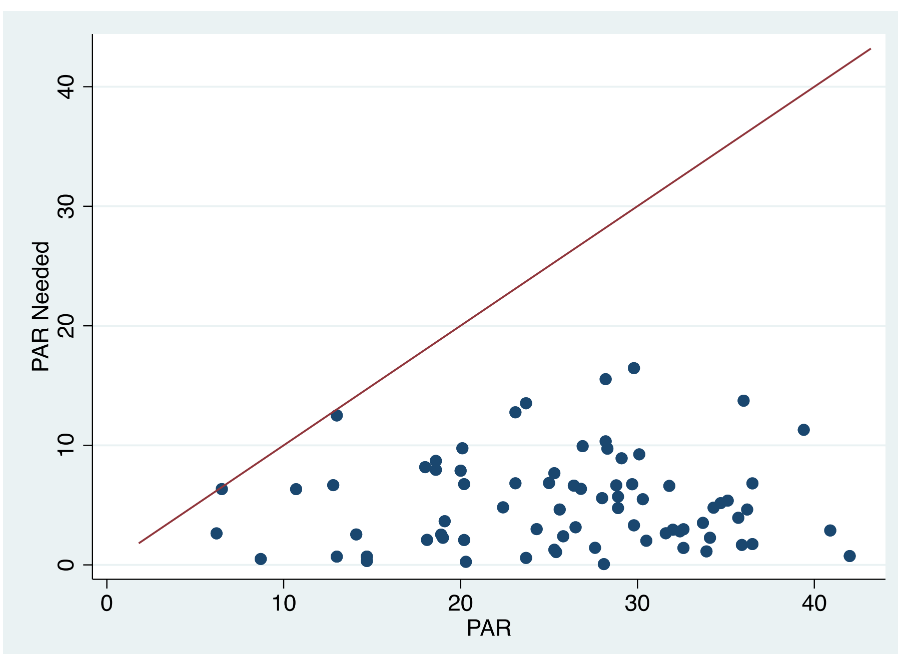

Figure 14. Scatterplot of PAR needed (dB) vs Fitcheck PAR earplugs (dB) (n=199 workers)

5.2.2.6 Potentially important covariates related to stress, work culture, overall health, and sleepiness and their relationship with accidents, near-misses, and injuries

Bivariate logistic regression models were run to evaluated potential associations between stress, work culture, overall health, sleepiness, fatigue, and work demands and the four injury-related outcomes (accident in past year, near miss in past year, work injury in past year, and serious work injury in past year). The results of these models (**Table 21**) did not identify any statistically significant associations between the predictors and odds of having an accident in the past year or work injury in past year. Two predictors were associated with significantly increased risk of near-miss in the past year: job safety score (OR = 1.09, SE = 0.03, $p<0.01$) and NASA-TLX Frustration demand (OR = 1.09, SE = 0.05, $p=0.05$). A single predictor, NASA-TLX Time demand, was associated with significantly increased risk of a serious work injury in the past year (OR = 1.16, SE = 0.08, $p=0.04$). These results indicate that specific work factors may influence risk of near-miss or serious work injury.

Table 21. Bivariate models of self-reported and measured covariates related to stress, work culture, overall health, sleepiness, and work demands by odds of accident, near-miss, or injuries (n = 202 subjects)

Variable	Accident in past year				Near-miss in past year				Work injury in past year				Serious work injury in past year			
	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p
Health	191 (211.3)				189 (208.4)				196 (238.3)				194 (105.3)			
≤ Good		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
Very good		0.62	0.35	0.40		0.45	0.26	0.17		1.33	0.82	0.64		1.04	1.19	0.97
Excellent		0.61	0.33	0.36		0.77	0.42	0.64		1.97	1.18	0.26		1.94	2.11	0.54
Fitness	189 (209.4)				187 (207.9)				194 (237.5)				192 (103.8)			
≤ Good		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
Very good		0.72	0.27	0.37		1.51	0.59	0.29		1.57	0.58	0.22		3.07	2.43	0.16
Excellent		0.48	0.30	0.24		0.76	0.48	0.67		1.21	0.65	0.72		2.56	2.64	0.36
Perceived Stress Scale (PSS)	184 (203.6)	1.02	0.03	0.48	182 (200.6)	1.00	0.03	0.97	188 (223.7)	0.99	0.03	0.73	188 (93.2)	1.01	0.05	0.85
Safety A**	189 (205.0)				187 (202.4)				190 (224.8)				189 (93.0)			
Response A		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
Response B		1.75	0.72	0.18		2.15	0.88	0.06		1.23	0.52	0.62		1.51	1.05	0.55
Safety B***	187 (198.4)				185 (202.0)				187 (220.9)				187 (91.3)			
Response A		1.00	--	--		1.00	--	--		1.00	--	--		1.00	--	--
Response B		1.71	0.61	0.13		1.14	0.40	0.71		0.86	0.29	0.64		0.41	0.28	0.20
Job Safety Score (JSS)	189 (206.7)	1.00	0.02	0.93	187 (194.7)	1.09	0.03	<0.01	189 (220.6)	1.05	0.02	0.06	189 (93.4)	1.01	0.04	0.87
Epworth Sleep Scale (ESS)	186 (202.8)	1.07	0.04	0.13	184 (199.4)	1.07	0.05	0.13	186 (220.0)	1.03	0.04	0.47	186 (92.7)	0.96	0.07	0.57

Variable	Accident in past year				Near-miss in past year				Work injury in past year				Serious work injury in past year			
	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p	n (AIC)	OR	SE	p
Fatigue Severity Scale (FSS)	174 (186.1)	1.04	0.02	0.08	172 (187.4)	1.04	0.02	0.08	174 (201.1)	1.06	0.02	<0.01	175 (91.5)	1.00	0.04	0.96
Sleepiness*	191 (206.7)	1.24	0.14	0.06	189 (208.5)	1.09	0.13	0.45	198 (238.9	1.25	0.13	0.03	194 (103.7)	1.19	0.21	0.34
Stress*	Did not converge				187 (210.5)				196 (243.6)				Did not converge			
None						1.00	--	--		1.00	--	--				
Very little						1.36	0.96	0.66		2.20	1.51	0.25				
A little						1.30	0.91	0.71		2.67	1.80	0.15				
Some to much						2.07	1.50	0.31		2.28	1.64	0.25				
NASA TLX demands*																
Mental*	191 (207.7)	1.07	0.05	0.12	189 (208.1)	1.04	0.4	0.30	198 (240.8)	1.07	0.04	0.10	194 (103.2)	1.08	0.07	0.24
Physical*	191 (207.3)	1.08	0.05	0.09	189 (208.1)	1.05	0.05	0.31	198 (242.3)	1.05	0.04	0.29	194 (103.5)	1.08	0.08	0.31
Time*	191 (208.8)	1.05	0.05	0.24	189 (208.0)	1.05	0.05	0.30	198 (241.4)	1.06	0.04	0.15	194 (100.3)	1.16	0.08	0.04
Effort*	191 (208.9)	1.05	0.05	0.27	189 (208.2)	1.04	0.05	0.35	198 (239.8)	1.08	0.04	0.06	194 (100.9)	1.15	0.09	0.06
Frustration*	191 (210.1)	0.99	0.05	0.81	189 (205.4)	1.09	0.05	0.05	198 (242.6)	1.04	0.04	0.36	194 (104.6)	1.01	0.07	0.94

*Indicates variable collected at the shift level and averaged to the person level

**Safety A was a question with two response choices; A (i.e., Safety is at the forefront of my mind when working) and B (i.e., Safety is important, but other factors sometimes limit my ability to work safely)

***Safety B was a question with two response choices; A (i.e., Injuries occur at work because people don't take enough interest in safety) and B (i.e., Injuries at work will always occur, no matter how hard people try to prevent them)

5.2.2.7 Predictors of Personal Attenuation Ratings

Bivariate and multivariate linear regression models were used to explore potential predictors of PARs achieved by participants who wore earplugs (**Table 22**). In the PAR-unadjusted models, hearing loss ≥25 dB HL at 1-2-4- kHz, age, and perceived hearing health were found to be significantly and negatively associated with PARs (β values -0.11 to -5.08, p values 0.006-0.03). Additionally, an interaction was noted in the PAR-unadjusted model that evaluated combination of tinnitus and hearing loss; workers with tinnitus and hearing loss had significantly lower PAR values (β = -6.33, SE = 2.30, p=0.007) than those with no tinnitus and hearing loss (the reference group). In fully adjusted PAR model 1, which included main effects for hearing loss and tinnitus, hearing loss ≥25 dB HL at 1-2-4- kHz was again significantly associated with a reduced PAR (β = -5.67, SE = 1.99, p=0.005). In fully adjusted PAR model 2, which included the interaction term for hearing loss and tinnitus, two categories were significant: workers with tinnitus and no hearing loss had significantly higher PARs (β =3.64, SE = 1.74, p=0.04), and workers with tinnitus and hearing loss had significantly lower PARs (β = -6.05, SE = 2.45, p=0.02). These results indicate that both hearing loss and tinnitus influence workers' PARs.

Table 22. Linear regression models for predictors of personal attenuation ratings (PARs)

	PAR-Unadjusted (n = 148 – 150)				PAR-Model-1 (n = 143, $R^2_{Adj.}$ = 0.04)			PAR-Model-2 (n = 143, $R^2_{Adj.}$ = 0.07)		
Predictors	**R^2**	**β**	**SE**	**p**	**β**	**SE**	**p**	**β**	**SE**	**p**
Hearing loss ≥25 dB HL at 1-2-4 kHz	0.05	-5.08	1.83	0.006	-5.67	1.99	0.005			
Age (years)	0.02	-0.11	0.06	0.07	0.05	0.07	0.44	-0.65	0.07	0.33
SRT_1	<0.01	0.27	0.36	0.45	0.38	0.38	0.33	0.41	0.38	0.28
% Time earplug worn	<0.01	<0.01	0.02	0.73	<-0.01	0.02	0.89	<-0.01	0.02	0.95
TWA_{NIOSH} (dBA)	<0.01	0.07	0.12	0.56	<-0.01	0.13	0.95	<-0.01	0.14	0.63
Tinnitus (Y)	<0.01	0.63	1.50	0.68	1.62	1.57	0.31			
Hearing rating	0.03	-2.70	1.23	0.03						
Frequency of high noise exposure at work	<0.01	0.98	0.85	0.25						
Tinnitus & hearing loss interaction	0.09									
No Tinnitus & HL		1.00						1.00		
Tinnitus & No HL		3.28	1.63	0.05				3.64	1.74	0.04
No Tinnitus & HL		-0.54	2.77	0.84				-0.24	2.93	0.93
Tinnitus & HL		-6.33	2.30	0.007				-6.05	2.45	0.02

5.2.2.8 Predictors of Hearing Loss

Bivariate and multivariate logistic regression models were used to explore potential predictors of hearing loss among participants (**Table 23**). In the HL-unadjusted models, a total of six predictors were significantly associated with hearing loss. Five of these were associated with increased risk of hearing loss: age (OR = 1.09, SE = 0.02, p<0.01); SRT_1 (OR = 1.35, SE = 0.10, p<0.01); TWA_{NIOSH} (OR = 1.09, SE = 0.02, p = 0.05); tinnitus (OR = 2.70, SE = 0.94, p <0.01), and hearing rating (OR = 5.78, SE = 2.07, p<0.01). Only a single bivariate model identified a significantly protective factor: PAR (OR = 0.94, SE = 0.02, p<0.01). In fully adjusted HL model 1, three variables remained significant. Age and SRT_1 were associated with increased risk of hearing loss (OR = 1.07, SE = 0.02, p<0.01 and OR = 1.26, SE = 0.15, p=0.05, respectively). PAR remained significantly protective against risk of hearing loss (OR = 0.93, SE = 0.03, p=0.01).

Table 23. Logistic regression models for predictors of hearing loss

	HL-Unadjusted (n = 175 – 179)			**HL Model 1 (n = 143)**		
Predictors	**OR**	**SE**	**p**	**OR**	**SE**	**p**
PAR	0.94	0.02	<0.01	0.93	0.03	0.01
Age (years)	1.09	0.02	<0.01	1.07	0.02	<0.01
SRT_1	1.35	0.10	<0.01	1.26	0.15	0.05
% Time earplug worn	1.00	<0.01	0.97	1.00	<0.01	0.57
TWA_{NIOSH} (dBA)	1.09	0.02	0.05	1.07	0.05	0.17
Tinnitus (Y/N)	2.70	0.94	<0.01	2.37	1.17	0.08
Hearing rating	5.78	2.07	<0.01			
Frequency of high noise exposure at work	0.89	0.17	0.53			

5.2.2.9 Combined effect of noise, hearing loss, and HPD on injuries

Based on the results of the bivariate models of the four injury outcomes (accident, near-miss, work injury in past year, serious work injury in past year), two outcomes were selected for inclusion in our final models: near-miss in past year, and work injury in past year.

The bivariate and multivariate logistic regression models for near-miss in past year are shown in **Table 24**. Among the NM-unadjusted models, only two predictors were significantly associated with near-miss in the past year. These were the fatigue severity score (OR = 1.04, SE = 0.02, p = 0.04) and previous severe work injury over working lifetime (OR=2.36, SE = 0.78, p = 0.01). In fully adjusted NM Model 1, two different predictors were significant: diagnosed HL (OR = 3.2, SE = 1.65, p = 0.03) was associated with a significantly increased risk of near-miss, and years of work in high noise was significantly protective (OR = 0.95, SE = 0.02, p = 0.02). A second model, NM Model 2, was run that included an interaction term for hearing loss and use of hearing protection (HPDs). In this model, work in high noise was again significantly protective (OR = 0.94, SE = 0.02, p = 0.02), and the group with hearing loss and HPD use had an extremely high risk for near-miss injury (OR = 9.5, SE = 7.53, p<0.001). A final model, NM3, was run to test multiple interactions between noise, hearing loss, and HPD use. Odds of reporting a near-miss in the last year were highest among participants who experienced workshifts ≥85 dBA, wore HPDs, and had not been diagnosed with a hearing loss (OR = 4.49, SE = 3.22, p=0.04).

Table 24. Logistic regression models for predictors of near-miss in last year

	NM-Unadjusted					**NM Model 1** (N=157; AIC=169.7)			**NM Model 2 (2-way interaction)** (N=157; AIC=171.5)			**NM Model 3 (3-way interaction)** (N=148; AIC=178)		
Variable	N	OR	SE	p	AIC	OR	SE	p	OR	SE	p	OR	SE	p
% shift ≥85 dBA	206	1.02	0.01	0.19	254.3	1.02	0.02	0.37	1.02	0.02	0.40	-	-	-
Fatigue severity score (FSS)	176	1.04	0.02	0.04	197.6	1.01	0.03	0.58	1.01	0.03	0.60	1.04	0.03	0.08
Diagnosed HL (Y)	198	1.89	0.68	0.08	231.0	3.20	1.65	0.03	-	-	-	-	-	-
HPD use (ever)	204	1.38	0.47	0.35	250.3	3.00	1.76	0.06	-	-	-	-	-	-
Previous serious work injury	207	2.36	0.78	0.01	249.3	1.80	1.80	0.21	1.80	0.80	0.22	1.54	0.70	0.34
Job safety score (JSS)	191	1.09	0.03	0.00	205.1	1.10	0.03	0.09	1.10	0.04	0.12	0.97	0.03	0.26
Sleep last night (hours)	204	0.80	0.10	0.07	246.1	0.80	0.80	0.21	0.80	0.14	0.20	0.95	0.16	0.76
Work in high noise (years)	187	0.98	0.01	0.20	221.4	0.95	0.02	0.02	0.94	0.02	0.02	0.97	0.02	0.23
Perceived stress score (PSS)	190	1.01	0.03	0.83	223.0	0.97	0.04	0.50	0.97	0.04	0.54	1.03	0.04	0.49

	NM-Unadjusted					NM Model 1 (N=157; AIC=169.7)			NM Model 2 (2-way interaction) (N=157; AIC=171.5)			NM Model 3 (3-way interaction) (N=148; AIC=178)		
Variable	N	OR	SE	p	AIC	OR	SE	p	OR	SE	p	OR	SE	p
2-way Interaction														
No HL, No HPD	-	-	-	-		-	-	-	1.00	-	-			
No HL, Yes HPD	-	-	-	-		-	-	-	1.92	2.40	0.60			
Yes HL, No HPD	-	-	-	-		-	-	-	2.69	1.69	0.12			
Yes HL, Yes HPD	-	-	-	-		-	-	-	9.50	7.53	<0.001			
3-way interaction														
<85dBA, No HPD, No HL	-	-	-	-		-	-	-	-	-	-	1.00	-	-
<85dBA, No HPD, Yes HL	-	-	-	-		-	-	-	-	-	-	-	-	-
<85dBA, Yes HPD, No HL	-	-	-	-		-	-	-	-	-	-	3.71	2.89	0.09
<85dBA, Yes HPD, Yes HL	-	-	-	-		-	-	-	-	-	-	4.82	4.68	0.11
≥85dBA, No HPD, No HL	-	-	-	-		-	-	-	-	-	-	3.77	4.16	0.23
≥85dBA, No HPD, Yes HL	-	-	-	-		-	-	-	-	-	-	-	-	-
≥85dBA, Yes HPD, No HL	-	-	-	-		-	-	-	-	-	-	4.49	3.22	0.04
≥85dBA, Yes HPD, Yes HL	-	-	-	-		-	-	-	-	-	-	5.20	5.12	0.09

Table 25 shows the results of bivariate and multivariate logistic regression models with the outcome work injury in the past year. In the WI-unadjusted models, three variables were significantly associated with increased risk of a work injury in the past year. These were the Fatigue Severity Score (OR = 1.10, SE = 0.02, p=0.01), previous serious work injury (OR = 3.5, SE = 1.15, p <0.001), and sleepiness (OR = 1.23, SE = 0.12, p = 0.04). Fully adjusted WI model 2 includes main effects for hearing loss (HTLs ≥25 dB HL at 1-2-4 kHz) and HPD use; in this model four predictors were significantly associated with work injury in the past year. These variables, all of which were associated with increased risk of injury, were: HPD use (OR = 3.6, SE = 1.82, p = 0.01); Fatigue Severity Score (OR = 1.1, SE = 0.03, p<0.001); previous serious work injury (OR 3.1, SE = 1.35, p = 0.01) and safety A (OR = 3.2, SE = 1.66, p=0.03). Finally, WI Model 3 included an interaction term for hearing loss and HPD use. In this model, three predictors reached statistical significance: Fatigue Severity Score (OR = 1.10, SE = 0.03, p<0.001); previous serious injury at work (OR = 2.96, SE = 1.32, p = 0.02); and safety A (OR = 3.25, SE = 1.73, p = 0.03). Additionally, the group of workers with no hearing loss and reporting use of HPD had a significantly increased risk of work injury in the past year (OR = 3.02, SE = 1.69, p=0.05).

Table 25. Logistic regression models for predictors of work injury in last year

Variables	WI-Unadjusted					WI Model 2 (N=157; AIC=174.3)			WI Model 3 (Interaction) (N=157; AIC=175.8)		
	N	OR	SE	p	AIC	OR	SE	p	OR	SE	p
TWA_{MSHA}≥95	206	0.95	0.04	0.15	261.3	0.93	0.05	0.19	0.93	0.05	0.19
HPD use (ever)	204	1.44	0.48	0.27	258.1	3.60	1.82	0.01	-	-	-
Fatigue Severity Score (FSS)	176	1.10	0.02	0.01	205.7	1.10	0.03	<0.001	1.10	0.03	<0.001
HTL ≥25 dB	198	0.94	0.35	0.86	243.5	0.73	0.35	0.51	-	-	-
Previous serious work injury in lifetime	193	3.50	1.15	<0.001	248.8	3.10	1.35	0.01	2.96	1.32	0.02
Safety A (response A=ref)	192	1.48	0.59	0.33	229.3	3.20	1.66	0.03	3.25	1.73	0.03
Sleepiness	205	1.23	0.12	0.04	255.7	1.23	0.18	0.14	1.23	0.17	0.15
Time in industry (years)	187	1.01	0.01	0.28	231.1	1.01	0.02	0.44	1.02	0.02	0.39
Perceived stress score (PSS)	190	1.00	0.03	0.90	228.9	0.98	0.04	0.73	0.99	0.04	0.72
Interaction											
No HL, No HPD	-	-	-	-		-	-	-	1.00	-	-
No HL, Yes HPD	-	-	-	-		-	-	-	3.02	1.69	0.05
Yes HL, No HPD	-	-	-	-		-	-	-	0.36	0.44	0.40
Yes HL, Yes HPD	-	-	-	-		-	-	-	2.50	1.65	0.17

Summary of specific aim 2 *Collectively, the results of our specific aim 2 assessments of risk of injuries associated with noise, HPD use, and hearing loss indicated that miners at the ten participating sites showed high rates of hearing loss and HPD use, and had high exposures to occupational noise. The vast majority of users reported using earplugs, all workers achieved sufficient attenuation given their full-shift noise exposures, and most workers were overprotected (i.e., had PAR in excess of what was required to reduce them below the relevant exposure limit, Figure 12). The results of our app-based audiometric test showed moderate to strong correlations with Fitcheck-based measures of hearing thresholds (Table 16). Reports of injuries and near-misses were rare within the past year, but nearly half of all workers had been injured during their career (Table 13). While we developed a number of novel noise metrics in pursuit of Subaim 2a, none was determined to be associated with injury risk. Linear regression models suggest interactive effects of hearing loss and HPD use on achieved PAR, with workers with tinnitus and no hearing loss having significantly higher PARs, and workers with tinnitus and hearing loss had significantly lower PARs (Table 21). Logistic regression modeling identified age and speech reception threshold as significant factors for increased risk of hearing loss, and PAR as a significantly protective factor for hearing loss (Table 22). Logistic regression models indicated that Fatigue Severity Score, previous serious work injury, and safety perception were associated with significantly higher risk of near miss in the past year, and also identified an interaction of workshift noise ≥85 dBA, hearing loss, and HPD use on near miss risk, with workers with no hearing loss, workshift noise ≥85 dBA, and reporting use of HPD having a significantly increased risk of work injury in the past year (Table 23). Finally, logistic regression models showed that Fatigue Severity Score, previous serious injury at work, and safety perception were associated with a significantly increased risk of work injury in the past year, and also identified an interactive effect between hearing loss and HPD use, wherein workers with no hearing loss and reporting use of HPD had a significantly increased risk of work injury in the past year (Table 24). These results are directly relevant to Specific Aim 2 and suggest that noise is not a significant risk factor for occupational near miss or nonfatal injury when controlling for use of HPDs, hearing status, fatigue, sleepiness, work experience, and perceived stress. The results also highlight the importance of ensuring that workers receive appropriate attenuation from their HPDs, and that this attenuation needs to be considered in light of their hearing status.*

6.0 Dissemination Efforts and Highlights

6.1 Dissemination of Data collected for Aim 1

A single publication is planned for the data collected in Aim 1. The focus is to describe NFDL injury and occupational fatality rates for 1983 to 2018 for all mines nation-wide by SIC and SOC and how noise from a Job Exposure Matrix (JEM) is associated with NFDL injury and occupational fatality rates among mines and miners. These collected counts and rates will be added to our JEM website to start the development of an injury and fatality risk database. This dataset, like our JEM, will be open source and free for use through the website we host (http://noisejem.sph.umich.edu/).

6.2 Dissemination of Data collected for Aim 2

Individual, personalized reports were developed for each of the 202 participants using RMarkdown (Boston, MA, US). These letters were mailed to the safety directors at each mine in sealed envelopes in early March. The safety directors were instructed to return the letters to each miner while keeping in mind that all data contained is confidential and up to the participant him/herself to share. In addition to the participant letters, we generated 11 personalized site reports that allowed comparison of the site specific results to those of their parent company and the overall study averages.

Parts of this data have been presented by a graduate student at the National Hearing and Conservation Conference in February.

Two master's students have utilized the data collected during the summer of 2019 for Aim 2 for their thesis. One has been successfully defended and the other is pending defense summer of 2020.

We plan to publish three manuscripts describing Specific Aim 2, each of them currently at various points in the development process. The first manuscript, a result of the defended thesis, will focus on how what factors are associated with hearing loss and personal attenuation rating (PAR) among miners. The second, a result of the pending thesis, will focus on the association between noise exposure using novel and traditional metrics and injury risk among miners. The third manuscript will bring all of these factors together while taking into consideration hearing protection device fit and use.

7.0 Conclusions and Impact Assessment

The personalized letters developed for each participant as a result of this research provided specific guidance to the individual about their noise exposure, hearing ability, work demands and stress, and how their hearing protection fit. This represents direct feedback to a subpopulation at risk, and provided a direct benefit to participating workers. The manuscripts that we are preparing will convey the results of our work to professional and academic readers, and may motivate changes in corporate policies related to noise and injury risks in US mines.

Overall, our results suggest that noise may be a significant risk factor for nonfatal and fatal occupational injuries, but that after controlling for use of HPDs, hearing status, fatigue, sleepiness, work experience, and perceived stress, the independent risk of noise on nonfatal injuries is no longer significant. The results also highlight the importance of ensuring that workers receive appropriate attenuation from their HPDs, and that this attenuation needs to be considered in light of their hearing status.

We have already begun dissemination of these results through conference presentations and manuscript preparation. We anticipate that our findings may have a large impact on hearing conservation and injury prevention programs in the mining industry, as they highlight the need to tailor HPD use to specific worker characteristics, including hearing ability and tinnitus, in order to reduce near-miss and injury risk.

8.0 Recommendations for Future Work

A logical extension of our findings involves the development and evaluation of a refined hearing conservation program designed to tailor HPDs to the needs of specific workers. Such a program would incorporate information about workers' noise exposures, hearing ability, achieved PAR, and tinnitus. In the event that the Alpha Foundation submits another request for proposals, we would plan to submit a proposal along these lines. A secondary area of future research would involve the development of novel types of HPDs that can be better tuned or tailored to individual workers' needs, and to pilot test the efficacy and effectiveness of such devices among mining workers.

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10.0 Appendices:

Table of Contents

1.0 Baseline Survey

BASELINE NOISE, HEARING LOSS, HEARING PROTECTION, AND INJURY SURVEY

SUBJECT ID: ____

DATE: ______________________ MM/DD/YYYY

PLEASE PROCEED TO PAGE 2

Pt. 1: YOU AND YOUR EMPLOYMENT

1. **What is your current job title?**
   ____
2. **How long have you worked in your current job for your current employer?**

   _______ years ________ months

3. **How many hours per week do you usually work in your current job?**
   ________hours/week

4. **What is the total amount of time you have worked in this industry?** _______ years ________ months

Pt. 2: HEALTH AND FITNESS (Ware, 1996)

5. **In general, would you say your health is:**

   [ ]1 Excellent [ ]2 Very Good [ ]4 Good [ ]4 Fair [ ]5 Poor

The following questions are about activities you might do during a typical day. <u>Does your health now limit you</u> in these activities? If so, how much?

	YES, limited a lot	YES, limited a little	NO, not limited at all
6. **Moderate activities** such as moving a table, pushing a vacuum cleaner, bowling, or playing golf.	[ ]1	[ ]2	[ ]3
7. Climbing **several** flights of stairs**.**	[ ]1	[ ]2	[ ]3

During the <u>past 4 weeks</u>, have you had any of the following problems with your work or other regular daily activities <u>as a result of your physical health</u>?

	YES	NO
8. **Accomplished less** than you would like.	[ ]1	[ ]2
9. Were limited in the **kind** of work or other activities.	[ ]1	[ ]2

During the <u>past 4 weeks</u>, have you had any of the following problems with your work or other regular daily activities <u>as a result of any emotional problems</u> (such as feeling depressed or anxious)?

	YES	NO
10. **Accomplished less** than you would like.	[ ]1	[ ]2
11. Were limited in the **kind** of work or other activities.	[ ]1	[ ]2

12. **During the <u>past 4 weeks</u>, how much <u>did pain interfere</u> with your normal work (including work outside the home and housework)?**

    [ ]1 Not at all [ ]2 A bit [ ]4 Moderately [ ]4 Quite a bit [ ]5 Extremely

These questions are about how you have been feeling during the past 4 weeks.

For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks…

	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
13. Have you felt calm and peaceful?	[ ]1	[ ]2	[ ]3	[ ]4	[ ]5	[ ]6
14. Did you have a lot of energy	[ ]1	[ ]2	[ ]3	[ ]4	[ ]5	[ ]6
15. Have you felt down-hearted and blue?	[ ]1	[ ]2	[ ]3	[ ]4	[ ]5	[ ]6

16. **During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?**

[ ]1 All of the time [ ]2 Most of the time [ ]4 Some of the time [ ]4 A little of the time [ ]5 None of the time

17. **How would you describe your overall fitness?**

[ ]0 Poor [ ]1 Fair [ ]2 Good [ ]3 Very Good [ ]4 Excellent

Pt. 3: NOISE EXPOSURE AND HEARING (Nondahl, 2002)

18. **How often are you exposed to high noise at work?** ***"High noise" means or loud enough that person has to raise their voice to talk to someone about 3 feet away.***

[ ]1 None of the time [ ]2 A little of the time [ ]3 Some of the time [ ]4 Most of the time [ ]5 All of the time

19. **For how many years have you worked in high noise?** ________ years

20. **How would you rate your hearing?**

[ ]1 Good [ ]2 A little trouble [ ]3 A lot of trouble [ ]4 Deaf or nearly deaf

21. **Do you have any difficulties with your hearing?**

[ ]1 Yes [ ]0 No

22. **Have you ever seen a doctor about problems with your ears?**

[ ]1 Yes [ ]0 No

*If yes, please explain:*____

23. **Have you ever been told by a doctor that you had a hearing loss?**

[ ]1 Yes [ ]0 No

24. **In the past year have you had buzzing, ringing, or noise in your ears?**

[ ]1 Yes [ ]2 No

25. **How severe is this noise in your ears in its worst form?**

[ ]1 Mild [ ]2 Moderate [ ]3 Severe

26. **Does this noise cause you to have problems getting to sleep?**

[ ]$_1$ Yes [ ]$_2$ No

27. **How often do you have this noise in your ears after spending time in high noise at work?**

[ ]$_1$ All of the time [ ]$_2$ Most of the time [ ]$_4$ Some of the time [ ]$_4$ A little of the time [ ]$_5$ None of the time

Pt. 4: HEARING PROTECTION (Reddy, 2014)

28. **What percentage of time do you <u>usually</u> use ear plugs or ear muffs when you are exposed to high noise at work? *"High noise" means loud enough that person has to raise their voice to talk to someone about 3 feet away.***

_________ % of time in high noise

29. **What type of hearing protection do you primarily use at work? (Check all that apply)**

[ ]$_1$ Foam Earplugs [ ]$_2$ Custom Earplugs
[ ]$_3$ Pre-molded Earplugs [ ]$_4$ Ear Muffs
[ ]$_5$ Double protection (earplugs *and* earmuffs) [ ]$_6$ None

30. **At times when you <u>don't wear</u> earmuffs or earplugs when exposed to noise, it is because: (*please check all that apply*)**

a)	You are not clear as to when you should wear them	[ ]
b)	You can't hear properly to do your work (e.g., warning signals, machine performance)	[ ]
c)	You can't communicate properly with other workers	[ ]
d)	They are uncomfortable	[ ]
e)	They get in the way of other safety equipment	[ ]
f)	You are used to noise at work	[ ]
g)	Your co-workers often don't wear them	[ ]
h)	Your co-workers find it funny when you wear them	[ ]
i)	Someone else does something noisy without warning	[ ]
j)	Other *(please list):* ______________________________	[ ]

Pt. 5: STRESS (Cohen, 1983)

31. **In the <u>last month</u>, how often have you been upset because of something that happened unexpectedly?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

32. **In the <u>last month</u>, how often have you felt that you were unable to control the important things in your life?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

33. **In the <u>last month</u>, how often have you felt nervous and "stressed"?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

34. **In the <u>last month</u>, how often have you felt confident about your ability to handle your personal problems?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

35. **In the <u>last month</u>, how often have you felt that things were going your way?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

36. **In the <u>last month</u>, how often have you found that you could not cope with all the things that you had to do?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

37. **In the <u>last month</u>, how often have you been able to control irritations in your life?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

38. **In the <u>last month</u>, how often have you felt that you were on top of things?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

39. **In the <u>last month</u>, how often have you been angered because of things that happened that were outside of your control?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

40. **In the <u>last month</u>, how often have you felt difficulties were piling up so high that you could not overcome them?**

[ ]$_0$ Never [ ]$_1$ Almost never [ ]$_2$ Sometimes [ ]$_3$ Fairly often [ ]$_4$ Very often

Pt. 6: INJURIES

41. **In the <u>last month</u> have you had any injuries, health conditions, or medical treatments that affected your ability to balance or walk?**

[ ]$_1$ Yes [ ]$_0$ No

*If yes, please explain:*____

42. **<u>In the last month,</u> have you had any injuries, health conditions, or medical treatments that affected your ability to do your normal work?**

[ ]1 Yes [ ]0 No

*If yes, please explain:*____

43. **Over your <u>lifetime</u>, about how many times have you been seriously injured at work?** ***Serious injuries require first aid treatment, treatment in a medical clinic or office, or treatment at a hospital.***

______________times

44. **In the <u>last year</u>, about how many times have you been <u>seriously</u> injured at work?** ***Serious injuries require treatment in a medical clinic or office, or treatment at a hospital.***

______________times

45. **In the <u>last year</u>, about how many <u>total</u> times have you been injured at work?** ***This includes all injuries, even minor injuries that did not require first aid or other treatment.***

______________times

46. **In the <u>last year</u>, for your <u>worst</u> work-related injury, what were you doing at the time of injury?** ***Please give as much detail as possible.***

[ ]1 Not injured in last year → ***GO TO QUESTION 51***

____
____

47. **In the <u>last year</u>, for your <u>worst</u> work-related injury, what type of medical care did you receive?**

[ ]1 No medical care
[ ]2 First aid at work
[ ]3 Treatment in a medical clinic or office
[ ]4 Treatment at hospital
[ ] Other:_________________

48. **In the <u>last year</u>, for your <u>worst</u> work-related injury, how much work did you miss?**

[ ]1 Did not miss any work and worked regular job
[ ]2 Did not miss any work but could not do regular job
[ ]3 Missed work: _______________ days

49. **In the <u>last year</u>, for your <u>worst</u> work-related injury, what body part or parts were injured?** ***Please check all that apply***

[ ]1 Head	[ ]2 Eye(s)	[ ]3 Face	[ ]4 Mouth/teeth
[ ]5 Neck	[ ]6 Shoulder	[ ]7 Arm	[ ]8 Hand
[ ]9 Chest	[ ]10 Spine	[ ]11 Waist	[ ]12 Hip
[ ]13 Thigh	[ ]14 Knee	[ ]15 Lower leg	[ ]16 Ankle
[ ]17 Foot	[ ]18 Abdomen	[ ] Other__________________	

50. **In the last year, for your worst work-related injury, what type of injury did you sustain?** ***Please check all that apply***

[ ]$_1$ Contusions/abrasions
[ ]$_2$ Burns/scalds
[ ]$_3$ Concussions
[ ]$_4$ Cuts/lacerations
[ ]$_5$ Punctured wounds
[ ]$_6$ Amputations
[ ]$_7$ Dislocations
[ ]$_8$ Fractures (simple/compound)
[ ]$_9$ Sprains/strains
[ ]$_{10}$ Asphyxiation
[ ]$_{11}$ Internal bleeding
[ ]$_{12}$ Electric shock
[ ] Other______________________

51. **In the last year, how often do you think were you almost in an accident or almost injured at work?**

[ ]$_1$ Never or almost never
[ ]$_2$ Less than half of your work days
[ ]$_3$ About half of your work days
[ ]$_4$ More than half of your work days
[ ]$_5$ Every work day or almost every work day

52. **In the last year, how many times were you almost in an accident that could have resulted in a serious injury?**

_____________ times

53. **In the last year, how many times were you involved in an incident that resulted in damage or breakage to a tool, equipment, vehicle, or facility, but no injuries to you or others?**

_____________ times

Pt. 7: SAFETY (Reddy, 2014)

54. **Please read the two statements carefully and choose the *one* which is most true for you.**
Please choose *either* a *or* b.

[ ]$_1$ a. Safety is at the forefront of my mind when working
[ ]$_2$ b. Safety is important, but other factors sometimes limit my ability to work safely

55. **Please read the two statements carefully and choose the one which is most true for you.**
Please choose *either* a *or* b.

[ ]$_1$ a. Injuries occur at work because people don't take enough interest in safety
[ ]$_2$ b. Injuries at work will always occur, no matter how hard people try to prevent them

Think about your current job. Do you agree or disagree that each of the following words or phrases describes your job? Place an ✕ or ✓ mark in the appropriate box for each statement.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
56. **Dangerous**	☐1	☐2	☐3	☐4	☐5
57. **Safe**	☐1	☐2	☐3	☐4	☐5
58. **Hazardous**	☐1	☐2	☐3	☐4	☐5
59. **Risky**	☐1	☐2	☐3	☐4	☐5
60. **Unhealthy**	☐1	☐2	☐3	☐4	☐5
61. **Could get hurt easily**	☐1	☐2	☐3	☐4	☐5
62. **Unsafe**	☐1	☐2	☐3	☐4	☐5
63. **Fear for health**	☐1	☐2	☐3	☐4	☐5
64. **Chance of death**	☐1	☐2	☐3	☐4	☐5
65. **Scary**	☐1	☐2	☐3	☐4	☐5

Pt. 8: SLEEPINESS

On any given day, how likely are you to doze off or fall asleep in the following situations?

	No chance of nodding off	Slight chance of nodding off	Moderate chance of sleeping	High chance of falling asleep
66. **Sitting inactive in a public place**	☐1	☐2	☐3	☐4
67. **Sitting and reading**	☐1	☐2	☐3	☐4
68. **Watching TV**	☐1	☐2	☐3	☐4
69. **As a passenger in a car for an hour without a break**	☐1	☐2	☐3	☐4
70. **Lying down in the afternoon when time permits**	☐1	☐2	☐3	☐4
71. **Sitting and talking to someone**	☐1	☐2	☐3	☐4
72. **Sitting quietly after lunch without alcohol**	☐1	☐2	☐3	☐4
73. **In a car, while stopped for a few minutes in traffic**	☐1	☐2	☐3	☐4

Pt. 9: FATIGUE (Chalder, 1993)

During the last week, I have found that:

	Disagree	←				→	Agree
74. **My motivation is lower when I am fatigued.**	1	2	3	4	5	6	7
75. **Exercise brings on my fatigue.**	1	2	3	4	5	6	7
76. **I am easily fatigued.**	1	2	3	4	5	6	7
77. **Fatigue interferes with my physical functioning.**	1	2	3	4	5	6	7
78. **Fatigue causes frequent problems for me.**	1	2	3	4	5	6	7
79. **My fatigue prevents sustained physical functioning.**	1	2	3	4	5	6	7
80. **Fatigue interferes with carrying out certain duties and responsibilities.**	1	2	3	4	5	6	7
81. **Fatigue is among my three most disabling symptoms.**	1	2	3	4	5	6	7
82. **Fatigue interferes with my work, family or social life.**	1	2	3	4	5	6	7

Pt. 10: ABOUT YOU

Date of Birth:________/_________/____________mm/dd/yyyy

Age:______________ years Sex: [ ]1 Male [ ]2 Female[ ]3 Other/Prefer not to say

Height:______________ feet and inches

Weight:___________ pounds

Thank you for your participation!

2.0 Daily Survey

NOISE, HEARING LOSS, HEARING PROTECTION, AND INJURY SURVEY

SUBJECT ID:________ **Date**___________

DAILY ACTIVITIES

1. **What time did you begin work today?** _____:_____ [ ]$_1$ AM [ ]$_2$ PM
2. **What time did you finish work today?**_____:_____ [ ]$_1$ AM [ ]$_2$ PM
3. **What work activity did you do for the <u>longest amount of time</u> today?**

____

____
____

NOISE AND HEARING PROTECTION

4. **How often did you use ear plugs or ear muffs when you were exposed to high noise at work today? *"High noise" means loud enough that a person has to raise their voice to talk to someone 3 ft away.*** **(Check one.)**

   [ ]$_1$ None of the time [ ]$_2$ A little of the time [ ]$_3$ Some of the time [ ]$_4$ Most of the time [ ]$_5$ All of the time

5. **What type of hearing protection did you use at work today? (Check all that apply)**

   [ ]$_1$ Foam Earplugs
   [ ]$_2$ Custom Earplugs
   [ ]$_3$ Pre-molded Earplugs
   [ ]$_4$ Ear Muffs
   [ ]$_5$ Double protection (earplugs *and* earmuffs)
   [ ]$_6$ None

6. **Please circle the noise level you spent the *most* time in at work today**

Normal speaking voice or quieter	As loud as a vacuum	As loud as a motorcycle	As loud as a chainsaw	As loud as a siren or louder
1	2	3	4	5

SAFETY AND NEAR-MISSES

7. **Did you experience a <u>narrow escape</u> from injury at work today?** [ ]$_1$ Yes [ ]$_0$ No ***IF NO → GO TO 8***

   a. **What time did this narrow escape happen?** ______:______ [ ]$_1$ AM [ ]$_2$ PM

   b. **Where did this narrow escape happen?**____

   c. **What were you doing when this narrow escape happened?**

   ____

   ____
   ____

   d. **Were you wearing hearing protection at the time the narrow escape happened?** [ ]$_1$Yes [ ]$_0$No

   e. **What treatment do you think you would have needed if you <u>had not</u> escaped?**

   [ ]$_1$ No treatment
   [ ]$_2$ First aid treatment only
   [ ]$_1$ Non-emergency medical treatment
   [ ]$_2$ Emergency medical treatment

8. **Did you have an <u>incident</u> at work today that resulted in damage to a tool, equipment, vehicle, or the facility, but <u>no injuries</u> to you or others?** [ ]1 Yes [ ]0 No ***IF NO → GO TO 9***

   a. **What time did this incident happen? ______:______** [ ]1 AM [ ]2 PM

   b. **Where did this incident happen?**

   ____

   c. **What were you doing when this incident happened?**

   ____

   ____

   d. **Were you wearing hearing protection at the time the incident happened?** [ ]1Yes [ ]0No

   e. **How much damage would you say the incident caused?**

   [ ]1 Almost no damage, hardly noticeable [ ]2 Slight damage, but no repair required
   [ ]3 Some damage, repair required [ ]4 Major damage - large repair or replacement

9. **Were you <u>injured</u> at work today? *Include any injury, even if you did not need first aid or medical treatment*** [ ]1 Yes [ ]0 No ***IF NO → GO TO 10***

   a. What time did this injury happen? ______:______ [ ]1 AM [ ]2 PM

   b. Where did this injury happen?____

   c. What type of injury did you get?______________________________

   ____

   f. **Were you wearing hearing protection at the time the injury happened?** [ ]1Yes [ ]0No

   g. **What body part was injured? ________**

   ____

   h. **What were you doing when this injury happened?**

   ____

   ____

   i. **What treatment did your injury require, if any?**

   [ ]1 No treatment [ ]2 First aid treatment only
   [ ]3 Non-emergency medical treatment [ ]4 Emergency medical treatment

SLEEP

10. Circle the number from 1 to 9 that best reflects your current level of sleepiness:

Extremely alert		Alert		Neither alert nor sleepy		Sleepy – but no difficulty remaining awake		Extremely sleepy – fighting sleep
1	2	3	4	5	6	7	8	9

11. How many hours did you sleep last night (not number of hours spent in bed)?

________ hours

12. How well did you sleep last night?

Worst sleep Possible				Neither good nor bad				Best sleep possible	
1	2	3	4	5	6	7	8	9	10

STRESS

13. Please rate the overall level of stress you experienced today:

Not very stressful	Very little stress	A little stress	Some stress	Much stress	Very much stress	Caused panic
1	2	3	4	5	6	7

DEMANDS

14. Please place an 'X' on the scales below to rate the demands that were placed on you <u>at work today</u>:

a. MENTAL DEMAND How **mentally demanding** was your work?

Very low Very high

b. PHYSICAL DEMAND How **physically demanding** was your work?

Very low Very high

c. TIME DEMAND **How hurried or rushed** was the pace of your work?

Very low Very high

d. EFFORT How **hard did you have to work** today to accomplish your level of performance?

Very low Very high

e. FRUSTRATION How **insecure, discouraged, irritated, stressed, and annoyed** were you at work?

Very low
Very high

3.0 Informed Consent Form

Assessing Noise Exposures, Hearing, and Risk of Injuries among Miners

Written Consent Form

1) Background Information

   Dr. Rick Neitzel of the University of Michigan (UM) invites you to participate in a study of the influence of noise exposures, hearing loss, and use of hearing protectors on injury risk . We are studying workers at your worksite. We are asking you to participate.

   We want you to know that being in this study is entirely voluntary. You may choose not to be in the study, or may pull out of the study at any time. You will receive some benefits from taking part, and the research will provide information that might be used to help people in the future. Before you agree to participate to be in the study, please take as much time as you need to have your questions answered.

2) What is the purpose of the study?

   The purpose of this study is to learn about injury risks among miners that result from exposure to high noise, use of hearing protectors like earmuffs and earplugs, and hearing loss.

3) What will I be asked to do?

   At the start of the study, we will ask you to complete a survey about you, your work, and your health. The survey will take about 15 minutes of your time. After the survey, we will ask you to complete a standard hearing test (called an audiometric test), as well as a similar test that measures how much noise your hearing protectors block. We will ask you to wear a noise meter (dosimeter) for 3 consecutive workdays. On each of these days, we will ask you to complete an activity log to detail your work activities, health, and any accidents or injuries you experienced during the day. We will share with you the results of your own noise measurements, hearing tests, and hearing protector tests after you complete the tests.

   Your picture may be taken as part of our research. However, you do not have to have your picture taken to participate.

4) Are there any benefits or risks associated with my participation?

   Benefits: This research will benefit you by giving you information about your noise levels, your hearing, and the amount of noise your hearing protectors block.

   Risks: We believe our study presents no foreseeable risks to you. The study involves trained research staff using standard occupational health and research practices.

5) Will I receive any payment for participating in the study?

   You will receive $50 as a thank-you for each 3 consecutive day period of participation up to twice.

6) What are my participation alternatives?

   In order for you to be in the study, you must agree to be in the study. You may withdraw your permission and discontinue participation at any time. You can skip any survey or activity diary questions that you are not comfortable answering.

7) Will my information and study results be kept confidential?
We plan to publish the results of this study. However, we will not include any information that would identify you. To keep your information safe, all study data will be kept in secure locations at UM. Only study personnel at these locations will have access to your data. All study data will be stored at UM for 10 years, and may be used in the future for further analysis. However, analyses will be of coded data not linked to your actual identity. We may share your research data with other investigators without asking for your consent again, but it will not contain information that could directly identify you.

8) What if I have further questions?
If you have any questions during this study, you may contact Dr. Rick Neitzel at 734-763-2870.

If you have questions regarding your rights as a participant in research, please contact the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board, 2800 Plymouth Rd. Building 520, Suite 1169, Ann Arbor, MI 48109-2800, +1 734 936 0933, irbhsbs@umich.edu.

Consent

By signing this paper, you are agreeing that the purpose and details of the study have been explained to you. You are agreeing to participate. You will be given a copy of this paper for your records and a signed copy will be kept with the study records.

[ ] Yes [ ] No	I consent to completing the study survey.
[ ] Yes [ ] No	I consent to a hearing test and test of how much noise my hearing protectors block.
[ ] Yes [ ] No	I consent to having my noise exposures measured and to completing a daily activity, accident, and injury diary.
[ ] Yes [ ] No	I consent to the de-identified retention of my study data.

Signed____ Date: ___/___/___

[ ] Yes [ ] No	I consent to having my picture taken.

Signed____ Date: ___/___/___

Print name: ____________________________________

FOR STUDY USE ONLY
Investigator: _____________________________________Date: ___/___/___

Table 1.1.1 Industry NFDL Injury Rates 1983-2002

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Coal	Anthracite	10.04	10.88	11.58	10.9	12.84	12.61	17.65	14.97	14.49	13.94	14.24	14.05	16.47	12.77	10.22	11.05	8.61	12.21	10.16	9.54
	Bituminous	6.57	6.6	6.05	6.63	9.16	9.61	9.24	9.13	9.12	8.56	8.21	8.18	7.39	6.33	6.19	6.42	5.97	5.96	5.29	5.37
	Total	6.61	6.64	6.11	6.68	9.19	9.64	9.31	9.18	9.17	8.61	8.28	8.24	7.49	6.41	6.24	6.47	6.00	6.03	5.32	5.40
Metal	Alumina (Mill)	1.47	1.48	1.74	2.11	2.93	3.76	3.49	2.59	3.51	3.06	2.92	2.35	2.35	3.61	3.3	2.42	2.23	1.46	1.79	1.76
	Aluminum Ore	2.89	2.97	2.33	3.31	1.35	1.75	0	2.47	1.72	4.73	1.61	5.43	0	-	1.48	1.18	4.43	1.66	2.67	3.81
	Antimony	-	44.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryl	2.94	1.84	3.84	1.02	2.78	0	0.94	-	3.72	2.96	2.39	3.33	1.17	1.18	3.08	2.16	3.22	0	1.15	1.49
	Chromite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.3
	Cobalt	-	-	-	-	21.59	-	-	62.81	-	-	14.17	0	-	-	-	-	-	-	-	-
	Copper Ore	2.17	2.72	2.69	3.28	3.41	3.56	3.04	2.64	2.56	2.14	2.28	2.89	1.92	1.39	2.27	2.46	1.93	1.68	1.24	1.42
	Gold (lode and placer)	5.55	4.36	4.05	4.56	5.37	5.23	4.92	4.22	3.55	3.29	3.16	2.87	3.17	3.84	2.74	2.15	2.48	2.64	2.19	1.97
	Iron ore	3	3.31	2.56	3.19	5.97	6.76	5.71	5.77	6.54	4.67	4.44	3.57	3.44	3.34	3.48	2.98	2.96	2.34	2.61	2.28
	Lead/Zinc Ore	6.97	5.2	4.58	4.42	5.33	4.76	5.74	4.48	3.55	2.7	3.46	4.4	2.57	3.34	2.17	2.94	2.16	3.72	3.11	3.03
	Manganese	2.33	7.23	22.92	5.46	5.54	7.7	9.34	4.93	7.38	3.08	5	2.27	2.42	2.95	6.66	4.88	8.08	5.31	4.26	8.11
	Mercury	3.53	3.82	2.17	3.13	12.59	4.35	4.85	-	-	-	-	-	-	-	-	-	-	-	-	-
	Metal ores, NEC	4.03	1.38	10.52	9.11	12.52	384.62	-	2.19	-	0	-	-	-	-	0	1.96	0	-	2.71	5.33
	Molybdenum	4.54	3.56	4.08	3.01	2.2	2.47	4.2	3.63	4	2.97	3.2	3.08	4.07	2.4	3.04	5.21	3.49	2.63	1.11	2.19
	Nickel	-	5.08	10.84	16.44	-	-	-	7.22	4.92	0.83	-	-	-	4.36	-	-	-	-	-	-
	Platinum group	22	11.2	-	-	3.3	5.04	2.63	3	5.21	13.83	11.91	9.53	11.26	10.6	8.44	11.06	12.84	8.38	5.08	4.6
	Rare earths	3.39	2.26	1.87	3.85	5.67	2.5	4	0	1.5	1.34	2.34	0.77	1.18	0.28	0.29	25.04	1.25	0	1.95	2.1
	Silver ores	5.89	6.51	4.06	5.1	5.94	8.82	9.17	8.21	7.92	4.71	5.23	5.44	4.73	3.03	3.51	3.03	5.12	4.58	3.21	3.07
	Titanium	3.84	0.66	2.98	2.05	2.14	1.31	2.96	1.66	2.02	1.35	2.61	0.53	2.07	1.24	0.94	3.23	1.26	2.25	1.45	2.89
	Tungsten	9.28	6.92	5.88	2.43	1.36	3.65	3.76	1.14	3.42	-	5.59	-	5.79	1.5	4.71	2.25	-	-	-	-
	Uranium	3.23	4.03	4.2	5.28	4.32	5.23	4.4	3.05	6.71	3.82	2.95	2.76	7.06	6.83	6.67	9.99	10.92	5.27	6.94	8.3
	Uranium - vanadium ores	9.42	12.82	8.05	13.17	9.4	12.17	3.79	6.72	4.37	6.77	-	-	-	4.52	-	9.74	9.46	5.31	7.62	-
	Vanadium	1.99	8.22	1.2	0	1.76	0.92	2.53	2.49	-	1.59	4.63	4.12	2.46	3.28	1.95	1.71	1.02	0	13.13	5.76
	Zircon	-	7.81	3.72	3.73	7.91	10.28	8.95	11.5	4.06	-	-	-	-	4.07	-	3.87	-	3.64	-	8.32
	Total	3.47	3.53	3.21	3.66	4.53	4.99	4.67	4.07	3.97	3.24	3.23	3.12	2.89	3.01	2.89	2.82	2.81	2.51	2.22	2.28
Nonmetal	Aplite	2.76	3	0	5.33	0	-	5.63	2.66	5.78	2.79	-	2.87	-	3.13	0	0	3.13	3.16	0	-
	Asbestos	2.67	3.75	3.12	2.59	4.69	13.03	2.64	6.61	5.01	12.56	11.16	9.27	7	7.52	7.41	14	11.54	11.57	-	27.89
	Barite	6.18	7.63	5.95	6.19	4.98	7.44	7.82	9.37	4.76	4.91	7.65	5.13	9.46	7.46	5.25	6.25	4.94	6.09	7.3	7.49
	Boron Materials	4.75	2.88	1.9	2.97	2.18	1.99	1.33	1.55	1.72	1.49	2.67	2.99	1.76	3.12	2.05	1.32	1.85	2.44	1.89	1.2
	Brucite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	Cement	3.32	4.44	5.14	4.6	4.95	5.98	4.88	5.23	4.45	4.76	4.78	4.6	3.84	3.81	3.84	4.15	4.17	4.57	4.66	4.32
	Chemical and fertilizer, NEC	-	-	-	-	-	-	6.57	4.22	3.36	3.74	0	3.56	3.05	2.02	1.47	4.4	24.49	3.41	4.41	8.15
	Clay (common)	2.91	2.99	2.32	1.98	3.24	3.95	3.77	3.38	3.74	3.74	3.07	3.01	2.99	2.33	2.69	2.43	2.73	2.3	2.56	2.26
	Clay (fire)	6.12	5.2	3.92	3.11	6.29	6.31	6.06	6.62	7.39	7.12	7.32	8.15	7.58	3.8	7.03	4.94	4.26	6.27	4.15	6.11
	Clay, Ceramic and refractory, NEC	4.59	1.21	7.68	0	7.1	7.67	1.78	2.76	28	5.47	5.54	0	4.87	10.58	2.57	4.12	5.07	6.72	4.73	3.02

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	Construction S&G; Sand, common	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Feldspar	3.95	5.49	4.69	5.34	4.54	5.15	6.15	3.59	4.41	7.13	1.49	4.25	2.77	3.23	2.81	2.19	2.91	5.86	2.91	5.13
	Fluorspar	3.78	3.46	3.79	2.99	8.59	5.14	6.92	4.38	5.04	5.47	6	1.77	7.24	0	-	17.26	-	-	-	-
	Gemstones	-	-	-	-	-	220.99	9.05	17.55	11.35	9.12	6.69	8.43	9.1	6.11	8.62	3.85	5.3	5.11	7.96	9.88
	Gilsonite	5.08	12.27	15.2	4.99	5.66	10.77	7.35	10.5	13.11	5.27	12.14	9.28	7.23	4.49	3.48	3.29	4.9	5.05	3.3	9.41
	Granite (crushed and broken)	4.64	3.3	3.2	3.16	3.81	3.94	3.71	4.39	4.44	4.08	3.39	3.17	3.34	3.35	3.52	3.38	2.98	3.28	3.47	3.36
	Granite (dimension)	12.39	14.02	10.72	10.16	14.58	15.4	14.73	12.91	15.38	14.6	14.76	18.52	9.97	10.12	10.56	14.76	9.01	12.28	8.92	6.93
	Gypsum	3.32	2.03	2.29	3.14	3.01	3.03	2.45	2.27	4.05	1.9	2.23	2.36	2.41	3.04	2	2.11	3.01	2.79	2.9	1.19
	Kyanite	4.69	3.02	4.34	3.67	4.72	4.61	5.89	5.35	2.88	2.33	6.19	3.48	4.98	4.64	3.6	9.27	6.66	3.84	3.66	2.24
	Leonardite	6.41	5.83	6.73	0	0	11.1	21.82	6.47	9.48	0	6.2	12.38	49.7	5.32	20.89	17.06	8.54	5.95	12.36	27.44
	Lime	5.2	4.71	3.93	4.06	4.39	5.69	5.91	4.82	4.99	5.25	5.2	5.76	4.62	5.34	3.49	4.29	4.21	5.03	4.65	4.47
	Limestone (crushed and broken)	4.33	4.45	4.49	4.98	5.28	5.62	5.88	5.67	6.06	5.52	5.45	5.26	4.88	4.64	4.48	4.55	4.56	4.61	4.52	4.48
	Limestone (dimension)	5.83	7.82	5.76	10.21	9.78	11.32	11.68	11.56	9.99	13.88	8.75	10.12	7.07	9.04	8.54	8.11	8.67	10.59	10.29	8.15
	Lithium	1.42	3.63	2.13	0.65	1.67	0.86	0.95	6.78	1.4	2.73	0	0	1.28	0	0	-	-	-	-	-
	Magnesite	5.44	7.08	5.39	10.56	11.99	13.59	7.71	4.29	5.91	4.32	0	1.39	2.22	5.35	2.35	2.64	3.99	10.07	7.29	5.16
	Marble (crushed & broken)	1.99	2.44	2.8	2.16	2.37	3.42	2.63	3.42	1.37	2.01	1.74	1.83	0.93	1.29	2.67	2.29	2.11	3.94	3.2	5.62
	Marble (dimension)	7.37	13.41	10.5	13.19	9.5	9.5	6.83	6.26	7.87	10.2	6.33	13.08	10.7	6.87	17.28	12.98	17.44	11.82	11.27	4.32
	Mica	5.61	3.55	4.48	4.77	3.97	7.31	5.84	5.65	3.35	3.84	6.18	4.02	3.36	4.2	1.07	3.95	2.93	1.84	4.85	4.57
	Nonmetallic minerals, NEC	7.48	9.36	5.92	5.39	6.86	10.2	7.63	8.76	7.84	7.03	7.09	7.01	5.77	5.39	6.19	5.77	7.28	6.23	5.39	4.32
	Oil mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil sand	-	-	15.24	-	-	5.73	6.02	0	63.9	0	-	-	0	25.97	0	-	-	-	-	-
	Oil shale	2.41	2.34	2.09	4.55	4.98	10.49	3.66	4.82	3.55	-	-	-	-	0	-	-	-	-	-	-
	Perlite	10.84	4.67	10.83	10.9	10.17	10.25	17.14	15.59	6.36	6.68	8.39	5.73	5.07	6.65	6.79	6.39	5.38	6.57	5.85	7.9
	Phosphate rock	1.65	1.2	1.07	1.3	1.84	2.34	2.73	2.8	2.22	2.27	1.83	1.3	1.22	1.32	1.39	1.68	2.48	2.46	2.53	2.37
	Pigment mineral	-	-	-	-	-	4.91	20.9	13.78	5.06	3.52	2.42	7.53	5.48	-	5.64	2.33	3.54	1.97	4.08	11.14
	Potash	2.26	2.12	2.45	2.47	3.74	2.4	3.16	3.78	4.5	3.21	4.13	1.57	2.38	1.99	3.08	2.36	1.27	1.86	2.82	1.76
	Potash, soda, & borate minerals, NEC	2.93	4.65	3.88	6.01	3.02	2.21	3.75	5.83	4.51	5.17	12.7	-	-	-	14.46	9.48	-	-	-	0
	Pumice	12.5	7.92	4.38	11.18	12.06	9.38	15.81	11.4	18.8	10.82	9.5	10.31	12.37	4.11	11.66	8.68	10.38	8.54	14.19	5.17
	Pyrites	-	-	-	-	15.41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Salt (evaporated)	5.04	3.47	5.64	7.5	6.13	6.75	7.73	11.35	8.12	6.67	4.4	4.62	2.66	4.41	3.51	4.88	4.25	1.7	2.77	3.41
	Salt (rock)	4.56	4.4	4.63	5.22	4.43	4.35	4.87	6.03	4.14	2.1	3.26	3.15	2.17	2.42	2.14	2.38	3.16	2.19	2.53	1.94
	Sand & gravel	7.53	8.19	8.03	8.61	8.31	8.51	9.67	9.37	9.2	8.83	8.41	8.46	7.62	7.47	7.34	7.66	7.21	7.52	6.73	6.85

Canvass	Industry	Year																			
		1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
	Sand, Industrial; Ground silica/quartz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sandstone (crushed & broken)	5.26	5.9	6.04	4.56	5.65	5.88	6.38	6.79	6.9	5.81	7.48	6.34	4.92	5.24	6.46	5.28	5.54	4.61	4.56	4.27
	Sandstone (dimension)	23.03	5.66	6.48	10.91	7.03	9.78	7.17	6.84	12.92	12.87	14.48	15.93	12.71	11.08	11.86	11.14	10.81	11.14	8.87	7.89
	Shale (common)	7.47	9.29	12.46	9.79	9.29	7.73	7.12	6.42	3.98	5.72	6.67	7.47	6.7	7.11	4.54	5.96	4.99	3.35	4.93	6.23
	Slate (crushed & broken)	6.4	3.87	3.93	3.68	6.64	7.18	12.08	8.86	6.04	8.45	6.86	2.95	5.73	5.87	4.97	5.92	7.74	7.14	2.24	13.23
	Slate (dimension)	5.42	6.02	6.64	10.1	8.75	12.9	8.66	10.37	13.05	10.62	11.68	11.02	13.31	8.23	10.64	10.54	12.02	12.01	11.01	8.44
	Sodium compounds	2.58	2.61	2.58	2.38	2.39	2.94	3.69	3.8	2.79	2.41	1.68	2.24	-	-	-	-	-	-	-	4
	Stone, crushed & broken, NEC	7.31	8.53	10.18	7.62	8.21	9.36	9.18	9.36	7.48	10.72	10.52	8.73	8.4	7.92	9.63	7.42	7.63	7.95	8.03	7.17
	Stone, dimension, NEC	12.93	14.22	18.56	19.36	9.63	16.65	8.32	16.87	8.83	7.61	9.8	15.02	12.17	7.73	9.18	8.73	9.26	14.5	10.95	8.27
	Talc, soapstone, & pyrophylite	7.95	4.86	5.4	5.31	5.92	6.02	5.73	6.89	4.85	4.25	5.48	3.83	4.51	4.46	2.36	3.24	4.39	3.56	1.85	3.67
	Traprock (crushed & broken)	5.6	5.8	4.67	4.53	6.31	5.98	7.02	6	5.19	4.41	4.62	5.72	4.74	5.2	4.64	4.41	3.83	3.18	3.42	4.2
	Traprock (dimension)	3.21	0	0	0	7.34	-	0	2.5	6.26	10.02	3.32	2.34	2.07	2.53	2.18	2.73	1.6	-	0	11.18
	Trona	6.48	2.48	3.26	2.6	3.03	2.27	3.51	3.83	3.62	2.58	2.15	4.55	3.48	2.54	2.47	2.98	2.38	3.34	3.64	4.23
	Vermiculite	2.7	5.52	6.69	4.47	2.34	3.73	3.43	4.67	5.72	4.11	2.12	3.47	3.71	3.14	1.75	4.16	1.75	2.76	1.66	5.24
	Total	4.57	4.63	4.54	4.81	5.27	5.72	5.96	5.90	5.74	5.38	5.34	5.26	4.72	4.49	4.46	4.61	4.58	4.78	4.64	4.60

Table 1.1.2 Industry NFDL Injury Rates 2003-2018

Canvass	Industry	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Coal	Anthracite	10.94	8.24	7.04	9.53	7.06	10.13	8.97	8.78	8.58	7.21	7.3	8.45	4.89	6.4	6.34	4.65
	Bituminous	4.8	4.35	3.94	3.68	3.67	3.32	3.19	2.89	2.8	2.71	2.67	2.77	2.61	2.72	2.88	2.5
	Total	4.84	4.38	3.96	3.71	3.69	3.36	3.23	2.92	2.84	2.74	2.71	2.81	2.63	2.77	2.92	2.53
Metal	Alumina (Mill)	1.64	1.59	3.27	2.98	2.79	2.65	3.02	3.07	3.53	3.85	2.76	5.12	2.92	2.21	2.63	1.54
	Aluminum Ore	5.25	-	5.63	6.22	1.72	3.68	4.47	0	-	1.62	1.56	2.26	0	5	2.69	2.58
	Antimony	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryl	3.05	-	1.6	6.72	1.45	0	0	-	2.89	0	0	0	0	0	-	1.27
	Chromite	-	-	-	-	-	-	-	-	1.79	3.49	-	15.65	-	-	-	-
	Cobalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Copper Ore	1.68	1.75	2.25	2.27	2.65	2.58	1.84	1.57	1.31	1.14	1.35	1.1	1.4	1.47	1.36	1.4
	Gold (lode and placer)	2.2	1.95	2.09	1.55	1.62	1.48	1.13	1.22	1.37	1.5	1.66	1.33	1.07	0.89	0.97	0.73
	Iron ore	1.57	1.44	1.35	1.12	1.29	1.34	1.66	1.08	0.92	1.14	2.08	1.97	1.51	1.63	1.31	1.34
	Lead/Zinc Ore	2.41	2.63	2.16	1.95	3.7	2.63	1.88	2.57	2.08	2.03	2.18	2.38	1.88	2.89	2.48	1.53
	Manganese	6.96	2.8	8.61	4.15	4.44	9.92	5.37	25.6	4.72	3.5	2.48	-	-	-	-	-
	Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Metal ores, NEC	3.58	8.32	1.1	6.3	5.85	3.35	3.25	4.37	5.84	3.95	0	1.93	2.77	5.3	-	2.58
	Molybdenum	1.87	1.8	1.61	3.45	2.81	2.7	3.06	1.96	1.65	1.41	1.41	1.09	0.88	1.45	0.82	2.03
	Nickel	-	-	-	-	-	-	-	-	-	-	-	-	0	0.48	0	0.41
	Platinum group	5.83	3.07	1.99	2.19	1.94	1.83	2.51	2.86	1.97	2.63	2.37	2.75	2.21	2.06	1.97	2.15
	Rare earths	1.45	-	1.37	-	-	0	0	0.74	0	0.28	1.56	0.86	1.14	-	-	2.9
	Silver ores	3.04	2.62	4.66	4.45	3.32	3.74	2.86	5.09	4.09	3.3	3.13	2.69	2.9	2.38	1.6	1.18
	Titanium	1.91	2.91	1.19	1.26	0.99	0.57	2.96	1.58	3.25	1.36	0.53	0	0	0.88	0	0.74
	Tungsten	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Uranium	4.78	6.97	7.14	3.67	0	4.14	7.38	2.74	1.66	0.98	1.02	2.81	0	1.69	0	0
	Uranium - vanadium ores	-	15.56	11.89	-	-	26.59	0	-	-	-	-	-	-	-	-	-
	Vanadium	1.18	6.76	2.08	-	1.62	0.88	1.17	1.02	0	-	3.13	5.25	4.4	-	7.69	9.25
	Zircon	5.03	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	2.16	1.98	2.22	2.05	2.20	2.10	1.76	1.68	1.58	1.58	1.76	1.71	1.49	1.43	1.32	1.20
Nonmetal	Aplite	0	2.87	2.73	0	-	-	-	10.27	15.14	-	4.58	-	4.44	4.65	-	5.26
	Asbestos	84.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barite	6.18	7.02	7.64	4.72	5.43	4.22	3.07	3.57	2.66	2.96	3.25	2.76	3.97	1.32	4.27	2.69
	Boron Materials	0.82	0.46	0.66	0.88	0.68	0.5	0.32	0.17	0.4	0.12	0.99	0.28	0.14	0.31	0.15	0.66
	Brucite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cement	4.27	3.73	3.58	3.04	2.77	2.56	2.99	2.64	2.33	2.63	2.25	2.3	2.18	2.21	1.79	1.7
	Chemical and fertilizer, NEC	22.96	8.87	8.36	1.84	1.95	3.59	5.61	5.25	5.46	1.73	3.49	13.21	4.2	6.16	8.91	3.15
	Clay (common)	1.77	2.03	2.1	1.55	2.14	2.45	3.17	1.92	1.85	1.85	1.72	1.3	1.26	1.1	1.4	1.41
	Clay (fire)	1.9	2.3	2.31	3.12	1.93	2.66	4.1	2.34	3.86	1.11	3.19	3.41	2.87	3.14	2.73	7.45
	Clay, Ceramic and refractory, NEC	2.77	3.74	2.48	2.15	1.91	2.55	2.11	1.94	1.94	2.12	3.75	2.55	3.67	1.36	2.8	2.16

Canvass	Industry	Year															
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Construction S&G; Sand, common	-	-	-	-	-	-	-	-	-	-	6.15	4.17	3.69	3.74	4.67	2.54
	Feldspar	6.33	4.02	1.53	1.53	4.36	2.88	2.88	1.72	3.32	2.26	2.53	0	2.53	-	2.24	3.11
	Fluorspar	9.62	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-
	Gemstones	3.77	0	3.93	1.44	2.99	2.06	4.06	2.5	3.03	4.48	9.92	2.79	3.86	0.39	0.61	4.15
	Gilsonite	13.15	3.8	4.83	5.69	8.22	15.64	5.47	6.06	4.67	6.63	1.31	0.67	0.93	1.43	0	0
	Granite (crushed and broken)	3.24	3.25	3.04	2.82	2.79	2.68	1.98	2.57	2.9	2.64	2.5	2.92	2.63	2.42	2.25	2.32
	Granite (dimension)	5.98	6.93	7.41	7.37	3.74	6.86	8.04	5.72	6.85	16.73	13.21	11.85	5.91	8.54	6.26	10.32
	Gypsum	2.86	1.87	2.77	0.82	1.66	2.17	1.47	2.42	1.28	2.57	2.86	1.81	2.48	2.12	2.48	1.74
	Kyanite	6.69	3.35	6.2	4.73	3.18	4.49	1.57	3.64	4.15	3.16	6.8	3.52	6.41	1.5	2.23	2.99
	Leonardite	18.65	15.78	11.85	6.88	14.39	26.38	16.09	0	13.55	5.11	7.02	9.07	4.95	20.71	6.08	4.65
	Lime	3.97	3.31	4.13	3.19	3.61	3.68	3.1	3.52	2.4	2.45	2.35	2.73	2.5	2.5	1.97	2.31
	Limestone (crushed and broken)	4.41	4.05	3.74	3.57	3.38	3.35	3.52	3.49	3.38	3.43	3.34	3.44	3.44	2.75	2.81	3.02
	Limestone (dimension)	8.3	7.33	8.55	8.44	7.06	8.29	4.31	5.6	4.42	5.1	5.85	6.12	4.71	4.78	5.7	4.11
	Lithium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Magnesite	1.33	0	2.58	3.29	1.24	1.12	4.99	5.84	3.32	3.32	9.64	3.08	4.46	3.63	0.87	4.03
	Marble (crushed & broken)	5.71	6.62	6.77	3.5	4.86	3.57	3.11	2.38	1.75	1.55	1.27	1.25	2.84	2.63	3.07	2.12
	Marble (dimension)	12.82	6.39	9.33	14.31	14.36	14.38	6.25	2.99	3.51	8.08	5.82	10.82	14.36	4.08	3.93	3.6
	Mica	2.22	2.23	2.01	1.83	0	4.84	1.71	3.31	-	1.23	-	8.16	1.83	-	4.28	11.96
	Nonmetallic minerals, NEC	4.36	5.05	5.12	3.61	5.99	5.46	3.85	3.65	2.96	3.78	4.17	3.14	2.57	2.08	2.96	2.86
	Oil mining	-	-	-	-	-	-	-	-	-	-	-	7.02	0	0	0	-
	Oil sand	-	-	-	-	0	1.16	-	-	-	-	5.78	0	0	-	-	0
	Oil shale	-	-	-	2.12	-	0	-	-	-	-	-	-	-	-	-	-
	Perlite	2.32	4.99	4.54	3.37	3.59	3.57	10.7	4.03	1.58	1.16	2.29	3.49	7.08	0	6.88	6.24
	Phosphate rock	1.94	2.79	1.94	1.38	1.85	1.14	1.28	1.03	1.05	1.25	0.97	1.07	0.66	0.57	0.85	0.61
	Pigment mineral	6.4	6.93	10.72	12.72	2.71	3.94	3.04	-	2.39	1.1	2.13	-	1.47	2.21	4.11	2.45
	Potash	1.9	1.48	1.61	3.38	4.12	4.69	3.33	2.33	2.24	0.9	0.79	0.92	1.41	0.9	0.58	0.33
	Potash, soda, & borate minerals, NEC	-	-	-	20.79	17.93	-	-	-	-	-	-	-	-	-	-	-
	Pumice	6.95	6.64	5.88	6.24	7.45	8.79	0	5	3.89	19.66	4.71	-	7.98	15.79	-	5.82
	Pyrites	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Salt (evaporated)	1.33	-	4.58	-	3.24	3.35	3.61	4.11	3.02	-	0	1.62	0.81	1.61	5.52	2.44
	Salt (rock)	2.17	1.67	1.61	1.7	1.66	1.85	1.75	2.17	1.57	1.84	1.42	1.44	1.13	0.99	1.15	1.2
	Sand & gravel	7.18	6.37	6.29	6.44	6.04	6.23	6	6.32	5.24	5.65	6.08	5.41	5.45	5.7	5.16	4.62

Canvass	Industry	Year															
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Sand, Industrial; Ground silica/quartz	-	-	-	-	-	-	-	-	-	-	2.41	3.48	2.67	2.84	3.23	2.87
	Sandstone (crushed & broken)	3.88	3.83	3.5	3.32	4.21	3.58	3.87	3.63	2.6	3	3.16	2.31	1.71	2.51	2.23	2.96
	Sandstone (dimension)	10	8.9	10.22	9.5	9.05	11.49	7.78	11.57	5.31	5.42	5.49	12.14	13.06	8.1	7.06	6.85
	Shale (common)	5.12	5.98	4.07	3.55	5.28	5.77	6.24	3.75	4.65	5.66	3.23	5.49	5.66	3.85	4.01	4.92
	Slate (crushed & broken)	4.25	25.83	44.34	16.28	0	0	2.97	-	0	9.78	-	-	6.28	-	0	0
	Slate (dimension)	5.39	5.57	5.71	8.65	3.81	3.76	5.23	10.97	3.94	4.89	4.6	5.64	2.7	1.73	3.18	6.43
	Sodium compounds	-	-	-	-	-	-	-	-	-	-	-	24.83	-	-	-	-
	Stone, crushed & broken, NEC	6.71	7.52	6.44	6.34	5.77	4.9	6.95	6.08	6.56	5.93	5.21	6.31	5.6	4.59	4.98	5.14
	Stone, dimension, NEC	10.17	8.74	7.89	7.82	7.08	7.15	8.26	7.06	9.72	8.84	5.12	6.79	6.74	5.65	6.57	8.33
	Talc, soapstone, & pyrophylite	4.55	1.07	2.84	3	4.29	1.51	3.43	1.86	1.3	1.25	0.62	3.38	2.07	2.61	2.86	4.52
	Traprock (crushed & broken)	4.12	4.79	3.33	3.56	3.96	3.98	4.07	2.53	2.9	3.12	3.52	3.63	2.98	3.8	3.2	3
	Traprock (dimension)	3.33	1.64	11.3	4.74	5.66	-	8.94	-	9.21	5.39	-	0	5.61	2.34	3.32	3.21
	Trona	3.65	4.48	3.83	3.04	3.13	2.81	2.66	1.5	1.31	1.22	1.07	1.35	1.64	1.55	0.86	0.6
	Vermiculite	3.36	4.44	4.46	0	1.36	2.84	0	3.96	2.51	-	2.27	7.28	-	2.91	1.33	4.16
	Total	4.50	4.27	4.14	3.81	3.71	3.60	3.45	3.31	3.01	3.14	2.95	3.00	2.87	2.73	2.61	2.60

Table 1.2.1 Industry Fatality Rates 1983-2002

Canvass	Industry	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Coal	Anthracite	0.07	0	0.58	0.26	0	0.09	0.1	0.16	0	0	0.09	0.27	0.39	0	0	0.11	0.11	0	0	0
	Bituminous	0.05	0.08	0.04	0.06	0.04	0.03	0.05	0.04	0.05	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.05	0.03
	Total	0.05	0.08	0.04	0.06	0.04	0.03	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.05	0.03
Metal	Alumina (Mill)	0.02	0	0	0	0.03	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0.04
	Aluminum Ore	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0
	Antimony	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryl	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
	Chromite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Cobalt	-	-	-	-	0	-	-	0	-	-	0	0	-	-	-	-	-	-	-	-
	Copper Ore	0.01	0.05	0.03	0.01	0.04	0.01	0	0.05	0.03	0	0.04	0	0.03	0.01	0.02	0.02	0	0.01	0.01	0.02
	Gold (lode and placer)	0.04	0.09	0.04	0.01	0.06	0.02	0.03	0.01	0.04	0.02	0.02	0.05	0.02	0.01	0.02	0	0.06	0.04	0.04	0.02
	Iron ore	0.04	0	0	0.02	0.02	0.01	0.02	0.01	0	0	0.01	0.01	0	0	0	0.01	0.01	0.01	0	0
	Lead/Zinc Ore	0.06	0.15	0.18	0	0	0.14	0.04	0.1	0	0.08	0	0.04	0.04	0.04	0.04	0.05	0.05	0	0	0
	Manganese	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mercury	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
	Metal ores, NEC	0	0	0	0	0	0	-	0	-	0	-	-	-	-	0	0	0	-	0	0
	Molybdenum	0.09	0.03	0.07	0.06	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0
	Nickel	-	0	0	0	-	-	-	0	0	0	-	-	-	0	-	-	-	-	-	-
	Platinum group	0	0	-	-	0	0	0.24	0.21	0.55	0.29	0	0	0.23	0	0	0	0	0.11	0.15	0
	Rare earths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Silver ores	0.08	0.13	0.12	0.06	0.06	0.04	0.08	0.04	0	0.06	0	0.11	0	0.05	0	0.05	0	0	0.18	0
	Titanium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0	0	0
	Tungsten	0	0	0	0	0	0	0	0	0	-	0	-	0	0	0	0	-	-	-	-
	Uranium	0	0.08	0.06	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Uranium - vanadium ores	0	0	0	0	0	0	0	0	0	0	-	-	-	0	-	3.25	0	0	0	-
	Vanadium	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
	Zircon	-	0	0	0	0	0	0	0	0	-	-	-	-	0	-	0	-	0	-	0
	Total	0.03	0.05	0.04	0.02	0.04	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.01
Nonmetal	Aplite	0	0	0	0	0	-	0	0	0	0	-	0	-	0	0	0	0	0	0	-
	Asbestos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
	Barite	0	0	0	0	0	0	0	0	0	0.55	0	0	0	0	0	0	0	0	0	0
	Boron Materials	0.08	0	0	0	0	0	0	0	0.12	0	0	0	0.23	0	0	0	0	0	0	0
	Brucite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-
	Cement	0.01	0.04	0.02	0.01	0.01	0	0.02	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0	0.03
	Chemical and fertilizer, NEC	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Clay (common)	0.02	0.02	0	0.01	0.01	0	0	0	0	0.02	0	0	0.02	0	0.01	0.01	0	0	0	0
	Clay (fire)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Clay, Ceramic and refractory, NEC	0	0	0	2.44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Canvass	**Industry**	**Year**																			
		1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
	Construction S&G; Sand, common	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Feldspar	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fluorspar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	-	-	-
	Gemstones	-	-	-	-	-	0	9.05	0	0	0	0	0	0	0	0	0	0	1.28	0	0
	Gilsonite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Granite (crushed and broken)	0.07	0.07	0.08	0.02	0.02	0.02	0	0.02	0.02	0	0	0.02	0.04	0.04	0.04	0.02	0	0.04	0	0
	Granite (dimension)	0	0.16	0.18	0.16	0.29	0	0.36	0	0	0	0.2	0.66	0.38	0	0.2	0	0.17	0.16	0	0.66
	Gypsum	0	0	0	0.15	0	0	0.1	0	0	0	0.13	0	0	0	0	0	0.14	0	0	0
	Kyanite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leonardite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lime	0	0.03	0	0	0	0	0	0	0	0	0.09	0	0.03	0	0	0.03	0	0.03	0	0.09
	Limestone (crushed and broken)	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.03	0.02	0.03	0.02	0.01	0.04
	Limestone (dimension)	0	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0	0.13	0	0.08
	Lithium	0.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-
	Magnesite	0	0	0	0	0	0	0	0	0	0	0	1.39	0	0	0	0	0	0	0	0
	Marble (crushed & broken)	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Marble (dimension)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mica	0	0	0.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nonmetallic minerals, NEC	0	0.14	0	0.07	0.07	0	0	0	0	0.07	0	0	0	0	0	0	0	0.08	0	0
	Oil mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil sand	-	-	0	-	-	0	0	0	0	0	-	-	0	0	0	-	-	-	-	-
	Oil shale	0	0	0	0	0	0	0	0	0	-	-	-	-	0	-	-	-	-	-	-
	Perlite	0	0	0	0	0	0	0.5	0.46	0	0	0	0	0	0	0	0	0	0	0	0
	Phosphate rock	0.02	0.02	0	0	0.02	0.05	0	0	0	0.02	0.05	0	0.02	0	0	0.02	0.03	0	0	0
	Pigment mineral	-	-	-	-	-	0	0	0	0	0	0	0	0	-	0	0	0	0	0	0
	Potash	0.06	0.13	0	0.09	0	0	0.06	0	0.06	0	0.08	0	0.12	0	0	0	0	0	0	0
	Potash, soda, & borate minerals, NEC	0.24	0	0	0	0.27	0	0	0	0	0	0	-	-	-	1.45	0	-	-	-	0
	Pumice	0	0	0	0	0	0	0	0	0.94	0	0	0	0	0	0	0	0	0	0	0
	Pyrites	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Salt (evaporated)	0	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salt (rock)	0.05	0.05	0.05	0.05	0	0	0	0.16	0	0	0	0	0.05	0	0	0.06	0	0	0	0
	Sand & gravel	0.2	0.12	0.09	0.12	0.12	0.05	0.02	0.06	0.08	0.04	0.08	0.04	0.04	0.07	0.1	0.08	0.08	0.08	0.06	0.08

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	Sand, Industrial; Ground silica/quartz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sandstone (crushed & broken)	0.11	0.11	0	0	0	0	0	0.04	0	0	0	0.05	0	0	0	0.05	0	0.05	0	0
	Sandstone (dimension)	0	0.57	0	0	0	0	0	0	0	0	0	0	0	0.43	0	0	0.22	0	0	0
	Shale (common)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Slate (crushed & broken)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Slate (dimension)	0	0.4	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sodium compounds	0	0	0	0	0	0	0	0	0	0	0	0.05	-	-	-	-	-	-	-	0
	Stone, crushed & broken, NEC	0	0.25	0.09	0	0.31	0	0.09	0.05	0.12	0	0	0	0.06	0.18	0.12	0.17	0.06	0.05	0.06	0.05
	Stone, dimension, NEC	0	0	0	0	1.07	0	0	0	0	0	0	0.52	0	0	0	0	0	0	0	0
	Talc, soapstone, & pyrophylite	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Traprock (crushed & broken)	0	0.06	0	0	0.09	0.11	0	0.08	0	0	0	0.04	0.04	0.04	0.04	0.08	0.04	0	0	0
	Traprock (dimension)	0	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	-	0	0
	Trona	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0.03	0	0	0	0
	Vermiculite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0.05	0.06	0.04	0.04	0.04	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.03

Table 1.2.2 Industry Fatality Rates 2003-2018

Canvass	Industry	Year															
		2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Coal	Anthracite	0	0.21	0.23	0.26	0	0.19	0	0	0	0	0	0	0	0	0.18	0.18
	Bituminous	0.03	0.03	0.02	0.05	0.04	0.02	0.01	0.05	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02
	Total	0.03	0.03	0.02	0.05	0.04	0.02	0.01	0.05	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02
Metal	Alumina (Mill)	0	0	0	0	0.04	0	0	0	0	0	0	0	0	0	0	0
	Aluminum Ore	0	-	0	0	0	0	0	0	-	0	0	0	0	0	0	0
	Antimony	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Beryl	0	-	0	0	0	0	0	-	0	0	0	0	0	0	-	0
	Chromite	-	-	-	-	-	-	-	-	0	0	-	0	-	-	-	-
	Cobalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Copper Ore	0	0	0.01	0	0.01	0.01	0.01	0.01	0	0	0	0	0	0.01	0.01	0
	Gold (lode and placer)	0.01	0.02	0.02	0	0.02	0.03	0.01	0.03	0.02	0.01	0.01	0.01	0.02	0	0.01	0.01
	Iron ore	0	0	0.02	0.04	0.04	0	0	0	0	0	0	0.02	0	0	0	0
	Manganese	0	0	0	0.07	0.05	0.04	0.08	0	0	0	0	0	0.04	0	0	0
	Mercury	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-
	Metal ores, NEC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Molybdenum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
	Nickel	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0	0
	Platinum group	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
	Rare earths	0	0	0.07	0	0	0	0	0	0.08	0	0	0	0	0	0	0
	Silver ores	0	-	0	-	-	0	0	0	0	0	0	0	0	-	-	0
	Titanium	0	0	0	0	0	0	0	0	0.08	0	0.12	0.07	0	0	0	0
	Tungsten	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Uranium - vanadium ores	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vanadium	-	0	0	-	-	0	0	-	-	-	-	-	-	-	-	-
	Zircon	0	0	0	-	0	0	0	0	0	-	0	0	0	-	0	0
	Total	0.00	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00
Nonmetal	Aplite	0	0	0	0	-	-	-	0	0	-	0	-	0	0	-	0
	Asbestos	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Barite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Boron Materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brucite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cement	0.01	0.01	0.01	0	0.01	0.01	0	0.02	0	0.03	0.01	0	0	0.01	0.01	0
	Chemical and fertilizer, NEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Clay (common)	0.02	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0	0
	Clay (fire)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Clay, Ceramic and refractory, NEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Canvass	Industry	Year															
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Construction S&G; Sand, common	-	-	-	-	-	-	-	-	-	-	0	0	0	0.22	0	0.09
	Feldspar	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0
	Fluorspar	0	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-
	Gemstones	0	0	0	0	0	0	0	0	0	1.49	0	0	0	0	0	0
	Gilsonite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Granite (crushed and broken)	0.02	0	0.02	0	0.04	0	0	0	0	0	0.05	0.04	0.04	0.04	0	0
	Granite (dimension)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.89	1.03
	Gypsum	0	0	0	0	0	0	0	0	0	0	0.24	0.45	0	0	0	0
	Kyanite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lead and/or Zinc Ore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Leonardite	0	0	0.04	0	0	0.03	0	0.03	0	0	0.03	0.05	0	0	0	0.03
	Lime	0.01	0.03	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.05	0.01	0	0.02	0.02	0.01
	Limestone (crushed and broken)	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0
	Limestone (dimension)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lithium	0	0	0	0	0	0	0	0	0	0	0	0	0	0.91	0	0
	Magnesite	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0
	Marble (crushed & broken)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Marble (dimension)	0	0	0	0	0	0	0	0	-	0	-	0	0	-	0	0
	Mica	0.1	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0.11	0
	Nonmetallic minerals, NEC	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-
	Oil mining	-	-	-	-	0	0	-	-	-	-	0	0	0	-	-	0
	Oil sand	-	-	-	0	-	0	-	-	-	-	-	-	-	-	-	-
	Oil shale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perlite	0	0	0.03	0	0	0	0	0	0	0	0	0	0.05	0	0	0
	Phosphate rock	0	0	0	0	0	0	0	-	0	0	0	-	0	0	0	0
	Pigment mineral	0	0	0.11	0	0	0.1	0	0	0	0	0	0	0	0	0	0
	Potash	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-
	Potash, soda, & borate minerals, NEC	0	0	0.65	0	0	0	0	0	0	0	0	-	0	0	-	0
	Pumice	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pyrites	0	-	0	-	0	0	0	0	0	-	0	0	0	0	0	0
	Salt (evaporated)	0	0	0	0	0	0	0.05	0	0	0	0.06	0.04	0	0	0	0
	Salt (rock)	0.08	0.07	0.07	0.05	0.05	0.03	0.05	0.02	0.04	0.06	0.02	0.12	0.08	0.07	0.05	0.07
	Sand & gravel	-	-	-	-	-	-	-	-	-	-	0.04	0.03	0	0	0	0

Canvass	Industry	Year															
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	Sand, Industrial; Ground silica/quartz	0	0	0.05	0	0.06	0	0	0	0	0	0	0.08	0	0	0	0
	Sandstone (crushed & broken)	0	0	0	0.15	0	0	0	0.61	0	0	0	0	0.69	0	0	0
	Sandstone (dimension)	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0	0	0
	Shale (common)	0	0	0	0	0	0	0	-	0	0	-	-	0	-	0	0
	Slate (crushed & broken)	0	0	0	0	0	0	0	0	0	0	0.92	0	0	0	0	0
	Slate (dimension)	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
	Sodium compounds	0.09	0	0.04	0.13	0	0.05	0.07	0.08	0.22	0	0.07	0	0	0	0.07	0
	Stone, crushed & broken, NEC	0.18	0	0	0	0	0	0	0.18	0	0	0	0	0	0	0	0.23
	Stone, dimension, NEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Talc, soapstone, & pyrophylite	0.05	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0.07
	Traprock (crushed & broken)	0	0	0	0	0	-	0	-	0	0	-	0	0	0	0	0
	Traprock (dimension)	0	0.05	0.05	0	0.04	0	0	0	0	0	0	0	0	0	0	0
	Trona	0	0	0	0	0	0	0	0	0	-	0	0	-	0	0	0
	Vermiculite	0	0	0	0	-	-	-	0	0	-	0	-	0	0	-	0
	Total	0.03	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.02

Table 1.3.1 Industry Noise Measurements 1983-2002

Canvass	Industry	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Year																			
Coal	Anthracite	-	-	-	83.7 (8.0)	84.2 (7.0)	84.2 (7.1)	84.3 (7.1)	84.5 (6.9)	83.9 (7.4)	84.0 (7.7)	83.9 (7.0)	85.0 (7.5)	83.4 (8.3)	83.8 (8.1)	83.0 (8.0)	82.6 (8.4)	82.7 (11.1)	82.8 (12.4)	80.9 (12.0)	79.7 (11.4
Coal	Bituminous	-	-	-	83.7 (8.0)	84.2 (7.0)	84.2 (7.1)	84.3 (7.1)	84.5 (6.9)	83.9 (7.4)	84.0 (7.7)	83.9 (7.0)	85.0 (7.5)	83.4 (8.3)	83.8 (8.1)	83.0 (8.0)	82.6 (8.4)	82.7 (11.1)	82.8 (12.4)	80.9 (12.0)	79.7 (11.4
Coal	**Total†**	-	-	-	83.7 (8.0)	84.2 (7.0)	84.2 (7.1)	84.3 (7.0)	84.5 (6.9)	83.9 (7.3)	84.0 (7.7)	83.9 (7.0)	85.0 (7.4)	83.4 (8.3)	83.8 (8.1)	83.0 (8.0)	82.6 (8.4)	82.7 (11.1)	82.8 (12.4)	80.9 (12.0)	79.7 (11.4
Metal	Alumina (Mill)	82.8 (6.6)	82.7 (6.7)	83.6 (7.0)	86.9 (5.3)	89.5 (4.0)	79.9 (10.1)	84.0 (8.3)	87.6 (5.5)	82.6 (8.0)	81.8 (7.7)	81.2 (9.7)	80.0 (7.1)	80.7 (4.9)	77.9 (8.2)	90.9 (5.4)	88.0 (3.3)	93.4	87.3 (4.1)	80.2 (7.9)	85.0 (5.2)
Metal	Aluminum Ore	87.2 (6.5)	78.5 (9.3)	-	-	-	80.5 (3.1)	77.8 (5.3)	80.1 (6.3)	77.7 (5.1)	81.7 (8.0)	73.4	85.5 (4.5)	-	78.9 (5.9)	74.1 (7.1)	-	-	-	-	-
Metal	Antimony	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metal	Beryl	91.8 (3.7)	85.7 (3.6)	80.2 (10.8)	86.9 (9.5)	83.9 (10.4)	80.6 (11.5)	84.6 (6.0)	84.2 (4.0)	91.2 (5.5)	-	86.9 (1.8)	76.2 (5.5)	80.6 (6.0)	78.7 (9.8)	75.8 (10.2)	-	-	81.6 (6.0)	-	-
Metal	Chromite	-	-	-	-	84.3 (7.2)	87.2 (6.2)	90.0	77.0 (0.5)	-	77.1	-	69.7	-	-	-	-	-	79.0 (7.3)	68.7 (1.7)	-
Metal	Cobalt	-	-	81.4 (3.9)	71.3 (5.8)	74.1	-	-	84.6	-	-	-	71.8 (11.2)	72.1 (10.0)	-	-	-	-	-	-	-
Metal	Copper Ore	83.9 (8.4)	83.0 (9.2)	83.9 (7.3)	85.4 (9.8)	83.3 (7.7)	88.4 (8.1)	84.8 (8.8)	83.7 (8.4)	84.8 (8.1)	84.8 (9.8)	83.2 (8.9)	84.3 (9.4)	82.5 (7.5)	81.8 (8.1)	81.5 (10.1)	79.0 (8.3)	83.0 (6.9)	86.2 (8.7)	85.6 (5.5)	86.2 (7.8
Metal	Gold (lode and placer)	85.4 (8.8)	86.3 (10.2)	84.8 (9.8)	84.8 (9.4)	86.8 (8.9)	84.4 (9.2)	85.3 (7.9)	86.1 (8.9)	86.3 (9.1)	85.3 (8.7)	84.8 (8.7)	85.8 (9.6)	84.8 (9.6)	83.7 (10.4)	83.8 (10.6)	86.3 (9.8)	87.7 (1.7)	89.2 (9.1)	84.3 (8.0)	84.0 (9.5
Metal	Iron ore	82.2 (9.1)	81.9 (8.6)	79.6 (8.5)	81.1 (8.4)	81.6 (7.8)	85.6 (8.1)	83.8 (7.0)	82.8 (6.8)	81.5 (7.8)	80.4 (7.5)	82.4 (7.2)	80.7 (8.2)	81.2 (7.6)	80.7 (7.1)	82.2 (7.6)	83.7 (7.1)	88.4 (0.5)	86.2 (6.7)	83.8 (6.3)	83.5 (5.3
Metal	Lead/Zinc Ore	89.6 (7.6)	87.9 (8.7)	89.5 (7.1)	88.4 (9.0)	86.6 (9.0)	87.1 (9.6)	89.8 (8.9)	88.9 (7.1)	87.3 (9.9)	88.5 (8.8)	85.3 (9.7)	83.6 (8.8)	85.1 (8.8)	84.6 (10.1)	82.5 (9.9)	84.6 (10.2)	83.1 (5.8)	87.6 (5.8)	86.9 (8.8)	83.0 (3.3
Metal	Manganese	85.9 (4.3)	80.9 (6.7)	74.1 (6.3)	80.6 (10.3)	85.1 (4.9)	84.3 (4.3)	82.7	78.1 (6.0)	83.0 (6.5)	85.0 (5.8)	80.4 (9.0)	79.5 (7.8)	79.4 (8.1)	79.6 (5.8)	84.4 (4.1)	87.4 (1.7)	95.1	79.8	85.0 (4.5)	86.5 (4.7
Metal	Mercury	88.9 (3.3)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Metal	Metal ores, NEC	85.7 (8.7)	90.7 (6.2)	89.4 (9.9)	86.0 (6.3)	88.6 (3.5)	84.6 (6.9)	89.0 (0.5)	91.9 (11.4)	83.6 (7.2)	84.5 (14.2)	87.9 (2.1)	82.7	77.4 (8.2)	84.0 (9.5)	77.7 (8.9)	86.4 (10.1)	84.0 (4.3)	83.1 (2.5)	83.6 (2.2)	80.2 (6.0
Metal	Molybdenum	84.6 (6.3)	82.1 (7.8)	81.5 (9.9)	80.8 (10.1)	91.7 (13.8)	80.3 (8.1)	87.1 (10.2)	79.9 (7.5)	80.0 (9.6)	86.2 (2.4)	99.0	82.1 (7.6)	83.9 (5.6)	84.9 (6.1)	82.6 (6.3)	88.7 (8.0)	85.4 (8.7)	84.4 (6.8)	80.8	87.6 (6.0
Metal	Nickel	-	84.5 (11.1)	89.6	84.0 (1.5)	-	-	-	-	-	87.3 (1.4)	75.2 (1.7)	-	77.6 (6.3)	-	-	-	-	-	-	-
Metal	Platinum group	-	96.8 (5.5)	-	100.8 (2.0)	90.2 (9.4)	92.0 (4.1)	99.4	86.4 (7.5)	93.5 (8.7)	89.0 (11.2)	103.2 (6.0)	95.0 (12.9)	91.7 (11.7)	86.0 (8.6)	97.1 (11.7)	-	89.1 (2.6)	93.7 (10.4)	102.5 (6.7)	97.4 (4.8
Metal	Rare earths	84.1 (2.0)	82.6 (11.7)	77.9 (7.3)	79.8 (7.8)	76.7 (4.8)	80.9 (10.2)	85.2 (7.4)	80.6 (8.8)	-	86.4 (4.1)	82.3 (19.6)	101.0 (0.3)	-	-	-	86.2 (4.6)	-	85.5 (1.4)	83.5 (1.1)	86.6
Metal	Silver ores	84.6 (9.4)	85.5 (9.0)	87.9 (10.4)	86.5 (10.6)	86.3 (10.6)	82.3 (10.1)	89.3 (10.3)	85.4 (11.6)	87.4 (8.7)	86.6 (7.8)	83.6 (8.0)	85.7 (5.9)	78.6 (9.3)	87.3 (9.0)	83.8 (3.1)	85.9 (11.9)	89.3 (9.3)	88.8 (8.5)	95.1 (6.6)	85.2 (3.1
Metal	Titanium	-	-	95.6 (2.6)	-	88.1 (1.6)	-	84.2 (5.2)	-	84.8 (3.0)	-	69.3 (5.1)	84.6 (7.9)	80.0 (4.6)	80.7 (6.2)	76.1 (3.9)	81.6 (5.1)	-	86.1 (4.4)	66.1 (4.3)	-

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	Tungsten	91.4 (5.8)	85.9 (7.1)	83.2 (0.2)	-	-	-	-	-	-	86.5 (0.9)	-	-	-	-	-	-	-	-	-	-
	Uranium	86.3 (9.6)	87.2 (11.1)	93.1 (8.6)	89.9 (9.5)	88.6 (9.3)	94.4 (9.6)	89.7 (12.6)	88.9 (10.2)	76.2 (7.5)	85.8 (5.1)	67.2	83.7 (4.3)	75.3 (9.1)	78.3 (10.6)	75.9 (3.0)	90.6 (1.2)	-	-	76.5 (6.0)	-
	Uranium - vanadium ores	86.2 (12.4)	91.6 (8.5)	87.9 (10.1)	90.6 (9.5)	95.1 (6.3)	93.9 (10.7)	95.2 (11.1)	94.6 (10.8)	103.0 (5.2)	-	-	65.4 (4.2)	73.6 (6.5)	66.2	91.0 (7.3)	-	-	-	-	-
	Vanadium	-	77.4 (9.2)	-	-	-	89.9 (1.2)	93.4 (11.1)	-	-	-	-	74.1 (5.8)	-	77.3 (5.7)	-	-	88.1 (0.8)	-	-	-
	Zircon	-	-	84.7	-	89.5	84.3 (3.7)	88.0 (1.2)	85.9 (0.4)	91.7 (4.5)	86.6 (2.7)	86.8	-	80.8 (2.3)	79.0 (7.9)	77.3	-	73.7 (7.7)	-	-	85.2 (5.0)
	Total	84.5 (9.0)	84.9 (9.6)	84.3 (9.9)	84.2 (9.7)	85.8 (9.2)	85.6 (9.5)	85.7 (8.8)	84.8 (8.7)	84.6 (8.9)	83.4 (8.6)	83.6 (8.6)	83.8 (9.5)	82.8 (8.6)	82.6 (9.1)	83.1 (10.3)	85.3 (8.8)	86.6 (3.3)	87.2 (8.1)	84.3 (8.4)	85.5 (7.8)
Nonmetal	Aplite	90.1	-	-	-	-	-	-	88.0 (0.5)	89.2 (0.6)	-	-	83.8 (8.8)	85.2 (4.1)	73.9 (4.9)	-	-	-	82.2 (7.8)	83.3 (3.5)	84.4 (2.6)
	Asbestos	87.2 (4.1)	82.5 (3.0)	87.7 (4.3)	81.2 (14.9)	84.0 (9.1)	83.4 (5.7)	88.9 (3.9)	81.3 (6.9)	84.7 (3.3)	83.7 (4.7)	-	81.0 (7.2)	-	79.3 (5.9)	89.8 (0.0)	-	-	80.2 (8.0)	87.8 (2.6)	78.7 (7.4)
	Barite	82.5 (6.5)	82.2 (8.0)	82.1 (8.2)	81.5 (6.8)	81.4 (6.8)	85.6 (8.4)	82.4 (7.2)	82.6 (6.3)	82.2 (7.3)	85.3 (5.1)	85.5 (3.7)	82.2 (8.1)	81.3 (7.8)	80.6 (7.7)	80.1 (6.7)	82.5 (7.9)	78.0 (6.0)	86.6 (4.8)	80.5 (7.6)	82.6 (5.4)
	Boron Materials	83.6 (7.1)	76.3 (5.1)	82.5 (3.5)	78.9 (8.3)	82.4 (9.3)	79.7 (11.2)	75.5 (7.5)	78.0 (4.8)	90.8 (7.9)	90.8 (5.1)	84.0 (6.8)	84.9 (9.4)	78.5 (7.7)	82.4 (8.9)	-	74.1 (4.6)	-	89.1 (6.8)	80.1 (5.1)	82.7 (0.6)
	Brucite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93.3 (2.6)	66.8	-
	Cement	84.3 (7.4)	82.2 (7.9)	83.8 (8.1)	83.5 (7.7)	83.8 (8.0)	83.4 (7.8)	82.8 (7.6)	82.7 (7.6)	83.5 (7.4)	81.5 (7.9)	81.8 (7.8)	82.9 (7.7)	71	81.7 (7.7)	80.7 (8.6)	81.7 (7.9)	83.6 (5.1)	84.9 (6.4)	85.1 (5.7)	84.4 (5.7)
	Chemical and fertilizer, NEC	-	-	-	-	-	-	88.3 (1.0)	-	-	-	-	73.0 (4.7)	-	77.6 (2.3)	-	-	-	-	-	79.4 (2.7)
	Clay (common)	84.9 (6.5)	84.5 (6.6)	84.4 (7.0)	84.2 (6.9)	84.7 (6.7)	83.4 (7.3)	82.4 (7.3)	84.0 (7.1)	81.9 (8.6)	83.2 (7.5)	83.0 (7.2)	81.6 (8.1)	82.2 (7.3)	81.8 (7.8)	82.0 (8.1)	81.5 (6.7)	82.5 (7.5)	81.7 (7.1)	83.9 (5.9)	83.2 (6.5)
	Clay (fire)	84.9 (6.1)	86.5 (7.5)	88.7 (3.2)	88.3 (9.4)	84.1 (6.8)	83.7 (9.1)	84.9 (7.9)	87.3 (6.2)	83.1 (8.6)	82.6 (8.1)	81.1 (8.7)	83.7 (8.1)	80.6 (7.4)	82.3 (8.3)	80.6 (9.3)	83.9 (5.8)	85.3 (4.2)	85.2 (6.1)	82.8 (4.9)	79.5 (8.4)
	Clay, Ceramic and refractory, NEC	79.6 (9.1)	82.3 (5.3)	86.3 (5.2)	82.4 (9.7)	87.0 (8.7)	84.7 (5.5)	86.3 (8.9)	84.3 (7.2)	79.9 (9.1)	84.8 (6.6)	82.7 (7.9)	81.2 (8.9)	81.7 (7.0)	81.3 (7.2)	80.4 (7.4)	80.7 (5.6)	83.5 (5.2)	82.4 (5.5)	85.3 (6.3)	83.9 (9.1)
	Construction S&G; Sand, common	86.3 (7.2)	86.2 (7.5)	85.8 (7.6)	85.7 (7.8)	86.4 (7.5)	85.7 (7.5)	85.6 (7.2)	85.0 (7.7)	83.5 (8.2)	83.6 (8.2)	83.4 (8.0)	82.6 (8.2)	81.9 (8.2)	81.5 (8.3)	81.0 (8.3)	82.1 (8.7)	85.4 (6.6)	84.1 (6.8)	82.9 (6.9)	82.7 (6.7)
	Feldspar	88.2 (4.4)	82.5 (9.5)	81.8 (8.8)	85.5 (7.1)	83.0 (3.8)	85.7 (4.9)	84.4 (5.5)	86.9 (4.3)	82.4 (8.4)	82.5 (6.9)	82.3 (7.1)	83.7 (7.6)	82.3 (8.1)	81.9 (8.1)	82.1 (4.9)	79.5 (6.5)	78.9 (7.1)	84.4 (7.7)	82.2 (4.9)	77.0 (10.1)
	Fluorspar	87.8 (2.1)	79.1	-	84.4 (7.0)	96.5 (8.4)	87.6 (8.1)	85.9 (1.4)	93.5 (5.4)	67.1	92.2 (10.3)	97.1 (7.5)	85.2 (10.3)	87.8 (11.5)	86.0	83.7 (3.2)	-	72.5 (11.5)	-	-	84.2 (0.4)

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	Gemstones	-	83.0	88.0 (2.6)	82.2	-	-	-	75.7 (13.6)	77.4	81.0 (9.5)	90.4 (1.1)	79.4 (10.5)	83.6 (4.9)	79.7 (8.4)	85.9	-	84.0 (11.0)	82.7 (4.5)	-	79.3 (22.7
	Gilsonite	80.6 (9.7)	83.3 (9.8)	83.4 (10.9)	87.0 (12.9)	94.0 (7.4)	84.8 (8.7)	84.5 (7.0)	85.9 (2.9)	72.3 (8.8)	81.7 (19.4)	76.8	87.1 (4.5)	89.0 (6.6)	85.9 (6.7)	-	77.0 (7.5)	-	88.7 (8.0)	87.9 (8.3)	-
	Granite (crushed and broken)	85.8 (7.3)	84.8 (6.7)	84.6 (6.7)	84.3 (7.0)	85.6 (8.0)	84.4 (7.4)	82.9 (7.4)	83.0 (8.0)	82.1 (8.1)	81.5 (7.6)	81.2 (8.1)	80.9 (7.8)	80.9 (8.1)	79.9 (8.0)	80.4 (7.2)	81.2 (7.8)	81.5 (9.3)	84.3 (6.1)	83.7 (6.4)	83.4 (6.4)
	Granite (dimension)	86.6 (11.5)	84.0 (11.3)	89.8 (6.1)	88.3 (10.0)	89.7 (9.5)	86.3 (8.5)	92.4 (11.5)	92.0 (8.7)	88.6 (10.2)	86.6 (9.3)	85.7 (8.5)	88.3 (9.0)	89.3 (10.4)	87.5 (9.3)	88.4 (10.9)	85.6 (7.7)	86.9 (9.7)	93.3 (6.8)	88.9 (9.4)	88.5 (6.9)
	Gypsum	85.3 (6.0)	83.0 (9.1)	83.1 (8.3)	85.1 (9.5)	84.9 (8.3)	84.1 (7.9)	85.4 (6.8)	85.0 (7.5)	84.5 (8.2)	84.0 (8.7)	82.6 (8.6)	84.1 (7.7)	81.9 (8.5)	81.7 (8.3)	81.8 (8.6)	84.8 (8.5)	83.6 (7.4)	86.3 (6.3)	84.6 (5.2)	84.3 (7.0)
	Kyanite	78.9 (4.8)	87.9	-	83.8 (8.5)	79.8 (9.0)	92.6 (5.1)	95.4	85.6 (4.0)	-	85.2 (5.3)	-	78.1 (6.7)	77.9 (7.2)	80.2 (6.3)	81.1 (6.2)	78.8 (9.4)	72.1	85.8 (4.1)	84.1 (5.9)	85.4 (4.6)
	Lead and/or Zinc Ore	79.9 (5.6)	76.4 (8.3)	81.7 (7.4)	84.5 (5.7)	78.8 (6.6)	84.5 (5.9)	-	90.6 (1.2)	81.7 (4.0)	85.0	84.5 (5.0)	85.6 (4.6)	83.0 (6.0)	84.0 (11.5)	85.7 (6.3)	78.0 (4.4)	77.1 (1.1)	86.0 (0.8)	83.4 (5.2)	88.9
	Leonardite	85.5 (7.2)	84.1 (8.9)	82.9 (7.5)	83.6 (7.2)	85.2 (7.0)	84.3 (7.1)	83.5 (7.1)	84.2 (6.7)	81.4 (7.4)	83.7 (7.1)	82.4 (6.8)	81.5 (7.6)	81.0 (7.3)	81.1 (7.8)	82.0 (8.1)	83.0 (9.2)	79.5 (8.7)	82.0 (7.3)	82.9 (5.8)	84.4 (5.4)
	Lime	86.5 (7.2)	86.3 (7.3)	86.2 (7.1)	86.3 (7.3)	86.2 (7.3)	85.5 (7.3)	85.2 (7.2)	85.1 (7.8)	84.4 (8.0)	84.1 (8.0)	83.7 (7.9)	83.3 (7.9)	82.7 (8.2)	81.8 (8.1)	81.8 (8.1)	82.9 (8.4)	83.6 (8.0)	84.6 (6.7)	83.4 (6.7)	83.1 (6.7)
	Limestone (crushed and broken)	84.0 (8.8)	87.3 (10.2)	85.0 (5.9)	89.9 (4.9)	88.1 (8.5)	87.1 (6.5)	86.2 (7.5)	85.9 (8.3)	85.6 (9.0)	86.7 (5.0)	86.8 (9.8)	84.4 (8.3)	84.6 (9.7)	83.5 (7.1)	86.4 (10.6)	86.8 (6.9)	91.4 (2.6)	87.0 (6.5)	86.9 (6.8)	88.0 (5.8)
	Limestone (dimension)	85.3 (7.3)	84.6 (6.9)	85.1 (5.2)	83.3 (9.4)	84.1 (7.7)	88.9 (1.5)	85.8 (5.0)	83.3 (4.8)	79.1 (6.8)	80.0 (11.3)	85.6 (3.9)	80.0 (7.9)	82.4 (6.7)	86.2 (3.4)	90.7 (2.1)	-	-	-	-	-
	Lithium	81.2 (12.5)	87.0 (7.7)	-	91.9 (0.1)	-	106.1 (0.7)	70.7 (0.8)	-	-	-	84.3 (2.6)	-	89.4 (9.2)	77.3	80.1 (4.4)	70.0	100.5	89.0 (4.5)	-	83.3 (7.3)
	Magnesite	84.3 (6.9)	85.2 (7.0)	85.4 (6.4)	87.2 (6.5)	83.8 (6.6)	84.1 (6.1)	84.9 (7.8)	82.7 (8.0)	80.5 (7.1)	81.1 (7.9)	81.4 (6.2)	84.3 (6.6)	83.3 (7.3)	76.6 (8.3)	78.0 (9.2)	83.8 (9.8)	84.5 (6.7)	87.3 (4.7)	83.0 (5.8)	86.5 (7.6)
	Marble (crushed & broken)	93.1 (8.8)	89.8 (15.3)	76.7 (14.2)	80.0 (10.2)	86.5 (5.2)	87.9 (6.0)	89.0	81.6 (9.5)	86.6 (11.1)	81.2 (8.9)	86.9 (5.8)	84.3 (8.3)	88.6 (5.5)	89.7 (8.3)	87.9 (10.0)	98.4 (9.4)	81.5 (7.9)	87.8 (6.9)	80.8 (6.2)	83.0 (4.4)
	Marble (dimension)	81.3 (6.7)	80.6 (9.0)	82.0 (4.6)	82.5 (7.9)	82.5 (7.3)	81.5 (5.7)	84.2 (4.3)	83.7 (7.1)	78.6 (7.6)	82.2 (5.8)	78.7 (7.1)	81.9 (7.0)	82.3 (6.9)	82.6 (6.8)	80.1 (6.7)	77.1 (10.0)	80.4 (9.2)	83.0 (5.1)	79.7 (4.3)	83.9 (5.7)
	Mica	88.8 (7.6)	86.4 (10.1)	84.4 (6.3)	87.2 (6.7)	82.2 (7.7)	84.1 (3.7)	83.8 (9.5)	83.3 (7.8)	81.7 (6.8)	83.8 (11.0)	83.6 (8.8)	80.1 (7.8)	81.6 (7.9)	83.4 (7.0)	79.9 (6.7)	82.7 (7.0)	84.2 (6.3)	87.8 (6.7)	80.8 (6.7)	83.1 (4.0)
	Nonmetallic minerals, NEC	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oil mining	-	-	-	-	-	92.1 (3.3)	-	-	75.2 (2.4)	-	-	-	-	-	-	-	-	-	-	-
	Oil sand	83.9 (8.4)	83.0 (10.8)	74.5 (7.2)	78.5 (6.7)	80.1 (9.2)	84.0 (6.0)	74.5 (11.7)	71.0 (10.5)	76.7 (7.6)	78.0 (4.1)	71.1 (6.5)	-	68.5	72.4 (9.5)	-	-	-	-	-	-
	Oil shale	78.6 (6.3)	83.7 (6.5)	83.9 (7.2)	80.1 (8.8)	79.2 (8.7)	81.6 (6.3)	79.1 (10.8)	84.5 (7.6)	76.6 (7.2)	80.1 (7.5)	80.1 (8.2)	83.4 (9.0)	81.4 (6.5)	78.1 (8.7)	79.4 (7.0)	76.2 (7.3)	83.1 (3.8)	79.8 (4.8)	82.0 (5.8)	84.7

Canvass	Industry	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	Perlite	86.7	88.2	86.9	86.4	85.7	86.5	85.4	84.5	85.8	86.2	81.9	81.3	82.2	82.5	81.3		87.8	84.2	83.4	83.3
		(10.8)	(7.0)	(7.5)	(7.7)	(7.1)	(7.8)	(6.2)	(8.9)	(8.3)	(9.4)	(8.2)	(7.4)	(7.4)	(7.5)	(7.0)	-	(8.3)	(4.9)	(4.8)	(6.0
	Phosphate rock	84.2							86.6	77.8	74.4		79.7	82.7	77.6	83.6		81.1	85.9	79.1	
		(2.3)	87.1	78.0	-	-	-	84.6	(3.1)	(14.0)	(7.2)	-	(11.3)	(5.0)	(7.5)	(3.4)	-	(10.2)	(2.2)	(4.8)	-
	Pigment mineral	87.3	88.6	88.1	83.7	83.8	85.9		88.0	87.8	87.1	80.8	79.7	88.9	82.8	91.8	81.1		81.4		
		(5.7)	(5.7)	(6.9)	(6.9)	(6.2)	(2.2)	-	(4.5)	(8.4)	(5.6)	(7.6)	(5.7)	(7.1)	(8.8)	(6.3)	(5.6)	-	(5.6)	-	-
	Potash							77.6			83.2						84.0	75.3		78.2	
		-	-	-	-	71.5	-	(1.3)	-	-	(3.5)	-	-	-	-	76.6	(9.2)	(4.7)	-	(10.1)	-
	Potash, soda, & borate minerals, NEC	85.0	83.3	86.6	86.5	74.3	78.5	83.9	83.1	83.1	85.4	81.7	83.5	81.7	83.3	79.5	83.8		83.5	83.6	82.5
		(9.6)	(7.0)	(6.5)	(9.7)	(6.3)	(6.1)	(7.9)	(8.3)	(8.1)	(9.5)	(6.8)	(7.1)	(8.8)	(8.9)	(9.0)	(8.1)	91.9	(6.7)	(4.6)	(5.5)
	Pumice					78.8															
		-	-	-	-	(6.2)	85.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pyrites				79.2	84.5				83.7	86.7	62.6	86.9		80.8	75.9				74.7	81.0
		-	-	-	(10.7)	(5.3)	-	-	-	(2.6)	(3.8)	(1.3)	(2.7)	-	(13.7)	(3.9)	-	-	-	(3.0)	(1.5)
	Salt (evaporated)	89.8	90.5	89.3	85.0	86.2	85.7	85.8	85.6	85.0	84.1	85.6	84.7	84.3	84.4	84.7	89.9	85.3	86.7	85.3	86.7
		(5.2)	(5.5)	(5.7)	(6.7)	(6.0)	(5.8)	(5.3)	(6.9)	(7.2)	(8.2)	(7.8)	(8.1)	(8.6)	(7.3)	(7.1)	(5.5)	(10.0)	(6.2)	(7.0)	(7.4)
	Salt (rock)	81.7	79.0	82.5	83.2	82.4	85.3	82.8	84.1	80.2	81.1	82.5	82.3	76.6	80.0	78.1	86.5	76.0	82.7	81.8	79.7
		(9.2)	(11.2)	(9.0)	(6.5)	(6.9)	(7.4)	(7.0)	(6.8)	(8.4)	(7.3)	(7.2)	(8.0)	(7.7)	(8.5)	(8.6)	(5.4)	(9.0)	(7.4)	(7.6)	(6.7)
	Sand & gravel	81.5	82.8	82.3	82.5	81.9	83.5	83.0	81.8	79.0	81.3	79.4	80.4	77.0	77.4	77.7	77.1	76.9	80.2	80.0	79.6
		(9.2)	(7.8)	(7.0)	(8.4)	(8.0)	(7.6)	(9.3)	(7.7)	(7.8)	(7.3)	(9.0)	(8.8)	(7.8)	(7.7)	(8.1)	(7.6)	(7.5)	(6.1)	(6.2)	(6.1)
	Sand, Industrial; Ground silica/quartz	84.5	86.0	85.7	84.6	85.5	83.4	83.2	82.9	81.1	81.3	81.8	80.6	79.0	79.8	80.8	79.7	79.2	82.9	81.8	80.8
		(7.6)	(7.5)	(7.3)	(8.5)	(8.3)	(7.3)	(7.6)	(7.7)	(8.3)	(8.7)	(8.1)	(7.6)	(7.9)	(7.8)	(7.8)	(8.5)	(8.5)	(6.3)	(6.7)	(6.8)
	Sandstone (crushed & broken)	86.3	83.6	83.3	81.9	86.1	86.4	82.9	81.0	81.0	78.8	81.3	81.0	79.9	79.7	79.8	80.7	82.1	83.1	84.4	82.3
		(5.5)	(6.6)	(4.9)	(5.9)	(5.0)	(6.1)	(6.5)	(8.4)	(7.6)	(6.3)	(7.3)	(7.4)	(7.9)	(8.5)	(6.8)	(8.7)	(5.3)	(7.7)	(6.1)	(5.8)
	Sandstone (dimension)	85.5	86.1	84.6	83.0	81.0	82.8	84.0	83.5	83.7	83.8	82.8	81.9	82.3	81.2	79.7	82.9	78.9	82.2	83.9	83.1
		(6.7)	(6.2)	(6.3)	(7.1)	(8.5)	(7.4)	(7.3)	(8.8)	(7.4)	(7.5)	(8.9)	(8.5)	(8.6)	(7.7)	(7.7)	(7.7)	(6.9)	(7.9)	(6.1)	(6.7)
	Shale (common)	84.2	86.1	85.2	90.5	83.8	84.3	83.6	82.9	87.2	79.9	82.2		82.3	85.1	83.3	79.6	71.3	76.6	82.1	78.4
		(4.1)	(4.0)	(4.7)	(3.8)	(5.2)	(4.4)	(7.0)	(7.2)	(7.5)	(9.5)	(8.9)	72.5	(6.0)	(8.9)	(8.9)	(7.3)	(12.4)	(10.0)	(7.2)	(8.6)
	Slate (crushed & broken)	85.7	85.0	86.4	85.5	86.1	86.1	87.5	87.3	81.5	80.0	85.8	83.4	85.9	82.2	84.6	84.6	84.1	86.1	82.9	83.8
		(5.5)	(5.1)	(4.4)	(6.2)	(4.9)	(5.6)	(6.8)	(7.9)	(6.7)	(7.4)	(7.1)	(6.9)	(6.2)	(6.7)	(7.4)	(6.7)	(6.8)	(6.4)	(9.2)	(7.6)
	Slate (dimension)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sodium compounds	87.8	86.8	86.1	86.0	85.9	86.1	86.0	85.0	84.3	85.7	84.6	84.1	83.0	83.1	82.5	82.2	83.2	84.7	83.6	83.1
		(8.1)	(8.0)	(8.1)	(7.7)	(7.9)	(7.7)	(7.7)	(7.5)	(8.1)	(8.1)	(7.9)	(8.2)	(8.7)	(8.3)	(8.5)	(8.4)	(7.2)	(6.7)	(7.6)	(7.2)
	Stone, crushed & broken, NEC	91.3	88.7	90.9	87.9	88.7	88.4	88.0	88.8	87.8	87.0	85.7	87.8	85.1	83.5	84.7	86.4	83.1	88.1	87.4	85.2
		(8.1)	(8.5)	(8.9)	(8.6)	(9.0)	(7.9)	(8.6)	(11.6)	(9.6)	(8.2)	(9.3)	(8.7)	(9.3)	(9.8)	(8.3)	(12.3)	(6.2)	(8.8)	(9.3)	(8.4)

Canvass	Industry	Year																			
		1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
	Stone, dimension, NEC	83.8 (7.9)	83.2 (8.4)	79.3 (8.0)	83.2 (7.7)	80.9 (8.4)	84.0 (6.6)	84.6 (7.7)	82.8 (6.6)	84.1 (9.2)	84.0 (7.9)	81.0 (8.7)	82.4 (7.5)	79.6 (8.9)	81.5 (8.9)	81.8 (10.3)	82.3 (9.4)	81.5 (5.9)	82.9 (6.3)	81.2 (6.2)	79.8 (6.5)
	Talc, soapstone, & pyrophylite	83.8 (7.9)	83.2 (8.4)	79.3 (8.0)	83.2 (7.7)	80.9 (8.4)	84.0 (6.6)	84.6 (7.7)	82.8 (6.6)	84.1 (9.2)	84.0 (7.9)	81.0 (8.7)	82.4 (7.5)	79.6 (8.9)	81.5 (8.9)	81.8 (10.3)	82.3 (9.4)	81.5 (5.9)	82.9 (6.3)	81.2 (6.2)	79.8 (6.5)
	Traprock (crushed & broken)	86.6 (7.4)	86.6 (6.8)	86.4 (6.7)	86.8 (6.4)	86.8 (7.6)	86.0 (7.6)	85.9 (6.7)	87.1 (7.2)	84.1 (8.4)	85.4 (8.5)	83.9 (8.6)	83.5 (7.8)	83.3 (8.0)	82.8 (8.2)	81.7 (8.0)	81.8 (7.5)	83.7 (7.7)	84.6 (5.5)	83.6 (6.2)	83.5 (6.3)
	Traprock (dimension)	90.3 (7.5)	88.5 (5.4)	70.8	85.4 (4.5)	-	74.6 (13.9)	86.4 (5.4)	79.2 (8.8)	91.2 (2.1)	84.1 (11.9)	90.5 (12.7)	86.0 (3.5)	81.5 (5.1)	-	79.6 (8.0)	-	82.5 (7.1)	83.8 (3.2)	-	81.0 (6.6)
	Trona	87.2 (3.8)	-	85.2 (7.0)	84.2 (9.7)	82.8 (8.6)	86.0 (7.3)	81.1 (1.5)	79.6 (11.2)	88.2 (6.8)	76.6 (4.8)	84.7 (9.9)	82.3 (8.2)	84.3 (8.9)	82.1 (10.4)	84.0 (10.6)	86.9 (10.1)	79.5 (9.3)	85.6 (4.3)	-	-
	Vermiculite	82.6 (10.1)	78.9 (7.5)	84.7 (6.0)	78.3 (10.1)	83.7 (7.0)	80.3 (8.7)	75.2 (8.6)	83.0 (8.8)	77.1 (6.4)	83.6 (6.8)	86.2 (4.9)	85.4 (5.9)	85.1 (8.8)	87.7 (12.7)	84.8 (5.6)	-	86.1 (2.9)	84.4 (2.2)	84.2 (3.4)	83.3 (3.5)
	Total	86.1 (7.5)	85.6 (7.7)	85.5 (7.5)	85.5 (7.7)	85.9 (7.6)	85.3 (7.5)	85.0 (7.4)	84.8 (7.8)	83.7 (8.3)	83.8 (8.2)	83.4 (8.1)	82.9 (8.1)	71	81.7 (8.2)	81.5 (8.2)	82.4 (8.6)	86.6 (6.3)	84.4 (6.8)	83.3 (6.9)	83.1 (6.7)

Note: Prior to 1999, the Mine Safety and Health Administration (MSHA) set the permissible exposure limit (PEL) for noise at 90 dBA as an 8-hour time-weighted average (TWA) with an exchange rate of 5 dB and a sound level range from 90 to at least 140 dBA. Beginning in 1999, synchronized with the requirements of Hearing Conservation Programs (HCPs) outlined by 30 CFR Part 62, MSHA set an action limit (AL) for noise at 85 dBA with an exchange rate of 5 dB and a new sound level range from 80 to 130 dBA.

Table 1.3.2 Industry Noise Measurements 2003-2014

Canvass	Industry	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Coal	Anthracite	79.8 (11.2)	79.2 (10.8)	79.2 (11.0)	78.7 (10.6)	79.1 (10.6)	79.3 (10.4)	78.7 (10.2)	79.3 (10.1)	78.9 (9.9)	78.6 (9.8)	79.0 (9.9)	78.8 (9.9)
Coal	Bituminous	79.8 (11.2)	79.2 (10.8)	79.2 (11.0)	78.7 (10.6)	79.1 (10.6)	79.3 (10.4)	78.7 (10.2)	79.3 (10.1)	78.9 (9.9)	78.6 (9.8)	79.0 (9.9)	78.8 (9.9)
Coal	**Total**	79.8 (11.2)	79.2 (10.8)	79.2 (11.0)	78.7 (10.6)	79.1 (10.6)	79.3 (10.4)	78.7 (10.2)	79.3 (10.1)	78.9 (9.9)	78.6 (9.8)	79.0 (9.9)	78.8 (9.9)
Metal	Alumina (Mill)	89.9 (3.1)	86.3 (6.7)	82.1 (5.6)	86.3 (4.0)	77.3 (8.0)	85.6 (4.6)	85.5 (7.0)	85.8 (3.9)	86.0 (7.8)	82.5 (5.4)	85.2 (3.8)	-
Metal	Aluminum Ore	-	76.1 (2.9)	-	89.3 (0.5)	79.5 (3.3)	-	84.0 (2.9)	78.6 (6.9)	80.3 (3.2)	81.9 (2.3)	-	-
Metal	Antimony	-	-	-	-	-	-	-	-	-	-	92.0 (0.1)	-
Metal	Beryl	-	-	-	76.5 (3.8)	75.0 (10.1)	-	-	79.4 (7.8)	74.9 (7.7)	-	81.0 (5.6)	80.4 (5.0)
Metal	Chromite	77.2 (6.6)	-	-	-	-	75.0 (5.7)	-	-	-	83.6 (3.9)	-	-
Metal	Cobalt	-	-	-	-	-	-	-	-	-	-	-	-
Metal	Copper Ore	83.0 (5.4)	84.7 (4.7)	83.9 (7.4)	83.1 (5.6)	85.9 (7.5)	89.4 (6.2)	82.1 (5.3)	80.7 (7.3)	81.2 (6.8)	81.8 (7.0)	81.9 (6.4)	84.3 (2.8)
Metal	Gold (lode and placer)	86.6 (8.5)	84.1 (8.0)	90.6 (8.8)	90.0 (8.3)	89.4 (7.0)	89.3 (7.5)	84.7 (6.9)	85.0 (7.5)	85.4 (8.8)	83.5 (9.2)	82.2 (7.5)	79.1 (6.3)
Metal	Iron ore	83.7 (5.9)	82.7 (6.5)	83.7 (6.5)	85.1 (7.2)	83.7 (5.9)	89.7 (5.1)	84.6 (5.9)	81.3 (6.5)	87.7 (6.0)	85.9 (6.2)	82.7 (6.5)	83.4 (4.9)
Metal	Lead/Zinc Ore	85.4 (5.6)	85.3 (5.8)	87.1 (8.0)	87.3 (7.4)	91.5 (7.0)	88.8 (5.0)	83.3 (7.0)	84.0 (5.0)	82.9 (7.0)	81.7 (6.7)	81.1 (8.0)	77.5 (13.1)
Metal	Limestone (crushed and broken)	-	-	-	-	-	-	-	-	-	-	-	-
Metal	Manganese	83.5 (3.6)	87.7 (3.0)	86.8 (0.8)	-	-	89.5 (2.0)	-	81.6 (1.6)	-	-	82.2 (0.7)	-
Metal	Mercury	-	-	-	-	-	-	-	-	-	-	-	-
Metal	Metal ores, NEC	89.4 (5.7)	82.5 (9.0)	85.8 (8.4)	87.2 (3.3)	-	-	85.6 (3.4)	79.9 (6.6)	83.6 (4.5)	-	83.3 (9.7)	-
Metal	Molybdenum	88.9 (8.9)	89.3 (3.3)	88.3 (5.4)	87.9 (5.8)	92.9 (6.6)	90.0 (2.8)	83.2 (6.3)	82.3 (7.2)	81.6 (6.5)	81.7 (5.3)	81.1 (6.5)	-
Metal	Nickel	-	-	-	-	-	-	-	-	91.5 (6.2)	87.3 (4.6)	91.9 (4.4)	-
Metal	Platinum group	93.2 (10.0)	98.3 (4.0)	93.6 (4.4)	92.2 (7.8)	92.5 (9.3)	95.8 (4.1)	92.2 (0.7)	85.8 (6.9)	85.1 (5.1)	83.9 (3.2)	-	-
Metal	Rare earths	-	-	81.1 (12.9)	75.6	-	-	73.6 (4.9)	69.9 (5.5)	-	-	69.3	-
Metal	Silver ores	-	-	-	-	-	-	-	-	-	-	-	-

Canvass	Industry	Year											
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Titanium	81.2 (2.0)	85.3 (5.5)	-	83.3	-	-	85.6 (1.8)	80.7 (2.9)	-	80.1 (3.2)	-	-
	Tungsten	-	-	-	-	-	-	-	-	-	-	-	-
	Uranium	-	75.9 (8.6)	91.3 (7.7)	-	79.6 (7.4)	89.6 (6.4)	88.9 (4.6)	85.1 (6.4)	83.1 (7.2)	84.3 (9.3)	80.1 (8.2)	-
	Uranium - vanadium ores	-	91.5 (5.5)	101.9 (5.6)	-	-	84.7 (2.6)	86.2 (3.8)	-	-	-	-	-
	Vanadium	-	-	-	-	-	-	-	-	-	-	-	-
	Zircon	73.9 (6.1)	-	82.2 (3.3)	-	-	-	-	-	-	-	-	-
	Total	86.6 (8.2)	84.7 (7.3)	88.4 (8.6)	87.8 (7.7)	88.1 (7.9)	88.6 (6.2)	84.6 (6.5)	82.7 (7.4)	83.0 (7.5)	83.1 (7.2)	82.3 (6.8)	82.7 (4.4)
Nonmetal	Aplite	-	82.2 (2.1)	84.0 (2.6)	87.4 (1.3)	83.3 (2.2)	-	-	-	84.7 (1.7)	83.6 (0.7)	-	-
	Asbestos	-	-	-	-	-	-	-	-	-	-	-	-
	Barite	85.0 (7.1)	83.1 (6.1)	84.7 (4.9)	86.9 (6.2)	80.7 (6.5)	86.2 (4.1)	82.9 (4.4)	81.6 (4.9)	85.4 (3.5)	82.4 (4.5)	84.1 (8.5)	84.4 (4.8)
	Boron Materials	77.1 (8.3)	82.5 (1.8)	-	81.1 (0.8)	77.7 (0.7)	-	77.1 (8.3)	-	80.2 (0.4)	-	81.1 (5.6)	-
	Brucite	-	78.5 (1.7)	-	76.2 (7.0)	-	-	70.8 (7.1)	-	-	-	-	-
	Cement	83.1 (6.3)	84.4 (6.6)	84.3 (6.2)	85.6 (5.9)	85.9 (6.9)	85.8 (5.5)	83.6 (6.0)	81.8 (6.3)	82.4 (7.2)	83.8 (6.0)	80.9 (7.0)	83.4 (7.6)
	Chemical and fertilizer, NEC	74.5 (4.6)	-	-	79.9 (1.9)	73.6 (4.8)	84.3 (2.5)	82.3 (0.6)	79.8 (5.2)	83.1 (2.5)	-	70.2	-
	Clay (common)	82.5 (5.9)	82.4 (6.4)	83.2 (6.9)	83.6 (6.1)	84.5 (7.4)	87.0 (6.5)	81.4 (6.6)	80.2 (6.0)	81.9 (6.2)	80.9 (6.6)	81.8 (6.4)	82.7 (2.9)
	Clay (fire)	85.3 (5.8)	83.4 (5.3)	82.8 (5.7)	77.9 (3.5)	87.2 (3.7)	80.1 (9.2)	76.5 (6.5)	77.6 (9.8)	77.0 (7.9)	80.2 (3.7)	78.5 (5.2)	-
	Clay, Ceramic and refractory, NEC	84.7 (4.4)	81.0 (8.7)	79.6 (6.6)	83.7 (7.1)	82.2 (5.7)	86.8 (2.6)	82.1 (7.2)	81.2 (7.2)	81.6 (5.2)	77.6 (7.8)	80.2 (4.6)	-
	Construction S&G; Sand, common	81.9 (6.5)	81.8 (6.6)	81.5 (6.8)	82.5 (6.7)	83.3 (6.8)	83.8 (6.7)	79.5 (7.0)	78.3 (6.7)	79.0 (6.9)	78.9 (6.7)	78.7 (6.8)	77.2 (7.2)
	Feldspar	81.2 (9.8)	83.1 (7.8)	82.3 (9.3)	82.6 (6.2)	81.3 (7.3)	85.8 (3.7)	81.0 (4.5)	82.6 (3.4)	84.3 (4.8)	79.7 (7.8)	77.5 (6.0)	-
	Fluorspar	-	-	-	-	-	87.2 (4.3)	80.7 (2.8)	-	80.2 (3.0)	79.8 (4.2)	86.2 (2.7)	-
	Gemstones	-	91.8 (11.9)	-	-	78.6 (10.4)	-	75.6 (5.4)	78.0 (5.5)	87.8 (2.8)	91.8 (0.8)	81.2 (14.2)	99.1
	Gilsonite	-	-	-	-	-	-	82.1 (5.1)	83.1 (4.0)	82.2 (4.2)	88.7 (2.6)	-	-

Canvass	Industry	Year											
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Granite (crushed and broken)	83.3 (6.4)	82.1 (6.3)	81.7 (6.2)	83.6 (6.3)	83.8 (6.0)	86.5 (7.0)	79.5 (6.6)	79.9 (6.7)	79.5 (7.1)	79.6 (6.3)	78.9 (6.5)	78.2 (3.7)
	Granite (dimension)	90.7 (10.9)	88.3 (8.8)	90.7 (8.3)	83.9 (9.7)	90.0 (9.2)	93.2 (7.0)	85.9 (7.6)	86.8 (11.2)	86.2 (8.6)	87.1 (7.6)	84.1 (7.2)	85.8 (1.6)
	Gypsum	84.0 (8.5)	83.4 (8.3)	84.8 (6.8)	84.6 (6.3)	86.6 (6.5)	88.5 (5.6)	79.8 (6.5)	81.2 (6.7)	81.5 (6.8)	81.4 (5.7)	82.3 (7.7)	81.8 (9.5)
	Kyanite	86.9 (5.9)	82.6 (5.8)	79.0 (2.2)	-	85.5 (4.4)	93.9 (3.6)	84.3 (2.4)	80.0 (0.1)	82.3 (4.7)	83.4 (3.1)	83.7 (2.9)	-
	Lead and/or Zinc Ore	85.4 (5.6)	85.3 (5.9)	87.1 (8.0)	87.3 (7.5)	91.5 (7.0)	88.8 (5.0)	83.3 (7.0)	84.0 (5.0)	82.9 (7.0)	81.7 (6.7)	81.1 (8.0)	77.5 (14.1)
	Leonardite	81.3 (5.3)	-	88.9 (1.5)	86.6 (2.5)	86.2 (2.4)	-	82.7 (6.2)	80.7 (8.4)	79.6 (5.0)	83.2 (3.2)	81.1	-
	Lime	83.5 (5.4)	83.5 (5.8)	83.1 (5.5)	86.1 (4.2)	84.8 (4.4)	87.6 (4.6)	83.1 (6.0)	81.3 (7.2)	81.8 (5.9)	81.7 (6.7)	82.4 (5.4)	82.5 (5.7)
	Limestone (crushed and broken)	82.2 (6.8)	82.0 (6.7)	81.9 (6.8)	83.2 (7.1)	84.5 (6.3)	85.3 (5.7)	80.8 (6.7)	80.1 (6.7)	80.1 (6.5)	80.1 (6.7)	79.5 (6.8)	79.5 (7.3)
	Limestone (dimension)	84.8 (6.4)	86.2 (7.3)	87.2 (9.3)	87.0 (6.3)	88.2 (7.3)	89.5 (4.6)	83.5 (6.7)	84.5 (5.5)	85.9 (6.3)	84.2 (7.3)	83.9 (6.5)	79.3 (7.2)
	Lithium	-	-	-	-	-	-	-	-	-	-	-	-
	Magnesite	-	-	65.9 (5.1)	-	-	-	87.4 (3.2)	-	-	-	74.4 (5.1)	-
	Marble (crushed & broken)	86.8 (5.8)	84.8 (5.5)	89.5 (7.0)	83.2 (3.4)	82.8 (7.5)	90.1 (7.3)	81.1 (6.4)	75.7 (7.0)	76.5 (2.7)	78.5 (5.8)	82.8 (4.7)	-
	Marble (dimension)	81.3 (4.7)	83.4 (6.0)	83.0 (4.9)	82.5 (9.5)	88.2 (7.1)	86.8 (1.3)	85.6 (8.4)	83.4 (7.8)	86.7 (0.4)	78.7 (4.4)	83.4 (4.3)	-
	Mica	83.1 (4.0)	82.4 (5.6)	91.2 (0.4)	85.8 (4.3)	82.9 (4.7)	-	79.4 (7.9)	81.5 (3.1)	81.7 (7.9)	-	82.0 (5.6)	-
	Nonmetallic minerals, NEC	82.3 (5.3)	83.6 (5.2)	84.1 (5.0)	84.9 (4.7)	83.7 (5.6)	87.7 (4.9)	79.8 (6.3)	79.5 (6.3)	83.4 (3.1)	81.5 (6.6)	84.1 (5.2)	-
	Oil mining	-	-	-	-	-	93.1 (4.7)	-	-	-	-	-	-
	Oil sand	-	-	-	-	72.4 (1.9)	-	-	-	70.7 (4.1)	-	-	-
	Oil shale	72.4	-	84.8 (11.2)	77.5 (10.2)	-	-	-	-	-	70.5	73.1 (8.4)	-
	Perlite	79.9 (6.8)	75.7 (5.3)	72.5 (9.2)	78.4 (5.0)	82.4 (4.8)	79.0 (7.9)	81.7 (5.8)	80.2 (5.5)	81.2 (2.8)	82.0 (2.1)	77.1 (8.5)	-
	Phosphate rock	85.1 (6.7)	81.1 (6.5)	82.3 (6.9)	87.6 (8.1)	90.2 (10.0)	89.6 (5.9)	84.2 (6.1)	80.7 (7.3)	82.6 (9.0)	82.6 (5.9)	79.9 (4.7)	84.2 (4.7)
	Pigment mineral	89.1 (2.3)	89.0 (1.2)	-	-	89.1 (3.0)	-	88.0 (2.4)	-	-	89.4 (3.3)	-	-
	Potash	79.9 (6.6)	79.8 (6.7)	84.9 (7.5)	98.2	76.0 (6.3)	89.3 (2.3)	80.8 (4.6)	85.1 (2.5)	81.0 (0.8)	-	-	-

Canvass	Industry	Year											
		2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Potash, soda, & borate minerals, NEC	78.1 (6.1)	-	81.2 (1.6)	-	-	-	76.2 (5.1)	-	-	-	-	-
	Pumice	80.4 (7.1)	78.3 (7.9)	79.5 (6.1)	88.8 (5.0)	77.9 (7.1)	79.0 (9.3)	78.0 (6.6)	78.3 (4.3)	81.9 (4.1)	80.8 (6.7)	79.0 (5.7)	-
	Pyrites	-	-	-	-	-	-	-	-	-	-	-	-
	Salt (evaporated)	74.9 (6.8)	-	-	-	78.1 (2.9)	-	76.4 (3.4)	-	78.0 (2.2)	79.1 (7.6)	-	-
	Salt (rock)	82.5 (7.0)	84.0 (7.7)	86.3 (7.0)	89.7 (3.1)	85.0 (5.8)	87.1 (6.3)	85.7 (7.0)	83.8 (5.8)	84.9 (5.4)	83.5 (5.8)	82.9 (6.5)	-
	Sand & gravel	80.2 (6.8)	78.5 (7.5)	80.6 (6.5)	80.0 (6.6)	81.0 (8.3)	82.4 (8.0)	77.6 (7.1)	77.8 (6.8)	78.4 (7.0)	78.7 (7.7)	75.6 (7.8)	76.8 (4.5)
	Sand, Industrial; Ground silica/quartz	79.1 (6.8)	80.3 (6.3)	79.6 (7.3)	81.3 (5.9)	80.7 (5.9)	84.8 (6.3)	80.1 (6.4)	77.4 (6.3)	79.6 (6.2)	78.9 (5.9)	79.0 (6.8)	79.8 (6.0)
	Sandstone (crushed & broken)	81.0 (5.9)	80.9 (6.0)	79.1 (6.7)	82.3 (6.7)	81.9 (6.6)	85.1 (7.0)	79.4 (6.6)	78.9 (6.0)	80.0 (5.8)	77.7 (6.7)	77.4 (6.5)	78.9 (3.0)
	Sandstone (dimension)	83.5 (5.7)	82.8 (7.6)	84.7 (7.3)	84.0 (7.2)	85.3 (6.1)	88.2 (5.1)	83.0 (6.3)	82.1 (6.4)	83.5 (7.2)	80.7 (7.2)	81.0 (6.1)	85.5 (2.5)
	Shale (common)	82.1 (7.1)	83.2 (6.3)	81.7 (4.9)	79.2 (6.3)	86.7 (6.3)	84.0 (5.6)	77.8 (7.7)	76.8 (6.1)	81.5 (6.3)	80.2 (6.5)	78.7 (6.3)	-
	Slate (crushed & broken)	81.1 (9.6)	81.4 (8.6)	82.3 (4.3)	83.6 (4.0)	89.3 (3.8)	71.5 (13.1)	80.3 (6.9)	84.0 (7.3)	83.2 (8.2)	82.7 (2.6)	67.6 (4.7)	88.8 (1.8)
	Slate (dimension)	85.8 (5.8)	87.4 (5.9)	85.4 (6.1)	88.9 (7.3)	90.4 (5.1)	88.1 (5.4)	84.5 (8.0)	83.8 (9.5)	80.7 (8.9)	91.0 (7.6)	82.5 (8.9)	95.2 (5.5)
	Sodium compounds	-	-	-	-	-	-	-	-	-	-	81.2 (1.8)	-
	Stone, crushed & broken, NEC	83.3 (7.2)	83.0 (6.7)	81.7 (7.1)	82.7 (7.1)	83.3 (7.0)	83.3 (7.8)	79.3 (7.1)	79.0 (7.2)	81.2 (6.6)	80.2 (6.9)	79.2 (8.1)	81.2 (3.8)
	Stone, dimension, NEC	86.4 (7.4)	84.7 (7.9)	85.3 (9.0)	85.4 (9.3)	87.3 (7.6)	90.1 (9.6)	84.5 (7.8)	83.4 (8.1)	82.8 (8.1)	82.6 (7.1)	84.0 (8.2)	86.2 (5.7)
	Talc, soapstone, & pyrophylite	80.0 (5.6)	82.0 (6.7)	81.0 (5.5)	82.1 (5.9)	83.5 (5.9)	85.5 (2.5)	79.2 (5.4)	78.0 (4.5)	78.6 (4.7)	79.2 (4.4)	81.8 (5.3)	78.9 (4.0)
	Traprock (crushed & broken)	82.1 (5.6)	82.7 (6.7)	82.5 (6.9)	84.5 (8.2)	84.4 (6.5)	87.3 (5.9)	81.1 (6.6)	78.3 (8.2)	81.2 (7.0)	79.3 (6.8)	79.4 (6.8)	73.4 (9.1)
	Traprock (dimension)	87.8 (9.8)	88.5 (1.2)	86.2 (13.2)	84.3 (10.2)	85.5 (9.5)	-	82.3 (6.7)	87.5 (1.7)	83.7 (2.7)	81.0 (7.3)	75.1	-
	Trona	87.1 (6.3)	86.3 (10.5)	89.7 (8.8)	86.8 (10.4)	86.7 (10.9)	92.4	85.5 (8.9)	85.9 (6.8)	84.5 (7.8)	83.2 (9.3)	85.1 (5.4)	-
	Vermiculite	84.1 (3.4)	83.5 (1.6)	82.7 (7.0)	-	72.7	94.3 (0.6)	80.3 (5.0)	80.1 (4.9)	76.7 (6.0)	80.3 (6.9)	75.3 (4.8)	-
	Total	82.4 (6.7)	82.2 (6.7)	82.2 (7.1)	83.3 (7.0)	84.2 (6.8)	85.5 (6.6)	80.5 (7.0)	79.7 (7.0)	80.2 (6.9)	80.2 (6.9)	79.7 (7.0)	80.1 (7.7)

Note: Prior to 1999, the Mine Safety and Health Administration (MSHA) set the permissible exposure limit (PEL) for noise at 90 dBA as an 8-hour time-weighted average (TWA) with an exchange rate of 5 dB and a sound level range from 90 to at least 140 dBA. Beginning in 1999, synchronized with the requirements of Hearing Conservation Programs (HCPs) outlined by 30 CFR Part 62, MSHA set an action limit (AL) for noise at 85 dBA with an exchange rate of 5 dB and a new sound level range from 80 to 130 dBA.

Table 2.1.1 Occupational NFDL Injury Counts 1983-2002

Occupation	SOC	Year																			
		1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Building Cleaning and Pest Control Workers	37-2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction Trades Workers	47-2000	3021	3419	3019	3173	4086	4614	4717	4549	4173	3668	3325	3430	3033	2601	2599	2500	2200	2203	2086	1933
Extraction Workers	47-5000	3822	3890	3471	3604	4514	4869	4576	4453	4093	3625	3028	3333	2816	2411	2364	2488	2232	1993	1717	1555
Helpers, Construction Workers	47-3000	12	8	5	7	5	6	4	8	3	5	9	1	8	8	2	6	6	7	10	8
Material Moving Workers	53-7000	2089	2202	1916	2075	2852	2948	2976	3158	2680	2457	2091	2082	1854	1541	1454	1523	1320	1381	1233	1143
Metal Workers and Plastic Workers	51-4000	469	530	499	518	690	642	577	614	521	464	404	411	364	301	314	355	299	246	210	225
Motor Vehicle Operators	53-3000	633	722	645	805	934	989	1025	984	835	775	764	786	647	606	592	571	550	510	483	423
Other Installation, Maintenance, and Repair Occupations	49-9000	85	79	72	105	107	120	112	120	90	63	80	53	46	39	34	42	27	23	41	54
Other Protective Service Workers	33-9000	8	15	14	13	16	13	24	15	16	19	6	11	13	6	8	5	3	4	2	6
Supervisors of Construction and Extraction Workers	47-1000	640	689	649	694	880	953	913	982	880	857	760	726	625	568	488	513	499	510	427	419
Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	49-3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2.1.1 Occupational NFDL Injury Rates 1983-2002

Occupation	SOC	Year															
		2003†	**2004†**	**2005†**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Building Cleaning and Pest Control Workers	37-2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	0.05	0.10
Construction Trades Workers	47-2000	31.09	29.51	28.22	28.91	26.43	27.33	26.64	29.13	26.06	26.28	36.61	35.58	30.67	27.11	26.04	23.26
Extraction Workers	47-5000	-	-	-	-	-	-	2661.73	1531.88	-	-	1291.89	-	-	-	555.02	451.25
Helpers, Construction Workers	47-3000	5.26	2.48	1.77	1.69	3.92	5.80	-	-	3.64	-	-	-	-	-	3.15	2.88
Material Moving Workers	53-7000	44.90	40.74	39.26	38.31	37.60	34.13	34.66	28.76	29.63	25.17	47.26	42.47	35.84	25.94	28.41	26.22
Metal Workers and Plastic Workers	51-4000	35.80	31.12	29.17	25.65	25.27	20.73	23.79	22.49	19.89	13.24	10.43	13.75	11.52	11.48	7.53	8.48
Motor Vehicle Operators	53-3000	11.20	10.70	10.43	9.17	9.03	9.73	6.61	7.44	7.36	6.07	6.33	5.71	5.41	4.54	3.69	4.07
Other Installation, Maintenance, and Repair Occupations	49-9000	22.52	25.00	28.18	5.10	5.80	6.60	0.85	0.84	0.78	1.00	14.84	14.61	9.11	8.34	7.72	6.50
Other Protective Service Workers	33-9000	0.38	0.50	0.12	0.37	0.24	0.85	0.69	0.44	0.34	0.36	0.51	0.36	0.37	0.23	0.00	0.33
Supervisors of Construction and Extraction Workers	47-1000	-	-	-	-	-	-	-	-	39.28	37.53	37.62	34.96	26.52	27.60	23.58	20.86
Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	49-3000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.47	0.00	0.08	0.08

† Rates were calculated from NFDL count divided by the total employment count within each Minor SOC grouping, multiplied by 100

Table 2.2.1 Occupational Fatality Counts 1983-2002

Occupation	SOC	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Construction Trades Workers	47-2000	27	36	18	25	23	19	18	26	15	13	11	14	19	11	10	8	15	11	12	11
Extraction Workers	47-5000	22	55	28	31	27	19	37	26	21	25	20	21	16	16	10	17	21	14	20	8
Helpers, Construction Workers	47-3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Material Moving Workers	53-7000	24	22	16	22	19	9	6	14	17	10	9	9	14	14	6	5	7	13	6	11
Metal Workers and Plastic Workers	51-4000	2	0	0	2	3	0	1	3	3	2	1	2	1	2	3	1	0	0	0	2
Motor Vehicle Operators	53-3000	7	16	4	12	7	8	10	9	9	5	5	5	7	4	8	3	5	5	1	5
Other Installation, Maintenance, and Repair Occupations	49-9000	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0
Other Protective Service Workers	33-9000	0	0	3	1	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0
Supervisors of Construction and Extraction Workers	47-1000	18	31	18	21	17	10	14	12	14	7	15	5	5	8	9	11	9	8	7	5

Table 2.2.2 Occupational Fatlity Rates 2003-2018

Occupation	SOC	Year															
		2003†	2004†	2005†	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Construction Trades Workers	47-2000	0.13	0.17	0.24	0.18	0.11	0.11	0.07	0.16	0.13	0.20	0.15	0.15	0.15	0.09	0.11	0.07
Extraction Workers	47-5000	-	-	-	-	-	-	7.41	34.78	-	-	14.86	-	-	-	4.82	2.85
Helpers, Construction Workers	47-3000	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Material Moving Workers	53-7000	0.26	0.08	0.25	0.42	0.39	0.22	0.20	0.30	0.19	0.13	0.36	0.26	0.04	0.21	0.08	0.19
Metal Workers and Plastic Workers	51-4000	0.19	0.00	0.35	0.17	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motor Vehicle Operators	53-3000	0.11	0.08	0.11	0.05	0.10	0.08	0.08	0.09	0.00	0.08	0.05	0.13	0.07	0.05	0.09	0.07
Other Installation, Maintenance, and Repair Occupations	49-9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.11
Other Protective Service Workers	33-9000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Supervisors of Construction and Extraction Workers	47-1000	-	-	-	-	-	-	-	-	0.30	1.18	1.04	0.80	0.52	0.41	0.43	0.58

†Rates were calculated from fatality count divided by the total employment count within each Minor SOC grouping, multiplied by 100

Table 2.3.1 Occupational Noise Measurements 1983-2002

Occupation	SOC	Year																			
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Building Cleaning and Pest Control Workers	37-2000	-	76.2 (16.3)	80.0	79.1 (6.2)	87.2 (8.1)	88.3	64.4	76.6	82.2 (9.8)	81.4 (9.4)	-	68.9 (5.3)	83.3 (3.2)	82.5 (7.8)	62.8 (2.0)	-	90.7	-	94.6	-
Construction Trades Workers	47-2000	84.5 (7.4)	81.0 (10.1)	79.8 (8.5)	79.8 (8.6)	80.4 (7.6)	81.2 (7.1)	81.8 (7.0)	82.0 (6.2)	80.3 (7.7)	82.0 (8.1)	83.4 (8.2)	81.5 (8.2)	80.1 (7.2)	79.9 (7.2)	79.0 (8.1)	82.0 (8.4)	87.9 (1.1)	82.1 (7.1)	81.8 (5.3)	81.4 (7.2)
Extraction Workers	47-5000	86.4 (7.9)	86.2 (8.1)	86.0 (7.8)	86.1 (7.7)	86.4 (7.4)	86.0 (7.1)	85.8 (7.2)	85.7 (7.3)	84.8 (8.0)	84.9 (7.9)	84.8 (7.9)	84.3 (8.0)	83.6 (8.1)	83.1 (8.2)	82.8 (8.4)	84.7 (8.2)	87.7 (6.5)	84.6 (7.0)	83.5 (7.0)	83.2 (6.8)
Helpers, Construction Workers	47-3000	77.6	-	-	95.9	83.0 (0.6)	97.2	-	83.6 (5.2)	83.7 (5.9)	70.6 (2.9)	-	85.2	80.4 (9.9)	82.0 (3.0)	71.2 (17.7)	72.3	-	82.4 (3.7)	-	-
Material Moving Workers	53-7000	84.7 (7.8)	83.6 (8.4)	83.6 (8.5)	82.1 (8.8)	81.5 (9.0)	82.7 (8.8)	81.8 (8.2)	81.9 (8.1)	81.4 (8.7)	81.8 (8.3)	80.9 (8.4)	81.5 (8.0)	79.9 (8.1)	80.8 (9.3)	80.9 (8.5)	79.9 (9.3)	84.1 (4.9)	85.3 (6.5)	84.0 (6.8)	83.8 (7.1)
Metal Workers and Plastic Workers	51-4000	80.3 (9.8)	80.1 (8.9)	80.6 (8.4)	79.8 (8.5)	81.0 (7.8)	81.0 (7.2)	80.0 (8.0)	82.0 (8.2)	80.2 (7.6)	79.8 (8.0)	79.5 (8.1)	80.5 (7.7)	78.7 (8.0)	79.5 (6.5)	80.8 (7.3)	80.0 (7.6)	88.1 (0.2)	82.1 (6.5)	82.4 (6.0)	83.3 (3.8)
Motor Vehicle Operators	53-3000	85.5 (6.0)	84.7 (6.7)	84.5 (6.6)	84.6 (7.1)	84.7 (6.9)	84.4 (6.6)	84.2 (6.9)	84.3 (6.9)	83.7 (7.1)	83.7 (7.3)	83.5 (7.1)	83.4 (7.3)	82.9 (7.4)	82.6 (7.5)	82.5 (7.7)	82.5 (7.9)	80.2 (0.9)	85.0 (6.2)	83.6 (6.1)	83.6 (6.1)
Other Installation, Maintenance, and Repair Occupations	49-9000	85.0 (6.5)	85.1 (7.0)	84.2 (7.5)	85.3 (7.3)	85.5 (8.4)	85.0 (6.7)	85.3 (7.1)	85.3 (7.3)	83.8 (7.8)	82.9 (7.6)	83.7 (7.8)	83.2 (7.4)	71	83.4 (7.3)	82.4 (8.4)	84.1 (8.8)	81.6 (7.3)	85.0 (6.0)	84.1 (6.5)	84.4 (6.6)
Other Protective Service Workers	33-9000	-	-	-	77.2 (6.4)	90.0	-	-	-	-	-	68.1 (8.8)	79.8 (18.3)	-	-	-	81.4 (7.3)	-	-	-	-
Supervisors of Construction and Extraction Workers	47-1000	81.8 (7.5)	79.8 (8.1)	80.6 (7.6)	82.3 (8.4)	82.3 (7.6)	81.9 (8.4)	81.8 (7.6)	81.4 (8.4)	79.3 (8.9)	80.9 (8.4)	80.2 (8.1)	79.3 (8.2)	78.8 (7.8)	77.9 (8.1)	77.2 (7.9)	78.5 (8.1)	83.2 (2.6)	80.9 (6.4)	80.6 (7.2)	79.7 (6.7)
Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	49-3000	81.0 (7.2)	81.7 (7.5)	81.0 (8.4)	81.0 (8.4)	80.9 (8.0)	80.8 (7.6)	81.5 (7.6)	81.4 (7.5)	80.1 (8.3)	82.0 (7.0)	81.5 (7.9)	80.0 (7.5)	80.2 (7.9)	79.6 (7.3)	79.8 (7.8)	80.4 (7.7)	87.9	83.2 (7.0)	82.1 (6.5)	81.0 (5.9)

Note: Prior to 1999, the Mine Safety and Health Administration (MSHA) set the permissible exposure limit (PEL) for noise at 90 dBA as an 8-hour time-weighted average (TWA) with an exchange rate of 5 dB and a sound level range from 90 to at least 140 dBA. Beginning in 1999, synchronized with the requirements of Hearing Conservation Programs (HCPs) outlined by 30 CFR Part 62, MSHA set an action limit (AL) for noise at 85 dBA with an exchange rate of 5 dB and a new sound level range from 80 to 130 dBA.

Table 2.3.2 Occupational Noise Measurements 2003-2014

Occupation	SOC	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Building Cleaning and Pest Control Workers	37-2000	-	-	79.6 (18.0)	-	-	84.8	-	-	73.7	81.3	88.3	-
Construction Trades Workers	47-2000	80.9 (6.4)	82.4 (4.8)	81.3 (7.1)	83.6 (5.2)	80.3 (6.1)	84.6 (6.0)	80.8 (6.0)	80.6 (7.0)	80.8 (6.9)	81.4 (6.9)	80.0 (6.8)	80.4 (8.6)
Extraction Workers	47-5000	82.4 (6.9)	82.3 (6.8)	82.4 (7.3)	83.6 (7.2)	84.5 (7.1)	85.9 (6.9)	80.5 (7.1)	79.9 (7.2)	80.4 (7.1)	80.3 (7.2)	80.0 (7.2)	80.6 (7.8)
Helpers, Construction Workers	47-3000	-	75.3 (8.0)	81.2 (3.9)	-	-	91	79.2	-	71.6 (12.1)	-	60.5	-
Material Moving Workers	53-7000	83.3 (7.0)	84.6 (6.8)	84.2 (7.0)	84.0 (7.3)	84.6 (8.0)	86.6 (5.4)	82.7 (7.3)	80.4 (6.7)	83.0 (7.5)	82.2 (7.5)	81.1 (6.9)	78.9 (8.0)
Metal Workers and Plastic Workers	51-4000	83.0 (7.5)	81.9 (6.4)	82.4 (6.3)	83.2 (6.3)	83.5 (5.8)	84.6 (6.0)	81.9 (5.6)	80.7 (6.2)	79.1 (5.8)	80.0 (5.1)	78.5 (5.8)	83.6 (6.1)
Motor Vehicle Operators	53-3000	82.9 (6.2)	82.3 (5.9)	82.8 (6.8)	83.9 (7.0)	85.0 (6.3)	86.2 (5.8)	81.2 (6.6)	80.4 (6.6)	80.1 (6.4)	80.2 (6.1)	79.9 (6.4)	80.1 (7.0)
Other Installation, Maintenance, and Repair Occupations	49-9000	84.0 (6.1)	83.8 (5.9)	83.6 (6.1)	84.4 (6.2)	85.5 (5.2)	85.8 (5.3)	82.9 (5.8)	81.9 (6.0)	82.1 (6.3)	82.0 (5.9)	81.4 (6.2)	82.5 (5.8)
Other Protective Service Workers	33-9000	-	-	-	-	-	-	-	-	-	-	-	-
Supervisors of Construction and Extraction Workers	47-1000	80.8 (6.9)	79.2 (6.3)	79.2 (6.2)	79.0 (6.6)	81.0 (6.5)	82.5 (6.8)	77.6 (6.9)	77.7 (6.8)	78.7 (7.2)	77.6 (7.0)	76.5 (7.6)	77.1 (7.1)
Vehicle and Mobile Equipment Mechanics, Installers, and Repairers	49-3000	80.9 (5.7)	81.2 (6.3)	80.5 (6.5)	81.1 (6.2)	82.7 (5.0)	84.8 (5.2)	79.6 (6.4)	78.9 (6.6)	79.1 (6.8)	79.9 (6.2)	79.1 (6.7)	80.0 (5.6)

Note: Prior to 1999, the Mine Safety and Health Administration (MSHA) set the permissible exposure limit (PEL) for noise at 90 dBA as an 8-hour time-weighted average (TWA) with an exchange rate of 5 dB and a sound level range from 90 to at least 140 dBA. Beginning in 1999, synchronized with the requirements of Hearing Conservation Programs (HCPs) outlined by 30 CFR Part 62, MSHA set an action limit (AL) for noise at 85 dBA with an exchange rate of 5 dB and a new sound level range from 80 to 130 dBA.

Table 3.1.1 Summary Data on Company 1 – Limestone Mines

Year	Limestone 1				
	Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	1.3	-	-	-
1984	0	2.4	-	-	-
1985	0	1.3	-	-	-
1986	0	1.4	-	-	-
1987	0.43	3.0	-	-	-
1988	0	1.9	-	-	-
1989	0	5.0	-	-	-
1990	0	4.1	-	-	-
1991	0	3.3	-	-	-
1992	0	3.3	-	-	-
1993	0	4.9	-	-	-
1994	0	3.1	-	-	-
1995	0	0.5	-	-	-
1996	0	2.7	-	-	-
1997	0	3.0	-	-	-
1998	0	3.6	-	-	-
1999	0	1.7	-	-	-
2000	0	3.3	6.8	-	-
2001	0	3.0	4.0	-	-
2002	0	1.3	6.7	-	-
2003	0	2.7	3.9	79.9	72.4
2004	0	5.1	1.5	81.4	79.3
2005	0	4.6	5.6	-	-
2006	0	3.2	3.9	-	-
2007	0	2.6	10.8	-	-
2008	0	0	0	-	-
2009	0	6.1	3.5	-	-
2010	0	1.0	0	92.4	92.0
2011	0	3.3	1.4	85.1	83.7
2012	0	4.5	17.1	82.9	76.6
2013	0	4.2	24.3	-	-
2014	0	1.7	12.8	-	-
2015	0	1.6	2.8	-	-
2016	0	3.4	2.6	-	-
2017	0	3.0	4.9	93.5	92.6
2018	0	2.7	8.3	-	-
2019	0	0	11.0	-	-

Year	Limestone 2				
	Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	0	-	-	-
1984	0	0	-	-	-
1985	0	0	-	-	-
1986	0	3.3	-	-	-
1987	0	13.9	-	-	-
1988	0	0	-	-	-
1989	0	5.7	-	-	-
1990	0	0	-	-	-
1991	0	4.6	-	-	-
1992	0	15.0	-	-	-
1993	0	8.1	-	-	-
1994	0	7.3	-	-	-
1995	0	10.2	-	-	-
1996	0	6.6	-	-	-
1997	0	7.9	-	-	-
1998	0	8.9	-	-	-
1999	0	5.5	-	-	-
2000	0	5.6	21.9	91.1	89.0
2001	0	3.4	43.0	-	-
2002	0	3.5	21.9	90.8	90.5
2003	0	6.4	3.9	90.9	90.7
2004	0	2.7	1.9	84.4	81.1
2005	0	2.8	23.1	-	-
2006	0	2.8	0	-	-
2007	0	3.0	8.3	90.1	88.1
2008	0	3.5	16.9	-	-
2009	0	3.5	4.2	-	-
2010	0	0	11.7	88.8	87.1
2011	0	0	41.2	-	-
2012	0	15.5	7.2	-	-
2013	0	9.4	22.4	-	-
2014	0	6.2	4.1	-	-
2015	0	2.9	18.9	-	-
2016	0	4.3	6.9	-	-
2017	0	2.4	0	-	-
2018	0	2.4	0	-	-
2019	0	0	0	-	-

Year	Limestone 3				
	Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	1.2	-	-	-
1984	0	1.7	-	-	-
1985	0	0.8	-	-	-
1986	0	2.6	-	-	-
1987	0	5.5	-	-	-
1988	0	4.6	-	-	-
1989	0	6.3	-	-	-
1990	0	0	-	-	-
1991	0	138.9	-	-	-
1992	0	3.4	-	-	-
1993	0	2.9	-	-	-
1994	0	2.6	-	-	-
1995	0	2.1	-	-	-
1996	0	3.2	-	-	-
1997	0	2.1	-	-	-
1998	0	3.2	-	-	-
1999	0	2.3	-	-	-
2000	0	4.5	0	-	-
2001	0	7.8	13.7	85.1	82.6
2002	0	2.2	2.9	-	-
2003	0	0	0	-	-
2004	0	2.4	0	-	-
2005	0	1.2	6.6	-	-
2006	0	2.0	2.8	-	-
2007	0	3.1	0	-	-
2008	0	3.2	0	-	-
2009	0	2.6	3.9	79.3	82.2
2010	0	0	2.5	-	-
2011	0	1.2	13.9	89.6	89.0
2012	0	1.2	16.7	-	-
2013	0	2.4	11.5	-	-
2014	0	3.6	2.5	91.2	89.7
2015	0	1.2	0	-	-
2016	0	4.3	5.6	88.1	86.7
2017	0	1.1	3.0	-	-
2018	0	0	5.2	86.2	83.3
2019	0	0	0	83.6	79.9

Year	Limestone 4				
	Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	4.9	-	-	-
1984	0	0	-	-	-
1985	0	3.9	-	-	-
1986	0	2.7	-	-	-
1987	0	4.9	-	-	-
1988	0	3.9	-	-	-
1989	0	3.3	-	-	-
1990	0	2.5	-	-	-
1991	0	7.0	-	-	-
1992	0	1.9	-	-	-
1993	0	6.5	-	-	-
1994	0	9.0	-	-	-
1995	0	3.1	-	-	-
1996	0	4.1	-	-	-
1997	0	2.0	-	-	-
1998	0	4.0	-	-	-
1999	0	9.1	-	-	-
2000	0	12.7	14.3	94.5	94.0
2001	0	10.3	35.4	-	-
2002	0	2.1	28.8	-	-
2003	0	3.6	27.3	-	-
2004	0	4.4	15.3	96.0	95.4
2005	0	4.5	12.0	-	-
2006	0	2.4	7.3	-	-
2007	0	0.7	0	-	-
2008	0	0	12.3	86.8	77.0
2009	0	2.1	10.0	88.1	89.0
2010	0	0	29.7	-	-
2011	0	1.4	7.4	87.9	86.8
2012	0	0	9.2	88.2	87.1
2013	0	7.9	11.2	-	-
2014	0	0	21.7	-	-
2015	0	1.3	2.9	-	-
2016	0	3.2	2.6	-	-
2017	0	1.3	8.1	92.1	91.3
2018	1.12	2.2	3.3	93.3	92.8
2019	0	0	5.0	-	-

Table 3.1.2 Summary Data on Company 1 – Lime Mines

Year	Lime 1					Lime 2				
	Rates			Noise		Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	0	0	-	-	0	0	0	-	-
1984	0	0	0	-	-	0	0	0	-	-
1985	0	0	0	-	-	0	0	0	-	-
1986	0	0	0	-	-	0	0	0	-	-
1987	0	0	0	-	-	0	0	0	-	-
1988	0	0	0	-	-	0	0	0	-	-
1989	0	0	0	-	-	0	0	0	-	-
1990	0	0	0	-	-	0	0	0	-	-
1991	0	0	0	-	-	0	0	0	-	-
1992	0	0	0	-	-	0	0	0	-	-
1993	0	0	0	-	-	0	0	0	-	-
1994	0	0	0	-	-	0	0	0	-	-
1995	0	0	0	-	-	0	0	0	-	-
1996	0	0	0	-	-	0	0	0	-	-
1997	0	0	0	-	-	0	0	0	-	-
1998	0	0	0	-	-	0	0	0	-	-
1999	0	0	0	-	-	0	0	0	-	-
2000	0	5.4	10.5	87.4	85.4	0	0	0	-	-
2001	0	10.5	36.4	-	-	0	0	5.0	83.7	79.5
2002	0	6.1	0	88.4	86.2	0	0	0	-	-
2003	0	8.7	26.7	85.6	82.4	0	0	48.5	-	-
2004	0	1.4	7.5	85.5	81.7	0	0	0	-	-
2005	0	2.9	0	-	-	0	0	10.2	83.0	79.9
2006	0	13.0	14.1	90.9	89.0	0	0	0	-	-
2007	0	7.9	20.3	-	-	0	0	0	-	-
2008	0	3.2	6.9	90.0	88.3	0	0	0	-	-
2009	0	0	4.4	88.3	87.0	0	0	0	-	-
2010	0	1.7	12.8	89.6	87.8	0	0	24.1	88.8	84.8
2011	0	3.5	8.2	-	-	0	0	3.5	-	-
2012	0	0	5.4	-	-	0	0	13.2	-	-
2013	0	7.9	8.1	83.4	78.5	0	0	4.9	85.2	81.6
2014	0	1.9	10.5	80.7	77.1	0	0	0	-	-
2015	0	5.7	12.9	85.9	83.6	0	0	3.7	83.5	80.6
2016	0	0	7.1	-	-	0	0	2.7	81.8	79.0
2017	0	3.8	10.5	82.8	80.2	0	0	2.8	88.0	87.3
2018	0	1.8	2.9	81.9	78.1	0	0	0	-	-
2019	0	0	6.4	81.4	77.1	0	0	9.4	85.6	83.4

Table 3.2.1 Summary Data on Company 2 – Sand Mines

Year	Sand 1					Sand 2					Sand 3					Sand 4				
	Rates			Noise		Rates			Noise		Rates			Noise		Rates			Noise	
	Fatality	NFDL	S&S	80dBA	90dBA	Fatality	NFDL	S&S	80dBA	90dBA	Fatality	NFDL	S&S	80dBA	90dBA	Fatality	NFDL	S&S	80dBA	90dBA
1983	0	1.9	-	-	-	0	4.2	-	-	-	0	0	-	-	-	0	0	-	-	-
1984	0	7.1	-	-	-	0	3.0	-	-	-	2.73	0	-	-	-	0	38.6	-	-	-
1985	0	1.7	-	-	-	0	0	-	-	-	0	4.4	-	-	-	0	28.1	-	-	-
1986	0	0	-	-	-	0	2.2	-	-	-	0	0	-	-	-	0	0	-	-	-
1987	0	5.1	-	-	-	0	0	-	-	-	0	0	-	-	-	0	26.5	-	-	-
1988	0	1.8	-	-	-	0	6.1	-	-	-	0	3.0	-	-	-	0	0	-	-	-
1989	0	1.8	-	-	-	0	6.6	-	-	-	0	8.5	-	-	-	0	7.3	-	-	-
1990	0	1.8	-	-	-	0	9.3	-	-	-	0	3.0	-	-	-	0	11.4	-	-	-
1991	0	1.7	-	-	-	0	7.6	-	-	-	0	10.3	-	-	-	0	7.7	-	-	-
1992	0	3.4	-	-	-	0	5.2	-	-	-	0	6.4	-	-	-	0	25.6	-	-	-
1993	0	12.1	-	-	-	0	3.7	-	-	-	0	0	-	-	-	0	14.7	-	-	-
1994	0	0	-	-	-	0	6.7	-	-	-	0	9.1	-	-	-	0	0	-	-	-
1995	0	0	-	-	-	0	10.1	-	-	-	0	2.4	-	-	-	0	4.2	-	-	-
1996	0	1.7	-	-	-	0	1.5	-	-	-	0	8.7	-	-	-	0	0	-	-	-
1997	0	3.5	-	-	-	0	3.0	-	-	-	0	0	-	-	-	0	0	-	-	-
1998	0	6.2	-	-	-	0	2.9	-	-	-	0	4.4	-	-	-	0	0	-	-	-
1999	0	1.5	-	-	-	0	5.0	-	-	-	0	16.9	-	-	-	0	0	-	-	-
2000	0	2.9	6.1	83.5	78.1	0	1.7	15.4	84.9	80.1	0	4.7	5.4	85.6	84.1	0	22.2	0	81.3	79.5
2001	0	1.5	0	-	-	0	8.7	26.9	-	-	0	12.9	4.7	84.6	83.7	0	0	0	-	-
2002	0	0	14.8	81.1	80.0	0	3.7	6.5	78.6	72.6	0	14.9	2.6	-	-	0	24.1	0	82.1	79.3
2003	0	1.9	0	78.8	71.5	0	4.3	5.3	85.3	84.4	0	7.3	0	-	-	0	0	0	-	-
2004	0	3.7	5.9	83.1	80.4	0	1.8	8.8	-	-	0	0	0	84.3	82.8	0	0	0	84.5	83.1
2005	1.86	1.9	15.2	-	-	0	1.4	10.8	-	-	0	2.4	0	80.1	78.7	0	0	0	-	-
2006	0	0	0	-	-	0	0.9	4.0	-	-	0	2.5	0	-	-	0	0	0	-	-
2007	0	1.4	17.4	-	-	0	1.0	14.1	87.7	88.2	0	2.5	0	-	-	0	0	0	-	-
2008	0	1.2	14.4	90.6	89.1	0	3.1	18.2	-	-	0	4.9	8.6	77.7	74.2	0	0	0	-	-
2009	0	0	0	-	-	0	2.4	24.2	-	-	0	10.3	19.3	69.8	75.3	0	0	0	81.1	84.4
2010	0	1.8	18.9	84.7	82.4	0	3.4	14.2	79.9	75.4	0	6.3	69.2	85.1	82.0	0	28.0	0	79.6	78.2
2011	0	0	12.0	78.8	74.5	0	1.1	6.2	81.3	76.9	0	2.1	4.5	77.6	71.8	0	0	5.5	73.4	67.4
2012	0	0	10.5	83.3	79.5	0	0	20.4	79.3	74.7	0	6.3	4.4	78.6	74.3	0	0	0	-	-
2013	0	0	10.5	80.0	75.8	0	1.7	1.9	79.1	76.1	0	2.1	10.2	78.7	82.4	0	0	0	75.8	69.5
2014	0	0	7.8	-	-	0	1.6	14.1	81.3	76.7	0	0	0	80.5	74.7	0	0	0	-	-
2015	0	4.2	0	80.1	75.7	0	0.8	8.0	78.3	70.2	0	0	0	-	-	0	0	0	73.6	63.4
2016	0	2.2	5.0	80.2	72.6	0	1.2	45.4	-	-	0	3.6	13.8	75.0	70.3	0	0	0	-	-
2017	0	0	3.4	82.4	77.8	0	0.5	3.4	76.0	69.6	0	1.2	8.9	76.4	80.5	0	0	0	78.9	76.5
2018	0	0	39.7	81.4	76.7	0	1.7	9.7	-	-	0	2.2	4.0	-	-	0	8.5	0	-	-
2019	0	0	1.7	-	-	0	0	22.8	84.2	81.5	0	0	2.1	-	-	0	0	0	-	-

Table 4.1 Bivariate Negative Binomial Analysis for NFDL Injuries

Variable		**Dispersion**	**IRR**	**95% CI**		**AIC**
	N			LL	UL	
SIC	1779					
TWA_{MSHA}		3.65				9200.5
< 70 dBA (ref)			1	-	-	
70 to < 75 dBA			2.10	1.06	4.21	
75 to < 80 dBA			1.88	0.99	3.57	
80 to < 85 dBA			1.82	0.97	3.45	
85 to < 90 dBA			1.99	1.06	3.79	
90 to < 95 dBA			2.00	1.05	3.89	
95 to < 100 dBA			1.97	0.96	4.11	
≥ 100 dBA			2.56	1.10	6.09	
Year		3.49	0.98	0.97	0.99	9114.8
SIC code*		1.37	*	*	*	9229.9
SOC (1983-2002)	173					
TWA_{MSHA}		567.47				105761.6
< 75 dBA (ref)			1	-	-	
75 to < 80 dBA			1.23	0.23	12.46	
80 to < 85 dBA			6.39	1.41	60.64	
85 to < 90 dBA			9.03	1.95	86.42	
90 to < 95 dBA			1.53	0.22	17.58	
95 to < 100 dBA			1.82	0.23	21.72	
≥ 100 dBA			0.07	-	17.29	
Year		763.09	0.96	0.93	0.99	145228.84
Minor SOC code		6.85				2844.02
Construction Trade (ref)			1	-	-	
Extraction			1.01	0.85	1.18	
Helpers, Construction			0.00	0.00	0.00	
Material Moving			0.63	0.54	0.74	
Metal and Plastic			0.13	0.11	0.15	
Motor Vehicle			0.22	0.18	0.26	
Other Installers, Maintenance, and Repair			0.02	0.01	0.26	
Other Protective Service			0.00	0.00	0.01	

Variable	N	Dispersion	IRR	95% CI		AIC
Supervisors of Construction and Extraction			0.21	0.17	0.25	
	N			LL	UL	
SOC (2003-2014)	87					
TWA_{MSHA} (per 5 dBA)		1248.91	0.89	0.35	2.29	30710.72
Year		1402.43	1.09	0.85	1.45	25960.15
Minor SOC code		0.99				577.12
Construction Trade (ref)			1	-	-	
Extraction			62.15	41.64	95.76	
Helpers, Construction			0.11	0.07	0.19	
Material Moving			1.25	0.94	1.65	
Metal and Plastic			0.73	0.55	0.98	
Motor Vehicle			0.28	0.20	0.39	
Other Installers, Maintenance, and Repair			0.35	0.25	0.48	
Other Protective Service			0.01	0.00	0.03	
Supervisors of Construction and Extraction			1.26	0.85	1.92	
	N			LL	UL	
MV	151					
TWA_{MSHA}		4.23				746.07
< 80 dBA (ref)			1	-	-	
80 to < 85 dBA			0.85	0.52	1.37	
85 to < 90 dBA			0.83	0.52	1.37	
≥ 90 dBA			0.95	0.54	1.65	
Year		3.77	0.95	0.92	0.98	719.54
S&S Rate		4.32	1.00	0.98	1.02	744.31
SIC code		4.20				741.84
Lime			1	-	-	
Limestone			0.71	0.43	1.18	
Sand			0.81	0.49	1.33	

Table 4.1.1 Supplement to Table 4.1

SIC code	IRR	LL	UL
Alumina (Mill)	1.00	-	-
Aluminum Ore	1.14	0.81	1.61
Aplite	1.74	1.20	2.54
Asbestos	3.05	2.26	4.15
Barite	2.21	1.72	2.84
Beryl	1.00	0.72	1.39
Boron Materials	0.68	0.51	0.91
Cement	1.49	1.15	1.93
Chemical and fertilizer, NEC	2.23	1.61	3.13
Chromite	1.33	0.50	4.05
Clay (common)	0.98	0.75	1.27
Clay (fire)	1.80	1.39	2.32
Clay, Ceramic and refractory, NEC	1.85	1.43	2.40
Coal, Anthracite	4.18	3.25	5.39
Coal, Bituminous	2.20	1.70	2.85
Cobalt	16.06	8.89	32.30
Construction S&G; Sand, common	1.96	1.01	4.16
Copper Ore	0.82	0.63	1.08
Feldspar	1.44	1.11	1.87
Fluorspar	1.93	1.38	2.71
Gemstones	2.69	2.02	3.59
Gilsonite	2.86	2.17	3.77
Gold (lode and placer)	1.09	0.84	1.41
Granite (crushed and broken)	1.25	0.96	1.62
Granite (dimension)	4.18	3.26	5.35
Gypsum	0.90	0.69	1.18
Iron ore	1.14	0.88	1.48
Kyanite	1.69	1.30	2.21
Lead and/or Zinc Ore	1.27	0.98	1.65

SIC code	IRR	LL	UL
Leonardite	4.84	3.73	6.30
Lime	1.60	1.24	2.07
Limestone (crushed and broken)	1.70	1.32	2.19
Limestone (dimension)	3.17	2.47	4.07
Lithium	0.81	0.56	1.19
Magnesite	2.37	1.75	3.23
Manganese	2.67	2.05	3.47
Marble (crushed & broken)	1.12	0.86	1.46
Marble (dimension)	3.74	2.92	4.80
Mercury	1.34	0.51	4.10
Metal ores, NEC	1.96	1.45	2.67
Mica	1.44	1.10	1.89
Molybdenum	1.09	0.84	1.42
Nickel	3.16	1.96	5.31
Nonmetallic minerals, NEC	2.27	1.76	2.92
Oil sand	13.25	7.31	26.69
Oil shale	1.56	1.09	2.26
Perlite	2.58	2.01	3.32
Phosphate rock	0.66	0.50	0.87
Pigment mineral	2.33	1.71	3.17
Platinum group	2.25	1.73	2.93
Potash	1.06	0.80	1.40
Potash, soda, & borate minerals, NEC	2.73	1.76	4.38
Pumice	3.61	2.81	4.64
Pyrites	5.86	2.59	16.45
Rare earths	1.44	1.06	1.98
Salt (evaporated)	1.70	1.24	2.36
Salt (rock)	1.10	0.84	1.43
Sand & gravel	2.79	2.17	3.58
Sand, Industrial; Ground silica/quartz	1.12	0.54	2.47

SIC code	IRR	LL	UL
Sandstone (crushed & broken)	1.84	1.43	2.37
Sandstone (dimension)	3.87	3.02	4.96
Shale (common)	2.34	1.82	3.01
Silver ores	1.81	1.40	2.34
Slate (crushed & broken)	3.41	2.63	4.43
Slate (dimension)	3.21	2.50	4.11
Stone, crushed & broken, NEC	2.93	2.28	3.75
Stone, dimension, NEC	3.96	3.10	5.07
Talc, soapstone, & pyrophylite	1.47	1.17	1.84
Titanium	0.77	0.56	1.06
Traprock (crushed & broken)	1.70	1.32	2.19
Traprock (dimension)	2.01	1.50	2.70
Trona	1.14	0.87	1.49
Tungsten	2.80	1.63	5.10
Uranium	1.82	1.39	2.38
Uranium - vanadium ores	4.05	2.97	5.57
Vanadium	1.07	0.71	1.63
Vermiculite	1.33	1.01	1.74
Zircon	2.70	1.89	3.91

Table 4.2 Supplement to Table 3

SIC code	IRR	LL	UL
Alumina (Mill)	1	-	-
Aluminum Ore	1.09	0.79	1.52
Aplite	1.78	1.25	2.57
Asbestos	2.76	2.07	3.71
Barite	2.12	1.66	2.69
Beryl	0.94	0.69	1.30
Boron Materials	0.63	0.47	0.83
Cement	1.42	1.11	1.82
Chemical and fertilizer, NEC	2.48	1.79	3.45
Chromite	1.66	0.66	4.83
Clay (common)	0.93	0.72	1.20
Clay (fire)	1.70	1.33	2.18
Clay, Ceramic and refractory, NEC	1.75	1.36	2.25
Coal, Anthracite	4.17	3.27	5.32
Coal, Bituminous	2.13	1.67	2.74
Cobalt	13.10	7.40	25.80
Construction S&G; Sand, common	2.65	1.40	5.45
Copper Ore	0.79	0.61	1.02
Feldspar	1.37	1.07	1.76
Fluorspar	1.75	1.27	2.45
Gemstones	2.76	2.10	3.66
Gilsonite	2.60	1.99	3.39
Gold (lode and placer)	1.03	0.80	1.32
Granite (crushed and broken)	1.21	0.95	1.56
Granite (dimension)	4.21	3.32	5.35
Gypsum	0.88	0.68	1.13
Iron ore	1.06	0.82	1.36
Kyanite	1.71	1.33	2.21
Lead and/or Zinc Ore	1.23	0.96	1.57

SIC code	IRR	LL	UL
Leonardite	4.87	3.79	6.27
Lime	1.53	1.20	1.96
Limestone (crushed and broken)	1.64	1.29	2.10
Limestone (dimension)	3.12	2.46	3.96
Lithium	0.66	0.46	0.94
Magnesite	2.32	1.71	3.16
Manganese	2.56	1.99	3.30
Marble (crushed & broken)	1.12	0.87	1.44
Marble (dimension)	3.69	2.90	4.69
Mercury	1.00	0.40	2.89
Metal ores, NEC	1.90	1.42	2.55
Mica	1.31	1.01	1.70
Molybdenum	1.05	0.82	1.35
Nickel	2.42	1.53	3.98
Nonmetallic minerals, NEC	2.14	1.68	2.74
Oil sand	11.70	6.57	23.00
Oil shale	1.28	0.90	1.84
Perlite	2.41	1.89	3.08
Phosphate rock	0.65	0.50	0.85
Pigment mineral	2.21	1.65	2.97
Platinum group	2.33	1.79	3.05
Potash	1.03	0.79	1.35
Potash, soda, & borate minerals, NEC	2.52	1.65	3.97
Pumice	3.48	2.73	4.44
Pyrites	4.77	2.16	12.80
Rare earths	1.37	1.02	1.85
Salt (evaporated)	1.68	1.23	2.29
Salt (rock)	1.04	0.81	1.34
Sand & gravel	2.73	2.15	3.48
Sand, Industrial; Ground silica/quartz	1.52	0.76	3.24

SIC code	IRR	LL	UL
Sandstone (crushed & broken)	1.77	1.39	2.26
Sandstone (dimension)	3.78	2.98	4.80
Shale (common)	2.21	1.73	2.82
Silver ores	1.77	1.38	2.26
Slate (crushed & broken)	3.36	2.62	4.32
Slate (dimension)	3.14	2.47	3.98
Stone, crushed & broken, NEC	2.83	2.23	3.60
Stone, dimension, NEC	3.88	3.06	4.92
Talc, soapstone, & pyrophylite	1.38	1.11	1.71
Titanium	0.79	0.58	1.08
Traprock (crushed & broken)	1.64	1.29	2.10
Traprock (dimension)	2.12	1.60	2.82
Trona	1.11	0.86	1.44
Tungsten	2.21	1.31	3.94
Uranium	1.84	1.42	2.38
Uranium - vanadium ores	4.07	2.99	5.57
Vanadium	0.99	0.67	1.48
Vermiculite	1.26	0.97	1.63
Zircon	2.40	1.71	3.43

Table 4.3 Bivariate Logistic Regression Analysis of Fatalities

Variable	N	**OR**	**95% CI** LL	UL	**AIC**
SIC	1826				
TWA_{MSHA} (per 5 dBA)		1.14	1.01	1.30	1990.19
Year		0.98	0.97	0.99	1986.22
Mine Type					1927.93
Coal		1	-	-	
Metal		0.13	0.06	0.24	
Nonmetal		0.09	0.05	0.17	
SOC	260				
TWA_{MSHA} (per 5 dBA)		1.47	1.09	1.99	328.45
Year		0.97	0.94	1.00	332.27
Major SOC code*					232.39
Protective Service (33-0000) (ref)		1	-	-	
Construction and Extraction (47-0000)		9.18	3.42	27.81	
Installation, Maintenance, and Repair (49-0000)		0.39	0.08	1.55	
Production (51-0000)		3.40	1.10	11.48	
Transportation and Material Moving (53-0000)		181.33	29.88	3575.2	

* Among fatalities, minor SOC codes did not converge, so the occupations were converted to major SOC instead