Chapter 8
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The Implementation of the Hierarchical Hazard Control Model to Assess the Respiratory Protection of Quarry and Allied Workers in Namibia

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ABSTRACT

The increased risks of adverse respiratory outcomes among quarry and allied workers are affected by high levels of cumulative dust exposure, which is a significant concern in the occupational health sector in developing countries, like Namibia. The study examines respiratory protection practices among quarry and allied workers in Namibia, amidst rising concerns over occupational respiratory disorders due to prolonged exposure to respirable dust. Using the Hierarchical Hazard Control Model, the study assessed the Engineering Controls, Administrative Controls, Educational/Training Programmes, and Medical Surveillance Measures in dust controls for 304 quarry and allied workers in the Erongo, Otjozondjupa, and Kunene regions. This study used self-administered questionnaires to collect data from the quarry and allied workers, between November and December 2022. A Chi-square (χ^2) test was used to determine the association between the level of employee respiratory protection and individual factors significant at p=0.000. Findings showed a statistically significant association between employee respiratory protection and employment status ($\chi 2(1) = 7.592$, $p = 0.000$), job category ($\chi^2(9) = 37.742$, $p = 0.000$), educational level ($\chi^2(3) = 68.517$, $p = 0.000$) and worksite ($\chi^2(8) = 282.178$, $p = 0.001$). A strong positive correlation between worksite and respiratory protection ($r=0.7$, $p<0.01$), negative correlation between worksite protection and education/training programs ($r=0.841$, $p<0.05$) was found. The findings underscore a critical gap in implementing effective engineering controls and training programs, increasing

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the risk of respiratory illnesses among workers. In conclusion, the study revealed that quarry and allied workers could not effectively implement engineering controls to reduce workers' exposure to respirable dust due to the lack of an occupational respiratory health framework, safety regulations and enforcement, and education and training. The study also provided evidence that most allied and quarry workers did not undergo the mandatory medical examination, as a request of limited hazard control measures. Recommendations include a need for an occupational respiratory health framework for quarry and allied workers to ensure occupational respiratory health.
Effective government policy that will enhance occupational safety and health in mining and quarrying is necessary for accident prevention in Namibia.

Keywords: Hierarchical hazard; respiratory diseases; quarry and allied workers; respiratory protection; occupational safety.

1. INTRODUCTION

Quarry mining in Namibia is an important business sector as it employs a significant population as well as contributing to the country's Gross Domestic Product (GDP). The mining and quarrying sector contributes 11.7 percent to the Namibian GDP (Nambinga & Mubita, 2022). Apart from satisfying the ever-growing needs of a rapidly growing population for infrastructural development and urbanization, quarrying activities have helped to provide direct and indirect jobs for many people living in host communities (Ogbonnaya et al., 2016). Quarry mining, charcoal production, and construction are the key industries in which workers are exposed to respirable dust (Szymendera, 2017). In the aforementioned industries, dust particles are generated when sand, gravel, clay, stones, concrete, bricks, and quartz are broken, stirred, or otherwise disturbed through cutting, drilling, mixing, blasting, grinding, or crushing (Draid *et al.,* 2015). Inhaled dust penetrates deep into the lungs, putting the quarry workers at an elevated risk of incurable work-related illness (WRI), particularly respiratory disorders such as lung cancer, pneumoconiosis, asthma, chronic obstructive pulmonary disease, silicosis, and kidney disease (Wadsworth *et al.,* 2019). A high prevalence of silicosis, asthma, and adverse respiratory symptoms like cough, chest pain, and dyspnea has been reported among workers engaged in quarrying. Additionally, quarrying also poses a danger to workers due to injuries caused by rocks falling on the workers, accidents during the use of machinery along with eye problems (Nemer et al., 2020). The prevalence of occupational respiratory hazards and mortality is on the increase in Namibia (Nangolo, 2019). The increased risks of adverse respiratory outcomes among charcoal workers are affected by high levels of cumulative dust exposure (Hamatui *et al.,* 2016). In addition, dust was reported as a common physical hazard at the study sites, with some workers reporting difficulties breathing in Namibia (Nghitanwa & Zungu, 2017). To curb this public respiratory concern, authorities worldwide, including Namibia, have been developing various respiratory safety measures/techniques to help reduce the huge amount of dust inhaled by employees (Shihepo et al., 2024).

Kumar, Gupta, Agarwal, and Singh (2016) acknowledge that Mining and construction industry workers face occupational hazards due to a lack of legal protection and unorganized structures. According to (Geng & Saleh, 2015), effective government policy and safety regulations enhance occupational safety and health in mining and quarrying and are necessary for accident prevention. However, Sanmiquel et al. (2015) argued that despite new laws being introduced to enhance occupational safety, accidents of different nature still occur, including fatal accidents. A Research study conducted by Amukugo & Nangombe (2017) states how a policy framework, such as the Namibian National Health policy framework, outlines the guidelines of actions of the public servants. Namibia lacks an occupational respiratory health framework for quarry and allied workers to ensure occupational respiratory health.

In addition, the Namibian Labour Act makes provision for general protection for workers, but the enforcement of worker protection is inadequate. Thus, the need for training and awareness amongst quarry and allied workers regarding respiratory hazards and the use of PPE which is also lacking in quarry mines in Namibia. The lack of an occupational respiratory health framework, safety regulations and enforcement and education and training may lead to increased injury rates (Long et al., 2015).

Although several national programs are implemented in Namibia to prevent the onset of and reduce occupational respiratory conditions, they appear ineffective. There is a lack of a framework that is directed towards establishing a sustainable and integrated system that accommodates occupational respiratory health. Other complementing frameworks, such as the Namibian National Health Policy Framework, are silent on occupational respiratory conditions. This framework emphasises clinical and public health respiratory conditions more than the private sector, in which most quarries operate (Amukugo & Nangombe, 2017). In line with this, a need to move towards area-specific approaches, such as a framework in occupational respiratory health, as an effective and integrated prevention and control program approach to challenge the high prevalence of occupational respiratory conditions in quarry mines. Therefore, this study sought to explore respiratory protection among Namibian quarry and allied workers, as the study enriches previous studies on dust exposure.

2. MATERIALS AND METHODS

The study used a quantitative cross-sectional design to collect data on respiratory protection among Namibian quarry and allied workers from three regions, namely Erongo, Otjozondjupa and Kunene regions, as shown in Fig. 1 (Shihepo et al., 2024). The sample size was enabled through Taro Yamane's formula, denoted by n=N/(1+Ne^2) n = sample size, while N = population size. Substituting N with 1112 (which is the target population extracted from the total number of quarry and allied workers as indicated in Table 1) at a 95% confidence level and 5% level of significance, the sample size (n) should be more than 286 hence the study adopted 304 as the sample size for quarry and allied workers (Shihepo et al., 2024).

To ensure reliability, the questionnaire was subjected to a pilot test to assess the relevance, sensitivity, and acceptability of the questions. The results validated the questionnaire's consistency and accuracy, determining its effectiveness and allowing for modifications to suit the study's objectives, thus ensuring its validity. A pilot test was conducted in Otavi, with 5% of the study sample being pretested with the questionnaire and the interview guide. The pilot test was carried out on quarry and allied workers from Sargberg Charcoal in August 2022, thus participants with characteristics similar to those selected for the main study. The pilot study enabled the investigator to develop participant approach skills, which was an effective way of recruiting participants for the main study.

This study used self-administered questionnaires to collect data from the quarry and allied workers, between November and December 2022 (Shihepo et al., 2024). Validity was ensured through in-depth scrutiny of the standing literature to classify conceptual dimensions and evaluation of the questionnaire by a series of research specialists from the Namibia University of Science and Technology and research supervisors (Leung, 2015). Research seminars in article writing at NUST/DRIP contributed to the credibility of this study.

The study involved participants who were given the option to decline or withdraw from the research through informed consent, ensuring they understood the importance of making an informed decision before participating in the study. Confidentiality and anonymity were ensured by not revealing the source of data and omitting identifying information. All data was held strictly confidential, as the researcher was the only one who knew the source or origin of the data. Subsequently, the data was kept in a password-secured computer only accessible by the researcher. It was explained to the participants (managerial staff, quarry workers, and allied workers) that they were not liable for punishment, victimisation or mistreatment following their involvement or not in the study. In this study, the participants had no direct benefits from their participation; however, there are indirect benefits from the implementation of recommendations as per the study findings. The researcher obtained ethical clearance and approval to conduct the study from the Namibia University of Science and Technology, with ethical clearance from the Ministry of Health and Social Services, and from the selected participating companies in the study.

Collected data were exported to SPSS version 28, and exploratory data analysis was performed to check for missing data and assess the distribution of numerical variables. Descriptive statistics and precise categorical data were presented as numbers (*n*) and percentages (%) (Shihepo et al., 2024). A Chi-square (χ^2) test was used to determine the association between the level of employee respiratory protection and individual factors significant at p=0.000. A 2-tailed Pearson correlation was done to establish the relationship between selected individual and work-related factors and the level of employee respiratory protection at both 0.01 and 0.05 levels of significance. A linear multiple regression analysis ascertained if selected individual and work-related factors predict the level of employee respiratory protection at 95 CI; p=0.000 (Shihepo et al., 2024).

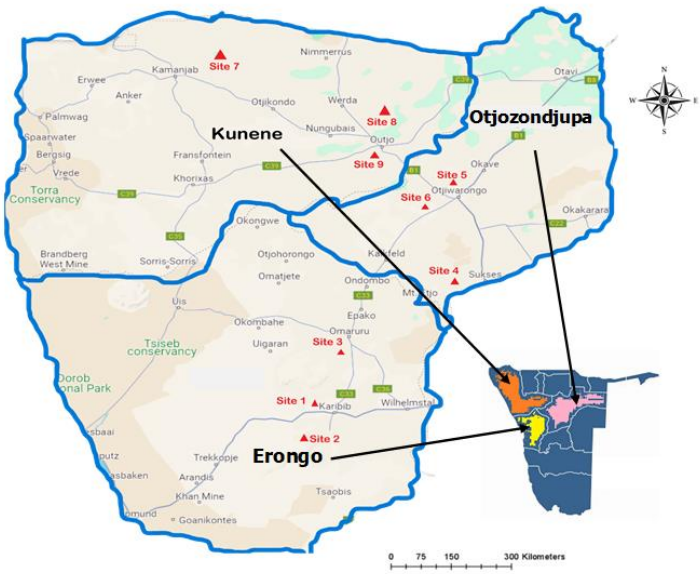

Fig. 1. Research study data collection sites

3. RESULTS

Delineated in Table 1, respondents' demographic characteristics, the most dominant age group is 25-34 years with 53% (n=161), trailed by 35-44 years with 26.3% (n=80) (Shihepo et al., 2024). Participants aged 55-65 years were the least represented with 1% (n=3). There were more males, 74.7% (n=227), than females, 25.3% (n=77), working in quarries and construction sites. Most participants were single, 89.1% (n=271), compared to those who were married, 10.9% (n=33).

The majority of the quarry and allied workers attained a secondary school education level of 53% (n=161), followed by primary education of 31.6% (n=96). Only 6.9% (n=21) reached the tertiary level (Shihepo et al., 2024).

Almost all 92.1% (n=280) quarry and allied workers were fully employed, whereas only 7.9% (n=24) worked on a part-time basis. The bulk of the participants, 27% (n=134), worked under stone blasting, followed by bagging 18.8% and loading 13.2%. Few individuals, 3% of the respondents, worked as builders, and 4.3% worked in stone collection and grinding as well as polishing. The majority of quarry and allied workers, 40.1% (n=122), worked for 1-3 years, followed by those working for 4-7 years, 37.2% (n=113). Only 2.6% (n=8) worked for more than 10 years.

Table 1. Respondents' demographic characteristics

Demographic Variable	Characteristic	Frequency (n)	Percent (%)
Age	18-24 years	40	13.2
	25-34 years	161	53
	35-44 years	80	26.3
	45-54 years	20	6.6
	55-65 years	3	1
	Total	304	100
Gender	Male	227	74.7
	Female	77	25.3
	Total	304	100
Marital Status	Single	271	89.1
	Married	33	10.9
	Total	304	100
Educational Level	None	26	8.6
	Primary level	96	31.6
	Secondary level	161	53.0
	Tertiary level	21	6.9
	Total	304	100.0
Employment Status	Full time	280	92.1
	Part-time	24	7.9
	Total	304	100
Working Experience	Less than a year	34	11.2
	1-3 years	122	40.1
	4-7 years	113	37.2
	7-10 years	27	8.9
	More than 10 years	8	2.6
	Total	304	100

3.1 Dust Exposure at Work

The study pursued the proportion of quarry and allied workers exposed to dust at work, as portrayed by the results in Fig. 2 (Shihepo et al., 2024).

As shown in Fig. 2: Proportion of quarry and allied workers exposed to workplace dust, the majority of quarry and allied workers (91.1%) were exposed to dust at work, while only 8.9% were not (Shihepo et al., 2024).

4. PROTECTION OF QUARRY AND ALLIED WORKERS FROM RESPIRATORY CONDITIONS AND INFECTIONS

The current protection of Namibian quarry and allied workers from respiratory conditions and infections is presented using the hierarchical hazard control model. The hierarchy of controls ranks (5) five levels of actions to reduce or

remove hazards from the most to least effective (Shihepo et al., 2024). Premised on this study's outcomes, three (3) level action controls for reducing respiratory hazards have been identified from the most to least effective as engineering controls, administration controls and use of PPE/C.

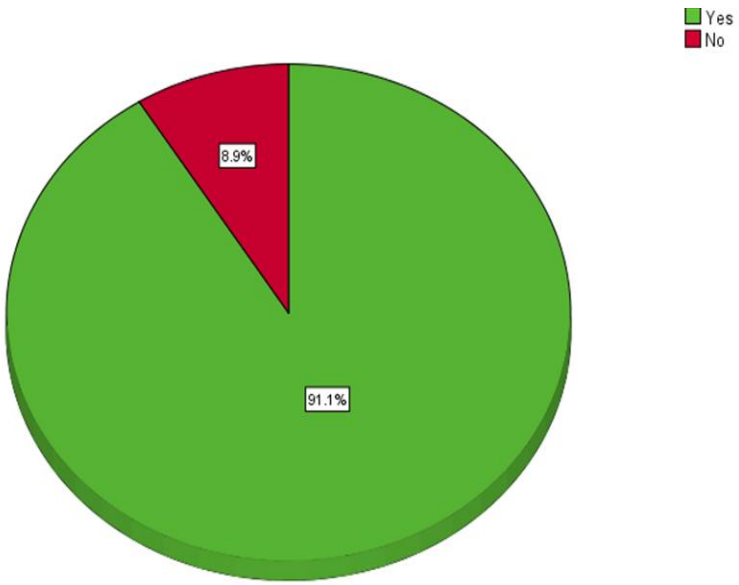

Fig. 2. Proportion of quarry and allied workers exposed to workplace dust

4.1 Engineering Controls

The use of water mists and sprays (wet drilling) is an effective engineering control measure for the protection of employees exposed to dust in quarry mines and construction sites. As shown in Table 2: Engineering controls used in protecting quarry and allied workers below, majority of the participants 87.1% (n=265), indicated that water sprays were not used in reducing the amount of dust emitted in the atmosphere as a result of the mining and construction processes (Shihepo et al., 2024). The application of water mists was not a common practice in protecting quarry and allied workers, as almost all the respondents 98% (n=298), failed to acknowledge.

4.2 Administrative Controls

The application of administrative controls in protecting quarry and allied workers was revealed in the form of educational/training programs and medical surveillance measures (Shihepo et al., 2024).

Table 2. Engineering controls used in protecting quarry and allied workers

	Yes		No	
	Frequency (n)	**Percentage (%)**	**Frequency (n)**	**Percentage (%)**
Water Sprays (wet drilling)	39	12.9	265	87.1
Water Mists	6	2	298	98

Table 3. Employee educational awareness/training

Question	**Response**	**Frequency(n)**	**Percent (%)**
Are you aware of any health and safety guidelines or company policies	Yes	119	39.1
	No	185	60.9
	Total	304	100
Are you trained on the importance, use and care of PPE/C	Yes	74	24.3
	No	230	75.7
	Total	304	100

4.3 Educational /Training Programmes

Employee education/training is a critical element of any complete protection of employees from workplace hazards, as it imparts information on how to protect themselves and co-workers. This article assesses health and safety training among quarry and allied workers in Namibia and reveals the following results in Table 3: Employee educational awareness/training (Shihepo et al., 2024).

Less than a quarter of the participants, 24.3% (n=74), were trained on the importance of PPE/C, while the majority, 75.7% (n=230), did not receive such training. Subsequently, most quarry and allied workers, 60.9% (n=185), did not know any guidelines or company policies on PPE/C, while more than a quarter 39.1% (n=119) were knowledgeable.

4.4 Medical Surveillance Measures

This article assesses the existence of a medical surveillance programme as part of a respiratory protection initiative. All the quarry and allied workers (100%) did not undergo pre-employment medical checkups (Shihepo et al., 2024). Upon employment, only 11.8% (n=36) of the workers acknowledged going for periodic medical examinations compared to 88.2% (n=268) who did not. None of the employees requires medical examinations to ensure the worker can use the PPE without risk to their own health.

4.5 Association between Employee Level of Respiratory Protection with Individual and Work-Related Factors

A Chi-square test was performed to ascertain the association between the level of employee respiratory protection and the following individual factors: age, gender, marital status, employment status, working experience, job category, frequency of PPE/C utilisation, and educational level work site.

Table 4. The association between individual and work-related factors and employee respiratory protection

	Value	df	Asymptotic Significance (2-sided)
Age	5.618	3	0.006
Gender	0.053	1	0.818
Marital status	0.338	1	0.561
Employment status	7.592	1	0.000
Working experience	12.275	4	0.015
Job category	37.742	9	0.000
Frequency of PPE/C utilisation	0.708	1	0.004
Educational level	68.517	3	0.000
Worksite	282.178	8	0.000

As shown in Table 4: The association between individual and work-related factors and employee respiratory protection, the Pearson Chi-Square test result portrays a statistically significant association between employee respiratory protection and employment status at $\chi^2(1) = 7.592$, $p = 0.000$; employee respiratory protection and job category at $\chi^2(9) = 37.742$, $p = 0.000$; employee respiratory protection and educational level at $\chi^2(3) = 68.517$, $p = 0.000$; employee respiratory protection and worksite at $\chi^2(8) = 282.178$, $p = 0.000$ (Shihepo et al., 2024). However, there was no statistically significant relationship between employee respiratory protection and age at $\chi^2(3) = 5.618$, $p = 0.006$, employee respiratory protection and gender at $\chi^2(1) = 0.053$, $p = 0.818$, employee respiratory protection and working experience at $\chi^2(4) = 12.275$, $p = 0.015$.

4.6 Correlation of Individual and Work-Related Factors with the Level of Employee Respiratory Protection

A Pearson correlation was performed to establish the relationship between selected individual and work-related factors (work site, age, gender, marital status, religion, level of education, employment status, working experience, job category) and the level of employee respiratory protection as indicated in Table 5: Individual and work-related factors correlation with the level of employee respiratory protection (Shihepo et al., 2024).

Table 5. Individual and work-related factors correlate with the level of employee respiratory protection

Correlation variables	Pearson Correlation
Level of employee respiratory protection and worksite	.700**
Level of employee respiratory protection and age	.142*
Level of employee respiratory protection and gender	0.013
Level of employee respiratory protection and marital status	-0.033
Level of employee respiratory protection and employment status	0.057
Level of employee respiratory protection and working experience	0.036
Level of employee respiratory protection and job category	.331**
Level of employee respiratory protection and training	-.841*
Level of employee respiratory protection and educational level	-.424**

***Correlation is significant at the 0.01 level (2-tailed).; *Correlation is significant at the 0.05 level (2-tailed).*

There was a strong positive correlation between employee respiratory protection and worksite (r=0.7) at 99% CI (2-tailed) as well as a weak positive association between employee respiratory protection and age (r=0.142) at 95% CI. The level of employee respiratory protection showed a positive weak correlation with job category (r=0.331) at 99% CI, a strong positive relationship with training (r=0.841) at 95% CI, and a moderately weak association with the level of education (r=0.424) at 99% CI (Shihepo et al., 2024). There was no significant correlation between the level of employee respiratory protection and gender (r=0.013) employment status (r=-0.057), marital status (r=0.033), and working experience (r=0.036).

4.7 Multiple Regression Analysis of the Level of Employee Respiratory Protection and Selected Individual and Work-Related Factors

Selected individual and work factors were assessed in a standard regression analysis to predict the level of employee respiratory protection. Table 6: Model Summary analysis of the level of employee respiratory protection and selected individual and work-related factors provides an overview of the model summary analysis (Shihepo et al., 2024).

Table 6. Model Summary analysis of the level of employee respiratory protection and selected individual and work-related factors

R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	Change Statistics			Sig. F Change
					F Change	df1	df2	
0.72	0.518	0.501	0.285	0.518	31.467	10	293	0.000

Predictors: (Constant), work site, age, gender, marital status, religion, level of education, employment status, working experience, job category.

The prediction model summary was statistically significant, F (10, 293) = 31.467, p = 0.000, as more than half (52%) of the selected individual factors accounted for the level of employee respiratory protection (R^2 = 0.501, Adjusted R^2 = 0.518). There was a medium-high degree of correlation denoted by R=0.72 (Shihepo et al., 2024). These findings imply that selected individual and work-related factors highly influenced the level of employee respiratory protection.

5. DISCUSSION

This study revealed the inability of quarry mines and construction employers to apply feasible respirable dust engineering controls in the form of water mists and sprays. According to Gürcanl, Baradan and Uzun (2015), respirable dust engineering controls are designed to remove or reduce the hazard at the source, meaning suppressing, diluting, or diverting dust generated by mining, construction and associated activities. Respirable dust engineering controls include proper ventilation systems, the use of water sprays, water mist (wetting agents) and control booths or environmental cabs to enclose equipment operators (National Institute for Occupational Safety and Health, 2021). These findings entail that Namibian quarry and allied workers have no engineering controls in place to reduce their exposure to respirable dust (Shihepo et al., 2024). You *et al*. (2019) argue that engineering controls provide more consistent and reliable protection than other interventions because the controls are not dependent on an individual's performance, supervision or intervention to function as intended.

There is a lack of administrative controls such as educational/training programmes, among Namibian quarry and allied workers. According to Zhou *et*

al. (2014), administrative controls provide additional guidance and procedures, demonstrating the company's commitment to safety and enhancing the overall safety culture of the workplace. In protecting quarry and allied workers, administrative controls come in the form of educational programmes and medical surveillance. With insufficient educational/training programmes, employees are prone to developing knowledge gaps on respiratory protection, making it difficult for them to cooperate and actively participate in precautionary safety and protection measures. The luck-lustre of training entails that Namibian quarry and allied workers are more inclined to occupational-related lung disease risks as well as negative attitudes, inadequate knowledge and bad practices in respiratory protection equipment (Shihepo et al., 2024). During training, employees interact with trained professionals who can provide instruction and understanding in the correct use of PPEs which will serve to overcome employee resistance to proper PPE usage (National Institute for Occupational Safety and Health, 2021). Educational and training programmes on safety precautions and behaviours, especially proper use of PPE, have shown to be effective methods to increase knowledge and prevent respiratory symptoms and diseases related to quarry, construction, and allied exposures (Alemu *et al.,* 2020).

Moreover, the study results showed that all the quarry and allied workers did not undergo a mandatory initial medical examination (Shihepo et al., 2024). Health surveillance in respiratory protection is an outline of repeated employee medical assessments and getting information, which includes history tracking, regular physical examinations, chest X-rays and lung function tests (Almberg, Friedman, Rose, Go, & Cohen, 2020). In addition, NIOSH (2019) states that initial examination assists in the early detection of respirable dust-related illnesses and conditions that may make the miner more susceptible to the toxic effects of respirable dust. Thus, without initial examination, Namibian quarry and allied workers are the least protected from respiratory conditions, thereby heightening the risk of becoming impaired without early detection (Chen, Cheng, Xie, & Su, 2022). Without initial examination, early detection and intervention of respiratory illness are slowed, allowing greater disease progression and deteriorating health outcomes. Also pointed out in the findings is the inability of most quarry and allied workers to undergo periodic medical examinations. Deprived of an individual medical baseline (initial medical examinations), valuable in assessing any future health changes and a comparable point (periodic examination), the protection of quarry and allied workers from respirable dust-related illnesses is minimal (Coffman *et al*., 2021; Shihepo et al., 2024).

Furthermore, employees were evaluated medically to be sure about their ability to use a respirator, because using a respirator may create a psychological burden on employees, depending on the type of respirator, the type of job, and the workplace condition in which the respirator is used (Shihepo et al., 2024). Medical surveillance measures include medical examinations which review an employee’s medical and work history and a physical examination. The medical and work history covers an employee’s present and past work exposures, illnesses, and any symptoms indicating respirable dust-related diseases and compromised lung function (Lancet, 2019).

In the present article, most quarry and allied workers were not provided with PPE/C despite it being a mandatory obligation enshrined in the Namibian Labour Act. Without PPE/C protection, from respiratory conditions is jeopardised. Personal protective equipment (PPE) controls are the last line of defence in protecting workers from dust exposure when engineering and administrative controls are not feasible or do not provide adequate protection (Alemu *et al.,* 2020). The study noted that the majority of those provided with PPE/C were given free of charge. These findings are in line with the fact that respirators approved by NIOSH and suitable for their intended purpose must be provided by employers at no cost to mine and construction workers to effectively protect themselves from respirable dust (Alemu *et al.,* 2020). Workers being given respirators for free at work lessens their susceptibility to respirable dust (Shihepo et al., 2024).

The use of PPE/C among quarry and allied workers was inconsistent, as most individuals occasionally used PPE/C. These findings imply that Namibian quarry and allied workers lack adherence to the use of PPE/C; hence, they become susceptible to developing respiratory conditions and related illnesses (Shihepo et al., 2024). According to Ashley and O'Connor (2017), PPE provides direct protection to workers as a supplementary control. Compliance with respiratory protection guidelines in many industries is troublingly low, especially among workers in construction and mining (Dhatrak and Nandi, 2020). Conversely, the use of PPE decreased the intermediate risk of respiratory injury by 44%, the maximum risk by 32%, and increased the chances of no risk of respiratory effects by 24% (Yarpuz-Bozdogan, 2018).

Premised on the findings, the type of PPE/C given to Namibian quarry and allied workers is biased towards protecting the general body (overalls) rather than the respiratory system, which is the priority given the nature of their work. With very few employees using respirators, the degree of protection becomes low thereby placing an increased risk of respiratory adverse health effects associated with exposure to respirable dust. NIOSH (2019) recommend the use of respirators as an interim measure when engineering and administrative controls are not effective in maintaining worker exposure to respirable dust at or below the proposed PEL (Shihepo et al., 2024). Contrary to the findings of the current article, the use of respirators as an interim measure in maintaining worker exposure to respirable dust at or below the proposed PEL is recommended (NIOSH Health, 2019).

Evidence from the article findings revealed the use of disposable N95 and surgical masks against respirable dust exposure. Lee *et al.* (2005) contend that respirators have different levels of protection and are used in a variety of conditions; hence, it is important to understand which respirator will protect against specified dust PEL exposures. Disposable N95 respirators protect against larger dust particles, of which quarry mines and construction sites can generate smaller and finer particles (Zgambo, 2015). Conversely, half-facepiece respirators protect from smaller particles of dust, and full-facepiece respirators provide eye and respiratory protection. On the other hand, surgical masks are the

least protective with a filtration efficiency between 25.7-61.5%, and half-facepiece P100 respirators were the most protective with 96.5-98.9% filtration efficiency (Sapbamrer *et al.,* 2021; Shihepo et al., 2024). Therefore, the continued dust exposure by the quarry and allied workers emphasises the importance of filtering facepiece respirators (FFRs) in dusty environments (Lee *et al.,* 2005).

The findings also showed that of the employees supplied with respirators, none did not obtain respirator fit testing. In the total absence of respirator fit testing, it is axiomatic that quarry and allied works in Namibia are not adequately protected against breathing respirable dust and contaminated ambient air (Shihepo et al., 2024). Research supports the use of respirators for lung protection while working with hazardous occupational inhalants; hence, fit testing becomes necessary to ensure maximum respiratory protection (National Center for Environmental Health, 2014). Respirator fit testing is performed to confirm the correct mask size without air leaks to protect individuals from hazardous inhalants (Ashley & O'Connor, 2017). This means that before an employee is required to use any respirator facepiece, the employee must be fit-tested with the same make, model, style and size of respirator that will be used. As revealed by the study findings, less than half of the quarry and allied workers were not adequately protected by respirators due to excessive facial hair. The use of respirators is commonly affected by fit factors such as facial hair (Shihepo et al., 2024). If a tight seal is not maintained between the facepiece and the employee's face, contaminated air will be drawn into the facepiece and breathed by the employee (Rengasamy et al., 2017). In general, the presence of beards and wide sideburns had a detrimental effect on the performance of the respirators (Jacobsen et al., 2021). This means that Namibian quarry and allied workers with excessive facial hair, including stubble and wide sideburns, which interfere with the seal, cannot expect to obtain as high a degree of respirator performance as clean-shaven individuals (Shihepo et al., 2024). OSHA concludes that poorly fitting facepieces expose workers to contaminants and that the use of an effective fit testing protocol is the best way of determining which respirator facepiece is most appropriate for each employee (Momyer, 2016).

Premised on the regression model, the level of education, age, working experience, and worksite risk perception predict or influence how quarry and allied workers are protected from respiratory infections and conditions (Shihepo et al., 2024). Research published across various occupations shows several individual factors as important determinants of the level of respiratory protection among quarry and allied workers. These factors include personal characteristics such as age, gender, work experience, level of education, knowledge (training) of respiratory protection hazards and risk perceptions of respiratory protection (Z'gambo, 2015). The educational level of quarry and allied workers greatly influenced respiratory protection. Lower educational levels of primary level and below as noted among most Namibian quarry and allied workers, entail lower respiratory protection, as some of the employees might fail to comprehend and apply respiratory protection information. A study by Almberg, Friedman, Rose, Go and Cohen (2020) found that the respondent's level of education significantly

affected respiratory protection, particularly when comparing respondents with and without formal education. However, the difference between individuals with basic education and those with higher education was not statistically significant. Research findings by Jacobsen, Schaumburg, Sigsgaard and Schlünssen (2021) showed that people who did not complete formal education also did not protect themselves from respiratory hazards as they shunned the proper PPEs at work (Shihepo et al., 2024).

Worksite risk perception has shown an influence on quarry and allied workers' respiratory protection. The protection motivation theory states that risk perception and use of personal protective equipment increase when workers have a reason for concern. In most instances, employees are cognisant of protecting themselves from respiratory conditions as a result of having suffered some respiratory illness. Sehsah*,* El-Gilany and Ibrahim *(*2020) settle that workers who had experienced an accident or incident in the past felt less safe and were more aware of the risks than those who had not experienced an accident or incident, hence they are more prone to protect themselves. When workers are made aware of the hazards in their workplace, they are more inclined to use PPE to protect themselves from exposure to the hazards. Conversely, if workers are provided with PPE but are not told why or how to use PPE, likely, such PPE will not be utilised. Kumar *et al.* (2016) point out the importance of workers having knowledge of the hazards and risks posed by their work and how they can protect themselves from these hazards (Shihepo et al., 2024).

6. CONCLUSION

The study revealed that quarry and allied workers could not effectively implement engineering controls to reduce workers' exposure to respirable dust due to the lack of an occupational respiratory health framework, safety regulations and enforcement, and education and training. The study provided evidence that most allied and quarry workers did not undergo the mandatory medical examination, as a request of limited hazards control measures. This contradicts the claim made by NIOSH, which argued that construction and mining companies should provide new employees with such examinations. Despite being mandated by the Labour Act of Namibia to provide protective equipment, the study revealed that 91 percent of quarry and allied workers in the study were not given the necessary equipment, and water sprays and misting systems were limited, thus exposing the quarry and allied workers to respiratory dust. The exposure to respiratory dust by quarry and allied workers is aligned to the Hierarchical Hazard Control Model, which states that implementing hazard controls in quarry mines highly prevents respiratory infections and is regarded as effective. Without proper equipment, workers are at risk of experiencing respiratory conditions that are detrimental to their health (Shihepo et al., 2024).

The study found that the type of PPE used by workers in Namibia is biased toward protecting the general body instead of the respiratory system. In addition, the use of PPE in the study was not consistent, and only a few quarry and allied workers used a respirator, which means that their level of protection was low.

This could result in adverse health effects because of exposure to dust. The study revealed that none of the employees had obtained a fit test. It is apparent that allied and quarry workers in Namibia do not have the required protection against dust and air contamination. The study showed that less than half of the employed individuals had adequate protection due to their facial hair (Shihepo et al., 2024). The study supports the concept of the protection motivation theory, which states that when workers are concerned about their safety, they tend to use more protective equipment, but also workers with inadequate knowledge, training and education about workplace hazards control measures still risk respiratory dust exposure.

7. RECOMMENDATION

The study recommends the need for an occupational respiratory health framework specifically for quarry and allied workers to ensure control measures are adequately implemented and enforced. Quarry mines should also ensure daily health and safety checks and periodical medical testing for all quarry and allied workers to ensure that medical fit testing for PPE in dust conditions. Finally, the study also recommends education and training to enhance safety awareness for quarry and allied workers.

8. STUDY IMPLICATIONS

The practicality of the study implies that there is a need for an occupational respiratory health framework, policy enforcement, and education and training to enhance quarry and allied workers' safety. These implementations will adequately help the Namibian Labours Act to make provisions specifically for quarry and allied worker protection.

The study also contributes to the literature as it is aligned with the Protection motivation theory and the Hierarchical hazard control model, by revealing that when workers are concerned about their safety, tend to use more protective equipment.

Finally, on a policy level, the study shows an urgent need for an occupational respiratory health framework for quarry and allied workers to ensure occupational respiratory health.

Effective government policy that will enhance occupational safety and health in mining and quarrying is necessary for accident prevention in Namibia.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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