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Assessment of Dust Exposure and Risk of Respiratory Diseases among Stone Quarry Workers in Karibib, Namibia

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ABSTRACT

Background

Namibia has been experiencing an increase in occupational respiratory conditions among quarry workers mainly attributed to noncompliance with OHS provisions by the mining companies in the Erongo Region. Community members have also become a victim of respiratory conditions and disorders due to dust expose from surrounding quarry activities.

Objective

The study assessed respirable dust exposure and the prevalence of respiratory symptoms among quarry workers and community members in the Erongo region of Namibia.

Methods

A quantitative descriptive cross-sectional study was conducted among 233 quarry workers and community members from selected quarries. GilAir dust monitoring pump measured respirable dust levels and questionnaires were used to collect data on respiratory symptoms.

Results

Quarry workers were found to be exposed to moderately high levels of dust (0.85 mg/m³ mean) as compared to community members (0.62 mg/m³). Varying dust exposure levels were found across all four sites and job categories. Site A and excavation job category had the highest dust levels. All sites recorded levels within the recommended occupational exposure limit values. The most prevalent respiratory symptoms reported by the quarry workers were coughing (57%) and the corresponding percentage among the non-exposed group was lower at 14%.

Conclusion

No association between respiratory diseases/disorders and dust exposure levels were found, which could be explained by observed compliance with national and international Occupational Exposure Limit (OEL) for quarrying dust or it could be by chance, which is influenced by a small sample size or healthy worker effect.

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KEYWORDS: *Respirable dust, dust exposure, quarry workers,), Time Weighted Average (TWA)*

INTRODUCTION

Respirable dust particulates from quarries are greatly connected to deadly occupational respiratory disorders and diseases such as lung cancer, pneumoconiosis, chronic asthma and tuberculosis.[1] A strong relationship between dust exposure and an increase in respiratory symptoms among quarry workers.[2] A health surveillance programme that focuses on quarries located in the Erongo Region of Namibia, reported an increasing trend of occupational respiratory disorders among quarry workers.[3] This includes persistent coughing and phlegm, breathlessness and wheezing, which has been postulated to be attributed to noncompliance with Occupational Health and Safety (OHS) provisions by

the mining companies. Other than quarry workers, community members have also become victims of respiratory conditions and disorders due to continuous exposure to poor air quality caused by surrounding quarry activities.[4] To the best of our knowledge, this is the first Namibian study that investigates dust exposure among quarry workers' and community members. In light of this, the study evaluated health risks and respiratory diseases occurrences among quarry workers and members of the surrounding community.

Methods

A descriptive cross-sectional study design was employed to assess dust exposure levels and to compare respiratory health outcomes associated with dust exposure among quarry workers and the non-exposed group, from surrounding communities.

Study site and area background:

The study sites were located on the outskirts of Karibib town in the Erongo region. Karibib Town has more than 8 quarries. Karibib Town Council owns 97 square kilometres of the townland, with an estimated population of 16 807 inhabitants as calculated using the growth rate of 3.4% per year.[3] For ethical reasons, the name of the study sites in this research is referred to as Quarry A, B, C, and D all being stone quarries.

Sample size:

The sample size was calculated based on the country prevalence (4.1%) for respiratory symptoms for 2014.[4]Sample size calculation formula: n = 1.952 P (100-P)/E2, where n = sample size, P = proportion of the population, E = acceptable margin of error (5%). n =1.952x4.1 (100-4.1.)/52= 60 (59.8), plus 10% [6*7=42] of each of the following covariates (age, gender, smoking, history of TB, family history of respiratory-related diseases, occupational history, other environmental factors) and 10 % for refusal. The sample size was 113 participants, each for quarry workers and community members.

The study sampled 120 quarry workers from all 4 quarry sites located on the outskirts of Karibib town. All workers were invited to participate, and no sampling was done. A systematic random sampling approach was used to select a total of 113 community members. In brief, every 3rd household in the street was approached and an adult member of the household (older than 18) was invited to participate in the study. On average, for each site, 30 workers and 28 community members were selected.

Data collection

All (N= 233) study participants completed a standardised interviewer-administered questionnaire. The questionnaire obtained data on participants' health, duration of a shift, period of exposure, daily activities, previous work history, respiratory illness symptoms, and a number of hospital visits in the past 12 months?

The Gil Air RC Dust Sampling Pump was used to measure personal dust concentrations, based on the NIOSH Method 0600, using 37mm PVC filter operating at 2.2 volume

Purposive sampling was used to select workers for personal dust monitoring, representing each job function/category. Personal dust levels were measured according to job categories to establish the job category with high, medium or low exposure levels.

A total of 40 quarry workers across all job categories were sampled for respirable dust assessment while 10 samples were purposely selected for silica analysis employing the extreme or deviant style. Extreme or deviant purposive sampling enabled the researcher to further investigate outliers or participants that had shifted from normal established dust exposure level trend. Thus, the highest dust exposure levels were referred for crystalline silica assessment

The dust sampling was conducted on an eight-hour full-shift (from 07h 00 to 15h 00) thus observing the Time Weighted Average (TWA) with selected workers wearing the sampling train with pump at their workplaces.

Gravimetric analysis of personal dust exposure

Dust exposure levels among the quarry workers were classified into three levels of low, medium and higher exposure. This was done by first calculating mean dust levels from the collected personal respirable dust levels and then extrapolating these mean dust levels to all similar exposure groups (SEG) such that all the quarry workers at all the sites in the study were allocated a mean dust level. Mean dust levels were then computed in SPSS to create three mean dust exposure levels as shown below.

Table 1: Mean and Cumulative dust exposure levels

Exposure level	Mean dust level (mg/m³)		Cumulative dust level (mg/m³)	
	Minimum	Minimum	Maximum	Maximum
Low	0.13	0.83	33.33	0.55
Medium	0.56	33.34	67.08	1.03
High	1.04	67.09	100.00	2.19

In addition to the mean dust exposure levels, cumulative dust exposure levels were also allocated to the quarry workers in the study. Cumulative dust exposure for each worker was calculated by multiplying the mean dust level per position by the number of years in the position. Percentile groups on cumulative dust levels were then computed in SPSS to create three cumulative dust exposure levels as shown above.

Data Analysis

The data were analysed using Statistical Package for Social Sciences (SPSS) version 22, after data cleaning. The Kolmogorov-Smirnov and Shapiro-Wilk tests showed that the data were non-normally distributed ($p<0.05$) and therefore non-parametric statistical methods were used in the subsequent bivariate and multivariate analysis. The chi-square test of association was used to compare the prevalence of the assessed health outcomes according to the quarry sites, years worked at the site, job descriptions, dust exposure levels and the prevalence of respiratory symptoms according to exposure to quarry work (i.e. between the quarry workers versus a sample of community members not involved in quarry work). The Kruskal-Wallis test as well as Spearman's Rho correlational analysis were used to examine relationships.

Logistic regression modelling was run to identify risk factors for respiratory symptoms. A less strict cut off p-value of 0.25 was set for the selection of variables to include the final model. This was done to avoid excluding variables that are known to have an effect on respiratory diseases. The logistic regression models accounted for confounding variables such as age and gender, among others.

Results

Demographic information

The socio-demographic profiles of the study participants are presented in Table 2. Of the 120 quarry workers, 114 (95%) were male and only 6 (5%) were female. In contrast, of the **96 non-exposed** respondents, **79% were female and 21% male.** The mean age, height, weight and BMI for the quarry workers were all highly comparable to corresponding measures in the control group.

Table 2: Socio-demographic information of study participants

Variables	Frequency and percentage (%)			
	Quarry workers (n=120)		Non-exposed(n=96)	
Gender				
Male	114	(95)	20	(21)
Female	6	(5)	76	(79)
Educational attainment				
No education	19	(16)	-	-
Primary school	72	(60)	-	-
Secondary school	29	(24)	-	-
Job specification				
Cleaner	12	(10)	-	-
Drilling	18	(15)	-	-
Excavator	21	(18)	-	-
Loading	31	(26)	-	-
Supervisor	16	(13)	-	-
Wire Saw	22	(18)	-	-
	Mean and standard deviation (SD)			
Age (years)	32.7	(7.4)	32.5	(10.0)
Work experience (years)	5.7	(2.6)	3.1	(2.1)
Height (cm)	169.6	(6.4)	168.1	(6.8)
Weight (kg)	67.1	(14.3)	68.3	(15.0)
BMI	23.4	(5.2)	24.2	(5.4)

A low prevalence of smoking was observed among both quarry and community members (Table 2). A significant ((p=0.01) difference in the prevalence of smoking among quarry workers (22%) and community members (5%) was observed. The percentage of non-smokers was lower at Site B (60%) compared to Site A (78%), Site C (87%) and Site D (88%) and this difference was statistically significant (p=0.01).

Respiratory symptoms

Table 3 presents the frequencies and percentages of respondents who reported the listed respiratory symptoms. The most prevalent respiratory symptoms reported by the quarry workers were coughing (57%) and the corresponding percentage among the non-exposed group was lower at 14%. Episodes of phlegm and shortness of breath were reported by about a quarter of the quarry workers and, once again, the percentage of the non-exposed community members who reported these symptoms was much lower at only 1% to 3%. Shortness of breath was equally reported by quarry workers (23%) and the non-exposed (22%). Apart from a single case of asthma among the quarry workers, none of the study participants reported any of the other listed symptoms. Altogether, there were significantly more reports of coughing, phlegm in the morning, phlegm during the day or night and increased cough or phlegm among quarry workers than among the non-exposed (p=0.01).

Table 3: Prevalence of respiratory symptoms among quarry workers and non-exposed participants

Symptoms	Frequency and percentage (%)	
	Quarry workers (n=120)	Non-exposed (n=96)
Cough	68 (57)	13 (14) *
Phlegm in the morning	31 (26)	3 (3) *
Phlegm during day or night	31 (26)	2 (2) *
Increased cough or phlegm	26 (22)	1 (1) *
Shortness of breath	28 (23)	21 (22)
Chest wheezy or whistling	- -	- -
Attacks of bronchitis	- -	- -
Attacks of emphysema	- -	- -
Asthma	1 (1)	- -
Chest tuberculosis	- -	- -
Any other chest illness	- -	- -

***p<0.05**

A logistic regression model was run to identify risk factors for respiratory symptoms. The process involved an initial run of univariable models to identify variables suitable for inclusion in the subsequent multivariable model. A less strict cut off p-value of 0.25 was set for the selection of variables to include the final model. This was done to avoid excluding variables that are known to have an effect in relation to respiratory diseases.

The variables that were included in the multivariable model were gender, age, type of cooking fuel, exposure to quarry work and length of exposure and Table 4 presents the odd ratios for the respiratory symptoms by the above predictor variables. First, quarry workers were significantly more likely to report coughing than non-exposed participants (OR=8.52, 95% CI: 2.57-28.29). Quarry workers were also significantly more likely to report phlegm in the morning than non-exposed participants (OR=8.94, 95% CI: 1.46-54.73). However, quarry workers were significantly less likely to report shortness of breath compared to non-exposed participants (OR=0.26, 95% CI: 0.09-0.72).

Apart from the quarry workers versus the non-exposed group odds comparisons above, the results show that users of non-electric fuel were significantly more likely to report shortness of breath compared to users of electric sources (OR=3.13, 95% CI: 1.03-9.52). Males were also significantly more likely to report shortness of breath compared to females (OR=4.19, 95% CI: 1.44 -12.15).

Table 4: Adjusted odd ratios for respiratory symptoms

Variables	Cough		Phlegm in the morning		Phlegm during day/night		Increased cough/phlegm		Shortness of breath	
	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI	Adjusted OR	95% CI
Gender	0.66	0.20 - 2.19	1.00	0.20 – 5.11	1.08	0.18 – 6.37	3.79	0.33 – 43.02	**4.19***	1.44 – 12.15
Age	2.33	1.00 - 5.46	0.49	0.17 – 1.45	0.39	0.12 – 1.22	0.59	0.18 – 1.95	1.97	0.80 – 4.86
Type of cooking fuel	2.77	0.91 - 8.42	1.47	0.27 – 7.91	0.52	0.10 – 2.64	-	-	**3.13***	1.03 – 9.52
Exposure to quarry work	**8.52***	2.57 - 28.29	**8.94***	1.46 – 54.73	**19.05***	2.16 – 168.26	6.61	0.61 – 71.61	**0.26***	0.09 – 0.72
Length of exposure	1.42	0.39 - 5.12	0.36	0.04 – 3.16	0.21	0.02 – 1.92	0.24	0.03 – 2.23	0.21	0.04 – 1.08

Prevalence of respiratory symptoms is shown according to smoking history for both the quarry workers and the non-exposed participants in Table 5 The chi-square test of association results showed that differences in the prevalence of symptoms by smoking history were not statistically significant.

Table 5: Prevalence of respiratory symptoms by smoking

Quarry Workers (n=120)	**Smokers (n=26)**	**Non-smokers (n=94)**
Cough	13 (50)	55 (59)
Phlegm in the morning	6 (23)	25 (27)
Phlegm during day or night	6 (23)	25 (27)
Increased cough or phlegm	6 (23)	20 (21)
Shortness of breath	5 (19)	23 (25)
Asthma	- -	1 (1)
Non-exposed group (n=96)	**Smokers (n=5)**	**Non-smokers (n=91)**
Cough	- -	13 (14)
Phlegm in the morning	- -	3 (3)
Phlegm during day or night	- -	2 (2)
Increased cough or phlegm	- -	1 (1)
Shortness of breath	- -	21 (23)
Asthma	- -	- -

***p<0.05**

Binomial logistic regression was done (Table 6) to predict the risk of obstructive or restrictive lung function from smoking among the quarry workers. Smoking was shown to be a significant predictor of lung function (OR=11.91, 95% CI: 3.29-43.13).

Table 6: Binomial logistic regression – smoking and lung function

							95% CI	
	B	**S.E.**	**Wald**	**df**	**Sig.**	**Exp(B)**	**Lower**	**Upper**
Smoking	2.48	0.66	14.24	1.00	**0.00***	11.91	3.29	43.13
Constant	-3.11	0.51	37.13	1.00	0.00	0.04		

Dust exposure

Table 7 presents quarry workers according to levels of dust exposure (i.e. low, medium and high dust exposure). The percentage of workers in the high mean dust exposure category was significantly high at Site A (59%) compared to the other three sites (p=0.01). The percentage of workers in the high mean dust exposure category was also significantly higher among excavators (81%) compared to the other job specifications (p=0.01).

Table 9: Dust exposure levels among quarry workers (n=120)

Variables	Frequency and percentage (%)		
	Low mean dust exposure	Medium mean dust exposure	High mean dust exposure
Quarry site			
Site A (n=27)	8 (30)	3 (11)	**16 (59) ***
Site B (n=30)	10 (33)	16 (53)	4 (13)
Site C (n=30)	9 (30)	13 (43)	8 (27)
Site D (n=33)	14 (42)	7 (21)	12 (36)
Job specification			
Cleaner (n=12)	8 (67)	1 (8)	3 (25)
Drilling (n=18)	9 (50)	9 (50)	0 (0)
Excavator (n=21)	0 (0)	4 (19)	**17 (81) ***
Loading (n=31)	1 (3)	22 (71)	8 (26)
Supervisor (n=16)	5 (31)	3 (19)	8 (50)
Wire Saw (n=22)	18 (82)	0 (0)	4 (18)
Work experience			
1-3 years (n=25)	9 (36)	8 (32)	8 (32)
4-6 years (n=50)	18 (36)	14 (28)	18 (36)
7-9 years (n=36)	8 (22)	16 (44)	12 (33)
10 years or more (n=9)	6 (67)	1 (11)	2 (22)

***p<0.05**

Silica exposure

The correlation between silica exposure and the lung function assessments was examined using Spearman's rho correlation and as shown in Table 8, there was no significant correlation between the silica exposure and any of the lung function measures.

Table: 8 Spearman's Rho correlation between silica exposure and lung function among quarry workers (n=10)

r_s =correlation coefficient, *p<0.05

FVC1 Pred%	r_s	0.11
	p-value	0.77
FEV1 Pred%	r_s	-0.04
	p-value	0.91
FEV1/FVC Pred%	r_s	0.09
	p-value	0.81
PEFR Pred%	r_s	-0.04
	p-value	0.92

Discussions

The study found varying dust levels across all four sites, with Site A having the highest exposure and Site B having the least exposure. This trend follows study results with varying mean concentrations of respirable dust from four different locations ranging from 0.02-4.26 mg/m3 in Ghana quarries.[5]

The peak dust exposure limit was below NOIH's respirable dust exposure limits of 1.0 mg/m3. This is an indication that all sites under study were generating dust within permissible levels which suggests reduced exposure. These results contrast with high charcoal dust exposure levels that exceeded the US OSHA endorsed limit of 3.5 mg/m^3 with factories 1 and 3 bearing the peak dust levels of 25.9 mg/m^3 and 19.4 mg/m^3 respectively.[6]

Within the entire sites, the excavation job category was highly exposed while the wire saw was the least exposed. Excavation produced more dust due to the process of rigging and rubble moving. Wire saw had the least exposure because the water wetting method was used hence the amount of dust generated during working was dissuaded. These findings concur that excavation generates high dust amounts in comparison to other selected jobs within the quarrying sites.[7] However, in all the job categories, dust exposure was below NIOSH recommended exposure limits.

Quarry workers (0.85 mg/m³) were relatively more exposed to respirable dust than community members (0.62 mg/m³). This variation in exposure was attributed to differences in exposure times and distance from the source of dust generation. These findings are consistent with a similar study which reported varying levels of dust concentration as the distance from the source either increased or decreased.[8] The mean dust concentration levels from the source of dust generation at 0m were 0.165mg/m3, at 200m was 0.04mg/m3 and at 500m was 0.005mg/m3. In the same study, a negative correlation coefficient affirmed a reduction in dust concentration levels as the distance from the source increased as well. The decrease in dust concentration due to the increase in distance from the source is a result of the dilution effect caused by the wind. A different study showed that mean dust concentrations decreased significantly with increased distance.

There was no statistically significant association between the dust exposure categories and the prevalence of respiratory symptoms among the quarry workers. However, respiratory symptoms were reported among quarry workers (exposed) more than in community members (non-exposed). Binomial logistic regression models ran, statistically showed that quarry work was a significant predictor for cough, phlegm in the morning, phlegm during the day or night, and increased cough or phlegm ($p<0.05$). The current study results are in linearity with a study that discovered that quarry workers had developed several respiratory ailments which consisted of shortness of breath, wheezing, coughing and chest pains.[10] Close to 85% incidences of respiratory health effects (signalled by respiratory symptoms) amongst quarry manual stone workers.[11] This suggests that continued exposure to dust from quarrying activities bears the capability of increased susceptibility to respiratory health effects.

Among the quarry workers, cleaners recorded the highest prevalence of respiratory symptoms, yet they were the least exposed group. Respiratory symptoms such as phlegm, coughing and wheezing were commonly found among sweepers (cleaners).[12] This can be attributed to the fact that cleaners were more exposed to mineral and organic dust from cleaning, and they lacked sound respiratory protection equipment. Cleaners could have been assigned light duties because of their ill-health conditions which might include coughing and some other respiratory conditions. These findings point out that quarry workers' risk for developing respiratory symptoms is influenced mainly by individual factors and to a lesser extent exposure to dust.

Recommendations

A key recommendation based on our findings is the need to monitor the health status of workers regularly by Health surveillance to ensure early detection in workers' health, especially those linked to lung impairment. This is particularly so as the study found that there were no medical examinations records at any of the studied sites. The establishment of a watchdog agency will help in the enforcement of dust control measures in the quarries. However, the prescribed interventions should be low cost and incorporate medical surveillance. Moreover, environmental management systems which include a dust management plan should be employed at the quarries to mitigate dust generation. Dust monitoring should be carried out to establish dust exposure levels of different job categories. The establishment of dust exposure levels streamlines adherence to occupational exposure standards and limits of the concentrations of the dust generated from the different stages of their operations. The quarry workers should be adequately sensitised on the adverse health effects of exposure to quarry dust and the importance of using personal protective equipment while at work. A collaboration of all stakeholders in quarry mining by the Namibian government, through the Ministry of Health and

Social Services and Ministry of Labour and Social Services, should enforce occupational health and safety-related standards to protect the health of workers in quarries.

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