

Respiratory health of stonecrushers from the informal sector in Tanzania

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ABSTRACT

Background and objective: The prevalence of dust-related respiratory problems and relationships between health endpoints and respirable dust among stonecrushers in an informal sector quarry in Dar-es-Salaam, Tanzania, were investigated.

Methods: Exposure and respiratory health outcomes, and associations between years of exposure and respiratory outcomes were assessed in 200 workers, employed for at least one year at the quarries.

Results: The mean area respirable dust level was 1.2 mg/m³, with a mean exposure duration of 7.5 years. Men had a substantially higher reporting rate of chronic cough and chronic phlegm, compared to females. A high prevalence of mild breathlessness was reported by both sexes. Exposure was associated with a non-significant, loss in FEV₁ and increased risk for frequent cough; frequent episodes of phlegm and symptoms of chronic bronchitis.

Conclusions: Stonecrushers in the informal sector of Dar-es-Salaam seem to be at increased risk for the development of adverse respiratory outcomes, in a dose-response manner. Cost-effective interventions are necessary to protect these marginalised self-employed workers with little resources for engineering dust controls.

Keywords: stonecrushers, respirable dust, informal sector, lung function, respiratory symptoms

INTRODUCTION

Stonecrushing is an occupation dating back to antiquity. The hazards faced by these workers have been documented by observers and historians alike.¹ Technological development over the ages has meant better hazard control, and reduced health outcomes for most workers in this occupation.

However, the consequences of globalisation and the rapidly changing working environment, particularly in developing economies, has resulted in a greater informalisation of work, creating worksites with almost no resources to address hazard control. For stonecrushers in developing countries this has meant uncontrolled dusty and hazardous working environments resulting in potentially increased risk to adverse health outcomes.²⁻⁴

The informal sector constitutes rapid economic growth points in most developing countries including Tanzania. In Dar-es-Salaam almost 60% to 70% of the younger workforce is currently employed in this sector.⁵ Stonecrushing is one of the activities in the informal economy,⁶ offering employment to more than 7000 workers in Dar-es-Salaam alone – predominantly women workers.⁷

There have been limited studies that have documented the exposures and health outcomes generally, or respiratory outcomes specifically, among stonecrushers internationally. No systematic studies have been done in southern Africa. There are several reports of exposure studies from India and Iran, all of which indicate mean exposures of respirable dust exceeding international or local standards, ranging from 1.24 mg/m³ in Iran through to 39.7 mg/m³ in India.^{2,8}

The Indian studies have provided some insight into respirable health outcomes among these workers. A high prevalence of respiratory symptoms and poorer lung function have been described among Indian stonecrushers,^{3,4} while a substantially increased statistically significant risk for the presence of respiratory symptoms, radiographic changes as well as reduced lung function have been described.⁹⁻¹¹



Photo courtesy: TOHS, Dar-es-Salaam, Tanzania

Much of the risk for the development of respiratory diseases could be attributed to the silica content of the rock in these quarries. However, when compared to other dusty, silica exposed industries, stonecrushing seems to have a lower risk for outcomes such as silicosis and tuberculosis. In a study investigating slate pencil workers and stonecrushers, the prevalence of TB among stonecrushers was 10.7%, compared to the slate workers of 22.5%.¹²

Stonecrushing involves several steps starting from rock blasting, excavation, manual crushing, sieving and loading onto trucks. The crushed stones are used in different types of construction including making concrete, building houses and road construction. These activities are done manually where workers are exposed to numerous work-related hazards, including silica dust, chemicals, poor work design, extreme heat and mechanical hazards.

This paper forms part of a larger project among informal sector workers in the southern African region, conducted among stonecrushers and metal fabricators in Dar-es-Salaam, Tanzania, and sawmill workers and brickmakers in Maputo, Mozambique. These were projects located

Health (NIOSH) Occupational History Questionnaire¹³ used in the US Coal Workers' X-ray Surveillance Program was modified to obtain details on lifetime occupational histories in this stonecrushing working population.

Measures of symptom outcomes were obtained from the questionnaire, and were defined as follows:

- Cough greater than three months: answer yes to "do you usually cough like this on most days (or nights) for as much as three months each year?"
- Phlegm production greater than three months: answer yes to "do you bring up phlegm like this on most days (or nights) for as much as three months each year?"
- Cough and phlegm greater than three weeks: answer yes to "have you had periods or episodes of (increased) cough and phlegm lasting for three weeks or more each year?"
- Breathlessness when walking: answer yes to "do you have to stop for breath when walking at your own pace on level ground?"
- Breathlessness when dressing: answer yes to "are you too breathless to leave the house or breathless on dressing and undressing?"

"In Dar-es-Salaam almost 60% to 70% of the younger workforce is currently employed in this sector."

within the Work and Health in Southern Africa (WAHSA) Programme. The objective of this paper is to describe the prevalence of dust-related respiratory outcomes and relationships between health endpoints and respirable dust in a sample of Tanzanian stonecrushers from an informal quarry. This is the first study to document these findings in southern Africa.

METHODOLOGY

The study was approved by the Ethics Committees of the Medical Research Council in Tanzania and the University of KwaZulu-Natal. Written informed consent was obtained from each participant.

Selection of the stonecrushing quarry and study sample

The quarry at Kigamboni was randomly selected from three existing quarries in Dar-es-Salaam. All the workers employed at Kigamboni were selected into the study (N=200).

Worker interviews

Standardised questionnaires were administered by trained interviewers to each participant. Items included demographics, respiratory symptoms, chest illnesses, detailed work histories (past and current employment details), tobacco use and family history. The US National Institute of Occupational Safety and

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- Usual wheeze: answer yes to “does your chest sound wheezy or whistling on most days and nights?”

Participants were also asked to report on the doctor-diagnosed diseases – although access to healthcare was likely to be limited in this population, this was considered the best approach to obtain standardised responses from the sample.

A detailed smoking history was obtained from each participant, as well as information on six AIDS-related symptoms, namely excessive weight loss, mouth sores, lymphadenopathy, persistent diarrhoea, prolonged fever and shingles. Any participant with two or more of these symptoms was considered to be HIV positive.

The questionnaires were administered in the language of the worker’s choice – either English or Swahili. The English version of the questionnaire was translated and back-translated by independent linguists. The administrators chosen were fluent with the chosen language of the worker.

Lung function assessments

Due to resource constraints, only a subset of the workers (n=62) were invited to undergo spirometry. These workers were randomly selected from the larger sample. Lung function assessments were conducted by a medical doctor trained in spirometric assessments, following American Thoracic Society standardised criteria,¹⁴ using a Vitalograph – Alpha III Model 6000 spirometer. The equipment was volume calibrated with a 3 litre calibrated syringe, every four hours on the days of testing. Each participant was required to perform minimum three acceptable and reproducible curves, assessed by the doctor conducting the tests. The three tests where the FEV₁ was within 10% of each other were accepted. A maximum of five tests were performed by each participant. The results of three participants were excluded as acceptable tests could not be performed.

Chest radiography

The same subset of workers who performed spirometry, underwent chest radiography. Radiographs were subsequently read independently by two experienced readers, one of whom is a NIOSH “B” Reader. These films were read according to the International Labour Organization Classification of Pneumoconiosis.

Evaluation of exposure

A total of 86 respirable dust samples were collected from the different work sites at the quarry, according to the National Institute of Occupational Safety and Health (NIOSH) prescribed method 0600.¹⁵ Each worker participating in exposure assessment was asked to fix the sampler at the collar of the shirt for eight hours while at work. The sites were selected in a non-random manner, with high exposure activities being over sampled. Although workers regularly change tasks over a working week, and occasionally during the course of a day, for the purposes of characterising exposure, workers were requested to perform the selected task for the full work-shift of approximately eight hours. Respirable dust was collected on cellulose acetate filters with a pore size of 0.8 microns placed in a 37 mm cyclone connected to a SKC pump with a flow rate of 1.9 l/min. The samples were transported to the laboratory in a protective suitcase and analysed quantitatively by gravimetric analysis using a Mettler microbalance with a detection limit of 0.01 mg. Silica concentration of the dust was not quantified because of the lack of appropriate facilities to conduct these assessments. Field and laboratory blank filters were used. Any gain or loss in weight on the blank filters was used to determine expected changes on the final mass concentration of the sampled filter.

For the purposes of this report, exposure is described as years employed in the stonecrushing quarry. Because of the constant inter-change of jobs on the quarry site among workers, with many different tasks being done within a working week for varying periods of time, it was not possible to develop any more sophisticated exposure metrics such as cumulative exposure, based on the quantitative assessments that were conducted. Historical exposure data was not available, however, the methods used in stonecrushing at this quarry have not changed meaningfully over the years, thus exposure levels are unlikely to have varied much. During data analysis, years of exposure was used as a continuous variable, and converted into tertiles – low (<3 years), medium (>3 and ≤ 6 years) and high (> 6 years) exposure categories.

ANALYSIS

The primary outcome variables of interest were the lung function parameters FEV₁, FVC and the ratio FEV₁/FVC, as well as respiratory symptoms. The primary exposure variable

Table 1. Demographic profile of the stonecrushers

Demographic variables	Male (n=101)	Female (n=99)
Age (years) (SD)	34.9 (1.4)	37.3 (1.3)
Years worked in quarry (range)	7.3 (1-62)	7.7 (1-41)
Height (cm) (SD)*	166.7 (1.3)	158.2 (0.9)
Weight (kg) (SD)*	59.6 (1.9)	62.7 (2.3)
Current smokers (%)	30 (29.7)	9 (9.1)
Never smokers	69 (68.3)	89 (89.9)
Ex-smokers	2 (1.98)	1 (1.01)

* This data was only available for those who had formal assessments done (n=62)

Table 2. Respirable dust concentration (GM in mg/m³ and GSD*) for various exposures groups and by job title among stonecrushers

Tasks	n	GM	GSD	Range
Loading	5	0.1	2.6	0.1–1.6
Digging and carrying	1	0.3	–	–
Digging	3	0.5	3.8	0.2–1.0
Sieving	16	0.6	2.7	0.2–1.6
Crushing and sieving	2	0.6	2.6	0.3–1.3
Weighing	4	0.9	1.3	0.9–1.3
Sorting	1	1.0	–	–
Crushing	49	1.02	2.8	0.2–6.3
Lifting stones from pit	1	2.0	–	–
Crushing and loading	4	2.8	4.4	0.8–19.9
Total	86	1.2	2.9	0.1–19.9

*GM – geometric mean, GSD – geometric standard deviations

“... workers are exposed to numerous work-related hazards, including silica dust, chemicals, poor work design, extreme heat and mechanical hazards.”

was years of exposure. Covariates examined were: smoking status, previous dusty occupations and history of tuberculosis. All analysis was done using STATA version 10.

Although lung function prediction equations have been proposed for persons of African origin,¹⁵⁻¹⁷ there was a lack of confidence about the validity of these equations in this particular population: the available equations for females are from South Africa, while no equations exist for men of East African origin. For this reason, multivariable regression models for FEV₁ and FVC adjusted for age, height and sex were computed as described by Vollmer et al. among a population of Chinese men and women.¹⁸ Multivariable regression was conducted to determine relationships between exposure and lung function, while adjusting for likely confounders such as smoking, history of TB and sex. Logistic regression models for dichotomous outcomes (respiratory symptoms) and exposure variables were developed.

Because this sample included both men and women, much of the data was analysed, stratified by sex.

RESULTS


Demographic profile

In the overall sample (N=200), the mean age was 36 years. There were 99 (48%) women, whose mean age slightly exceeded that of men (37.3 vs. 34.9 years), with additional small variations in terms of height and weight. While the years of exposure varied slightly, the difference in smoking profiles was substantial – 76% of the current smokers were men (Table 1).

Exposure assessment

A total of 86 respirable dust samples were obtained from a variety of job activities. These tasks were performed for the full work shift during which the sampling was conducted. There were substantial exposure differences among the

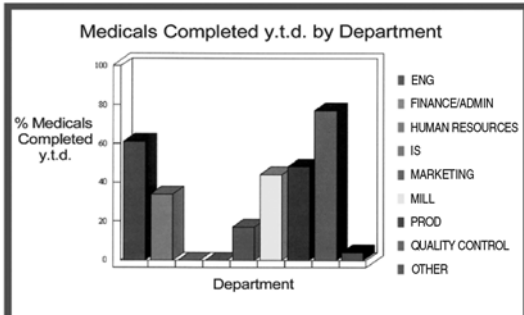
different tasks, with low mean levels recorded for tasks such as loading (0.1 mg/m³) through to high exposures for tasks such as crushing and loading (2.4 mg/m³). The overall geometric mean of 1.2 mg/m³ has little value because of the non-random method of activity selection for sampling. At least four of the different tasks (sorting, crushing, lifting stones from pit and crushing and loading) were associated with exposures higher than the 1 mg/m³ (Table 2).



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Lung function status

Mean forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC), obtained from multivariable regression equations, adjusting for age and height, were 2.8 l/min (SD: 0.6) and 3.8 l (SD: 0.5) respectively among the men, and 2.2 l/min (SD: 0.4) and 3.0 l (SD: 0.4) respectively among women. Ratio of FEV₁ and FVC was 71.1% and 69.9% for men and women respectively. A substantial percentage (36%) of the sample had an FEV₁/FVC ratio of <75%.

Presentation of symptoms and doctor-diagnosed diseases

Reported prevalences of doctor-diagnosed respiratory diseases were: asthma (3% (n=6)), chronic bronchitis (3% (n=6)), emphysema (0% (n=0)) and tuberculosis (2% (n=4)). Interestingly these low reports of doctor-diagnosed diseases contrasted with the prevalence symptoms as reported by the participants.

Reporting of symptoms of breathlessness and wheeze did not differ markedly between males and females, however symptoms of chronic cough and phlegm production did (Table 3). Men had a substantially higher reporting rate of chronic cough and chronic phlegm (18.8% for both (n=19), compared to females with rates of 8.1% (n=8) and 10.1% (n=10) for cough and phlegm respectively. A high prevalence of mild breathlessness was reported by both sexes (20.8% (n=21) and 19.2% (n=19) for men and women respectively).

The association between HIV positive (prevalence 27.0%) and doctor-diagnosed TB was significant (chi square p value = 0.03).

Radiographic findings

The overwhelming majority of films were read as normal (60.9%), with 19.6% being read as 0/1 and 1/0 respectively. No films were Category II or above.

Health outcomes and exposure relationships

Logistic regression models assessing the relationship

between years of exposure and symptoms adjusted for sex, current and ex-smoking, doctor-diagnosed TB (Table 4), indicated an excess exposure related risk for the symptoms of frequent cough, frequent phlegm and breathlessness, but these were not statistically significant (Table 4). A protective effect was noted for wheeze.

According to linear regression models assessing the relationship between spirometry and years of exposure and adjusted for sex, height, age, doctor-diagnosed TB and smoking status, FEV₁ was associated with 2 ml loss per year of exposure of work in the quarries, in excess of annual age-related declines of lung function. This was, however, not statistically significant (95% CI: -0.02 – 0.01). FVC did not show this dose-response.

Of particular interest was the substantial effect of doctor-diagnosed tuberculosis on both symptoms and lung function, within this population. TB resulted in an 848 ml lower FEV₁ (95% CI: -1.5 – -0.26) and a 732 ml lower FVC (95% CI: -1.5 – 0.001). The adjusted risk estimates for the symptoms of interest associated with TB ranged from 8.8 to 1.5 – although with very large confidence intervals, all statistically significant. When the HIV variable was introduced into the model, these risk estimates were reduced, but remained statistically significant. No interaction between TB and exposure was seen.

No statistically significant relationship was seen between X-ray categories and exposure categories.

DISCUSSION

This study, despite its limitations, was suggestive of dust-related adverse respiratory outcomes among stonecrushers. The study, the first among stonecrushers in southern Africa, documented a high prevalence of respiratory symptoms within this sample of workers, together with clinically important lung function deficits.

As already noted, this paper is based on a larger project conducted among informal sector workers in Dar-es-Salaam and Maputo. The project focused on documenting the risks faced by these workers, and their

Table 3. Reported respiratory symptoms and doctor-diagnosed diseases from stonecrushers

Symptoms and disease outcomes	Male (n=101) (%)	Female (n=99) (%)
Chronic cough	19 (18.8)	8 (8.1)
Chronic phlegm	19 (18.8)	10 (10.1)
Chronic cough and phlegm	13 (12.9)	7 (7.1)
Mild breathlessness	21 (20.8)	19 (19.2)
Severe breathlessness	3 (3.0)	4 (4.0)
Frequent wheeze	12 (11.9)	12 (12.1)
Doctor-diagnosed asthma	3 (3.0)	3 (3.0)
Doctor-diagnosed chronic bronchitis	4 (3.9)	2 (2.0)
Doctor-diagnosed emphysema	0 (0.0)	0 (0.0)
Doctor-diagnosed tuberculosis	1 (1.0)	3 (3.0)

overall health status. The data generated from the project provided an opportunity to describe the respiratory health of these marginalised workers, and to describe any exposure-outcome relationships. However, because the project was not *a priori* designed to address any specific epidemiological hypothesis, this restricted our ability to define any relationship with substantial confidence, if such relationships did exist.

Despite these shortcomings, stonecrushers in this study had prevalences of chronic respiratory outcomes such as chronic cough, frequent phlegm production and breathlessness similar to those which have been reported in other studies among respirable dust exposed workers.¹⁹⁻²¹ The prevalence of symptoms among Indian stonecrushers was substantially higher than our study, with prevalences of chronic cough of 50%, wheeze 17%

Table 4. Odds ratios for symptoms from logistic regression models

Symptom	Odds ratio	Confidence interval
Frequent cough	1.3	0.47 – 3.8
Frequent phlegm	2.4	0.79 – 7.5
Breathlessness	1.5	0.64 – 3.6
Wheeze	0.4	0.15 – 0.93

All models adjusted for sex, current and ex-smoking, doctor-diagnosed TB, chronic bronchitis and asthma

and phlegm production of 40%. These differences are not surprising given the high levels of exposure recorded among the Indian workers – respirable dust of 18.9 mg/m³ with a 5.8% silica concentration.⁹ A protective dust-related effect was noted for wheeze (OR=0.4, 95% CI: 0.15 – 0.9) – this is probably best explained by our small sample

“At least four of the different tasks (sorting, crushing, lifting stones from pit and crushing and loading) were associated with exposures higher than the 1 mg/m³.”

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size, or possibly the presence of a healthy worker effect, with those experiencing respiratory symptoms choosing to leave the working environment.

The lung function deficits identified in our study were similar to those seen in the studies on Indian stoneworkers. Among Indian stoneworkers (a generally younger population with much shorter duration of exposure than our sample), the age and height unadjusted mean FEV₁ was similar among males and females (2.72 l/min) while FVC was 3.34 and 2.78 among males and females respectively. A statistically significant decreasing trend in lung function was noted with increasing years of exposure.³ An exposure-related difference in lung function was found in another sample of Indian stonecrushers – the mean values of lung function among these stonecrushers were significantly lower than the mean values reported for normal South Indian healthy males.⁴

Because of the open environment, respirable dust levels within a quarry are likely to be much lower than those seen in an underground mine, with a possible lower prevalence of adverse respiratory outcomes. In this setting, dust levels ranged from 0.1 mg/m³ to 2.4 mg/m³. Dust levels in similar settings internationally were within the range found in this study: 1-4 mg/



Photo courtesy: TOHS, Dar-es-Salaam, Tanzania

m³ (mean=2.7 mg/m³) among Indian stonecrushers,²² 9.46 mg/m³ among Iranian stoneworkers.² In another Indian stonecrushing study, the mean respirable dust level was much higher than documented among other studies (39.7 mg/m³) – it is unclear why this difference existed.⁸ Low respirable dust levels have been recorded among other mining entities, such as opencast coalmining operations, where none of the mean dust levels exceeded 1 mg/m³.²³

As for any quarry, underground or opencast mine environment, respiratory symptoms and lung function loss are generally attributable to silica exposure. We were not able to quantify the concentration of silica concentration of the dust to which these workers were exposed. The absence of radiographic evidence of silicosis (1/1 or above 1/0 according to the International Labour Organization Classification) – despite the moderately high levels of respirable dust and a mean duration of employment of 7.6 years would have suggested that the prevalence of silicosis would have been much higher had the silica concentration been substantial.

As indicated above the small sample size limited the ability of the project to prove exposure-outcome relationships. Nevertheless, an adjusted excess risk was found for the presence of chronic cough and phlegm production with the higher exposure category, although this was not statistically significant. Similarly, an adjusted exposure-related dose-response loss in FEV₁ was seen with increasing years of exposure to dust, although this could have been a finding due to chance alone. The loss in lung function over a 40-year working life is estimated at about 80 ml. This is of marginal clinical significance. The direction and size of these dust-related estimates is supported by findings among other respirable dust exposed workers,²⁴ but much lower than that found among Thai stonecarvers, where an 18 ml loss in FEV₁ was associated with each year of exposure.²⁵

A less unexpected, but nevertheless, striking finding in this study was the strong association of outcomes with past history of doctor-diagnosed TB – this despite the low prevalence (2%). Lung function loss was significant, and the odds ratios for symptoms were high. It is likely that a relationship between exposure to silica and the development of TB existed within this sample, however this was not borne out by our data.

CONCLUSION AND RECOMMENDATIONS

In conclusion, respirable dust is likely to produce adverse outcomes among informal sector stonecrushers. Silicosis was not a substantial problem within this sample, but this needs further assessment.

“A less unexpected . . . finding . . . was the strong association of outcomes with past history of doctor-diagnosed TB – this despite the low prevalence (2%).”

Dust abatement is essential but is problematic in this resource-constrained working environment.

Innovative strategies for dust control need to be considered in this working environment. Because of the highly resource-constrained environment, there are limited options available to these workers. Interventions need to include increasing awareness of dust-related hazards through training programmes, provision of low cost hazard control, such as masks, wetting strategies and administrative controls, such as leaving site during blasting, and delayed returned to site afterwards. However, all of these require financial investment beyond the means of these workers. State intervention is necessary to implement these or any other hazard control strategy. Regular medical surveillance and environmental monitoring must also be provided by the state.

LESSONS LEARNED

- Stonecrushers within the informal sector are likely to experience poor respiratory health.
- Symptoms may be associated with exposure to dusty working environments.
- These workers, because of a lack of resources, may not readily seek health care.
- Informal stonecrushers lack the resources to control the hazards in their working environment.

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