Town and Country Planning Act 1990 – Section 78 Town and County

Planning (Development Management Procedure) (England) Order

2015 Town and Country Planning (Inquiries Procedure) (England) Rules 2002

Summary Proof of Evidence of Dave Langton

for Stop The Quarry Campaign – Rule 6 Party

Impacts of Silicosis Peer Reviewed Literature

Land at Lea Castle Farm, Wolverley Road, Broadwaters, Kidderminster, Worcestershire

Proposed sand and gravel quarry with progressive restoration using site derived and imported inert material to agricultural parkland, public access and nature enhancement

Application reference: 19/000053/CM

Appellant's name: NRS Aggregates Ltd

Appeal reference: APP/E1855/W/22/331009

31 January 2023

Peer reviewed research in the effect of quarry sites on health

Author Qualifications

As a resident that lives within 400m of the proposed new site

I want to open with my firm objection of this proposal. I moved here just over a year ago, and it is likely that where I live doesn't exist on the plans submitted by NRS Aggregates as the housing post dates the reports submitted.

I have a 3-year-old daughter, who will likely be starting at Wolverley Primary School, which is also <800m from this site.

I currently lecture at a local college within Health and Social Care, with a subject specialism in Psychology and Research Methods. I hold a Hons. BSc degree in Forensic Psychology at a 2:1. Although not an expert in environmental science, I am able to extrapolate research findings outside of my field due to my knowledge of peer reviewed research and understanding of data analysis and statistical reports compiled in this research.

I have spent most of my academic career examining research, and from what I have found regarding the effects of quarries on health, I am puzzled to why it would considered when in the image above – you have a quarry on the left side of the road, with its workers requiring PPE – to crossing over the road to Primary School, where children will be learning and playing, with no PPE.

Review of Research on the effects of silicosis

My report is solely based on this empirical research, and not my interpretation of their findings.

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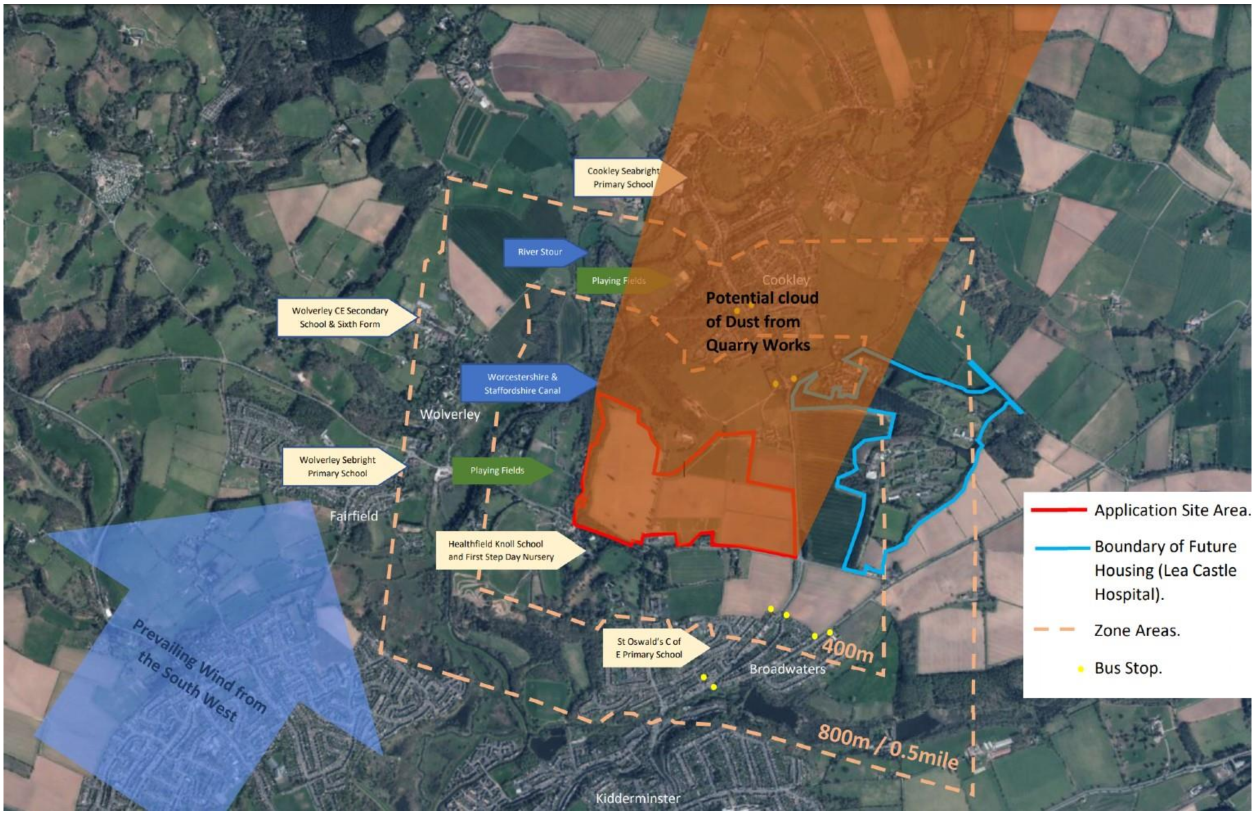


1 A recent study (partly funded by an office of the World Health Organisation) examined lung function and respiratory health of two populations who lived close to a quarry site. The control group lived more than 500m from the site, with the 'exposed' group living less than 500m from the site. Below is a brief outline of these finding. (Source Appendix 1)

2. Lung function parameters were significantly lower among the exposed group compared to the control group; mean forced vital capacity (FVC) was 3.35 L vs. 3.71 L ($p = 0.001$), mean forced expiratory volume in the first second (FEV_1) was 2.78 L vs. 3.17 L ($p = 0.001$). Higher levels of airway restriction were found among the exposed group. Among the exposed group, lung function parameters worsened with the increasing closeness of home to the quarry site. This study demonstrates the negative health effects of environmental dust exposure among two communities living near quarry sites (Nemer, Giacaman and Huesseini, 2020). . (Source Appendix 1)

3. The report highlights something key, ($p = 0.001$). This means that the difference found between both control and exposed group was less than 0.001% due to 'chance'. 0.05 is the benchmark for scientific research, and this is vastly below this.

4. This would be classified as statistically significant, suggesting these differences are unlikely to be simply ‘chance’.

5. Also noted in this research was compounding negative health effects of living close to quarry over an extended period of time (El-Salamoni, Ibrahim and El-Din, 2015). The prevalence of abnormal pulmonary function tests (PFT) was significantly higher (p = 0.025) when comparing those who had access to PPE, compared to those did not (El-Salamoni, Ibrahim and El-Din, 2015). . (Source Appendix 2)

6. Outside of this, researchers questioned the locals about their health, and reported the following:

People who live in close proximity to the quarry sites reported exposure to dust at home (98%), land destruction (85%), plant leaves covered with dust (97%), and an inability to grow crops (92%). The exposed group reported significantly higher eye and nasal allergy (22% vs. 3%), eye soreness (18% vs. 1%), and dryness (17% vs. 3%), chest tightness (9% vs. 1%), and chronic cough (11% vs. 0%) compared to the control group.

This is not the sole piece of empirical research to suggest these findings:

Symptoms And Lung Function Values In Nigerian Men And Women Exposed To Dust Generated From Crushing Of Granite Rocks (Urom, Antai and Osim, 2004). . (Source Appendix 3)

Respirable dust level was higher in the dust-emitting sites (1.087±0.243mg/m^3) than in the control areas (0.099± 0.007 mg/m^3; p <0.001).

All the values of lung function indices except FEV$_1$% were significantly lower in the dust-exposed group than their control group. (p < 0.001 for FEV$_1$, FVC and PEFR) thus, suggesting restrictive lung defect among the exposed individuals. Lung function indices correlated negatively with longer exposure.

The incidence of the major respiratory symptoms viz: unproductive cough, chest pain, catarrh and dyspnoea among the test group were higher (p<0.05-0.001) than in control group.

Environmental Impact Assessment of Quarries and Stone Cutting Industries in Palestine: Case Study of Jammain (Sayara, 2016). . (Source Appendix 4)

Concerning the health situation, the study demonstrated that there is high prevalent rate of diseases caused as a result of these industries and particularly due to air pollution; cough and cold, dyspnoea, inflammation of nasal, Asthma and hearing impairment due to noise pollution were the most prevalent *diseases. Furthermore, these industries cause stress and discomfort to people and affect their homes as different degrees of crack are developed due to vibrations.*

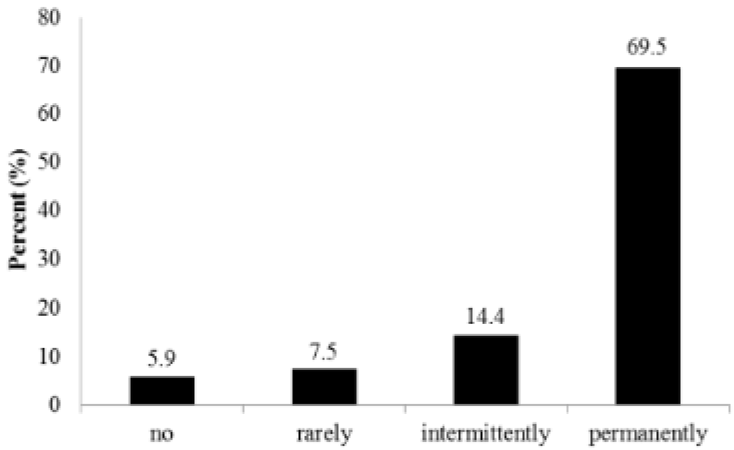


Figure 2. Percentage of respondents about the presence of dust in the air.

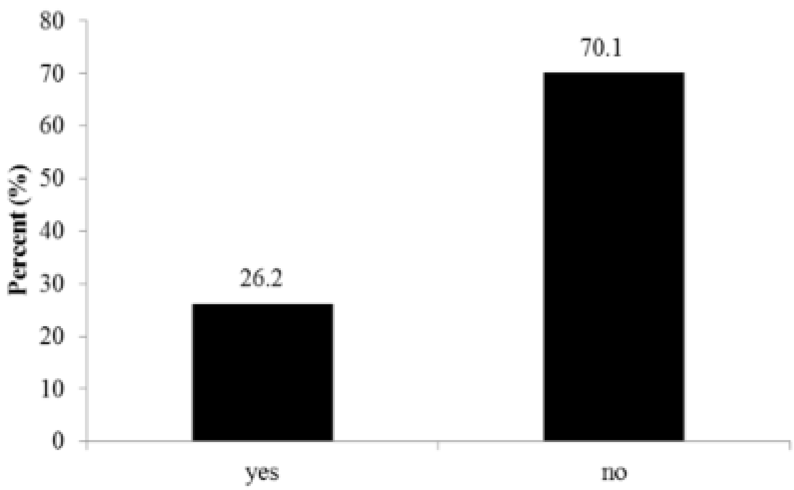
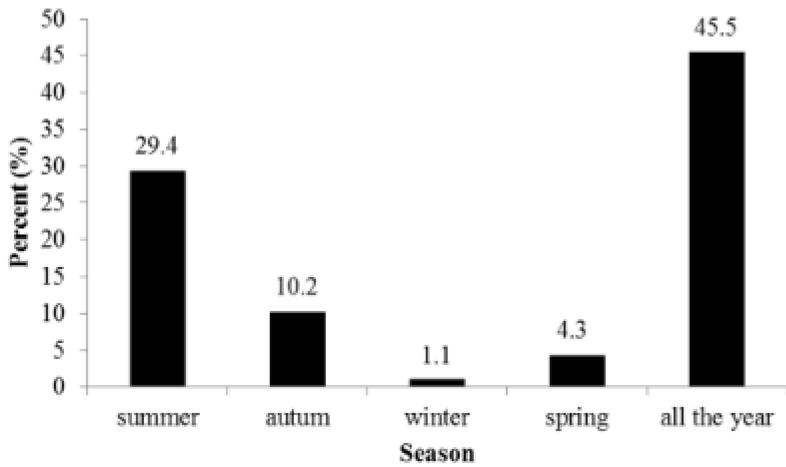


Figure 3. Percentage of respondents if dust is limited to working hours.



The produced particulate matter remains suspended in the atmosphere, and even some of them are deposited (dry deposition), they are mostly re-suspended due to wind, trucks movement and human activities in general.

It was clear throughout the study that quarries and stone industries have adverse impact on the environment and human health. The most impact is attributed to the generated particulate matter (dust) as a result of the different activities associated with these industries. High concentrations of different particulate matter were found in the study area, and this was reflected and confirmed by residents in the surrounding as most of the respondents (70%) confirmed that air is permanently dusty, and the conditions are not limited to working hours, where higher effects are normally noticed in summer season. Also, the study showed that these industries have negative impact on water resources, and about 68% of the respondents confirmed that groundwater in polluted as a result of these industries and their wastes. Concerning the health situation, the study demonstrated that there is high prevalent rate of diseases caused as a result of these industries and particularly due to air pollution; cough and cold, dyspnoea, inflammation of nasal, Asthma and hearing impairment due to noise pollution were the most prevalent diseases. Therefore, and according to the aforementioned findings, an environmental management and mitigation solutions should be considered for sustainable utilization of these resources without harming the environment and humans.

Clinical Conditions Associated with Environmental Exposures: an Epidemiologic Study in Two Communities in Juana Díaz, Puerto Rico (Calo et al., 2009) . (Source Appendix 5)

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Residents of Guayabal were more likely to have bronchitis (adjusted POR=5.5; p-value<0.05), nasal allergies (adjusted POR=4.2; p-value=0.01), nasal congestion (adjusted POR=2.9; p-value=0.02), and nausea and vomiting (adjusted POR=8.7; p-value<0.01). This was for a site in close proximity of a quarry.

This study provides statistical evidence for the design of an analytical epidemiologic study aimed at evaluating the potential effect of quarrying on adverse health outcomes in the community of Guayabal.

Non-occupational exposure to silica dust (Bhagia, 2012). . (Source Appendix 6)

Studies from India found silicosis and other respiratory inflammatory diseases among close populations to stone mining.

7. Although there is arguably much more research out there, in my time conducted this literature review, I could find no evidence that quarrying did not have 'some' impact on the local community, as highlighted by the research above.

This included:

- Silicosis and other respiratory inflammation diseases.
- Reduced lung function.
- Increased allergens affecting eyes, chest and chronic coughing.
- Respirable dust levels were higher in these communities.
- The longer the exposure, the greater the risk.
- Negative effects of quarrying were not solely limited to working hours.
- Particulates remained suspended in the air, and could be re-suspended by wind, traffic and human movements.

The most considerable of these being Silicosis.

"Silicosis is a long-term lung disease caused by inhaling large amounts of crystalline silica dust, usually over many years.

Silica is a substance naturally found in certain types of stone, rock, sand and clay. Working with these materials can create a very fine dust that can be easily inhaled.

Once inside the lungs, it causes swelling (inflammation) and gradually leads to areas of hardened and scarred lung tissue (fibrosis). Lung tissue that's scarred in this way doesn't function properly.

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People who work in the following industries are particularly at risk (abbreviated):

- *mining and quarrying*

Treating silicosis

There's no cure for silicosis because the lung damage can't be reversed. Treatment aims to relieve symptoms and improve quality of life.

The condition may continue to get worse, leading to further lung damage and serious disability, although this may happen very slowly over many years." (NHS, 2021) . (Source Appendix 7)

The danger of this is highlighted in a recent (August 2022) study where accelerated silicosis was found in a woman, who was asymptomatic, employed for 4 years and the first case of this condition at a rhyodacite and rhyolite quarry (Leong et al., 2022). . (Source Appendix 8)

The condition itself is difficult to predict, as mentioned via the NHS, it can take years to manifest. As highlighted within the recent study by Leong et al. (2022), may remain asymptomatic before symptoms reveal themselves.

In another study, 19 out of 79 works were diagnosed with silicosis, one of these had only worked at the quarry for 1 year, with the average length of service of 8 years (Mittal and Gupta, 2017). . (Source Appendix 9)

A longitudinal study over 12 years also highlighted the risk of silicosis and its link to premature death, which was even found within children. More than 25% of silicosis cases are those that are exposed to dusty industries at an early age (Hatman et al., 2021). . (Source Appendix 10)

I would once again highlight the image at the start of this, a roads breadth separates a quarry site from a Primary School.

Fortunately, a Labour MP has acknowledged the risks associated with quarrying. A private member's bill launched by MP Matt Western is at its 2nd reading in parliament (UK Parliament, 2022). . (Source Appendix 11)

"A Bill to introduce a presumption in planning decision-making against approving quarry development in close proximity to settlements; to require the risks of proposed quarrying sites to health and the environment, including through silica dust, to be assessed as part of the planning process; to make provision about the use of quarries for waste disposal; and for connected purposes."

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Although a private member's bill, success has been echoed in legislation such as protecting children and young people, as seen in a similar private member's bill (Sunbeds (Regulation) Act 2010) that prevented children and young people accessing these.

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Appendix 10 - Altundaş Hatman, E., Acar Karagül, D., Kuman Oyman, E., Tüzün, B., Şimşek, K. O., & Kılıçaslan, Z. (2021). Premature Deaths Due to Silicosis in Turkey, 2006-2017: A Twelve-Year Longitudinal Study. *Balkan Medical Journal*, *38*(6), 374–381.

Appendix 11 - UK Parliament (2022) *Quarries (Planning) Bill*. Available at: https://bills.parliament.uk/bills/3080 [Accessed: 20/11/2022]

Appendix 1

Lung Function and Respiratory Health of Populations Living Close to Quarry Sites in Palestine: A Cross-Sectional Study

by Maysaa Nemer *, Rita Giacaman and Abdullatif Husseini

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Int. J. Environ. Res. Public Health **2020**, *17*(17), 6068; https://doi.org/10.3390/ijerph17176068

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(This article belongs to the Special Issue New Challenges and Crucial Topics for 2030 Public Health)

Abstract

Table of Contents

Environmental exposure to dust from quarrying activities could pose health dangers to the population living nearby. This study aimed to investigate the health effects of dust exposure on people living close to quarry sites and compared them with those who live far from the quarry sites. A cross-sectional comparative study was conducted among 79 exposed participants, who lived less than 500 m away from the quarry sites, and 79 control participants who lived more than 500 m away. All participants answered a questionnaire on dust exposure at home and health effects, as well as performed a lung function test in which both reported and measured health effects were investigated. People who live in close proximity to the quarry sites reported exposure to dust at home (98%), land destruction (85%), plant leaves covered with dust (97%), and an inability to grow crops (92%). The exposed group reported significantly higher eye and nasal allergy (22% vs. 3%), eye soreness (18% vs. 1%), and dryness (17% vs. 3%), chest tightness (9% vs. 1%), and chronic cough (11% vs. 0%) compared to the control group. Lung function parameters were significantly lower among the exposed group compared to the control group; mean forced vital capacity (FVC) was 3.35 L vs. 3.71 L (p = 0.001), mean forced expiratory volume in the first second (FEV_1) was 2.78 L vs. 3.17 L (p = 0.001). Higher levels of airway restriction were found among the exposed group. Among the exposed group, lung function parameters worsened with the increasing closeness of home to the quarry site. This study demonstrates the negative health effects of environmental dust exposure among two communities living near quarry sites in Palestine. The results highlight the importance of developing and strictly enforcing rules and regulations in Palestine to protect population health.

Keywords: environmental exposure; quarry dust; respiratory disease; lung function tests; Palestine

1. Introduction

The stone and marble industry is one of the most important and active industrial sectors in Palestine and contributes to about 25% of Palestine's overall industrial revenues and 4.5% of the total Palestinian Gross National Product [1]. The total number of stone and marble facilities in the West Bank and Gaza Strip is 1124. These vary between quarries, factories, and cutting workshops [2]. Stone quarrying is a multistage process by which rock is extracted from the ground and crushed to produce aggregate, which is then screened into desired sizes for immediate use or for further processing to manufacture secondary products [2].

Despite economic importance, the stone industry has a serious negative impact on the environment at both of its types of sites: quarries and cutting workshops. The rock extraction process in quarries is the main source of dust as well as other problems, including noise, vibration, and land disturbance [3,4]. Quarrying poses a danger to workers due to injuries caused by rocks falling on the workers, accidents during the use of machinery, and dust exposure, which is the main cause of respiratory and pulmonary problems, in addition to eye problems [5,6,7].

Dust exposure in quarries and its health impact on workers has been investigated and reported both internationally and in Palestine. Several epidemiological studies worldwide suggested an association between respiratory impairment and occupational exposure to dust [8]. A high prevalence of silicosis, asthma, and adverse respiratory symptoms like cough, chest pain, and dyspnea have been reported among workers engaged in quarrying [7,9,10]. Considerable lung function impairments have been reported in quarry workers [11,12]. Studies of stone cutting workers in Palestine showed that the workers suffered from several respiratory symptoms including chronic cough, sputum production, recurrent rhinitis and shortness of breath, and had a significant deterioration in lung function [5,6].

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Solid materials in the form of smoke, dust, and vapor generated during quarrying can usually suspend over a long distance in the air, and particulate matter in the air is transported from the generation point to other far areas [13]. If the quarries are located in places where there is a living population, people living in the area will also be exposed to dust. Environmental exposure to dust has been raised as an important issue to consider among populations living close to quarries in different areas around the world [13,14]. Previous studies found that people residing close to quarry sites have a higher prevalence of respiratory symptoms compared to those not exposed to quarry dust [15]. Specific reported adverse health effects by people who reside nearby quarry sites include nasal infection, cough, and asthma [13,16]. Additionally, a study investigated how the ecosystem and residents were possibly affected by nearby quarry activity found out that the frequency of certain symptoms such as cough, sneezing, and asthma, and illnesses have increased after quarry activities in the area began [17].

Exposure to quarry dust has been associated with deterioration in lung function among the quarry or mining workers [18,19,20]. Previous studies have shown that quarry and stone cutting workers had lower forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), and FVC/FEV_1 compared to unexposed control groups, in China [21], Libya [19], and Palestine [5,6]. Only one study from Nigeria has investigated lung function among a mixed group of workers and residents who live near quarry sites compared to a control group, which found lower lung function parameters among the workers and nearby residents compared to the control group [22].

In Palestine, there was only one study that investigated the overall environmental impacts of stone quarry work in Jammain village located in the north of the West Bank. This study found high concentrations of dust particles in the surrounding area of quarry sites, and a high prevalence of reported symptoms among the nearby population, including cough, dyspnea, nasal inflammation, as well as hearing impairment. Asthma was also reported among approximately 30% of the respondents. Approximately 75% of the declared sample reported that they suffered from noise pollution as a result of quarry activities [23].

Although previous research, in Palestine and worldwide, showed that populations living near quarry sites are exposed to dust and suffer from adverse health effects, no previous research has measured the lung function of such populations in comparison with those who live far away from quarry sites. Therefore, this study aimed to investigate the health effects of dust exposure on people living close to quarry sites and compare them with those who live far from the quarry sites in Birzeit, a town community located in the central West Bank.

2. Methods

2.1. Study Design, Site, and Population

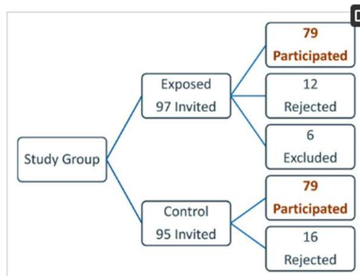
A cross-sectional comparative study was conducted between September 2019 and January 2020. The study was conducted in Birzeit, a Palestinian town in the Ramallah Governorate located 7.5 km north of Ramallah City. It has about 7000 inhabitants [24]. The study population consisted of two groups: the exposed group, which included household members who live in houses next to quarry sites by 0–500 m, and the control group, which included household members living in the same town, whose houses are more than 500 m away from the quarry sites. It has been found that, at a distance of more than 500 m, the concentration of suspended particulate matter is significantly reduced [23], which will, therefore, reduce the dust exposure. Thus, the houses of the control group members were located in areas that are more than 500 m away from the quarry sites.

2.2. Study Sample

According to the information collected from the Birzeit Municipality, there is a total of three main quarrying and stone cutting sites in Birzeit town. We selected a random sample of around 100 household members who live near each quarry site within a circle of 500 m diameter (exposed group), and a random sample of around 100 household members who live at more than 500 m away from the quarry site, i.e., populations out of the 500 m radius were selected (control group). The three available quarry sites inside the boundaries of Birzeit town were located on the community map (Q1, Q2, Q3). A circle with the quarry at the center and a radius of 500 m was drawn around each quarry site. All the houses within the area of the circle were included in the exposed group. All the houses outside the area of the circle were included in the control group. The houses were randomly selected from each group until we reached the needed number of houses from each group (30–40 houses) depending on the number of people available in each house.

Inclusion criteria were considered to be all household members who have been living in the house for at least one year, and are 18 years old or above. Exclusion criteria included: any household member who has lived for less than a year in the house, and who is below the age of 18 years.

A total of 192 participants were invited to participate. Of those, 158 agreed to participate, 28 refused to participate, and six have lived in the house for less than a year, thus excluded from the study. Three participants refused to perform the lung function test. This made the total number of participants 158: 79 living in households close to the quarry sites (exposed group), and 79 away from them (control group) (Figure 1).



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The number of participants who came from the same household ranged from 1–3 participants, with only one household that included three participants, 31 households included two participants each, and the rest of the participants, 93, each came from one household. Having more than one observation from the same household, as in our case, might raise the issue of clustering, as we will have two levels: the participants (level 1), and the household (level 2), known as naturally occurring clusters. However, as we have a large number of clusters (households), with a very small number of participants in each cluster, a situation known as "sparsely clustered data" [25], we have not used a multi-level model for analysis [25,26].

2.3. Questionnaire

The questionnaire was administered face to face and included demographic and socioeconomic information (age, sex, level of education, type of work), smoking habits and history, location of the house from the quarry site (distance), frequency of dust exposure, years of living in the area, the year when the quarry was established nearby, general health conditions, specific respiratory symptoms (used to detect asthma and chronic obstructive pulmonary disease (COPD), and adapted from an internationally standardized respiratory questionnaire) [27], allergic symptoms, eye and nose symptoms, and auditory symptoms related to noise exposure.

2.4. Lung Function Test (Spirometry)

Lung function tests (spirometry) have been widely used to detect deterioration in the respiratory function among occupational and non-occupational groups exposed to dust [19,22,28,29,30]. The main lung function parameters are forced vital capacity (FVC) and forced expiratory volume in the first second (FEV_1) [31,32]. Normal spirometry means that all measured parameters (FVC, FEV_1, and FEV_1/FVC) are 80% or higher of the expected values compared to their sex, age, height, weight, smoking, and ethnicity [32,33,34]. An obstructive pattern means that FEV_1 is lower than 80% of the predicted value, FVC is reduced but to a lesser extent than the FEV_1, and the ratio is also reduced to a lower than 0.7 [32,33]. A restrictive pattern means that both FEV_1 and FVC are reduced to lower than 80% of the predicted value, and the ratio is normal (above 0.7) [32,33].

Lung function tests were performed by a trained researcher using a portable Spirometer (MicroLab, Vyaire Medical GmbH, Germany). Measurements were carried out according to standard protocols of the American Thoracic Society (ATS) guidelines [31]. Participants were given enough time to understand the test procedure and provide the required flows. During the test, participants were seated, with the lips firmly applied around the disposable mouthpiece and using a nose clip. Three reproducible attempts were allowed for each participant, and the best flow was automatically selected by the spirometer.

2.5. Data Collection

The data collection was conducted by two fieldworkers, who visited the houses, invited the inhabitants to participate, and explained the aim and the process of participation in the study. The fieldwork was conducted in the period from September 2019 to January 2020. After taking informed written consent, the participants were interviewed and asked the questions of the questionnaire and then asked to perform the lung function test.

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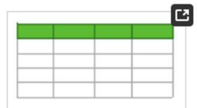
2.6. Statistical Analysis

Descriptive statistics were performed to compare results between the two groups to make sure that they are comparable in terms of demographic and socioeconomic factors. Means and standard deviations were used to present continuous variables, and frequencies were used to present dichotomous variables. Our outcome variables were specific respiratory symptoms, asthma, nasal and eye infections, and lung function parameters (FEV_1, FVC, and the FEV_1/FVC ratio). Data on dust exposure at home, environmental effects of quarry activities on the residents, and air pollution from quarry activities were analyzed for the exposed group separately. Comparisons between the two study groups were performed by an independent t-test for continuous variables, χ^2 test for dichotomous variables, and linear regression was used when comparing the lung function parameters between the two groups, to adjust for sex, age, height, weight, and smoking between them, factors that are known to affect the lung function results. All statistical analyses were performed using the SPSS V.24.0 software for Windows. All *p* values were two-sided, and a *p*-value < 0.05 was considered significant.

3. Results

There were variations in the exposed and control groups by sex (39 men vs. 8 men and 40 women vs. 71 women, respectively), mean age (37 years vs. 32 years, respectively), smoking status (12 smokers vs. 2 smokers, respectively), and employment status (28 unemployed vs. 47, respectively). These two groups were similar in the mean number of years of education (Table 1). None of the participants is a quarry or stone cutting worker.

Table 1. General characteristics of the two study groups.



3.1. Environmental Effects of Quarrying Activities on the Population Living Nearby

The mean distance between the houses of the exposed group and the quarry sites was 247.2 m, with a range of 50–500 m. The residents in this group have lived in the area for 9.98 years on average, with a range of 3–33 years. The main environmental effects of the quarrying activities which were reported by the exposed group included land destruction (85%) which means a change in the features of the land and the landscape, inability to grow crops in the surrounding area (92%), and that there is need for land restoration (87%). Only 33% of respondents reported that there were heaps of waste and holes filled with water around the quarry sites, and 8% reported that the farmlands around the quarry sites were filled with water coming from the quarry work. The residents reported that the landscape has changed over the past ten years due to the quarrying activities in the area. Table 2 shows that 67% described the landscape to be vegetative or green 10 years ago, while 20% described it to be vegetative at the time of the study. Additionally, 11% described the landscape to be bare 10 years ago, while 51% described it to be bare at the time of the study.

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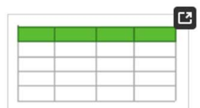
Table 2. Landscape as described by the population living close to the quarry sites (*n* = 79).



One of the most adverse effects of quarrying activities, as described by the residents, was dust. Almost all the participants (98%) reported that dust settles on their house roofing, surfaces, and clothing at home; 97% reported that the leaves of plants and crops around the house are covered with dust, and 96% reported that plants do not grow well when the dust covers their leaves. On the effects of dust on vision, only 20% of the participants reported that dust prevents them from seeing things a distance away. Figure 2 shows that most participants reported that the main source of dust in their area was the quarry activity and that the dust movement increased during sunny and dry weather. In addition, they reported that vehicles that transport quarry products produce more dust in the area. Participants also reported that quarrying activities are the main source of noise in the area (75%), but few reported that this had affected their hearing (14%). Almost all the participants reported that there are no vibration effects of the quarrying activities, with only one participant reported that quarrying caused cracks of their building due to vibration. Figure 3 includes a picture of one exposed and another unexposed community at Birzeit Town, showing the effects of dust on the exposed community on the nearby houses and the green areas, compared to the unexposed community with more green areas and less amount of dust.

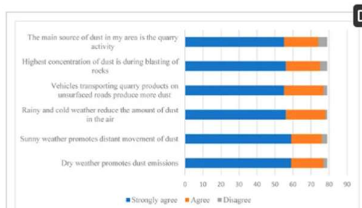


Figure 2. Dust and air pollution from quarry activities as described by the population close to the quarry sites (*n* = 79).

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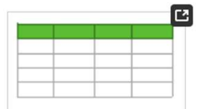
Figure 3. Pictures of exposed and unexposed communities at Birzeit Town.

3.2. Reported Symptoms and Diseases

The exposed group reported more rhinitis (13% vs. 3%), eye or nasal allergy (22% vs. 3%), and irritant eye symptoms including tearing (19% vs. 1%), soreness (18% vs. 1%), and dryness of the eye (17% vs. 3%) compared to the control group, Table 3. Asthma and bronchitis were reported by two participants in the exposed group and none in the control group. For the respiratory symptoms, chest tightness, shortness of breath and chronic cough were significantly higher among the exposed group compared to the control group; 9% vs. 1%, 25% vs. 1%, and 11% vs. 0%, respectively, Table 3.

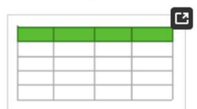
Table 3. Self-reported prevalence of general respiratory symptoms and diseases among the two study groups.



3.3. Lung Function

The mean values of lung function parameters for the exposed group were lower than those for the control group. When the two groups were compared using a linear regression model, adjusting for sex, age, height, weight, and smoking, the exposed group had significantly lower values of FEV_1, FVC, and FEV_1/FVC compared with the control group, Table 4.

Table 4. Means and adjusted differences in lung function parameters between the two study groups.



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Normal spirometry (normal FVC, FEV_1, and FEV_1/FVC ratio) was found among 43 exposed participants compared with 71 control participants. Only one exposed participant showed mild obstruction (low FEV_1, normal FVC, low ratio), and one showed moderate obstruction (very low FEV_1, normal FVC, very low ratio). Mild restriction (low FVC, normal FEV_1, and normal ratio) was found among 15 exposed compared to 7 control participants. Moderate restriction (low FVC, low FEV_1, and normal ratio) was found among 13 exposed compared to one control participant. Severe restriction (very low FVC, low FEV_1, and normal ratio) was found among the three exposed participants. The participants in the exposed group differed in lung function parameters according to the distance from the quarry site. The closer to the quarry site, the lower FVC, and FEV_1 they had, Figure 4.

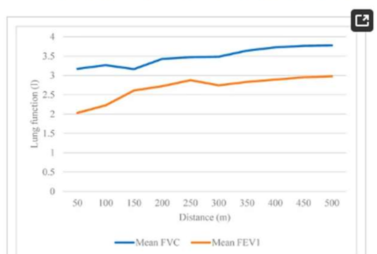

Figure 4. Lung function parameters among the exposed group according to the distance from the quarry site.

3.4. Mitigation Measures as Agreed by the Participants

Participants in the two groups were asked about the most important measures for mitigation of adverse effects of the quarrying activities on the environment and the living populations. The main measures agreed on were: establishing barriers around the quarry sites, water should be used when cutting and on the road when transporting the quarry products to decrease the amount of dust, developers should not place residential areas close to quarrying zones, a license should not be given to quarries close to residential places, and violators of rules and regulations should be prosecuted.

4. Discussion

This study showed that the population living in close proximity (50–500 m) to quarry sites in Birzeit town are exposed to dust in their households, with 69% reporting that the main source of dust in their area was the quarry activities, and with the dust increasing in dry and sunny weather. Our study confirms what was reported in a case study in another Palestinian village in the north of the West Bank, Jammain village, where 70% of the living populations in the area close to the quarry sites were suffering from the dusty environment with dust increasing during the summer season [23]. Additionally, in a study in Hebron, a southern West Bank Palestinian city, it has been reported that the quarrying and stone cutting activities have an adverse impact on the environment and populations, mainly affecting air quality, surface, and groundwater, and contaminating agricultural soil [35]. Our study participants also reported that quarrying activities caused land destruction and the inability to grow crops. Other studies in the region found similar results. A case study conducted in Jordan found that stone cutting activities were a main source of contamination of the water and soil in the area, as well as being a main source of noise level [4].

This study also showed that people who live close to quarry sites (exposed group) reported significantly higher respiratory, eye and nasal symptoms compared to people who live far from the quarry sites (control group). Our results indicate that living in close proximity to quarry sites, which is a main source of dust, is a potential factor for increasing the prevalence of eye and respiratory symptoms. It has been found that dust is one of the most invasive and potentially irritating sources for the eyes and respiratory system [14,15,36]. Research has shown that dust concentration, deposition rates, and potential impacts tend to decrease rapidly away from the dust source [3,23]. This explains why our control participants, who live more than 500 m away from the quarry sites, have reported significantly lower symptoms. The study from Jammain village has shown that the main reported health effects among the populations living close to the quarry sites were nasal inflammation, cough, and hearing impairment [23]. Although several studies in Palestine and the region have investigated the environmental effects of the quarrying activities in terms of water, air, and soil pollution, there is a limited number of studies that investigated the health effects among the populations who live nearby. Studies from India found silicosis and other respiratory inflammatory diseases among close populations to stone mining [14], while a study conducted in Puerto Rico found an elevated prevalence of bronchitis and nasal allergy among the communities who live close to quarry sites compared to others who live far from them [15].

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who live far from them [15].

Lung function parameters were significantly lower for the exposed group compared with the control group, even after adjustment for sex, age, height, weight, and smoking. The lung function parameters showed that 43 out of the 76 exposed participants had normal spirometry, while almost all of the control participants (71 out of 79) had normal spirometry. Obstructive lung function impairment was found among two out of the 76 exposed participants, while restrictive impairment was found among 31 out of the 76 exposed participants. Among the control participants, none showed obstruction, and eight out of 79 showed restriction. Patterns of lung function among people exposed to dust have been mostly reported as obstruction or a combination of obstruction and restriction [28,37,38]. The obstructive pattern indicates a disease caused by the airway to be narrowed or blocked, making it difficult to exhale the air completely, as in asthma and COPD, while restrictive pattern indicates a disorder that makes it difficult to fill the lung completely with air because of interstitial lung problem such as lung fibrosis [39]. Two studies in Palestine which measured lung function for quarry workers found a combination of both obstruction and restriction [5,6]. One of those studies found more restriction among the ones with longer years of exposure [6]. Research studies indicated that the chemical content of the stone could be the main cause of respiratory diseases, such as silica, which was found to be a main causing agent of obstructive and restrictive lung diseases [11,37]. The analysis of the stone from quarries in Palestine has shown that it is mainly composed of calcium carbonate ($CaCO_3$) from mining limestone, as well as silicon dioxide (SiO_2), also known as silica or quartz [40,41]. Studies found that dust particles, which disperse in the air and are easily inhaled, decrease as it travels to long-distance [13,14]. This explains our findings among the exposed group, which showed that the lung function parameters are lower among the participants who live closer to the quarry sites.

Chronic exposure to dust has been shown to cause deterioration in lung function among several groups of working populations [42,43,44]. Several studies worldwide, including Palestine, have shown that quarry workers had lower lung function than unexposed control groups, and it was lower among the workers with longer duration of work in quarries [6,9,19,21,30,45]. Lower lung function parameters than the expected values generally indicate the possibility of chronic respiratory and lung disease [32]. As the exposed group showed lower lung function parameters than the control group, indicating that people living close to the quarry sites have a stronger possibility of developing lung disease. Previous studies that measured the lung function of people exposed to dust were only conducted among quarry or mining workers [9,11,19,20,30]. Only one study, conducted in Nigeria, assessed lung function among a mixed group of workers and residents who live near quarry sites compared to a control group [22]. The Nigerian study's findings, although including a mixture of workers and residents, were similar to ours, as it found that workers and exposed residents had lower lung function parameters than the unexposed control group [22].

The size class and concentration of the particulate matter released from the quarrying activities in the environment have an effect on the type and extent of the adverse respiratory health effects [46]. Coarse particles larger than 10 micrometers in diameter are usually filtered in the nose and throat, thus not causing significant health problems, while fine particles (1–10 micrometers), as in quarry dust particles may have larger adverse health effects as they can reach the bronchi and cause bronchitis [46,47,48], as reported by some of the exposed participants. Very small particles of less than one micrometer could reach the alveoli [49]. This is also reflected in the lung function impairment since particles of 1–10 micrometers are known to cause more restrictive lung function impairment compared to those smaller than one micrometer, which will result in a more obstructive pattern [50,51].

compared to those smaller than one micrometer, which will result in a more obstructive pattern [30,31].

As far as the authors are aware, this is the first study that investigated both reported and measured respiratory effects of environmental exposure to quarry dust among living populations in Palestine. Using both reported and measured health outcomes helped to understand the extent of the health effects and to reduce recall bias. Additionally, having a control group of the unexposed population, who lived far from the quarry sites but in the same town, helped to compare the health conditions as a result of close quarry dust exposure. However, this study has some limitations. First, the sample distribution that we had resulted in significant differences between the two groups of participants in sex, age, and smoking could have a direct effect on the compared health effects, especially lung function. The reason why the exposed group included a larger number of men than the control group is likely due to the availability of men at the house at the time of the interviews since most of the control group participants were employees, while the exposed group were workers in small workshops with more flexible time and availability at home. Additionally, the control group had a larger number of women, who were mostly unemployed and staying at home most of the time. This also explains the low number of smokers in the control group which constitutes the largest number of women among the participants, who were mostly non-smokers. To reduce the effect of these differences, they were adjusted for in the analysis when comparing lung function. Another limitation of the study is the lack of quantitative sampling of the dust using environmental samplers, which could have added a very important angle of the investigation, in terms of the concentration of the particulate matter and the size class of them. As it is known that the health effects of dust exposure depend on these factors.

5. Conclusions

The present study has investigated the environmental effects of quarrying activities on the populations living nearby and compared the respiratory health status of those populations with a control group of the population who lives at more than 500 m away from quarry sites. To the best of our knowledge, this is the first study in Palestine that assessed both reported and measured respiratory health effects among people living close to quarry sites. The study showed that the population that lives close to quarrying activities is exposed to a harmful amount of dust, as they reported having more respiratory and eye symptoms, and had increased levels of lung function impairment as compared with the unexposed population at the same town. The results of the study highlight the importance of developing and strictly enforcing rules and regulations in Palestine to protect population health, especially those related to the locations of quarries and the need to establish a system inside the quarry locations to reduce the amount of emitted dust in the surrounding environment.

Author Contributions

Conceptualization: M.N., A.H., and R.G.; data curation: M.N.; formal analysis: M.N.; investigation: M.N.; methodology: M.N., A.H., and R.G.; writing—original draft: M.N.; writing—review and editing: R.G. and A.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare there are no conflicts of interest.

Ethics Approval

Ethical approval was obtained from the Institute of Community and Public Health's Research Ethics Committee at Birzeit University, and the World Health Organization's Research Ethics Review Committee. All participants gave written informed consent.

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Appendix 2

Pulmonary Problems among Stone Cutting Workers in West Bank-Palestine

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Pulmonary Problems among Stone Cutting Workers in West Bank-Palestine

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Abstract

Introduction: Respiratory problem is one of the major health hazards in dust-exposed workers; it is a major cause of morbidity and mortality all over the world.

Objectives: To determine the prevalence of respiratory problems and lung function impairment (PFI) among Palestinian stone cutting workers, and to investigate its association with work conditions and other risk factors.

Method: During April-June 2012, a cross-sectional study was conducted among 259 male workers, who were available at all stone-saw workshops (n=42) located around the valley between Nablus and Tulkarm in the northern part of West Bank, Palestine. Respiratory problems and lung function were studied through interviews questionnaire, detailed history, clinical examination and spirometry.

Results: The respondents were all males, with mean age of 36.8 years and with 13.4 years mean duration of current work. Complaints of chronic cough, chest pain and wheezes were present among 28.2%, 17.8% and 3.8% of workers respectively. The prevalence of abnormal pulmonary function test among workers was 21.6%, with 20.1% of workers had restrictive lung disease and 1.5% showing obstructive lung disease. Multivariate regression, showed that smokers, longer duration of work, and PPE non users have higher risk for developing abnormal pulmonary function test (OR 4.5; CI: 1.01-20.2; p=0.049), (OR 2.1; CI: 1.03-4.5; p=0.04) and (OR 2.1; CI; 1.04-4.5; p=0.03) respectively.

Conclusion: Chronic exposure to dust in stone cutting Industry may increase the risk of respiratory problems and impaired lung function; cigarette smokers, long duration of work and non usage of Personal Protective Equipments (PPE) are at higher risk.

Key Words: *Stone cutting – Respiratory problem – Pulmonary function test – Palestine.*

Introduction

OCCUPATIONAL exposure to dust is a well-known phenomenon, especially in developing countries [1,2]. Although sources of air pollutants include power plants, cement factories, refineries and petrochemical industries, the emission of particulates is quite high from quarries [3].

Stone cutters process crude stone into masses and blocks (by cutting, shaping, breaking, processing, polishing, removal of sections, etc.) into desirable sizes, patterns and degrees of finishing; this is done by using manual and mechanical work tools, for the purpose of building, decorating, creation of statues and similar goals. Hazards at stone cutting workshops include pneumoconiosis due to exposure to mineral dust and silicosis as a result of prolonged exposure to dust containing free silica [4].

Inhalable dust is produced when the stone is cut and by the breaking of the stones on the quarry floor during the transit of the vehicles. The bench and block cutting is wet, with minimal exposure to fine dust when assisting the cutting. Nevertheless, when the mud dries on the quarry floor, workers are exposed to the inhalation of dust raised by the wind and the transit of the vehicles. The dust, in the case of stone, contains quartz which can cause silicosis, depending on the amount of quartz actually present in the dust and the diameter of free silica particles [5].

The health impacts of working in stone quarrying industry have been well documented [6,7]. For instance, numerous epidemiological studies have supported the association between respiratory impairment and occupational exposure to dust [6].

Also, high prevalence of silicosis has been reported among workers engaged in quarrying shale sedimentary rock in India. According to Urom, et al., [8] the major respiratory symptoms

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among quarry workers include non-productive cough, chest pain, catarrh and dyspnea. Considerable pulmonary function impairments have been reported in quarry workers [9,10].

In a study by Ghotkar, et al., [11] the prevalence of respiratory morbidity among stone quarry workers was 32.5%, based on radiological study; the severity of pulmonary function impairment was significantly associated with increasing age, duration of exposure to dust, smoking status and presence of chronic obstructive airways disease on radiological study. It was shown that dusts generated from granite quarrying contain 71% silica [12,13]. The occupationally related lung diseases are most likely due to the deposition of dust in the lung and are influenced by the type of dusts, the period of expo-sure, the concentration and the size of the airborne dust in the breathing zone [14].

Palestinian workers in stone cutting workshops are at higher risk of occupational diseases due to the lack of awareness of safety rules and their enforcement. So, it is essential to understand the health related risks associated with stone cutting, particularly in developing countries as Palestine, where there is often a lack of legislation governing the environmental performance of quarrying corporations.

There is also scarcity of research and data about occupational health problems among quarrying workers in Palestine. To our knowledge, no similar studies have been done.

The output of this research will be an approach to improve our knowledge about occupational health in Palestine and will have implications for developing and implementing health and safety interventions and policies within stone industry and for developing new guidelines for health and safety of stone industry workers. It will also be useful for quarrying managers, policy makers, contractors and employees on greater understanding of the personal and environmental factors that influence workers health and will form a base for further research and training in the field of occupational health and safety in the future.

This work aims to determine the prevalence of respiratory problems, and impairment of lung function among stone cutting workers, and to identify the risk factors associated with it. The oveall objective is the promotion of Occupational Health in Palestine through improvement of work conditions of quarrying workers (stone saws) to prevent work-related health problems.

Material and Methods

Study design:

This is a cross-sectional study with analytical component among stone-cutting Palestinian workers.

Study setting:

There are approximately 244 stone-cutting workshops, in which more than 1500 male workers work, in the West Bank and Gaza. Workshops are found primarily in the Hebron, Nablus, Jenin, Taulkarem and Ramallah areas, with less concentration in Gaza. The current study was done in 42 stone-cutting worshops (of all 244, mentioned previously) located around the valley between Nablus and Taulkarem areas in the nothern part of West Bank. These 42 worshops constitute a non random sample of all stone cutting workershops in West Bank; they share the same geographic, climatic and socioeconomic conditions and they are using the same instruments and machines. These workshops consist mainly of iron roofed warehouses and hangars in relatively open areas to ensure the largest volume of ventilation.

Study population and study sample:

All workers in the selected 42 workshops were recruited in the study. They were 259 male workers distributed as 153 (59.1%) workers are working inside the cutting workshops and 106 (40.9%) are working around the cutting workshop as managerial, aiders, clerks and others. The workers have many different tasks; some are directly work inside with the main cutting machine, others involved in manual stone hand polishing and pilling, and many of them are involved in many stages of production process. Workshops are generally open from 7:30 am to 17:00pm, six days a week.

Study period:

The study was conducted during the period from 1st of April to 30th of June 2012. Selected April to June months because it is a season when a maximum number of workers are usually available at workplace because of increased demand for stones during next summer season as more raw material are needed for buildings construction locally and abroad.

Tool of the study:

1- All available workers were personally interviewed using self formulated questionnaires which collected data about socio demographic characterstics, full occupational history, working conditions/environment, and health related complaints.

2- Medical examination of workers including chest clinical examination.

3- *Pulmonary function test (spirometry):* A portable computerized Spiro-meter was used. The device belongs to the Ministry of Health (Occupational Health Department). Spirometry was performed by trained researcher using a spirometer (Spirovit SP-1, Schiller America, Doral, FL) and following standard procedures (ATS, 1995; Enright et al., 1991) **[30,31]**. Prior to spirometry, participants underwent weight and height measurements. The test procedure was explained to the subjects and a demonstration of the test procedure was given. The subjects were allowed to sit quietly for 10 minutes to become mentally and physically relaxed prior to testing. The best forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were recorded and the FEV_1/FVC ratio was calculated. Results were automatically printed according to Diagnostic criteria: By spirometry results: A- Normal (free), B- Impairment of lung function: 1- Restrictive, 2- Obstructive, 3- Combined.

Data management and analysis:

Data were entered and analyzed using the Statistical Package for Social Science (SPSS 21). Continuous variables are expressed as mean and Standard Deviation. Categorical variables are expressed as frequencies and percents. Chi square was used to examine the relationship between Categorical variables. Multivariate logistic Regression was used for studying independent factors affecting the occurrence of lung impairment.

Ethical considerations:

No harmful interventions and the tests are accepted by the workers and labor union official approval from the Palestinian ministries of health and labor obtained. The workers were given a short oral introduction in Arabic about the research and its objective. They were informed that their data is confidential and it won't affect their work performance. None of the workers withdraw at any point of the research.

Results

This cross sectional study aims to investigate respiratory health problems of stone cutting workers and risk factors associated with pulmonary function impairment. It was conducted during the period from 1st of April to 30th of June 2012.

The present study shows that 81.9% of the studied participants were older than 25 years, and 18.1% were aged 25 years and less. The mean age was 36.85±11.41 years. All participants were males, and 79.2% of them were married. About 51.4% were urban residents and 48.6% were rural residents. A minority of workers had university education (13.9%). About 60.2% were currently cigarette smokers. As regard chest complaints, 28.2%, 17.8% and 3.8% of workers reported chronic cough, chest pain and wheezes respectively. Spirometry revealed that 21.6% of participants had abnormal (impaired) lung function test. The vast majority of cases with impaired lung function were restrictive (20.1%), and only 1.5% of workers were obstructive.

Table (2) shows that 59.1% were directly involved with machines inside the workshop, while 40.1% were less involved, being in managerial jobs as for example. The mean duration of work experience of the studied participants was 13±9.1 years with the work duration ranging from a minimum of 1 year to a maximum of 40 years. One third (33.6%) of participants were involved in working more than 8 hours daily. Only slightly more than one third (35.9%) of the participants reported that they used Personal Protective Equipments (PPE) most of the time, while 64.1% reported that they sometimes used PPE.

Table (3) illustrates the relation between different risk factors and abnormal pulmonary function among workers; there was no significant difference between workers with different age groups as regard Pulmonary Function Test (PFT) as 24.%, 21.2%, 18.7% and 25.4% of workers <25 years, 25-34 years, 25-34 years and >45 years had abnormal PFT respectively. (p=0.806). The current study demonstrates that there is statistically significant association between smoking and abnormal PFT, as 26.9% of smokers had Abnormal PFT, and on the other hand, 13.6% of non smokers had abnormal PFT (p=0.011).

As regards work place characteristics, 18.9% of workers inside the stone cutting firm had abnormal PFT compared to 23.5% of those working outside and this difference is statistically non significant (p=0.370). However, a significant increase in percentage of workers with abnormal PFT was found with the increase of duration of exposure, as 16.1%, 20.9% and 36% of workers with exposure duration ≤10yrs, 11-20yrs and >21 years had abnormal PFT respectively (p=0.016).

The prevalence of abnormal PFT among those who sometimes/rarely use PPE was significantly higher (p=0.025) than that among always/most of the time using it (25.9% Vs 14%).

After adjusting to all factors using backward logistic regression, it is shown in (Table 4) that smoking, longer duration of work, and PPE usage are independent factors affecting PFT, as smokers, workers with longer duration of work, and non users of PPE have higher risk for developing abnormal PFT (OR 4.5; CI: 1.01-20.2; *p*=0.049), (OR 2.1; CI: 1.03-4.5; *p*=0.04) and (OR 2.1; CI; 1.04-4.5; *p*= 0.03) respectively.

Table (1): Description of personal and medical characteristic of the participants.

Socio-demographic characteristics	Number	Percent (%)
Age group (in years):		
Less than 25	47	18.1
25-34	66	25.5
35-44	75	29.0
45+	71	27.4
Age (mean ± SD)	36.85±11.41	
Residence:		
Urban	133	51.4%
Rural	126	48.6%
Marital status:		
Single	53	20.5
Married	205	79.2
Divorced	1	0.4
Education:		
School level	223	86.1
University level	36	13.9
Smoking status:		
Current smoker	156	60.2
Current non-smoker	103	39.8
Complaints of chronic cough:		
Yes	73	28.2
Complains of chest pain:		
Yes	46	17.8
Complaints of wheezes:		
Yes	10	3.8
Lung functions:		
Normal spirometery	203	78.4
Abnormal spirometry	56	21.6
Detailed lung functions:		
Normal spirometery	203	78.4
Restrictive	52	20.1
Obstructive	4	1.5

Table (2): Description of occupational history and working conditions.

Type of work and working conditions	Number	Percent (%)
Type of work:		
Manual worker inside the workshop	153	59.1
Management (clerk)/other	106	40.9
Duration of work:		
≤10yrs	118	45.6
11-20yrs	91	35.1
>21yrs	50	19.3
Duration of work in years (Mean ± SD)	13±9.1	
Work more than 8 hours daily:		
Yes	87	33.6
No	172	66.4
Using PPE:		
Most of the time	93	35.9
Sometimes	166	64.1

Table (3): Association of abnormal PFT with the personal and work characteristics of the participants.

Personal and work characteristics	Normal PFT		Abnormal PFT		*p*-value
	N	%	N	%	
Age group:					
<25 years	37	78.7	10	21.3	0.806
25-34 years	52	78.8	14	21.2	
35-44 years	61	81.3	14	18.7	
45+ years	53	74.6	18	25.4	
Residence:					
Urban	100	75.2	33	24.8	0.20
Village	103	81.7	23	18.3	
Education:					
School level	174	78.0	49	22.0	0.732
University and higher	29	80.6	7	19.4	
Smoking:					
Smoker	114	73.1	42	26.9	0.011**
Non smoker	89	86.4	14	13.6	
Type of work:					
Worker inside	86	81.1	20	18.9	0.370
Management/others	117	76.5	36	23.5	
Duration of work:					
≤10yrs	99	83.9	19	16.1	0.016**
11-20yrs	72	79.1	19	20.9	
>21yrs	32	64.0	18	36.0	
Working hours:					
>8 hours	66	75.9	21	24.1	0.484
8 hours	137	79.7	35	20.3	
PPE:					
Always/most of the time	80	86.0	13	14.0	0.025**
Sometimes	123	74.1	43	25.9	

*: Chi-square test. **: Significant.

Table (4): Multivariate logistic regression to study independent factors associated with abnormal PFT.

	Adjusted OR	95% C.I. for adjusted OR		*p*	Sig
		Lower	Upper		
Smokers	4.516	1.861	10.202	0.028	S
Duration of work	2.181	1.235	4.595	0.036	S
Using PPE (none)	2.178	1.041	4.554	0.039	S

*: Logistic regression.

Discussion

According to the available studies and literature, the stone and marble sector is considered to be one of the most significant and most active industries in Palestine. This sector contributes approximately 5% to Palestine's overall industrial income **[15]**. Various procedures and operations are involved in this work including stone cutting, loading and crushing. Based on these operations, the workers are employed at different places as per the nature of work and are exposed to dust of different concentrations.

The stone-quarry manual workers are exposed to dust from the rocks they cut; especially during saw-cutting and finishing, theses dust contain silica dust [16] which may lead to pulmonary problems (silicosis). Silicosis appears after prolonged exposure to silica dust. Besides, it depends upon a number of other factors such as size of the particle; concentration of silica particles in the air, duration of exposure, particle surface characteristics including the age of the particle and the concentration of trace metals such as iron [17].

The present study was, therefore, designed to evaluate the respiratory effects (lung function) of occupational exposure to dust in stone cutter workers. The objectives of this study were to study the deterioration of pulmonary function in stone cutter workers and its relation with different personal and work factors.

In the current study more than 70% of the participants were working on a full-time basis (8 hours daily), with 30% of cases working more than 8 hours a day indicating that the workers are at a high risk of exposure to the respirable quarry dust. Moreover, only 13.9% of the respondents had higher level education, suggesting a low level of awareness of the respondents about the health impact of the respirable quarry dust.

The current study showed a relatively low prevalence of respiratory complains of cough (28.2%), chest pain (17.8%) and wheezes (3.8%) when compared with result of previous study conducted in Iran which reported irritating cough in 75% of the respondents [18], also in Nigerian study among quarry workers reported high prevalence of respiratory problems; the most common problems were occasional chest pain (47.6%), occasional cough (40.7%) [19]. On the contrary, our results are similar to another study conducted in Rio De Janeiro, Brazil [20] that reported cough in 31.9% of workers.

The current study showed that 21.6% of participants had abnormal (impaired) lung function test by spirometer with the vast majority of cases (20.1%) had restrictive lung disease (Table 1) which mostly indicated presence of silicosis. This figure is higher than that estimated by Mathur (1996), who reported that about 10% of sand stone quarry workers suffered from silicosis [21].

Among all 259 participants-workers, 153 (59%) of the participants were working inside the site of stone cutting; more exposed to dust and 106 (41%) were mostly workers outside the cutting site but they are close to working area; indicating that inside workers are at a higher risk of exposure to the respirable stone cutting dust. In spite of this, we found no significant difference between workers inside and outside as regard prevalence of pulmonary problem (Table 3). These results are in disagreement with data reported by Subhashini and Satchidhanandam, (2002), who found that all functional values were lower in workers than in controls [22]. This was insignificant effect could be explained by the fact that inside and outside workers shared the same environment with almost equal level of exposures.

Smoking has been demonstrated in this study to be a significant contributing factor in reduction of ventilatory function, as 24.5% of smokers had abnormal PFT, while only 17.3% of non smokers had abnormal PF (Table 3). This agree with a study conducted in Nigeria that reported a significant reduction in lung functions among smokers [23] results of previous studies have also concurred that decline in lung function values is significantly higher among individuals with both silica and tobacco exposure than in those with either one [24,25], however in contrast to this result, Ghotkar, et al., (1995) found no significant difference between mean values of pulmonary function indices of non-smoker and smoker male workers [11].

The current study showed an increase in percentage of workers with abnormal PFT among workers with longer duration of exposure, as 18.6%, 20.9% and 30% of workers with exposure duration ≤10yrs, 11-20yrs and >21 years had abnormal PFT respectively (Table 3). Similarly, Singh et al., (2006) noticed that defects in lung ventilation were significantly related to the duration of exposure more than 20 years [26]. This observation was also in agreement with data reported by Urom et al., (2004), who found that the lung function indices correlated negatively with duration of employment [27]. Moreover, Singh et al., (2007) found that exposure duration and exposure concentrations are the main factors responsible for the reduction in forced vital capacity of lungs, and damage the respiratory tract of quarry workers [28]. Furthermore, CH Kiran et al., (2014) reported that the % reduction of pulmonary function values was positively correlated with duration of their work [29].

It was found that those who wear PPE more regularly had lesser percentage of pulmonary restriction compared to those who rarely use, which emphasizes the importance of PPE in decreasing respiratory problem among quarry workers. This agree with Nigerian study that reported lack of PPE usage in the quarry industrial site as one of the causes for the high prevalence of some of the respiratory problems reported in this study [19].

In this study, there was no statistical significant difference between workers with abnormal PFT and those with normal PFT as regard age, residence, and level of education. (Table 3). This was similar to Nwibo et al., (2012) study among quarry worker who reported no association between age and pulmonary function **[19]**.

To study independent factors affecting development of impaired PFT among stone saw workers, a backward logistic regression model was performed to adjust for confounding factors (Table 4). It revealed that the smoking, longer duration of work, and non usage of PPE are independent factors affecting PFT, as smokers, workers working more than 20 years illness, and non users of PPE have higher risk for developing abnormal PFT (OR 4.5; CI: 1.01-20.2; p=0.049), (OR 2.1; CI: 1.03-4.5; p=0.04) and (OR 2.1; CI; 1.04-4.5; p=0.03) respectively.

Conclusion and recommendation:

Data from the present study suggest that chronic exposure to hazards from cutting of rocks may increase susceptibility to respiratory problems and impaired lung function with cigarette smoking, not usage of PPE and increased length of service as additional predisposing risk factors.

Suggested mitigating measures include provision of safety measures (e.g., face mask), discouraging workers from tobacco/cigarette smoking through public health education, frequent assessment of lung functions and redeployment of workers with severely reduced lung functions to other less hazardous occupations, and above all, provision of legislative instrument by the government making establishment of stone saw workshop without adequate provision of necessary safety measures a punishable offence.

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الملخص العربى

مقدمة: تعتبرالمشاكل التنفسية من المخاطر الصحية عند العمال الذين يتعرضون للغبار، حيث يتاثر العمال بالعديد من المخاطر الصحية وبالاصابة من امراض مهنية متعددة فى جميع انحاء العالم.

الأهداف: الغرض من هذه الدراسة هو تحديد مدى انتشار المشاكل التنفسية وكفاءة الرئة ذات الصلة بالعمل بين العاملين فى ورش مناشير الحجر الفلسطينية، وربطها ظروف العمل وعوامل الخطر بهذه النتائج.

المنهجية: خلال الفترة من بداية ابريل الى نهاية يونيو ٢٠١٢، أجريت دراسة مقطعية تحليلية شملت ٢٥٩ من العمال الذكور، الذين كانوا متوفرين فى كل ورش منشار الحجر (العدد = ٤٢)، والتى تقع حول الوادى بين نابلس وطولكرم فى شمال الضفة الغربية– فلسطين، حيث تم تقييمهم من خلال مقابلات بإستخدام استبيان معد خصيصا، مع التاريخ المرضى والمهنى المفصل وكذلك الفحص السريرى الذى احتوى على قياس كفائة الرئه.

النتائج: كان جميع العمال من الذكور، وكان متوسط الفئة العمرية ٣٦.٨٥ سنة، ومتوسط مدة الخدمة ١٣.٣٦ سنة. وقد شكى ٢٨.٢٪ من سعال مزمن و١٧.٨٪ الام فى الصدر و٣.٨٪ من صفير فى الصدر. وكان معدل انتشار ضعف كفائة الرئة ٢١.٦٪ و٢٠.١٪ من العمال يعانون من مرض محدد للرئة. وقد تم التعرف على العلاقة ذات الدلالة ($p<$٠.٠٥) من التحليل متعدد المتغيرات بين ضعف كفاءة الرئة والمتغيرات من نوع العمل، التدخين، مدة العمل، عدم استخدام معدات الحماية الشخصية، والتدخين والإقامة.

الخلاصة: التعرض المزمن للغبار فى صناعة مناشير الحجر يمكن ان يزيد خطر الاصابة من المشاكل التتفسية وضعف كفاءة الرئة. العمال الذين يدخنون السجاير، ويقضون فترة اطول فى العمل ولا يستعملون وسائل الحماية الشخصية يعتبرون فى خطر اكثر من غيرهم.

Appendix 3

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SYMPTOMS AND LUNG FUNCTION VALUES IN NIGERIAN MEN AND WOMEN EXPOSED TO DUST GENERATED FROM CRUSHING OF GRANITE ROCKS IN CALABAR, NIGERIA.

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Summary: *This study was carried out to determine lung function and respiratory and non-respiratory symptoms among men and women exposed to dust emitted from crushing of granite rocks and to compare them with control men and women not exposed to any known air pollutant. The sites were the granite rock crushing industries in old Netim, Akamkpa Local Government Area of Cross River State, Nigeria. Respirable dust level was higher in the dust-emitting sites (1.087±0.243mg/m^3) than in the control areas (0.099±0.007 mg/m^3; p <0.001). The mean anthropometric parameters (age, body weight and height) between the two groups were not significantly different. However, all the values of lung function indices except FEV$_1$% were significantly lower in the dust-exposed group than their control group. (p < 0.001 for FEV$_1$, FVC and PEFR) thus, suggesting restrictive lung defect among the exposed workers. Lung function indices correlated negatively with duration of service of the granite industry workers. The incidence of the major respiratory symptoms viz: unproductive cough, chest pain, catarrh and dyspnoea among the test group were higher (p<0.05-0.001) than in control group. Among the presenting non-respiratory symptoms, headache and night sweat were more common in the dust-exposed group than the control subjects (p<0.001). Chronic exposure to dust generated from crushing of granite rocks impairs lung function and causes some respiratory and non-respiratory symptoms in men and women. Length of service was a predisposing risk factor.*

Key Words: *Lung function, Granite, Dust, Symptoms*

Introduction

Every year, there are 50 million cases of occupational respiratory diseases caused by inhalation of toxic dust and chemicals, which are allergenic and carcinogenic agents. (19) A lot of dust and gases are generated in rock crushing and mining industries. Precautionary measures against inhalation of dust at the rock crushing sites are generally poor or non-existent owing to lack of resources by the management of the industries and ignorance of the rock crushers. The granite rock crushing companies in Old Netim, Akamkpa, Cross River State of Nigeria generates a lot of dust in its vicinity hence, chronically exposing the workers to the granite dust. Some dusty occupations impair lung function, and cause pneumoconiosis (Osim et al, 1996; Wang et al, 1997; Kampalath et al, 1998). Unfortunately, our knowledge about what dusts and chemicals cause disease and how, is imprecise (Ellenhorn and Barcelloux, 1998). Furthermore, explosives used for rock blasting are emulsion explosives (EMEX) or ammonium nitrate fuel oil (ANFO) mixed with poisonous gases e.g carbon-monoxide, carbon-dioxide, nitrous fumes and ammonia which are reported to damage the respiratory system and impair lung function (Sawa et al, 1981; Douglas et al, 1989; Raphael et al, 1989). There are few reports on the effect of exposure to granite dust in exposed workers in several parts of the world (Ng et al, 1992; Melmberg et al, 1993; Graham et al, 1994; Eisen et al, 1995). There are however, no reports on Africans concerning the effects of granite dust on the health of exposed workers. Respiratory and other associated symptoms other than carcinogenic effects have not been reported. Therefore, the aim of the study was to determine the lung function status as well as respiratory and other associated symptoms of Nigerian men and women chronically exposed to dust generated from the granite rock crushing industries in Old Netim in Akamkpa local government area of Cross River State of Nigeria.

Materials and Methods

Subjects

The subjects comprised test and control groups. The test group comprised 344 men and 27 women who were exposed to dust generated from crushing of granite rocks in Old Netim, Akamkpa, Cross River State of Nigeria. Their duration of exposure to dust ranged from 4 months (0.33 year) to 20 years. Fourteen percent of the males were either cigarette smokers or past smokers while none of the females was a cigarette smoker. The control group comprised of 216 men and 111 women who were not exposed to any known air pollutant. Fifteen percent of the males were either active cigarette smokers or past smokers. None of the control females was a cigarette smoker. The anthropometric parameters, viz; age, height and body weight of the test and control groups were similar. Their smoking habit was also similar. Forced vital capacity (FVC), Forced expiratory volume in one second (FEV_1), FEV_1 as a percentage of FVC (FEV_1%) and Peak expiratory flow rate (PEFR) were used to assess lung function. A vitalograph spirometer (Vitalograph Limited, Buckingham, England) was used to measure FVC and FEV_1, while FEV_1% was computed. A mini-Wright peak flow meter (Airmed Clement Clark International Ltd, England) was used to measure PEFR. The dust-exposed workers namely: company workers, tipper drivers, middlemen and villagers were exposed to dust for about 8 hours daily for five days each week since the company operated for 8 hours everyday and five days a week.

Test Procedure

The subjects were called in groups and instructed to the test procedures after which the procedures were demonstrated to them for better understanding. A questionnaire was completed after which the tests were performed on the subjects individually. The questionnaire recorded; names, smoking habit, and history of respiratory (pulmonary) and non-respiratory diseases, while height without shoes and weight with light clothing were measured and recorded.

Dust Sampling

The concentration of respirable dust in both test and control sites was measured using a gravimetric dust sampler manufactured by the Department of Physics, University of Calabar, Nigeria. The instrument measured the concentration of respirable dust as it maintains a constant supply of air at a rate of 2 litres per minute through its filter for 4 hours. The Respirable dust was sampled in four control and four test sites and their means were calculated.

Comparisons Performed

From the forced expiratory spirograms, comparisons between ventilatory function indices (FVC, FEV, FEV_1% and PEFR) were done for dust exposed subjects and their controls. The incidence (%) of respiratory and other symptoms in the dust levels in test sites were compared. The mean concentrations of respirable dust levels in test and control sites were also compared.

Statistical Analysis

The student's unpaired t-test was employed in the comparison of ventilatory function indices and dust levels in the control and test environments. Chi square-test was used to test for significance between percentages Data are presented as mean and standard error of the mean (SEM). A P-value of <0.05 was considered as significant.

Results

The anthropometric parameters and ventilatory functions indices of adult male and females in control sites and those in dusty were compared. There were no statistically significant differences in the mean anthropometric values between the two group. On the other hand, the ventilatory functions indices FEV_1, FEC and PEFR in the control group were significantly higher ($p<0.001$) than in the dust-exposed (test) group. However, in both males and females, there was no significant difference ($p>0.05$) in the value of FEV_1% between the control and test subjects (Tables 1 and 2).

Table 1: Comparison of mean values of anthropometric parameters (age, height and weight) and ventilatory function indices (FVC, FEV1, FEV1% and PEFR) of adult males in control sites with those industries

Parameters	Control (N = 216)	Test (N = 344)	p-value
Age (yrs)	33.29±0.56	32.45±0.43	NS
Height (m)	1.74±0.01	1.76±0.04	NS
Weight (kg)	67.17±0.71	67.69±0.50	NS
FVC (L)	3.90±0.08	3.49±0.05	***
FEV_1 (L)	3.10±0.07	2.73±0.05	***
FEV_1%	78.25±0.80	77.34±0.67	NS
PEFR (L/min)	569.36±5.91	508.71±4.64	***

*NS = Not statistically significant, *** = p<0.001*

Table 2: comparison of mean values of anthropometric parameters (age, height and weight) and ventilatory function indices (FVC, FEV1, FEV1% and PEFR) of adult females in control sites with those industries

Parameters	Control (N = 111)	Test (N = 27)	p-value
Age (yrs)	28.79±0.61	27.96±1.13	NS
Height (m)	1.65±0.01	1.67±0.01	NS
Weight (kg)	65.48±1.26	64.8±2.26	NS
FVC (L)	2.70±0.07	2.18±0.09	***
FEV_1 (L)	2.14±0.06	1.72±0.09	***
FEV_1%	79.71±0.99	77.28±2.79	NS
PEFR (L/min)	345.53±6.68	308.81±12.37	***

*NS = Not statistically significant, *** = p<0.01*

The duration of service of male subjects in the granite-dust generating industries correlated negatively with lung function indices. FEV_1, FVC and PEFR showed a significant negative correlation (p<0.0) with duration of service in males, while FEV_1% versus length of service was not significant (figures 1, 2 and 3). Among the females, only PEFR showed a significant negative correlation (p<0.001) with the duration of service (Figure 4).

Comparison of respiratory symptoms observed among the dust-exposed and control groups shows that the incidence of unproductive (dry) cough, chest pain, catarrh and dyspnoea were also significantly higher in the dust-exposed group than in the controls (p<0.05 – 0.001). However, the incidence of productive cough and sneezing were similar in the two groups (P<0.05) (Table 3).

The non-respiratory symptoms studied revealed significantly higher incidences of headache and night-sweat in the dust-exposed group than in their controls (p<0.001, respectively), (Table 4). However, weight loss and fever were not significantly different in the two groups of subjects.

The mean concentration of atmospheric dust level in the vicinity of the granite rock crushing industries was 1.087±0.242mg/m^3 which was significantly higher than in the control sites – 0.099±0.007mg/m^3 (p<0.001).

Table 3: Comparison of respiratory symptoms observed among control and dust exposed subjects

Respiratory Symptoms	Dust-Exposed Subjects Incidence in % (N = 371)	Control Subjects Incidence in % (N = 327)	Level of Significance
Cough			
Dry	7.28	3.24	***
Productive	15.09	14.98	NS
Chest pain	8.09	3.98	***
Dyspnoea	2.70	1.53	*
Catarrh	26.95	19.57	**
Sneezing	11.52	8.21	*

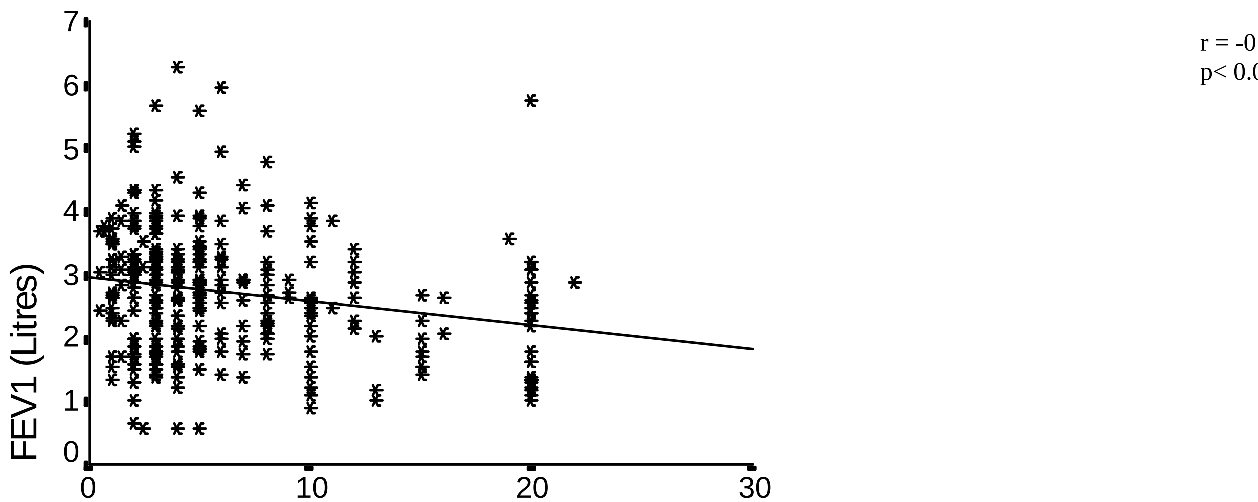
** = p<0.05, ** = p<0.01, *** = p<0.001, NS = Not statistically significant*

Table 4: comparison of respiratory symptoms observed among control and dust exposed subjects

Respiratory Symptoms	Dust-Exposed Subjects Incidence in % (N = 371)	Control Subjects Incidence in % (N = 327)	Level of Significance
Headache	10.51	4.28	***
Weight	1.35	0.92	NS
Night sweat	1.62	0.00	***
Fever	5.93	5.81	NS

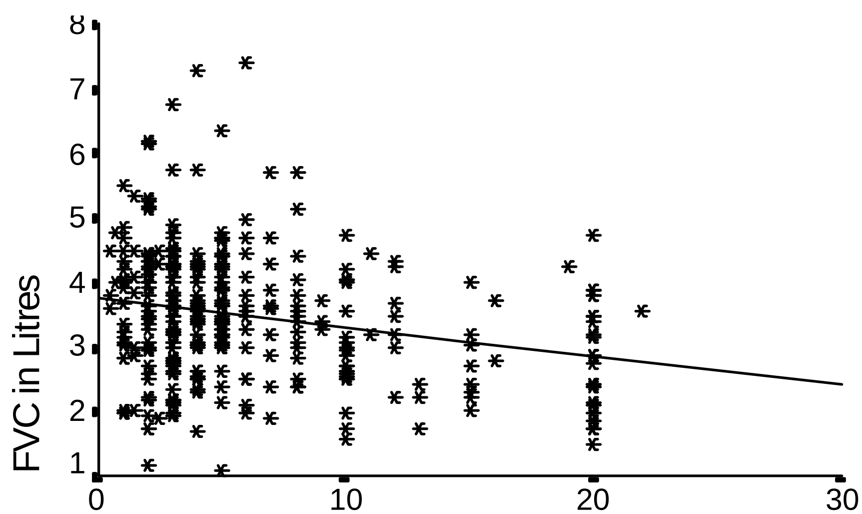
NS = Not statistically significant, *** = p<0.001

Fig. 1 Correlation between duration of service and FEV_1 (Test-males)



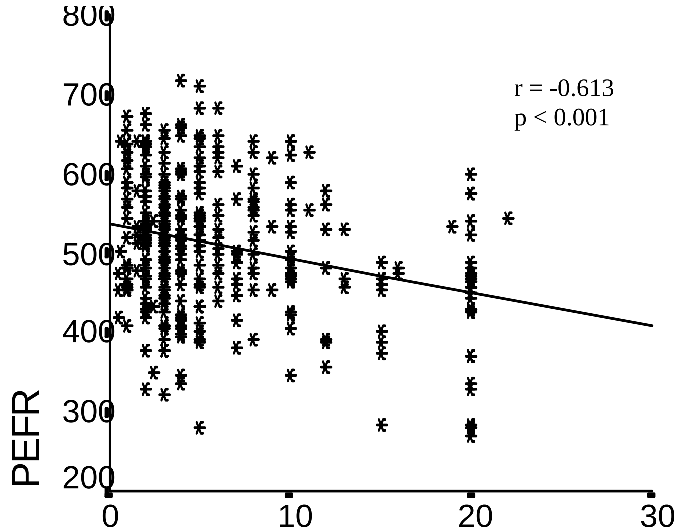
Duration of service (years) males exposed to granite dust

FIG. 2 Correlation between duration of service and FVC (L) of males exposed to granite dust



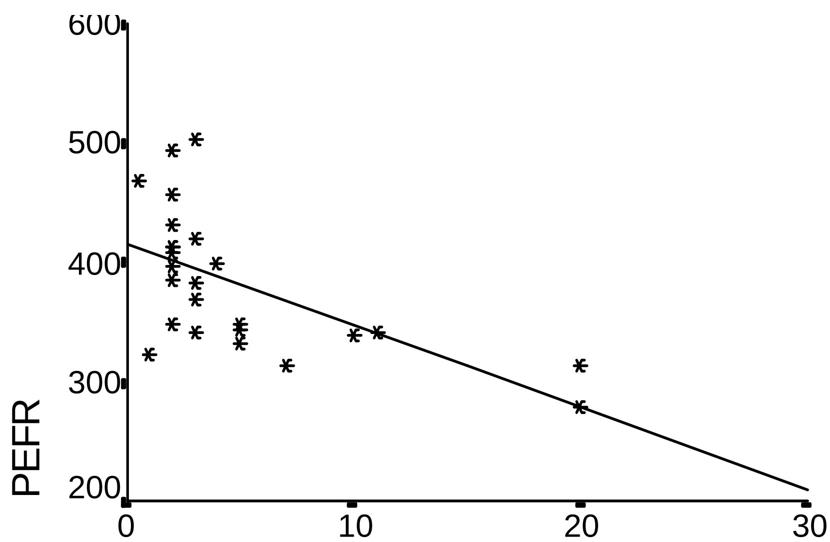
Duration of service (years) of male workers in granite industry

FIG. 3 Correlation between duration of service and PEFR (L/min) of males exposed to granite dust



Duration of service (years) of males exposed to granite dust

FIG. 4 Correlation between duration of service and PEFR (L/min) of females exposed to granite dust



Duration of service (years) of females exposed to granite dust

Discussion

The mean values of ventilatory function indices for the control group obtained in this study were similar to values reported for apparently healthy adult male and female Nigerians (Osim and Esin, 1996). Several investigators have shown that anthropometric parameter have significant relationship with lung function indices (Johnson and Erasmus, 1968; Aderele and Oduwole, 1983; Jaja and Fagbenro 1995). Therefore, it was necessary to ensure that the anthropometric parameters of the two groups (control and test) were similar as was done in this study.

The results obtained in this study showed that mean values of FVC, FEV_1 and PEFR of men and women in the granite industry were significantly lower than the values of those in control sites. FEV_1% was however, not significantly different. These deviations are characteristics of restrictive lung defect (West, 1979). So the subjects living or working in the vicinity of the dust-emitting granite rock-crushing industry in Old Netim in Akamkpa LGA of Cross River State of Nigeria generally showed a restrictive lung function impairment.

Although our results show a significant lowering of lung function values in the dust-exposed subjects compared to their control group, it was not possible to determine all the factors that may be responsible for lung function impairment in the dust-exposed subjects. However, dust sampling in both dusty and control environments suggests that chronic exposure to granite dust may be a factor since the respirable dust level in the dusty environment was very high when compared to the control environment. Granite rocks contain quartz (silica), plagioclase and feldspar (Ekwueme, 1993). Although the relatively high dust level might be a factor, there may be other confounding causative factors. Poisonous gases such as carbon monoxide, carbon dioxide, nitrous fumes and ammonia are emitted from the explosives used in rock blasting which reportedly damage the respiratory system and impair lung function (Raphael *et al*, 1989; Kocks and Scot 1990 and Harre *et al*, 1997). It is therefore possible that poisonous gases contributed to the impairment of lung function of subjects in the dusty environment. Unfortunately, environmental gas levels were measured owing to technical problems.

Correlation tests also showed that the lung function of dust-exposed male and female workers in the industry decreased significantly with increased length of their service. The worsening of lung function with length of service is indicative of the importance of the duration of exposure as one of the major resdisposing factors in the aetiology of lung function impairment among the granite-dust exposed male and female workers studied. The major presenting respiratory symptoms were unproductive cough, chest pain, catarrh and dyspnoea, and these were significantly higher in the dust-exposed subjects than in their controls. As stated earlier, respirable dust level in the vicinities of the granite rock crushing industries was higher than in control sites. Silica in the dust is allergenic and may therefore irritate the respiratory tact leading to unproductive cough and other respiratory symptoms (Ellenhorn and Barcelloux, 1998). Although the results showed significant lowering of lung function values in the dust-exposed subjects when compared to their control, the reduction (10-15%) was not large. The efficiency of the dust-exposed workers was not yet compromised. However, correlation test of duration of service and lung function indices showed that with time lung function impairment will be worse and could be fatal. As there was no radiographic examination, it is not possible to know if pneumoconiosis had set in the dust-exposed workers. Lung function tests are a means of early detection of lung functional impairment even without radiographic signs of the disease (Wright *et al*, 1988). So frequent lung function testing in vicinity of granite rock blasting industry should be enforced and precautionary measures should be introduced in the industry studied. Workers severely affected should be redeployed to other less hazardous areas.

In conclusion, chronic exposure to dust from crushing of granite rock can impair lung function and causes respiratory and other symptoms. Length of exposure is a predisposing risk factor.

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Appendix 4

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Environmental Impact Assessment of Quarries and Stone Cutting Industries in Palestine: Case Study of Jammain

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Abstract

Although quarries and the stone industries represent a significant industrial sector in Palestine in terms of production and exports and thus enhancing the economic situation, these operations have adverse impact on the environment and human health. The present study revealed that particulate matter (dust) produced as a result of the different activities associated with these industries causes several problems to the environment and people living in the area. Measurements of air quality showed that high concentrations of different particulate matter are in the study area. In this regard, the majority of the people (70% of the respondents) confirmed that air is permanently dusty, and the conditions are not limited to working hours, where higher effects are normally noticed in summer season. Also, the study showed that these industries have negative impact on water resources, and about 68% of the respondents confirmed that groundwater in polluted as a result of these industries and their wastes. Concerning the health situation, the study demonstrated that there is high prevalent rate of diseases caused as a result of these industries and particularly due to air pollution; cough and cold, dyspnea, inflammation of nasal, Asthma and hearing impairment due to noise pollution were the most prevalent diseases. Furthermore, these industries cause stress and discomfort to people and affect their homes as different degrees of crack are developed due to vibrations.

Keywords

Quarries, Stone Cutting Industries, AirPollution, WaterPollution, ImpactAssessment

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1. Introduction

Quarrying and stone cutting industry are economically important activities worldwide. In Palestine like other countries, stone and marble industry is a growing and successful industry. The competiveness of Palestinian marble and stone derives from two sources: first, its origin from the Holy Land "Jerusalem Gold Stone" which creates spiritual and symbolic imagery in the minds of much of the world's population, and the second, the variety of colors and textures of the products [1, 2].

The available data about these industries in Palestine estimates that there are approximately more than 300 quarries and 1000 factories and workshops which yield over 100 million tons of raw stone, and approximately 25 million square meters of stone per annum. Accordingly, this implies that Palestine represents approximately 4% of the world's production of stone and marble [1]. Actually, this industry contributes approximately 4.5% to gross national product (GNP) and 5.5% to gross domestic product (GDP). Total investment in the industry is estimated at around $700 million, making it a major employer of Palestinian capital (15-20,000 direct jobs), with greater proportion than any of

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the other major Palestinian industries [1, 2].

Although quarrying and stone cutting industries have a great role in improving the economical situation, these activities are normally associated with environmental and health impacts. In this regard, dust or particulate matter (PM) is the main source of air pollution caused by such industries, where degree of pollution by such source of pollution depends on the local microclimate conditions, the concentration of dust particles in the ambient air, the size of the dust particles and their composition [3]. Concerning the environmental impact, quarries and stone cutting industries cause ecological disturbance, destruction of natural flora, pollution of air, land and water, instability of soil and rock masses, landscape degradation [4]. On the other side and regarding their health impact, dust and emissions resulted from these industries canlead to chronic health effects; for instance decreased lung capacity and lung cancer resulting from long-term exposure to toxic air pollutants [5]. Furthermore, a very high degree of respiratory morbidity is associated with these industries. Fine rock and mineral dust of many kinds have been shown to be carcinogenic when inhaled [6]. Control of particulate pollution is a matter of both health and aesthetics. Increasing attention is being paid to the impacts of dust on human health, as finer particles can be inhaled and breathed into the lungs and cause harm. It is generally recognized that dust up to 10 µm can be inhaled beyond the larynx and dust up to 4 µm can be breathed into the lungs [7]. Potential health impacts are almost exclusively linked to the presence of airborne dusts, in particular respirable particles, i.e. those that are less than 10 µm in diameter (also known as PM_{10}), have the potential to affect human health, including effects on the respiratory and cardio-vascular systems [8]. According to Banez, et al [8], inhalation of dusts can cause "pneumoconiosis" which is a term that refers to a group of lung diseases. The objective of the current research was to assess the impact of quarries and stone cutting industries on the environment, mainly air quality and water pollution. Also, the assessment of their impact on people health within the surrounding area, by determining the main diseases, injuries, death caused by such activities. Furthermore, the study tried to shed light on other impacts associated with these activities like vibration, cracks in home, and noise pollution.

2. Materials and Methods

2.1. The Study Area

In Palestine, there are a large number of quarries and stone cutting industries as mentioned before. To assess their impact on different aspects and sectors, Jammain was select as the study area; it is about 530 m above the sea level and locates in the southern part of Nablus district (about 16km) in the West bank, Palestine, as shown in Fig. (1). It has about 10000 inhabitants. The selected area is one of the most famous areas of quarrying and stone cutting industries. It has more than 60 quarries and 40 stone cutting industries.

Figure 1. Map showing the study area.

2.2. Data Collection and Analysis

Data for assessment process was obtained from primary and secondary sources. Primary data which was collected by questionnaires that have been structured for these objectives. 200 questionnaires were distributed in the field to residents in the target area and some workers in quarries. Also, and in order to have a clear image about the situation, interviews were conducted, this included interviews with people in the area, workers, physician, health centers, and formal interviews with the mayor of Jammain and other opinion leaders in the areas were also contacted for relevant information. Moreover, there were field observations to working sites and other areas to determine the effects of the industry operations.

Secondary data was obtained using 5 channels (PM_1, $PM_{2.5}$, PM_7, PM_{10} and TSP) laser-operated portable OPC, (Aerocet 531, MetOne, USA) for measurement of the particulate matters (dust). It is an automatic instrument that estimates PM in a range of 1, 2. 5, 7 and 10 µm in aerodynamic diameters in mass mode, and $PM \leq 0.5$ and $PM \leq 10$ in count mode. Additionally, a real time measurements of the concentration of hydrogen cyanide (HCN) mg/m^3, ammonia (NH_3) ppm, sulfur dioxide (SO_2) ppm, ozone (O_3) ppm, hydrogen sulfide (H_2S) ppm, carbon monoxide (CO) %, total volatile organic compounds (TVOCS) ppm, carbon dioxide (CO_2) ppm, nitric oxide (nitrogen monoxide) (NO) ppm, nitrogen dioxide (NO_2) ppm, temperature ˚C, relative humidity (%RH), dew point ˚Cand humidity ratio lb/lb were performed with a multi-gas electrochemical gas sensors (TG-501 and TG-502 Direct Sense Tox multi-gas monitor sensors, GraywolfTM Sensing Solutions, USA). The probes were attached in parallel to each other and in series with a trend logging pre-programmed pocket personal computer (PC). The pocket PC was programmed for logging the average data for each 10 minutes interval over all the measuring period. All probes calibration was performed at the supplier company before use.

Three sampling locations were selected; these locations were about 500-700m far from quarries or stone cutting industries. The instruments were placed 2-3m above the ground level, and sampling was conducted for one hour in each location. Also, a location far from working site was selected as a control.

Data analysis was performed using Chi-square tests for significantly difference ($p<0.05$) in Statistical Package for Social Sciences (IBM, SPSS, version 15). Microsoft Excel 2007 (Microsoft Office, 2007) was used for calculation and presentation of figures.

3. Results and Discussion

3.1. Air Quality

Quarries and stone cutting industries activities are normally associated with different types of pollution. Air pollution is regarded as the most notable one, where particulate matter (dust) with diameter 1-75µm are generated and found in the surrounding areas of such activities. Particles with aero-dynamic diameters of less than 50µm (termed Total Suspended Particulate matter, or TSP) can become suspended in the atmosphere, and those with aerodynamic diameters of less than 10µm termed PM_{10} (inhalable particles) can be transported over long distances [9], and enter the human respiratory system [10]. Table 1 demonstrates the concentration of particulate matter during the sampling campaigns.

Table 1. Concentration of Particulate Matter in sampling locations.

Location	Day	PM_1 (mg/m^3)	$PM_{2.5}$ (mg/m^3)	PM_7 (mg/m^3)	PM_{10} (mg/m^3)	TSP (mg/m^3)
Location 1: Albatin	1	0.0045	0.0105	0.2160	0.2335	0.2475
	2	0.0049	0.0454	0.4031	0.6389	0.8759
	3	0.0035	0.0615	0.1795	0.2340	0.2920
	4	0.0013	0.0203	0.1480	0.1973	0.2597
Location 2: Almeqtala	1	0.0015	0.0045	0.0530	0.0580	0.0615
	2	0.0015	0.0105	0.0400	0.0675	0.0980
	3	0.0113	0.1960	1.9087	3.1853	4.3930
	4	0.0023	0.0350	0.6047	1.0080	1.5910
Location 3: AlmarjAlsharqi	1	0.0017	0.0077	0.3520	0.4577	0.5567
	2	0.0073	0.0938	0.7228	0.9310	1.3003
	3	0.0128	0.1453	0.6388	1.0615	1.9793
	4	0.0059	0.0701	0.7921	1.3256	1.8453

As it can be seen in Table 1, the concentrations of the particulate matter in all sampling sites were high as they were selected close to working sites. However, these concentrations are normally decreased with distance as they dispersed, but still they have an impact on human and environment in general. Concerning the gas emissions, the concentrations were very low (data not shown here), and below standard pollution threshold.

About 70% of the respondents (Figure 2) indicated that the air in the targeted area is permanently dusty as a result of quarrying and stone cutting industries. It is worth to mention that not only working in the sites is the only source of dust, but also the movement of trucks from and to these sites produces big amounts of dust and other pollutions resulted from fuel combustion. Furthermore, about 70% of the respondents (Figure 3) confirmed that the effect of the dust is not limited to working hours.

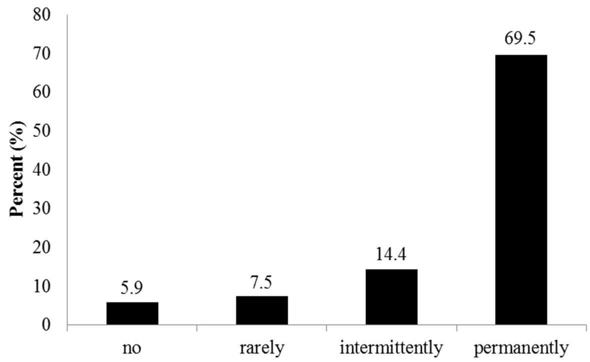

Figure 2. Percentage of respondents about the presence of dust in the air.

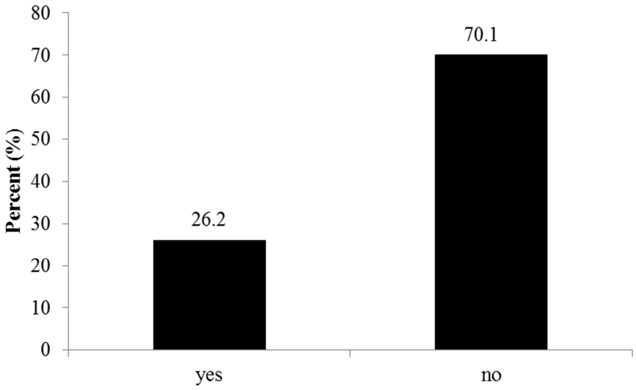

Figure 3. Percentage of respondents if dust is limited to working hours.

The study showed (Figure 4) that the people living within the targeted area suffering from quarries and stone cutting industries almost all the year (45.5% of the respondents) as working in these sites take place throughout the year. However, when comparing the most affected season, summer was the highest one (29.5% of the respondents), which is reasonable as dispersion of dust is highly affect by dominant weather conditions. Indeed, the produced particulate matter remains suspended in the atmosphere, and even some of them are deposited (dry deposition), they are mostly re-suspended due to wind, trucks movement and human activities in general. In winter which is the lowest affected season (1.1% of the respondent), the precipitation helps in sinking these pollutants (wet deposition) and most of the produced dust is wetted and mixed with soil, where another part is transported with runoff, and this reduced its negative impact as demonstrated in Figure 4. These results are in agreement with the results obtained by El-Nashar [11]; such that summer season was the strongest season concerning dust deposition.

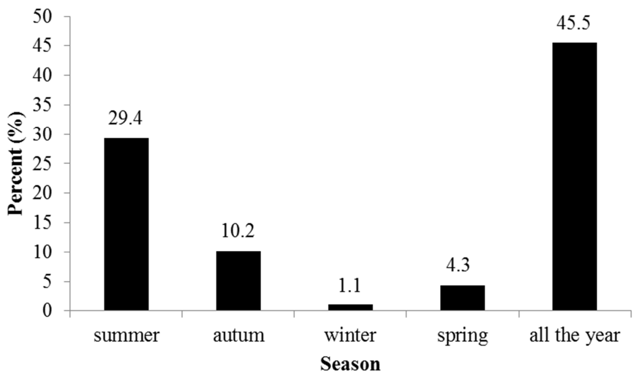

Figure 4. Percentage of respondents about the season that is mostly affected by dust.

3.2. Water Quality and Pollution

Quarries and stone cutting industries operations impact the environment in several ways, and water pollution is a major concern in such operations. For instance quarry dust can change the chemistry of water resources by dissolving in them, it can also settle in water bodies and cause pollution. Furthermore, these operations disrupt the existing movement of surface water and groundwater; they interrupt natural water recharge and can lead to reduced quantity and quality of drinking water for residents and wildlife near or downstream from a quarry site.

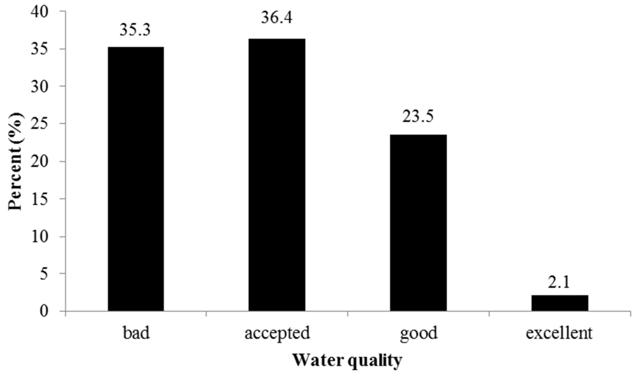

Figure 5. Percentage of respondents about water quality.

According to respondents who answered the question related to water quality, Figure 5 indicates that 36.4% of respondents showed that water quality is accepted as a result of quarrying and stone cutting industries, while 35.3% of respondents indicated that water quality is bad. Also it shows that 23.5% of respondent pointed that a good water quality appear, where 2.1% of respondents showed that water quality is excellent. Accordingly, one can conclude that quarrying and stone cutting affect water quality [12].

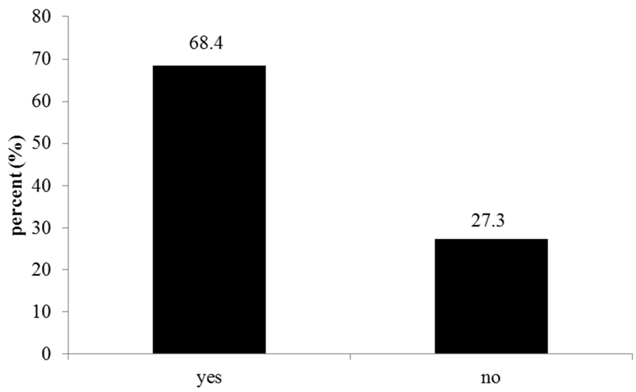

Figure 6. Percentage of respondents about the impact on groundwater.

It is clear from Figure 6 that operations in the quarries and stone cutting industries highly affect groundwater resources, as about 68.4% of the respondents agreed upon such impact. In fact, the removal of top soil and surface rock strata can increase the vulnerability of groundwater to contamination [13]. This is because of the karst characteristics of hard limestone and high infiltration rate of disturbed sands [12, 13, 14, 15]. In this regard, and according to Al-Jabari and Sawalha [16], the problems related to water consumption and random wastewater dumping from this industry has been classified as one of the major environmental problems in the

West Bank. Improper management of the stone cutting industry wastes is the main reason for the increasing of the Total Suspended Solids (TSS) levels in Hebron groundwater.

3.3. Impact on Health Situation

Dust is one of the most visible, invasive, and potentially irritating impacts associated with quarrying, and its visibility often raises concerns that are not directly proportional to its impact on human health and the environment [17]. Dust may occur as fugitive dust from excavation, from haul roads, and from blasting, or can be from point sources, such as drilling, crushing and screening [18]. Site conditions that affect the impact of dust generated during extraction of aggregate and dimension stone include rock properties, moisture, ambient air quality, air currents and prevailing winds, the size of the operation, proximity to population centers, and other nearby sources of dust. Dust concentrations, deposition rates, and potential impacts tend to decrease rapidly away from the source [17]. Health effects associated with quarrying and stone cutting industries activities are noteworthy. The research revealed that there is high prevalent rate of diseases (figure 7) as a result of these operations. The impact of high-pitched and other noises is known to include damage to the auditory system, cracks in buildings, stress and discomfort [19].

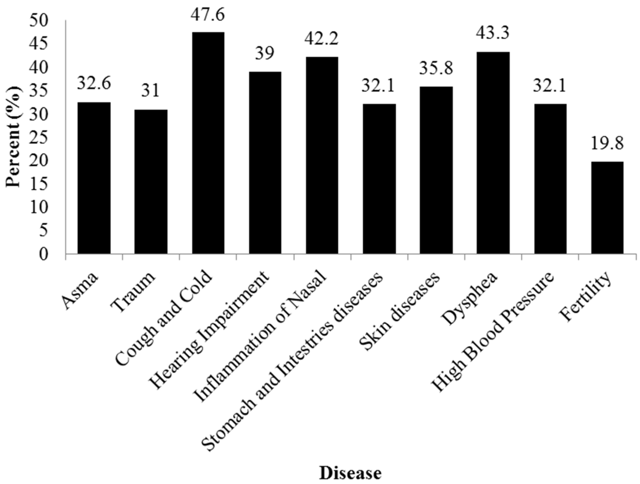

Figure 7. Percentage of respondents about diseases.

Figure 7 indicates that cough and cold, dyspnea, inflammation of nasal and hearing impairment are the most prevalent diseases (47.6%, 43.3%, 42.2, 39 respectively). Also, 35% of respondents showed that skin diseases are caused by these operations. This figure also shows that 32.6% of respondents pointed out that Asthma are caused by these activities, while 32.1% indicated that they cause high blood pressure. Consequently, one can conclude that quarrying and stone cutting industries cause various diseases to workers or people who live close to operations.

Beside the health problems and diseases mentioned before, several incidents occur in these operations (Figure 8). Fractures are most prevalent incidents (13.9% of the respondents) as workers have to deal with heavy rocks and equipments. Some of these accidents cause permanent disabilities (10.2%), whereas 3.7% of the respondents indicated that these incidents are fatal. In most cases, these incidents are caused by the absence of monitoring and controlling regulations.

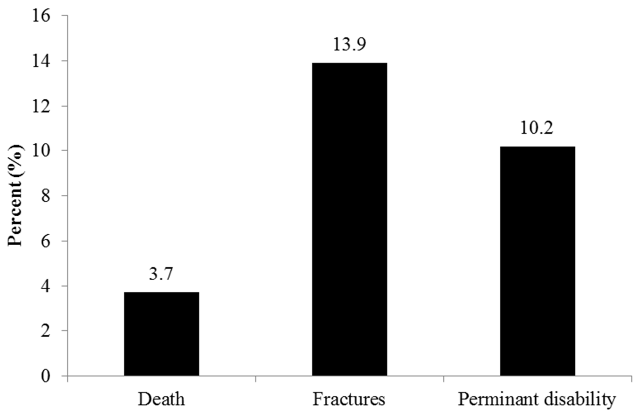

Figure 8. Percentage of respondents about accidents in quarries and stone cutting industries.

3.4. Vibration, Cracks and Noise Pollution

Vibrations and noise pollution are associated with many types of equipment used in quarries and stone cutting industries operations, but blasting is considered the major source. Vibration has affected the stability of infrastructures, buildings, and homes of people living near to these working sites [19].

Figure 9 and figure 10 present the respondent's answers regarding vibrations, noise and cracks as a result of operation in quarries and stone cutting industries. As shown in figure 9, (35.3%) of respondents showed that vibrations always occur as a result of working and equipment, while 28.3% of respondents indicated that vibration rarely occur as a result of working and equipment. This implies that quarrying and stone cutting industries cause vibrations. Also, about 75% of the respondents indicated that they are suffering from noise pollution as a result of these operations. In this regard, noise pollution may include noise from vehicle engines, loading and unloading of rock into steel dumpers, chutes, power generation, and other sources. According to figure 10 and field observations, some buildings were observed to have developed different degrees of cracks. These cracks were basically due to strong vibrations coming from rock blasting and other activities within these sites [19].

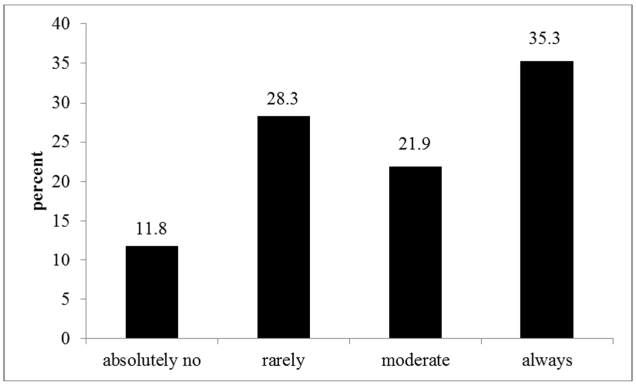

Figure 9. Percentage of respondents about vibrations due to working and equipments.

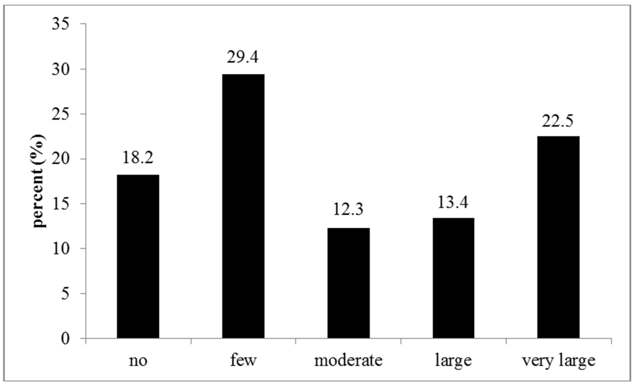

Figure 10. Percentage of respondents about the degree of cracks.

4. Conclusion

It was clear throughout the study that quarries and stone industries have adverse impact on the environment and human health. The most impact is attributed to the generated particulate matter (dust) as a result of the different activities associated with these industries. High concentrations of different particulate matter were found in the study area, and this was reflected and confirmed by residents in the surrounding as most of the respondents (70%) confirmed that air is permanently dusty, and the conditions are not limited to working hours, where higher effects are normally noticed in summer season. Also, the study showed that these industries have negative impact on water resources, and about 68% of the respondents confirmed that groundwater in polluted as a result of these industries and their wastes. Concerning the health situation, the study demonstrated that there is high prevalent rate of diseases caused as a result of these industries and particularly due to air pollution; cough and cold, dyspnea, inflammation of nasal, Asthma and hearing impairment due to noise pollution were the most prevalent diseases. Therefore, and according to the aforementioned findings, an environmental management and mitigation solutions should be considered for sustainable utilization of these resources without harming the environment and humans.

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Appendix 5

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Clinical conditions associated with environmental exposures: an epidemiologic study in two communities in Juana Díaz, Puerto Rico

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Abstract

BACKGROUND: A population-based cross-sectional design was used to compare the prevalence of respiratory and general symptoms and of respiratory and heart diseases in two communities of Juana Díaz, Puerto Rico: Guayabal, exposed to particulate matter from quarries and diesel exhaust; and Río Cañas Abajo, which has no such exposure.

METHODS: A probabilistic sampling design was used to obtain a representative sample of households and 288 residents of the selected households were interviewed. Adjusted PORs were estimated to assess the relationship between diseases/symptoms and place of residence using logistic regression models. To estimate the parameters of this model, a multilevel approach was used in order to control for potential correlation among residents of the same block.

RESULTS: A higher prevalence of general and respiratory symptoms and of respiratory diseases was observed for residents of Guayabal when compared to Río Cañas Abajo ($p < 0.05$). Residents of Guayabal were more likely to have bronchitis (adjusted POR = 5.5; p-value < 0.05), nasal allergies (adjusted POR = 4.2; p-value = 0.01), nasal congestion (adjusted POR = 2.9; p-value = 0.02), and nausea and vomiting (adjusted POR = 8.7; p-value < 0.01).

CONCLUSIONS: The perception of the community of Guayabal of a higher prevalence of symptoms and health conditions was supported by the present findings. This study provides statistical evidence for the design of an analytical epidemiologic study aimed at evaluating the potential effect of quarrying on adverse health outcomes in the community of Guayabal.

Keywords

Environmental exposures; Quarries; Diesel exhaust; Respiratory diseases; Chronic diseases; General symptoms

Appendix 6

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Non-occupational exposure to silica dust

L. J. Bhagia

Go to:

Abstract

Occupational exposure to silica occurs at workplaces in factories like quartz crushing facilities (silica flour milling), agate, ceramic, slate pencil, glass, stone quarries and mines, etc., Non-occupational exposure to silica dust can be from industrial sources in the vicinity of the industry as well as non-industrial sources. Recently, public concern regarding non-occupational or ambient exposure to crystalline silica has emerged making it important to gather information available on non-occupational exposures to silica dust and non-occupational silicosis. This paper reviews various non-occupational exposures reported in literature including some studies by the author. Methodology used in assessment of non-occupational exposures, standards for non-occupational exposures to silica dust and indirect estimation of cumulative risk % are also discussed.

Keywords: Non-occupational exposure, quartz, silica, silicosis

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INTRODUCTION

Silica (SiO_2, CAS No. 7631-86-9) is found in abundance in nature. Pure crystalline silica that is not combined with any other elements is called free silica. When combined with other elements, the compound is called silicate. Free silica occurs in different polymorphic forms like quartz, cristobalite, tridymite, and tripoli. Although identical chemically, they differ from each other in their crystal structure. Crystoballite and tridymite are products of high temperatures and may be observed in volcanic ash[1] and are rarely found in industrial samples.[2] The exposure to silica dust produces lung diseases like silicosis and silico-tuberculosis. It also increases the risk of tuberculosis, nonmalignant renal disease, and autoimmune diseases. Silica has also been classified as a carcinogen by International Agency for Research on Cancer (IARC).[3] The exposure to crystalline silica can be occupational or non-occupational.

Workers are exposed to dust containing crystalline silica for about 8 h per day and are at the risk of developing silicosis and silico-tuberculosis.

Recently, public concern regarding non-occupational or ambient exposure to crystalline silica has emerged, making it important to gather information available on non-occupational exposures and non-occupational silicosis. Non-occupational exposures are rarely estimated or measured in community environment or in the vicinity of silica-based industry. Non-occupational exposure to silica dust can be from industrial as well as nonindustrial sources. Non-occupational exposure from non-industrial sources occurs naturally due to desert dust and sand storms in hilly areas.[4,5] Some farming, construction, and demolition activities also contribute to the environmental exposure.[6] Non-occupational exposure from industrial sources occurs when dust emitted from factories like quartz crushing, agate grinding, ceramics, slate pencil, mining and milling of sand stones, silica flour milling, granite, etc., goes to the environment and people staying in the vicinity are affected.[7] Relation between occupational exposure and prevalence of silicosis and silico-tuberculosis has been established beyond doubt in many occupations.[8–11] But, there have been very few studies which suggest that there can be non-occupational silicosis also. Silicosis is a very well-established disease, but the importance of this disease has been underestimated as an environmental disease. Several cases of non-occupational silicosis from non-industrial sources have recently been reported which are summarized below.

Go to:

NON-OCCUPATIONAL EXPOSURE TO SILICA DUST FROM NON-INDUSTRIAL SOURCES

Sepke[12] reported silicosis from street dust in 1961. Afterwards, Farina and Gambini[13] reported a rare case of silicosis from inhalation of desert sand. The first major study of environmental exposure to silica dust in India was reported by Saiyed *et al*.[5] An epidemiological survey was carried out by them to investigate the occurrence of non-occupational pneumoconiosis in central Ladakh, India, where there are no mines or industries. A total of 449 subjects were studied from three villages called Saboo, Shey, and Chushot, the prevalence of pneumoconiosis in these villages was 2.0, 20.1, and 45.3%, respectively.[5] The causative factors were suggested to be dust storms in spring and summer and an indoor air pollution but information regarding the frequency, duration and severity of dust storms, dust concentrations, particle size distributions, and the relation between soot and the pneumoconiosis is clearly lacking.[14] The disease was classified as pneumoconiosis instead of silicosis, probably due to a different interpretation when reading the chest X-ray films or due to lack of environmental data confirming silica dust exposure. Norboo *et al*.,[4] reported silicosis in a Himalayan village population. The Himalayan villages of Chuchot, Shamma, and Stok were surveyed because silicosis had been suspected from radiographs of some of the habitants. The villages are agricultural and Chuchot is exposed to frequent dust storms. In Chuchot, five of seven men and all the nine women examined, showed varying grades of silicosis compared with three of 13 men and seven of 11 women in Stok which lies 300 m higher and is exposed to fewer dust storms. Chemical analysis of inorganic dust in the lung showed that 54.4% was elemental silicon. This was similar to silicon content of dust collected from houses in Chuchot, which included many particles of respirable size (0.5–5 μm diameter). X-ray microanalysis showed that quartz formed 16-21% of inorganic lung dust. Franco and Massola[15] reported 6–9% quar tz in sedimented dust from the same Himalayan villages. These observations are consistent with the geological nature of Himalayan range in Ladakh.[15] In the same area, however, quartz content of 42.8% has been reported.[16] Patial[17] reported silicosis in nine males and eight females in the highlanders of a Himalayan desert and called the disease as mountain desert silicosis. Silicosis developed in these people even without working in silicosis prone workplace. He concluded that people were exposed to silica from the non-workplace silica-rich environment.

In all the above studies, cases of silicosis have been reported and the disease has been attributed to silica content in sedimented dust and/or lungs but there has been no attempt to measure silica dust (quartz) concentrations in the environment. However, there are studies where silica dust concentrations have been measured in community environment. Davis *et al*.,[1] reported that average quartz levels in US metropolitan areas are in the range of 1.1–8.0 $\mu g/m^3$ with an average of 3.2 $\mu g/m^3$. The percentage of quartz in total dichotomous mass (less than 15 µm aerodynamic equivalent diameter) varied from 2.5 to 8.2.[6]

Dust exposure is a major source of respiratory morbidity and mortality among agricultural workers.[18] In most of the developing countries farmers generally stay in the farms or in the vicinity of farms. Their dust exposures are partly occupational and partly non-occupational. In general, agricultural dusts may be divided into those of organic and inorganic origin. Organic dusts originate from plant and animal sources and are commonly the source of allergic diseases such as asthma. Inorganic dusts originate predominantly from the soil, and tend to result in non-allergic reactions in the lung.[19] Respirable quartz is found in soil dust, although weathering and chemical reactions may make it less fibrogenic than freshly fractured quartz in other operations like quarrying and sandblasting.[19,20] Silicosis has also been reported in agricultural workers. A case of silicosis was reported by Fennerty *et al*.,[21] in a Pakistani farmer who had been a peasant farmer in west Pakistan all his life and had worked in the fields from early childhood.

Most of his time had been spent in cultivation. Results of bulk chemical analysis of the dust deposits indicated that silica content was 58.4%. The highest dust exposures occur during soil preparation activities. Tractors pulling soil preparation equipments like plowing, discing, and planing generate large dust clouds. Median total particle exposures in an open cab range from 2-20 mg/m^3, but exposures up to 100 mg/m^3 have been reported.[19]

The respirable fraction of dusts in tractor cabs is generally 5–40%, with total respirable concentrations commonly observed between 1 and 5 mg/m^3. These exposures may be called occupational for tractor drivers, but dust generated goes to the environment and others working in the farms or residing in the vicinity of farms are also exposed. A study of dust samples from 12 farms in Alberta, Canada, found 0.8–17.5% crystalline silica.[22] Silicosis has also been reported in tractor drivers working on sandy soils on tree farms.[23]

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NON-OCCUPATIONAL EXPOSURE TO SILICA DUST FROM INDUSTRIAL SOURCES

As mentioned earlier, non-occupational exposure from industrial sources occurs when dust emitted from silica-based industries goes to the environment and people staying in the vicinity are affected. There have been very few studies in the vicinity of the industry where non-occupational exposures to crystalline silica and nonoccupational silicosis have been reported[7,24–26] in slate pencil and agate industries.

Sand quarry, near California

It has been mentioned by Ruble and Goldsmith[27] that Goldsmith[24] reported particulate matter less than 10 μm (PM-10) and silica levels measured at two sites near a sand quarry, near California. Mean PM-10 concentrations for sites were 18.9 and 18.2 μg/m^3, and mean silica concentrations were 1.33 and 1.11 μg/m^3, respectively from 6–7% silica content in the PM-10 dust. Mean silica concentration at the two sites is 1.22 μg/m^3 [Table 1]. No cases of silica-related diseases were reported.

Table 1

Non-occupational exposure to silica dust in vicinity of different industries

Industry	Location	PM-10 quartz concentration (μg/m^3)	Mean quartz content (%)	Reference No.
Sand quarry	Exposed (vicinity)	1.22	6-7	27
Slate pencil industry	Exposed (vicinity)	49.15 (10)	15.00-18.79	7
	Control (away)	3.51 (5)	2.91	
Agate industry	Exposed (vicinity)	15.28 (20)	5.61	25, 26
	Control (away)	3.03 (14)	1.87	

Figures in the parenthesis indicate number of samples. PM-10: Particulate matter less than 10 μm

Slate pencil industry, India

Slate pencil industry is an unorganized small-scale industry mainly located in and around Mandsaur, Madhya Pradesh, India. A small village called Multanpura about 6 km away from Mandsaur having 6 km^2 area has about 100 slate pencil manufacturing facilities. Cutting of the stone is carried out manually with electrically operated saws. The subsequent operations of collecting, sorting, and packing are carried out manually near the cutting machine. Saiyed *et al*.,[9] reported that total and respirable dust levels near cutting machine were 46.47 and 10.41 mg/m^3, respectively. Medical survey revealed that prevalence of silicosis in this industry was 54.6%, of these 17.7% of workers had progressive massive fibrosis. Consequently, they installed local exhaust ventilation with the cutting machine in order to reduce dust concentration in the work environment. Efficacy of the dust control devices was tested by Ghodasara *et al*.,[28] and was reported to be 95–97%. During our visit to slate pencil industry in 2005, it was observed that dust-laden air is sucked by a fan and is thrown out in the community environment. There were no bag filters. Lot of dust is emitted from chimneys. The height of the chimney is just 10–12′ from the ground. People residing in the village are also exposed to the airborne silica dust, although they are not engaged in this occupation. Bhagia[7] reported high concentrations of quartz in ambient environment of the village using PM-10 high volume samplers and vertical elutriators. Vertical elutriators have a median cut off at 10 μm and a maximum cut off at 15 μm.[7] Dust collected by vertical elutriator was used for analyzing percentage of quartz in dust samples using Fourier transform infrared spectroscopy. The percentage of quartz was multiplied by PM-10 dust concentration to get ambient quartz concentration. The average quartz concentration in the vicinity of slate pencil industry are in the range of 41.07 to 57.22 $\mu g/m^3$ at two locations within the village with an average of 49.15 $\mu g/m^3$ for the village where as the quartz concentration at the control site, 5 km away from the Multanpura village is 3.51 $\mu g/m^3$ [Table 1]. Prevalence of non-occupational silicosis and non-occupational silico-tuberculosis in the vicinity (exposed sites) was reported to be 12.6 and 6.3%, respectively.[29]

Agate industry, India

Agate industry has been developed primarily as a cottage or household industry mainly located in and around Khambhat, Gujarat, India. Grinding and polishing of agate puts it in semiprecious category of ornamental stones. A variety of articles like necklaces, earrings, cufflinks, key chains, ashtrays, etc., are made from agate. The process of making necklaces and other decorative articles includes baking of the stones, chipping of stones, grinding, and polishing. Amongst various processes, agate grinding activity, where the agate beads are ground against the rotating emery wheel, generates lots of silica dust in the work environment. During the preliminary visits, it was observed that this dust not only pervades the work environment, but also the community environment. Consequently, the family members of the house where agate grinding activities are carried out and the people residing in the vicinity are also exposed to the airborne silica dust, although they are not engaged in this occupation.

An epidemiological study in agate industry carried out by Sadhu *et al.*,[11] showed that the prevalence of silicosis was 40.7% in agate workers. Environmental hygiene survey[30] also showed that dust concentrations in the work environment were much higher than the permissible exposure limits. Bhagia *et al.*,[26] also reported high dust concentrations in agate grinding operations. These observations motivated National Institute of Occupational Health (NIOH) to measure non-occupational exposure to silica dust in the vicinity of agate industry.

Bhagia *et al.*,[25,26] reported ambient air pollution study with the objectives of assessing quartz concentrations in the vicinity of agate industry. Four sites in the vicinity of agate industry, namely, Shakarpur, Hajju fajju no mohallo, Vadva-metpur and Bhoi-bari were selected as exposed sites. In addition to exposed sites, one locality in the city called Nareshwar, which was away from these units was also selected as a control site in the city. The other two control sites, Rohini and Pandad villages, where epidemiological study was carried out for control subjects were 10–15 km away from Khambhat.

People living in the vicinity of agate industry are exposed to an average 24 h crystalline silica (quartz) concentration of 15.28 μg/m^3, whereas in control localities, away from agate industry, they are exposed to an average crystalline silica concentration of 3.03 μg/m^3 [Table 1]. No cases of non-occupational silicosis were reported from control sites.[26] Prevalence of non-occupational silicosis and non-occupational silico-tuberculosis was reported to be 5.8 and 2.4%, respectively.[26]

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AMBIENT AIR QUALITY STANDARDS FOR SILICA

National ambient air quality standards (NAAQS) for suspended particulate matter (PM-10) are stated in terms of 24-h average concentrations with a primary standard of 150 μg/m^3 and a secondary standard of 50 μg/m^3.[6,31] Central Pollution Control Board (CPCB, India, 1994)[32] standard based on 24-h PM-10 dust concentration is

100 μg/m^3 for residential localities. Although there is no ambient air quality standard for crystalline silica, Environmental Protection Agency (EPA)[6,33] suggested interim annual air quality standard (IAAQS).[6,33] EPA concluded that "for healthy individuals not compromised by other respiratory ailments and for ambient environments expected to contain less than 10% crystalline silica fraction in PM-10, the maintenance of 50 μg/m^3 annual NAAQS for PM-10 should be adequate to protect against the silicotic effects from ambient crystalline silica exposures". This standard was based upon average ambient concentrations of silica in United States and risk was calculated by converting ambient exposures to equivalent occupational exposures.[6] No epidemiological studies were carried out in the community to derive the standards. Considering a maximum of 10% silica in dust, an interim standard of 5 μg/m^3 for ambient silica can be assumed. The most important and common observation in the vicinity of agate and slate pencil industries [Table 1] is that the quartz concentrations in exposed localities are more than 5 μg/m^3 and in the control localities quartz concentrations are less than 5 μg/m^3.

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INDIRECT ESTIMATION OF CUMMULATIVE RISK PERCENTAGE

The comparison of interim standard of 5 μg/m^3 for quartz[6] (EPA) with our observations suggest that ambient exposure to quartz in the vicinity of agate and slate-pencil industries poses potential risk of silicosis. For derivation of ambient air quality standard for crystalline silica EPA[6] used a method, which converts ambient exposures to the equivalent occupational exposures. Cumulative risk (%) can then be computed from graphs of cumulative risk percentage vs cumulative silica exposures. People living in the vicinity of agate industry are exposed to an average 24-h crystalline silica (quartz) concentration of 15.28 μg/m^3, whereas in control localities they are exposed to an average crystalline silica concentration of 3.03 μg/m^3 [Table 1]. Relation between continuous and occupational exposures[6] is defined by Continuous exposure = TWA occupational exposures × (5 days/7 days) × (10 m^3 air breathed at work/20 m^3 total air breathed in a day).

The occupational equivalents of exposure of 15.28 and 3.03 μg/m^3 in exposed and controlled localities using above equation are 0.042 and 0.0084 mg/m^3, respectively for agate industry. A 70-year exposure to these occupational equivalents would result in cumulative silica exposures of 2.94 mg/m^3 × years and 0.59 mg/m^3 × years for exposed and control localities, respectively. Cumulative risk (%) for these values was computed by log-logistic cumulative risk model of Hnizdo and Sluis-Cremer,[8] which is represented by following equation:

$$F(CD) = 1 - [1 + CD^{1/\delta} \times \exp(-\mu/\delta)]^{-1}$$

Where, CD = cumulative dose, μ = 1.298, and δ = 0.2111[6]

The cumulative risk (%) for exposed and control localities computed from above equation was found to be 26.11 and 0.02%, respectively for agate industry. Similarly, risk % for slate pencil industry was found to be 99 and 0.04% for exposed and control sites, respectively. The cumulative risk for an ambient exposure to 5 μg/m^3 (an interim air quality standard for silica, based on findings of EPA) was 0.33%.

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DISCUSSION

Computation of cumulative risk is only an approximation because cumulative risk (%) depends on many factors such as silica particle size distribution in PM-10 dust, surface properties, and sources of quartz. EPA[6] derived the standard for ambient silica exposures by converting ambient exposures to occupational exposures. The curve for cumulative risk (%) versus cumulative silica exposure was used by EPA,[6] which was based upon respirable dust (≤5 μm). The concentration of silica in ambient dust is generally higher in large size fractions in the range of 2.5-15 μm and in dust fractions less than 2.5 μm.[1,6] Others like

Buckman and Brandy,[34] and Ruble and Goldsmith[27] also reported that particulates greater than 10 μm contain more silica than particulates having diameters less than 10 μm. This may be so because quartz is harder than most minerals and does not disintegrate to fine particles easily as reported by Ayer.[35] This may be the reason why cases of silicosis are not reported from metropolitan cities of USA. But in the vicinity of silica-based industry; quartz comes from crushing, cutting, and grinding operations. The total airborne dust collected from work environment of agate industry was analyzed for particle size. It was found that 90% of the particles are having diameters less than 5 μm.[25,26] These particles get dispersed in the vicinity of agate industry. This is in contrast to the natural dust in which percentage of fine quartz particles is less. To certain extent, it justifies the conversion of ambient exposures to occupational exposures by EPA[6] in estimating risk in the vicinity of silica-based industry because cumulative occupational exposures are based upon respirable dust (≤5 μm). Secondly, airborne quartz in the vicinity of agate and slate pencil industry is freshly fractured. It has been reported that freshly fractured silica is much more cytotoxic than aged quartz.[6,36,37] Considering all these arguments, a question arises whether there should be separate silica standard for community environment (non-occupational exposure to silica dust from nonindustrial sources) and the environment in the vicinity of industry emitting silica particles (non-occupational exposure to silica dust from industrial sources).

Another question is whether the standard should be based on PM-10 dust or it should be based on respirable dust (less than 4 or 5 μm) or PM-2.5 because silicosis is the restrictive type of lung disease. Hearl[38] suggested the use of industrial hygiene techniques for measurement of crystalline silica in ambient environment. Bhagia[7] used PM-10 high volume samplers (1,100 liter per minute (LPM)) and vertical elutriators with median cutoff at 10 μm and a maximum cutoff at 15 μm (7.4 LPM) for measurement of silica in the vicinity of slate and agate industries. Davis *et al.*,[1] used dichotomous samplers with a maximum cutoff at 15 μm. The manual dichotomous sampler (16.7 LPM) is used for routine compliance monitoring in USA for PM-10 and PM-2.5. To answer all the questions discussed above, lot of field studies are required with simultaneous monitoring of PM-10, PM-2.5, and respirable dust (less than 4 or 5 μm) in the vicinity of silica-based industry as well as in the community environment. Our observations [Table 1] show that quartz concentrations (PM-10) in the vicinity of agate and slate pencil industries are more than 5 $\mu g/m^3$, while in control localities away from these industries are less than 5 $\mu g/m^3$. For the time being, an interim ambient air quality standard of 5 $\mu g/m^3$ for silica with PM-10 measurement with a cumulative risk of 0.33% appears reasonable.

Go to:

Footnotes

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Conflict of Interest: None declared.

Go to:

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Appendix 7

Silicosis

Silicosis is a long-term lung disease caused by inhaling large amounts of crystalline silica dust, usually over many years.

Silica is a substance naturally found in certain types of stone, rock, sand and clay. Working with these materials can create a very fine dust that can be easily inhaled.

Once inside the lungs, it causes swelling (inflammation) and gradually leads to areas of hardened and scarred lung tissue (fibrosis). Lung tissue that's scarred in this way doesn't function properly.

People who work in the following industries are particularly at risk:

- stone masonry and stone cutting – especially with sandstone
- construction and demolition – as a result of exposure to concrete and paving materials
- worktop manufacturing and fitting
- pottery, ceramics and glass manufacturing
- mining and quarrying
- sand blasting

Signs and symptoms

The symptoms of silicosis usually take many years to develop, and you may not notice any problems until after you've stopped working with silica dust.

The symptoms can also continue to get worse, even if you're no longer exposed.

Silicosis usually develops after being exposed to silica for 10-20 years, although it can sometimes develop after 5-10 years of exposure. Occasionally, it can occur after only a few months of very heavy exposure.

Main symptoms

The main symptoms of silicosis are:

- a persistent cough
- persistent shortness of breath
- weakness and tiredness

If the condition continues to get worse, these symptoms may become more severe.

Some people may eventually find simple activities such as walking or climbing stairs very difficult and may be largely confined to their house or bed.

The condition can ultimately be fatal if the lungs stop working properly (respiratory failure) or serious complications develop, but this is rare in the UK.

Further problems

Silicosis can also increase your risk of getting other serious and potentially life-threatening conditions, including:

- tuberculosis (TB) and other chest infections
- pulmonary hypertension
- heart failure
- arthritis
- kidney disease
- chronic obstructive pulmonary disease (COPD)
- lung cancer

When to see your GP

See your GP if you think there's a possibility you could have silicosis.

They'll ask you about your symptoms and work history, and listen to your lungs with a stethoscope.

They'll want to know about any periods when you may have been exposed to silica and whether you were issued with any safety equipment, such as a face mask, when you were working.

If silicosis is suspected, you may be referred to a specialist for further tests to confirm the diagnosis.

Tests you may have include:

- a chest X-ray to detect abnormalities in the structure of your lungs
- a computerised tomography (CT) scan of your chest to produce more detailed images of your lungs
- lung function testing (spirometry), which involves breathing into a machine called a spirometer to assess how well your lungs are working

A test for TB may also be recommended because you're more likely to get TB if you have silicosis.

Treating silicosis

There's no cure for silicosis because the lung damage can't be reversed. Treatment aims to relieve symptoms and improve quality of life.

The condition may continue to get worse, leading to further lung damage and serious disability, although this may happen very slowly over many years.

The risk of complications may be reduced if you:

- ensure you're not exposed to any more silica
- stop smoking (if you smoke)
- have regular tests to check for TB, if advised by your doctor
- have the annual flu vaccine and the pneumococcal vaccine

You may be offered long-term oxygen therapy if you're having difficulty breathing and have low levels of oxygen in your blood.

Bronchodilator medicines may also be prescribed to widen your airways and make breathing easier.

You'll be given a course of antibiotics if you develop a bacterial chest infection.

In very severe cases, a lung transplant may be an option, although there are strict health requirements to meet before this will be considered.

Preventing silicosis

Silicosis can be prevented by avoiding prolonged exposure to silica dust.

In the UK, all workplaces must comply with The Control of Substances Hazardous to Health Regulations 2002, which sets a workplace exposure limit for silica.

Your employer should:

- warn you about any risks to your health
- make sure you're aware of the correct procedures to reduce your risk of exposure to silica dust
- supply you with the necessary equipment to protect you

You can read more detailed information about the control of exposure to silica dust on the Health and Safety Executive website.

Claiming compensation

If you've been diagnosed with silicosis, you may be able to claim compensation in one of the following ways:

- **industrial injuries disablement benefit** – a sum of money paid weekly to people with silicosis who were exposed to silica while in employment (but not self-employment) and to people who have silicosis and lung cancer
- **launch a civil claim for compensation through the courts** (you'll need to get legal advice about how to do this)
- **claim a lump sum in compensation under the Pneumoconiosis etc. (Workers' Compensation) Act 1979** – if you have silicosis, or you're the dependant of someone who has died from the condition, and you haven't been able to get compensation through the courts because the employer liable has stopped trading

You can read more about Industrial Injuries Disablement Benefit on the GOV.UK website.

Page last reviewed: 01 July 2021
Next review due: 01 July 2024

Appendix 8

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JOURNAL ARTICLE

Unexpected case of accelerated silicosis in a female quarry worker

Get access

Tracy L Leong ✉, Hari Wimaleswaran, David S Williams, Nicole S Goh, Ryan F Hoy

Occupational Medicine, Volume 72, Issue 6, July 2022, Pages 420–423, https://doi.org/10.1093/occmed/kqac016
Published: 25 April 2022

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Summary

Silicosis is a progressive and irreversible fibrotic occupational lung disease caused by inhalation of respirable crystalline silica (RCS). Recently, outbreaks have been reported in industries involving direct work with high silica-containing materials, such as artificial stone. Here, we describe an unexpected diagnosis made in an asymptomatic 33-year-old female worker employed for 4 years at a quarry for rhyodacite and rhyolite which contain 70% silicon dioxide. Chest computed tomography demonstrated small nodules in the upper lobes and larger ill-defined areas of opacity. Bronchoalveolar lavage revealed fine birefringent material within the cytoplasm of alveolar macrophages, representing silica. Transbronchial biopsies of lung parenchyma and endobronchial ultrasound-guided transbronchial needle aspiration of mediastinal lymph nodes did not reveal features of sarcoidosis, tuberculosis, or malignancy. As such, a diagnosis of accelerated silicosis was confirmed and represents the first reported case in a female worker at a rhyodacite and rhyolite quarry.

Keywords: occupational respiratory disease, pneumoconioses, silicosis
Issue Section: Case reports

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malignancy. As such, a diagnosis of accelerated silicosis was confirmed and represents the first reported case in a female worker at a rhyodacite and rhyolite quarry.

Appendix 9

Peer reviewed research in the effect of quarry sites on health

Silico-tuberculosis, silicosis and other respiratory morbidities among sandstone mine workers in Rajasthan- a cross-sectional study

Saranya Rajavel[1], Pankaja Raghav[1], Manoj Kumar Gupta[1], Venkiteswaran Muralidhar[2]

Affiliations expand

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- PMCID: PMC7162522
- DOI: 10.1371/journal.pone.0230574

Free PMC article

Abstract

Background: Exposures to respirable crystalline silica causes silicosis, pulmonary tuberculosis, chronic obstructive pulmonary disease, lung cancer, autoimmune disorders and chronic renal disease. The aim of this study was to find out the prevalence of silico-tuberculosis, silicosis and other respiratory morbidities in sandstone mine workers in Jodhpur district of Rajasthan.

Methods: It was a cross-sectional study done in sandstone mines in Jodhpur. A total of 15 mines were selected. The sample size was calculated and fixed to 174 mine workers. Chi-square and t-test were applied to draw inferences.

Results: The mean age of the mine workers was 39.13 ± 11.09 years. Three fourth (75.3%) of the workers were working for more than ten years in mines. Around 30.0% had a history of tuberculosis. Abnormal spirometry was found in 89.2% of workers. Around 42% of mine workers were found with abnormal chest x-rays. Prevalence of silicosis was 37.3%, silico-tuberculosis was 7.4%, tuberculosis was 10.0%, and other respiratory diseases like emphysema and pleural effusion were diagnosed among 4.3% workers.

Conclusion: Prevalence of silico-tuberculosis, silicosis and other respiratory morbidities are high among sandstone mine workers.

Conflict of interest statement

The authors have declared that no competing interests exist.

Figures

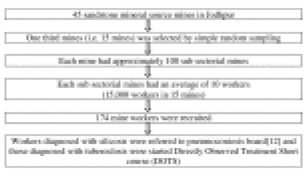

Fig 1. Flowdiagram of selection of mines,...

Fig 2. Flow diagram for investigation of...

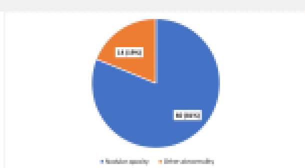

Fig 3. Abnormalities in chest Radiograph of...

Fig 4. Chest X-ray of an sandstone...

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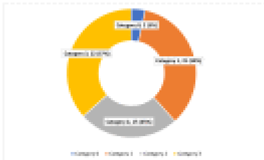

Fig 5. Profusion distribution of small nodular...

Appendix 10

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Premature Deaths Due to Silicosis in Turkey, 2006–2017: A Twelve-Year Longitudinal Study

Elif Altundaş Hatman,[1] Duygu Acar Karagül,[2] Eliz Kuman Oyman,[2] Bahar Tüzün,[3] Kadir Onur Şimşek,[2] and Zeki Kılıçaslan[4]

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Abstract

Background

Deaths due to epidemics of silicosis still continue to be reported both in developing and developed countries, and silica exposure from different sectors remains an important occupational health concern.

Aims

To identify characteristics of silicosis cases by focusing on a developing country and evaluate the frequency of and factors related to premature deaths and also reveal preventable causes of premature deaths in silicosis.

Study Design

Retrospective cohort.

Methods

We reviewed the records of 9769 patients who were diagnosed with occupational diseases in İstanbul Occupational Diseases Hospital between 2006 and 2017. According to International Classification of

Diseases (ICD)-10 codes, 1473 silicosis cases were detected. The sociodemographic characteristics, job characteristics, comorbidities, serological, functional, and radiological data, and follow-up time were obtained from the medical records. Mortality data were gathered from The National Death Notification System of Ministry of Health.

Results

The study examined 9769 cases diagnosed with an occupational disease, and 15.0% (n = 1473) of them were diagnosed with silicosis. The median age of silicosis patients was 40.0 years, and 26.9% of them were child labor when they started to work in dusty industries.

Child labor was mostly seen among dental technicians (57.7%), denim sandblasters (46.4%), and miners (37.0%). In the follow-up period, 26.3% of Teflon sandblasters, 11.1% of coal miners, 8.6% of denim sandblasters had died before their average life expectancy, and the years of loss of life was 26.0 ± 11.6 years all over the group. Premature death was associated with occupation [hazard ratio (Teflon sandblasting): 3.93, CI: 1.43-10.78; hazard ratio (marble production): 4.4, CI: 1.02-19.21]; large opacities in posterior anterior chest X-ray [hazard ratio: 2.14, CI: 1.18-3.86]; tuberculosis [hazard ratio: 2.60, CI: 1.42-4.76]; and reduction in forced vital capacity (forced vital capacity% ≤80) during diagnosis [hazard ratio: 4.43, CI: 2.22-8.83].

Conclusion: More than a quarter of silicosis cases are those who start working in dusty industries at an early age. Factors associated with premature death in patients with silicosis are patient occupation, large opacities on chest X-ray, tuberculosis, and pulmonary function loss at diagnosis.

Keywords: Child labor, dental technicans, occupational lung diseases, sandblasting, silicotuberculosis

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Introduction

Silicosis is an occupational lung disease due to crystalline silica exposure via inhalation, which leads to a range of clinical outcomes including mild pulmonary function loss, mortality, and years of life lost (YLL) as a result of inflammation and fibrosis in the lung parenchyma.[1]

Despite the exposure limit values have been well established and effective prevention measures have been proposed, the worldwide epidemic of silicosis continues. In total, 2.3 million workers in United States, 11.5 million workers in India, and 3-5 million workers in European countries have still been exposed to crystalline silica.[2-4] At the same time, the pneumoconiosis rate increased 18%, 20%, 35%, and 33% between the years of 2013 and 2016 in Turkey.[5]

Even though silicosis is a preventable disease, deaths due to epidemics of silicosis also continue to be reported both in developing and developed countries across various industries and remain an important occupational health concern. Silicosis mortality rate has been found as 28.8 per 100 000 person–years, and the high intensity of exposure has also been associated with an increased risk of death in a pooled analysis of 6 cohorts.[6] Especially intensity of silica exposure, young age, conglomerate masses, smoking, concomitant tuberculosis, and genetic polymorphism in TNF-alpha or desmoplakin gene have been defined as factors increasing mortality in silicosis.[7-9] Silicosis has also been related with premature deaths, and YLL due to silicosis is 26.5 years before 65 years between the ages of 15 and 44 in the United States. Stone quarrying has the greatest YLL across all the industries in the United States with 23.5 years.[10]

In cases where silicosis could not be prevented completely, it is important to determine the factors affecting premature deaths and to prevent premature deaths in patients with silicosis. Recent studies on the causes of mortality in silicosis concentrate either on the intensity of silica exposure which has been the direct reason for silicosis or reveal irreversible factors such as genetic polymorphism.[6,9,11] On the other hand, if silicosis has developed, at least avoiding premature deaths and YLL should be prioritized.

Identifying characteristics and differences of silicosis cases in developing countries vis-à-vis developed countries could be important to prevent both the development of silicosis diseases and premature deaths. This study aims to identify characteristics of silicosis cases by giving an example from a developing country and evaluate the frequency of premature deaths, factors related to premature deaths, and also reveal preventable causes of premature deaths in silicosis.

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Material and Methods

This study was designed as a retrospective cohort and conducted between May 2018 and April 2019. Researchers reviewed the records of all patients who had a diagnosis of an occupational disease in İstanbul Occupational Diseases Hospital (IODH) between January 1, 2006, and December 31, 2017. İstanbul Occupational Diseases Hospital was 1 of 3 hospitals for the diagnosis and treatment of occupational diseases in Turkey between 1980 and 2011 and served the provinces in Marmara region and the coastal Aegean cities which have 40% of total workforce of Turkey.[12] Some other health institutions were authorized after 2011; however, IODH still is the main health center that diagnoses most of the occupational disease cases in the region.

The ethical approval was obtained from the Ethics Committee of İstanbul University School of Medicine 1630(2018/1602), and research permission was obtained from IODH.

It was found that 9769 people were diagnosed with an occupational disease in IODH during the 12-year period. According to the ICD-10 code J62.8 (pneumoconiosis due to other dust-containing silica), 1473 silicosis cases were detected among all occupational diseases. The sociodemographic characteristics (gender, age of diagnosis, and smoking status), job characteristics (industry, duration of exposure, and age of first exposure to silica) of patients, comorbidities, functional and radiological data, and follow-up time were obtained from the medical records. Mortality data were gathered from The National Death Notification System of Ministry of Health (NDNSMH).

Definitions and Classification of Data

Dusty industries were defined based on the history of occupational exposure to silica dust in jobs with high-risk exposure to silica. Dusty industries were classified as denim sandblasting, metal casting and blasting, dental prosthesis production (blasting), ceramic production, ship construction (abrasive blasting), glass production, tunnel construction-stone quarry, coal mining, granite production, Teflon sandblasting, sand production, or others.[13]

Since there is no information about the silica concentration of the workplaces in records, total duration of work in high-risk jobs (years) was used to determine the amount of exposure intensities.

Comorbidities were classified as other occupational diseases (noise-induced hearing loss, lumbar and other intervertebral disc disorders, allergic contact dermatitis, adhesive capsulitis of shoulder, etc.), other pulmonary diseases apart from silicosis and tuberculosis (asthma, chronic obstructive pulmonary disease, bronchitis, etc.), and tuberculosis.

Premature death is the measure of years of potential life lost due to death occurring before the average life expectancy at birth. In death cases, premature deaths and YLL in premature deaths were calculated based on the date of death and life expectancy at birth. Life expectancy values were obtained from “Life expectancy at birth in European countries by sex, 2016” tables published by Turkish National Statistical Office, 2017.[14] Life expectancy at birth in Turkey was 80.8 years in women and 75.3 years in men in 2017.

Statistical Analysis

In descriptive statistics, measures of central distribution and tendency, frequencies and percentages were used. Shapiro–Wilk test was used to test normality. While chi-square test and Fisher's exact test were performed to compare categorical variables, Student's *t*-test and Mann–Whitney *U*-test were used to compare 2 independent groups, and Kruskal–Wallis test was performed to compare more than 2 independent groups because of abnormal distribution. Dunn's test was used for multiple comparisons when the significant result was obtained in the Kruskal–Wallis test as post hoc test. The multivariate Cox proportional hazards regression model was used to explore the independent risk factors associated with premature deaths. Univariate analysis results that were statistically significant were included in the Cox proportional hazard model. Some work activities that can generate respirable silica dust particles are much more hazardous than others. The jobs known with high silica exposure like glass production, granite production, coal mining, denim and Teflon sandblasting were separated from the others so 6 occupation categories were included in multivariate Cox regression analysis. All predictor variables were entered into the full model, until the best-fitting model (including occupation, tuberculosis, pulmonary function loss, and large opacities in Computed Radiography (CR)) was found.

Results were reported as hazard ratio (HR) for Cox analyses, with 95% CI in parentheses, and the data were analyzed in SPSS 21.0 program.

Go to:

Results

The study examined 9769 cases diagnosed with an occupational disease, and 15.0% (n = 1473) of them were diagnosed with silicosis. The mean age of silicosis patients was 40.4 ± 10.2 (17.0-85.0) years, and 26.9% of them were child labor when they started to work in dusty industries. Child labor was mostly seen in dental technicians (57.7%), denim sandblasters (46.4%), and miners (37.0%).

Distribution of cases according to occupation was as follows: denim sandblasting 21.1% (n = 311), metal casting sandblasting 16.8% (n = 247), dental prosthesis production (sandblasting) 13.3% (n = 196), ceramic production 10.7% (n = 157), ship construction 7.7% (n = 110), glass production 6.1% (n = 90), tunnel construction-stone quarry 4.1% (n = 61), coal mining 3.8% (n = 55), granite production 1.9% (n = 28), Teflon sandblasting 1.4% (n = 21), and sand production 0.8% (n = 12).

Median exposure duration was 12.0 (4 months to 47 years) years. A quarter of cases (25.0%, n = 362) were exposed to silica for 5 years or less, and mean diagnosis age for this group was 33.5 ± 9.0 years. One-fifth of all cases (19.7%, n = 289) were exposed to silica for 6-10 years, and mean diagnosis age for the group was 36.9 ± 8.6 years. Half of all cases (55.4%, n = 810) were exposed to silica for more than 10 years, and mean age at the diagnosis for this group was 44.7 ± 8.8 years. Data on pulmonary function tests and International Labour Organization (ILO) classification of patients during diagnosis and comorbidities are shown in Table 1.

Table 1.

Cohort Descriptives (n = 1473)

	n (%)	**Mean (±SD) or Median (Min-Max)**
Demographics		
Gender		
Female	9 (0.6)	
Male	1464 (99.4)	
Smoking status		
Never smoker	282 (19.1)	
Ex-smoker	356 (24.2)	
Current smoker	516 (35.0)	
Unknown	319 (21.7)	
Tobacco exposure (pack-year)		13.0 (0.5-130.0)
Job characteristics		

	n (%)	Mean (±SD) or Median (Min-Max)
Industries		
Denim sandblasting	311 (21.1)	
Metal casting and blasting	247 (16.8)	
Dental prosthesis production (blasting)	196 (13.3)	
Ceramic production	157 (10.7)	
Ship construction	110 (7.7)	
Glass production	90 (6.1)	
Tunnel construction-stone quarry	61 (4.1)	
Coal mining	56 (3.8)	
Granite production	28 (1.9)	
Teflon sandblasting	21 (1.4)	
Sand production	12 (0.8)	
Others	183 (12.4)	
Age of first exposure (years)		23.0 (9.0-58.0)
Child labor		
Yes (<18 year old)	371 (26.9)	
No (≥18 year old)	1006 (73.1)	
Duration of exposure (years)		12.0 (0.3-47)
Pulmonary function tests		
FEV1%		88.0 (13.0-139.0)
FVC%		90.0 (21.0-143.0)
FEV1/FVC		81.0 (30.0-113.0)
FVC classification		
FVC% ≤ 80	420 (28.9)	
FVC% > 80	1032 (71.1)	
FEV1/FVC classification		
FEV1/FVC ≥ 70	1249 (86.2)	
FEV1/FVC < 70	200 (13.8)	
ILO classification		
Category 1	666 (45.6)	

	n (%)	Mean (±SD) or Median (Min-Max)
Category 2	400 (27.4)	
Category 3	216 (14.8)	
Large opacities	177 (12.1)	
Comorbidities		
Pulmonary comorbidity	164 (18.1)	
Occupational comorbidity	278 (18.9)	
Tuberculosis	109 (7.6)	
Survival		
Age of diagnosis (years)		40.0 (17.0-85.0)
Duration of silicosis (months)		60.0 (4-455)
Survival		
Dead	76 (5.2)	
Alive	1383 (93.9)	
Unknown	14 (1.0)	
Age of death		49.2 (25.7-91.2)
YLL		26.0 ± 11.6
Second examination		
Yes	551 (37.4)	
No	922 (62.6)	

Open in a separate window

Missing variables were not analyzed so column percentages of available variables are given in the table. FEV, Forced Expiratory Volume; FVC, forced vital capacity; YLL, years of life lost.

Comparison of different occupational groups by some characteristics of workers is given in Table 2. The first exposure age, duration of exposure, diagnosis age, reduction in FVC (FVC% ≤ 80) at the time of diagnosis, large opacities in posterior anterior chest X-ray (PA-CXR) at the time of diagnosis, premature deaths, and YLL were statistically different between the occupational groups ($P < .001$). Denim sandblasters were characterized with the second youngest age of first exposure [19.0 (10.0-48.0) years] after dental technicians [17.5 (9.0-37.0) years]. They also had the shortest exposure duration [3.0 (0.3-28.0) years], the youngest age of diagnosis [31.0 (18.0-56.0) year], the second highest rate of reduction in FVC [50.0% (n = 152)] after Teflon sandblasters [70.0%],[14] the highest rate of having the large opacities during diagnosis [28.4% (n = 87)], and the highest YLL [37.1 (18.2-49.5) years]. Of all premature deaths, 39.4% (n = 26) were denim sandblasters.

Table 2.

Comparison of Different Occupational Groups by Some Characteristics of Workers

	Age of First Exposure (Years)†, Median (Min-Max)	Duration of Exposure (Years)†, Median (Min-Max)	Age of Diagnosis (Year-old)†, Median (Min-Max)	FVC% ≤ 80‡, % (N)	Large Opacities‡, % (N)	Years of Lost Life (Years)†, Median (Min-Max)
Denim sandblasting	19.0 (10.0-48.0)*	3.0 (0.3-28.0)*	31.0 (18.0-56.0)*	50.0 (152)*	28.4 (87)*	37.1 (18.2-49.5)*
Metal casting and blasting	26.0 (12.0-49.0)	12.0 (1.0-44.0)	41.0 (26.0-65.0)	18.6 (46)	3.6 (9)	21.1 (8.2-42.6)
Dental prosthesis production (blasting)	17.5 (9.0-37.0)*	20.0 (2.0-47.0)	40.0 (22.0-67.0)	23.8 (46)	9.9 (19)	31.3 (18.3-40.9)*
Ceramic production	24.0 (16.0-48.0)	17.0 (2.0-33.0)	43.0 (27.0-70.0)	15.5 (24)	3.2 (5)	27.1 (21.5-34.4)
Ship construction	24.0 (11.0-48.0)	15.0 (1.0-40.0)	42.0 (17.0-67.0)	15.7 (17)	0.9 (1)	20.0
Glass production	24.0 (13.0-50.0)	15.5 (0.8-33.0)	43.0 (25.0-70.0)	28.4 (25)	17.8 (16)	20.6 (6.3-41.3)
Tunnel construction-stone quarry	25.0 (13.0-43.0)	17.0 (1.0-30.0)	49.1 (28.0-77.0)	37.7 (23)	27.9 (17)*	18.7 (5.5-32.0)
Coal mining	21.0 (15.0-50.0)	20.0 (1.0-39.0)	57.0 (24.0-85.0)	49.1 (26)*	14.8 (8)	9.0 (3.3-33.1)
Marble production	23.0 (13.0-40.0)	19.0 (2.0-33.0)	43.0 (22.0-65.0)	35.7 (10)	10.7 (3)	30.6 (19.0-42.2)*
Teflon sandblasting	27.0 (12.0-48.0)	10.0 (2.0-16.0)	41.5 (26.0-54.0)	70.0 (14)*	19.0 (4)	22.1 (20.1-33.4)
Sand production	23.0 (15.0-36.0)	15.0 (3.0-32.0)	41.0 (27.0-55.0)	25.0 (3)	25.0 (3)	-

	Age of First Exposure (Years)†, Median (Min-Max)	Duration of Exposure (Years)†, Median (Min-Max)	Age of Diagnosis (Year-old)†, Median (Min-Max)	FVC% ≤ 80‡, % (N)	Large Opacities‡, % (N)	Years of Lost Life (Years)†, Median (Min-Max)
Others	24.0 (10.0-58.0)	13.0 (1.0-45.0)	41.0 (24.0-64.0)	18.6 (34)	2.7 (5)	16.7 (8.0-44.0)

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* $P < .001$.
†Kruskal– Wallis test [Table does not include ranks so measures of central tendency (median, maximum, and minumum) are given.]. ‡Chi-square test.

At least 76 patients (5.2% of all patients) had died, and 86.8% (n = 66) of them were premature deaths, 4.5% of silicosis patients had died before their average life expectancy. In the follow-up period, 26.3% (n = 5) of teflon sandblasters, 11.1% (n = 6) of coal miners, 8.6% (n = 26) of denim sandblasters had died before their average life expectancy and the YLL was 26.0 ± 11.6 years all over the group. Bivariate analyses indicated that the occupation (Teflon sandblasters) ($P < .001$), short duration of exposure ($P < .002$), reduction in FVC ($P < .001$), FEV1/FVC<70 ($P < .001$), large opacities in PA-CXR ($P < .001$), comorbid pulmonary diseases ($P < .001$), and tuberculosis ($P < .001$) were associated with premature death. Comparison of premature death and others according to some characteristics are shown in Table 3.

Table 3.

Comparison of Premature Death With Others by Some Characteristics (n = 1459)

	Premature Death (n = 66)		Others (n = 1393)		*P*
N (%)	Mean (±SD) or Median (Min-Max)	N (%)	Mean (±SD) or Median (Min-Max)		
Age of diagnosis		41.8±12.0		40.4±10.1	.277†
Duration of silicosis (months)		50 (4-335)		60 (4-348)	.001‡
Job characteristics					
Occupation					

	Premature Death (n = 66)		**Others (n = 1393)**		***P***
N (%)	**Mean (±SD) or Median (Min-Max)**	**N (%)**	**Mean (±SD) or Median (Min-Max)**		
Denim sandblasting	26 (8.5)		281 (91.5)		<.001[¶]
Metal casting and blasting	8 (3.2)		240 (96.8)		
Dental prosthesis production (blasting)	5 (2.6)		191 (97.4)		
Ceramic production	3 (1.9)		153 (98.1)		
Ship construction	1 (0.9)		109 (99.1)		
Glass production	6 (6.8)		82 (93.2)		
Tunnel construction-stone quarry	2 (3.4)		57 (96.6)		
Coal mining	5 (8.9)		51 (91.1)		
Granite production	2 (7.1)		26 (92.6)		
Teflon sandblasting	**5 (26.3)**		**14 (73.7)**		
Sand production	0 (0.0)		12 (100.0)		
Others	3 (1.7)		177 (98.3)		
Age of first exposure		23 (12-49)		23 (9-58)	.901[‡]
Duration of exposure		6.0 (0.8-33.0)		12.0 (0.3-47.0)	.002[‡]
Pulmonary function tests					
FEV1%		50 (19-116)		89 (13-139)	<.001[‡]
FVC%		63 (21-123)		91 (23-143)	<.001[‡]
FEV1/FVC		74 (43-112)		81 (30-113)	<.001[‡]
FVC% classification					
FVC% ≤ 80	**51 (12.3)**		**363 (87.7)**		<.001[§]
FVC% > 80	12 (1.2)		1013 (98.8)		

	Premature Death (n = 66)		Others (n = 1393)	*P*
N (%)	Mean (±SD) or Median (Min-Max)	N (%)	Mean (±SD) or Median (Min-Max)	
FEV1/FVC classification				
≥70	41 (3.3)		1197 (96.7)	<.001§
<70	**21 (10.6)**		**177 (89.4)**	
Large opacities in PA-CXR				
Yes	**33 (18.8)**		**143 (81.2)**	<.001§
No	31 (2.4)		1238 (97.6)	
Comorbidities				
Pulmonary comorbidity				
Yes	**21 (8.0)**		**243 (92.0)**	<.001§
No	37 (3.2)		1134 (96.8)	
Tuberculosis				
Yes	**18 (16.5)**		**91 (83.5)**	<.001§
No	39 (2.9)		1286 (97.1)	

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Row percentages are given in the table. FVC, forced vital capacity; PA-CXR, posterior anterior chest X-ray.
†Student's *t*-test; ‡Mann–Whitney *U*-test; §Chi-square test; ¶Fisher's exact test.

The results of the Cox regression analysis are presented in Table 4. The occupation [HR (Teflon sandblasting): 3.93, CI: 1.43-10.78; HR (granite production): 4.4, CI: 1.02-19.21]; large opacities in PA-CXR [HR: 2.14, CI: 1.18-3.86]; tuberculosis [HR: 2.60, CI: 1.42-4.76]; and reduction in FVC (FVC% ≤ 80) during diagnosis [HR: 4.43, CI: 2.22-8.83] were all associated with premature death. The short duration of exposure time, FEV1/FVC < 70 during diagnosis, and comorbid pulmonary diseases were found to be associated with premature death in bivariate analyses; however, no significant association between them and premature death was found in Cox regression.

Table 4.

Cox Regression Analysis of Premature Deaths in Silicosis

	HR (95% CI)	***P***
Occupation		
Others*	1	
Glass production	1.56 (0.53-4.60)	.418
Granite production	4.44 (1.02-19.21)	.046**
Denim sandblasting	1.08 (0.57-2.05)	.799
Coal mining	1.11 (0.25-4.82)	.883
Teflon sandblasting	3.93 (1.43-10.78)	.008**
Tuberculosis		
No*	1	
Yes	2.60 (1.42-4.76)	.002**
Pulmonary function loss		
FVC% >80*	1	
FVC% ≤80	4.43 (2.22-8.83)	<.001**
Large opacities in CR		
No*	1	
Yes	2.14 (1.18-3.86)	.011**

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* *P* < .05.
*Reference group. FVC, forced vital capacity; HR, hazard ratio.

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Discussion

More than a quarter of silicosis cases were child labor when they started to work in dusty industries. At least 5.2% of silicosis patients had died and 4.5% of silicosis patients also had died before their average life expectancy and the YLL was 26.0 years in follow-up period in this study. Especially, sandblasters are under the risk of premature deaths of silicosis. This study shows the relationship among patient premature deaths and occupation, large opacities in PA-CXR, tuberculosis, and pulmonary function loss.

ILO reported that the 73 million children between the age of 5 and 17 years work in hazardous industries, mostly including construction, mining and manufacturing industries, which increase the risk of the development of silicosis.[15] Although it is estimated that child labor is common in industries with high risk of silicosis in both developing and undeveloped countries, only a limited number of studies revealed the real aspect. In Brazil, 44.7% of silicosis cases worked as stone polishers and miners, and in Turkey, similarly 45.2% of silicosis cases worked as denim sandblasters who had begun sandblasting before they were 18 years of age.[16,17] As shown in this study, child labor was seen in approximately 6 in 10 dental technicians followed by nearly half of denim sandblasters and more than 1 in 3 miners in all silicosis cases. This study does not only show that child labor in dusty industries results in a high rate of silicosis but also shows that the rate of child labor is very high among dental technicians with silicosis, which has not been previously identified as a risky industry for intensive child labor. The fact that these workers began to work when they were still children should serve as a warning for public authorities, and they should take more effective and deterrent actions to prevent child labor.

Although there have been case series and case notifications from different sectors in recent years,[16,18-20] silicosis cases are seen more frequently in traditional industries like mining, drilling, quarrying, ceramic production, and construction which are known to be related with silicosis[21,22] However, in our study, approximately 60% of all cases were from sandblasting-derived industries such as denim sandblasting, metal casting and sandblasting, dental prosthesis production (sandblasting), ship construction (abrasive blasting), and Teflon sandblasting. The results show the industrial distribution of silicosis cases in a developing country. Similarly, a recent study in China found that the ferrous metal processing industry is one of the industries where silicosis cases were found the most.[21] These results may be related to the fact that silicosis is seen less frequently as a result of implementing occupational health and safety regulations in the traditional industries compared with the new industries which do not provide adequate occupational health and safety conditions.

Despite the short-term exposure and the young age of diagnosis, the highest rate of reduction in FVC, the highest rate of large opacities, and the greatest YLL in all occupational groups should be related to intensive exposure to silica in sandblasters in our study. On the other hand, previous research shows that the freshly fractured silica formed during sandblasting is more likely to produce free radicals, hence its fibrogenic potential is also higher, which may explain both the highest rate of sandblasting activities in silicosis cases and large opacities in sandblasters in the study.[23,24]

After the outbreak of silicosis in Turkey, denim sandblasting was banned,[25] however, sandblasting still continues in other industries. Sandblasting is a hazardous method for human health which is used to make clean surfaces in various industries; it can be substituted by alternative methods.

Within the scope of the research, cause-specific mortality rate could not be calculated and discussed, since researchers were not given access to NDNSMH for cause-specific mortality. Therefore, premature death, another important measurement which refers to the measure of years of potential life lost due to death occurring before the average life expectancy at birth, was used as the output of the research.

At least 5.2% of silicosis patients had died and 4.5% of silicosis patients also had died before their average life expectancy and the YLL was 26.0 years in the follow-up period in this study. In China, it is similarly reported that silicosis has the highest mean YLL with an average of 22.1 years.[26] In total, pneumoconiosis- and silicosis-related YLL was 26.5 years according to Centers for Diseases Control and Prevention weekly report, and stone products had the greatest YLL with 23.5 years across all the industries.[10,26] The study revealed that denim sandblasters who started working in young ages may have the greatest YLL due to deaths in denim sandblasters from subacute or accelerated silicosis. According to another study, 6.2% of denim sandblasters died at a mean age of 24 years in the 4 years follow-up period.[27]

Another limitation of the research is the absence of data on silica exposure intensities. However, this study shows that there is a significant relationship between the duration of exposure and the age of diagnosis. This may be related to the appearance of disease at a young age with a short duration but intense exposure. Previous studies also point out that workers in traditional industries may develop chronic silicosis with a slow progression due to low exposure intensity. On the contrary, in other industries, workers may be diagnosed with acute and accelerated silicosis over a short period of time, due to high-intensity silica concentrations.[28]

This study yielded that Teflon sandblasters have 3.93 times, workers who work in granite industry have 4.40 times, silicosis patients with large opacities in PA-CXR have 2.14 times, cases with silicotuberculosis have 2.60 times, and patients with a decreased pulmonary function during diagnosis have 4.43 times increased risk for premature death.

Some industries could be riskier for premature deaths because of high-intensive exposure to silica. This study shows an association between some occupations (Teflon sandblasting, granite production) and premature deaths. On average, granite naturally contains 70-77% crystalline silica by weight.[29] Sandblasting of Teflon pan manufacturing causes commonly acute form of silicosis, and mortality was high.[30]

Large opacities in PA-CXR are caused by the large conglomerate masses of dense fibrosis is called progressive massive fibrosis (PMF) and reduced the respiratory functions of smokers and non-smokers in a major way. National Institute for Occupational Safety and Health reported 10% of coal miners and another study showed 9.6% of denim sandblasters had large opacities in PA-CXR.[16,31] In this study, it was determined that 12.1% cases had large opacities in PA-CXR, and having large opacities increases the risk of premature death 2.14 times. In a study conducted with silicosis patients, it was determined that patients who had profusion category 2, 3 and large opacities had higher risk of mortality and type C opacity had the highest risk with standardized mortality ratio 8.92.[8] Development of large opacities in silicosis patients reduces the quality of life and more importantly can lead to premature death. New studies and further research are needed to determine which silicosis patients have higher risk of developing PMF. Since there is no treatment for silicosis as of today, these patients should be monitored more frequently.

It has been determined that people with silicosis had 2.8-39 times higher risk of having tuberculosis compared to healthy individuals.[3,31] Among silicosis patients, incidence of active tuberculosis has been found as 32% and the prevalence of latent tuberculosis has been shown to be 46.6-61%.[32] In our study, frequency of tuberculosis cases seems to be lesser compared to other countries. This might be due to decrease in incidence of tuberculosis in Turkey, or it might be caused by data deficiencies. Tuberculosis mortality rate in silicosis patients is being discussed through numerous studies. Silicosis cases with tuberculosis have 3.75 times higher risk of death.[19] In United States, 13.7% patients who died from silicosis was also diagnosed with tuberculosis between 1968 and 2006.[33] This study shows that among 109 participants, tuberculosis resulted in premature death for 16.5% of the individuals, and risk of premature death has increased 2.6 times for individuals who had tuberculosis.

Silicosis increases the risk of tuberculosis, and silicotuberculosis increases the risk of death. However, the fact that both of the diseases are preventable yet they continue to take lives is thought provoking. In silicosis cases, precautions must be taken before tuberculosis occurs, and every case must be inspected carefully for latent tuberculosis infection. Necessary tests must be performed, and patients who have been deemed suitable must start preventive treatment.

The studies indicate that reduced lung function was more likely to be associated with higher categories of silicosis (ILO 3) than with lower categories; however, in our study, both reduced lung function and large opacities in PA-CXR are associated with premature death as independent variables. The risk of premature death increases 4.43 times for cases whose reduction in FVC% ≤80 during diagnosis. Reduction in FVC at the beginning should be a warning sign for clinicians.

More than a quarter of silicosis cases were child labor when they started to work in dusty industries. This should serve as a warning for public authorities who should take more effective and deterrent actions to prevent child labor. Sandblasters are under the risks of premature death due to silicosis. This study shows the relationships among patient premature deaths, occupation, large opacities in PA-CXR, tuberculosis, and pulmonary function loss. More attention should be given to tuberculosis prevention in silicosis.

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Footnotes

Ethics Committee Approval: The ethical approval was obtained from the Ethics Committee of İstanbul University School of Medicine 1630(2018/1602) and research permission from IODH.

Patient Consent for Publication: N/A.

Data-sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Concept - E.A.H., Z.K.; Design - E.A.H.; Supervision - E.A.H.; Data Collection and/or Processing - D.A.K., E.K.O., B.T., K.O.Ş.; Analysis and/or Interpretation - E.A.H., D.A.K., E.K.O., B.T., K.O.Ş.; Literature Review - E.A.H., D.A.K., E.K.O., B.T.; Writing - E.A.H., D.A.K., E.K.O., B.T.; Critical Review - E.A.H., Z.K.

Conflict of Interest: The authors have no conflicts of interest to declare.

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Appendix 11

UK Parliament

Parliamentary Bills

House of Commons

Quarries (Planning) Bill

Private Members' Bill (under the Ten Minute Rule)

Originated in the House of Commons, Session 2021-22

Last updated: 4 May 2022 at 17:13

Commons — Lords — Final stages

See full passage

Details | News | Stages | Publications

Long title

A Bill to introduce a presumption in planning decision-making against approving quarry development in close proximity to settlements; to require the risks of proposed quarrying sites to health and the environment, including through silica dust, to be assessed as part of the planning process; to make provision about the use of quarries for waste disposal; and for connected purposes.

Sponsor

Matt Western
Labour
Warwick and Leamington

Bill passage

Bill started in the House of Commons	Bill in the House of Lords	Final stages
1st reading	1st reading	Consideration of amendments
2nd reading	2nd reading	Royal Assent
Committee stage	Committee stage	
Report stage	Report stage	
3rd reading	3rd reading	

Key: Complete | In progress | Not applicable | Not yet reached