



Silica Dust Exposure, Respiratory Illness, and Occupational Morbidity in Rajasthan's Stone Grinding Industry

Dr. Prakash Chand Sharma

Associate Professor

Department of Zoology

Samrat Prithviraj Chauhan Government College, Ajmer, India

Abstract : In Rajasthan, the “Makrana-Ajmer-Beawar Industrial Region” of the Ajmer division is known for its concentrated growth of agro-mineral, metallurgical, and chemical-based industries. Beawar is one of the major industrial zones where stones are ground and milled as a raw material for ceramic industries. This study summarizes findings from 109 workers and 35 persons in control group. It was found that workers in units that primarily grind quartz are at a higher risk of occupational diseases due to their exposure to extremely high levels of silica. Workers involved in the collection process were found to be the most susceptible to severe dust-related diseases, this is due to the high severity of exposure. Collection (15.45 mg/m³) and Bagging (12.94 mg/m³) produce over 3 times more dust than dressing (3.30 mg/m³).

Along with respiratory morbidity, there is prevalence of non-respiratory morbidity among workers in this workplace. Approximately 39% of workers reported experiencing at least one respiratory issue, compared to only 15% in the control group. Prevalence of respiratory morbidity including shortness of breath (36%), acute coughing (28%), chronic coughing (31%), irritation in throat (15%) and chest congestion (14%) was observed among workers. However, 55.96 percent of workers reported no respiratory complaints. Noise Induced Hearing Loss (NIHL) including speech disturbance (44%) and hardness of hearing (20%) was also prevalent among stone grinders and millers. Skin related morbidity, however, is not significant among workers (8%) when compared to control group. Nearly 56% of workers reported one or more incidences of minor injuries during their job in last one year. Clinically proven cases of silicosis (9.2%), silicotuberculosis (4.5%) and COPD (6.4%) were also revealed in the study.

Index Terms - Stone milling, shortness of breath, NIHL, Silicosis, COPD.

I. INTRODUCTION

Throughout history, the focus of environmental issues has been on the risks they pose to human life and health. Humans, in turn, have attempted to modify the environment for their own advantage, which has also resulted in potential hazards. (Shrivastava, 2004). The most significant health risks are often shouldered by the less privileged in our societies. Health threats are predominantly found among the impoverished, those with limited formal education, and those in lower-tier occupations. These risks tend to cluster and accumulate overtime (WHO, 2002).

Rajasthan is responsible for approximately 22% of the country's industrial mineral output. The state currently mines 61 minerals, 39 of which are major and 22 are minor. Most workers in the mining and mineral industry are unorganized labor (GoI, 2010). They often face substandard working conditions in various aspects such as limited space, inadequate ventilation, poor lighting, extreme temperatures, high humidity, lack of hygiene and cleanliness, and insufficient protection against accidents. (NCEUS, 2008). As a result, they are exposed to various health risks, prone to accidents, and subject to conditions of lawlessness.

According to the Policy on Pneumoconiosis (Including Silicosis) Detection, Prevention, Control and Rehabilitation (2019), respiratory illness is a leading cause of illness and death in Rajasthan. Interestingly, rural areas have a higher prevalence of respiratory diseases than urban areas. This is primarily due to dusty conditions, inadequate sanitation, and widespread mining and quarrying activities and related industries. (GoR, 2019).

In Rajasthan, the “Makrana-Ajmer-Beawar Industrial Region” of the Ajmer division is known for its concentrated growth of agro-mineral, metallurgical, and chemical-based industries. (Bhalla, 2008). The mining and mineral processing sectors in Rajasthan draw a large amount of affordable labor from both nearby and distant areas (Husain, 2008). Industries involved in stone crushing and grinding thrive near the Aravalli hills, particularly in the Beawar subdivision. Within this industrial region, Beawar is a small yet thriving city in the Ajmer district. It is nestled among the Aravalli hills at a latitude of 26°06' north and a longitude of 74°17' east, with an average elevation of 447.14 meters above mean sea level.

In the city of Beawar, nearly 400 small-scale enterprises, most of which are unregistered, are involved in stone grinding and milling operations. These units produce fine powder of various grades from a range of minerals such as quartz, feldspar, mica,

china clay, etc. These powders either have their own end uses or are transported to other industries to be used as raw materials or additives in the manufacturing of other products like glass, ceramics, refractories, chemicals, etc. (Mamoria and Mishra, 2007). They are exposed to the mineral dust produced during the manufacturing, storage, and packaging of mineral powder. (Purohit et al., 1992). Naturally, the respiratory system becomes the target organ for these airborne contaminants, as it serves as the main entry point for most airborne pollutants in the workplace environment of mineral-based small-scale enterprises. (Kashyap, 1994). A significant percentage of particulate matter that is 10 micrometers in size (PM₁₀) tends to deposit in the bronchi and lungs, potentially causing health damage. Particles that are smaller than 2.5 micrometers (PM_{2.5}) tend to penetrate deeper into the gas exchange regions of the lung (Viswanathan, 1978).

Undoubtedly, the health risks for workers exposed to fine stone dust are severe, potentially leading to various health conditions (Srivastava, 2022). As such, it becomes imperative to investigate and understand the impact of occupations such as grinding and milling on the health of these workers.

II. MATERIAL AND METHODS

Dust samples were collected using a personal air sampler (PAS; APM 800, envirotech, India), with a cyclone for Total Suspended Particulate (TSP) and without one for Respirable Suspended Particulate Matter (RSPM). The sampler was placed in the 'personal breathing zone (PBZ)' of workers at the most dust-prone operating locations to assess personal exposure to dust. The sampler operated at a flow rate of 2.0 LPM (liters per minute) for a duration of three hours. Following this, the samples were analyzed using the gravimetric method to estimate the levels of TSP and RSPM.

In this study, we utilized a modified version of the 'Kuppuswami Socio-economic scale' (Kumar et al., 2007) to determine the Socio-economic Status (SES) of individuals. Questionnaires were used in this study to identify morbidity distribution among 109 workers in stone grinding and milling units, as well as 35 individuals in a control group comprised of managerial staff. Self-reported histories of clinically confirmed silicosis, silicotuberculosis, and COPD were recorded based on previous medical records, government disability certificates, and hospital radiological documentation presented by the workers (GoR, 2019). These questionnaires also aid in the selection and inclusion of individuals for medical examinations, as well as in defining and categorizing risk groups. In this study, the questionnaires were designed based on standard formats but were modified and translated into Hindi to ensure their practical applicability within the cohort.

III. RESULTS AND DISCUSSION

The estimation of personal exposure to dust was carried out through gravimetric analysis. This exposure was measured during various operations, including dressing (which involves crushing stones to pebble size), feeding (the manual process of adding stones to the stone feeding soot), and collection and bagging. The study found that workers in units that primarily grind quartz are at a higher risk of occupational diseases due to their exposure to extremely high levels of silica.

Table 1: Workplace dust concentration in various operations

Particulars of operation	Average of observed concentrations of dust (mg/m3)	Free Silica (%)	Personal Limit of Exposure	% of samples below PLE	Average Severity of exposure
in terms of total dust (TSP)					
Dressing	3.299	64.596	0.450	25	4.802
Feeding	4.960			16.67	7.219
Collection	15.446			0	22.482
Bagging	12.944			0	18.840
Average	9.162			10.42	13.340
in terms of respirable dust (RSPM)					
Dressing	1.314	64.596	0.150	33.33	1.913
Feeding	2.169			25	3.156
Collection	4.925			0	7.169
Bagging	3.970			0	5.778
Average	3.095			14.58	4.504

The study revealed that dust exposure exceeded the permissible limit of exposure. In the study 3-hour grab samples at 2.0 LPM were used to assess peak operational exposure rather than representing a strict 8-hour time-weighted average (TWA). Only a small fraction of the samples, 10.42% for Total Suspended Particulate (TSP) and 14.58% for Respirable Suspended Particulate Matter (RSPM), were found to be below the Permissible Limit of Exposure (PLE). The average TSP was measured at 9.162 mg/m³, while the average RSPM was found to be 3.095 mg/m³ based on long-term averages. Similar findings were also reported by Kumari et al. (2021) showing PM concentrations exceeding occupational exposure limits by multiple fold.

It was observed that the severity of exposure varied across different operations in the order of

Collection>Bagging>Feeding>Dressing

Workers involved in the collection process were found to be the most susceptible to severe dust-related diseases. This is due to the high severity of exposure, which was measured at 22.48 for total dust and 7.17 for the respirable fraction based on long-term average exposure.

Wagh (2006) reported that exposure to dust was highest near the source of dust generation. This finding was echoed by Bahrami et al. (2008), who found that hopper workers were exposed to 9.46 mg/m³ of total dust and 1.24 mg/m³ of respirable dust,

that was more than process workers, drivers, and office employees. Bahrami and Mahjub (2008) reported respirable dust concentrations 40 times higher than the Permissible Exposure Limit (PEL). Bhagia et al. (2007) identified maximum exposure in stone feeding in jaw crusher, near the hammer mill during collection, and during bagging and packing near the vibrating screen. Poor maintenance, inadequate housekeeping, and leakage were identified as factors contributing to severe air contamination (Srivastava 2022).

Yingratanasuk et al. (2002) reported quartz exposure among stone carvers in Thailand that was 0.5–8 times greater than the ACGIH-TLV. Bang and Suhr (1998) found that 41% of Total Suspended Particulate (TSP) samples and 73% of Respirable Suspended Particulate Matter (RSPM) samples exceeded the Norwegian TLV for quartz in different parts of the slate industry in Alta, Northern Norway. Exposure to free silica higher than permissible limits can lead to silicosis. Both low-level long-term exposure (Mital et al. 1964; Kuempel et al. 2003) and high-level short-term exposure (Ziskind et al. 1976; Buchanan et al. 2003) can significantly increase the risks of silicosis.

The distribution of morbidity among workers and the control group is outlined in Table 2, while the statistical analysis of these findings can be found in Table 3. A limitation of this study is the selection of managerial personnel as the comparison group. While convenient for baseline comparisons within the same enterprise, differences in socioeconomic status, educational background, physical exertion, and domestic fuel exposure between manual laborers and administrative staff may confound self-reported morbidity. Future investigations should employ socioeconomically matched controls from non-dusty occupations. Approximately 39% of workers reported experiencing at least one respiratory issue, compared to only 15% in the control group. Aside from throat irritation and acute coughing, other respiratory ailments were significantly more prevalent (P -value <0.05 at 95% confidence limit) among workers exposed to silica. This aligns with the findings of Ghotkar et al. (1995), who reported a 32.5% prevalence of respiratory morbidity among quarry workers.

Table 2: Morbidity distribution among workers in the study areas and control group

Disease		Workers (n=109)	Control (n=35)
Respiratory ailments	Shortness of breath	39 (35.78)	05 (14.29)
	Irritation in throat	17 (15.60)	03 (05.71)
	Acute coughing	31 (28.44)	04 (11.43)
	Chronic coughing	34 (31.19)	01 (02.85)
	Wheezing except in cold	14 (12.84)	00 (00.00)
	Acute Phlegm	28 (25.69)	02 (05.71)
	Chronic Phlegm	32 (29.36)	00 (00.00)
	Chest Congestion	16 (14.68)	00 (00.00)
	Chest pain	08 (07.34)	00 (00.00)
	No complain	61 (55.96)	28 (80.00)
Noise Induced Hearing Loss	Speech disturbance	48 (44.04)	00(00.00)
	Hard hearing	22 (20.18)	00(00.00)
	Decreased performance	37 (33.94)	00(00.00)
	Ignore/reported no loss	61 (55.96)	35 (100.0)
Work associates skin problems		09 (08.26)	01 (02.86)
Eye Disease	Redness and Irritation	22 (20.18)	02 (05.71)
Mechanical hazards	Minor Injury	61 (55.96)	04 (11.43)
	Major Injury	04 (03.67)	00 (00.00)

It was estimated that chronic coughing and acute phlegm were the main respiratory ailments among exposed group which had 11 fold and 4.5 times higher risk of development in exposed group compared to control considering the relative risk (11.0) and odds ratio (15.41), this suggests higher prevalence of chronic coughing in workers, this was also true for acute phlegm (risk ratio 4.5 and odds ratio 5.7). Furthermore, statistically significant elevations were observed for shortness of breath ($P= 0.0073$), acute phlegm ($P= 0.0039$), and chest congestion ($P= 0.0043$), with test powers exceeding 50% under continuity correction.

Sachdeva et al. (2021) found breathlessness (92%) and chronic cough (61.9%) to be the predominant presenting symptoms in stone crusher workers, with less than 3% reporting regular mask or PPE usage. Pankaj et al. (2020) evaluated sandstone workers in Jodhpur, Rajasthan, using ILO chest radiography and spirometry, reporting high rates of silicosis (37.3%) and respiratory impairment, which align with the findings of this study. Bhagia et al. (2014) found that silicosis and silico-tuberculosis are common among silica exposed workers.

Table 3: Statistical analysis of morbidity among workers compared to control

Disease		Risk factor (%)		Mid-P exact	Relative risk	Odds ratio	Power (%)	
		Exposed	Control				Normal	with CC
Respiratory ailments	Shortness of breath	35.78	14.29	0.0073	2.5	3.343	67.38	58.90
	Irritation in throat	15.60	05.71	0.1569	1.82	1.971	32.30	21.67
	Acute coughing	28.44	11.43	0.192	2.5	3.080	53.29	43.58
	Chronic coughing	31.19	02.85	7.52E-4	11.0	15.41	93.35	89.58
	Wheezing	12.84	00.00	8.14E-3	-	-	60.88	46.55
	Acute Phlegm	25.69	05.71	3.99E-3	4.5	5.704	72.09	62.86
	Chronic Phlegm	29.36	00.00	1.76E-5	-	-	96.06	93.37
	Chest Congestion	14.68	00.00	4.34E-3	-	-	67.49	54.57
	Chest pain	07.34	00.00	0.043	-	-	37.69	20.66
NIHL	Speech disturbance	44.04	00.00	1.0E-7	-	-	99.91	99.80
	Hard hearing	20.18	00.00	6.09E-4	-	-	83.03	74.63

	Decreased performance	33.94	00.00	2.6E-6	-	-	98.47	97.25
Work associates	skin problems	08.26	02.86	0.153	2.9	3.060	19.20	08.47
Eye Disease	Redness and Irritation	20.18	05.71	0.020	3.5	4.172	51.57	40.33
Mechanical hazards	Minor Injury	55.96	11.43	9.63E-7	4.9	9.849	99.79	99.60
	Major Injury	03.67	00.00	0.162	-	-	20.78	03.04

*Note: Relative Risk (RR) and Odds Ratio (OR) could not be calculated directly for zero-cell categories without applying continuity corrections.

Iftikhar et al. (2009) also found cough with or without sputum, dyspnea and wheezing as major symptoms of respiratory impairment after exposure to airborne dust rich in silica. In Mexico, Zubieta et al. (2009) reported respiratory morbidity in order shortness of breath (46%) > wheezing and coughing (12%) > elevated sputum production (10%). Manhas et al. (2008) also found shortness of breath in all workers and productive cough in 70%. Yingratanasuk et al. (2002) reported highest morbidity among stone carvers in Thailand, from phlegm (26.8%) followed by cough (16.5%), dyspnea (12.4%), chronic bronchitis (6.2%) and wheezing (4.1%). Deshmukh (1984) in a similar study found 47% subjects with breathlessness, 30% with cough and 17% with chest pain. Clinically proven cases of silicosis (9.2%), silico-tuberculosis (4.5%) and COPD (6.4%) were also reported by workers in this study.

Apart from respiratory ailments, prevalence of noise induced problems in workers were also significant (P value <0.05). Nandi and Dhatrik (2008) reported that noise induced hearing loss (NIHL) is the second most common form of acquired hearing loss after age related loss (presbycusis). They found that noise over 85dBA in industries bilaterally and symmetrically affect the higher frequencies between 3 to 6 kHz. They found that this type of impairment initially leads to loss in clarity in perceiving speech and then interfere with daily activities. Joshi et al. (2003) also found dip at 4 kHz. Tay (1996) also found high percent of NIHL in quarrying and grinding workers in Singapore. Self-reported hearing impairment was markedly higher among workers, with 44.04% reporting speech disturbance and 20.18% reporting hardness of hearing, compared to none in the control group ($P < 0.001$). The statistical comparison between groups for these acoustic symptoms exhibited high power (> 74% with continuity correction). Almost 56% of workers and all individuals in the control group reported ignoring ambient workplace noise. Sayler et al. (2018) observed highest average noise exposure (mean = 89dBA) among stone loaders working in stone processing units in Thailand.

Although work-associated skin problems were more prevalent in workers than controls (8.26% vs. 2.86%; RR = 2.9, OR = 3.06), this difference was not statistically significant ($P = 0.153$), reflecting low statistical power (8.47% with continuity correction). Conversely, eye redness and irritation were significantly elevated among exposed workers (20.18% vs. 5.71%; $P = 0.020$, RR = 3.5, OR = 4.17).

Minor mechanical injuries were reported by 55.96% of workers compared to 11.43% of controls, demonstrating a highly significant elevation in risk ($P = 9.63 \times 10^{-7}$; RR = 4.9, OR = 9.85) with statistical power exceeding 99%. Tiwari et al. (2003) found high rate of negligence to minor injuries (32.2%). They revealed illiteracy and poverty as a base cause for this. Also lack of knowledge and practice and workers' coverage in social security schemes added to the problem. Zubieta et al. (2009) also reported lack training of workers regarding safety, hearing conservation and respiratory protection as a major cause of disease and injury.

REFERENCES

- [1] Bahrami AR, Golbabai F, Mahjub H, Qorbani F, Aliabadi M, Barqi M. 2008. Determination of exposure to respirable quartz in the stone crushing units at Azendarian-west of Iran. *Ind Health*, 46: 404-8.
- [2] Bahrami AR, Mahjub H. 2003. Comparative study of lung function in Iranian factory workers exposed to silica dust. *East Mediterranean Health Journal*, 9(3): 390-8.
- [3] Bang BE, Suhr H. 1998. Quartz exposure in the slate industry in northern Norway. *Ann Occup Hyg*, 42(8): 557-63.
- [4] Bhagia LJ, Tiwari RR, Sharma YK, Saiyed HN. 2007. Silicosis and its control in small scale silica mills in India. *GOHNET*, 12: 12-5.
- [5] Bhagia LJ, Dodia SL, Shaeikh MI. 2014. Silica Dust Exposure and Efficacy of Dust Control System in Small Silica Flour Mills, India. *Global J Res Analysis*, 3(4): 28-31.
- [6] Bhalla LR. 2008. *Geography of Rajasthan*, 7th Edition. Kuldeep Publications, Jaipur, pp 241.
- [7] Buchanan D, Miller BG, Soutar CA. 2003. Quantitative relations between exposure to respirable quartz and risk of silicosis. *Occup Environ Med*, 60: 159-64.
- [8] Deshmukh PA. 1984. Chest diseases in industry. *Ind J Tub*, XXXI: 53-64.
- [9] Government of India (GoI). 2010. India 2010, A reference annual, 54th Edition. Publication division, ministry of information and broadcasting, Government of India 2010, pp 1286. ISBN: 978-81-230-1617-7.
- [10] Government of Rajasthan (GoR). 2019. Policy on Pneumoconiosis (Including Silicosis) Detection, Prevention, Control and Rehabilitation. Department of Social Justice and Empowerment, Government of Rajasthan.
- [11] Ghotkar VB, Maldhure BR, Zodepy SP. 1995. Involvement of lung and lung function tests in stone quarry workers. *Indian J Tub*, 42: 155-160.
- [12] Husain M. 2008. *Human geography*, 3rd Edition. Rawat Publications, New Delhi, pp 582. ISBN: 978-81-703-3724-9.
- [13] Iftikhar B, Khan MH, Hussain H, Iqbal M, Jadoon GS. 2009. Relationship between silica dust exposure and chronic obstructive pulmonary disease in workers of dust generating industries of district Peshawar. *Gomal J Med Sci*, 7(1): 46-50.
- [14] Joshi SK, Devkota S, Chamling S, Shrestha S. 2003. Environmental noise induced hearing loss in Nepal. *Kathmandu Univ Med J*, 1(3): 177-83.
- [15] Kashyap SK. 1994. Occupational pneumoconiosis and tuberculosis -Oration. *Ind J Tub*, 41: 73-6.
- [16] Kumar N, Shekhar C, Kumar P, Kundu AS. 2007. Kuppaswamy's socio-economic status scale-updating for 2007. *Indian J pediatrics*, 74: 1131-2.
- [17] Kumari R, et al. 2021. Assessment of occupational dust exposure and respiratory health status of stone crusher workers. *Environ Sci Pollut Res*, 28: 43285-43297.

- [18] Kuempel ED, Attfield MD, Vallyathan V, Lapp NL, Hale JM, Smith RJ, Castranova V. 2003. Pulmonary inflammation and crystalline silica in respirable coal mine dust: dose-response. *J Biosci*, 28: 61-9.
- [19] Mamoria CB, Mishra JP. 2007. Advanced geography of India, 14th Edition. Sahitya Bhawan, Agra, pp 762. ISBN: 81-728-8298-X.
- [20] Manhas DK, Manhas BK, Khanna SL, Modi D. 2008. Clinicoradiological profile of silicosis in stone crusher workers. *NAPCON-2007*, 48.
- [21] Mital OP, Singh SK, Raj B. 1964. Silicotuberculosis in surface workers with a case report. *Indian J Tub*, XI(2): 98-101.
- [22] Nandi SS, Dhatrak SV. 2008. Occupational noise-induced hearing loss in India. *Indian J Occup Environ Med*, 12(2): 53-56.
- [23] National Commission for Enterprises in the Unorganized Sector (NCEUS). 2008. Report on conditions of work and promotion of livelihoods in the unorganized sector. Academic Foundation, pp 390. ISBN: 978-81-718-8678-4.
- [24] Pankaj B, Sharma N, Vyas S, et al. 2020. Silico-tuberculosis, silicosis and other respiratory morbidities among sandstone mine workers in Rajasthan. *PLOS ONE*, 15(4): e0230574.
- [25] Purohit SD, Gupta PR, Gupta ML, Chauhan A. 1992. Acute silicosis in handlers of silica powder bags. *Lung India*, 10(4): 145-8.
- [26] Sachdeva RA, Dawar S, Nagar S, Parashar D, Sachdeva S. 2021. Clinico-radiological profile of silicosis patients presenting at a tertiary care centre of Haryana, India. *Indian J Respir Care*, 10: 47–52.
- [27] Sayler SK, Long RN, Nambunmee K, Neitzel RL. 2018. Respirable silica and noise exposure among stone processing workers in northern Thailand. *J Occup Environ Hygiene*, 15(2): 117-124.
- [28] Shrivastava AK. 2004. Nature Conservation. APH Publishing House, New Delhi, pp 345. ISBN: 978-81-764-8596-8.
- [29] Srivastava AK, et al. 2022. Burden of silicosis among stone crushing workers in India. *Occupational Medicine*, 72(6): 366–371.
- [30] Tay P. 1996. Severe noise-induced deafness - a 10 year review of cases. *Singapore Med J*, 37: 362-364.
- [31] Tiwari RR, Narayan R, Saiyed HN. 2003. Knowledge and practices regarding injury care among stone quartz workers. *Ind J Med Sci*, 57(7): 300-2.
- [32] Viswanathan R. 1978. Health hazards of air pollution and smoking. *Indian J Tub*, XXV(1): 19-26.
- [33] Wagh ND, Pachpande BG, Patel VS, Attarde SB and Ingle ST. 2006. The influence of workplace environment on lung function of flour mill workers in Jalgaon urban center. *J Occup Health*, 48: 396-401.
- [34] World Health Organization (WHO). 2002. The world health report 2002 - Reducing risks, promoting healthy life. World Health Organization, pp 248. ISBN: 9789241562072.
- [35] Yingratanasuk T, Seixas N, Barnhart S, Brodtkin D. 2002. Respiratory health and silica exposure of stone carvers in Thailand. *Int J Occup Environ Health*, 8(4): 301-8.
- [36] Ziskind M, Jones RN, Weill H. 1976. Silicosis - state of the art. *Am Rev Respir Dis*, 113:643-65.
- [37] Zubieta IX, Brown G, Cohen R, Medina E. 2009. An international effort to improve hazardous working conditions in Mexico. *Int J Occup Environ Health*, 15: 14-20.