Assessment of Occupational Injuries, Health, and Risk Faced by Stone Crushing Industry Workers

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Abstract

Background and Purpose

The prevalence of occupational injuries among blue-collar workers is higher in the stone quarry and crushing industries due to a larger number of high-risk activities and an iterant nature of work. These occupational injuries, in turn, caused workers' ill health and reduced working capacity, as well as death, which eventually contributed to the loss of the gross domestic product. We aimed at assessing the attributes of occupational injuries and the risk associated with the hazards that prevailed in the stone-crushing industry.

Methods

Data were collected from thirty-two stone-crushing factories using a semi-structured questionnaire and analyzed to show their relationship with different variables. The proposition of Occupational Health and Safety Management Systems (OHSAS 18001:1999) was used to define hazards, and the risk levels associated with the most frequent hazardous events were measured using a Semi-Quantitative Risk Assessment Matrix.

Results

82% of injuries were found to occur between 12:00 to 18:00 hours. Almost one-fifth of the injuries fell in major and critical severity categories, which caused the workers to be absent for a week to more than a month. Exposure to excessive dust, working without personal protective equipment, and improper lifting and handling techniques caused one-third of injuries. Wrist and hand/fingers, back and lower back, feet/toe, eye, knee, arm, neck and head, and ankle were found as most injured body parts.

Conclusion

Our finding suggests that all the significant hazards identified posed a high level of risk, which makes this industry one of the most hazardous industries.

1. Introduction

Work is critical to people's lives, and it is an essential condition for the survival of a family or a society. Globally, workplace or occupational hazards are deemed the critical reason for fatality and disability among the working population (Mänty et al. 2021). According to Pega et al. (2021), two million people die globally each year from work-related diseases and injuries, which makes occupational hazards the leading cause of morbidity and mortality. Furthermore, according to ILO, workers suffer 480 million occupational accidents annually, among which 2.3 million caused a fatality, and the rest were non-fatal (ILO 2013). This means that every 15 seconds, 151 workers are involved in a work-related accident, and one of them dies. The International Labor Organization (ILO) deems occupational health and safety issues so crucial that more than three-fourths of its standards and instruments have been devised to address this issue either wholly or partly (Alli 2008). Globally, about 50–70% of the existing labor force working in developing countries encounter a massive physical workload or nonstandard working settings. Hence, the prevalence of occupational injuries among blue-collar workers, including unskilled manual workers, machine operators, industrial truck drivers, trades workers, and technicians, is higher in the industrial sectors (Australian Bureau of Statistics 2013; Won et al. 2007). These occupational injuries, in turn, may cause the loss of the global Gross Domestic Product (GDP) by nearly 5% (Alli 2008). Additionally, as can be seen in Amponsah and Dartey (2011), workers' ill health and reduced working capacity may lose approximately 10%–20% of the Gross National Product (GNP) of many developing countries. Besides, among the global workers, only a tiny minority (5–10%) has been facilitated with occupational health services (Aderaw et al. 2011). The scenario is much worse in developing countries like Bangladesh.

Stone quarry and crushing industries are considered one of the most hazardous industries worldwide due to two reasons: a larger number of high-risk activities and a less stable workforce. As stated in European Agency for Safety and Health at Work (2008), the number of quarry workers who died at work by accident is double the number of construction workers and thirteen times the number of laborers working in manufacturing industries. However, workers involved in this sector are often trained on the job and adopt their trainers' shoddy practices and attitudes. Occupational health services, especially health education for workers, are often limited or non-existent. Moreover, no notification or registration system for occupational hazards exists in these unorganized labor-intensive industries. As a consequence, these groups of workers have little or no knowledge about work-related hazards and risks and training on workplace safety.

Thus, the research works to assess the work related-hazards in different industries, including the stone quarry and crushing industry, have been going on for many years. Farzana et al. (2014) studied the noise pollution of the stone crusher machine at Jaflong, Sylhet, and found that the maximum noise level at the nearby crushing machine was more than the level prescribed by NIOSH and was unsafe for occupational health. Masrur et al. (2010) identified the production of stone dust during stone crushing as a major health hazard and tried to minimize the dust production sustainably. Kabir et al. (2018) examined the workers' respiratory health problems at stone-crushing industries in Bangladesh. They pointed out that coughing was the most prevalent respiratory problem among the workers, followed by shortness of breath, wheezing, and chest tightness due to mineralogical materials like dust, fumes, and ashes released into the environment. Semple et al. (2008) researched workers' exposure to particulate matter in the Indian stone crushing industry. Silica exposure level was found to be very high. A similar study carried out by Sivacoumar et al. (2006) in Chennai found that the concentration of particulate matter in the air in 26 locations surpassed the Indian National Standards. From the pulmonary function tests, they observed the workers' average pulmonary function values significantly lower as compared to normal south Indian healthy males.

A similar scenario is also reported in the studies conducted in other industries. Jadhav et al. (2022) investigated the occurrence of musculoskeletal disorders (MSD) in different body parts of workers engaged in hand-crafted footwear manufacturing activity using the Rapid Upper Limb Assessment (RULA) method. They reported a high occurrence of MSD, and most frequently affected body areas were low back, neck, hips/thighs/buttocks, shoulder, elbows, hand and wrist, knees and upper back. Islam et al. (2017) conducted a cross-sectional study on occupational health hazards and safety practices among the workers of the tannery industry in Bangladesh. They concluded that the majority of the workers were suffering from various occupational diseases caused by various work-related hazards. Philip et al. (2014), in their study, showed that half of the workers engaged in automobile repair in India were ignorant to the health problems linked with their occupational exposures, and thereby the use of personal protection was deficient. Wenlan Yu et al. (2013) investigated the occupational hazards among 8300 Chinese female workers in the electronics industry and reported that half of the female workers were unprotected from various occupational hazards. Ahmed and Akter (2011) reported that accidents and injuries, minor to major or severe, frequently occur in the construction sector. In general, construction workers mainly suffer from health hazards and diseases like hearing loss, skin diseases/allergies, asthma, lung cancer, headache, back pain, jaundice, silicosis, asbestosis, bronchitis, white finger disease, and neurological disorder. Iqbal et al. (2010) illustrated that occupational injury is a severe problem in the cement industry of Bangladesh, although most of the injuries (79.1%) result in temporary disability. The study revealed that 82.81% of injuries occurred in the arm, leg, hand finger, eye, and head, while 76.56% of injuries were caused by bucket elevator, weight lifting, belt conveyor, and welding. Moreover, Khan et al. (2006) investigated the pattern of occupational injuries among the laborers working in the chemical industries of Bangladesh. The study showed that among the injured workers, 75.24% of them were affected by hand, feet, head, arm, face, and eye injuries. Moreover, 57.14% of the accidents occurred in the first shift (6 AM to 2 PM), 34.52% in the second shift (2 PM to 10 PM), and 8.34% in a third shift. Valves, pipelines, pumps, carrying and lifting, vehicles, and grinding caused 70.93% of injuries at work.

From the above literature, it is evident that work-related injuries and diseases are highly prevalent among blue-collar workers in the industrial sector resulting in the loss of GDP of a country. Due to the involvement of high-risk activities and the iterant nature of workers, stone quarry and crushing industries are deemed as one of the most hazardous industries worldwide. However, no systematic research has been done to explore the attributes of occupational hazards and their associated risks in the stone-crushing industry of Bangladesh. This article, therefore, aims at assessing the most frequent occupational hazards and their associated risks of injuries faced by workers of the stone-crushing industry. This study focuses on

- ascertaining the attributes of work-related injuries and health issues among the laborers working in the stone-crushing industry; and
- assessing the risk linked with the identified work-related hazards.

2. Materials And Methods

2.1 Study design and area

A stone-crushing site-based cross-sectional study was carried out to ascertain the attribute of occupational injuries and health, determine the predominant work-related hazards, and then assess the risk faced by the employees working in the stone-crushing factories located at Ballaghat, Jaflong of Sylhet, the northeast zone of Bangladesh.

2.2 Study population and sample size

In this study, the employees directly involved in the stone crushing process were considered. However, the workers not engaged continuously in their work for at least six months in the aforesaid factories and the administrative employees were excluded from the study. The employees who were not present at the interview during data collection time were also excluded.

There are thirty-two stone-crushing factories in the studied region, and around five hundred and sixty laborers working in these factories met the study's inclusion criteria. Of them, four hundred and thirty-one workers agreed to take part in the face-to-face but confidential interview. Three hundred eighty-eight workers responded to all the questions during the interview. Thus, the response rate was almost 90% as some (around 10%) of the respondents skipped a few questions. The data thus obtained from interviewing the workers who fully responded to the questionnaire were analyzed.

2.3 Survey tool

Based on the primary survey, published literature on the subject of interest, and physicians' expert opinions, a standardized questionnaire comprising open and closed-ended questions was developed and used to interview the workers. This questionnaire was constructed to collect three types of data: (a) demographic data of the respondents, (b) occupational injury and health attribute data, and (c) data required for risk assessment: occupational hazards, the likelihood of occurrence of an incidence, and its severity.

2.4 Data collection

In this study, a volunteer-based participatory approach was used to collect the data. Since most employees (93.5%) working in stone-crushing factories had little or no formal education, they were interviewed one-by-one in Bangla (in their native language) using the semi-structured questionnaire developed by ourselves. While interviewing the workers, appropriate confidentiality was maintained. Moreover, the freedom to skip any questions or quit at any stage of the interview was ensured. The data thus collected were processed and analyzed using SPSS version 20.

2.5 Data Analysis

In this study, the Pareto analysis was done frequently to determine the vital few that were the most dominant (Tembo et al. 2020). Besides, among the three risk assessment methods, a semi-quantitative method organizing hazards into a relative scale or utilizing a Risk Assessment Matrix (RAM) was used as the most chosen method of describing the risk in the industry (Ling et al. 2014). In this method, the risk is defined as Risk Value (RV) = Severity (S) x Likelihood (L). Severity is ascertained based on injury to health, while the likelihood is measured based on observation to gain information on a particular hazard causing an accident. Table 1 shows the risk assessment matrix used in a semi-quantitative risk assessment method to ascertain the level of the risk value, i.e., if it is high, medium, or low.

Table 1
Risk Assessment Matrix (RAM) for semi-quantitative risk assessment

			Likelihood of exposure (L)								
			Unexpected (1/10 ⁶)		Rarely (1/10 ³ -1/10 ⁴)	Expected (1/10 ² - 1/10 ³)	Likely (1/10 – 1/10 ²)	Most Likely (1/10)			
			1		2		3		4		5
Severity (S)	None	1	1		2		3		4		5
	Insignificant	2	2		4		6		8		10
	Minor	3	3		6		9		12		15
	Major	4	4		8		12		16		20
	Critical	5	5		10		15		20		25
Low Risk Level (RV = 1–5)			Medium Risk Level (RV = 6–10)				High Risk Level (RV = 11–25)				

3. Results And Discussion

3.1 Demographic Characteristics of the Respondents

Table 2 shows the frequency distribution of different demographic variables of the respondents. It demonstrates that the sample consists of more males (70.10%) than females (29.90%). This scenario was due to long working hours and the high laborious nature of the job of the stone-crushing factories, even though the sex ratio found in the last census is almost equal. Young adults (58.20%) constituted more than half of the respondents. Among the respondents, 70.60% had no formal education, 22.90% had the primary level, and only 6.50% had secondary level education. Most of the respondents were full-time (93%) workers. Job categories of the respondents were distributed as carrying and lifting personnel (78.40%), machine operator (7.20%), welder (2.80%), supervisor (2.60%), maintenance personnel (1.50%), and

others (7.5%). Of 388 respondents, 18% had less than three years, 21.60% had between 3 to 5 years, 24.50% had between 5 to 8 years, and 35.80% had more than eight years of service in these factories. The majority of the respondents worked 9 to 12 hours (57.20%), followed by 6 to 8 hours (35.80%), and more than 12 hours (7%) per day.

Table 2
Frequency distribution of different demographic variables

Demographic variables	Category	Frequency	Percentage
Sex	Male	272	70.10
	Female	116	29.90
Age group	Young adult (18–30 yrs.)	226	58.20
	Early middle age (31–40 yrs.)	131	33.80
	Late middle age (41–51 yrs.)	31	8.00
Education level	No formal education	274	70.60
	Primary (up to 5th grade)	89	22.90
	Secondary (6th to 10th grade)	25	6.50
Employment	Fulltime	361	93.00
	Part-time	23	5.90
	Self-employed	3	0.80
	Replacement worker	1	0.30
Job category	Carrying and lifting personnel	304	78.40
	Machine operator	28	7.20
	Welder	11	2.80
	Supervisor	10	2.60
	Maintenance personnel	6	1.50
	Others	29	7.50
Length of service	0.5 to 3 years	70	18.00
	3 to 5 years	84	21.60
	5 to 8 years	95	24.50
	More than 8 years	139	35.80
Working time per day	6 to 8 hours	139	35.80
	9 to 12 hours	222	57.20
	More than 12 hours	27	7.00

3.2 Distribution of Injury Severity Experienced by Workers

Figure 1 exhibits the distribution of injury severity that the workers experience during their work due to accidents. In this study, all respondents encountered accidents during their job span in these factories resulting in injury, and the severity of injuries experienced varies from insignificant to critical. Among the respondents, the severity of 40% of injured workers was found insignificant that required either no medical treatment or a small duration of a break from their work, usually several hours for recovery. 41% of injured workers suffered from injuries with minor severity, which required first aid treatment or bed rest at home, usually several days, for recovery. 15% of workers experienced injuries with major severity, which required specialized medical treatment or hospitalization for recovery. The remaining 4% of workers suffered from injuries with critical severity, which resulted in partial disability and might take several months under medical treatment or hospitalization for recovery. Moreover, we can see from the figure above that 81% of the injuries were minor and insignificant, whereas the rest, 19%, were critical and major and caused loss of both man and production hours.

3.3 Distribution of Consequences of the Injuries

As can be seen in Fig. 2, due to injuries caused by accidents, 41% of the injured workers remained absent from work for two hours to a day, 33% for a day to a week, 13% for a week to a month, and 9% were absent for more than a month. Moreover, 3% of the workers became partially disabled because of accidents, whereas 1% died. It is also evident from the figure that 74% of injured workers remained absent from work for two hours to a week since a significant percentage (81%) of injured workers suffered from injuries with insignificant and minor severity, as shown in Fig. 1. On the other hand, the rest, 22% of injured workers, remained absent from work for a week to more than a month as they experienced injuries with major and critical severities.

3.4 Distribution of Injuries by Time of Occurrence

Figure 3 presents the distribution of injuries and the time of occurrence of the accidents. Of 388 responses, 1.80% injuries occurred in between 8:00–10:00 hour, 12.63% injuries occurred in between 10:00–12:00 hour, 26.80% injuries occurred in between 12:00–14:00 hour, 37.37% injuries occurred in between 14:00–16:00 hour, 18.30% injuries occurred in between 16:00–18:00 hour and rest 3.10% injuries occurred after 18:00 hour in working days. It can be seen that the fewest (1.80%) injuries occurred in the morning period (08:00–10:00 hour) when the workers start to work, and most (37.37%) injuries occurred in the afternoon period (14:00–16:00 hour). It can also be seen from the figure that 82.47% of injuries took place during 12:00–18:00 hours. This distribution of injuries is due to workers' fatigue that increases with time in this highly repetitive and laborious job. Hence, the occurrence of the accident is strongly associated with the time of accidents.

3.5 Distribution of Injuries by Body Parts

Figure 4 shows that 84.21% of total injuries occurred in the wrist and hand/fingers, back and lower back, feet/toe, eye, knee, arm, neck and head, and ankle. Among which 18.83%, 14.56%, 12.71%, and 9.98% of the total injuries occurred in the wrist and hand/fingers, back and lower back, feet/toe, and eye, respectively; the rest (15.79%) of the injuries occurred in other parts of the body. The dominance of injuries in the aforesaid body parts was due to the fact that workers did not use such personal protective equipment (PPE) as long sleeve gloves, barrier coats, face shields, hard hat, and safety boots, and applied improper techniques for the frequent lifting and carrying of the heavy objects during the work period. It is worth mentioning that despite the workers' positive attitude towards the PPE use, almost 97% of the stone-crushing factories were observed to have neither proper PPE nor PPE in the proper condition or of proper size.

3.6 Distribution of Different Occupational Health and Injuries among Workers

Table 3 demonstrates that lacerations/irregular tear of skin, back and lower back pain, contusion/bruise, eye irritation and red-eye, crushed hand/fingers/toes, headache, sharp and deep cuts or indent, restriction of joint movement, cough, difficulties in breathing, skin irritation and dermatitis, abrasions, and nose irritation constituted 82.03% of the total occupational injuries and ill-health found among the workers. Difficulties in hearing, throat irritation, ear irritation, visual fatigue/eye strain, amputations of fingers and hand, burning, bone fracture and dislocations, skull fracture, infected wounds, vibration white fingers, and electrocution comprised the remaining 17.97% of the injuries and ill-health. As most of the lifting and carrying personnel had to lift and carry a heavy load, back and lower back pain was commonly found among the workers. Crushed fingers/hand/toe was due to the falling of objects. Dust was responsible for eye irritation, red-eye, and headache. Laceration and the deep cut were due to sharp objects and stone chips.

Table 3
Frequency distribution of occupational health and injuries

Occupational Health and Injury Categories	Frequency	Percentage (%)	Cumulative (%)
Lacerations/irregular tear of skin	340	8.72	8.72
Back and lower back pain	317	8.13	16.85
Contusion/bruise	289	7.41	24.26
Eye irritation and red eye	277	7.10	31.36
Crushed hand/fingers/toes	265	6.79	38.15
Headache	249	6.38	44.54
Sharp and deep cuts or indent	241	6.18	50.72
Restriction of joint movement	234	6.00	56.72
Cough	228	5.85	62.56
Difficulties in breathing	202	5.18	67.74
Skin irritation and Dermatitis	197	5.05	72.79
Abrasions	196	5.03	77.82
Nose irritation	164	4.21	82.03
Difficulties in hearing	156	4.00	86.03
Throat irritation	149	3.82	89.85
Ear irritation	135	3.46	93.31
Visual fatigue/Eye strain	68	1.74	95.05
Amputations of fingers and hand	50	1.28	96.33
Burning	32	0.82	97.15
Bone Fracture and dislocations	32	0.82	97.97
Skull Fracture	29	0.74	98.72
Infected wounds	24	0.62	99.33
Vibration white fingers	19	0.49	99.82
Electrocution	7	0.18	100.00

3.6.1 Distribution of Occupational Health and Injuries over Gender

Table 4
Distribution of occupational health and injuries over gender

Occupational Health and Injury Categories	Between Groups		Within Groups	
	Male	Female	Male	Female
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)
Lacerations/irregular tear of skin	232 (68)	108 (32)	232(8.7)	108(8.7)
Back and lower back pain	218 (69)	99 (31)	218(8.2)	99(8.0)
Contusion/bruise	201 (70)	88 (30)	201(7.5)	88(7.1)
Eye irritation and red eye	194 (70)	83 (30)	194(7.3)	83(6.7)
Crushed hand/fingers/toes	182 (69)	83 (31)	182(6.8)	83(6.7)
Headache	170 (68)	79 (32)	170(6.4)	79(6.4)
Restriction of joint movement	168 (72)	66 (28)	168(6.3)	66(5.3)
Sharp and deep cuts or indent	164 (68)	77 (32)	164(6.2)	77(6.2)
Cough	151 (66)	77 (34)	151(5.7)	77(6.2)
Skin irritation and Dermatitis	137 (70)	60 (30)	137(5.1)	60(4.9)
Difficulties in breathing	129 (64)	73 (36)	129(4.8)	73(5.9)
Abrasions	126 (64)	70 (36)	126(4.7)	70(5.7)
Nose irritation	107 (65)	57 (35)	107(4.0)	57(4.6)
Throat irritation	102 (68)	47 (32)	102(3.8)	47(3.8)
Difficulties in hearing	98 (63)	58 (37)	98(3.7)	58(4.7)
Ear irritation	91 (67)	44 (33)	91(3.4)	44(3.6)
Visual fatigue/Eye strain	56 (82)	12 (18)	56(2.1)	12(1.0)
Amputations of fingers and hand	33 (66)	17 (34)	33(1.2)	17(1.4)
Burning	25 (78)	7 (22)	25(0.9)	7(0.6)
Bone Fracture and dislocations	22 (69)	10 (31)	22(0.8)	10(0.8)
Skull Fracture	18 (62)	11 (38)	18(0.7)	11(0.9)
Infected wounds	17 (71)	7 (29)	17(0.6)	7(0.6)
Vibration white fingers	17 (89)	2 (11)	17(0.6)	2(0.2)
Electrocution	7 (100)	0 (0)	7(0.3)	0(0.0)
Total	2665 (68)	1235 (32)	2665 (100)	1235 (100)

Table 4 presents the distribution of occupational health and injuries between and within different gender groups. It is apparent from the table that, on average, the prevalence of injuries and ill-health among male workers (68%) was more than double the percentage of the female workers (32%) for each occupational health and injury category. This distribution pattern reflects the ratio of male to female workers engaged in stone-crushing factories. Besides, the top ten occupational health and injury categories accounted for two-thirds of the total injuries prevalent among the male workers were lacerations/irregular tear of skin, back and lower back pain, contusion/bruise, eye irritation and red-eye, crushed hand/fingers/toes, headache, restriction of joint, sharp and deep cuts or indent, cough, and skin irritation and dermatitis. On the other hand, all injury categories remained the same except restriction of joint and skin irritation and dermatitis for female workers. Difficulties in breathing and abrasions replaced these two injury categories.

3.6.2 Distribution of Occupational Health and Injuries over Age

Table 5 provides the distribution of occupational health and injuries between and within age groups. This table is quite revealing in several ways. First, unlike the injury distribution reported in (Khan et al., 2006), on average, the prevalence of injuries and ill-health was predominantly higher among young adults than the early middle age and the late middle age groups. Injuries and ill-health were found to have distributed as

54.0%, 37.0%, and 9.0% among young adults, early middle age, and late middle age groups, respectively. This distribution pattern is due to the dominant number of workers from young adult groups over the other two groups as the work in these factories is highly laborious and repetitive. Second, lacerations, back and lower back pain, contusion/bruise, eye irritation and red-eye, crushed hand/fingers/toes, sharp and deep cuts or indent, headache, restriction of joint movement, and cough were the commonly occurring occupational health and injury categories that comprised almost two-thirds of the total injuries and ill-health prevalent among each of the three age groups.

Table 5
Distribution of occupational health and injuries over age

Occupational Health and Injury Categories	Between Age Group			Within Age Group		
	Young Adult	Early Middle Age	Late Middle Age	Young Adult	Early Middle Age	Late Middle Age
	(18–30 yrs.)	(31–40 yrs.)	(41–51 yrs.)	(18–30 yrs.)	(31–40 yrs.)	(41–51 yrs.)
	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)
Lacerations	197 (58)	116 (34)	27 (8)	197(9.3)	116(8.0)	27(8.1)
Back and lower back pain	176 (56)	115 (36)	26 (8)	176(8.3)	115(8.0)	26(7.8)
Contusion/bruise	164 (57)	104 (36)	21 (7)	164(7.7)	104(7.2)	21(6.3)
Eye irritation and red eye	160 (58)	96 (35)	21 (8)	160(7.5)	96(6.7)	21(6.3)
Crushed hand/fingers/toes	149 (56)	97 (37)	19 (7)	149(7.0)	97(6.7)	19(5.7)
Sharp and deep cuts or indent	132 (55)	88 (36)	21 (9)	132(6.2)	88(6.1)	21(6.3)
Headache	131 (52)	94 (38)	24 (10)	131(6.2)	94(6.5)	24(7.2)
Restriction of joint movement	124 (53)	88 (38)	22 (9)	124(5.8)	88(6.1)	22(6.6)
Cough	114 (50)	93 (41)	21 (9)	114(5.4)	93(6.4)	21(6.3)
Abrasions	109 (56)	72 (37)	15 (8)	109(5.1)	72(5.0)	15(4.5)
Difficulties in breathing	104 (52)	81 (40)	17 (8)	104(4.9)	81(5.6)	17(5.1)
Skin irritation and Dermatitis	104 (53)	77 (39)	16 (8)	104(4.9)	77(5.3)	16(4.8)
Nose irritation	91 (55)	60 (37)	13 (8)	91(4.3)	60(4.2)	13(3.9)
Difficulties in hearing	85 (54)	51 (33)	20 (13)	85(4.0)	51(3.5)	20(6.0)
Throat irritation	78 (52)	57 (39)	14 (9)	78(3.7)	57(4.0)	14(4.2)
Ear irritation	71 (53)	53 (39)	11 (8)	71(3.3)	53(3.7)	11(3.3)
Visual fatigue/Eye strain	25 (37)	35 (51)	8 (12)	25(1.2)	35(2.4)	8(2.4)
Amputations of fingers	23 (46)	18 (36)	9 (18)	23(1.1)	18(1.2)	9(2.7)
Burning	23 (72)	9 (28)	0 (0)	23(1.1)	9(0.6)	0(0.0)
Bone Fracture and dislocations	20 (63)	10 (31)	2 (6)	20(0.9)	10(0.7)	2(0.6)
Infected wounds	16 (67)	6 (25)	2 (8)	16(0.8)	6(0.4)	2(0.6)
Skull Fracture	15 (52)	10 (34)	4 (14)	15(0.7)	10(0.7)	4(1.2)
Vibration white fingers	12 (63)	7 (37)	0 (0)	12(0.6)	7(0.5)	0(0.0)
Electrocution	2 (29)	5 (71)	0 (0)	2(0.1)	5(0.3)	0(0.0)
Total	2125 (54)	1442 (37)	333 (9)	2125 (100)	1442 (100)	333 (100)

3.6.3 Distribution of Occupational Health and Injuries over Work Experience

Table 6 illustrates the distribution of occupational health and injuries between and within different work experience groups. It can be seen from the data that there is a clear trend of increasing prevalence of injuries and ill-health among the workers with their work experience.

Overall, injured workers with more than five years of job experience comprised two-thirds of all injuries they suffered. Moreover, the table above shows that irrespective of the length of work experience; lacerations, crushed hand/fingers/toes, back and lower back pain, contusion/bruise, eye irritation and red-eye, sharp and deep cuts, restriction of joint movement, and headache constituted around 60% of all occupational injuries and ill-health suffered by each of the work experience groups.

Table 6
Distribution of occupational injuries and ill health over work experience in stone-crushing factories

Occupational health and Injury categories	Between Groups				Within Groups			
	0.5+ (yrs)	3+ (yrs)	5+ (yrs)	8+ (yrs)	0.5+ (yrs)	3+ (yrs)	5+ (yrs)	8+ (yrs)
	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)	Freq. (%)
Lacerations	55 (16)	68 (20)	87 (26)	130 (38)	55 (10.5)	68 (9.1)	87 (8.2)	130 (8.3)
Crushed hand/fingers/toes	53 (20)	58 (22)	62 (23)	92 (35)	53 (10.1)	58 (7.7)	62 (5.8)	92 (5.9)
Back and lower back pain	46 (15)	66 (21)	82 (26)	123 (39)	46 (8.8)	66 (8.8)	82 (7.7)	123 (7.9)
Contusion/bruise	38 (13)	60 (21)	77 (27)	114 (39)	38 (7.2)	60 (8.0)	77 (7.3)	114 (7.3)
Eye irritation and red eye	37 (13)	54 (19)	79 (29)	107 (39)	37 (7.0)	54 (7.2)	79 (7.4)	107 (6.8)
Sharp and deep cuts	35 (15)	51 (21)	65 (27)	90 (37)	35 (6.7)	51 (6.8)	65 (6.1)	90 (5.8)
Abrasions	31 (16)	42 (21)	55 (28)	68 (35)	31 (5.9)	42 (5.6)	55 (5.2)	68 (4.3)
Restriction of joint movement	31 (13)	49 (21)	58 (25)	96 (41)	31 (5.9)	49 (6.5)	58 (5.5)	96 (6.1)
Headache	29 (12)	49 (20)	70 (28)	101 (41)	29 (5.5)	49 (6.5)	70 (6.6)	101 (6.5)
Skin irritation and Dermatitis	27 (14)	35 (18)	61 (31)	74 (38)	27 (5.1)	35 (4.7)	61 (5.7)	74 (4.7)
Cough	26 (11)	40 (18)	64 (28)	98 (43)	26 (5.0)	40 (5.3)	64 (6.0)	98 (6.3)
Throat irritation	20 (13)	27 (18)	45 (30)	57 (39)	20 (3.8)	27 (3.6)	45 (4.2)	57 (3.6)
Difficulties in breathing	17 (8)	44 (22)	54 (27)	87 (43)	17 (3.2)	44 (5.9)	54 (5.1)	87 (3.6)
Difficulties in hearing	17 (11)	30 (19)	40 (26)	69 (44)	17 (3.2)	30 (4.0)	40 (3.8)	69 (4.4)
Nose irritation	16 (10)	22 (13)	53 (32)	73 (45)	16 (3.0)	22 (2.9)	53 (5.0)	73 (4.7)
Burning	9 (28)	4 (13)	8 (25)	11 (34)	9 (1.7)	4 (0.5)	8 (0.8)	11 (0.7)
Ear irritation	9 (7)	20 (15)	43 (32)	63 (46)	9 (1.7)	20 (2.7)	43 (4.1)	63 (4.0)
Visual fatigue/Eye strain	9 (13)	11 (16)	16 (24)	32 (47)	9 (1.7)	11 (1.5)	16 (1.5)	32 (2.0)
Amputations of fingers	6 (12)	6 (12)	12 (24)	26 (52)	6 (1.1)	6 (0.8)	12 (1.1)	26 (1.7)
Bone Fracture	5 (16)	5 (16)	7 (22)	15 (46)	5 (1.0)	5 (0.7)	7 (0.7)	15 (1.0)
Infected wounds	3 (13)	2 (8)	9 (37)	10 (42)	3 (0.6)	2 (0.3)	9 (0.8)	10 (0.6)
Skull Fracture	3 (10)	5 (17)	8 (28)	13 (45)	3 (0.6)	5 (0.7)	8 (0.8)	13 (0.8)
Vibration white fingers	2 (11)	1 (5)	5 (26)	11 (58)	2 (0.4)	1 (0.1)	5 (0.5)	11 (0.7)
Electrocution	1 (14)	1 (14)	1 (14)	4 (58)	1 (0.2)	1 (0.1)	1 (0.1)	4 (0.3)
Total	525(13)	750(19)	1061(28)	156 (40)	525(100)	750(100)	1064(100)	1564(100)

3.7 Distribution of Injuries by Agents of Accidents

From Table 7 illustrating the distribution of injuries by agents of injuries and ill-health, it is evident that 80% of injuries and ill-health were caused by falling objects, dust, personal protective equipment (PPE), lifting and handling technique, lifting and handling objects, machine edge and stone chips, flying objects, noise, and work types. Hence, according to Pareto principal, these were the vital few agents causing the majority of occupational injuries and ill-health. Among these vital agents; falling objects, dust, and PPE caused one-third of occupational injuries and ill-health. The rest of the agents, i.e., posture, elevated work area, moving machinery, rotating/moving parts, work floor, and electric wires and equipment combinedly resulted in 20% of injuries and ill-health.

Table 7
Distribution of injures by agents of injuries and ill-health

Agents of injuries and ill-health	Frequency	Percentage (%)	Cumulative (%)
Falling object	385	13	13
Dust	302	10	23
Personal protective equipment (PPE)	292	10	33
Lifting and handling technique	289	10	43
Lifting and handling objects	244	8	52
Machine edge and stone chips	213	7	59
Flying object	211	7	66
Noise	207	7	73
Work type	196	7	80
Posture	192	7	87
Elevated work area	115	4	90
Moving machinery	110	4	94
Rotating/moving parts	82	3	97
Work floor	58	2	99
Electric wires and equipment	30	1	100

3.8 Distribution of injured workers by injury severity and exposure time

Table 8
Distribution of injured workers by injury severity and exposure time

Injury severity					
Working time per day	Critical	Major	Minor	Insignificant	Total
6 to 8 hours	2 (0.5%)	22 (5.7%)	60 (15.5%)	55 (14.2%)	139 (36%)
9 to 12 hours	13 (3.4%)	30 (7.7%)	88 (22.7%)	91 (23.5%)	222 (57%)
More than 12 hours	1 (0.3%)	6 (1.5%)	10 (2.6%)	10 (2.6%)	27 (7%)
Total	16 (4%)	58 (15%)	158 (41%)	156 (40%)	388 (100%)

Table 8 describes how occupational injuries and ill-health are distributed over exposure time and how the injury severities vary with the workers' exposure time. However, a closer inspection of the table shows an inverse U-shaped relationship between the injured workers and their exposure time. Besides, irrespective of the severity of the injuries and ill-health the workers experienced, the data presents the same relationship with the exposure time for each injury severity category. Taken the demographic data in Table 2 together, these results suggest that a strong association exists between the aforesaid relationship patterns and variation in the number of workers engaged in their work with the duration of working hours.

3.9 Risk Assessment of Stone-crushing Work

3.9.1 Identification of Hazardous Event

In this study, to identify a hazard, the definition proposed by Occupational Health and Safety Management Systems (OHSAS 18001:1999) was used, i.e., in this case, the term 'hazard' is meant by 'anything (a source or a situation) that can cause harm or be the potential source of harm to a worker in terms of injury or ill-health'. (Boyle, T. 2015; Canadian center for occupational health and safety (CCOHS) 2017; Health and Safety Executive (HSE) 2017). Hence, the sources of workplace hazardous events can vary in a wide range. However, as shown in Table 9, the most dominant nine hazardous events were selected through Pareto analysis for risk assessment, as these were responsible for 80% of total occupational injuries and ill-health.

3.9.2 Risk Matrix based on Risk Assessment

For risk analysis, five definitions were used for categorizing both the severity of injuries and the likelihood of exposure. The probability of the hazardous events and injury severity resulting from the events were taken from collected data to assess risk value. Then, the risk value (RV) was calculated by multiplying the likelihood of exposure of an event with corresponding severity. Finally, the risk level for the hazardous events was calculated based on comparing obtained RV with RAM values, and the result is summarized in Table 9.

Table 9
Risk level of dominant hazardous events

Hazardous events	Freq.	Related Injuries	Risk Value			Risk Level
			L	S	L×S	
Struck by falling object	13%	Tearing skin, cut and bleeding, crushing body parts	5	3	15	High
Exposure to excessive dust	10%	Itching, cough and inhaling problems, skin and eyes irritating	5	5	25	High
Working without PPE	10%	Injured body parts	5	4	20	High
Improper lifting and handling technique	10%	Back and low back pain, musculoskeletal disorders	5	3	15	High
Frequent lifting and handling of heavy objects	8%	Fatigue, back and low back pain, musculoskeletal disorders	4	4	16	High
Sharp machine edge and stone chips	7%	Tearing of skin, deep cut and bleeding	4	3	12	High
Struck by flying object	7%	Tearing skin, cut and bleeding	4	4	16	High
Exposure to excessive noise	7%	Hearing difficulties, headache	4	5	20	High
Highly repetitive work	7%	Fatigue, stress	4	4	16	High

Table 9 shows the risk level for the most frequent hazardous events in the stone crushing industry, along with related injuries and ill-health. It has been found that all those hazardous events posed a high-risk level. Among the dominant nine hazardous events, exposure to excessive dust, exposure to excessive noise, and working without PPE were the top three high-risk hazardous event. Since those nine hazardous events constituted 80% of total injuries and all of them posed a high risk, it can be concluded that the stone crushing industry is a high-risk industry where injuries and ill-health are inevitable without appropriate control and safety measures.

Though it is apparent that struck by falling objects resulted in the highest percentage of injuries, exposure to excessive dust posed the highest risk. This unexpected outcome is because exposure to excessive dust caused injuries and ill-health with higher severity than struck by falling objects. The frequent lifting and handling of heavy objects, improper lifting and handling techniques, and the highly repetitive nature of the job make the workers of this sector vulnerable to musculoskeletal disorders, fatigue, and stress. Sharp edge and stone chips were found to cause tearing of the skin, deep cut, and bleeding while handling the material manually. Moreover, struck by flying crushed stone was observed to cause tearing skin, cut, and bleeding. In addition, the stone crusher machine and vibrator produced excessive noise, which caused headaches and resulted in hearing difficulties due to prolonged exposure.

4. Conclusions

This study has been conducted to assess the attributes of occupational injuries, health issues, and associated risks faced by the stone-crushing industry workers. Due to the laborious nature of the job and long working hours, most workers were males. The occurrence of injury was found inevitable in this industry due to improper and inadequate safety measures, although the workers suffered mostly from injuries with insignificant and minor severities. The highest number of injuries occurred between 12:00 and 16:00 hours due to increased fatigue and extended working periods. Wrist and hand/fingers, back and lower back, feet/toe, eye, knee, arm, neck and head, and ankle were found as the

most affected body parts. Most body parts injuries occurred since workers did not use personal protective equipment (PPE). Regardless of gender, age, and work experience, most of the workers suffered from lacerations, back and lower back pain, contusion, eye irritation, crushed hand/fingers/toes, sharp and deep cuts, and headache caused by exposure to excessive dust, working without PPE, improper lifting and handling techniques, frequent lifting and handling of heavy objects, sharp edge and stone chips, and struck by flying objects. All dominant hazardous events possessed a high-risk level, which turns this industry into a high-risk industry for the workers.

Declarations

Statement of ethics approval: The ethical committee of the SUST Research Centre (Funding organization) thoroughly reviewed the ethical issues associated with this study and approved the grant for conducting this study after making necessary revisions to the initially submitted proposal.

Statement of Competing Interest: The authors declare no competing interest.

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Figures

Figure 1

Distribution of injury severity

Figure 2

Consequence of the accidents

Figure 3

Distribution of injuries by time of occurrences

Figure 4

Distribution of injuries by body parts