Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2017
(ICMERE2017) 18 – 20 December, 2017, Chittagong, Bangladesh

ICMERE2017-PI-326

OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT OF A METAL FABRICATION INDUSTRY IN SYLHET, BANGLADESH

Mohammad Iqbal[1*], Bhupendra Sarker[1], Niloy Paul[1] and Md. Sumon Rahman[2]
Dept. of Industrial and Production Engineering
[1]Shahjalal University of Science and Technology, Sylhet, Bangladesh
[2]Jessore University of Science and Technology Jessore, Bangladesh

iqbalm_ipe@yahoo.com*, srkrmithu@gmail.com, niloyipe@gmail.com, summon.just16@gmail.com.

Abstracts- *Healthy and safe workplace environment have positive impact on the key driving force of any industry, the human resource. Therefore, it should be the foremost concern of any manager's thinking and a priority in the organization's strategy because of humanitarian reasons and the financial benefits. Although most South Asian countries already have some occupational health and safety laws and regulations but the cultures lack motivation to comply with laws and strict compliance. Also the employers lack a comprehensive understanding about the benefit of having a healthy and safe work environment. In a society which is not disability sensitive it is even more difficult to rehabilitate people who are victims of unsafe work environments. However, despite having an obvious link with poor working conditions, impairment/disability and poverty; minimal research has explored these interlinked issues. This dearth of knowledge is also an important indication of less attention paid to this most important agenda that results in frequent reported and non-reported hazards in the workplaces in countries like Bangladesh. The objective of this study was to find out the most threatening health and safety factors that are associated with the workers' lives in a metal fabrication industry situated at Sylhet City. Cumulatively 11 health factors with 21 sub-factors and 10 safety factors with 41 sub-factors were formulated and analyzed. Principal Components Analysis (PCA) was applied to identify threatening sub-factors using Statistical Package for the Social Sciences (SPSS). According to PCA the 13 threatening health sub factors out of 21 sub-factors and 9 threatening safety sub factors were chosen out of 41 safety sub-factors respectively. A conceptual model was developed for the metal fabrication industry for taking immediate actions. Another conceptual framework for the Occupational Health and Safety Management System (OHSMS) was also suggested for the management showing the implementation process of Occupational Health and Safety into the metal fabrication industry.*

Key words: Occupational Health, Safety, Metal, Workplace and Environment.

1. INTRODUCTION

Health and safety at work are considered to be very important issues as they are intrinsically linked with the overall well-being of working people. However, status of occupational health and safety in developing countries like Bangladesh is especially problematic, with workers bound to work in an unsafe working environment where there is little regard for safety issues and inadequate monitoring from any public or civil society agency. Poor safety and health record of locations where poor people are ‘employed’ also contributes to worsening the situation. Hence, occupational health and safety is very important irrespective of the type of employment, or size or sector or location of the workplace because of its strong connection with extreme poverty and wellbeing [1].

Although most South Asian countries already have some occupational health and safety laws and regulations but the cultures lack motivation to comply with laws and strict compliance. Also the employers lack a comprehensive understanding about the benefit of having a healthy and safe work environment. In a society which is not disability sensitive it is even more difficult to rehabilitate people who are victims of unsafe work environments. However, despite having an obvious link with poor working conditions, impairment/disability and poverty; minimal research has explored these interlinked issues. This dearth of knowledge is also an important indication of less attention paid to this most important agenda that results in frequent reported and non-reported hazards in the workplaces in countries like Bangladesh.

2. RESEARCH OBJECTIVES

The objectives of the research are as follows-

(a) To find out the most threatening health and safety sub factors among all the factors of the metal fabrication industry using Statistical Package for the Social Sciences (SPSS).

(b) To propose Occupational Health and Safety models to implement occupational health and safety in the metal fabrication industry.

3. REVIEW OF PREVIOUS WORKS

This section discusses previous works related to the present works. A researched paper under the title “Assessment of Fire Risk in the Ready-Made Knitting Garment Factories by Using Fire Risk Index” focused on the fire safety in the readymade garment industries using calculation of fire index [2]. Md. Sifat Zaman and Md. Zahir Rayhan in their paper titled “Investigation of injuries, Accidents and Hazards of a Garment Factory and Their Effect On labor Availability” tried focus on the overall occupational injuries and accidents that had happened in a garment industry and introduced solutions to avoid them [3]. Penny Mccall Howard in paper titled “Occupational Health and Safety” discussed the current scenario of occupational health and safet [4]. Michael B Walker and Surendra Pratap, in their research paper titled “Hyperbolic Discounting in Occupational Safety and Health in South Asia” discussed and addressed the occupational rules and regulations of the south Asian region [5]. Joshi SK, Shrestha S, Vaidya S, Kathmundu in their paper titled “Occupational Safety and Health Studies” revealed the overall status of the occupational health and safety of the different industries situated throughout country. It also addressed how to improve the condition of the country’s working environment [6]. Serkan Aydin in his article on “Broadcasting Industry and Occupational Health and Safety” stated that occupational health and safety affects economic actions in every business sectors by protecting the employee’s health [7].

A journal article on “Modernization and Trends in Occupational Health and Safety in the People’s Republic of China” by Margaret M Quinn, Laura Punnett, David C. Christniani, Charles Levenstein and David H. Wegman discussed how china started implementing the Occupational Health and Safety in their industrial sector, how they approached and implemented the concept[8]. Another journal article on “Occupational health and safety Management: Safe work environment in local Automotive garage in Ghana” by Augustine Abrampa Apreko, Lydia Sylvia Danku, Maxwell Selase Akple and Johnson Aboagye, Ho polytechnic, described the level of knowledge of the local artisans regarding clean and safe environment in the automotive garages in Ghana[9]. A research paper on “Impact on Workers Health and Safety on Worker and Productivity” by Mohammad Nazmul Haq and Salaha Uddin Chowdhuri Shaju, Shahjalal University of Science and Technology in 2016 assessed the occupational health and safety of a melamine industry and the brought up the workers current health conditions and the problems they encounter in the industry [10].

4. RESEARCH METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Before exploring the research methodology options, the type of research should be identified, since the choice of methodology for the research follows naturally for the clear definition of the research. Research is an original contributor to the existing stock of knowledge making for its advancement. It is the pursuit of truth with the help of study, observation, comparison and experiment [11]. This research has been carried out to bring forth the threatening health and safety factors for the workers, working in the metal fabrication industry. Figure 1 represents the methodology of this research.

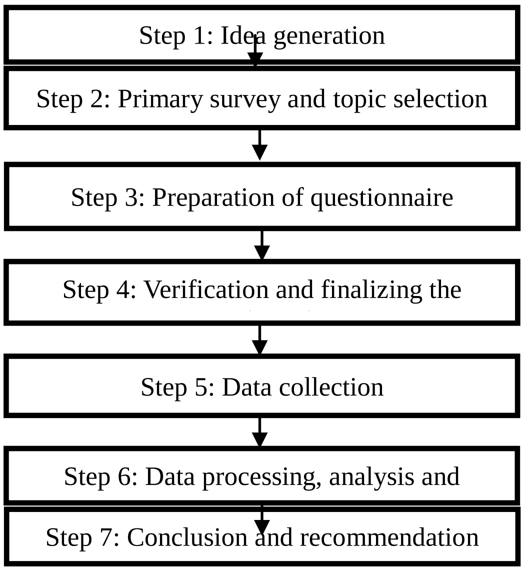

Fig. 1: Research methodology.

5. ANALYSIS AND FINDINGS

5.1 Sample Size Calculation

The following formula has been used to determine the sample size required to complete the study. The components are also described below:

$$n = \frac{z^2 pq}{E^2}$$

Where,
n = Sample Size
z = z value associated with confidence level of 95% (1.96)
p = Estimated proportion of success (0.5 used for sample size needed)
q = (1-p) or estimated the proportion of failures
E = Specify level of precision/ Level of Confidence/Margin of error {e.g. 0.08}
E^2 = Square of the maximum allowance for error between the true proportion and sample proportion

$$n = \frac{z^2 \times pq}{E^2}$$

$$= \frac{1.96^2 \times 0.5(1-0.5)}{0.08^2} = 150$$

Here the z value is taken from a confidence level of 95% which is the standard for the kind of analysis is being conducted. Confidence level of 99% is used for pharmaceutical experiments or military research works.

The estimated proportion of success or P value is taken as per the previous research work [10].

The margin of error is associated with the size of the total population. It is standard to use any given integer percentile from 1 to 10. The larger the total population the smaller the margin of error becomes. As, in this case the total population is 255, a margin of error of 8% is used for this study.

5.2 Formation of Collected Data

Data has been formatted according to questionnaire between the ranges 1 to 5 which means highly unsatisfied, unsatisfied, moderate, satisfied and highly satisfied respectively.

5.3 Analysis of Collected Data

Analysis of collected data has been done by Microsoft Excel and Statistical Package for Social Sciences (SPSS) software. Factor analysis, Frequency test, Principal Components Analysis and KMO & Bartlett's test of sphericity has been used to find threatening factors. Analysis of collected data is presented in the following section.

5.4 Frequency Analysis

Descriptive statistics are used for summarizing data frequency. Frequency analysis is a descriptive statistical method that shows the number of occurrences of each response chosen by each respondent.

5.5 Factor Analysis

The Factor Analysis has been applied for the identification of the threatening occupational health and safety factors. As it requires no pre-existing of functional relationships and is well-known for data reduction. It is used to reduce large number of variables into a few numbers of core factors. Factor analysis takes a minimum standard to proceed. Kaiser-Meyer-Olkin (KMO) & Bartlett's test is used to determine whether factor analysis can be done or not. KMO & Bartlett's test is described in the following paragraphs.

5.5.1 KMO and Bartlett`s Test

KMO & Bartlett's test of sphericity tests whether the correlation matrix is significantly different than the identity matrix, i.e. whether the variables are significantly correlated with each other or not. The Kaiser-Meyer-Olkin is the measure of sampling adequacy, which varies between 0 and 1. The values closer to 1 are better and the value of 0.6 is the suggested minimum. In the Bartlett's Test of Sphericity if the P-value is less than 0.05, it is suggested that the variables are significantly correlated with each other. These tests provide the minimum standard to proceed for Factor Analysis.

Hypothesis test regarding interrelationship between the health factor variables is shown below:
Null Hypothesis H0: There is no statistically significant interrelationship between variables.
Alternate Hypothesis H1: There may be a statistically significant interrelationship between variables.

Table 1: KMO and Bartlett's Test (Health Factor).

KMO Measure of Sampling Adequacy		.673
Bartlett's Test of Sphericity	p-value	.000

5.5.1.1 KMO Test

Here, KMO = 0.673> 0.6 which indicates that the sample is adequate and we may proceed with the Factor Analysis.

5.5.1.2 Bartlett's Test

The p-value is .000 < 0.05(95% level of Significance is used), we therefore reject the null hypothesis (H0) and accept the alternate hypothesis (H1) that there may be statistically significant interrelationship between variable. So the studied variables are significantly correlated. Therefore, we can proceed for factor analysis.

Hypothesis test regarding interrelationship between the safety factor variables is shown below:

Null Hypothesis H0: There is no statistically significant interrelationship between variables.

Alternate Hypothesis H1: There may be a statistically significant interrelationship between variables.

Table 2: KMO and Bartlett's Test (Safety Factor).

KMO Measure of Sampling Adequacy		0.623
Bartlett's Test of Sphericity	p-value	.001

5.5.1.3 KMO Test

Here, KMO = 0.623> 0.6 which indicates that the sample is adequate and we may proceed with the Factor Analysis.

5.5.1.4 Bartlett's Test

The p-value is .001< 0.05(95% level of Significance is used), we therefore reject the null hypothesis (H0) and accept the alternate hypothesis (H1) that there may be statistically significant interrelationship between variable. So the studied variables are significantly correlated. Therefore, next step factor analysis can be proceed.

5.4.2 Principal Component Analysis

Principal components analysis is similar to the factor analysis. The two analyses differ in data type. Factor analysis is based on a particular model for the data, whereas this is not the case for principal components analysis. As a factor extraction technique, we used principal components analysis. In principal components analysis decisions on how many factors to choose is based on total variance explained table and scree plot. In total variance explained table components have Eigen value greater than 1 is suggested to be selected. And in scree plot components place before the first elbow occurs after which Eigen values taper off gradually.

5.4.2.1 Principal components analysis of health factor

Variance explained table for health factors is given below:

Table 3: Total Variance Explained (Health Factor).

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.915	9.119	9.119
2	1.808	8.609	17.728
3	1.632	7.771	25.499
4	1.437	6.844	32.343
5	1.347	6.415	38.758
6	1.323	6.302	45.061
7	1.187	5.652	50.713
8	1.125	5.357	56.070
9	.988	4.704	60.774
10	.967	4.603	65.376
11	.925	4.403	69.780
12	.890	4.237	74.016
13	.851	4.051	78.068
14	.770	3.668	81.735
15	.736	3.505	85.240
16	.656	3.126	88.366
17	.612	2.913	91.279
18	.541	2.576	93.854
19	.496	2.362	96.216
20	.445	2.120	98.335
21	.350	1.665	100.000

Table 3 represents the Eigen value and percentage of variation of the components. As a factor reduction technique, Eigen value greater than 1 is used to sort highly influential health factors from others. 8 components have Eigen value which is greater than 1. From the table 4, the first 7 components within 8 components which is good enough as a proof for extracting only 7 components.

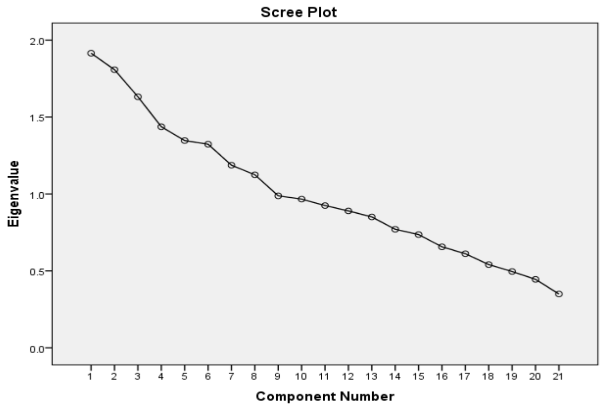

Fig. 2: Scree plot for health factors.

The principles of scree plot suggest extracting as many components as before the first elbow occurs in the Scree plot**.** In figure 2 the first elbow occurs after 5 points. So, 5 components have been extracted.

Five components are found from the scree Plot (figure 2). Each of these factors comprises of three or more variables shown in rotated component matrix. Among those first one is the most threatening factor to the workers. The following table describes the analysis in a descending order:

Table 4: Simplified Rotated component matrix (Health Factor).

Sub Factors	Rating
Sufficient latrines	-.795
Chips from machining	-.747
Metal parts	-.604
Hygienic	.449
Air inlets and outlets	.413
Sufficient	.698
Lightings and ventilation	-.669
Protection provided	.504
Welding of parts	.821
Adequate light settings	-.573
Formation of shadows	.632
Comfortable or not	.576
Exhaust fans	-.469

Table 5 represents the 13 threatening health sub factors that have been selected by principal components analysis. According to principal components analysis the 13 threatening health sub factors are sufficient latrines and urinals, disposal of chips from machining, disposal of metal parts, hygienic latrines and urinals , air inlets and outlets, sufficient dustbins and spittoons, lightings and ventilation in latrines and urinals, noise protection provided, dust and fumes formed by welding of parts, adequate light settings, formation of shadows, working temperature comfortable or not and exhaust fans for artificial ventilation.

5.4.2.2 Principal components analysis of safety factor

Total variance explained table for safety factor is given below**:**

Table 5: Total Variance Explained (Safety Factor).

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.965	12.111	12.111
2	3.722	9.078	21.189
3	3.560	8.684	29.872
4	2.742	6.688	36.561
5	2.325	5.670	42.230
6	2.097	5.114	47.345
7	1.946	4.747	52.091
8	1.565	3.817	55.909
9	1.434	3.499	59.407
10	1.406	3.429	62.836
11	1.297	3.162	65.998
12	1.170	2.853	68.852
13	1.130	2.756	71.607
14	1.110	2.708	74.315
15	.987	2.409	76.724
16	.969	2.362	79.086
17	.906	2.209	81.295
18	.847	2.066	83.361
19	.771	1.880	85.242
20	.702	1.712	86.953
21	.682	1.663	88.617
22	.617	1.505	90.122
23	.596	1.454	91.576
24	.544	1.327	92.903
25	.540	1.318	94.221
26	.475	1.159	95.379
27	.449	1.094	96.474
28	.403	.982	97.456
29	.349	.851	98.307
30	.297	.725	99.032
31	.160	.391	99.423
32	.096	.234	99.658
33	.065	.160	99.818
34	.039	.095	99.913
35	.022	.053	99.966
36	.014	.034	100.000
37	3.431E-16	8.367E-16	100.000
38	9.041E-17	2.205E-16	100.000
39	-6.076E-17	-1.482E-16	100.000
40	-1.228E-16	-2.995E-16	100.000
41	-4.281E-16	-1.044E-15	100.000

Table 5 represents the Eigen value and percentage of variation of the components. As a factor reduction technique, Eigen value greater than 1 is used to sort highly influential safety factors from others. 14 components have Eigen value which is greater than 1. From the table 6, it is seen that in the level of satisfaction more than 50% of the variations (52.091%) are explained by the first 7 components within 14 components which is good enough as a proof for extracting only 7 components.

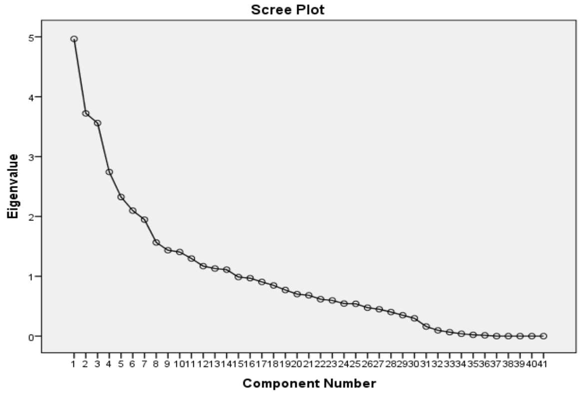

Fig. 3: Scree plot of safety factors.

The principles of Scree plot suggest extracting as many components as before the first elbow occurs in the Scree plot**.** Here in figure 4 the first elbow occurs after 1st point. So, 1 component is suggested by scree plot to be extracted.

One component factor is found from the Scree Plot. Considering Eigen value in total variance matrix and scree plot figure two components are taken into count. Each of these factors comprises of three or more variables shown in rotated component matrix. Among those, first one is the most threatening factor to the workers. Here the degree of contribution of the factors to workers health follows in a descending order.

Table 6: Simplified rotated component matrix (safety factors).

Sub Factors	Rating
Earthing of equipment	.988
Electric Awareness	.988
Cranes and lifting machines	.988
Fire drills	.988
Proper training Grinder	.562
Part of lathe stock bar reaching far	.836
Hydraulic brakes	.818
Safety sign Awareness	.726
Proper training in Gas Cutting	.575

Table 6 represents the 9 threatening safety sub factors that have been selected in principal components analysis. These threatening sub factors are earthing of equipment, electric awareness, cranes and lifting machines, fire drills, proper training grinder, part of lathe stock bar reaching far, hydraulic brakes, safety sign awareness and proper training in gas cutting. These safety sub factors are suggested by principal component analysis to have very negative influence in workers safety in the industry.

6. FINDINGS

In this study, using principal component analysis 13 threatening health sub factors have been selected from 21 health sub factors and 9 threatening safety sub factors have been selected from 41 safety sub factors. According to principal component analysis the 13 threatening health sub factors (table 5) are sufficient latrines and urinals, disposal of chips from machining, disposal of metal parts, hygienic latrines and urinals , air inlets and outlets, sufficient dustbins and spittoons, lightings and ventilation in latrines and urinals, noise protection provided, dust and fumes formed by welding of parts, adequate light settings, formation of shadows, working temperature comfortable or not and exhaust fans for artificial ventilation. According to principal component analysis the 9 threatening safety sub factors are earthing of equipment, electric awareness, cranes and lifting machines, fire drills, proper training grinder, part of lathe stock bar reaching far, hydraulic brakes, safety sign awareness and proper training in gas cutting.

7. RECOMMENDATIONS

7.1 RECOMMENDATIONS FOR IMMEDIATE ACTION

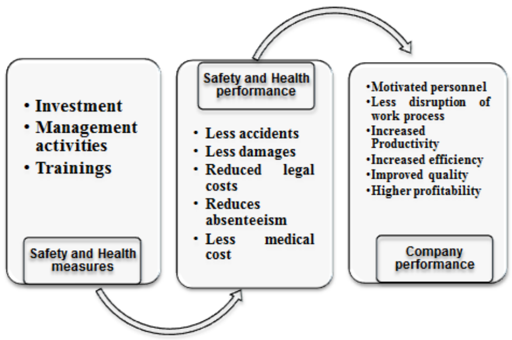

Fig. 4: A conceptual model developed for immediate actions.

Actions must be taken to ensure that the most threatening 13 health sub-factors and 9 safety sub-factors are not danger anymore. These sub-factors cover the more than 50% of the total variance explained (table 4 and 6). The immediate action plan is divided into 3 phases briefly described below:

Safety and health measure: In this stage the precautions against the most threatening health and safety sub-factors are taken to ensure that they are not at all threatening anymore. It will require the determination and commitment of the management. Also investments, frequent and dynamic managements activities and health and safety trainings by regular intervals.

Safety and health performance: In this stage the industry will enjoy the outcomes of the safety and health measures taken to minimize the danger of the most threatening factors. Due to the effort of the management and co-operation of the workers, fewer accidents will take place. Less legal costs and medical costs will save the company a fair share of the money allocated for these purposes. Ultimately this will result in reduced absenteeism and high morale of the workers.

Company performance: With lesser risk of health and safety dangers weighting the workers down, the workforce will be motivated to work. Fewer accidents will cause less disruption of work process which will result in increased productivity and efficiency. The quality of the work will improve significantly which ultimately will result in higher profitability.

7.2 Recommendations for Further Improvement

Implementing OHS in a workplace is not easy. A country where majority of the workers are illiterate and ignored of their rights and well-being, implementing OHS becomes quite a challenge if not the dedication of the top management is present in every step of the implementation process. This model would improve the total working scenarios and introduce a accidents and injury preventive culture at the workplace.

Here a conceptual model for the implementation of OHSMS is given [12]. The process is given in the following page:

The model is segmented in 5 sections described below:

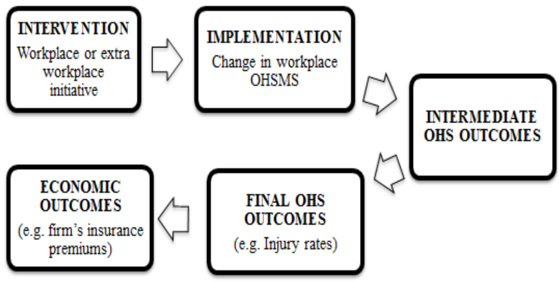

Fig. 5: Conceptual framework for the Occupational Health and Safety Management System (OHSMS).

Intervention: In this stage through extensive research and interview, the health and safety factors must be identified which might have detrimental impact on the workers lives. This part has already been done by this research paper.

Implementation: In this stage the pointed out health and safety factors must be taken into consideration and precautions must be taken against them so that they cannot be a threat anymore

Intermediate OHS outcomes: The implemented OHS steps must be observed and the immediate results are calculated in this stage.

Final OHS outcomes: In this stage the final OHS outcomes are calculated e.g. injury rate reduction, absenteeism rate reduction etc.

Economic outcomes: In this stage the final economic outcomes are calculated and utilized for further investigation by the top management of the organization.

8. CONCLUSION

In this research Statistical Package for the Social Sciences (SPSS) has been extensively used to point out threatening sub-factors among the total health and safety sub-factors that had been determined earlier. The Occupational Health and Safety is by far the most neglected part of majority of the industrial sector of Bangladesh and yet it is the most important part of any organization. The government and the owners of the industries situated throughout the country should be more cautious about Occupational Health and Safety which will surely minimize severe losses of the most important resource of any industry, human resource. Unless immediate and co-ordinated measure is taken, the lives of the ignored, illiterate workers will be at risk.

9. REFERENCES

1. Oashim Akram. *"Occupational health and safety in urban and peri-urban bangladesh: an important cause and consequence of extreme poverty"*, May, 2014.
2. Mohammad Mohibul Hasan, Md saklain Mustak, "*Assessment of fire risk in hte readymade knitting garments by fire indexing method",* Thesis published by the Dept. of Industrial and Production Engineering, Shahjalal University of Science and Technology, 2014.
3. Md. Sifat Zaman and Md. Zahir Rayhan, "*Investigation of injuries, accidents and hazards of a garment factory and their effect on labor availability*, Thesis published by the Dept. of Industrial and Production Engineering, Shahjalal University of Science and Technology, 2013.
4. Penny Mccall Howard, "Occupational health and safety*",* Maritime University of Australia, 2014.
5. Michael B Walker and Surendra Pratap, *"Hyperbolic Discounting In Occupational Safety And Health in South Asia",* University of Technology Sydney, Austrlia, 2012.
6. Joshi SK, Shrestha S, Vaidya S. "Occupational safety and health studies", Kathmundu Medical College, 2011.
7. Serkan Aydin, "Broadcasting Industry and Occupational Health and Safety", Marmara University, 2012.
8. Margaret M Quinn, Laura Punnett, David C. Christniani, Charles Levenstein and David H. Wegman, "Modernization and trends in occupational health and safety in the people's republic of china, *American Journal of Industrial Medicine*, 1987.
9. Augustine Abrampa Apreko, Lydia Sylvia Danku, Maxwell Selase Akple and Johnson Aboagye, *"Occupational health and safety management: safe work environment in local Automotive garage in Ghana"*, International Journal of Academia Research in Business and Social Sciences, Vol. 5, 2015.
10. Shaju, Mohammad Nazmul Haq and Salaha Uddin Chowdhuri, "*Impact on Workers Health and Safety on Worker and Productivity",* Thesis published by Shahjalal University of Science and Technology, 2016.
11. Arif M., Baidya U, Baruni A. *"Impact of Psychological Job Characteristics, Office Physical Environment and Office Furniture Mismatch On Job Satisfaction"*, Thesis published by Dept. of Industrial and Production Engineering, Shahjalal University of Science and Technology 2013.
12. Kimberley L Cullen, Amber Bielecky, Emma Irvin, Anthony John Culyer, *"The Effectiveness of Occupational Health and Safety Management System Interventions: A Systematic Review"*, 2007.