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Attributes of Occupational Injury Among Workers in the Chemical Industry and Safety Issues

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Case-study research was carried out with a view to find the attributes of occupational injury among workers in the chemical industry and to enhance safety issues. Injury data were collected and processed in terms of different variables, such as age, gender, skills, type of hazard, etc. Pareto analysis was then applied to find a pattern of occupational injury among the workers. The study revealed that 79.52% of the injured workers were in the 40–59 age group; 57.14% of accidents occurred during the 1st shift; 73.26% of accidents caused injury to hands, feet, chest to thigh, arms and eyes; and 70.93% of injuries were caused by pumps, carrying and lifting, vehicles, pipelines, valves, and grinding. Surprisingly, no one was injured in the group of temporary workers. The paper also provides specific suggestions followed by some action plans.

attribute occupational injury workers chemical industry safety issues

1. INTRODUCTION

Industrial accidents are the major cause of industrial injuries. In 1956, a WHO group defined an accident as "an unpremeditated event resulting in recognizable damage" (p. 43) [1]. According to another definition an accident is an "occurrence in a sequence of events [which] usually produces unintended injury, death or property damage" (p. 44) [1]. On the other hand industrial injury can be defined as "the result of unsafe acts and unsafe working condition while working in an industrial work environment. Causes of industrial injuries are classified as mechanical failure, defective material, electronic failure and faulty design of equipment, environmental condition, human failure, and working condition" (p. 246) [2].

However, every year throughout the world there are many industrial accidents and the world is paying heavily for that (i.e., for accidents and injuries) in terms of both human suffering and huge economic wastage. "In some highly industrialized countries industrial accidents are responsible for loss of 4 or 5 times as many working days as industrial disputes. Economic cost not only includes the compensation cost alone. It also includes loss of production, disruption of production schedules, damage to productive equipment and in case of large-scale accident major social dislocations" (p. 31) [3]. Despite some progress, the question of safety of the workers at work is still a serious threat. Whereas, "every worker has the right of access to occupational Health and Safety Services irrespective of the

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sector of economy size of the company or type of assignment and occupation" (p. 363) [4].

A proper health care system [5] should, therefore, be provided for control and prevention of industrial accidents among workers during their working period. Hence, in developing an efficient health care system, proper information on the status of occupational accidents/injuries in the industry are prime factors to be gathered. This necessity led experts of different levels to conduct an organized study or a survey to determine the attributes of occupational accidents/injuries among workers of various industrial sectors. In 1977, Booth [6] showed the proportion of accidents, i.e., machinery accidents 17.5%, transport 8%, handling goods 27.5% and hand tools 7%. Moreover, consequences of machinery and transport accidents were far more serious than those for handling goods and hand tools. In 1978, a study [7] showed causes of reported industrial accidents in the United Kingdom due to handling 25.5%, persons falling 18.1%, machinery 15.2%, striking against object 8.1%, transport 7.5%, being struck by falling objects 5.6%, hand tools 5.8% and others 14.1%. In 1992, Johmston [8] showed that occupational injury was the leading cause of death for people aged 31–44 in the USA. Data from the National Traumatic Occupational Fatality surveillance system providing information on occupational fatalities for the years 1980–1989 by industry indicated that workers employed in the construction industry had the largest number of injuries followed by transportation, communication and public utilities, and manufacturing. In 1997, Laym and Landen [9] conducted a descriptive analysis of nonfatal occupational injuries, to order the workers, by using a National Probability Sample of Hospital Emergency Department. They found that hands and fingers were most commonly injured (31.5%), followed by the shoulder and arm (16.5%); head and neck (16.3%); and back, trunk, and hip area (15.7%). By nature of injury, laceration (25.2%); contusions, abrasions and haematomas (21.6%); sprain and strains (17.3%); and fractures and dislocations (13.4%) accounted for the most injuries. In 2000, a study done by Khan [10] at the Sindhi Social Security Hospital Karachi also showed that the dominance of hand injuries approximated 75%, whereas other injuries involving limbs and axial skeleton were also fairly common 2.5%. In 2005 the Bureau of Labor Statistics (BLS) [11] showed that men accounted for 65.9% of total cases, which is higher than their employment share (55.2%) and their share of the hours worked (58.9%) among all private wage and salary workers. There was a significant decline in the numbers of injuries and illnesses with days away from work in workers 16–19 and 25–54 years old. Workers aged 20–24 accounted for 11.3% of injured workers, slightly higher than their share of the hours worked (10.4%). Workers aged 45–64 accounted for 31.8% of the injuries and illnesses with days away from work, lower than their share of the hours worked at 34.1% and compared to other sectors. Manufacturing had the highest proportion of injuries and illnesses occurring between the hours of midnight and 8 a.m.

However, in Bangladesh, despite an inadequacy in reporting systems, a few organized case studies have also been conducted. In 1990, Khan [12] conducted a study on injured patients attending the Emergency Department of General Hospital, Narayangonj, and found that an injury due to machinery was the second most common cause. Among the total number of injuries caused by machinery, 70.36% affected males and 29.64% affected females; 33.1% were found in the age group of 15–24. In 2001, a case study conducted by Haq [5] on injured workers reported in the Medical Departments of three selected UMC Jute Mills found that most (39.7%) injured workers were in the age group of 18–25, most accidents (77%) were minor in nature, most accidents (73.3%) occurred in the second shift (2 p.m. to 10 p. m.), most accidents (37.6%) occurred in the weaving section followed by 24% in the spinning section, most accidents (73%) occurred in hands and most accident (45.7%) were lacerated type of injury. Most (77%) injured workers were absent from work for more than 16 hrs and less than 20 days, most accidents (76%) occurred due to striking agents, and 88.2% of accident were caused by working agents. However, keeping the same goal in mind, i.e., developing a special

health care system that would eventually reduce accident cost and improve national productivity by preventing accidents, a systematic, organized case study, first time ever in Bangladesh, was conducted with a view to determine the attributes of occupational injury among workers at a selected fertilizer industry.

2. RESEARCH METHODOLOGY

A descriptive cross-sectional study was accomplished in a step-by-step manner on workers as well as on some management personnel of Natural Gas Fertilizer Companies in Bangladesh in 2002–2003.

In this study, variables such as age, gender, skill and worker's job type (i.e., master technician, highly skilled, skilled, semi-skilled, and unskilled), time of accident, injury in different body parts, agent of accident, and type of hazard, etc., were taken into consideration. Several members of the management and workers of different types were called upon to deliver relevant information associated with occupational injury and hazard.

The following sections cover the steps involved in this research study.

2.1. Step 1: Conducting Primary Survey

A primary survey was conducted to have a clear conception on the project area in order to develop a format with variables of interest.

2.2. Step 2: Preparing Primary Questionnaire

Based on the primary survey and knowledge gathered from the literature, the questionnaires were categorized into (a) injury data collection, and (b) data collection on existing safety conditions. Both categories were checked to ensure their validity.

2.3. Step 3: Verifying and Finalizing the Questionnaire

A necessary modification was made before finalizing both draft questionnaire categories followed by a group arrangement as per the objectives of the study.

2.4. Step 4: Data Collection

2.4.1. Questionnaire

Data on the variables considered as well as on existing safety conditions of the selected organization were collected from such injury- and safety-related departments as fire and safety department, and the medical center.

2.4.2. Focus group discussion

Four different groups were arranged among the workers. Each group consisted of 8–12 workers of different levels ranging from master technician to unskilled. These groups were mainly investigated on a specific topic of why workers were not using personal protective equipment (PPE).

2.5. Step 5: Data Processing and Analysis

In this step, the collected data were processed and analyzed on the basis of the variables defined earlier, i.e., age, gender, skills, etc. Analyzed data were used to conclude on important findings and to set necessary tasks. Pareto analysis was frequently performed on processed data in this research. Pareto analysis (named after Vilfredo Pareto, a 19th-century Italian economist), is a graphical representation showing the frequency of the causes of a problem. The main principle is to concentrate on solving the most critical, and often the most frequent, activities before devoting resources to the less frequently occurring areas [13]. Sometimes it is also termed the 80:20 rule [14]. Pareto analysis is a most commonly practiced technique in the area of quality management [13, 14, 15, 16]. However, in this research it was used to work out the percentage of injury type, age group, etc., that deserved closest attention and tightest control.

3. DATA ANALYSIS

A cross-sectional descriptive-type of study was conducted in 2002–2003. During data collection, 101 records were found in the accident-register books kept in the medical center and the fire and safety department. The data were collected from

June 1 to July 15, 2002, using the prescribed format.

3.1. Distribution of Injured Workers by Age Group

Table 1 shows that the majority (36.63%) of injured workers was in the 50–54 age group, 17.82% and 16.83% of injured workers were 40–44 and 45–49 respectively, and cumulatively 4.59% of injured workers were found in 20–34 age groups. Besides, from Figure 1 it is evident that among the eight selected age groups, almost 72% of total injuries occurred in only three age groups: 40–44, 45–49, and 50–54. This might be so because of poor hearing, poor sight, weaker physical strength, and slower reflex actions of older workers (40 and over) [17].

TABLE 1. Distribution of Injured Workers by Age Group

Age Group	Injured Workers	%
20–24	1	0.99
25–29	2	1.98
30–34	2	1.98
35–39	12	11.88
40–44	18	17.82
45–49	17	16.83
50–54	37	36.63
55–59	12	11.88
Total	101	100

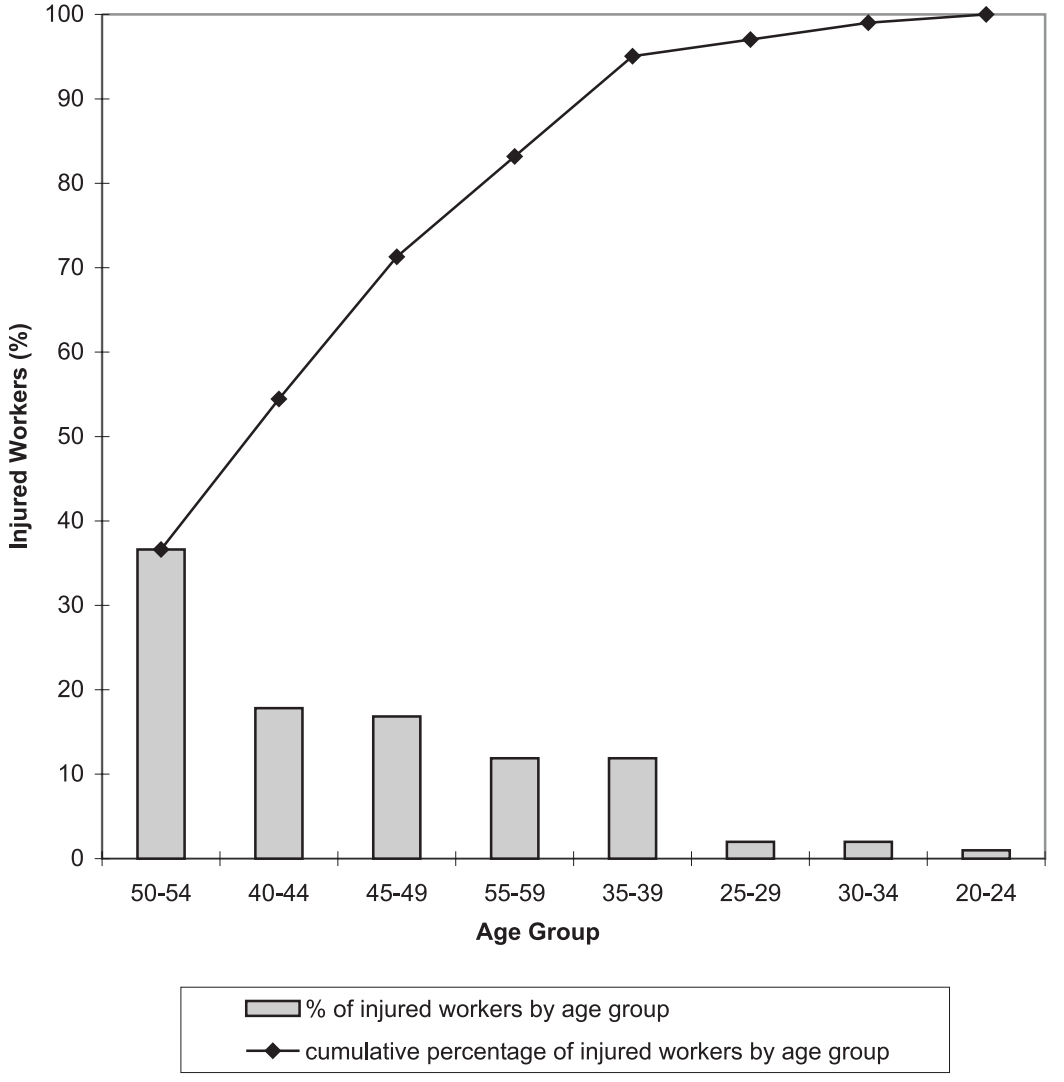

Figure 1. Pareto chart for injured workers by age group.

3.2. Distribution of Injured Workers by Body Parts

In Table 2 and Figure 2, it is shown that 75.24% of total injured workers faced hand, feet, arm, eye, face and head injury, among which 27.72, 18.81, 7.92 and 5.94% of the total injury occurred in hands, feet, eyes and head respectively; the rest (24.76%) of the injured workers suffered injury in other parts of the body. However, that type of injury pattern was seen to be due to workers not being used to such PPE as gloves, helmets, eye shields, etc., during their working hours.

TABLE 2. Distribution of Injured Workers by Body Parts

Body Part	Injured Workers	%
Hand	28	27.72
Feet	19	18.81
Chest to thigh	10	9.91
Arm	9	8.91
Eye	8	7.92
Face	6	5.94
Head	6	5.94
Ankle	5	4.95
Throat	4	3.96
Knee	2	1.98
Shoulder	2	1.98
Rear	2	1.98
Total	101	100

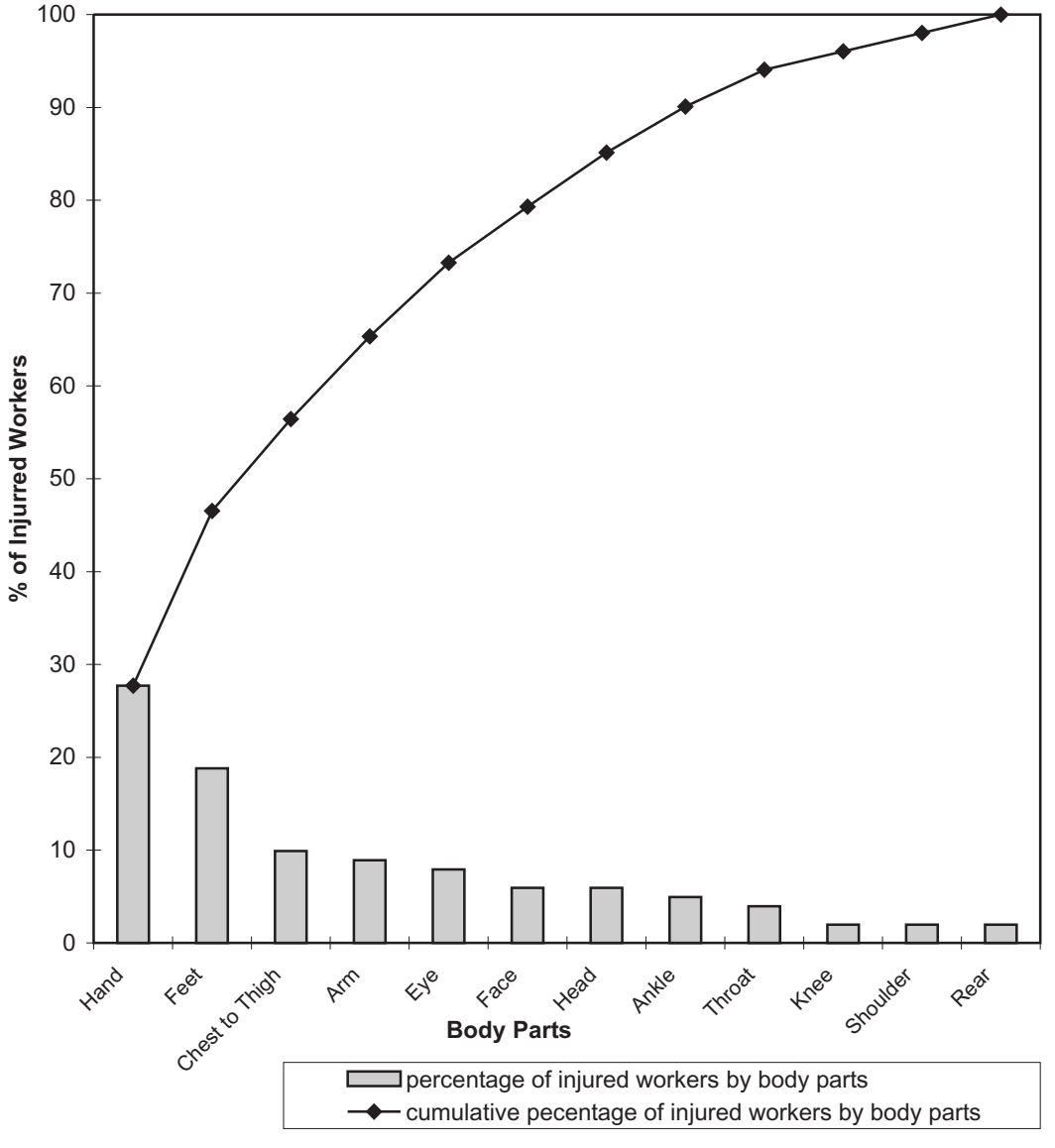

Figure 2. Pareto chart for injured workers by body parts.

3.3. Distribution of Injured Workers by Time of Occurrence

From Table 3, it can be seen that most (57.14%) and fewest (8.34%) injuries occurred in the first and third shifts respectively; and the rest (34.52%) were found in the second shift. Moreover, from Table 3, it is evident that 70–80% of injuries occurred in second and third shift units of each shift. Therefore, there was a strong relationship between the extent of accidents and the time of accidents.

TABLE 3. Distribution of Injured Workers by Time of Occurrence

Shift	Shift Unit*	Period (24-hr clock)	Injured Workers	% Based on Shift Total	% Based on Total
1st shift	1st	06–08	0	0	0
	2nd	08–10	16	33.33	19.05
	3rd	10–12	24	50.00	28.57
	4th	12–14	8	16.67	9.52
	Shift total		48		
2nd shift	1st	14–16	5	17.24	5.95
	2nd	16–18	16	55.17	19.05
	3rd	18–20	6	20.69	7.14
	4th	20–22	2	6.90	2.38
	Shift total		29		
3rd shift	1st	22–00	2	28.57	2.38
	2nd	00–02	3	42.86	3.57
	3rd	02–04	2	28.57	2.38
	4th	04–06	0	0	0
	Shift total		7		
	Total		84		100

Notes. *—a 2-hr period.

3.4. Distribution of Injured Workers by Skill

Table 4 shows that most (57.83%) injured workers were skilled; among them 24.1% and 18.07% were master technician and highly skilled workers respectively. It is worth mentioning that most (42.17%) injured workers were unskilled. Again from Figure 3, it is evident that master technician, highly skilled and unskilled workers accounted for around 85% of the total number of injured workers. This was so because of their overconfidence and lack of awareness as well as insufficient supply of PPE. However, these three factors were found to be the main reasons for not using PPE in the case of master technician, unskilled and highly skilled workers respectively. Since no medical facility except first-aid treatment was provided to temporary workers, they did not have any interest in reporting injuries either to the medical center or to the fire and safety department. This is the reason why no injured workers were found in the temporary worker group.

TABLE 4. Distribution of Injured Workers by Skill

Skill	Injured Workers	%
Master technician	20	24.10
Highly skilled	15	18.07
Skilled	11	13.25
Semi-skilled	2	2.41
Unskilled	35	42.17
Total	83	100

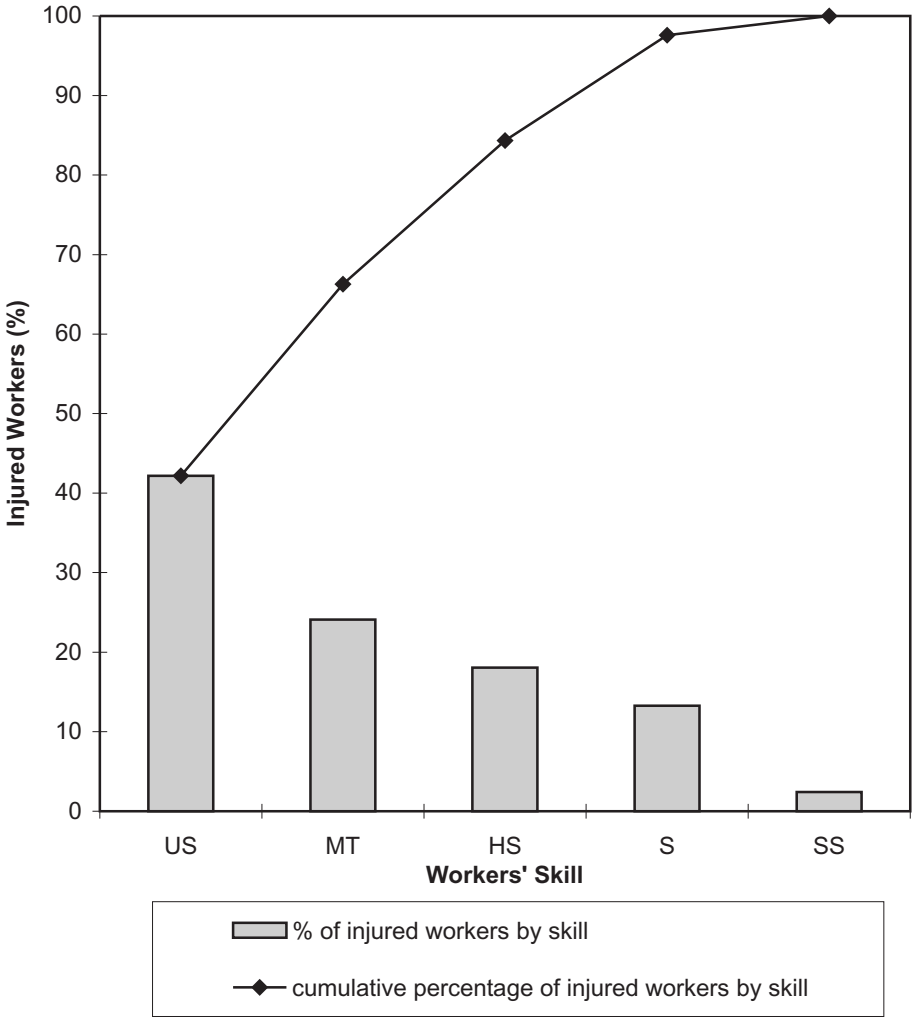

Figure 3. Pareto chart for injured workers by skill. *Notes.* US—unskilled, MT—master technician, HS—highly skilled, S—skilled, SS—semi-skilled.

3.5. Distribution of Injured Workers by Agents of Accident

From Table 5 and Figure 4, it is observed that pumps, carrying and lifting, vehicles, pipelines, valves, and grinding caused 70.93% of the total number of injuries, among which 47.68% of the injuries occurred due to pumps, carrying and lifting, and vehicles; the other 23.25% were caused by pipelines, valve, and grinding.

TABLE 5. Distribution of Injured Workers by Agents of Accident

Agent of Accident	Injured Workers	%
Pump	20	23.26
Carrying and lifting	12	13.95
Vehicles	9	10.47
Pipeline	8	9.30
Valve	7	8.14
Others	6	6.98
Grinding	5	5.81
Handling chemicals	5	5.81
Welding	5	5.81
Slipping	4	4.65
Conveyor	3	3.49
Blower	2	2.33
Total	86	100

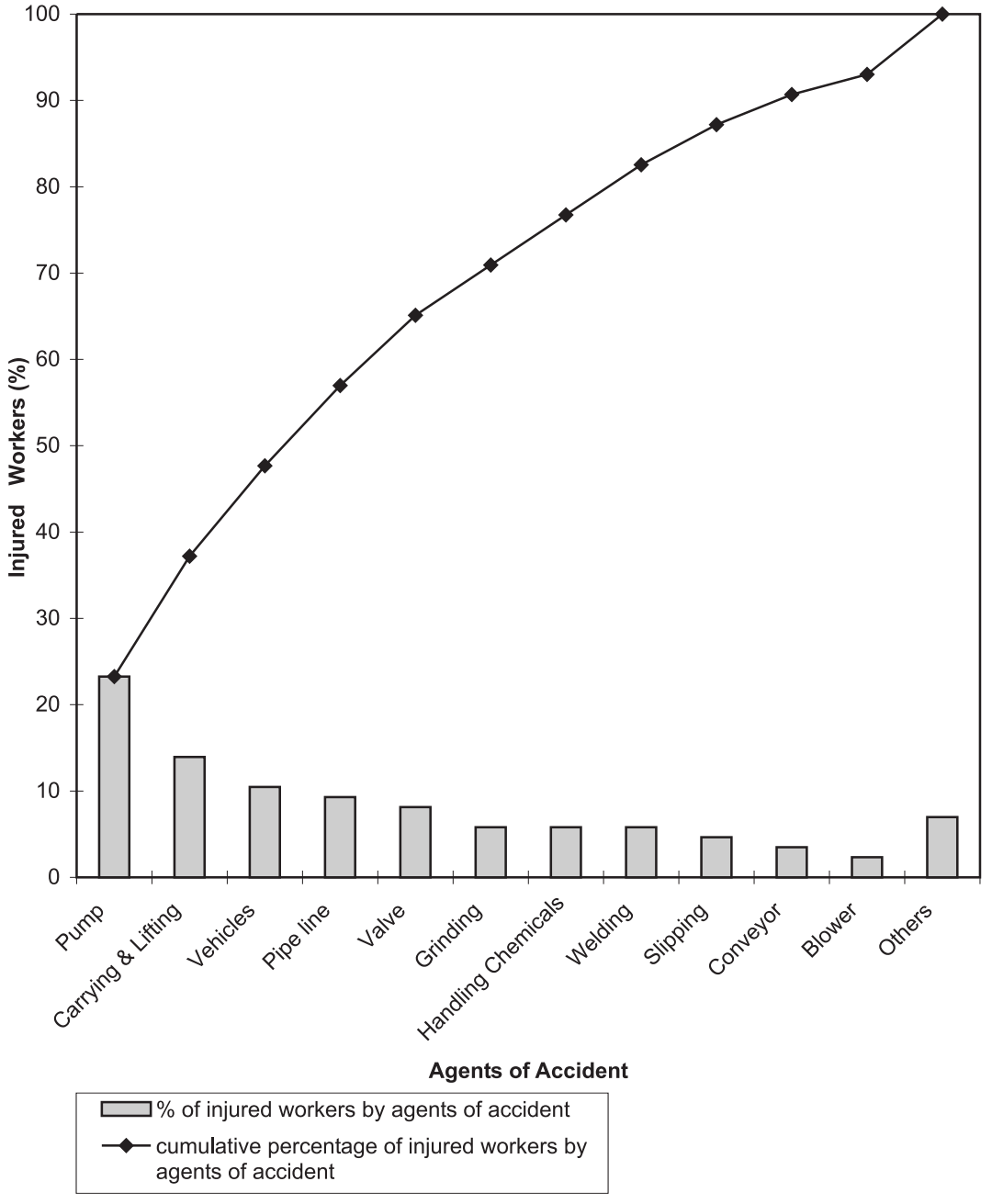

Figure 4. Pareto chart for injured workers by agents of accidents.

3.6. Distribution of Injured Workers by Type of Hazard

From Table 6, it is clear that mechanical and chemical hazards caused 69.77 and 27.91% of total injuries respectively; whereas only 2.33% of the total number of injuries occurred due to electrical hazards. That means that among all the chemical hazards, almost 70% were due to chemicals entrapped in pumps, pipelines and valves and 18% were caused by handling chemicals. However, these agents of accidents were found to be the cause of all face, eyes and arm injuries.

TABLE 6. Distribution of Injured Workers by Type of Hazard

Hazard	Injured Workers	%
Mechanical	60	69.77
Chemical	24	27.91
Electrical	2	2.33
Total	86	100

3.7. Distribution of Injured Workers by Type of Hazard and Major Agents of Accident

Table 7 shows that from among the 23.26% of injuries caused by pumps, 60% were mechanical hazards and the other 40% were chemical hazards. Besides, 13.95 and 10.47% of the total number of injuries caused by carrying and lifting, and vehicles respectively were all mechanical hazards. However, it is clear from Table 7 that injuries caused by major agents of accident were caused by mechanical or both mechanical and chemical hazards.

TABLE 7. Distribution of Injured Workers by Type of Hazard and Major Agents of Accident

	Agent of Accident											
	Pump		Carrying and Lifting		Vehicles		Pipeline		Valve		Grinding	
Hazard	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Mechanical	12	60	12	100	9	100	4	50	3	42.86	4	80
Chemical	8	40	—	—	—	—	4	50	4	57.14	1	20
Electrical	—	—	—	—	—	—	—	—	—	—	—	—
Total	20	100	12	100	9	100	8	100	7	100	5	100

3.8. Distribution of Injured Workers by Agents of Accident and Major Injured Body Parts

Table 8 shows that pumps, carrying and lifting, vehicles, and grinding caused 71.43% of all hand injuries; 78.95% of all feet injuries were caused by pumps, carrying and lifting, vehicles, pipelines, valves and grinding; and respectively 88.88 and 87.5% of total arm and eye injuries were due to pumps, carrying and lifting, vehicles, pipelines, and valves. It is worth mentioning that pumps, pipelines, and valves caused 100% of face injuries; whereas vehicles, pipelines, welding and slipping caused all head injuries.

TABLE 8. Distribution of Injured Workers by Agent of Accident and Major Injured Body Parts

	Body Part											
Agent of	Hand		Feet		Arm		Eye		Face		Head	
Accident	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Pump	9	32.14	5	26.32	2	22.22	1	12.50	1	20	—	—
Carrying and lifting	4	14.29	4	21.05	1	11.11	2	25.00	—	—	—	—
Vehicles	3	10.71	2	10.53	3	33.33	—	—	—	—	1	16.67
Pipeline	—	—	1	5.26	1	11.11	3	37.50	1	20	2	33.33
Valve	—	—	2	10.53	1	11.11	1	12.50	3	60	—	—
Others	2	7.14	—	—	1	11.11	—	—	—	—	—	—
Grinding	4	14.29	1	5.26	—	—	—	—	—	—	—	—
Handling chemicals	3	10.71	1	5.26	—	—	—	—	—	—	—	—
Welding	2	7.14	—	—	—	—	1	12.50	—	—	1	16.67
Slipping	—	—	—	—	—	—	—	—	—	—	2	33.33
Conveyor	—	—	2	10.53	—	—	—	—	—	—	—	—
Blower	1	3.57	1	5.26	—	—	—	—	—	—	—	—
Total	28	100	19	100	9	100	8	100	5	100	6	100

4. FINDINGS AND RESULTS

4.1. Distribution and Data Analysis

From the analysis applied to the distributed data, some important points show up very significantly.

- In process-based industry comparatively older workers, especially those above the age of 40, were responsible for the occupational injury that occurred. These aged workers naturally landed with improper physical capabilities and Pareto analysis statistically proved this fact.
- Pareto analysis revealed that hands, feet, eyes and heads were the body parts that were mostly injured. The relation between agents of accident and those body parts could explain the statistics.
- Most injuries happened in the first and second shift of a 24-hr day work. The third shift, the harmful one, was important. We found that the night shift was quite an efficient one and workers could focus on their work. So, days and evenings were periods when workers could be distracted from their work. Another psychological explanation could be used for the second and third units, when both units together contributed to most injuries in a shift of four units.
- Master technician, highly skilled and unskilled workers were found to be responsible for occupational injuries. A very frustrating reason for this was the overconfidence of master technician and highly skilled workers.
- Pumps, carrying and lifting, vehicles, pipelines, valves, and grinding were the vital few that contribute to occupational injury statistics. Basically these agents were the reason for injuries to the major body parts.
- Mechanical and chemical hazards—not electrical ones—were mainly responsible in this study. It could be concluded that lack of appropriate maintenance was the reason.
- As it was already mentioned, several agents of accident caused injuries in the major body parts of the workers. This was obviously because of overconfidence and lack of both PPE and awareness. In a word, lack of awareness and responsibility in both the authorities and workers could make this sort of injury very frequent.

4.2. Focus Group Discussion

Focus group discussion was conducted in four different groups; each group consisted of 8–12 workers of different levels ranging from master technician to unskilled. The topic was why workers were not using PPE. The information obtained from these group discussions is given in the following sections.

4.2.1. Master technicians

Figure 5 shows that 36% of workers at the master technician level said that overconfidence was the reason for not using PPE; 29% of them felt discomfort when using the PPE available. Moreover, 21% of this class complained that the equipment available was poorly maintained.

4.2.2. Highly skilled workers

Figure 6 shows that 34% of highly skilled workers indicated insufficient supply of PPE as compared to their requirements; whereas 33% of workers at this level said that the PPE available was poorly maintained. However, 22% of workers of the same group did not use the PPE during working hours because of their overconfidence.

4.2.3. Unskilled workers

It is evident from Figure 7 that 75% of unskilled workers involved in the group discussion mentioned lack of awareness of safety as the main reason for not using PPE at work. However, 25% of this class was also pointed to insufficient supply as the reason for their inability to use that equipment.

4.2.4. Workers of different levels

As shown in Figure 8, considering the total number of workers who took part in group discussion, insufficient supply, lack of proper maintenance, overconfidence and discomfort

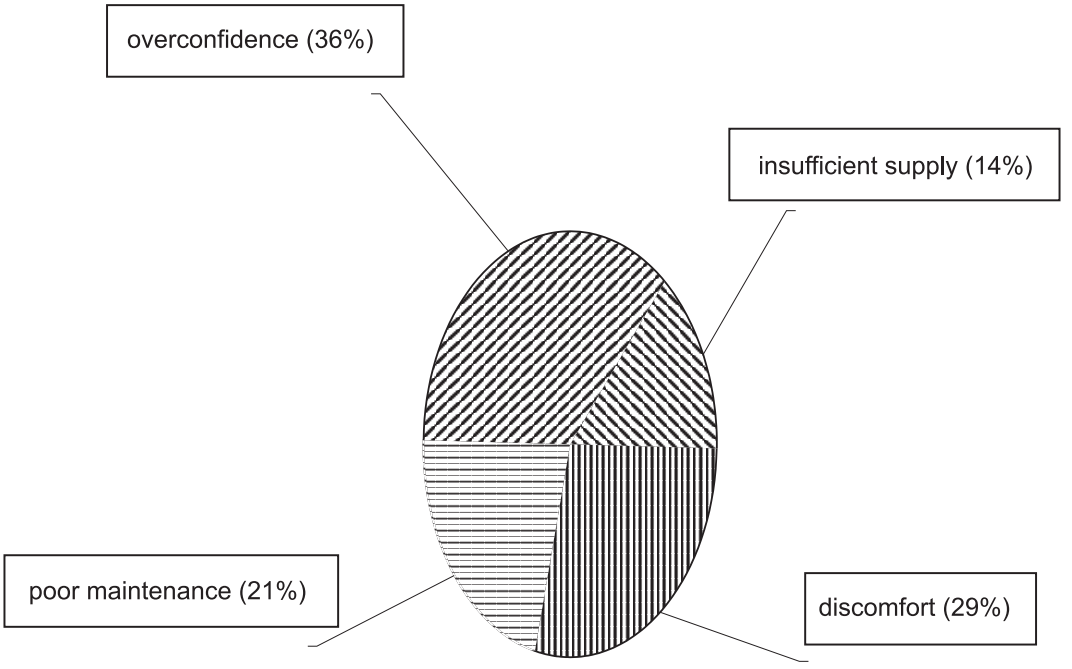

Figure 5. Pie chart based on total number of master technicians involved in group discussion.

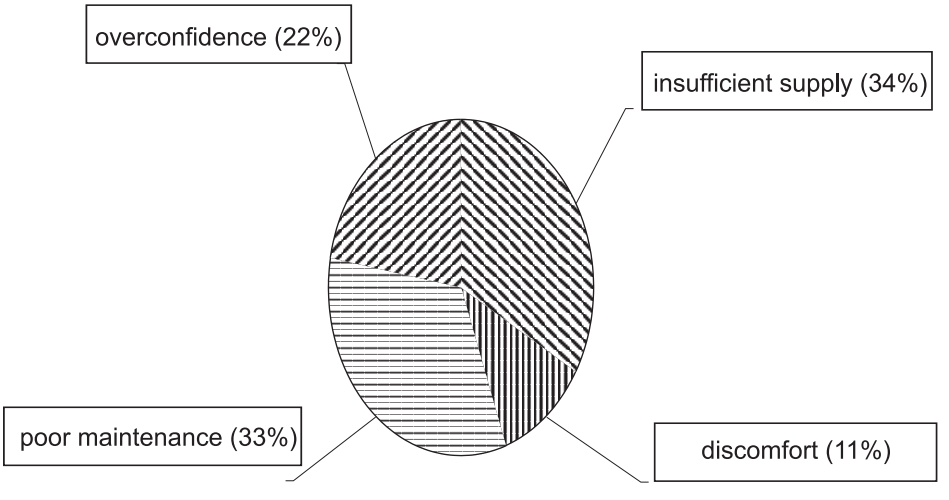

Figure 6. Pie chart based on total number of highly skilled workers involved in group discussion.

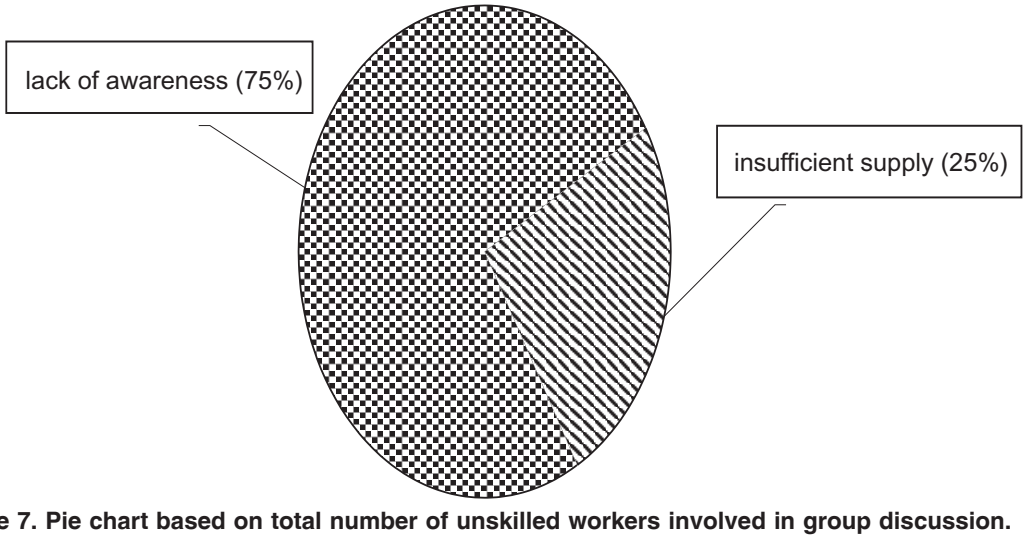

Figure 7. Pie chart based on total number of unskilled workers involved in group discussion.

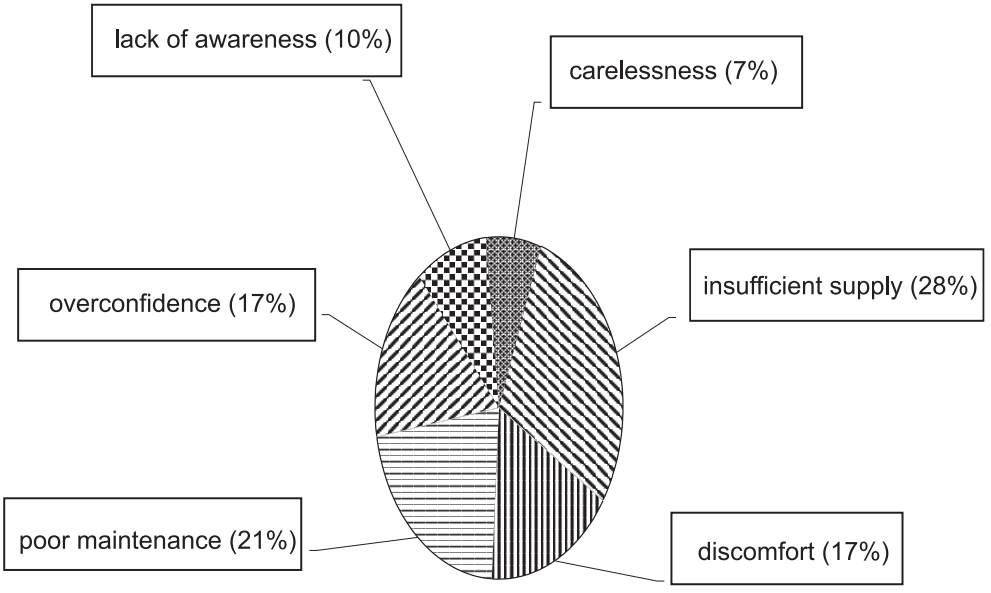

Figure 8. Pie chart based on total number of workers of different levels involved in group discussion.

were the major causes; whereas lack of awareness and carelessness were indicated as minor causes for PPE not being used.

5. RECOMMENDATIONS AND ACTION PLANNING

Occupational injury is a serious problem in any industry. As injuries lead to loss of productive hours along with loss of money in terms of compensation, it directly affects productivity in the industry in question. Hence, it is necessary to take some planned actions to reduce occupational injury.

5.1. Recommendations

Based on analysis, the following recommendations have been made.

- Regular medical check-ups of hearing, sight and strength of workers aged 40 and over.
- Provision of leisure during a shift to reduce fatigue and boredom.
- Arrangement of sufficient training for workers on safe operation of pumps, vehicles, pipelines and valves and also for workers engaged in carrying and lifting.
- Provision of proper safety guards against working agents or parts of agents, e.g., pumps, vehicles, pipelines, valves, carrying and lifting.
- Adequate supply and regular cleaning of PPE.
- The use of gloves and shoes while working on pumps and engaging in carrying and lifting; gloves and apron while working on vehicles; goggles and helmets during pipelines maintenance; face shields while working on valves; gloves for grinding, and handling chemicals.

5.2. Action Planning

The following actions could be taken into consideration in ensuring proper and efficient functioning of the recommendations made.

- Supply of adequate, well-maintained PPE would not be sufficient to eliminate the causes of not using PPE unless the organization takes the following actions.
  - Adequate training on the job, occupational health and formal safety;
  - Motivating workers to use PPE;
  - Developing workers' safety awareness using various methods of communication, e.g., leaflets, posters, safety tags;
  - Regular supervision of safety.

- As the organization considered in this study is a process industry, during any shift, leisure for all workers at the same time is not possible without interrupting or shutting down the whole process. That is why workers can be divided into different groups. A group may consist of workers from different departments in such a way that the production process remains unaffected. Then leisure can be provided at different times during a shift for one or two groups at a time. Leisure of 10 min after 2 hrs is suitable for light work [18].
- Ensuring the use of proper PPE, proper fencing against various working agents that might cause accidents, checking gas pockets and the possibility of a chemical explosion carefully

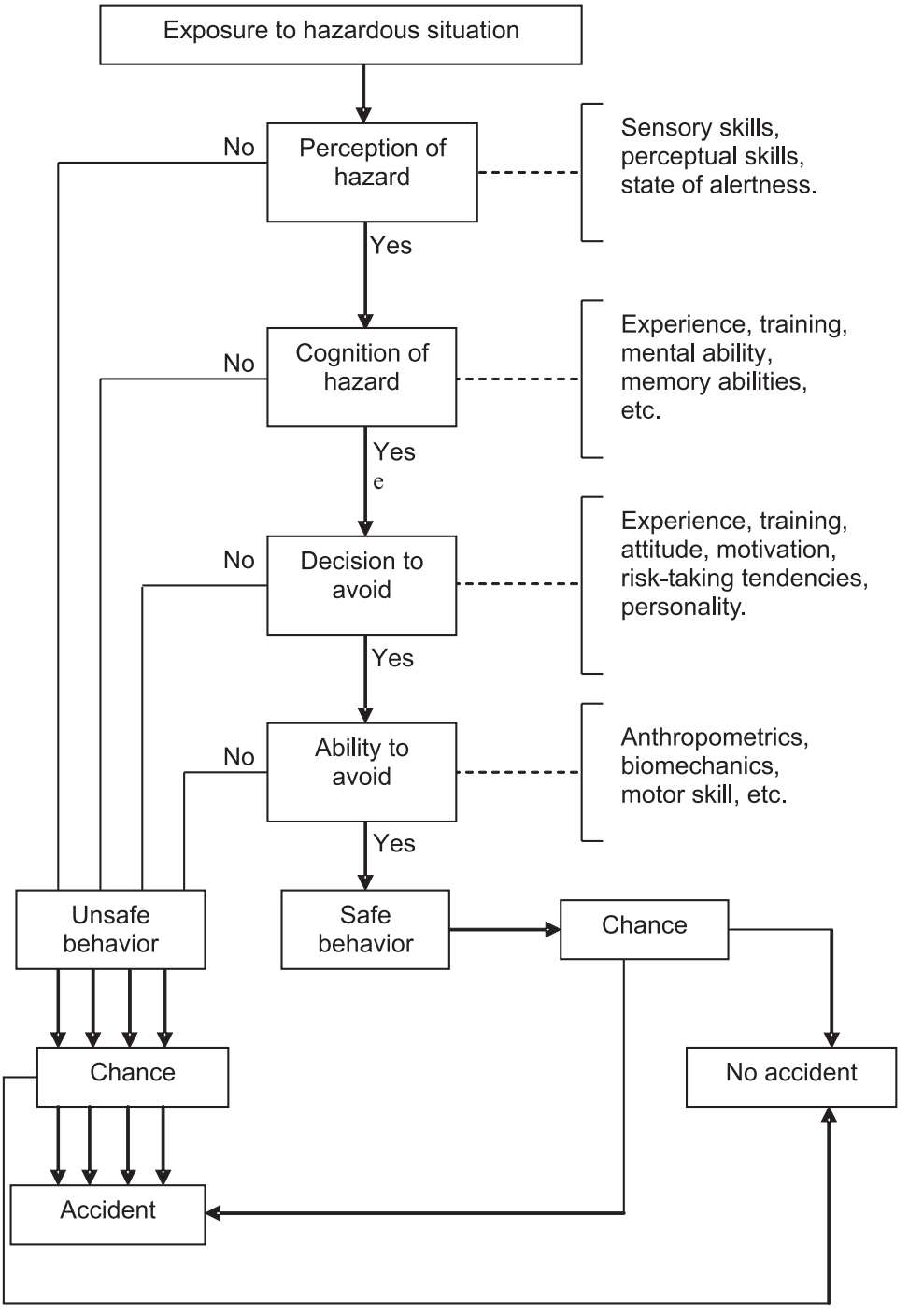

Figure 9. Accident sequence model proposed by Ramsey in 1985 (as cited in Helander, p. 39 [19]).

before work starts, and teaching workers about good carrying and lifting techniques for heavy loads.

- The accident sequence model, proposed by Ramsey in 1985 [19], shown in Figure 9 could be applied to avoid accidents in potentially hazardous situations.

6. CONCLUSION

This study has been conducted taking some variables into considerations with a view to get an overall picture of occupational injury among workers and to enhance safety conditions of the chemical industry studied. While conducting the study, it was found that workers aged over 40 were more exposed to injury; hands, feet, arms, eyes, face, and head were the most affected body parts. Most injuries occurred in the second and third shift units of each shift, i.e., there was a strong relationship between the extent of the accidents and the time of their occurrence; most of the injured people were master technician, highly skilled and unskilled workers; pumps, carrying and lifting, vehicles, pipelines, valves, and grinding caused most of the injuries. Injuries caused by major agents of accidents were mostly mechanical hazards or both mechanical and chemical hazards; pumps, carrying and lifting, vehicles, and grinding caused most of the hand injuries; Most feet injuries were caused by pumps, carrying and lifting, vehicles, pipelines, valves and grinding; most arm and eye injuries were due to pumps, carrying and lifting, vehicles, pipelines, and valves. Pumps, pipelines, and valves cause 100% of face injuries; whereas vehicles, pipelines, welding and slipping caused all the head injuries. It is also worth mentioning that an insufficient supply of PPE, poorly maintained PPE, discomfort when using PPE, and overconfidence were found to be the major causes of injury; whereas lack of awareness and carelessness was indicated as minor causes for not using PPE. However, to keep workers safe and sound physically as well as economically and to prevent loss of production time causing loss to employers, preventive actions recommended should be implemented and maintained carefully and sincerely.

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