Magnitude and Risk Factors of Injuries in a Glass Bottle Manufacturing Plant

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Abstract: Magnitude and Risk Factors of Injuries in a Glass Bottle Manufacturing Plant: Joy Bazroy et al. Department of Preventive and Social Medicine, Jawaharlal Institute of Postgraduate Medical Education and Research, India—A study was conducted in a glass bottle manufacturing plant in Pondicherry, India, to assess the magnitude and identify the risk factors of work-related injuries between January and December 1998. Three hundred and seventy-seven injuries were reported among 341 permanent workers followed up for one year (incidence=1,105.5/1,000 workers/yr). A higher load of injuries was noted in the first half of the night shifts and the second half of the other three shifts. Injuries were higher in the second half of the week and during the first half of the year. Hands and wrists were the most common sites of injury (40.6%), whereas the eye, foot, ankles and other body parts had 30%, 14.6%, 10.6% and 4.2% of injuries respectively. The commonest type of injury was cuts and lacerations (50.1%); injuries to the eye (due to foreign bodies, chemicals and welding sparks) accounted for 30%, sprains 8% and burns 7.1% of the injuries. A cohort of 75 workers chosen from the 341 permanent workers were followed up for the one year for identification of risk factors. Significant risk factors were age (less than 30 yr) and experience (less than 2 yr). Technical factors responsible for injury were a hazardous worksite in 37 (38.5%) cases, inadequate protection with safety wear in 32 (33%) cases and proximity to machines in 14 (14.6%) cases. Human factors identified were non-use of protective wear in 43 (45%), overconfidence in 18 (18.7%) and timing error while working with machines in 11 (11.4%) episodes.

Key words: Injuries, Glass bottle manufacturing plant

Scientific progress has made life more comfortable; but there exists the potential for permanent anatomical or physiological damage due to hazards especially among industrial workers. Traumatic occupational injuries lead to 10,000 deaths among workers annually. The International Labour Organisation has observed that an estimated 50 million work-related injuries occur every year or 160,000 every day. In the lower income countries such as those of south Asia and Africa, injuries are one of the leading causes of adult mortality and a major contributor to disability. Ergonomics related to work/machine interaction, working position, the suitability of instruments to the physical and physiological characteristics of the workers, psycho-social factors and environmental conditions (heat, cold, noise, air pollution) may affect workplaces and affect the health of the workers. The primary concern of occupational health and safety is the study of the dynamic inter-relationship between work and health and the attainment of the best balance between them.

It is necessary to carry out research for the prevention of occupational accidents and ill health caused by harmful factors in the work place. Equally important is the creation of working conditions and an environment that maintains and promotes the health of the workers. All these factors are integral in national development policies. Also, to protect the health of workers employed in a particular industrial enterprise, it is necessary to monitor the plant as a whole.

About 10 yr ago a glass bottle manufacturing plant was started in the service area of the Jawaharlal Institute Rural Health Centre (JIRHC), attached to the department of Preventive & Social Medicine, Jawaharlal Institute of Post-graduate Medical Education and Research (JIPMER), Pondicherry in south India. Ever since its inception there have been a large number of workers from this plant coming to the JIRHC for treatment of occupational injuries. The present study was conducted to find out the magnitude and pattern of injuries in the
Materials and Methods

This study was conducted at a glass bottle manufacturing plant located at Thutipet, about 13 km from JIPMER, Pondicherry, India. Thutipet is one of the field service areas of the JIRHC. Health services are provided to the workers in the factory by the JIRHC, which includes treatment and referral of the injuries.

The study was conducted for a period of one year (Jan–Dec 1998). There were 341 permanent male workers in the factory. The age range of these workers was 18 to 58 yr, of which the majority were in the 25 to 35 age group. A dispensary in the factory treats minor ailments of the workers and refers the more serious injuries to the JIRHC or JIPMER or to hospitals elsewhere. A register designed to collect information for the study was established at the dispensary and the management of the factory agreed to involve its paramedical workers to maintain the register and record all injuries occurring to the 341 workers during the study period. The paramedical workers were trained for this purpose and the entries in the register were checked for correctness twice a week. This register was used to record basic information about any injury reported, such as the day of the week, date, time, age of the worker, shift, department in which the worker was working, type and site of injury, etc.

A cohort of 75 workers were identified from among these 341 permanent workers employing a stratified random sampling technique. Stratification was done on the basis of the risk of injury in the departments where injuries are encountered, as follows: (i) Serious (permanent/disability lasting months). (ii) Moderately severe (disability lasting few days/weeks) and (iii) Minor (disability where the worker returns to work on the same day or the next day). The purpose of following up the sub-cohort was to have an intensive follow-up through a visit twice a week to the factory. Because of the limitation of time it was felt that about 75 workers could be adequately contacted every week. Therefore 75 workers were chosen to suit the convenience of these twice-a-week visits and sample size was not estimated on the basis of the anticipated odds-ratio or β error.

These 75 workers were followed up for a period of 1 yr. Initially these workers were interviewed to gather background information which included their work department, designation, age, education status, marital status, work experience in the factory, income, whether wearing spectacles for refractory errors, hand dominance, chronic illness, extent of use of protective wear and conditions in the working environment. Any injury to these 75 workers was noted during the visits to the factory, which were made twice a week.

Workers who had suffered an injury were interviewed in detail within two weeks of the injury. The following information was gathered:

1. Department where the injury occurred
2. Shift
3. Time of injury,
4. Description and reason for the occurrence of injury
5. Type and site of injury
6. Object/substance that caused the injury
7. Period of continuous work prior to the injury
8. Time when food last consumed
9. Use of alcohol in the last 12 h
10. Recent sleep disturbances
11. Presence of any family difficulty/tension
12. Presence of any acute illness and whether any medication was taken
13. Treatment for the injury
14. Referral for the injury if any
15. Period of absence from work after the injury.

The same investigator conducted both the interviews using schedules that were translated into the local language.

Table 1. Distribution of injury with shifts in the one year period

<table>
<thead>
<tr>
<th>Shift</th>
<th>No. of workers</th>
<th>1st half of the Shift</th>
<th>Injuries per worker</th>
<th>2nd half of the Shift</th>
<th>Injuries per worker</th>
<th>Total</th>
<th>Injuries per worker (overall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>87</td>
<td>48 (12.7%)</td>
<td>0.5</td>
<td>80 (21.3%)</td>
<td>0.9</td>
<td>128 (33.9%)</td>
<td>1.5</td>
</tr>
<tr>
<td>B</td>
<td>87</td>
<td>52 (13.8%)</td>
<td>0.6</td>
<td>64 (17%)</td>
<td>0.7</td>
<td>116 (30.8%)</td>
<td>1.3</td>
</tr>
<tr>
<td>C</td>
<td>55</td>
<td>34 (9%)</td>
<td>0.6</td>
<td>25 (6.6%)</td>
<td>0.4</td>
<td>59 (15.6%)</td>
<td>1.0</td>
</tr>
<tr>
<td>G</td>
<td>112</td>
<td>27 (7.1%)</td>
<td>0.2</td>
<td>47 (12.5%)</td>
<td>0.4</td>
<td>74 (19.6%)</td>
<td>0.7</td>
</tr>
<tr>
<td>Total</td>
<td>341</td>
<td>161 (42.6%)</td>
<td>0.2</td>
<td>216 (57.4%)</td>
<td>0.4</td>
<td>377 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

*Statistically significant difference using S.E. of difference between 2 proportions (1st half and 2nd half of shifts).
A=morning shift (6 am–2 pm), B=afternoon shift (2 pm–10 pm), C=night shift (10 pm–6 am), G=general shift (9 am–5 pm)
language and pre-tested. In the interviews of the cohort of 75 workers conducted after the injury a description of the occurrence of the accident and the reasons for its occurrence as elicited by the injured worker were recorded. For convenience these causes have been grouped as technical and human factors.

The data were primarily analysed with the FoxBASE programme. Time series analysis for the day of the week and month was done with the observed data. Standard error of proportions was used to find out the difference between the number of injuries in the 1st half and 2nd half of shifts. Chi square test was employed to identify the risk factors, whereas the strength of the association was determined by using the Odds Ratio.

Results

**Incidence and pattern of injuries**

a) Incidence of injuries: A total of 377 injuries were recorded in the 1-yr period among the 341 workers (incidence=1105.5/1000 workers/yr). These 377 injuries actually occurred to 185 (54%) workers; of those injured 105 (56.7%) had more than one injury either at the same time or at different times.

b) Relationship of injuries to time: The factory works in 4 shifts: 6 am to 2 pm (morning), 2 pm to 10 pm (afternoon), 10 pm to 6 am (night) and a general shift which is 9 am to 5 pm. Table 1 shows that except for the night shift, all shifts have a higher number of
injuries in the second half of the shift. Injury per worker is highest in the morning shift and lowest in the general shift. Time series analysis of the injuries revealed a peak of injuries towards the latter half of the week (Thursday—Saturday) as seen in Fig. 1 and during the first half of the year in the period January—May (Fig. 2). It is to be noted here that during the months of January to May the production load was higher, but during the months of September and October the production load was lower. This production load is higher in the first half of the year because of the greater demand for soft drink bottles in the summer months (March—June).

c) Worksite and injury: The chart (Fig. 3) shows the various departments involved in the process of glass bottle manufacture. The departments which had the

![Flow chart showing glass bottle manufacturing process](image)

**Fig. 3.** Flow chart showing glass bottle manufacturing process

<table>
<thead>
<tr>
<th>Department</th>
<th>No. of workers</th>
<th>No. of injuries</th>
<th>Injuries per worker</th>
<th>Injury type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Finished products &amp; Cold end</td>
<td>35</td>
<td>88 (23.3%)</td>
<td>2.4</td>
<td>Cuts, eye injuries, sprain</td>
</tr>
<tr>
<td>2. ACL</td>
<td>53</td>
<td>66 (17.5%)</td>
<td>1.2</td>
<td>Cuts, eye injuries, burns, crushing</td>
</tr>
<tr>
<td>3. Forming</td>
<td>54</td>
<td>66 (17.5%)</td>
<td>1.2</td>
<td>Cuts, eye injuries, burns, crushing</td>
</tr>
<tr>
<td>4. CNC &amp; Foundry</td>
<td>66</td>
<td>58 (15.4%)</td>
<td>0.9</td>
<td>Eye injuries, cuts, sprain</td>
</tr>
<tr>
<td>5. MRS</td>
<td>14</td>
<td>23 (6.1%)</td>
<td>1.6</td>
<td>Eye injuries, cuts, sprain</td>
</tr>
<tr>
<td>6. Glass</td>
<td>17</td>
<td>15 (4%)</td>
<td>0.9</td>
<td>Cuts, burns</td>
</tr>
<tr>
<td>7. Others</td>
<td>102</td>
<td>61 (16.2%)</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>341</strong></td>
<td><strong>377 (100%)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ACL=Applied ceramic labeling, CNC=Computerised numerical control, MRS=Mould repair shop
highest as well as the most of the serious injuries are the cold end & finished products, applied ceramic labelling, forming and computerised numerical control as shown in Table 2. Furthermore, the injury per worker is highest in the finished products & cold end which is followed by the mould repair shop, applied ceramic labelling, forming etc.

d) Anatomical site of injury: Hands and wrists were the most frequent sites of injury in 153 (40.6%) episodes, whereas the eyes, feet & ankles, legs and other sites accounted for 113 (29.9%), 55 (14.6%), 40 (10.6%) and 16 (4.2%) of the injuries, respectively.

e) Type of injury: The commonest type of injury was cuts and lacerations (189; 50.1%), followed by injuries to the eyes (113; 29.9%), sprains (30; 7.9%), burns (27; 7.1%), and others (18; 4.9%). Cuts and lacerations occurred mainly to the hand, whereas injuries to the eye resulted from foreign bodies, chemicals, welding sparks and heat radiation.

Risk factors and Ergonomics
A total of 96 injuries occurred to 44 of the 75 workers selected for the follow-up study in the 1-yr period.

i) Risk factors: Statistical analysis with the odds ratio revealed that age less than 30 yr, a monthly income of less than Rs. 4000 (approx. US$ 88) and work experience less than 2 yr are significantly associated with higher risk of injury (Table 3). Factors such as educational and marital status, hand dominance, designation at work, work shift, total experience in the factory, chronic illness, alcohol, smoking and use of protective measures were also studied as possible risk factors in the present study, but they were not found to be statistically significant.

Table 3. Risk factor analysis of Cohort study (n=75, total injuries=96)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Injured</th>
<th>Not injured</th>
<th>Odds-Ratio</th>
<th>Chi-square (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 30 yr</td>
<td>19</td>
<td>5</td>
<td>3.9 CI (1.8–8.4)</td>
<td>6.1 (0.013)</td>
</tr>
<tr>
<td>≥ 30 yr</td>
<td>25</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; Rs.4,000</td>
<td>29</td>
<td>10</td>
<td>4.0 CI (1.3–12.6)</td>
<td>8.4 (0.004)</td>
</tr>
<tr>
<td>≥ Rs.4,000</td>
<td>15</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Department experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 2 yr</td>
<td>19</td>
<td>4</td>
<td>5.6 CI (1.3–22.8)</td>
<td>6.4 (0.01)</td>
</tr>
<tr>
<td>≥ 2 yr</td>
<td>25</td>
<td>27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Technical Factors: The commonest technical factor responsible for the occurrence of injury was the environment in 37 cases (38.5%). At the worksite in various departments it was not uncommon to see broken pieces of glass and metal chips spilled on the floor, machines or tables. Though helmets, goggles, gloves, leather shoes and chest guards are provided to the workers in certain departments for specific job tasks, injury was noted in 32 episodes (33.3%) in spite of using the protective wear. Cuts through the gloves and eye injury resulting from unprotected angles of the goggles are common. Pieces of glass and metals chips are released as projectiles from machines and various processes. Machinery was responsible for 14 of the injuries (14.6%).

Human factors: Among human factors, not wearing protective wear seems to be the most important cause of injury as seen in 43 episodes (44.8%).

Workers provided with protective wear have cited reasons such as discomfort (for instance, sweating due to the goggles) for not using them. Overconfidence in the job due to familiarity with the mechanical process resulted in 18 (18.7%) of the injuries. Physical manipulation requiring moving in and out of moving machinery e.g. oiling the moving parts of the machine or picking out defective products from the machine or removing them from the conveyor belt resulted in timing errors leading to 11 (11.4%) of the injuries. In 4 episodes (4.1%), the cause of injury was due to a mistake by a co-worker (e.g. starting machinery without warning, spilling chemicals on others, etc). Certain jobs such as welding need prior training. This inexperience led to 3 instances of injury.

Discussion
The factory studied had a high incidence of injury of 1,106 injuries/1,000 workers/yr. The risk of a worker being injured in the plant is high, considering that 54% of the workers had an injury; and 56.7% of these injured workers had more than 1 injury. Population based studies show a much lower incidence of injuries as indicated in reports from Gordon et al from Punjab, India (116 injuries/1,000 population) and from Dutta et al from rural

Follow-up of the 75 workers reveals that most of the injuries were due to contact with glass (34.4%), machines (28.1%) and metal (16.6%), etc. Time series analysis of the injuries shows the highest injury rate per worker and also the highest number of injuries (33.9%) in the morning shift (6.00 am–2.00 pm), whereas the lowest injury rate per worker is in the general shift with the lowest number of injuries (15.6%) occurring in the night shift (10.00 pm–6.00 am). Most injuries during the daytime shift were also reported by Chadha et al.  and Bigos et al.  In contrast, Smith et al.  found a higher risk of injury in the night shift than in the morning shift in an engineering company. The reason for this is not clear. There was a statistically significant difference between the higher proportions of injuries in the second half of the shift as compared to the first half of the morning and general shifts. This probably could be due to fatigue and loss of concentration on part of the workers towards the later part of the shift as the manufacturing process is a continuous one.

The period around the weekend had a higher number of injuries. Clark et al. reported that 16% of the injuries were recorded on Saturdays and Mondays and 15% on Fridays from a study in an accident and emergency department. Smith et al. also reported a significant increase in the night-time admissions as the days of the week progressed. The weekly schedule at the plant needs to be studied further to identify the cause of the increase and take appropriate steps.

In the present study the first half of the year had a larger share of injuries than the second half. Enquiries of the management revealed that there was in fact a higher production load in the plant by way of contracts during the months in which a higher number of injuries were reported. While Dutta et al. in their study noticed a higher incidence during February and March and again during September and October, Chadha et al. found no significant difference in the number of injuries in an ammunition factory in relation to the months of the year.

Injuries to the hand and wrist accounted for more than 40% of the overall injuries. Marty et al. and Kelsey et al. reported that 1/3 of all work related injuries are to the hand. Chadha et al. reported that 42.2% of all injuries in an ammunition factory are to the hands; injuries to the eye (29.9%) are the 2nd most common in this factory. Ballal reports that in an iron forging industry in Saudi Arabia nearly 40% of injuries were to the eye.

In the present study, cuts and lacerations accounted for 50.1% of injuries, followed by eye injuries, (29.9%), sprains (7.9%) and burns (7.1%). Gupta and Chadha et al. also report similarly that cuts and lacerations were the commonest injuries in a leather and an ammunition factory respectively.

Analysis of the follow-up study led to the emergence of the following significant risk factors—

a) age below 30 yr. Similar findings of higher rates of injuries to younger workers in this age group have been reported. Davis PR et al. found that accidents occurred more frequently in the 31–48 yr age group in a telecommunication industry factory. Similarly rates of death due to work-related accidents were higher among older construction workers as seen in a study from South Korea.

b) a monthly income of less than Rs. 4000 (approximately US$ 88). In this study the lower paid workers had more injuries due to the type of work they were engaged in. Xiang H et al. found low family income to be a statistically significant risk factor of injury among agricultural workers, and Frumkin H et al. concluded from their study that the poor and minority worker population are more at risk of occupational injury.

c) an experience of less than 2 yr work in the department. The number of injuries is higher when a worker is new to the job and decreases as experience accumulates, as is borne out by other studies. Therefore, the management should pay attention to the fact that a new worker be properly trained and supervised in the initial stages.

It was also found that 43% of the injuries occurred within 3 h of a meal, 25% between 3–6 h and 31.3% more than 6 h after a meal. This trend in accidents, similar to that found among woodworkers, points to the fact that the hours immediately before and after a meal were the most injury-prone.

Most authors consider human factors to be responsible for 85% of accidents. Factors leading to injuries at work are inadvertence or recklessness, improper performance of the job task, lack of appropriate tools; it is also related to the settlement of private affairs at home. Other reported risk factors include fatigue; inexperience with powered machinery, failure to use properly installed safety guards, on power tools, reaching with the hand into clogged machinery, operating machinery soon after a meal and operating power presses. Most of the factors cited in these studies are similar to the technical and human factors identified in the present study. These need to be given high priority with regard to setting and establishing preventive measures.

The findings of the present study need to be viewed with caution, keeping its limitations in mind, chief among them being i) sample size was not calculated based on the expected odds ratio; ii) matching between case and control is limited due to the employment of a nested case-control design and iii) a large number of contract workers could not be included for follow-up as they are not in employment throughout the year.

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References