Analysis of Industrial Accidents in a Public Sector Power Company—Causes and Preventive Measures

N. N. Pisharody, Kanchan D. Bahukhandi, Prashant S. Rawat, and R. K. Elangovan

1 Introduction

Accidents are unexpected events resulting in unwanted or undesirable outcomes. Unwanted outcomes can include harm or loss to personnel, property, production or nearly anything that has some inherent value. These losses increase organization's operating cost through higher production costs, decreased efficiency, and long-term effects of decreased employees' morale and unfavourable public opinion (U.S. Department of Energy 2012). All accidents need not cause loss. Depending up on the consequences, types of accidents are classified as near miss, first-aid injury, non-reportable injury, reportable injury and fatality.

Near misses are harmless disruptions from normal operation without any personal injury or property loss. First-aid injuries are accidents in which the victim is returned back to workplace after treatment at first-aid centre. Non-reportable injuries are accidents in which victims are send to hospital with or without treatment at first-aid centre for further medical examination and victim returns to workplace within 48 h of the event, and Reportable injuries are accidents in which the victim is send to hospital with or without treatment at first-aid centre for further medical examination and victims returns to workplace after 48 h of the event and fatality are accidents with loss of life to one or more persons as consequence of accident.

N. N. Pisharody (✉)
Nuclear Power Corporation of India Limited, Anushaktinagar, Mumbai, Maharashtra 400094, India
e-mail: nnpisharody1965@gmail.com

K. D. Bahukhandi · P. S. Rawat
University of Petroleum and Energy Studies, Dehradun, Uttarakhand 248007, India

R. K. Elangovan
Directorate General Factory Advice Service and Labor Institutes, Mumbai, Maharashtra 400022, India

F. I. Khan et al. (eds.), *Advances in Industrial Safety*, Springer Transactions in Civil and Environmental Engineering, https://doi.org/10.1007/978-981-15-6852-7_15

Consequences of accidents vary from nil to loss of life. Near misses, first-aid injuries and non-reportable injuries are accidents with low consequences and high frequency, when compared with reportable injuries and fatalities which are with high consequences and low frequency. Therefore, accidents of low consequences give more opportunities for corrective measures to prevent accidents of high consequence. In order to develop a strong accident prevention system, reporting of accidents of low consequences and correction of causes should be imbibed in organizational safety culture. Studies also show that whenever line managers had shown increased focus in reporting and correcting of causes of accidents of low consequences, there were reductions in accidents of high consequences (Geoffrey 1991; Taylor and Lucas 1991; Lucas 1991; Masson 1991; Van der Schaaf 1991a, b; Jones et al. 1999; Phimister et al. 2003; Sonnemans and Korvers 2006; Sonnemans et al. 2010, NASA 2011). This implies that while organization shall take corrective measures to prevent reportable injuries and fatalities, it is equally important to promptly address causes of near misses, first-aid injuries and non-reportable injuries also (National Safety Council 1981; Lees 1996). Accidents are prevented by effective hazard control programme. This is achieved by means of engineering controls, administrative controls and personal protective equipment or human inference.

In this paper, analysis of 2179 accidents comprising of 1539 near misses, 366 first-aid injuries, 161 non-reportable injuries, 95 reportable injuries and 18 fatalities; occurred at 22 operating plants and 7 construction projects in a public sector power company in India during the period of 10 years from 2006 to 2015 with reference to IS-3786 "Method for the Computation of Frequency and Severity Rates for Industrial Injuries and Classification of Industrial Accidents" is described (IS-3786 2002).

The number of accidents is given Table 1, and proportion of each category of accident is given in Fig. 1. The paper brings out causes and recommendations to prevent accidents.

Table 1 Number of events during the period from 2006 to 2015

Year	Near miss	First-aid injury	Non-reportable injury	Reportable injury	Fatality	Total
2006	39	0	0	7	3	49
2007	46	0	2	18	3	69
2008	69	15	6	12	1	103
2009	93	11	17	10	1	132
2010	103	27	27	11	2	170
2011	172	53	17	6	1	249
2012	188	48	25	14	1	276
2013	241	80	22	8	3	354
2014	282	54	18	4	2	360
2017	306	78	27	5	1	417
Total	1539	366	161	95	18	2179

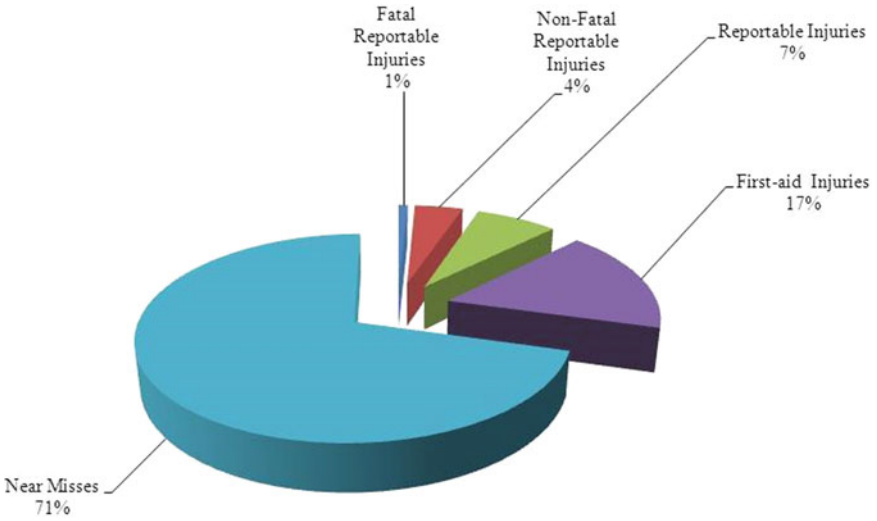

Fig. 1 Industrial accidents during the period from 2006 to 2015

2 Taxonomy

The paper comprises 12 sections. Section 1 presents Introduction. Section 2 gives taxonomy. Section 3 deals with brief description of Indian Standard IS-3786 applicable to the analysis. Sections 4–10 are on Analysis of Industrial Accidents based on IS-3786 as per "Agency", "Unsafe Mechanical or Physical Condition", "Unsafe Act", "Unsafe Personal Factor", "Type of Accident", "Nature of Injury" and "Location of Injury", respectively. Section 11 gives Discussion and Recommendations of analysis and Sect. 12 gives Conclusion of the analysis.

3 Indian Standard IS-3786

Bureau of Indian Standards (BIS) has issued IS-3786 "Method for the Computation of Frequency and Severity Rates for Industrial Injuries and Classification of Industrial Accidents" in the year 1983, and it was reaffirmed in the year 2002. Appendix-B of the standard gives guidelines for classification of accidents based on seven principal factors related to causation of accidents as given below:

B-1 Agency
B-2 Unsafe Mechanical or Physical Condition
B-3 Unsafe Act
B-4 Unsafe Personal Factor
B-5 Type of Accident

B-6 Nature of Injury
B-7 Location of Injury

Brief description the above factors is given below:

3.1 Agency

"Agency" is the object or substance, which is most closely associated with the accident causing injury and with respect to which adoption of a safety measure could have prevented the accident. Examples are machines, means of transportation, flying objects, scaffoldings, ladders, lifting machines, electrical conductors, electric hand tools, chemicals, gases, working environment, live animals, etc.

3.2 Unsafe Mechanical or Physical Condition

These are "Unsafe Mechanical or Physical Condition" related to Agency, which contributed to the causation of accident. Examples are improperly guarded agency, defects in agency, hazardous arrangement, procedure, etc. in or on apparel, improper illumination, unsafe dress or apparel, improper ventilation, etc.

3.3 Unsafe Act

"Unsafe Acts" are deviation from accepted and laid down safe procedure, which contributed to the causation of accidents. Examples are operating without authority, failure to secure or warn, operating at unsafe speed, marking safety devices inoperative, using unsafe equipment, hand instead of equipment, or equipment unsafely, unsafe loading, placing, mixing, combining, taking unsafe position or posture, etc.

3.4 Unsafe Personal Factor

"Unsafe Personal Factors" are anatomical, physiological or psychological characteristics which caused the unsafe act. Examples are unsuitable anatomical, physiological or psychological characteristics, lack of knowledge or skill, unsuitable mechanical or physical conditions, social environment, etc.

3.5 Type of Accident

"Type of Accident" is the manner in which the object or substance causing the injury comes into contact with the person or the movement of the injured person which resulted in the injury. Examples are fall of objects, fall of person, stepping or striking against or struck by object, caught or in between the objects, over exertion or wrong movements, exposure or contact with extreme temperature or electric current or harmful substances, explosions, etc.

3.6 Nature of Injury

"Nature of Injury" indentifies the injury in terms of principal physical characteristics. Since there is no injury to persons in case near misses, potential for the nature of injury is considered. Examples are fractures, dislocations, sprains and strains, concussions and other internal injuries, amputations and enucleations, wounds, superficial injuries, contusions and crushings, burns, acute poisonings, effects of weather, exposure and related conditions, asphyxia, effects of electric currents, effects of radiations, multiple injuries of different nature, etc.

3.7 Location of Injury

"Location of Injury" is the part of the injured person's body, directly affected by the injury. Since there is no injury to persons in case of near misses, potential location for the injury is considered. Examples are head, neck, trunk, upper limb; lower limb, etc.

4 Analysis of Industrial Accidents as Per "Agency"

Figure 2 gives proportion of **Agencies** caused Industrial Accidents during the period from 2006 to 2015.

52% of the Industrial Accidents were due to unsafe conditions and unsafe acts while working indoor and outdoor "**Working Environments**". Agencies in indoor working environment (43%) are floors, confined quarters, stairs, traffic and working surfaces, floor openings and wall openings, environmental factors such as lighting, ventilation, temperature, noise; water, fire or other unsafe conditions in structures, systems and components within the plant buildings. Agencies in outdoor working environment (9%) are weather, traffic and working surfaces, water, fire or other unsafe conditions in structures, systems and components outside the plant buildings.

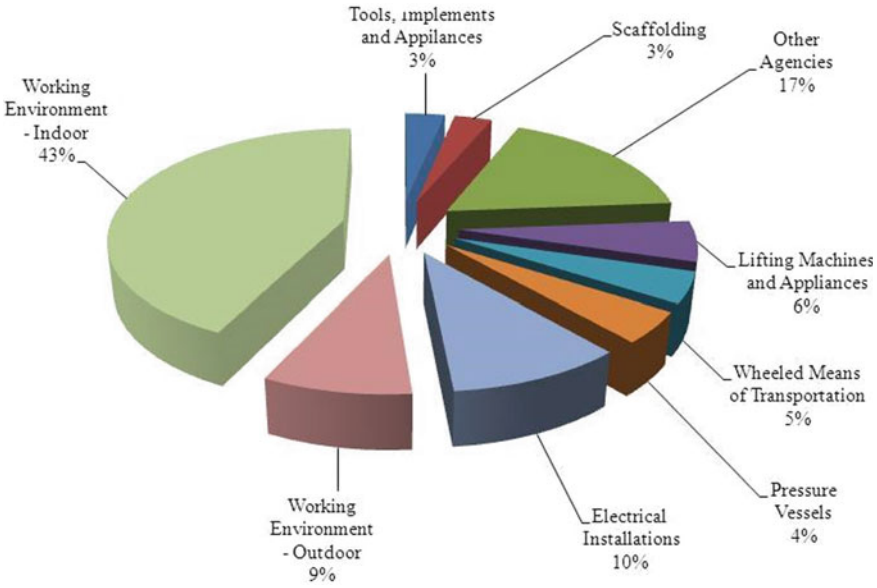

Fig. 2 "Agencies" during the period from 2006 to 2015

10% of Industrial Accidents were due to unsafe conditions and unsafe acts while working on "**Electrical Installations**", such as motors, switchgears, circuit breakers, cables lighting circuits or lamps, causing electric shock or potential to cause electrical shock to persons involved.

6% of the Industrial Accidents were due to deficiencies in "**Lifting Machines and Appliances**" such as EOT cranes, mobile crane, tower cranes, forklifts, elevators, slings or other lifting tools and tackles, which have caused injuries or potential to cause injuries to persons while using these equipments.

5% of the Industrial Accidents were due to **Wheeled Means of Transportation** such as light vehicles, trucks or buses, due to unsafe conditions and unsafe acts while using these vehicles.

4% of the Industrial Accidents were due to deficiencies in "**Pressure Vessels**" due to unsafe conditions, unsafe acts and shortfalls in periodic inspection of pressure vessels, pressurized components and gas cylinders or lack of supervision.

3% of the Industrial Accidents were due to deficiencies in "**Scaffolding**" such as loosely placed working platforms, hand railings, absence of toe boards or mid railings, which had caused or had potential to cause injuries to persons due to fall of persons or fall of objects from height.

3% of the Industrial Accidents were due to deficiencies in the "**Tools, Implements and Appliances**" due to unsafe acts while using tools, improper use of tool or non-use of required tools.

17% of the Industrial Accidents were attributed to deficiencies in "**Other Agencies**" which comprised of miscellaneous equipment such as transmission machinery

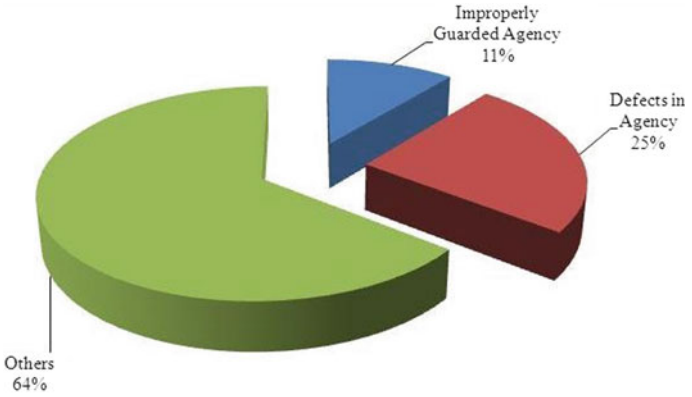

Fig. 3 "Unsafe materials or physical conditions" during the period from 2006 to 2015

(0.6%), metal working machines (1.2%), electric hand tools (0.1%), ladders and mobile ramps (2.1%), other unclassified equipment (9.4%), flying objects (0.7%), other substances and materials (0.5%), dusts, gases, liquids and chemicals (2.4%).

5 Analysis of Industrial Accidents as Per "Unsafe Materials or Physical Conditions"

Figure 3 gives proportion of "**Unsafe Materials or Physical Conditions**" caused Industrial Accidents during the period from 2006 to 2015.

64% of the Industrial Accidents occurred due to reasons "**Others**" such as hazardous working arrangement, lack of caution signage, lack of safe working platform, lack of safety net, lack of training or awareness, unsafe condition due to poor housekeeping, inadequate design or lay out, improper installation, not securing the equipment, improper storage of materials, wrong procedure, selection of wrong equipment or tools, unsafe tools, wrong identification, tagging or labelling of equipment, unsafe personal protective equipment or unsafe working place.

25% of the Industrial Accidents occurred due to material condition "**Defects in Agencies**".

11% of the Industrial Accidents occurred due to "**Improper Guarding of Agencies**".

6 Analysis of Industrial Accidents as Per "Unsafe Act"

Figure 4 gives percentage of "**Unsafe Acts**" caused Industrial Accidents during the period from 2006 to 2015.

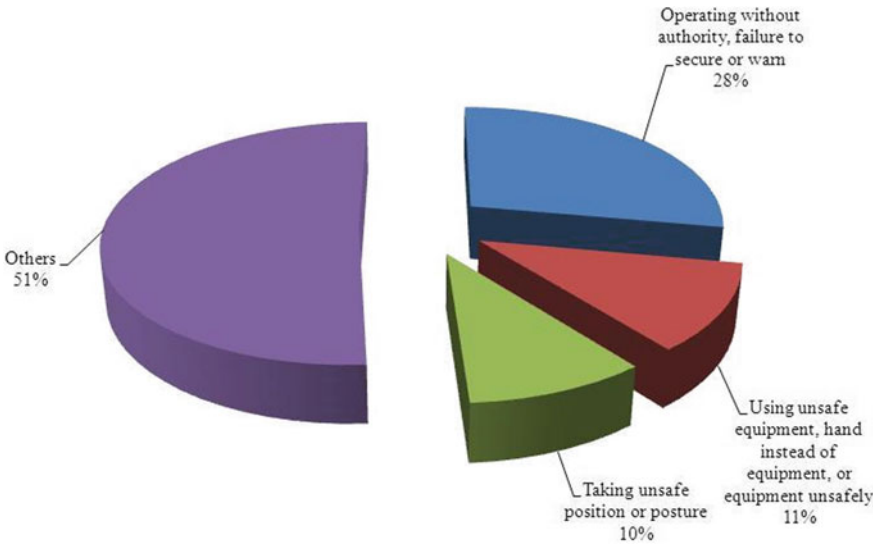

Fig. 4 "Unsafe acts" during the period from 2006 to 2015

51% of the Industrial Accidents occurred due to reasons "**Others**" such as conditions not checked before the job, wrong procedure or performing jobs without procedure, improper use of tools or non-use of required tools, improperly completed job, inadequate design review, ineffective communication and coordination, lack of attention to the job, non-use of required personal protective equipment or improper use of personal protective equipment, overloading, storing the materials in unsafe manner, use of wrong equipment, weakness in inspection and correction, horseplay by the workers, wrong labelling/tagging, lack of awareness of employees or shortfalls in supervision and enforcement of safety measures.

28% of the Industrial Accidents occurred due to "**Operating without Authority, Failure to Secure or Warn**" such as performing job without work permit, guaranteed isolation or authorization, not securing equipment in work places; or lack of caution signage or warning by the coworkers or work supervisors.

11% of the Industrial Accidents occurred while "**Using Unsafe Equipment, Hand instead of Equipment or Equipment Unsafely**" due to equipment deficiencies or unsafe equipment.

10% of the Industrial Accidents occurred due to "**Taking Unsafe Position or Posture**" by the employees due to lack of safe access, lack of knowledge of workers, weakness in supervision or lack of attention of workers to unsafe conditions at work places.

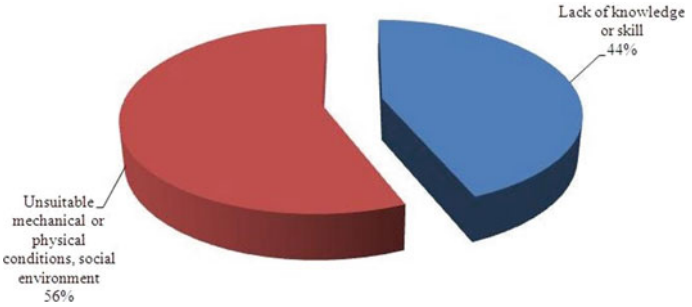

Fig. 5 "Unsafe personal factor" during the period from 2006 to 2015

7 Analysis of Industrial Accidents as Per "Unsafe Personal Factor"

Figure 5 gives percentage of "**Unsafe Personal Factor**" caused Industrial Accidents during the period from 2006 to 2015.

56% of the Industrial Accidents occurred due to "**Unsuitable Mechanical or Physical Conditions, Social Environment**" attributable to deficiencies in design and layout, material condition deficiencies, improper storage of materials or shortfalls in inspection and maintenance of structures, systems and components.

44% of the Industrial Accidents were due to "**Lack of Knowledge and Skill**" leading to unsafe acts by the employees either intentional or unintentional.

8 Analysis of Industrial Accidents as Per "Type of Accidents"

Figure 6 gives percentage of "**Types of Accidents**" caused Industrial Accidents during the period from 2006 to 2015. In case of Near misses, since there were no injuries, potential for types of accidents is considered.

27% of the Industrial Accidents were attributed to "**Stepping on or Sticking against or Struck by Objects**" due to deficiencies in material condition, design, layout and ageing of structures, systems and components; tripping hazards, poor housekeeping, placing materials in unsecured manner, lack of caution signage or warning, ineffective communication, non-use of correct tools, non-use of personal protective equipment or lack of supervision.

26% of the Industrial Accidents were due to "**Falls of Objects**" from structures, systems and components due to deficiencies in material condition or ageing, unsafe procedures, poor housekeeping and placing materials at height in unsecured manner.

14% of the Industrial Accidents were due to potential for "**Fall of Persons on the Same Level**" due to deficiencies in material condition, design, layout or ageing of

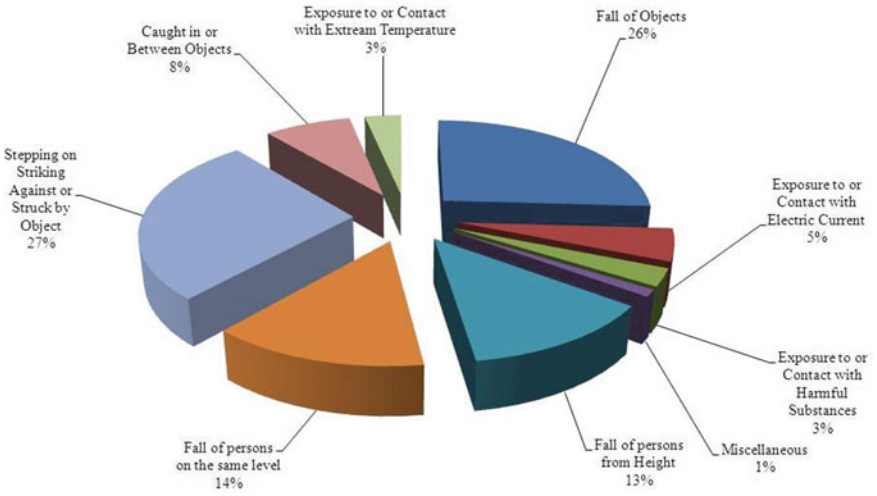

Fig. 6 "Types of accidents" during the period from 2006 to 2015

structures, systems and components, slipping on the floor due to spillage of materials or biological growth, tripping hazards, use of unsafe personal protective equipment, taking unsafe posture by the workers, unsafe procedures, unsafe act by the workers, poor housekeeping, lack of caution signage or warning; or low illumination.

13% of the Industrial Accidents were due to "**Fall of Persons from Heights**" due to unsafe scaffolding, platforms and ladders; lack of safe access for working height, lack of hard barricading and caution signage at height, uncovered openings or openings covered with soft materials, unsafe design and layout, tripping hazards at height, deficiencies in staircases, deficiencies in material condition, aging, not securing ladders, low illumination, unsafe acts by the workers, non-use of personal protective equipment or fall protection measures, use of unsafe personal protective equipment, unsafe procedures, non-adherence to procedures and work permit system, slipping on the floor due to spillage of materials, poor housekeeping; or ineffective supervision and communication.

8% of the Industrial Accidents were due to "**Caught in or Between the Objects**" attributed to shortfalls, identification of hazards and implementing risk control measures, lack of hard barricading or guarding with caution signage, uncovered openings or pits, unsafe storage of materials during transportation, ineffective supervision and communication, unsafe design and layout, lack of procedures, unsafe procedures, non-adherence to procedures and work permit system, uncovered openings, unsafe acts by the workers, placing materials in unsecured manner, unsafe platform, non-use of personal protective equipment or use of unsafe personal protective equipment, lack of safe access for working or low illumination.

5% of the Industrial Accidents were due to "**Exposure to or Contact with Electrical Current**" attributed to ageing of cables, wrong identification and tagging of

equipment, design, deficiencies in equipment, lack of guaranteed electrical isolation, lack of procedures, unsafe procedures, non-adherence to procedures and work permit system, ineffective supervision and communication, weakness in self checking and peer checking of equipment before the job, exposed live contacts of equipment and cable terminals, unsafe design and layout, non-use of personal protective equipment, lack of caution signage and markers for subsurface cables, use of cables with joints, lack of Earth Leakage Circuit Breakers in electrical circuits, lack of hard barricading with caution signage to restrict approach, low illumination or unsafe act by the employees.

3% of the Industrial Accidents were due to "**Exposure to or Contact with Extreme Temperature**" attributed to heating or sparks due to non-adherence to procedures and work permit system during hot works, unsafe procedures, sparks from damaged electrical cable by rodent attack or ageing, lack of arrangement for collecting welding and cutting spatters, ageing of equipment and components, storage of incompatible chemicals, use of cables with joints, un-insulated hot components of systems, lack of barricading and caution signage to restrict approach to hot components of the system and environment, water leakage on electrical systems, non-use of personal protective equipment, use of incorrect personal protective equipment, lack of supervision, shortfalls in design and layout, storage of flammable materials or oil leak at work places, overloading of electrical cables, lack of attention of workers to hazards in workplace or shortfalls in identification of hazards and implementing risk control measures.

3% of the Industrial Accidents were due to "**Exposure to or Contact with Harmful Substances**" due to deficiencies in material condition, design, layout and ageing of structures, systems and components; unsafe acts by the workers, ineffective supervision and communication, lack of procedures, unsafe procedures, non-adherence to procedures and work permit system, shortfalls in identification of hazards and implementing risk control measures, use of incorrect tools, non-use of personal protective equipment, use of incorrect personal protective equipment or lack of labels on chemical containers.

Remaining 1% of the Industrial Accidents classified as "**Miscellaneous**" were attributed to "Over Exertions or Wrong Movements" (0.4%), "Explosions" (0.2%) and "Others" (0.4%) which are not classified elsewhere.

9 Analysis of Industrial Accidents as Per "Nature of Injuries"

Figure 7 gives percentage of "**Nature of Injuries**" which caused Industrial Accidents during the period from 2006 to 2015. In case of near misses, since there were no injuries, potential for nature of injuries is considered.

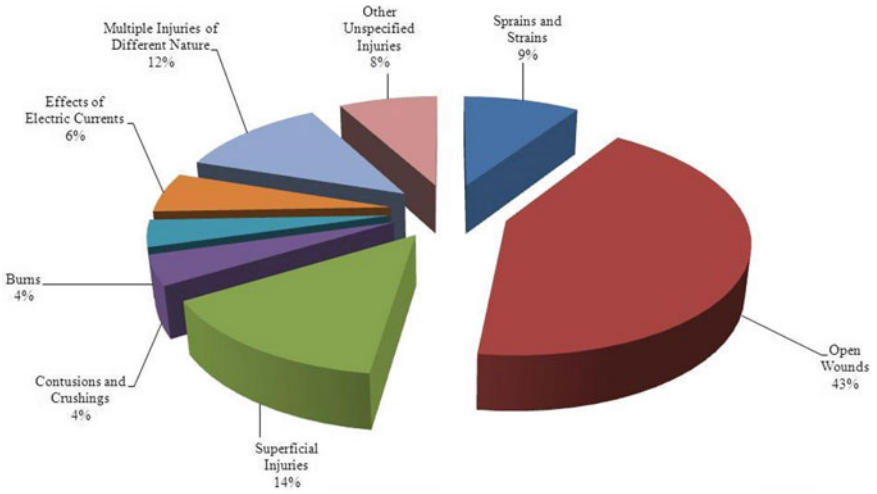

Fig. 7 "Nature of injuries" during the period from 2006 to 2015

The injuries or potential injuries are caused due to occurrence of various types of accidents attributed to unsafe conditions, unsafe acts and unsafe personal factors associated with various Agencies.

10 Analysis of Industrial Accidents as Per "Location of Injuries"

Figure 8 gives percentage of different "**Location of Injuries**" caused Industrial Accidents during the period from 2006 to 2015. In case of near misses, since there were no injuries, potential for locations of injuries is considered.

The injuries or potential injuries are caused due to occurrence of various types of accidents attributed to unsafe conditions, unsafe acts and unsafe personal factors associated with various Agencies.

11 Discussion and Recommendations

The paper presents a generic analysis of 2179 industrial accidents comprising of 1539 near misses, 366 first-aid injuries, 161 non-reportable injuries, 95 reportable injuries and 18 fatalities occurred in a public sector power company during the 10 years period from 2006 to 2015 with reference to IS-3786 (IS-3786 2002). The analysis

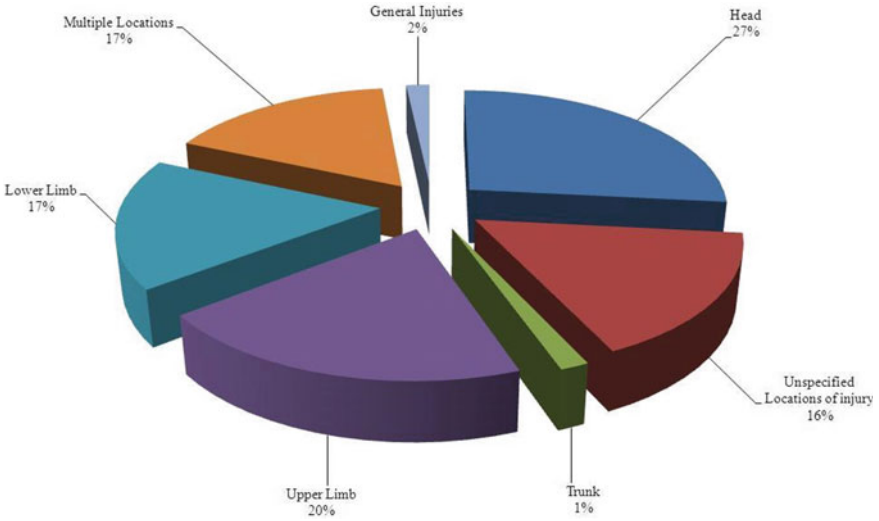

Fig. 8 "Location of injuries" during the period from 2006 to 2015

indicates that accidents occurred due to shortfalls in engineering controls, administrative controls and use of personal protective equipment to prevent accidents. Effective control measures as described below to address these shortfalls could prevent recurrence of accidents of similar kind:

1. Inadequate review of design and layout either at the initial design or subsequent modifications have caused accidents due to insufficient guarding or hard barricading with caution signage to restrict approach of workers to hazardous system components and work environment. This should be addressed by:

Engineering Controls:

- Engineering design of machine guards.
- Installing fencing or railings around the pits
- Covering floor and wall openings with hard materials of requisite strength to prevent fall of persons from height.
- Providing protective covering over the system components carrying corrosive or high-temperature fluids.
- Insulating exposed power terminals of electrical equipment
- Designing equipment ergonomically.

2. Lack of safe access for working at height and unsafe scaffoldings and platforms have caused accidents due to unsafe acts and unsafe posture of workers while performing jobs at height. This should be addressed by:

Engineering Controls:

- Using scaffolding and platform materials manufactured as per national or international standards.
- Ensuring safe access to and egress from platform for performing job at height.

Administrative Controls:

- Imparting skill-based training on scaffolding erection to the employees involved in erection of scaffoldings and platforms.
- Strengthening inspection and certification process of scaffoldings and platforms before use by competent agencies.
- Providing "Green" tags on scaffoldings certified safe for use and "Red" tags on scaffoldings under erection or dismantling or unsafe for use.
- Deploying workers with valid height pass who are medically and physically fit and authorized for working at 2.5 m and above height.

3. Short falls in inspection, maintenance and testing of structures, systems and components have caused accidents due to unsafe conditions attributable tripping hazards, material condition deficiencies and ageing of structures, systems and components, poor housekeeping, improper installation, not securing equipment, improper storage of materials, non-compliance to required number of fire extinguishers at the fire points or low illumination. This should be corrected by:

Engineering Controls:

- Providing hard barricading and caution signage to restrict approach to hazardous work locations.
- Insulating hot components of the system to prevent burn injury to workers on contact or exposure.
- Securing materials firmly at work place.
- Safe storage of materials during transportation.

Administrative Controls:

- Strengthening periodic inspection, preventive maintenance and testing structures, systems and components, and rectification of deficiencies attributed to material condition and ageing.
- Maintaining good housekeeping of workplace before, during and after the job.
- Inspection of equipment before performing job.
- Ensuring positive isolation of process systems before taking up works.
- Periodic illumination survey and ensuring sufficient illumination at work places as per statutory requirements.
- Ensuring preventive maintenance testing of vehicles.
- Providing required number of fire extinguishers at the fire points and ensuring this during periodic inspection and maintenance.

4. Unsafe act by the workers have caused accidents due to lack of procedural adherence, lack of awareness, unsafe posture of workers while performing job, lack of attention of the workers to hazards in the area, inadequate hazard identification and risk assessment and implementation of control measures and work permit system; improper earthing of work pieces and lack of arrangement for collecting welding and cutting spatters during welding, improper insulation on electrical cable, use of unsafe personal protective equipment, unsafe tools, defective equipment for performing job, lack of supervision and ineffective communication or coordination. This should be addressed by:

Engineering Controls:

- Conducting Job Hazard Analysis for hazardous job to identify hazards and risk involved in the job and implementation of control measures before execution.
- Use of right equipment and tools for performing job and training of workers on correct use.
- Providing safety net and fall protection measures.
- Using mechanical means for material handling instead of manual means.
- Use of cylinder valve cap or guard while shifting of gas cylinders

Administrative Controls:

- Emphasizing compliance to safety measures, procedural adherence and work permit system, job specific hazards during safety induction training, pre-job briefing, tool box talks and enforcing safety measures during work execution.
- Compliance to work permit system and guaranteed isolation of equipment before starting the job.
- Performing job with approved procedures and valid work permits.
- Providing arrangement for collection of welding and cutting spatters during welding.
- Imparting training on defensive driving to drivers and instructing them to comply with specified speed limits while driving vehicles.
- Imparting training on loading and stability to mobile crane mobile crane operators.
- Providing intermittent rest to the workers involved in continuous job.
- Effective supervision, communication and coordination by line managers and work supervisors.

Personal Protective Equipment:

- Use of right type and safe personal protective equipment in correct manner such as anchoring lanyard of full body harness to a firm structure, wearing chin straps of helmets, use of eye protection during hot works and wearing ear protection measures in high noise area.

5. Use of cables with joints, lack of Earth Leakage Circuit Breakers (ELCBs) in electrical circuits, inadequate insulation of live contacts of equipment and cable

terminals, failure to de-energize discarded electrical circuit, overloading of electrical cables, damage to electrical cable by rodent attack and ageing of cables, wrong identification or tagging or labelling of equipment have caused electrical accidents. This should be addressed by:

Engineering Controls:

- Avoiding joints in cables.
- If joints cannot be avoided in cables, join the cables with insulated electrical connectors.
- Providing ELCBs in electrical circuits.
- Providing hard barricading with caution signage to restrict approach to exposed and charged electrical equipment.
- Ensuring visible double earthing of electrical equipment.
- Providing visible cable markers for underground cables at the surface level.
- Restricting entry of mobile cranes with extended boom to the area below overhead electrical transmission and distribution lines by providing goal post barriers.
- Designing cable trays with excess capacity to accommodate additional cables envisaging future field modification works.
- Restricting number of cables in cable trays, enhancing capacity of cable trays or rerouting of cables through less loaded cable trays. Cable trays should not be filled in excess of 40–50% of the inside area of the tray or of the maximum weight based on the cable tray specifications (NFPA-70 2017).
- Closing openings in electrical equipment against rodent entry and using cables with sheathing protected against rodent attach.

Administrative Controls:

- Ensuring guaranteed isolation of electrical equipment and compliance to work permit system.
- Training of employees on precautions to be taken while working in electrical systems.
- Deploying electrically authorized persons for works on electrical systems.
- Periodic inspection and testing of cables with respect to ageing and replacement of cables with damage and expired service life.
- Self-checking and peer checking during identification, tagging or labelling of equipment and before execution of job on electrical systems.
- Obtaining clearance from electrical department before carrying out any excavation works.

Personal Protective Equipment:

- Using arc-resistant suits, hand gloves and face fields while carrying out works on electrical switch gears.
- De-energizing discarded electrical cables and providing tags on such circuits.

6. Unsafe storage and transportation of materials, wrong labelling equipment and storage of incompatible materials have caused accidents or has potential to cause accidents. This should be addressed by

Engineering Controls:

- Segregating materials with incompatible chemical properties during handling and storage.
- Chaining or securing of gas cylinders during transportation and storage.

Administrative Controls:

- Controlling storage of flammable and hazardous materials in work places by permit system for transit storage of these materials.
- Self-checking and peer checking during identification, tagging or labelling of materials.

12 Conclusion

Causes for most of the accidents are repetitive and multi-disciplinary in nature. This could be due to shortfalls in identification of root causes and enforcement of foolproof corrective measures. Prevention and control of accidents is a big challenge. Continual efforts are required to control or reduce probability and severity of accidents.

All accidents should be investigated as it provides valuable information on the genesis of accidents and deep insight on accident prevention. In order to make an accident investigation unbiased, it should be carried out by an independent team, not related to the area and job in which accident occurred. Accident investigation involves finding answers to five Ws and one H, i.e. What? When? Where? Why? Who? and How? Of these, How' involves identification of root cause by using "Five Why Technique", in which "Why" is asked five times to determine root cause.

Accident prevention and control measures should be included in the design and subsequent operation to bring risk within the acceptable limits. Risk control shall involve judicial application of engineering controls, administrative controls and use of personal protective equipment in the respective order of hierarchy of effectiveness. This will help to achieve **zero accident** in an organization.

Acknowledgements The authors acknowledge the support of Mr. Aloke Varshney, Chief Engineer and Mr. Pankaj Khot, Executive Director of the public sector power company for extending technical and administrative supports for carrying out study and conducting research.

The article has been written as a voluntary effort and has not of received any funding. Opinions expressed are those of authors and not of their organizations.

Conflicts of Interest None of the contributing authors have conflicts of interest to declare.

References

Geoffrey I (1991) Near miss reporting pitfalls for nuclear power plants. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford

IS-3786 (2002) 1983-Reaffirmed in 2002. Method for computation of frequency and severity rates for industrial injuries and classification of industrial accidents. Bureau of Indian Standard

Jones S, Kirchsteiger C, Bjerke W (1999) The importance of near miss reporting to further improve safety performance. J Loss Prev Process Ind 12:59–67

Lees FP (1996) Loss prevention in the process industries, 2nd edn. Butterworth-Heinnemann

Lucas DA (1991) Organizational aspects of near miss reporting. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford

Masson M (1991) Understanding, reporting and preventing human fixation errors. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford

NASA (2011) Accident precursor analysis handbook. National Aeronautics and Space Administration Office of Safety and Mission Assurance Washington, D.C. 2054

National Safety Council (1981) Accident prevention manual for industrial operations-administration and programmes, 8th edn. National Safety Council, USA

NFPA-70 (2017) National electric code. National Fire Protecion Association, USA

Phimister JR, Oktem U, Kleindorfer PR, Kunreuther H (2003) Near miss incident management in chemical process industry. Soc Risk Anal Risk Anal 23(3):445–459

Sonnemans PJM, Korvers PMW (2006) Accidents in the chemical industry: are they foreseeable? J Loss Prev Process Ind 19:1–12

Sonnemans PJM, Körvers PMW, Pasman HJ (2010) Accidents in "normal" operation—can you see them coming? J Loss Prev Process Ind 23:351–366

Taylor RK, Lucas DA (1991) Signals passed at danger: near miss reporting from a railway perspective. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford

U.S. Department of Energy (2012) DOE hand book on accident and operational safety analysis: vol I: accident analysis techniques, USA

Van der Schaaf TW (1991a) Development of a near miss management system at a chemical process plant. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford

Van der Schaaf TW (1991b) A framework for designing near miss management systems. Near miss reporting as a safety tool. Butterworth-Heinemann, Oxford