

Case Study Evaluation of Accident Risk Factors for Sustainable Safety Programme

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Abstract- Modern nations show great concern for safety management at workplace for obvious reasons. It's critical to curb the appalling toll of occupational injuries that continues to plague humankind, and mitigate the occurrence of occupational injuries and work-related illnesses as they are daily facts in most industries particularly in manufacturing related enterprises. These impart a substantial life and causing economic losses in the most technologically advanced nations as well as in many emerging world. This study presents manufacturing accident investigation in a suitable way to plan and manage safety programme in a manufacturing settings. An accident investigation register was administered for a period of 12 months to capture the needed data and these were analysed employing accident investigation procedure. 328 injuries were investigated among the 293 workers for this study duration. The anatomical sites of injury were the hands and the wrists with 169 (52%) instances, while the feet and the ankles, legs and other sites accounted for 81 (25%), 62 (19%) and 16 (5%) of these injuries respectively. The most effective solution for eliminating complex multiple risks were carefully investigated and analyzed based on the existing program. The probable best solution to ultimately benefit both the worker and the employer was then established. It was found that the accidents investigated were predictable due to the synergistic effects associated with coupling repetitive production and hand intensive stress, age and work experience.

Keywords- Manufacturing Accident Investigation; Risk Factors; Safety Programme; Manufacturing Settings; Repetitive Production

I. INTRODUCTION

Although there are enormous scientific and technological advances in human factors engineering (ergonomics), preventive medicine and other measures to prevent accidents that have made workplace safer, yet an estimated 120 million occupational injuries occur annually at workplaces world wide [1, 2, 3]. Apart from the cost due to downtime, overtime work, loss of machine hours, man hours, wages and equipment, and hospitalization, the tragedy associated with personal injury, disability and fatality is enormous [4, 5, 6]. In respect of fatalities, industrial accidents take the third place after vehicular accidents and homicide [6]. In lower income countries such as those in South Asia and Africa, injuries are one of the leading causes of adult mortality and a major contributor to disability [7, 8-11]. Death, illness and injury on such a scale impoverish individuals and their families, and challenge attempts to improve working conditions. When any of these occurs, there is a growing concern for improved safety management and evaluation to enhance sustainable safety performance [12]. Being an unsafe event, most accident preventive activities are called safety programmes [12, 13].

Occupational injuries and work-related illnesses are work-related musculoskeletal disorders (MSDs) as a result of bad

match between the workers, the work they perform and the equipment they use [14]. The increase in concerns for work-related injuries at workplace is well founded; as it is related to work/machine interaction, workstation design, working position; the suitability of instruments to the physical and physiological characteristics of the workers, psychological factors and environmental conditions (heat, cold, noise, air pollution) which may affect workplaces (workstations) and affect the health of the workers [15].

Literature is replete with studies that have depicted that the major risk factors contributing to the development of MSDs/injuries can be associated with a whole set of physical-ergonomic (force, frequency, awkward postures, extreme temperatures, vibrations, etc), hazardous exposures, workplace and process design, psychosocial, individual and work-organizational factors [16]. Thus, for an effective preventive measure in reducing work-related injury rates, several studies have been conducted to examine specific risk factors for work-related injuries [17, 18]. More so, several quantitative and qualitative evaluation techniques have been developed over the years from classical statistics, through risk assessment; system analysis, engineering economic factor, price deflation system analysis to system theory, data mining and artificial intelligence [19].

Nearly every type of work or industrial occupation has its own potential for causing injury and to prevent these injuries. It is important to understand the factors that lead to them [20]. These injuries and work-related illnesses result from multiple risks factors, affect different segments of working population, and occur in a myriad of occupations and industrial workplaces. It has caused immeasurable human suffering, contributing to a significant life and economic losses for enterprises and societies as a whole appearing pronounced in the industrialized nations as well as in the developing ones. Thus, the global burden of occupational injuries and work-related illnesses are colossal and are a major concern to industry, states, health services, insurance companies, labour, academia, workers' compensation board, the public and of course, the injured individuals themselves [21].

However, efforts towards prevention of accident at workplaces must be driven by data that identify the pattern, frequency and severity of these injuries. Charles-Owaba and Adebiyi [22] identified critical manufacturing safety prevention activities as training, personal protective equipment, guarding, awareness and accident investigation. In their work, the aggregate effect of these activities was considered. The challenge is to find out the extent of the significance contribution of each of these activities to manufacturing safety programme. These challenges may also include coping with an increased distribution of activities and

the related need to deal with dynamic task interdependencies, as well as coping with uncertainty and complexity [23]. More so, the emergence and accelerating economical, technological, social and environmental changes challenge working conditions and environment, and attempt to design and manage complex systems, embodying multiple feedback effects, long time delays and nonlinear responses to decisions [24, 25] that characterize risk factors at workplaces. Thus, an accident investigation approach that provides a framework for understanding the dynamic interrelationships that drive complex real-world system behaviour rather than statistical snapshots of this [12] has been adopted. This is because the primary purpose of safety evaluation is to determine the cause of accident with the express purpose of taking remedial action to prevent a recurrence and consequently, remedy the weakness in one or more of safety programme activities [19, 26].

This study examined manufacturing accident investigation as a suitable way for sustainable planning and managing safety program in manufacturing industries.

II. MATERIAL AND METHODS

This study was carried out in a manufacturing plant in Ilorin, Nigeria. For this research, the study population was 293 permanent workers in the plant and their age range is between 21 to 55 years, of which the majority were within the age bracket 25 to 45 years. The plant operates four shifts: three production shifts and one general shift and the workers put on long coats and anti-slip boots minimally. An accident investigation register was structured and employed to conduct a pilot study. Subject to the outcomes of a pilot study, appropriate amends were made in the register and the register was modified. The restructured accident investigation register was used to capture needed data on accidents/injuries over a 12 months period. The restructured and pre-tested register was employed to capture needed data on the following:

1. Department where the injury occurred,
2. Description and reason for the occurrence,
3. Type and site of injury,
4. Shift and time of injury,

5. Causes of injury,
6. Period of continuous work prior to injury,
7. Treatment for the injury,
8. Referral for the injury if any and period of absence from work after the injury.

This was established at the dispensary with the paramedic workers. The paramedics were educated for this purpose and the register's entries were checked at least thrice in a week. Oral interviews were also conducted after the review of the register. A description of occurrence of the accidents and the causes as obtained from the injured worker and register review were recorded. These were analysed using the accident investigation procedure that utilizes the most effective systematic risk management solution for reducing complex multiple risk factors by carefully investigating and analysing what being done. Afterwards, the primary method of risk assessment in an observational checklist was completed during a walk-through review of job or task to identify obvious risks concerns and primarily characterize the job functions and constraints of the workers. The checklist, which facilitated the identification of mismatches between applied force, frequency, and assumed postures, provides a systematic risk screening method for job analysis and were given a number ranking or a yes/no or true/false response.

III. RESULTS

A. Incidence and Pattern of Injuries

Incidence of Injuries: A total sum of 328 injuries were recorded for the study duration among the 293 workers with injury incidence (rates) of 1119.5/1000 workers/year. These injuries, in reality happened to 192 (66%) workers and 128 (67%) of those injured had more than one injury.

Work shift and Injury: The plant operates four shifts: the morning shift (Ms) 6am to 2pm; the afternoon shift (As) 2pm to 10pm; the night shift (Ns) 10pm to 6am and a general shift (Gs) 8am to 5pm. The observed data presented in Table I depicts that all shifts had a higher number of injuries in the second half of the shift except for the night shift. However, injury per worker is the highest during the morning shift and the lowest during the general shift.

TABLE I DISTRIBUTION OF INJURY WITH WORK SHIFTS BETWEEN TWO PROPORTIONS (1ST HALF OF SHIFT AND 2ND HALF OF SHIFT)

Shift	No. of Workers per Shift	1st Half of the Shift	Injuries per Worker	2nd Half of the Shift	Injuries per Worker	Total	Injuries per Worker (Total)
Ms	60	57(17.4%)	1.0	74(22.6%)	1.2	131	2.2
As	60	48(14.6%)	0.8	60(18.3%)	1.0	108	1.8
Ns	50	39(11.9%)	0.8	30(9.1%)	0.6	69	1.4
Gs	123	07(2.1%)	0.1	13(4%)	0.1	20	0.2
Total	293	151(46%)		177(54%)		328	

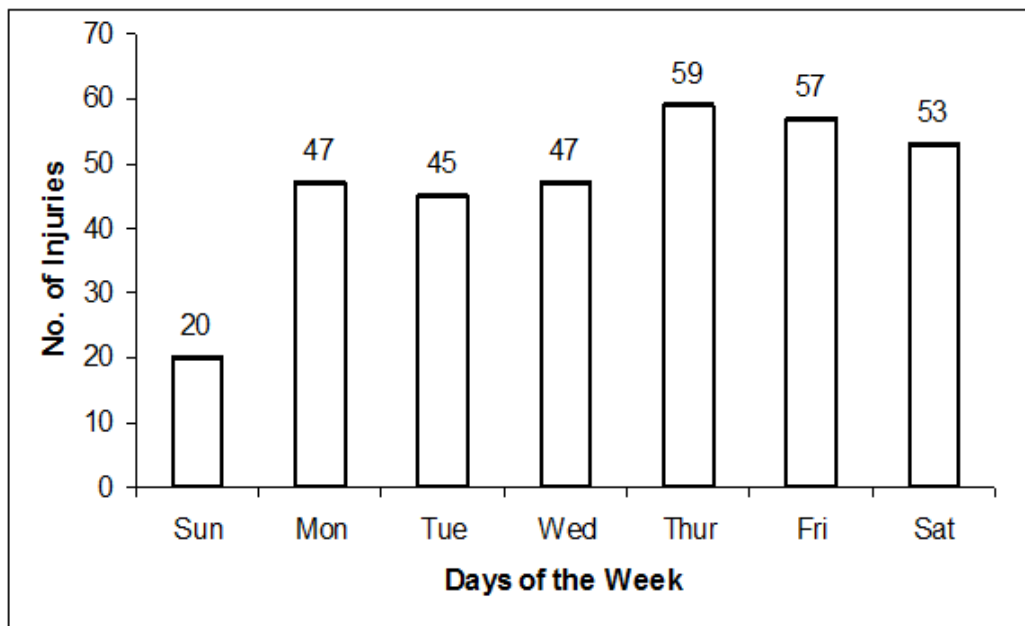


Figure 1 Variation of number of injuries with days of the week

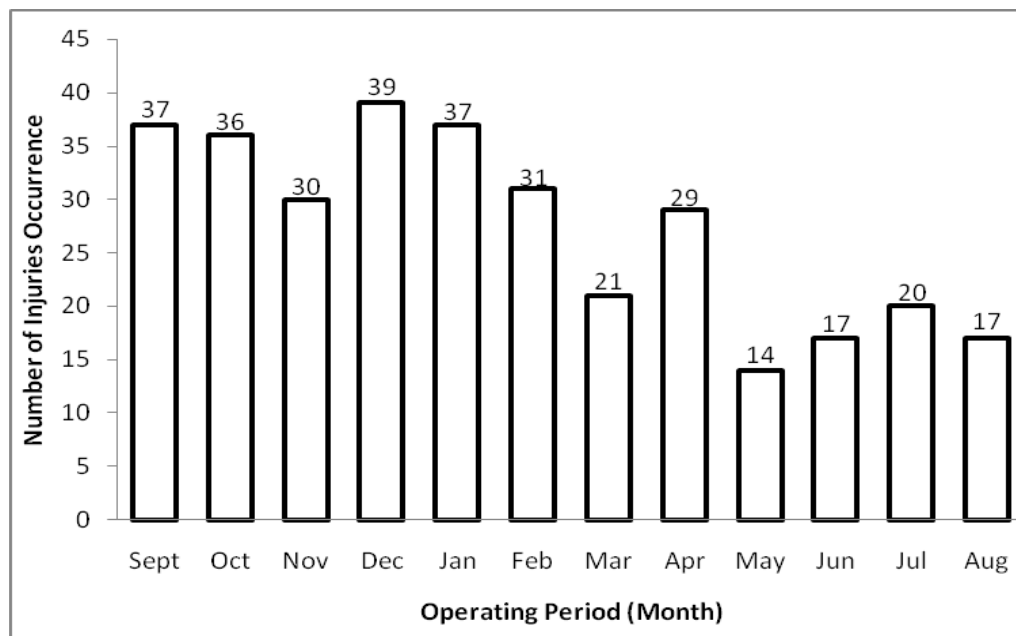


Figure 2 Variation of number of injuries with months of the year

Relationship of injuries with Days and Months: Time series analyses of injuries hit the climax of injuries in the latter half of the week; Thursday to Saturday as depicted in Fig. 1 and, during the first and the last quarters of the year; January and April and September and December as depicted in Figure 2.

Anatomical Site of Injury: The commonest anatomical sites of injury were the hands and the wrists with 169 (52%) instances, while the feet and the ankles, legs and other sites accounted for 81 (25%), 62 (19%) and 16 (5%) of these injuries respectively.

Types of Injury: The commonest types of injury were cuts and lacerations 194 (59%), sprains and strains 64 (20%) and others 70 (21%).

B. Magnitude and Risk Factors of Injuries

Causes of Injury: Injuries were caused as a result of object/substance such as bottle, metal chips, etc; technical and human factors both included. The objects/substances that caused the injury were bottle 161 (49%), machine 85 (26%), bottle tops (or metal chips) 53 (16%) and others such as ergonomics, process design, etc accounted for 29 (9%) of the injuries.

The commonest technical factor accountable for the incidence of injury was the environment 183 (54%) of the injuries; and while gloves, anti-slip boots and overalls are provided to the workers in certain departments for certain job tasks, injuries were noted in 105 (32%) occurrences despite using the protective wear(s). Machinery was accountable for 45 (14%) of injuries as pieces of bottles and metal chips were sometimes projectile from machines bottle burst and various other processes.

TABLE II RISK FACTORS ANALYSES OF INJURED WORKERS ($n_1=192$, $n_2=136$)

	Risk Factor	Workers' Actually No. of Injuries	>> One Injury
Age	Below 30	130(67.7%)	102(75.0%)
	30 and Above	62(32.3%)	34(25.0%)
Departmental Experience	Below 3 Years	133(69.2%)	93(68.3%)
	3 Years and Above	59(30.8%)	43(31.7%)

n_1 - Workers' actual number of injuries, n_2 - Workers' who suffered more than one injury

Among human factors, not using protective wear(s) seems to be the commonest cause of injury as observed in 124 (38%) occurrences; over indulgence or self-confidence on the job due to carelessness with the mechanical process resulted in 55 (17%) of the injuries and others such as inexperience resulted in 39 (12%) of the injuries.

Risk Factors: The observed data from the accident investigation procedure for risk factor analysis (Table II) by statistic percentage analysis, depicted that age less than 30 years, work experience less than three years and intensive hand dominance are significantly associated with high risk of injury. A whole set of factors such as educational status, work shift, total plant experience, use of protective wears, health status vis-à-vis musculoskeletal history in the area of the shoulders, the elbows, and more particularly of the neck and the wrists/hands and personal habits and extra professional activities (smoking, sport, etc) were also studied as risk factors, but were found to be stochastically negligible.

IV. DISCUSSION

The plant studied had a high incidence of injury of 1119.5/1000 workers/year and the risk of workers' being injured is high considering that 66% of the workers had an injury and 67% of those injured had more than one injury. All shifts had a higher number of injuries in the second half of the shift except for the night shift (Table I). However, injury per worker is the highest during the morning shift (40%) and the lowest during the general shift (6%) which compares favorably with other research work reported by Bazroy, et al. [27] and Bigos, et al. [28]. The time series analyses of injuries hit the climax of injuries in the latter half of the week; Thursday to Saturday (Fig. 1) and, during the first and the last quarters of the year; January and April and September and December (Fig. 2). Enquiries from the management revealed that there was a higher schedule pressure and workload during the period under review.

The observed data depicts that injuries were caused as a result of contact with bottles (49%), machines (26%), bottle tops (or metal chips) (16%) and others such as ergonomics, process design, etc (9%); and 52% of these injuries are in hand and wrist.

The stochastic percentage analysis of accident investigation observed data led to the emergence of the following significant risk factors:

- Age below 30-year. Bazroy, et al. [27], Bigos, et al. [28] and Agarwal [29] reported similar findings of higher rates of injuries for workers' of this age group.
- Departmental experience less than three years. The incidence of injuries is higher and/or exacerbated when a worker is new on a task/job and pick up as experience accumulates, as also reported by Bazroy, et al. [27], Chew

[30] and Xiang, et al. [31]. Thus, management should pay attention to properly trained and supervised new workers.

- Intensive hand dominance. In this study, the manual work had more injuries as a result of the workload, schedule pressure and the type of work deployment.

V. CONCLUSIONS

For industries to create an injury-free workplace, it is necessary to investigate hazards and identify risk factors for the occurrence of injury which must translate into prevention programmes that are well designed and assessed in the plant as a whole. An accident investigation approach, the most effective solution for eliminating workstation accidents was carried out with the aim to capture a transition to world-class safety program in manufacturing settings. Manufacturing systems and accidents were investigated, injured workers were interviewed; and risk factors were identified. Methods employed support developing a suitable way to study, design and optimize plan for investigating accidents and identifying risk factors; and selecting and implementing sustainable manufacturing safety program to ultimately benefit both workers and employers. Though reactive steps are the typical beginning point, proactive approaches should be instituted to prevent these kinds of problems from developing. This ongoing process emphasized on institution's efforts to review hazards before an injury or illness occurs in order to improve health and safety of workers, thus ultimately reducing the likelihood of exposure to risk factors of injuries and removing barriers to high performance.

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