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Analysis of different Factors Influencing Unsafe Behavioral at a Petroleum Refinery

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ABSTRACT: Petroleum refining is a high-hazard industry that processes thousands of tons of oil into various product lines each year. The presence of hydrocarbons makes the refinery sites very vulnerable to a variety of incidents and accidents affecting workers, the environment, and the surrounding economy. Work-related injuries, diseases, and fatalities have received considerable attention by researchers and have led to a greater awareness of incident causation in the workplace. It is assumed that the majority of work-related accidents are caused by workers' at-risk behaviors, which can be reduced through behavior modification and control of the factors leading to unsafe behavior. Most accidents and injuries emanating from workplaces are attributed to workers' unsafe behaviors, which are also a reflection of system deficiency and a hazardous work environment. A study was conducted in a typical petroleum refinery located on the eastern coast of Saudi Arabia. The refinery has a capacity of processing 450,000 barrels per stream day (BPSD) and has 2000 employees that include contractors.

The purpose of this case study was to analyze different factors contributing to unsafe behavior in a petroleum refinery. The study observed that organization/management factors, job factors, and individual factors contributed 34%, 43%, and 23%, respectively, towards unsafe behaviors at the refinery. Further analysis of the timing of the incidents showed that 64% of the incidents occurred due to unsafe acts or behaviors during the timing of shift change. The research concluded that if influencing factors and associated unsafe behaviors were controlled, the number of incidents and accidents could be reduced in the petroleum refinery.

KEYWORDS: Health, Safety, factors, organization, job, personal.

I. INTRODUCTION

Petroleum refining is a highly hazardous industry which processes thousands of tons of crude oil into various products each year, many of which are flammable and toxic to human health and the environment. Because of the wide variety of hydrocarbon hazards and their complexity, it is impossible to identify all of the hazards and impossible for the workers to know. In order to reduce these risks to life, property, or the wider environment, refineries are required to follow strict, mandatory safety practices. Industrial accidents represent a detrimental factor in many different sectors and constitute a threat to human life, equipment, and environmental damage. Because petroleum refineries are widely recognized as high-risk locations (Wood and Gyenes, 2015), the consequences of any dangerous event can be disastrous on both human and environmental levels. Any uncontrolled accident could have significant consequences for the immediate area (Christou, 1999). The consequences of such accidents cover various levels and may affect not only the industrial sites but also have environmental and socioeconomic impacts (Kadri and Châtelet, 2013). Every year, industrial accidents cause a number of deaths, injuries, and property losses due to petroleum refining operations. The process of learning from the occurrences of accidents is ideally acknowledged as one of the pillars of modern approaches to risk management and control (Dechy et al., 2008), which helps in preventing future recurrences. The extracted lessons learned can be used to ensure that resources are targeted where they can be of the most benefit (Hare et al., 2009).

Over the past few decades, scientific literature has been generated on the subject of learning from past accidents associated with industrial activities to understand how lessons can be learned to express better measures for preventing future accidents, and investigating them is crucial for the purpose of safety management (Vastveit et al., 2015; Cheng et al., 2013). Those research works were widely designed as statistical analyses of industrial accidents and past case studies for industrial risk assessment in various sectors, with the primary goal of uncovering new knowledge and

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identifying lessons to ensure that the accident under investigation does not occur again. Other studies have analyzed major accidents to learn about their causes and consequences and, furthermore, implement safety management measures for preventing future accidents, such as the studies of Khan and Amyotte (2007) and Kalantarnia et al. (2010), which were performed to analyze the Texas City refinery accident.

Accidents do not just happen; they are caused by unsafe acts, unsafe conditions, or a combination of both. Studies have noted that human behavior has a huge impact on accident prevention as 88% of accidents are attributed to unsafe acts, which are strongly aligned with employees' attitudes and behavior (Askaripoor T, Jafari MJ). A majority of studies have cited that targeting employees' behavior results in a vast reduction of accident occurrences at the workplace (Krause TR). Most studies have, however, focused on normative and prescriptive aspects of accident prevention and ignored the cognitive approach to safety, which fosters safe behavior in the workplace as a tool of accident minimization (Askaripoor T, Jafari MJ). The problem related to unsafe acts or careless employees can be resolved by closely monitoring and changing employees' behaviors (Dejoy, 2005). Despite most companies' having a well-managed safety management program, there are a significant number of accidents that occur. Therefore, it is believed that workers' attitudes are one of the possible causes.

Skalle et al. are of the view that assimilating human causal factors with technical factors could help in determining the root causes of accidents. A study by Norazahar et al. on the BP Deepwater Horizon accident in 2010 revealed that inadequate emergency preparedness, an unsafe environment, the physical ability of workers, and poor communication all contributed to human and organizational failures in the accident. Identifying common workplace safety issues enables a company to assess the problem areas. Brimm, M. et al. Behavioral change is not brought about by changing the person, but by changing their perception of accidents and changing the environment in which they work. It involves observing behavior and detecting unsafe activities, followed by directing or modifying behavior to achieve safe operation.

The objective of this study was to analyze significant factors that contributed to unsafe behaviors at petroleum refineries.

II. MATERIALS AND METHODS

2.1 Semi-Structured Survey and Data Collection

Semi-Structured Survey: To obtain a broad cross-section of worker opinions, survey sampling was used. Members of the company's Safety, Health, and Environment unit, who were not part of the research team, assisted with the sampling process. They created forms and questionnaires and coordinated with the information technology department in order to launch them on-line. Based on the company's organization chart, 2000 employees were employed in this refinery company. All employees' participants were recruited in the study. They were aged 18 to 58 years old. All employees were grouped into three categories based on their age: 1 (age 18–25), 2 (age 26–45) and 3 (age 45–58).

Survey – 1: A survey was conducted before starting the actual survey for collecting employee's opinion with regard to influencing factors contributing to unsafe behavior. A survey was conducted where employees were required to list down as many factors as they wanted which contribute to unsafe behavior. The result of the survey was used to establish a checklist leading to unsafe behavior. An analysis of the survey was conducted and different factors were categorized into three categories: organization/management factors, personal factors, and job factors.

Survey – 2: An online form is generated based on the survey-1. Before sending the survey, a general announcement was sent to all employees, informing them about the objectives of the survey. The employees were encouraged to respond and participate in the survey in order to implement an improvement initiative for the safety management system. Employees were to respond to each question where they felt most appropriate based on their experience, field observation, audit observation, audits, and site tour. The objective of survey-2 was to collect workers' opinions on different contributing factors leading to unsafe behaviors. Participation of employees was mandatory.

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Data collection: The survey was conducted between March and December in 2019 and 2020, and workers were given one-week time to respond and participate. The interview questions were classified into three categories:1-organizational factor and subcategory; 2-personal factor and subcategory; and 3-job factor and subcategory

Since the data collected was qualitative data and it was semi-structured, the data analysis was done easily. The collected data was converted into an excel sheet and analyzed to understand how the workers responded, which influenced unsafe behavior at the work place.

2.2 Statistical Analysis of Incident

Statistical analysis of the incident was conducted to identify the different causes and different influencing factors that contributed to unsafe behavior at the refinery. This helped the refinery organization to establish a behavior-based safety observation program.

Table1: Factors Influencing Unsafe Behaviors

Sr. No.	Factor	Subcategories
1	**Individual/Personal factors**	• low skill and competence level • tired staff • bored or disheartened staff • individual medical problems • Psychological condition • Physical Characteristics
2	**Job factors**	• illogical design of equipment and instruments • constant disturbances and interruptions • missing or unclear instructions • poorly maintained equipment • high workload • noisy and unpleasant working conditions.
3	**Organization and management factors**	• poor work planning, leading to high work pressure • poor SOPs • lack of safety systems and barriers • inadequate responses to previous incident • management based on one-way communications • deficient co-ordination and responsibilities • poor management of health and safety • poor health and safety culture.

III. RESULTS AND DISCUSSIONS

Root cause analysis of all incidents was conducted to identify the causes of incidents that occurred at the refinery. The main objective of the causes analysis was to identify the gaps in the safety management system so that an action plan could be established to fill them. The statistical analysis (figure1) showed that in 2017, 2018, and 2019, 77%, 80%, and 82% of incidents occurred due to unsafe acts, while 23%, 20%, and 17% of incidents occurred due to unsafe conditions. It is concluded that an average of 79.66% of incidents occurred due to unsafe acts or behaviors. Health and Safety Executives (HSE, 2002) concluded that human behavior is a contributing factor in approximately 80% of accidents.

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According to Heinrich, 88% of industrial accidents were caused by human unsafe behavior, 10% of accidents were caused by an unsafe psychological environment, and only 2% of accidents were attributed to unresisting factors. Heinrich's research results indicated that 98% of accidents could be prevented and controlled within human ability.

Further statistical analysis was conducted to identify different unsafe acts that contributed to incidents during 2017–2019 (figure 2). It was observed that 28% of incidents were caused by procedural violations, 23% of incidents were caused by using defective equipment, and 17% of incidents were due to failure in using PPE. All these unsafe acts can be modified with the intervention of a site supervisor, an improved training program, and a behavior-based safety program.

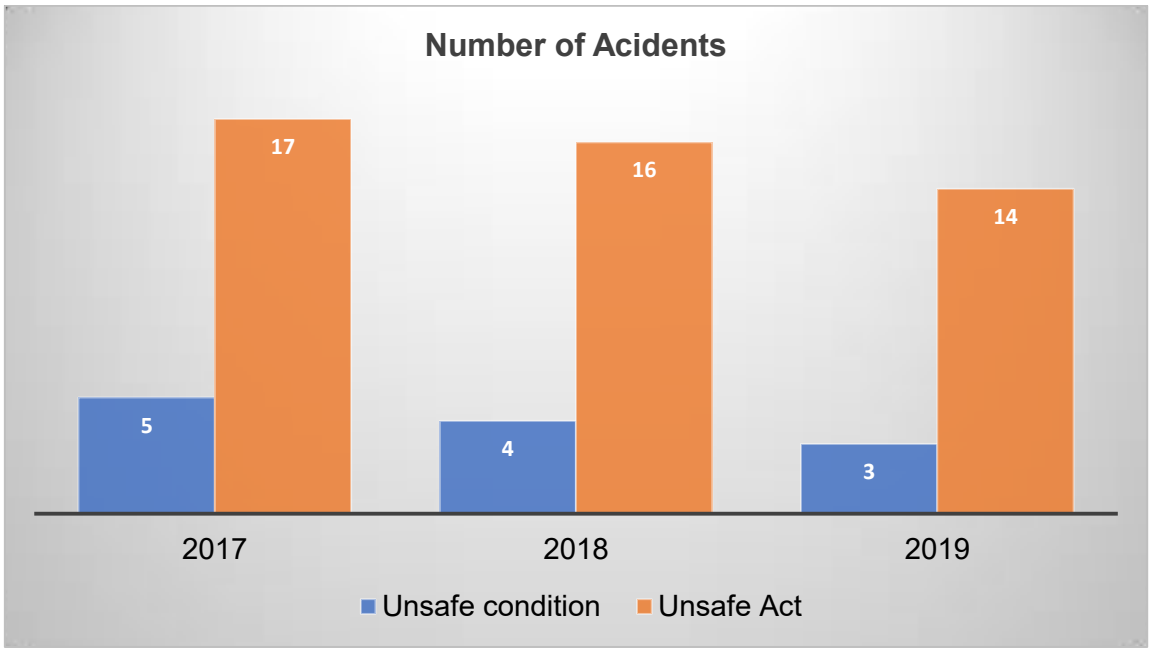

Figure 1: Number of Incident 2017 - 2019.

The petroleum refinery operates in two shifts; one shift from 6.00 am to 6.00 pm, while the second shift starts from 6.00 pm to 6.00 am. The timing of the incident was analyzed (figure 3). Most of the incidents occurred during the periods 4.00 am–8.00 am and 4.00 pm–8.00 pm. From figure 4, it was observed that 64% of incidents occurred between 4.00 am and 8.00 am and 4.00 pm and 8.00 pm. This could be due to self-induced or organizational pressure to finish the job before the end of the shift. When shift changes take place, new shift employees take some time to get familiarized with the tasks and activities from the previous shift. As per (NPRA 2009 National Safety Conference), 40% of plant incidents occur during startup, shutdown, and changeover periods in the oil industry. Every 2nd incident or accident in the process industry is related to communication errors that occurred during shift handovers. Therefore, it is reasonable for shift handover to be conducted in a unidirectional nature. Research from Ronald Lardner (The Keil Center, 1999) shows that when communications are conducted in a bi-directional or repetitive nature (questioning, validating, and repeating each handover item), the confidence and accuracy of the transferred knowledge is substantially improved.

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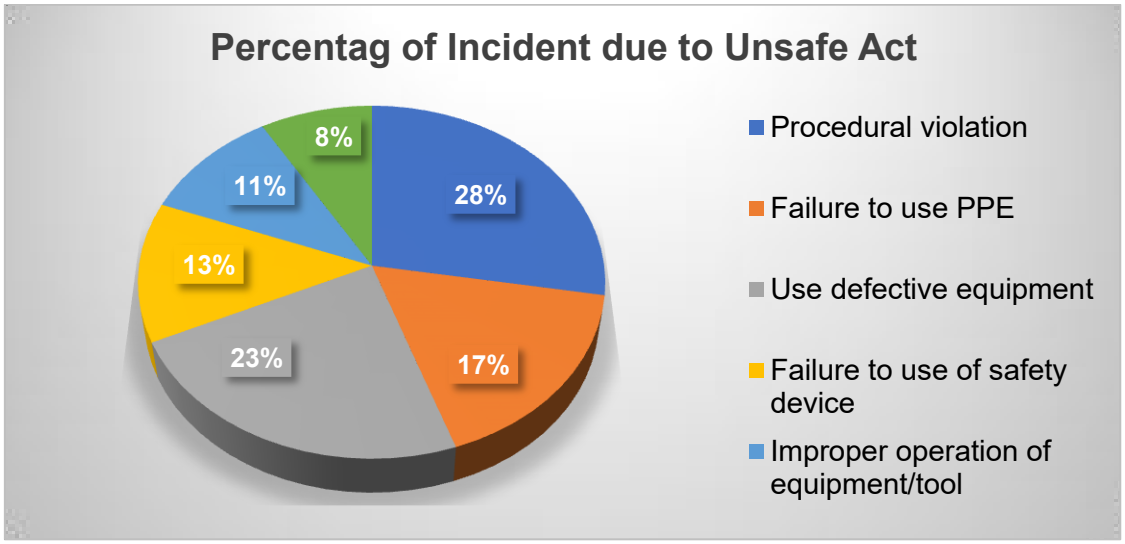

Figure 2: Average Percentage of Different Unsafe Act 2017-2019.

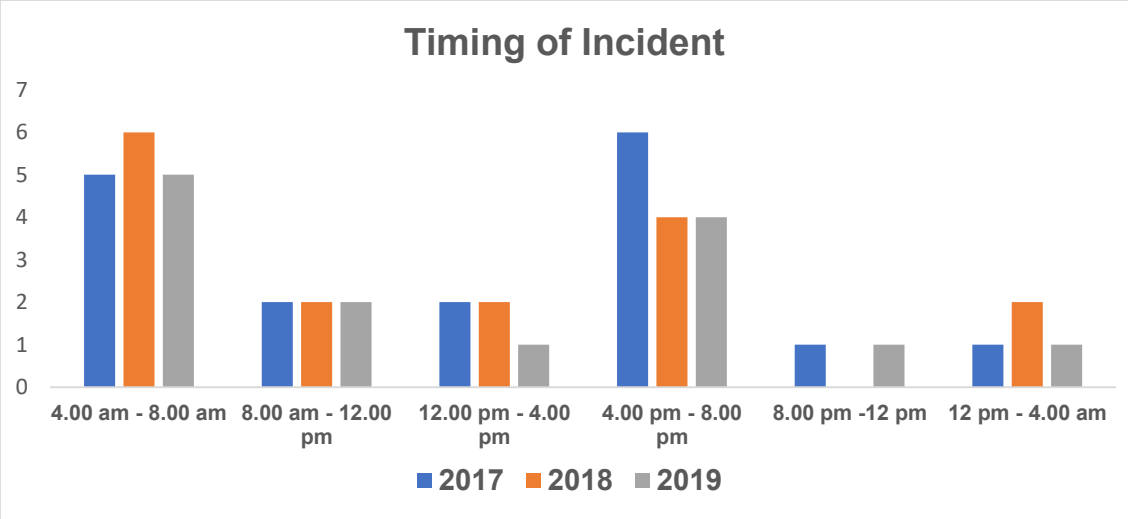

Figure 3: Statistical Analysis of Incident with Timing of Incident 2017-2019.

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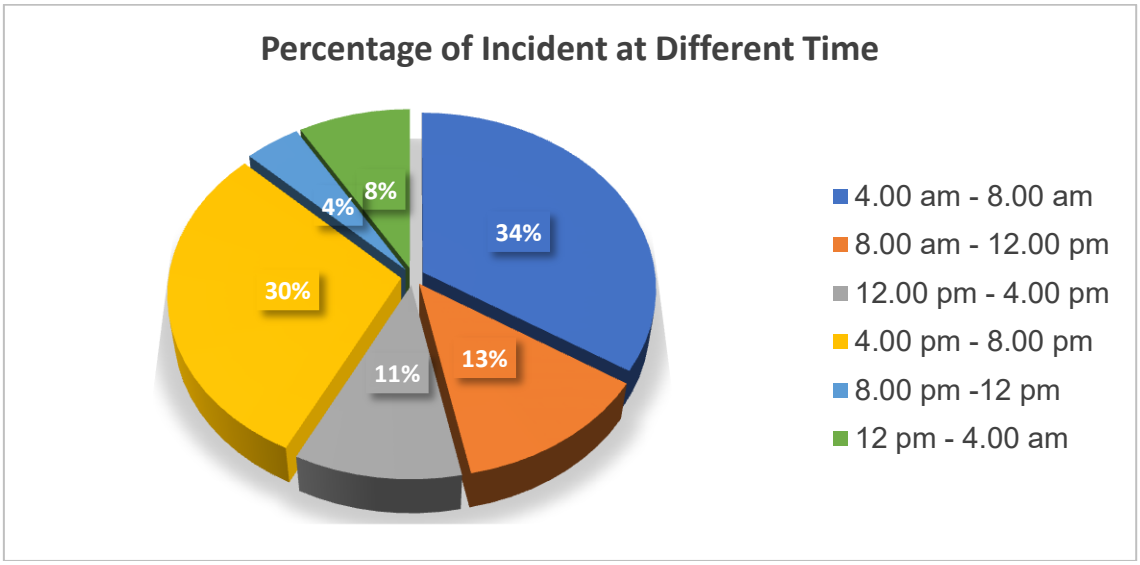

Figure 4: Average Percentage of Incident Occurred at Different Timing 2017-2019.

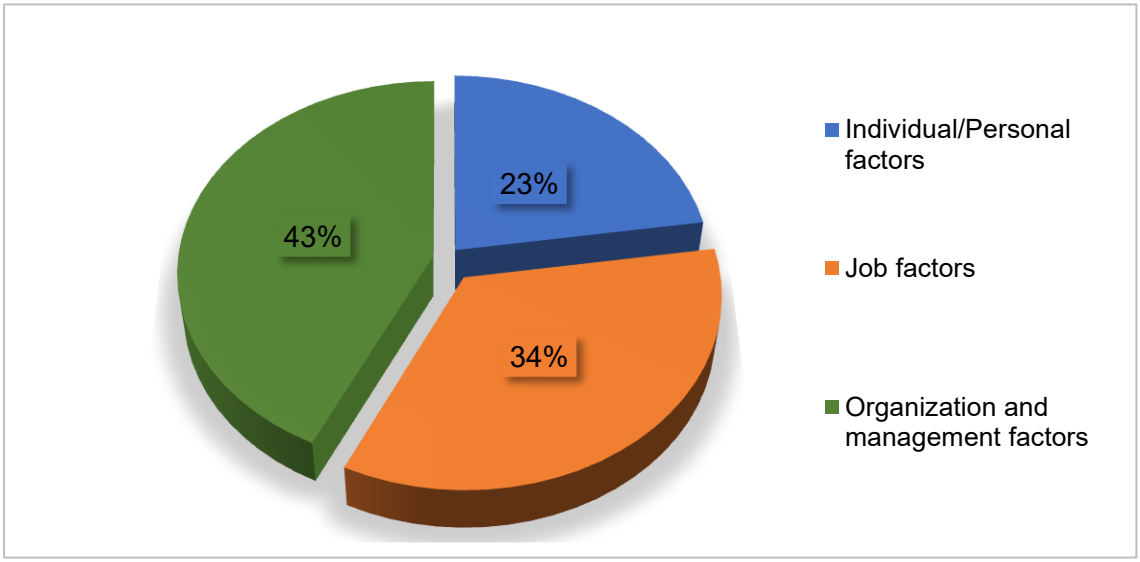

Figure 5: Percentage Contribution of Different Factors Influencing Unsafe behaviors 2017-2019.

Based on the survey conducted at the refinery, different influencing factors for unsafe acts and behaviors were analyzed and presented in figure 5. It was observed that 43% were organizational/managementfactors which have potentiated unsafe behaviors, while34% and 23% were the job factors and individual/personal factors, respectively, influencing unsafe acts and behaviors.

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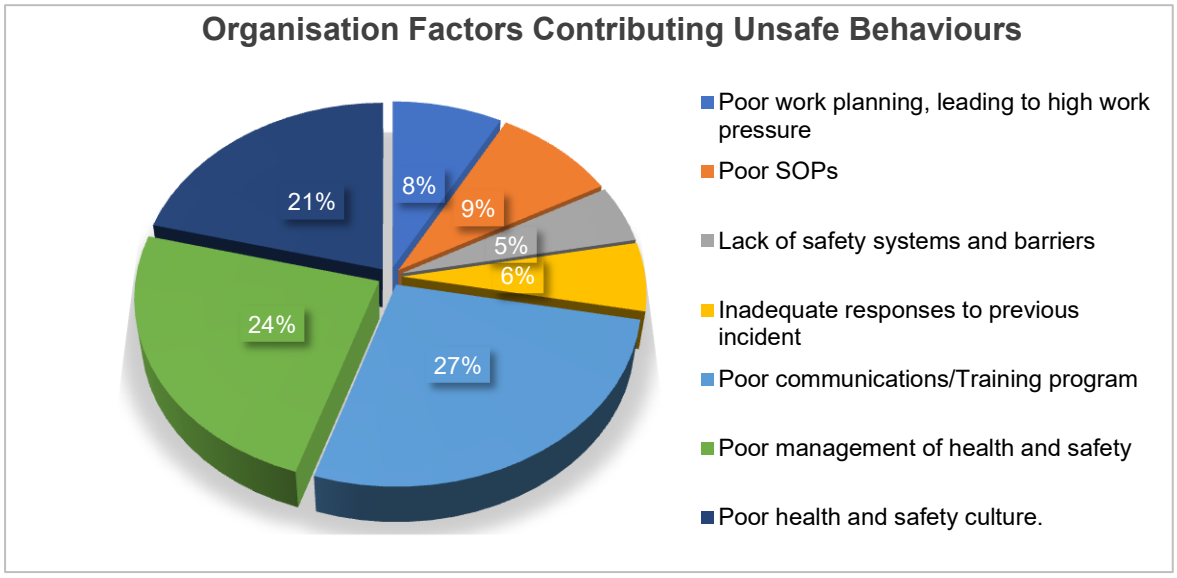

Figure 6: Percentage Contribution of Different Organization Factors Influencing Unsafe behaviors 2017 - 2019.

Figure 6 shows the percentages of different organizational factors for unsafe behaviors. Poor health and safety culture, poor health and safety management, and poor communication and training all contributed 21%, 24%, and 27% of unsafe behaviors, respectively. Organizational factors shape the context that contributes to at-risk work behavior and are also significant contributors to human errors in safe work behavior (Papazoglou, Aneziris 1999). It is apparent that perceptions of the manager's safety attitude and work behaviors directly affect workers' behaviors (Manzey, Marold 2009; Michael et al. 2005; Vecchio-Sadus, Griffiths 2004). Visible efforts from management exhibit deeper values and shared understanding held by management (Geldart et al. 2010; Fernández Muiz et al. 2007; Michael et al. 2005). Langford et al. (2000) found that when employees believe management cares about their personal safety, they are also more willing to cooperate to improve safety performance. In addition, such meaningful management actions in support of safety help to create a positive working environment that motivates safe work behavior and raises safety expectations (DeJoy et al. 2010; Mohaghegh, Mosleh 2009b). Under such circumstances, these will enable employees to transform from only compliance-based behavior to safety citizenship behavior; that is, intending to work more than what is simply prescribed by safety regulations (Gvekye, Salminen, 2007; Mearns, Reader 2008). Langford et al. (2000) also reported that employees are more willing to co-operate to improve safety performance when they believe management cares about their personal occupational safety.

The survey identified the different job factors contributing to unsafe behaviors and the result is presented in figure 7. It was observed that illogical design of equipment, poorly maintained equipment and high work load were considered to be major contributors to unsafe behavior at the petroleum refinery as they contributed 73% (illogical design of equipment 22%, poorly maintained equipment 24% and high work load 27%). Involvement and participation of staff in job, task, and equipment design and redesign is an important tool in the reduction of both stress levels and safety risks. Individuals are often able to identify and propose solutions to some of the ergonomic problems in their workplace, as is shown in many of the case studies. Designing tasks, equipment, and workstations to suit the user can reduce human error, accidents, and ill health.

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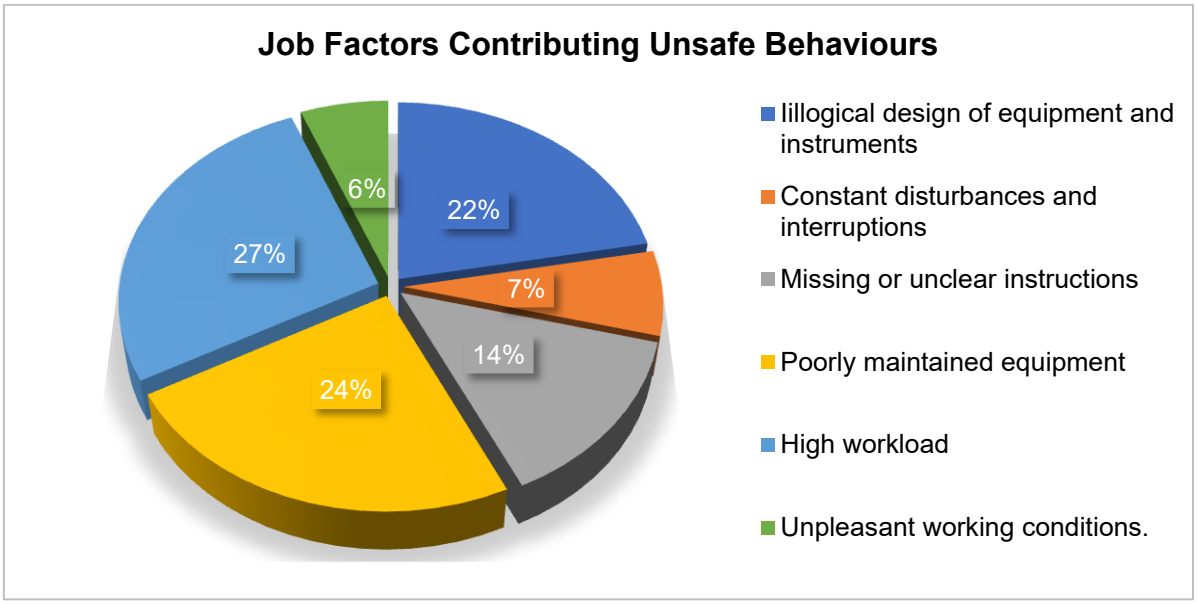

Figure 7: Percentage Contribution of Job Factors Influencing unsafe behaviors 2017-2019.

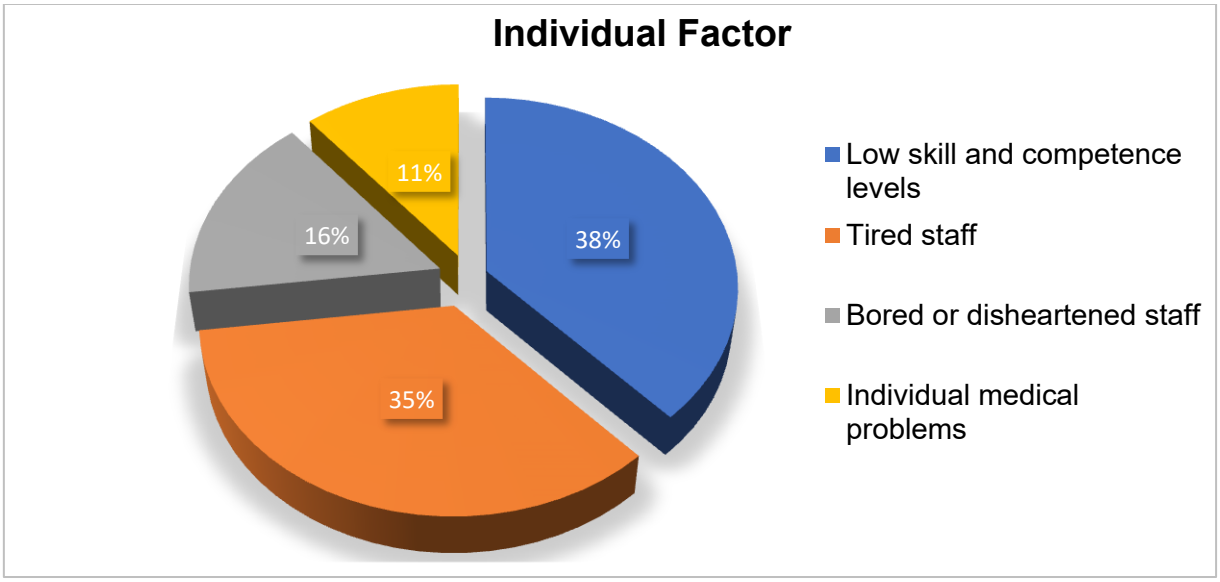

Figure 8: Percentage Contribution of Individual factors influencing unsafe behaviors 2017-2019.

An analysis of the different individual factors contributing to unsafe behavior was conducted and is presented in figure 8. It was observed that a major contribution to the induvial factors was from tired staff and staff with low skill and competence levels. As per the survey conducted in the petroleum refinery, low skill and competence levels contributed 38% while tired staff contributed 35% to unsafe behavior as per the survey conducted in This may be because the refinery is operating with optimized manpower and an insufficient training program due to cost cutting. With the implementation of a proper training program, workers' competence can be enhanced. Also, by restructuring the manpower requirements and with a proper break and rest system, unsafe behavior can be reduced. Cheng and colleagues (Cheng C-W, Yao H-Q, Wu T-C) reported that the vast majority of accidents in petrochemical companies are associated with inappropriate and inadequate safety training. Appropriate and adequate training programs have a direct effect on workers' safe behavior. Therefore, to control potential hazards and reduce or prevent accidents, regular

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educational training and effective safety interventions should be provided to reinforce workers' knowledge and raise their awareness about potential hazards in the workplace (Qinqin C, Jia Q, Yuan Z, Huang L, Liaudanskiene R, Varnas N, Ustinovichius L).

IV. CONCLUSION

Injuries, incidents, and accidents at the workplace contribute to lost production time, machinery damage, and man-hours lost. The study at this refinery concluded that management/organizational factors were major contributors to the unsafe behavior of employees. Additionally, most of the incidents and accidents occurred during the change of shift. The study recommended a behavior observation approach, which could potentially change unsafe behavior to safe behavior and reduce the occurrence of incidents and accidents at the refinery.

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