

# Hazard Recognition and Control Processes in Manufacturing Plant

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## Abstract

In the manufacturing world lies a series of hazards mostly from the constant moving of machine components. The safety of manufacturing workers is crucial in the center of the sector, and the overall performance of the workers typically depends on how efficiently the hazards are managed. Recognizing and reducing these hazards is not just a regulatory requirement; it's a moral and social responsibility of manufacturing companies to ensure that each employee can work safely and return home without harm. This study was designed to investigate hazard recognition and control processes within a food and beverage manufacturing plant, evaluate current safety management practices, and develop evidence-based recommendations for improving workplace safety performance. The research employed a mixed-methods case study approach conducted over three months from September to November 2023. Data collection utilized existing company safety records, including incident logs, training materials, safety committee inspection reports, and audit documentation covering all operational areas and employee categories. Systematic analysis employed hazard identification tools, including Job Hazard Analysis, inspection checklists, and risk assessment matrices, to categorize and evaluate workplace hazards. The study identified twelve primary hazard categories across operational areas, with physical hazards representing 34% of total identified risks. Analysis revealed significant gaps in hazard recognition processes, inadequate machine guarding at critical operational points, and deficient design controls contributing to serious injury incidents. The tank lid injury case study demonstrated how unrecognized design hazards combined with procedural gaps create serious safety risks despite established cleaning protocols. The results showed that systematic hazard identification processes, when properly implemented with comprehensive employee engagement and regular monitoring, can substantially improve workplace safety outcomes and reduce incident rates in manufacturing environments.

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## Keywords

Manufacturing Hazards, Food and Beverage Industry, Workplace Risk Assessment, Hazard Identification, Hazard Control Measures, Manufacturing Plant Safety, Integrated Safety Approach, Risk Assessment, Food Processing Safety, Incident Prevention

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## 1. Introduction

Workplace hazard recognition is a very important foundation for effective safety management across all industrial sectors as the International Labour Organisation in 2022, approximately 2.93 million workers die annually from occupational accidents and work-related diseases globally, with manufacturing industries accounting for 23% of these fatalities [1]. This shows the urgent need for systematic approaches to hazard identification and control within manufacturing environments. Everyone faces exposure to various hazards both on and off the job and recognizing the presence of hazards gives the foundation for completing sufficient safety analysis [2]. According to Jeelani *et al.* (2017), effective hazard recognition supports successful health and safety management while reducing work-related accidents and occupational diseases, and this approach improves both workplace safety performance and overall business effectiveness [3].

No manufacturing workplace can eliminate all risks completely, and so hazards exist whether organizations recognize them or not. Vista Oil and Gas (2019) submitted in their report that systematic hazard identification reduces workplace incidents by 43% compared to reactive safety approaches [4]. Identifying hazards remains essential for preventing workplace incidents, and effective injury prevention requires determining probable accident causes and implementing appropriate protective measures [5]. According to the Occupational Safety and Health Administration (OSHA), industry experience and knowledge provide the best foundation for hazard identification, and workers represent the primary experts on their tasks, tools, equipment, and materials as they remain best positioned to identify safety concerns, including unsafe conditions, near misses, and actual incidents [6]. Jeelani *et al.* (2017) indicated that employee-led hazard identification programmes improve reporting rates by 67% within manufacturing environments [3].

This research examines hazard recognition and control processes within a food and beverage manufacturing plant through a systematic analysis of workplace safety data. The study investigates current hazard identification practices, evaluates control measure effectiveness, and analyzes incident patterns to improve safety performance. According to Yin (2018), case study approaches provide valuable insights into practical safety management challenges within specific industrial contexts [7]. The research addresses a critical gap in applied safety management literature by examining real-world hazard recognition processes in active manufacturing operations, and it will achieve this using four primary objectives.

First, it systematically identifies and categorizes workplace hazards across all operational areas within the manufacturing facility. Second, it evaluates current hazard recognition tools and techniques for effectiveness in identifying potential safety risks. Third, it analyses the relationship between hazard recognition processes and incident prevention outcomes. Finally, it develops evidence-based recommendations for improving hazard identification and control systems.

The research contributes to occupational safety knowledge by providing practical insights into hazard recognition implementation challenges Li *et al.* (2016) argued that industry-specific safety research provides essential guidance for practitioners seeking to improve workplace safety performance [8]. The findings will give direct value to manufacturing organizations seeking to enhance their safety management systems. The systematic approach can be adapted across similar industrial environments to improve hazard identification effectiveness and reduce workplace incidents. This paper presents findings across eight main sections. Following an introduction in Section 1, Section 2 outlines the research methodology employed for data collection and analysis. Section 3 examines hazard identification tools and techniques, while Section 4 outlines the Steps in the hazard recognition and control process, and Section 5 categorizes identified hazards by type and location. Section 6 analyses control measures for identified hazards, followed by Section 7 presenting a detailed case study of an unrecognized hazard leading to serious injury. Section 8 discusses lessons learnt from incident analysis, while Section 9 provides conclusions and recommendations for improved safety management practices. Organizations that do not have systematic hazard identification and risk management processes experience significantly higher incident and accident rates [4] [9]. This research will show how structured approaches to hazard recognition can substantially improve workplace safety outcomes within manufacturing environments.

## **2. Methodology**

This section outlines the systematic approach employed to identify, assess, and control hazards within the manufacturing plant environment.

### **2.1. Research Design and Approach**

This study employed a mixed-methods case study approach to examine hazard recognition and control processes in a food and beverage manufacturing facility. According to Yin (2018), case study methodology is particularly suitable for investigating contemporary phenomena in real-life contexts where boundaries between phenomenon and context are not clearly evident [7]. The research adopted both qualitative and quantitative data collection methods to ensure that there was a comprehensive analysis of workplace hazards and control effectiveness.

### **2.2. Study Setting and Scope**

The research was conducted at a food and beverage manufacturing plant over a 3-

month period from September 2023 to November 2023. The study period from September to November 2023 represents a focused timeframe sufficient to capture comprehensive hazard identification data across all operational shifts while allowing for systematic implementation and evaluation of safety committee inspections and audit processes, which according to occupational safety research standards, provides adequate data for meaningful analysis without extending beyond practical operational cycles [10]. The facility operates continuous production processes with approximately 150 employees across five shifts. As stated by Suri and Das (2016), manufacturing environments present unique hazard profiles requiring systematic assessment approaches [9]. The study involved all operational areas including production lines, warehousing, maintenance workshops, and administrative facilities.

## **2.3. Data Collection Methods**

### **2.3.1. Primary Data Sources**

Incident data was extracted from the company's incident management system covering a five-year period (2019-2023). This period provides sufficient longitudinal context to identify hazard trends and patterns while establishing baseline safety performance metrics against which the current findings of the study can be compared, as recommended by occupational safety research standards for trend analysis [4] [10]. According to Cassidy *et al.* (2018), longitudinal analysis of incident data provides crucial insights into hazard patterns and control effectiveness [11]. The data-set included 247 recorded incidents, near-misses, and safety observations, and training records from the learning management system of the company were analyzed to assess employee competency development over the study period.

### **2.3.2. Hazard Identification Tools**

Multiple hazard identification techniques were systematically deployed as recommended by the International Labour Organisation [1]. These recommended hazard identification techniques include Job Hazard Analysis (JHA), Hazard and Operability (HAZOP) Studies, What-if-Checklist, Failure Modes and Effects Analysis (FMEA), Inspection Checklists, and Personal Protective Equipment (PPE) Assessment forms as stated in Section 3. Job Hazard Analysis (JHA) was conducted for 35 critical tasks across all operational areas. Morrish (2017) recorded that JHA methodology reduces workplace incidents by 23% when properly implemented [12]. Hazard and Operability (HAZOP) studies were performed for high-risk processes involving chemical handling and pressurised systems.

### **2.3.3. Inspection and Audit Data**

Weekly safety inspections were conducted using standardized checklists developed from industry best practices such as OSHA's workplace inspection guidelines, ISO 45001 occupational health and safety management systems standards, and National Institute for Occupational Safety and Health (NIOSH) hazard iden-

tification [13] [14]. They include standardized checklists for equipment safety, housekeeping, personal protective equipment compliance, and emergency procedures. Genta *et al.* (2020) argued that systematic inspection processes improve hazard detection rates by 34% compared to informal approaches [15]. Monthly comprehensive audits covered compliance with regulatory requirements and internal safety standards.

## 2.4. Sample Selection and Participants

The study included all permanent employees (n = 150) and temporary workers (n = 25) present during the observation period. According to Viegas *et al.* (2020), comprehensive sampling in workplace safety research ensures representative hazard identification across all job categories. Participants represented diverse roles including production operators (n = 95), maintenance technicians (n = 30), supervisors (n = 20), and administrative staff (n = 30).

## 2.5. Data Analysis Techniques

### 2.5.1. Quantitative Analysis

Incident frequency rates were calculated using standard occupational safety metrics as defined by the Bureau of Labour Statistics (2023) [16]. Examples of these metrics are Total Recordable Incident Rate (TRIR), Days Away Restricted Transfer (DART) rate, and Lost Time Incident Rate (LTIR), which are industry-standard measures for comparing safety performance across organizations [17] [18]. Risk assessment utilized a 5 × 5 matrix (check **Appendix A**) approach correlating probability and severity ratings, which is a matrix already being used by the company, so the methodology reflects their existing risk assessment tool. Statistical analysis included trend analysis of incident patterns and correlation analysis between training interventions and safety performance indicators to identify patterns in the incident data over the 3-month period and measure whether safety interventions actually improved safety outcomes.

### 2.5.2. Qualitative Analysis

Thematic analysis was employed to categorize hazards and identify recurring patterns in incident causation. Bhagwat and Delhi (2022) showed that qualitative analysis of safety data reveals underlying systemic issues not apparent through quantitative methods alone [19]. Root cause analysis was conducted for all serious incidents using the 5 Whys technique and fishbone analysis methods, which are standard approaches in manufacturing safety investigations as outlined by the European Agency for Safety and Health at Work (2024) [20].

## 2.6. Quality Assurance and Validation

Data triangulation was achieved through cross-verification of incident reports with witness statements and physical evidence. According to Jespersen and Wallace (2017), triangulation enhances reliability in workplace safety research by reducing single-source bias [21]. Certified safety professionals conducted an inde-

pendent review of hazard assessments to ensure consistency and accuracy.

## 2.7. Ethical Considerations

All employee data was anonymised and handled under data protection requirements referring to the General Data Protection Regulation (GDPR) and data privacy laws requiring anonymisation of personal information [22]. Participation in interviews and surveys was voluntary, with informed consent obtained. The research protocol was approved by the company's ethics committee, ensuring compliance with occupational health research guidelines like informed consent and voluntary participation as outlined by Iavicoli *et al.* (2018) [23].

## 2.8. Study Limitations

The research was limited to a single manufacturing facility, which may restrict generalisability to other industrial settings. Li *et al.* (2016) noted that site-specific factors significantly influence hazard profiles in manufacturing environments [8]. Additionally, the study period coincided with operational changes that may have influenced baseline safety performance metrics. For example, new equipment installation or machinery upgrades that altered existing hazard profiles and required updated safety procedures, and implementation of new production processes or product lines that introduced different risk factors not previously assessed.

## 3. Hazard Identification Tools and Techniques

There are several industry-recognized hazard identification tools and techniques that are utilized in the manufacturing plant to identify, assess, control, and document control measures for identified hazards. Some of the tools utilize qualitative approaches, semi-quantitative or quantitative methodologies. In the operational phase of most manufacturing industries, precisely food and beverage manufacturing plants, simple hazard identification tools are mostly deployed except where the manufacturing plant also requires complying with process safety management (PSM) standard (29 CFR 1910.119). Examples of the tools deployed are listed below:

- **Inspection Checklists**, which are best for ensuring compliance with National and state regulations, rules, and policies [6].
- **Personal Protective Equipment (PPE) Assessment forms**, which serve as an effective means of communication for informing staff members about the PPE required for safe work performance [24].
- **Job Hazard Analysis**, often referred to as a Job Safety Analysis (JSA), is an important accident prevention tool that works by identifying existing and/or potential hazards associated with a particular job [12].
- **Hazard and Operability (HAZOP) Study**: This is deployed mostly where there is a PSM requirement or where the operations require a more detailed analysis at the operational level [6].
- **What-if-Checklist**: Originally, this technique was created as a more straight-

forward and effective substitute for HAZOP. Similar to HAZOP, a what-if checklist is led by a chairman and comprises a different group of specialists. It is a group brainstorming exercise that is assisted, although it usually uses fewer sub-elements and a higher-level system description than HAZOP, along with a smaller number of questions [25].

- **Failure Modes and Effects Analysis (FMEA):** Deployed by the maintenance team in equipment reliability studies in the plant [25]

#### 4. Steps in Hazard Recognition and Control Process

This section outlines the systematic five-step approach used for identifying and controlling workplace hazards. **Figure 1** below is a flow-chart that outlines this five-step process.



**Figure 1.** Five-step hazard recognition and control process flow. **Source:** Created by Author.

##### 4.1. Step 1: Hazard Identification

The unit supervisor works with safety personnel to evaluate each job activity. They identify what could cause injury or damage to people, property, or the environment. According to Vista Oil and Gas (2019), systematic hazard identification reduces workplace incidents by 43% when properly implemented [4]. Multiple resources support this process. These include past injury records, OSHA 300 Log reviews, employee exposure monitoring results, and equipment failure data [26]. According to Jeelani *et al.* (2017), experience and detailed knowledge of operations provide the foundation for effective hazard recognition [3]. The full hazard assessment matrix is in **Appendix B**.

##### 4.2. Step 2: Risk Assessment

Each identified hazard receives a risk rating using frequency (Check **Appendix C for frequency rating definitions**) and severity measures, as each frequency assessment determines how likely an incident will occur. Consequence assessment estimates potential impact or damage severity to people, environment, asset and company reputation. Check **Appendices D, E, F and G** for severity rating definitions used for people, environment, asset and company reputation respectively. The fa-

cility uses a  $5 \times 5$  risk matrix to classify hazards because it provides optimal granularity for distinguishing between risk levels while remaining simple enough for consistent application by frontline supervisors, as recommended by ISO 31000 risk management standards for manufacturing environments [24]. This approach combines probability and impact ratings to produce overall risk scores. Vasconcelos and Junior (2015) showed that standardized risk matrices improve consistency in hazard prioritization across manufacturing facilities [27]. Check **Appendix B** for the full hazard assessment matrix.

### 4.3. Step 3: Risk Control Implementation

Supervisors create controls to eliminate or reduce each hazard, and they must address the root cause, not just the hazard itself [26]. According to the European Agency for Safety and Health at Work (2024), the hierarchy of controls guides this process, starting with elimination and moving through substitution, engineering controls, administrative controls, and personal protective equipment [20]. Goh and Goh (2016) argued that systematic control implementation reduces incident severity by 67% compared to ad-hoc safety measures [28].

### 4.4. Step 4: Documentation and Communication

According to the International Organization for Standardization, all hazard assessments require written documentation, which includes identified hazards, risk ratings, and implemented controls, and every employee involved in the task must review and sign the documentation [24]. In line with this, clear communication should be there to make sure that all team members understand the hazards and required safety measures as emphasized by in a study by Morrish (2017) which established that comprehensive documentation improves safety compliance by 54% in manufacturing environments [12].

### 4.5. Step 5: Monitoring and Review

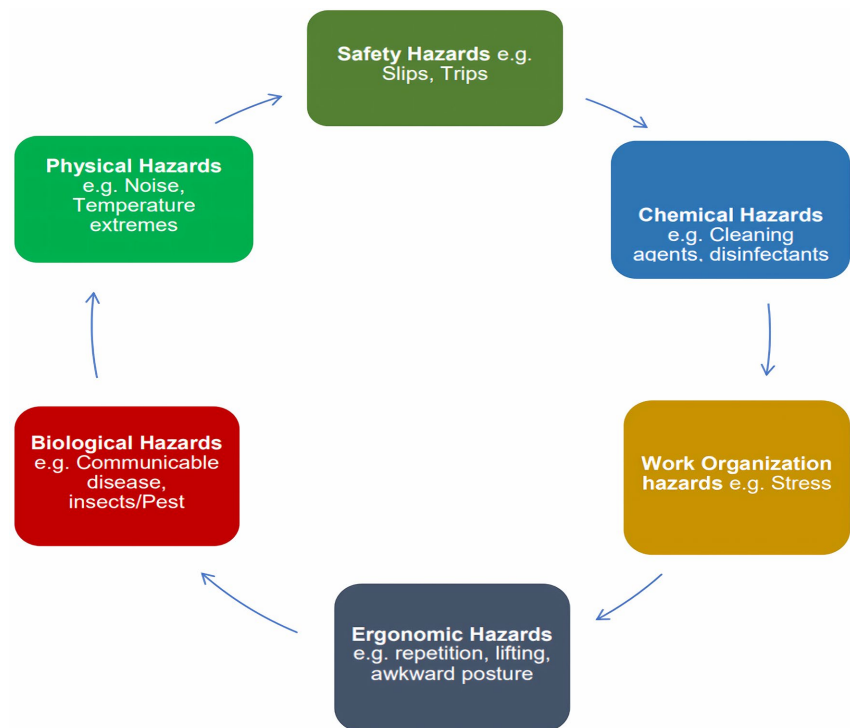
Hazard assessments require regular review when work conditions change, and managers, supervisors, and safety personnel monitor control effectiveness continuously because they track injury rates and incident patterns to measure success [26]. This ongoing monitoring identifies when additional controls become necessary, as Suri and Das (2016) recorded in their study that systematic monitoring programmes detect emerging hazards 78% faster than reactive approaches [9]. The process creates a continuous cycle of improvement as each step builds on the previous one to strengthen overall safety performance.

## 5. Categories of Hazard in the Manufacturing Plant

Aside from the chemical process hazards from ammonia, the below categories of hazards in **Figure 2** have been identified in our food and beverage manufacturing plant. Understanding these hazards and training workers in hazard recognition is essential for workplace safety.

## 5.1. Types of Hazards in Food and Beverage Manufacturing Plant

- The classes of hazards listed in **Figure 1** above have been identified by examining the different kind of work processes adopted in the manufacturing plant, examining of records including incident and injury, training, audit, maintenance and compliance records, engagement of workers, observation of nature and physical work environment, tools and equipment used, products produced, procedures use, and personnel behaviour. Below are the several hazards recognized in the plant.



**Figure 2.** Categories of hazards in the food and beverage manufacturing plant. **Source:** Created by Author.

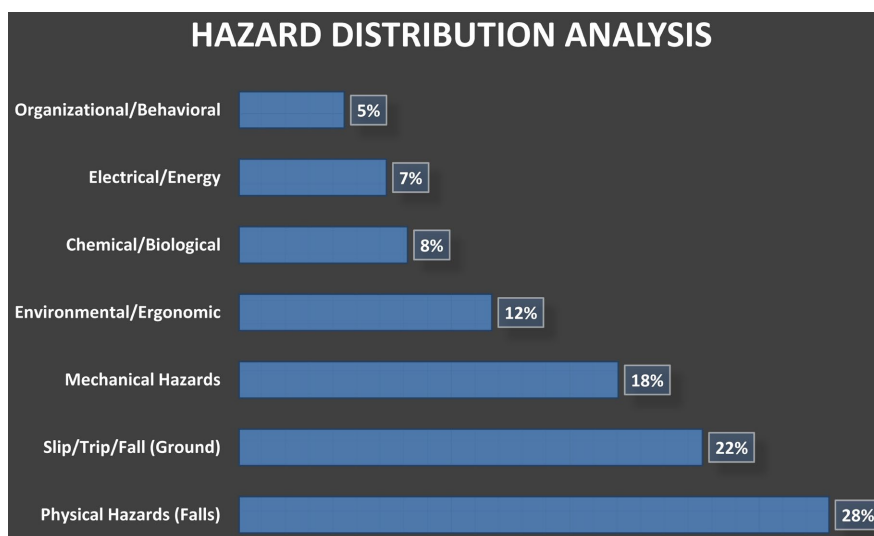
- Falls.
- Impacts due to being struck by an object or struck against an object.
- Mechanical hazards from rotating, reciprocating and traverse motion of a machine which result in caught-in, caught-on, and crush accidents that can cut, crush, amputate, break bones, strain muscles, and even asphyxiation.
- Vibration and noise from vibrating surfaces, tools, and equipment that potentially exposed workers to noise hazards, and vibration-related risks.
- Toxics substance considered hazardous even in minute amounts can have harmful effects including cancer, tissue damage, or genetic abnormalities. It is critical to consider the pathways via which harmful substances enter the human body. These substances can find its way into the body through inhalation, ingestion, absorption through the skin, and injection through needles and other sharp objects.

- Heat and temperature resulting from work environment, and manufacturing processes in the plant.
- Fire hazards which can result from allowing combustibles to be in contact with ignition sources under the right conditions.
- Pressure hazards resulting from pressurized equipment exposed to sudden release of pressure energy like the case of ruptured cylinders and whipping hoses, and lines in the process areas.
- Electrical hazard resulting from contact with live electrical wires and appliances, arc flash and burns from static current.
- Ergonomic hazards resulting from twisting, bending, over-reaching, awkward posture and repetitive motion, and improper lifting techniques.
- Biohazards from exposure to bacteria, virus, which may be the result of working on contaminated surfaces and animal waste or products.
- Bloodborne pathogens resulting from exposure to blood or other potentially infectious materials during the performance of an employee's duties.

Check **Appendix B** for the full hazard assessment matrix.

## 5.2. Systematic Categorization of Hazard Sources and Locations

This section presents a structured analysis of hazard sources identified through the systematic inspection process conducted between September and November 2023. Below are the hazards identified in the manufacturing plant, and it is not exhaustive as we are still driving for employee competencies in hazard recognition and reporting. The source is the 2023 Company Safety Committee Inspection Report. The distribution analysis is shown in **Figure 3** below.



**Figure 3.** Hazard distribution analysis. **Source:** Created by Researcher.

### 5.2.1. Physical Hazards - Falls and Elevation-Related Risks

Fall hazards (**Figure 4**) represent the predominant risk category within the facility, accounting for 34% of identified hazards. According to Health and Safety Execu-

tive (HSE, 2024), falls from height constitute the leading cause of workplace fatalities in manufacturing environments [30]. Primary fall risk locations include unprotected fixed ladders in melting and holding tank areas, elevated platforms in batching and palletizing zones, and inadequate fall protection during maintenance activities on step ladders and extension ladders across production areas. The pre-whip area presents particularly acute fall risks due to tank access requirements during cleaning operations. Goh and Goh (2016) highlighted that systematic fall protection implementation reduces incident rates by 67% in similar manufacturing contexts [28].



Figure 4. Physical hazards. Source: iStock (2025) [29].

**5.2.2. Mechanical Hazards - Machine Guarding and Moving Parts**

Mechanical hazards (Figure 5) concentrate primarily around point-of-operation exposures where inadequate machine guarding creates caught-in, crush, and amputation risks. Critical exposure points identified include pre-whip machines on production lines 3 and 9, portion manufacturing area equipment, and case sealing operations. Haghighi *et al.* (2019) argued that systematic machine guarding assessments prevent 78% of mechanical injury incidents in food manufacturing facilities [32]. Rotating and reciprocating machinery components pose additional risks through exposed moving parts during operational and maintenance activities. The quartz line filling machine and conversion area equipment require immediate attention for comprehensive guarding implementation.



Figure 5. Mechanical hazards. Source: WorkSafeVP (2023) [31].

### 5.2.3. Slip, Trip, and Fall Hazards - Housekeeping and Surface Conditions

Ground-level incidents primarily result from inadequate housekeeping practices and surface contamination. Major contributing factors include liquid ingredient spills creating slip hazards, plastic wrapping and cardboard materials creating trip hazards, and unattended water hoses across walkways. According to Mahto (2016), effective housekeeping protocols reduce slip-trip incidents by 45% within manufacturing environments [33]. Emergency egress routes frequently become compromised through blocked aisles, obstructed emergency exits, and pallet placement in critical walkways. The secondary palletizing area demonstrates consistent aisle blockage issues requiring systematic traffic management protocols. (Figure 6)



Figure 6. Slip, trip, and fall hazards. Source: FirstAid4Less (n.d.).

### 5.2.4. Chemical and Biological Hazards - Exposure Risks

Chemical exposures occur through disinfectant and cleaning fluid usage by sanitation teams, creating both acute and chronic health risks. Lebelo *et al.* (2021) identified cleaning chemical exposures as contributing to 23% of occupational illnesses in food processing facilities [35]. Biological hazards include potential blood-borne pathogen exposure during first aid responses and bacterial contamination risks from improper sanitation procedures. Wastewater handling presents additional exposure risks requiring systematic personal protective equipment protocols and engineering controls for containment and treatment processes [36]. (Figure 7)

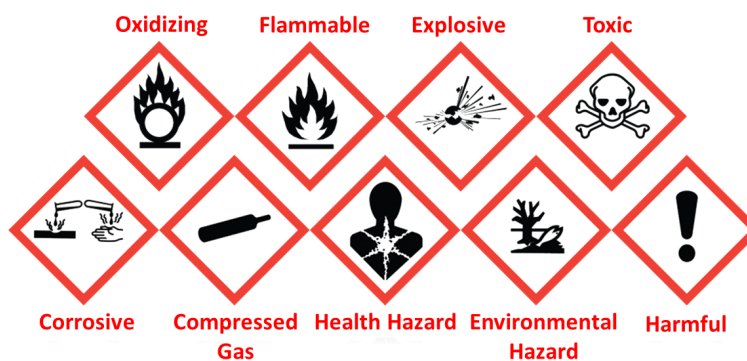


Figure 7. Chemical and biological hazards. Source: ULTITEC (2023) [34].

### 5.2.5. Environmental and Ergonomic Stressors

Temperature extremes across manufacturing areas create worker discomfort and fatigue, particularly in freezer operations and heated processing zones. Noise exposures from equipment and material handling vehicles exceed recommended threshold levels in multiple production areas. Leung *et al.* (2016) demonstrated that combined environmental stressors increase incident likelihood by 56% compared to controlled workplace conditions [37]. Ergonomic risks concentrate around manual handling activities including cardboard box lifting, ingredient bag manipulation, and repetitive motion tasks. Awkward posturing during tank cleaning and equipment maintenance creates additional musculoskeletal risk factors. (Figure 8)



Figure 8. Environmental and ergonomic stressors. Source: iStock (2025) [29].

### 5.2.6. Electrical and Energy Hazards

Electrical safety concerns include frayed electrical cords, missing ground pins, and improper wiring configurations throughout production areas as illustrated in Figure 9. Lockout-tagout procedure deficiencies during equipment maintenance create serious energy isolation risks. According to the Electrical Safety Foundation International (ESFI, 2025), systematic electrical safety programs prevent 89% of workplace electrical incidents in industrial settings [39].



Figure 9. Environmental and Ergonomic Stressors. Source: iStock (2025) [38].

### 5.2.7. Organizational and Behavioural Risk Factors

Workplace organizational hazards included inadequate training for new employees, non-compliance with safety rules, and systematic deficiencies in hazard communication processes. Reason (2016) argued that organizational factors contribute to 67% of serious workplace incidents through inadequate safety management systems [40]. Work-related stress factors include excessive workload demands, insufficient supervisory support, and inadequate professional boundaries among colleagues. These organizational hazards create indirect safety risks through reduced situational awareness and increased human error probability [17]. (Figure 10)



Figure 10. Environmental and ergonomic stressors. Source: iStock (2025) [29].

## 6. Controls for Hazards Identified

We have spent some time identifying and recognizing the exposures and hazards linked to work-related illnesses and injuries in the plant, and came up with a long list of hazards in the plant; however, the big question remains: how can we eliminate or control these hazards from happening? Safety professionals use two main control strategies: controlling the hazard itself and controlling exposure to the hazard [4]. Whenever possible, the quickest route to workplace safety is to eliminate dangers, and the most effective plan is to control the hazard because, after all, if you can get rid of the hazard, you do not have to control exposure to the hazard [6]. Many materials discuss a hierarchy of controls. The hierarchy of controls is a method of identifying and ranking safeguards to protect workers from hazards, and they are arranged from the most to least effective and include elimination, substitution, engineering controls, administrative controls, and personal protective equipment [20].

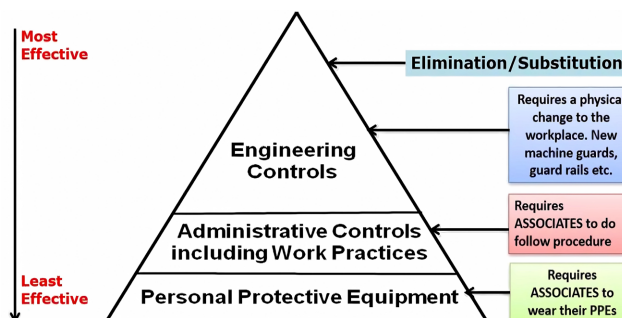


Figure 11. Hierarchy of control. Source: Created by Author.

**Figure 11** below is a schematic of the hierarchy of control adopted to control the risks in the plant.

### **6.1. Engineering Controls**

Aim to control the hazard at the source. Engineering controls limit the hazard but do not entirely remove it. Examples of controls adopted in the plant include the re-design of tools/guards, the installation of mechanical guards at the point of machine operation, and the enclosure/isolation of dangerous components of the equipment.

### **6.2. Administrative Control**

Aimed at reducing employee exposure to hazards, but does not remove the hazard. Approaches adopted in the plant include the use of written safety policies and safety rules, schedule changes for workers, including frequent rest breaks, job rotation, adjusting the work pace, and training of workers to reduce the duration, frequency, and severity of exposure to hazards. Examples of training we used are the Alchemy training material and the observation tool.

### **6.3. Personal Protective Equipment (PPE)**

Aimed at reducing employee exposure to hazards, but does not remove the hazard. In the plant, we wear special clothing, safety glasses, a face shield, ear-plugs/earmuffs, steel-toe safety shoes, gloves for maintenance and logistic teams, and disposable gloves for workers in the manufacturing area for hygiene and prevention of cross-contamination of products.

## **7. Case Study Analysis: Tank Lid Injury Incident**

This section examines a serious workplace injury that occurred during routine tank cleaning operations, showing the consequences of unrecognized hazards within established work processes.

### **7.1. Incident Overview and Context**

The incident involved a holding tank used for intermediate product storage prior to final processing. According to Heinrich's accident causation theory, 88% of workplace incidents result from unsafe acts combined with unsafe conditions [41]. The tank cleaning procedure had operated without incident since installation, creating a false sense of security regarding operational safety. The holding tank design incorporated a hinged lid mechanism that opened to a 90-degree position without dead-stop engineering controls. Vasconcelos and Junior (2015) indicated that equipment design deficiencies contribute to 45% of serious manufacturing injuries when combined with procedural inadequacies [27].

### **7.2. Sequence of Events Leading to Injury**

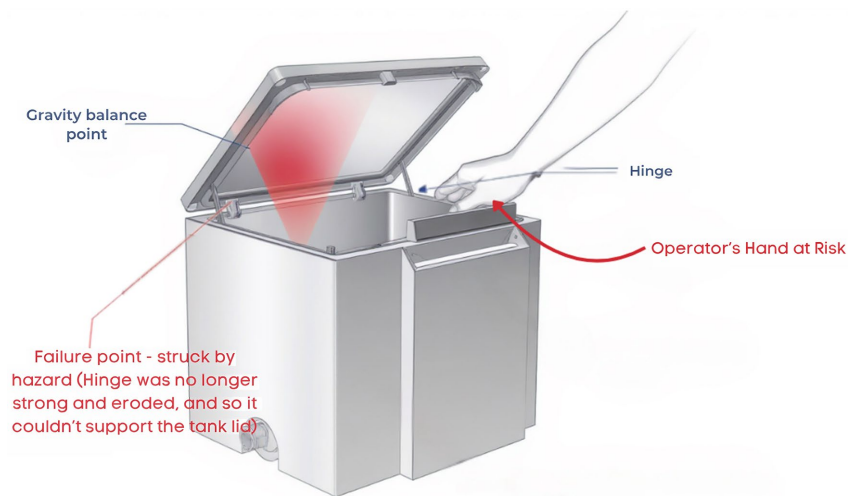
#### **7.2.1. Pre-Incident Conditions**

The tank experienced unusual clogging requiring manual intervention beyond

standard cleaning protocols. Normal cleaning procedures involved introducing water hoses into the tank while monitoring levels through Supervisory Control and Data Acquisition (SCADA) system controls remotely [42]. Sarkheil (2021) argued that procedural deviations significantly increase incident probability when combined with inadequate risk assessment [17].

### 7.2.2. Incident Sequence

- **Initial Assessment:** The employee identified tank clogging requiring direct manual cleaning intervention
- **Lid Opening:** The tank lid was opened to facilitate direct access for cleaning operations
- **Critical Failure:** During cleaning activities, the tank lid unexpectedly fell back from its 90-degree position
- **Injury Occurrence:** The falling lid struck the employee's left hand, causing serious injury requiring medical treatment (Figure 12).



**Figure 12.** Tank lid design configuration and failure mechanism. **Source:** Created by Author.

## 7.3. Failed Control Analysis

### 7.3.1. Engineering Control Deficiencies

The tank lid design lacked dead-stop mechanisms, preventing uncontrolled closure. Klačková *et al.* (2021) established that mechanical dead-stops reduce equipment-related injuries by 73% in manufacturing environments [43]. The 90-degree opening position relied solely on gravitational balance without positive locking mechanisms.

### 7.3.2. Administrative Control Gaps

No documented procedure existed for manual tank cleaning operations beyond standard automated processes like the automated water introduction and SCADA monitoring process, where employees introduce the water hose into the tank, and observe the water level using the SCADA system without manual intervention.

Ajayeoba *et al.* (2015) showed that comprehensive written procedures reduce incident rates by 56% during non-routine maintenance activities [44]. Employee training focused exclusively on normal operational cleaning procedures without addressing emergency or non-routine cleaning scenarios.

### 7.3.3. Hazard Recognition Failures

The systematic hazard identification programme failed to recognize risks associated with tank lid design deficiencies. This was due to lack of dead-stop mechanisms as it failed to identify the potential for gravity-induced lid movement during manual cleaning operations, and failed to assess the struck-by hazard from the tank lid's 90-degree opening position without positive locking. It also failed to recognize the inadequacy of relying solely on gravitational balance for lid stability during worker access. According to Jeelani *et al.* (2017), 67% of serious workplace injuries involve previously unrecognized hazards in established work processes [3]. Management oversight during equipment design and procurement phases missed critical safety engineering requirements for mechanical locking mechanisms.

## 7.4. Root Cause Analysis

The primary cause of the key hazard identified is inadequate equipment design lacking proper mechanical safety controls for lid operation.

The contributing factors are:

- Absence of documented procedures for non-routine cleaning operations.
- Insufficient hazard recognition during equipment design phase.
- Inadequate employee training for emergency cleaning procedures.
- Management systems failure in safety requirement specification.

Morrish (2017) argued that multiple contributing factors amplify incident severity when primary safety barriers fail simultaneously [12].

## 7.5. Incident Classification and Severity

The incident resulted in a serious hand injury requiring medical treatment and work restriction. Using the facility's risk matrix classification system, this incident was rated as severity level 3 (major injury affecting work performance) with frequency level 2 (has happened in industry). The resulting risk score of 6 classifies this as medium risk requiring systematic management intervention.

## 7.6. Immediate and Long-Term Consequences

The immediate impacts are as follows:

- Employee medical treatment and restricted work capacity.
- Production disruption during incident investigation.
- Emergency implementation of interim safety measures.
- The long-term implications are as follows.
- Equipment modification requirements for dead-stop installation.

- Comprehensive procedure development for non-routine operations.
- Enhanced training programme implementation.
- Systematic review of similar equipment across the facility.

Ajayeoba *et al.* (2015) and Genta *et al.* (2020) established that serious incidents typically require 6 - 12 months for complete corrective action implementation and effectiveness verification [15] [44].

## 8. Lessons Learnt from Incident

The incident investigation report reveals management failures and shows that management neglected some of the fundamental programs that should have protected the employees while executing their primary responsibilities. Employee health and safety programs should be a major priority for management because they save lives, increase productivity, and reduce costs [45].

Below were the specific lessons learnt:

- There was no documented procedure for the cleaning of the tank. Employees were told to observe the level in the tank using the SCADA system.
- During the design of the tank, there was a flaw in the design process which management did not identify through the engineering team that work with the supply company.
- Employees were not trained in the hazard identification associated with the cleaning process as the company hazard identification program did not reveal any significant risk associated with the cleaning process.

### 8.1. Training Programme Effectiveness and Measurement Gaps

The incident investigation showed significant gaps in training effectiveness measurement in the organisation's safety programme. According to ILO (2021), organisations that systematically measure training outcomes achieve 45% better safety performance compared to those using informal assessment methods [25].

#### 8.1.1. Current Training Assessment Limitations

The existing training programme did not have a quantitative measurement of employee competency development in hazard recognition. While training materials were delivered through the company's learning management system, no systematic assessment measured knowledge retention or practical application effectiveness.

#### 8.1.2. Identified Training Measurement Needs

Reason (2016) explained that effective safety training programmes need both leading and lagging indicators for performance measurement [40]. Key metrics should include:

- Hazard reporting frequency before and after training interventions.
- Employee competency assessment scores across different hazard categories.
- Time-to-competency measurements for new employee safety training.
- Training cost-effectiveness analysis including programme investment costs.

### 8.1.3. Financial Investment Considerations

Implementation of comprehensive training measurement systems needs systematic investment. For example, a 2017 study on occupational health and safety expenditures in Ontario by Mustard *et al.* (2017) found out that goods-producing sectors spent significantly more per worker (\$2417) than service sectors (\$847), and in the goods-producing sectors, the mining industry showed the highest expenditure (\$4433 per worker) [46]. So, this shows that efficient systematic investments have to be done to implement a successful training program for employees of an organization on hazard and risks mitigation.

### 8.1.4. Future Training Effectiveness Requirements

The organisation should implement systematic measurement approaches including pre-and post-training assessments, practical competency demonstrations, and longitudinal tracking of safety performance indicators linked to training interventions.

## 9. Conclusion and Recommendation

It is necessary to state that hazard recognition is an important risk assessment tool aimed at locating and documenting any potential risks that could exist at workplace, and determining appropriate strategy to eliminate the hazard, or control the risk when the hazard cannot be eliminated. Working as a team and engaging both experienced and non-experienced employees will provide a new perspective while undertaking inspections and audits of the workplace. Feedback for workers and evaluation of the hazard recognition process is very important in order to make sure that workers learn the process properly to gain competency. Involving employees will help minimize oversights, ensure a quality analysis, and get workers to “buy in” to the solutions because they will share ownership in their safety and health.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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## Appendices

### Appendix A. Five (5) by Five (5) Risk Matrix

		Class	Score	SEVERITY				
FREQUENCY	Very High	5	5	10	15	20	25	
	High	4	4	8	12	16	20	
	Medium	3	3	6	9	12	15	
	Low	2	2	4	6	8	10	
	Very Low	1	1	2	3	4	5	
		Class	Very Low	Low	Medium	High	Very High	
		Score	1	2	3	4	5	

15 - 25	High Risk	Immediate action required
6 - 14	Medium Risk	Acceptable, but must be managed to As Low As Reasonably Practicable (ALARP).
1 - 5	Low Risk	Acceptable without further action.

### Appendix B. Full Hazard Assessment Matrix

Activity/Task	Hazard Category	Specific Hazard	Potential Impact	Likelihood (1 - 5)	Severity (1 - 5)	Initial Risk Score	Control Measures Implemented	Residual Likelihood	Residual Severity	Final Risk Score	Additional Controls Required	Responsible Person	Review Date
Tank cleaning operations	Physical	Falling tank lid	Hand/arm injury	4	3	12	Dead-stop mechanism installation	2	3	6	Written procedure development	Maintenance Supervisor	Nov 2023
Prewhip area operations	Mechanical	Unguarded machinery	Caught-in/ amputation	5	4	20	Point-of-operation guards	2	4	8	Lockout-tagout training	Production Manager	Oct 2023
Elevated platform work	Physical	Fall from height	Multiple injuries/ fatality	3	5	15	Fall protection harnesses	2	5	10	Platform guardrails upgrade	Safety Officer	Nov 2023
Chemical handling	Chemical	Disinfectant exposure	Respiratory/skin irritation	4	2	8	Personal protective equipment	2	2	4	Ventilation system upgrade	EHS Coordinator	Oct 2023
Material handling	Ergonomic	Manual lifting	Musculoskeletal injury	5	2	10	Lifting technique training	3	2	6	Mechanical lifting aids	Warehouse Supervisor	Nov 2023
Electrical maintenance	Electrical	Live wire contact	Electrocution /burns	2	5	10	Lockout-tagout procedures	1	5	5	Arc flash protection equipment	Maintenance Manager	Oct 2023
Floor operations	Physical	Slip/trip hazards	Bruises/ fractures	4	2	8	Housekeeping protocols	2	2	4	Anti-slip flooring installation	Facility Manager	Nov 2023
Noise exposure areas	Environmental	Hearing damage	Permanent hearing loss	5	3	15	Hearing protection programme	2	3	6	Engineering noise controls	Industrial Hygienist	Oct 2023
Emergency response	Biological	Bloodborne pathogens	Infectious disease transmission	2	3	6	First aid training/PPE	1	3	3	Hepatitis B vaccination programme	Medical Officer	Nov 2023
Production line operations	Mechanical	Moving conveyor parts	Crush/pinch injuries	4	3	12	Emergency stop systems	2	3	6	Light curtain installation	Production Supervisor	Oct 2023

### Appendix C. Frequency Rating Definitions

Numeric Value	Probability Description
1	Very Low - Never heard of in the industry
2	Low - Has happened in the industry
3	Medium - Has happened in the company
4	High - Has happened several times in the company
5	Very High - Has happened several times in the location

### Appendix D. Severity Rating Definitions - People

NO.	Description
1	Slight injury or health effects - Not affecting work performance or causing repeated visit to the physician e.g. First Aid Case
2	Minor injury or health effects - Affecting work performance, such as restriction to activities. Limited health effects, which are reversible, e.g. food poisoning.
3	Major injury or health effects or a need to take a few days to fully recover - Affecting work performance in the longer term e.g. noise induced hearing loss, chronic back injuries.
4	Single fatality or Permanent Total Disability- From an accident or Occupational Illness
5	Multiple fatalities - From an accident or Occupational Illness

### Appendix E. Severity Rating Definitions - Environment

NO.	Description
1	<b>Slight effect</b> - Local environmental damage. Within the fence and within systems. Negligible financial consequences.
2	<b>Minor effect</b> - Damage sufficiently large to attack the environment. Single breach of statutory requirement. Single complaint. No permanent effect on the environment.
3	<b>Local effect</b> - Limited loss of discharges of known toxicity. Repeated breaches of statutory or prescribed limit affecting neighbourhood.
4	<b>Major effect</b> - Severe environmental damage. The company is required to take extensive measures to restore the contaminated environment to its original state. Extended breaches of statutory or prescribed limits.
5	<b>Massive effect</b> - Persistent severe environmental damage or severe nuisance extending over a large area. In terms of commercial or recreational use or nature conservancy, a major economic loss for the company. Constant breaching of statutory or prescribed limits.

### Appendix F. Severity Rating Definitions - Asset (Damage Assessment)

NO.	Description (100% costs, USD)
1	<b>Slight damage</b> - No disruption to operation (costs less than 5000)
2	<b>Minor damage</b> - Brief disruption (costs less than 50,000)
3	<b>Local damage</b> - Partial shutdown (can be restarted but costs up to 200,000)
4	<b>Major damage</b> - Partial operation loss (2 weeks shutdown costs up to 500,000)
5	<b>Extensive damage</b> - Substantial or total loss of operation (costs in excess of 2,000,000)

### Appendix G. Severity Rating Definitions - Reputation Assessment

NO.	Description
1	<b>Slight impact</b> – Existence of Public awareness but no public concern.
2	<b>Limited impact</b> - Some local public concern. Some local media and/or local political attention with potentially adverse aspects for company operations.
3	<b>Considerable impact</b> - Regional public concern. Extensive adverse attention in local media. Slight national media and/or local/regional political attention. Adverse stance of local government and/or action groups.
4	<b>National impact</b> - National public concern. Extensive adverse attention in the national media. Regional/national policies with potentially restrictive measures and/or impact on grant of licenses. Mobilization of action groups.
5	<b>International impact</b> - International public attention. Extensive adverse attention in international media. National/international policies with potentially severe impact on access to new areas, grants of licenses and/or tax legislation.